



**For the love of rivers:  
conservation ecology  
within an ecosystem  
services framework**

**Carla L. Atkinson**

THE UNIVERSITY OF  
**ALABAMA**  
B I O L O G Y



**To promote translation between disciplines we need to understand the interaction between organismal and ecosystem-level processes**



Why I love rivers



"Water is the critical issue of our lifetime and most our children's lifetime. The health of our waters is the principal measure of how we live on the land."

-Luna Leopold-

Why I love rivers



I came to the ACF first in 2006

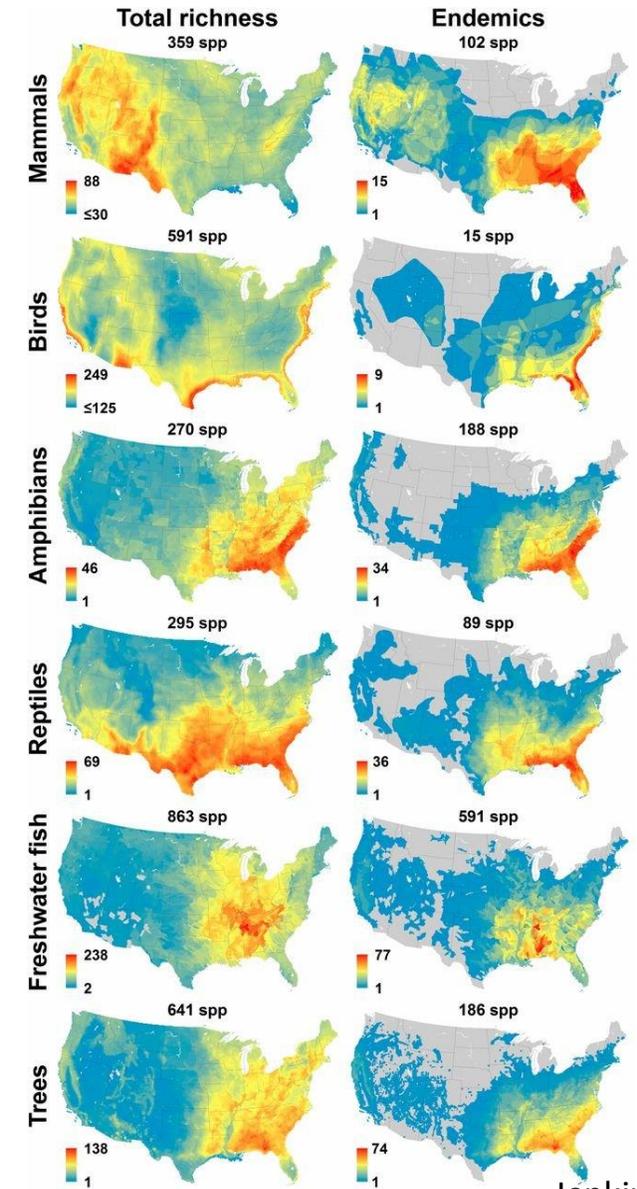
The map shows the ACF Basin, which is divided into three sub-basins: Upper Chattahoochee (green), Middle and Lower Chattahoochee (yellow), and Flint (red). The basin is located in the southeastern United States, covering parts of Alabama, Georgia, and Florida. The Gulf of Mexico is visible to the south.

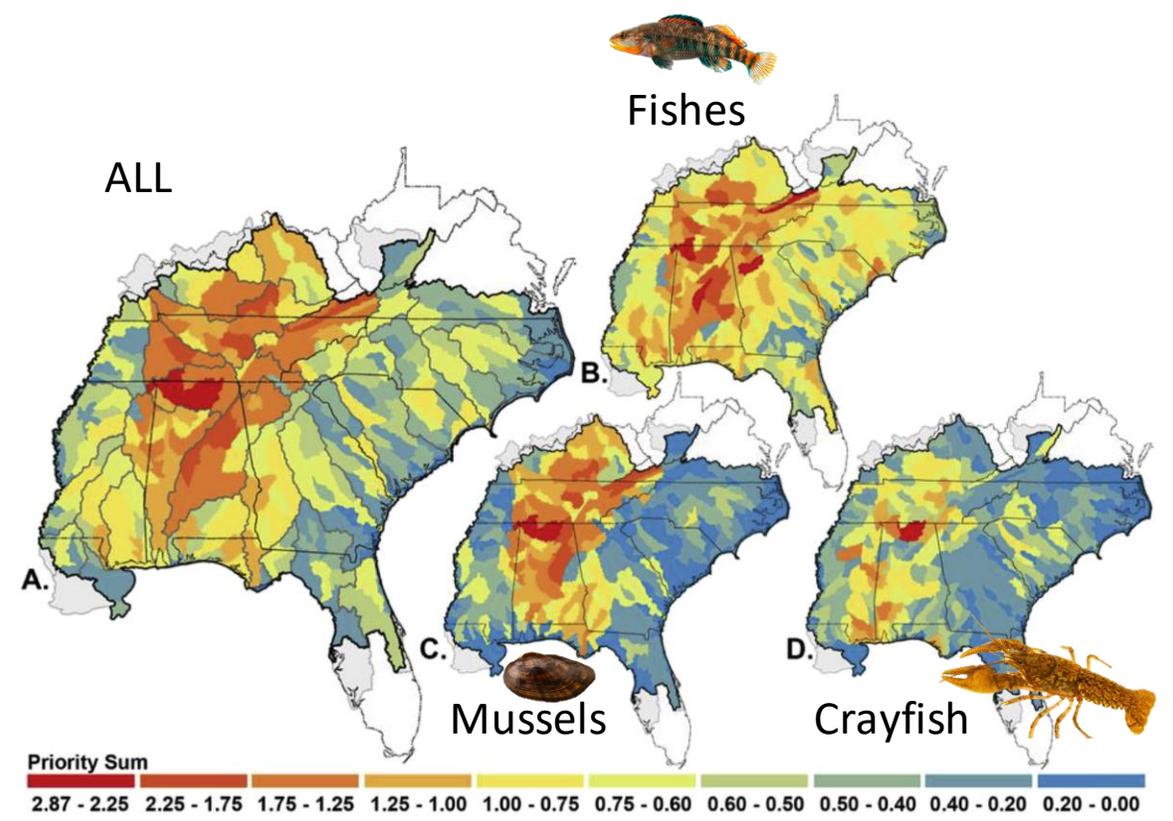
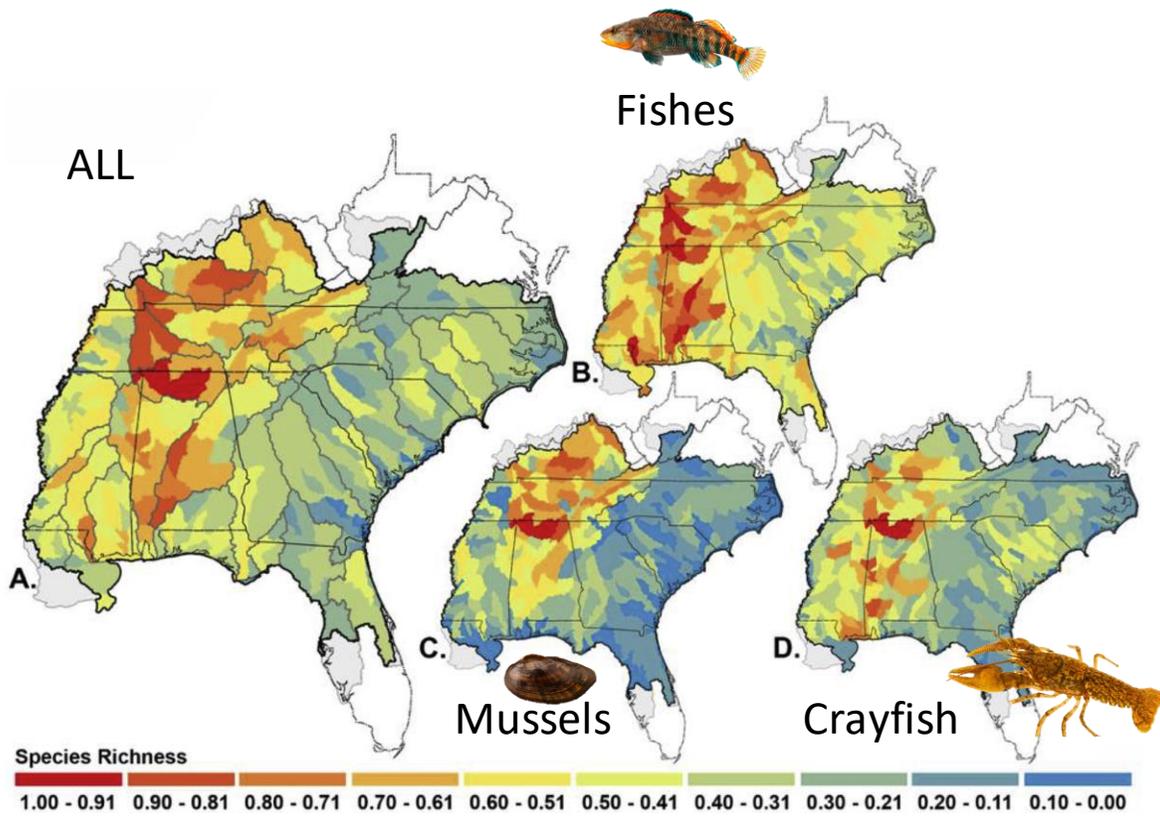
# Diversity of habitats





# Amazing diversity of the southeast





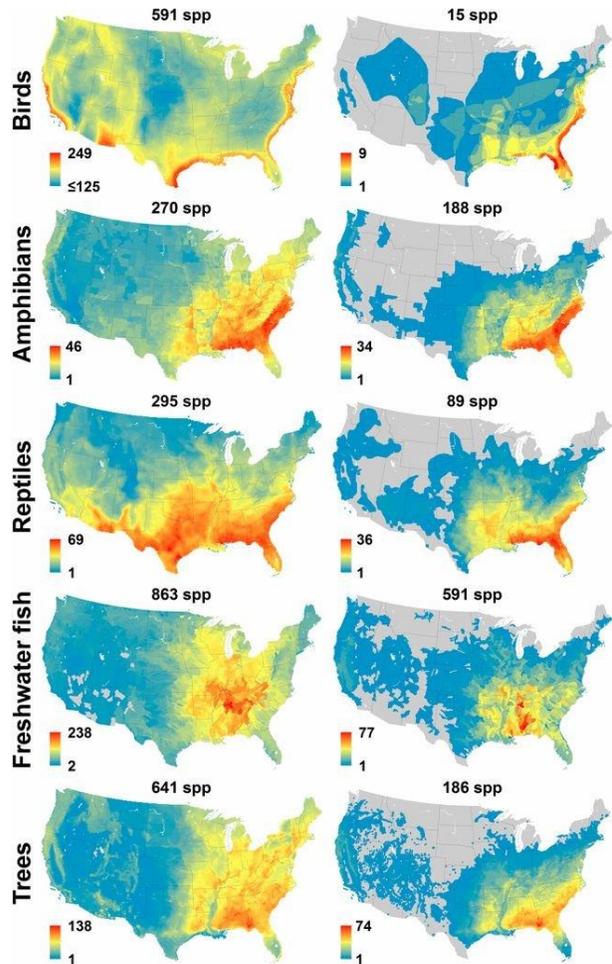
From Elkins et al. 2019

Southwest is a high priority area for species conservation

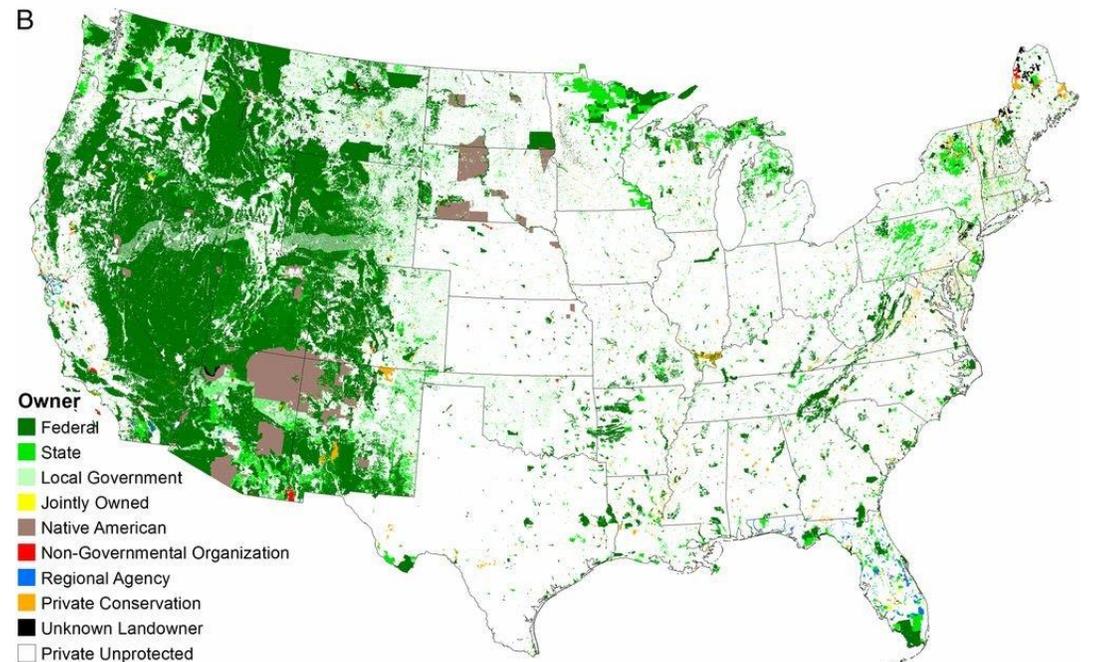
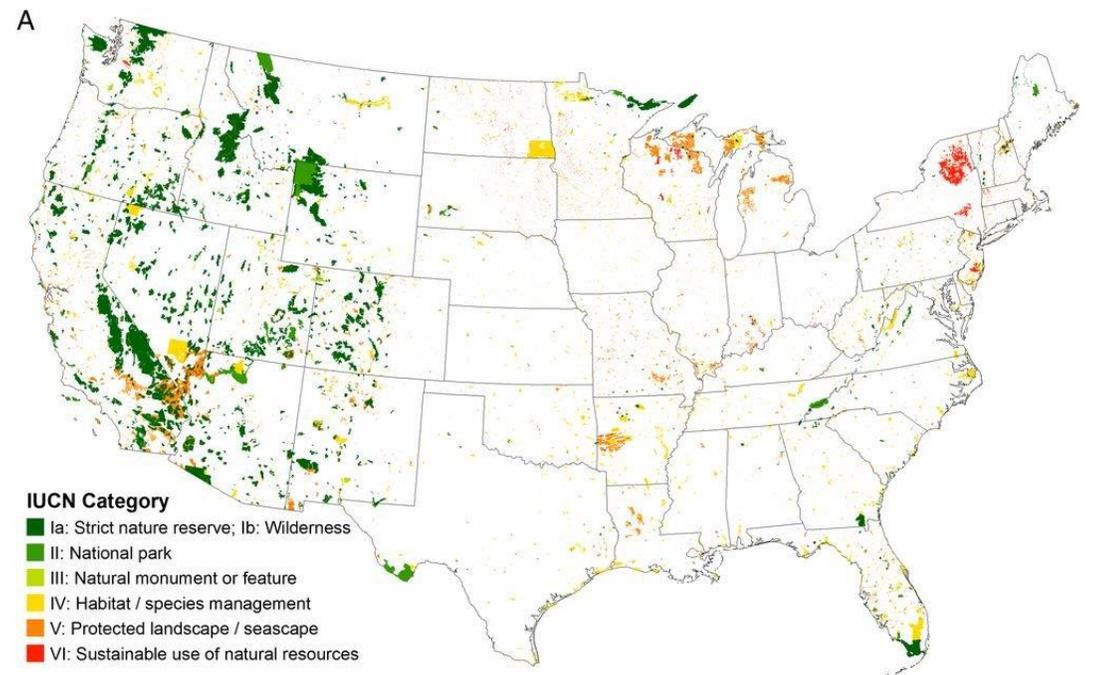
# US protected lands mismatch biodiversity priorities

Clinton N. Jenkins  , Kyle S. Van Houtan , Stuart L. Pimm, and Joseph O. Sexton [Authors Info & Affiliations](#)

April 6, 2015 | 112 (16) 5081-5086 | <https://doi.org/10.1073/pnas.1418034112>

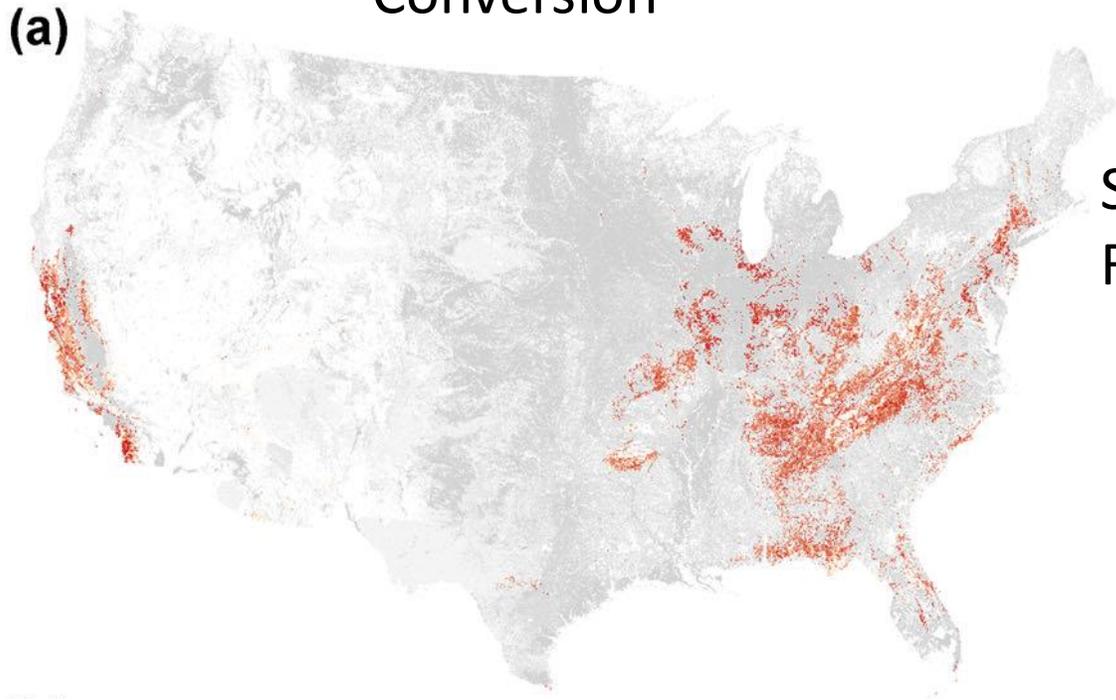


**Despite the fact the southeast USA, particularly aquatic systems, harbors the highest biodiversity, the southeast has very few protected lands**

