Information for EFSAB:

- Stream-ecology and flow relationships based on our ACF research
- Transferability of species preferences
- Defensibility of ACF work in context of controversy

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USGS Science Thrust Project:
Water Availability for Ecological Needs

Goal: develop a scientific basis for predicting ecological consequences of water-supply development in a river system

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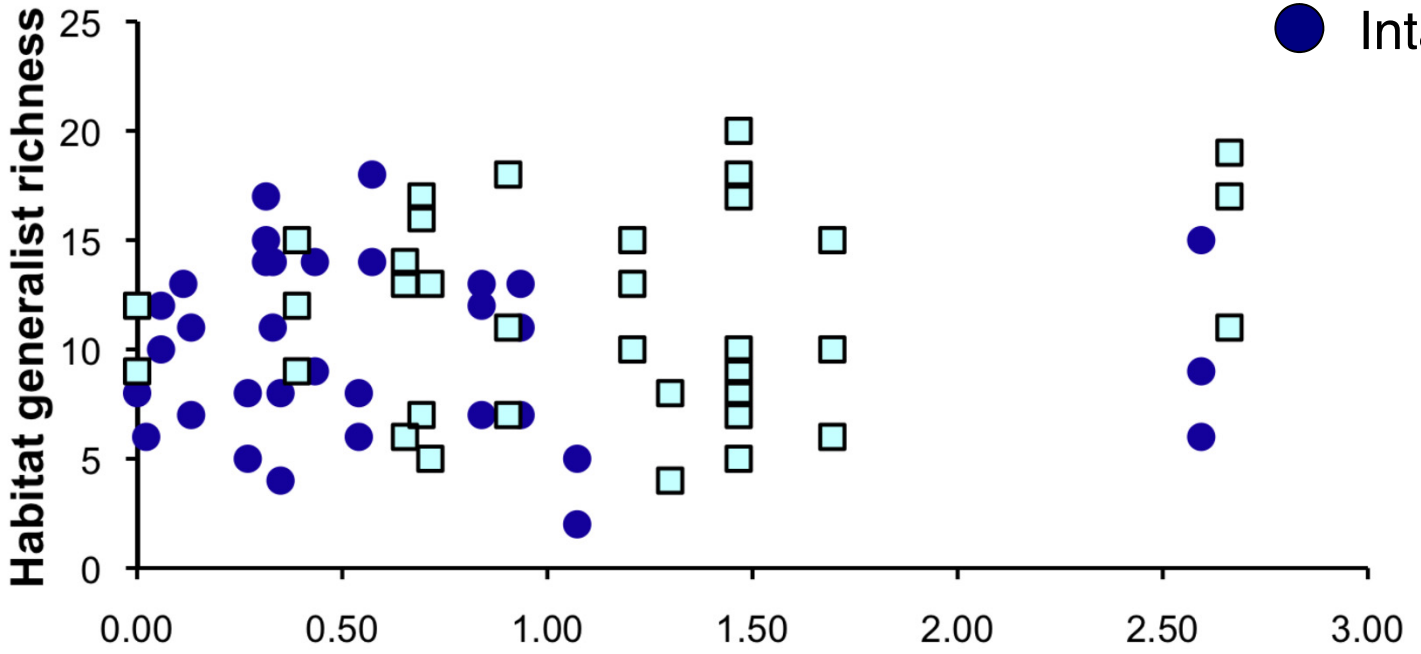
GA Piedmont study: 3 year study, fishes living downstream of 27 municipal withdrawals

Habitat generalist species richness *not* related to

- Withdrawal size
- Withdrawal type



Freeman, M. C. and P. A. Marcinek. 2006. *Fish assemblage responses to water withdrawals and water supply reservoirs in Piedmont streams. Environmental Management 38: 435-450.*

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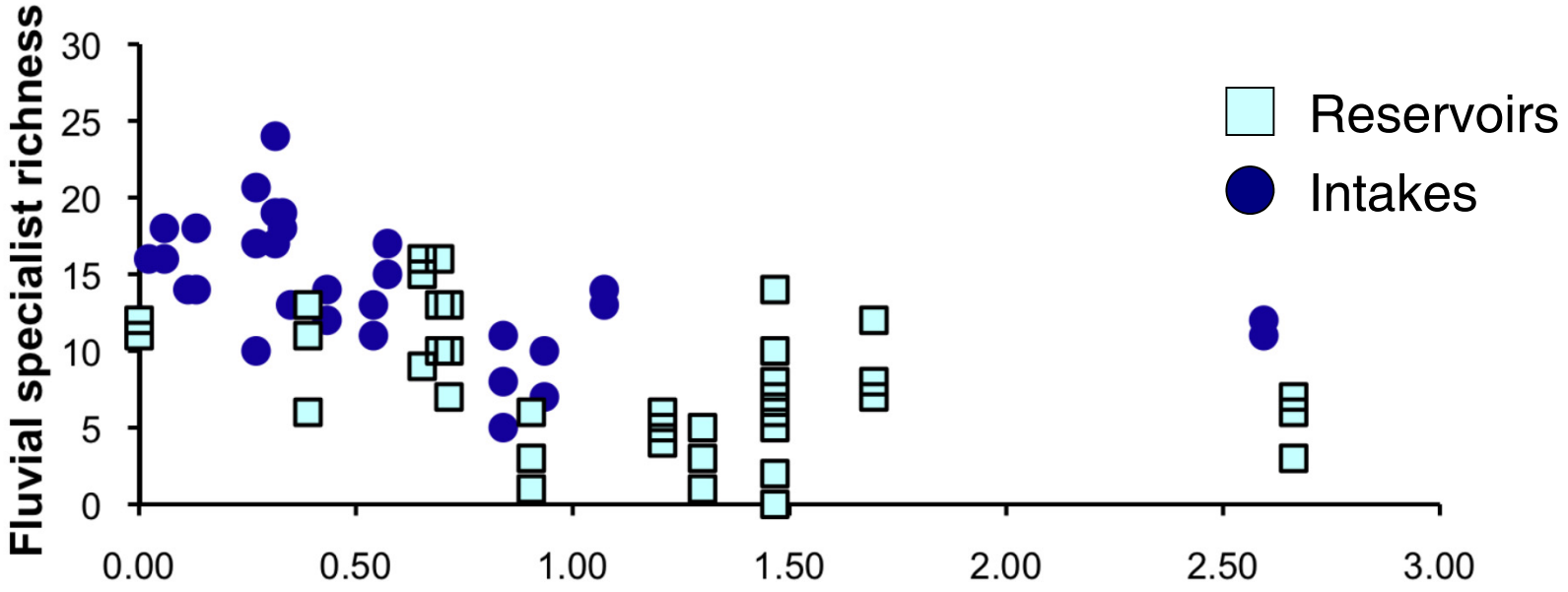
GA Piedmont study: 3 year study, fishes living downstream of 27 municipal withdrawals

Stream-dependent species richness declines:

- With increasing withdrawal size
- Below storage reservoirs



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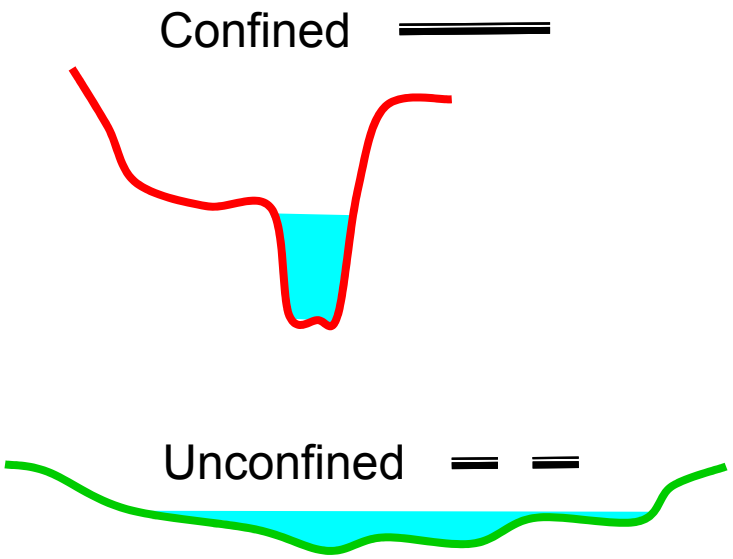
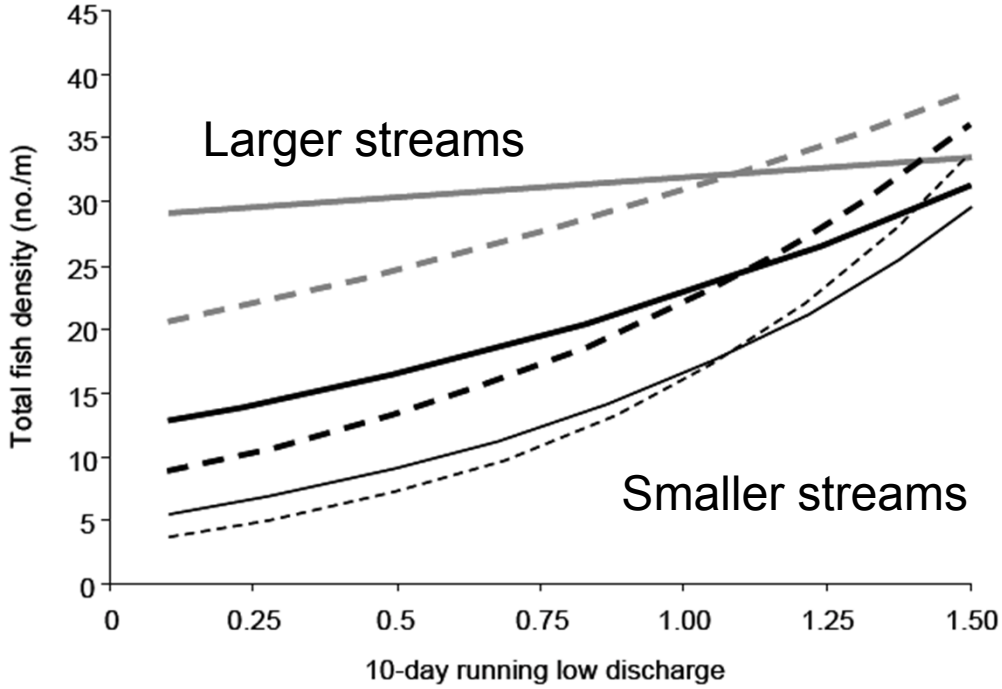
Freeman, M. C. and P. A. Marcinek. 2006. *Fish assemblage responses to water withdrawals and water supply reservoirs in Piedmont streams. Environmental Management 38: 435-450.*

Lower Flint study *: Strong geomorphic effects on response of fishes to variation in base flows

- Geology (Ocala limestone vs. Fall-line Hills)
- Channel morphology (confined vs. unconfined)





*

Peterson et al. 2009
McCargo and Peterson 2010

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Ecological responses to changes in flow regimes?

