

# A BAYESIAN BELIEF NETWORK TO PRIORITIZE CONSERVATION NEED AMONG DIVERSE AQUATIC TAXA

## INVESTIGATORS

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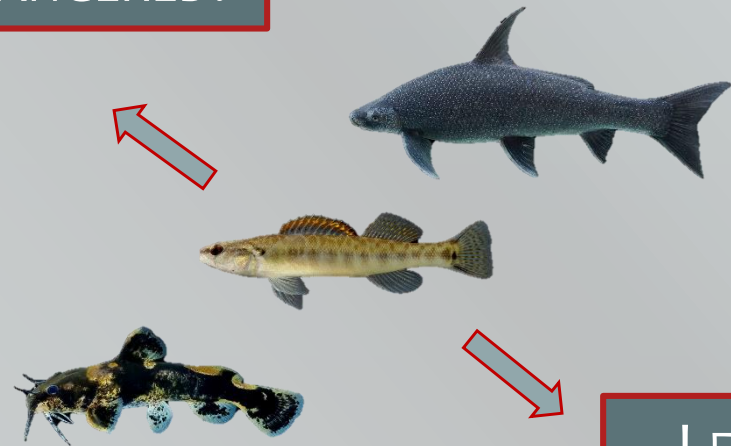
MICHAEL E. COLVIN

CRITICALLY  
ENDANGERED?

ENDANGERED?

IMPERILED?

NEAR  
THREATENED?



LEAST  
CONCERN?



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Gulf Coastal Plains & Ozarks  
Landscape Conservation Cooperative

# Need for Conservation Priorities

Conservation maintains  
“representative” biodiversity  
within administrative boundaries

- Aesthetic & economic values
  - Ecosystem services
  - Intrinsic value of life
- 
- Financial resources are limited
    - Need to prioritize geographic areas, species, or populations

Given resources to  
conserve few species,  
which do you choose?



How do you decide?

# Establishing Conservation Priorities

- State and federal legislation list threatened & endangered species
  - Relatively few target species
- Many conservation-prioritization frameworks exist
  - Use similar biological criteria & known threats
  - Assess extinction risk - most vulnerable and irreplaceable
  - Inform management decisions

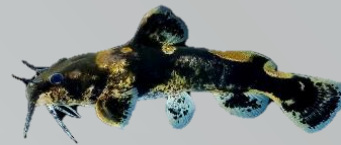
Sensitivity to:

Demographic stochasticity

Environmental stochasticity



Low risk



High risk

# Need for a New Approach

- No universally applicable conservation prioritization model
  1. Unable to represent uncertainty
  2. Operate at fixed spatial scales
  3. Unknown sensitivity to biological criteria
  4. High resource & labor demands
- Aquatic taxa feature especially poorly
  - Extinction risk: Aquatic > terrestrial taxa
  - Relatively understudied worldwide
  - Often excluded despite potential conservation significance

## Data Deficiencies

46% of  
Chondrichthyes



44% of Upper Yangtze  
River species



Current conservation  
status assigned to  
only ~20% of fishes

~32,000 fish species  
are unassigned

# Introducing Flexibility – Bayesian Belief Network

Objective: Demonstrate the utility of a Bayesian network analysis to identify fishes in need of conservation attention

- Accessible biological criteria & well-known threats
  - Ex. Life-history traits & museum databases
- Consistent with the concepts of redundancy, resiliency & representation (US Fish and Wildlife Service)

Improvements to future status assessments:

1. **Uncertainty**
  - Method to assess potentially rare but poorly known taxa
2. **Spatial Scale**
  - Applicable at different administrative & geographic scales
3. **Sensitivity to specific biological criteria**
  - Identify components driving status designation

# Bayes Net – A Probabilistic Model

**Data types: Expert elicitation & empirical**

Geographic Isolation		
Disjunct	33.3	
Peripheral	33.3	
Core	33.3	

Regional Occupancy		
Low	33.3	
Moderate	33.3	
High	33.3	
$0.5 \pm 0.29$		

Population Trend		
Relatively Stable	33.3	
Moderate Decline	33.3	
Strong Decline	33.3	

