Modeling and Predicting Ecological Futures for Freshwater Fishes

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Meghan Booknis

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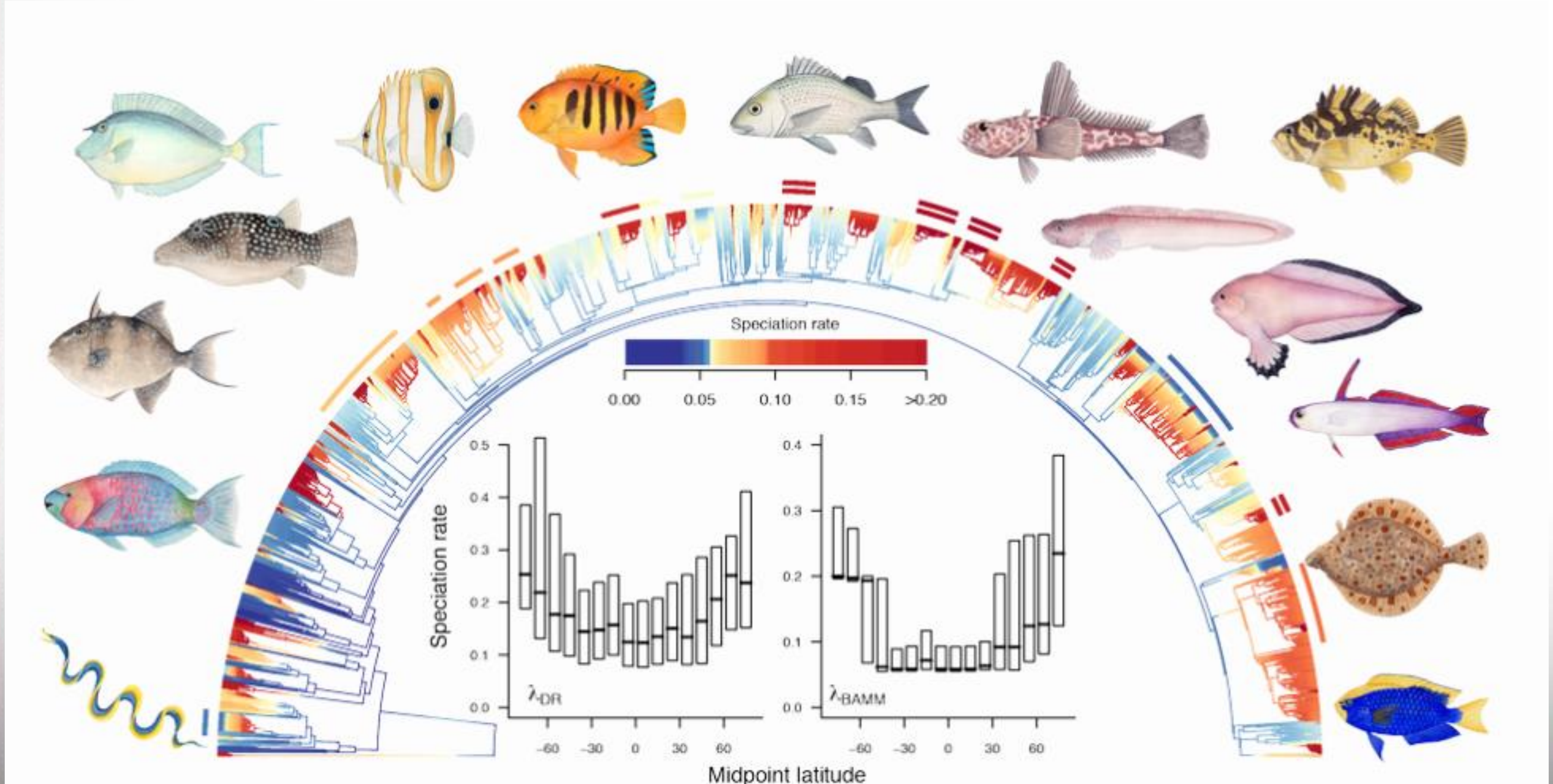
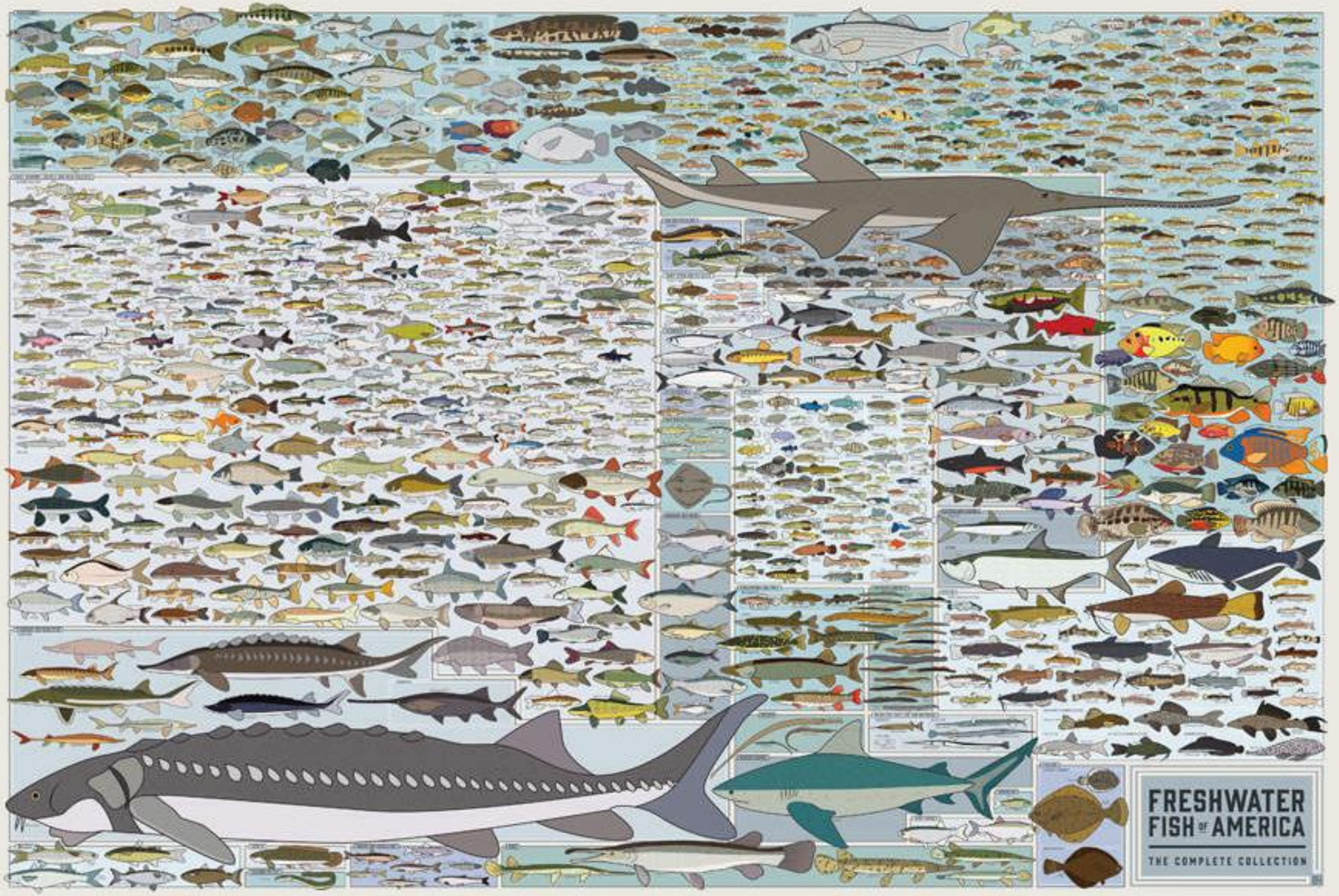
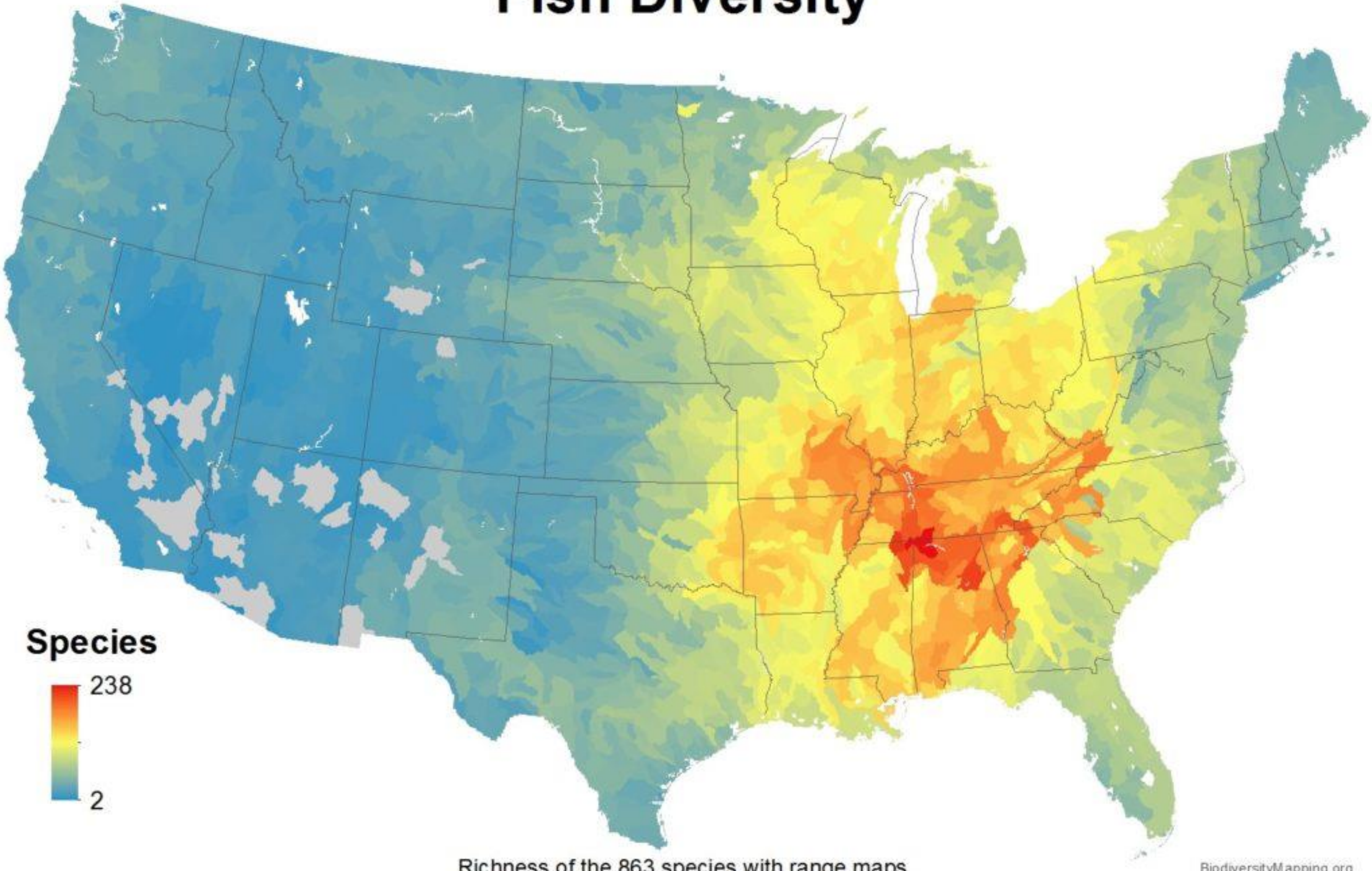
Fish Tree of Life

