Evaluation of potential factors limiting the expansion of Invasive Carp in the Ohio and Tennessee-Cumberland River basins: lessons to apply to the upper Mississippi

Erin Shepta, Luka Marques do Amaral, Caroline Arantes, Brent Murry

Collaborators: Mark Rogers, USGS/TN Tech
Andrew Stump, KY DFWR
Katie Zipfel, WV DNR
Craig Jansen, IN DNR

West Virginia University
DIVISION OF FORESTRY AND NATURAL RESOURCES

Modeling Factors Impacting the Establishment Success of Invasive Bighead and Silver Carp

Erin Shepta[1], Brent Murry[1], Caroline C. Arantes[1], Christopher Rota[1], Andrew Stump[2], Katherine Zipfel[3]

[1]West Virginia University, Davis College

[2]Kentucky Department of Fish and Wildlife Resources

[3]West Virginia Division of Natural Resources

Invasive Bighead and Silver Carp

Bighead Carp

(*Hypopthalmichthys nobilis*)

Silver Carp

(*Hypopthalmichthys molitrix*)

Source: Illinois Natural History Survey, photographer: *Charlie Gilpin Jr.*

Native Range: Eastern Asia

Introduced Range:

- **Bighead Carp** – 70 countries (worldwide)
- **Silver Carp** – 88 countries (worldwide)

Impacts:

- **Ecological** – large-bodied, low trophic planktivores
- **Economic** – disrupt native fisheries, injuries to boaters

Invasive Bighead and Silver Carp

Source: *U.S. Geological Survey*

Source: *Emily Carter*

Source: *Thad Cook*

Source: *Jason Goeckler*

Source: *Denny Simmons*/Courier & Press

Bighead and Silver Carp Invasion History

Introduction in the **Lower Mississippi River**

- Rapid population spread throughout the **Upper Mississippi River**

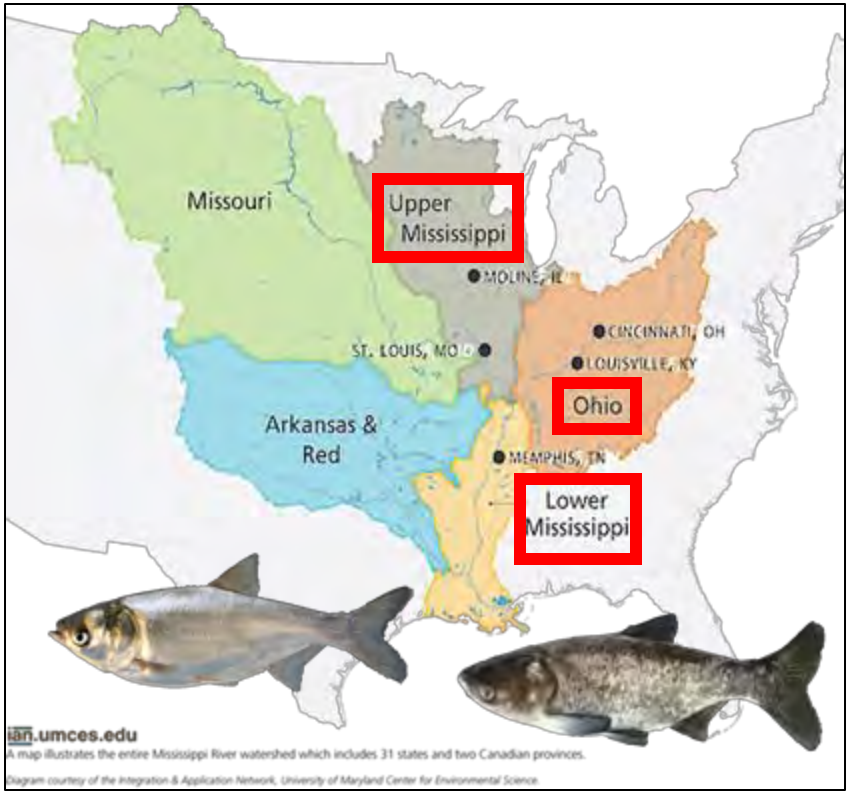
- Spread slowed/stalled in **Ohio River** basin

Questions:

1. Why has spread stalled in the Ohio River basin?

2. Can we apply lessons learned here to manage spread?

Kolar et al. (2005)



Maps on Mississippi River sub-basins accessed from https://ian.umces.edu/media-library/mississippi-river-watershed-map/

Study System: The Ohio River Basin

Invasion fronts describing a gradient of carp abundance, **reproduction**, and **recruitment**