Spatial Extent		
Small	33.3	
Medium	33.3	
Large	33.3	

Home Range Size	Network Connectivity	High	Low
Small	Low	25	75
Small	Moderate	75	25
Small	High	100	0
Moderate	Low	25	75
Moderate	Moderate	50	50
Moderate	High	75	25
Large	Low	0	100
Large	Moderate	25	75
Large	High	75	25

Population Size		
Low	50.0	
High	50.0	

Trophic Level		
Piscivore	33.3	
Invertivore	33.3	
Other	33.3	

$0.338 \pm 0.33$

No_Hybrid_Populations		
Present	50.0	
Absent	50.0	

Home Range Size		
Small	33.3	
Moderate	33.3	
Large	33.3	

Connectivity		
High	50.0	
Low	50.0	

Redundancy		
Adequate	50.0	
Inadequate	50.0	

Resiliency		
Adequate	48.6	
Inadequate	51.4	

Representation		
Adequate	47.2	
Inadequate	52.8	

Habitat Diversity		
Generalist	50.0	
Specialist	50.0	

Network Connectivity		
Low	33.3	
Moderate	33.3	
High	33.3	
$0 \pm 0$		

Conservation Status		
Critically Endangered	21.8	
Endangered	20.5	
Imperiled	19.5	
Near Threatened	27.3	
Least Concern	10.9	

