Evaluation of Potential Factors Limiting the Expansion of Invasive Carp

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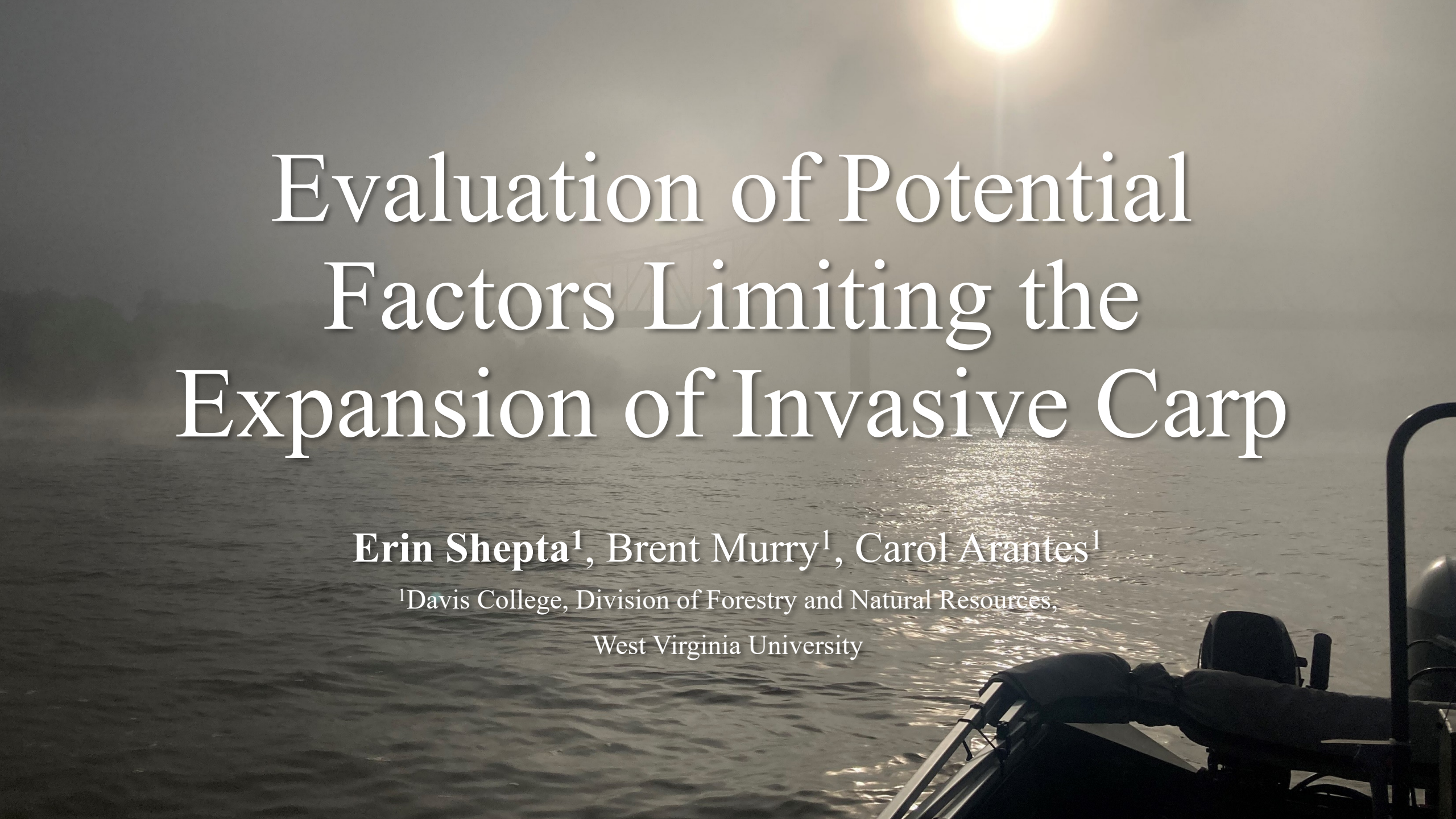


Asian Carp Invasion Background

- Four invasive carp species
  - Grass Carp (1960s)
  - Black Carp (1970s)
  - **Bighead Carp** (1970s)
    - *Hypophthalmichthys nobilis*
  - **Silver Carp** (1970s)
    - *Hypophthalmichthys molitrix*
      - Planktivores
      - Competition with native fish and mussels