36,681 fish species, including 18,642 freshwater




FRESHWATER
FISH OF AMERICA
THE COMPLETE COLLECTION

Fish Diversity



Richness of the 863 species with range maps

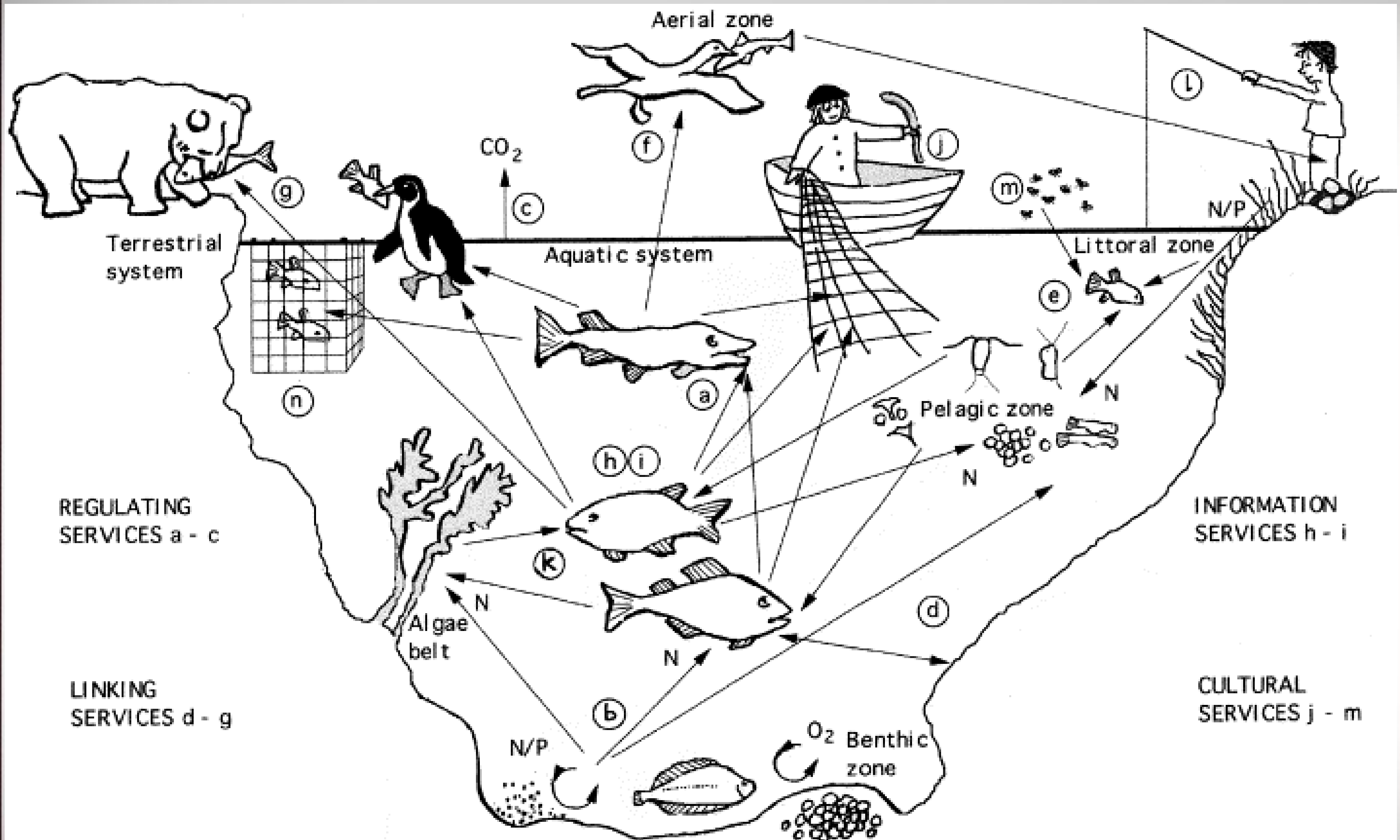
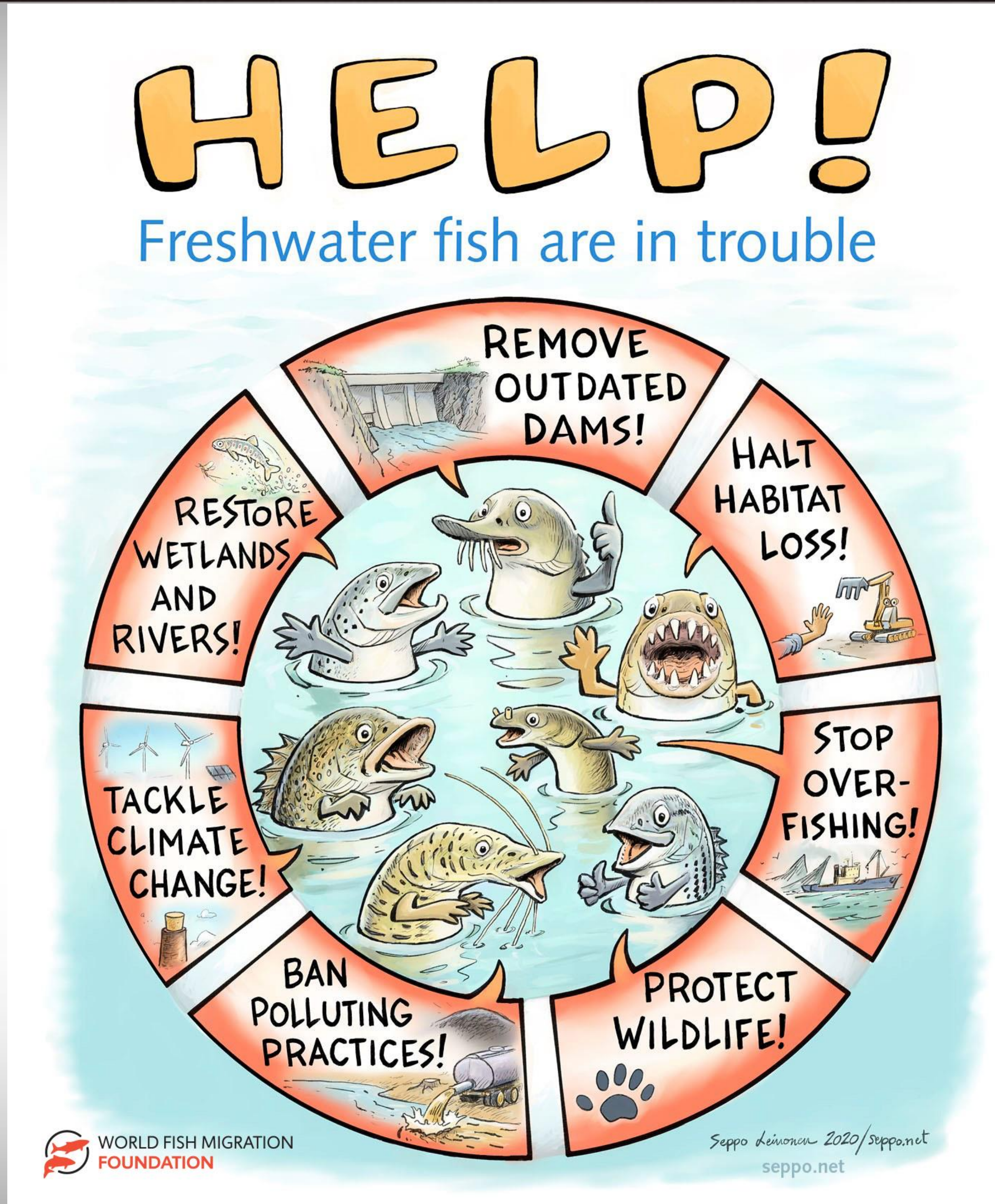
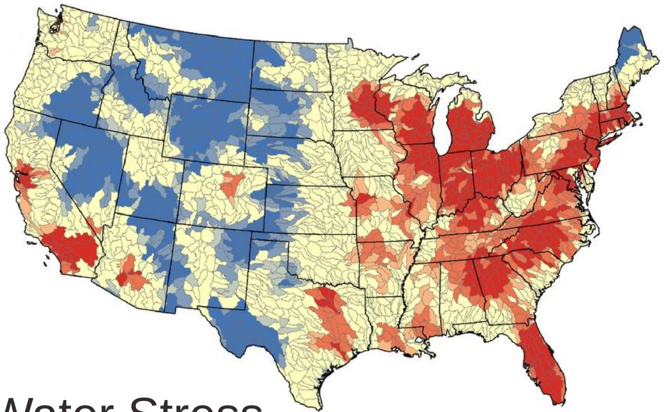


