Characterizing spatiotemporal patterns in benthic algal assemblage responses to reduced flow in a Central Texas intermittent river

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Intermittent Rivers and Ephemeral Streams (IRES)

- Lotic ecosystems
- Undergo desiccation and fragmentation[1]
- Complex spatial patterns
- Longitudinal disconnection

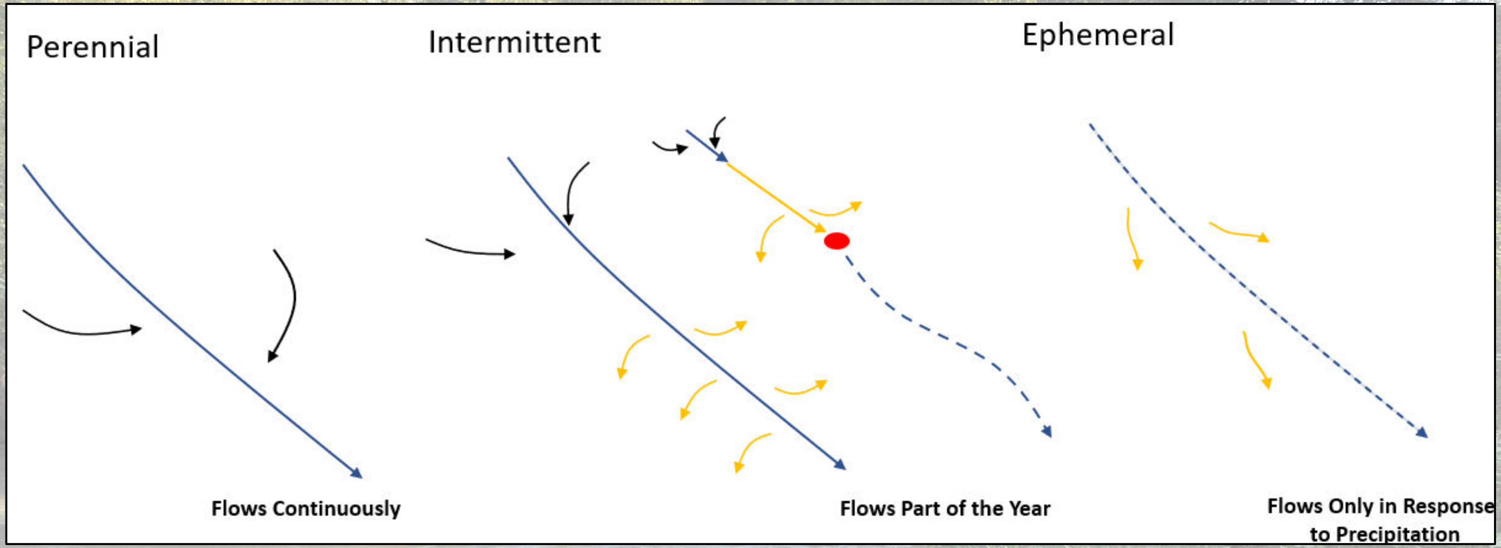

Image: Woessner, 2020

[1]Datry et al., 2017

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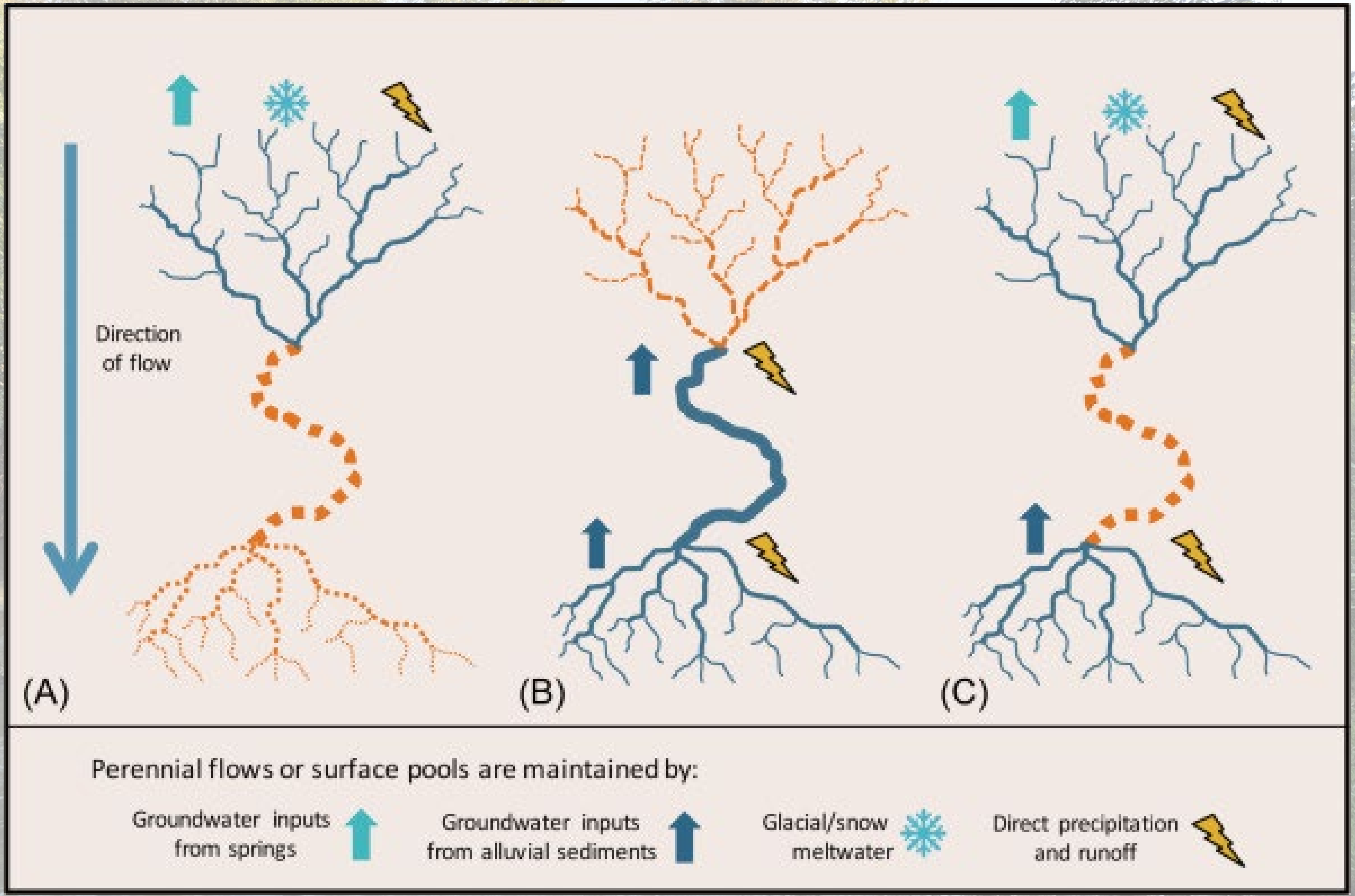

