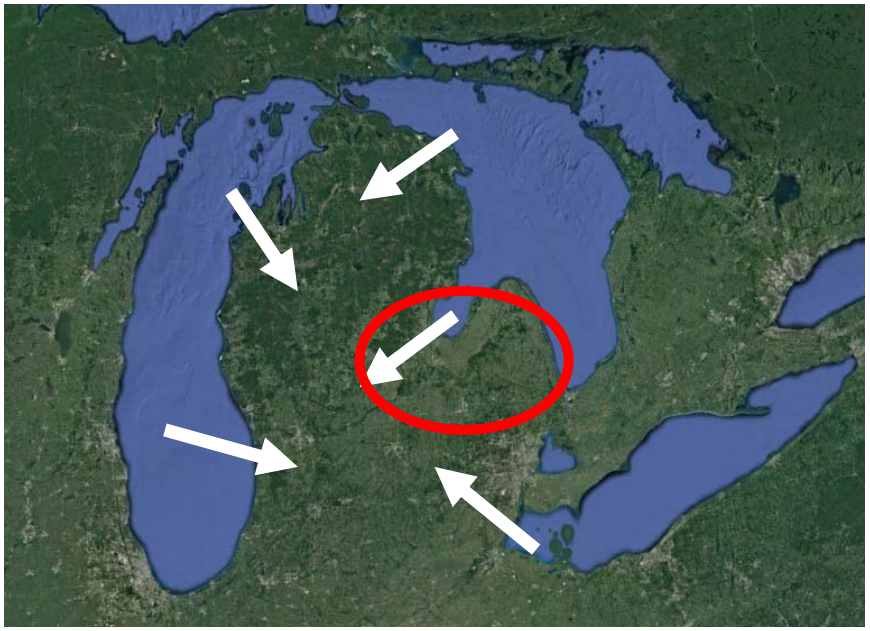
# Testing alternative hypotheses to explain Round Goby colonization of inland lakes and rivers using genomics data

**Nick Sard, John Robinson, Seth Herbst, and Kim Scribner**

# Outline

- Question: What is the most likely explanation of how the Round Goby has secondarily spread into Michigan systems from the Great Lakes?
- Background - Round Goby invasion
- Methodology
  - Sampling – where and why
  - Restriction site Associated DNA sequencing (RAD-seq)
  - Approximate Bayesian Computation
- Preliminary results – Flint River System
- Future work

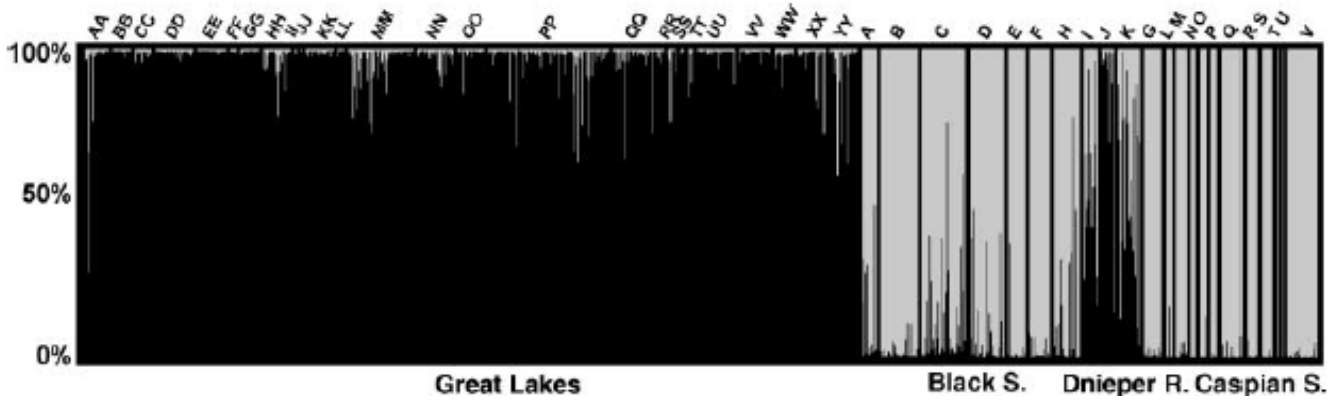


# Source of Round Goby invasion is likely the Dnieper River in Ukraine

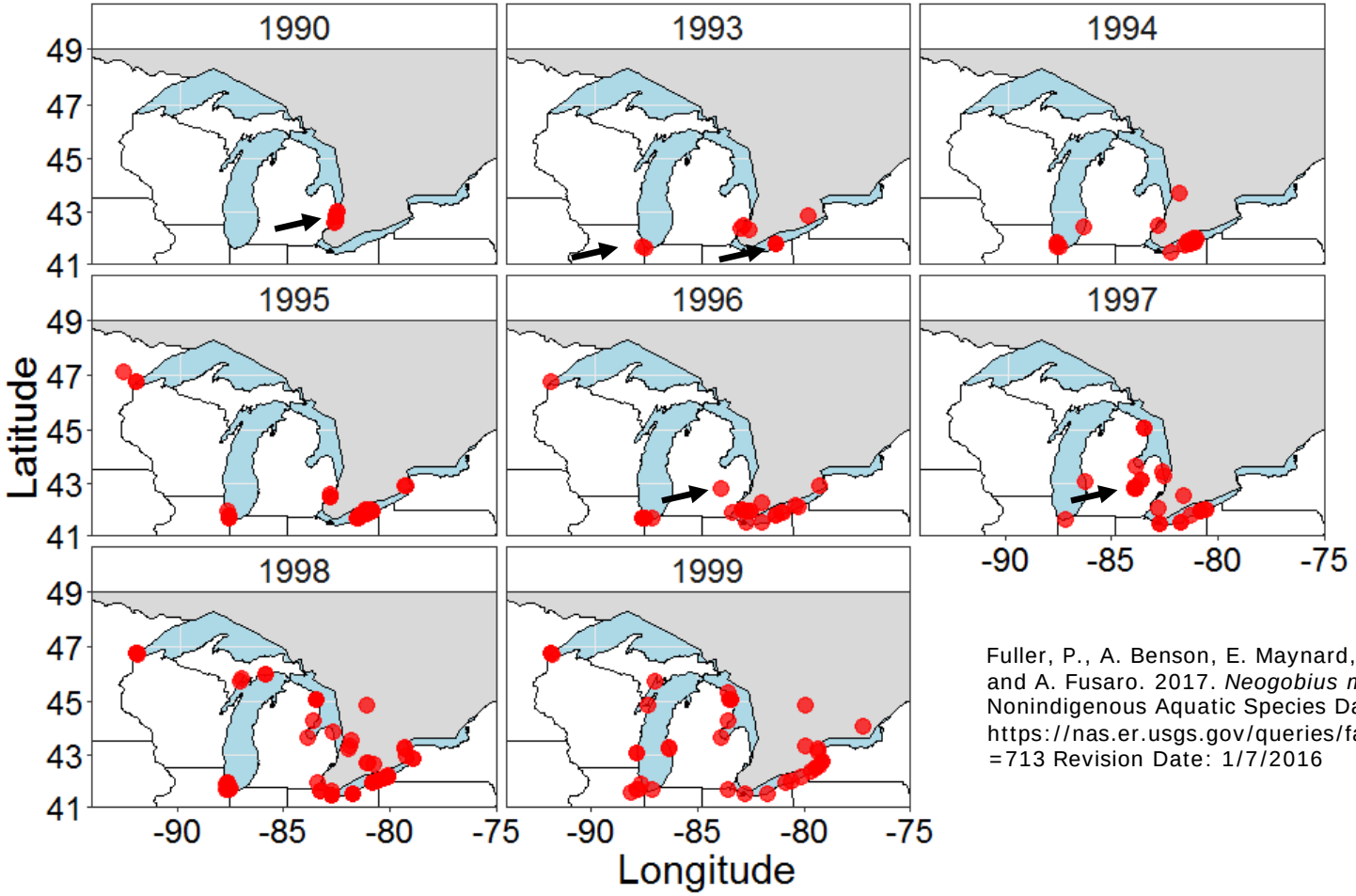
Molecular Ecology (2009) **18**, 64–79 doi: 10.1111/j.1365-294X.2008.04014.x

## Invasion genetics of the Eurasian round goby in North America: tracing sources and spread patterns

JOSHUA E. BROWN and CAROL A. STEPIEN
*Great Lakes Genetics Laboratory, Lake Erie Center and Department of Environmental Sciences, University of Toledo, 6200 Bayshore Rd, Toledo, OH 43618, USA*

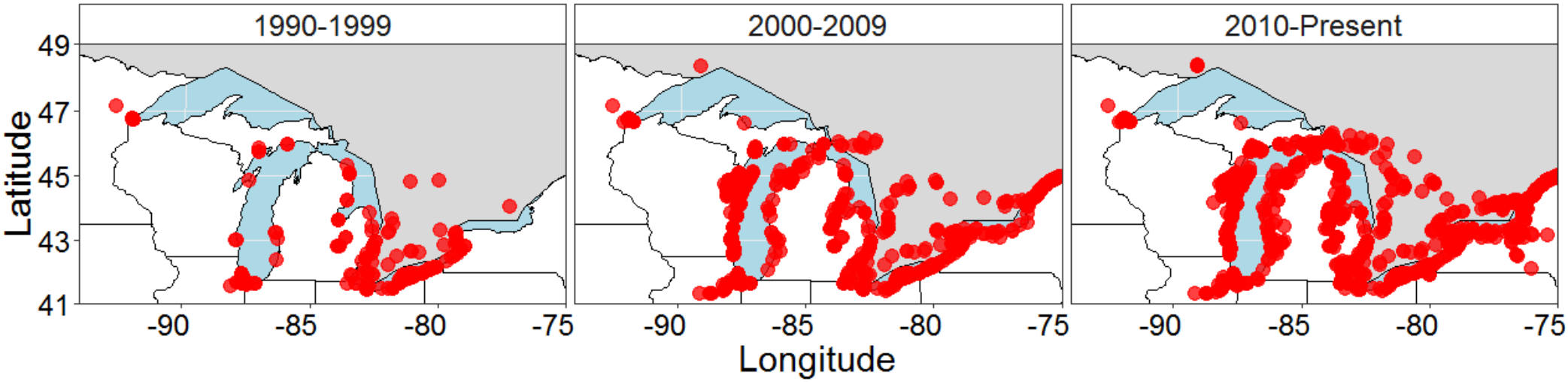


# Round Goby rapidly spread throughout the Great Lakes in the 1990s




Fuller, P., A. Benson, E. Maynard, M. Neilson, J. Larson, and A. Fusaro. 2017. *Neogobius melanostomus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=713 Revision Date: 1/7/2016

