Using herpetofauna to identify restoration strategies and for bio-monitoring on the South River

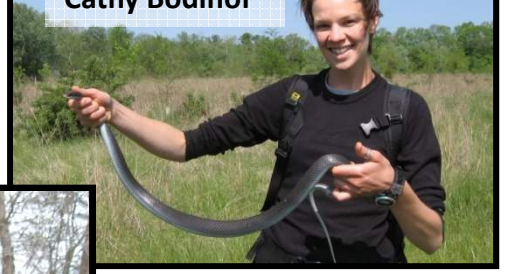
Virginia Tech

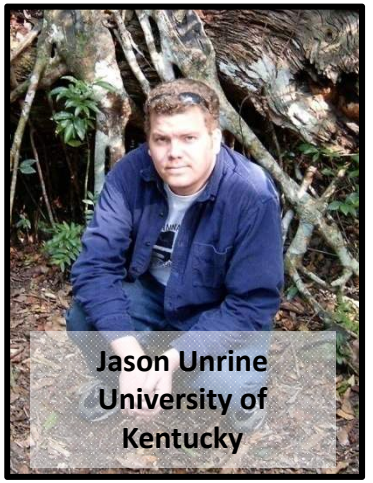
With a ~~little~~ *a lot of* help from my friends…


Devin Jones, Chad Stachowiak, Brittney Hopkins

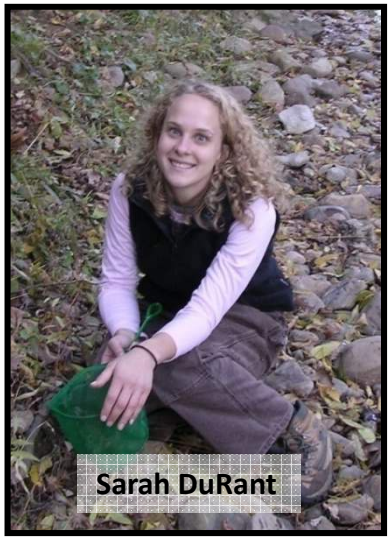

Bill Hopkins


Christine Bergeron

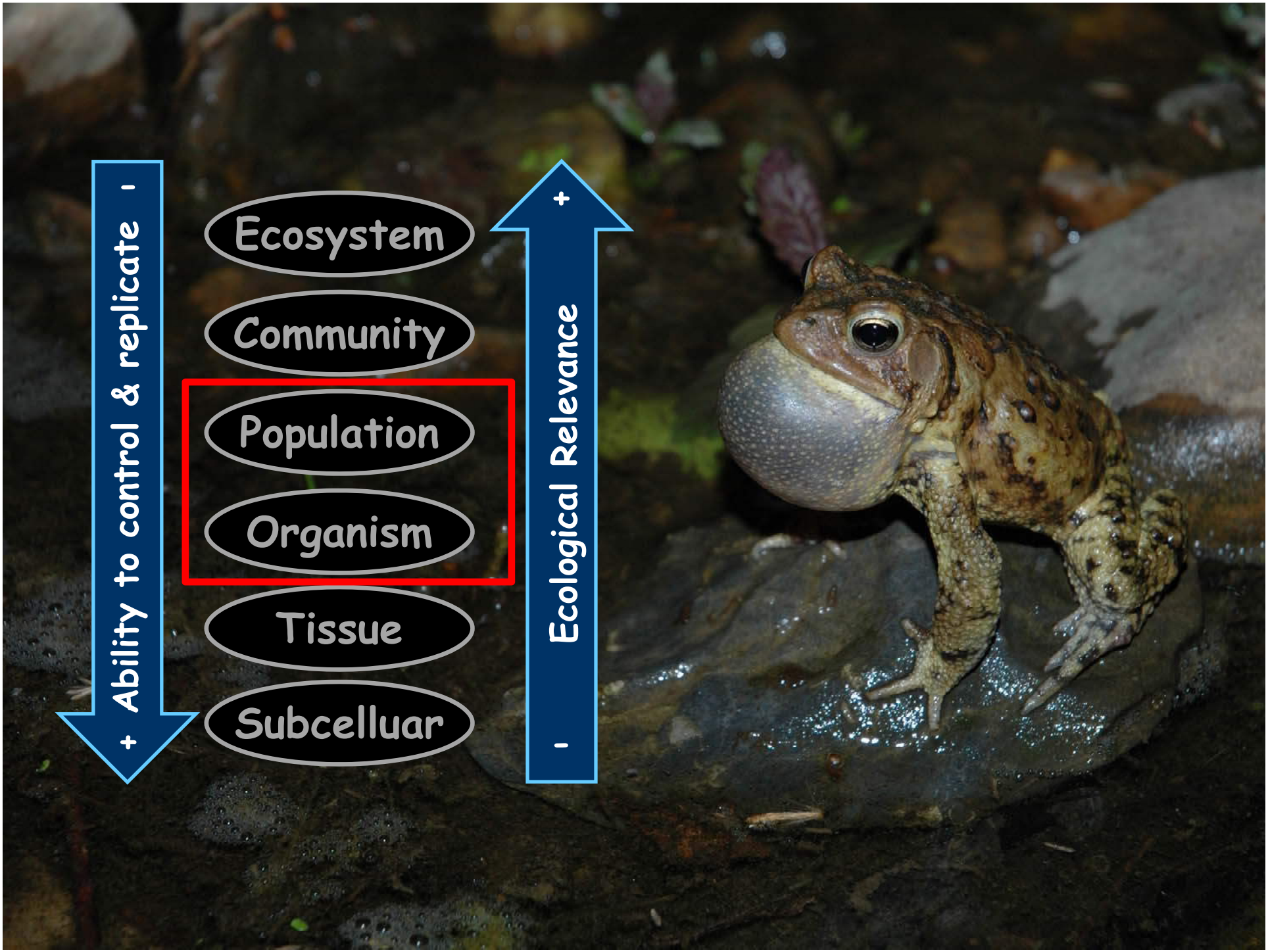

Cathy Bodinof


Jason Unrine
University of Kentucky

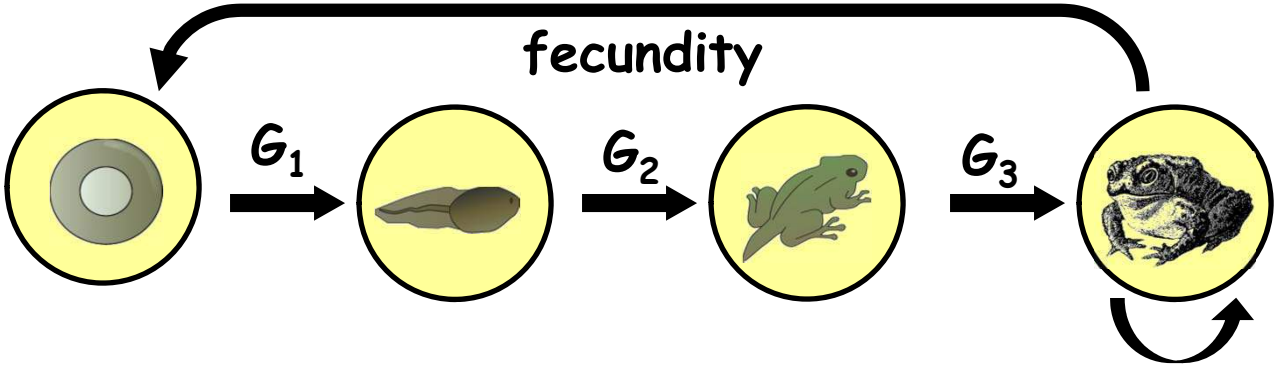

Brian Todd, Mark Hepner

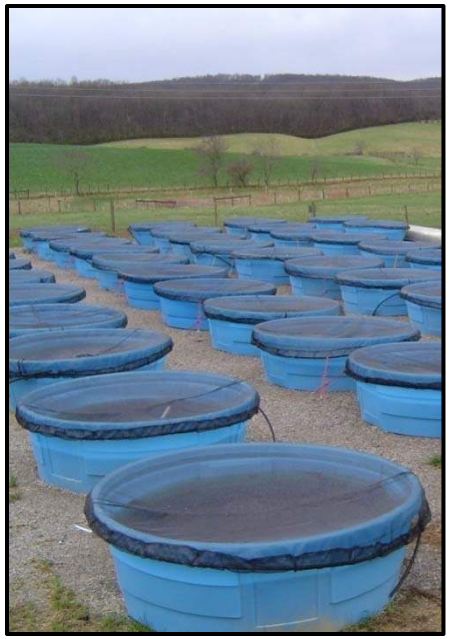

Sarah DuRant


John Burke, Sarah Budischak, Haruka Wada

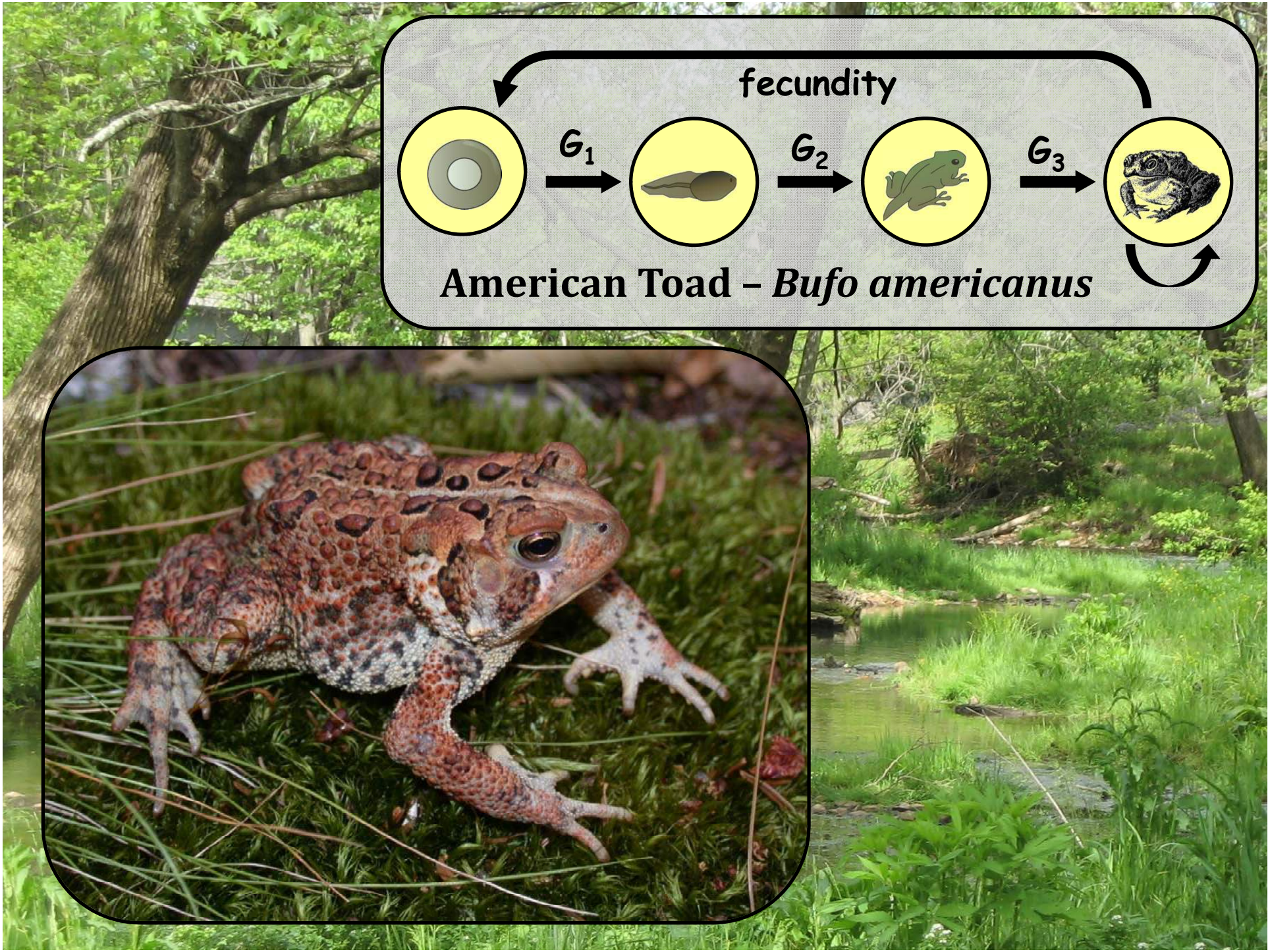

+ Ability to control & replicate -
Ecosystem
Community
Population
Organism
Tissue
Subcelluar
- Ecological Relevance +