Figure from Holmlund and Hammer (1999), *Ecological Economics*

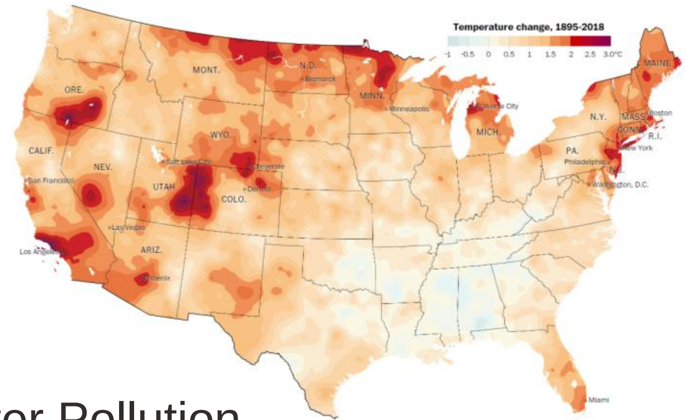

HELP!
Freshwater fish are in trouble
REMOVE OUTDATED DAMS!
HALT HABITAT LOSS!
STOP OVER-FISHING!
PROTECT WILDLIFE!
BAN POLLUTING PRACTICES!
TACKLE CLIMATE CHANGE!
RESTORE WETLANDS AND RIVERS!
WORLD FISH MIGRATION FOUNDATION
Seppo Leinonen 2020/seppo.net
seppo.net

Spatial Patterns of Threats in USA

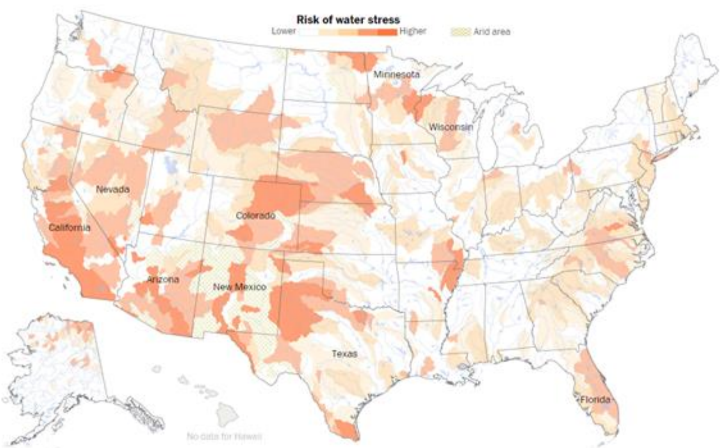
Freshwater Fishing Demand



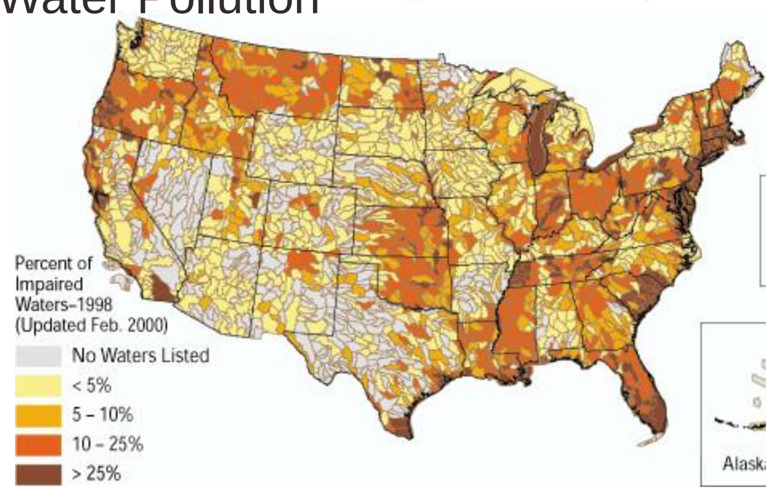
Warming Air Temperatures



Water Stress



Water Pollution



Figures from Davis and Darling (2017), *Diversity and Distributions*

What does the future hold for fishes in streams?

Methods for Developing Predictions

1. Species-discharge relationships

2. Trait-environment relationships

3. Species-environment relationships

4. Assemblage-level space-for-time substitutions

Species-discharge relationships

- Based on species-area concept
- Used to forecast alpha diversity (richness) declines as a function of discharge reduction

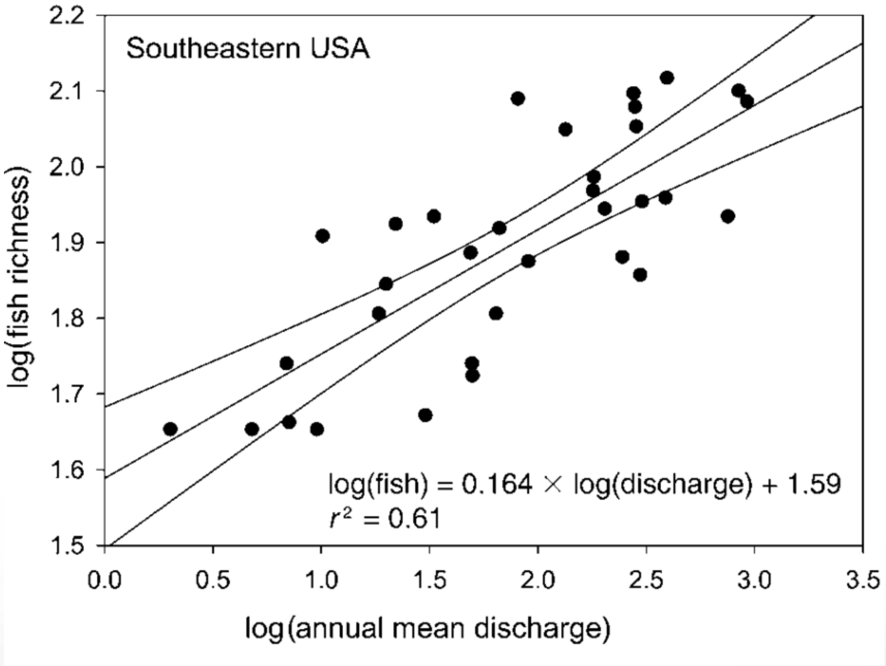


Figure from Xenopoulos and Lodge (2006), *Ecology*

Species-discharge relationships

- Based on species-area concept
- Used to forecast alpha diversity (richness) declines as a function of discharge reduction
- However, SDR are scale dependent and ecological mechanisms are unstudied