# Round Gobies have invaded many inland systems to date

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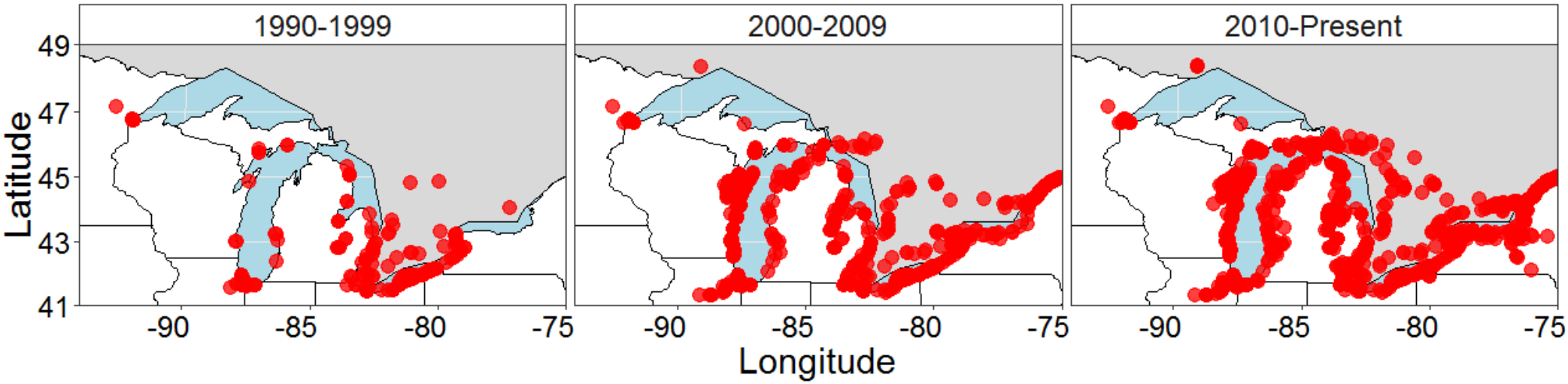
# Where did they come from? How many founded the population and when was it founded?

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# Vectors to explain invasion involve live-bait anglers

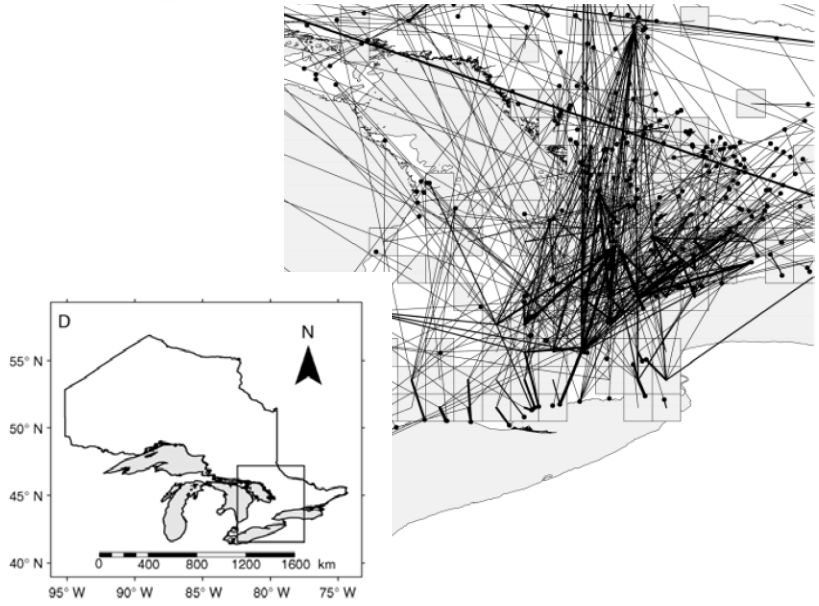
- Angler associated movement
  - Commercial bait industry
  - Personal collections
    - Distant Great Lakes locations
    - Local anglers collecting bait

*Ecological Applications*, 20(8), 2010, pp. 2286–2299


Least-cost transportation networks predict spatial interaction of invasion vectors

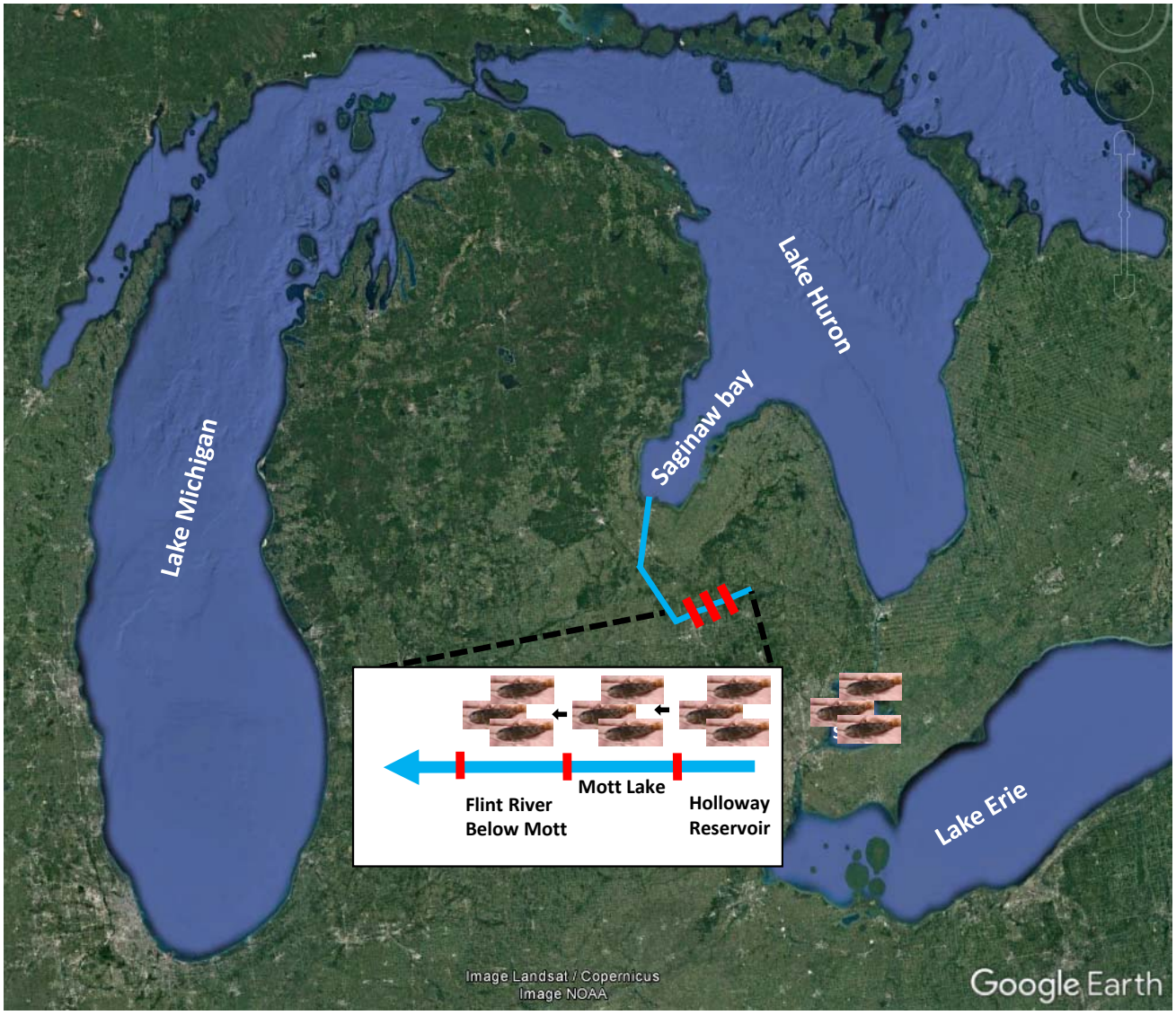
D. Andrew R. Drake[1,3] and Nicholas E. Mandrak[2]

[1]*Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2 Canada*
[2]*Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada, 867 Lakeshore Road, Burlington, Ontario L7R 4A6 Canada*



