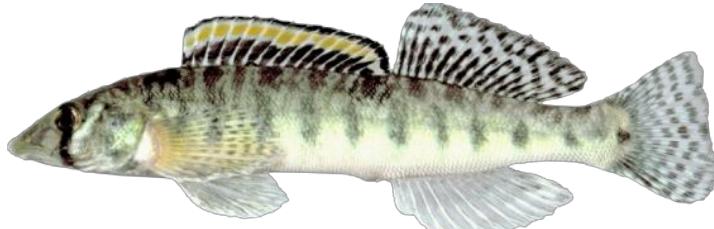
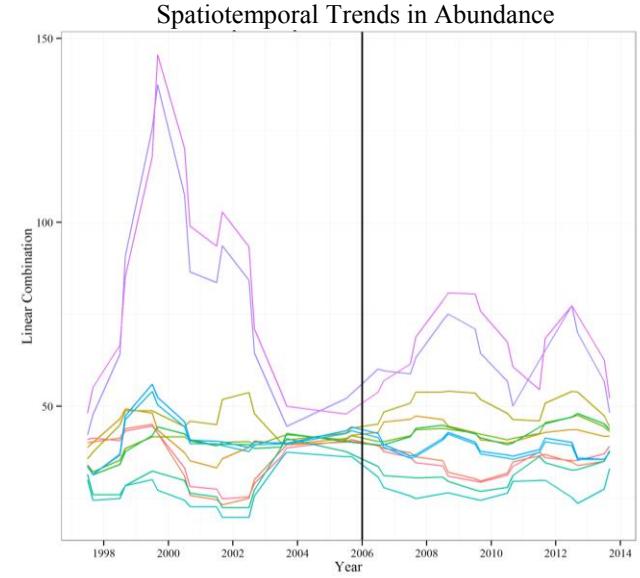
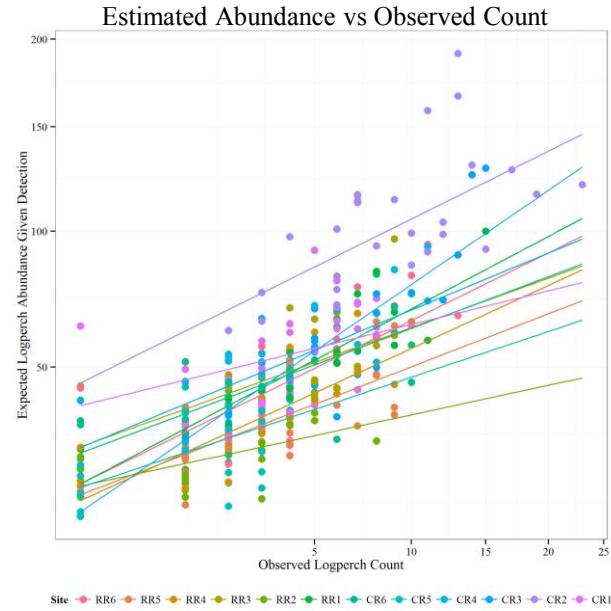
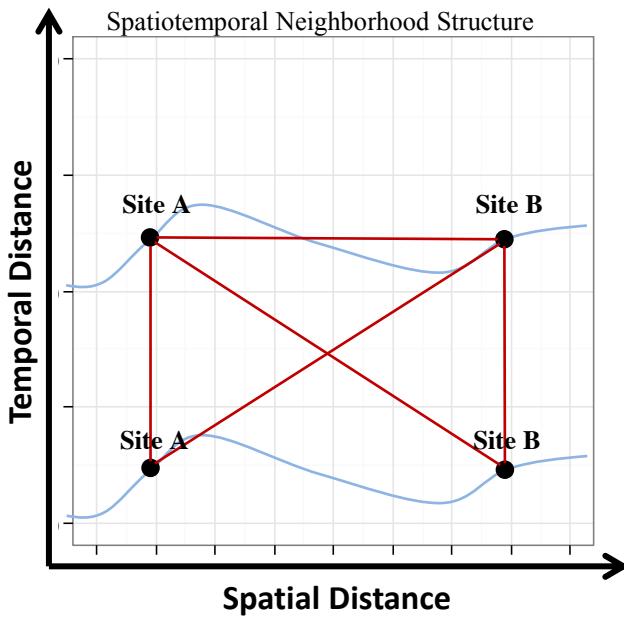


# ACCOUNTING FOR IMPERFECT DETECTION AND SPATIOTEMPORAL AUTOCORRELATION IN A BACI DESIGN TO MONITOR THE FEDERALLY ENDANGERED ROANOKE LOGPERCH

Gregory B. Anderson, James H. Roberts, and Paul L. Angermeier



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Site: RR6 (pink), RR5 (orange), RR4 (yellow), RR3 (green), RR2 (light green), RR1 (lightest green), CR6 (teal), CR5 (dark teal), CR4 (blue), CR3 (light blue), CR2 (purple), CR1 (lavender)



# ASSESSING EFFECTS OF ENVIRONMENTAL PERTURBATIONS

- Managers are often forced to make decisions regarding impacts of projects
- Assessment of environmental effects is difficult
  - Requires knowledge on the species of concern:
    - Time and duration of life cycle processes
    - Background levels of population dynamics and demography
    - Habitat requirements
  - Requires population monitoring
- Even with this information... assessment can have uncertainty
  - Do our observations reflect the true population dynamics?
  - Are we able to diagnose impacts correctly?

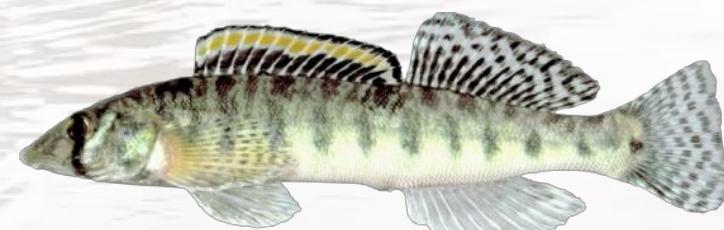


# ROANOKE RIVER FLOOD REDUCTION PROJECT (RRFRP)

- Upper Roanoke River has a history of flooding
  - Most devastating flood was in 1985
    - 10 human lives lost
    - Cost Roanoke-Salem ~\$440 million
- To mitigate future floods USACE instigated the RRFRP
  - Suite of channel and floodplain modifications
- Reach of river contains the endangered Roanoke logperch
- Incidental take permit required monitoring
  - Take cannot exceed 25% of pre-construction size



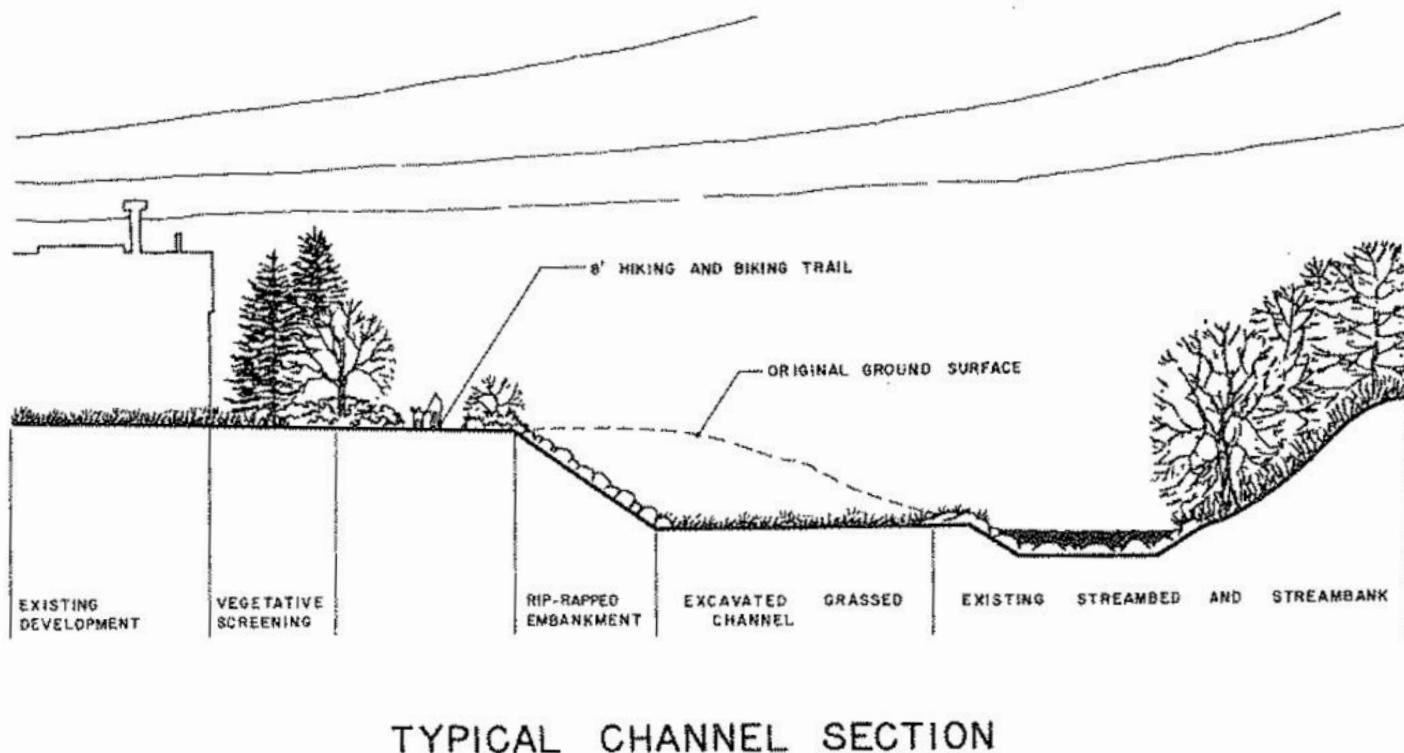
© Tommy Firebaugh



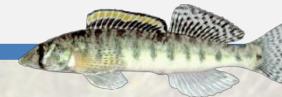
Roanoke logperch (*Percina rex*)  
© Noel Burkhead