Pluralistic Approach

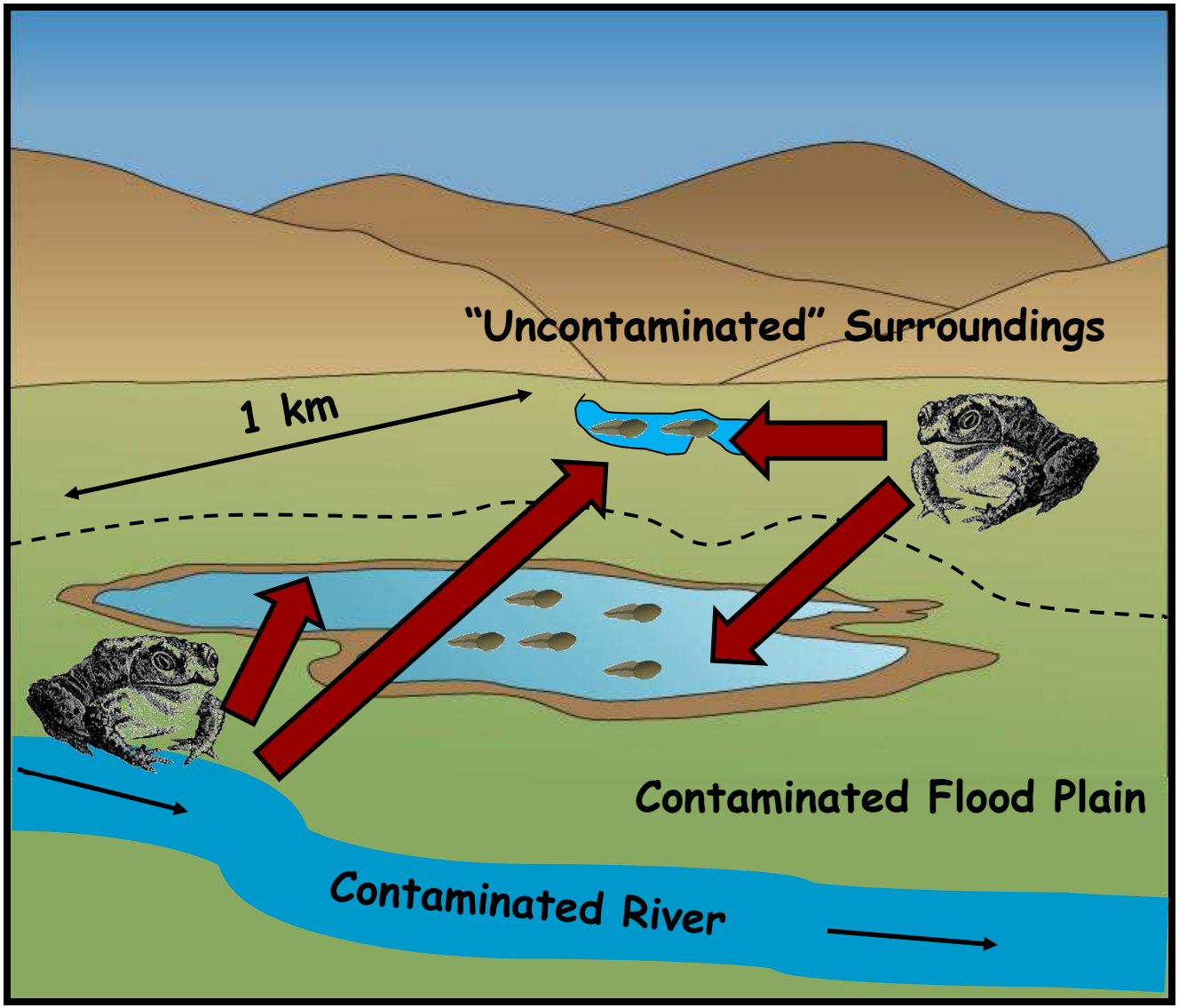




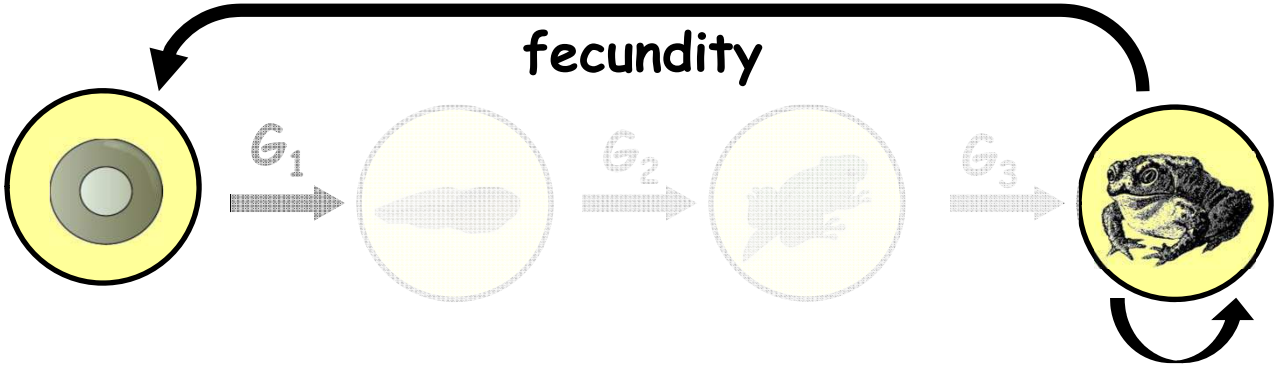
$$\begin{bmatrix} J1 \\ J2 \\ A \end{bmatrix}_{t+1} = \begin{bmatrix} 0 & 0 & (f\sigma_E Hg_m)(\frac{\sigma_{T\max}}{(1+d_{stoc.}L_t)^{\gamma}} Hg_m Hg_d)(\sigma_M Hg_m Hg_d) \\ \sigma_{J1} Hg_m & 0 & 0 \\ 0 & \sigma_{J2} Hg_m & \sigma_A \end{bmatrix} \times \begin{bmatrix} J1 \\ J2 \\ A \end{bmatrix}_t$$


fecundity
G_1
G_2
G_3
American Toad – *Bufo americanus*

Complex Life Cycles & Multiple Exposure Routes

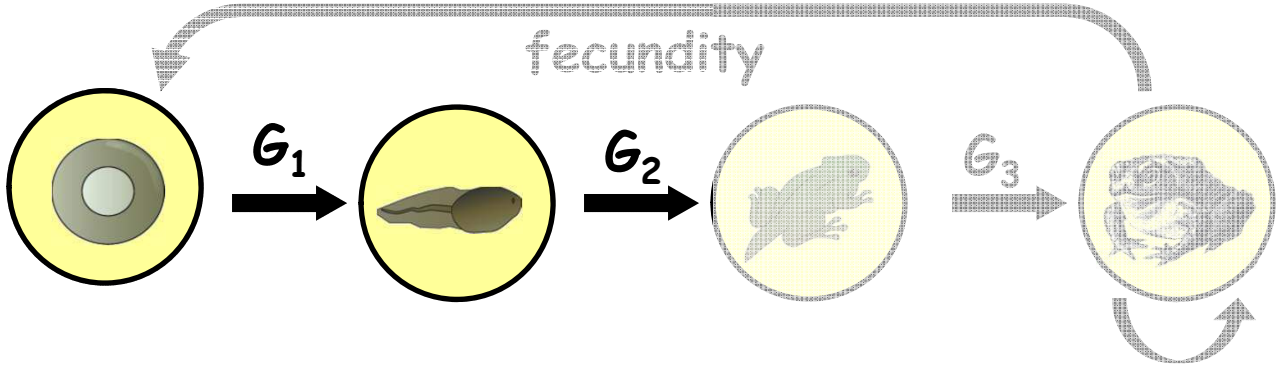


Individual - Level Effects

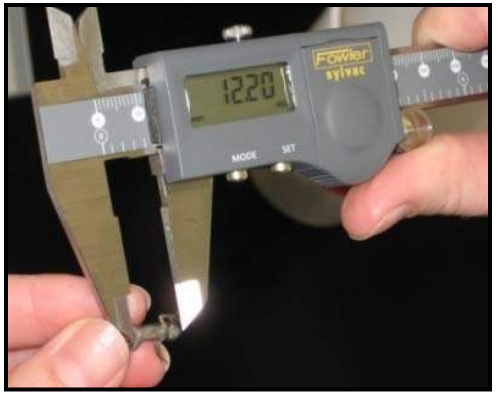


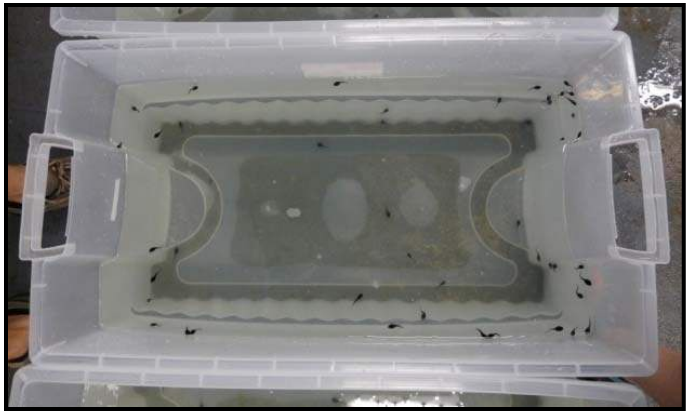
- **Effects of maternal Hg exposure on female reproductive success**

Individual - Level Effects

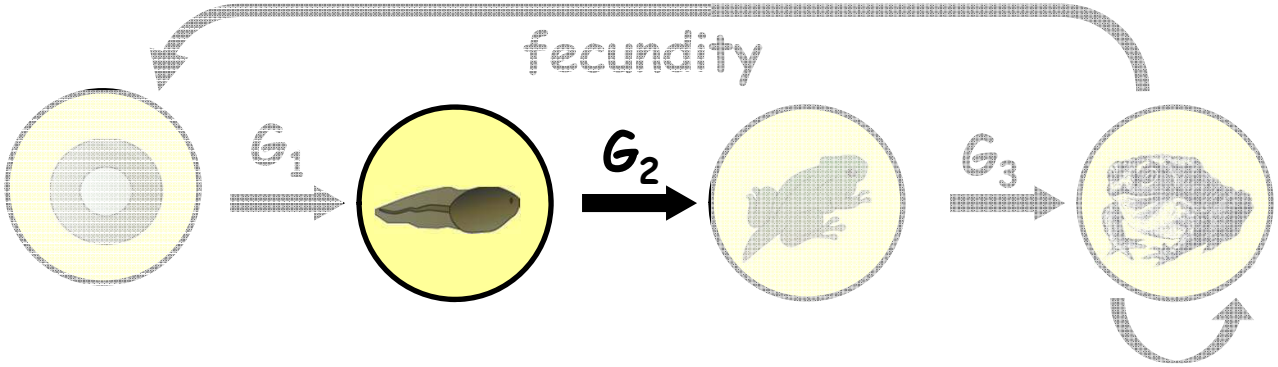


- Effects of maternal Hg exposure on female reproductive success
- Latent effects of maternal Hg

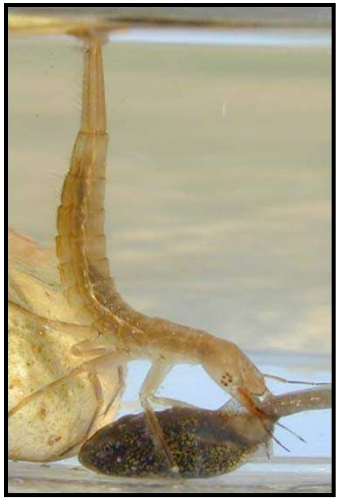




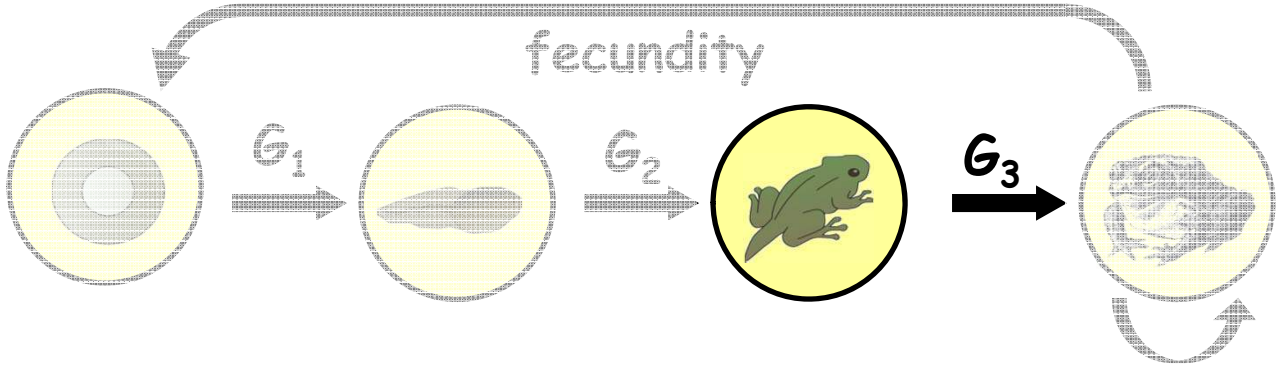
Individual - Level Effects



- Effects of maternal Hg exposure on female reproductive success
- Latent effects of maternal Hg (with and without predators)
- Individual & interactive effects of maternal and dietary Hg