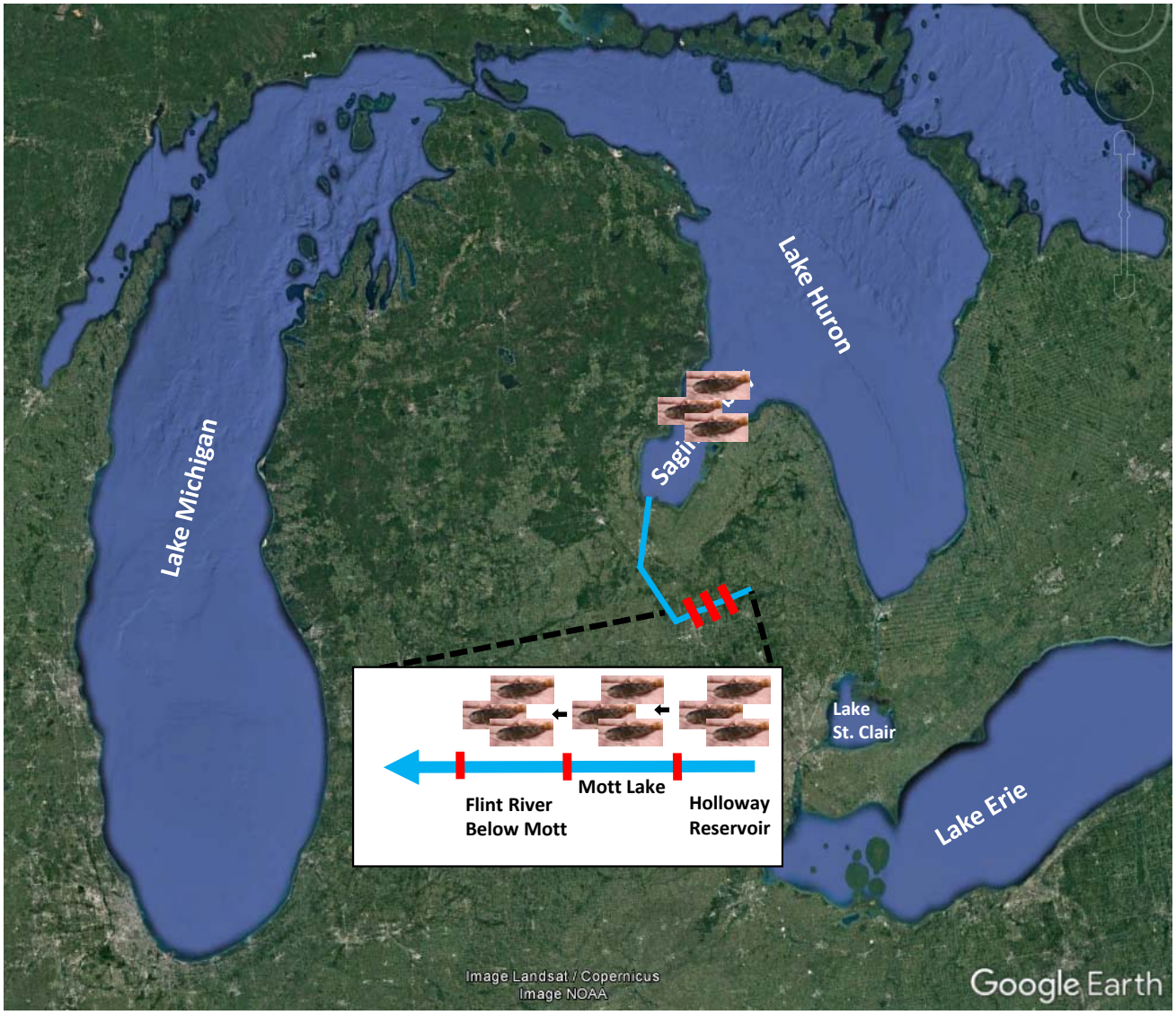
# Flint River Invasion

- Bait bucket from Lake St. Clair
  - Found Holloway first, then stepping stone model downstream



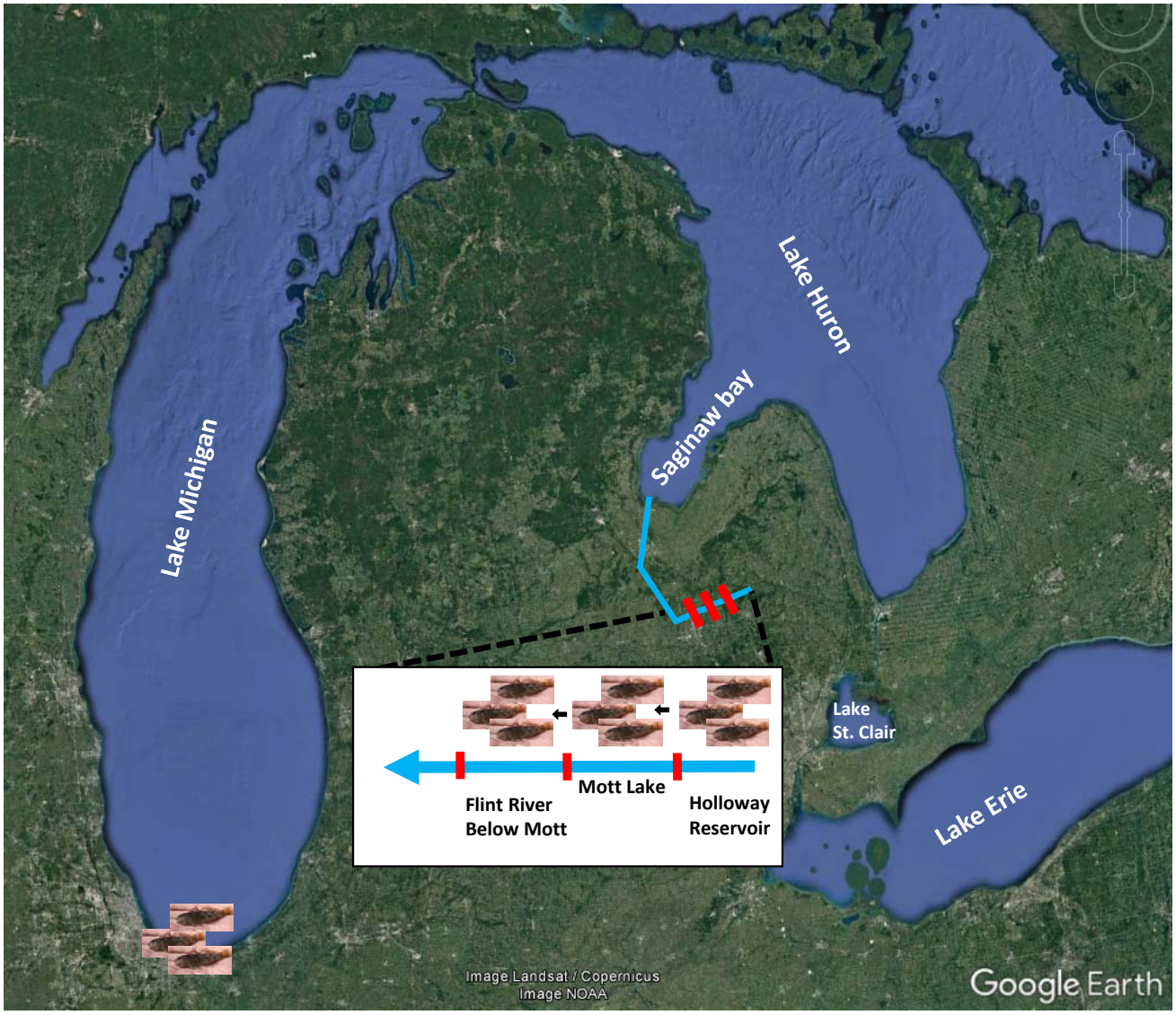
# Flint River Invasion

- Commercial bait from Saginaw Bay
  - Found Holloway first, then stepping stone model downstream



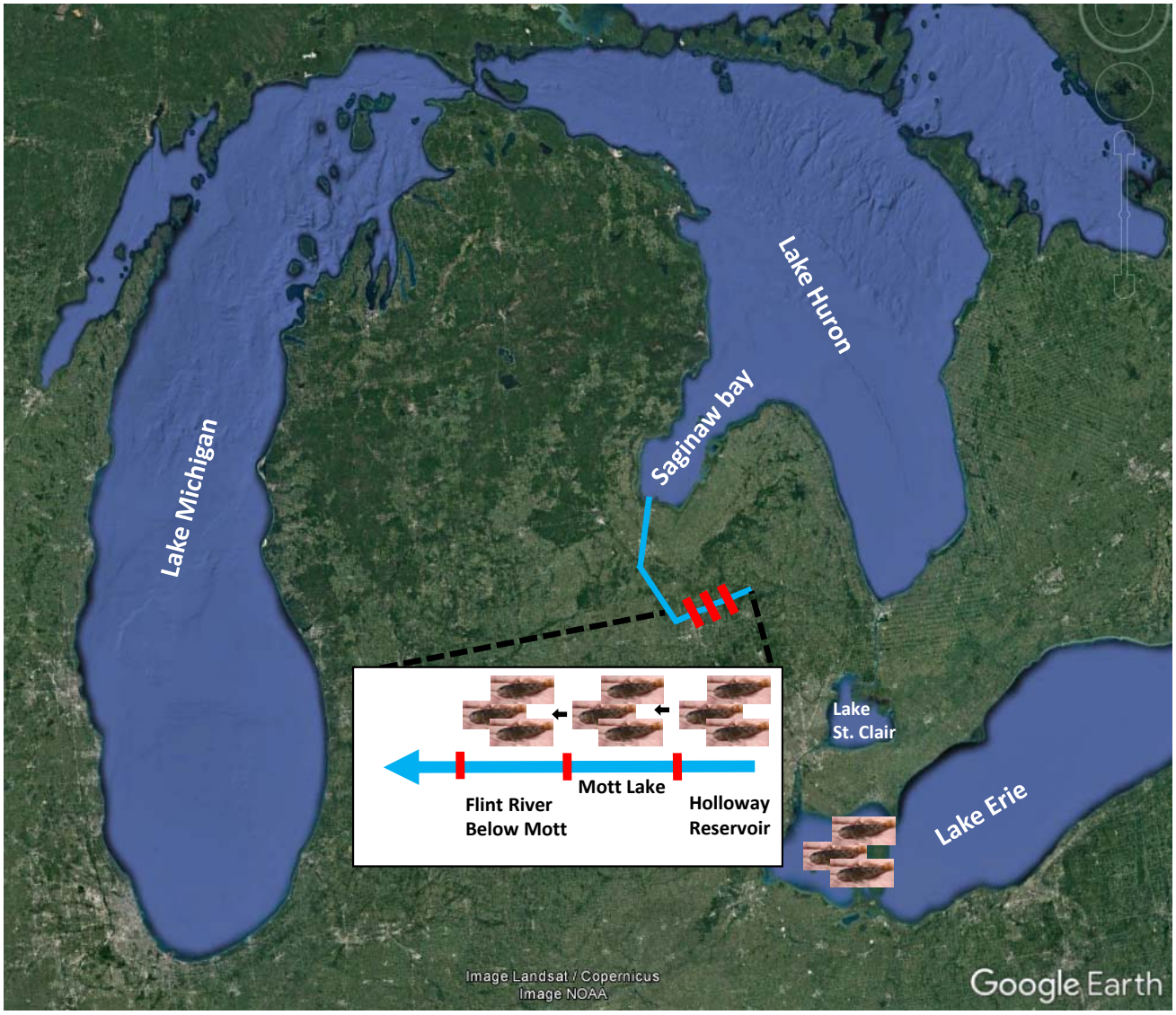
# Flint River Invasion

- Bait bucket from Lake Michigan
  - Found Holloway first, then stepping stone model downstream



