Predictive Distribution Models for Marsh Birds: Occupancy and Spatial Modeling to Facilitate Habitat Conservation

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General Issue

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- **Binary range map**
  - **Uninformative**
  - **Distribution ≠ uniform**

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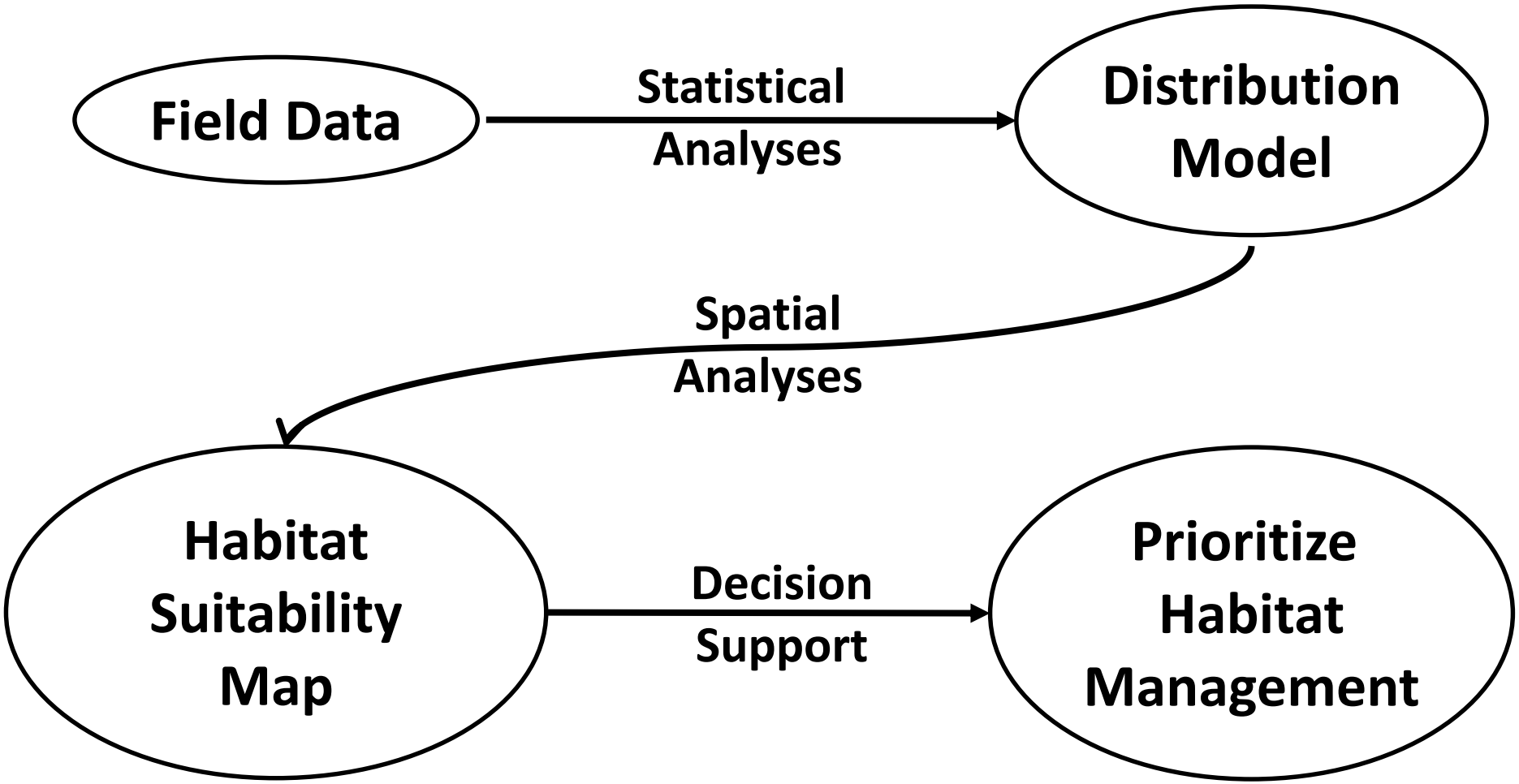
  - **Uninformative**
  - **Distribution ≠ uniform**
- **Important to refine predictions**
  - **Prioritizing management in space**

General Approach



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  - **Game birds**
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- **Populations declining**
  - **Habitat loss & degradation**

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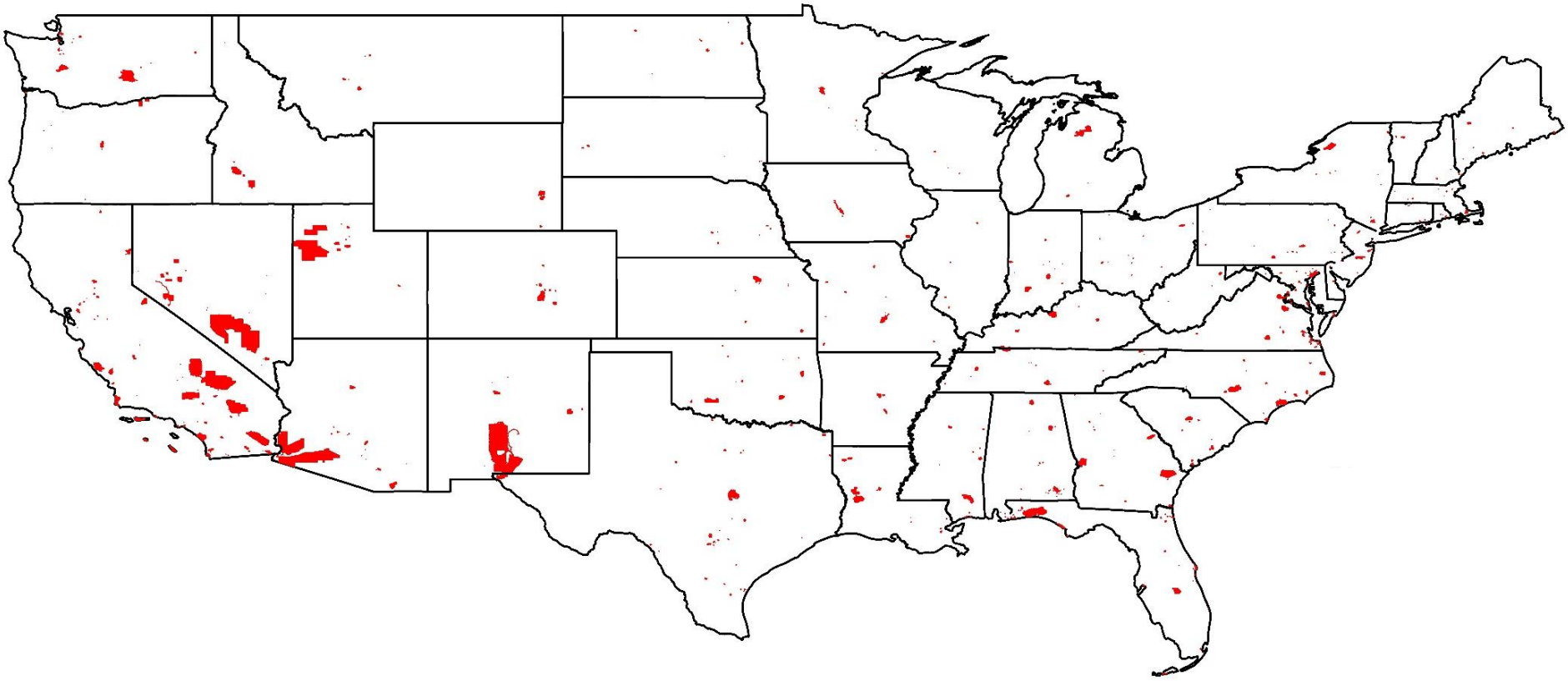
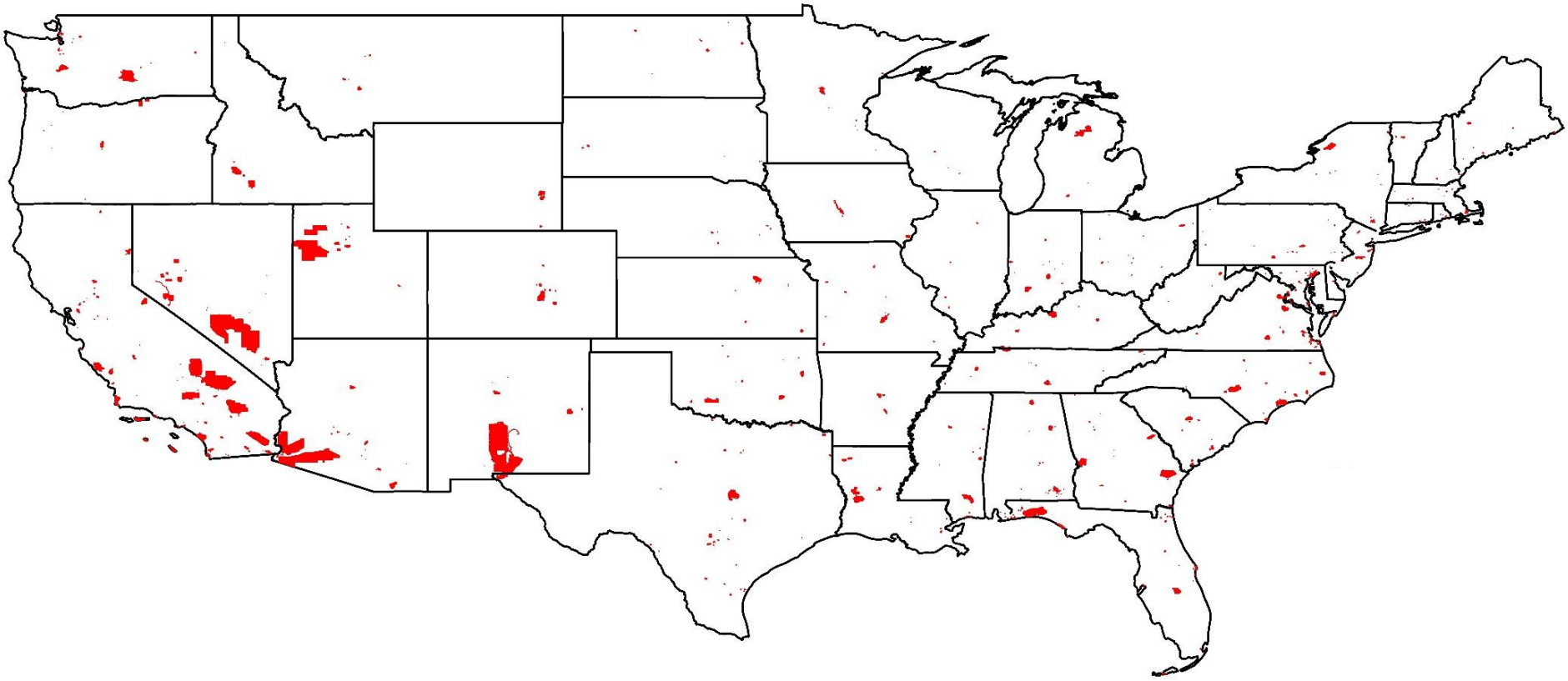
  - **DoD: include marsh birds in INRMPs**
  - **USFWS: inform land acquisition for NWR system**

Decision Support for DoD



- **INRMPs required at all 593 installations**

Decision Support for DoD



- **INRMPs required at all 593 installations**
- **Which marsh birds should be included at each site?**
  - **Focus site-specific plans, while conserving species group**

Objectives

1. **Develop optimally-predictive models of breeding distribution for marsh birds**
   - **First at range-wide extent**

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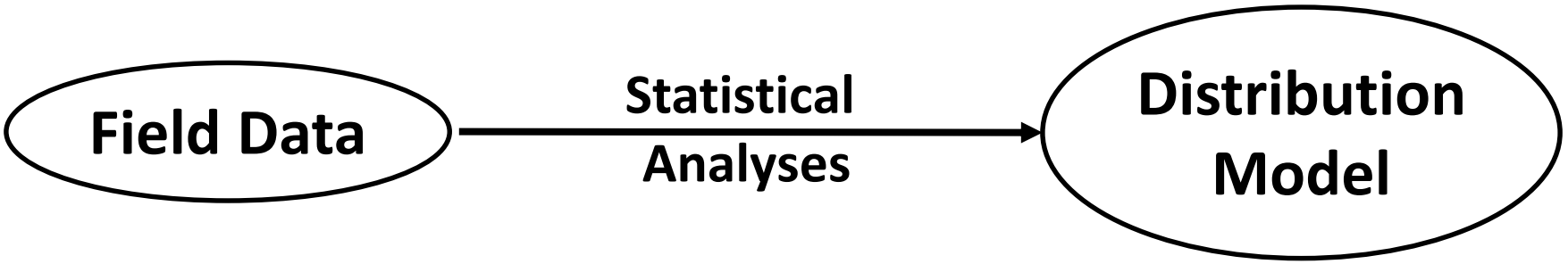
   - **First at range-wide extent**