Grass Carp

Black Carp

Bighead Carp

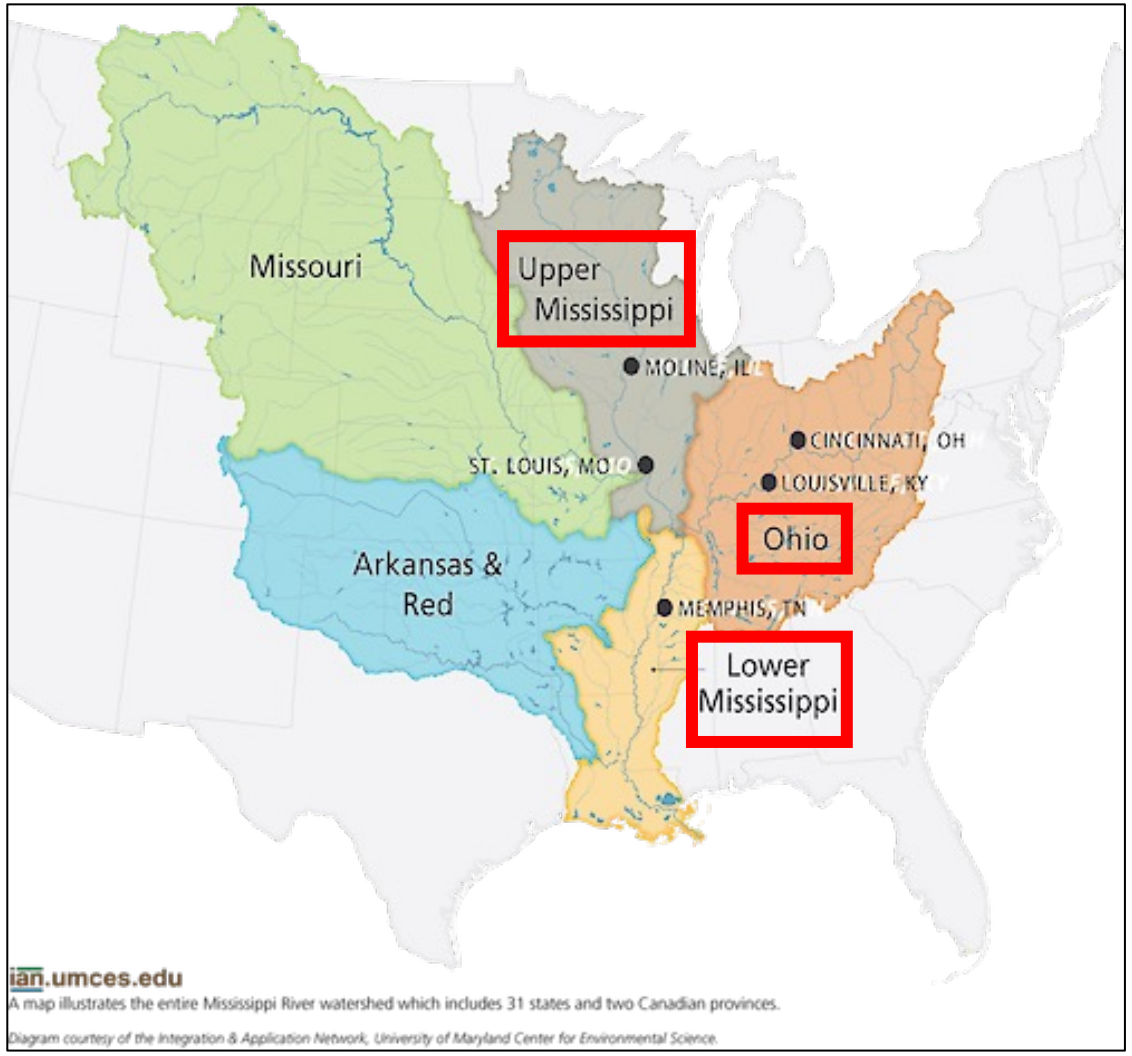
Silver Carp

Asian Carp Invasion History

Introduction in the Lower Mississippi River

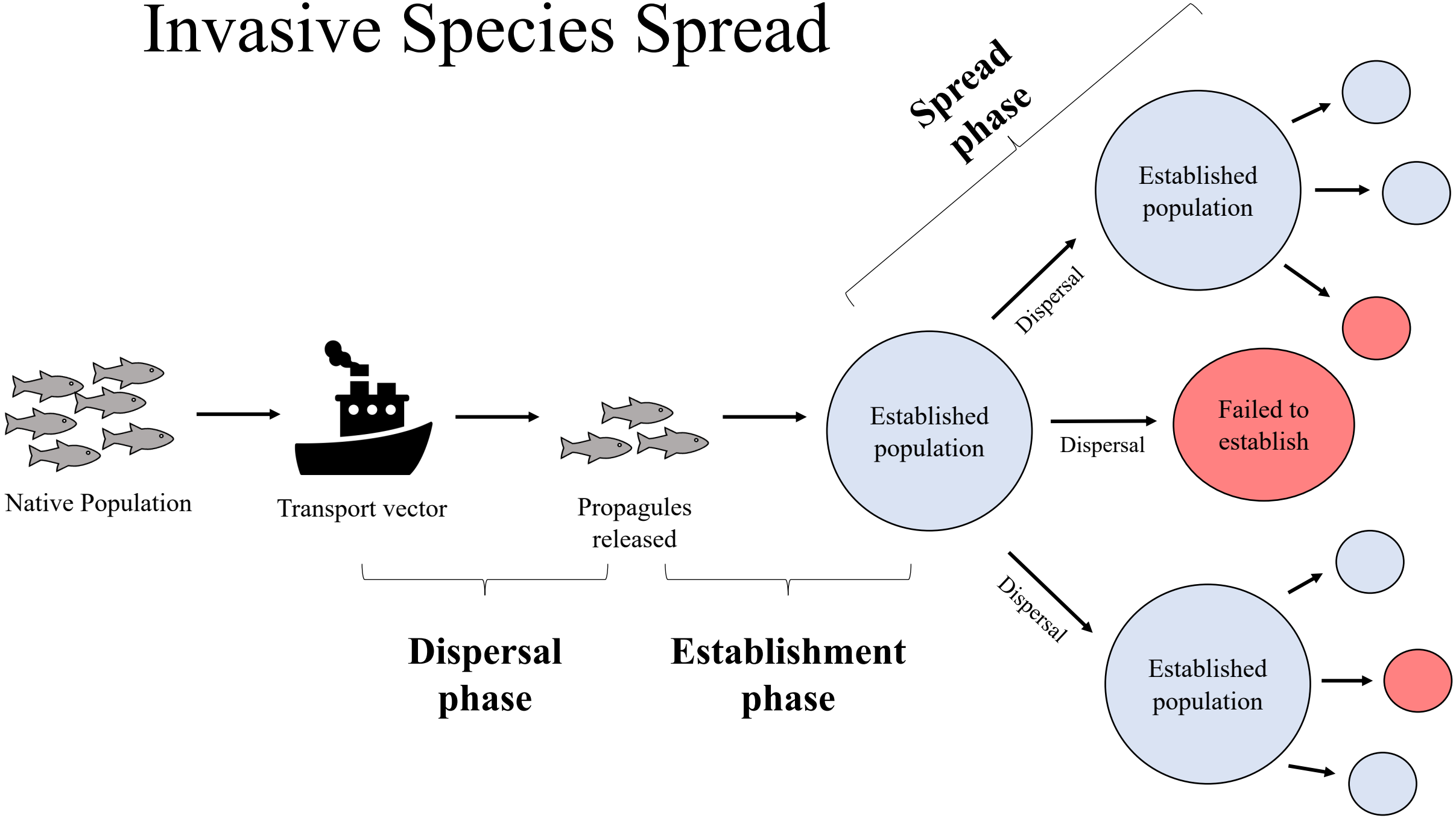
- Rapid population spread throughout the **Upper Mississippi River**
- Spread slowed/stalled in **Ohio River** basin