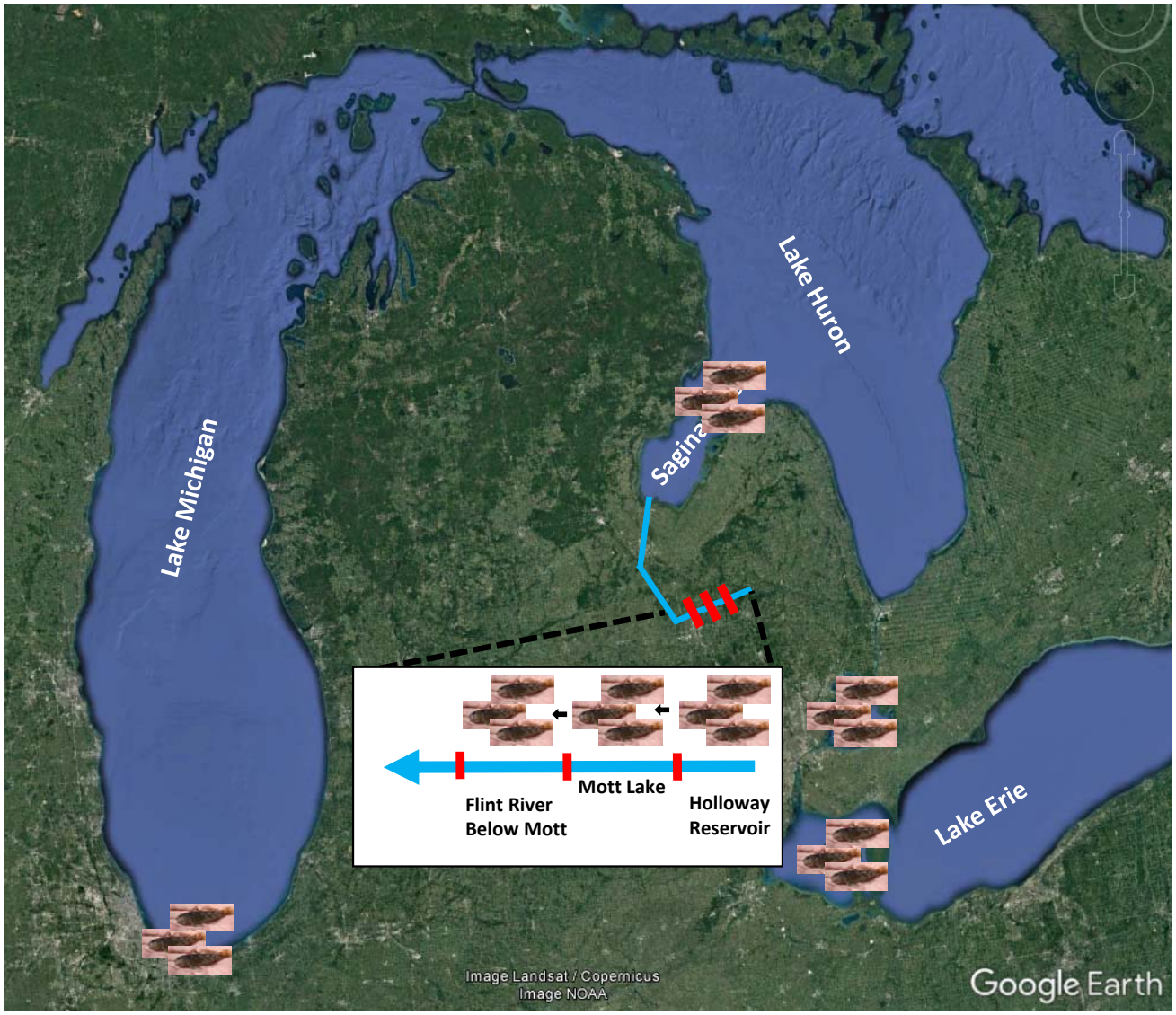
# Flint River Invasion

- Bait bucket from Lake Erie
  - Found Holloway first, then stepping stone model downstream



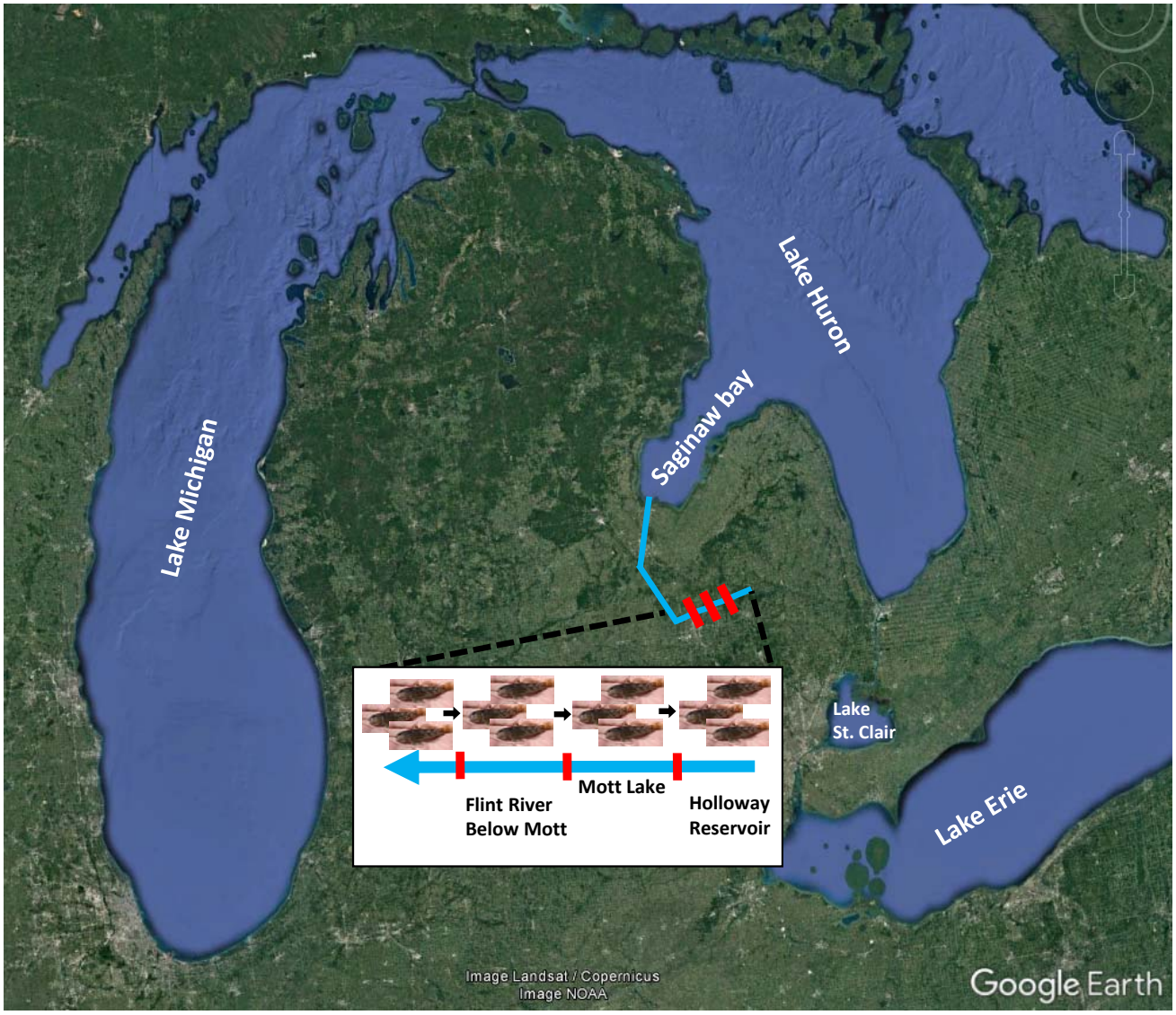
# Flint River Invasion

- Bait bucket Mixed Source
  - Found Holloway first, then stepping stone model downstream



# Flint River Invasion

- Local anglers in Flint System
  - Assisted movement upstream stepping stone model



# 5 basic downstream models & 1 upstream model

- St. Clair into Holloway Reservoir
- Commercial bait (Saginaw Bay) into Holloway Reservoir
- Lake Erie into Holloway Reservoir
- Lake Michigan into Holloway Reservoir
- Mixed source in Holloway
- Local collection → ***Up*stream stepping-stone model**

