PUERTO RICO STREAM FISHES: SAMPLING, DISTRIBUTION, AND INFLUENTIAL FACTORS

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USGS science for a changing world

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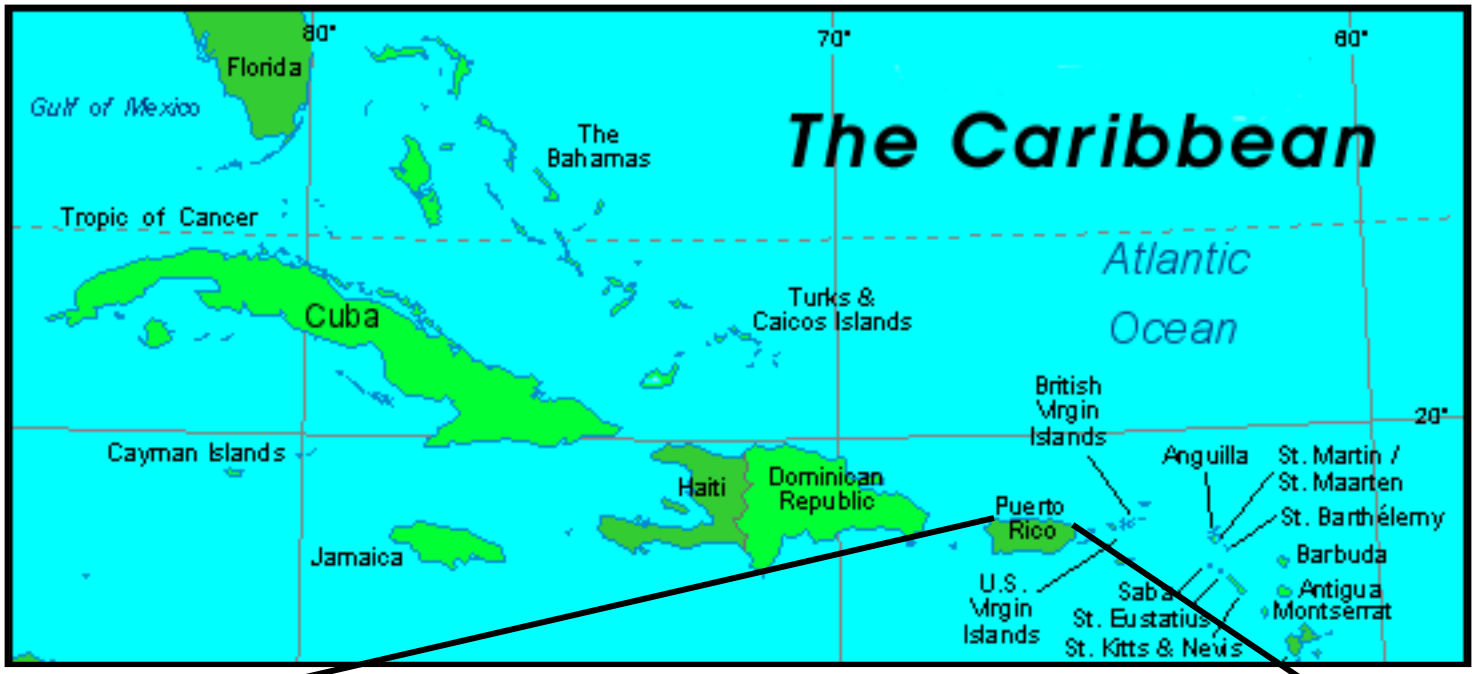
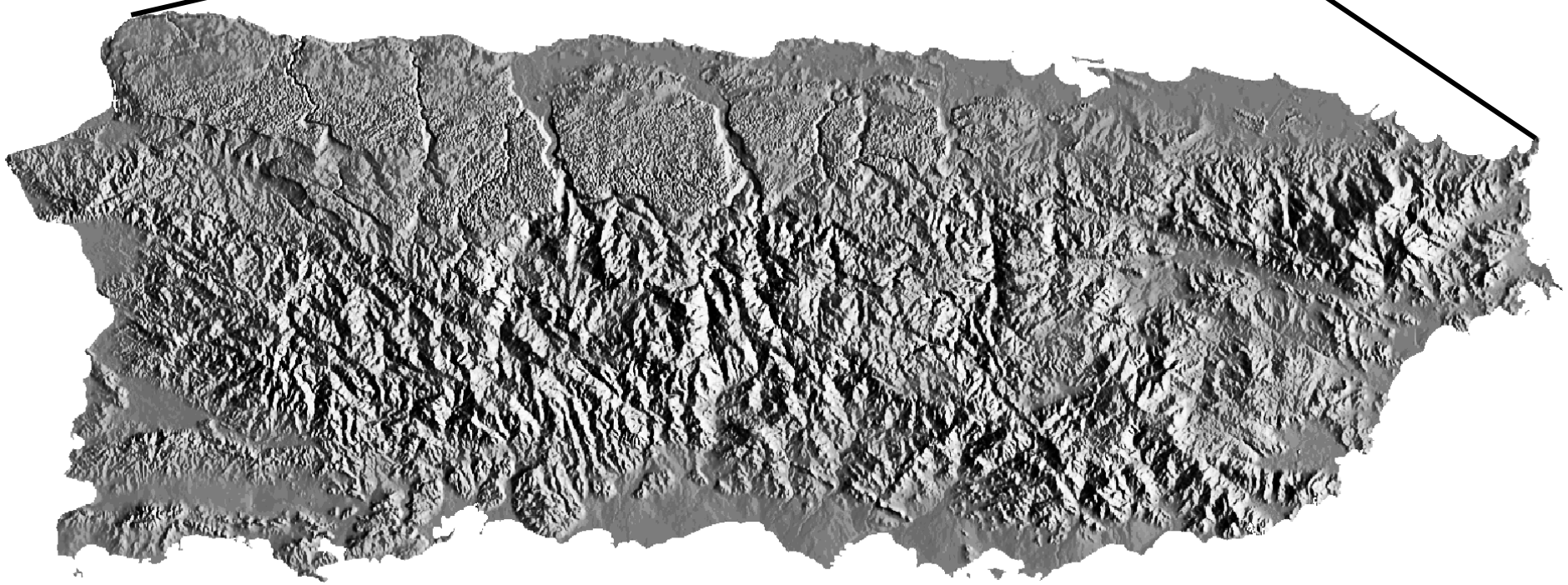
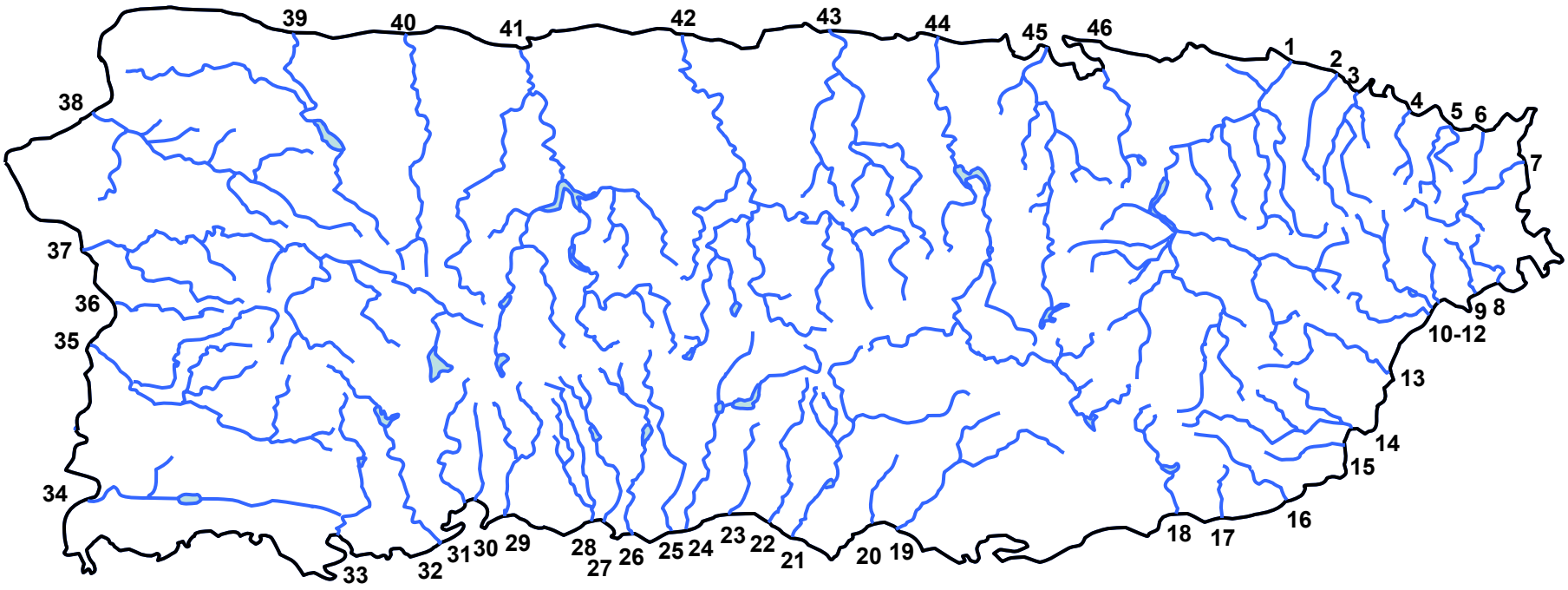

The Caribbean
Atlantic
Ocean
Gulf of Mexico
Florida
The Bahamas
Tropic of Cancer
Cuba
Turks & Caicos Islands
Cayman Islands
Haiti
Dominican Republic
Jamaica
Puerto Rico
British Virgin Islands
Anguilla
St. Martin / St. Maarten
St. Barthélemy
Barbuda
Antigua
Montserrat
Saba
St. Eustatius
St. Kitts & Nevis
U.S. Virgin Islands
80°
70°
60°
20°



Fishing



- **46** major river drainages
- **1,200** streams
- **0** natural freshwater lakes
- **>30** reservoirs

Streams provide:

- irrigation
- hydroelectric power
- drinking water
- cultural value
- recreation
- habitat

Importance of Management

"With proper management and protection of water quality, freshwater fishes will continue to be a valuable resource for the people of Puerto Rico."

Erdman 1984

Objectives

1. Evaluate sampling techniques for fish and habitat
2. Propose a standardized sampling protocol
3. Quantify fish population parameters
   - Distribution of native and introduced species
   - Richness, diversity, density, biomass
4. Relate fish populations to physical habitat
   - Instream habitat
   - Water quality
   - Riparian and watershed attributes

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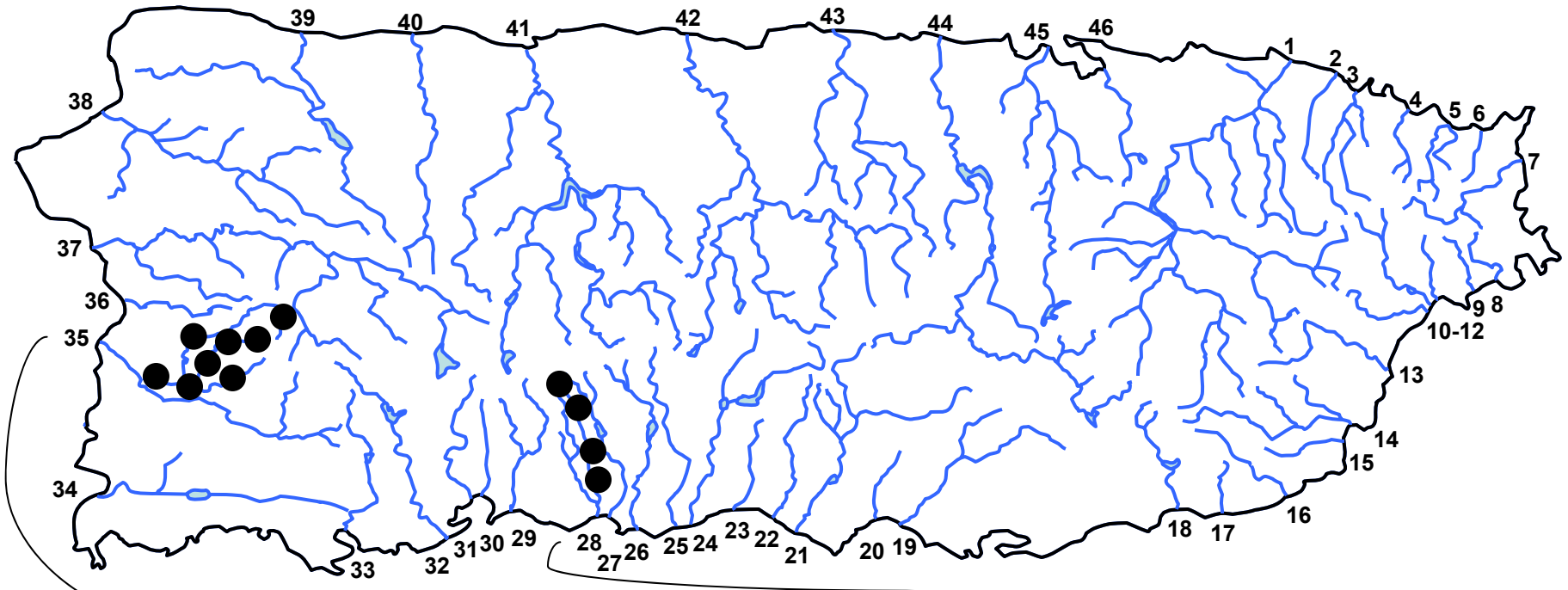