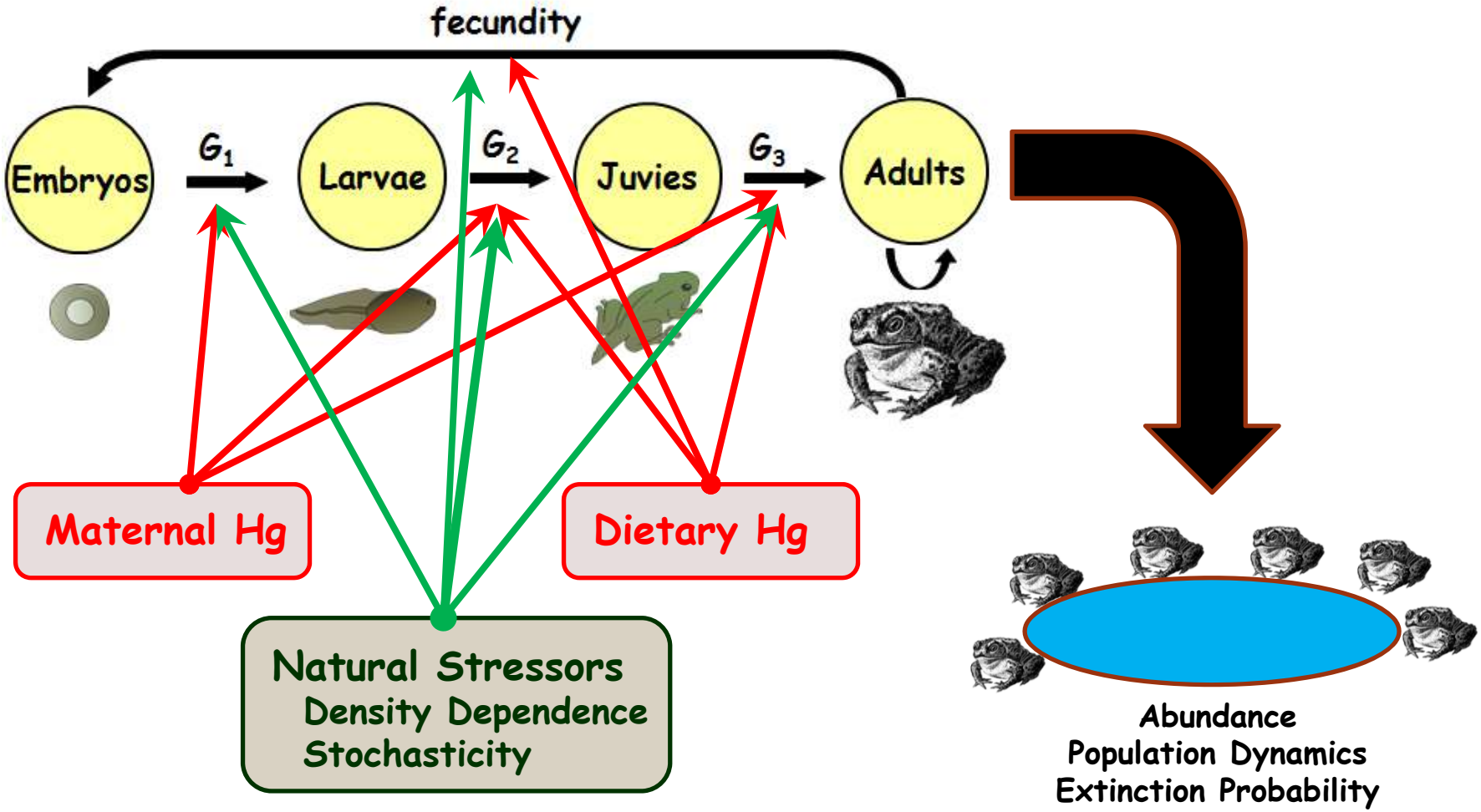
Individual - Level Effects



- **Effects of maternal Hg exposure on female reproductive success**
- **Latent effects of maternal Hg (with and without predators)**
- **Individual & interactive effects of maternal and dietary Hg**
- ***Even more*** **latent effects – terrestrial enclosures**

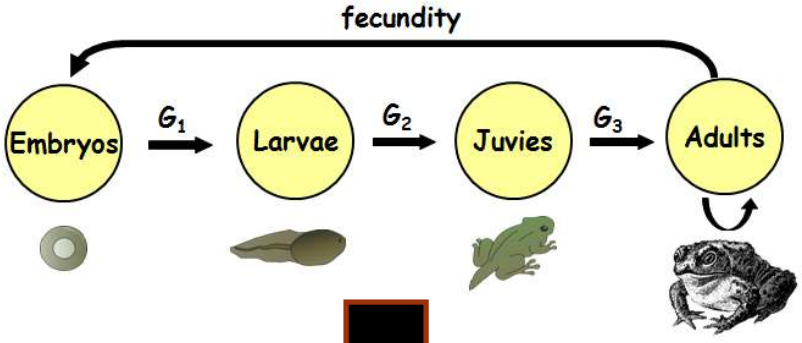
Age / Stage-based Population Model

American Toad (*Bufo americanus*)



Age / Stage-based Population Model

American Toad (*Bufo americanus*)



Mechanistic, Discrete-Time, Matrix Model

- 4 age classes
- 1 yr. time-step
- Density-dependence in the larval stage
- Environmental stochasticity
- Hg effects based on results of lab/mesocosm experiments

Sensitivity / Simulation Analyses

- **Sensitivity to Hg effects**
  - embryo, larval, juvenile, adult
- **Simulations:**
  - maternal & dietary Hg exposure
- **Endpoints:**
  - Quasi-extinction probability
  - Mean adult population size

Age / Stage-based Population Model

American Toad (*Bufo americanus*)

$$\begin{bmatrix} J1 \\ J2 \\ A3 \\ A \end{bmatrix}_{t+1} = \begin{bmatrix} 0 & 0 & (\phi_{A3} f \sigma_E)(\sigma_{L,t})(\sigma_M) & (f\sigma_E)(\sigma_{L,t})(\sigma_M) \\ \sigma_{J2} & 0 & 0 & 0 \\ 0 & \sigma_{J3} & 0 & 0 \\ 0 & 0 & \sigma_{A3} & \sigma_A \end{bmatrix} \times \begin{bmatrix} J1 \\ J2 \\ A3 \\ A \end{bmatrix}_t$$

$J1$ = # age 1 Juveniles
$J2$ = # age 2 Juveniles
$A3$ = # age 3 sub-adults/adults
A = # Adults

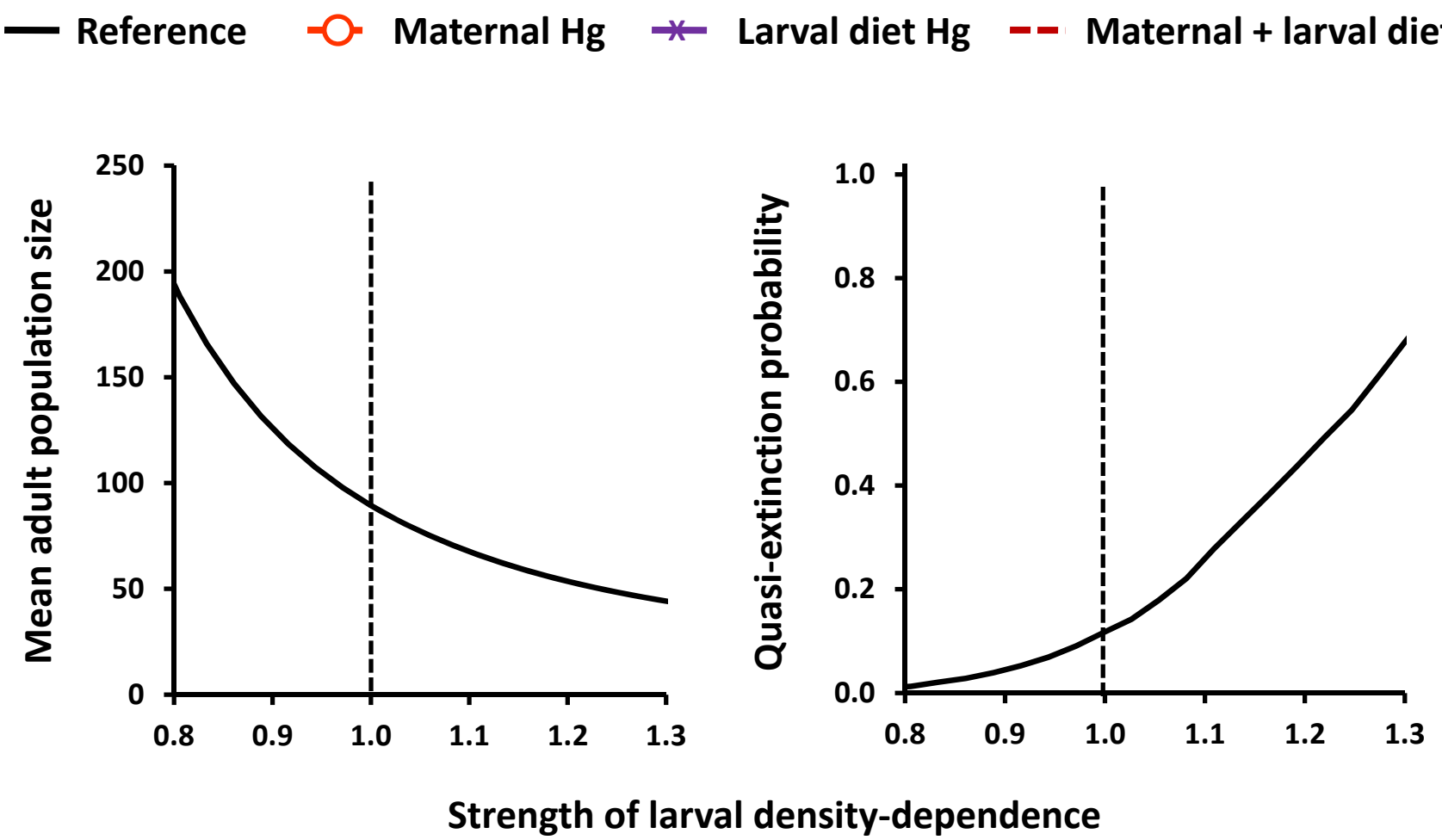
$\sigma_{E,L,M,J1,J2,A3,A}$ = survival (egg, larvae, metamorph, juvenile, adult)
f = clutch size
ϕ_{A3} = probability reproducing at age 3