→ **Downstream stepping-stone models, but from *different sources***

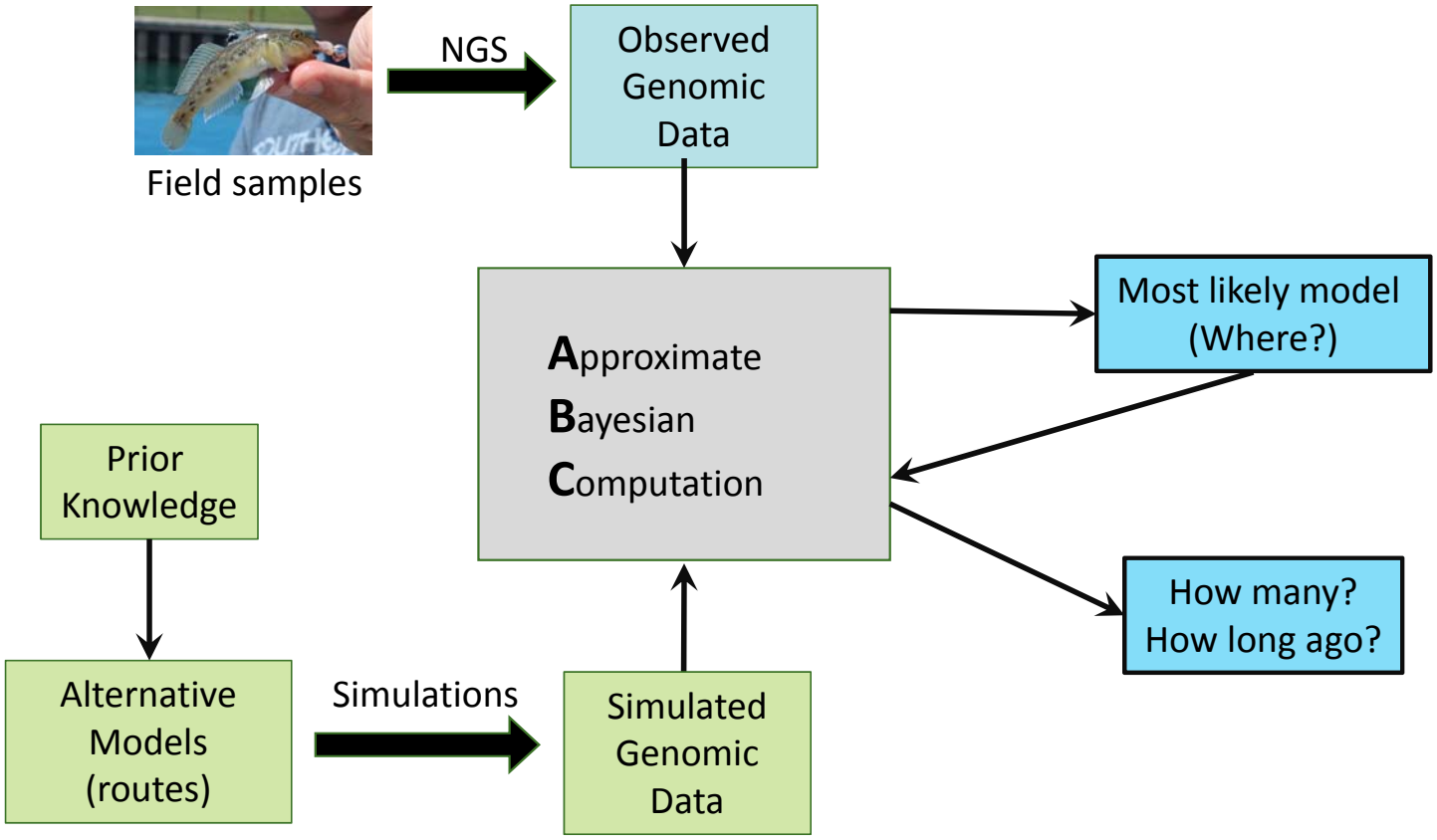
# USGS observations in Mott before Holloway

# We tested 11 models in total

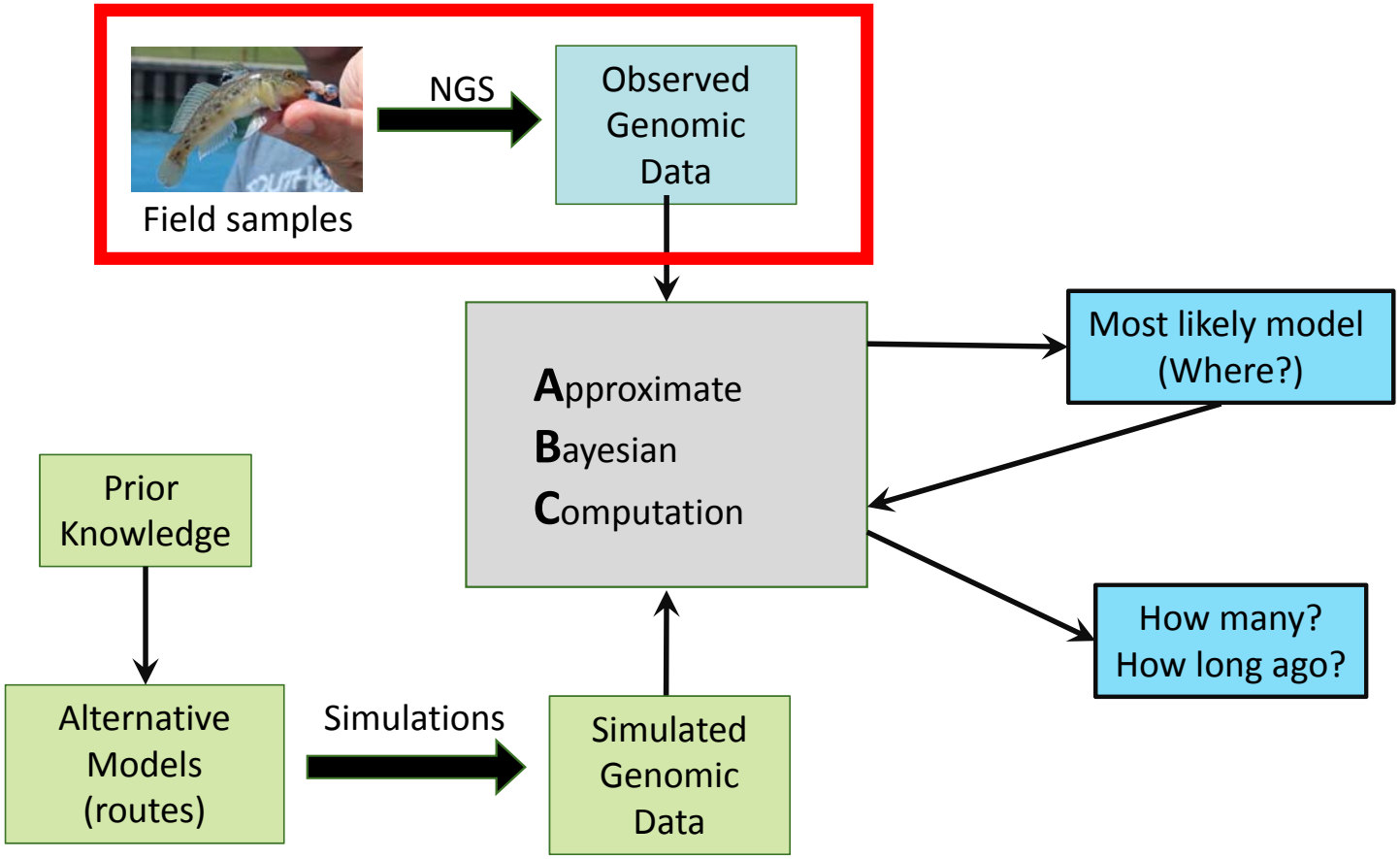
- St. Clair into Holloway Reservoir **(H)**
  - And Mott Lake **(HM)**
- Commercial bait (Saginaw Bay) into Holloway Reservoir **(H)**
  - And Mott Lake **(HM)**
- Lake Erie into Holloway Reservoir **(H)**
  - And Mott Lake **(HM)**
- Lake Michigan into Holloway Reservoir **(H)**
  - And Mott Lake **(HM)**
- Mixed source into Holloway **(H)**
  - And Mott Lake **(HM)**
- Local collection → ***Up*stream stepping-stone model, with potential for large bottleneck**