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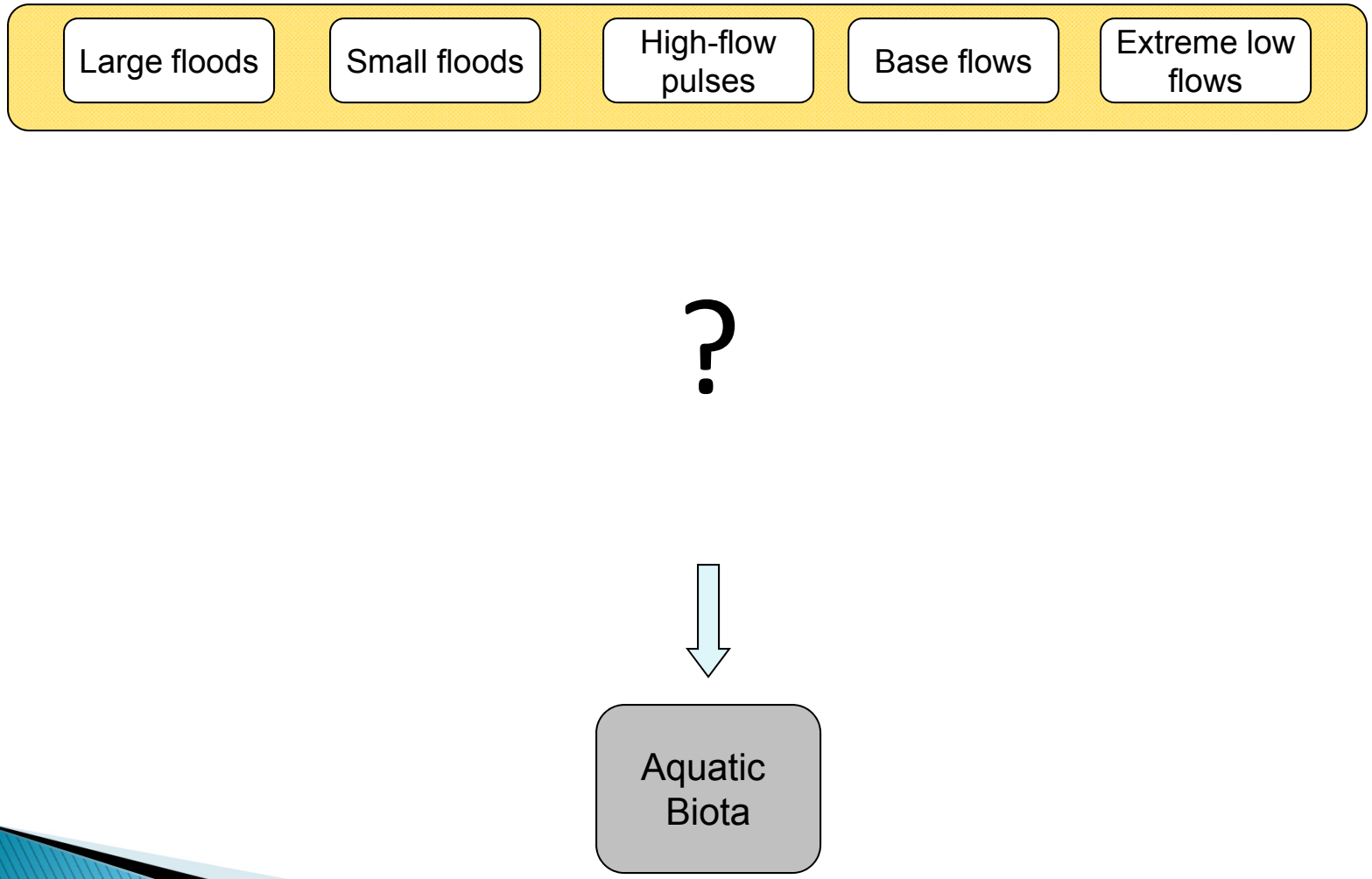
Flow regime components



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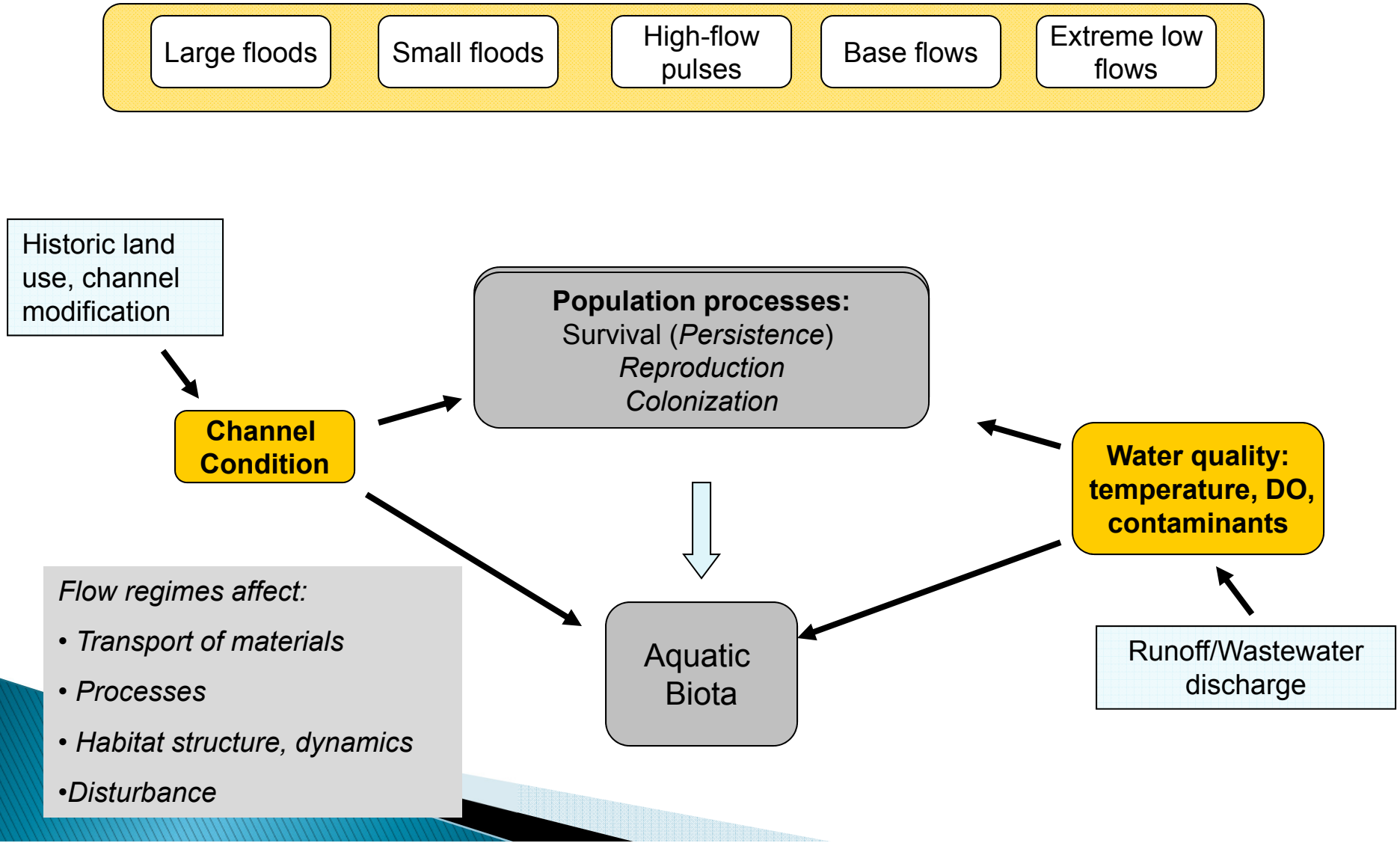
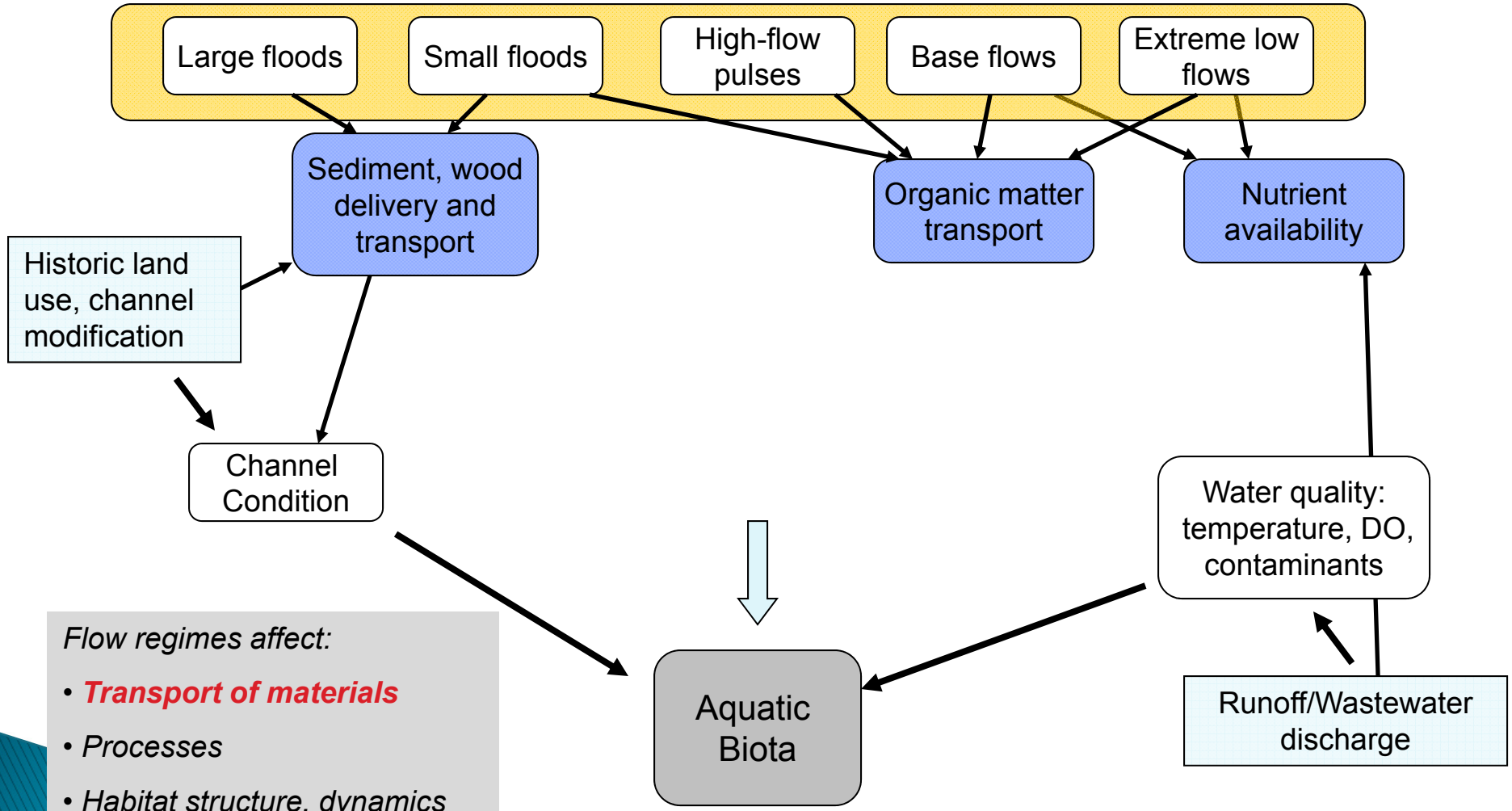
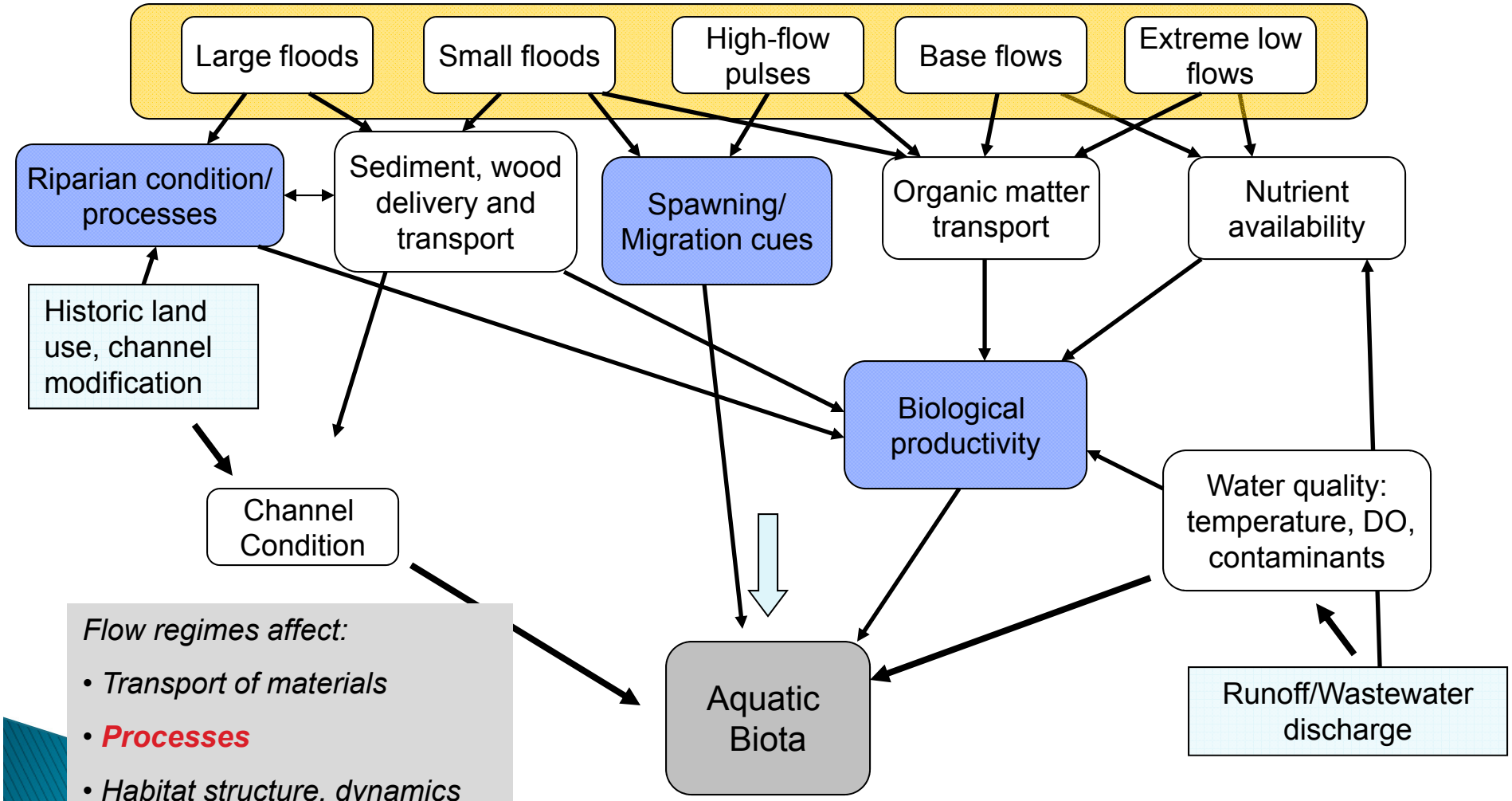