# ROANOKE RIVER FLOOD REDUCTION PROJECT (RRFRP)



**Figure 9.4** Bench Channel Method of Improving Capacity of Stream. Source: U.S. Army Corps of Engineers (1984).

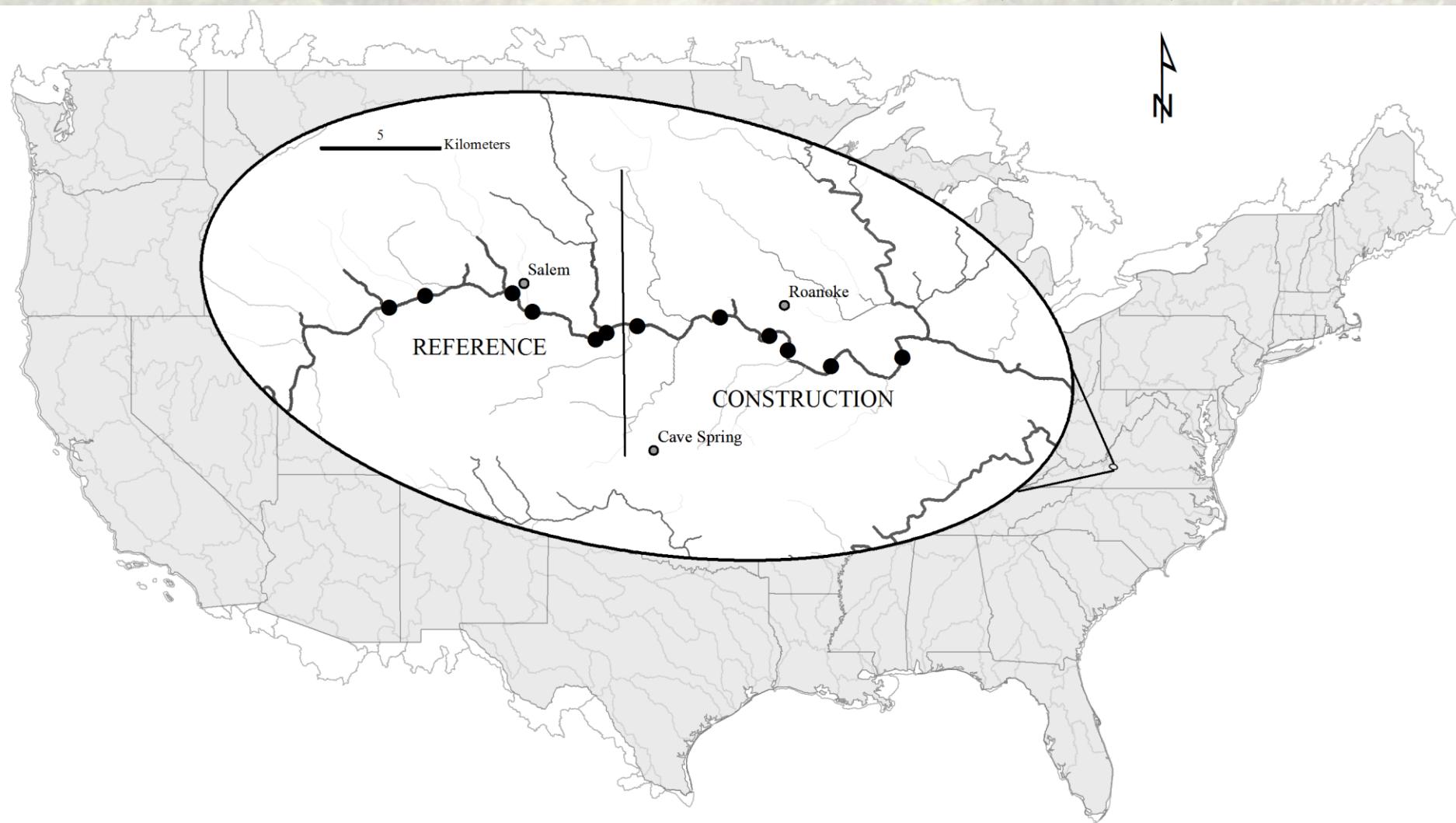


# ROANOKE RIVER FLOOD REDUCTION PROJECT (RRFRP)

- Population monitoring conducted for 17 years
- Samples collected under a Before-After-Control-Impact Design
  - 12 sites
    - 6 reference (control) upstream of construction
    - 6 construction (impact)
  - Sites sampled pre (1997-2003), during (2005-2011), and post construction (2012-onward)
    - Samples taken 2x a year (summer and fall)



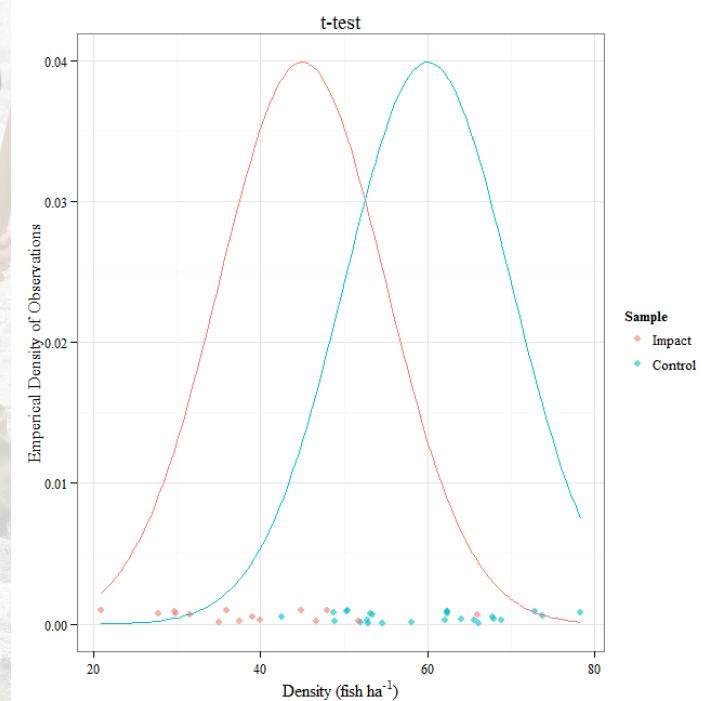
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  - Sites sampled pre (1997-2003), during (2005-2011), and post construction (2012-onward)
    - Samples taken 2x a year (summer and fall)
- Impacts were assessed using a one-tailed t-test
  - Population counts converted to density and average across reaches
  - Difference in reach means test
  - Seasons assessed independently





# IMPACT DETECTION

- In 2011, we detected a significant impact
  - Impact found only in fall samples
    - 22.4 (impact) vs. 34.7 (control) fish  $\text{ha}^{-1}$
    - p-value=0.049
  - No significant difference in summer samples
- This ambiguity prompted us to ask two questions:
  - 1) Do our observations reflect true population dynamics of Roanoke logperch?
  - 2) Are we able to diagnose impacts of RRFRP correctly?