→ **Downstream stepping-stone models, but from *different sources***

# Approximate Bayesian Computation (ABC) has three major steps

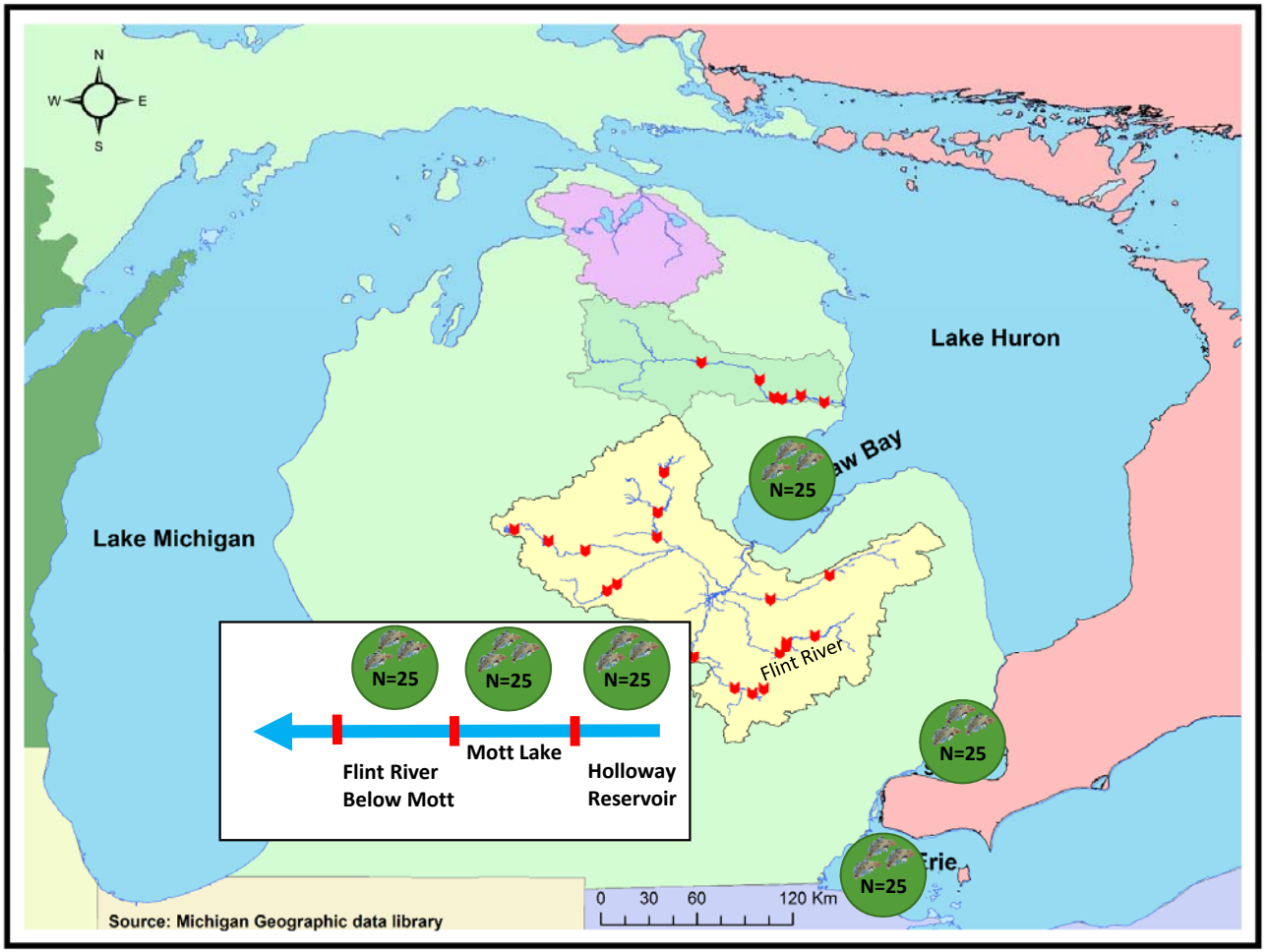


# ABC Step 1 – Collect and summarize observed data



# Sampling locations

- Three systems
  - Flint River
  - Au Sable River
  - Cheboygan River
- Most are segmented rivers
  - Dams or locks
- Vary in
  - Distance from populated areas
  - Recreational use



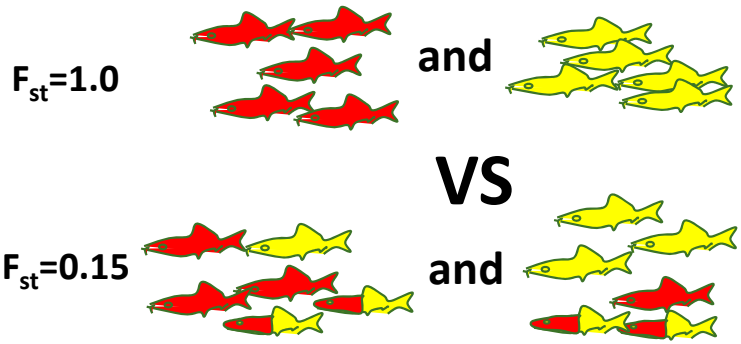
# Tissue samples were used to generate reduced representation libraries

- DNAs were extracted
- Libraries sequenced using a Illumina HiSeq
- Sequencing data processed using STACKs
- 9,075 loci for analysis

# Variation within and among sample collections provide information about colonization history

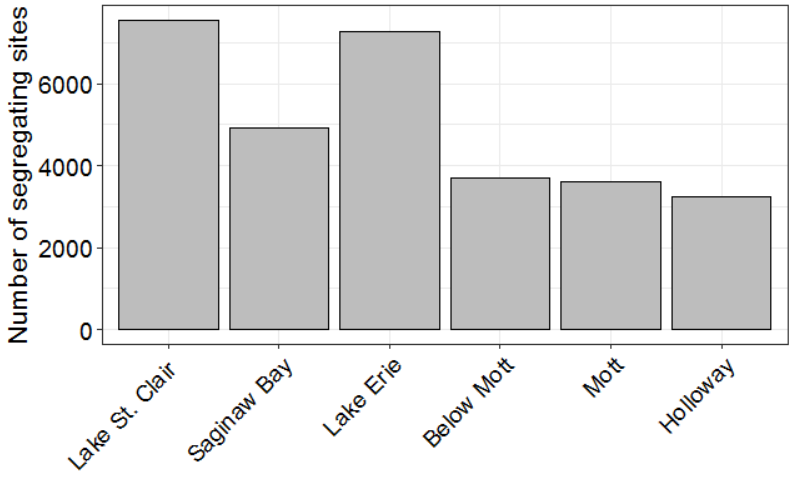
- Variation within
  - How many?
  - How long ago?


- Variation among
  - Where?
  - How long ago?




- Expectations
  - Lower diversity with small founding sizes
  - Higher diversity under mixed colonization model

# Summary statistics indicate strong founding event



# ABC Step 2 – Simulate data to represent alternative models

Field samples

NGS

Observed Genomic Data

**A**pproximate
**B**ayesian
**C**omputation

Most likely model (Where?)

How many? How long ago?

Prior Knowledge

Alternative Models (routes)

Simulations

Simulated Genomic Data

# We tested 11 models in total

- St. Clair into Holloway Reservoir
  - And Mott Lake
- Commercial bait (Saginaw Bay) into Holloway Reservoir
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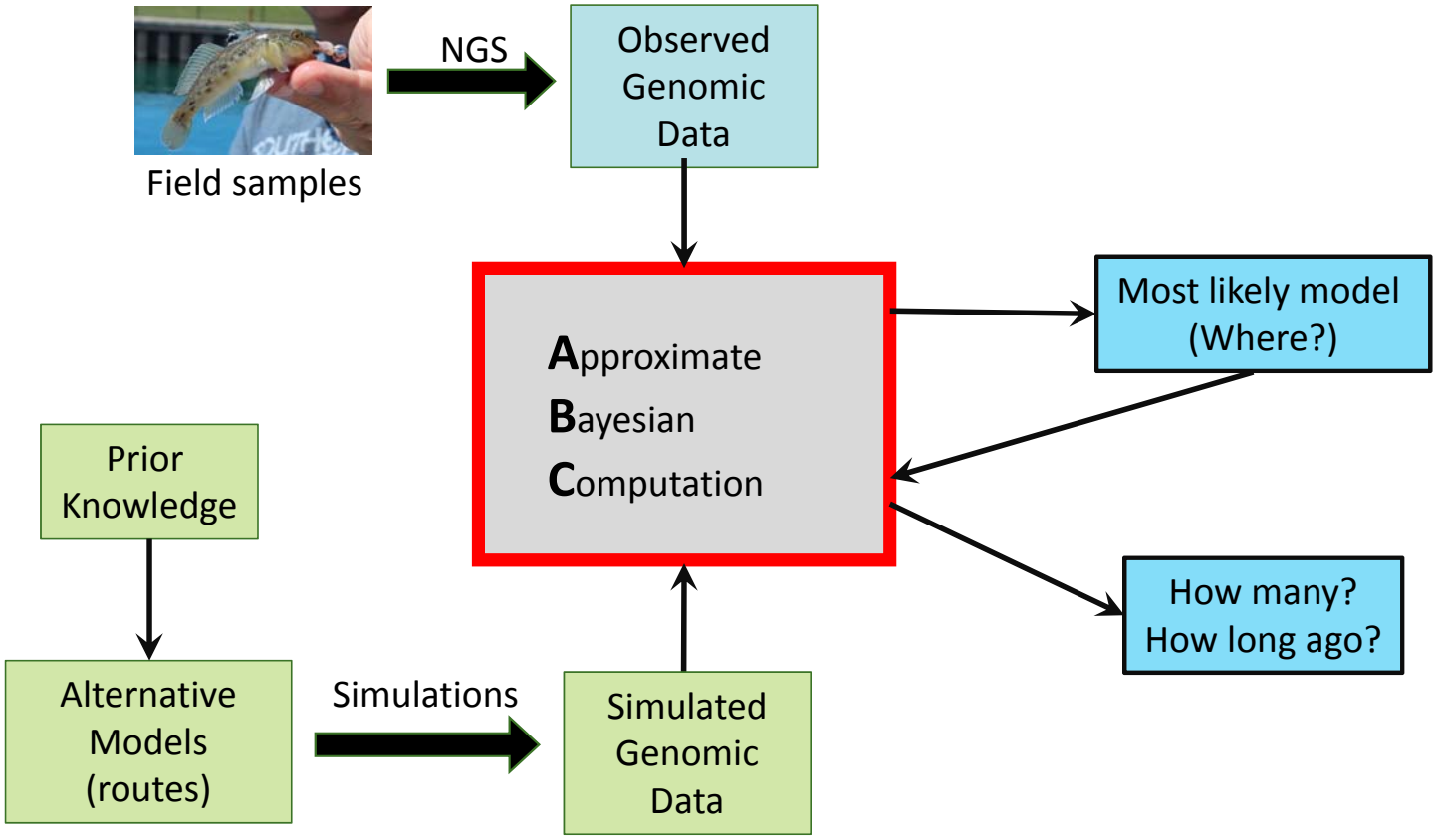
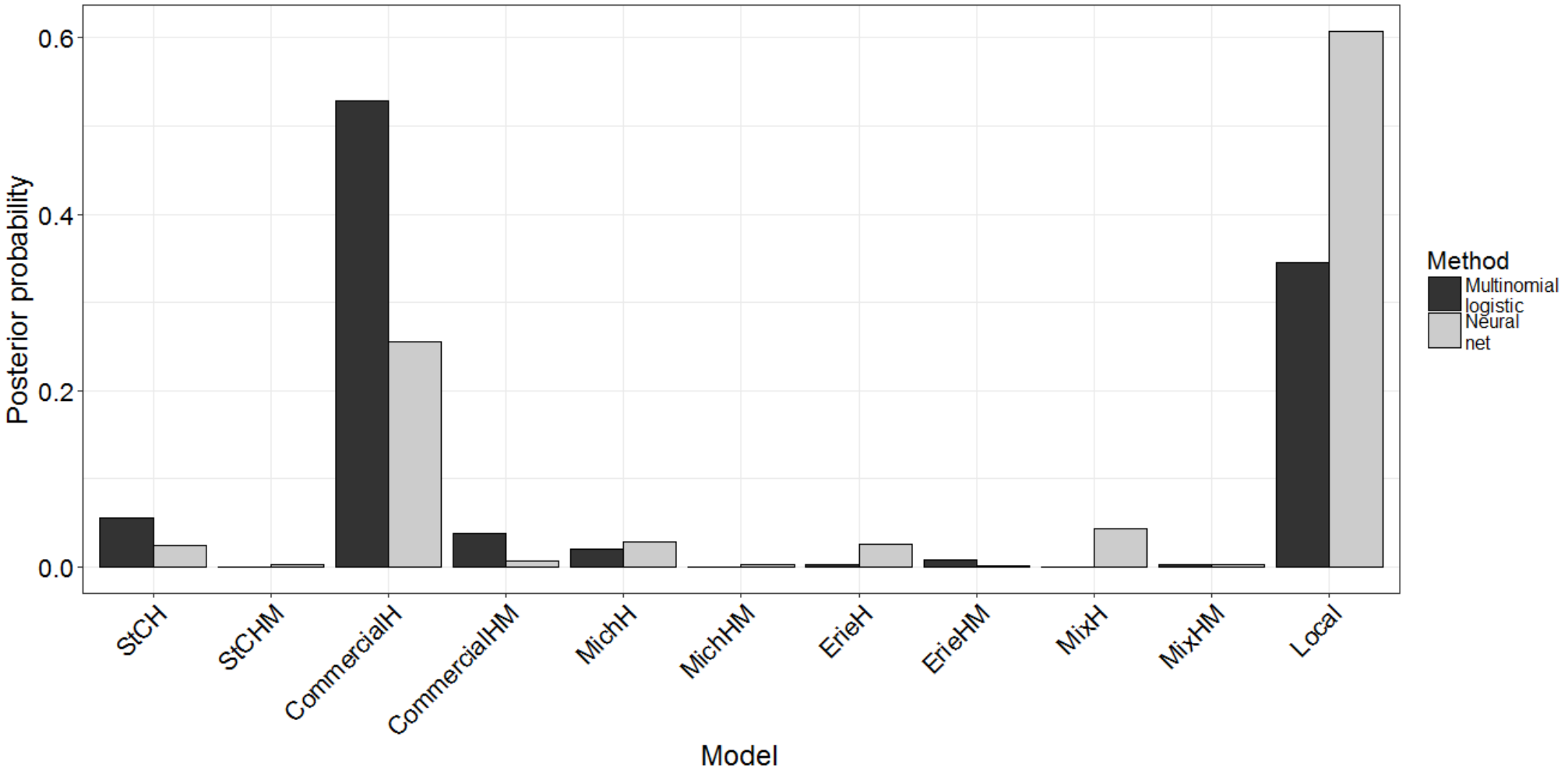
- Mixed source in Holloway
  - And Mott Lake
- Local collection → ***Up*stream stepping-stone model, with potential for large bottleneck**