2. **Predict optimal habitat for prioritizing conservation in space**
   - **DoD installations**

Objective 1: Develop Predictive Models



Field Data

Pied-Billed Grebe

American Bittern

Least Bittern

American Coot

Common Gallinule

Purple Gallinule

Limpkin

Black Rail

Clapper Rail

King Rail

Ridgeway's Rail

Virginia Rail

Yellow Rail

Sora

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Field Data

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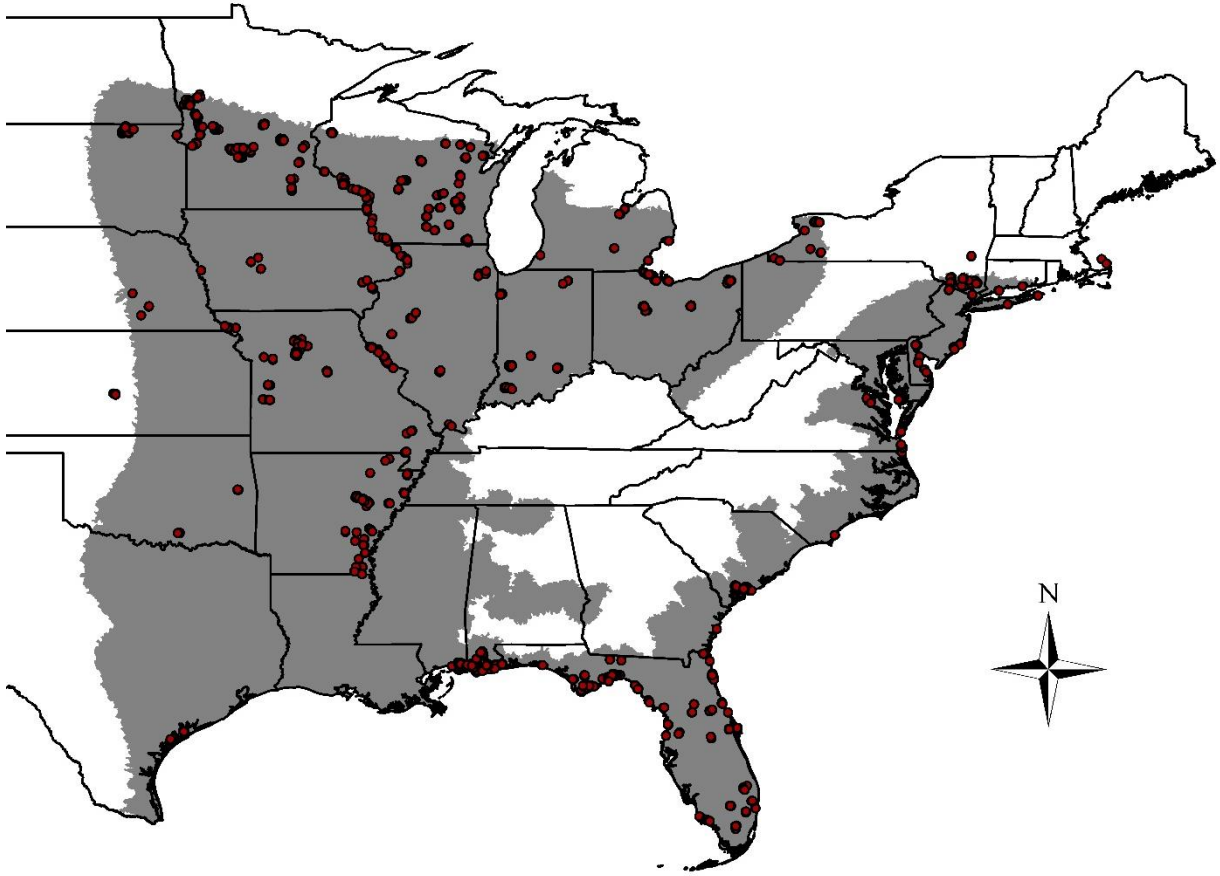
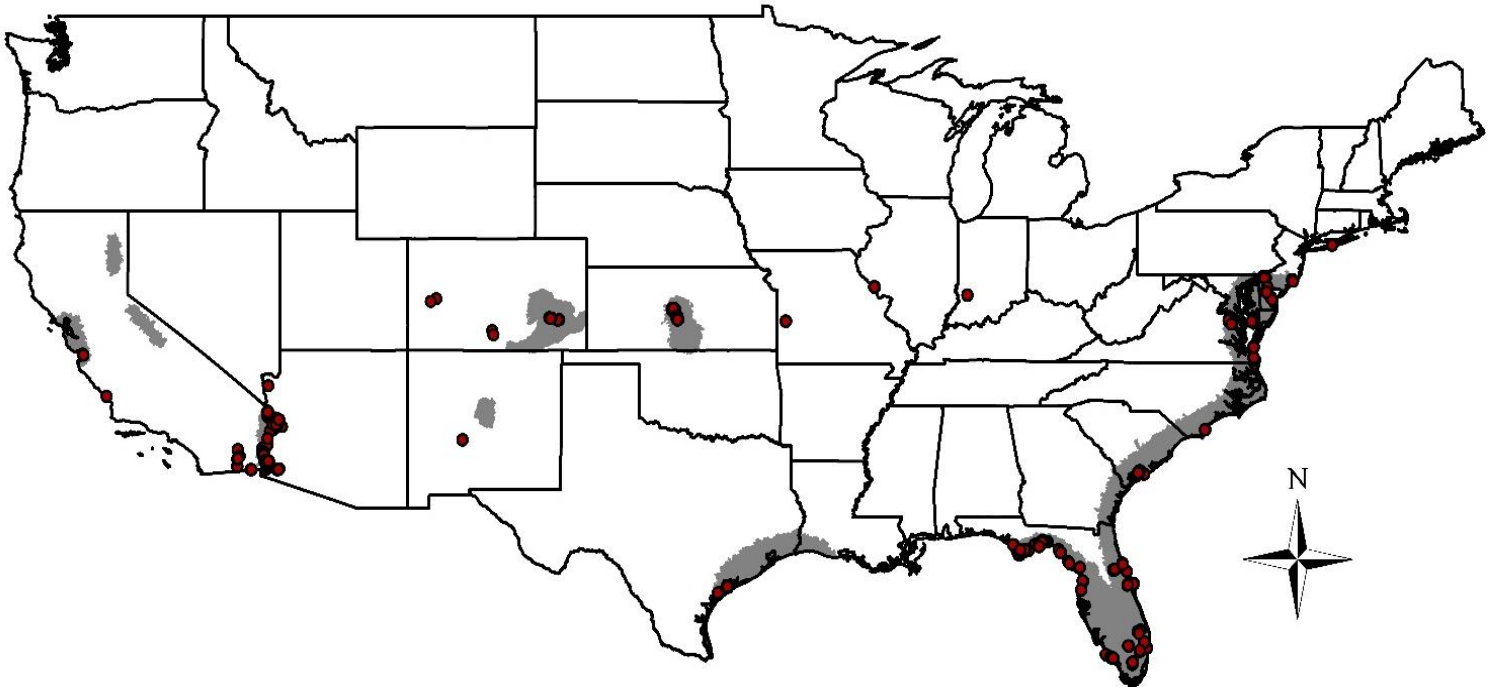
- **10-14 yrs/species (1999-2012)**
- **Detection-non-detection data**
- **Repeated call-broadcast surveys at each site**

Example: King Rail



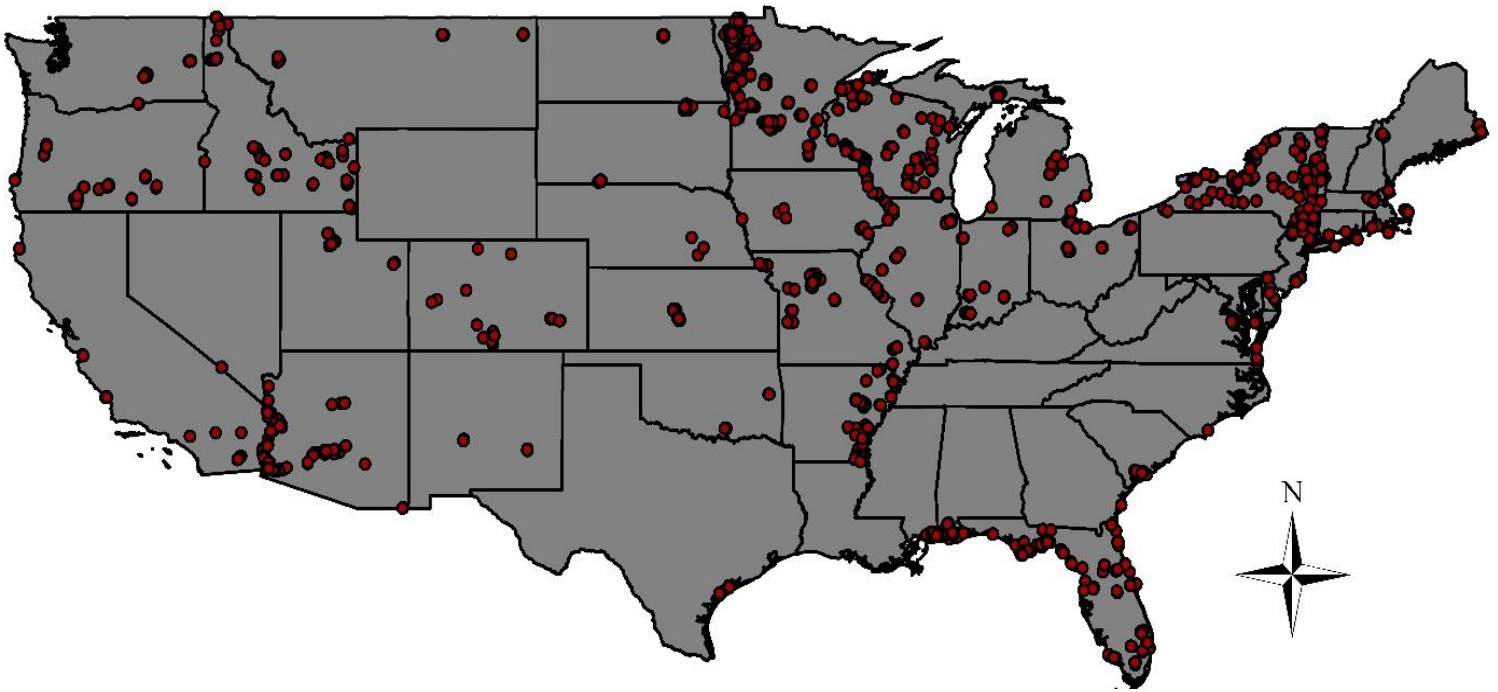
- **3645 sites, 14 yrs**

Example: Black Rail



- **2885 sites, 13 yrs**

Example: Pied-Billed Grebe



- **8457 sites, 14 yrs**

Statistical Analyses

- **Hierarchical occupancy models**

$$z_{i,t} \sim Bernoulli(\psi_i)$$

$$y_{i,j,t} \sim Bernoulli(z_{i,t} p_{i,j,t})$$

Statistical Analyses

- **Hierarchical occupancy models**
  - **Multi-season**

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Statistical Analyses

- **Hierarchical occupancy models**
  - **Multi-season**
  - **Model true distribution**
  - **Bayesian implementation (R + JAGS)**