Roanoke River USACE Benchcuts (2005)



## DETECTION IN BACI ANALYSES

- Commonly known that not all individuals are captured during sampling

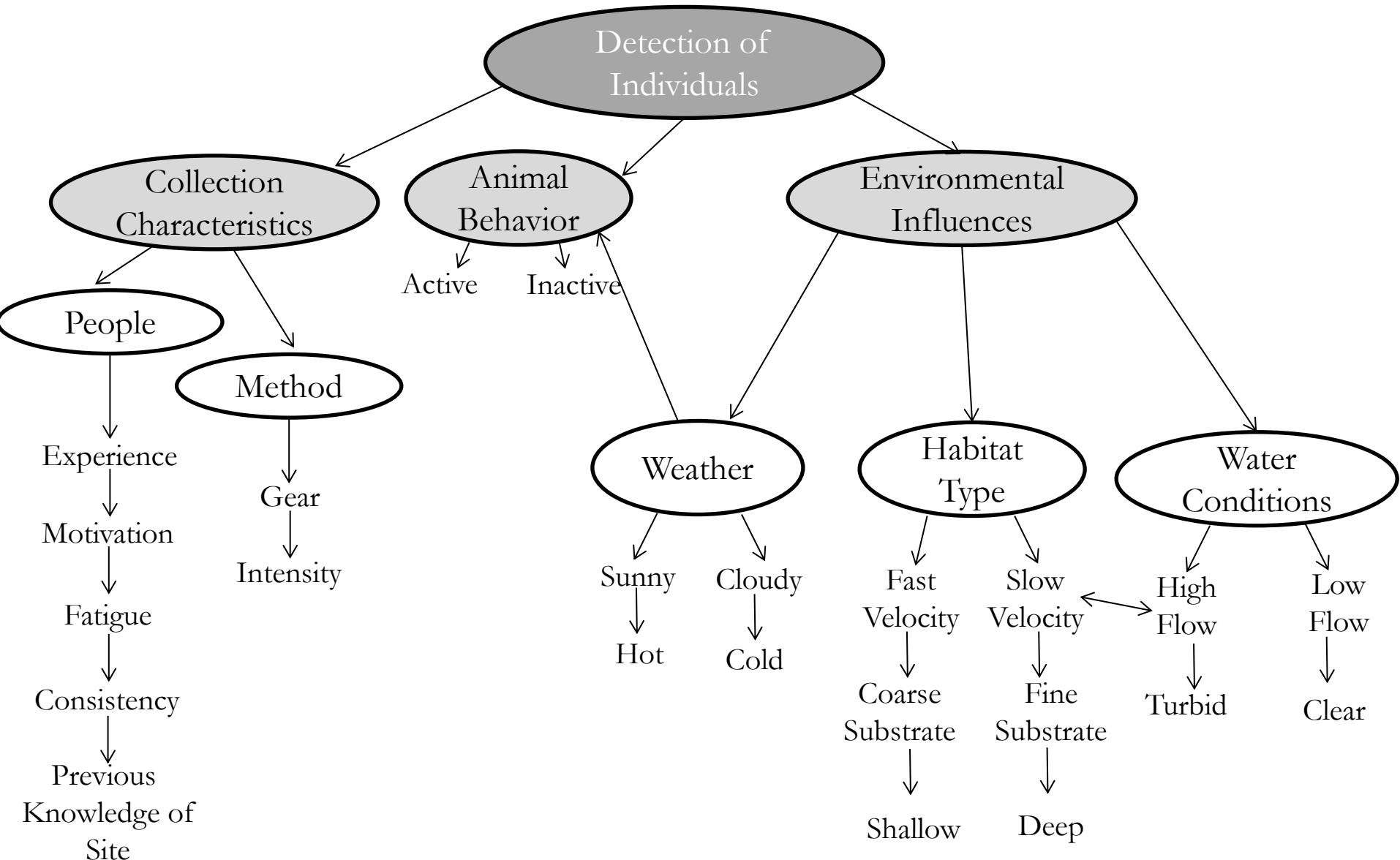
$$\text{Observed Count} = \frac{\text{True Abundance}}{\text{Detection Probability}}$$

- If detection is constant or random...observations provide a reliable index of abundance



# DETECTION IN BACI ANALYSES

- Commonly known that not all individuals are captured during sampling





## DETECTION IN BACI ANALYSES

- Commonly known that not all individuals are captured during sampling
- IF...these factors are not temporally and spatially consistent
  - Falsely accept/reject impact of project
  - Misinterpret size or shape of impact

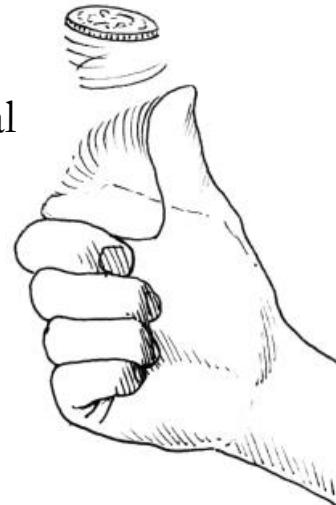


# DETECTION IN BACI ANALYSES

- We combat imperfect detection using  $N$ -mixture models
- Detection ( $p$ ) and true abundance ( $N$ ) are treated as two random variables
  - Coupled in paired generalized linear models

Observed Count  $\sim \text{Binomial}(N, p)$

A coin toss  
is a binomial  
random  
variable!



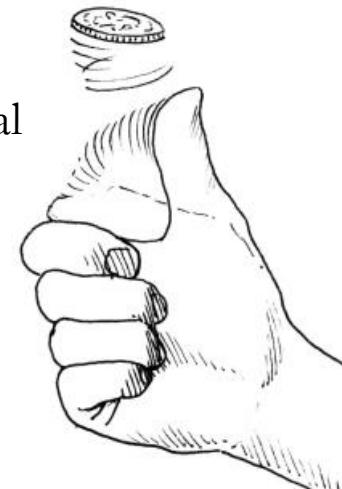


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A coin toss  
is a binomial  
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variable!



- $N$  is unobservable, but we can predict  $N$  by:
  - Specifying a distribution on  $N$  (e.g., Poisson, Negative Binomial)
  - Modeling both the mean of the distribution of  $N$  ( $\mu$ ) and  $p$  through linear regression

$$N \sim \text{Negative Binomial}(\mu, \alpha)$$

$$\log(\mu) = X\gamma$$

$$\text{logit}(p) = V\beta$$



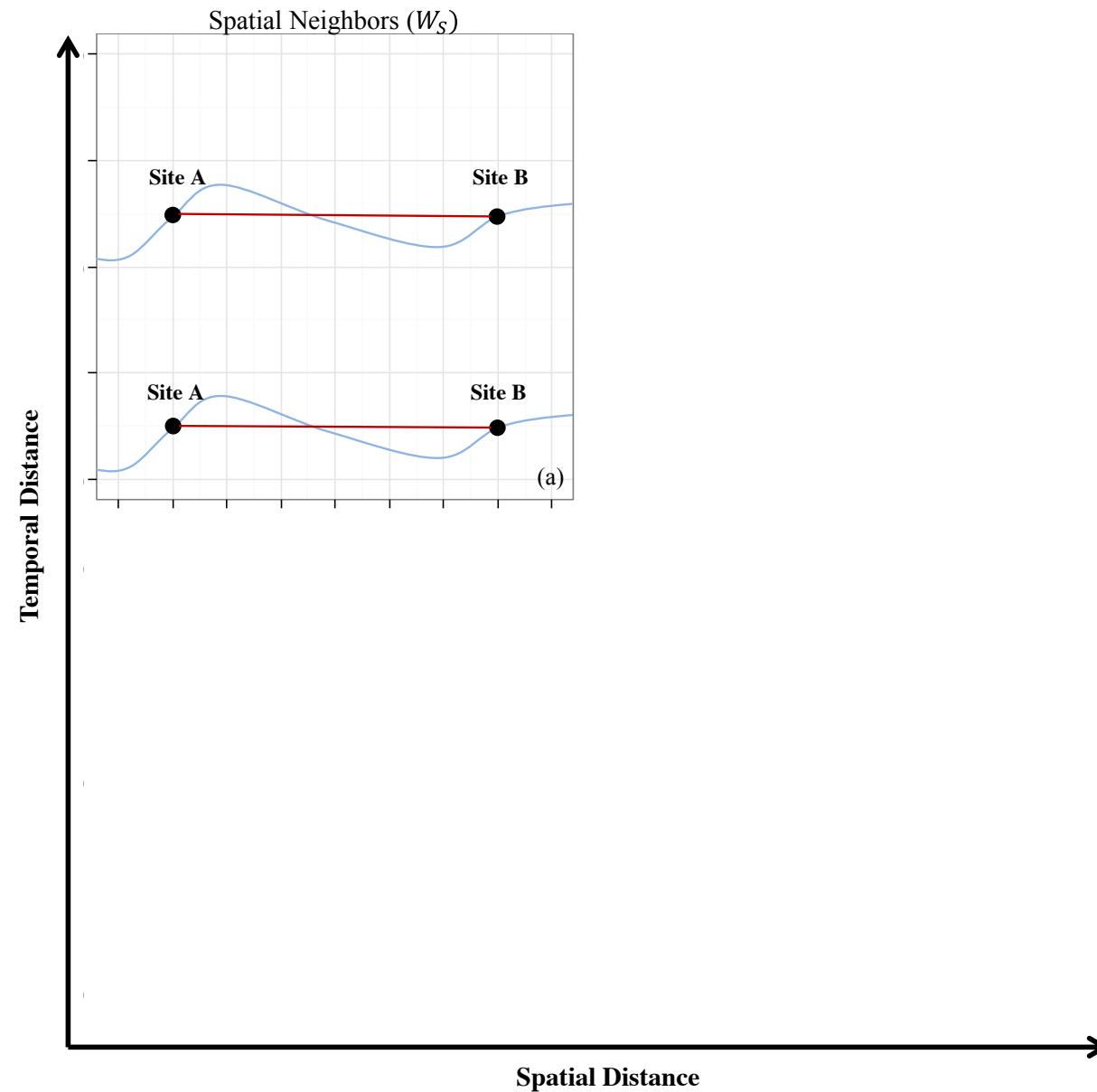
## SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES

2) Are we able to diagnose impacts of RRFRP correctly?