Río Guanajibo

- Mesic watershed
- 8 sampling sites

Río Cañas

- Xeric watershed
- 4 sampling sites

Summer 2005 Fall 2005 Spring 2006

Backpack electrofishing

- Steep slope
- Large substrate
- Shallow
- Narrow

Barge electrofishing

- Flat slope
- Small substrate
- Deep
- Wide

Sampling Methods

- 3-5 passes in upstream direction
- Mark-recapture and removal conducted concurrently
- Fish received a pass-specific mark
- Captured fish were marked, weighed, measured, identified, and released

Studied Species

Mountain mullet (Dajao)

- Water-column species in riffles and pools
- Omnivorous

Bigmouth sleeper (Guavina)

- Demersal species in slow pools with large substrate
- Carnivorous

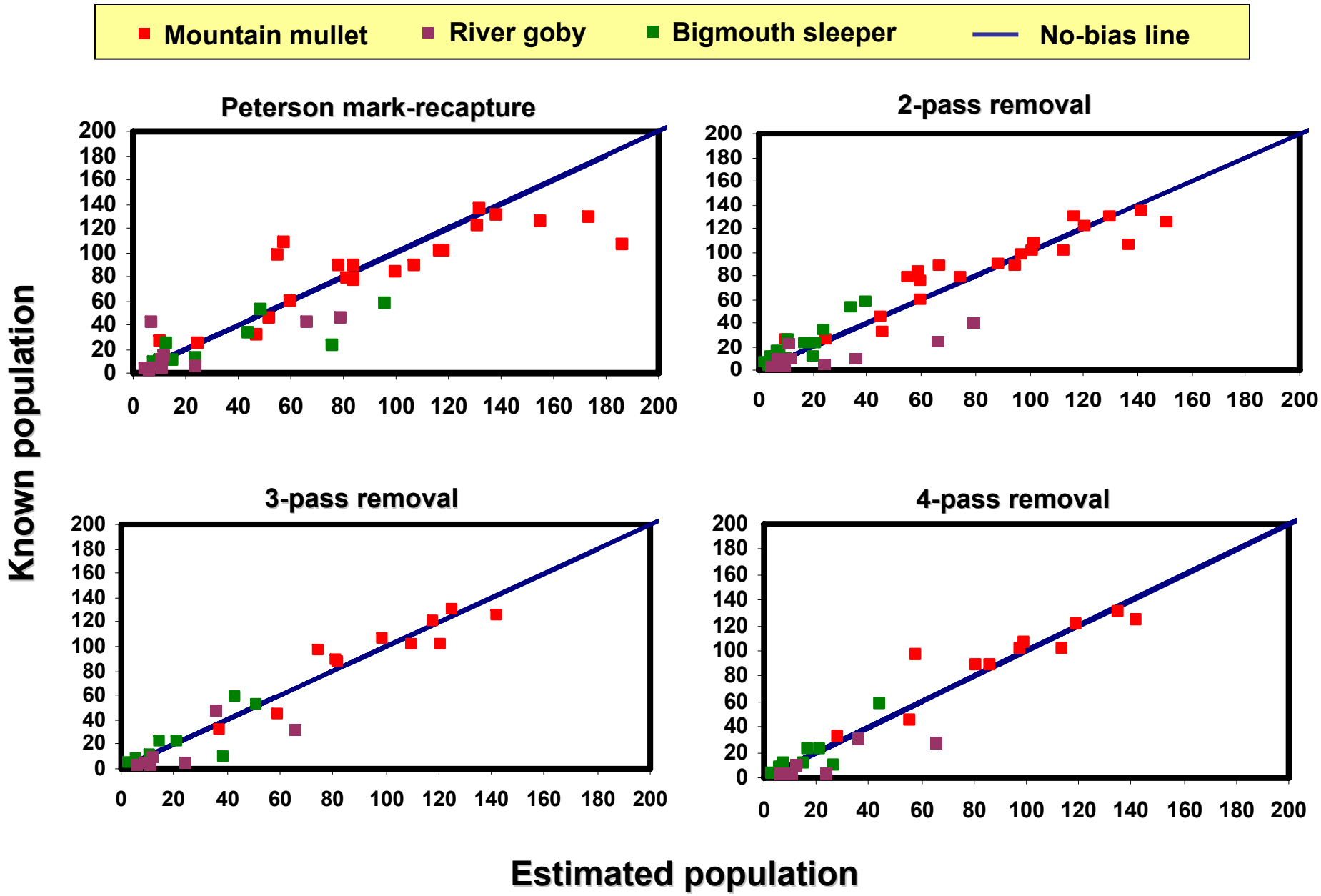
River goby (Saga)

- Demersal species utilizing sandy substrate
- Omnivorous

Bias Assessment

- Fish caught on first pass = known subpopulation (marked)
- Program CAPTURE via program MARK
- Recapture estimate for passes 2 and 3
- Removal estimate for passes 2–5
- Compare estimates to known subpopulation

Bias Assessment Results



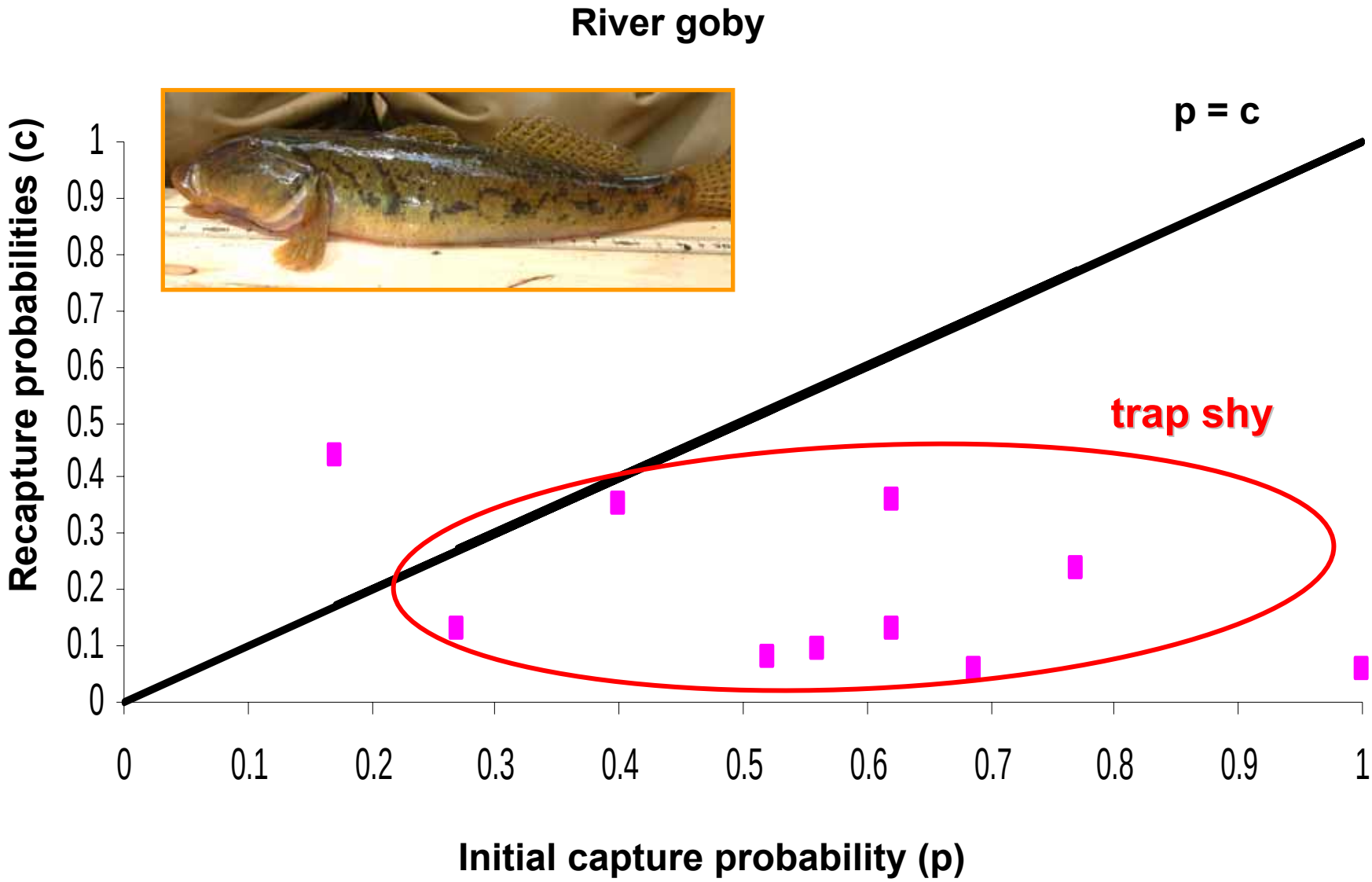
Types of Models

M_0	Equal catchability, p=c
M_b	Behavioral, p≠c, allows for variance in capture probability