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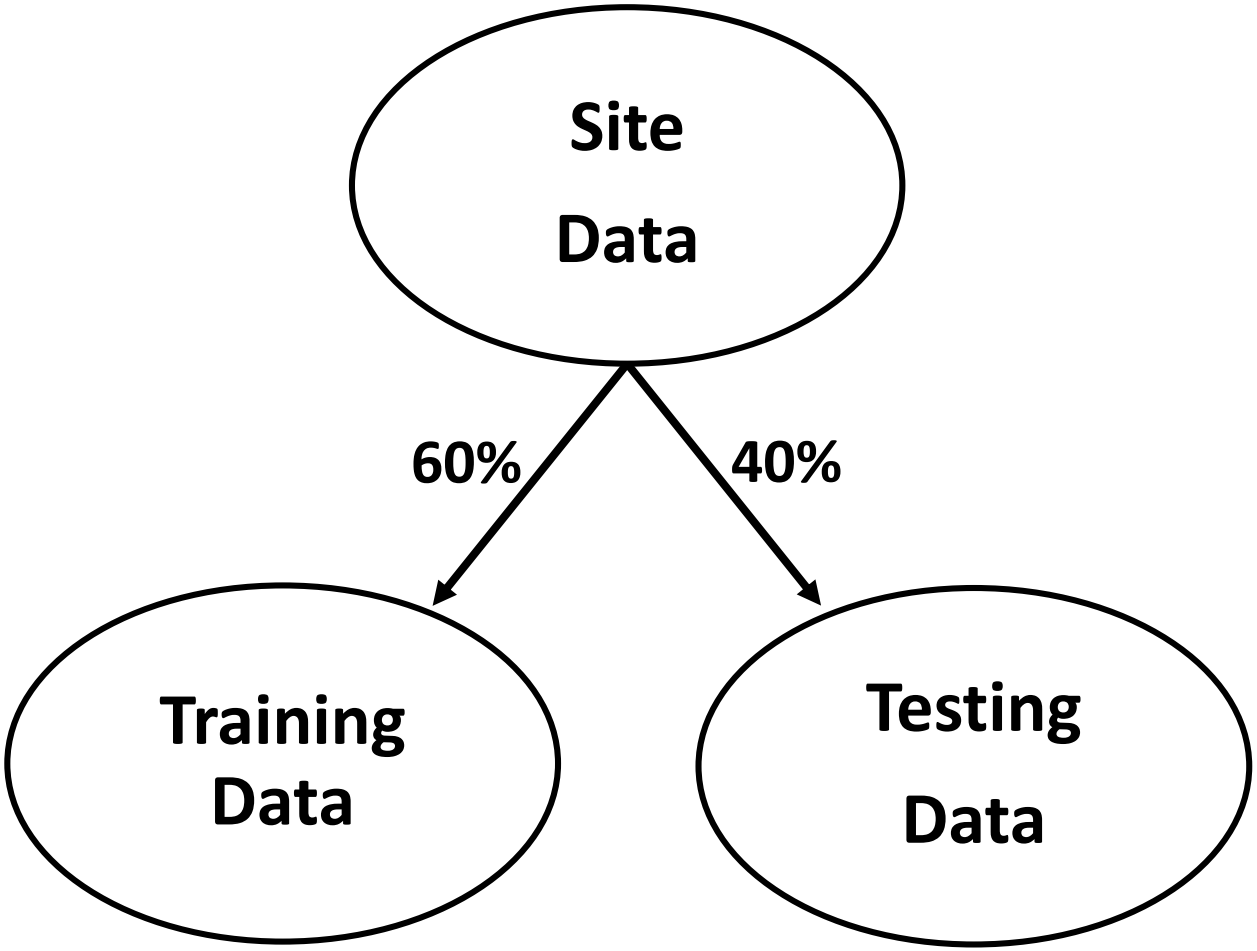
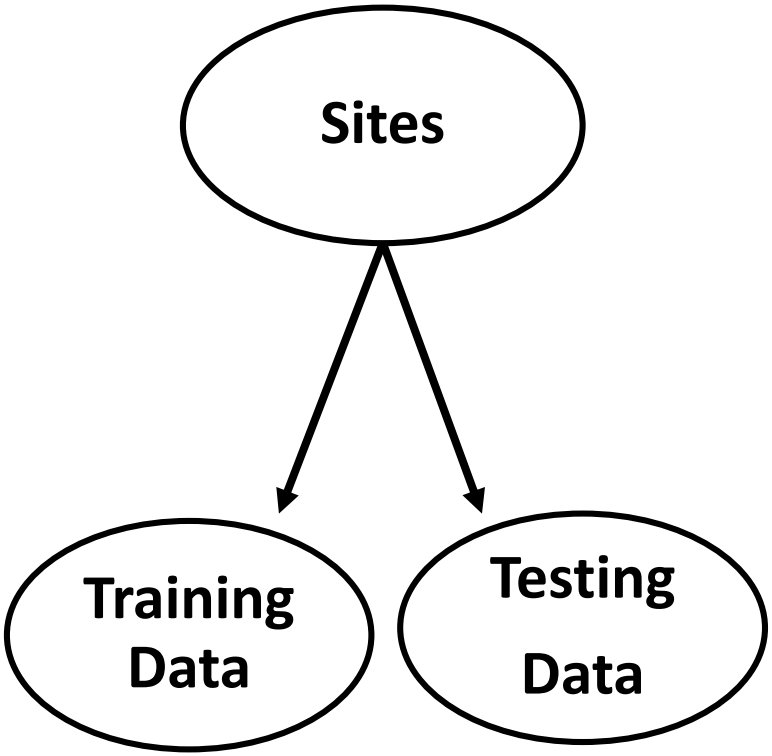
Model Selection



Model Selection

- **Log-scoring rule (Gelman et al. 2014, Hooten and Hobbs 2015, Broms et al. 2016)**
  - **Newer method**



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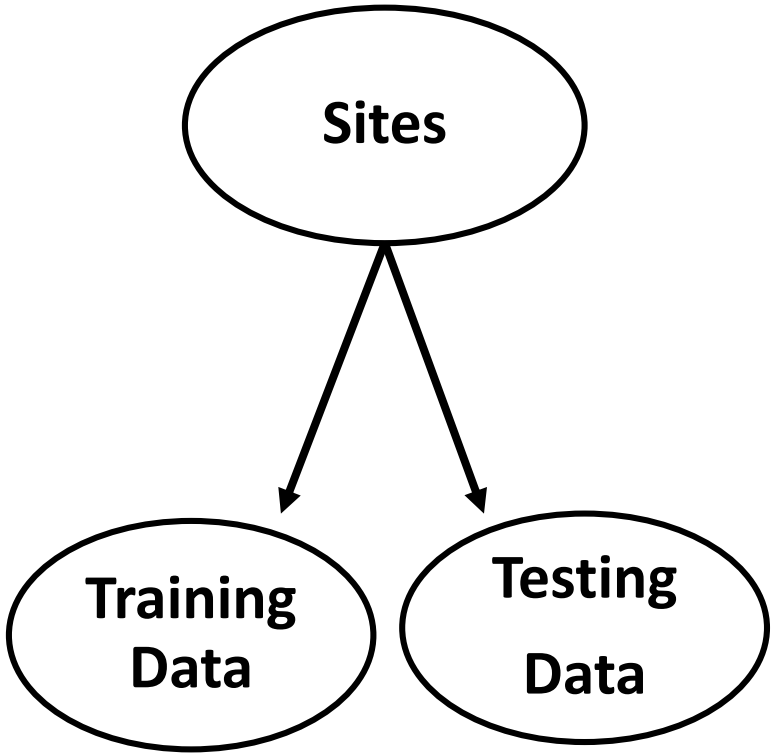
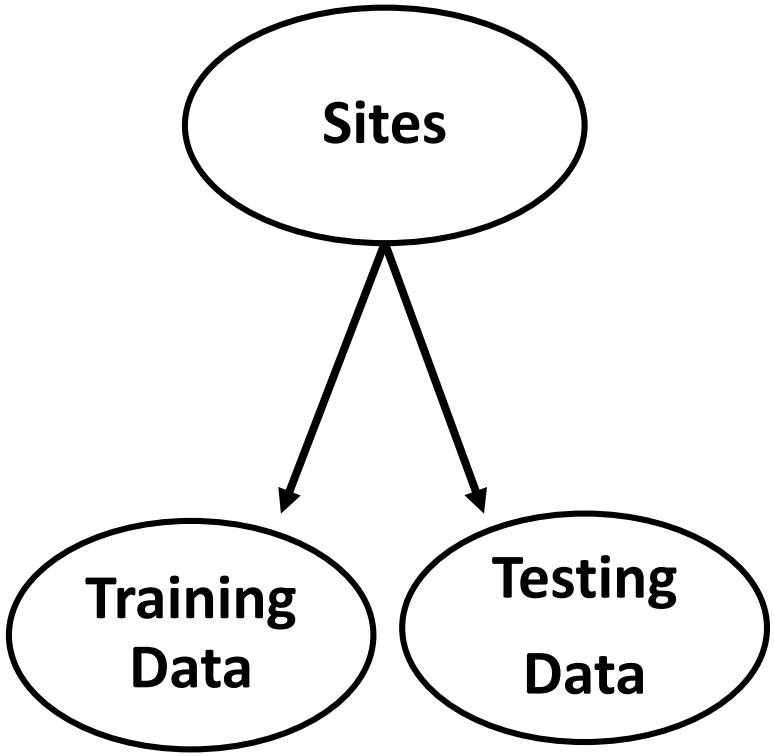


Model Selection

- **Log-scoring rule (Gelman et al. 2014, Hooten and Hobbs 2015, Broms et al. 2016)**
  - **Newer method**
  - **“Gold standard”**
  - **Fully Bayesian (parameter uncertainty)**



Habitat Predictors

- **Wetland attributes (NWI)**
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- **Land cover (GAP)**
  - **Agriculture, development, etc.**

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- **Animals respond to habitat composition at variety of scales (McGarigal et al. 2016)**
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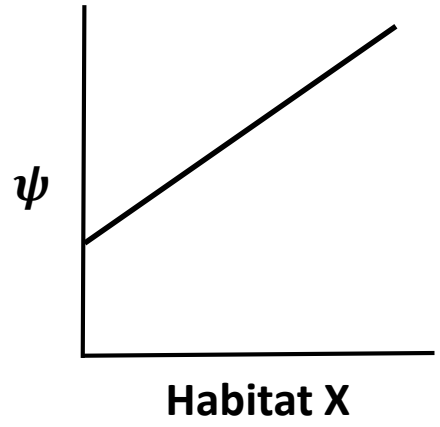

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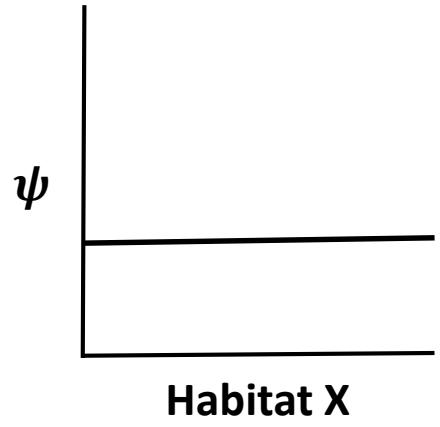
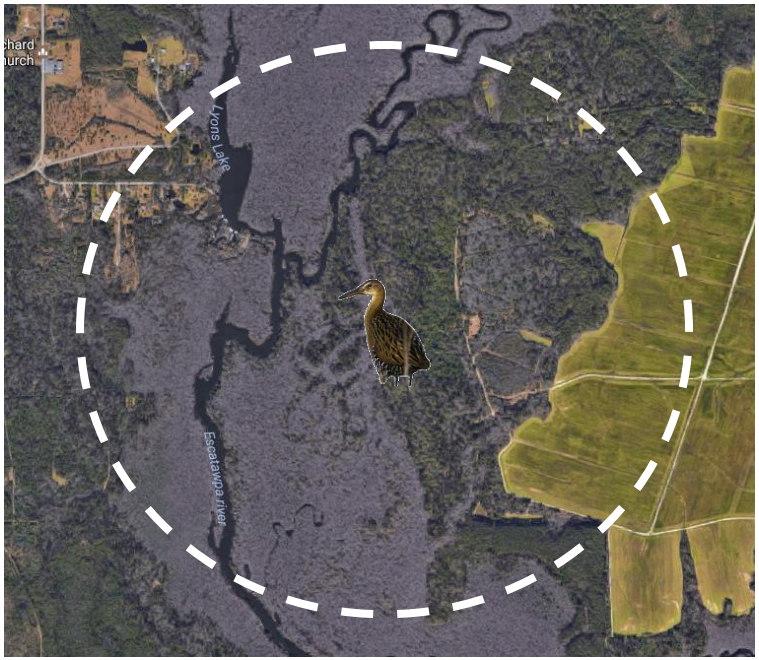
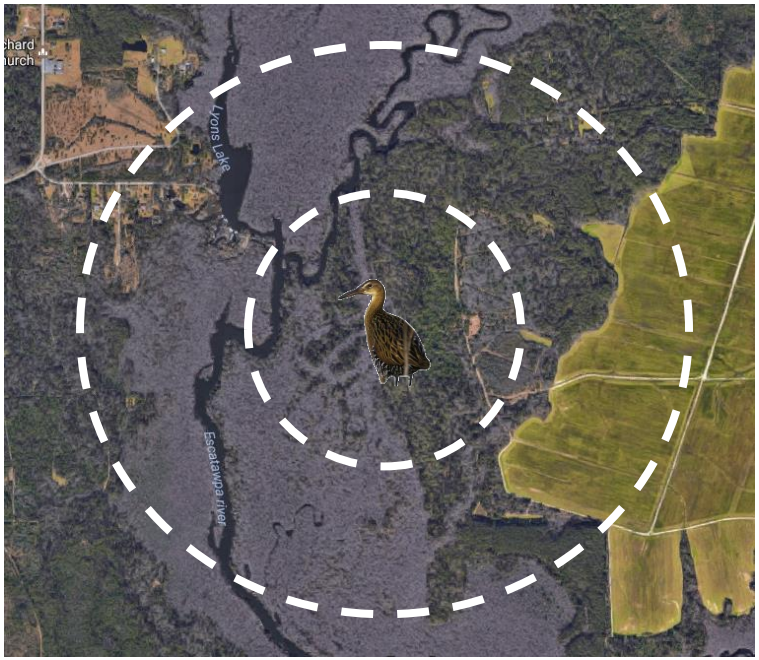