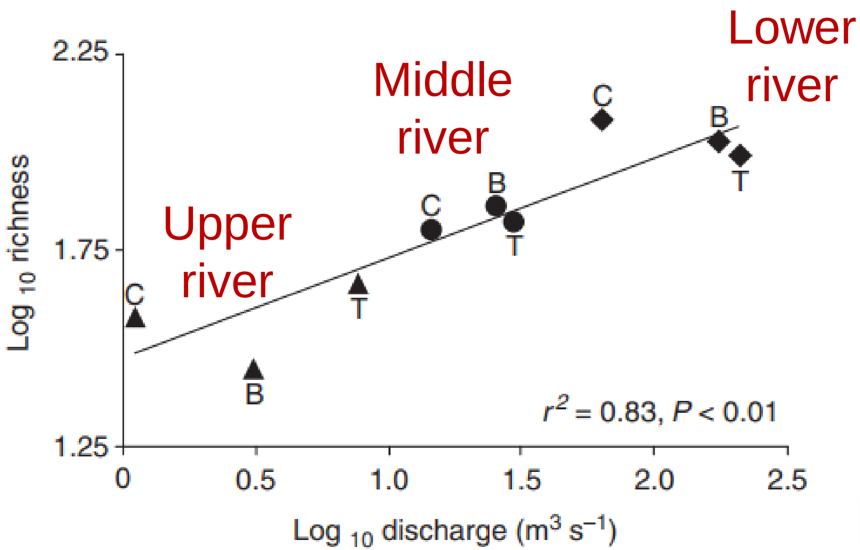


Figure from McGarvey and Ward (2008), *Freshwater Biology*

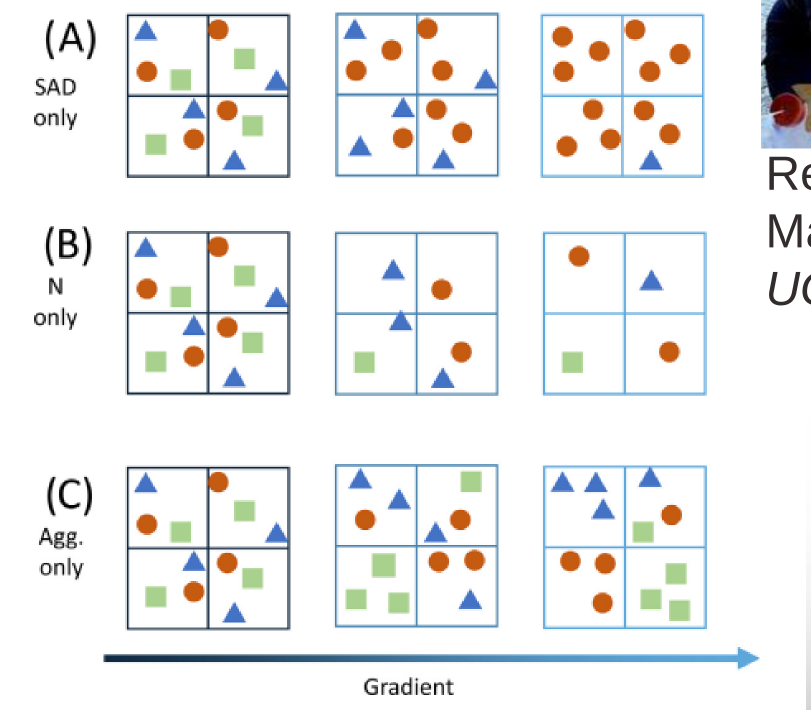
Species-discharge relationships

Our goal was to assess the scale-dependent community ecology mechanisms associated with SDR

Species abundance distribution (SAD)

Number of individuals (N)

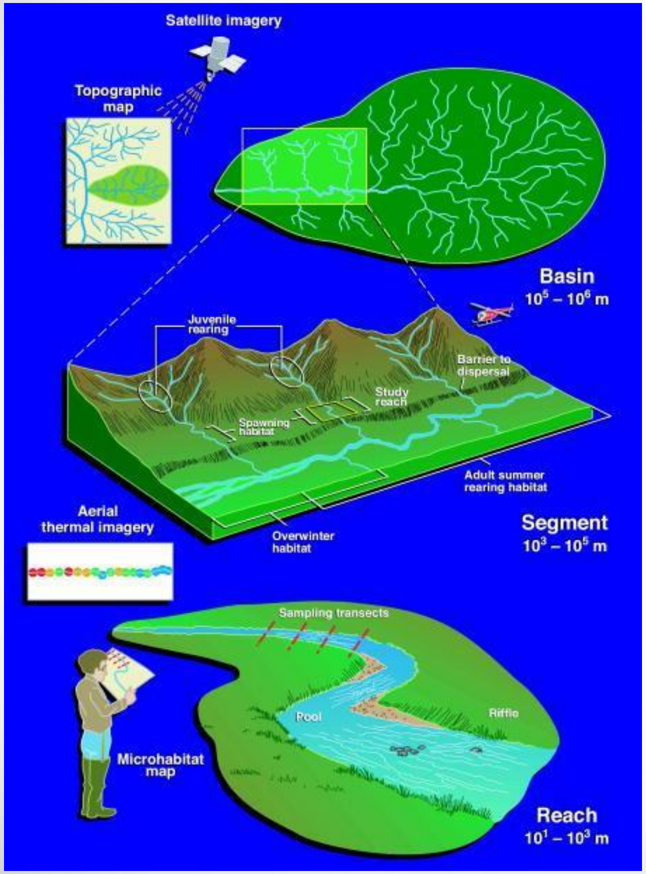
Spatial aggregation (Agg)



Rebecca Mangold
UG Student

Figure from McGlinn et al. (2021), *Ecology*

Species-discharge relationships



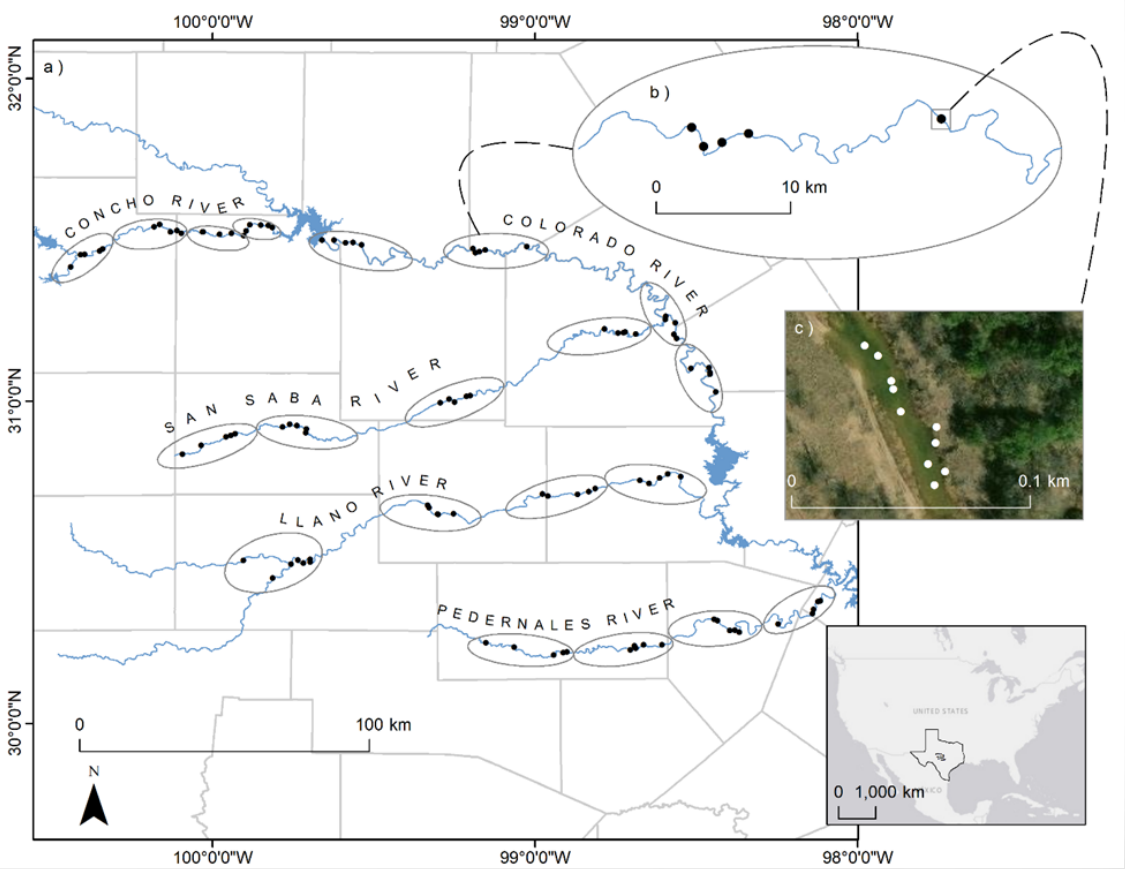


Figure from Fausch et al. (2002), *BioScience*

Species-discharge relationships

- The SDR varied by scale
  - Strongest at broadest scale

- Stream basin scale reduction in water will affect more species relative to segment or reach
  - Reach dewatering already happens
  - Likely offset by movement emigration/recolonization

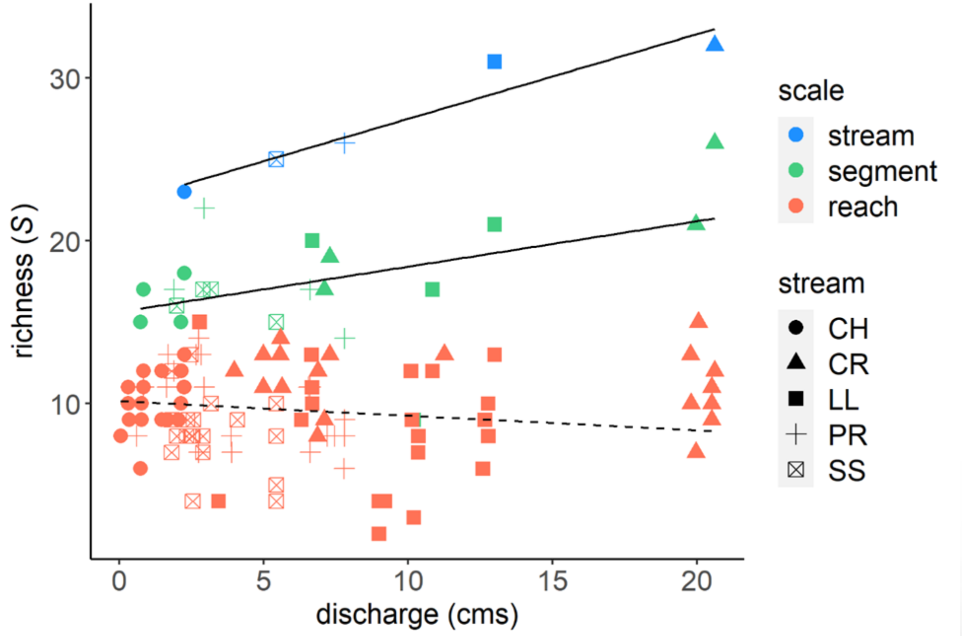


Figure from Mangold et al. (In Prep), *Ecology*

Species-discharge relationships

SDR

- The SAD was the mechanism most closely tied to SDRs across scales and increased in strength with scale