Image: Boulton et al., 2017

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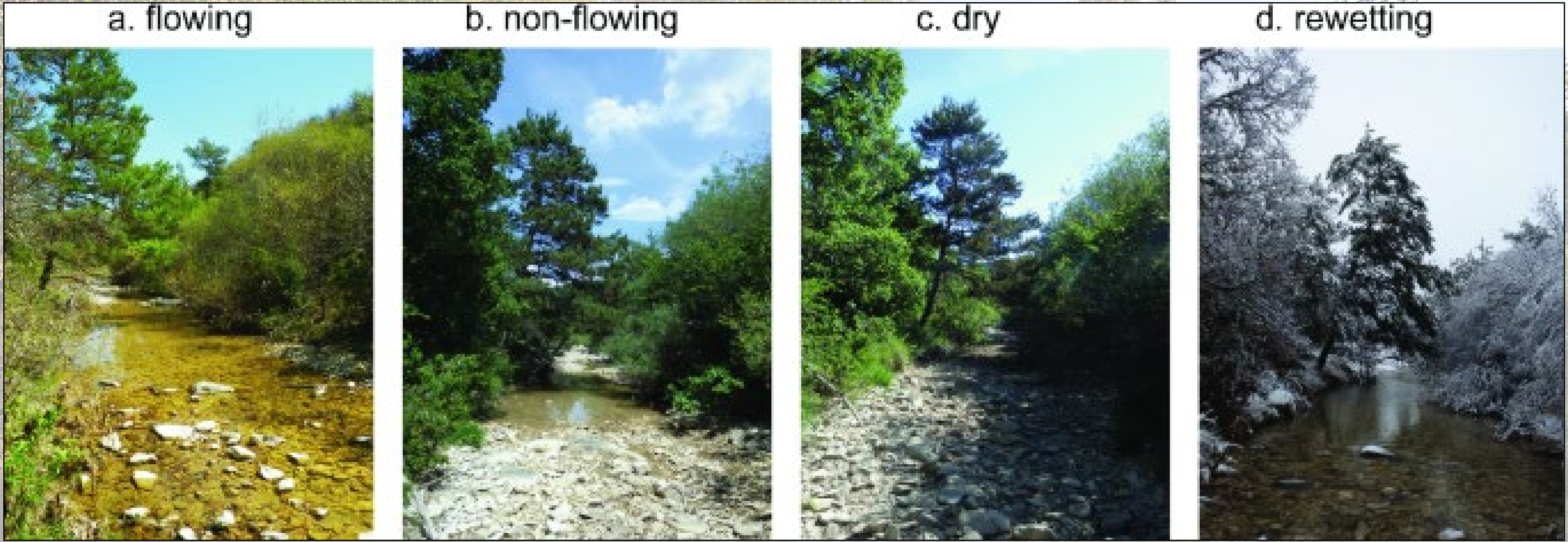
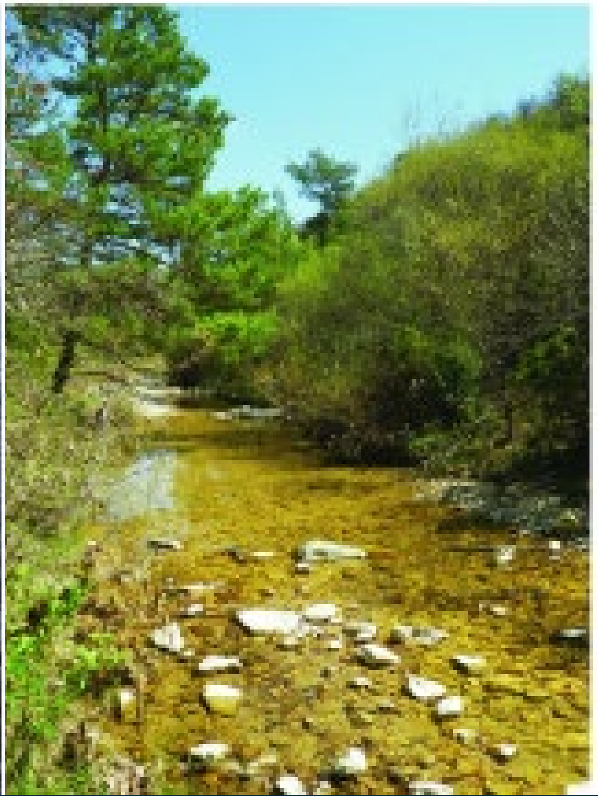