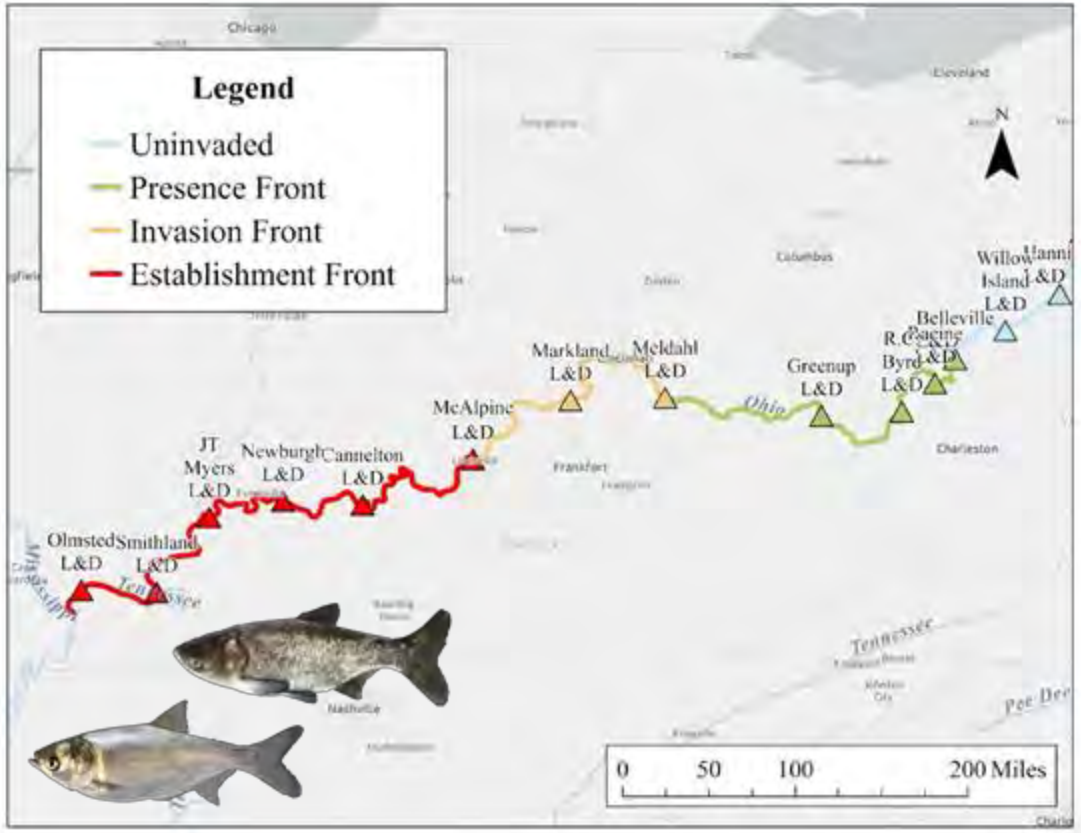
= adults, reproduction, recruitment

= adults, reproduction

= adults

= no carp

Knowledge Gap: No true measure of recruitment or reproduction success currently available for the Ohio River



Sampling Methods

Sample invasive carp across **3** age classes:

1. <u>Eggs/Larvae</u> -

Pre-gas bladder inflation

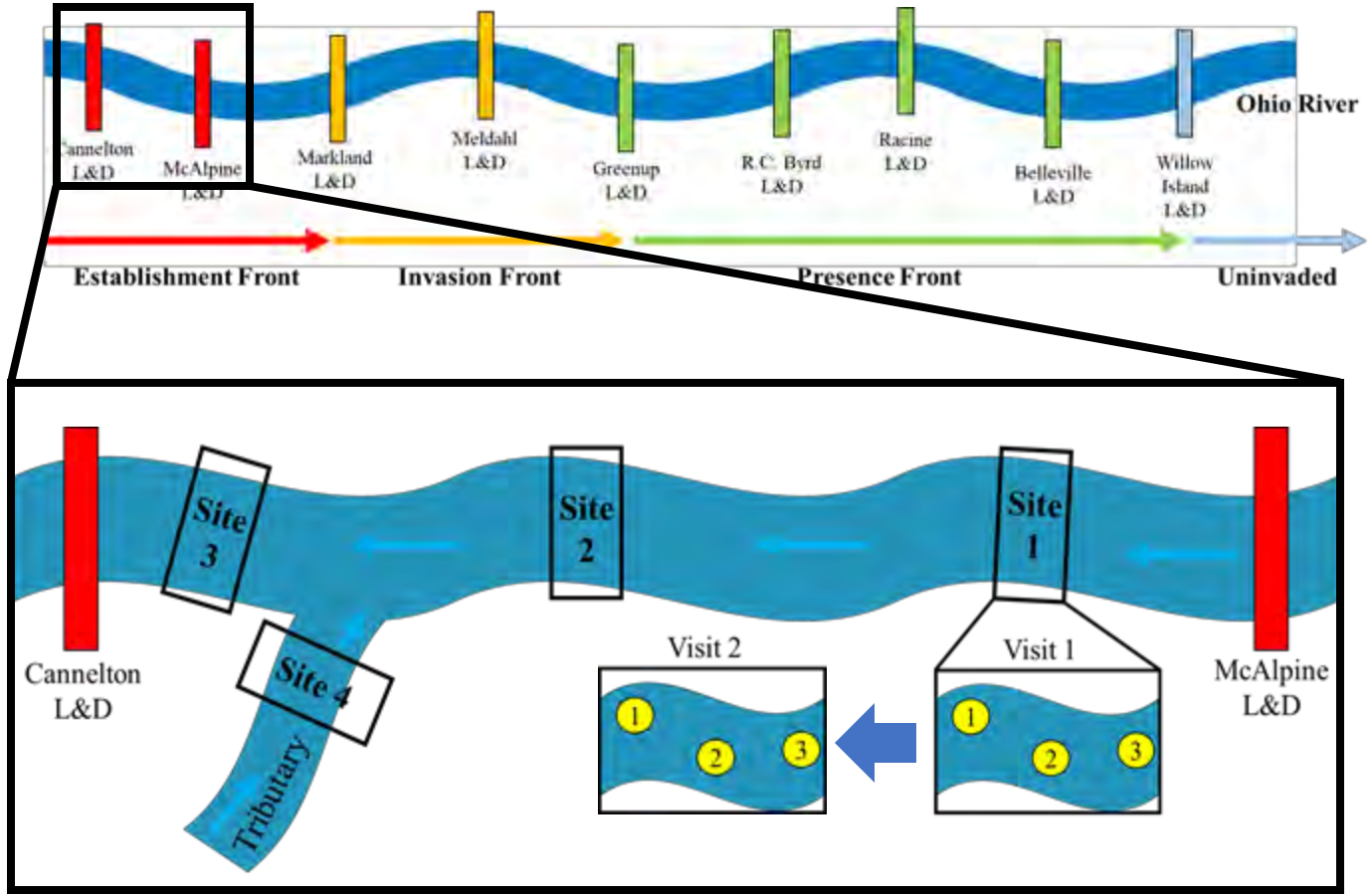
2. <u>Juvenile</u> -

<400 mm (likely 1-2 years), undeveloped gonads

3. <u>Adult</u> -

>400mm, mature identifiable gonads

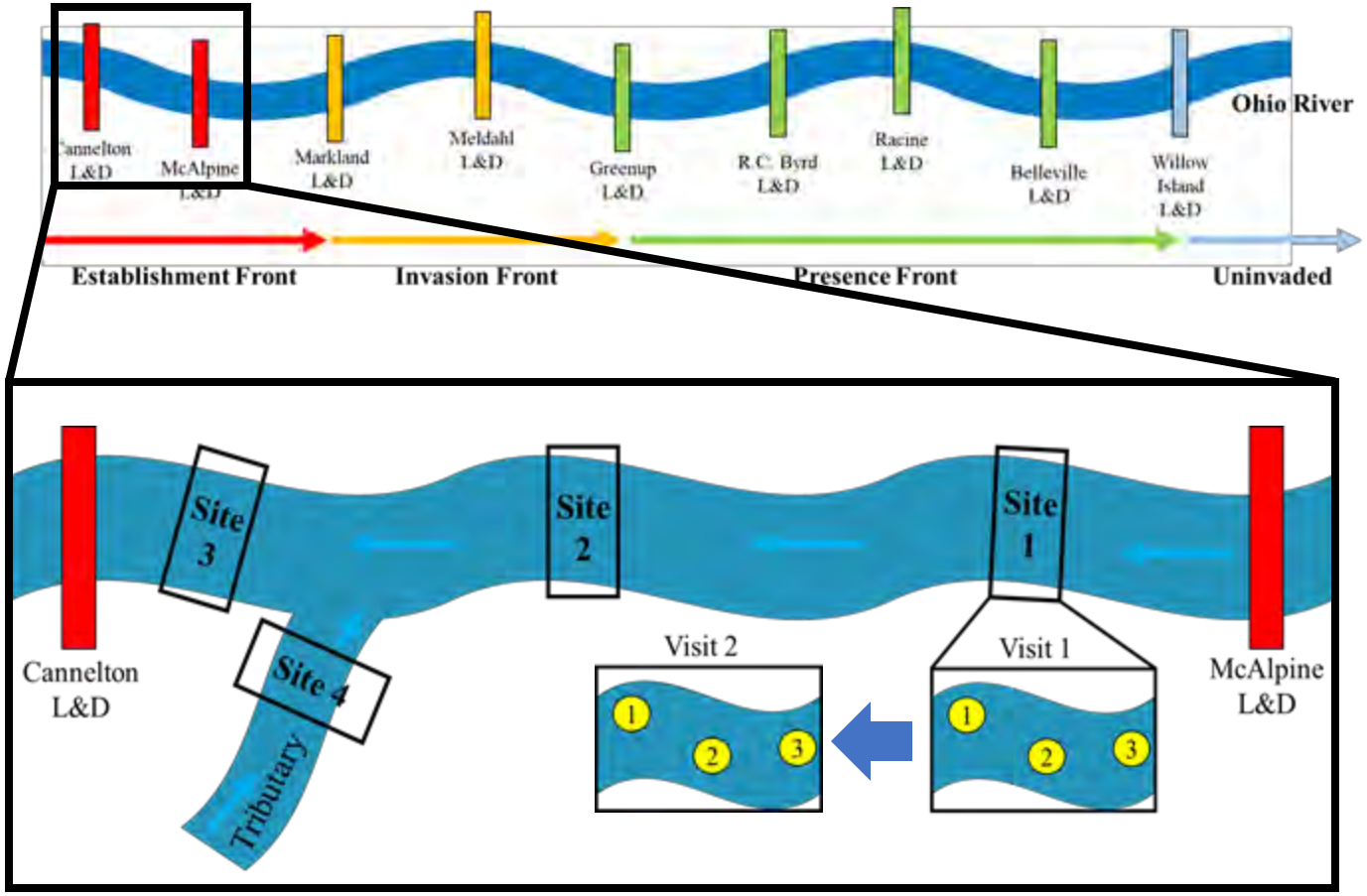
Robust Nested Sampling Design



Ohio River pools sampled on a **yearly basis**

Sites nested in pools sampled on a **yearly basis** as well as **several visit per year**

Robust Nested Sampling Design

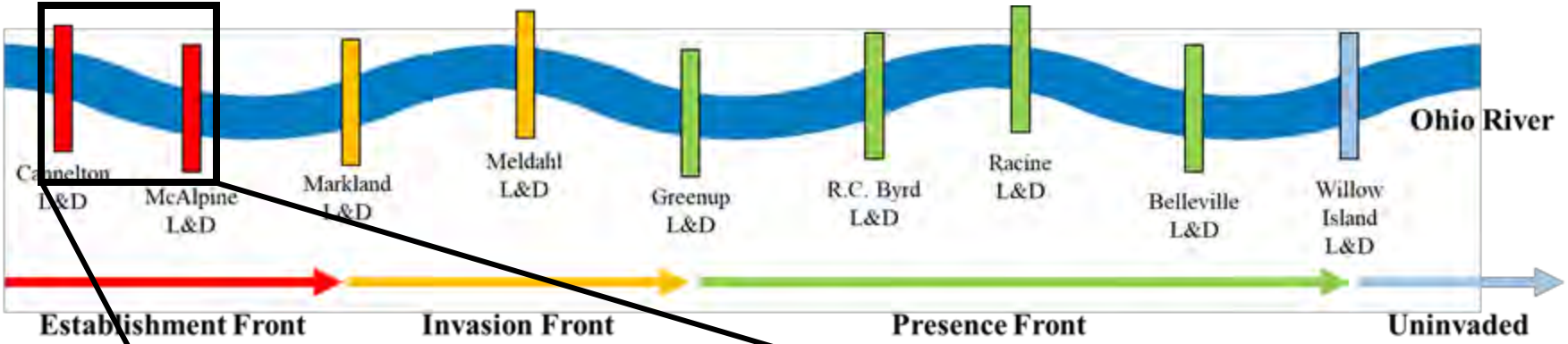


Investigate factors influencing establishment success at multiple spatial and temporal scale using a Bayesian **dynamic multi-scale occupancy model**

Parameters to be Estimated

1. Large-scale annual parameters

pool *i*

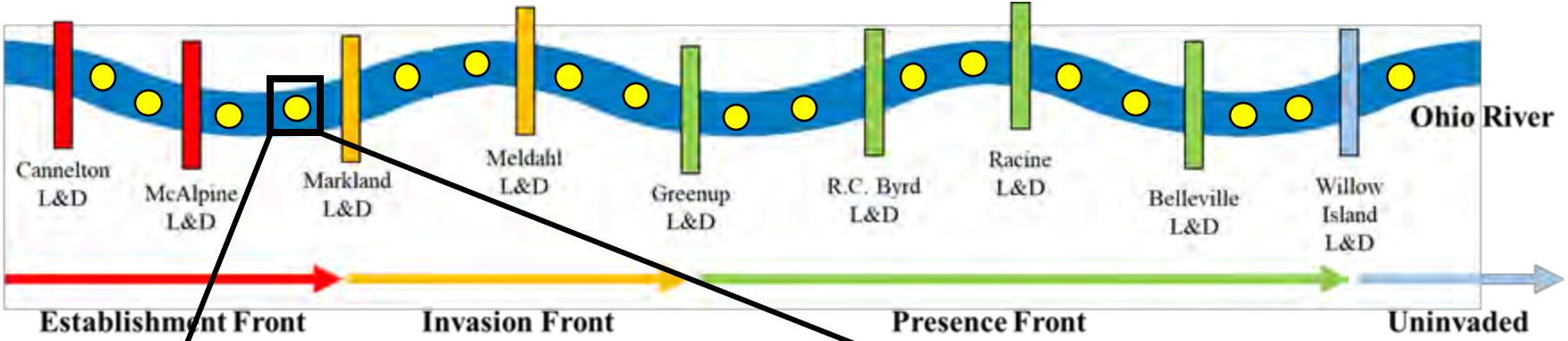


- Initial yearly pool-level occupancy (ψ_1)
- Yearly pool colonization probability (γ)
- Yearly pool persistence probability (φ)