Estimate (S/cms)	Reach	Segment	Stream
Agg.	-0.0065	0.0027	-0.0255
N	0.0443*	0.0263	0.0147
SAD	-0.0511*	0.0799*	0.457*
Net (Agg + N + SAD)	-0.0133	0.109	0.447
SDR Slope	-0.0893	0.279*	0.520*

These closely match

Figure from Mangold et al. (In Prep), *Ecology*

Species-discharge relationships

- Ecological models representing assemblages or communities along gradients might be parameterized to show greater evenness among species where space/discharge/energy input is greater

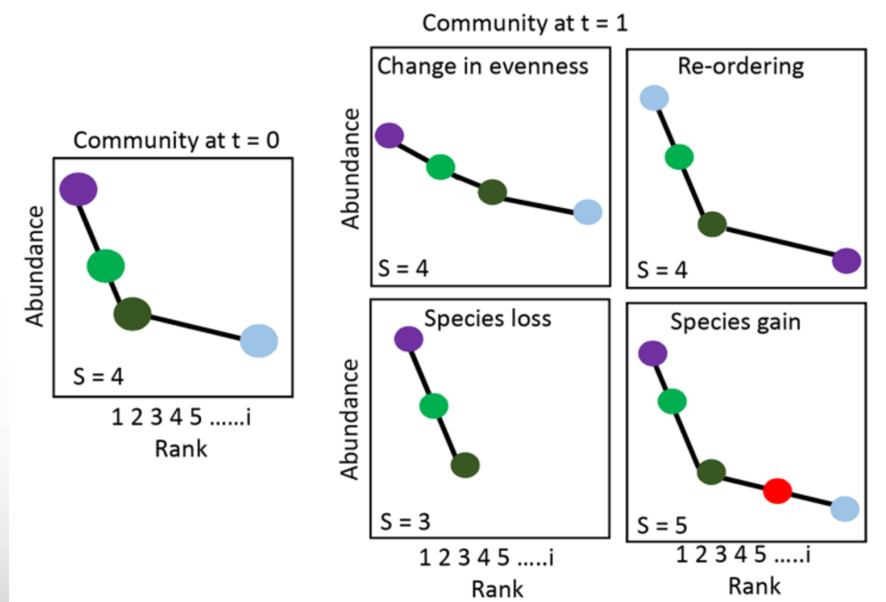


Figure from Avolio et al. (2019), *Ecosphere*

Trait-environment relationships

- Functional trait-environment relationships provide insight into mechanisms governing species occurrence
- Environmental change can then be used to predict trait occurrence

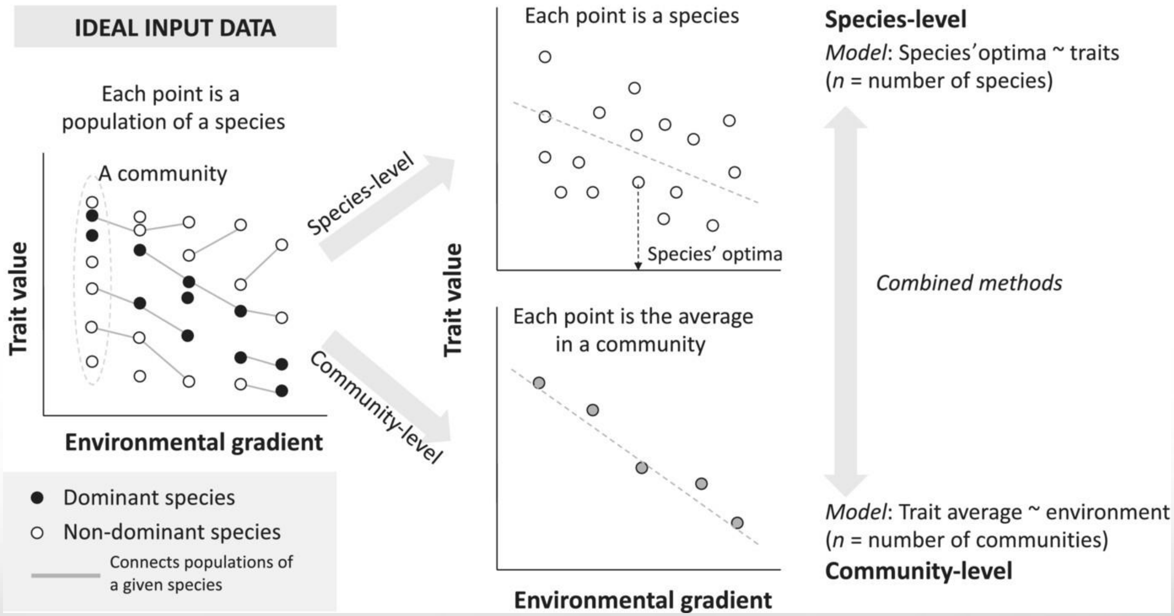
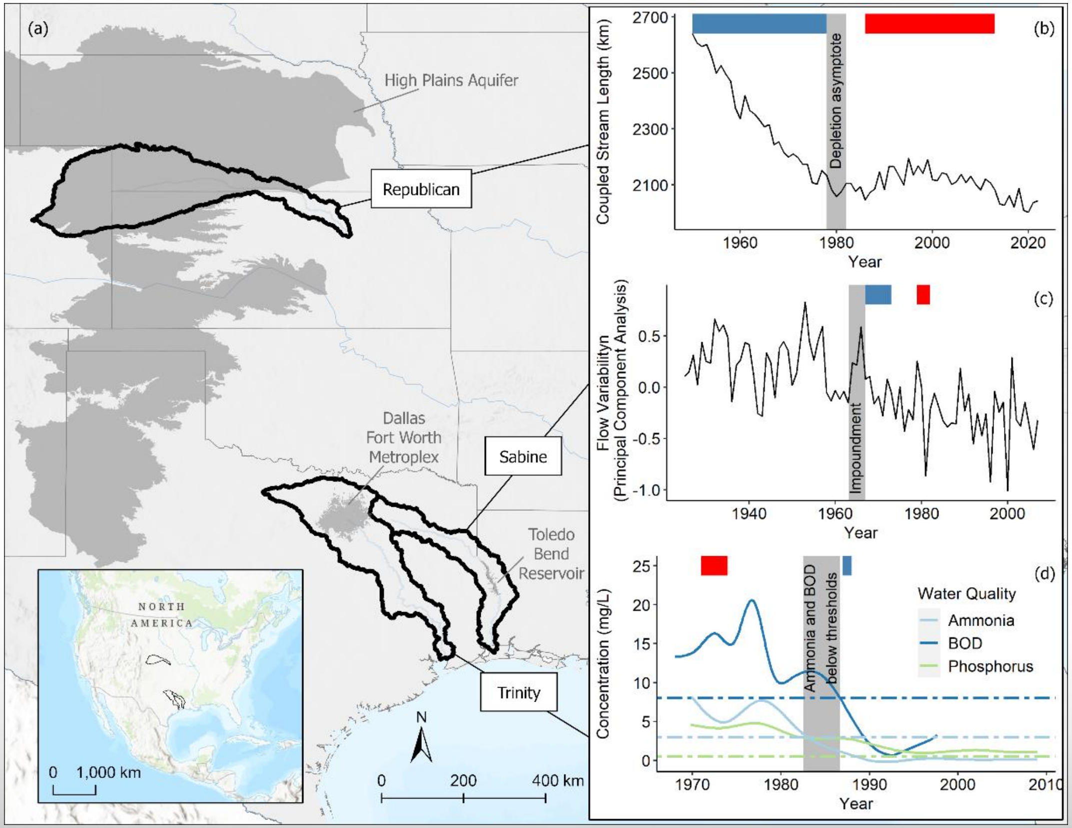
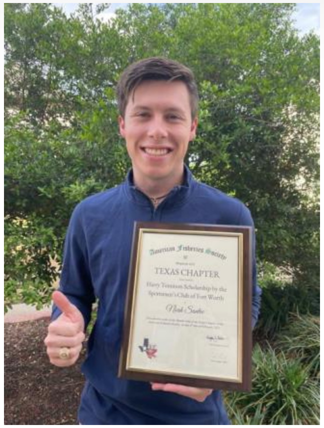


Figure from Leps and de Bello (2023), *Journal of Ecology*

Trait-environment relationships

Our goal was to test if environmental changes elicited similar trait responses across riverscapes