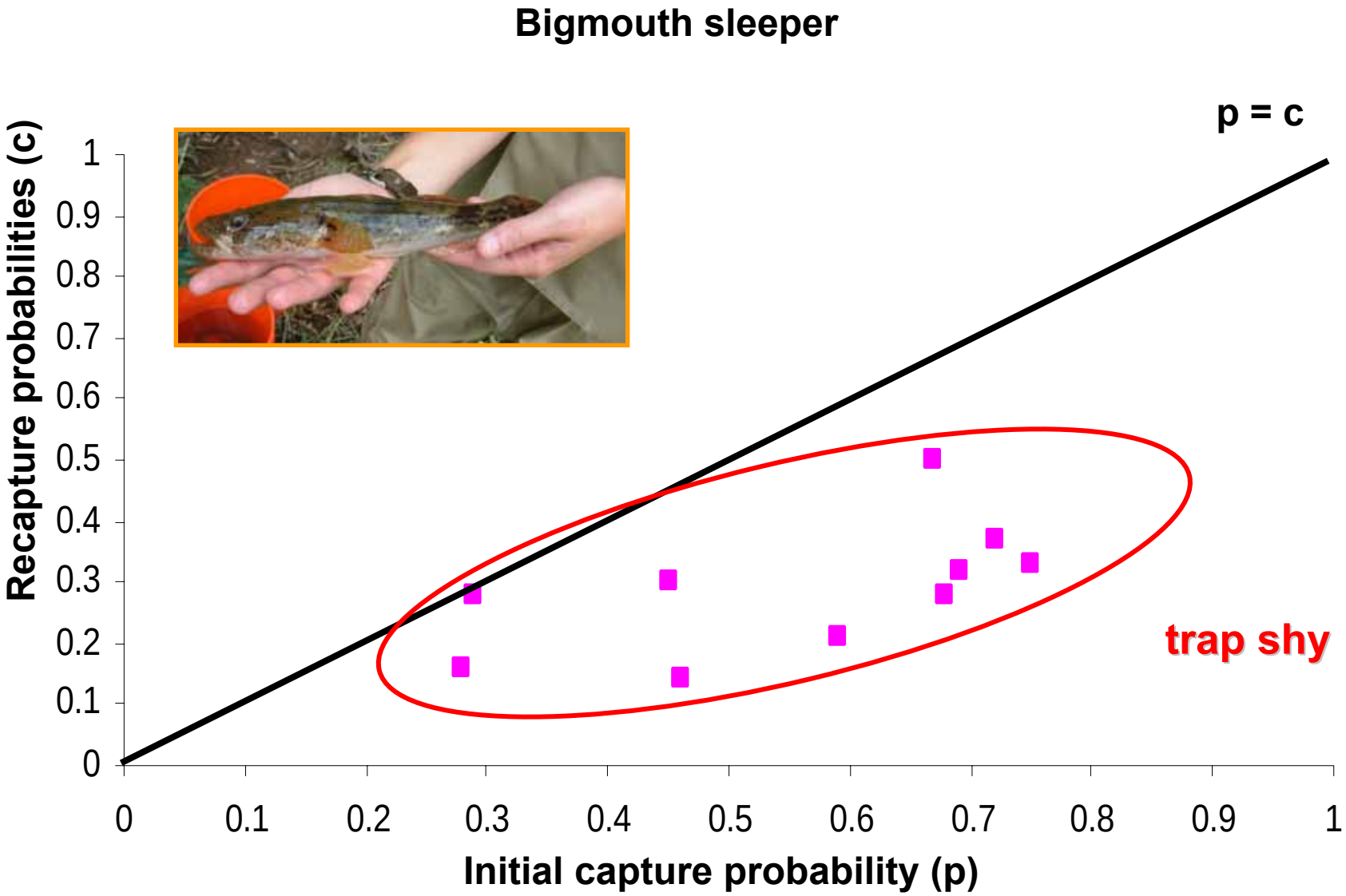
Behavioral Effect

River goby

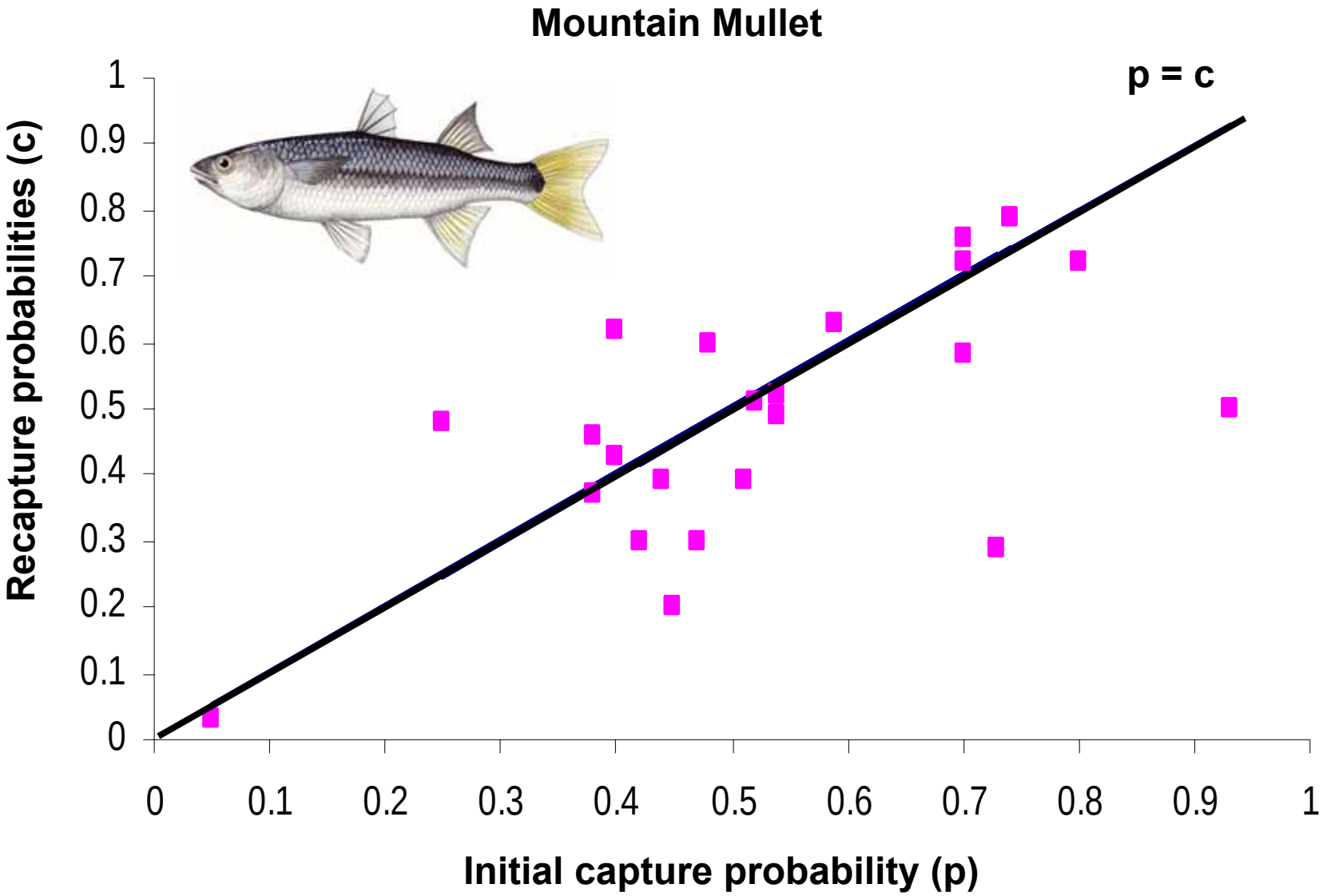
Behavioral Effect



Behavioral Effect



Behavioral Effect



Types of Models

M_0	Equal catchability, p=c
M_b	Behavioral, p≠c, allows for variance in recapture probability

Standardized Sampling Protocol

Electrofishing

- Backpack or barge

100–200 m reach

- Incorporates multiple habitat types

Three-pass removal

- Highest accuracy and efficiency

Model M_b

- Accounts for trap shyness of demersal species

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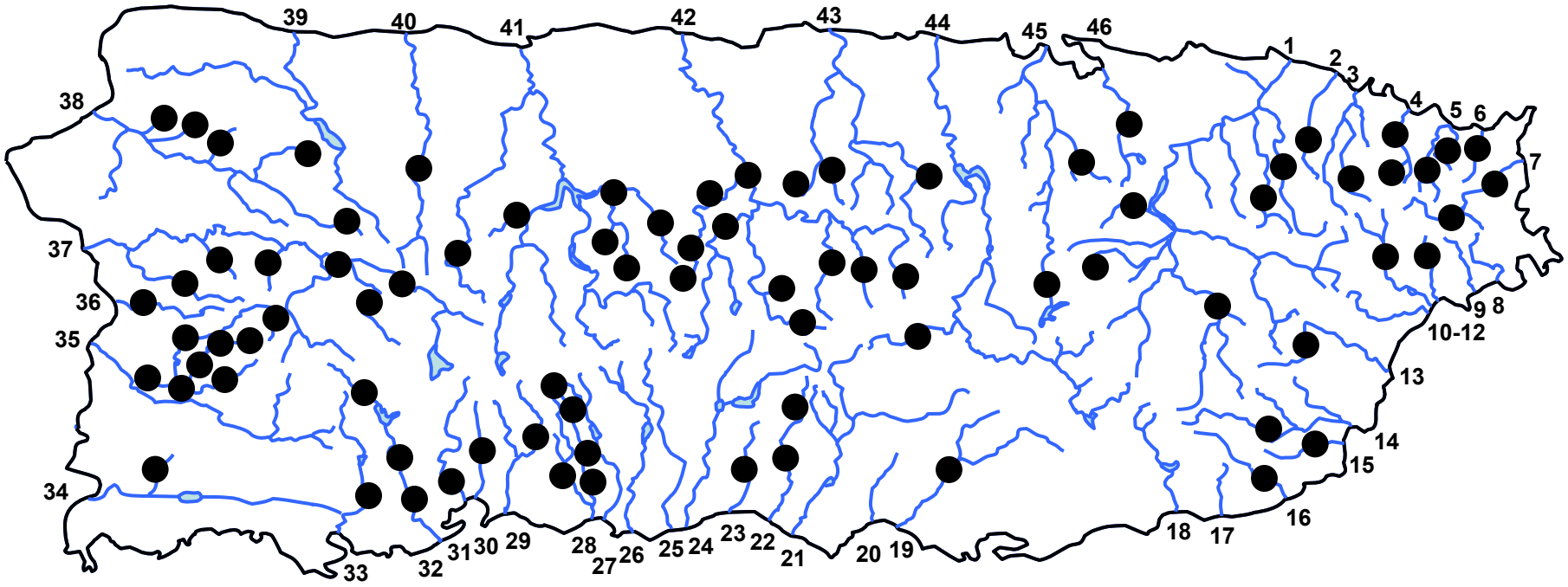
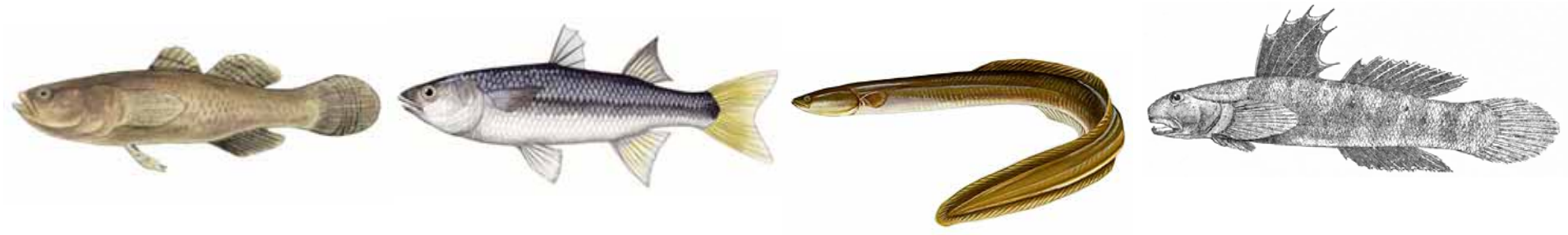
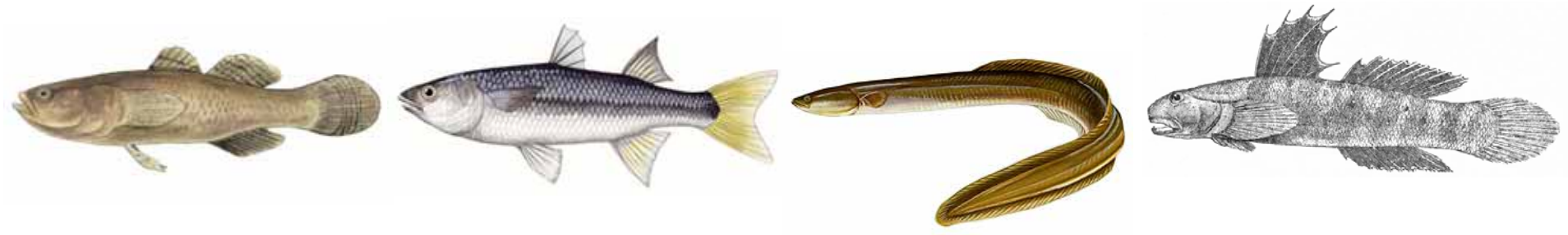
Island-Wide Sampling



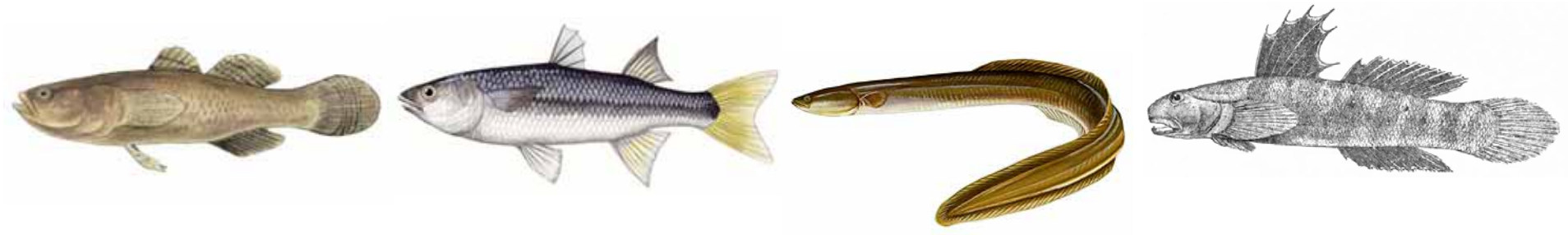
- 81 sites in 41 municipalities
- 34 of 46 river drainages
- Summer 2005 – Spring 2007



	All fish	Native	Introduced
No. Species	25	10	15
No. Fish			
Biomass (kg)			



	All fish	Native	Introduced
No. Species	25	10	15
No. Fish	50,798	22,016	28,782
Biomass (kg)			



	All fish	Native	Introduced
No. Species	25	10	15
No. Fish	50,798	22,016	28,782
Biomass (kg)	570.7	459.8	110.9

Smallscaled spinycheek sleeper (Morón),
Eleotris perniger

Bigmouth sleeper (Guavina),
Gobiomorus dormitor

Sirajo goby (Olivo), *Sicydium spp.*

River goby (Saga), *Awaous banana*

Mountain mullet (Dajao)
Agonostomus monticola

American eel (Anguila),
Anguilla rostrata

Fat Sleeper (Mapiro)

Dormitator maculatus

Not Sampled

White mullet (Jarea)
Mugil curema

Burro grunt (Viejo)
Pomadasys crocro

Fat snook (Robalo)
Centropomus parallelus

Gray snapper (Pargo prieto)
Lutjanus griseus

Introduced Fish Species

Poecilids

Mexican molly (*Poecilia sphenops*)

Guppy (*Poecilia reticulata*)

Sailfin molly (*Poecilia latipinna*)

Green swordtail (*Xiphophorus hellerii*)

Cichlids

Mozambique tilapia
(*Oreochromis mossambicus*)

Rebreast tilapia (*Tilapia rendalli*)

Convict cichlid
(*Archocentrus nigrofasciatus*)

Nile tilapia (*Oreochromis niloticus*)

Centrarchids

Largemouth bass (*Micropterus salmoides*)