Parameters to be Estimated

2. Small-scale annual parameters

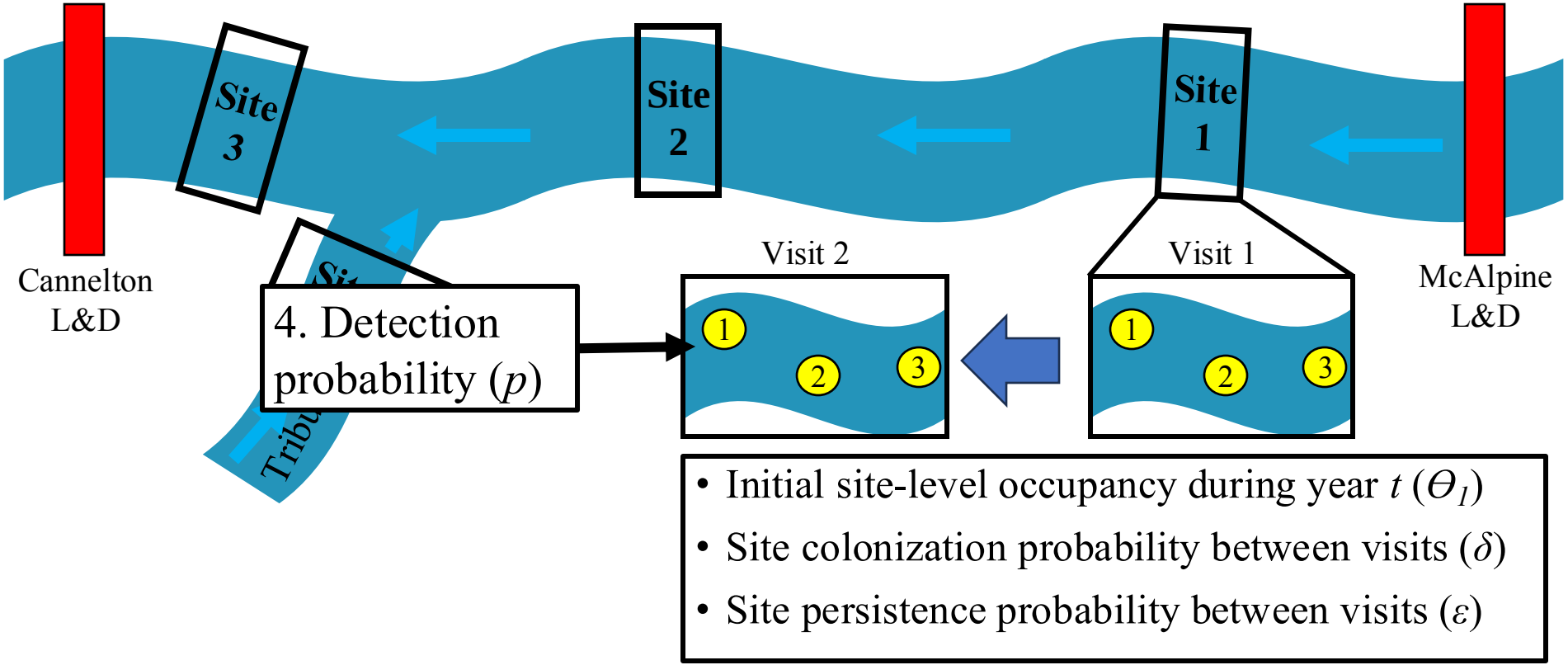
Site *j* in pool *i*



- Initial yearly site-level occupancy (ω_1)
- Yearly site colonization probability (λ)
- Yearly site persistence probability (ρ)

Parameters to be Estimated

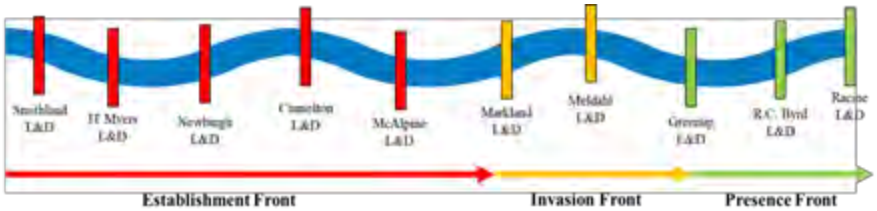
3. Small-scale intra-annual parameters



Dynamic Multi-Scale Occupancy Goals:

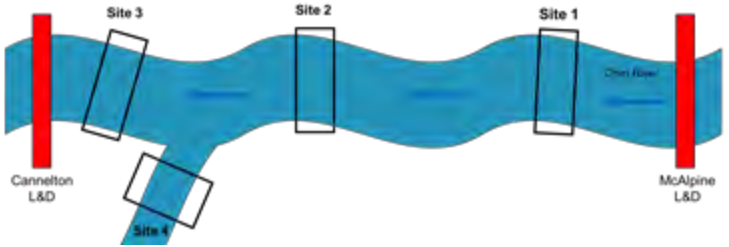
1. **Large-Scale Annual Parameters**

   What pools likely see consistent recruitment and reproduction?



2. **Small-Scale Annual Parameters**

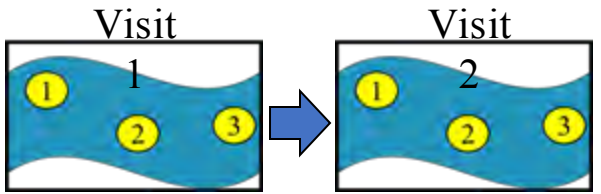
   What sites in pools likely support adult carp populations and successful recruitment?



3. **Small-Scale Intra-Annual Parameters**

   Where are adult carp throughout the year?

   Was it true recruitment?