Image: Datry et al., 2017

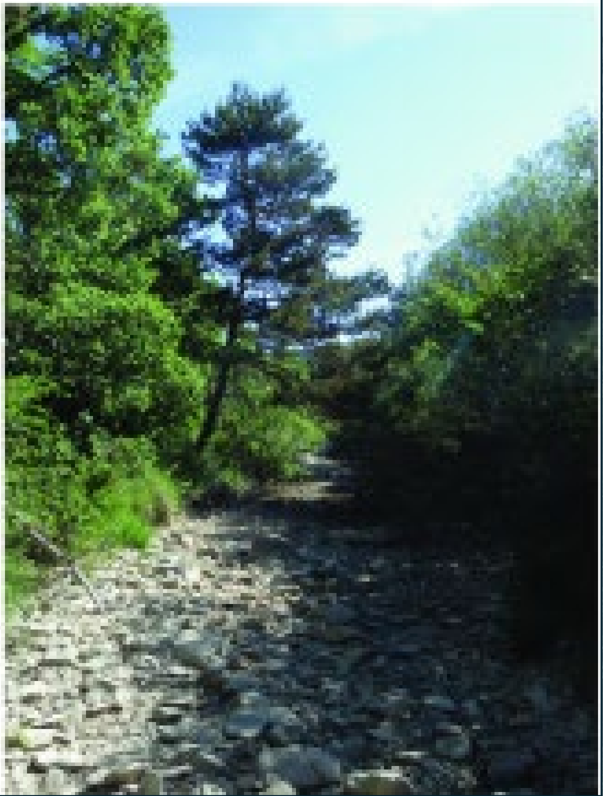
Expansion

Contraction



Fragmentation