- BACI designs have been criticized for their spatial and/or temporal pseudoreplication (Stewart-Oaten et al. 1986)
  - Population counts are treated as independent
  - Violates assumption *iid* assumption in errors
    - Underestimates standard errors
    - Increases risk of Type I error (rejection of null when it is true)
- This could mean a false detection of RRFRP impact
- Can also affect estimated slopes!

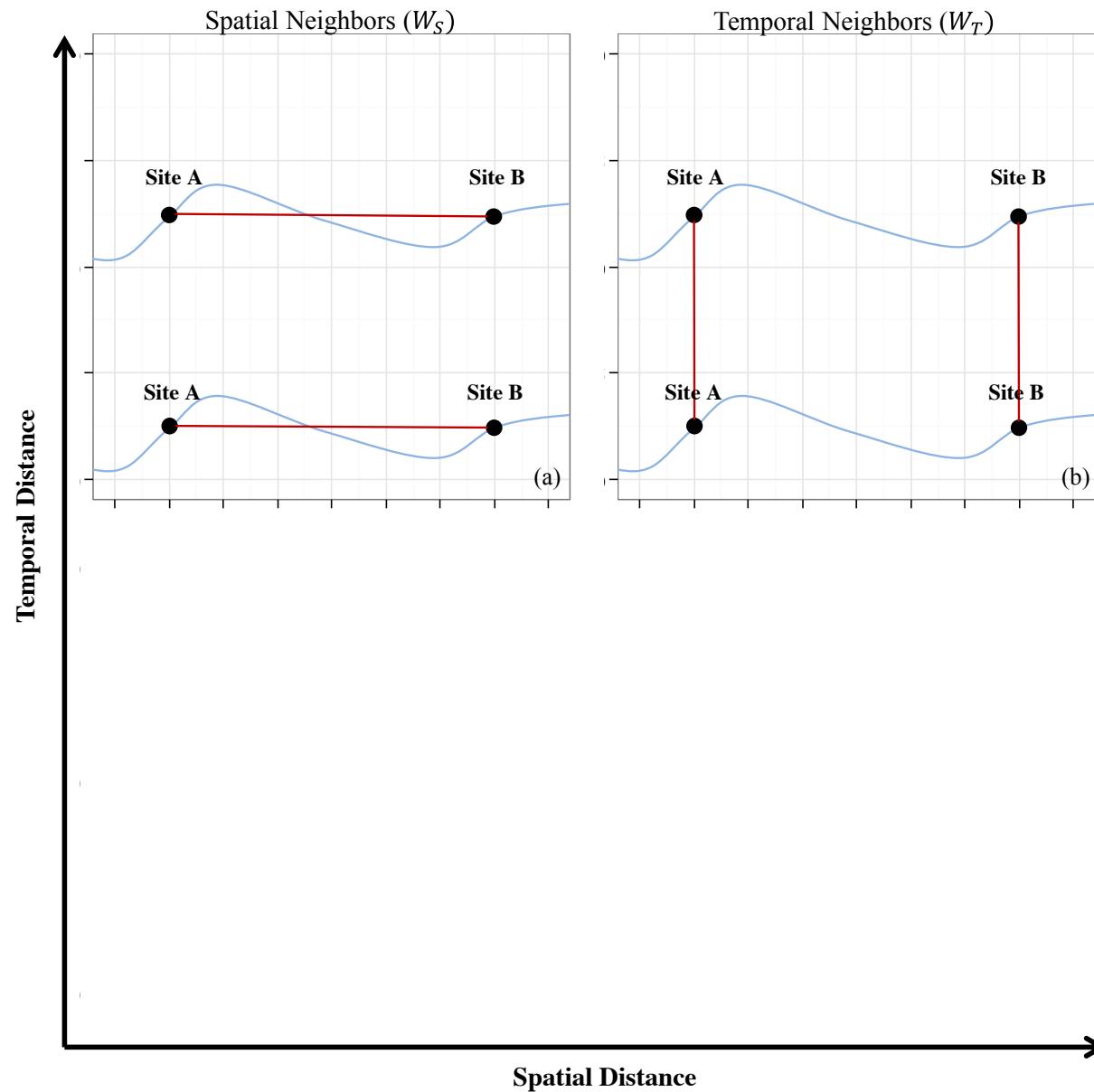


# SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES



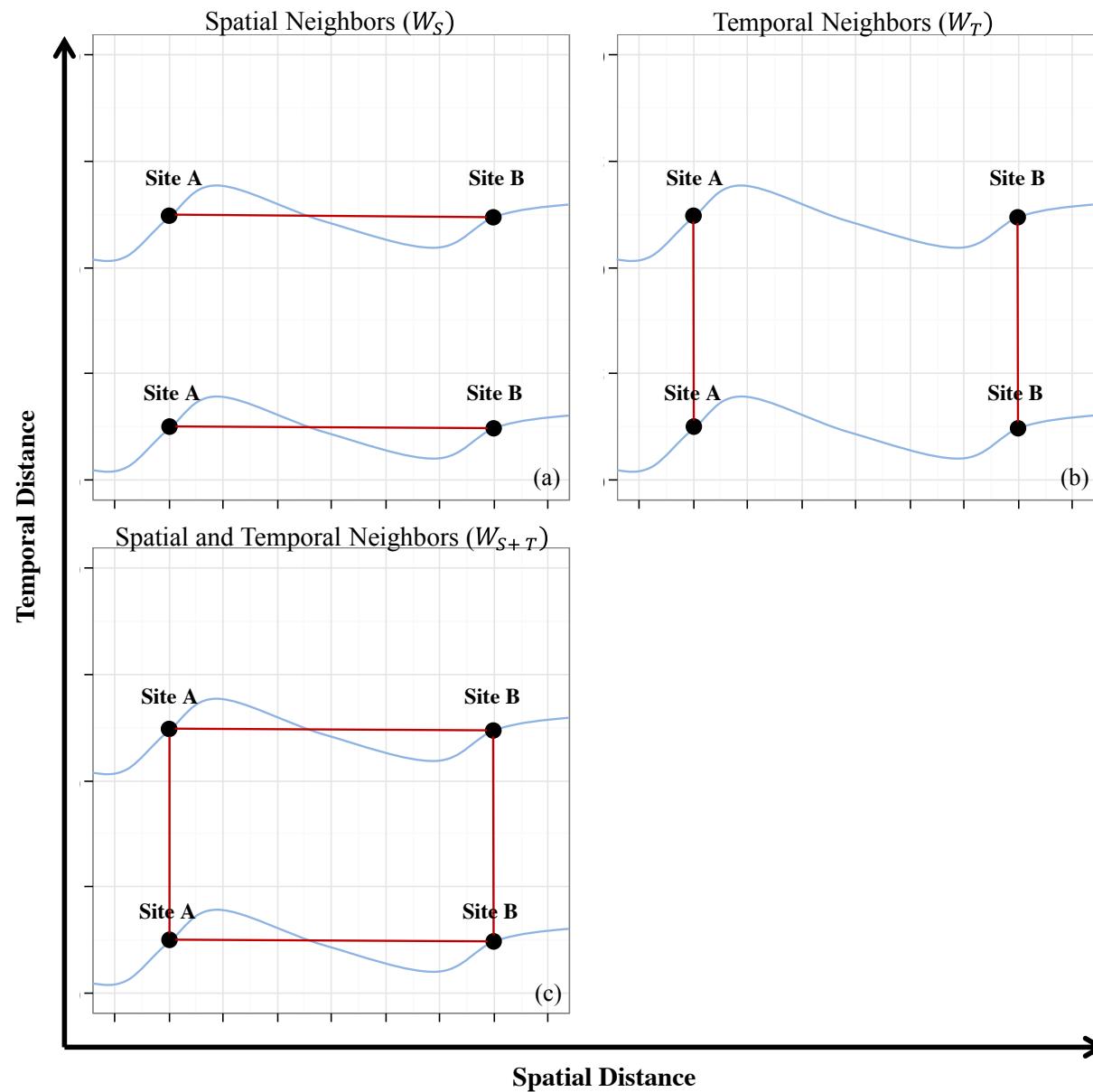


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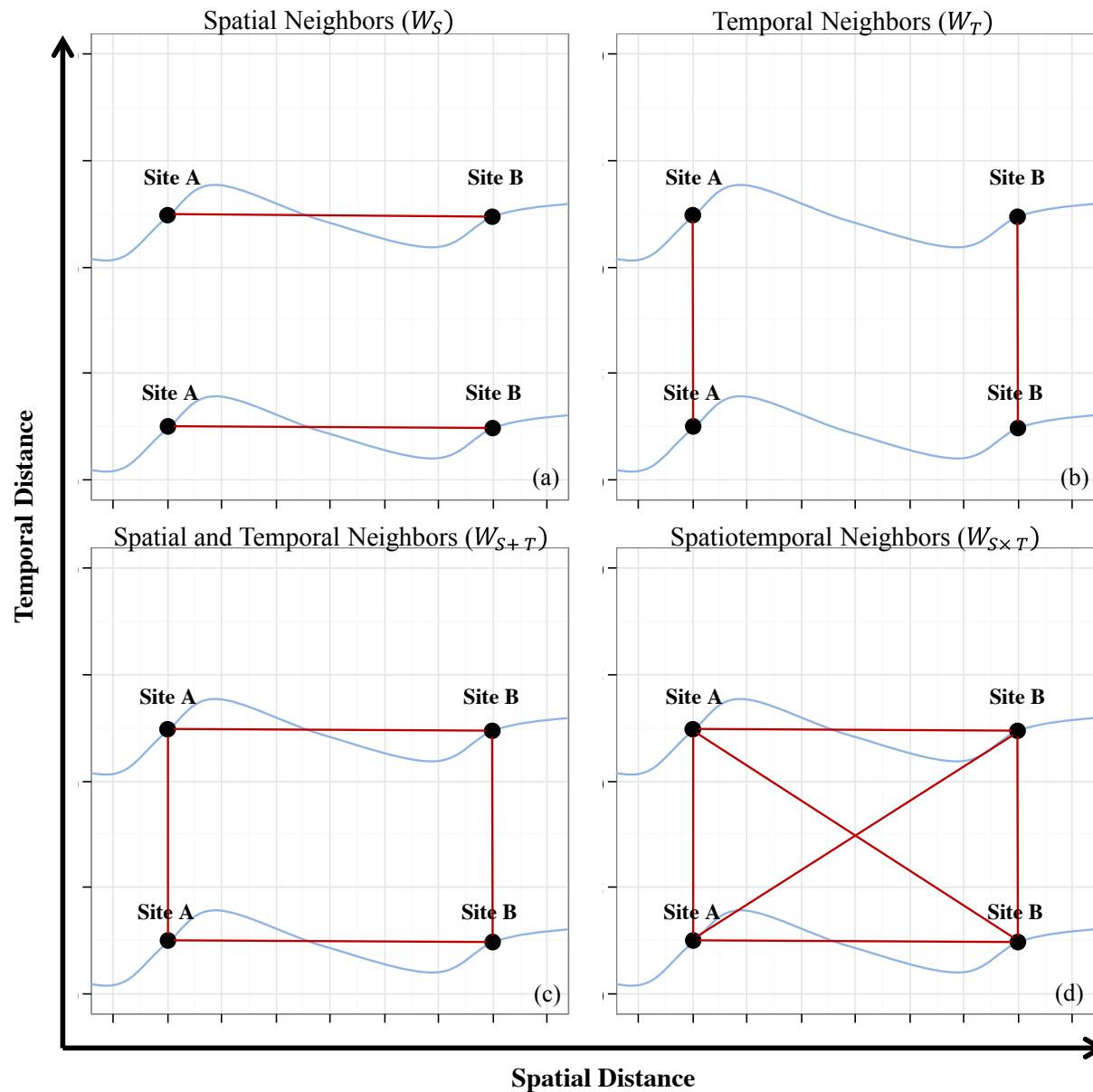


# SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES



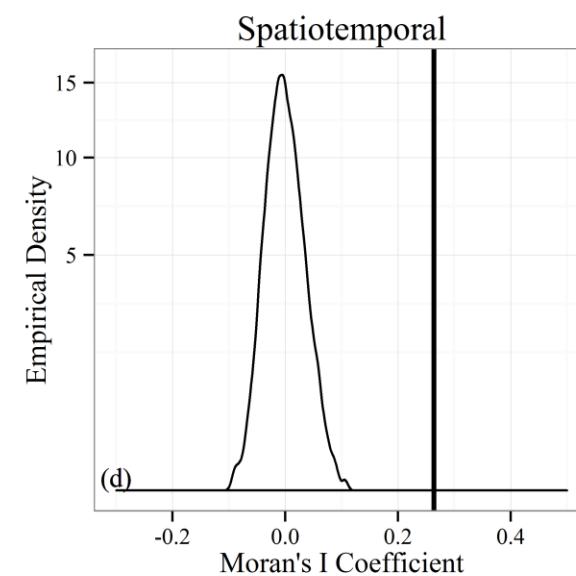