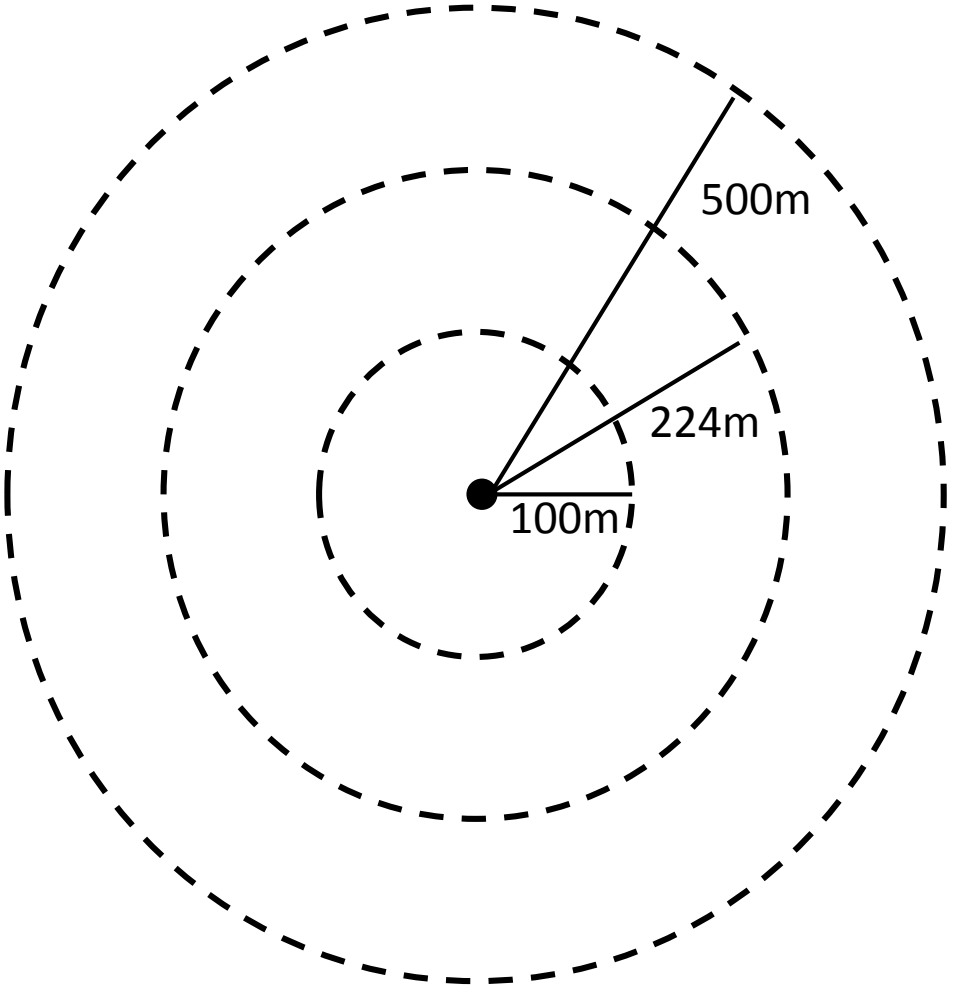
Scale-Specific Habitat Relations

- **Animals respond to habitat composition at variety of scales (McGarigal et al. 2016)**
  - **Nonlinear scaling (Hobbs 2003)**
- **Developing predictive models**
  - **Multiple scales**
  - **Scale optimization**



Habitat Predictors

- **Multi-scale measurement**
  - **100m, 224m, 500m**
  - **Scale optimization**



Selecting a Habitat Model

1. Select top detection model

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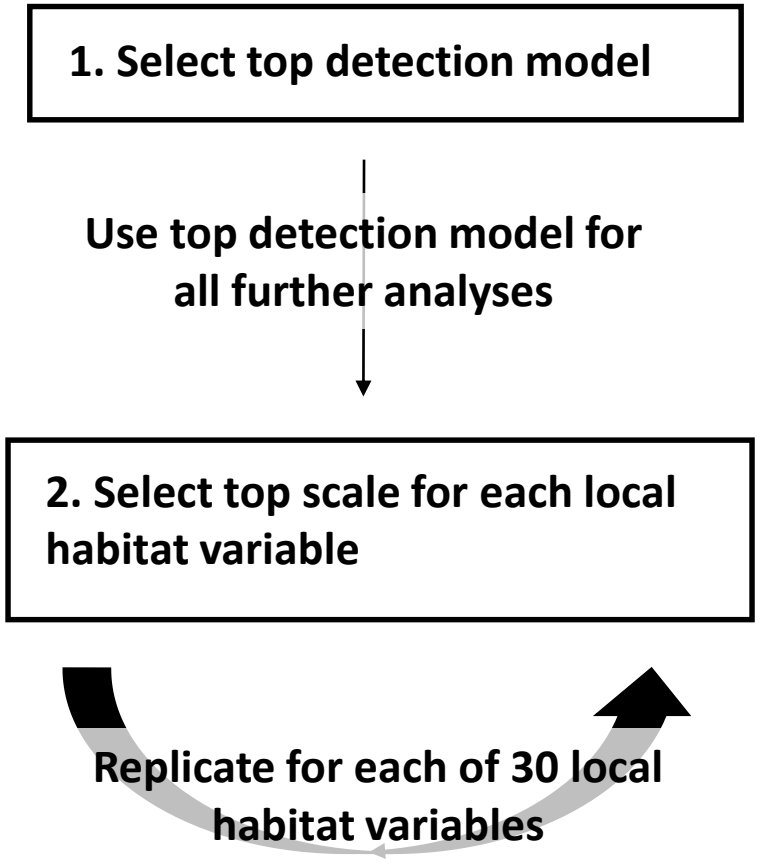
Use top detection model for all further analyses

2. Select top scale for each local habitat variable

Selecting a Habitat Model



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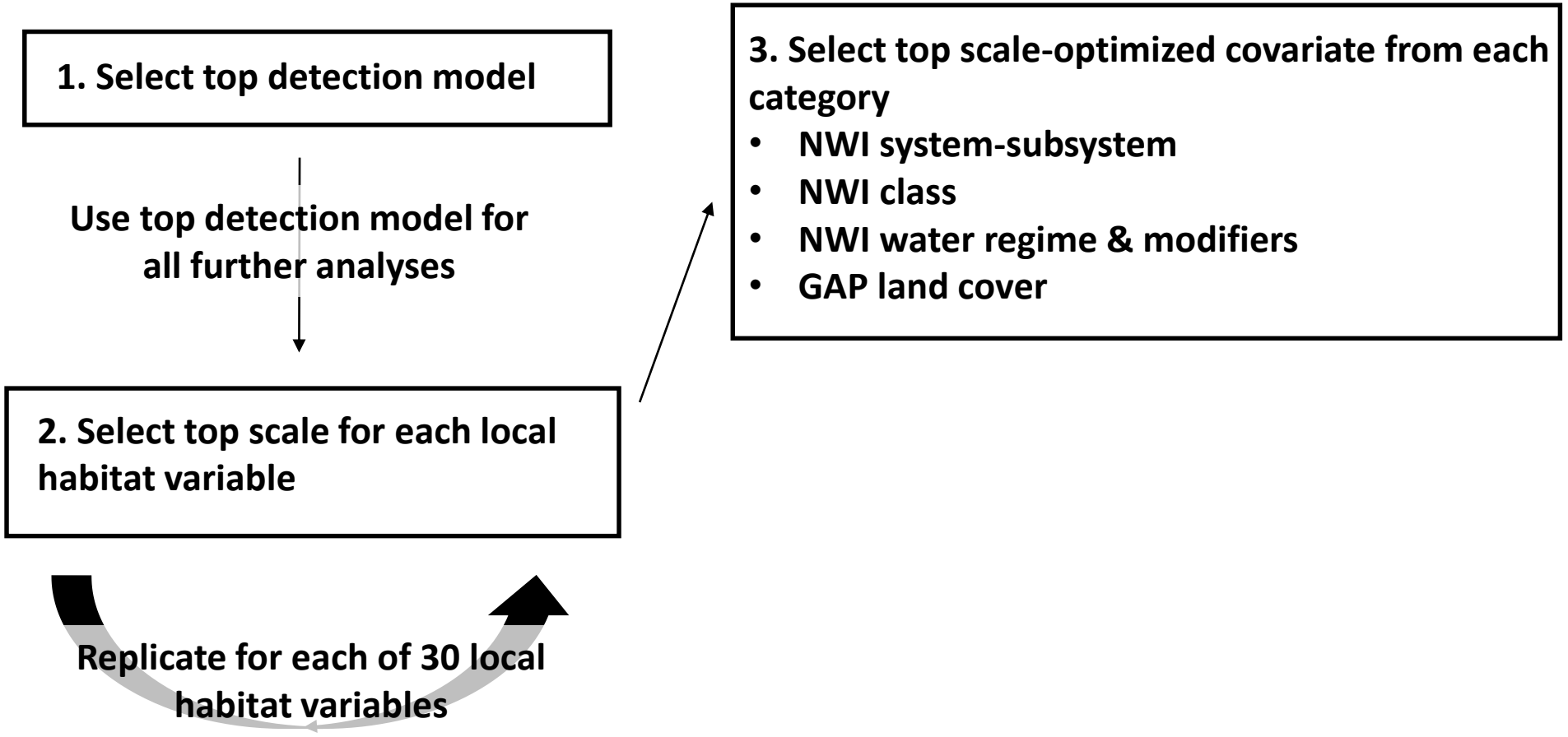

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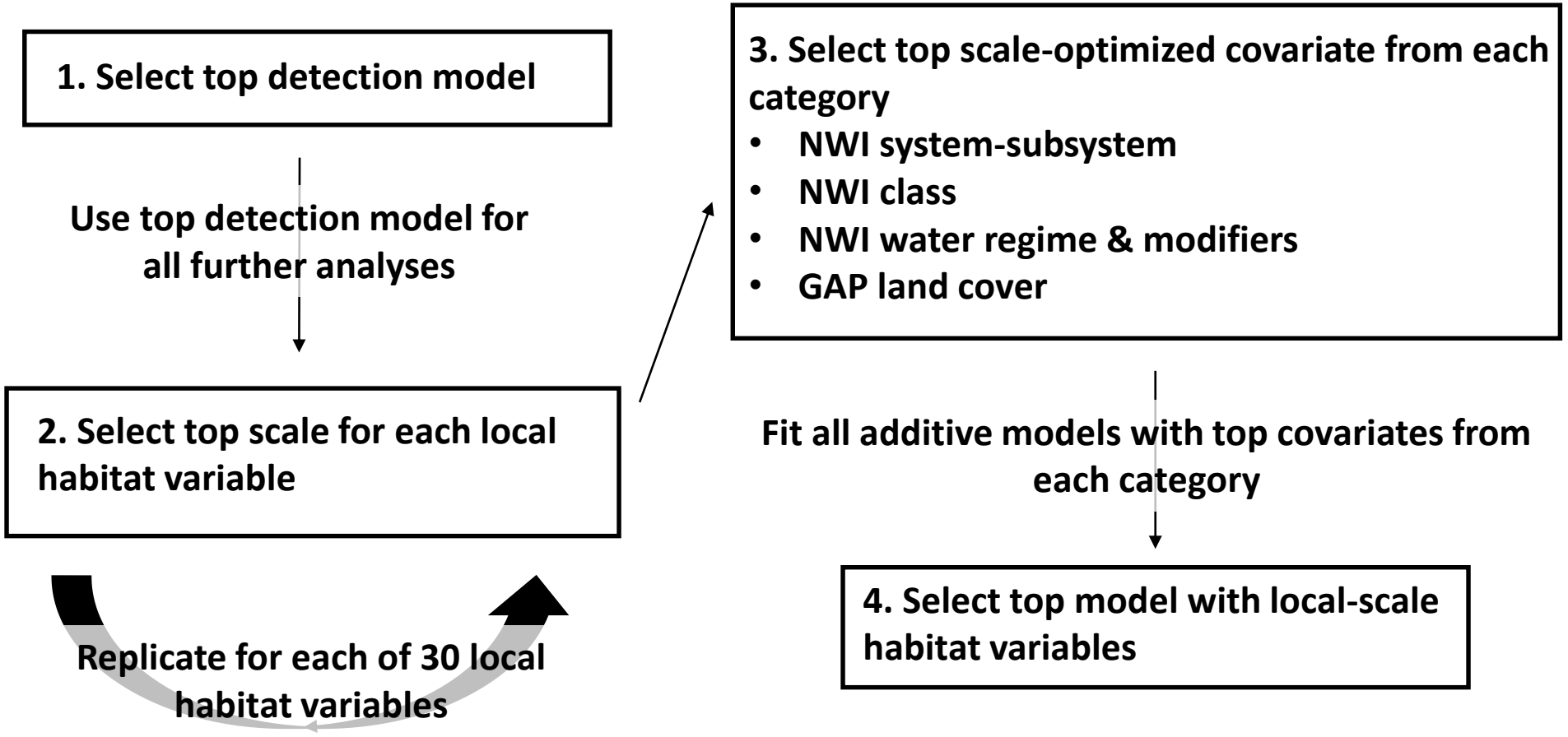