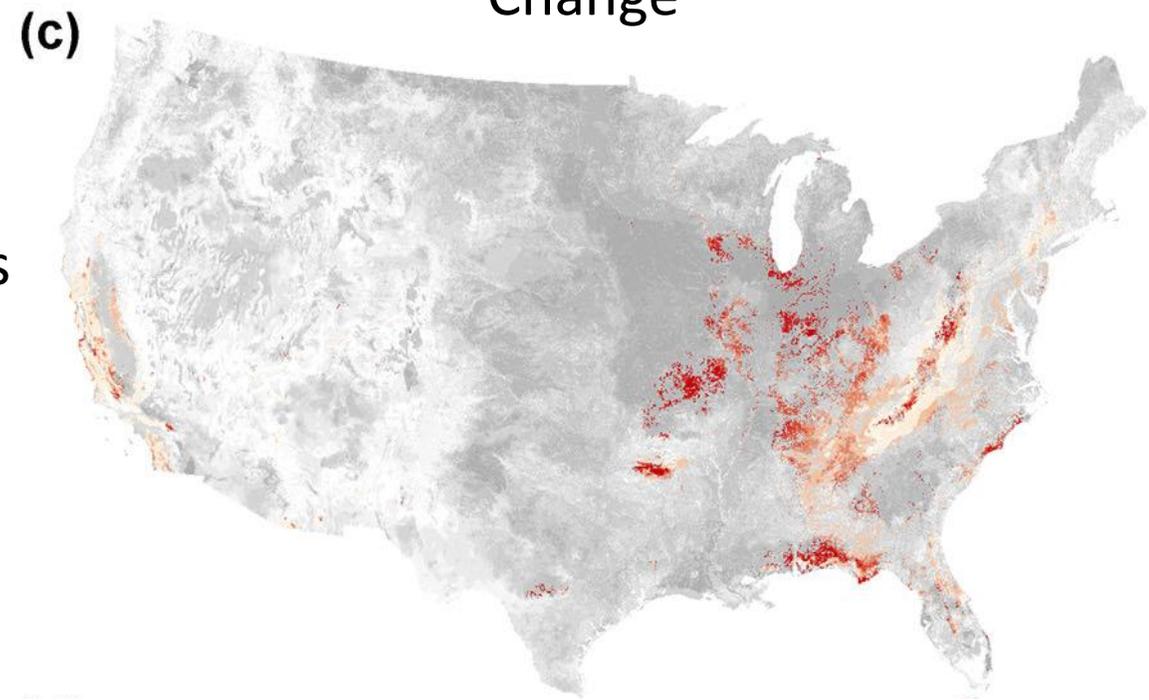


# Species richness in this region is at high risk due to both land conversion and climate change

Land  
Conversion



Climate  
Change

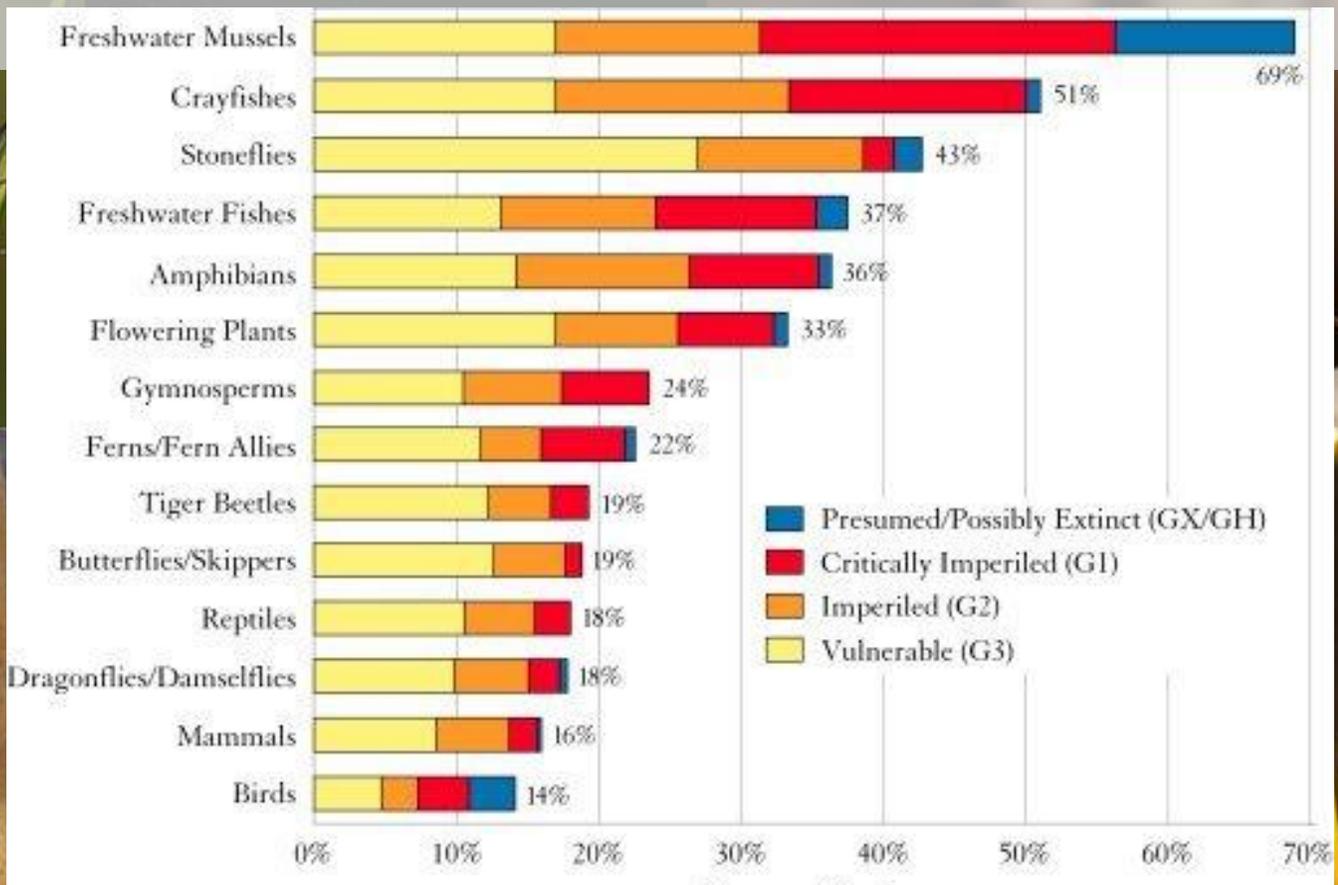


Species  
Richness





**Freshwaters experiencing declines in biodiversity at rates greater than those in terrestrial systems (extinction rates as high as 4%/decade, 5x > than terrestrial systems)**





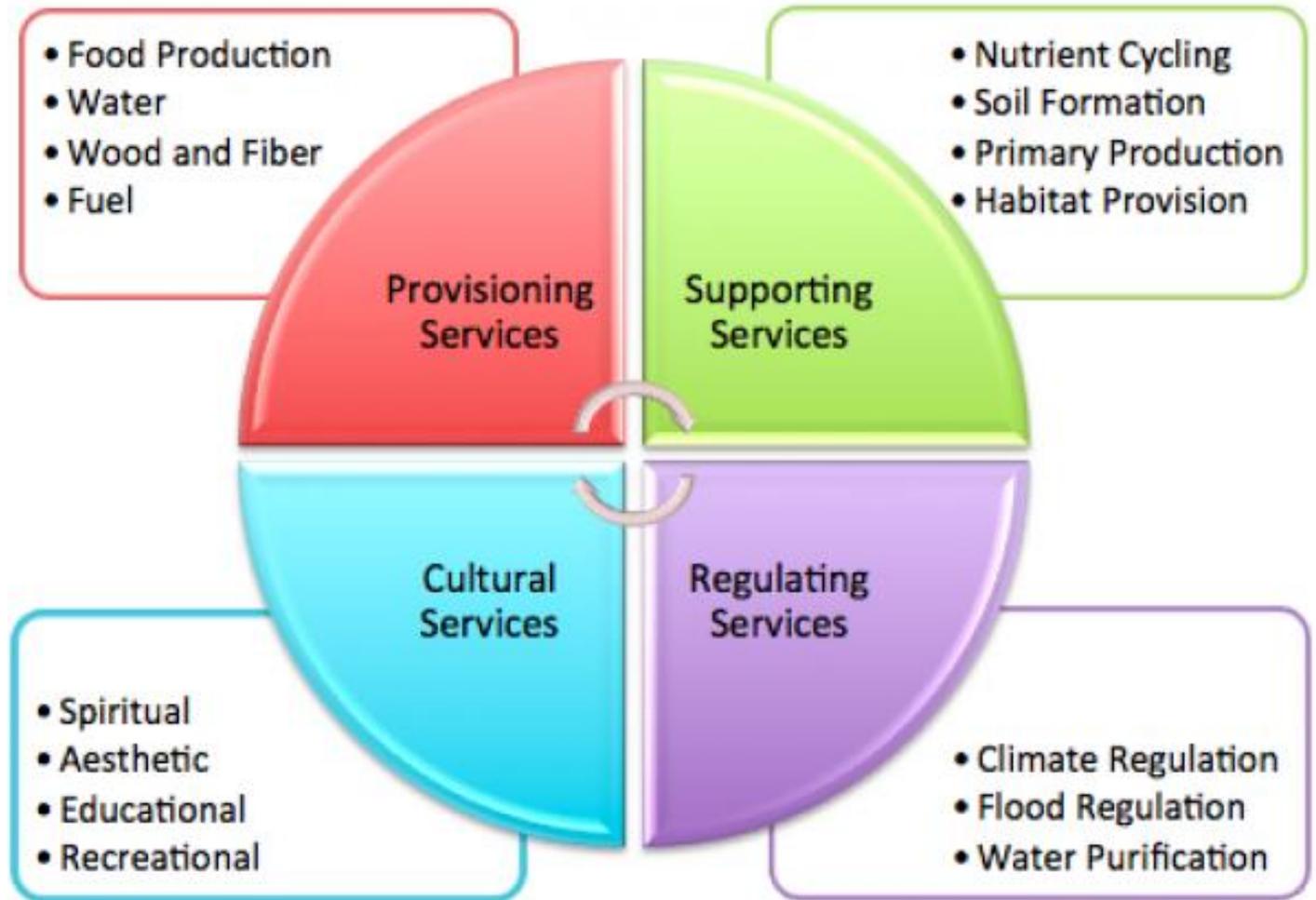
**Freshwaters experiencing declines in biodiversity at rates greater than those in terrestrial systems (extinction rates as high as 4%/decade, 5x > than terrestrial systems)**



**Freshwaters provide essential ecosystem services, and these are also in danger of being lost.**

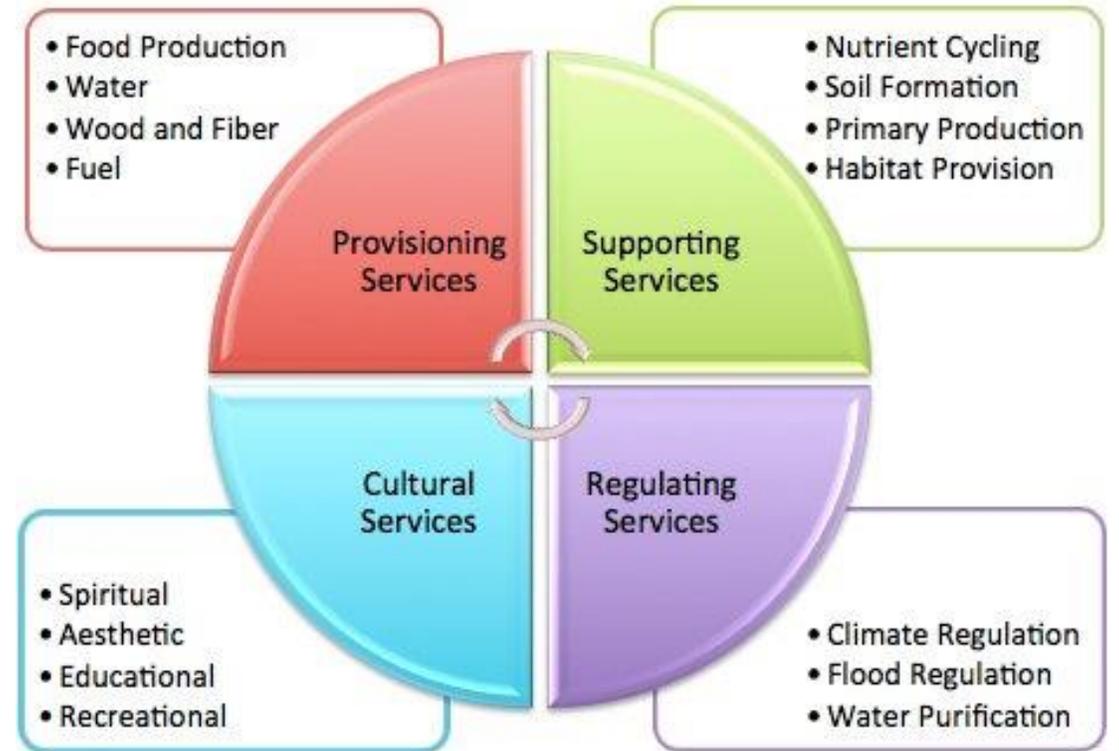


# What are ecosystem services?



Source: Millenium Ecosystem Assessment, 2005.

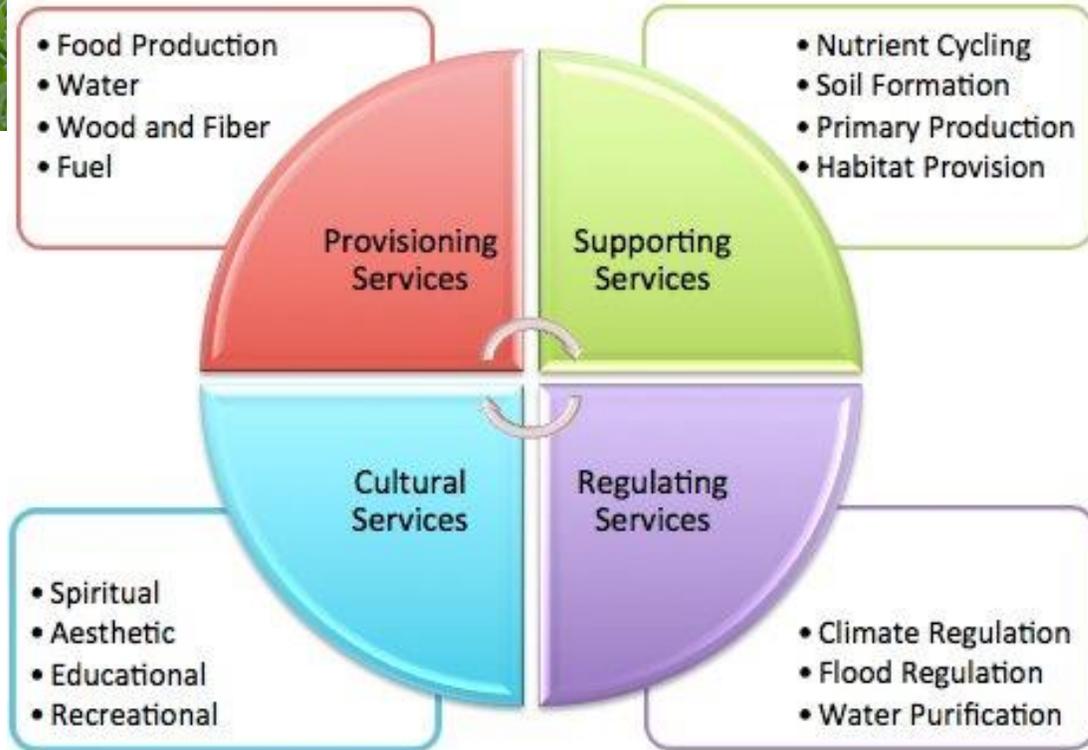
# Why does it matter?



Source: Millenium Ecosystem Assessment, 2005.



# This watershed supports many important ecosystem services



Source: Millenium Ecosystem Assessment, 2005.





However, tactics for promoting biodiversity and ecosystem services are often not congruent especially when it comes to species management



# Biodiversity Conservation

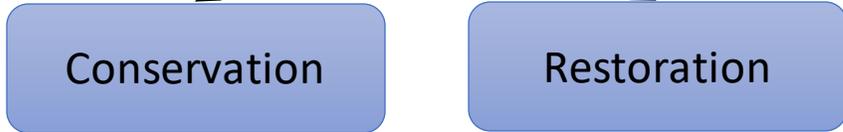
**Goals**



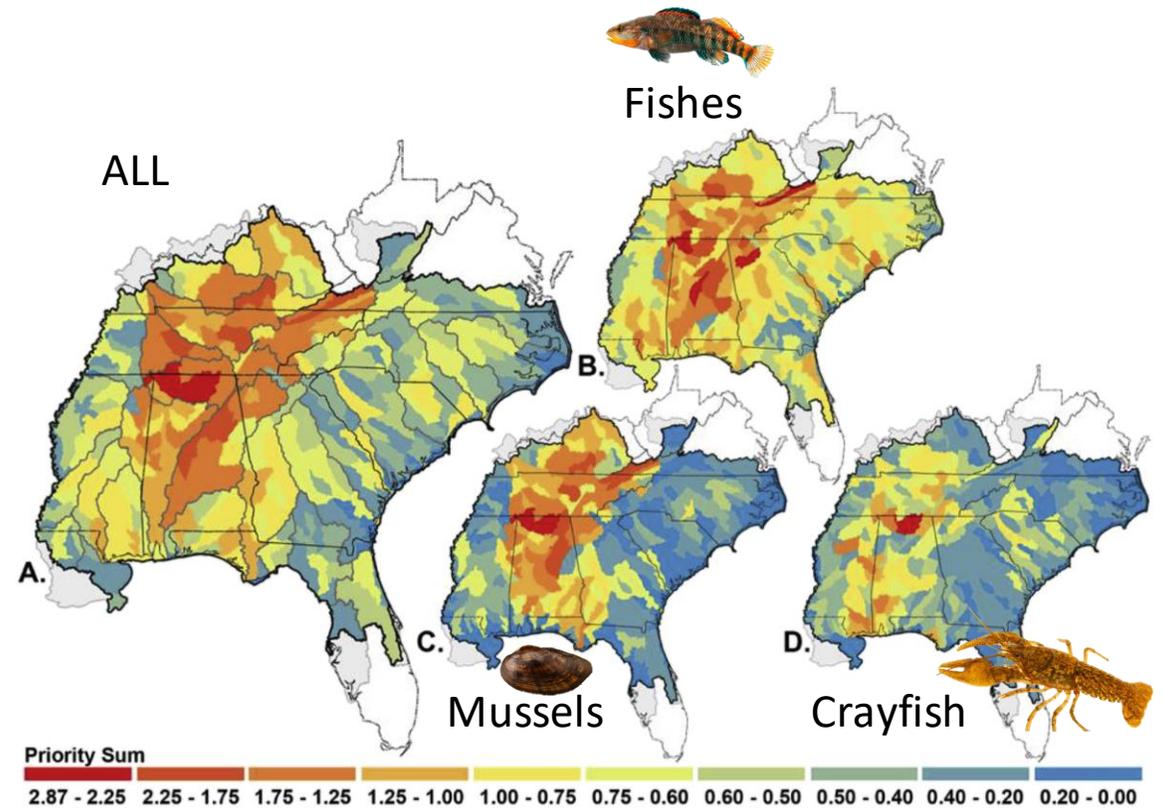
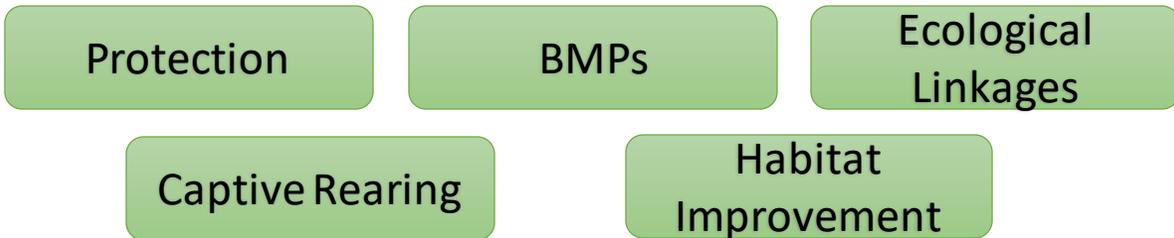
**Target**



**Strategies**

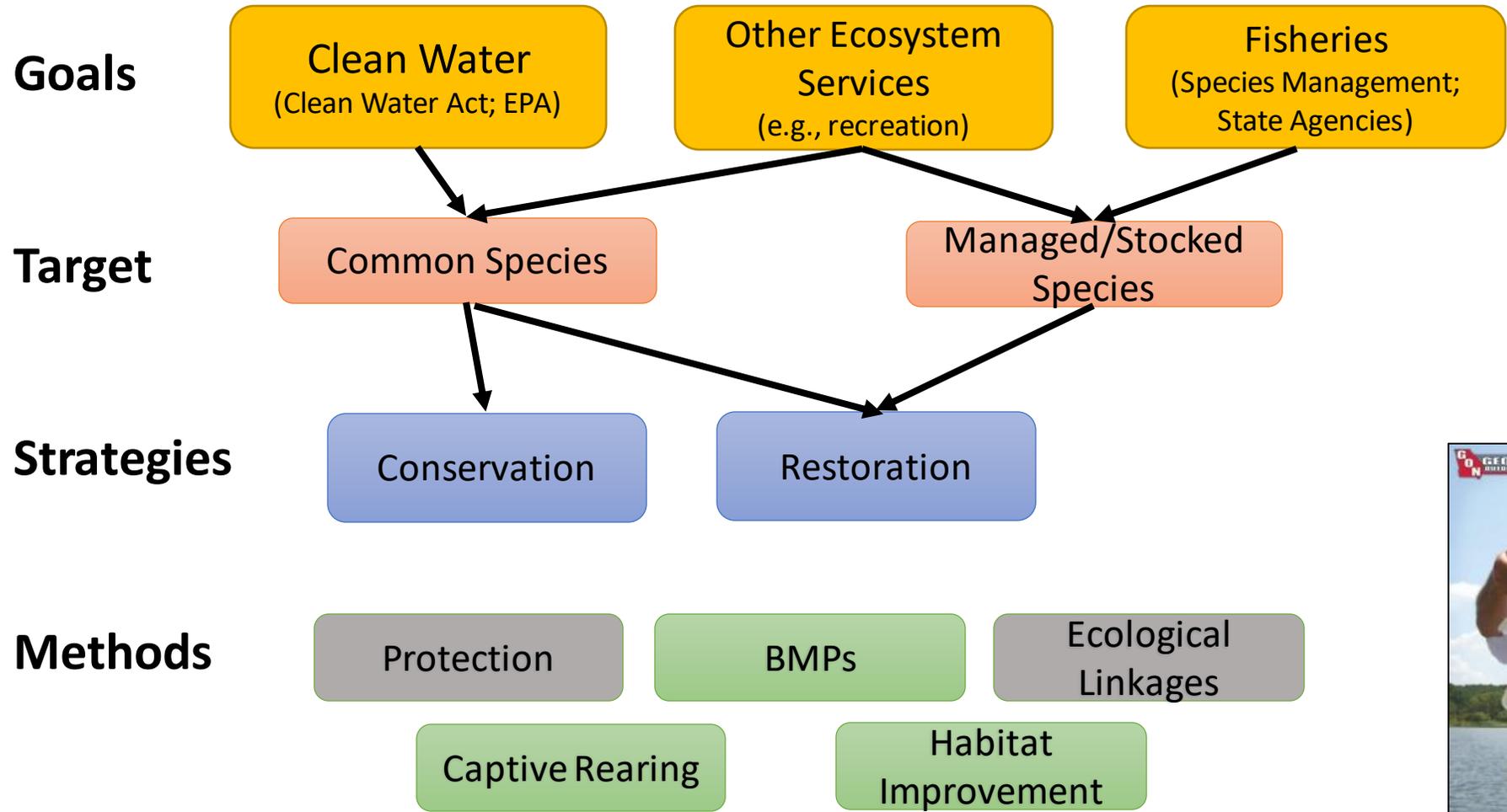


**Methods**



CRITERIA		Numerical thresholds	THREATENED CATEGORIES		
A	Population reduction		→	Critically Endangered (CR)	Endangered (EN)
B	Restricted geographic range				
C	Small population size & decline				
D	Very small or restricted population				
E	Extinction probability analysis				