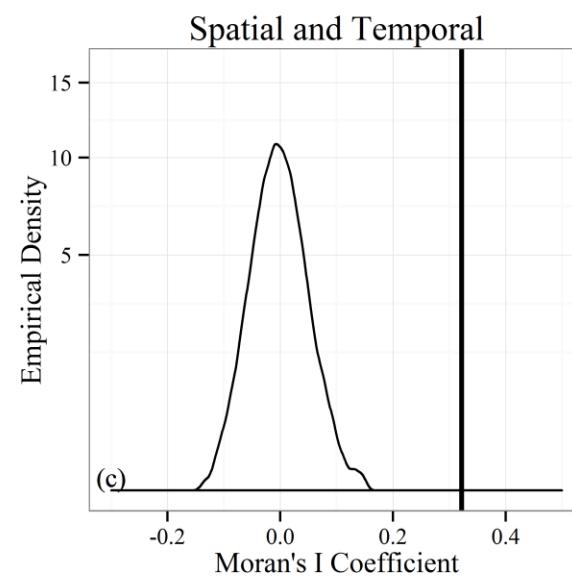
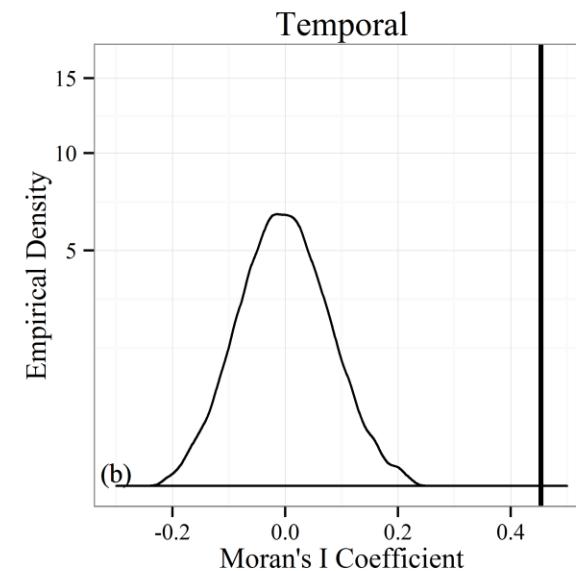
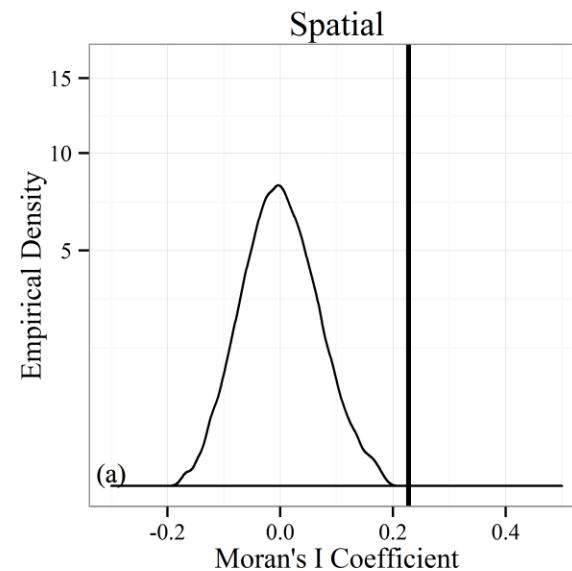


# SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES





# SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES





# SPATIOTEMPORAL AUTOCORRELATION IN BACI ANALYSES

- Spatiotemporal autocorrelation could be present within both detection and abundance
  - Autocorrelation in detection
    - Similar environmental conditions
    - Experience of team
    - Prior knowledge bias
  - Autocorrelation in abundance
    - Similar environmental conditions
    - Sites connected by dispersal
    - Many individuals survive and contribute to population dynamics