Large floods
Small floods
High-flow pulses
Base flows
Extreme low flows
Historic land use, channel modification
Channel Condition
Population processes:
Survival (Persistence)
Reproduction
Colonization
Water quality: temperature, DO, contaminants
Aquatic Biota
Runoff/Wastewater discharge
Flow regimes affect:
• Transport of materials
• Processes
• Habitat structure, dynamics
•Disturbance


Large floods
Small floods
High-flow pulses
Base flows
Extreme low flows
Sediment, wood delivery and transport
Organic matter transport
Nutrient availability
Historic land use, channel modification
Channel Condition
Water quality: temperature, DO, contaminants
Aquatic Biota
Runoff/Wastewater discharge
Flow regimes affect:
• Transport of materials
• Processes
• Habitat structure, dynamics
• Disturbance


Large floods
Small floods
High-flow pulses
Base flows
Extreme low flows
Riparian condition/ processes
Sediment, wood delivery and transport
Spawning/ Migration cues
Organic matter transport
Nutrient availability
Historic land use, channel modification
Biological productivity
Channel Condition
Water quality: temperature, DO, contaminants
Aquatic Biota
Runoff/Wastewater discharge
Flow regimes affect:
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• Processes
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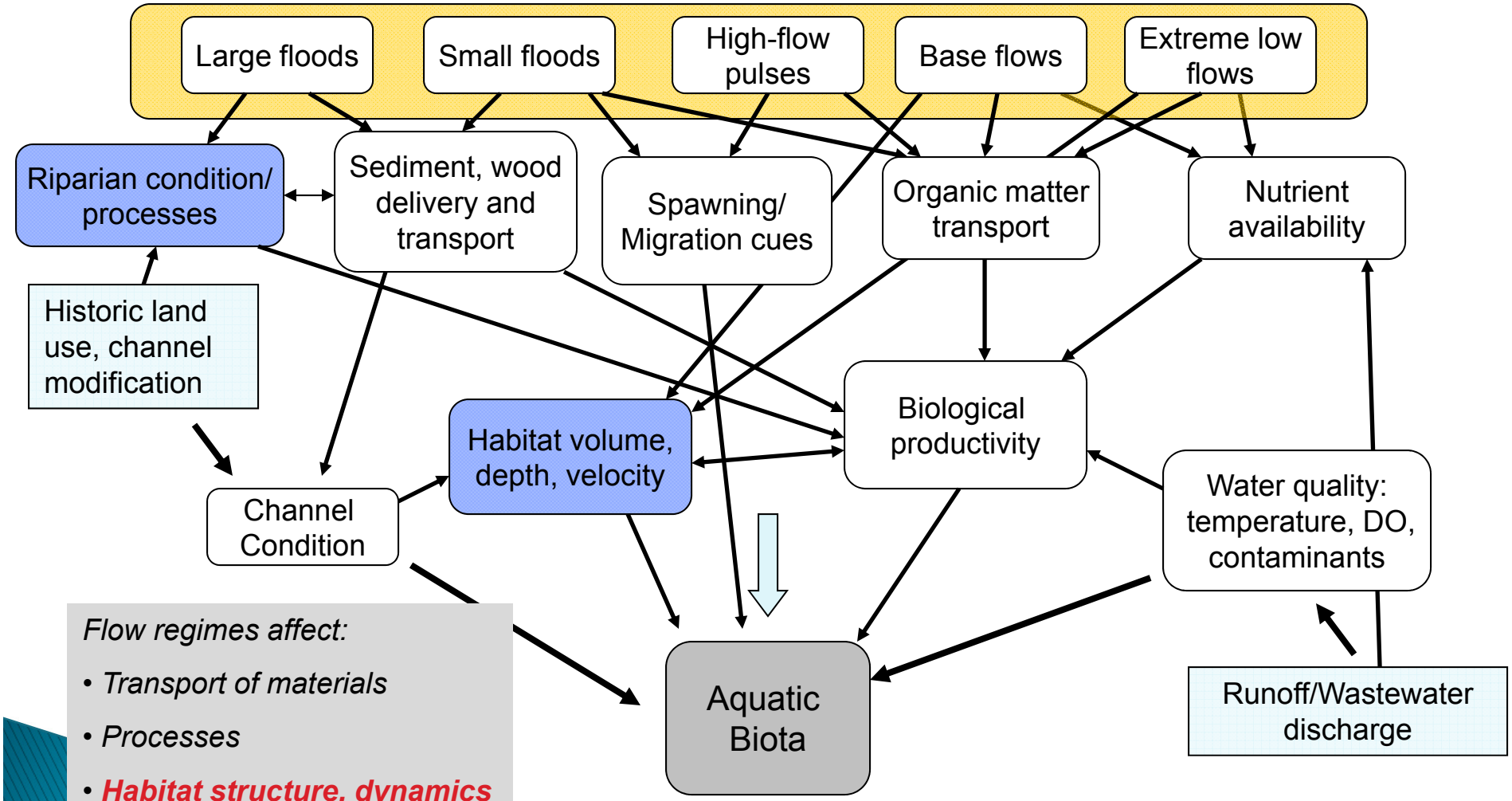
Large floods
Small floods
High-flow pulses
Base flows
Extreme low flows
Riparian condition/ processes
Sediment, wood delivery and transport
Spawning/ Migration cues
Organic matter transport
Nutrient availability
Historic land use, channel modification
Habitat volume, depth, velocity
Biological productivity
Channel Condition
Water quality: temperature, DO, contaminants
Aquatic Biota
Runoff/Wastewater discharge
Flow regimes affect:
• Transport of materials
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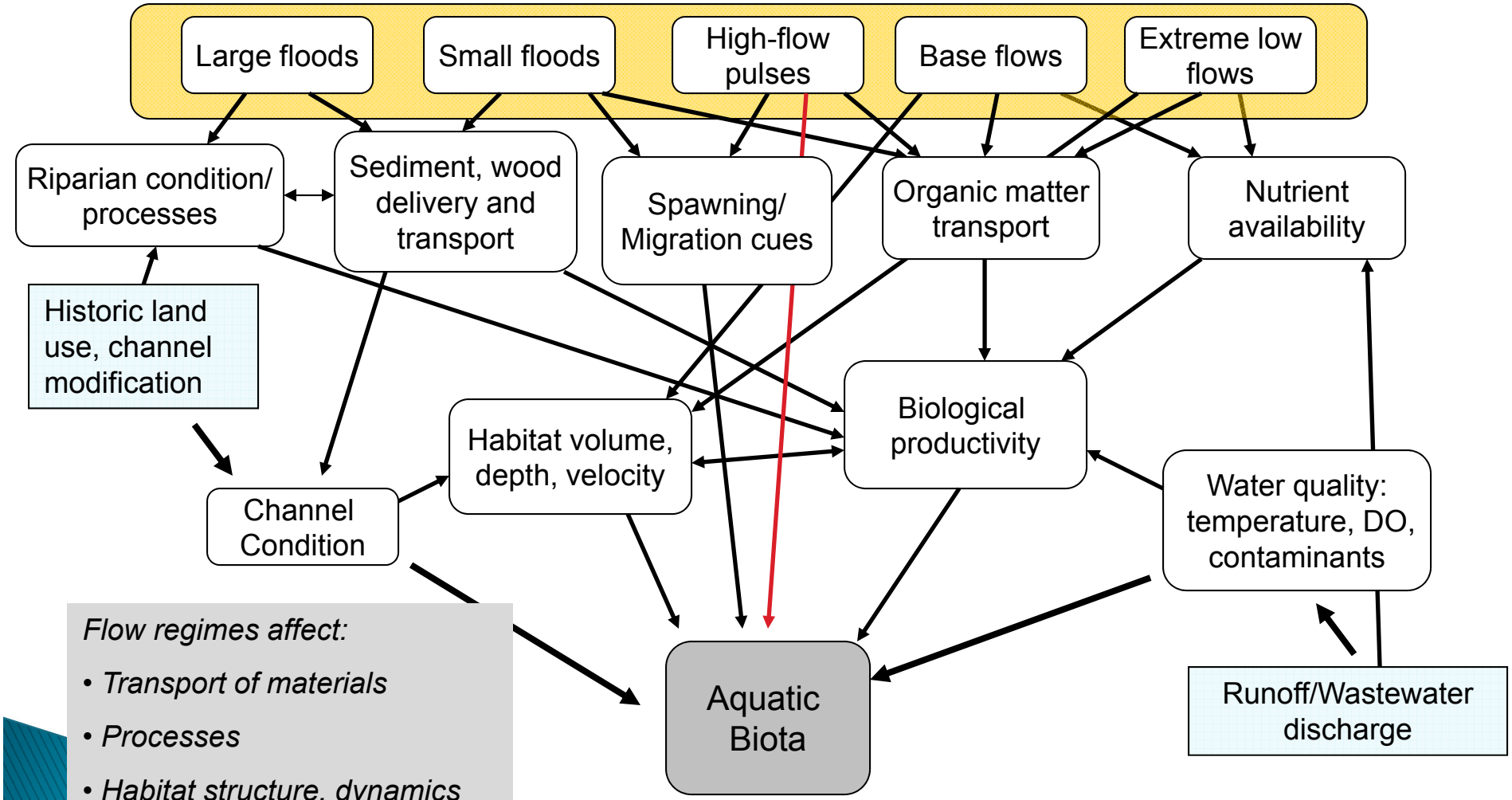
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Water quality: temperature, DO, contaminants
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Flow regimes affect:
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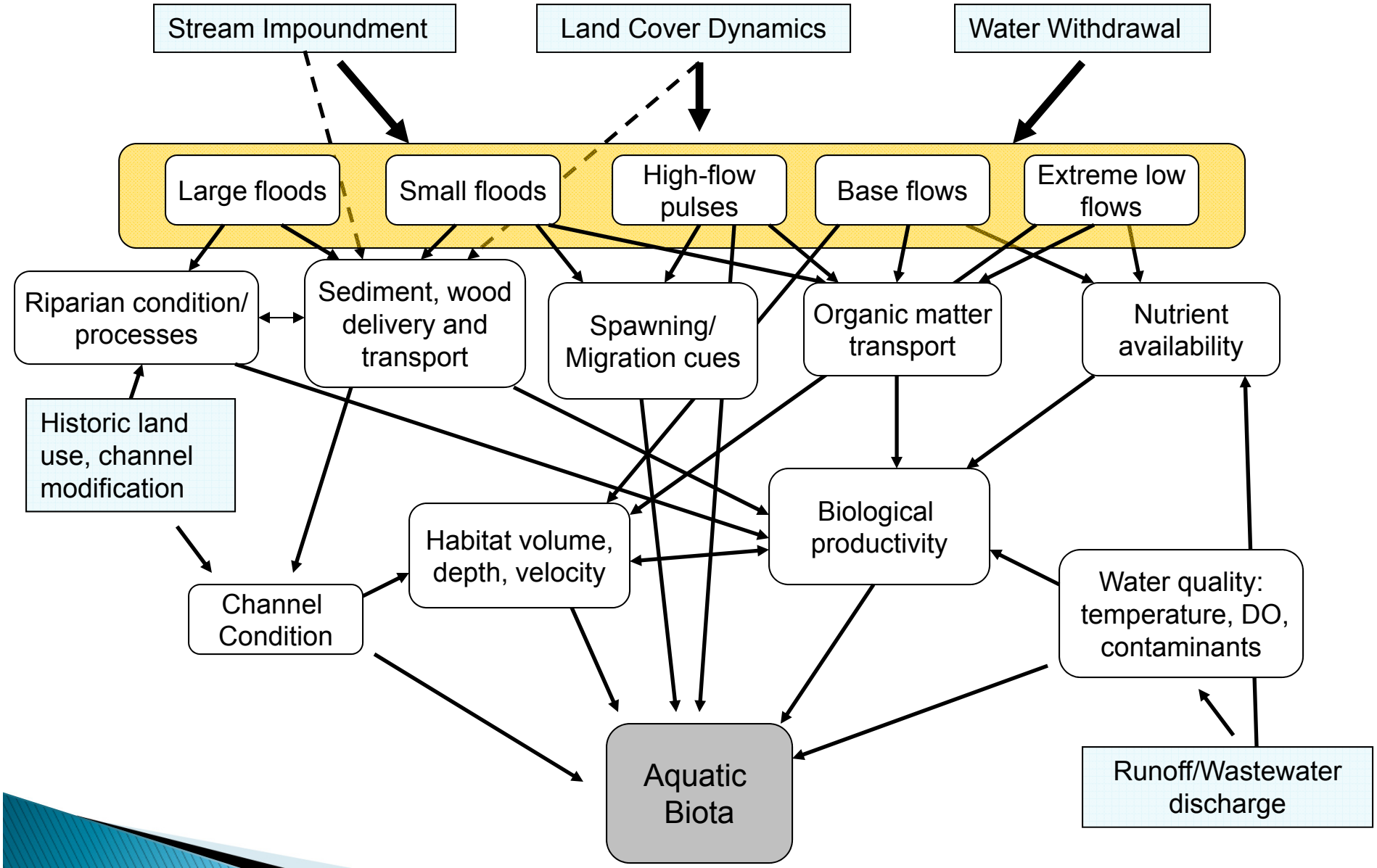