Desiccation



Photos: B. Launay

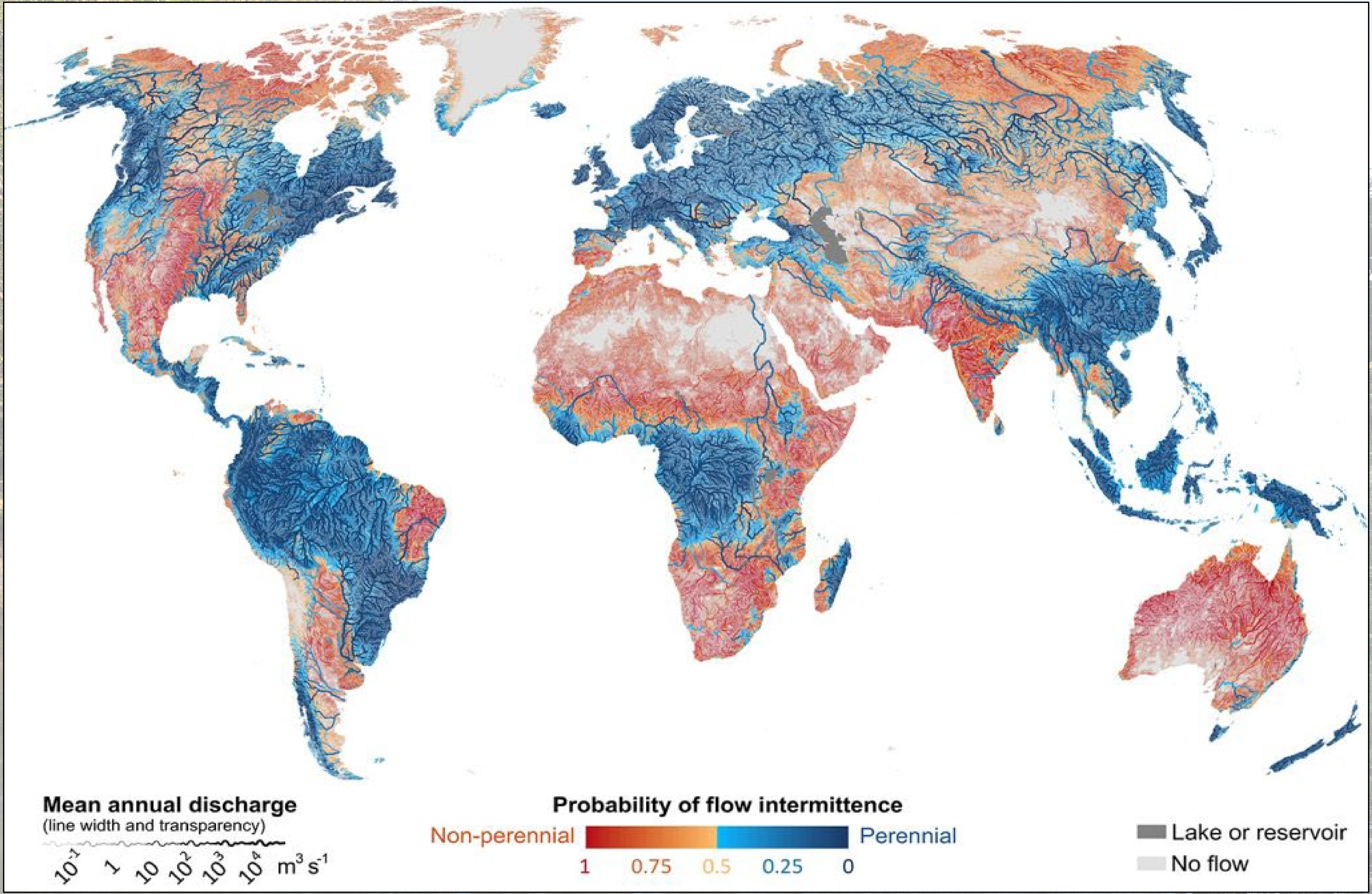
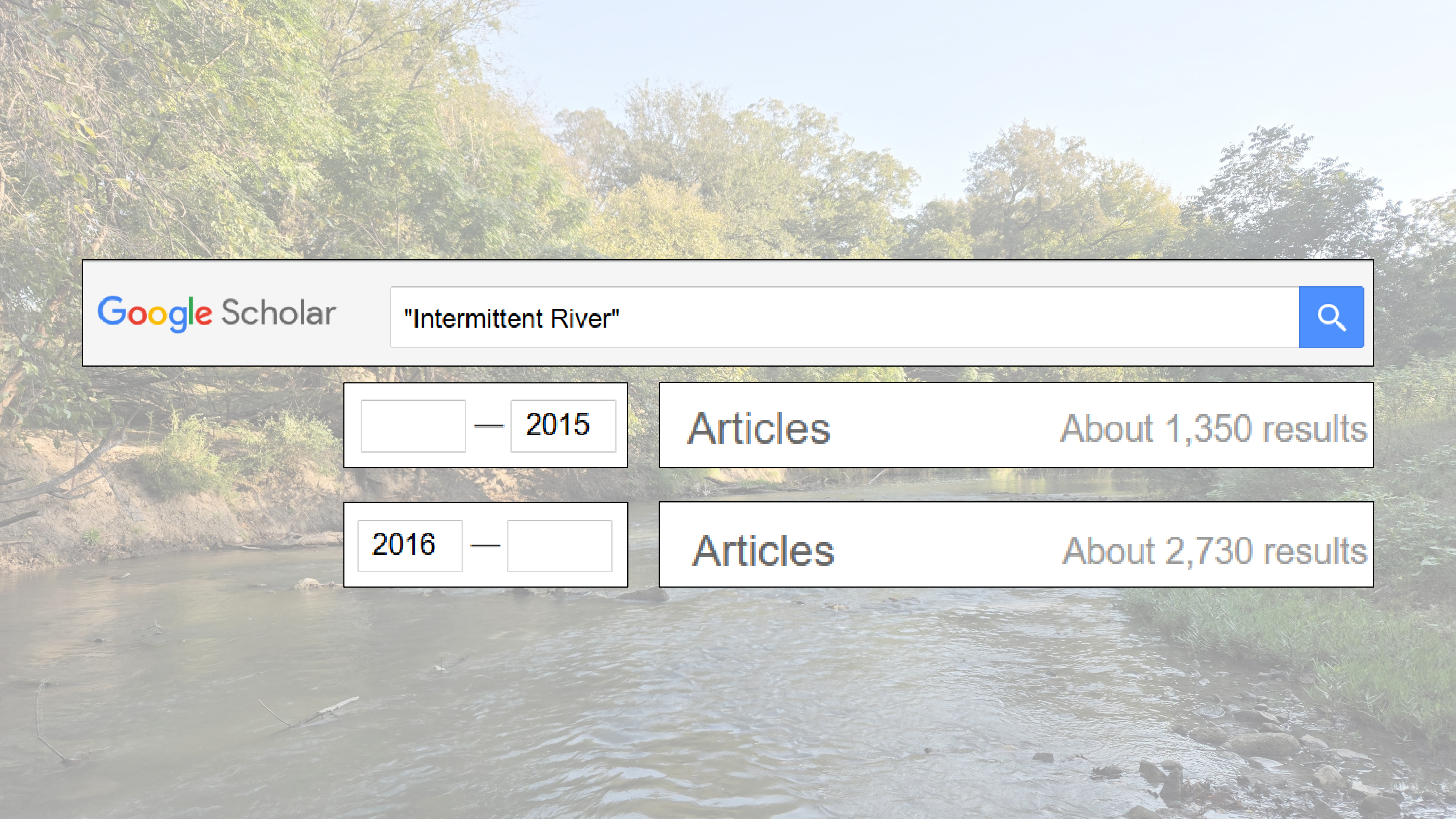