Simulation Study to Validate Model Structure

Goal: ensure model is capable of providing reliable predictions across a range of sampling designs

Steps:

1. Specify data-generating parameters
2. Specify sampling design
3. Simulate data
4. Run model (1000 times)
5. Assess output

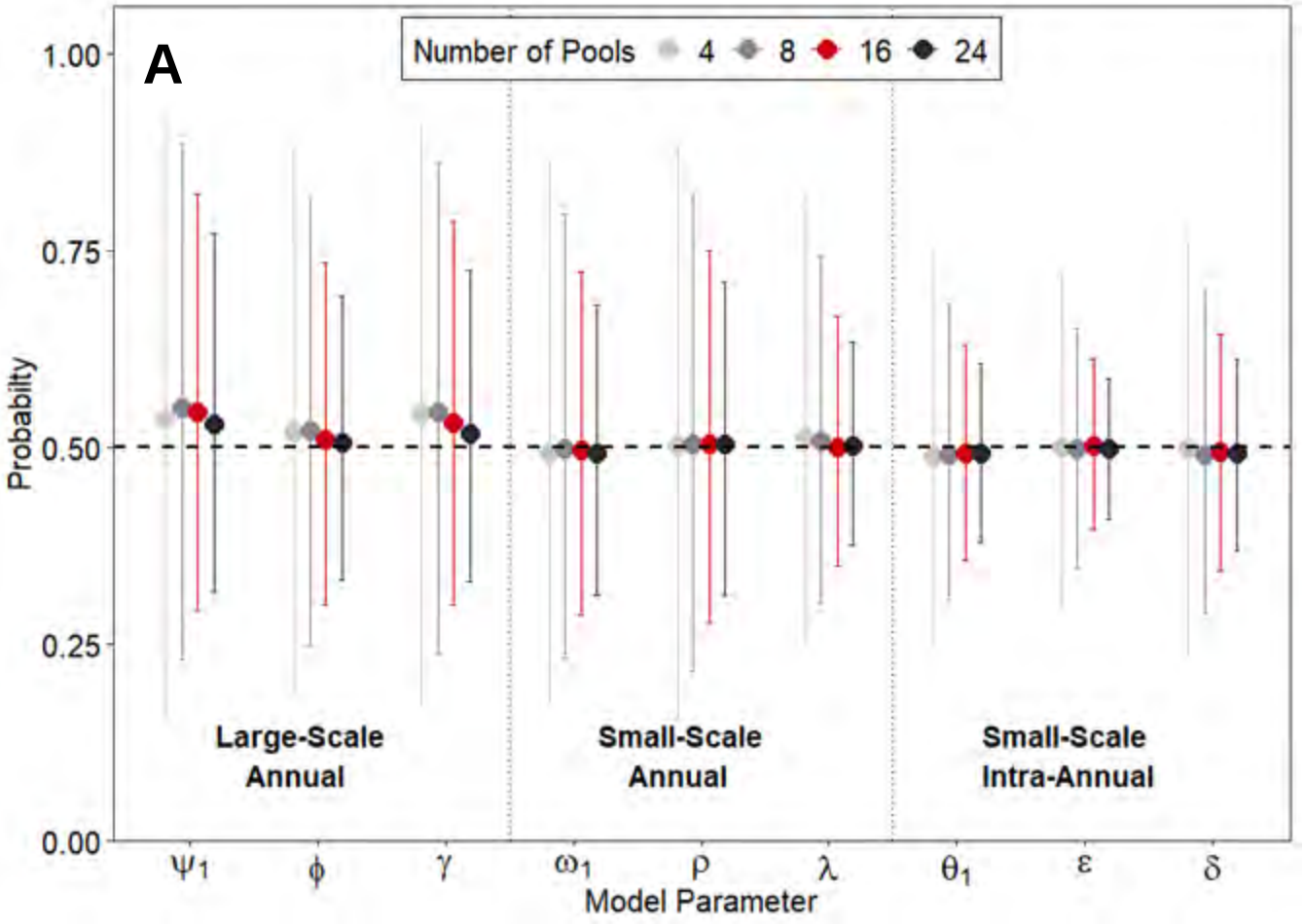
Spatial Replicates		Temporal Replicates	
# Pools	# Sites	# Years	# Visits
4			
8	2	2	2
16	4	4	4
24	8	8	8
	20	20	20

Results: Large-Scale Spatial Units

Increasing the number of pools:

↑ Accuracy of all parameters

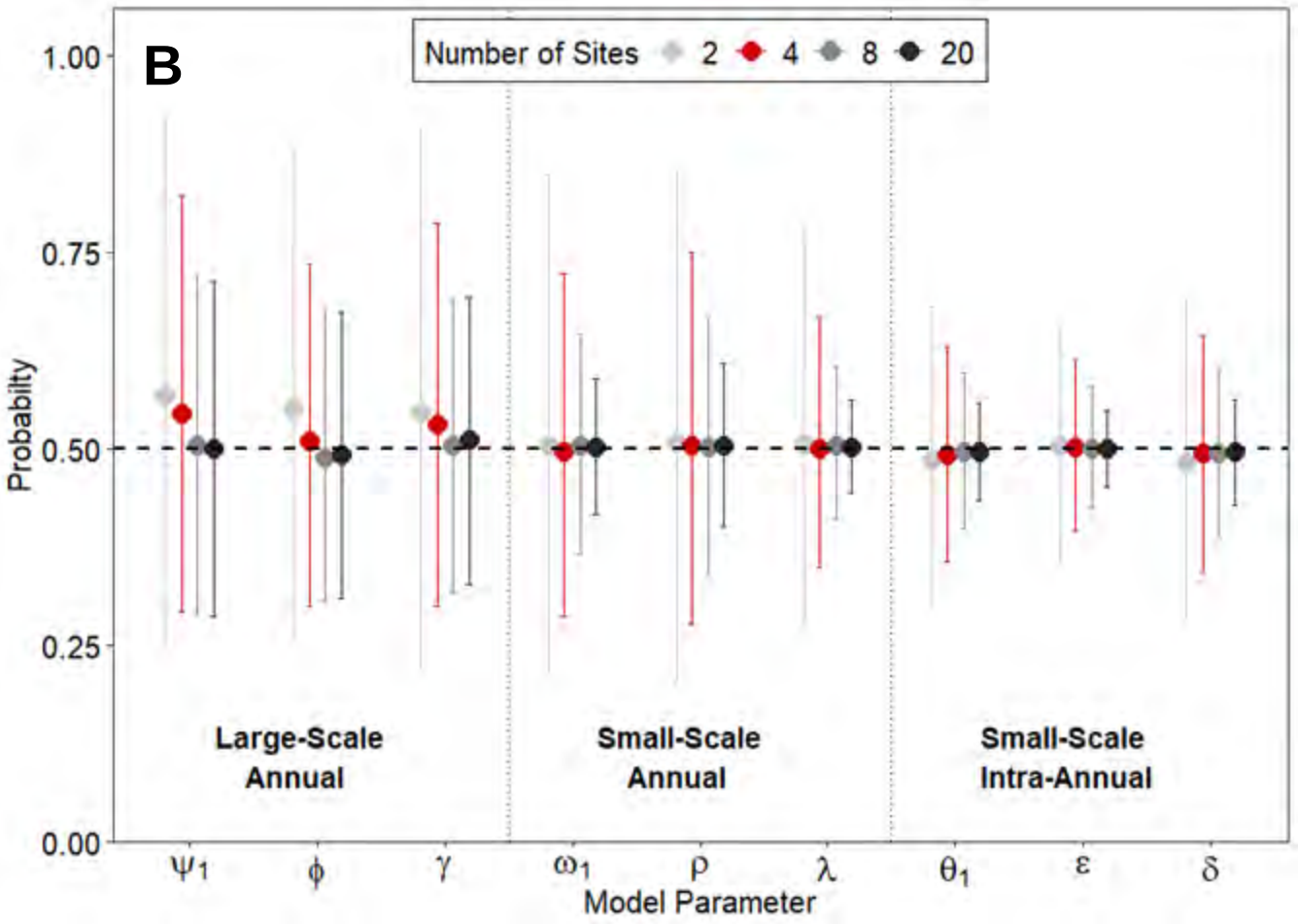
↑ Precision of all 95% CI



Results: Small-Scale Spatial Units

Increasing the number of sites:

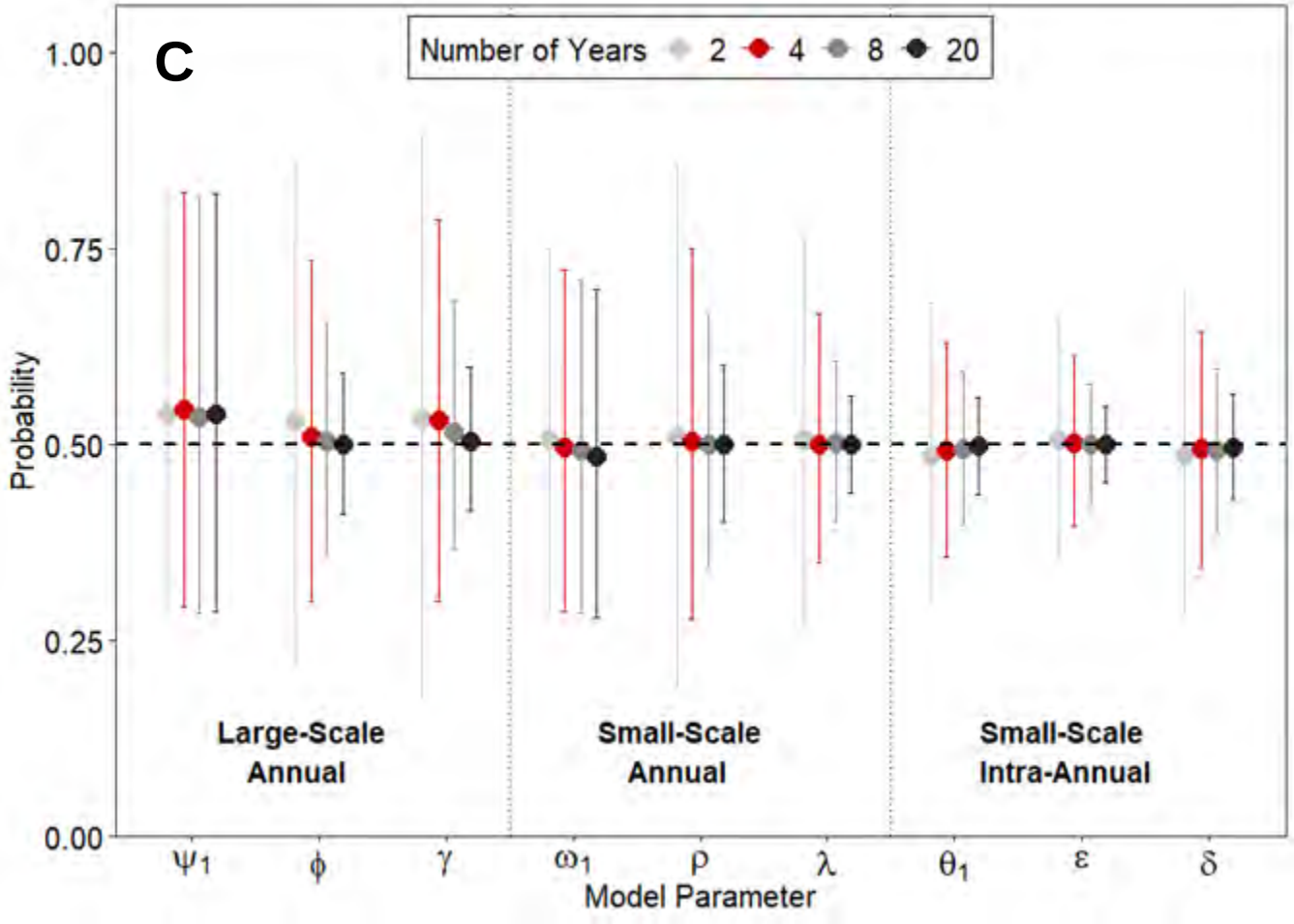
- ↑ Accuracy of all parameters
- ↑ Precision of all 95% CI up to a point



Results: Large-Scale Temporal Units

Increasing the number of years:

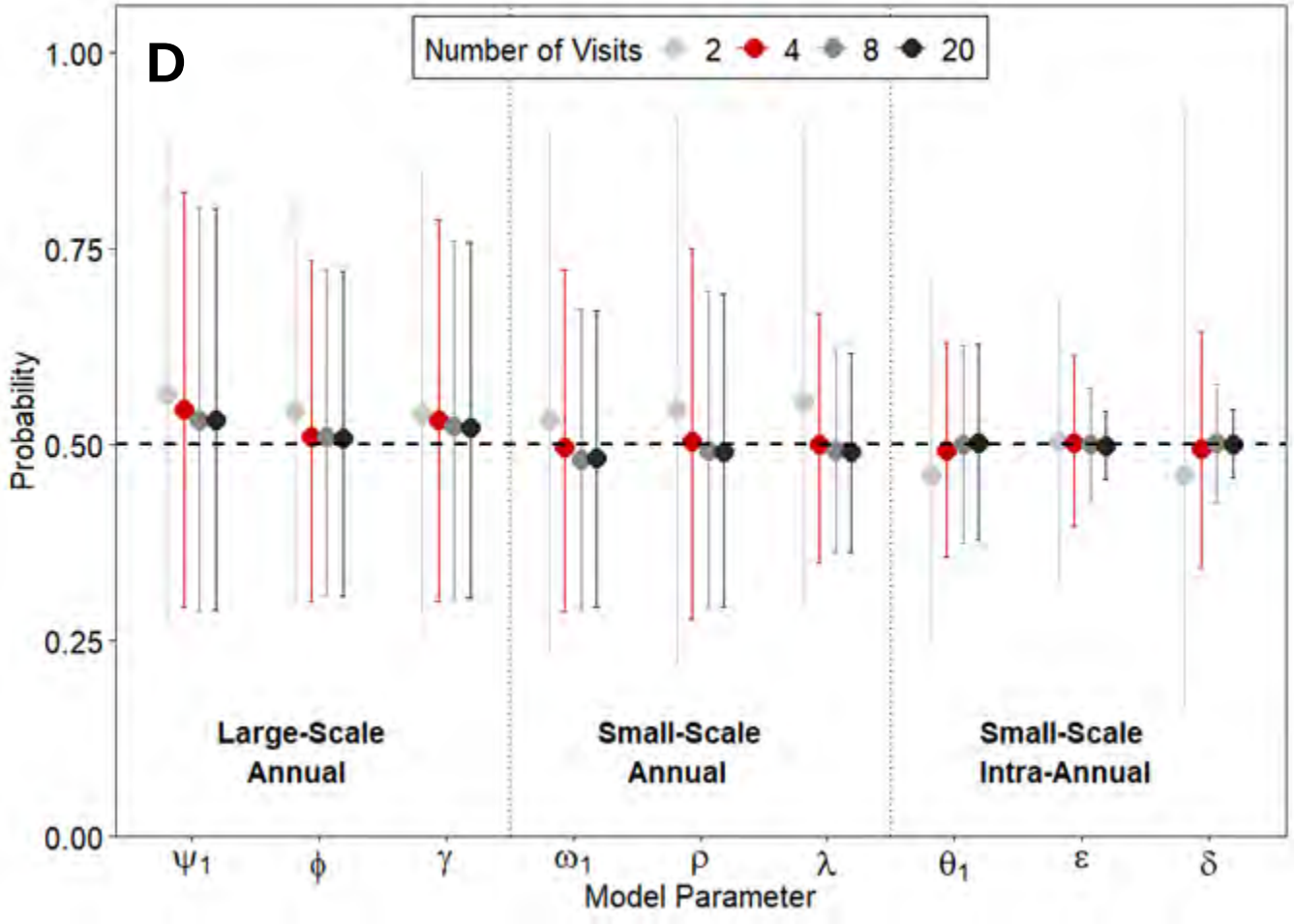
- ↑ Accuracy of most parameters
- ↑ Precision of most 95% CI



Results: Small-Scale Temporal Units

Increasing the number of visits:

- ↑ Accuracy of small-scale parameters
- ↑ Precision of small-scale 95% CI



Discussion - Carp Sampling Data

Adults

Pool = 16
Sites = 91 (max)
Years = 9
Visits = 6 (max)

Juveniles

Pool = 9
Sites = 19 (max)
Years = 8
Visits = 4 (max)

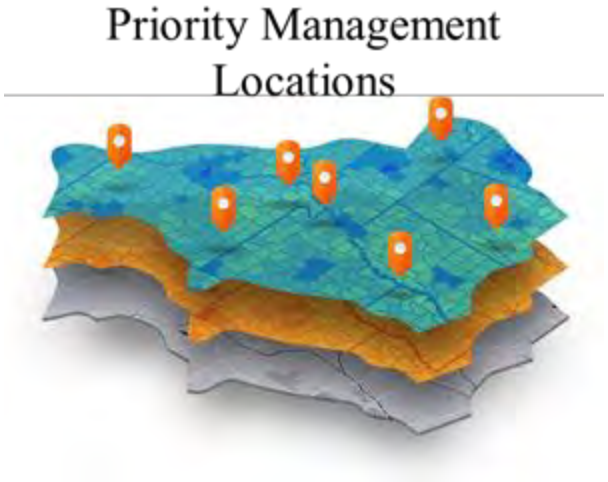
Eggs/Larvae

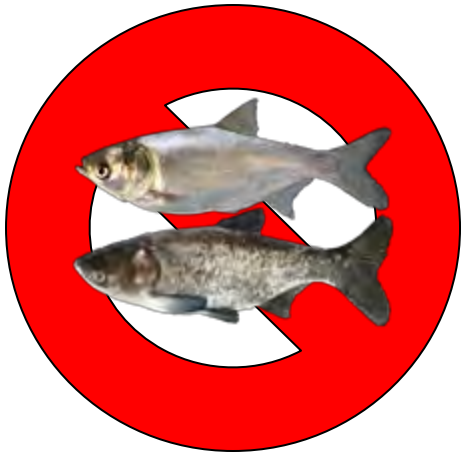
Pool = 9
Sites = 12 (max)
Years = 4
Visits = 9 (max)

Future Directions

1. Use dynamic multi-scale occupancy model on 3 age classes:
   - Adults - current distribution
   - Juvenile - recruitment
   - Eggs/larvae - reproduction

2. Combine results with collaborating agencies to make decision on carp management





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Thank you!

Erin Shepta

Doctoral Candidate, Natural Resource Science

es00064@mix.wvu.edu

Assessing Ecological Impacts of Invasive Carp in the Ohio River

Luka Marques do Amaral[1], Erin Shepta[1], Friedrich W. Keppeler[2], Brent Murry[1] and Caroline C. Arantes[1]

School of Natural Resources and the Environment | West Virginia University

Núcleo de Ecologia Aquática e Pesca da Amazônia | Federal University of Pará | Institute of Marine Sciences | Federal University of Ceará

WestVirginiaUniversity

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USGS science for a changing world

Introduction

U.S. Geological Survey

How do impacts vary?

Spatially

Temporally

Inter-Community

Objective

How invasive carp impacts, on native fish, vary spatially and temporally in the Ohio River?