$$L_t(A_t, A3_t, H_t) = \frac{(A_t + \phi_{A3} A3_t)(f\sigma_E)}{H_t}$$

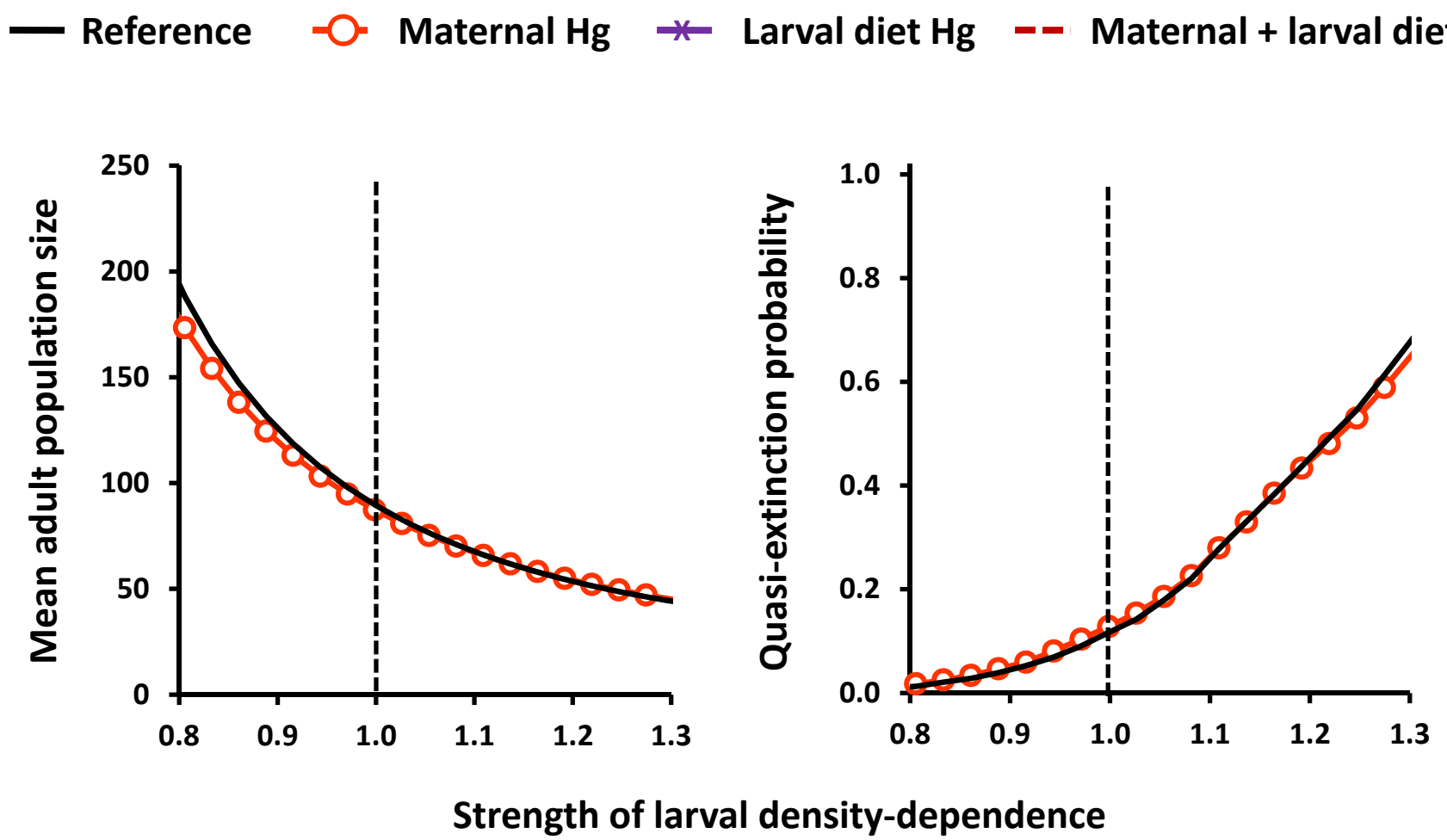
$$\sigma_{L,t}(L_t) = \frac{\sigma_{L\max}}{(1 + dL_t)^{\gamma}}$$

H = size of breeding habitat (m of shoreline)
L = # of larvae per m of shoreline
σ_{Lmax} = maximum larval survival at low density
γ = density dependence exponent
d = density dependence coefficient

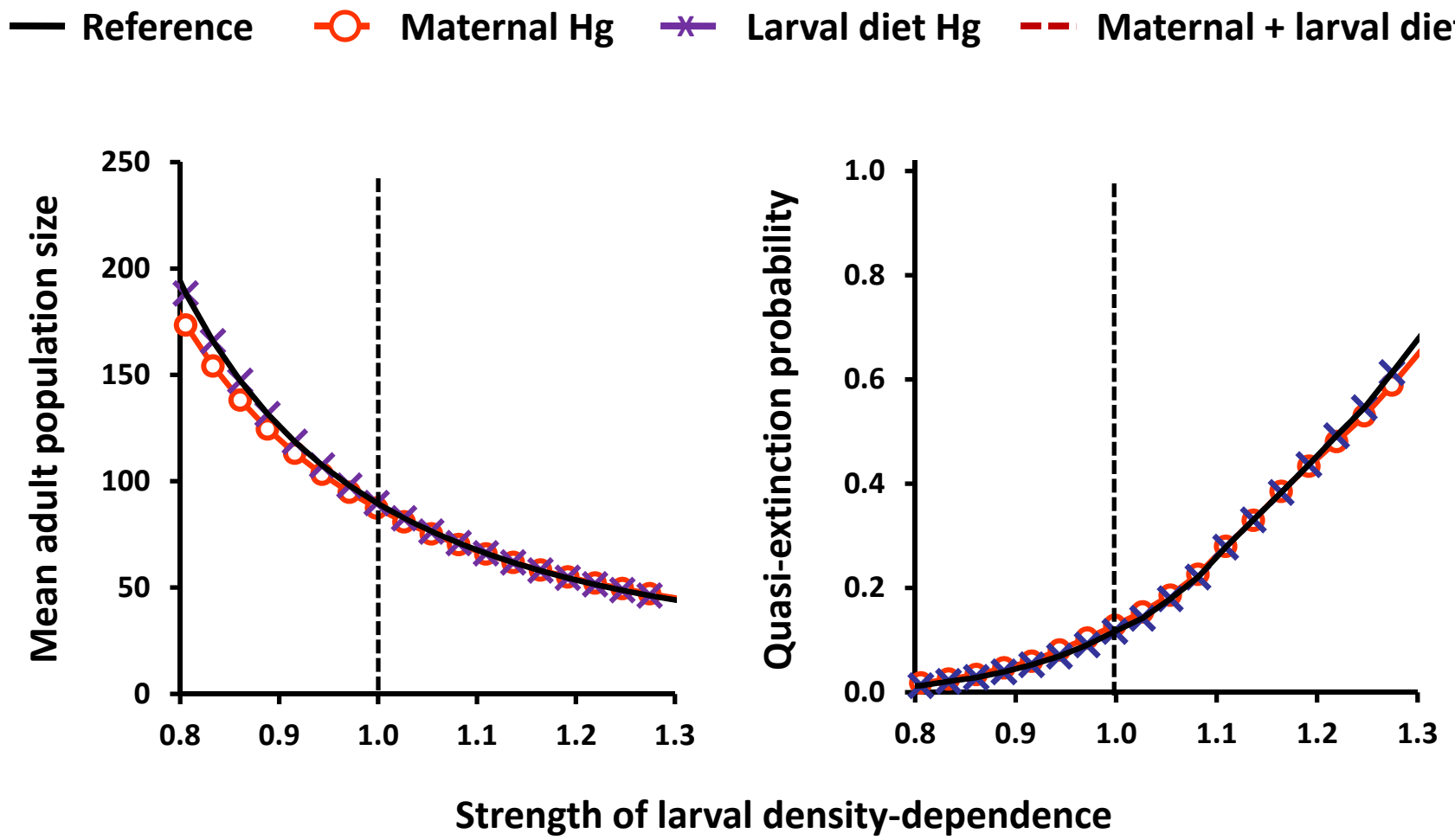
Results: Simulation Analyses



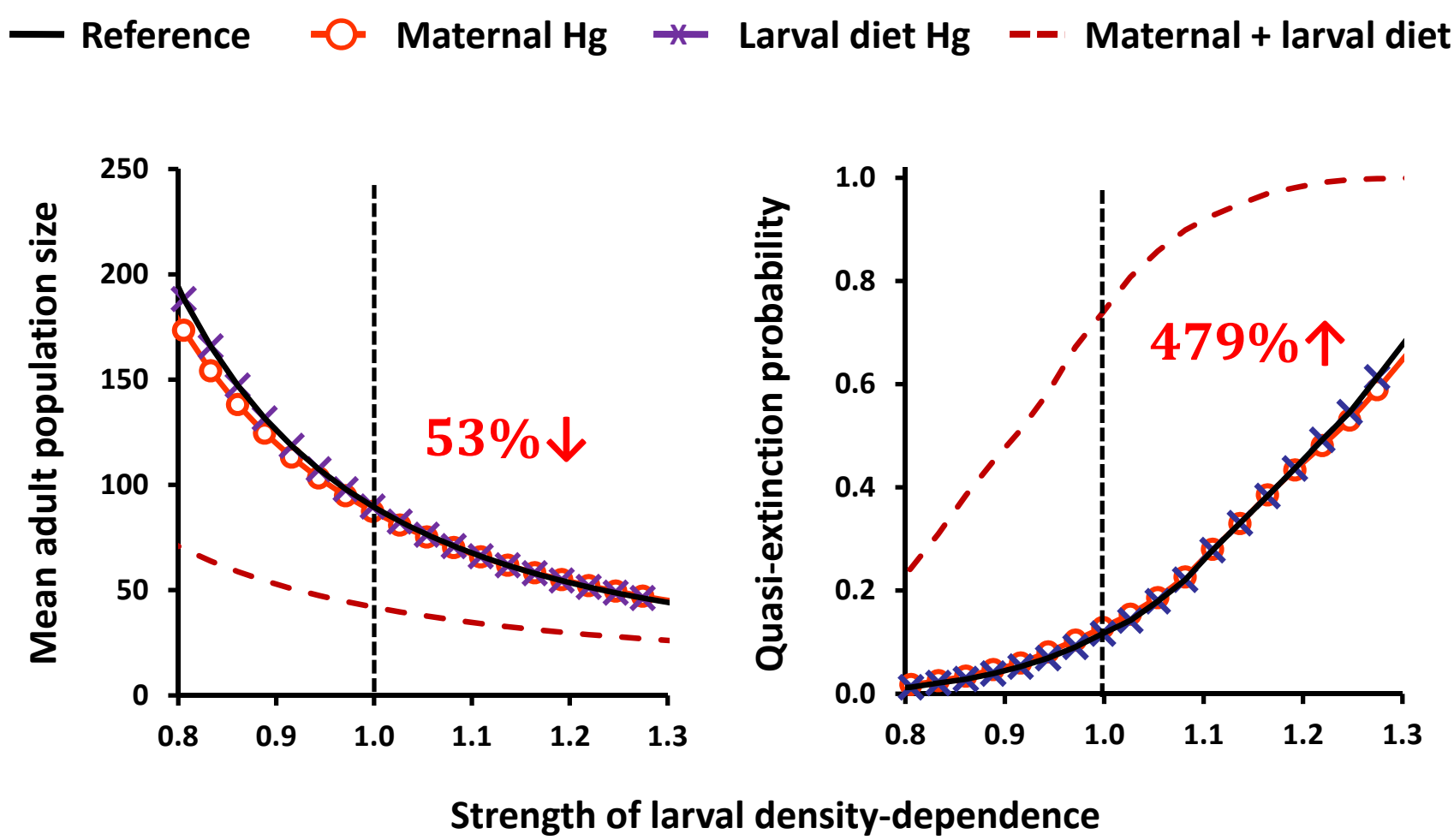
Results: Simulation Analyses



Results: Simulation Analyses



Results: Simulation Analyses



Conclusions

- **Embryonic effects and delayed maturity have minor population-level effects**

- **Late-larval and post-metamorphic effects have serious consequences**

- **<u>Maternal and dietary Hg *alone*</u>**

  minor effects on population dynamics

- **<u>Maternal and dietary Hg *together*</u>**

  ↓ adult density

  ↑ local extinction

The Path Forward: Implications for Restoration

- **Larval stage is a good target for restoration**

- **Reduce Hg exposure through larval diet**

- **Residual maternal effects have minor effects on abundance or extinction rate**