**What if we don't know the status of a box?**

# Uncertainty & Expert Elicitation

Home Range Size	
Small	33.3
Moderate	33.3
Large	33.3

Complete Uncertainty

Population Connectivity	
High	83.3
Low	16.7



Speckled Darter

Network Connectivity	
Low	0
Moderate	0
High	100
$0 \pm 0$	

Empirical Data

Home Range Size	
Small	85.0
Moderate	15.0
Large	0

Expert Elicitation

Population Connectivity	
High	96.2
Low	3.76

Network Connectivity	
Low	0
Moderate	0
High	100
$0 \pm 0$	

Empirical Data



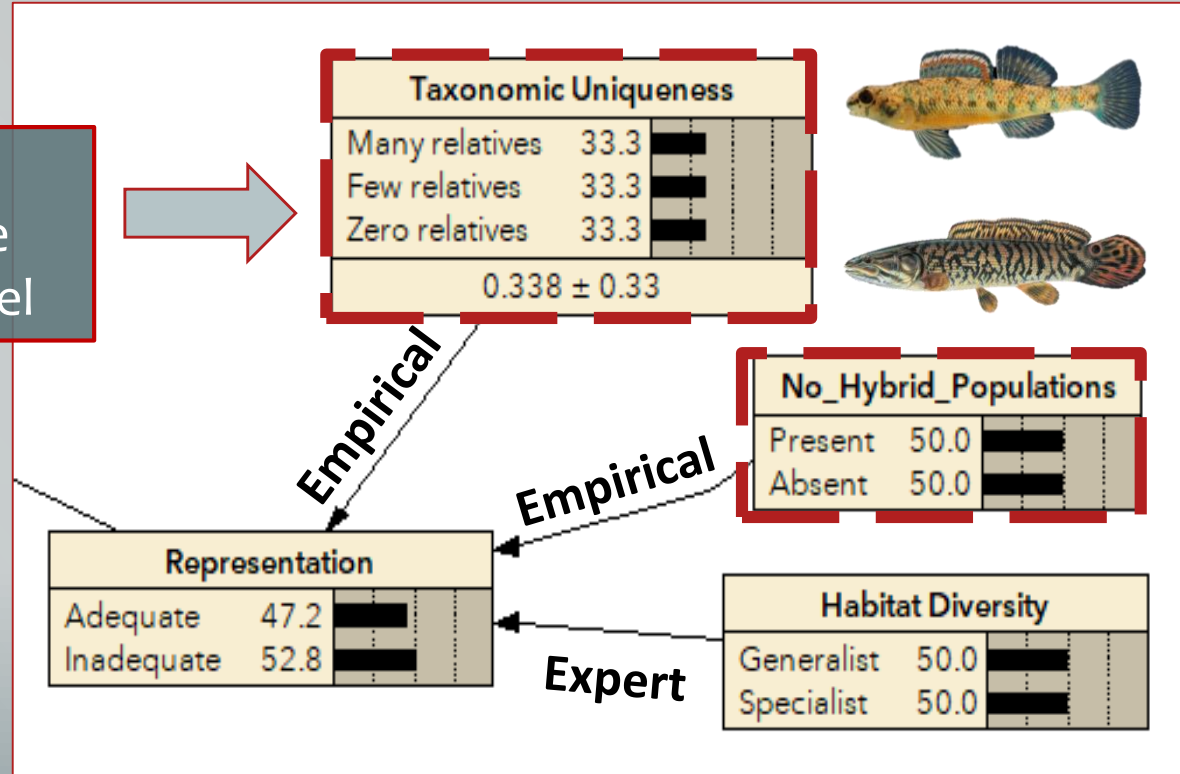
# Representation

**Definition:** The ability to adapt to changing environmental conditions over time

- Breadth of genetic & environmental diversity - within & among populations
- Adequate: risk is spread among genetically diverse populations in diverse habitats