Bluegill (*Lepomis macrochirus*)

Redbreast sunfish (*Lepomis auritus*)

Catfishes

Amazon sailfin catfish (*Pterygoplicthys pardalis*)

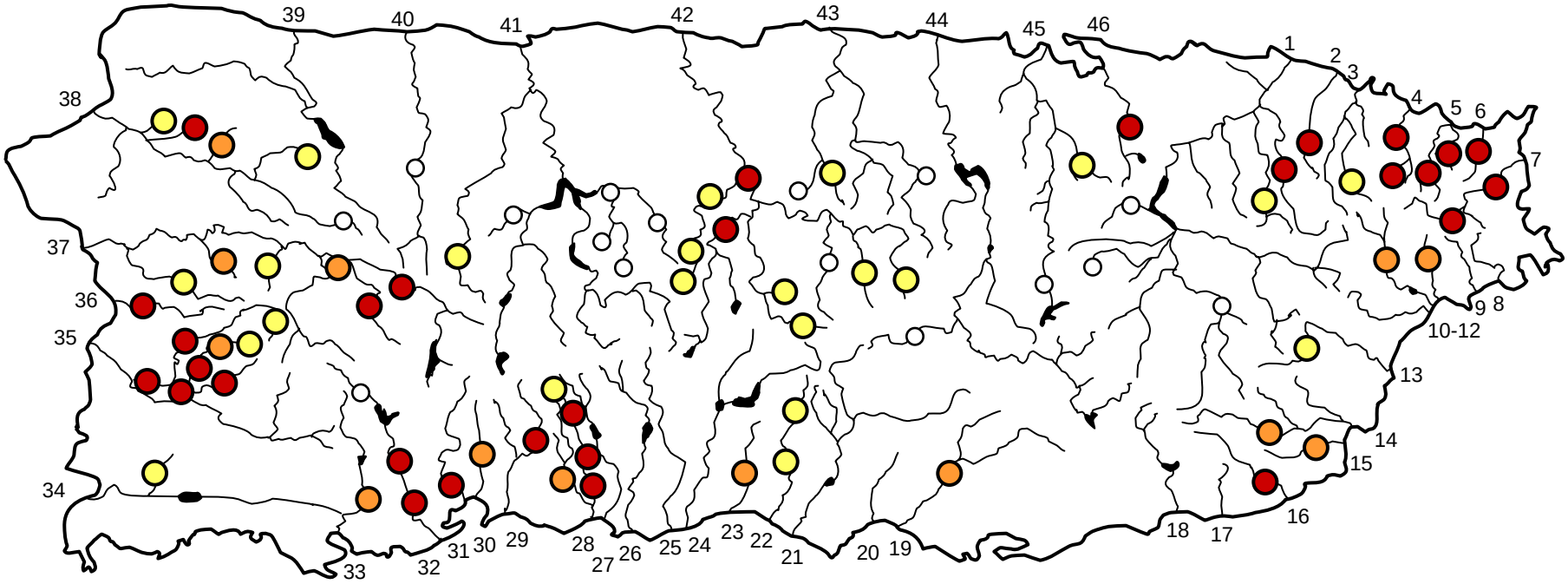
Channel catfish (*Ictalurus punctatus*)

Rosy barb (*Puntius conchonius*)

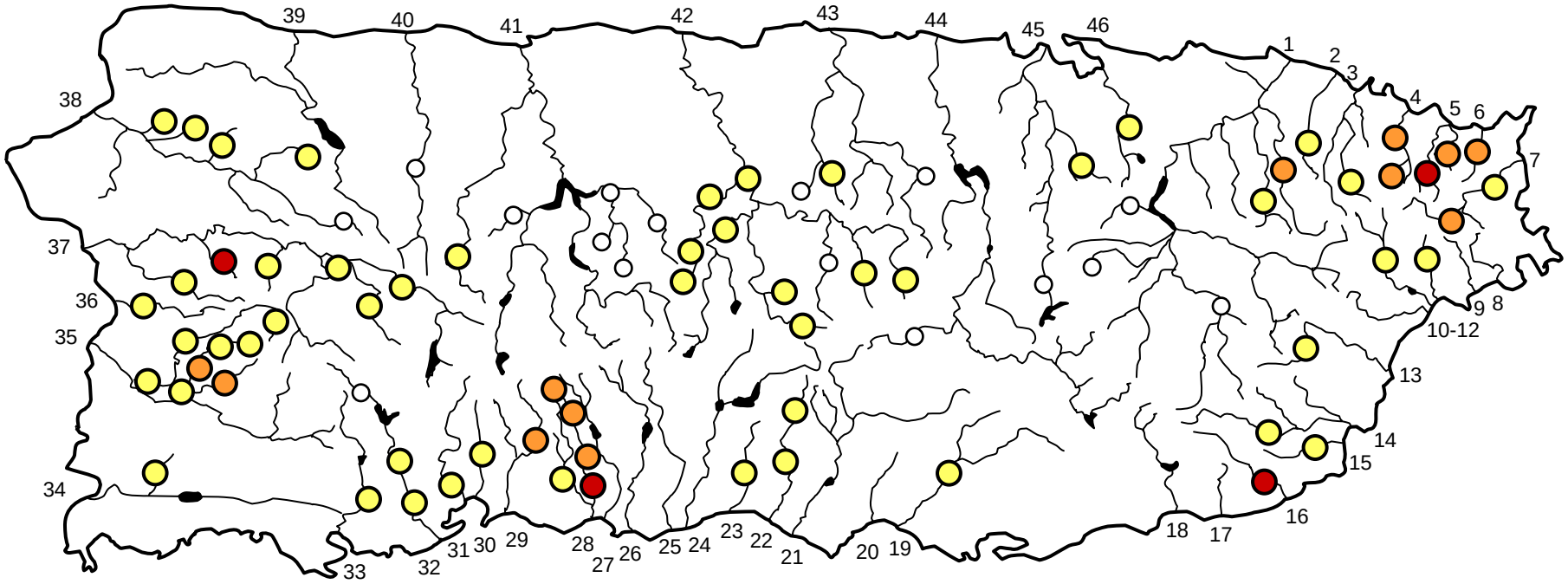
Newly discovered **(upstream of Lago Carraizo)**

Chinese algae-eater (*Gyrinocheilus aymonieri*)

Native Fish Species Richness



Native Fish Density



Fish/ha

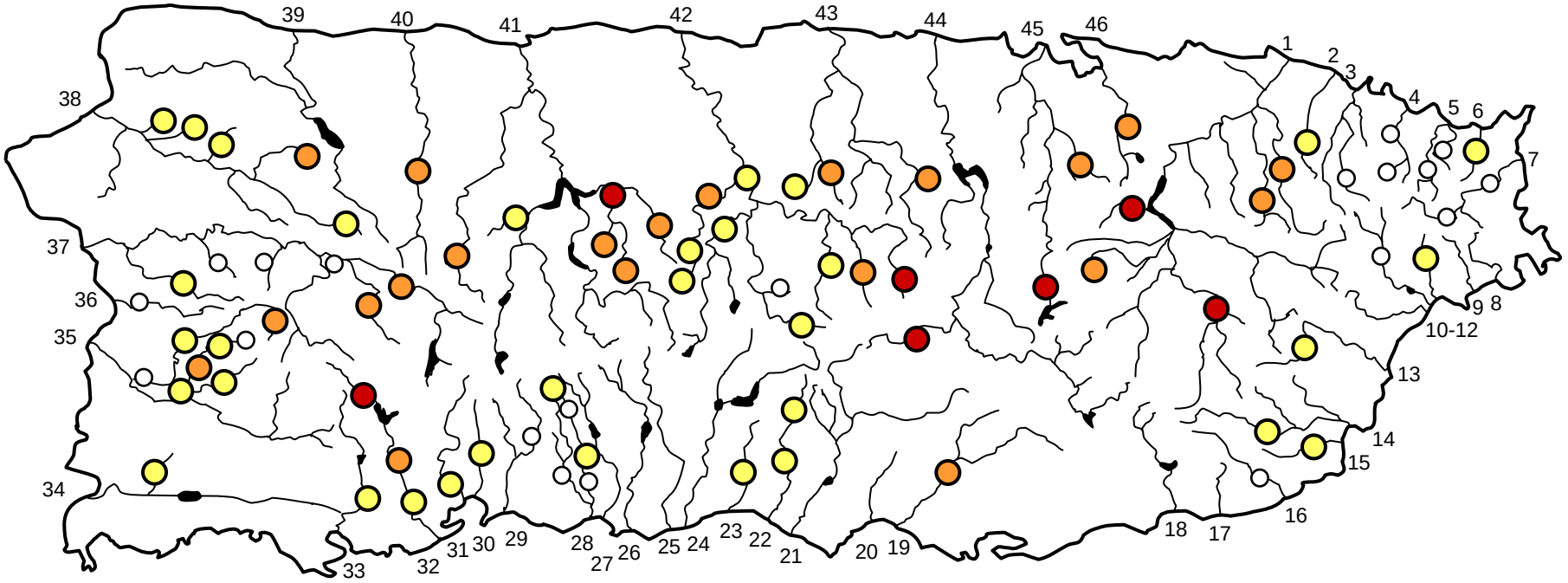
Not detected	1–10,000	10,001–30,000	> 30,000

Fish Passage?

Río Toro Negro

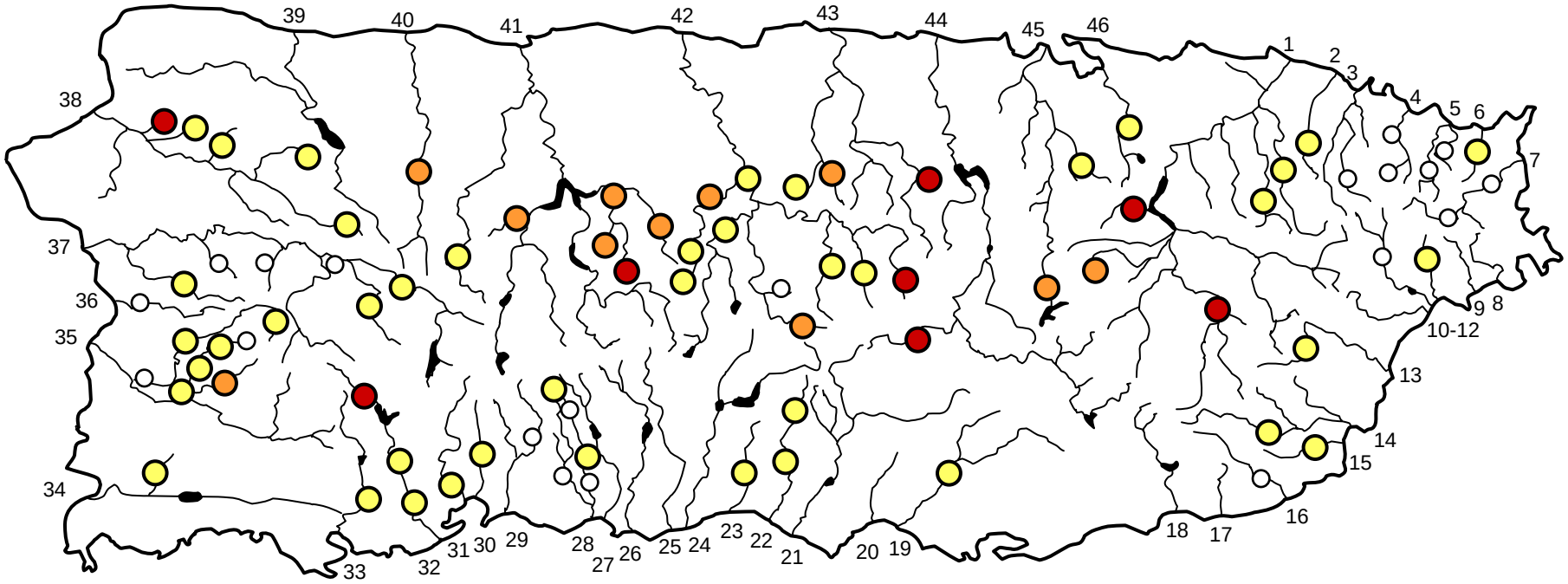
upstream of Ciales

Introduced Fish Species Richness



○ Not detected ● 1–2 species ● 3–4 species ● 5–11 species

Introduced Fish Density



Fish/ha

Not detected	1–10,000	10,001–30,000	> 30,000

Summary

- **Native** species detected in **33** of 34 drainages
  - Most abundant at lower elevations and in National Forest
  - None detected upstream of large reservoirs

- **Introduced** species detected in **26** of 34 drainages
  - Most abundant at higher elevations and upstream of large reservoirs
  - Few detected in rivers draining National Forest