The Path Forward:
Landscape Scale Dynamics

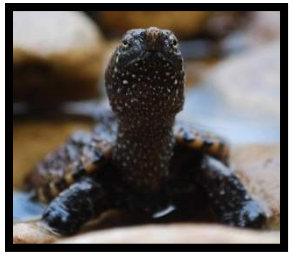
2010- ‘11 Research Objectives

Bioaccumulation & Non-destructive Techniques

Current Exposure & Food Web Models

Blood/Nail

Eggs

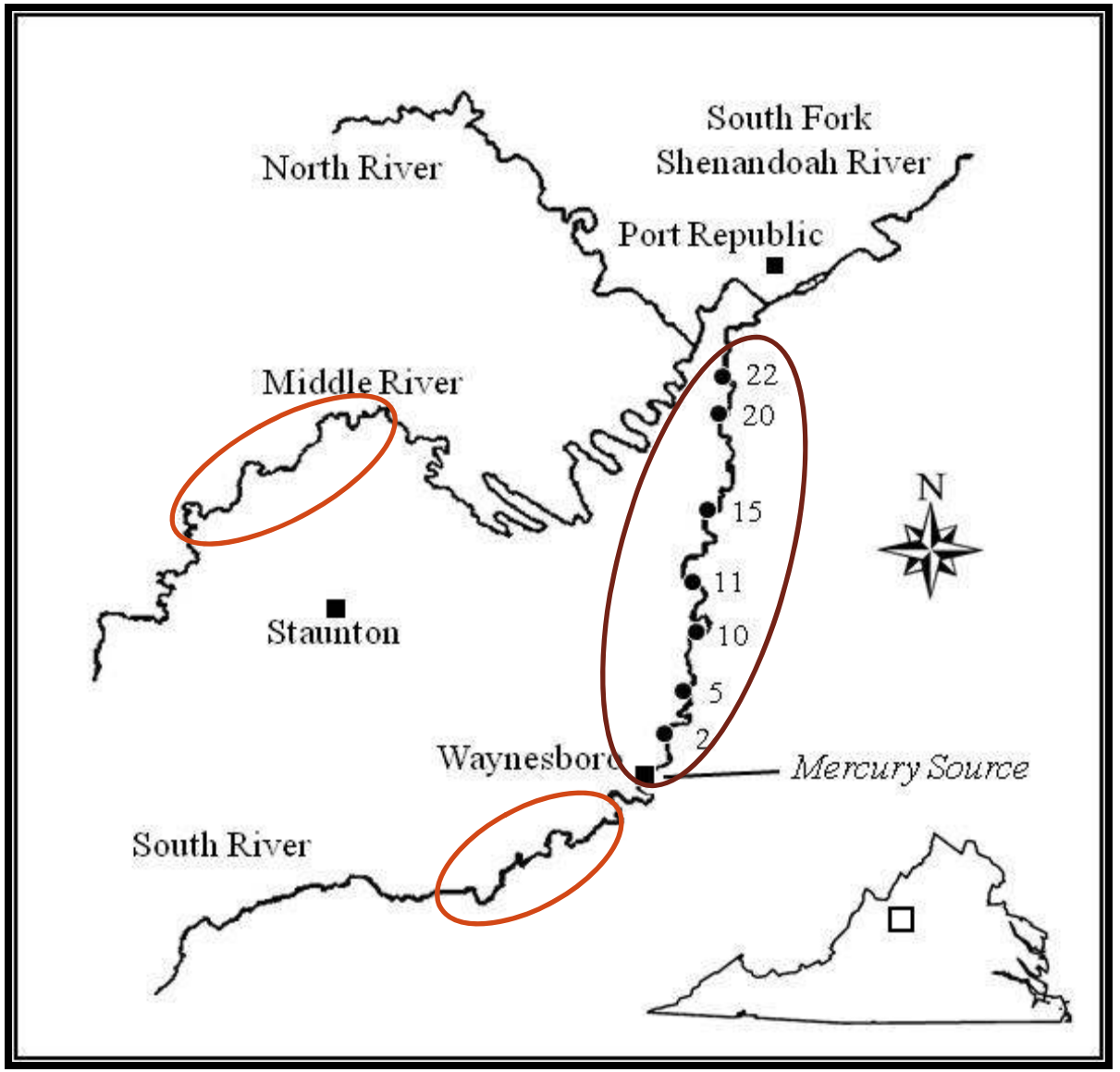


Reproductive Effects & Eco-risk

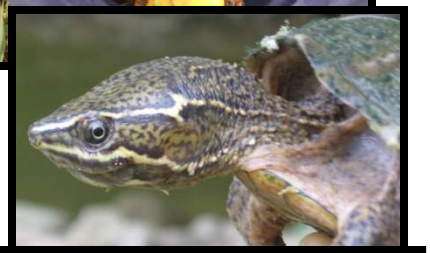
Muscle

Human Risk Assessment & Eco-risk

2010- ‘11 Sampling Sites



Total Captures (2010- ‘11)



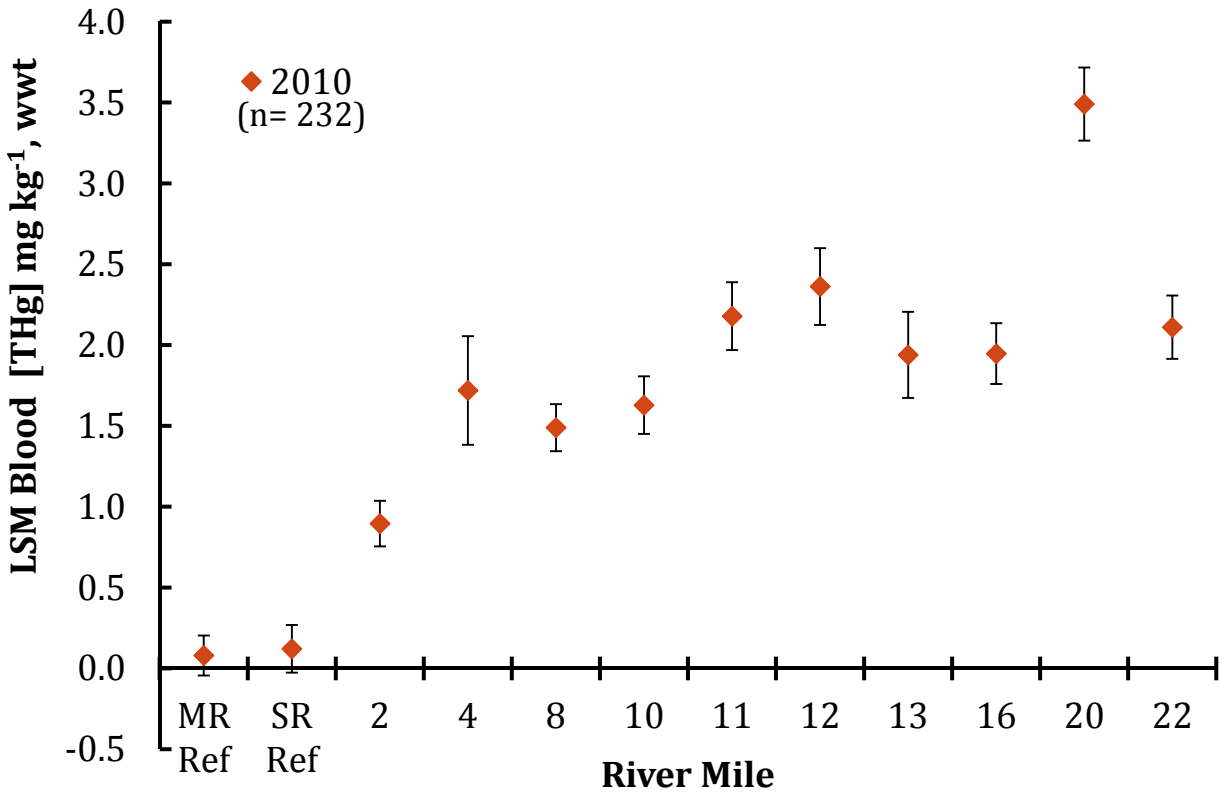
	Female	Gravid	Eggs
728 →	324	98	2,579
847 →	360	96	644
385 →	162	76	298
161 →	64	13	123

‘10-‘11 Marked **1,748** + ‘06 Marked **552** + Marked Hatchlings **~1,200** = **~3,500**