→ **Downstream stepping-stone models, but from *different sources***

# ABC Step 3 – Compare observed data to simulated data for each model



# Local anglers and Commercial bait from Saginaw Bay both have some statistical support



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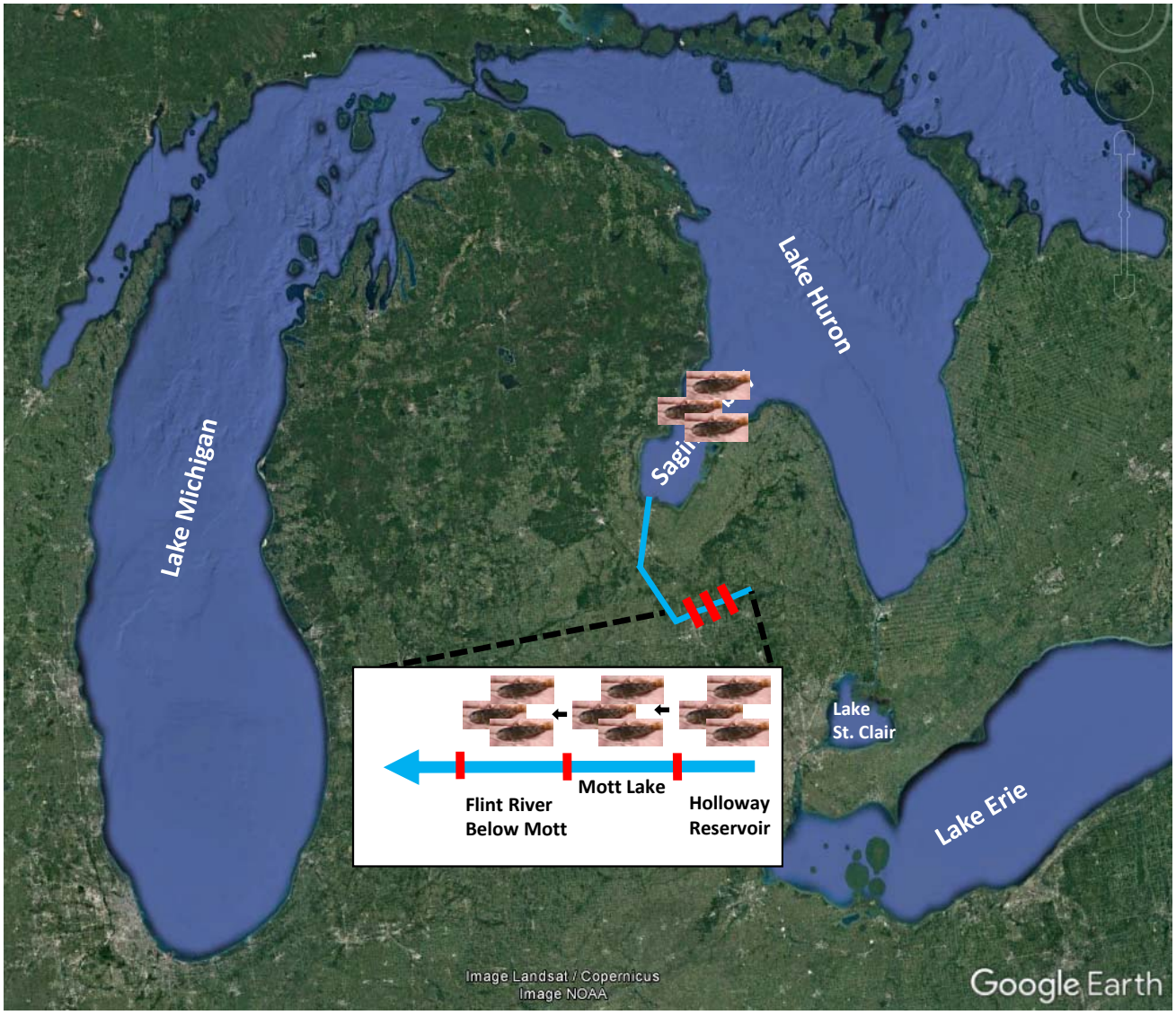

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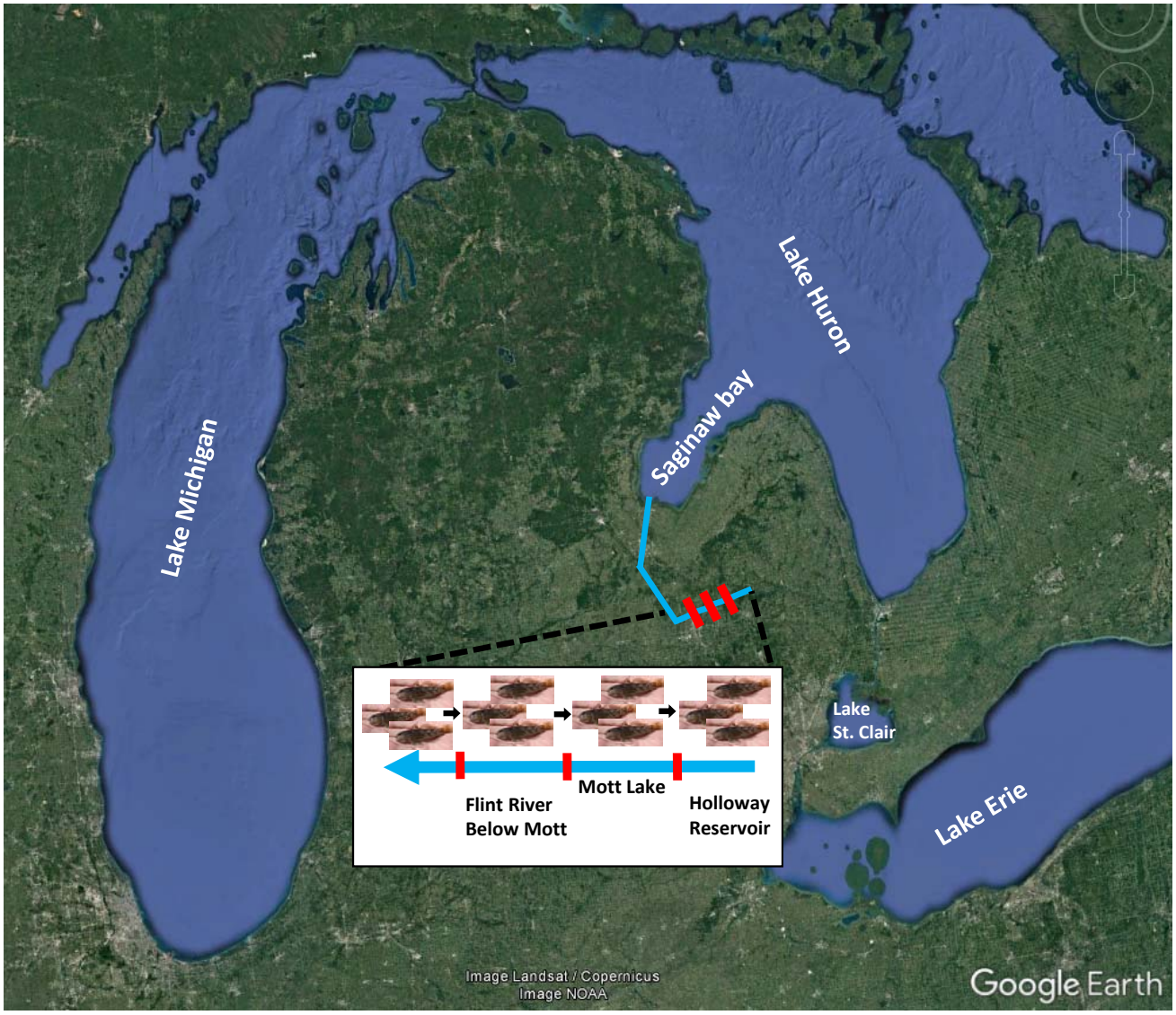