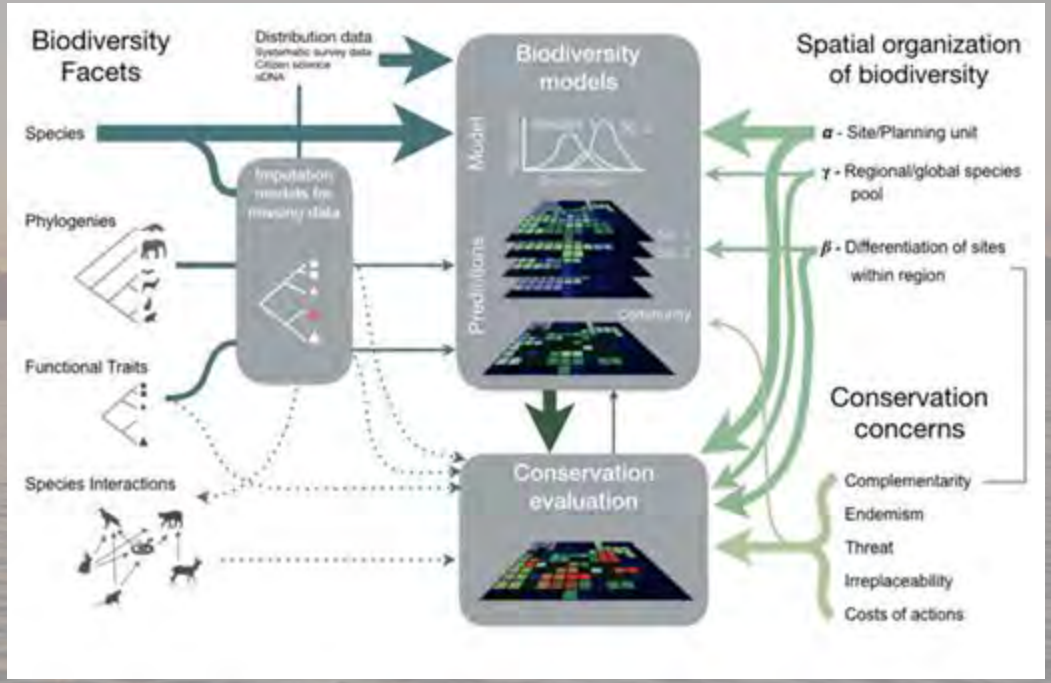
Introduction

Domaizon & Devaux (1999):
Silver Carp (*Hypophthalmichthys molitrix*) provoked shifts in assemblages of phytoplankton and zooplankton in France

Eggleton et al. (2024):
How fish assemblages differed before and after Bigheaded carp establishment?
Shifts in native fish assemblages

Introduction

Taxonomic: traditional (species diversity)
Chick *et al.* (2019) Silver carp and Recruitment of native sport fish
Functional: use of functional traits
Souza *et al.* (2023)
Phylogenetic: Kinship to infer Phylogenetic x Environmental



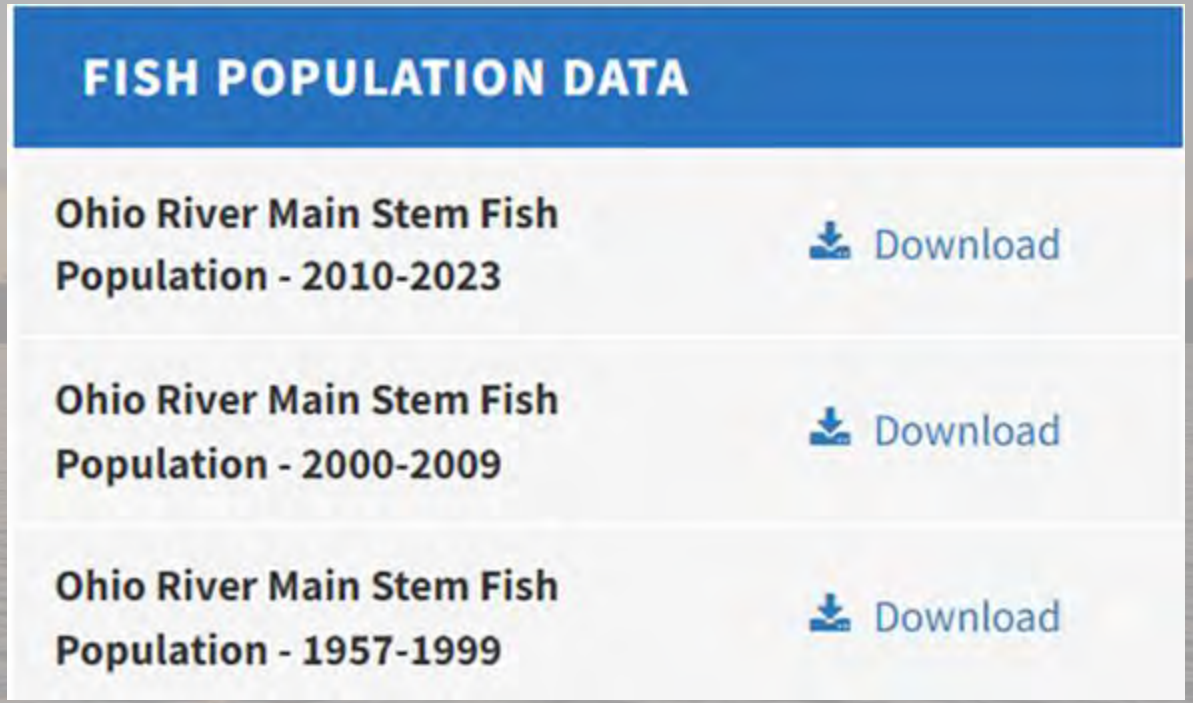
Losos (1996), Violle *et al.* (2007), Swenson (2011), Pollock *et al.* (2020), Keppeler *et al.* (2022)

Data

Ohio River Valley Water Sanitation Commission (ORSANCO)

Fish count Data

Publicly available



Data

Functional traits dataset

Global Ecology and Biogeography

A Journal of Macroecology

DATA ARTICLE

FISHMORPH: A global database on morphological traits of freshwater fishes

Sébastien Brosse, Nicolas Charpin, Guohuan Su, Aurèle Toussaint, Guido A. Herrera-R, Pablo A. Tedesco, Sébastien Villéger

First published: 17 September 2021 | https://doi.org/10.1111/geb.13395 | Citations: 27

Fisheries Magazine

Feature: Fisheries Research

Fish Traits: A Database of Ecological and Life-history Traits of Freshwater Fishes of the United States

Emmanual A. Frimpong, Paul L. Angermeier

First published: 26 February 2011 | https://doi.org/10.1577/1548-8446-34.10.487 | Citations: 204

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Sampling Sites

Sampling Events

Collected: 1991-2023

32 years

2-4 pools/year out of the 19

Boat Electrofishing

48* species

Analysis

Hierarchical Modelling of Species Communities

Temporal and Spatial autocorrelation

Response
Community matrix (site x species)
Explanatory variables
“Pool” (defined by the area between dams and locks)
“Year”
“Coordinates” (X,Y of every sampling event)
“Temperature” (Celsius)
“invasive carp abundance/presence-absence”

Random variables: “Year” and “Coordinates”

Expected results & Management implications

1. Invasive carp are altering native fish taxonomic composition over time and across space
2. Invasive carp are provoking shifts in functional traits in native fish communities over time and across space
3. Invasive carp are provoking declines in native planktivorous fish
4. Invasive carp are provoking declines in native predator fish

Management Implications

Thank you!

lm00104@mix.wvu.edu