**Continuous variable:**  
represents diversity at the  
species, genus & family level

**Calculation:**  
Inverse of the product of  
the number of cladogram  
branches at the genus,  
family & order nodes

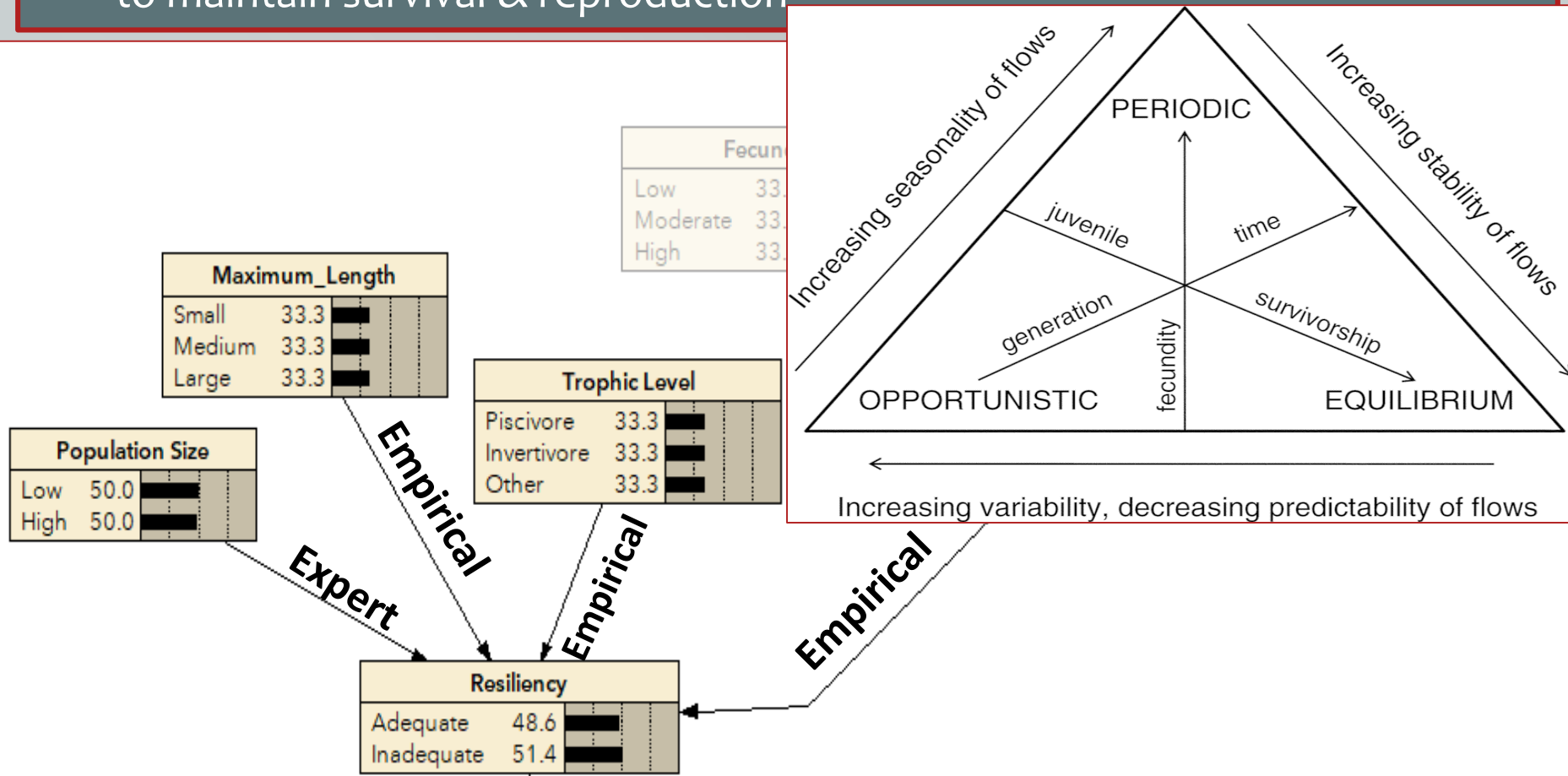




# Resiliency

**Definition:** The ability to withstand environmental stochasticity & localized disturbance events

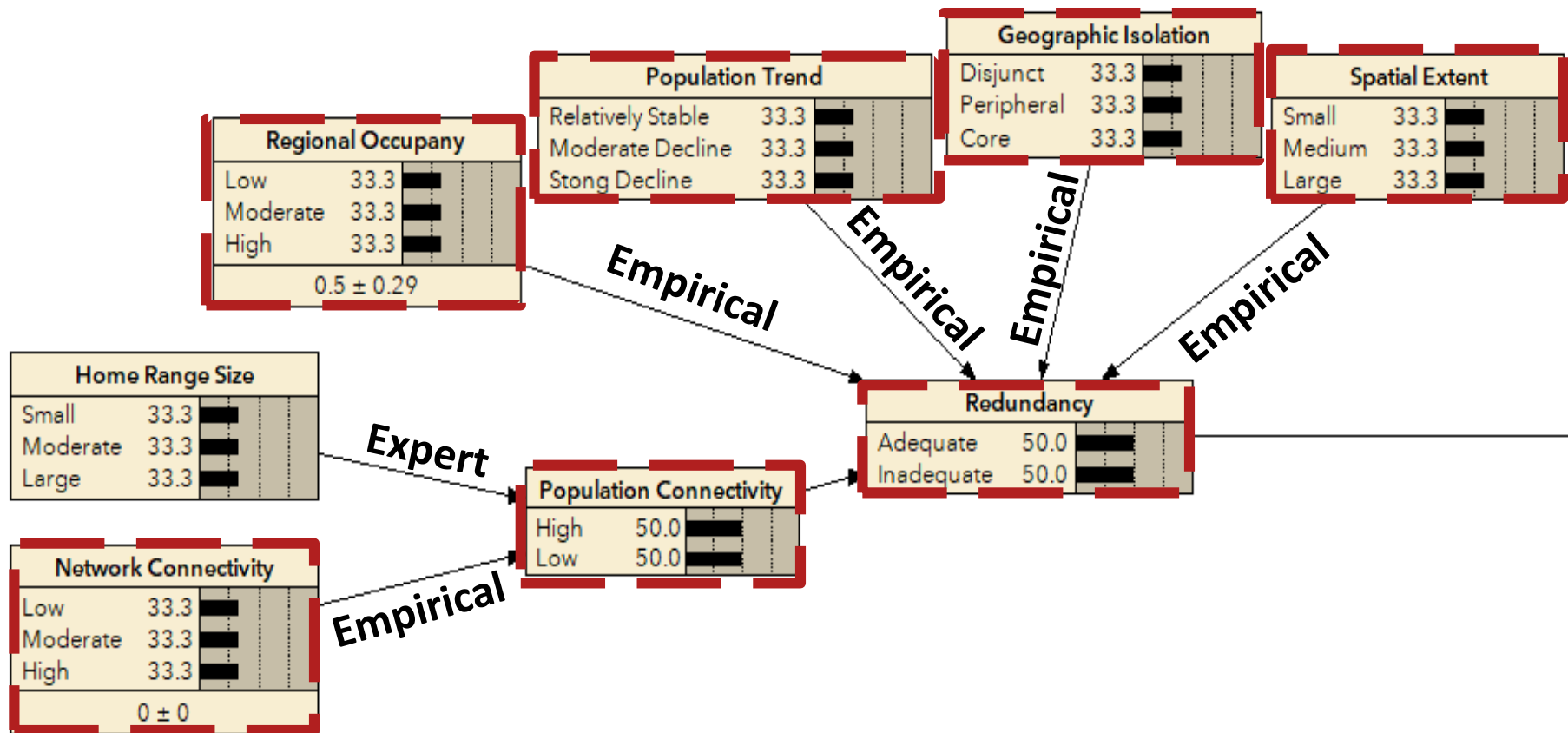
- Related to population demographics, species ecology & life-history traits
- Adequate: abundant individuals occupy habitats patches of suitable quality to maintain survival & reproduction