Image: Messager et al., 2021


Google Scholar
"Intermittent River"
— 2015
Articles
About 1,350 results
2016 —
Articles
About 2,730 results

- Primary producers
- Autochthonous source of energy and oxygen[1]

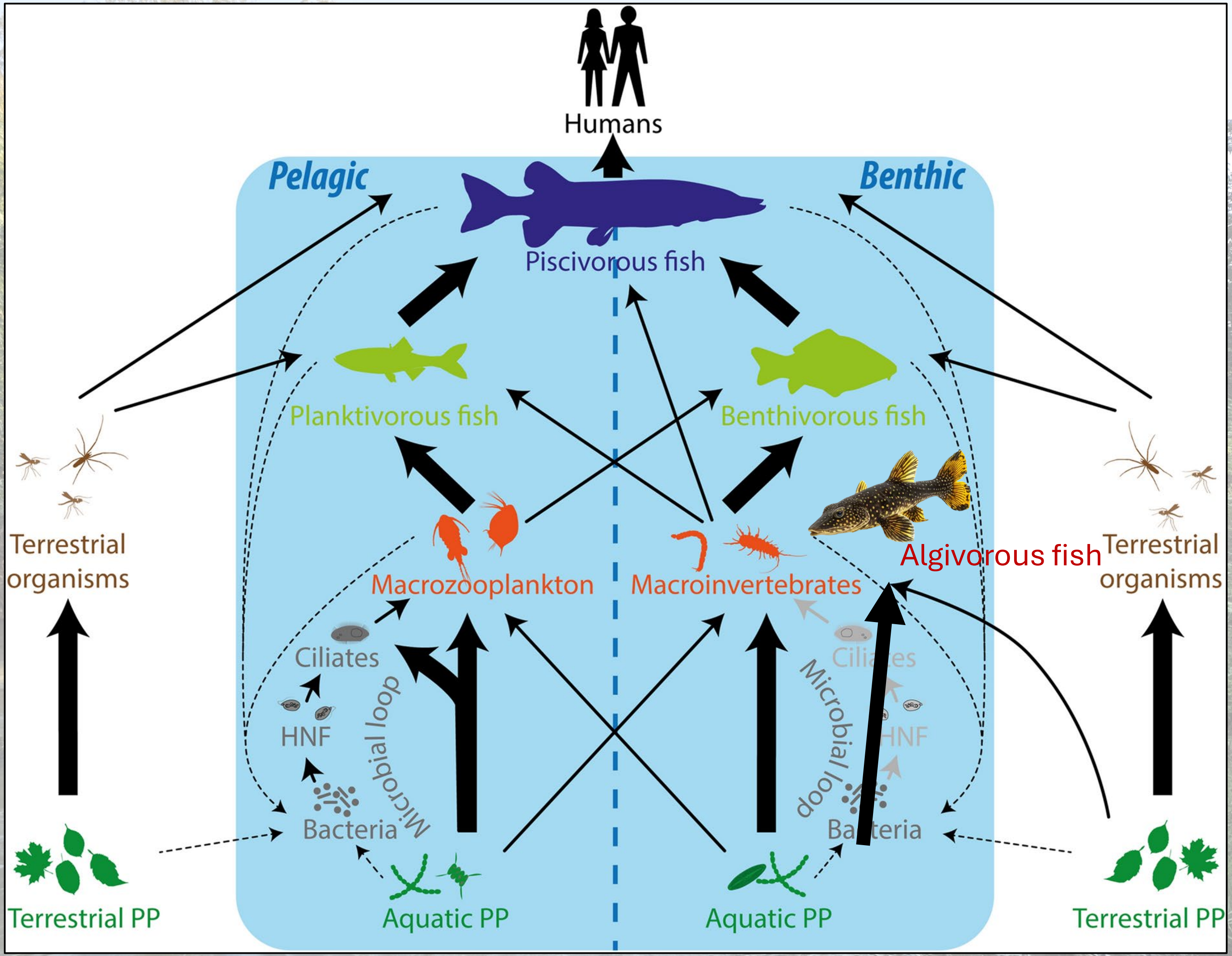