Current Exposure

Current Exposure in Adult Snapping Turtles

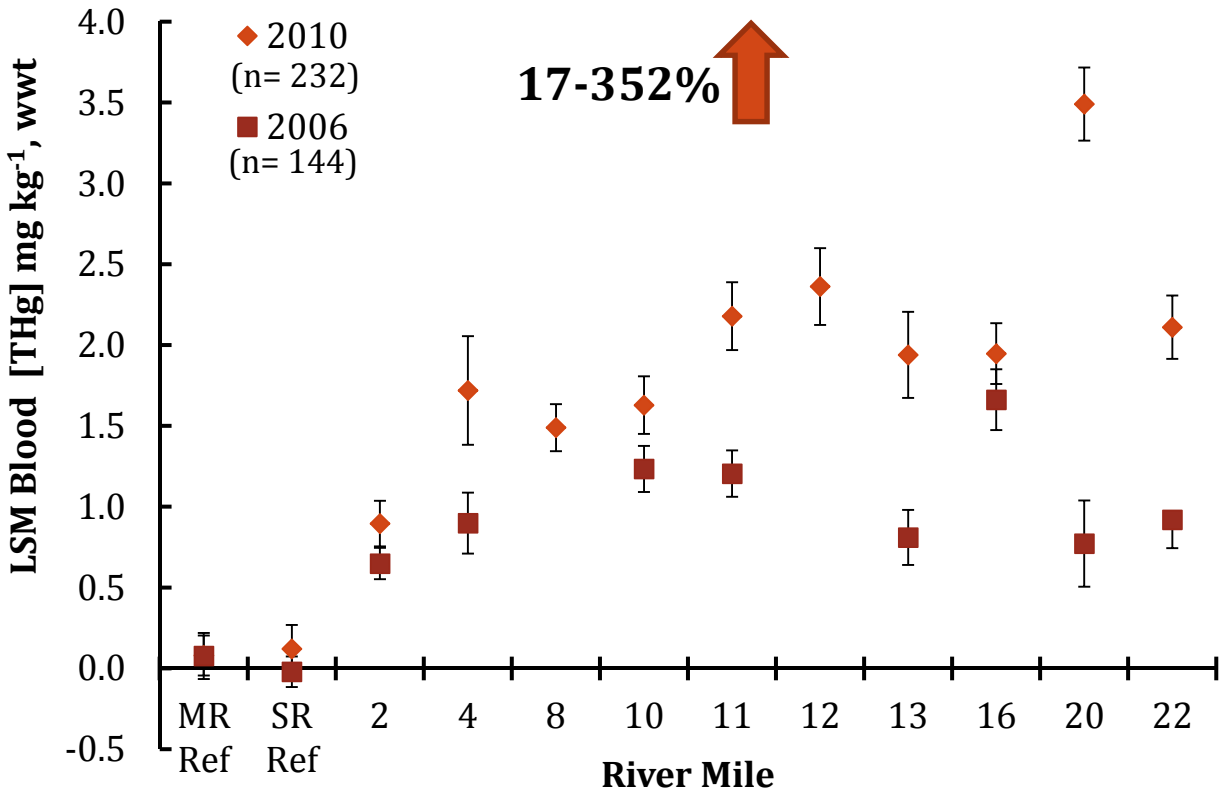
Blood



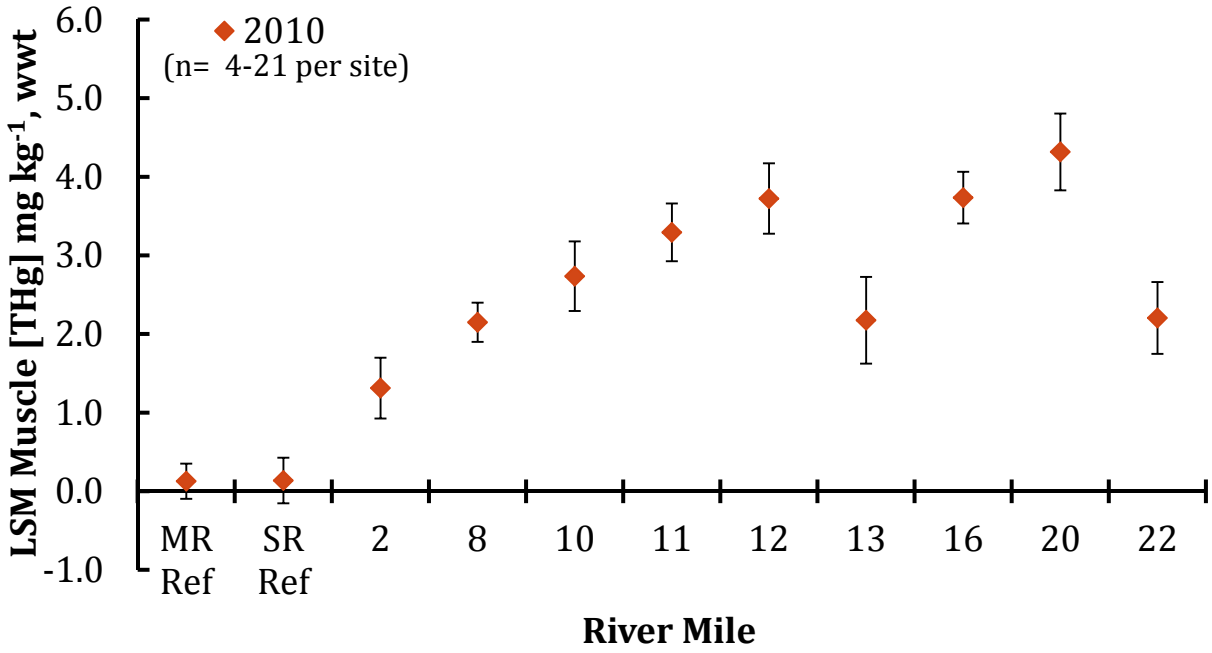
Current Exposure

Current Exposure in Adult Snapping Turtles

Blood



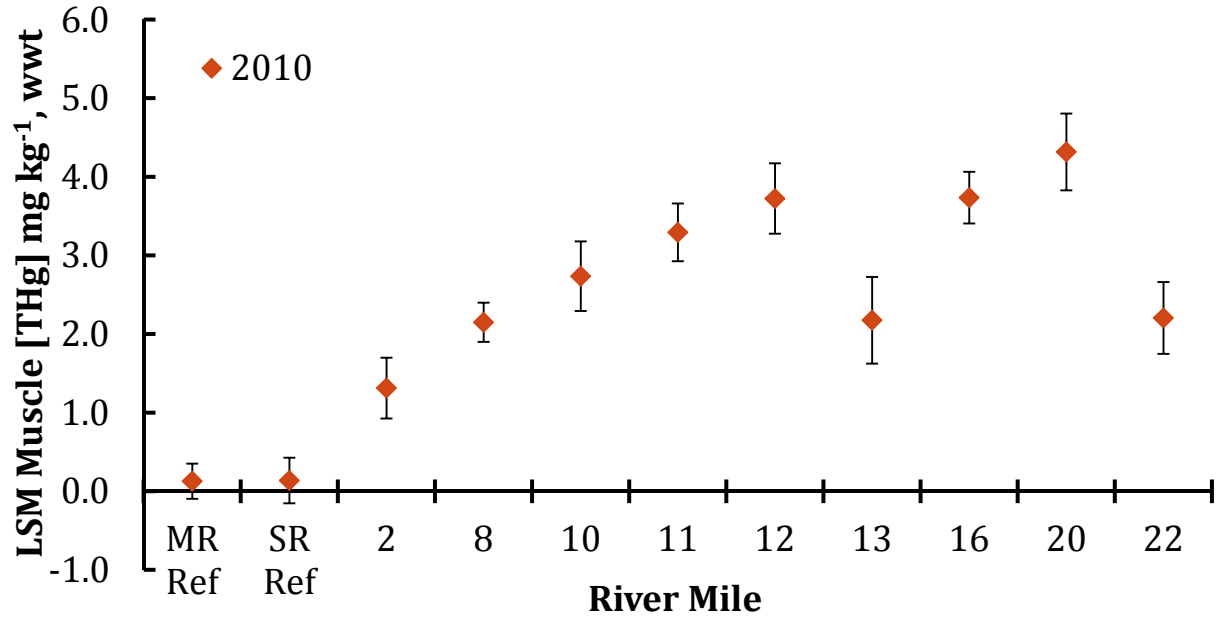
Spatial Patterns in Bioaccumulation

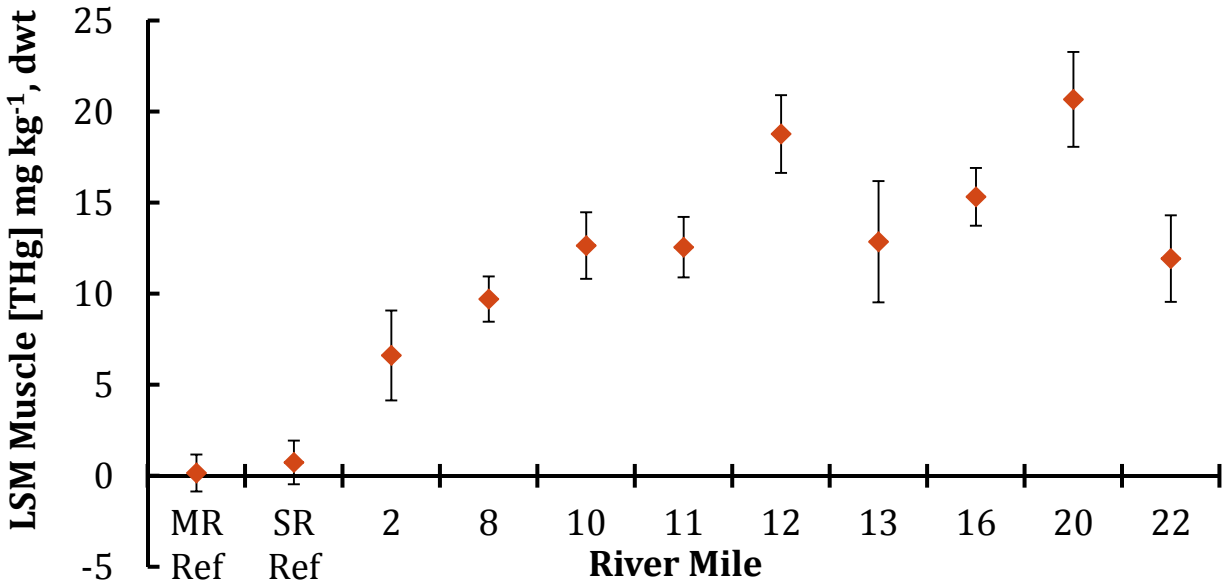


Muscle

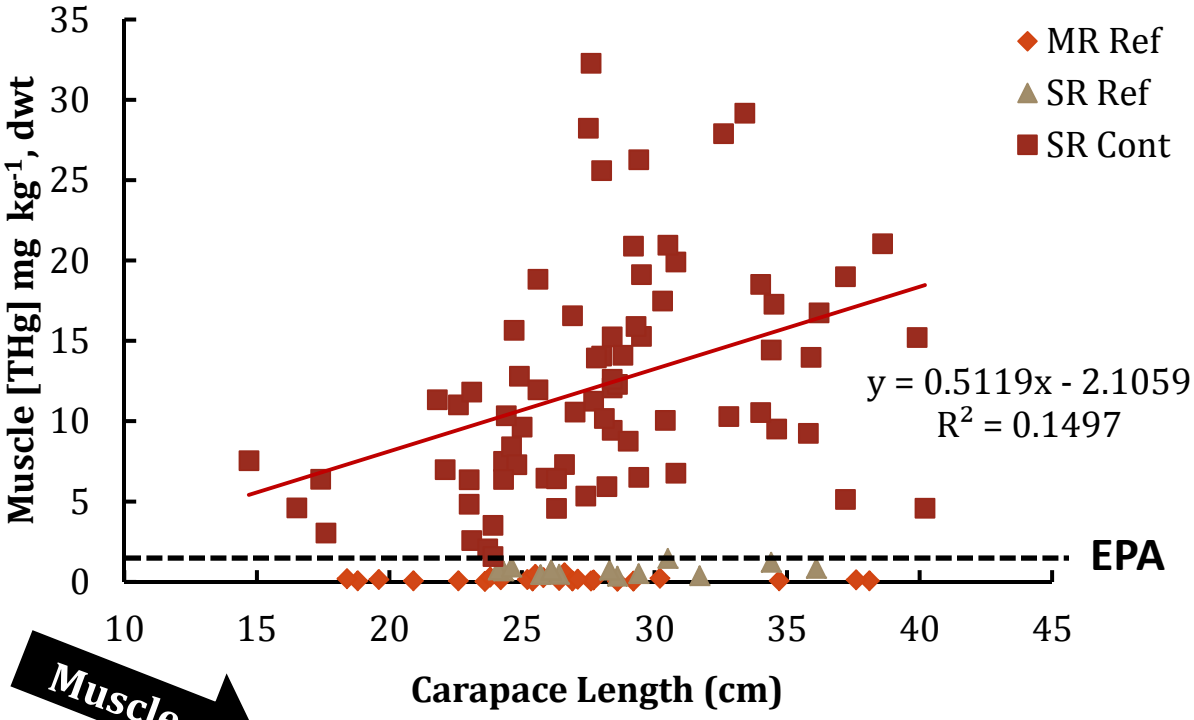
Adult Bioaccumulation & Human Exposure?

Spatial Patterns in Bioaccumulation





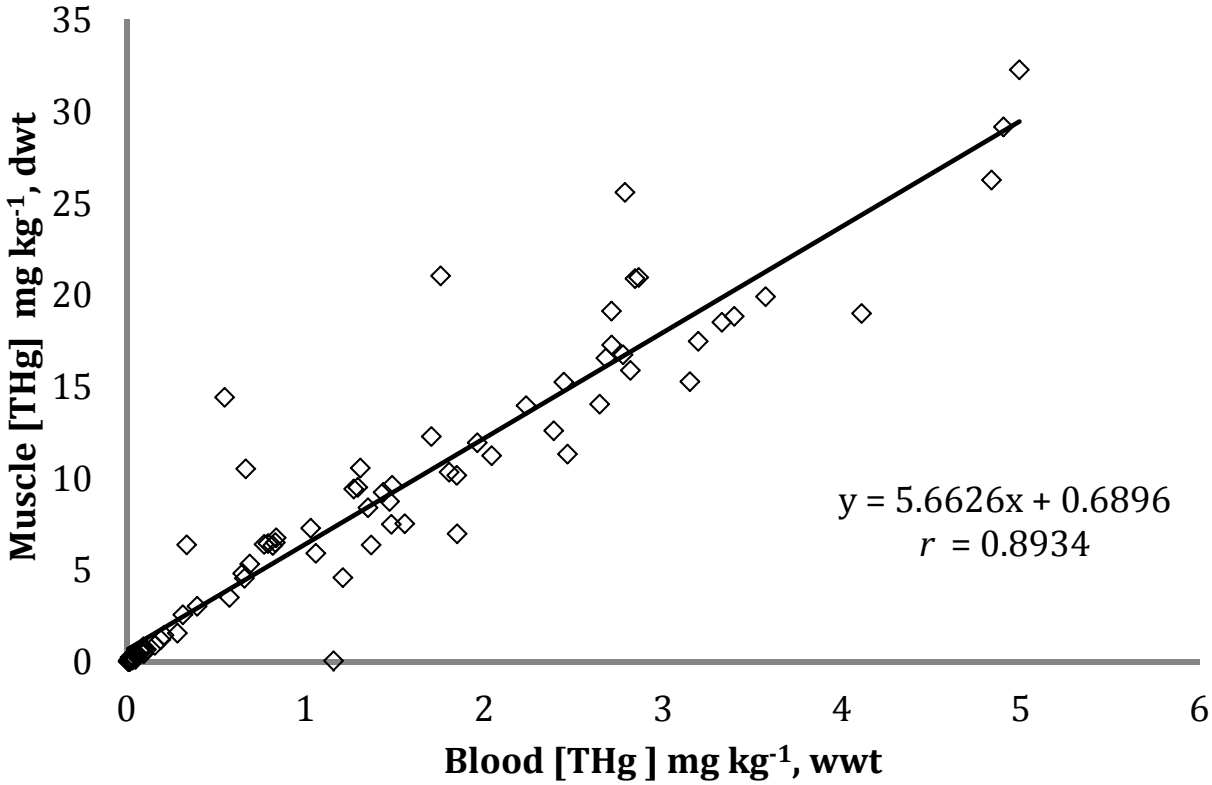
Demographic Patterns in Bioaccumulation



Muscle

Human Exposure?

Non-destructive Sampling



Blood serves as great non-destructive parameter for monitoring accumulation!