# Redundancy




**Definition:** The ability to withstand catastrophic events



- Related to the number, distribution & connectivity of populations
- Adequate: risk is spread among multiple, interacting populations



# Redundancy – Quantifying Population Connectivity

Home Range Size		
Small	33.3	
Moderate	33.3	
Large	33.3	

Network Connectivity		
Low	33.3	
Moderate	33.3	
High	33.3	
0 ± 0		

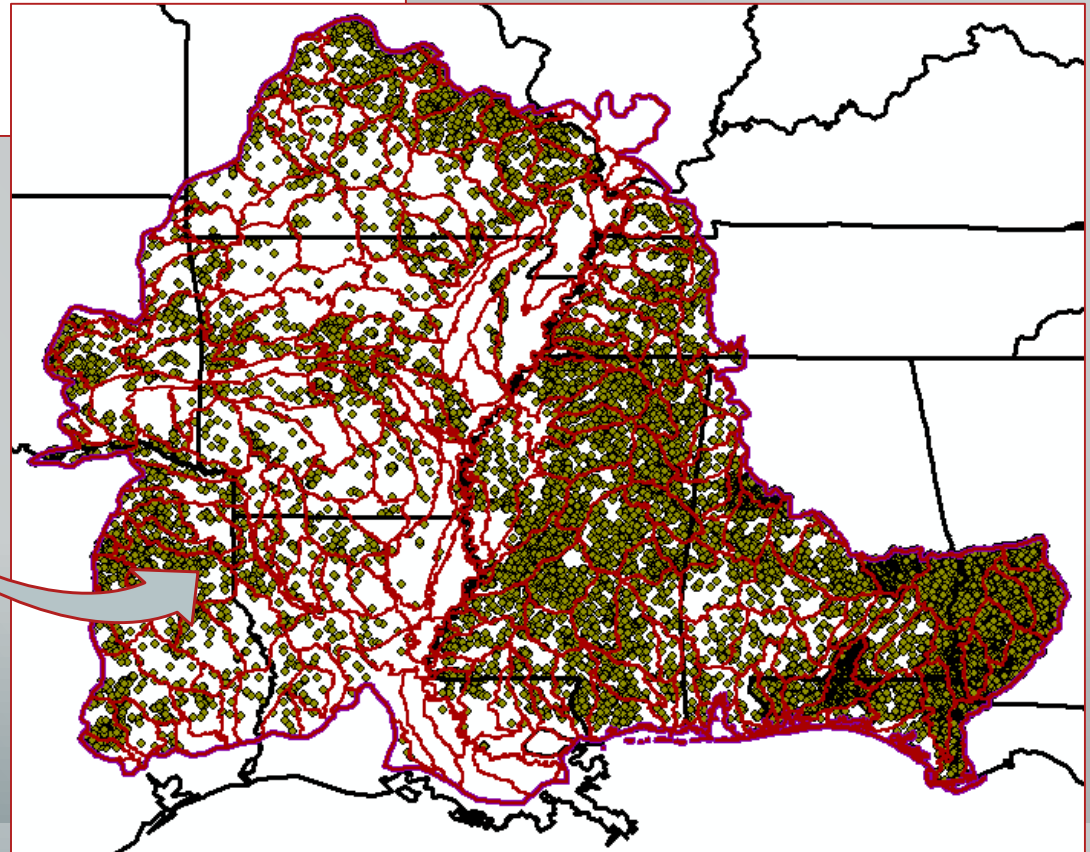
Connectivity		
High	50.0	
Low	50.0	

Home Range Size  
**Categorical variable:**

- Small – within segment
- Moderate – within stream
- Large – among streams

Network Connectivity  
**Continuous variable:**  
Mean unimpeded river distance (km)