Image: Mehner et al., 2022; Photo: Shakila Khatun

[1]Sabater et al., 2017

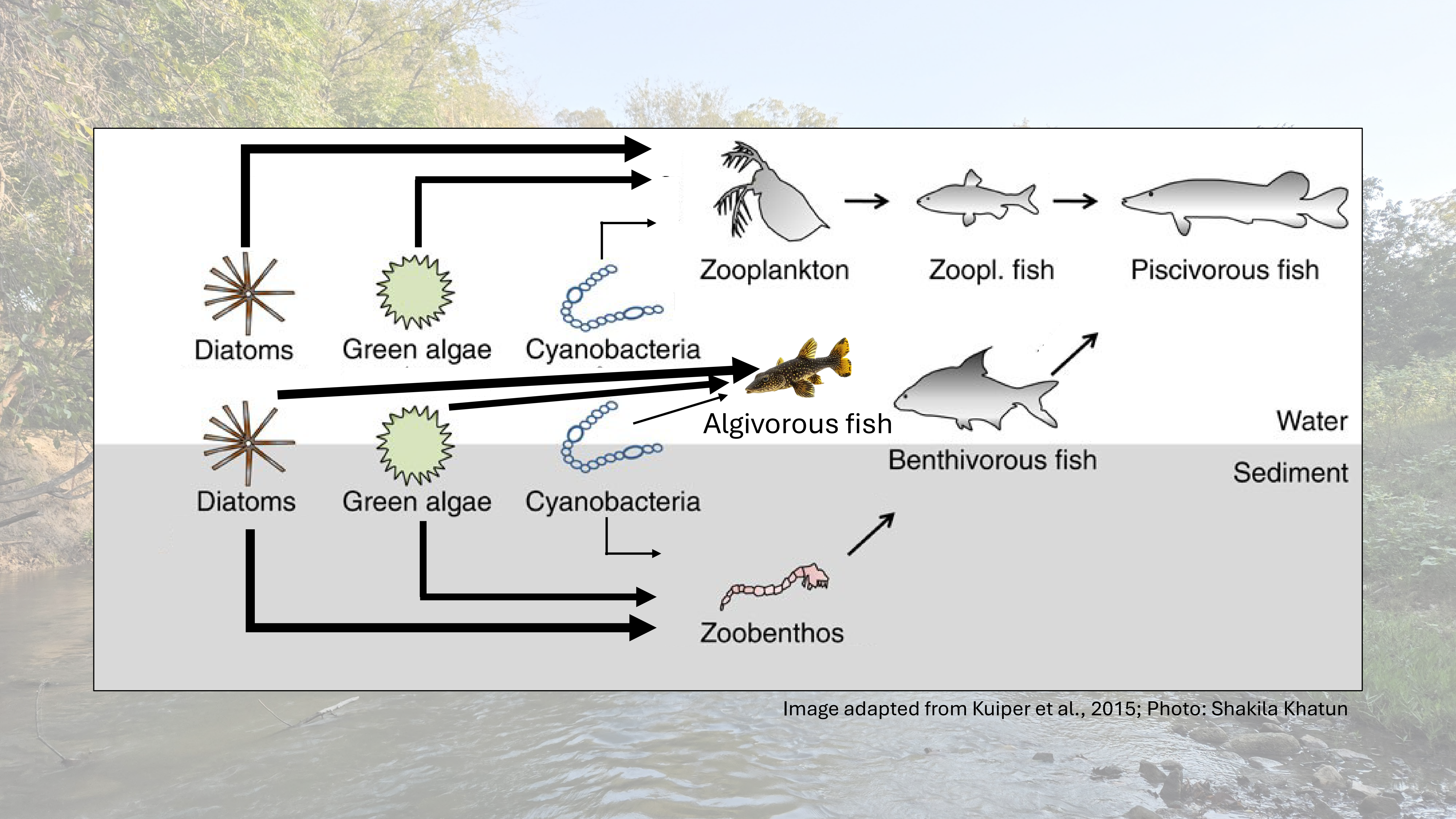


Image adapted from Kuiper et al., 2015; Photo: Shakila Khatun

- Dominant primary producer in many IRES systems[1]
- Respond quickly to changes in environment[2]