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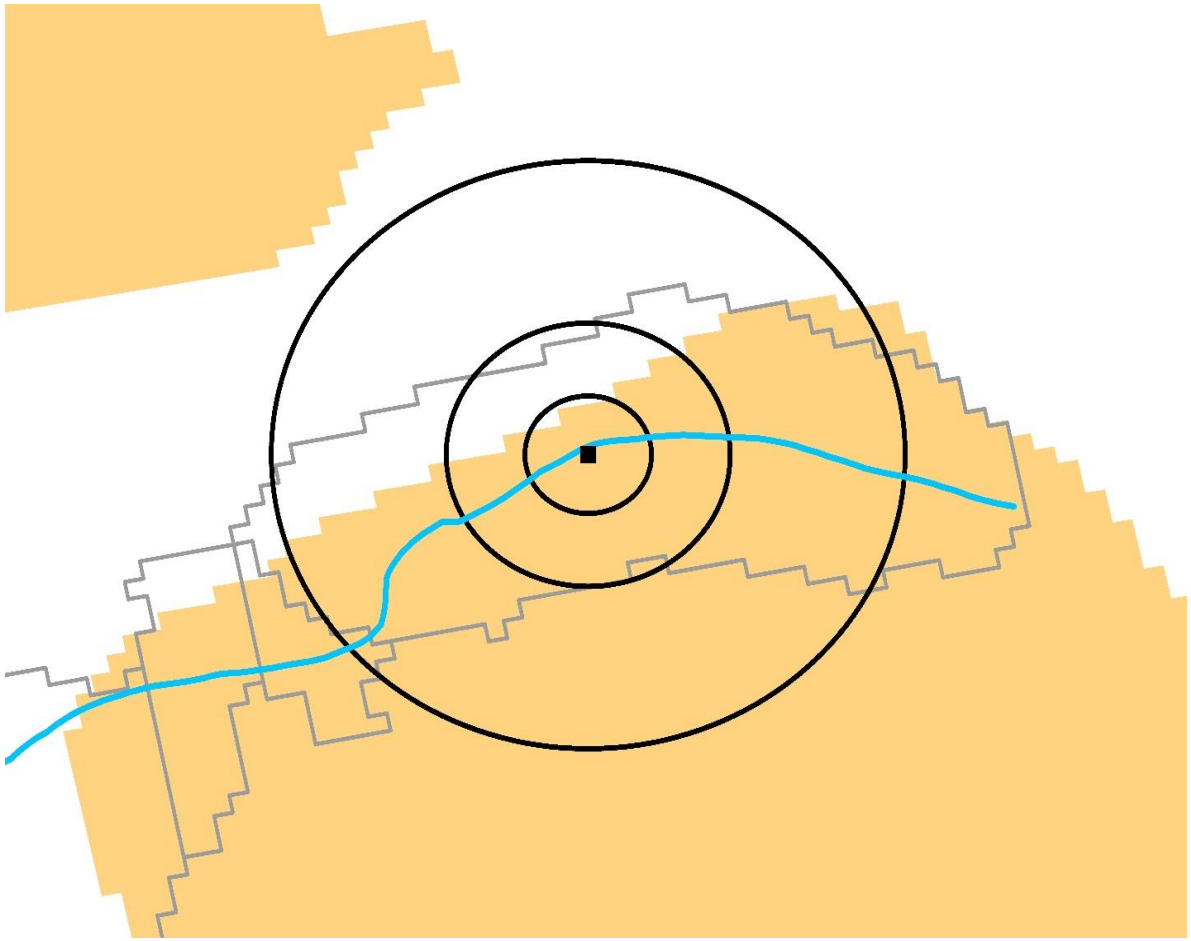
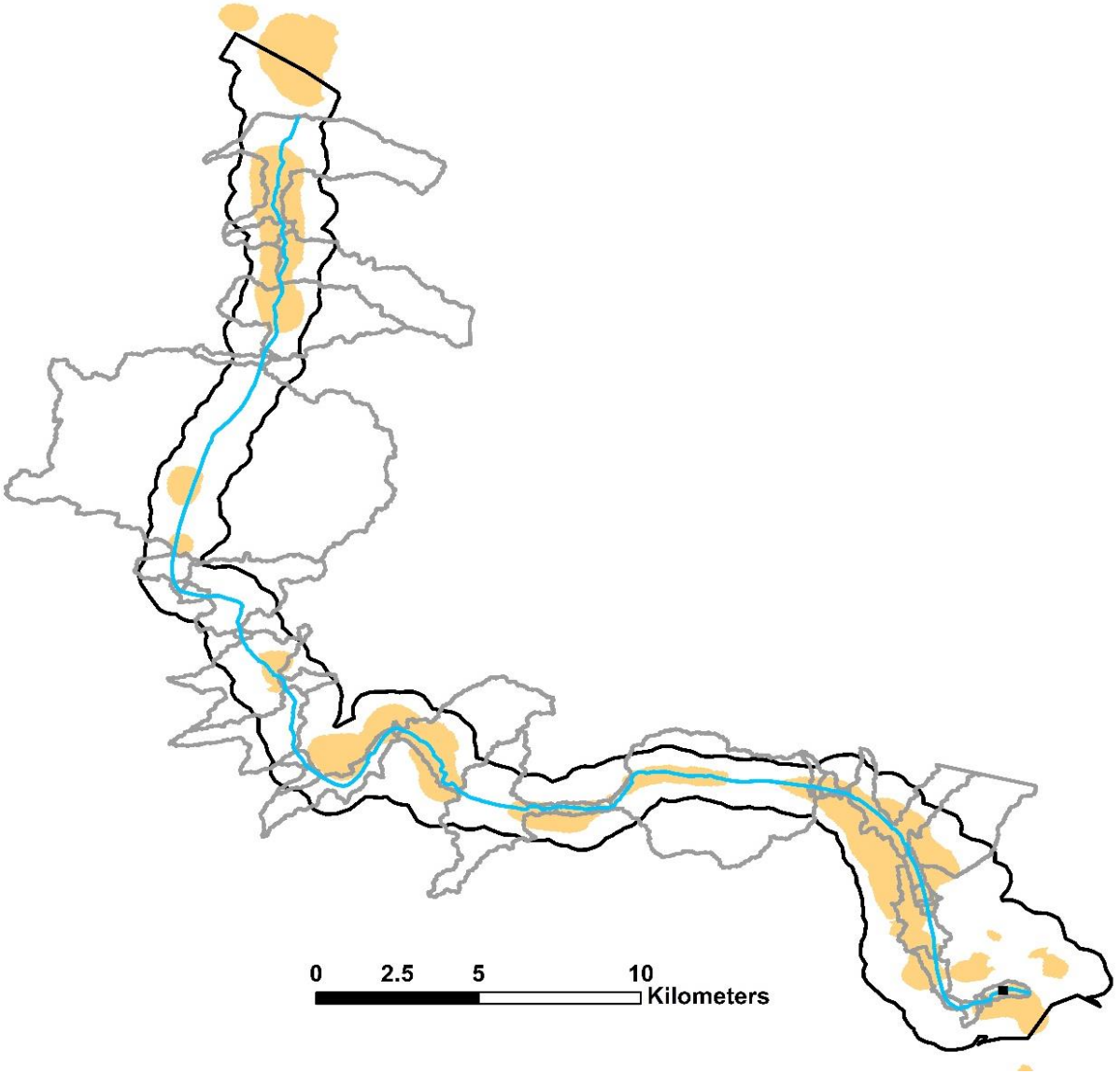
- **Hydrologic modification (NABD, NHDPlusV2)**
  - **Flow restriction, storage capacity (upstream dams), storage fluctuation (upstream dams)**
- **Multi-scale measurement**
  - **Catchment and network**
  - **Scale optimization**

Catchment Scale



Network Scale



Incorporating Broad-Scale Disturbance

1. Select top scale for each broad-scale disturbance variable

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Replicate for each of 10 broad-scale disturbance variables

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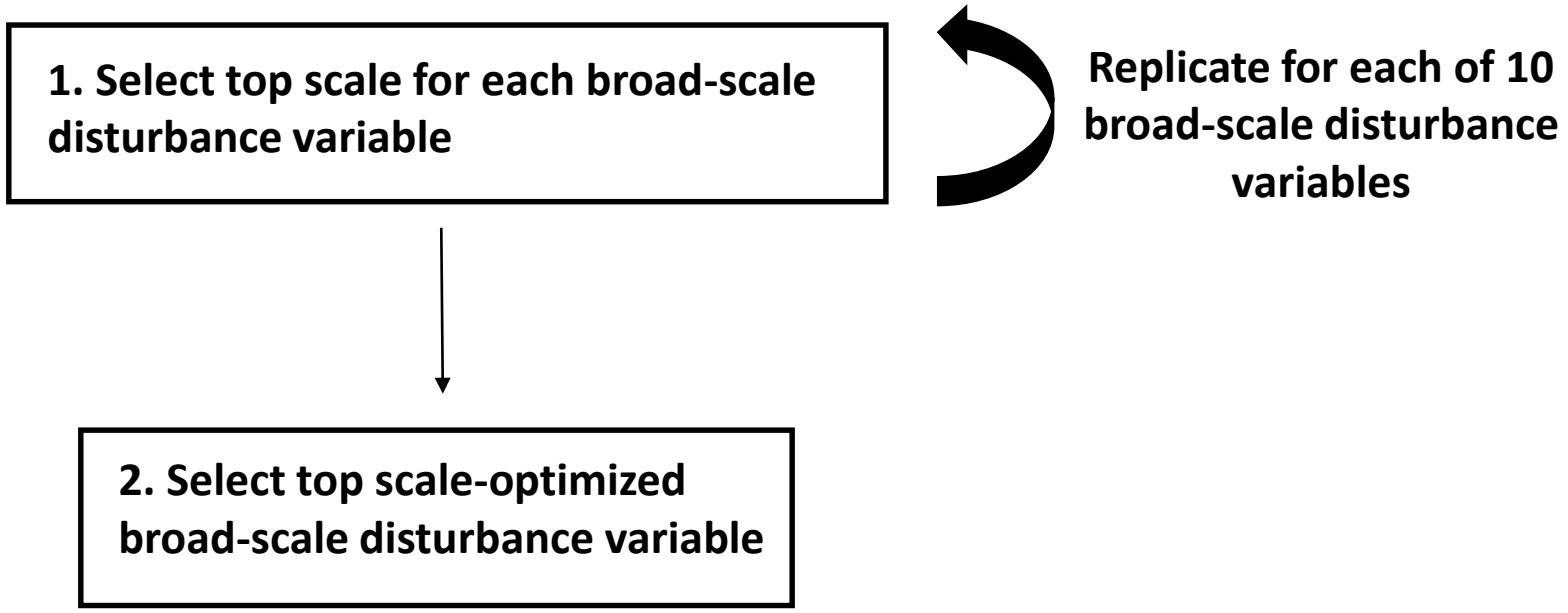