Objectives

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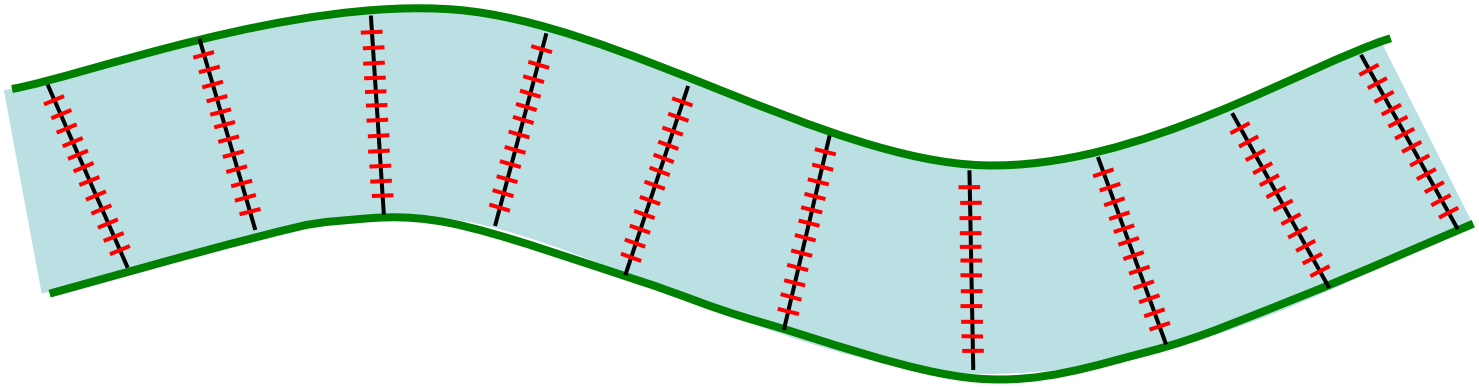
   - **Riparian and watershed attributes**

Instream and Riparian Habitat Surveys

- **Cross-sectional transect habitat survey**
- **Measure bank angle, width, depth, velocity, substrate, instream cover**



Water Quality Analyses

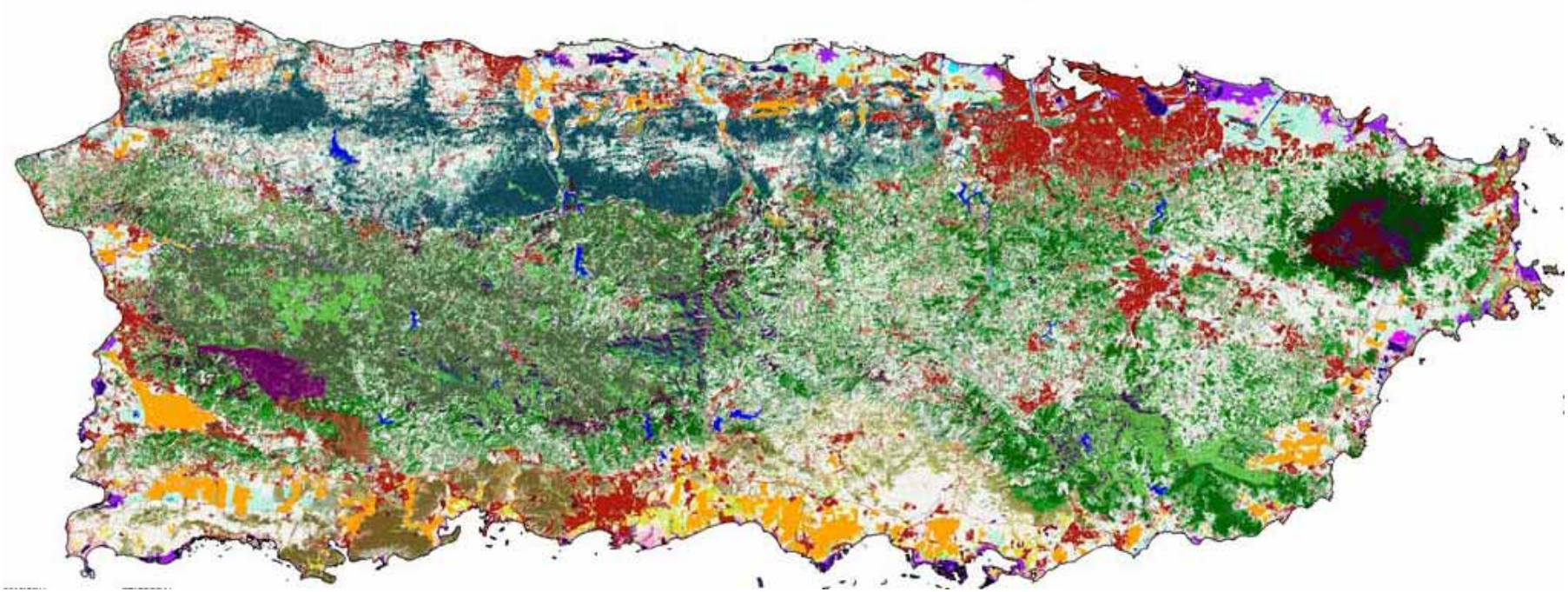
- Water temperature
- Total dissolved solids
- Conductivity
- Dissolved oxygen
- Salinity

- Nitrate
- Nitrite
- Ammonia
- Phosphorus
- Alkalinity
- Hardness
- pH
- Turbidity

Geographic Information System (GIS)

Puerto Rico Gap Analysis Program

- Land cover and ownership
- Quantified riparian buffer and upstream watershed of all 81 sites



Watershed and Riparian Attributes

Land cover (%)

- Agriculture
- Forest
- Freshwater
- Shrub and woodland
- Urban

Ownership (%)

- Private
- Public
  (PRDRNA, USFS)
- NGO
  (Utilities, Conservation Trust)

Watershed area (ha)

Road density (km/ha)

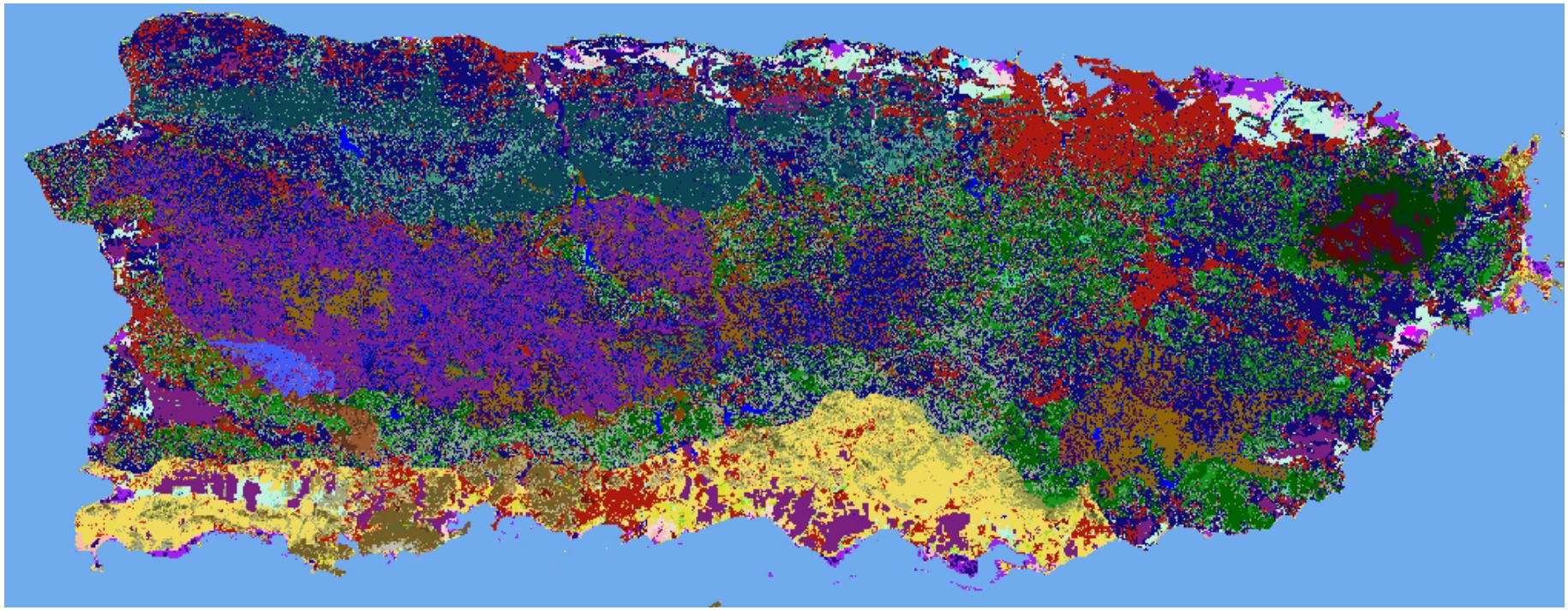
Elevation (m)

Stream gradient (%)

Distance to river mouth (km)

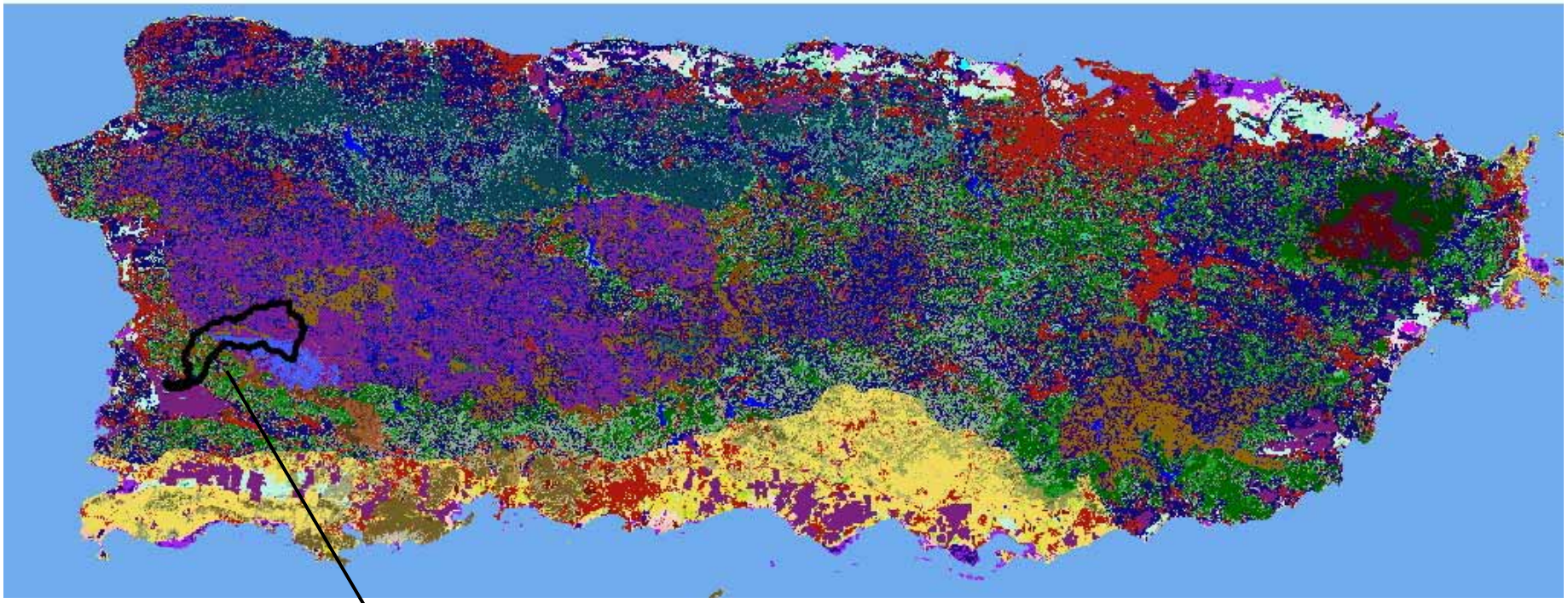
Downstream reservoir (present/absent)