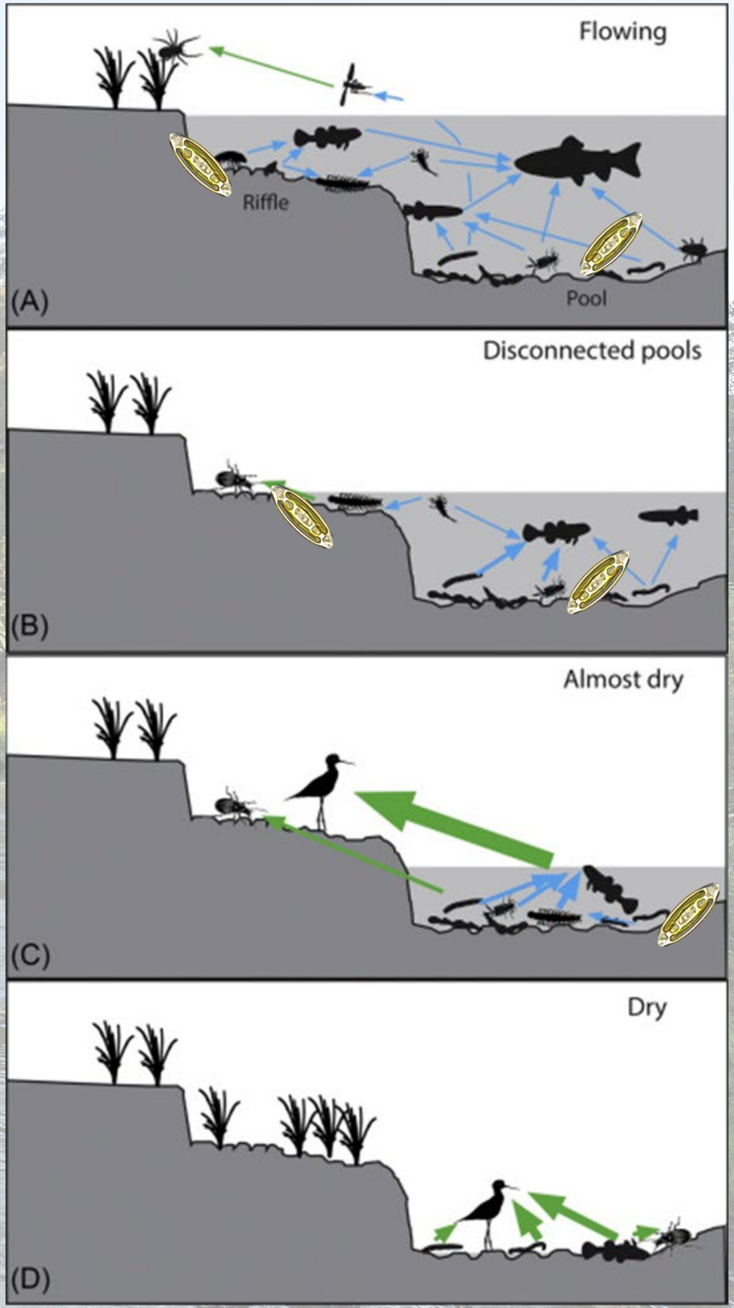


Image: McIntosh et al., 2017

[1]Sabater et al., 2017; [2]Stubbington et al., 2019

Google Scholar

"Intermittent river" "fish"

Articles About 1,880 results

Google Scholar

"Intermittent river" "invertebrates"

Articles About 977 results

Google Scholar

"Intermittent river" "benthic algae"

Articles About 106 results

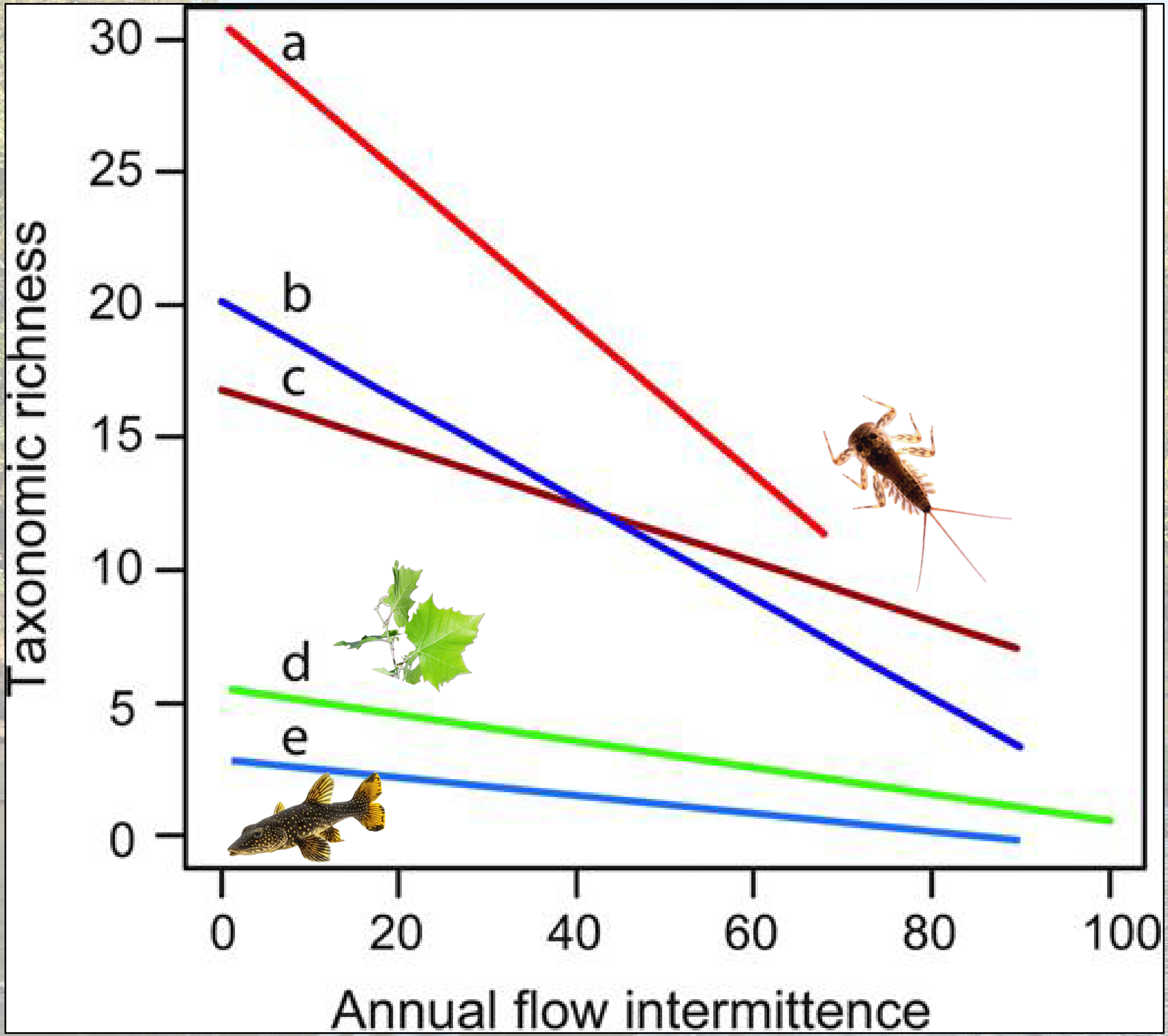


Image: Datry et al., 2014

Photo by: Stuart Crofts

Functional Diversity

"The value and range of those species and organismal traits that influence ecosystem functioning"
– Tilman, 2001