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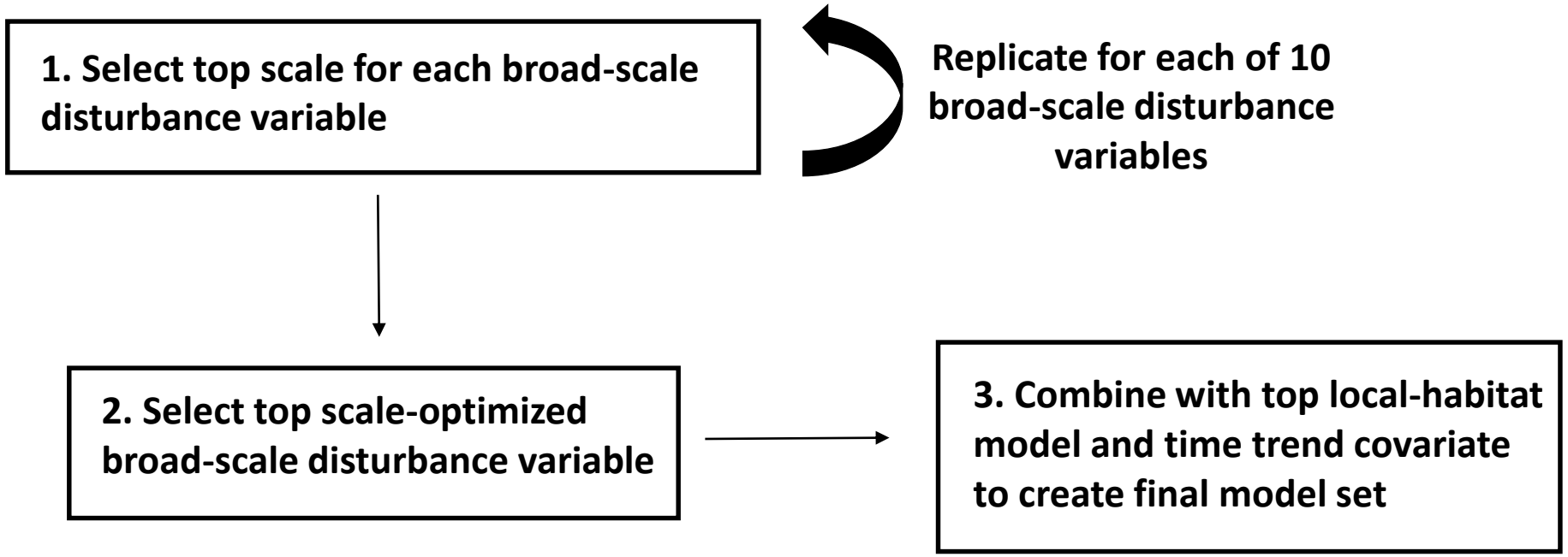

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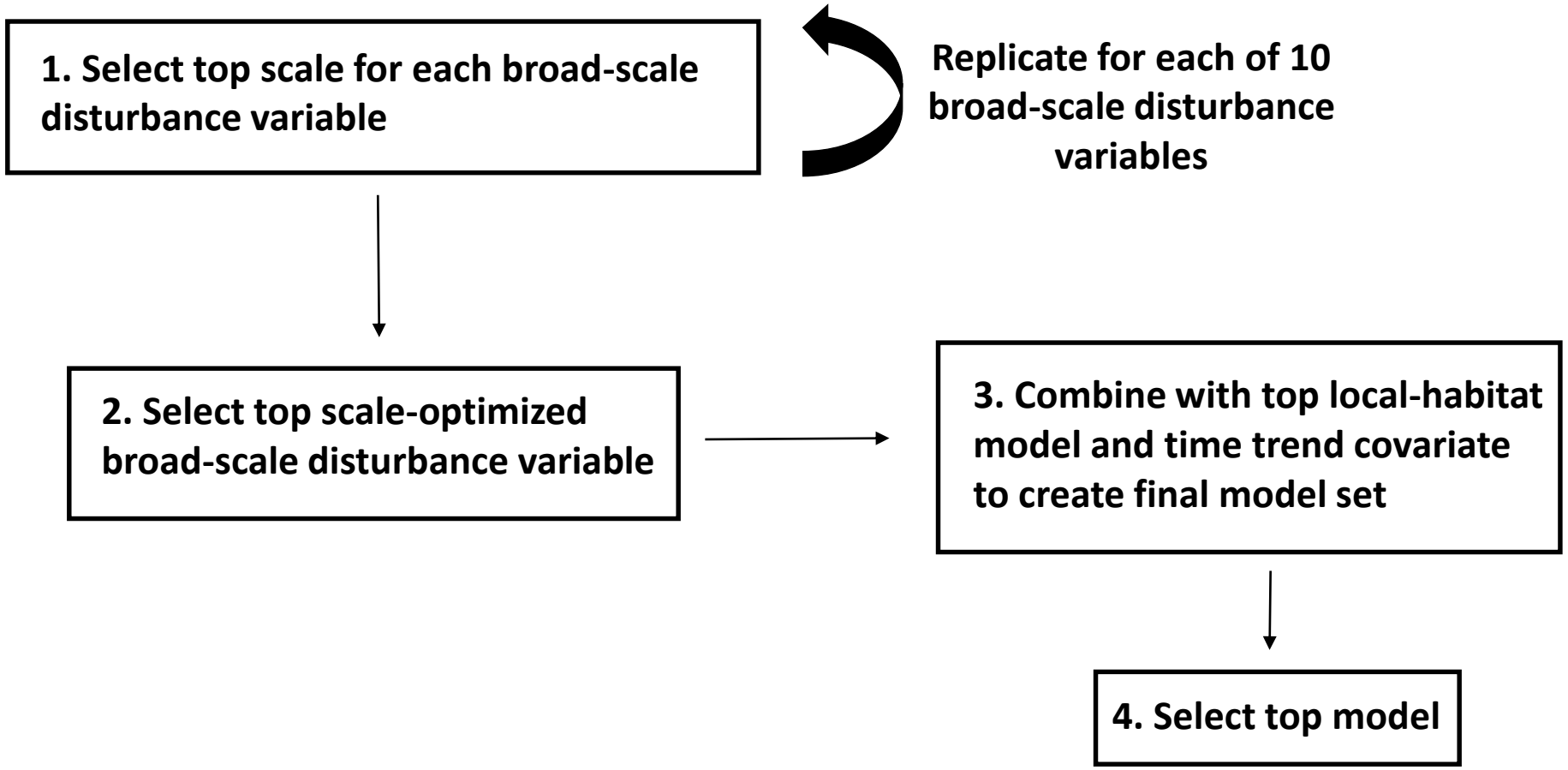

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  - **Accounted for imperfect detection**
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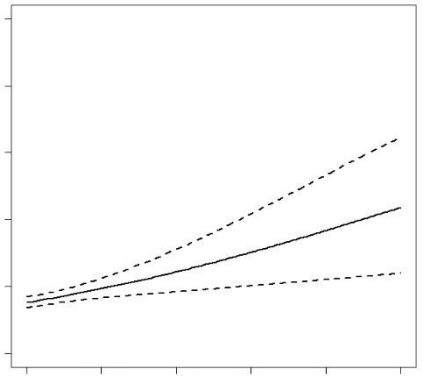
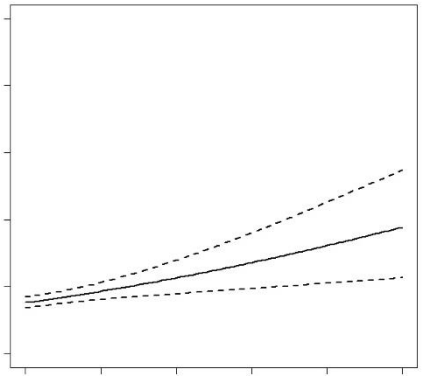
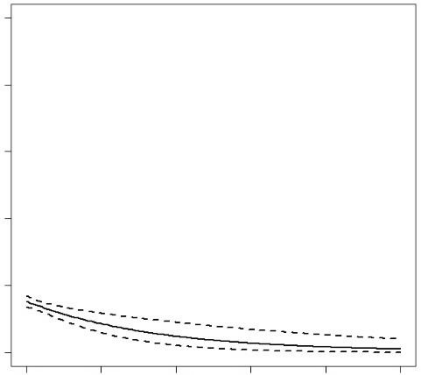
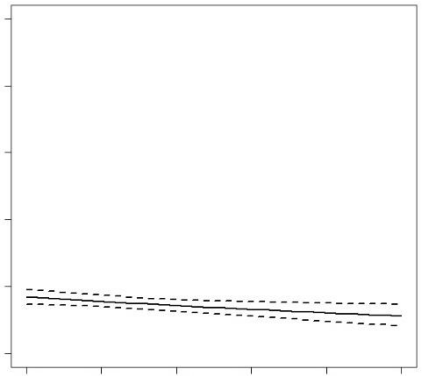
- **Selected best overall model using spatial predictive ability**
- **Replicated entire process for each species separately**