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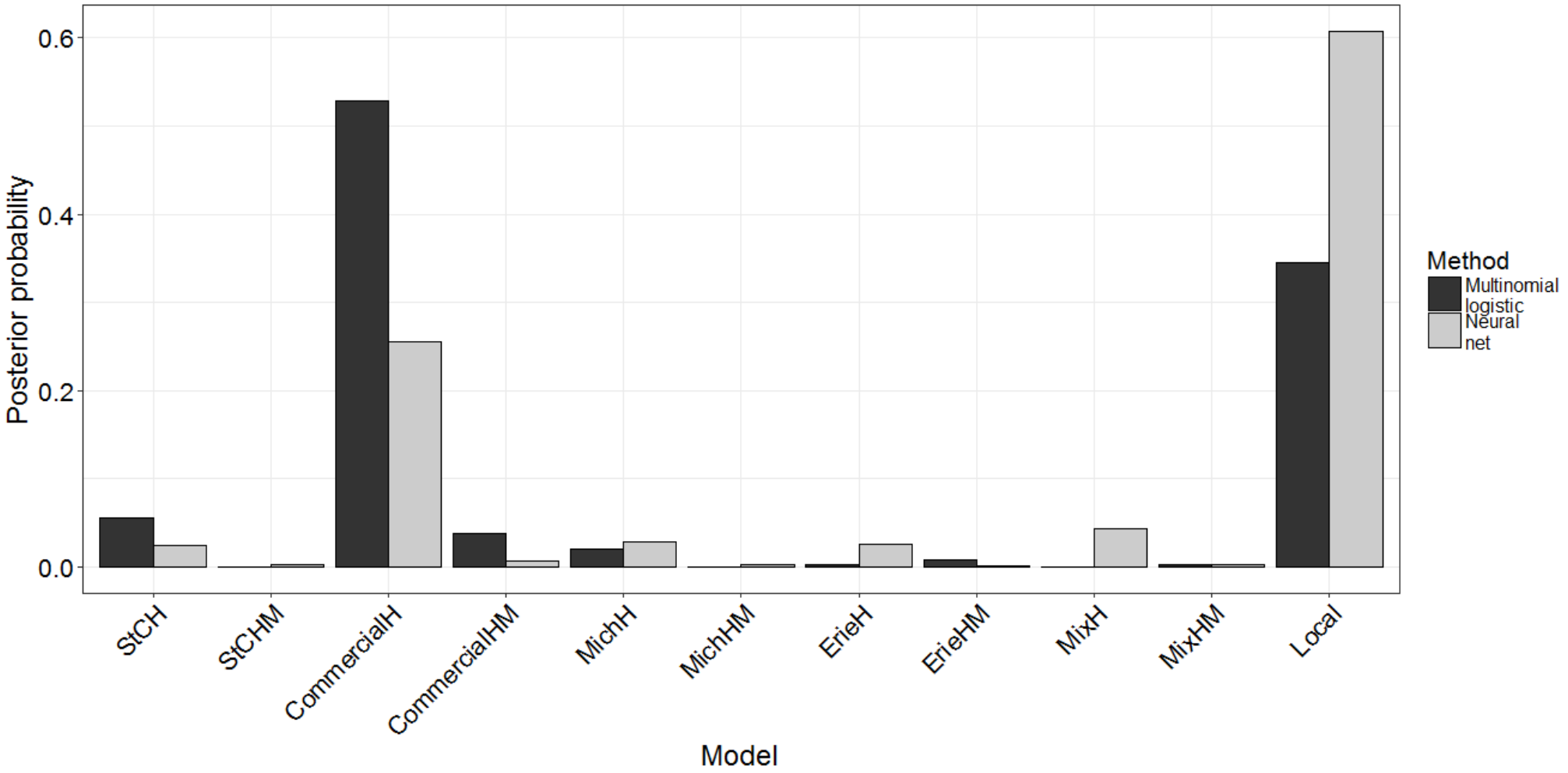
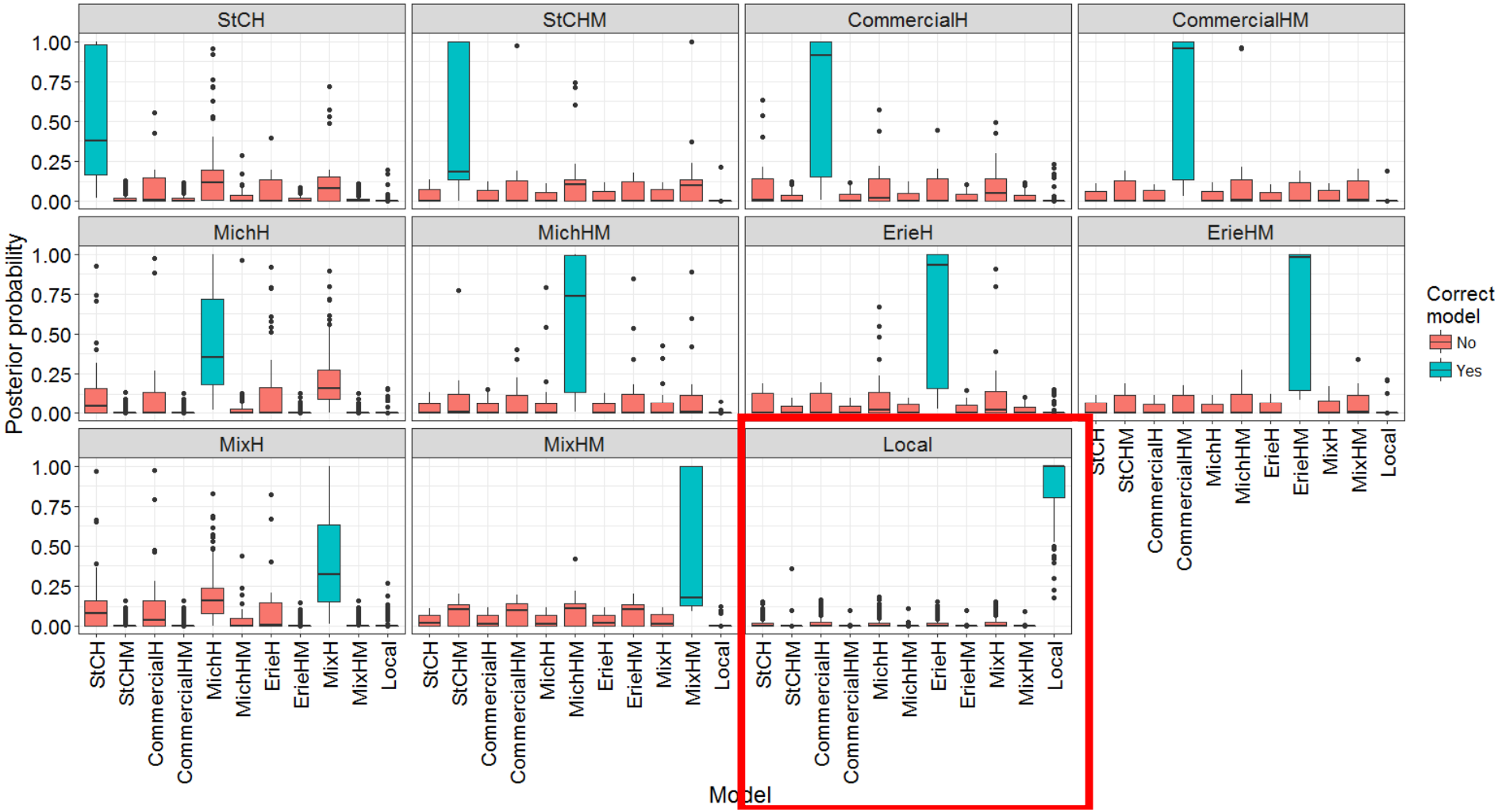
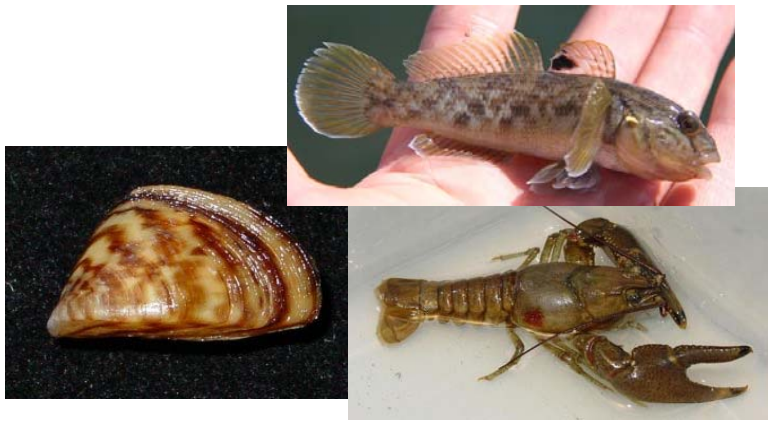


# Most models are distinct from each other



# Future work

- Expand number of simulations per model
  - Preliminarily focus on local scale awareness
- Analyses will consider three species:
  Round Goby, Rusty Crayfish, Zebra Mussel
  - Three systems:
    Au Sable, Cheboygan, Flint



- Project will help to identify
  - Parallel invasion processes
  - Species-specific aspects of inland lake colonization
- Similarities and differences in routes of invasion will help to generalize our findings to other ecologically distinct species

# Acknowledgements

**Michigan State University**
Dani Blumstein
Robert Holman
Jeannette Kanefsky

**Wayne State University**
Tom Dowling
Trevor Krabbenhoft

**Funding**
Michigan Department of Natural Resources
Great Lakes Restoration Initiative

**Contact information**
nicksard@gmail.com