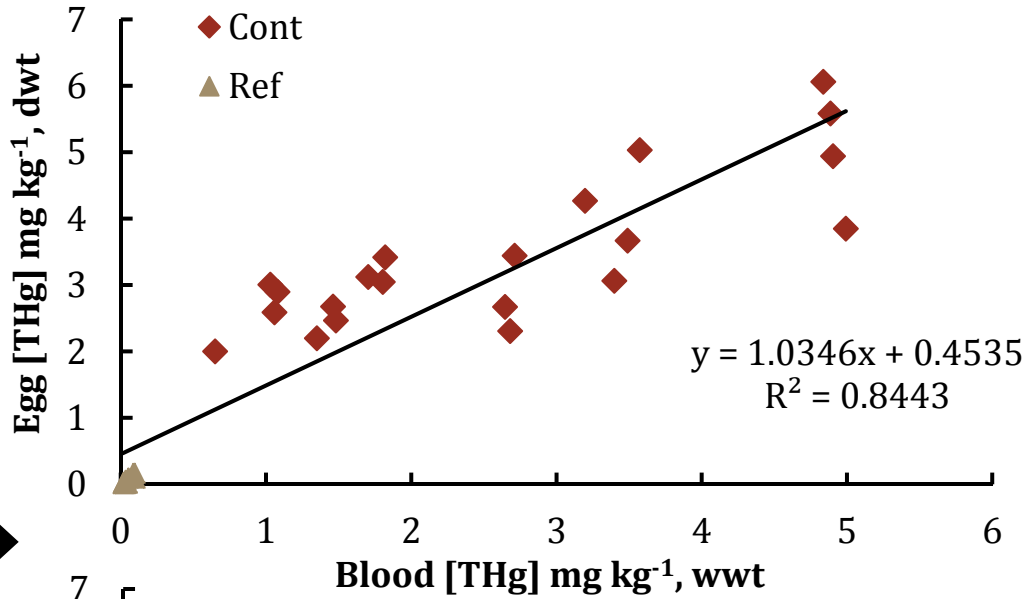
Maternal Transfer

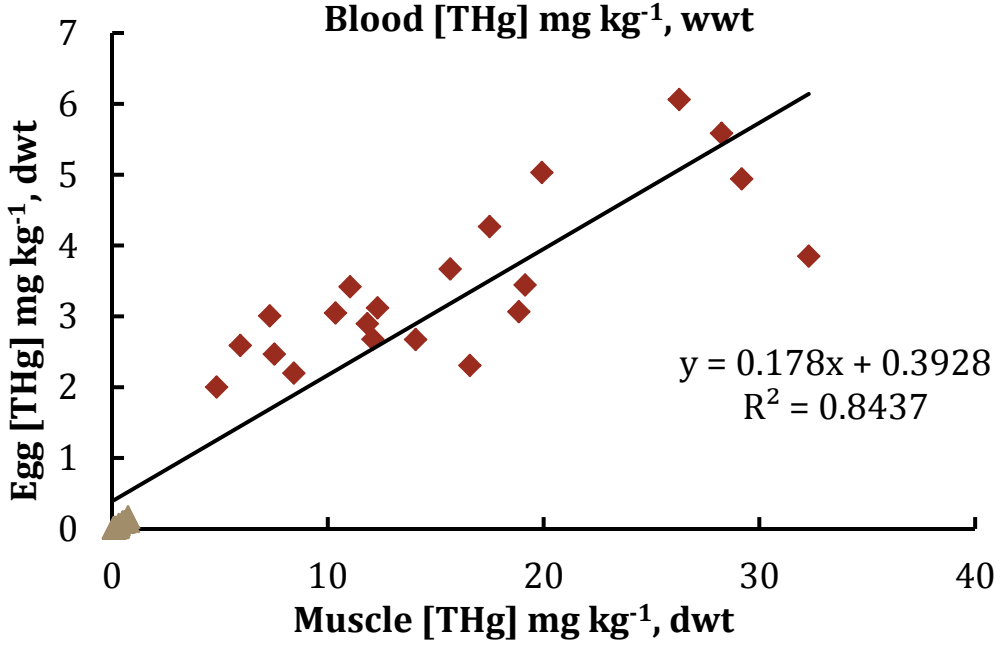
Eggs

Embryo Exposure
Predator Exposure

Maternal Transfer

Eggs





Research Objectives in Progress

Eggs

Embryo Exposure

Relationships between Hg & Hatching Success, Malformation Rates, & Overwintering Survival??

Biomonitoring

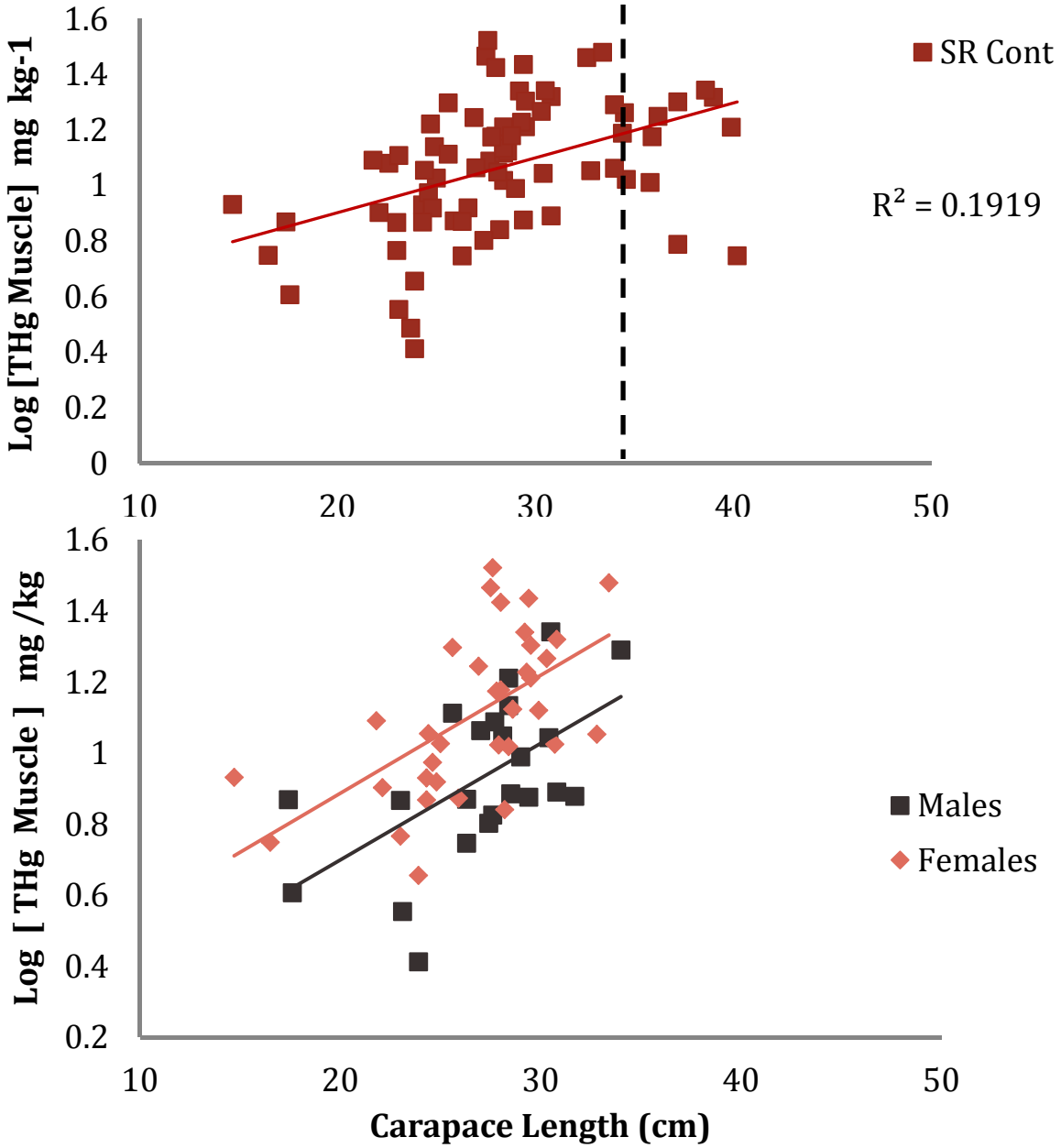
- **Human Health**
  - Aid in assessing risk

- **Wildlife Health**
  - Implications for predatory wildlife

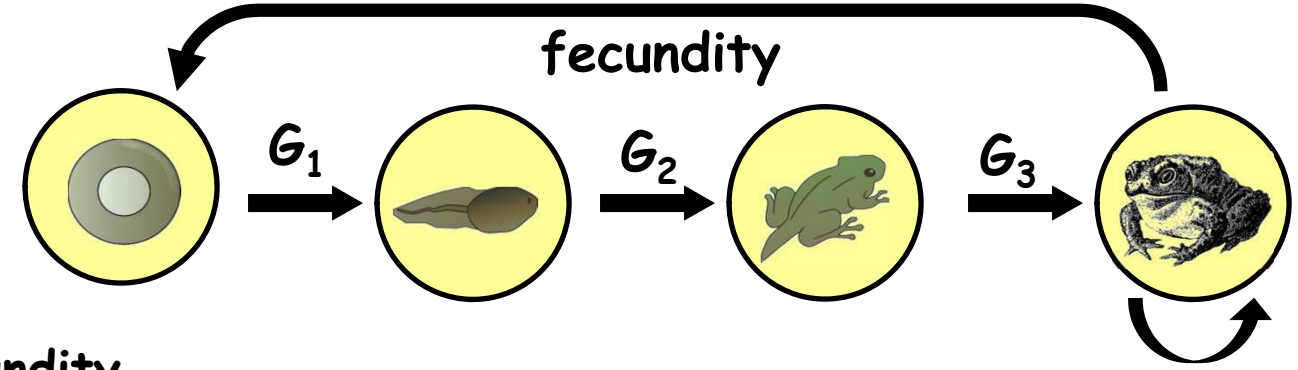
- **Turtle Health**
  - Current exposure
  - Reproductive effects

Riverfest 2011

Muscle Bioaccumulation



Individual-Level Effects

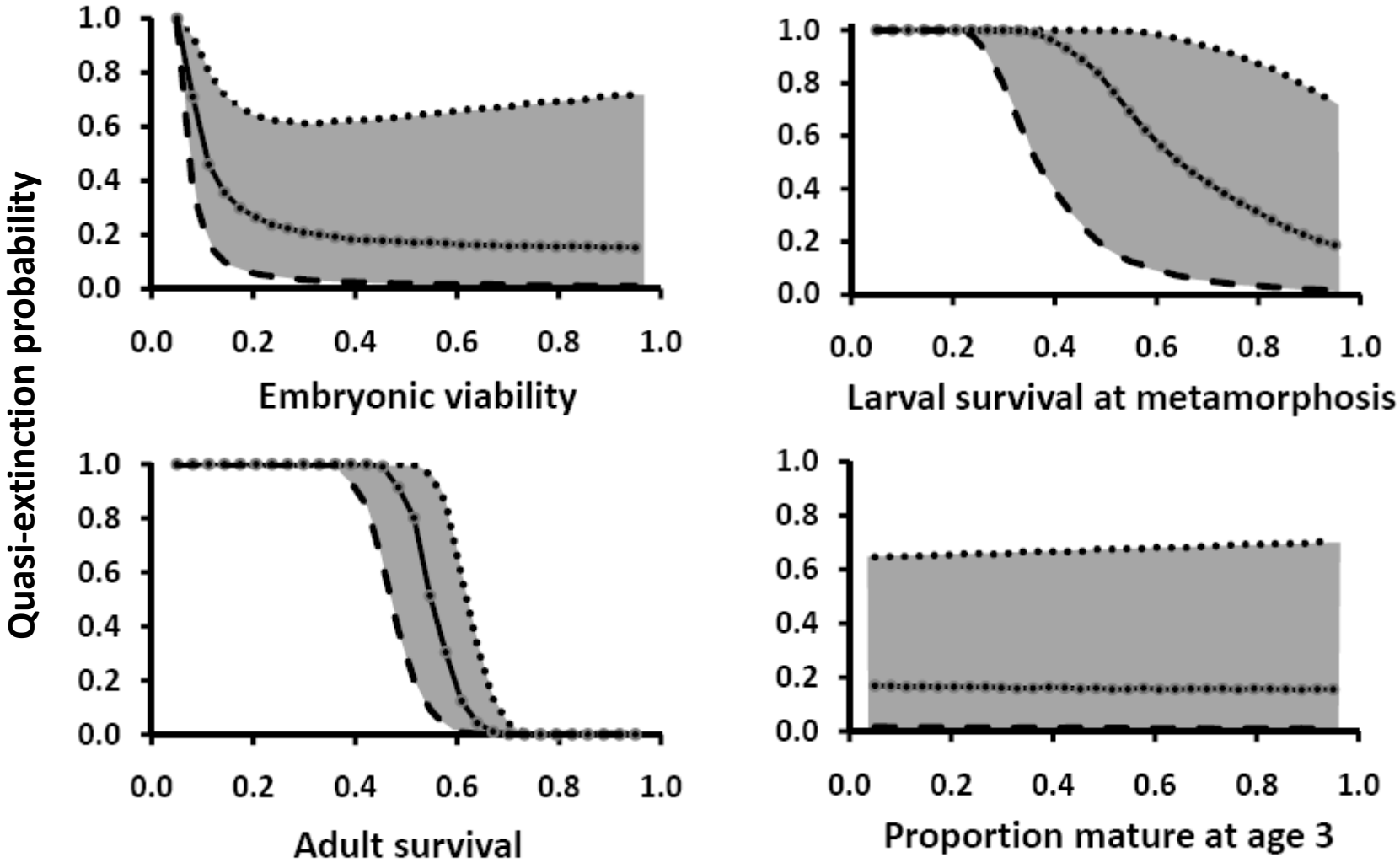


- No effects on fecundity
- Dietary Hg alone = minor growth effects
- Maternal Hg alone = growth effects = delayed maturity
- Maternal + Diet Hg + limited food = ↓50% larval survival

	Clutch Size	Embryonic Viability	Larval Growth	Larval Survival	Juvenile Survival	Juvenile Growth
Maternal	NE	-4% to -39% (annual variation)	-18% (ample food)	+16% to -17% (annual variation)	NE	-8%
Larval Diet	NA	NA	-26% (limited food)	NE	NE	NE
Maternal + Larval Diet	NE	-4% to -39% (annual variation)	-20% to -27% (food-dependent)	-50% (limited food)	NE	-8%