- **Question:** Why has spread stalled in the OTC River basins?
  - Environmental factors
  - Biotic interactions

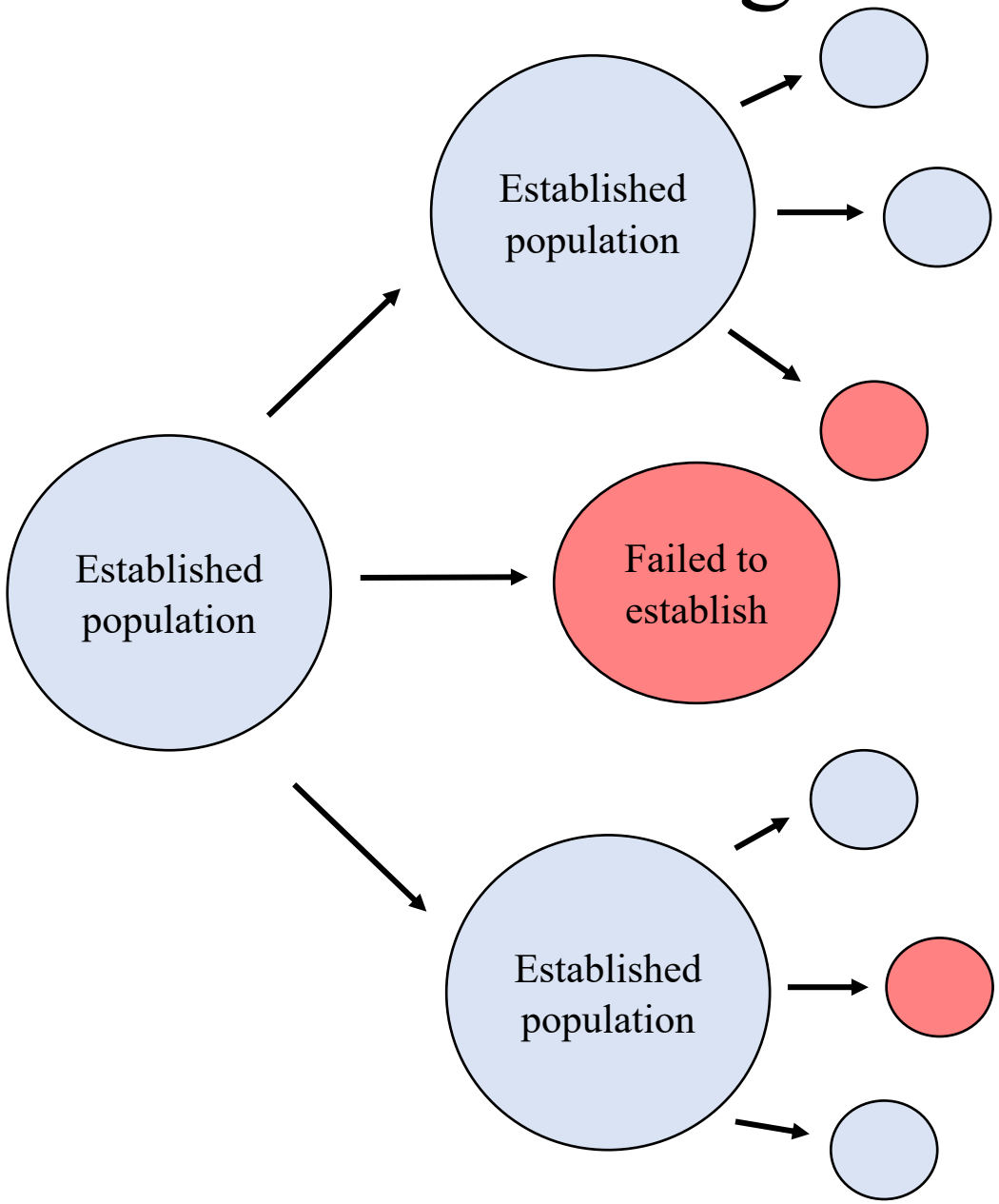


Maps on Mississippi River sub-basins accessed from https://ian.umces.edu/media-library/mississippi-river-watershed-map/