# Ecosystem Services – Water quality, Recreation/Fisheries



# Freshwater Mussels

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Shiny-rayed pocketbook

# ACF Harbors High Mussel Diversity

- ~32 species and 8 Endemics
- Six species are listed under the Endangered Species Act



Chipola slabshell

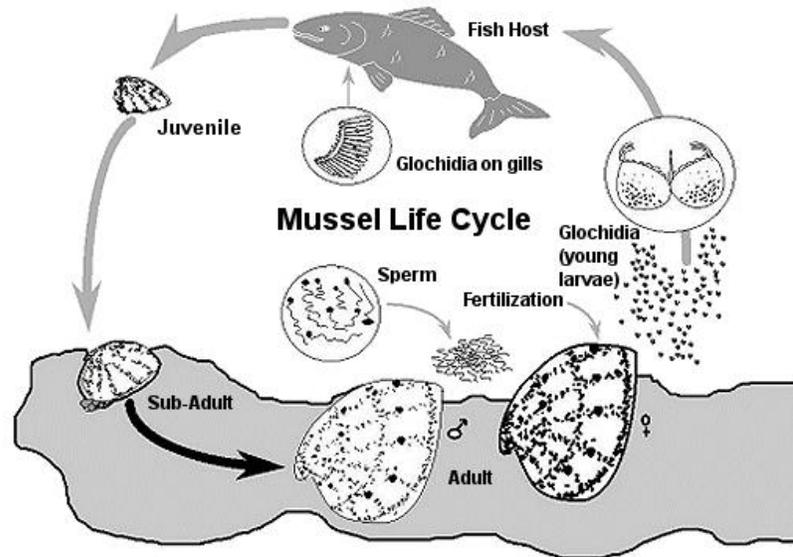


Fat threeridge

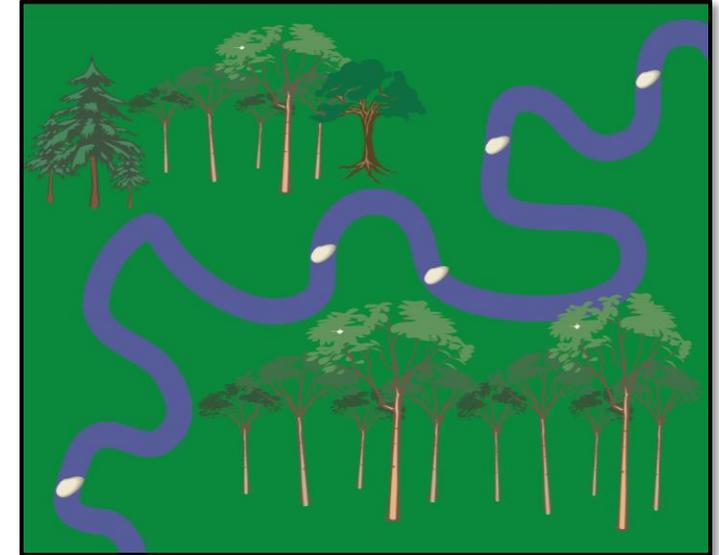
# Characteristics of FW Mussels



- Diverse group (~958 Unionoida)
- Long generation times
- Long-lived (6 – 100 yrs)

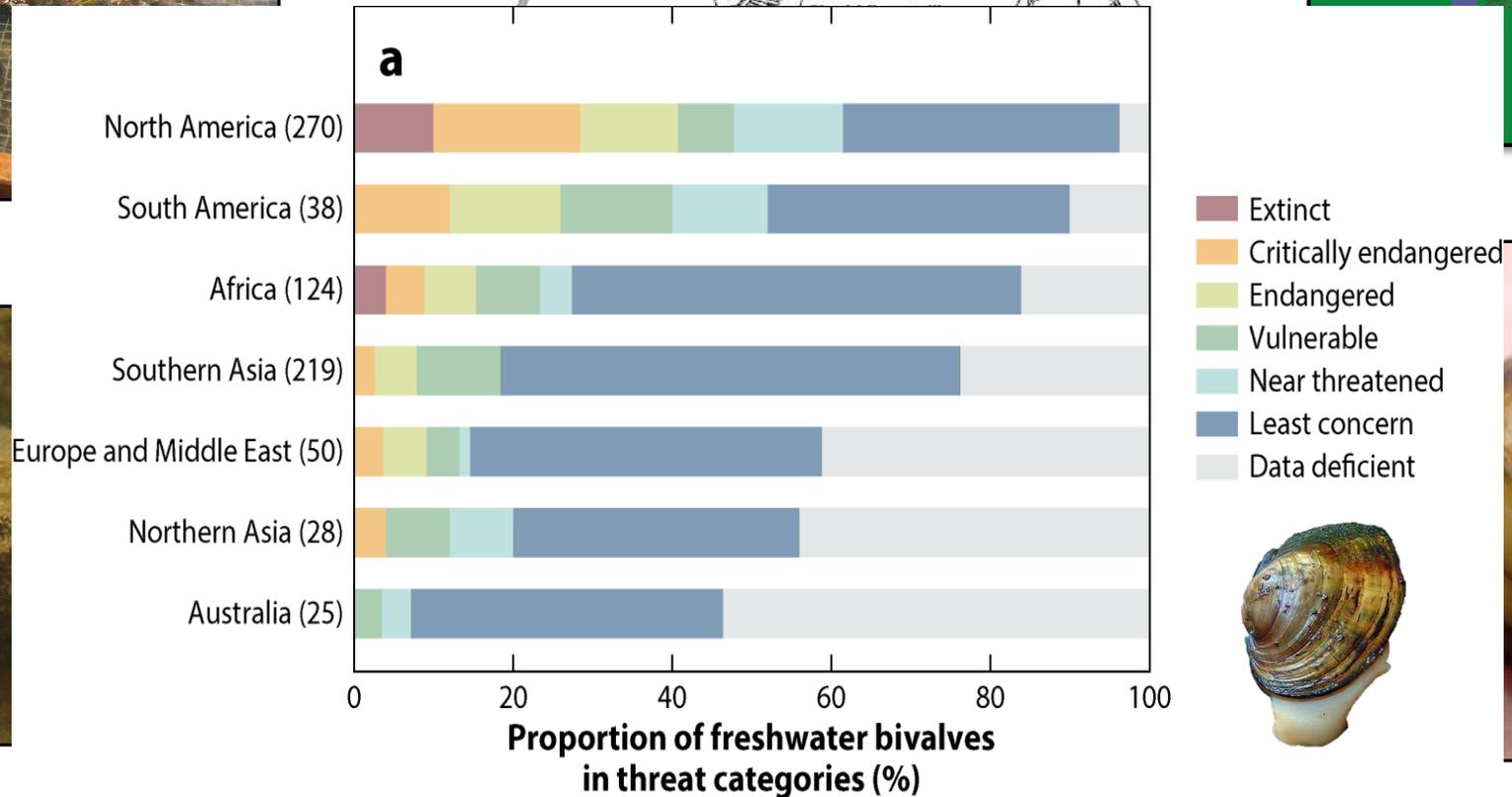
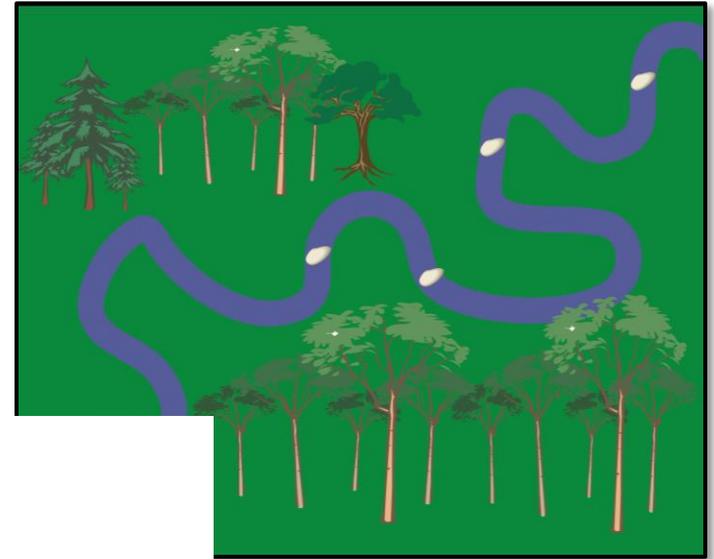
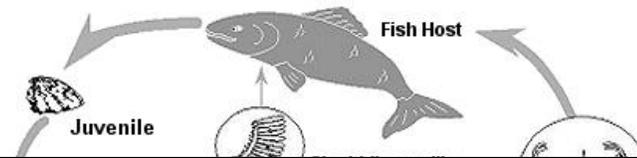
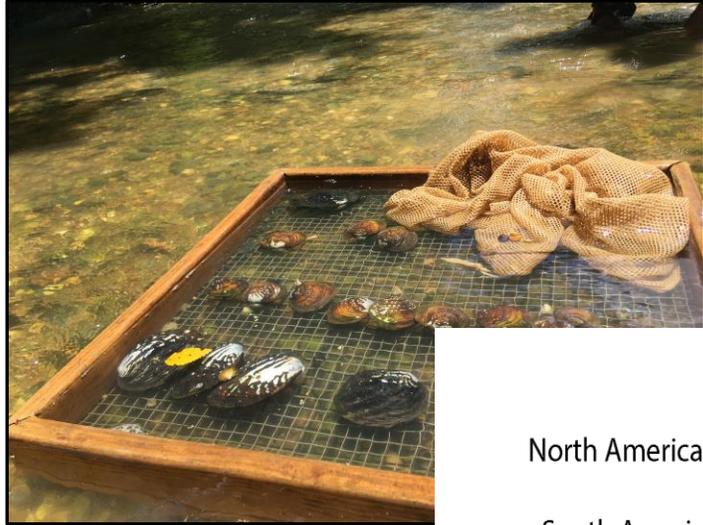


- Occur as dense, multispecies aggregations (mussel beds)
- Sedentary and can't move far
- Depend on fish for dispersal
- Different mussels use different fish



# Characteristics of FW Mussels

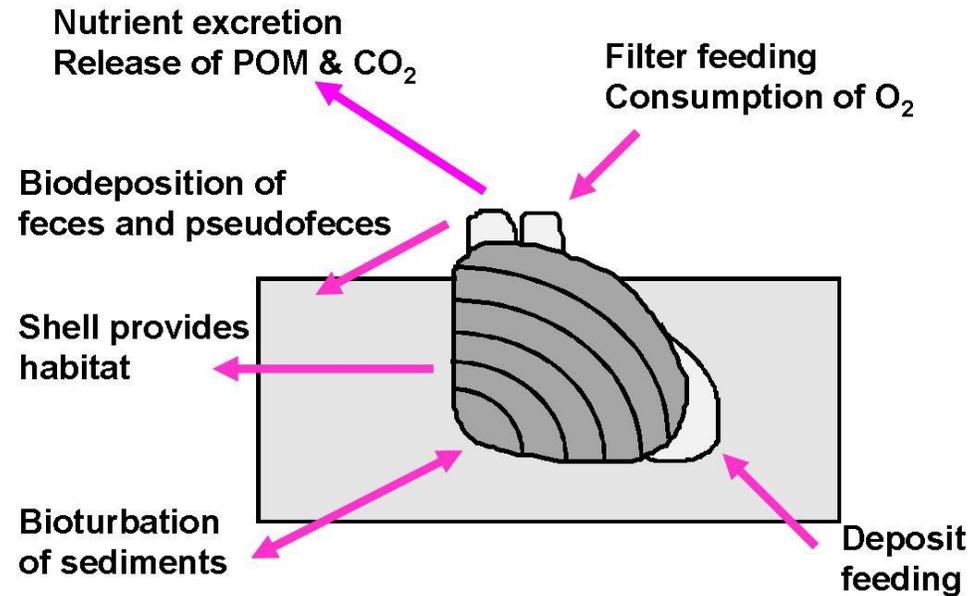
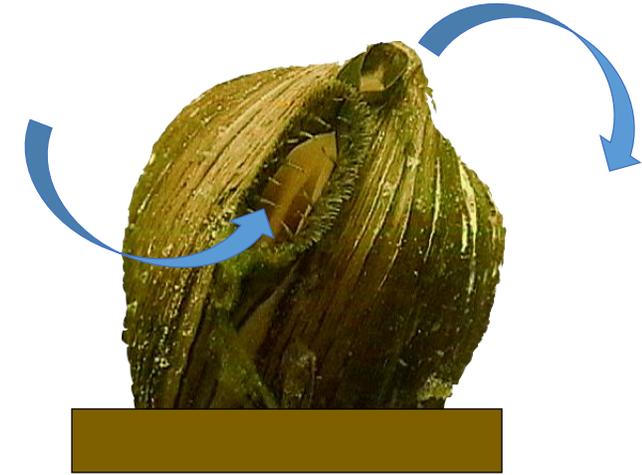
- Diverse group (~958 Unionoida)
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# FW Mussels are important and valuable



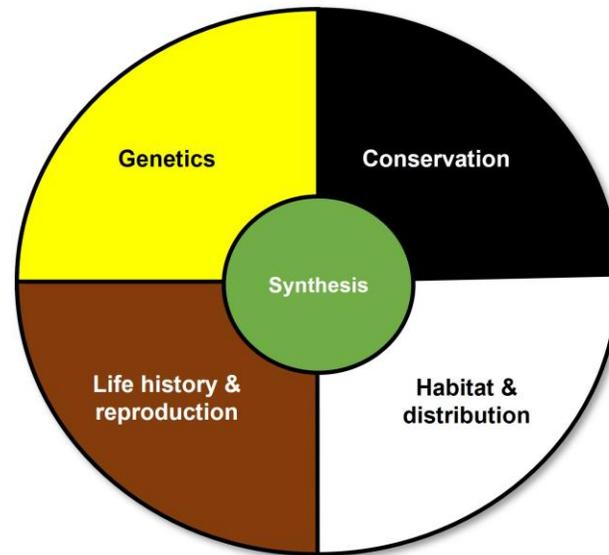
- Water purification (biofiltration)
- Nutrient recycling & storage
- Structural habitat
- Substrate modification
- Food for other organisms



# FW Mussels vary in their traits

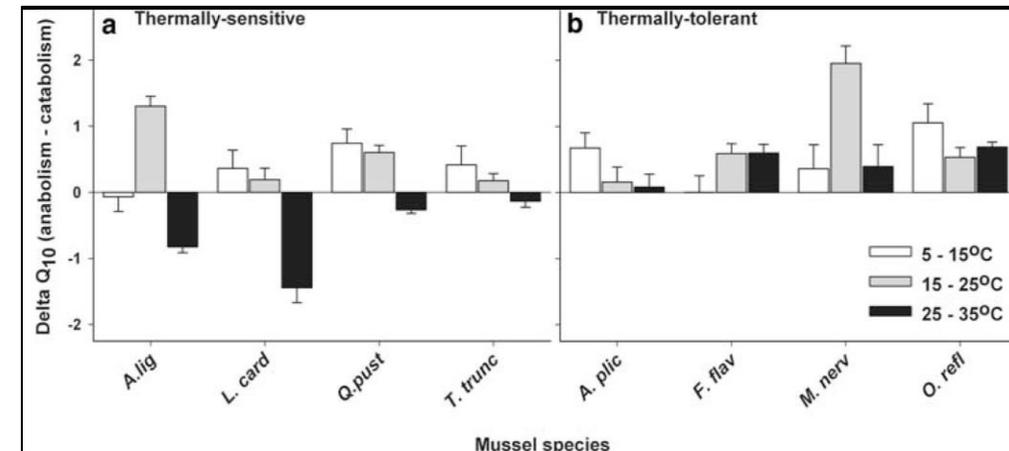


Vary tremendously in their life history traits resulting in variation in community structure and potential ecosystem impacts



Mussel Traits – NA Trait Database

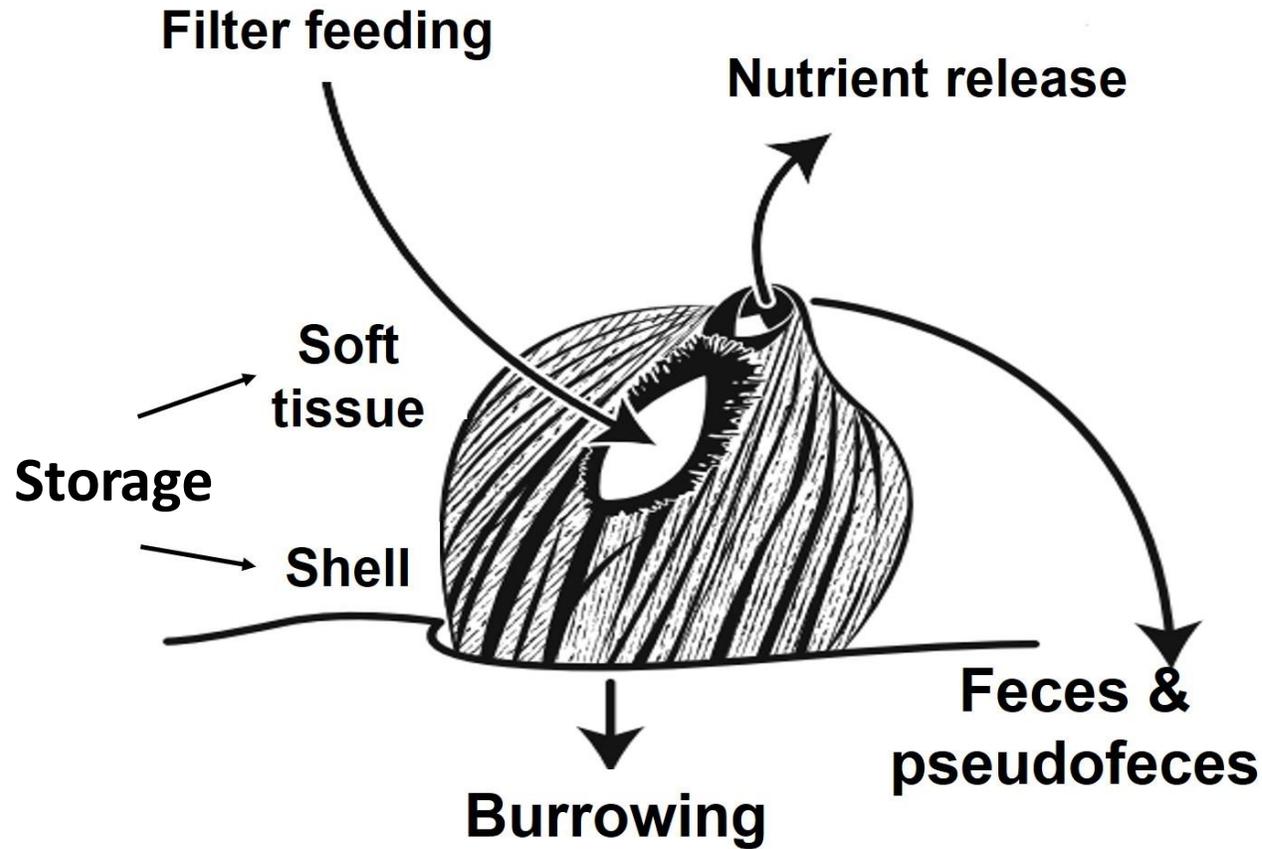
Hopper et al. *In prep*



Spoooner & Vaughn 2008, *Oecologia*

# Freshwater Mussels = Important Functions = Important Services

How do mussels contribute to the healthy functioning of ecosystems?