Results: King Rail

Scrub-shrub Wetland ψ 

Permanently Flooded ψ 

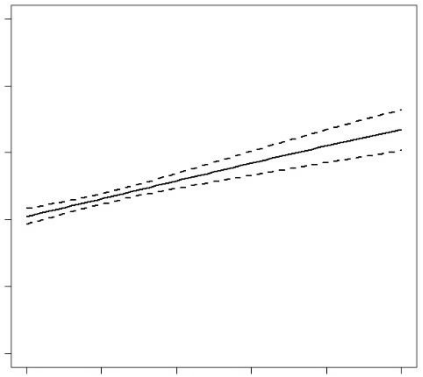
Developed ψ 

Agriculture (Network) ψ 

Results: Black Rail

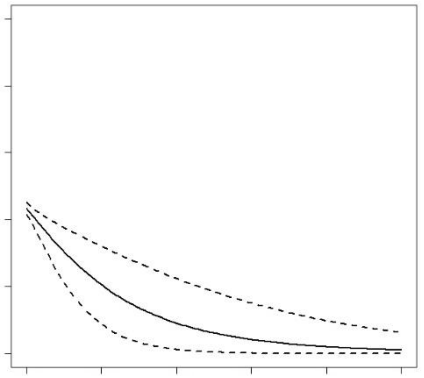
Scrub-shrub Wetland

ψ



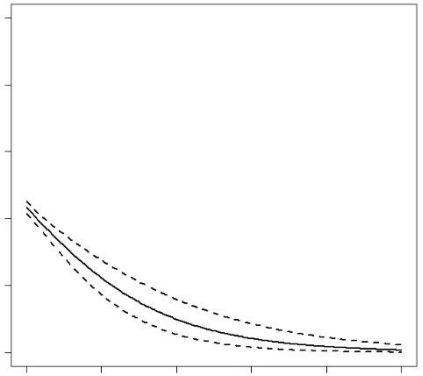
Artificially Flooded

ψ



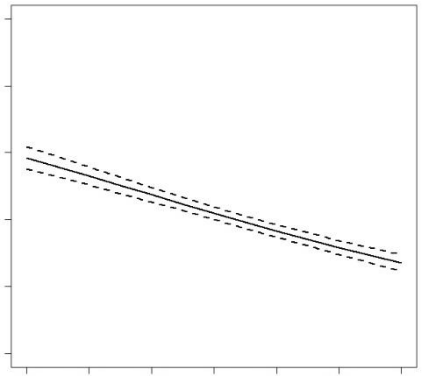
Developed

ψ

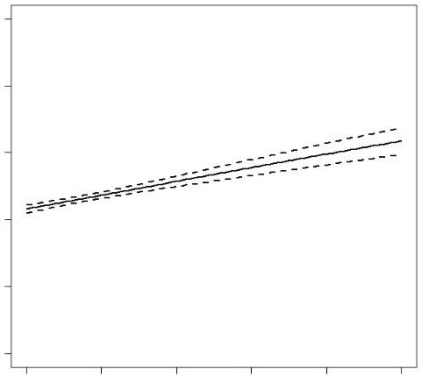


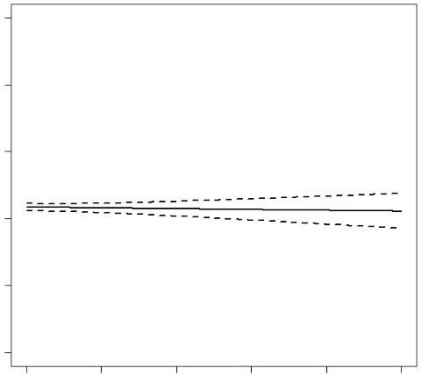
Time Trend

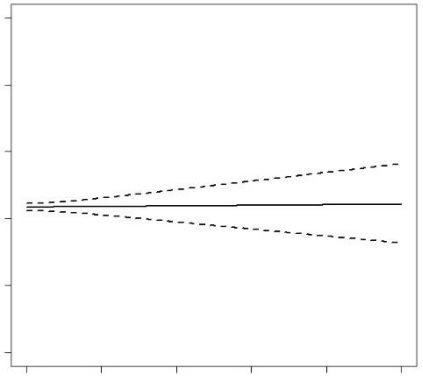
ψ

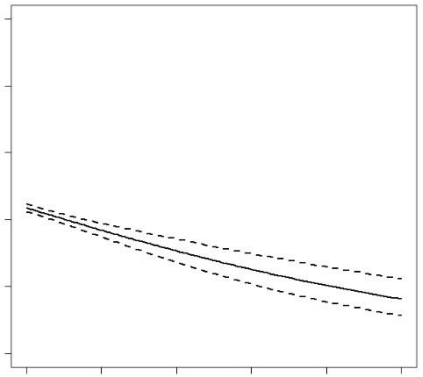


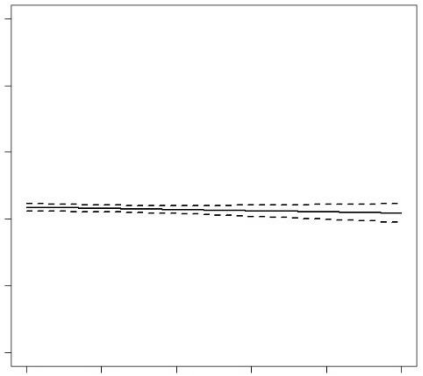
Results: Pied-Billed Grebe

Scrub-shrub Wetland ψ 

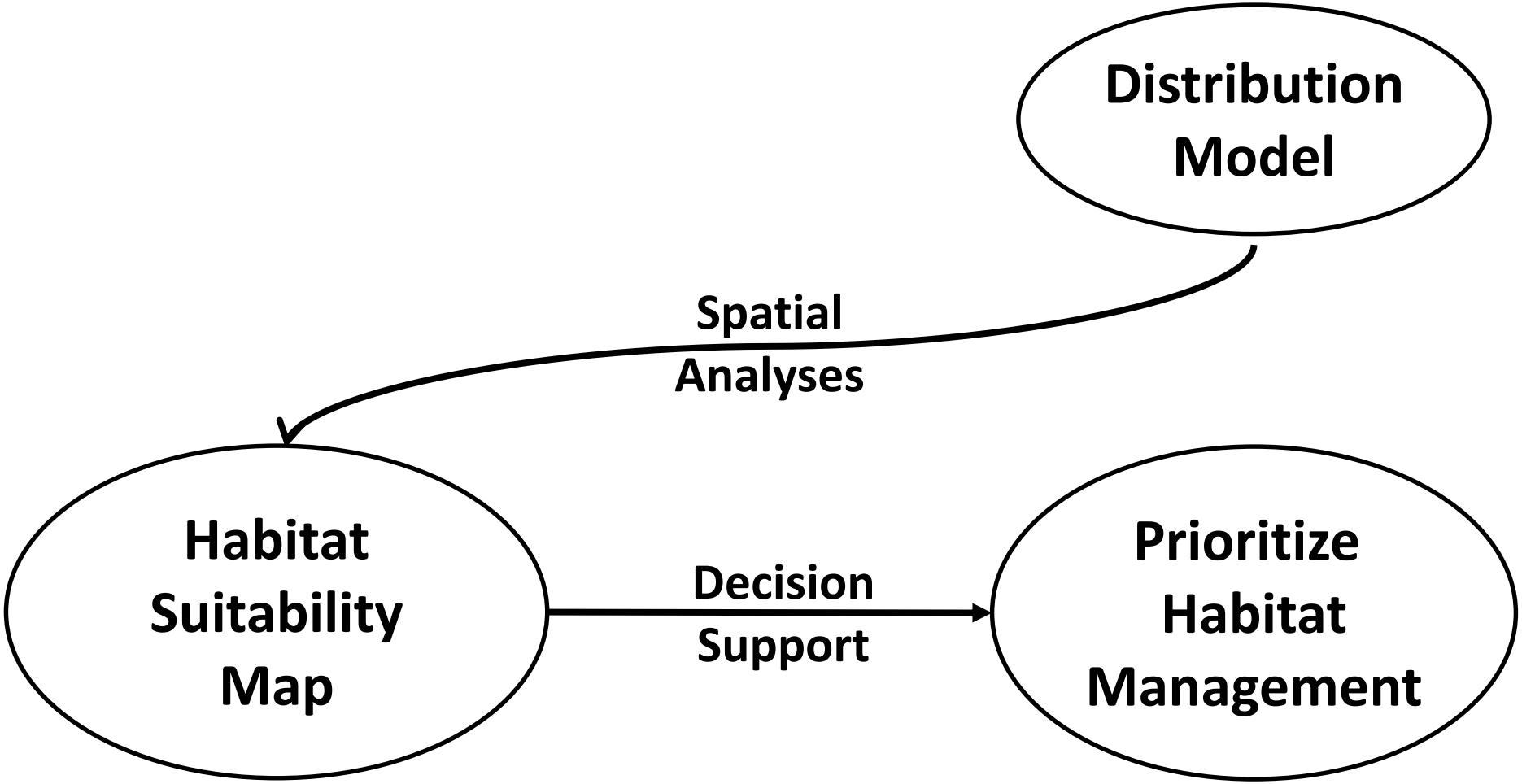
Artificially Flooded ψ 

Developed ψ 

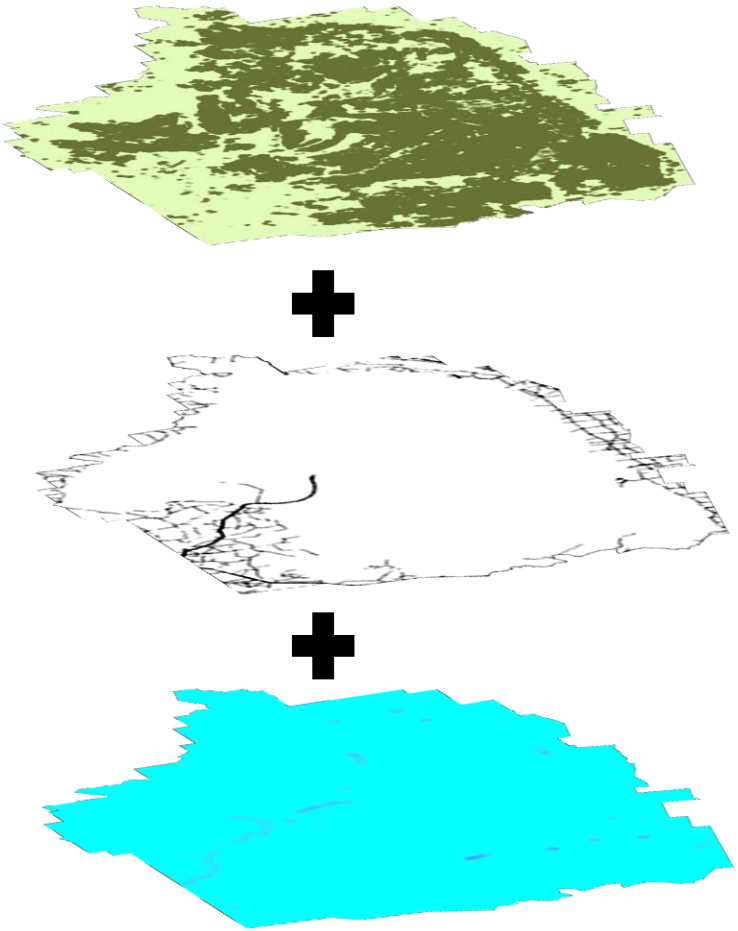
Riverine Lower-perennial ψ 

Agriculture (Catchment) ψ 

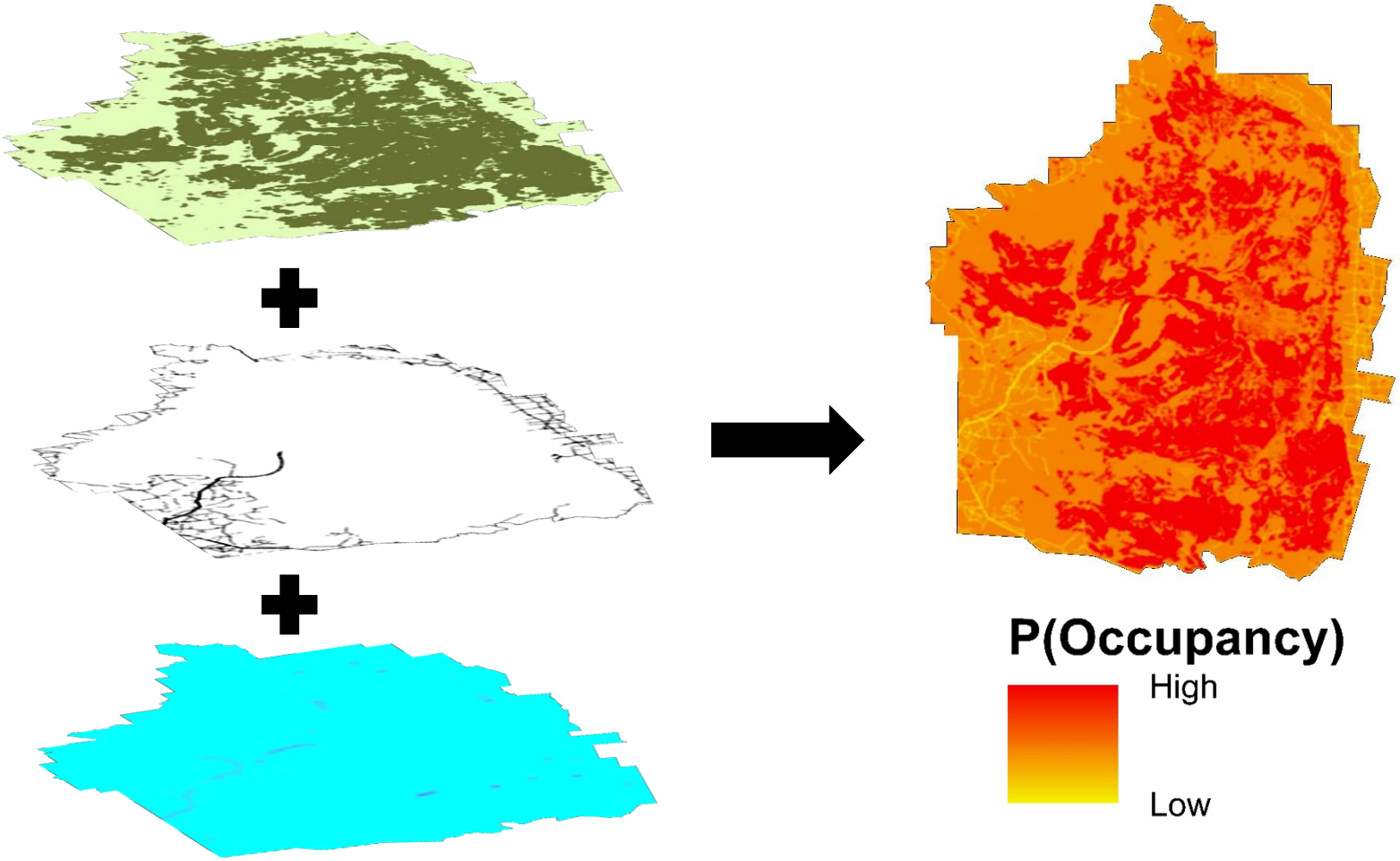
Objective 2: Spatial Analyses



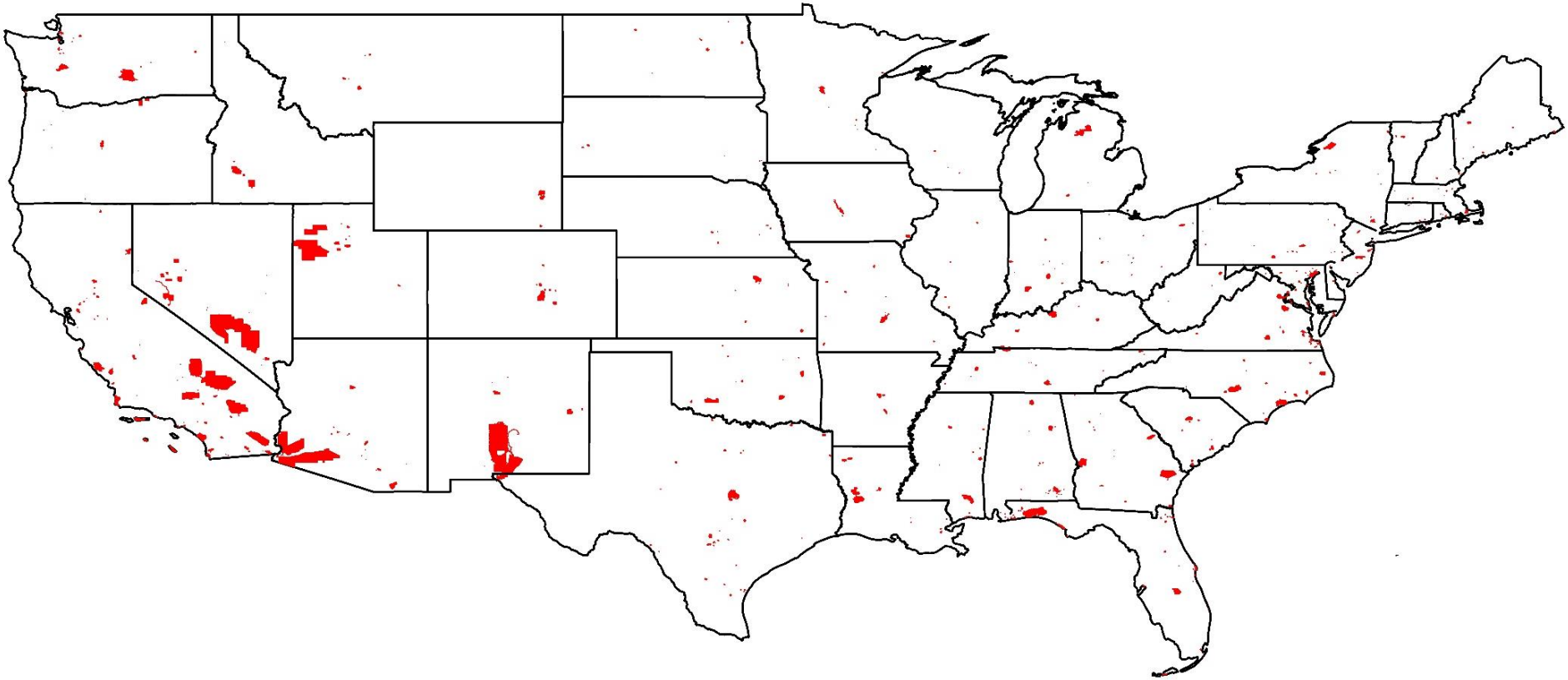
Spatial Analyses: Raster Regression



Habitat Suitability Maps



Decision Support for DoD



- **Projected P(occupancy) for all 593 installations for each species**

Ranking DoD Installations

- **Scaled area of optimal habitat**
  - **Fraction of all optimal habitat located at each site**
  - **Optimality threshold = top 30%**

$$\frac{\text{Area of optimal habitat at installation}}{\text{Total area of optimal habitat}}$$