Invasive Species Spread



Understanding Invasive Species Spread



Factors regulating spread rate across a landscape:

- ★ Spatial and temporal heterogeneity
- ★ Establishment/recruitment success
- Biotic interactions
  - Predation
  - ★ Competition
  - Mutualisms
- Ability to disperse

Environmental Heterogeneity

Question: Are abiotic conditions varying between/among watersheds, thus influencing the rate of spread?

Upper Mississippi River

Ohio River

Tennessee/Cumberland Rivers

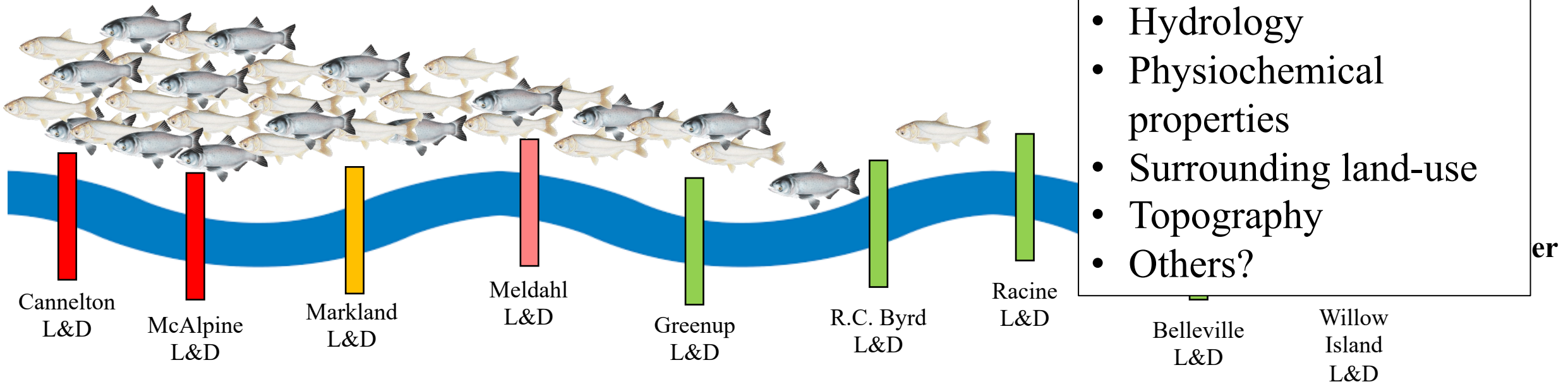
1. Collect existing data on local abiotic conditions
   - ORSANCO
   - Army Corps
   - ArcGIS
   - USGS

2. Identify key environmental differences that exist between basins

3.Incorporate carp datasets
   - Occupancy modelling for presence/absence of carp

Environmental Heterogeneity

Goal: To understand environmental characteristics that differ between basins and fronts?



- Hydrology
- Physiochemical properties
- Surrounding land-use
- Topography
- Others?