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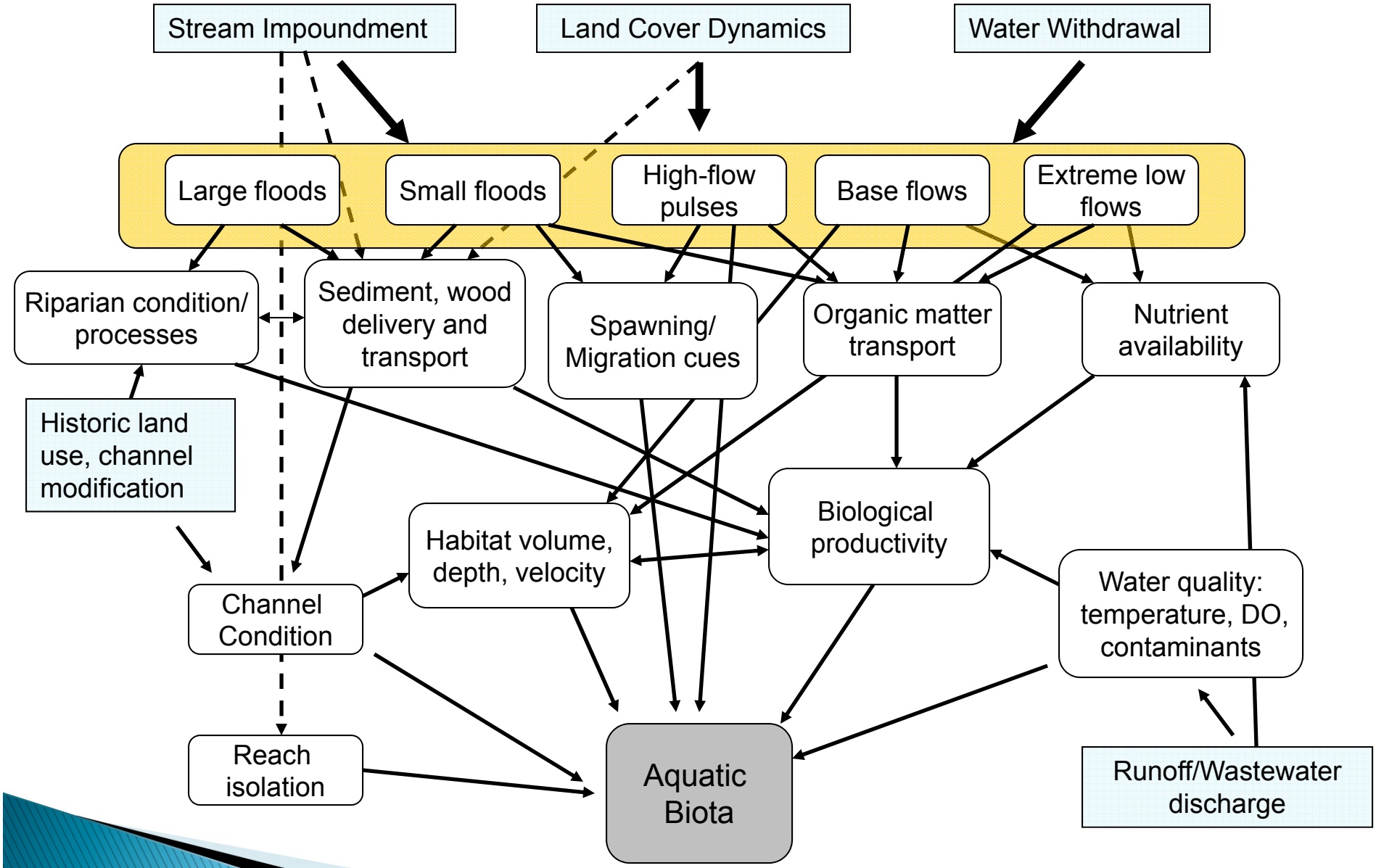

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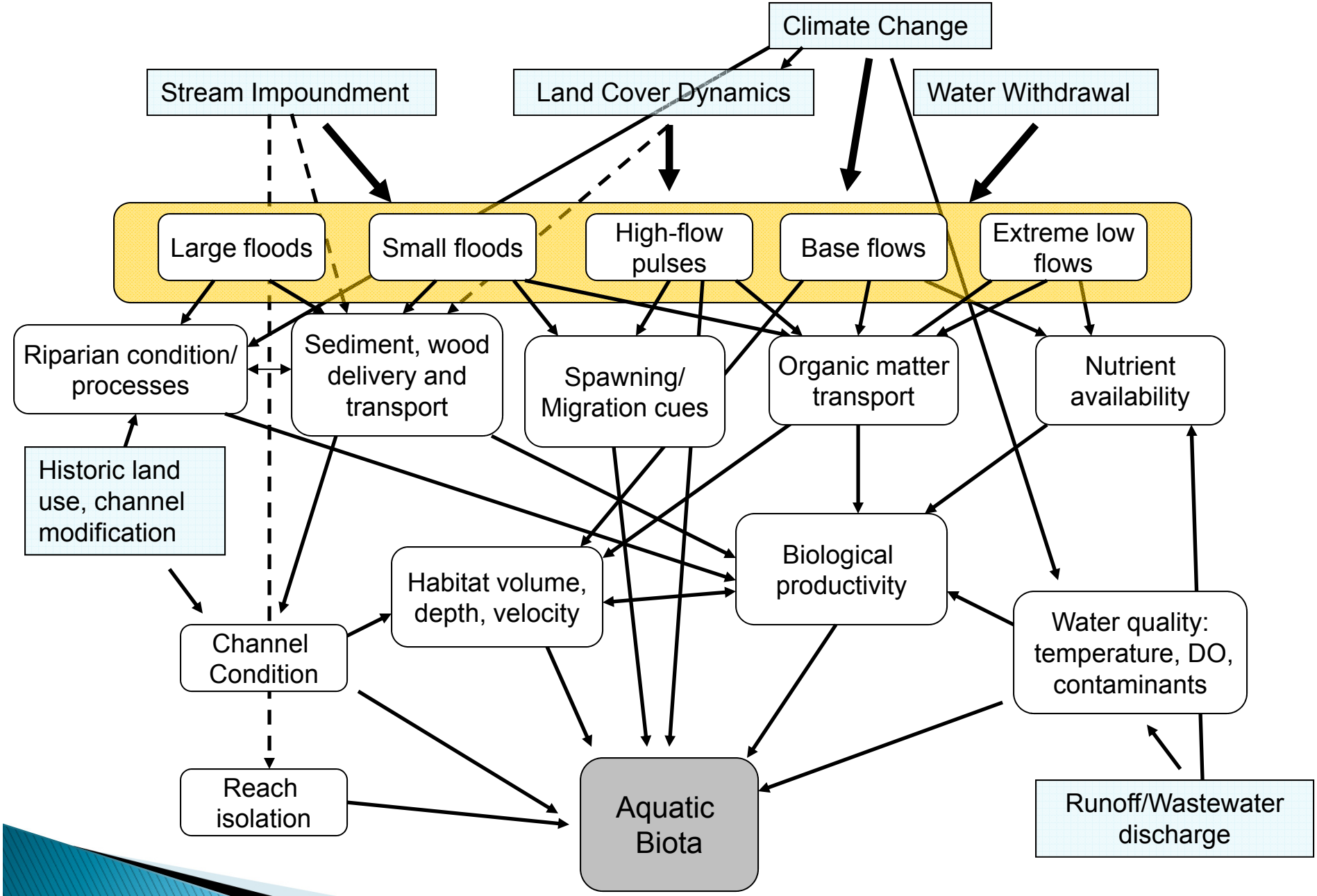