Noah
Santee
MS Student

Figure from Santee et al. (In Review), *Ecological Indicators*

Trait-environment relationships

Consistently responsive traits were life history (periodic-opportunistic), trophic (partial herbivory), and habitat (gravel use)

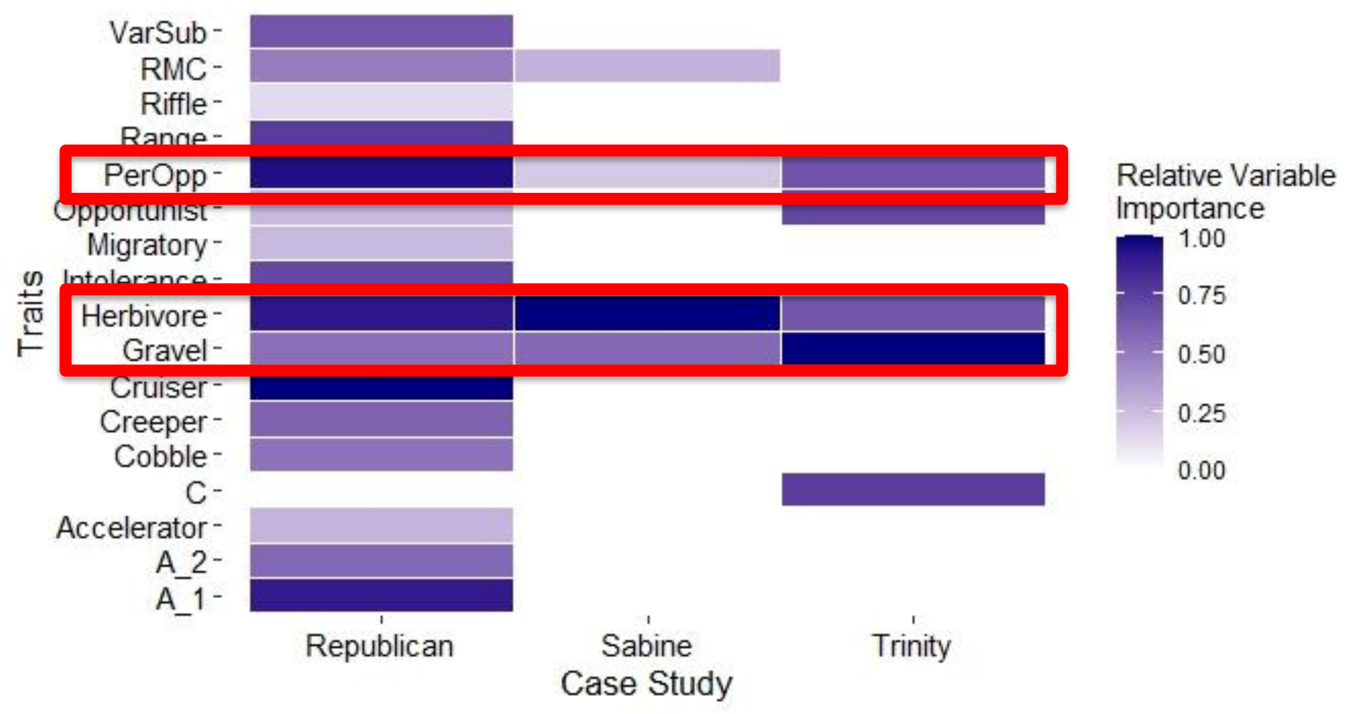


Figure from Santee et al. (In Review), *Ecological Indicators*

Trait-environment relationships

The directionality of change was consistent across drainages

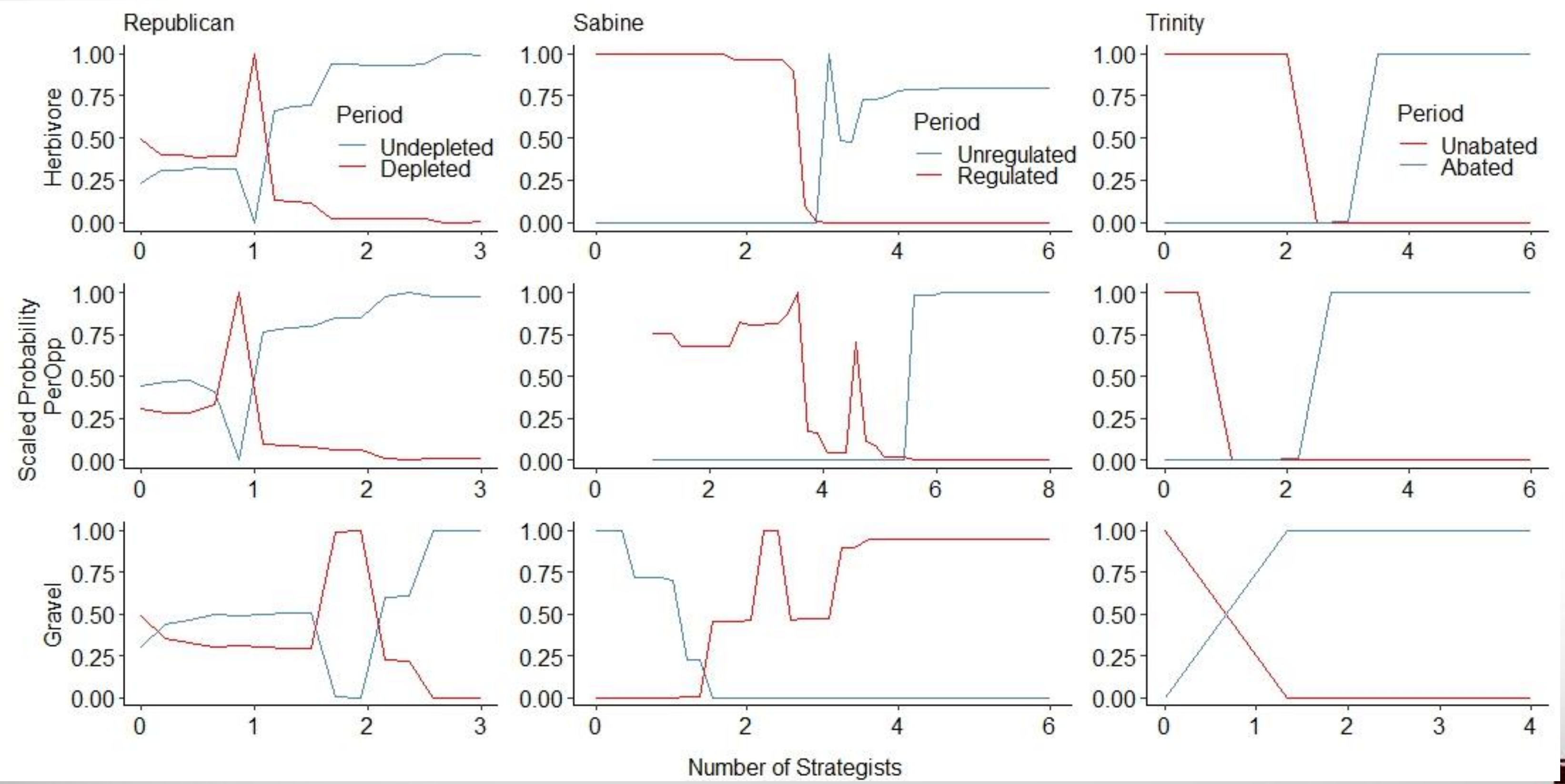


Figure from Santee et al. (In Review), *Ecological Indicators*

Trait-environment relationships

- Strategist richness was generally higher within rivers when flows were undepleted, unregulated, and pollution was abated
- These patterns might be predictive of change for rivers that experience alterations in the future
- Ecological models could be parameterized with threshold responses to these forms of environmental change

Figure from Santee et al. (In Review), *Ecological Indicators*

Species-environment relationships

- Indicator species are used to track ecological shifts
- Fish are a common indicator group
- Blue sucker is widely considered an indicator species for large rivers