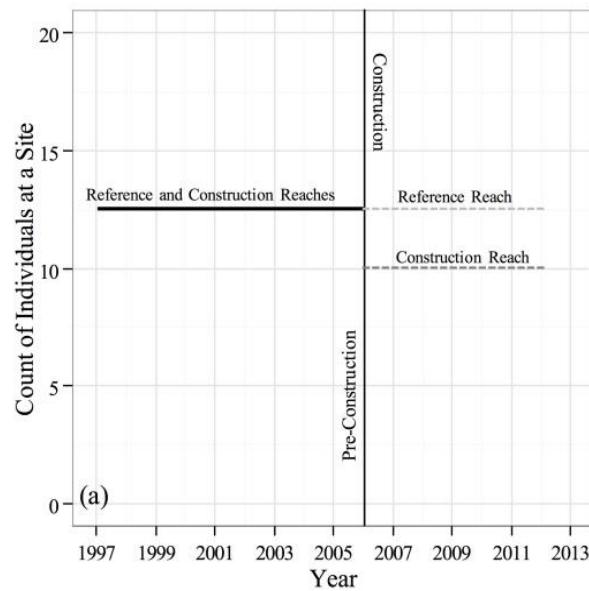


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    - Similar environmental conditions
    - Experience of team
    - Prior knowledge bias
  - Autocorrelation in abundance
    - Similar environmental conditions
    - Sites connected by dispersal
    - Many individuals survive and contribute to population dynamics
- To combat this issue, we utilized Moran's Eigenvector Maps
  - Spatial, temporal, spatial and temporal, and spatiotemporal
  - Eigenvectors were added as regressors for detection and/or abundance
    - Evaluated using AICc

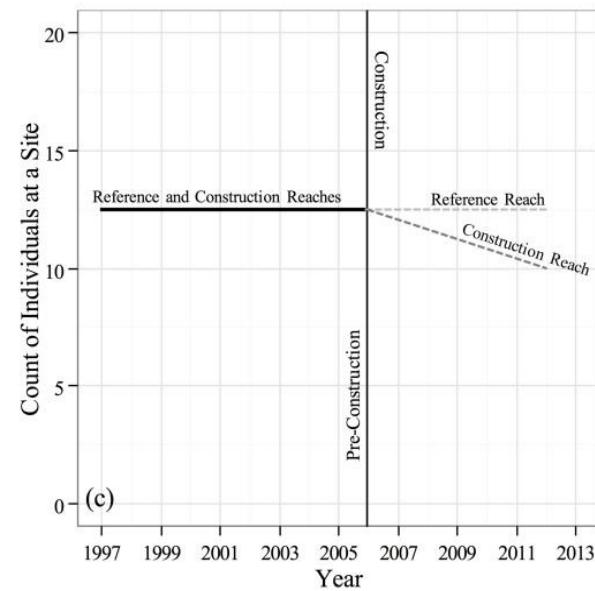
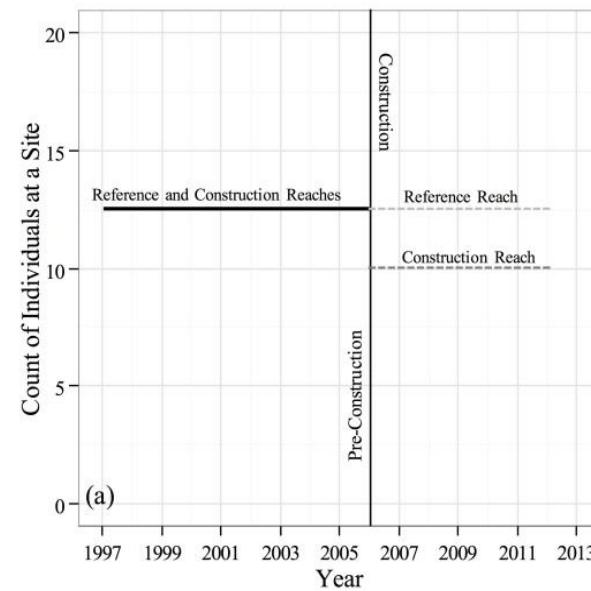


# DETECTION OF IMPACT



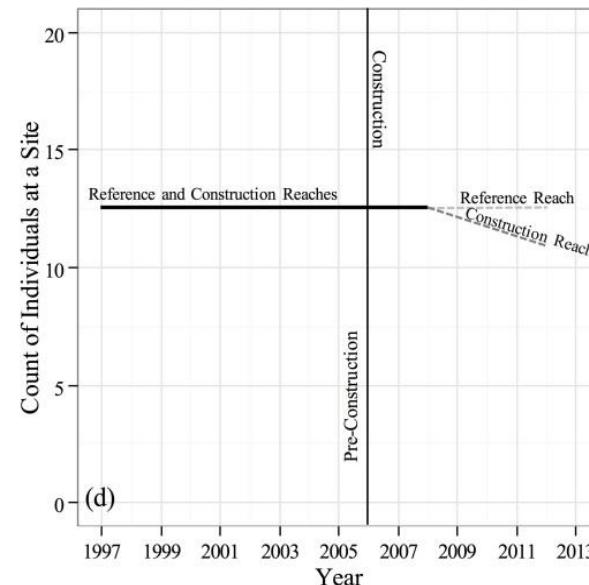
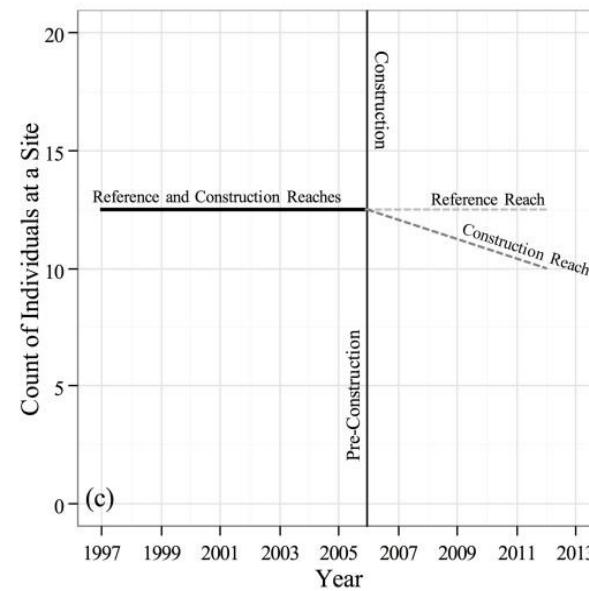
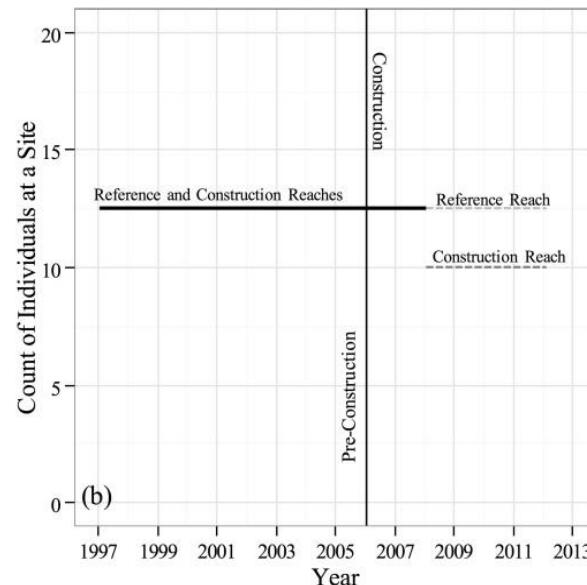
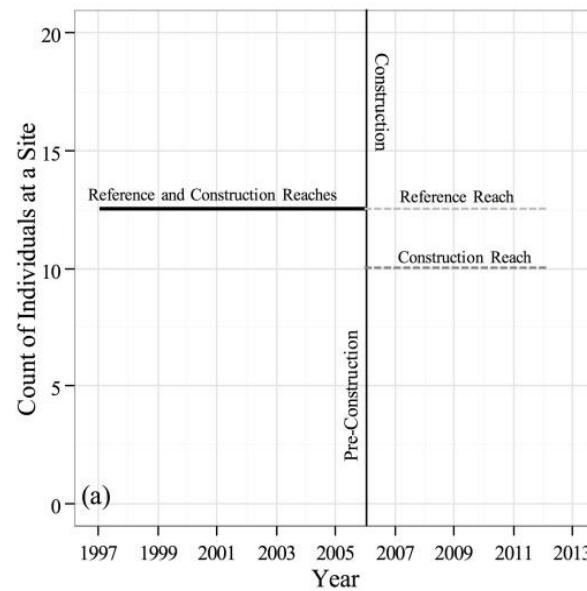