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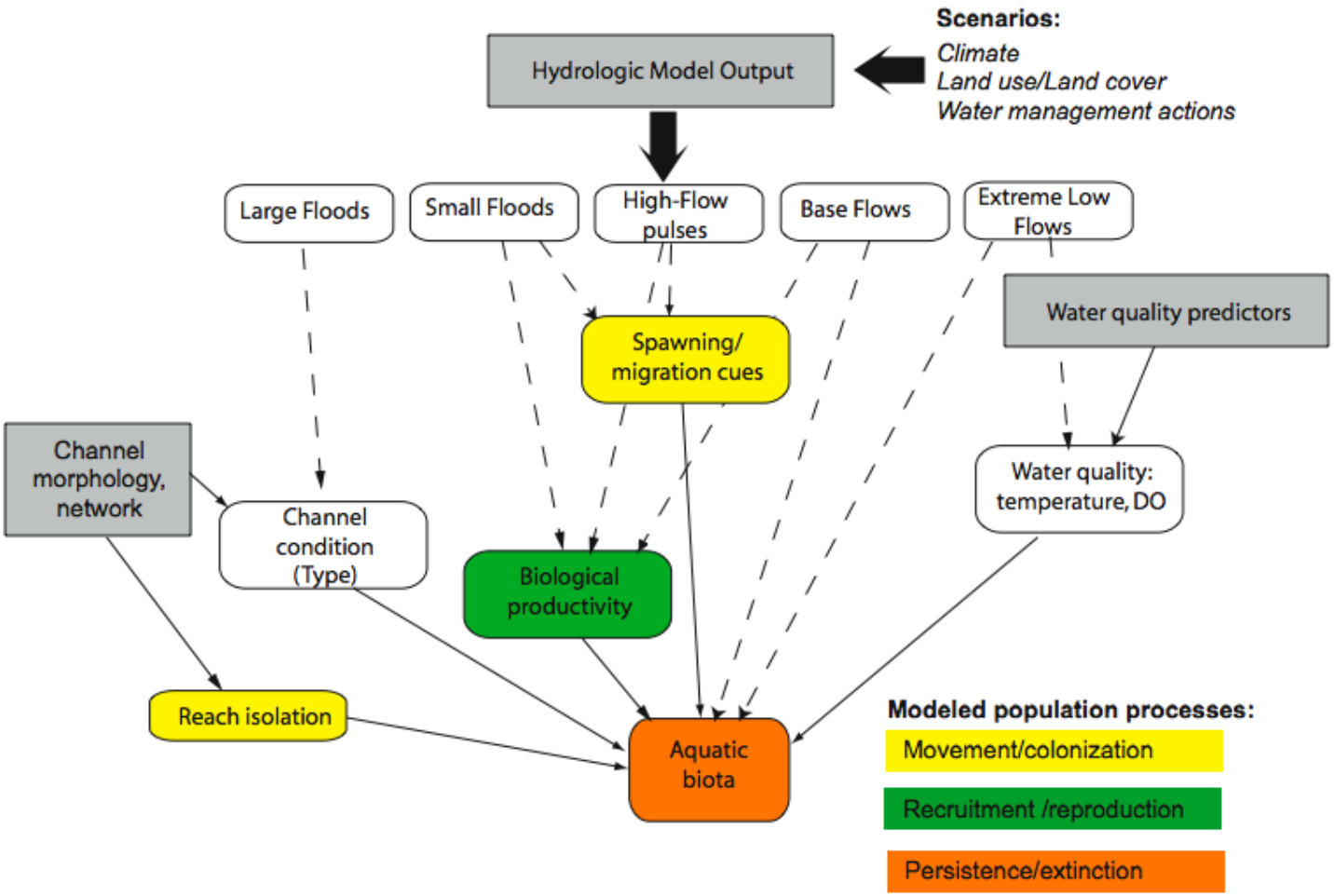
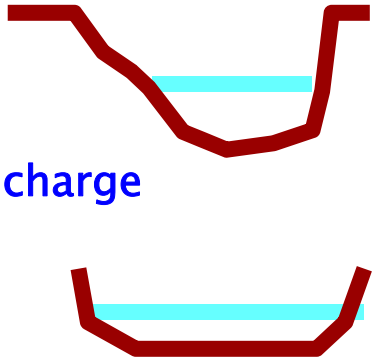
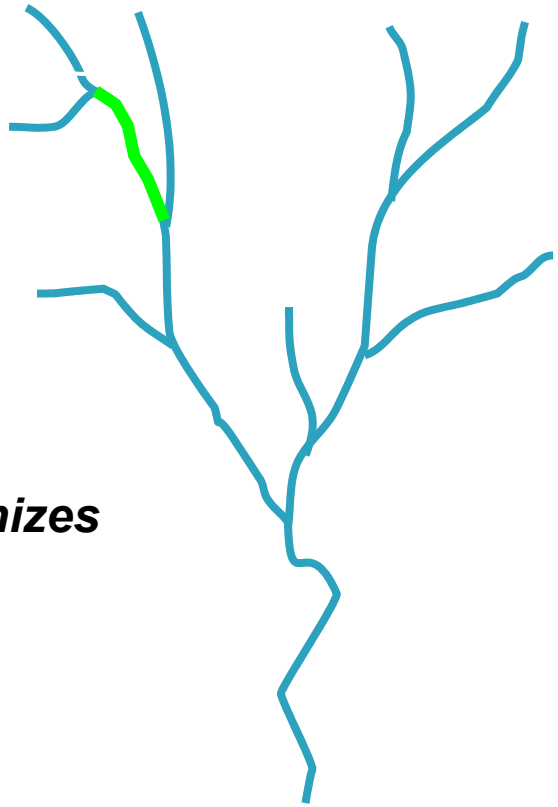

Scenarios:
Climate
Land use/Land cover
Water management actions
Hydrologic Model Output
Large Floods
Small Floods
High-Flow pulses
Base Flows
Extreme Low Flows
Water quality predictors
Spawning/ migration cues
Channel morphology, network
Channel condition (Type)
Biological productivity
Water quality: temperature, DO
Reach isolation
Aquatic biota
Modeled population processes:
Movement/colonization
Recruitment /reproduction
Persistence/extinction

USGS *Water Availability for Ecosystems*
Metapopulation response to flow variation: occupancy of stream segments

Geomorphic channel type (habitat template)





Probability a species ***persists, reproduces, or colonizes*** In a given year depends on:

- Species traits
- Channel type and stream size
- Location in the drainage network (connectivity)
- The seasonal flow regime in that year

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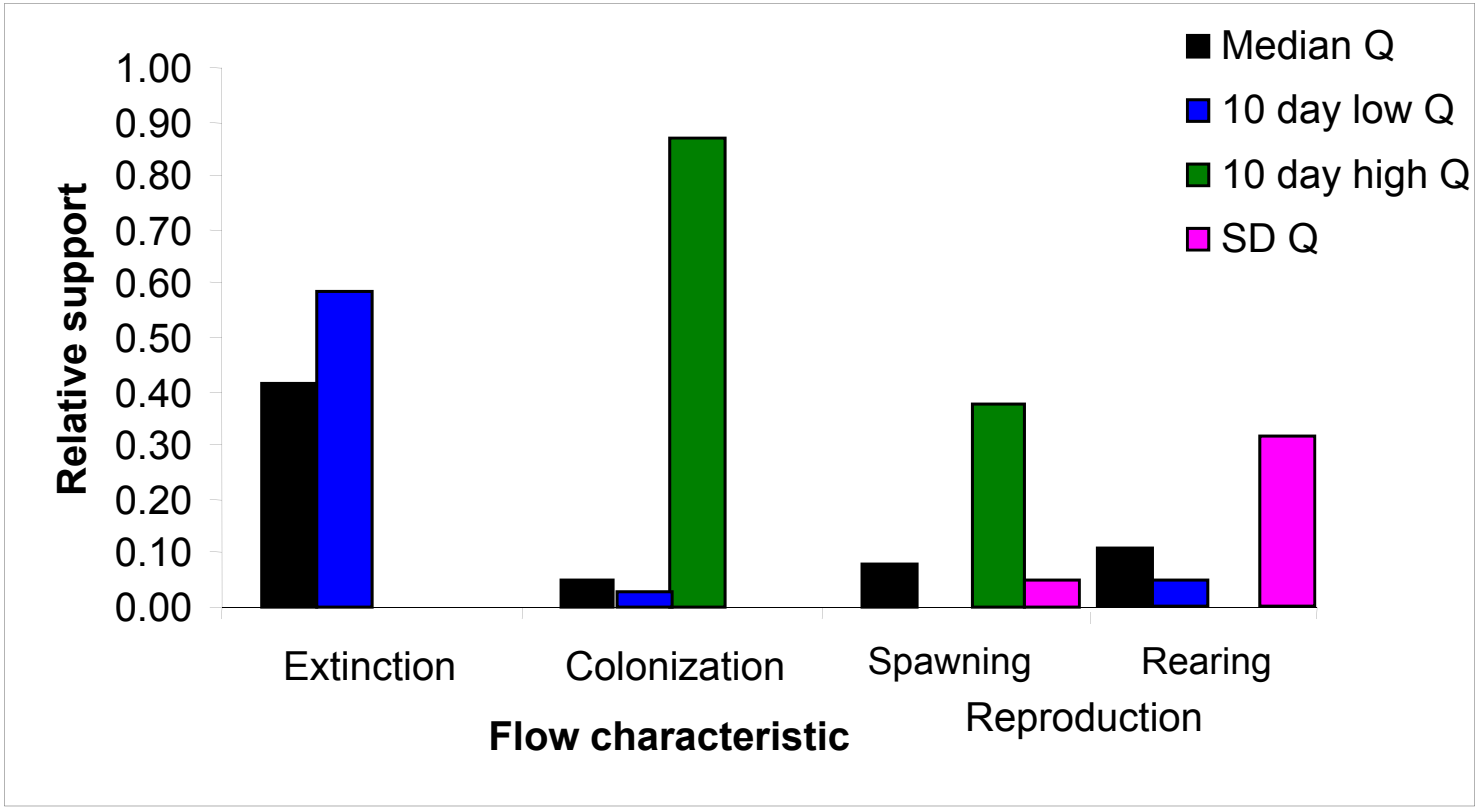
Modeling results



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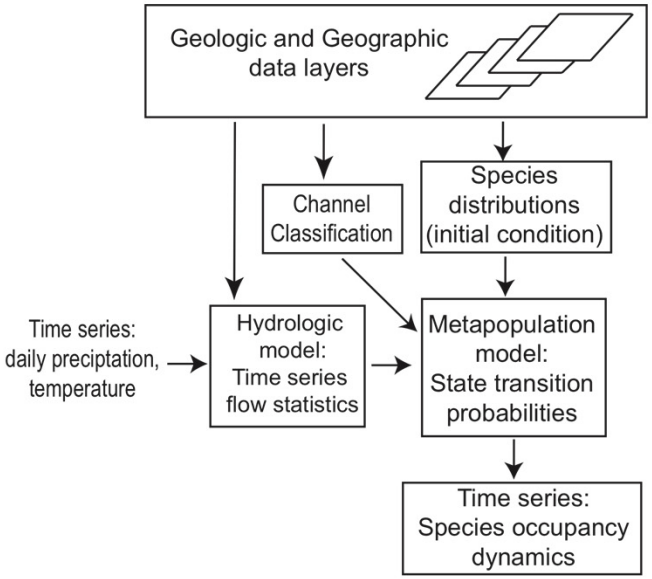
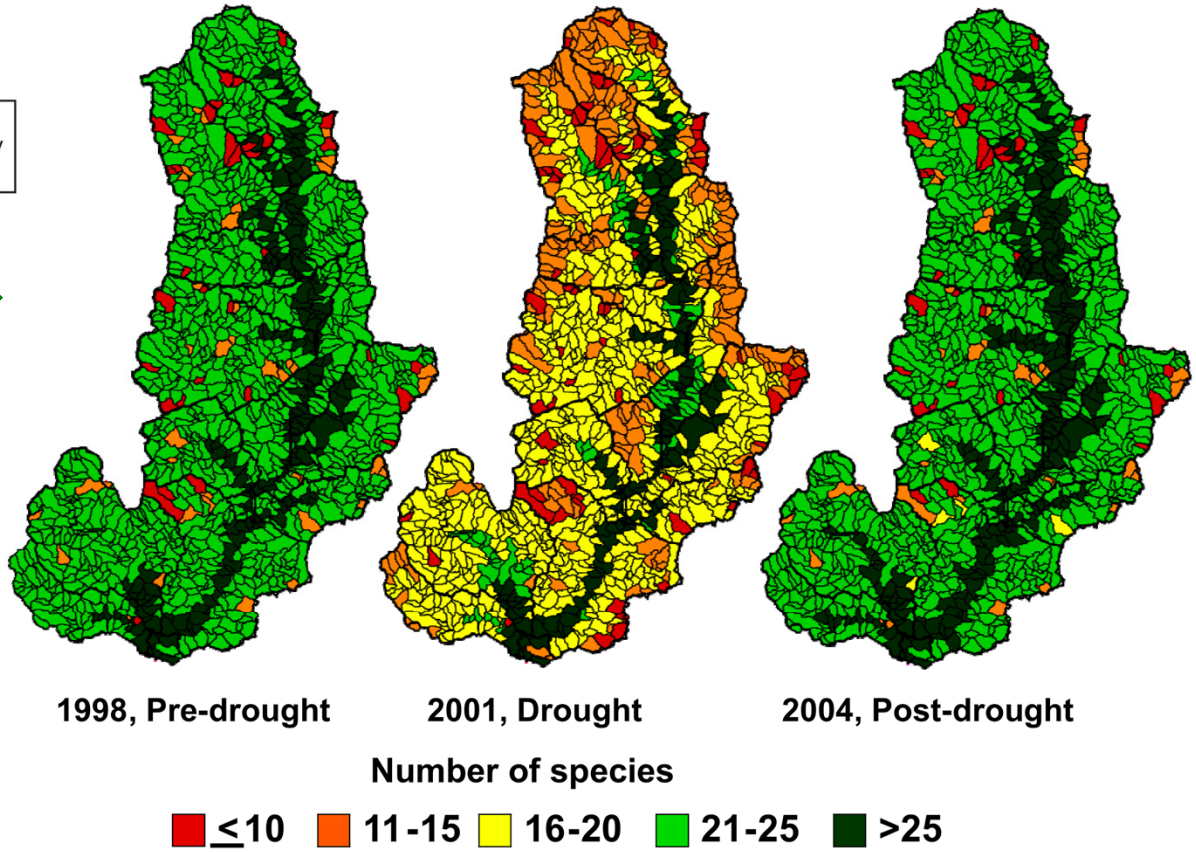
USGS OR-CRU