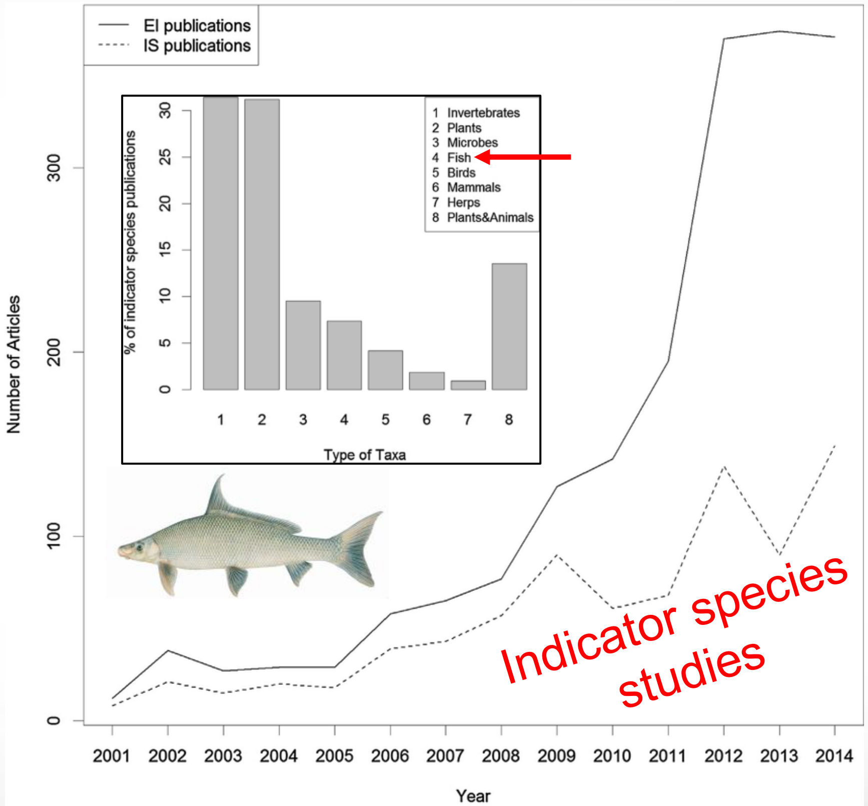
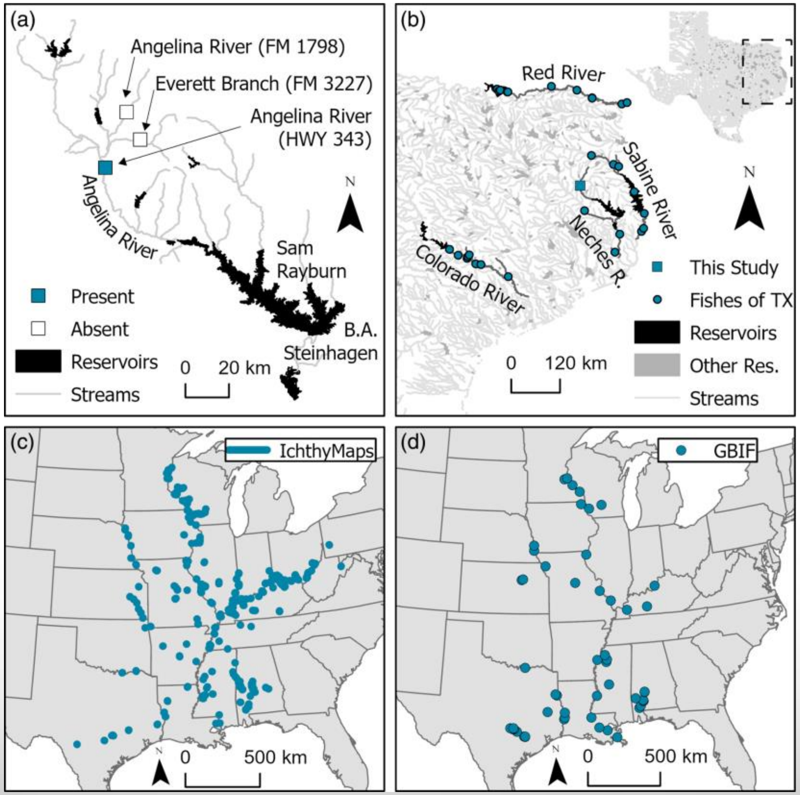
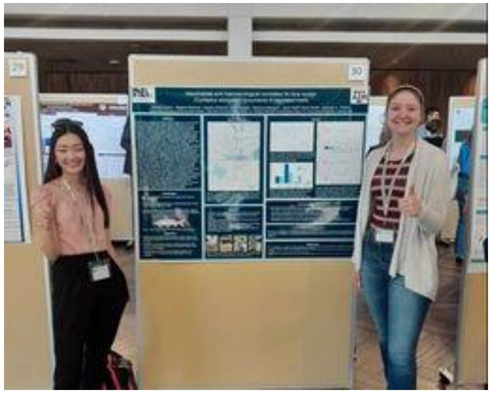


Figure from Siddig et al. (2016), *Ecological Indicators*

Species-environment relationships

Our goal was to assess relationships between Blue Sucker occurrence and gradients in stream fragmentation and flow regulation





Hannah Evans

Meghan Booknis

UG Students

Figure from Evans et al. (2023), *River Research and Applications*

Species-environment relationships

- Blue Sucker was absent where river regulation and fragmentation were combined
- Models predicting Blue Sucker response to changes in river regulation and fragmentation could be parameterized with the thresholds identified in this study

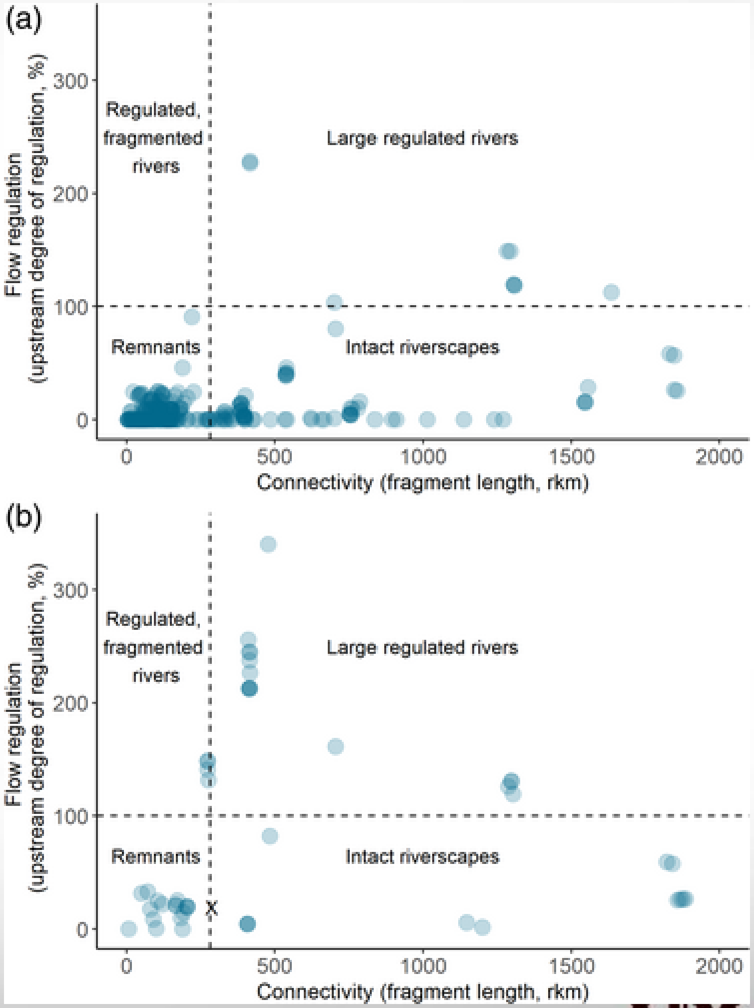


Figure from Evans et al. (2023), *River Research and Applications*

Space-for-time substitutions

- Space-for-time substitutions are useful for developing predictions for the future
- A central assumption to this framework is that the processes that contribute to change through space are the same that contribute to change through time
- These assumptions are reasonably met for aquatic systems affected by land cover land use change or along aridity gradients

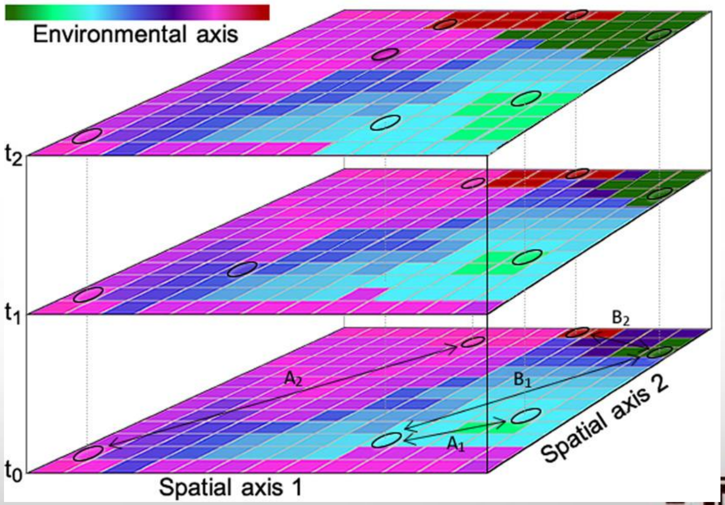
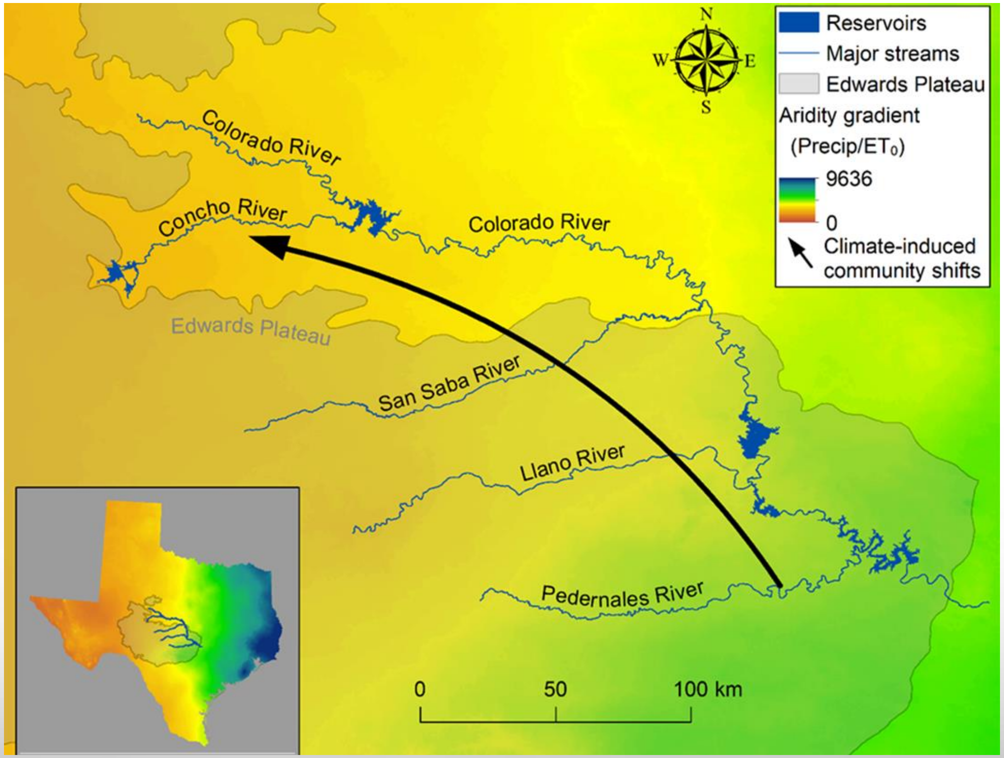