## Provisioning services

- Pearl culture
- Food
- Products from shell

## Regulating services

- Water purification

## Supporting services

- Nutrient cycling & storage
- Habitat provisioning
- Primary production

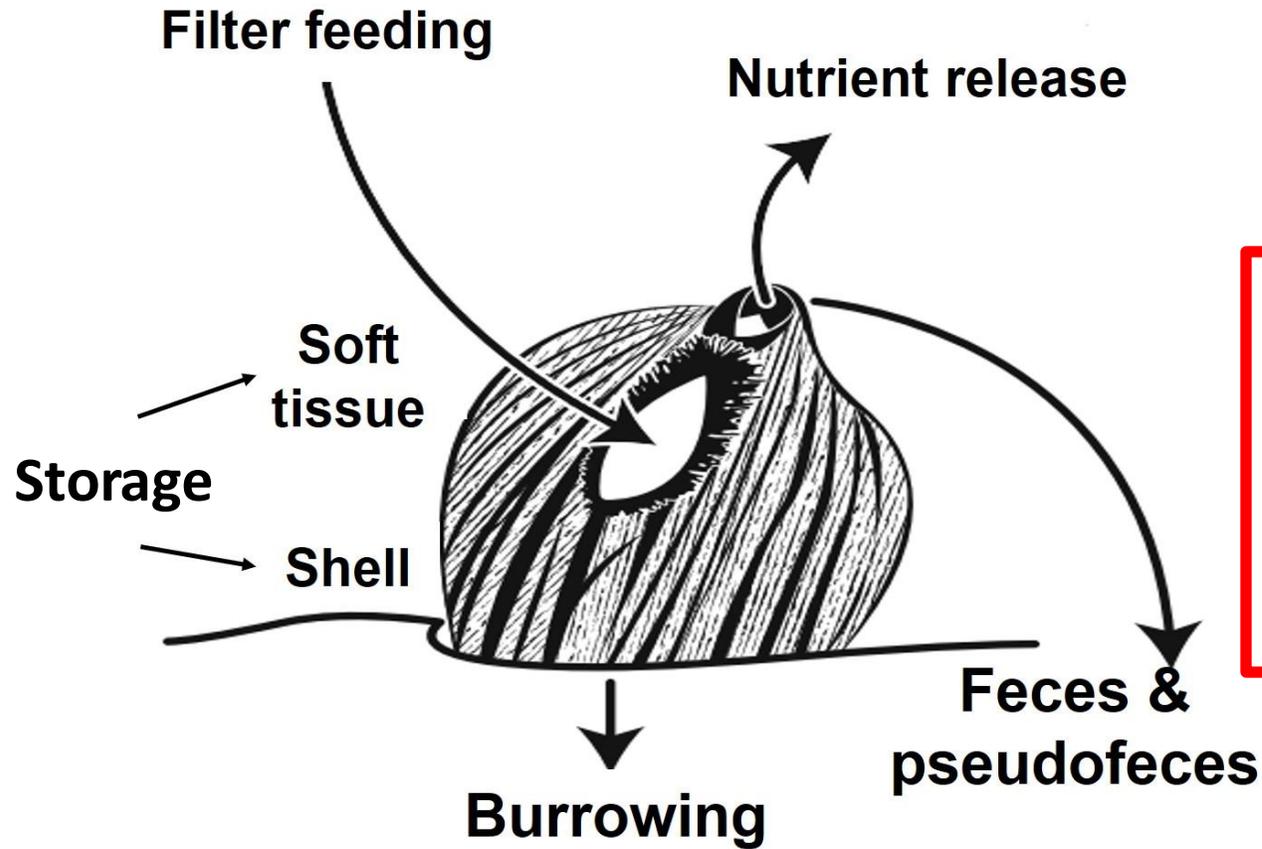
## Cultural services

- Spiritual enrichment
- Aesthetic experiences
- Education



# Freshwater Mussels = Important Functions = Important Services

How do mussels contribute to the healthy functioning of ecosystems?



## Provisioning services

- Pearl culture
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## Regulating services

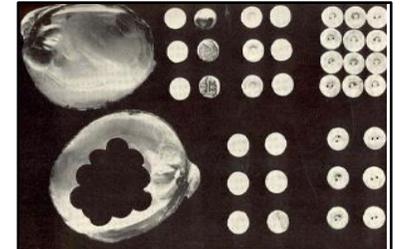
- Water purification

## Supporting services

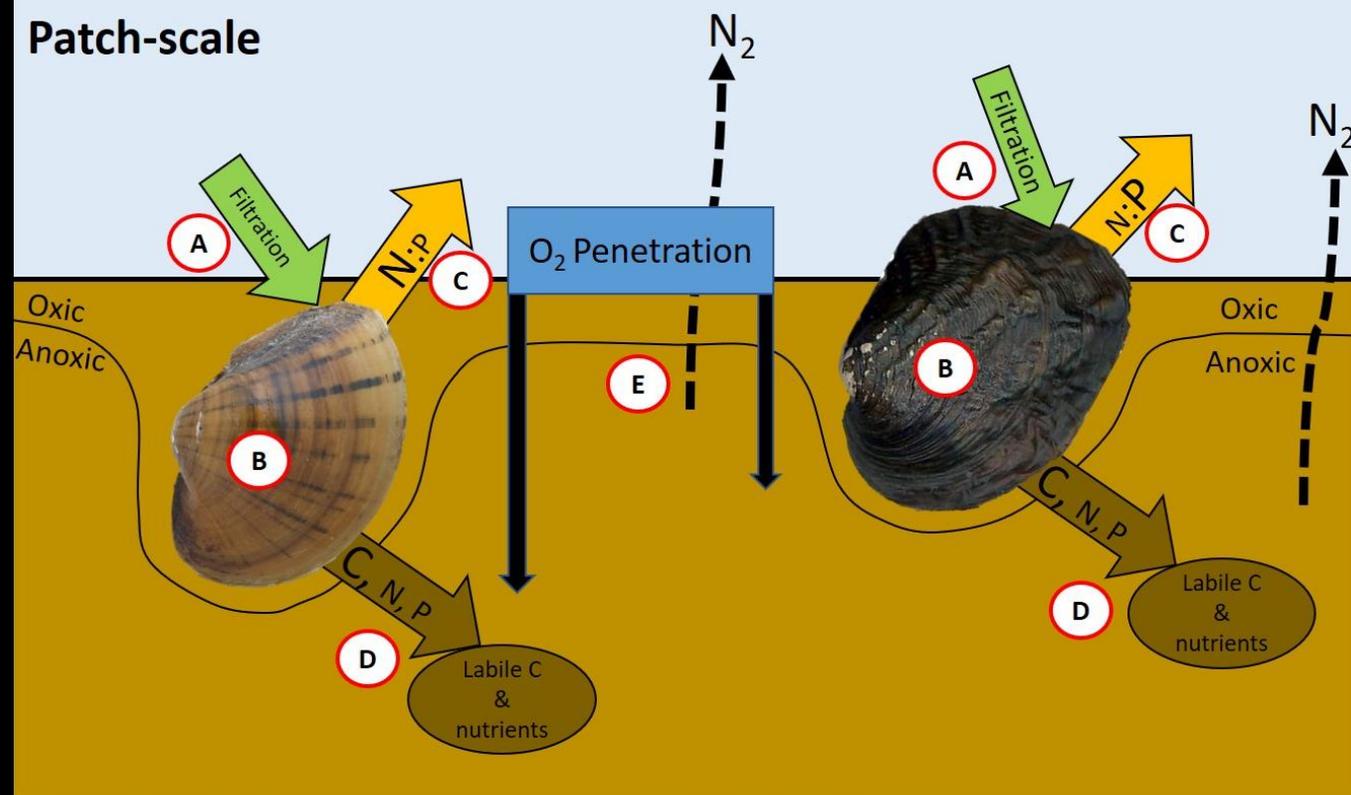
- Nutrient cycling & storage
- Habitat provisioning
- Primary production

## Cultural services

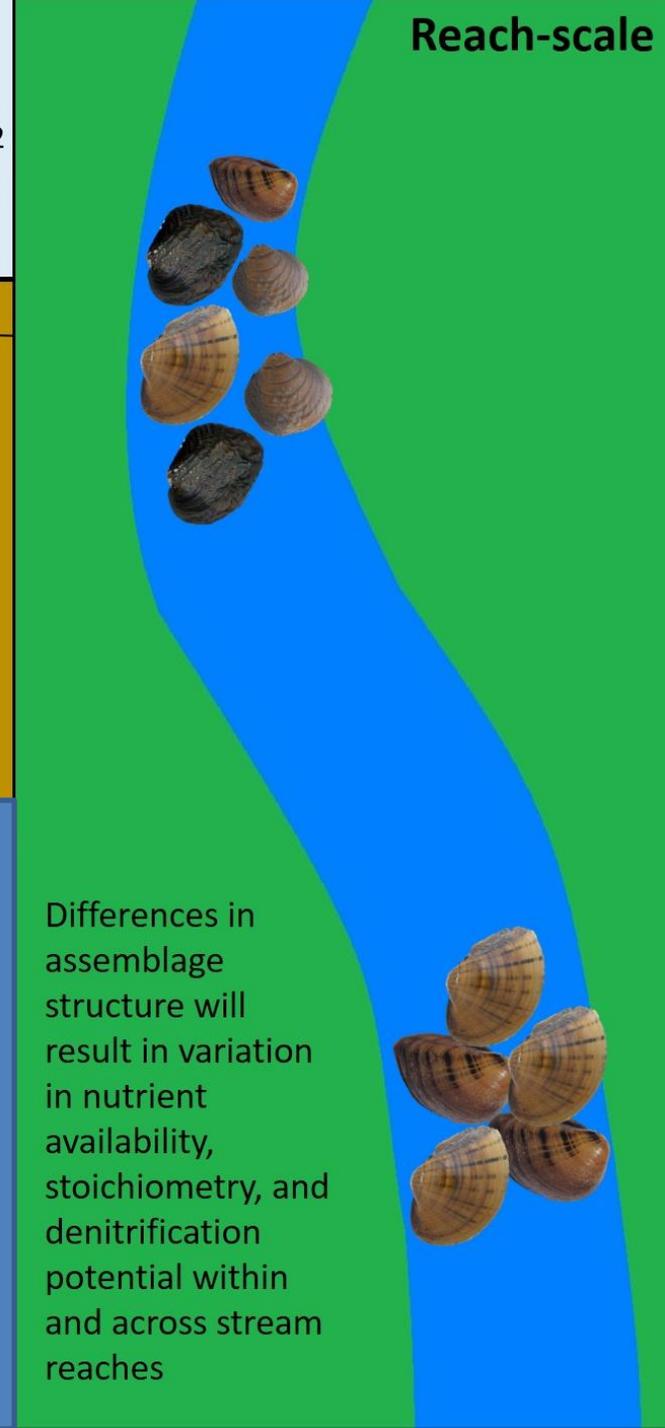
- Spiritual enrichment
- Aesthetic experiences
- Education



## Patch-scale



## Reach-scale



### Mussel function

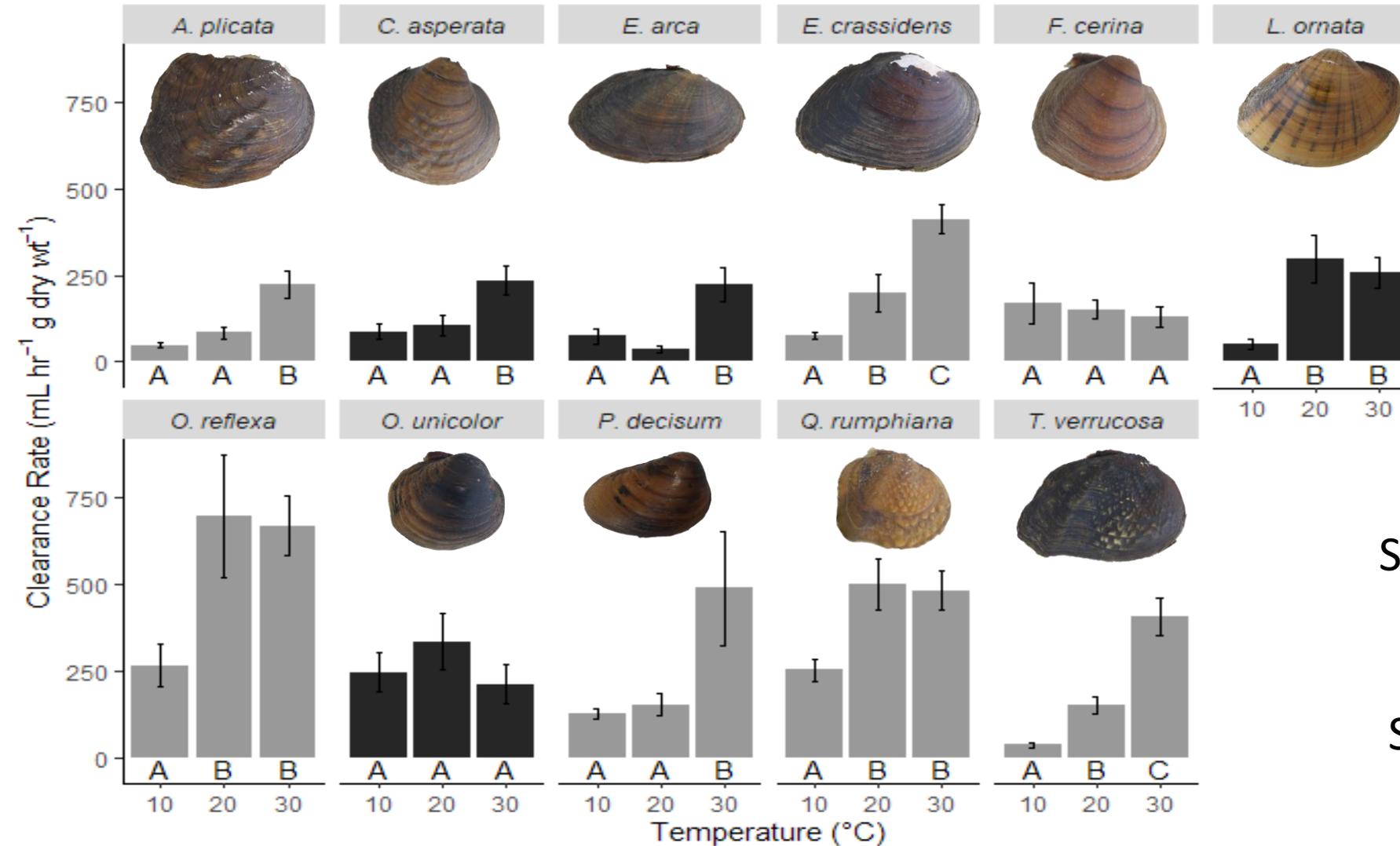
A	Filtration
B	Nutrient storage
C	Excretion
D	Biodeposition
E	Burying

**Different species often perform these functions differently – can result in varying provisioning of services**

Differences in assemblage structure will result in variation in nutrient availability, stoichiometry, and denitrification potential within and across stream reaches

# Filtration – regulating service

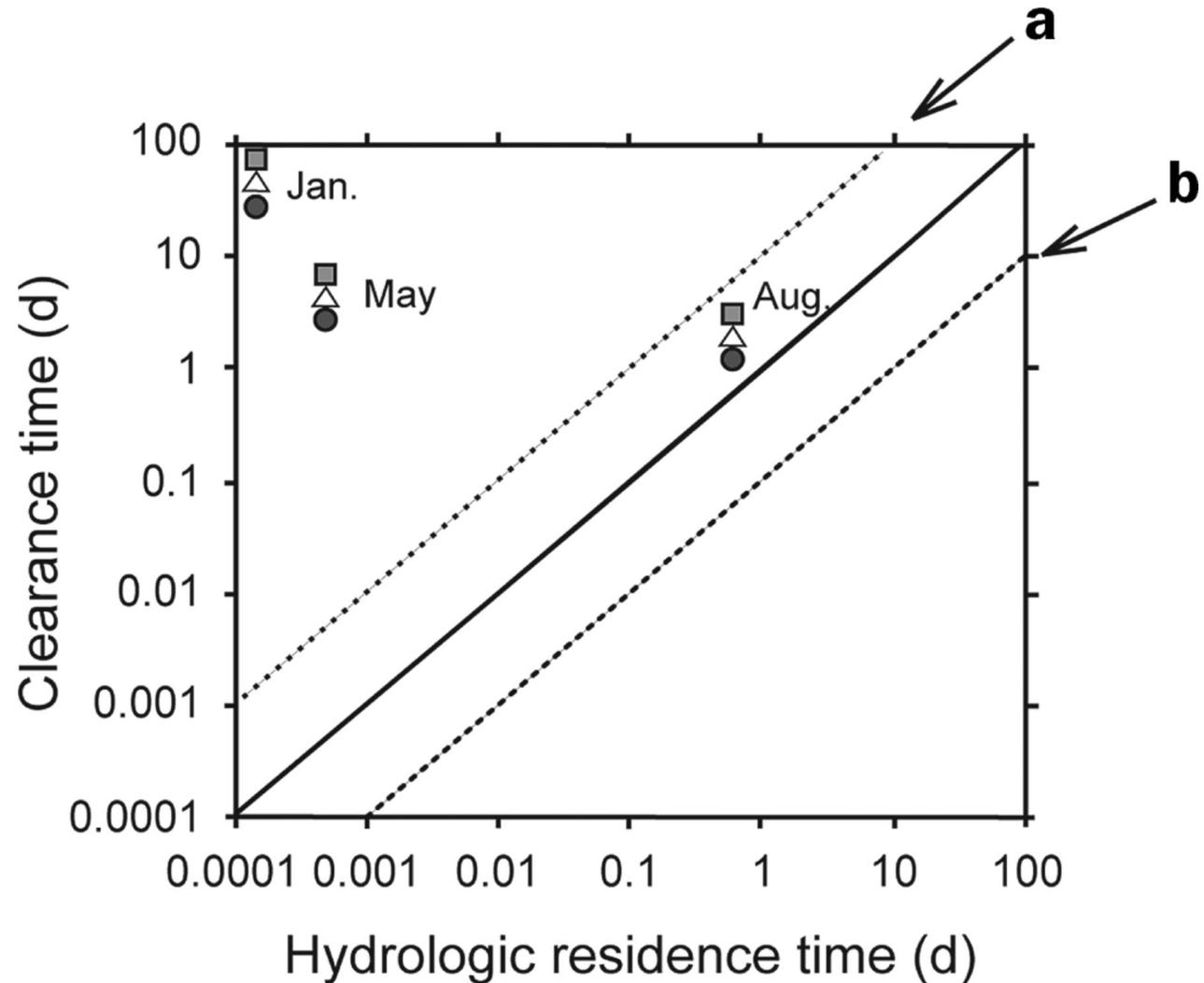
## A. Resource Acquisition



Species filter at different rates

Species filter differently across temperature

# Filtration – regulating service



Also, biomass and the environmental context shape the importance of these services