Watershed and Riparian Attributes



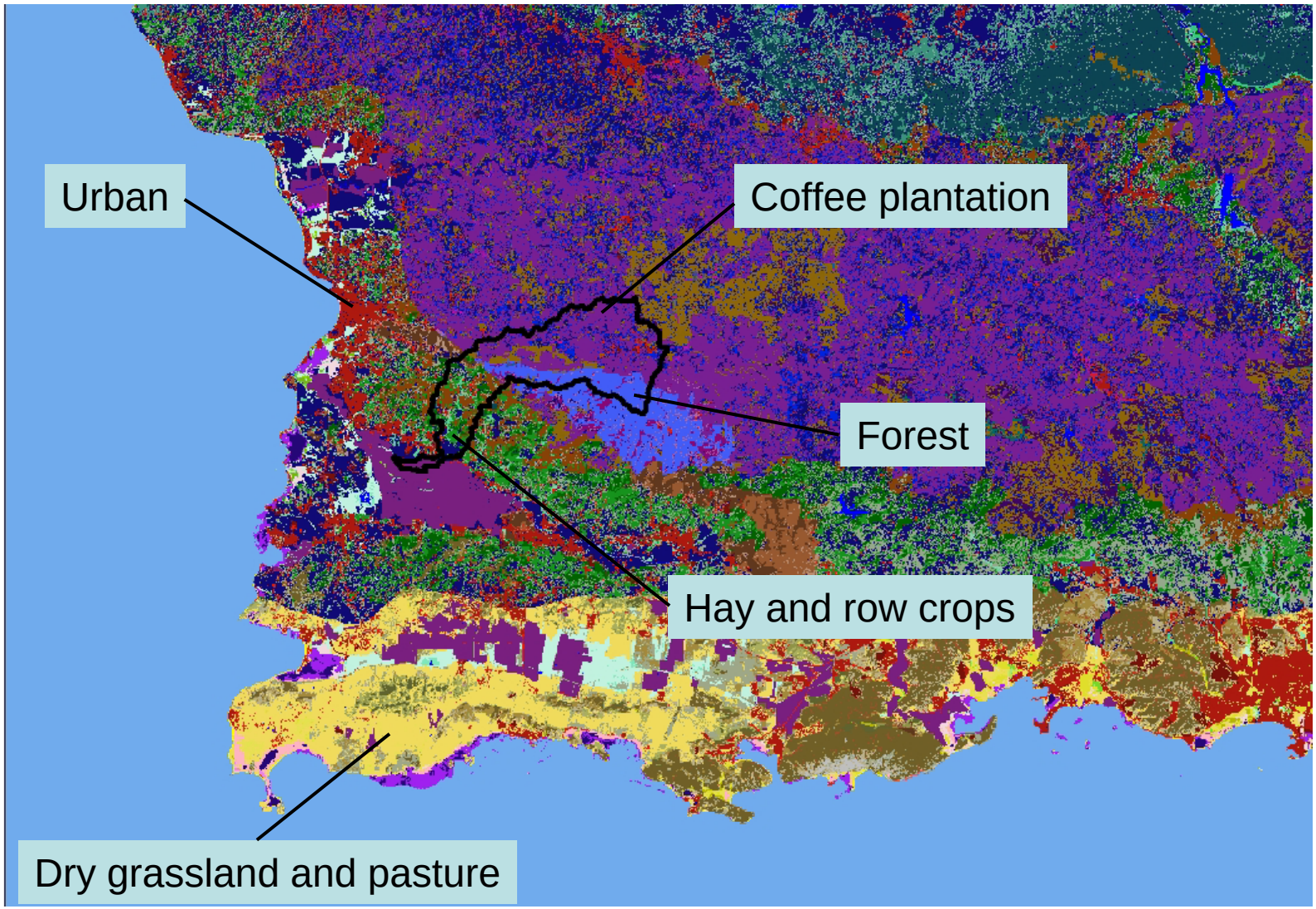
Watershed and Riparian Attributes

Land Cover



Watershed and Riparian Attributes

Río Rosario, Guanajibo River Basin



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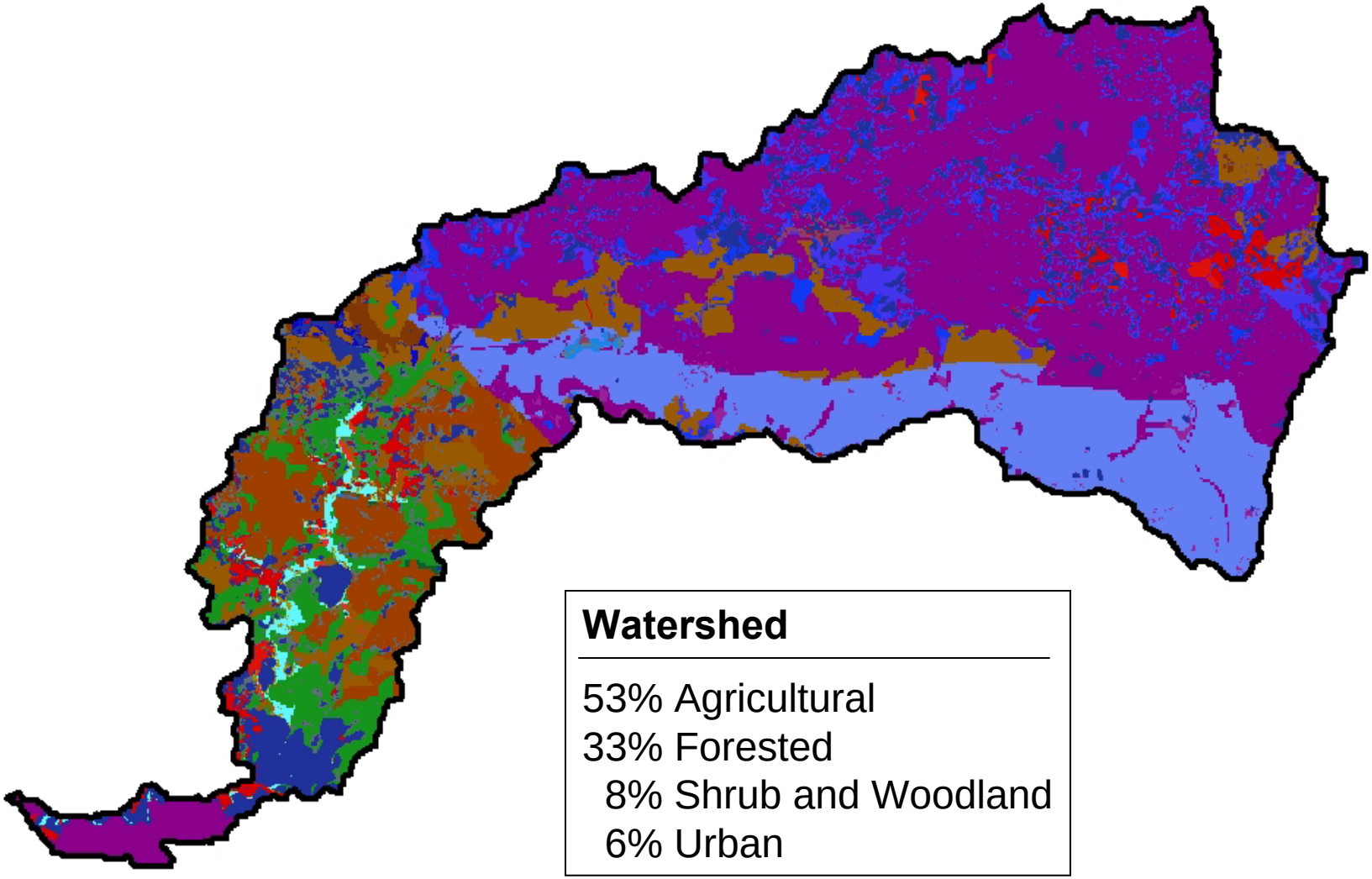

Watershed

53% Agricultural
33% Forested
  8% Shrub and Woodland
  6% Urban

Watershed and Riparian Attributes

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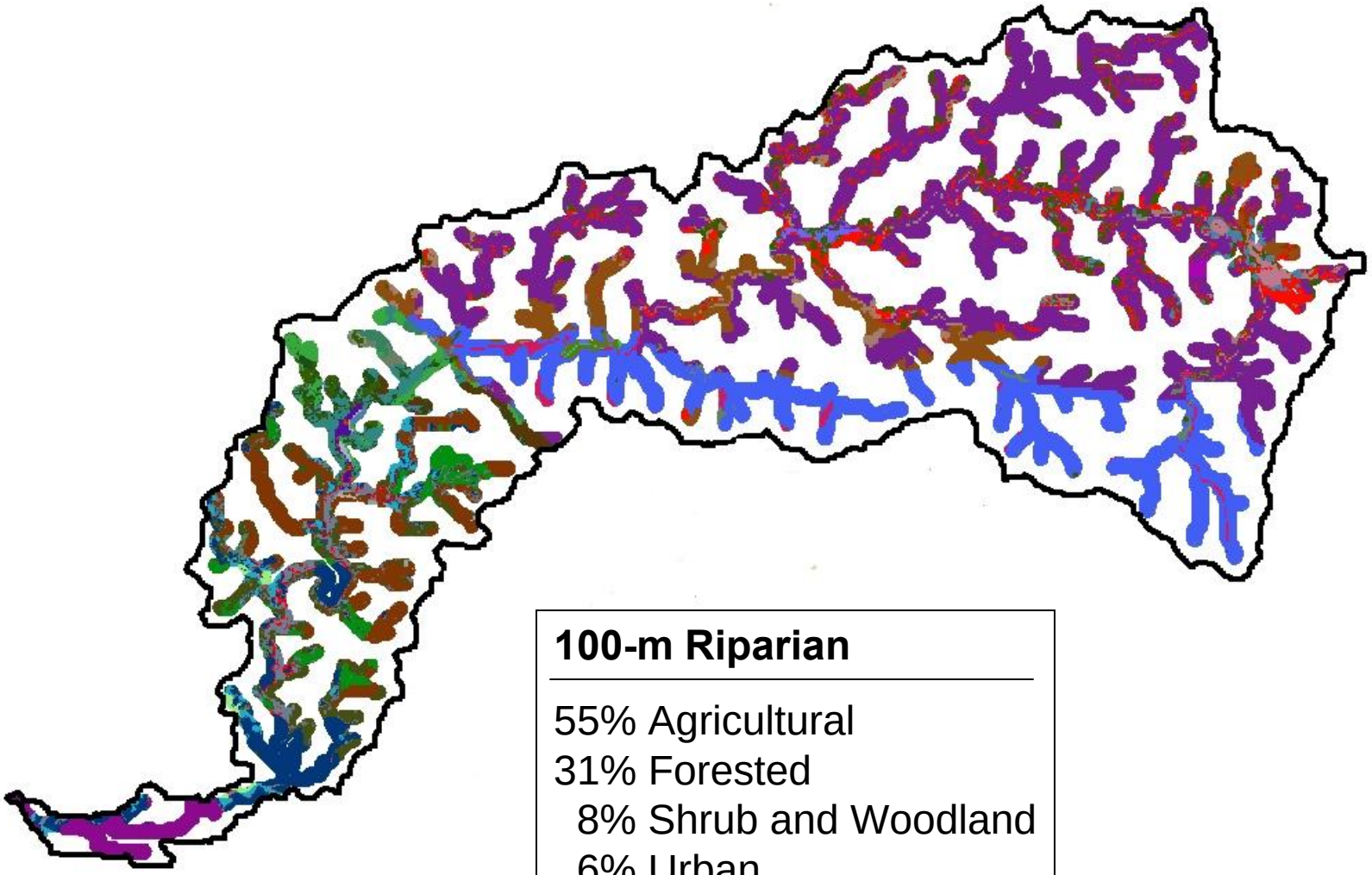
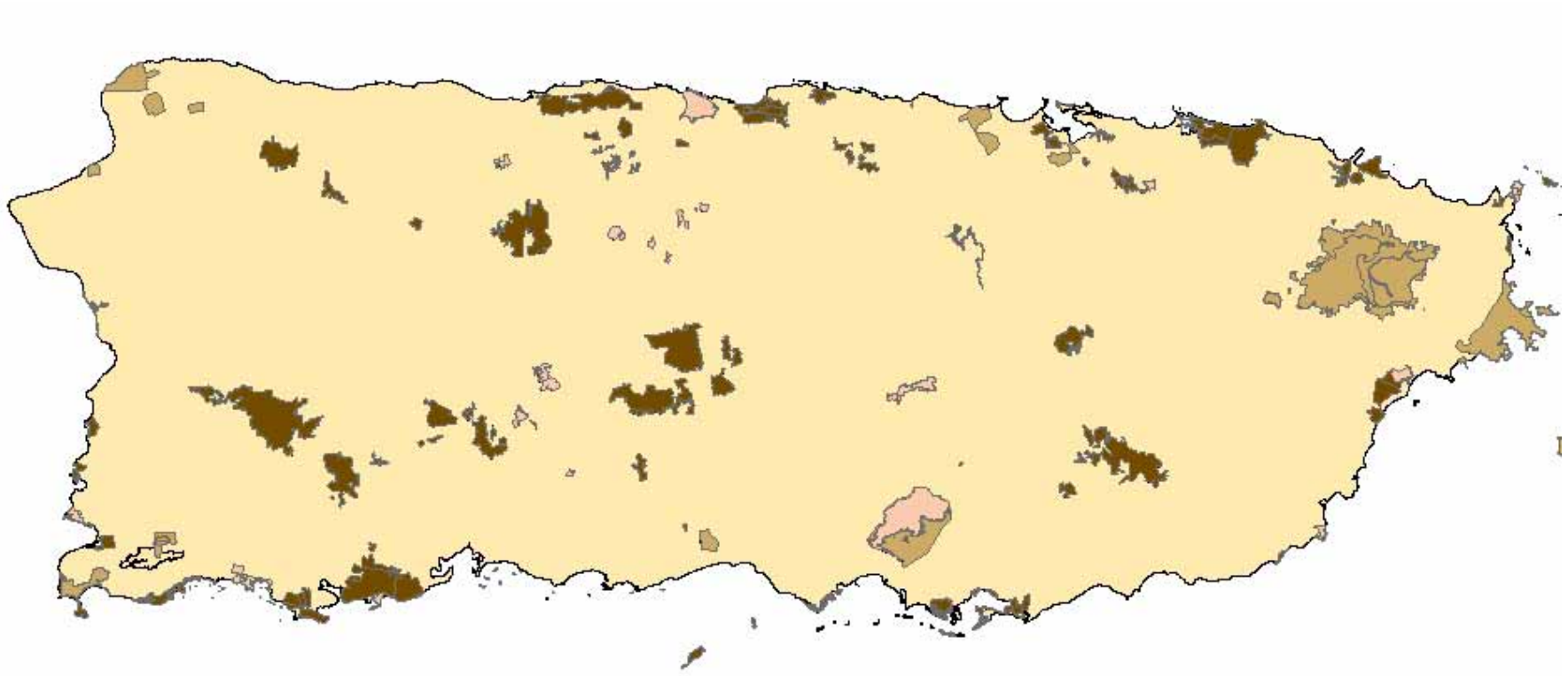