**Grouped as:**  
Low, Moderate, High



# Example Outputs for One Mississippi Basin

## Upper Big Black basin, Mississippi

- Museum Database – 3,671 records
- 228 sample events
- Years: 1934 – 2017
- ~92 species

Johnny Darter

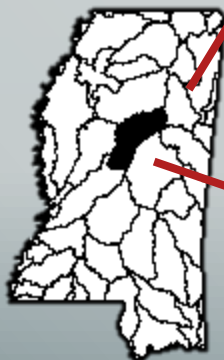
Conservation Status	
Critically Endangered	6.62
Endangered	11.5
Imperiled	15.3
Near Threatened	27.0
Least Concern	39.6

**More threatened:** Recapture rate at historic sites

Piebald Madtom

Conservation Status	
Critically Endangered	26.6
Endangered	26.1
Imperiled	18.3
Near Threatened	19.4
Least Concern	9.65

**More threatened:** Number and extent of populations



Upper Big Black (HUC-8), MS

# Piebald Madtom – Model Walkthrough

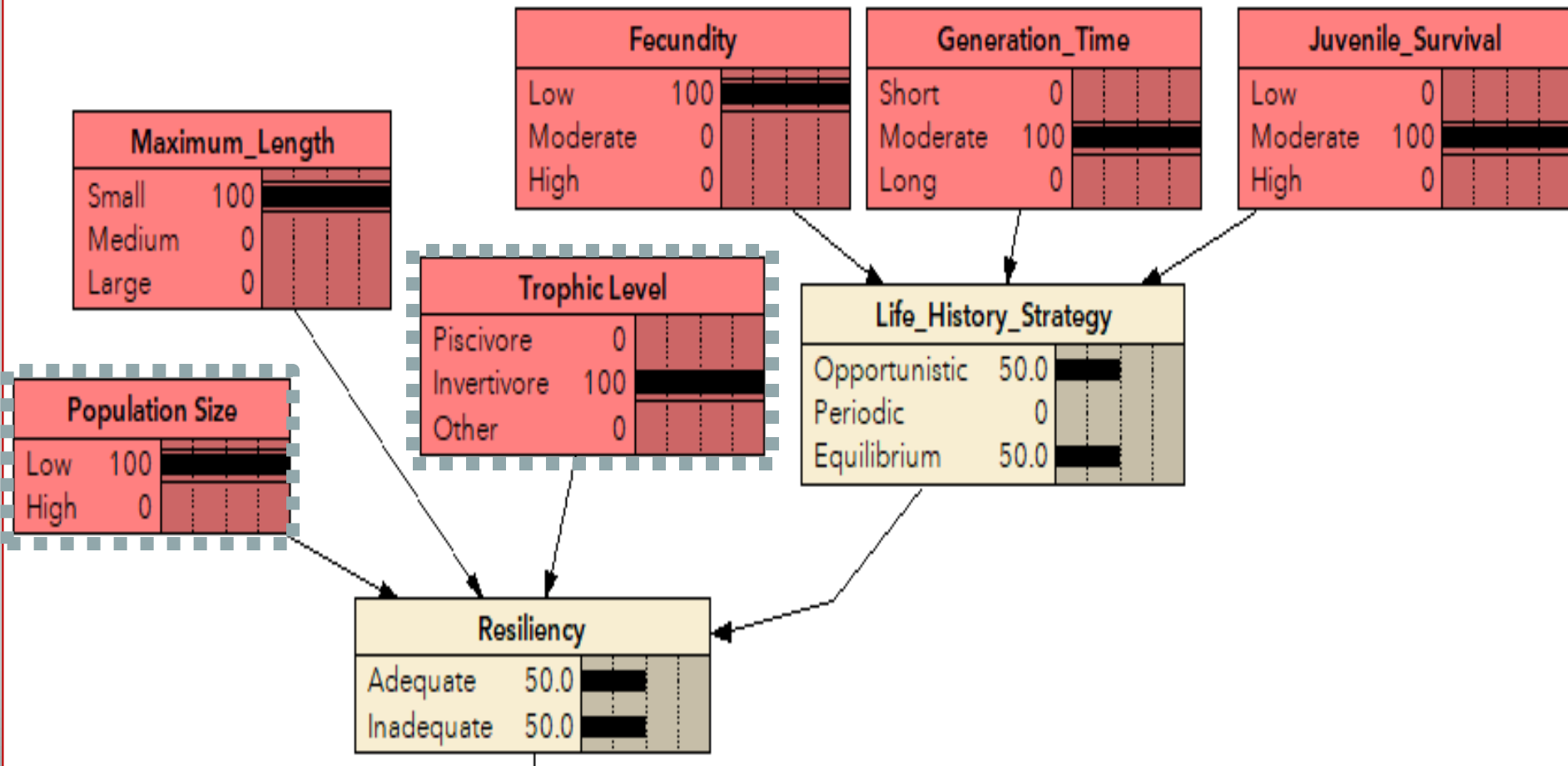
Taxonomic Uniqueness					
Many relatives	0				
Few relatives	100				
Zero relatives	0				
0.258 ± 0.14					