Seasonal time-step, metapopulation simulation of changes in fish species richness in relation to flow

Flow statistics
- Median seasonal Q
- CV seasonal Q
- Seasonal 10-d min Q
- Seasonal 10-max Q
- Min 10-d SD of flow



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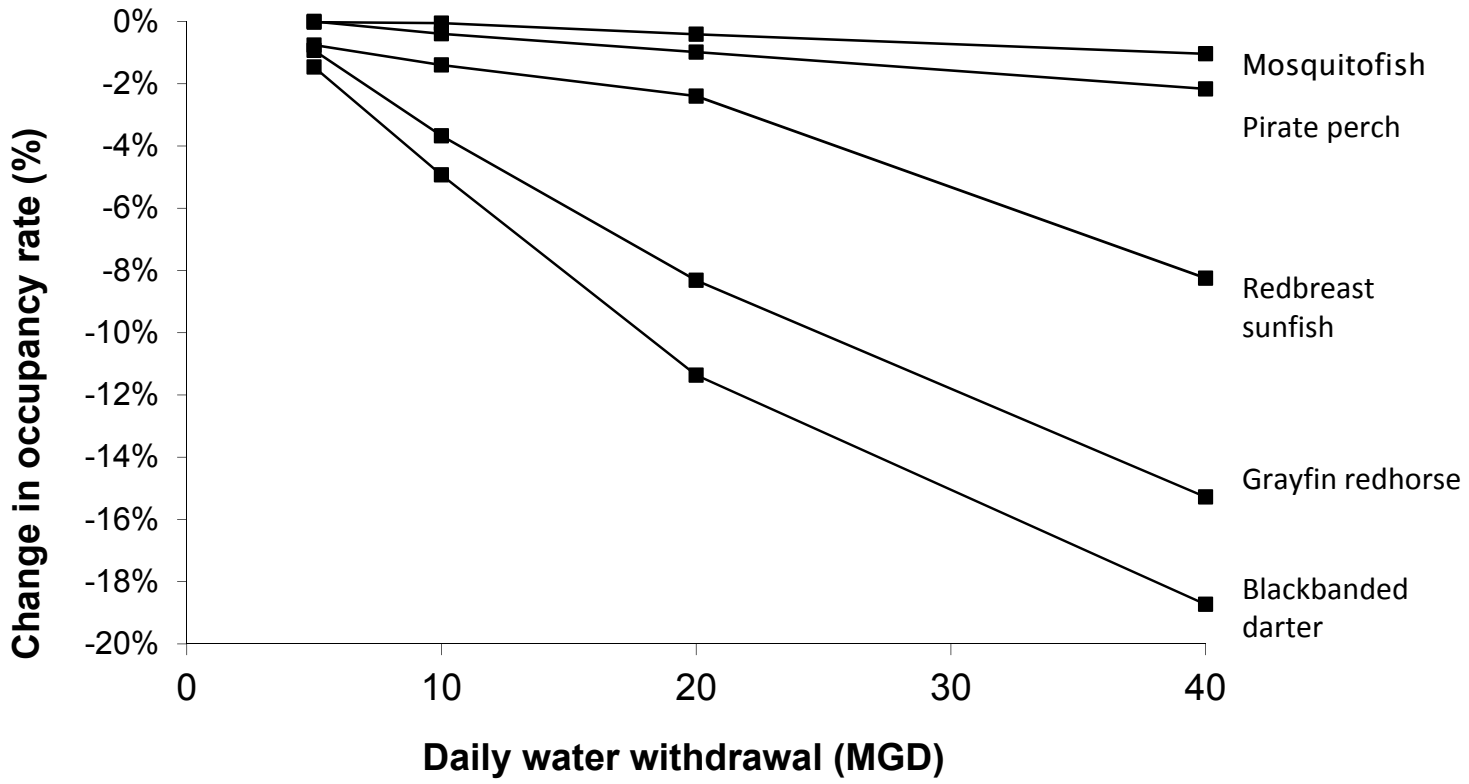
Simulated stream fish responses to withdrawals in Potato Creek basin

Change in species-specific occupancy with increasing withdrawal levels



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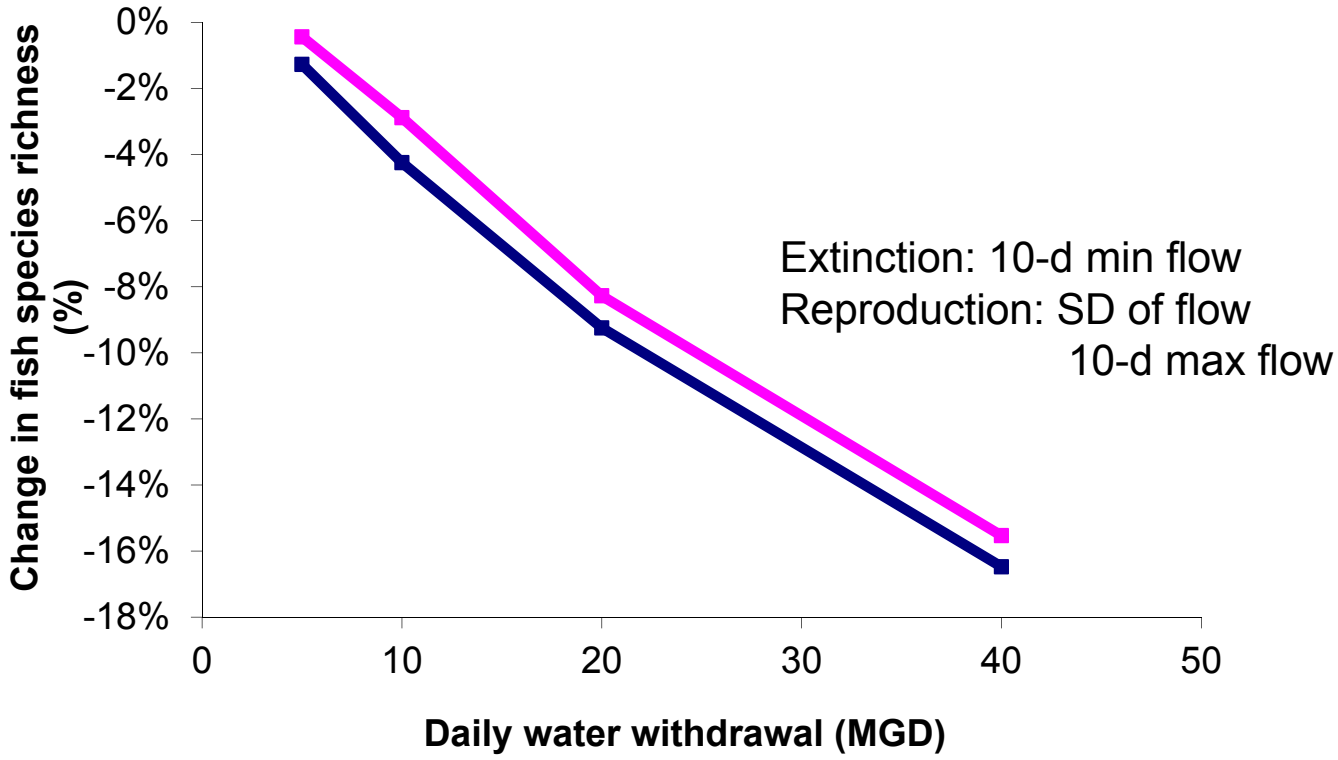
- Can evaluate model outcomes sensitivity to assumptions regarding mechanisms

Stream fish metapopulation model

Change in species richness with increasing withdrawal levels



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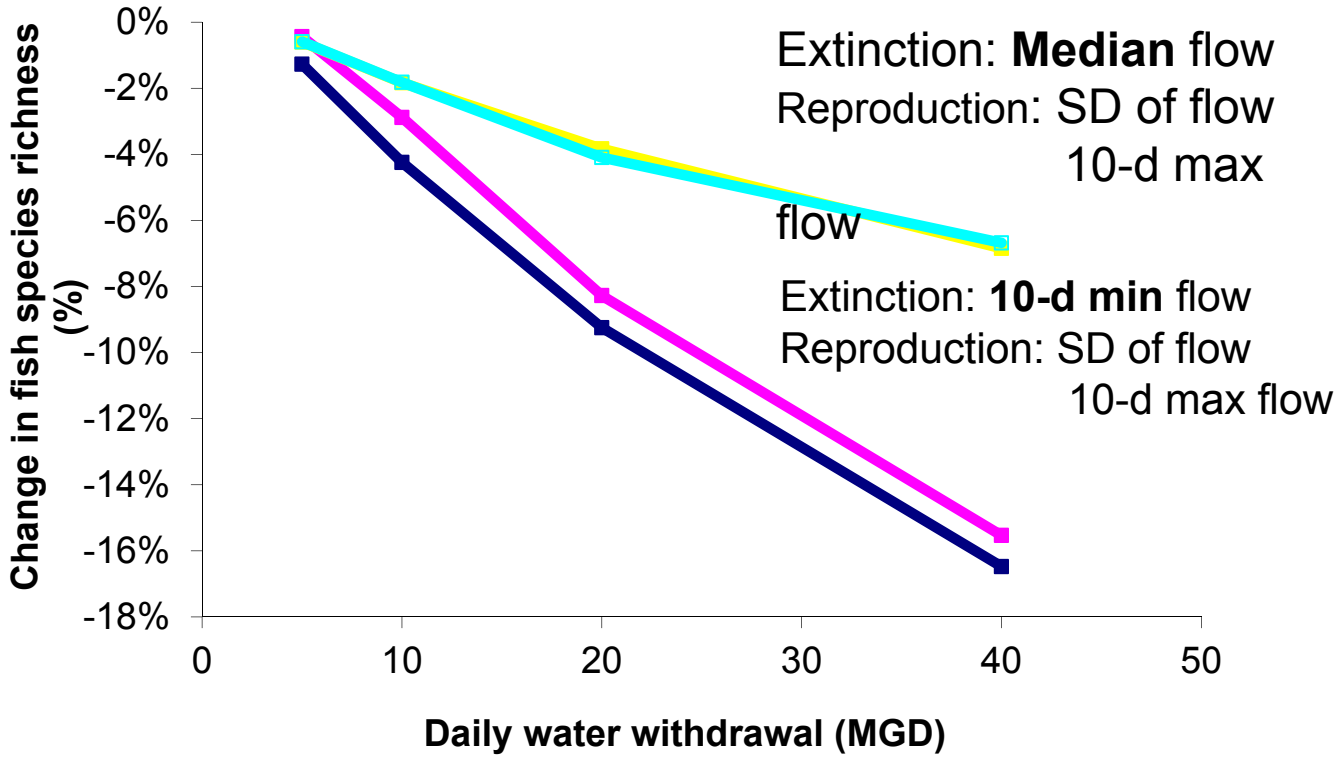