100-m Riparian

55% Agricultural
31% Forested
  8% Shrub and Woodland
  6% Urban

Watershed and Riparian Attributes

Land Ownership



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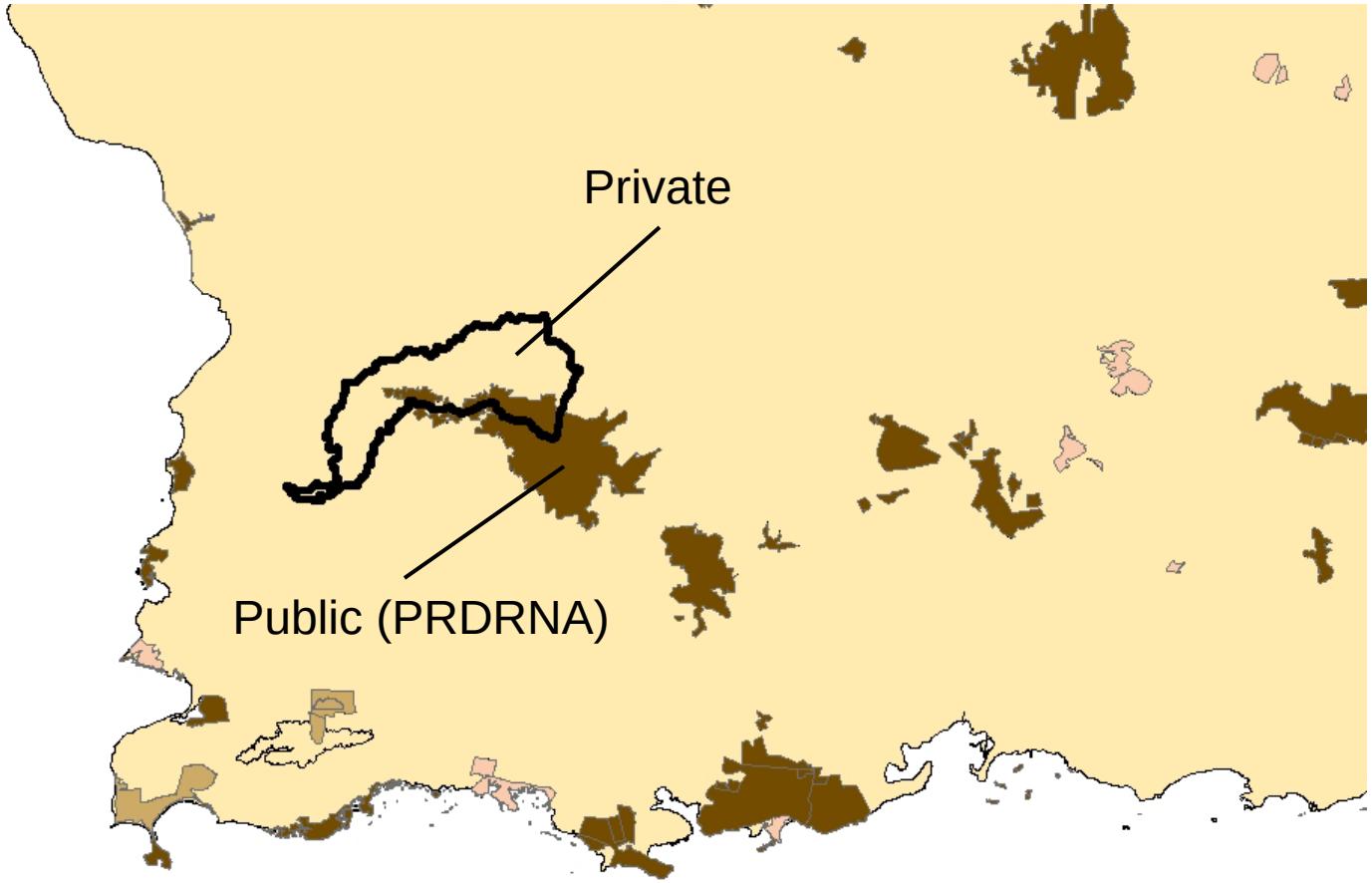

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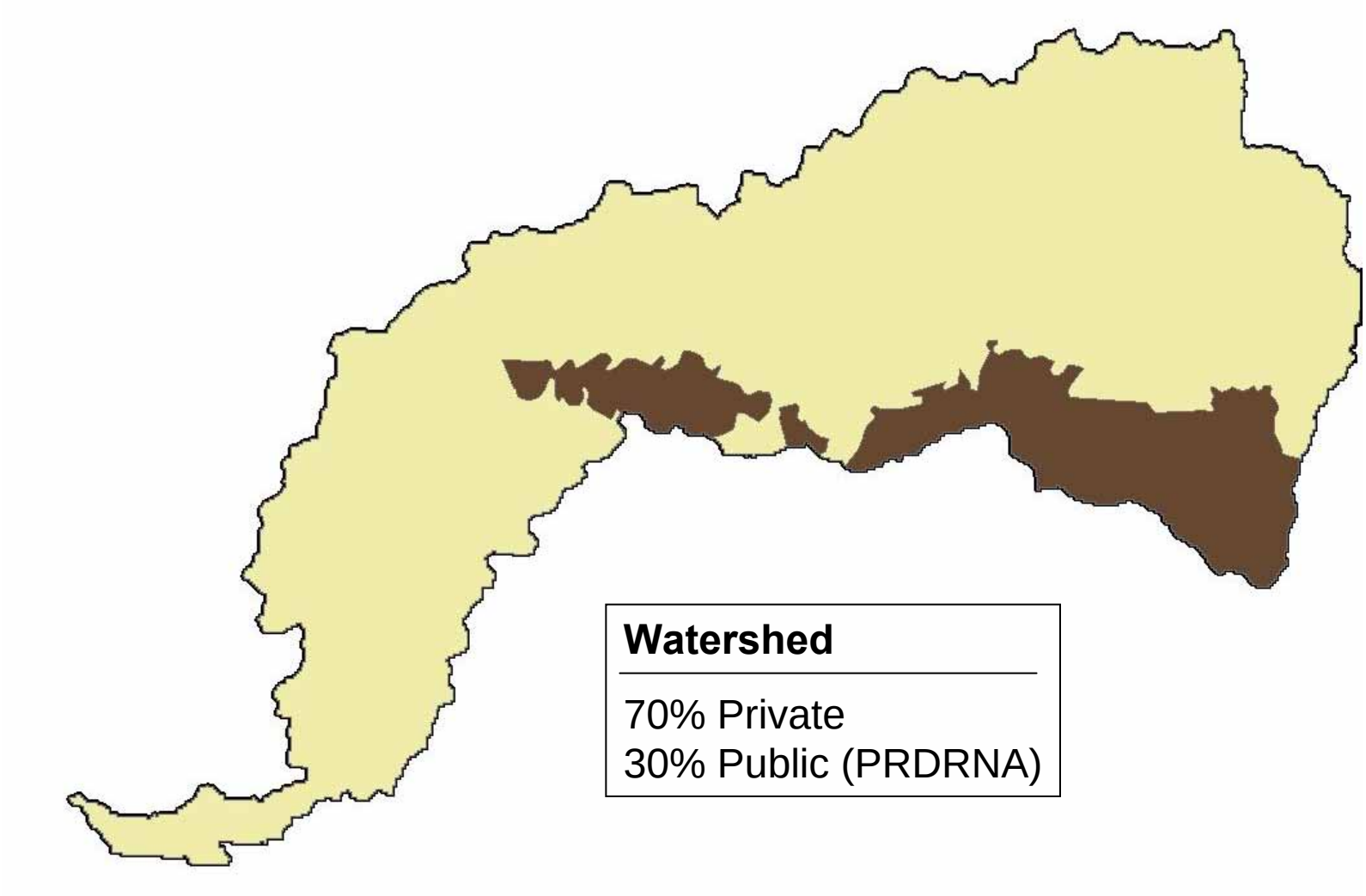

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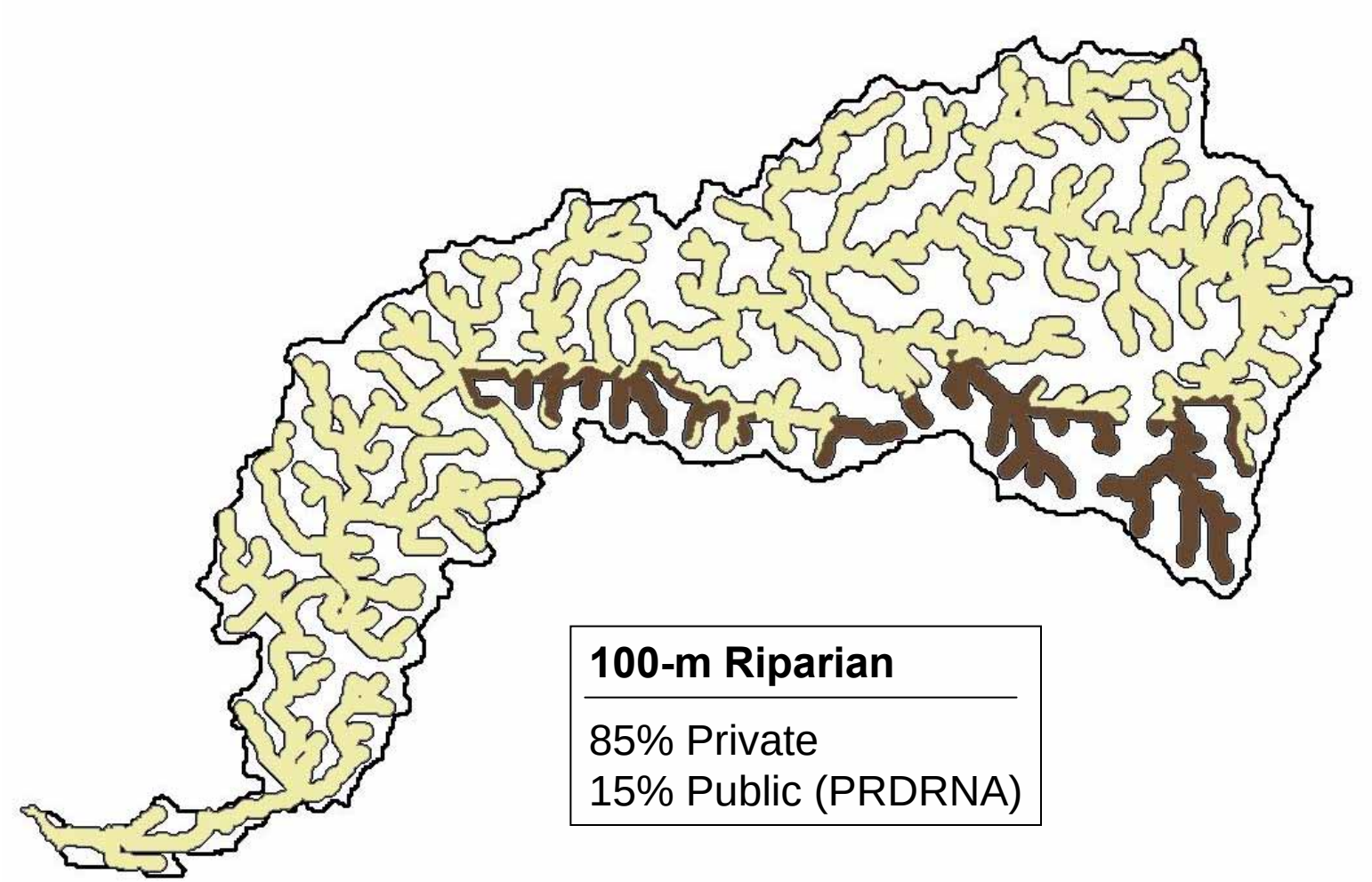