# Nutrient Storage – supporting service

## Soft Tissue Storage

### Niche volumes



● *Lampsilis ornata*



● *Obovaria unicolor*



● *Obliquaria reflexa*



● *Tritagonia verrucosa*



○ *Cyclonaias asperata*



● *Fusconaia cerina*



● *Pleurobema decisum*



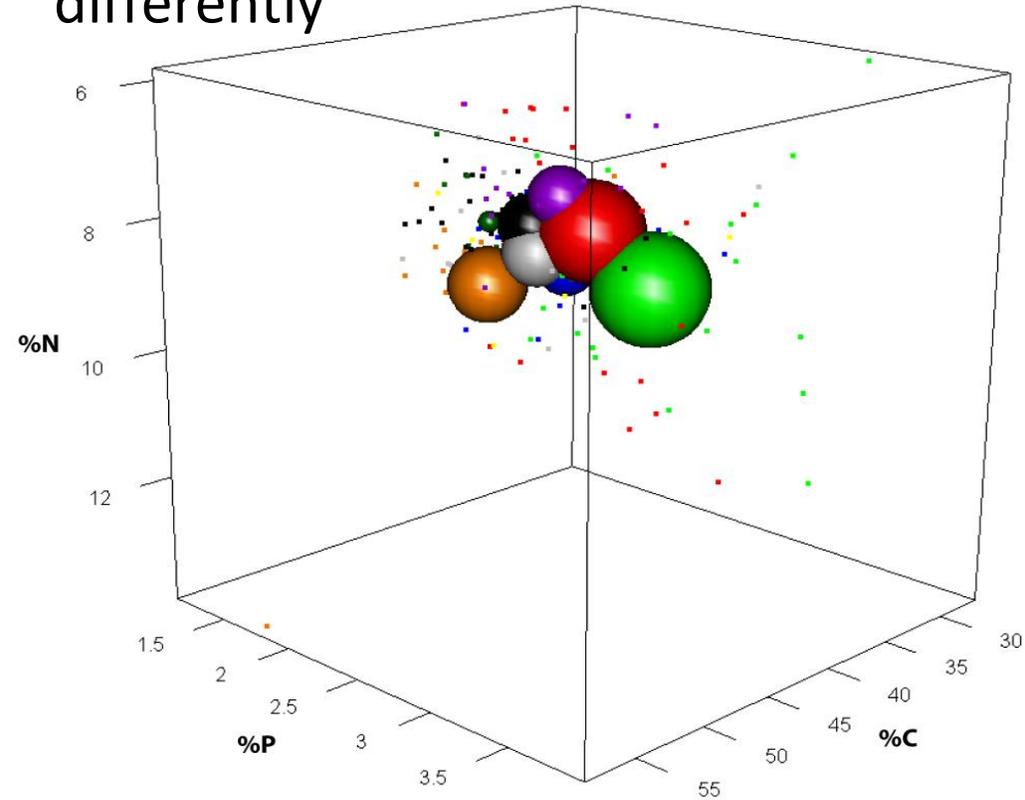
● *Elliptio arca*



● *Amblema plicata*

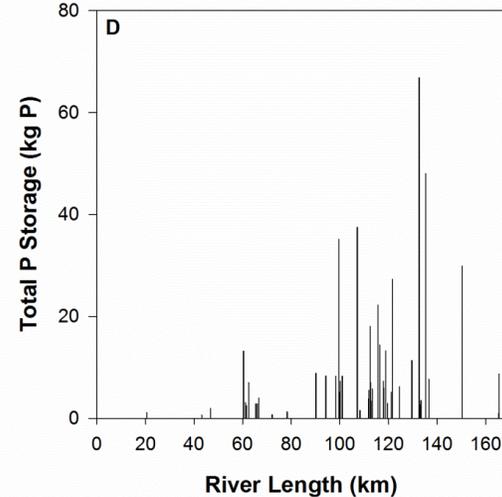
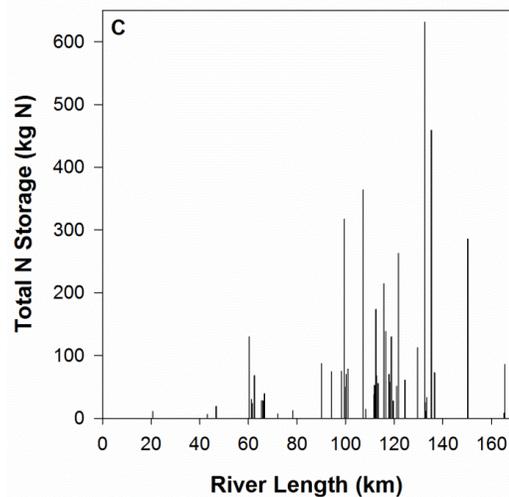
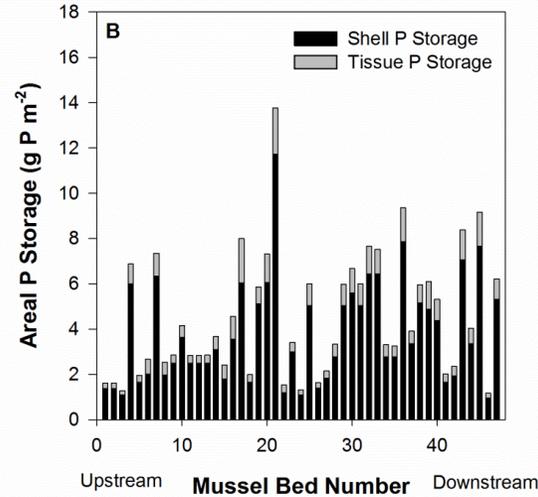
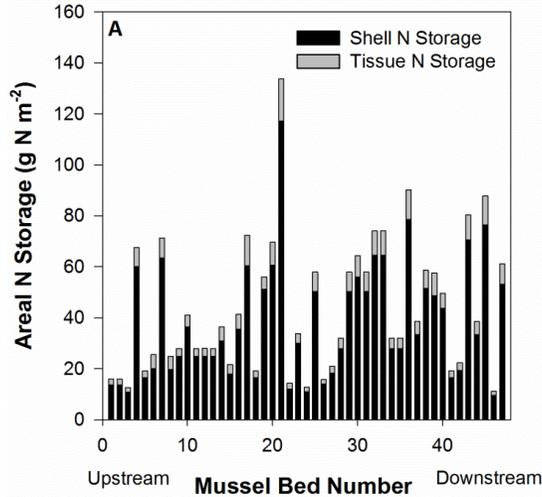


Species store nutrients differently



Atkinson, van Ee, and Pfeiffer, 2020 (*Ecology*)

# Nutrient Storage – supporting service

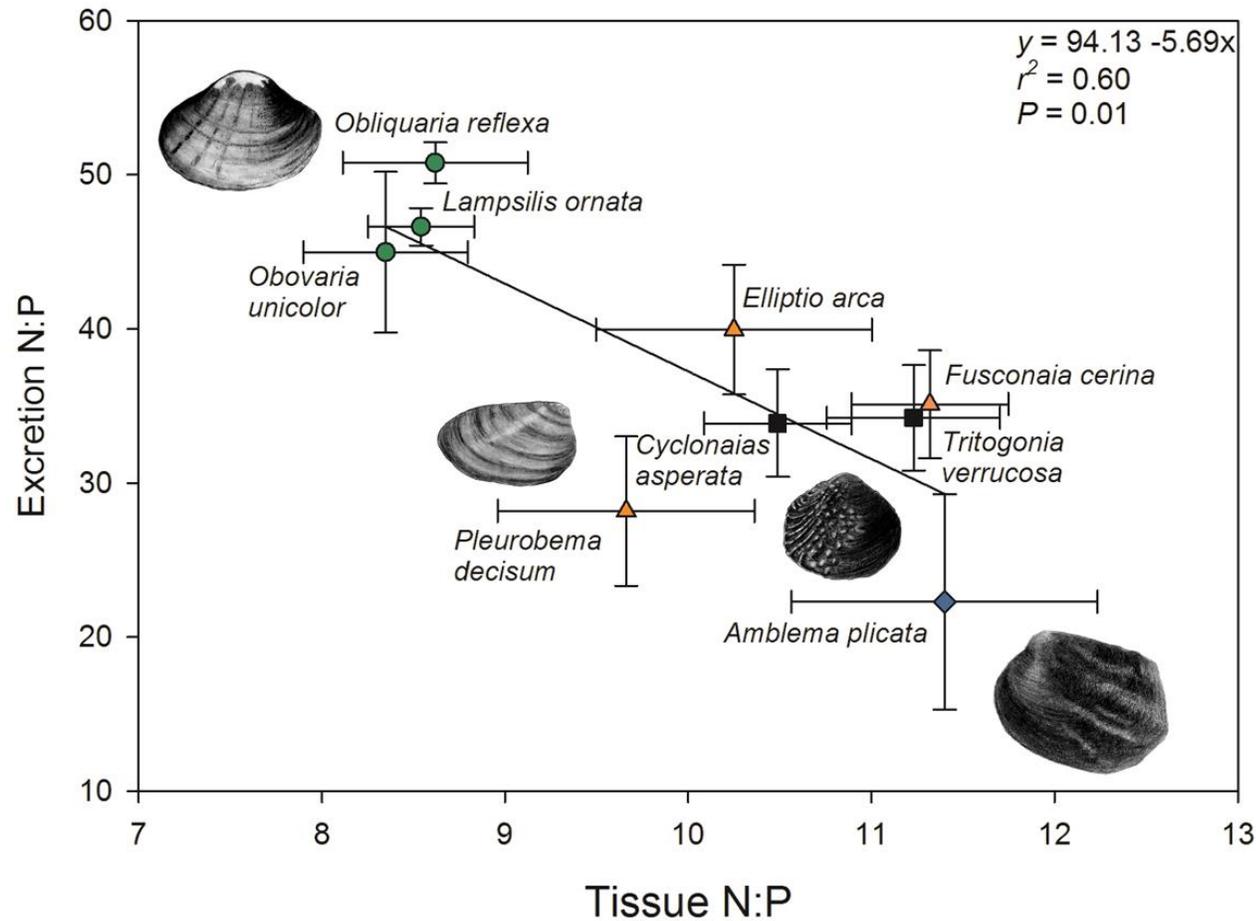


**Sequestration**

Mussels live 5 to >50 years

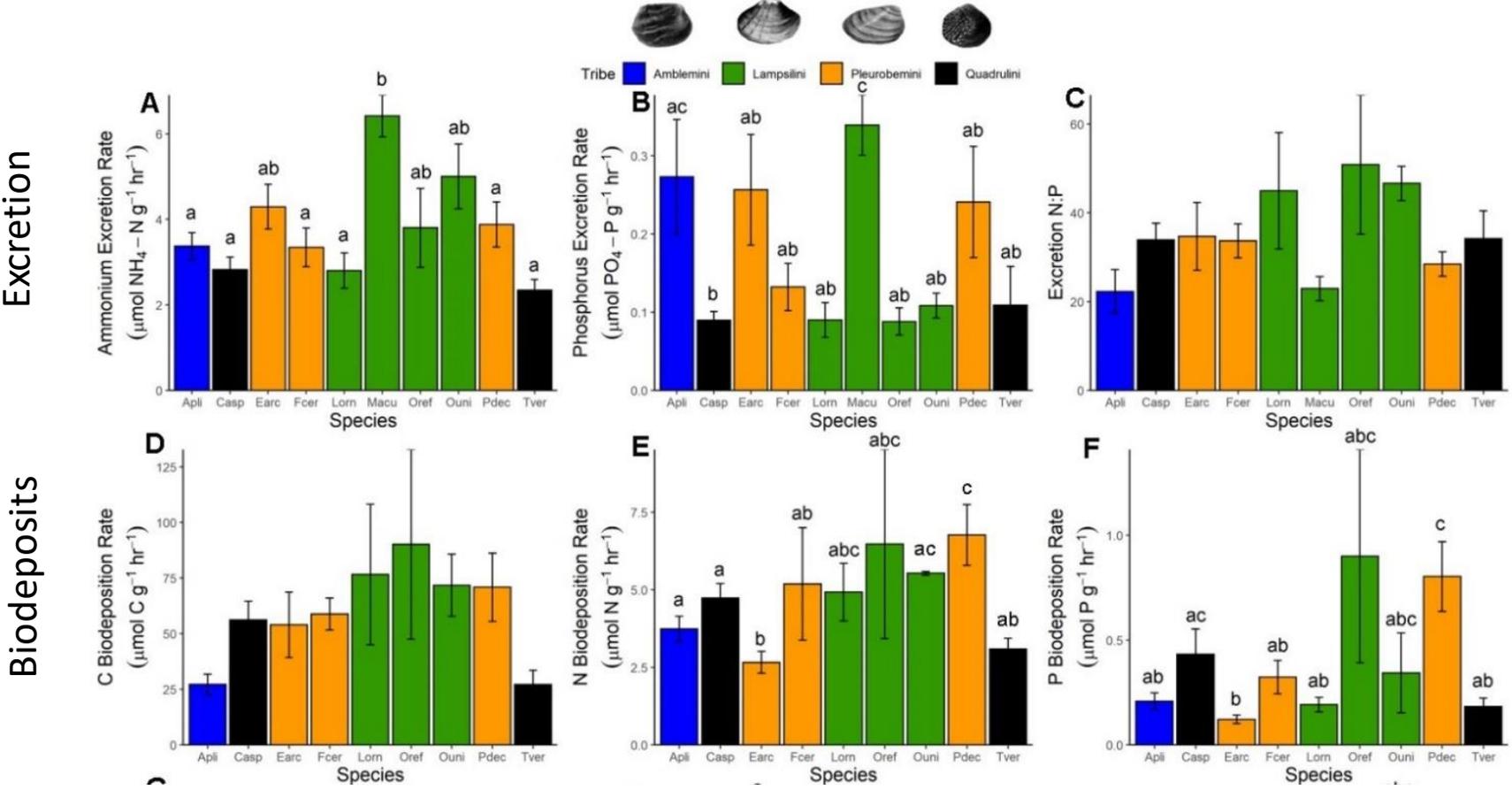
Shell = long term store, “nutrient sink”

# Concordance between Tissue and Excretion Stoichiometry

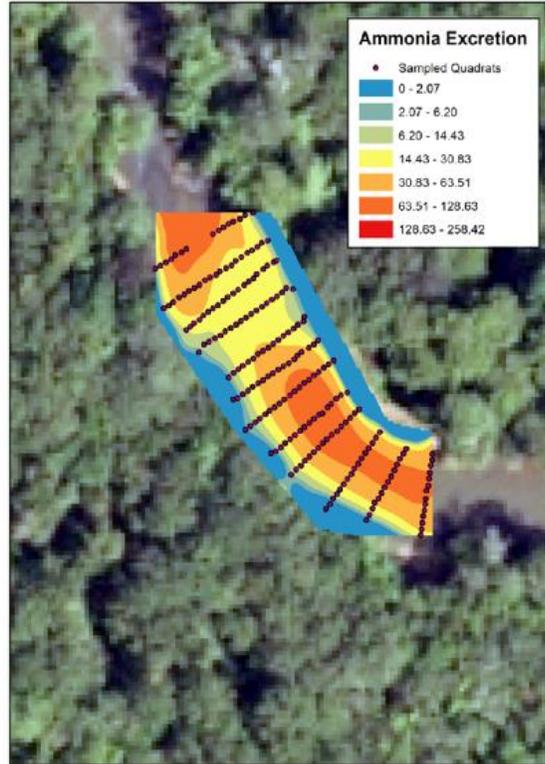


Meets the expectations of ecological stoichiometry

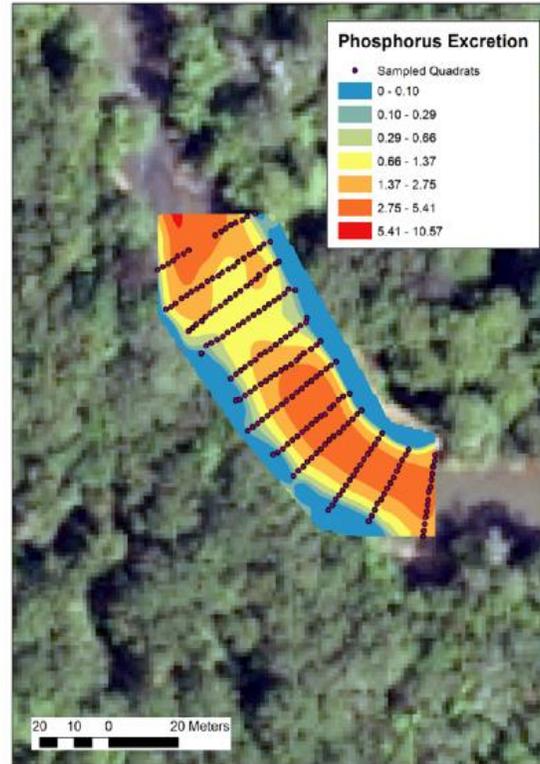
# Nutrient Recycling – supporting service



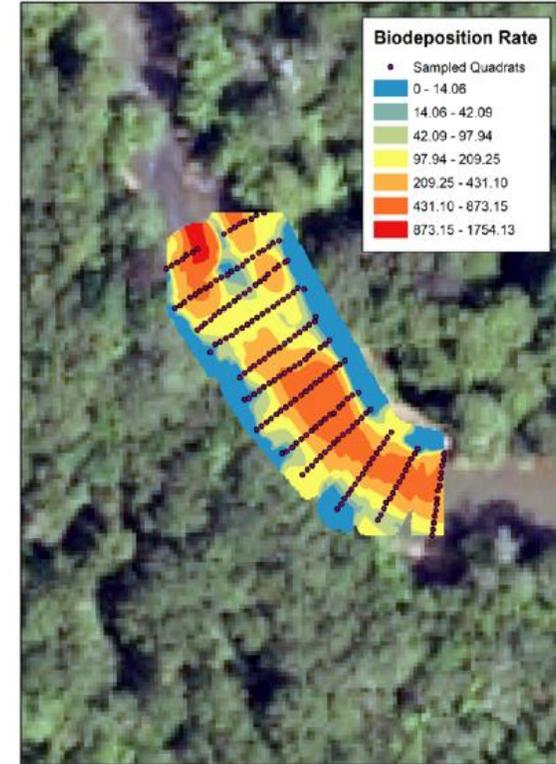
# Nutrient Cycling – supporting service



Average =  $41 \mu\text{mol N m}^{-2} \text{h}^{-1}$



Average =  $1.9 \mu\text{mol P m}^{-2} \text{h}^{-1}$



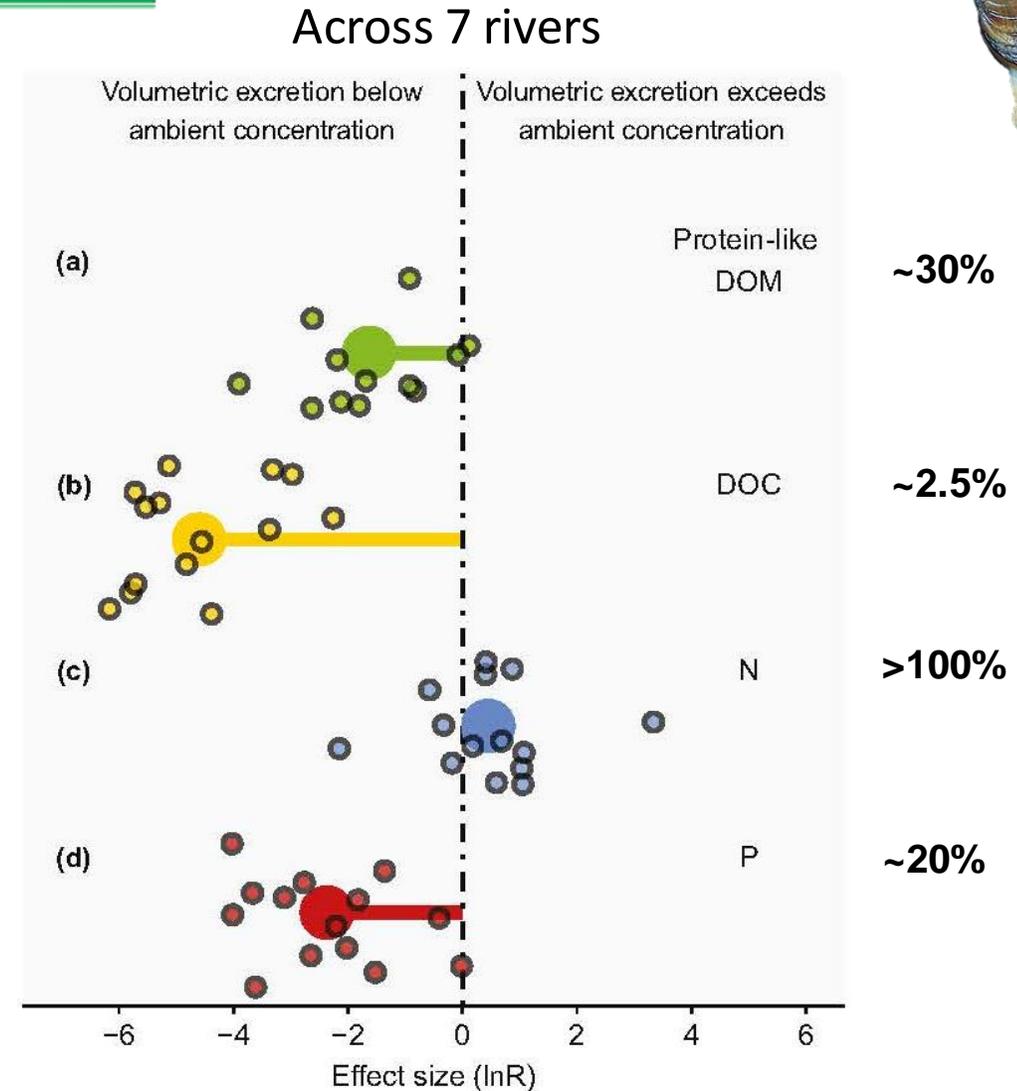
Average =  $243 \text{ mg DM m}^{-2} \text{h}^{-1}$