Establishment Front

- High abundance
- High reproduction

Invasion Front

- High/moderate abundance
- Little/no reproduction

Presence Front

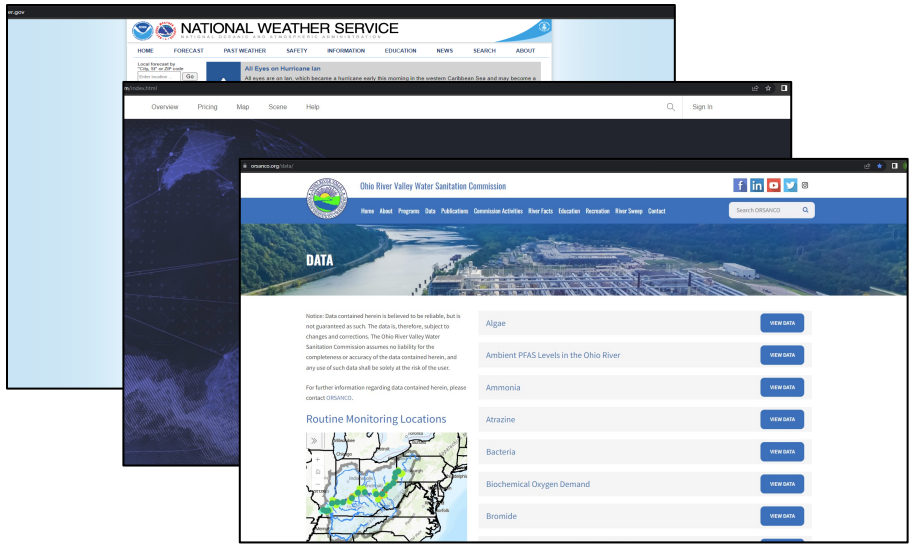
- Rarely encountered
- No reproduction

Uninvaded

- Never encountered

Environmental Data Collection

Existing data:
ORSANCO, NWS, ArcGIS, USGS, project collaborators



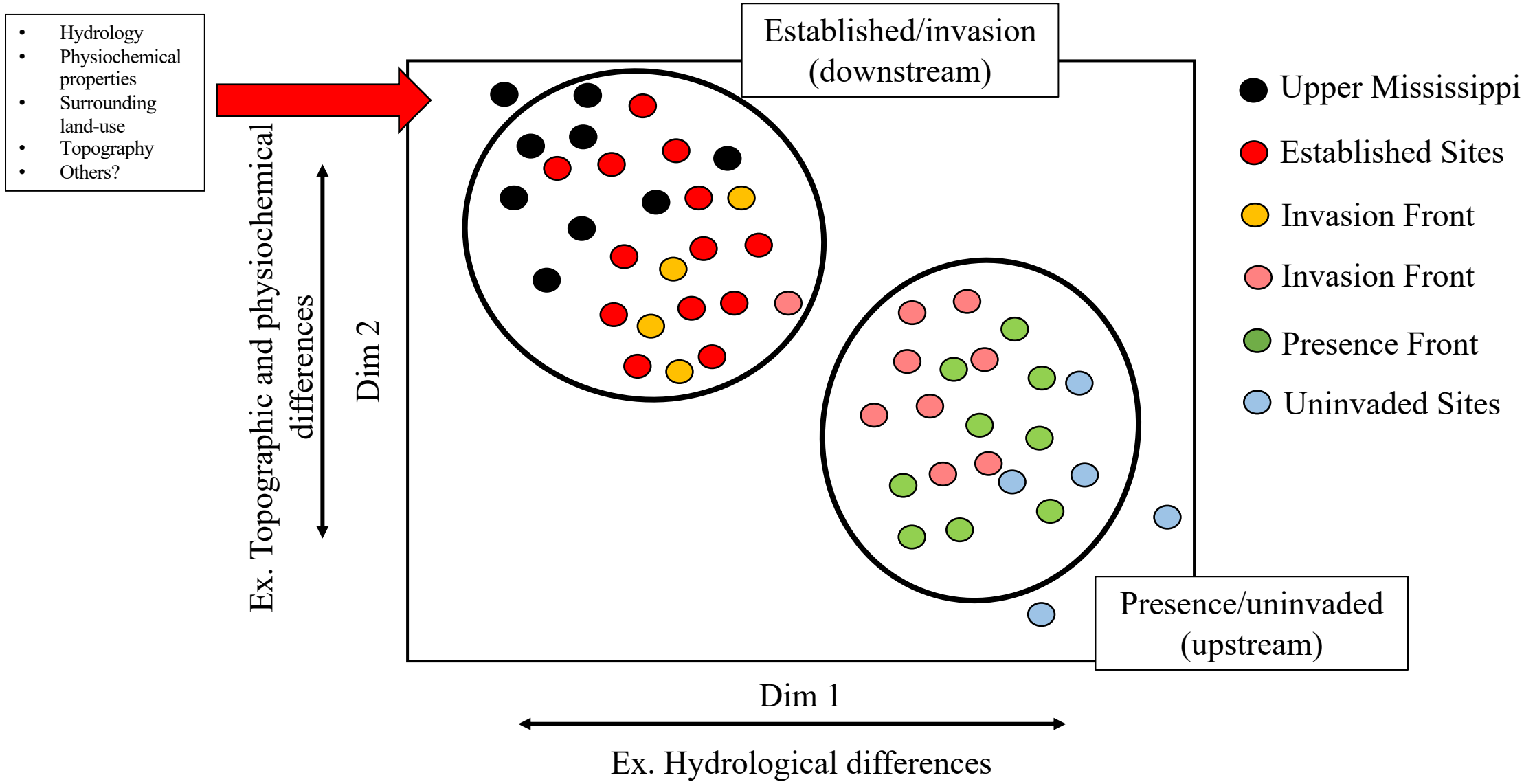
Site #	Front	Basin	Parameter 1	Parameter 2
1	Establishment	OH	##	##
2	Establishment	OH	##	##
3	Invasion	OH	##	##
4	Invasion	OH	##	##
5	Presence	OH	##	##
6	Presence	OH	##	##

- Physiochemical characteristics
- Topography
- Surrounding land-use
- Distance from dams
- Others?
- **Daily flow data**

Indicators of Hydrologic Alteration (IHA) model the Nature Conservancy
- 67 IHA parameters

Example Multivariate Analysis:

Goal: To understand major environmental characteristics that differ between basins and fronts



Recruitment Success

Question: Are local conditions influencing recruitment success?