# DETECTION OF IMPACT





# DETECTION OF IMPACT





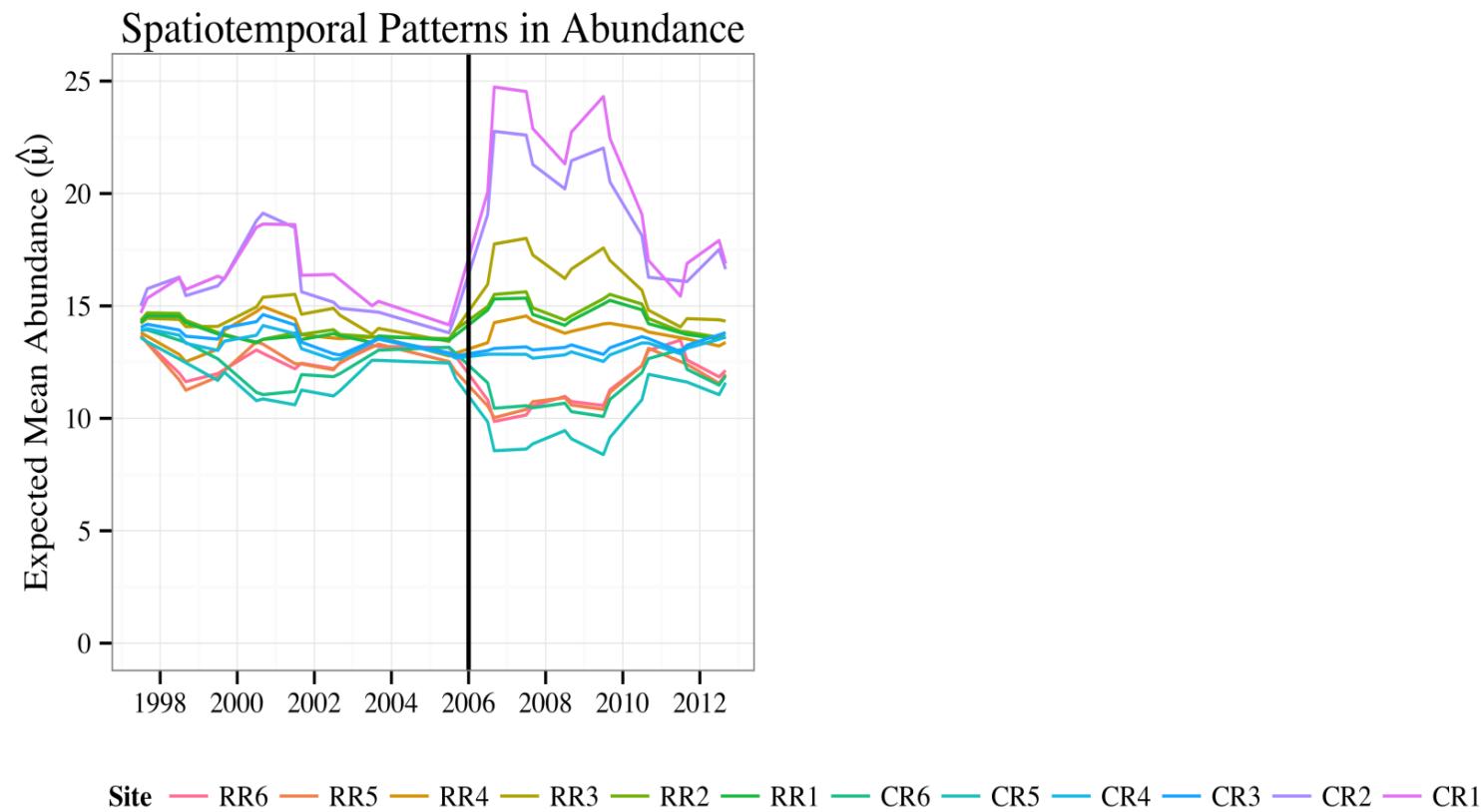
# RESULTS

- All models suggested that detection of individuals < 1
- Two eigenvectors were selected, one for both detection and abundance



## RESULTS

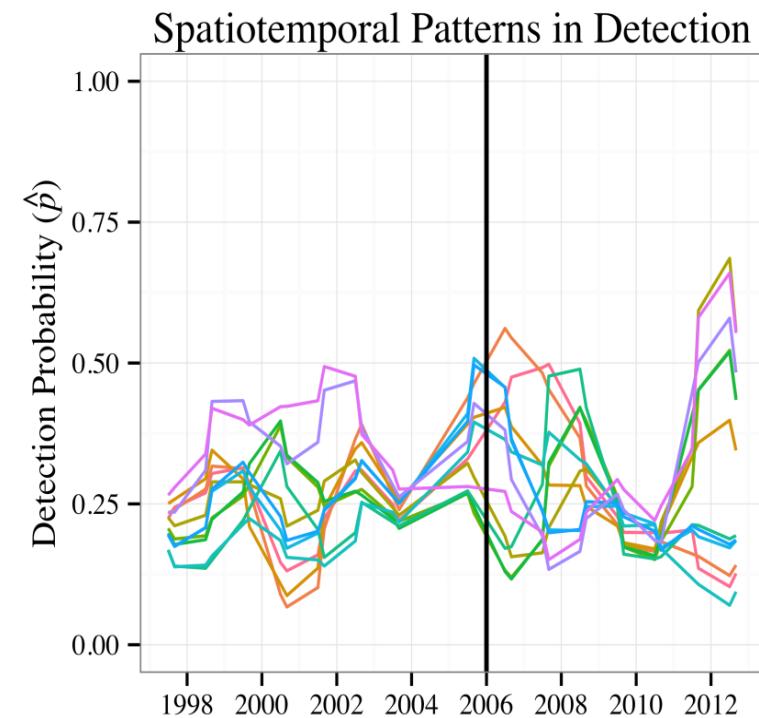
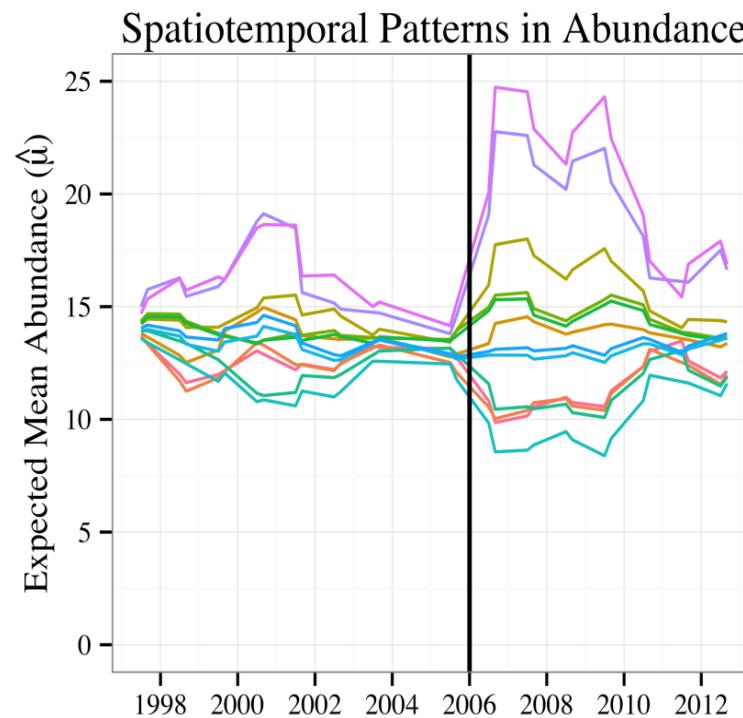
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# RESULTS

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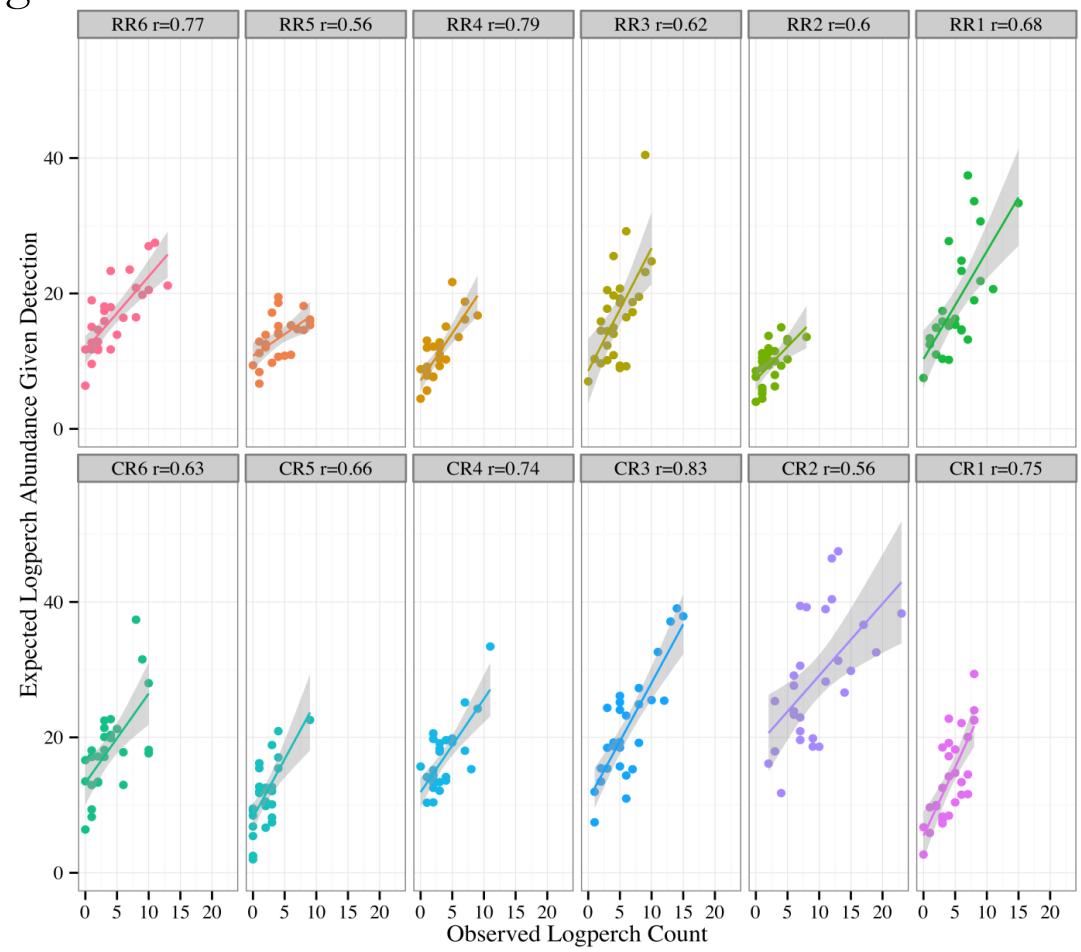