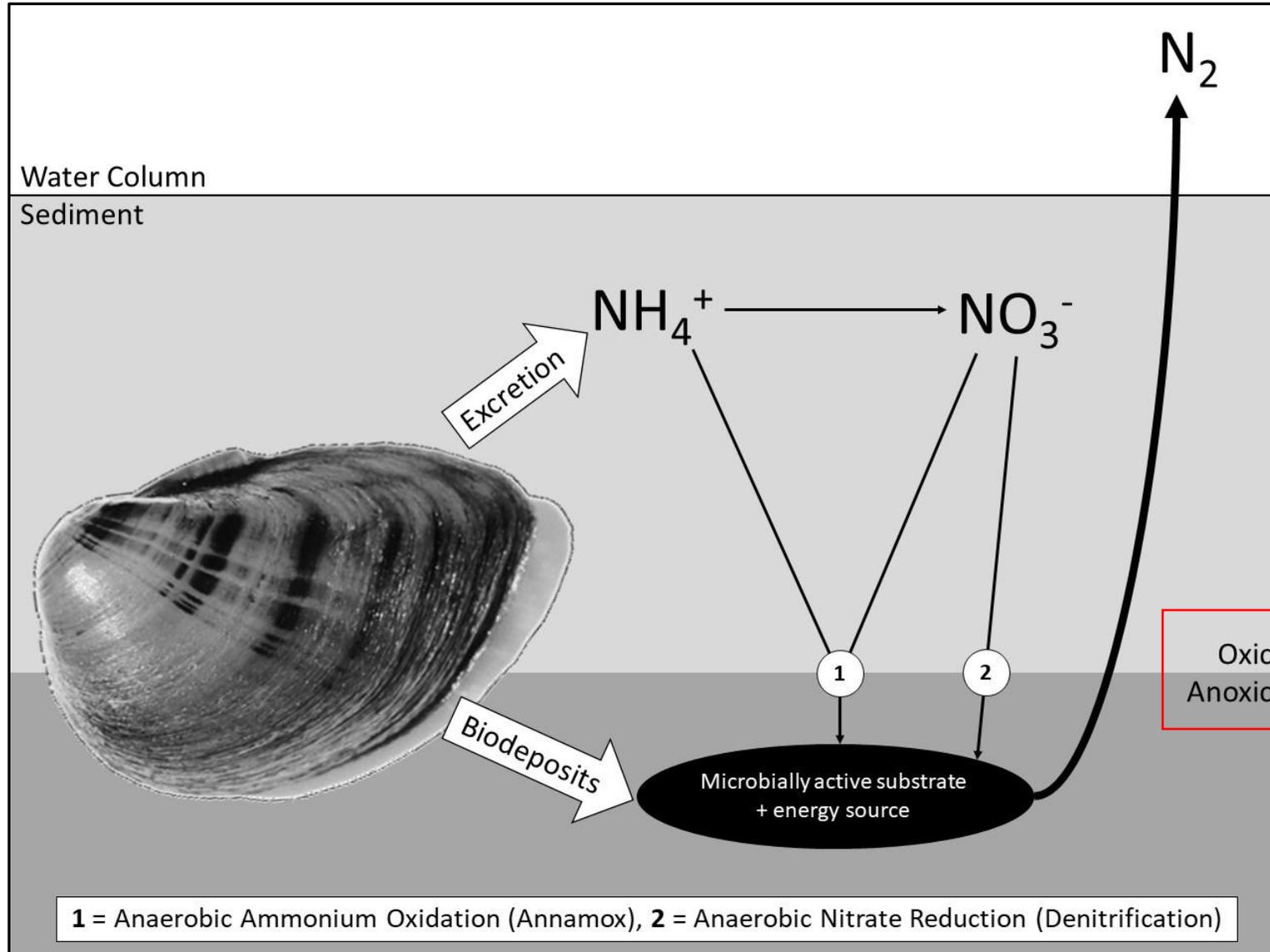
# Nutrient Cycling – supporting service



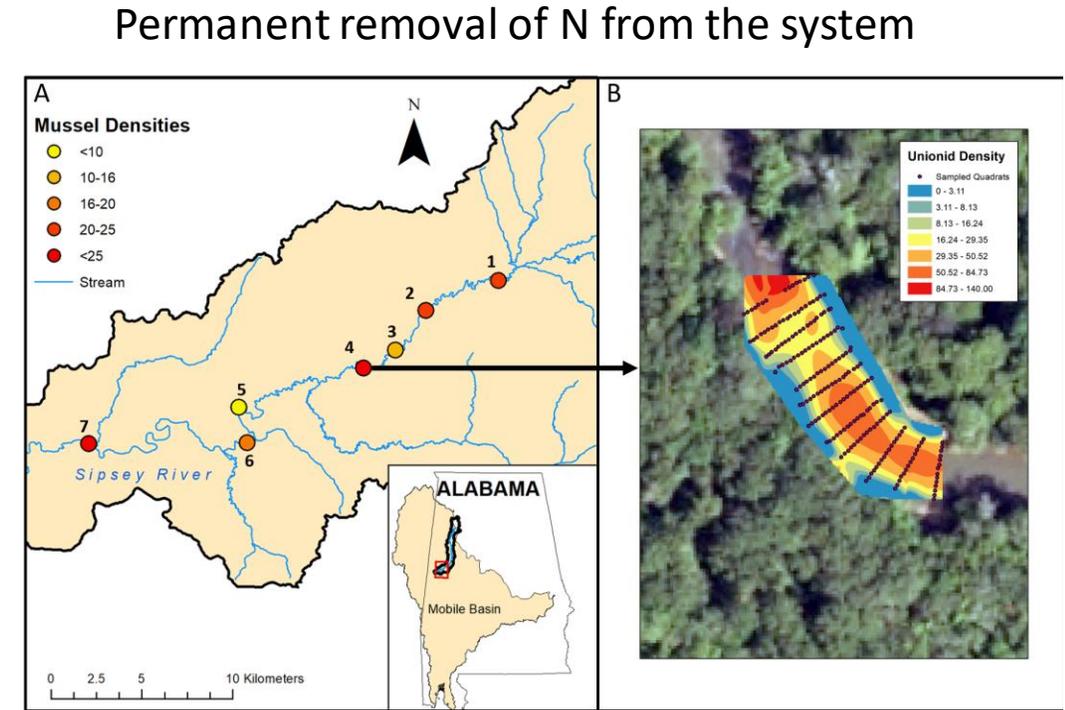
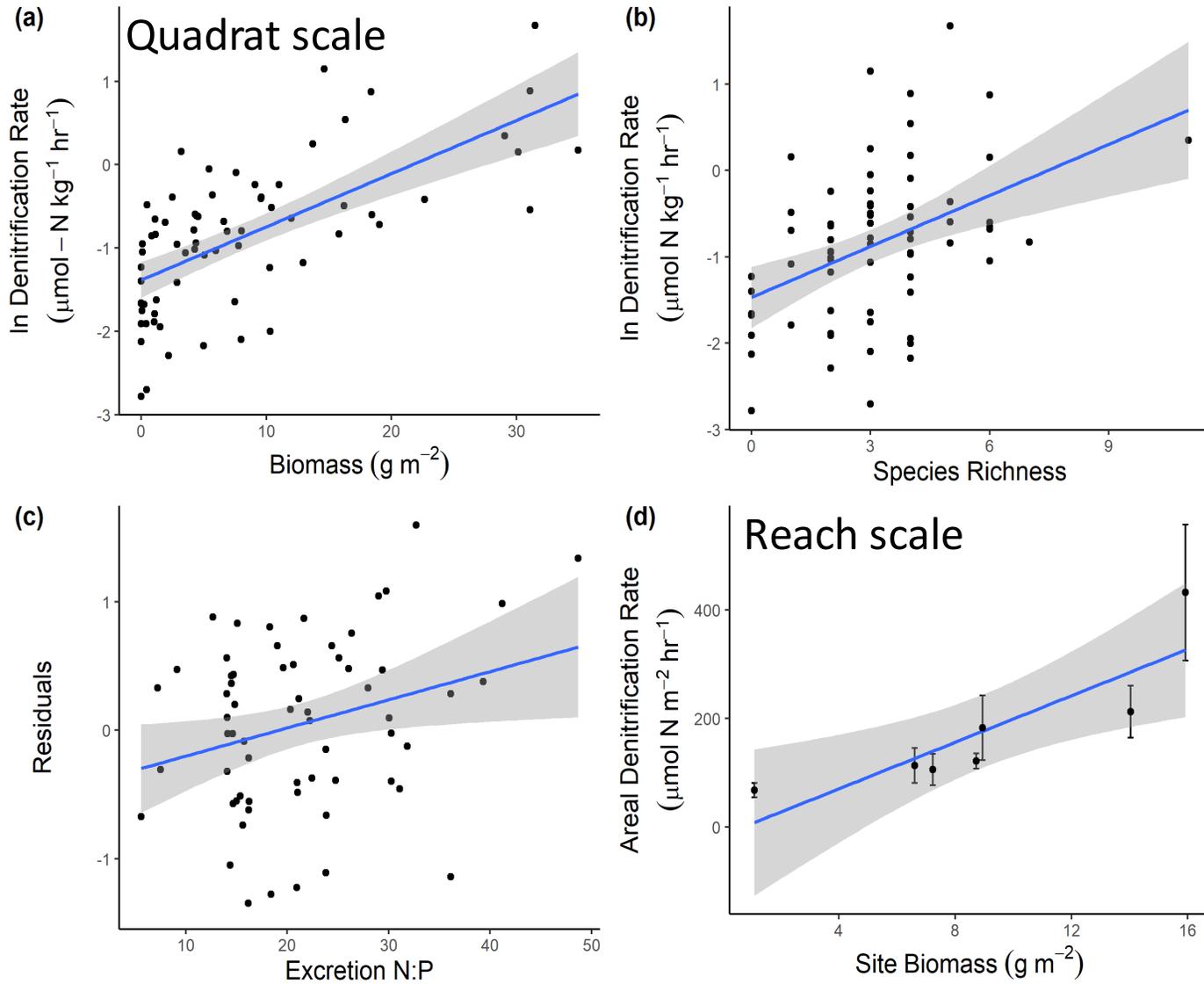
- Excretion can meet or exceed background nutrient conditions & demand
- Mussels are a major source of N, P, and labile DOM
- Labile DOM may be important for heterotrophic microbes that fuel river food webs



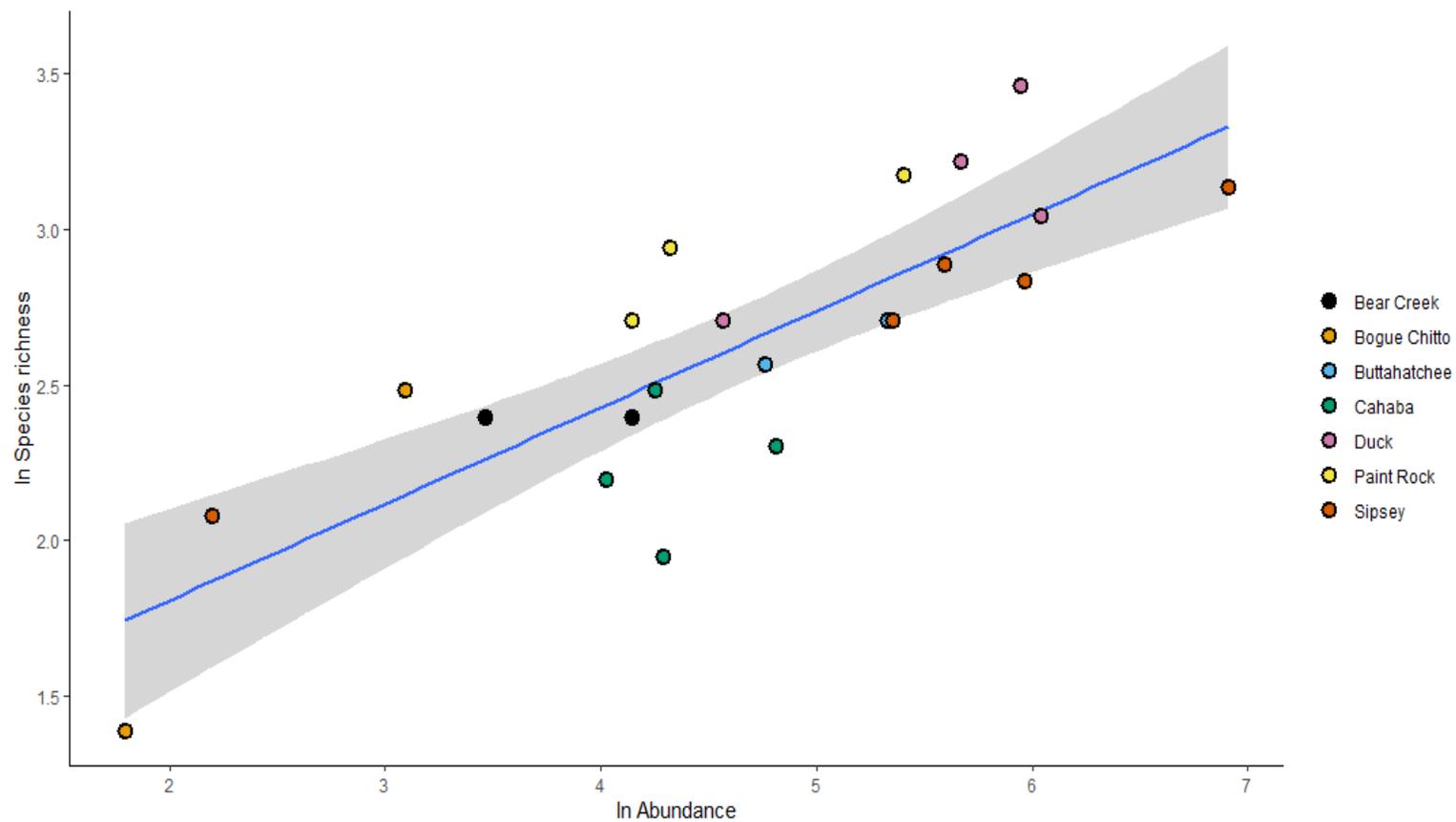
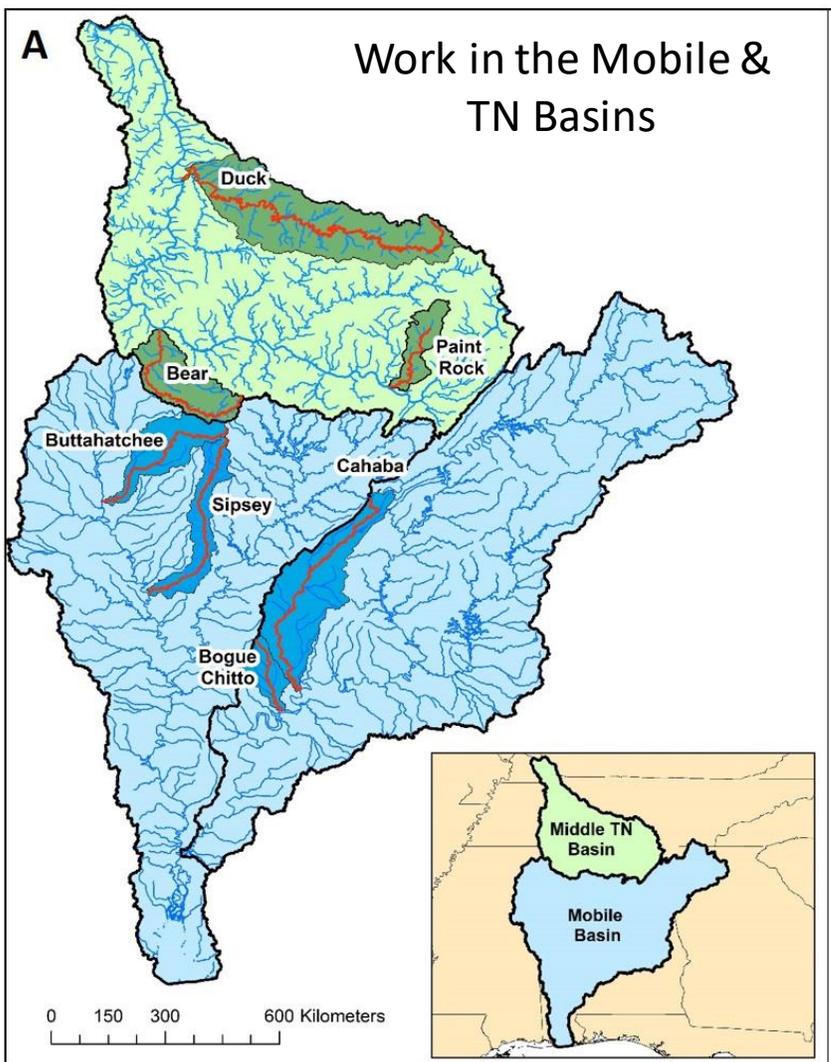
# Indirect Effects on Supporting Services