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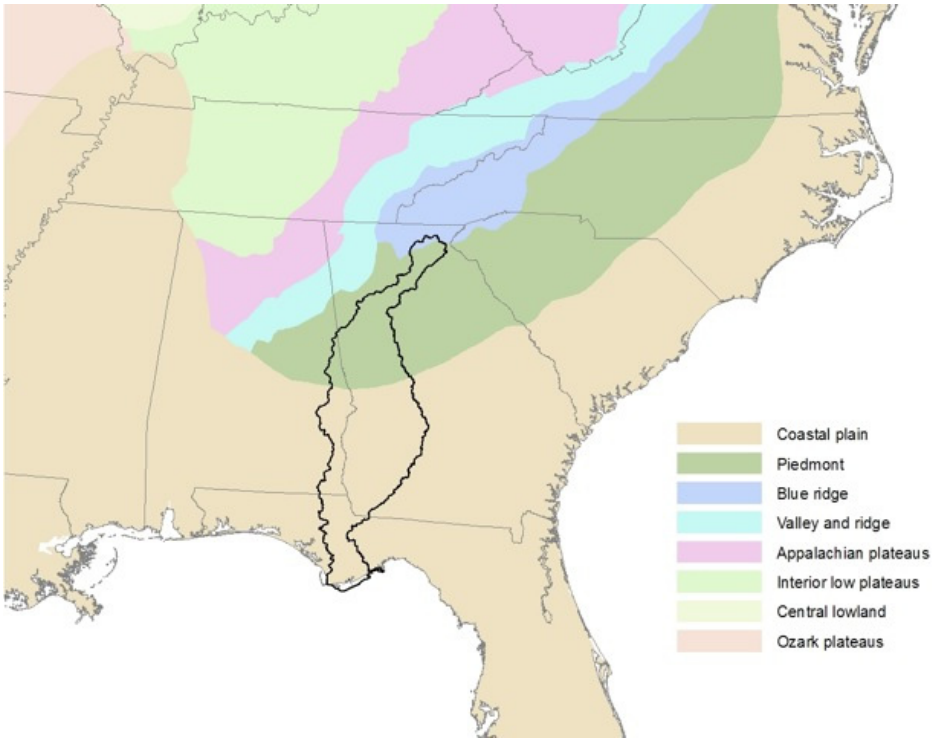
Apalachicola-Chattahoochee-Flint basin (ACF)



- 51,000 sq km
- Blue Ridge, Piedmont, Coastal Plain

- ca. 110 fish species (10 endemic species)

- ca. 27 extant freshwater mussel species (6 federally listed)

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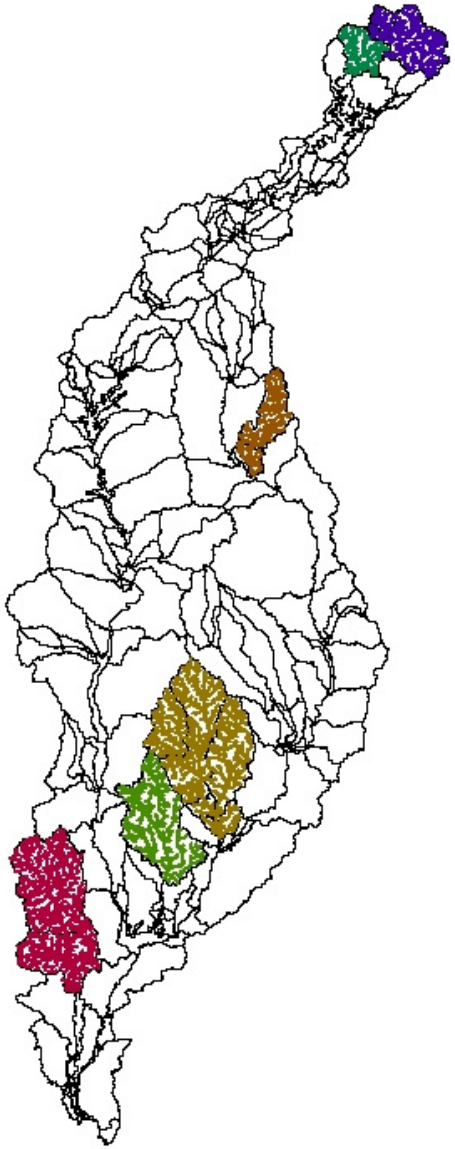
WaterSMART ACF – Environmental Flows Component

- Fine-resolution PRMS models for 6 sub-basins in 3 physiographic regions
- WaterSMART activities:
  - Current conditions flow model
  - Sample fishes and mussels to estimate meta/population dynamics in differing physiographies
  - Update model parameters
  - Simulate biota responses to flow alteration scenarios



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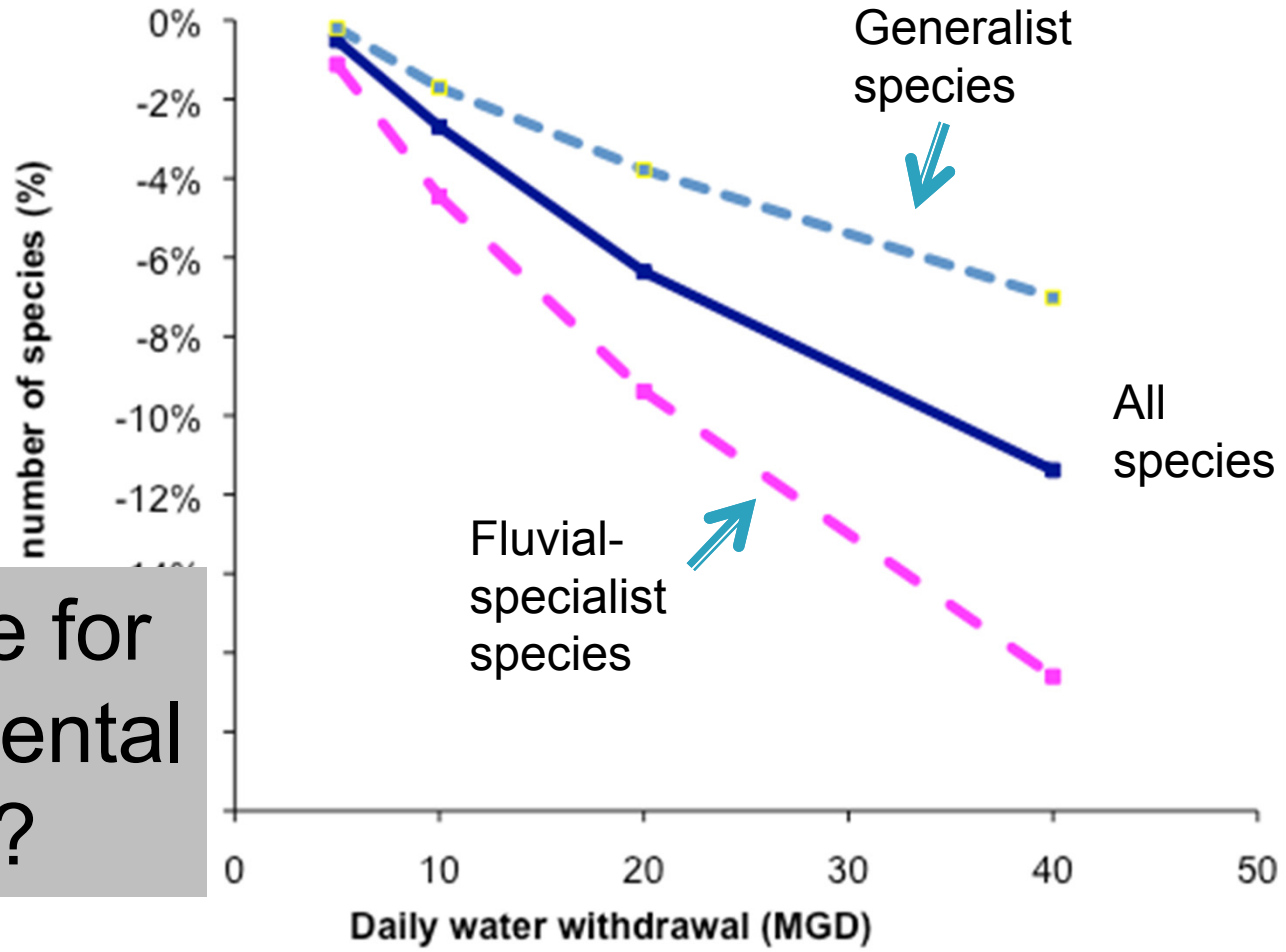
Simulated stream fish responses to withdrawals in Potato Creek basin

Change in species richness with increasing withdrawal levels



Guidance for 'environmental flows'?

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The ELOHA idea:

- We can use existing data & knowledge to identify predictable ecological responses to flow alteration
  - Provide a scientific basis for developing regional environmental flow standards

Arthington et al., 2006, "The challenge of providing environmental flow rules to sustain river ecosystems", Ecological Applications 16(4), 1311-1318.

Poff et al., 2010, "The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards", Freshwater Biology 55, 147-170.

ELOHA: a framework

- Start with regional hydrologic models
- Identify stream types expected to respond differently to flow alteration
- ***Model ecological responses to flow alteration*** **for each stream type**
- Use ecological models with socially-determined objectives to decide on flow requirements
- Monitor outcomes, improve models, repeat

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Challenge!

- Recent review*
  - 165 studies, response to flow alteration
  - 92% -> “negative ecological changes” with flow alteration
  - But, robust, transferable *quantitative* relationships lacking

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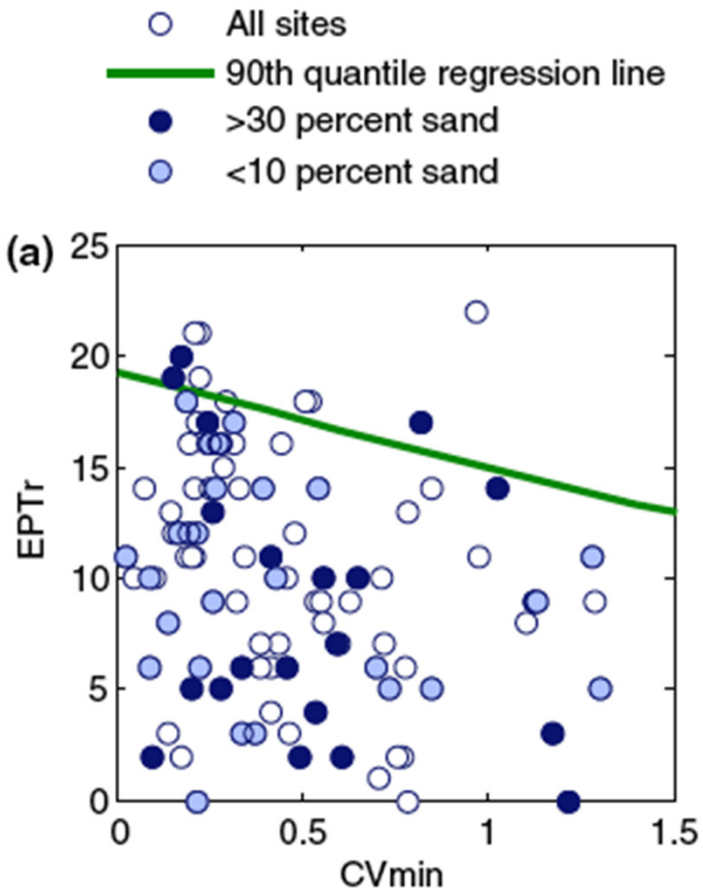
* Poff and Zimmerman, 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows. *Freshwater Biology 55:194-205.*

Challenge!