No_Hybrid_Populations					
Present	0				
Absent	100				

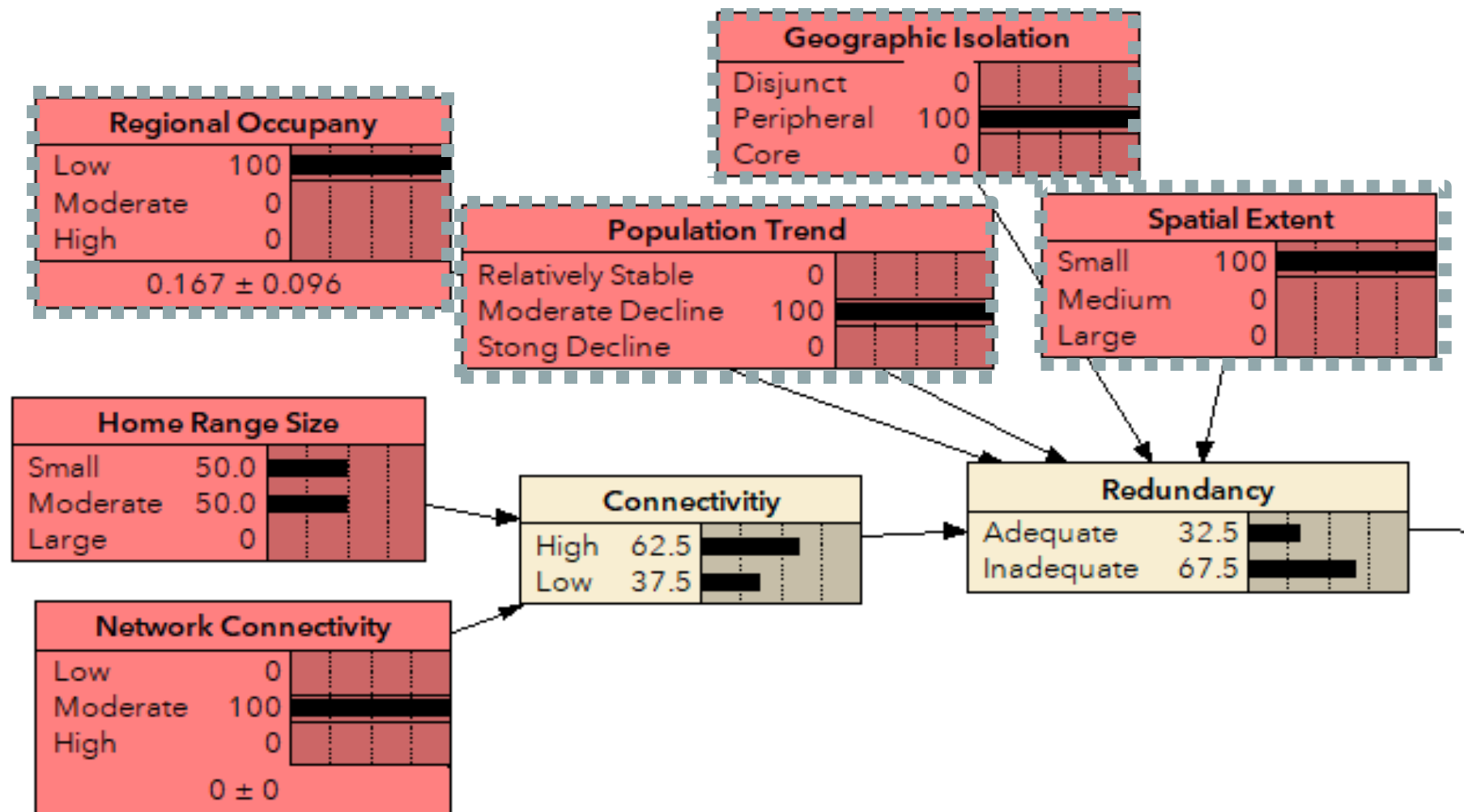
Representation					
Adequate	62.5				
Inadequate	37.5				