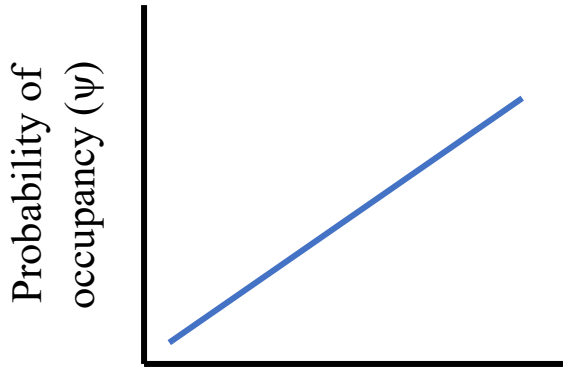
- Dynamic Occupancy modelling

Presence/Absence at a site
+
Environmental covariates
from previous analysis

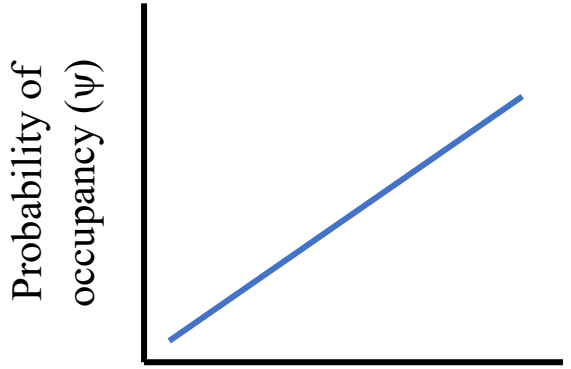
1. Occupancy (ψ_i)
2. Detection probability (ρ_i)

Predictive Models

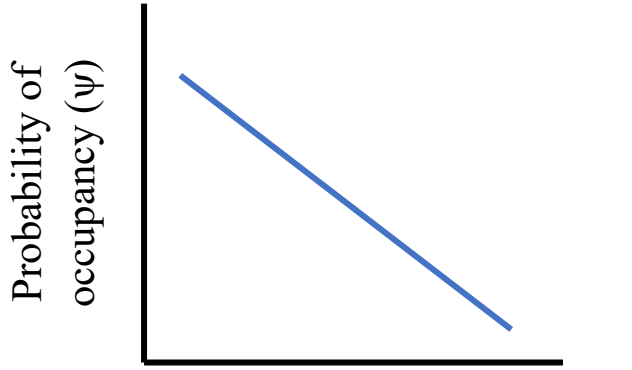
Eggs/Larval fish



Juveniles (YOY)



Adults



Dynamic Occupancy Models

Helps us account for changes in occupancy of sites over time

Ex. Silver Carp

Occupied Sites

Unoccupied Sites

Larval Fish

Juvenile Fish

Adult Fish

2010

Dynamic Occupancy Models

Helps us account for changes in occupancy of sites over time

Ex. Silver Carp

Occupied Sites

Unoccupied Sites

Larval Fish

Juvenile Fish

Adult Fish

2013

Dynamic Occupancy Models

Helps us account for changes in occupancy of sites over time

Ex. Silver Carp

Occupied Sites

Unoccupied Sites

Larval Fish

Juvenile Fish

Adult Fish

2018

Dynamic Occupancy Models

Helps us account for changes in occupancy of sites over time

Ex. Silver Carp

Occupied Sites

Unoccupied Sites

Larval Fish

Juvenile Fish

Adult Fish

2020

Dynamic Occupancy Models

Helps us account for changes in occupancy of sites over time

Ex. Silver Carp

Occupied Sites

Unoccupied Sites

Larval Fish

Juvenile Fish

Adult Fish

2023

Dynamic Occupancy Models

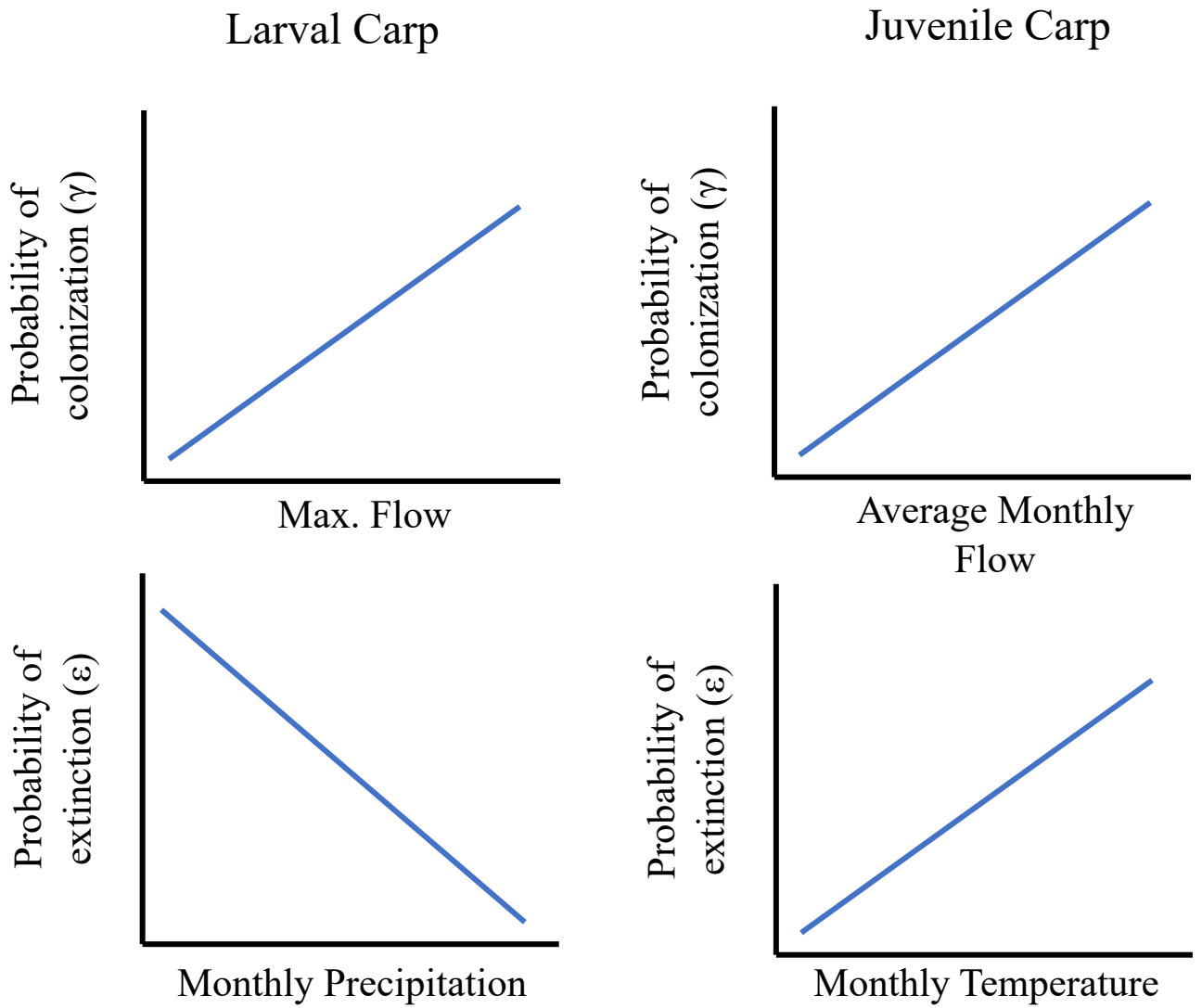
Dynamic models estimate the probability of 4 different parameters:

1. Initial occupancy (ψ_i)

2. Detection probability ($\rho_{i,t}$)

3. Colonization probability ($\gamma_{i,t}$)
The probability of an unoccupied site becoming colonized over a certain period

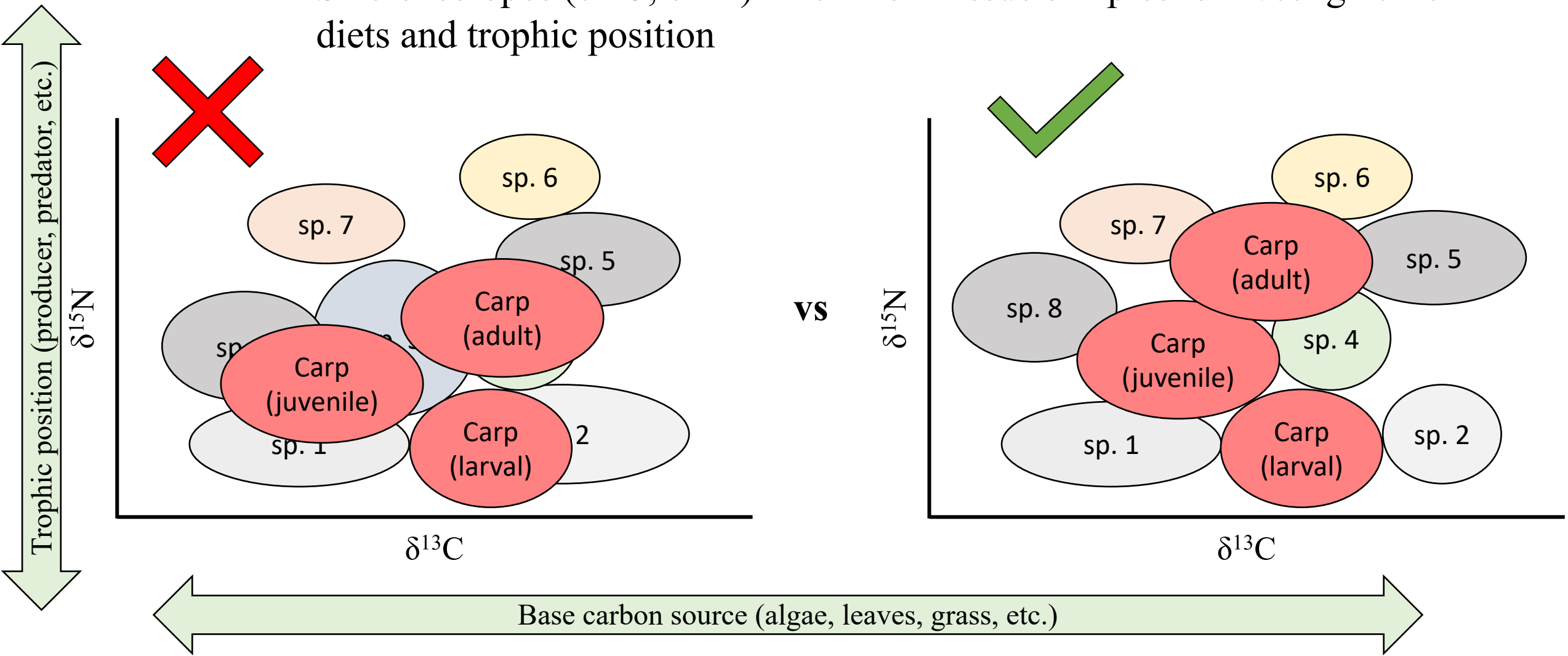
4. Extinction probability ($\varepsilon_{i,t}$)
The probability of an occupied site becoming extinct over a certain period



Biotic Interactions

Question: Are food web dynamics (i.e., niche overlap) offering resistance to invasive species spread?