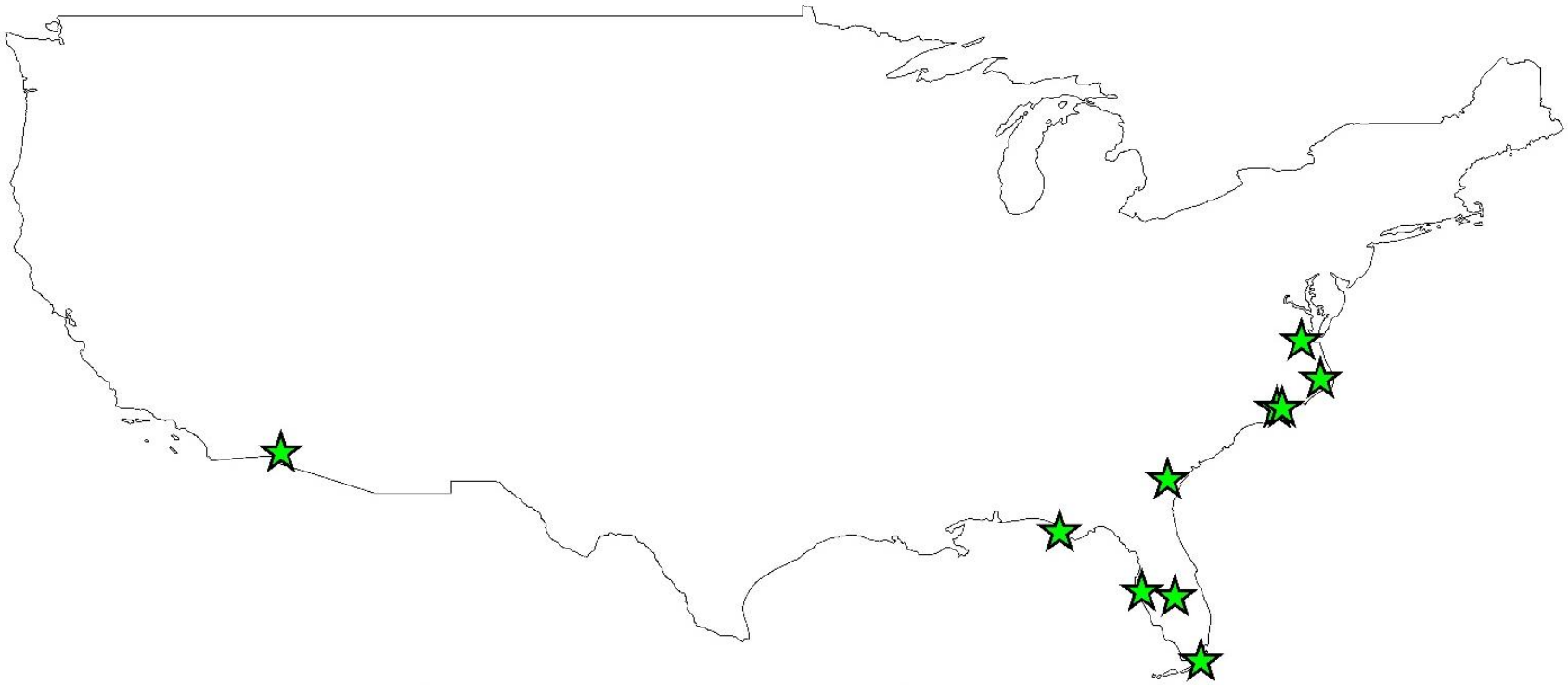
Ranking DoD Installations

- **Scaled area of optimal habitat**
  - **Fraction of all optimal habitat located at each site**
  - **Optimality threshold = top 30%**
- **Tested robustness of site rankings with other optimality thresholds**
  - **20%, 40%**

$$\frac{\text{Area of optimal habitat at installation}}{\text{Total area of optimal habitat}}$$

Top 10 Installations: King Rail

Top 10 Installations: Black Rail



Top 10 Installations: Pied-Billed Grebe

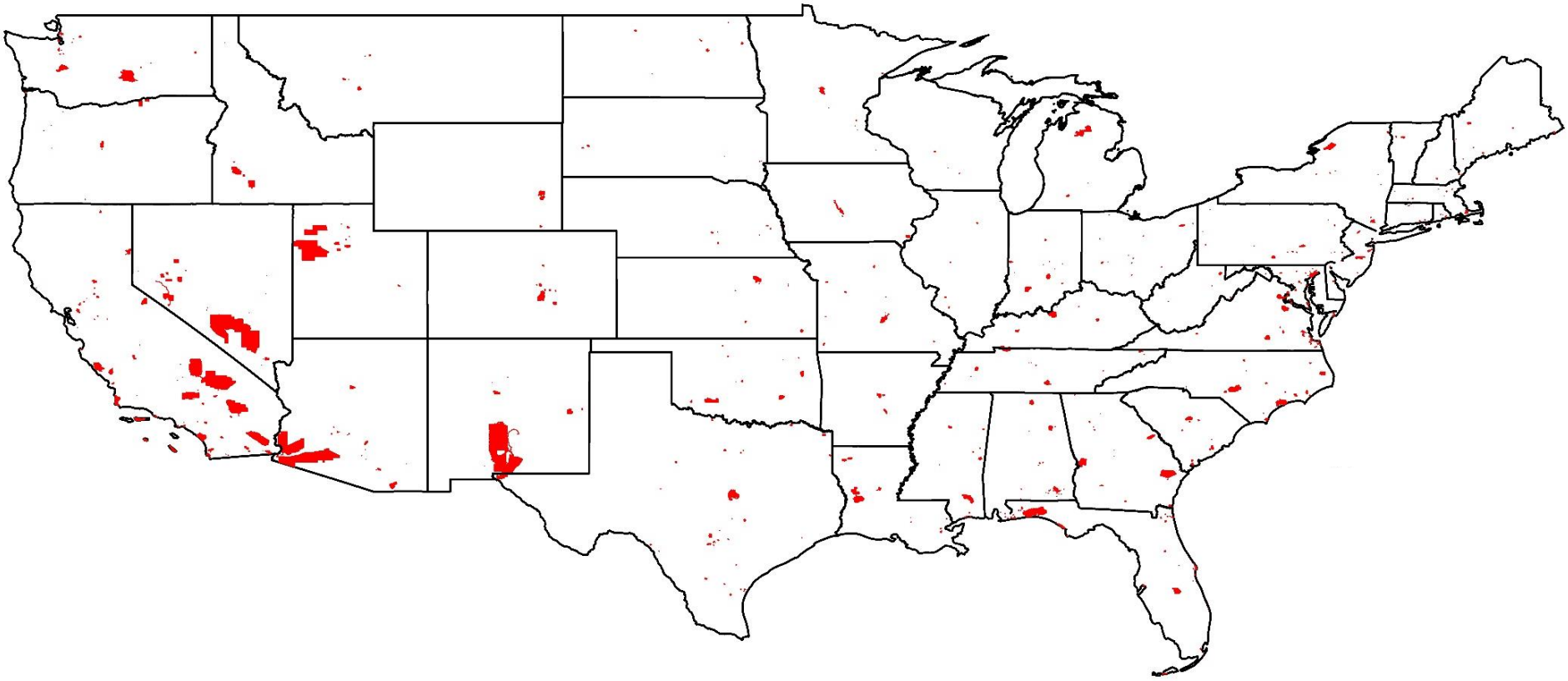
Top 10 Installations : All Species

- **Species-specific installation rankings robust to optimality threshold changes**

Use of Output Results

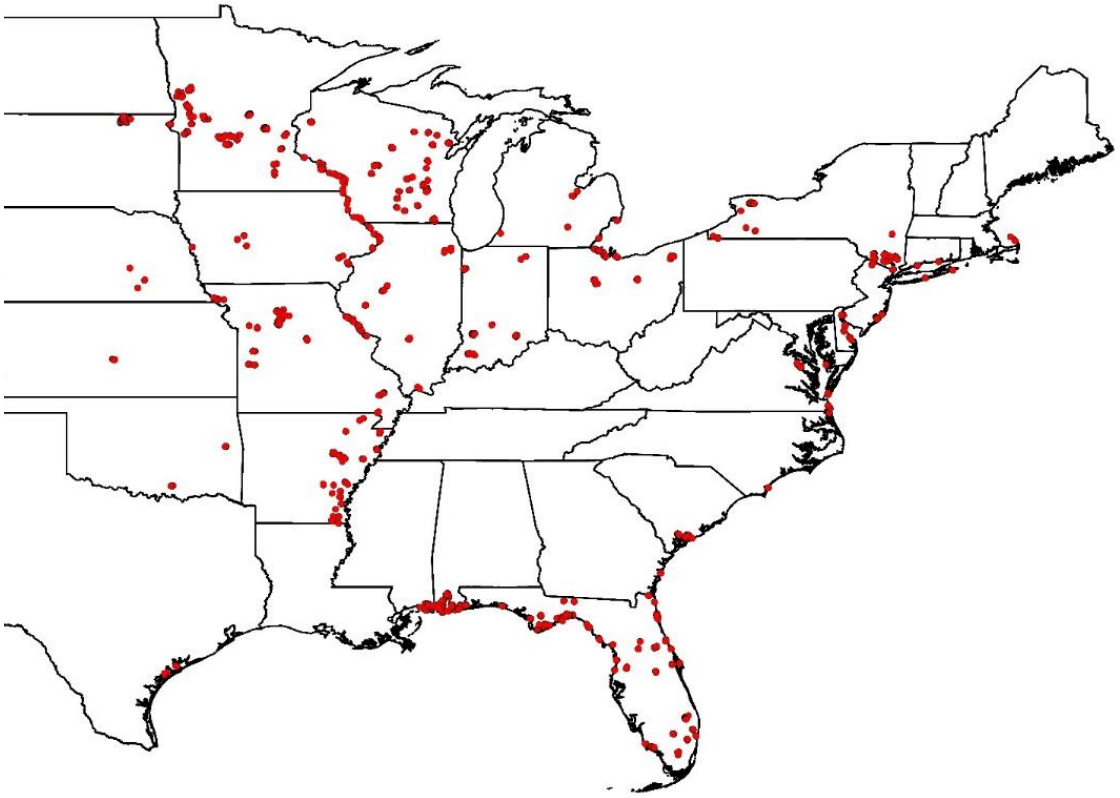
- **Species-specific inclusion of marsh birds in the INRMPs at relevant installations**

Summary and Conclusions



- **National-scale policy problem**
  - **Where to prioritize breeding habitat conservation on DoD lands?**

Summary and Conclusions



- **National-scale empirical assessment**
  - **Local-scale field data**
  - **State-of-art predictive modeling**

Summary and Conclusions

- **Map-based decision-support tools**
  - **Strategic habitat conservation over broad scales**
  - **Focus local-scale management on appropriate species**

Acknowledgments

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  - **DoD Legacy program**
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