Habitat Diversity					
Generalist	50.0				
Specialist	50.0				

# Piebald Madtom – Model Walkthrough



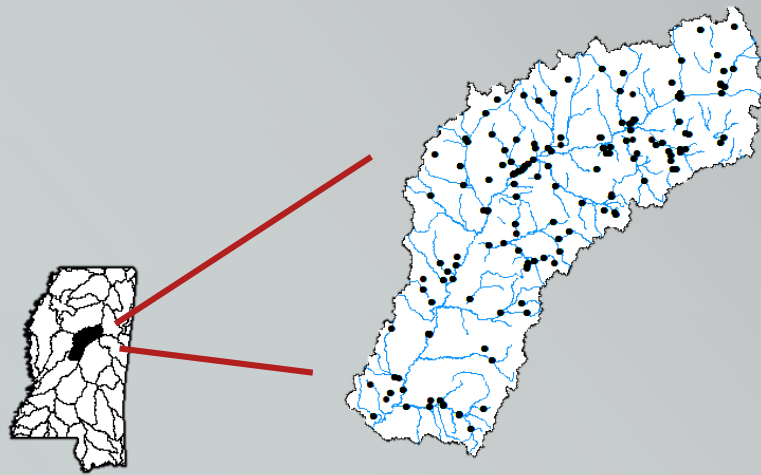
# Piebald Madtom – Model Walkthrough





# What happens if we change the scale?

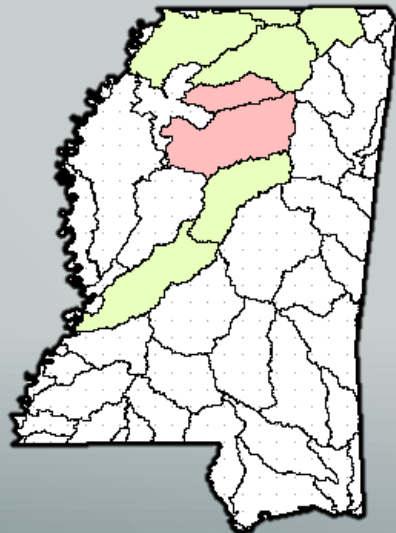
## Piebald Madtom Status



Upper Big Black (HUC-8), MS

Conservation Status		
Critically Endangered	26.6	██████████
Endangered	26.1	██████████
Imperiled	18.3	██████████
Near Threatened	19.4	██████████
Least Concern	9.65	██████████

## Upper Big Black basin



State of Mississippi

Conservation Status		
Critically Endangered	21.3	██████████
Endangered	23.6	██████████
Imperiled	18.1	██████████
Near Threatened	21.3	██████████
Least Concern	15.8	██████████

## Mississippi

# Prioritizing Conservation Efforts for Aquatic Taxa

A new tool to identify species in need of conservation attention

- Addresses concerns with other prioritization systems when applied to aquatic species
  1. Uncertainty – poorly known species & data limitations
  2. Spatial Scale – any spatial or administrative scale
  3. Straightforward parameterization & prompt decision
- Broad applicability to diverse aquatic taxa
  - Ex. Panama City Crayfish



## Moving forward:

- Further validation of the model structure
  - Federal partners assessing assigned & petitioned aquatic taxa
  - Training the model using species designated by USFWS



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