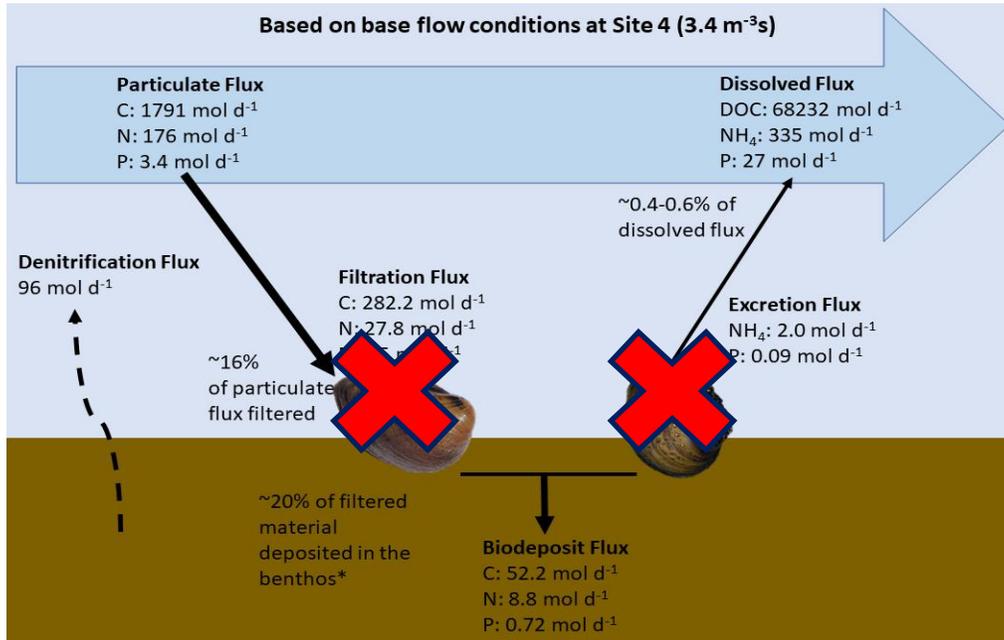
# Mussels Enhance Denitrification Rates



Maintain abundance = maintenance of biodiversity = maintenance of function

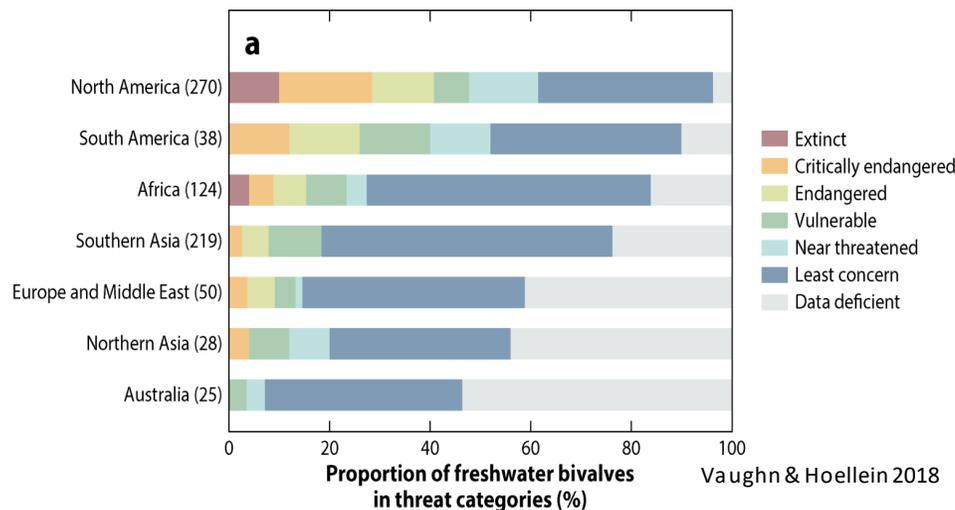


# Ecosystem management is important for both biodiversity and ecosystem services

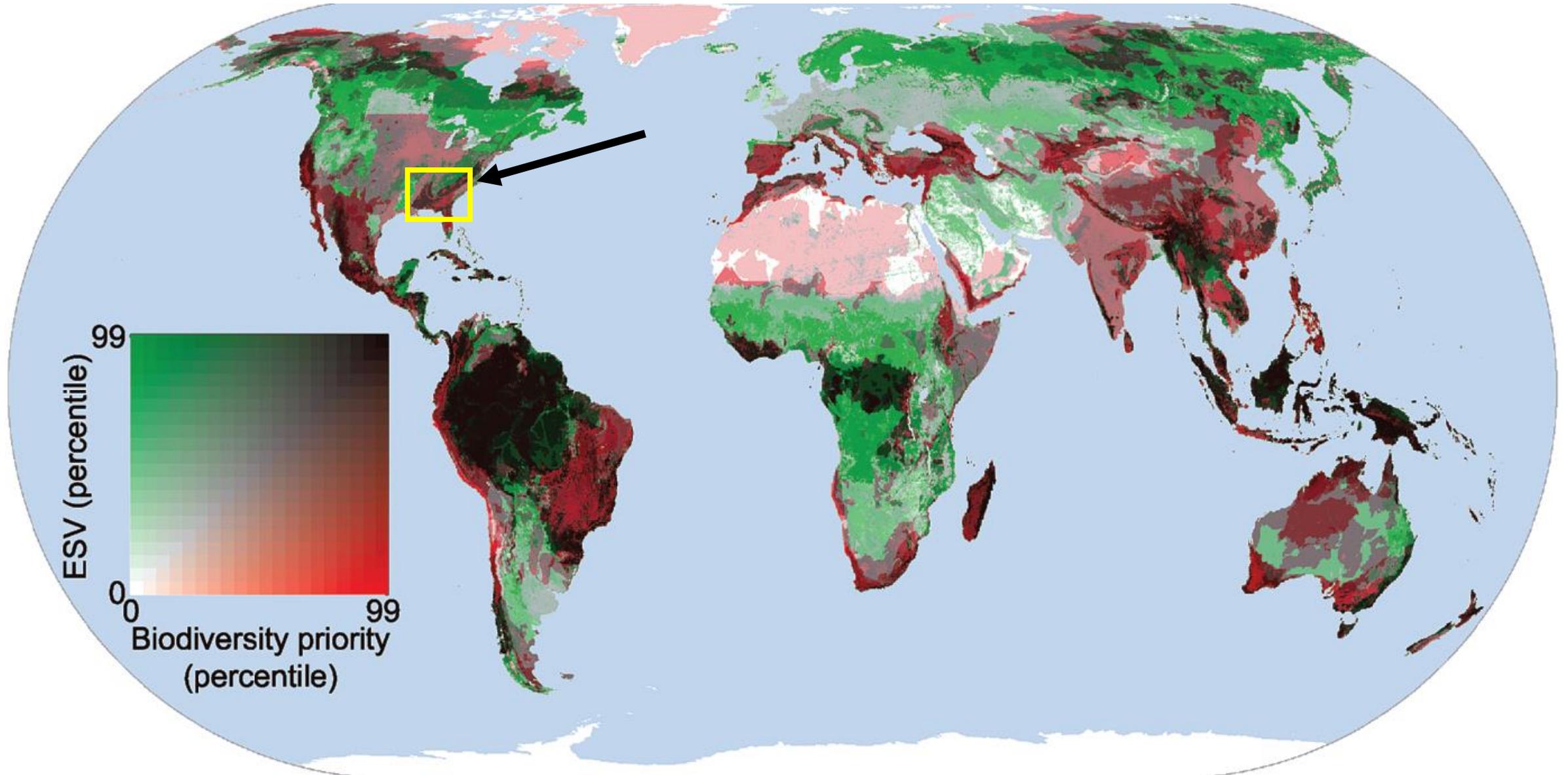


What does the loss of mussels result in for aquatic ecosystem service provisioning in the past/present/future?

Mussels appear to be more prone to declines than many other aquatic organisms.



# Both Biodiversity and Ecosystem Services are of High Priority Conservation Value in this Region



What to do to maintain ecosystem services and biodiversity in the ACF?

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# How to maintain ecosystem services and biodiversity in the ACF?

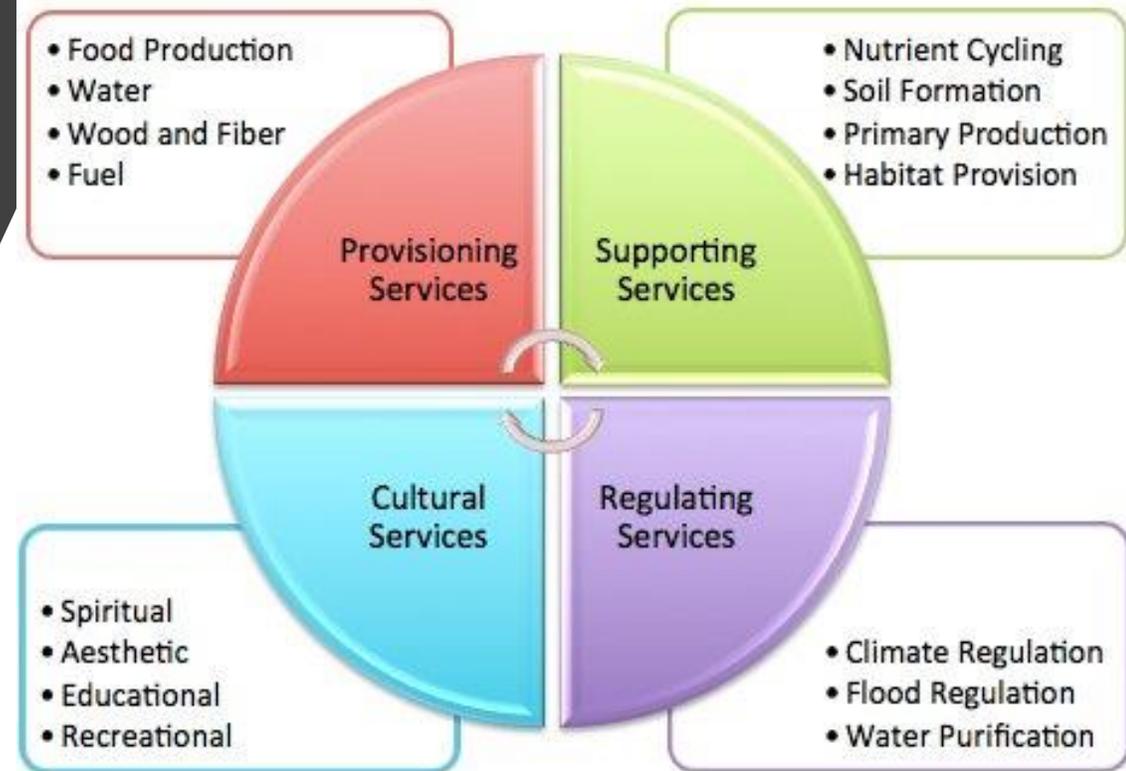
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- **Water quantity and conservation**
- Enhancement of riparian zones for sediment and nutrient mitigation
- **Better management that takes a whole system & multi-species approach**
- **Outreach and education**



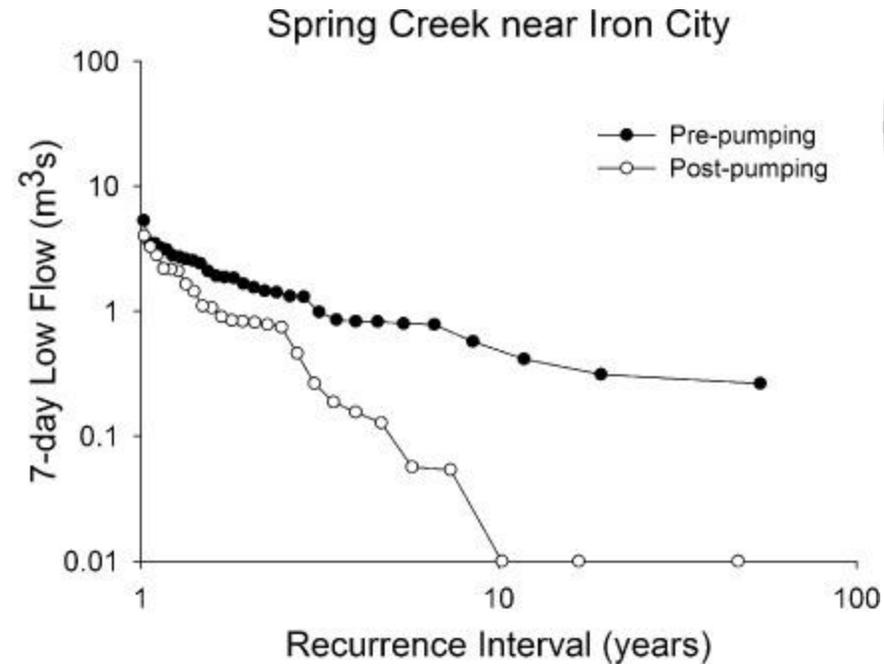
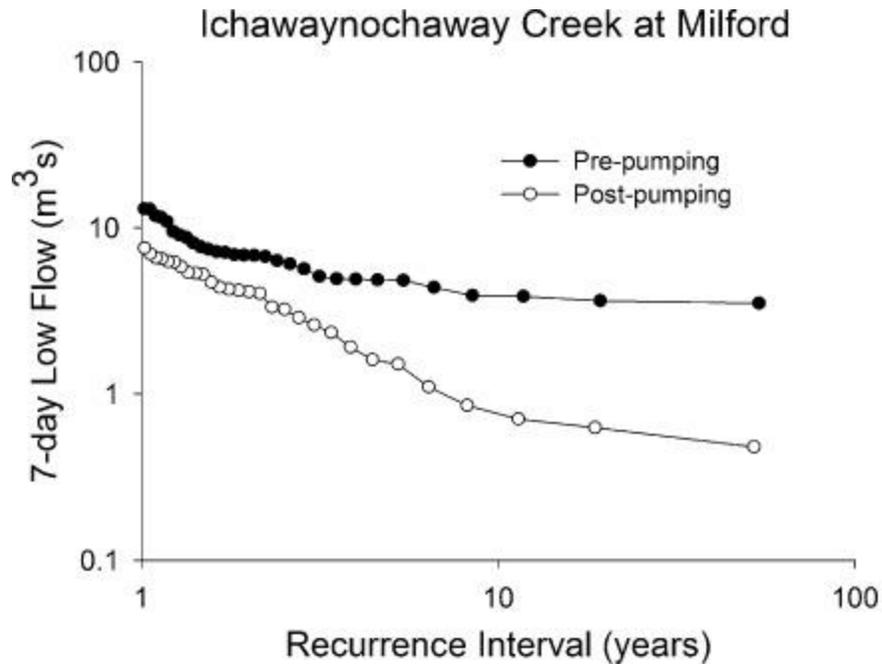


Some of these ecosystem services may result in conflicts among users



Source: Millenium Ecosystem Assessment, 2005.

# Need water to secure these ecosystem services



Irrigation is drawing down flows that reduces habitat for aquatic species & increases stream temperature

# Need water to secure these ecosystem services

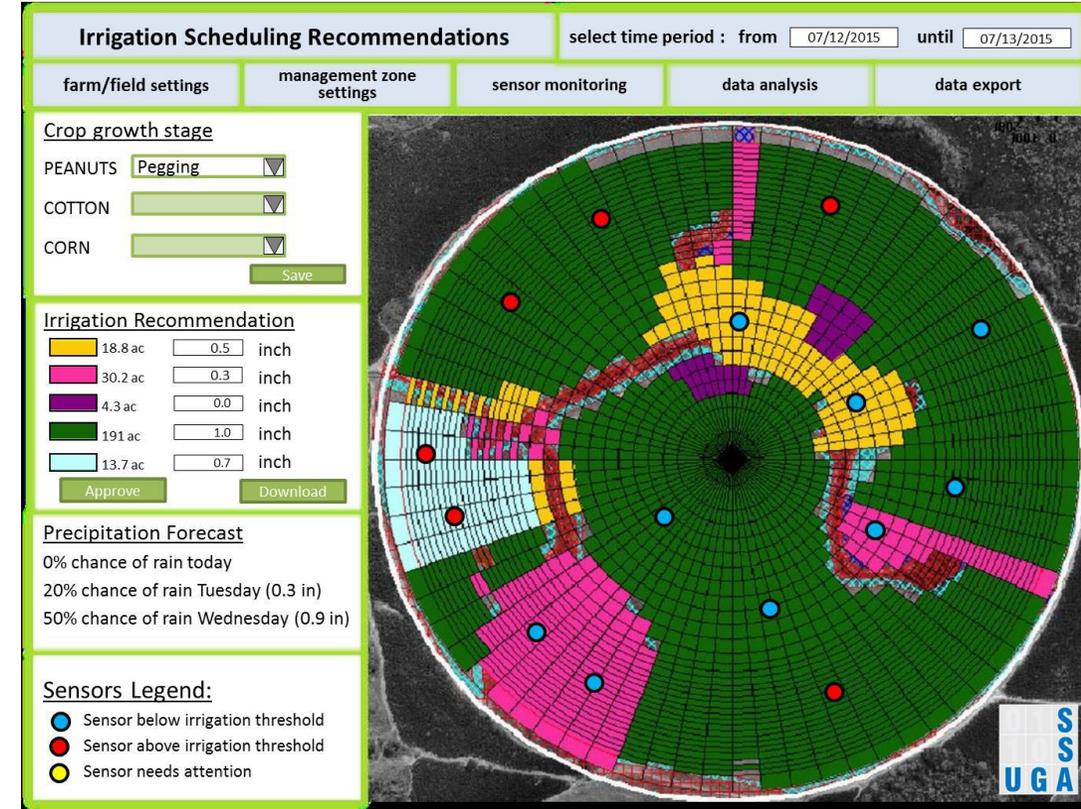
No aquatic organism provided ecosystem services without water!



# Need water to secure these ecosystem services



More efficient irrigation systems (e.g., dynamic variable rate irrigation)



Lake  
Seminole



Flow and water management strategies need to change and keep evolving based on science



*Alosa* spp.



*Elliptio  
crassidens*



*Alosa* spp.



*Elliptio crassidens*

ARTICLE

## Passage of Spawning Alabama Shad at Jim Woodruff Lock and Dam, Apalachicola River, Florida

**Shawn P. Young**

*Department of Forestry and Natural Resources, Clemson University, 115 Lehotsky Hall, Clemson, South Carolina 29634-0317, USA*

**Travis R. Ingram\* and Josh E. Tannehill**

*Georgia Department of Natural Resources, 2024 Newton Road, Albany, Georgia 31701, USA*

**J. Jeffery Isely**

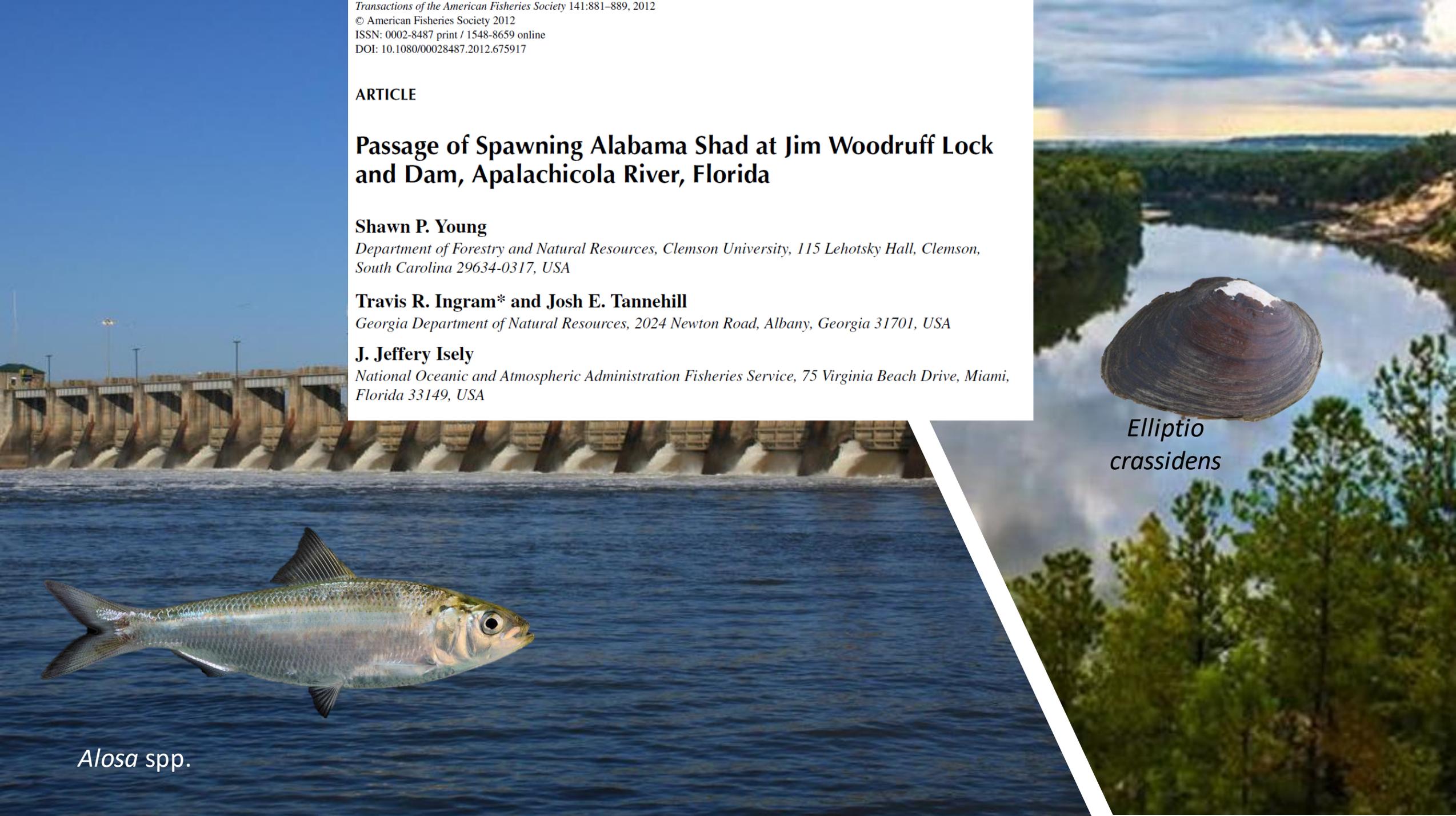
*National Oceanic and Atmospheric Administration Fisheries Service, 75 Virginia Beach Drive, Miami, Florida 33149, USA*



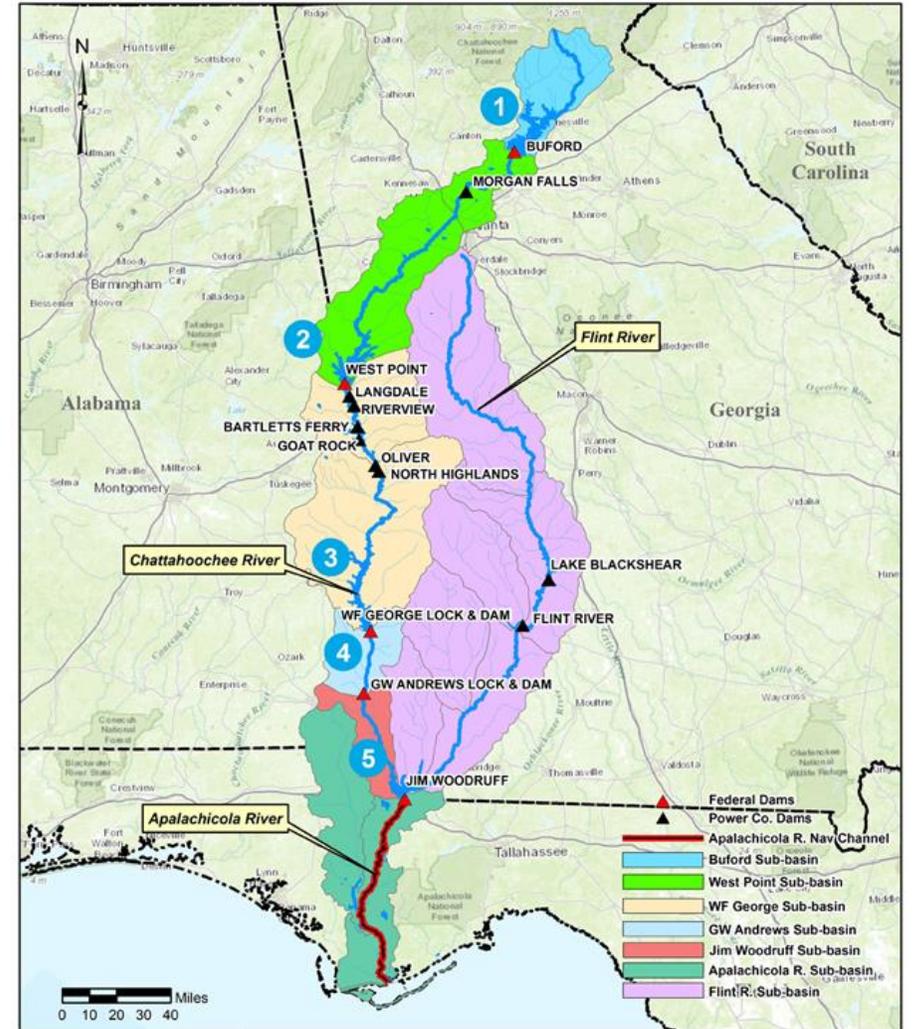
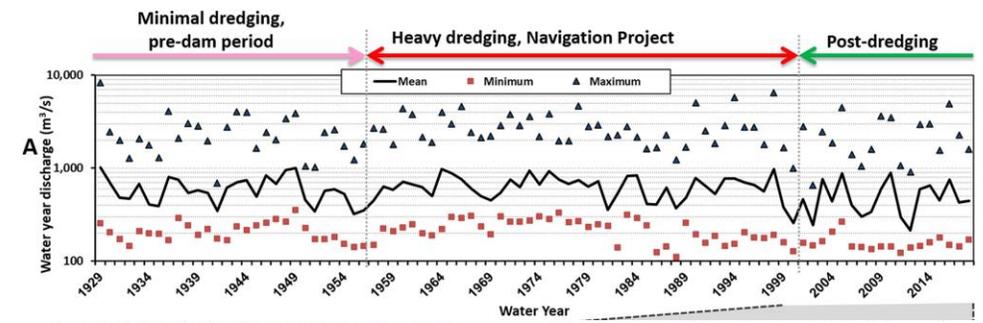
*Alosa* spp.