- Flow regime is one of many factors influencing ecological condition at a point in time

- Communities are dynamic

Result:
Noisy “flow-ecology” data



Ephemeroptera, Plecoptera, & Trichoptera ses richness vs. C of annual min flows
Sites from 11 Western US states

Konrad et al. 2008. Assessing streamflow characteristics as limiting factors on benthic invertebrate assemblages in streams across the western United States. *Freshwater Biology 53: 1983-1998*

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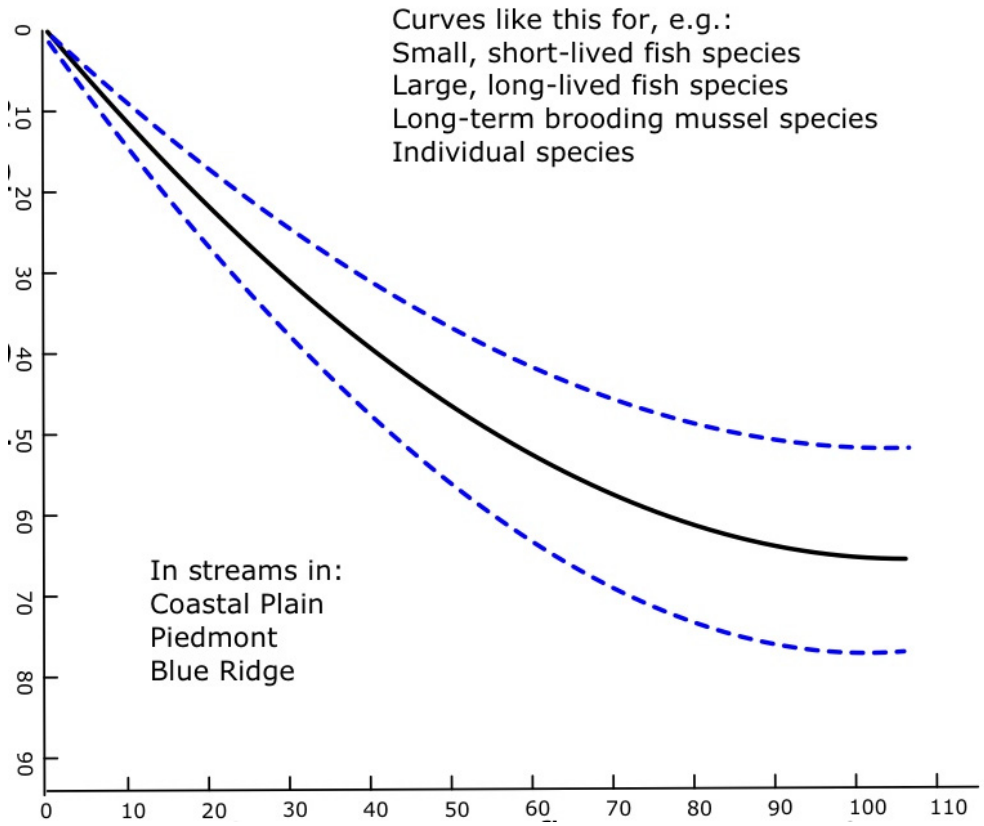
Potential product of empirically-based simulation studies:

- Simulated flow-ecological response curves for species groups & stream types, *based on flow effects on underlying processes*

- Guidance for monitoring to reduce uncertainties



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Estimation of Mussel Population Response to Hydrologic Alteration in a Southeastern U.S. Stream

James T. Peterson · Jason M. Wisniewski · Colin P. Shea · C. Rhett Jackson

Environmental Management 2011

5-year mark-recapture study, Sawhatchee Crk GA

3 listed mussel species

Survival negatively related to 10-d high flows during summer

Recruitment positively related to spring and summer flow

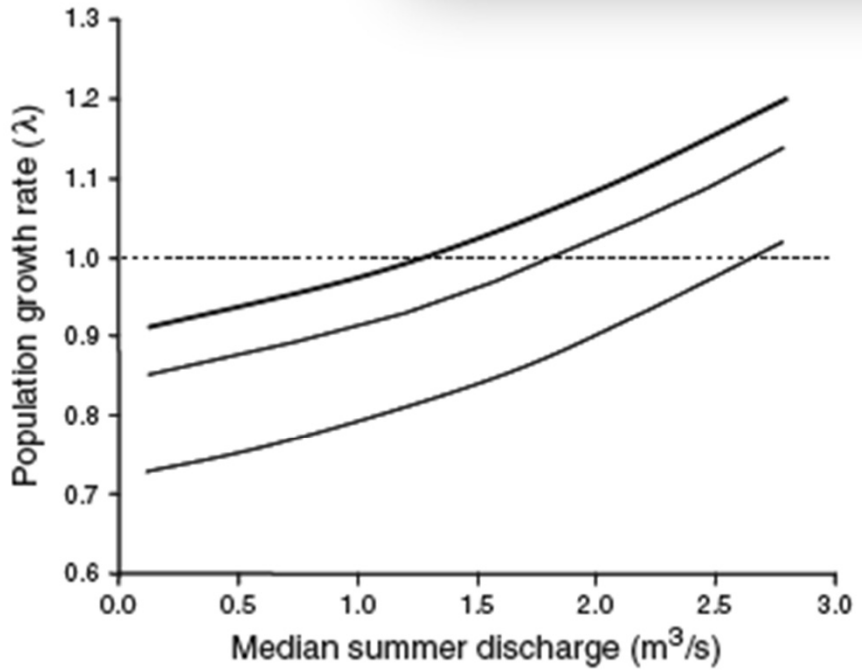

Fig. 3 Estimated mussel population growth rate versus median summer discharge for the maximum (*heavy solid line*), average (*medium solid line*), and minimum (*thin solid line*) annual survival observed during the Sawhatchee Creek study. Estimates based on best approximating survival and recruitment model

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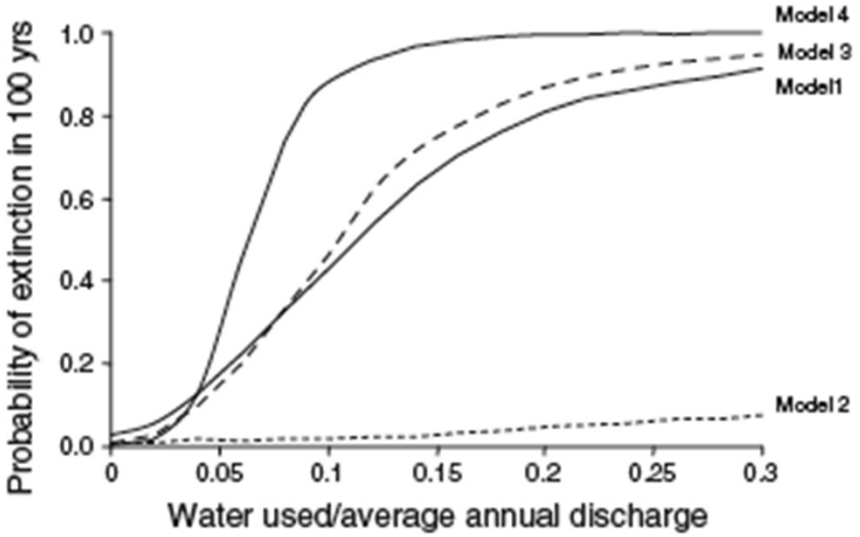

Fig. 5 Estimated probability of extinction in 100 years from 10,000 simulations of mussel persistence under varying levels of water use for the four best approximating survival (*labeled lines*) and recruitment models and assuming a 7Q10 minimum flow standard

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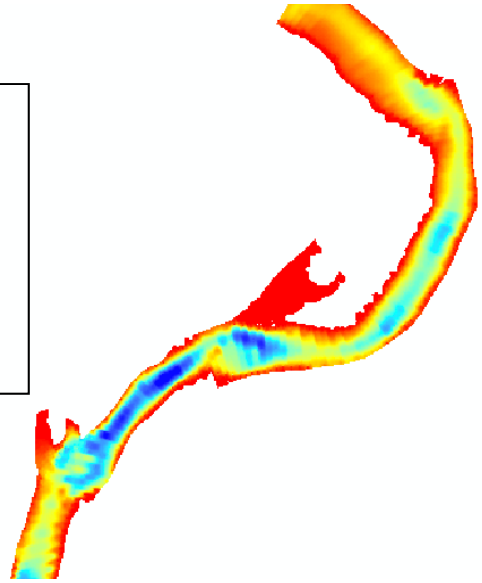
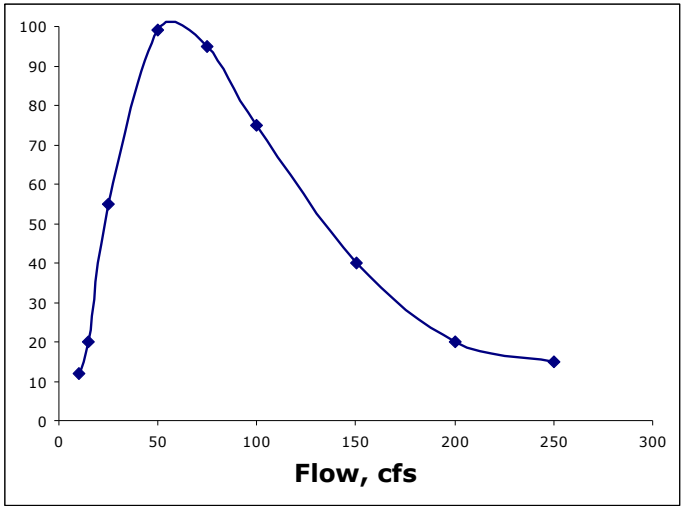
Transferability?

Question often asked in relation to flow-habitat models.

Model depth, velocity in relation to flow





2-Dimensional model

Do species use the same habitats in different rivers?

Alabama stream fish study*: Depth/velocity/ substrate criteria transferability for fishes in Piedmont and Coastal Plain streams

- *Good transferability: fish species that consistently use fast-water habitats - "riffle species"*
  e.g., Bronze darter, lipstick darter, greenbreast darter

- *Poor transferability: fish species not restricted to shallow, fast habitats – "pool and riffle species"*
  e.g., Alabama shiner, speckled darter

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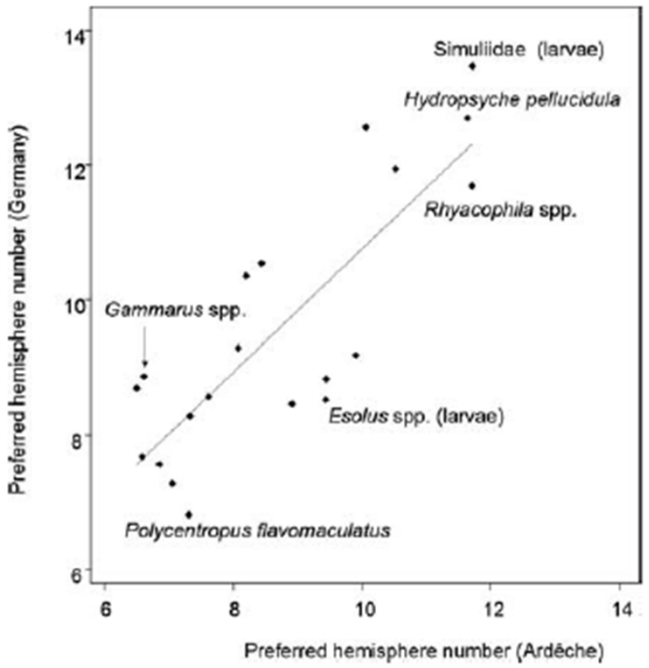
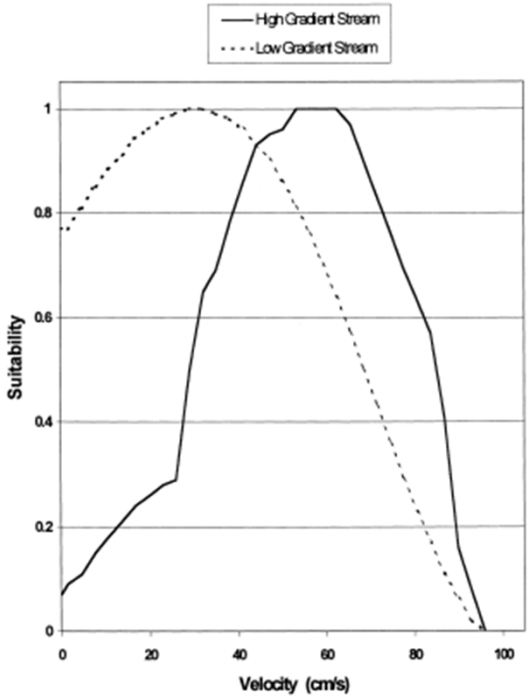
* Freeman, Bowen, Crance 1997. *Transferability of habitat suitability criteria for fishes in warmwater streams.* NAJFM 17:20-31.

Similarly: good transferability of near-substrate hydraulic criteria for some macroinvertebrates



From review by Lamaroux et al. 2010, River Research and Applications



Macroinvertebrate diversity in relation to velocity, Gore et al. 2001, Regulated Rivers, Research and Management

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Transferability?

Question also applies to estimated flow effects on populations & population processes

- *Hypothesized variation in flow-ecology relations among stream "types" is the basis for classification in ELOHA*

- *Testing context-dependence* of flow-population dynamics in WaterSMART and other research*

* System fragmentation
Reach isolation
Channel confinement and bed sediments
Water quality

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“Defensibility of the ACF work given the high degree of controversy?”

• Conceptual basis supported in best scientific understanding (*flow regimes* influence population processes via multiple mechanisms; species persistence an outcome of local survival, reproduction, dispersal dynamics)

- ELOHA and supporting studies
- Metapopulation dynamics
- Population viability theory

• Approach allows explicit evaluation of alternative hypotheses and propagation of uncertainty in outcomes

• Potential applications:

- Analysis of management alternatives in specific stream systems
- Derivations of relations between water management actions and biological outcomes, for differing contexts