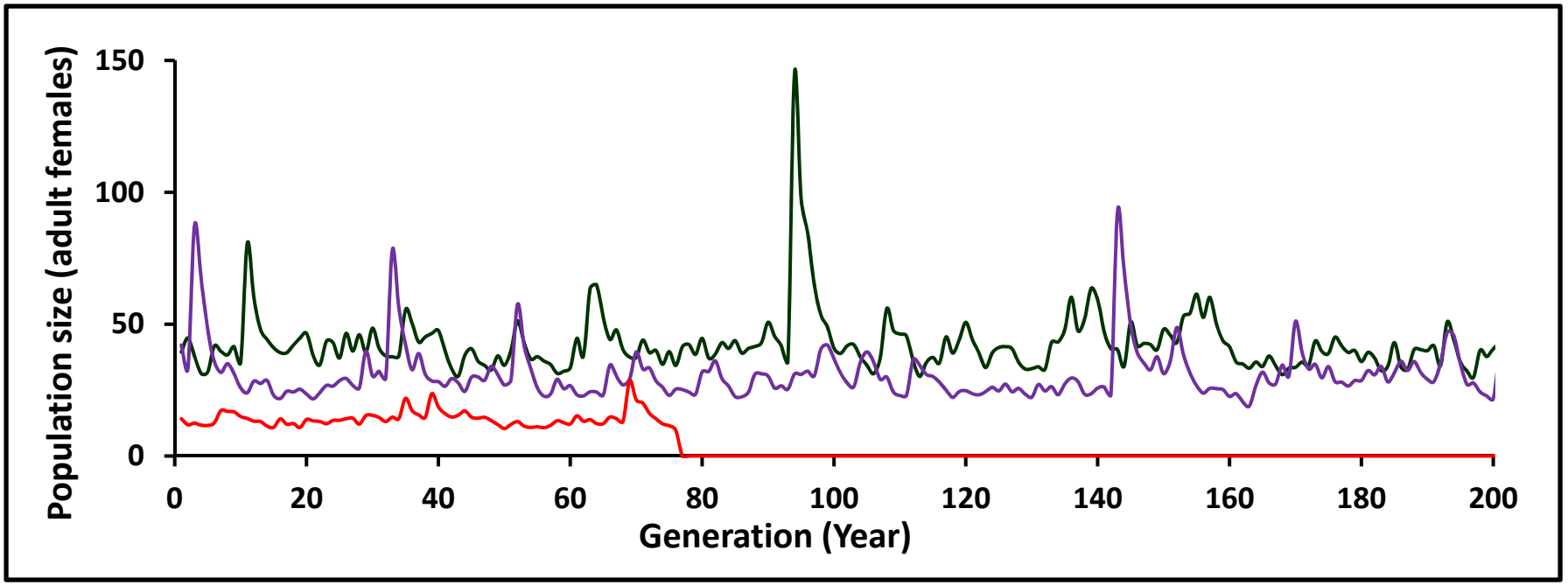
NE = no significant effect; NA = not a valid exposure route

Results: Model Sensitivity

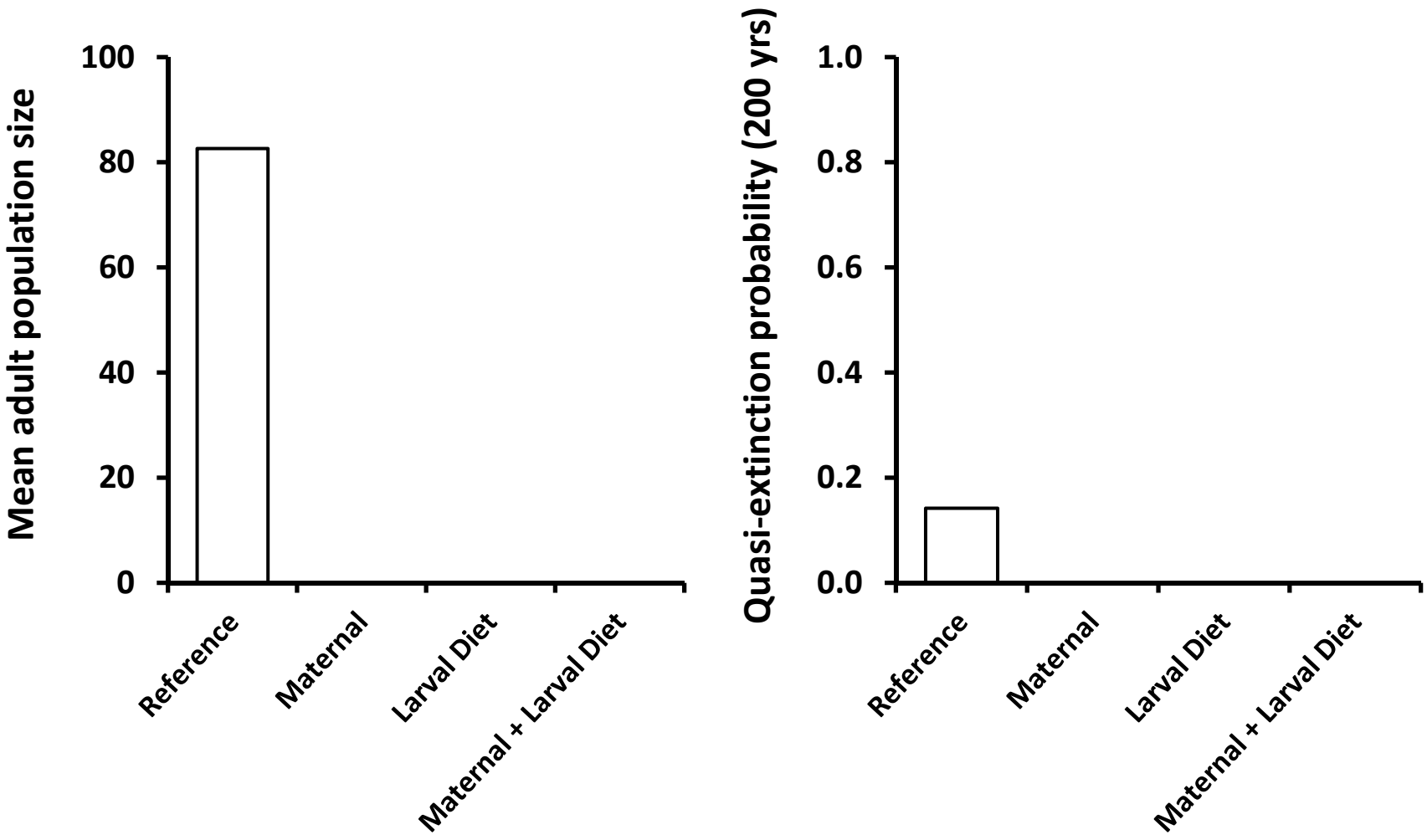


Simulation Analyses

$$\begin{bmatrix} J1 \\ J2 \\ A3 \\ A \end{bmatrix}_{t+1} = \begin{bmatrix} 0 & 0 & (\phi_{A3} f\sigma_E)(\sigma_{L,t})(\sigma_M) & (f\sigma_E)(\sigma_{L,t})(\sigma_M) \\ \sigma_{J2} & 0 & 0 & 0 \\ 0 & \sigma_{J3} & 0 & 0 \\ 0 & 0 & \sigma_{A3} & \sigma_A \end{bmatrix} \times \begin{bmatrix} J1 \\ J2 \\ A3 \\ A \end{bmatrix}_t$$



Results: Simulation Analyses



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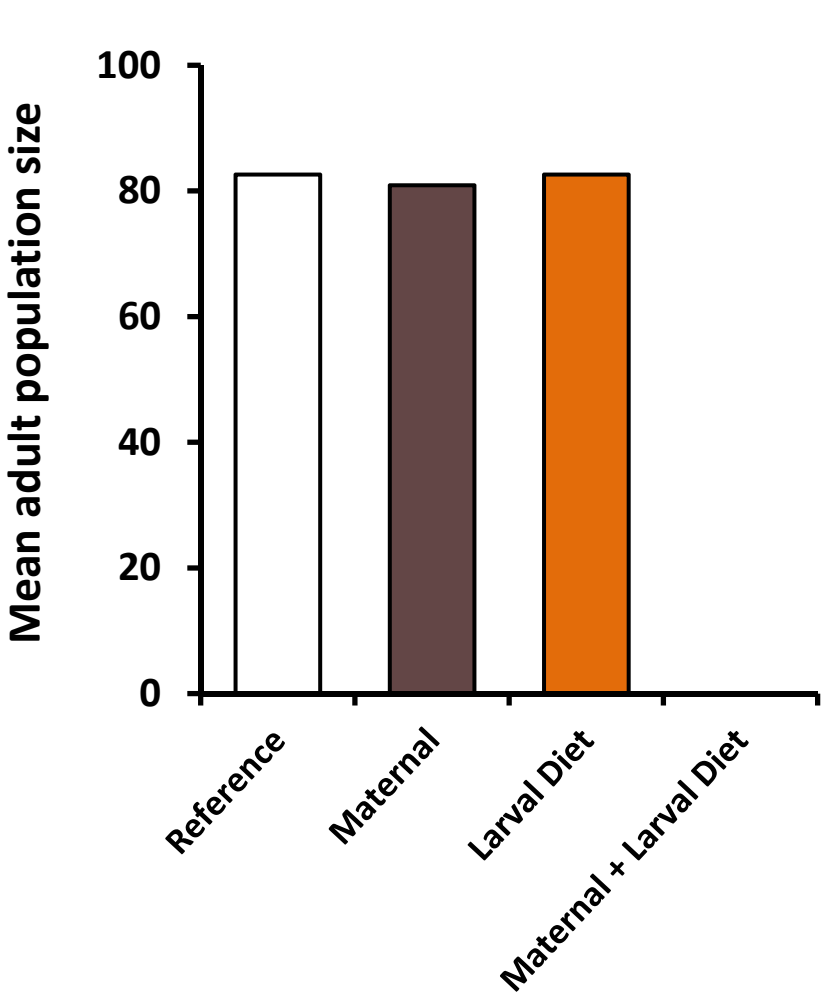

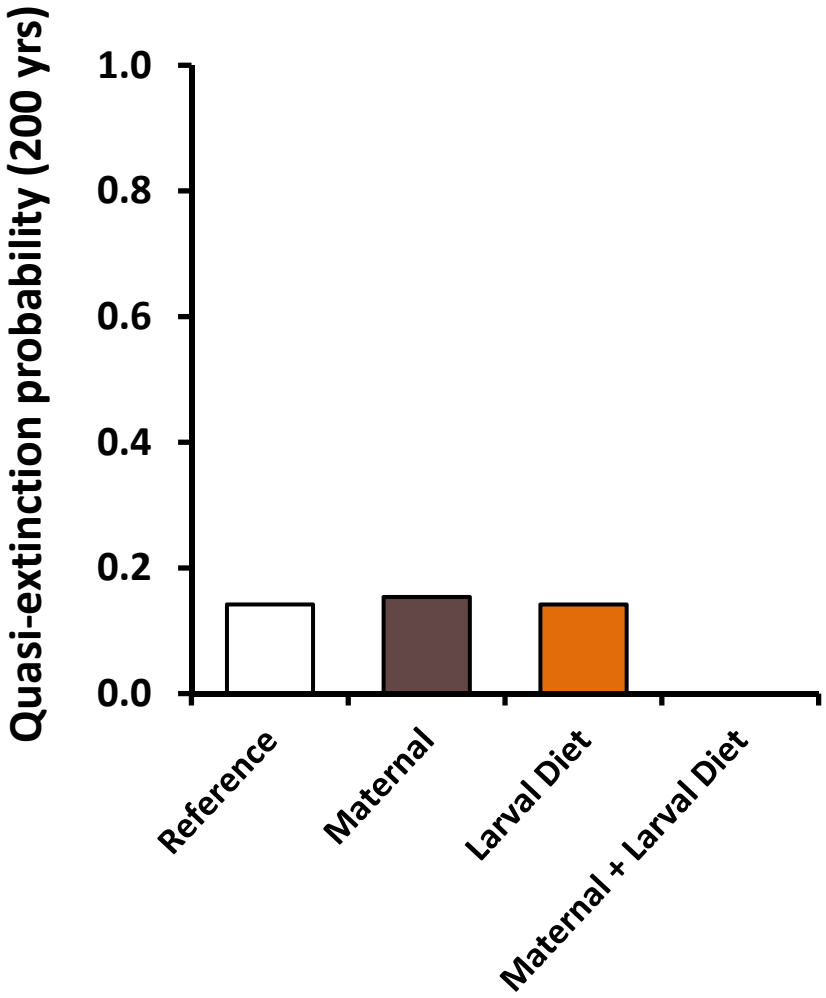

Results: Simulation Analyses