*Elliptio  
crassidens*



# Major channel and habitat modifications





Ogeechee tupelo

RIVER RESEARCH AND APPLICATIONS

*River Res. Applic.* **29**: 718–733 (2013)

Published online 9 March 2012 in Wiley Online Library  
(wileyonlinelibrary.com) DOI: 10.1002/rra.2567

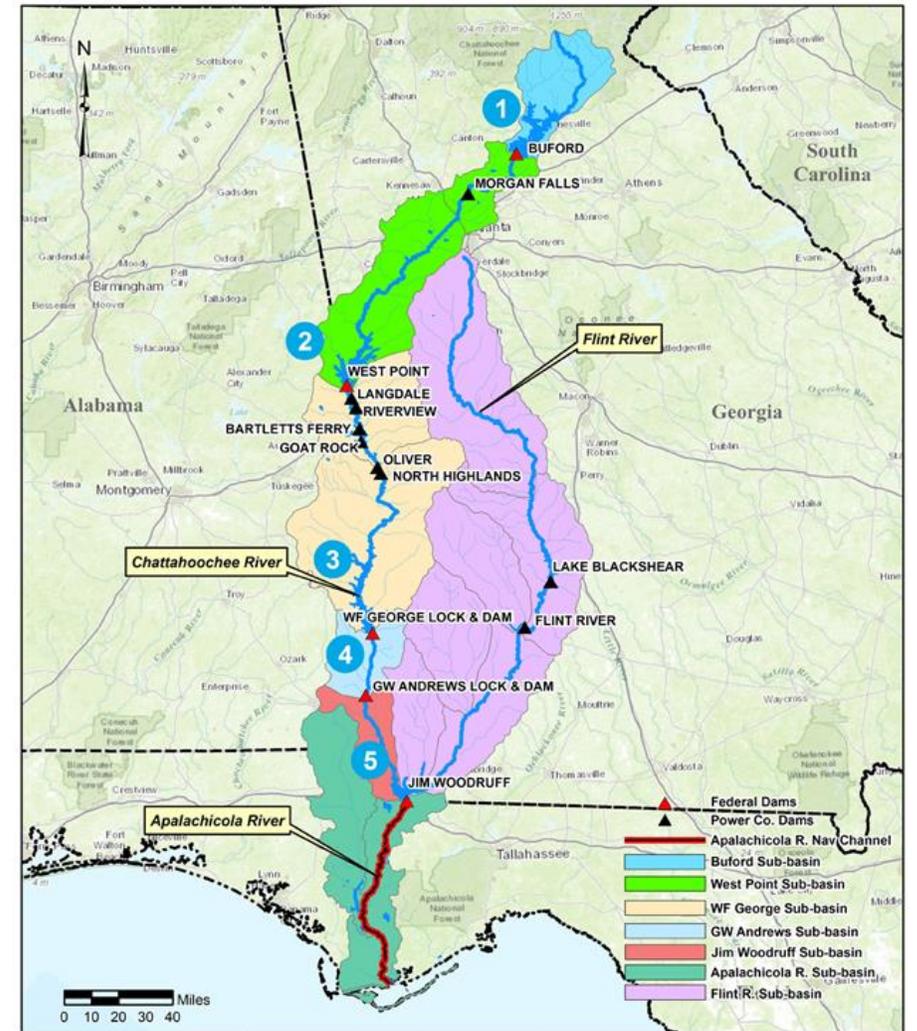
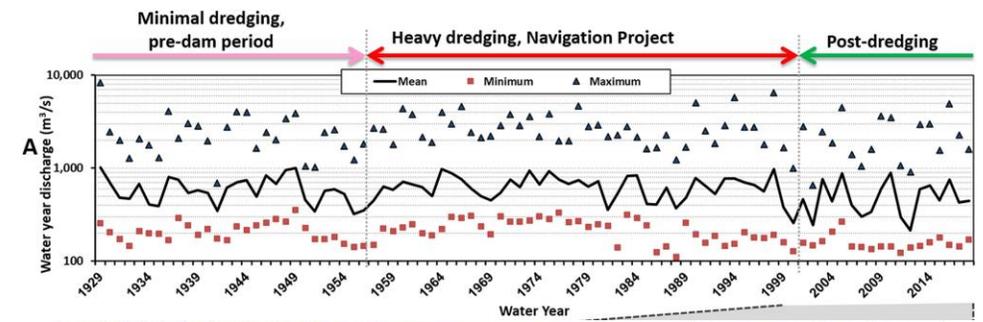
## IMPORTANCE OF FLOODPLAIN CONNECTIVITY TO FISH POPULATIONS IN THE APALACHICOLA RIVER, FLORIDA

O. T. BURGESS<sup>a</sup>, W. E. PINE III<sup>b\*</sup> and S. J. WALSH<sup>c</sup>

<sup>a</sup>University of Florida, Fisheries and Aquatic Science Program, Gainesville, Florida USA

<sup>b</sup>Department of Wildlife Ecology and Conservation, Fisheries and Aquatic Science Program, Gainesville, Florida USA

<sup>c</sup>Biological Survey, Southeast Ecological Science Center, Gainesville, Florida, USA



# More outreach and education



Existence Value



Ecosystem Services

There are still a lot of issues....



Lake Lanier,  
August 2007



Lake Lanier,  
October 2016

# There are still a lot of issues....

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Camp, E. V., W. E. Pine III, K. Havens, A. S. Kane, C. J. Walters, T. Irani, A. B. Lindsey, and J. G. Morris. 2015. Collapse of a historic oyster fishery: diagnosing causes and identifying paths toward increased resilience. *Ecology and Society* 20(3):45. <http://dx.doi.org/10.5751/ES-07821-200345>



*Insight*

## Collapse of a historic oyster fishery: diagnosing causes and identifying paths toward increased resilience

[Edward V. Camp](#)<sup>1</sup>, [William E. Pine III](#)<sup>2</sup>, [Karl Havens](#)<sup>3</sup>, [Andrew S. Kane](#)<sup>4,5,6</sup>, [Carl J. Walters](#)<sup>7</sup>, [Tracy Irani](#)<sup>8,9</sup>, [Angela B. Lindsey](#)<sup>9,10</sup> and [J. Glenn Morris, Jr.](#)<sup>11,12</sup>



NATIONAL

## Florida Closes Iconic Apalachicola Oyster Fishery

July 22, 2020 · 5:03 AM ET

Heard on Morning Edition



DEBBIE ELLIOTT



3-Minute Listen

+ PLAYLIST



# Concluding Thoughts

The ACF is a really special place that harbors incredible diversity and provides ecosystem services to millions of people

Implementation of policy needs to be more efficient

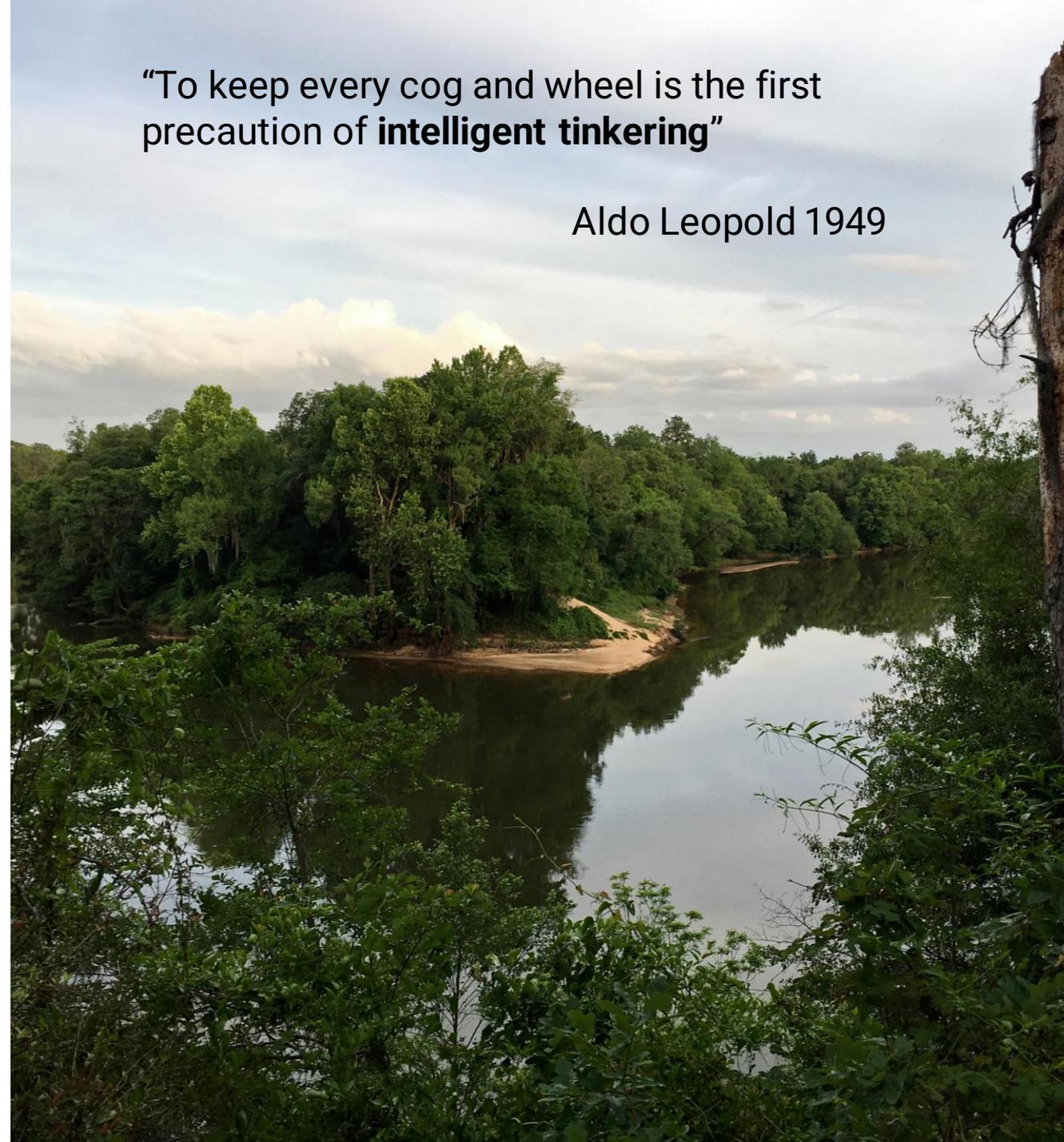
Progress is being made, but we need to work together more to meet common goals

More basic research is needed to understand how management activities influence species recovery and ecosystem services

In the face of climate change and further land conversion, we need to implement protection strategies that will preserve biodiversity and ecosystem services

“To keep every cog and wheel is the first precaution of **intelligent tinkering**”

Aldo Leopold 1949



# ANY QUESTIONS?

More info

Email: [clatkinson@ua.edu](mailto:clatkinson@ua.edu)

Website: <https://atkinsonlab.ua.edu>

@carlaLatkinson

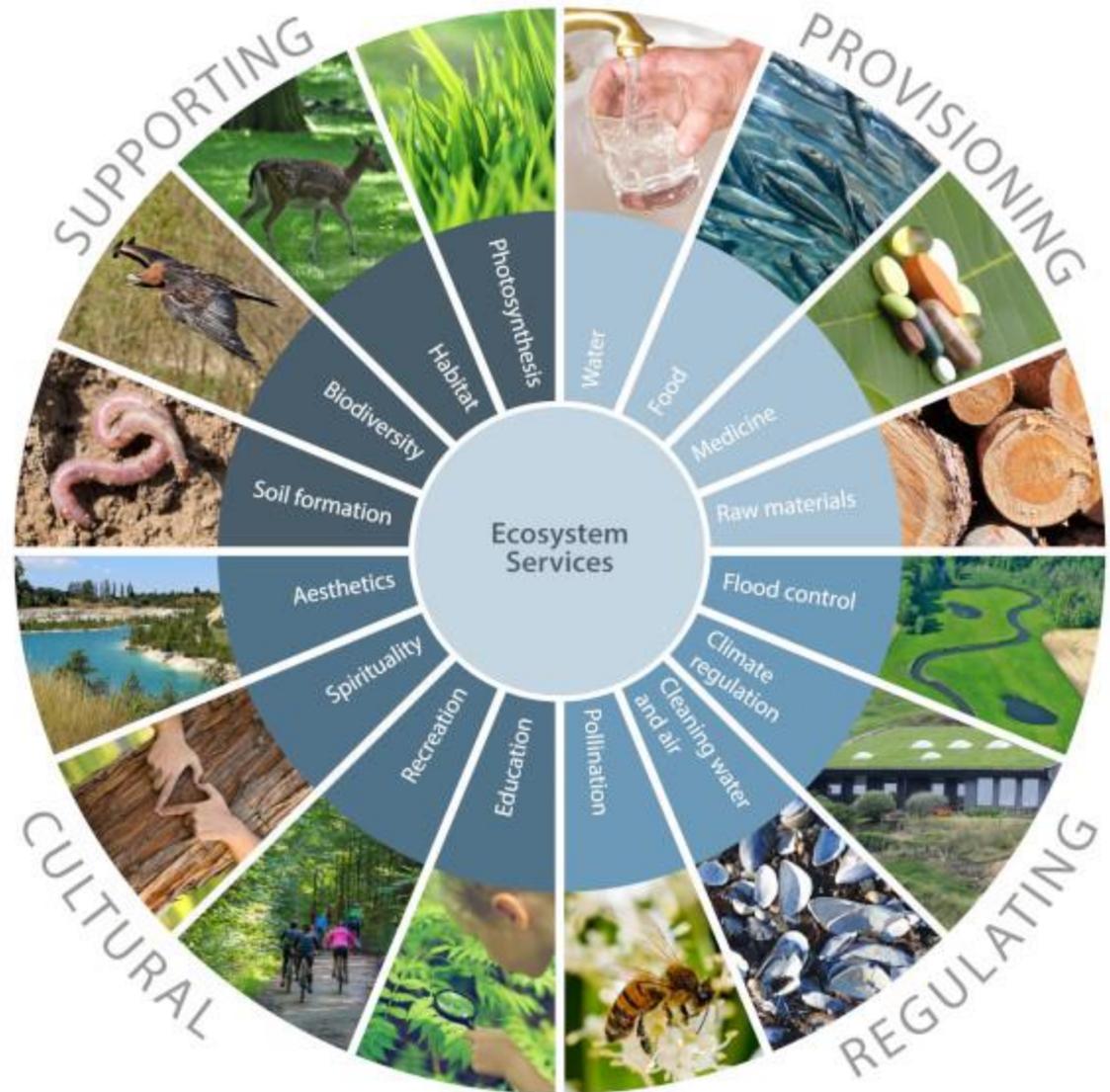


**“Mussels are not dismissible, even by those who have little interest in the natural world. Their presence is a signature of healthy aquatic ecosystems, to which they contribute as living water filters.”**

**- E.O. Wilson**

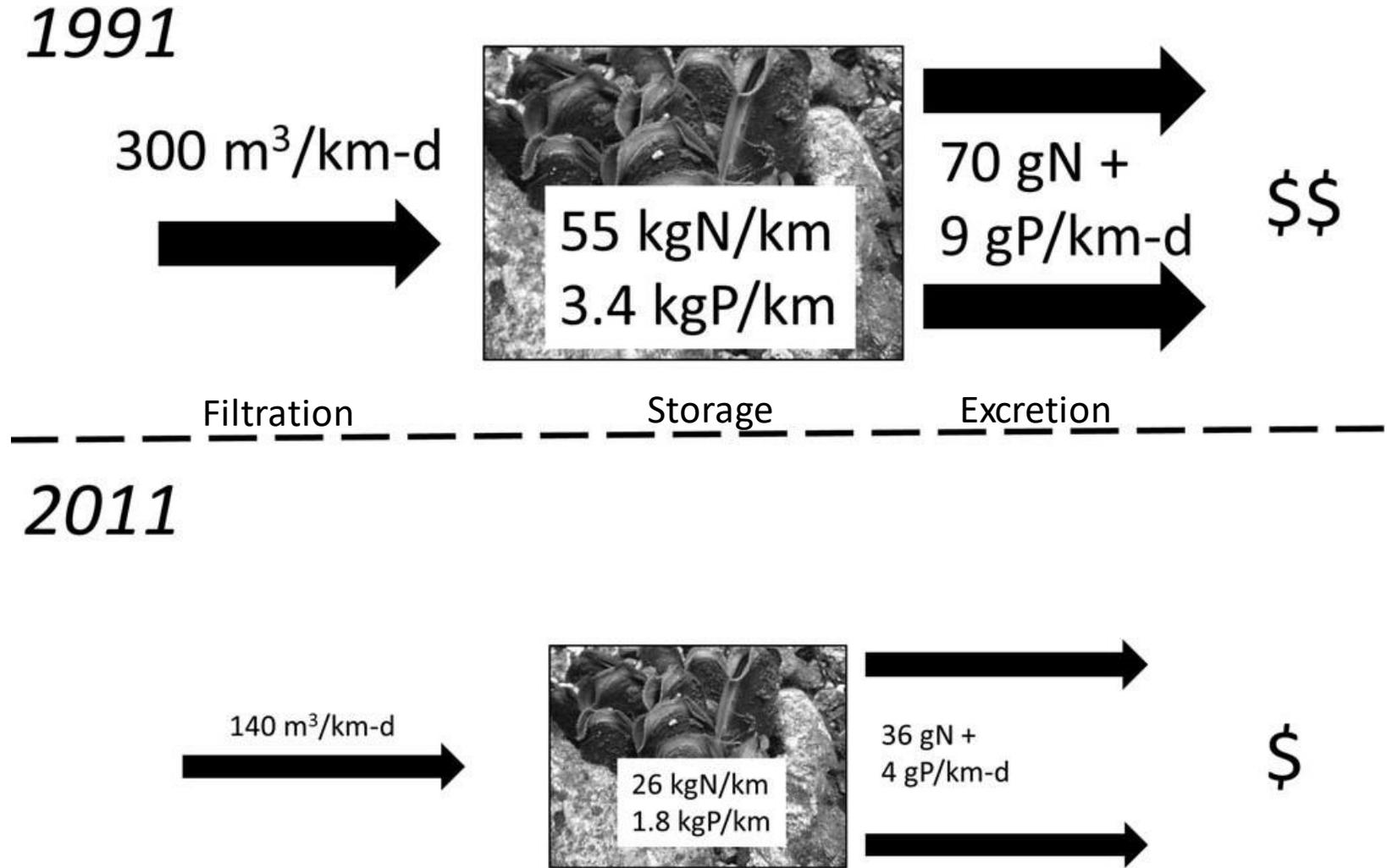
“To keep every cog and wheel is the first precaution of **intelligent tinkering**”

- Leopold 1949



# Reduction in Function = Reduction in Services

Species composition also matters!



Value ≠ Price

RIVER RESEARCH AND APPLICATIONS

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## IMPORTANCE OF FLOODPLAIN CONNECTIVITY TO FISH POPULATIONS IN THE APALACHICOLA RIVER, FLORIDA

O. T. BURGESS<sup>a</sup>, W. E. PINE III<sup>b\*</sup> and S. J. WALSH<sup>c</sup>

<sup>a</sup> *University of Florida, Fisheries and Aquatic Science Program, Gainesville, Florida USA*

<sup>b</sup> *University of Florida, Department of Wildlife Ecology and Conservation, Fisheries and Aquatic Science Program, Gainesville, Florida USA*

<sup>c</sup> *US Geological Survey, Southeast Ecological Science Center, Gainesville, Florida, USA*

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# Water Wars, Eastern Style: Divvying Up the Apalachicola-Chattahoochee-Flint River Basin

J.B. Ruhl

*Florida State University College of Law*

# Mussels strongly regulate biogeochemical cycling during base flow