Figure from Wogan and Wang (2018), *Ecography*

Space-for-time substitutions

Our goal was to assess how space-for-time substitutions along an aridity gradient approximated fish assemblage change under climate scenarios



Lindsey Elkins
MS Student

Figure from Elkins (2022), *TAMU Thesis*

Space-for-time substitutions

Aridity Gradient

Warmer / Drier

Cooler / Wetter

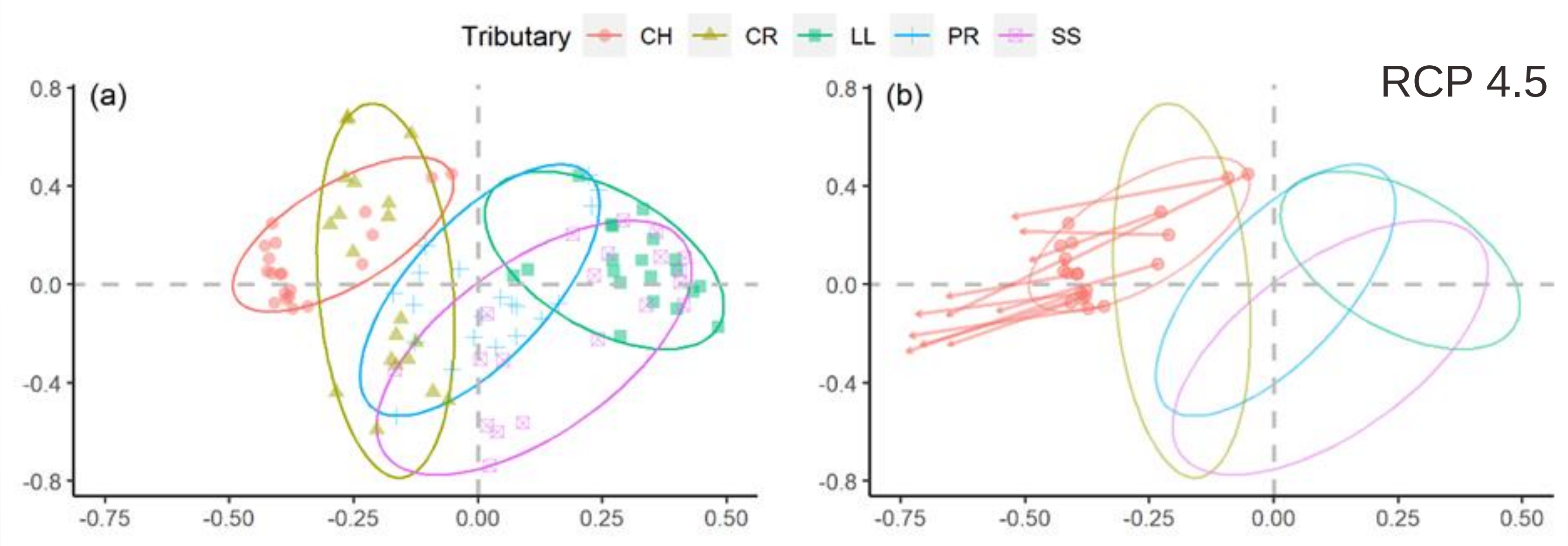


Figure from Elkins (2022), *TAMU Thesis*

Space-for-time substitutions

Aridity Gradient

Warmer / Drier

Cooler / Wetter

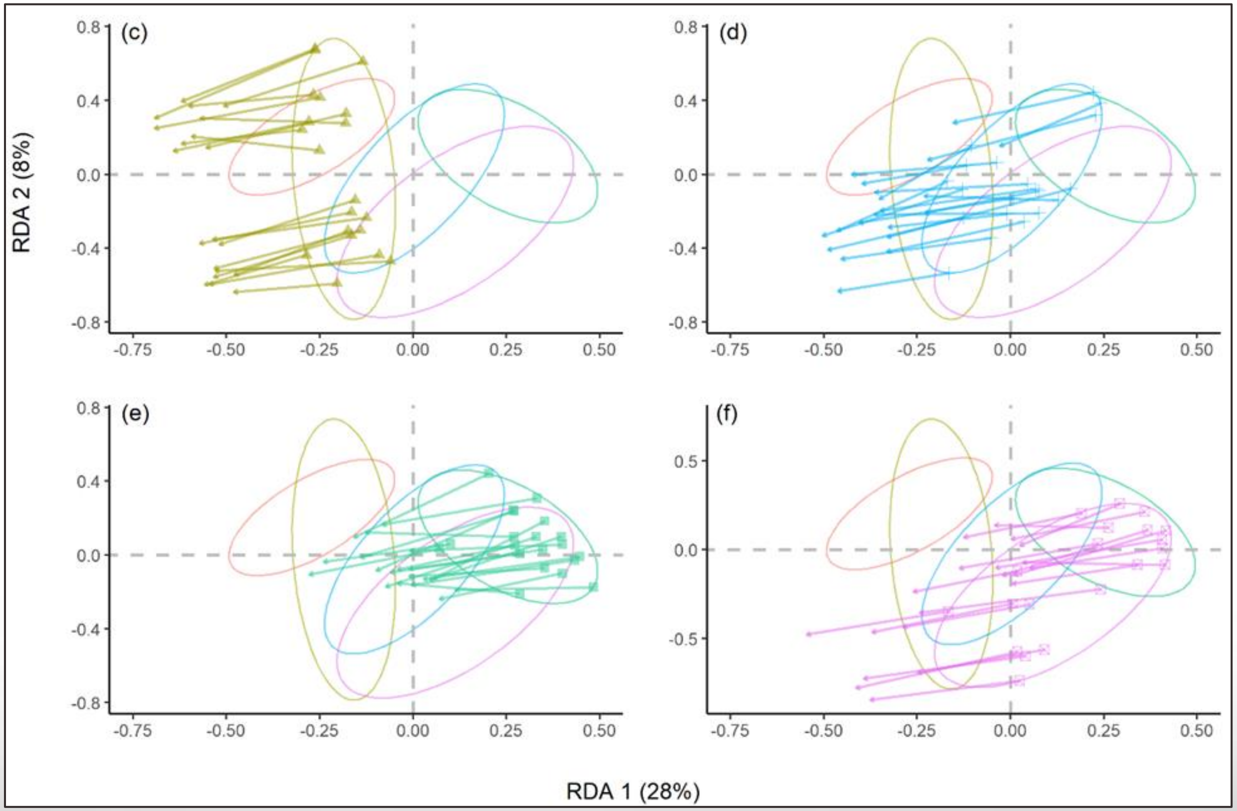


Figure from Elkins (2022), *TAMU Thesis*

Space-for-time substitutions

- Climate change projections (warmer, drier) showed fish assemblages “sliding” down an existing aridity gradient

- The direction of change was towards non-native and broadly distributed species but away from regionally endemic species

- Ecological models predicting the expansion of non-native species might include aridity covariates
  - Opportunity to make use of new data products (e.g., OpenET)

What is the future for freshwater fishes?

SDR Scale dependent and linked to species abundance distributions

TER Traits that response similarly across alterations can be used in monitoring and predicting

SER Indicator species can provide ecologically relevant thresholds for environmental change

STS Existing spatial gradients provide insight into future conditions

Broader implications

- USACE R&D Priorities
  - Mitigate and adapt to climate change
  - Ensure environmental sustainability and resilience
  - Revolutionize and accelerate decision making

- Models provide early detection of ecological process for all these priorities:
  - SDR model predicts fish dominance under water loss scenarios
  - TER model provides ecological indicators for decision making
  - SER model provides "actual numbers" to be used in management
  - STS model predicts expansion of non-native fish with climate change

Acknowledgements

- Many collaborators
- Todd Swannack
- Ashley Schutt
- This work was conducted in collaboration with the Texas Research Institute for Aquatic and Groundwater Ecology (TRIAGE) and was funded by the US Army Corps of Engineers' Aquatic Nuisance Species Research Program's focus on Next Generation Ecological Modeling.

Thank you for your attention!

Contact: Jperkin@tamu.edu
or if you're not into the whole brevity thing…
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