Site RR6 RR5 RR4 RR3 RR2 RR1 CR6 CR5 CR4 CR3 CR2 CR1



# RESULTS

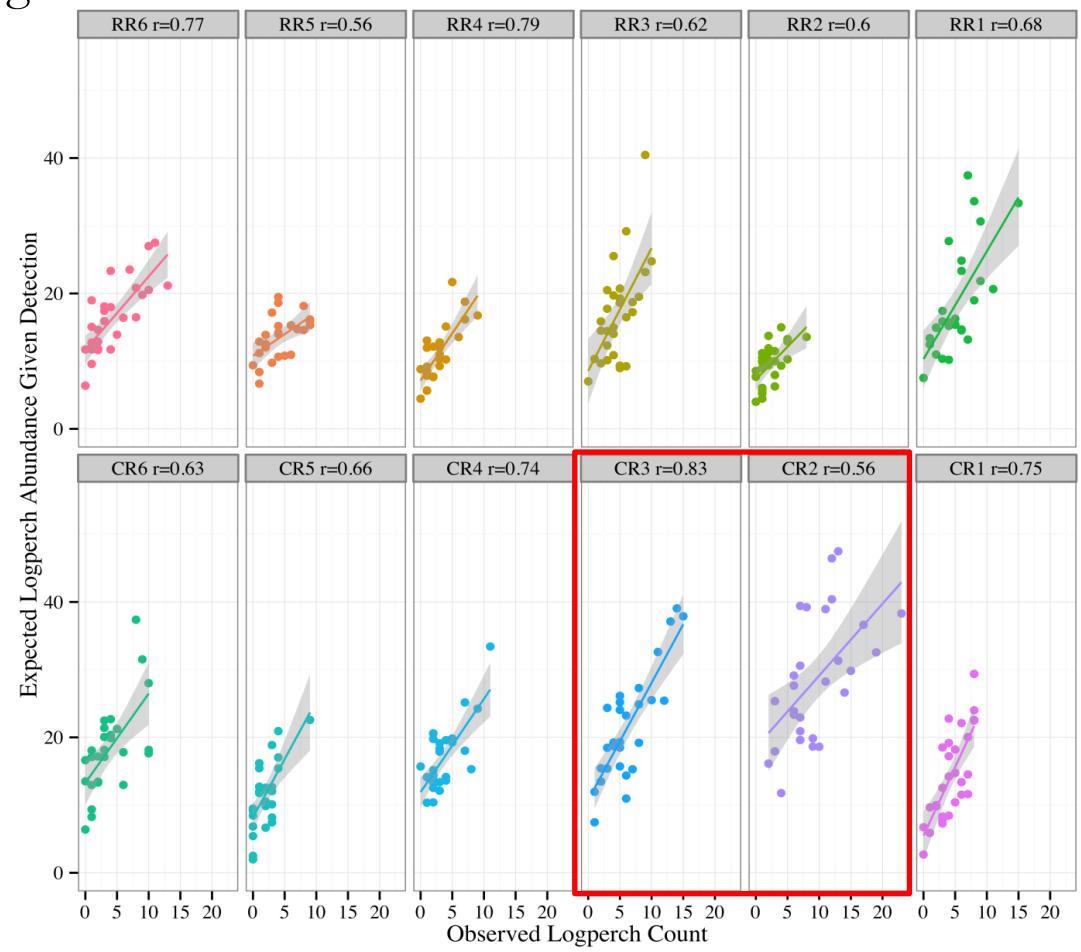
- Detection varied dramatically across sites and across time
  - As low as 0.05 to as high as 0.68
- Detection correlated with discharge





# RESULTS

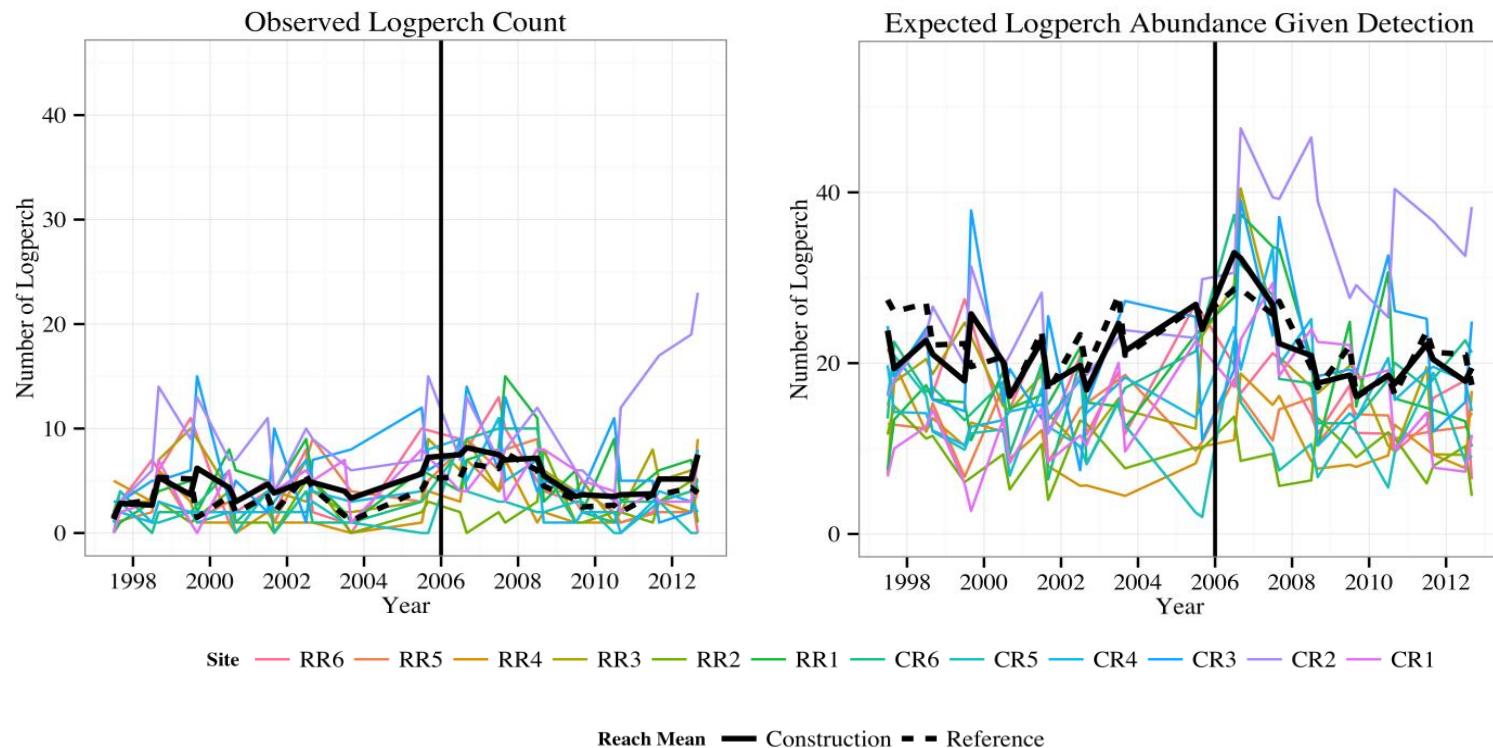
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  - As low as 0.05 to as high as 0.68
- Detection correlated with discharge





# RESULTS

- Abundance varied spatiotemporally
  - Varied between 2 and 48 individuals per site
- Very low probability that any site was unoccupied during a sampling event





# RESULTS

- After correcting for detection and spatiotemporal autocorrelation...
  - Little support for any impact of RRFRP
    - Some scenarios demonstrated higher abundance in the CR during impact





# DISCUSSION

- Modeling approach offers alternative to traditional BACI analyses
  - Accounts for detection bias
  - Explicit incorporation of spatial, temporal, and spatiotemporal dependent structures
- Analysis sensitive to definition of neighborhood matrix
- Results indicate no clear effect of the RRFRP



# ACKNOWLEDGMENTS

## Previous Project Leaders:

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- Brett Albanese
- Greg Galbreath

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- U.S. Geological Survey
- U.S. Fish and Wildlife Service

...and many field technicians