Watershed and Riparian Attributes

Mean Land Cover

	Watershed (%)	100-m Riparian (%)
Forest	42	57
Agriculture	40	25
Shrub & Woodland	14	14
Urban	4	4
Freshwater	(0.1)	0

Watershed and Riparian Attributes

Mean Land Ownership

	Watershed (%)	100-m Riparian (%)
Private	88	89
Public	12	11
Utility & NGO	(0.2)	(0.2)

Hierarchical Modeling

Dependent Variables

All fish

- Species richness
- Species diversity
- Density
- Biomass

Native fish

- Species richness
- Species diversity
- Density
- Biomass

Introduced fish

- Species richness
- Density
- Biomass

Independent Variables

Instream

- Stream width
- % cover

Water quality

- Temperature
- Conductivity
- Turbidity
- Nitrate

Watershed/Riparian

- Watershed area
- River kilometer
- Downstream reservoir
- Road density
- % of watershed owned publicly
- % of 30-m riparian is forest
- % of watershed is forest

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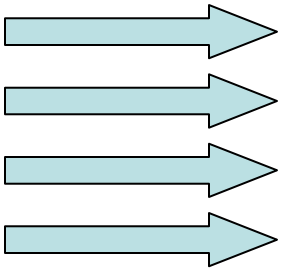

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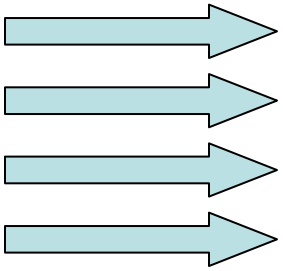

Independent Variables

Instream

- Stream width
- % cover

Water quality

- Temperature
- Conductivity
- Turbidity
- Nitrate

Watershed/Riparian

- **Watershed area**
- **River kilometer**
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- Road density
- % of watershed owned publicly
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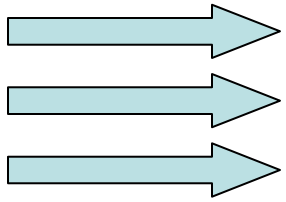


Independent Variables

Instream
- Stream width
- % cover

Water quality
- Temperature
- Conductivity
- Turbidity
- Nitrate

Watershed/Riparian
- **Watershed area**
- **River kilometer**
- **Downstream reservoir**
- **Road density**
- % of watershed owned publicly
- % of 30-m riparian is forest
- % of watershed is forest

Hierarchical Modeling

Conclusions

- **Watershed/Riparian variables most influential**
- **Basin-wide management most critical**

Independent Variables

Instream

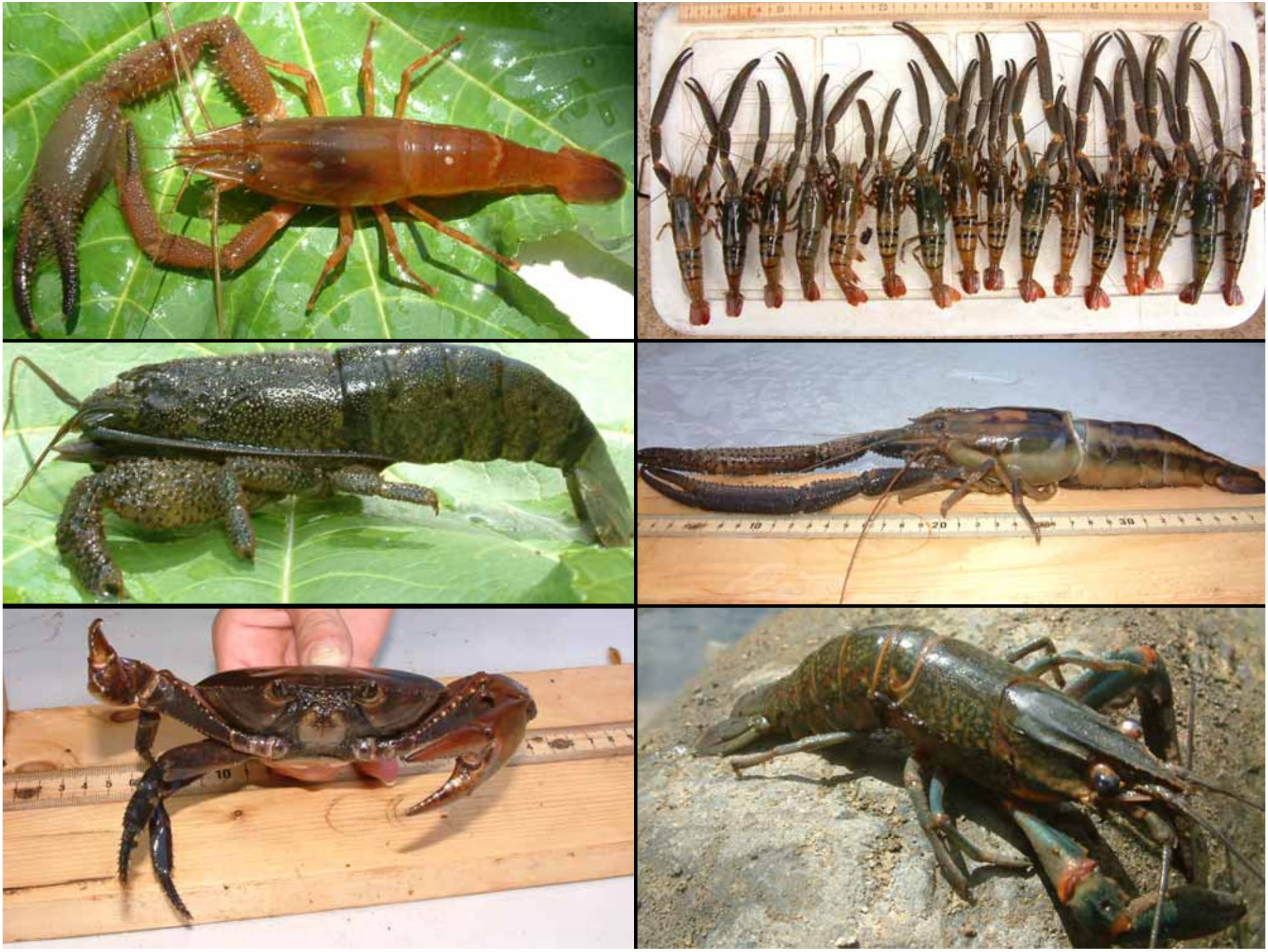
- Stream width
- % cover

Water quality

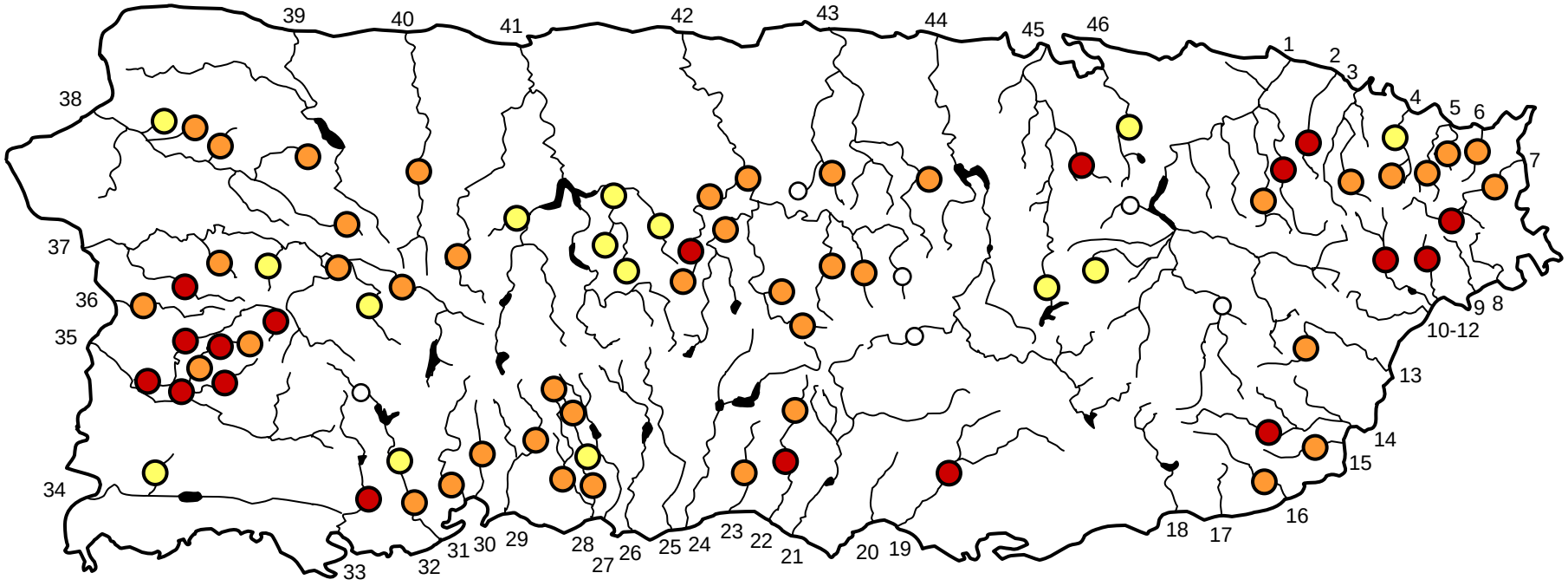
- Temperature
- Conductivity
- Turbidity
- Nitrate

Watershed/Riparian

- **Watershed area**
- **River kilometer**
- **Downstream reservoir**
- **Road density**
- % of watershed owned publicly
- % of 30-m riparian is forest
- % of watershed is forest

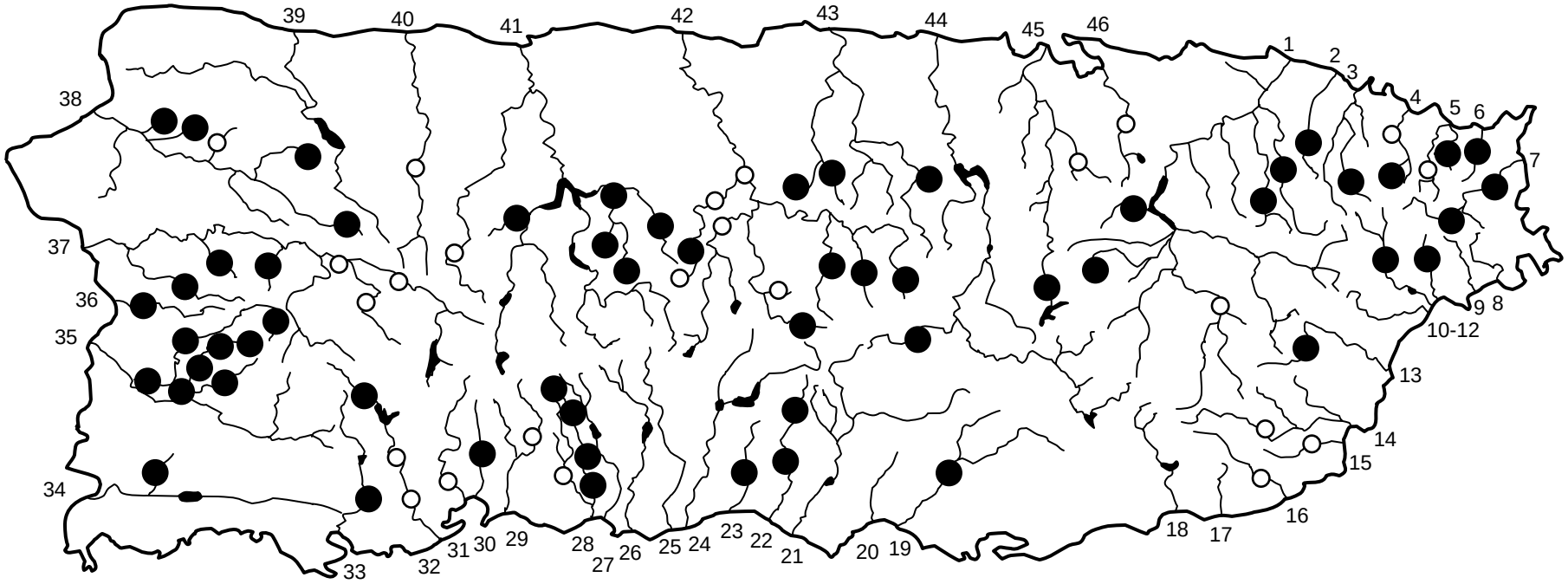


Native Shrimp Species Richness



Puerto Rican Freshwater Crab

Epilobocera sinuatifrons



○ Not detected ● Detected

Future Strategic Planning

What we learned

- How to sample
- Fish and crustacean distribution and abundance
- Habitat, water quality, watershed features
- Relationships among physical and biotic features

What we need to learn

- Inventory of dams and barriers
- Contaminants in fishes, prey, and sediment
- An island-wide stream assessment tool
  - e.g., Index of Biotic Integrity
- Better understand amphidromy dynamics
- Quantify fish habitat suitability for flow modeling