- Stable isotopes ($\delta^{13}C$, $\delta^{15}N$) taken from tissue samples to investigate fish diets and trophic position

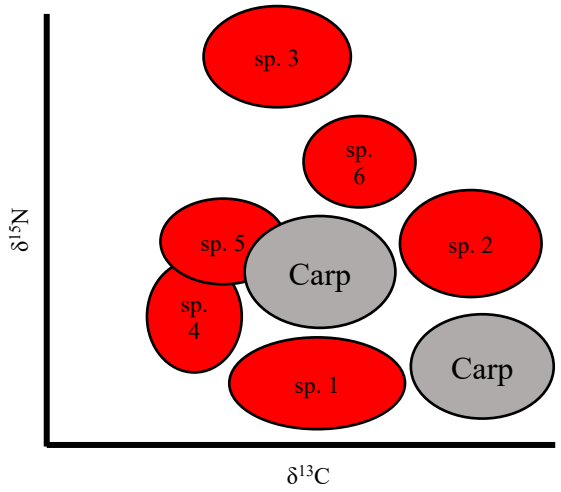


Biotic Interactions

Question: What are the food web dynamics within different fronts?

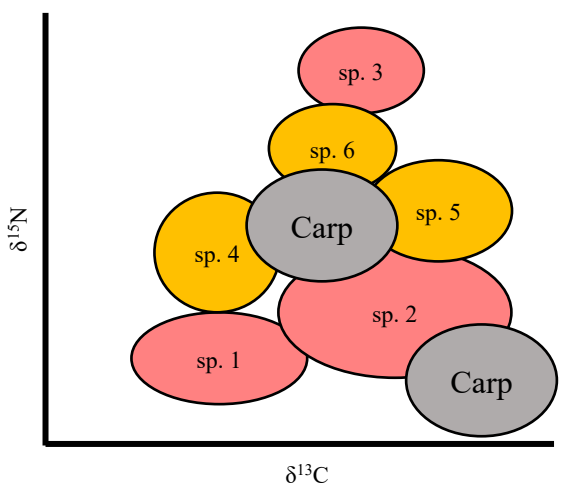
- Could community "saturation" offer some resistance to carp invasions?
- Hostile take-over vs opportunistic species?

Establishment Front



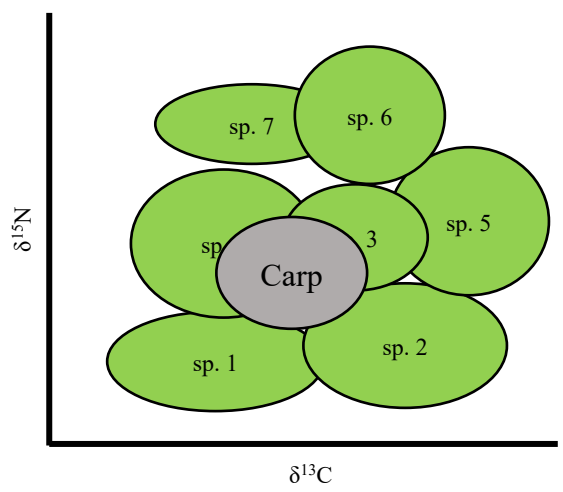
- Carp niches are **not** overlapping

Invasion Front



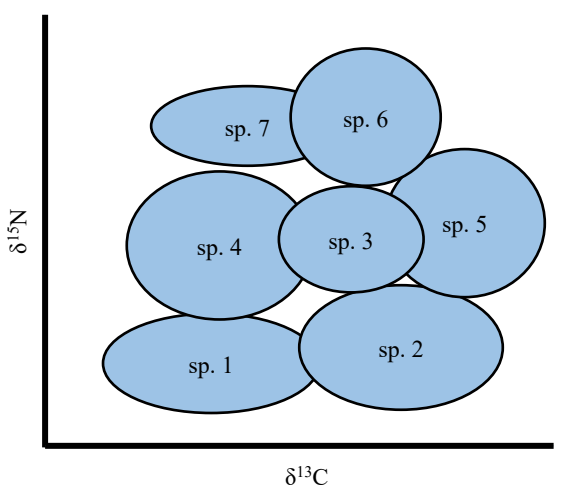
- More "saturated" communities
- Carp niches are **slightly** overlapping

Presence Front



- More "saturated" communities
- Carp niches are **completely** overlapping

Un-invaded



- Are there natural "holes" in these communities without carp present?

Looking to the Future…

1. Understanding key environmental variables that differ between the Upper Mississippi and Ohio Rivers

2. Using dynamic occupancy modeling to investigate local abiotic factors that are influencing carp success at different ages

3. Using stable isotope analysis to better understand biotic interactions that could be limiting the establishment of carp populations

Bighead Carp

Silver Carp

Black Carp

Grass Carp

Thank you!

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