Mougeotia

Oedogonium

Photos: Otago Regional Council & Manaaki Whenua; Vicente Franch Meneu

-Filamentous
-Mucilaginous

-Filamentous
-Non-mucilaginous

Photos: Otago Regional Council & Manaaki Whenua; Vicente Franch Meneu

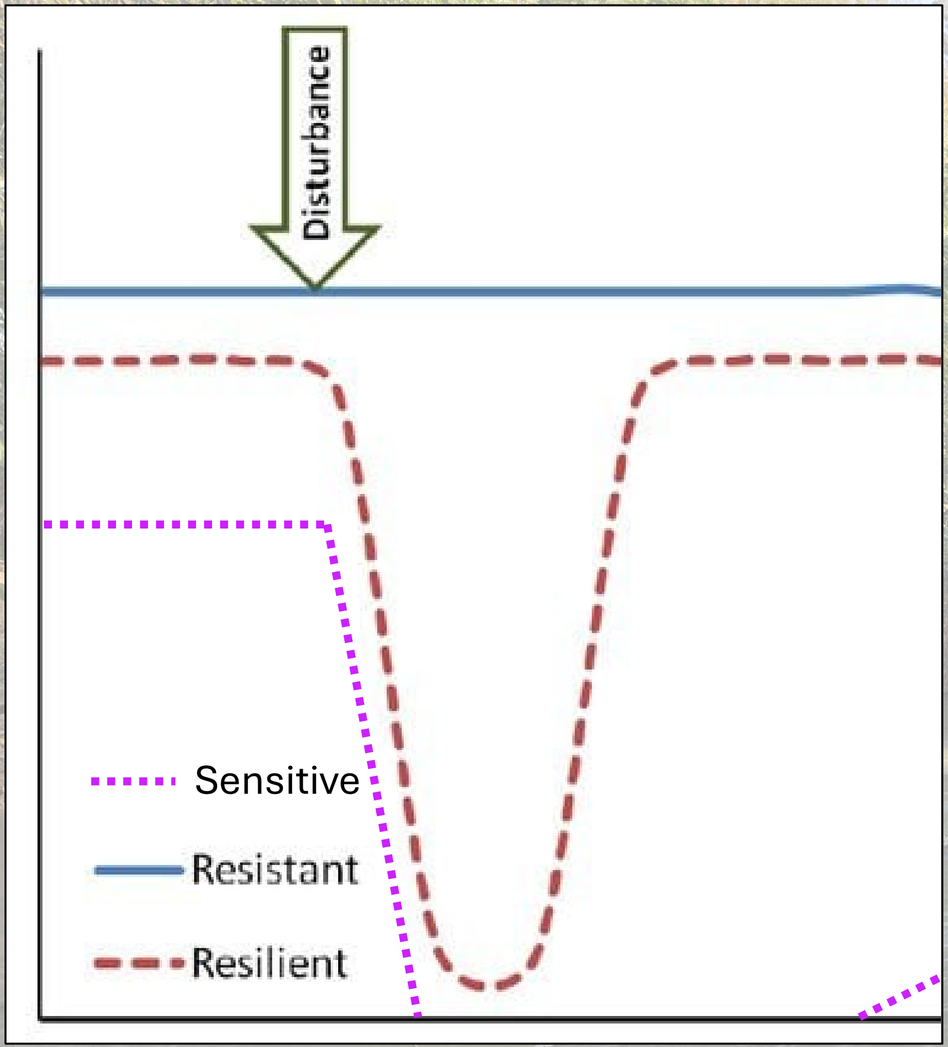
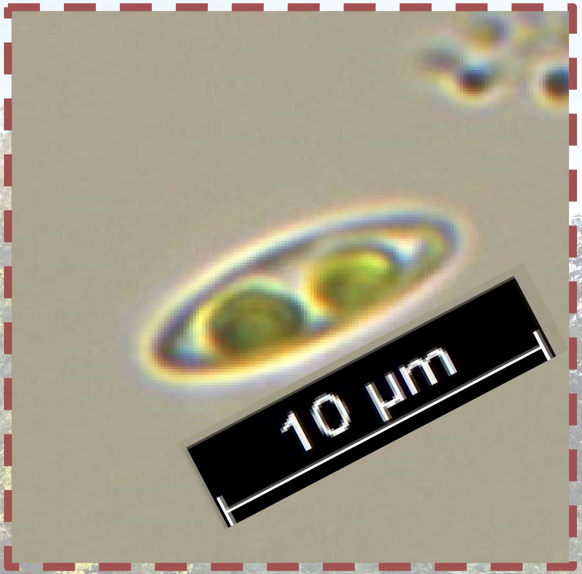


Image: Stovall, 2012



Functional Diversity in IRES

- Variable conditions present in IRES can cause higher functional diversity[1]
- Diatom diversity lowers under dessication[2]
- Few, if any, studies on functional diversity on whole algal assemblages in IRES

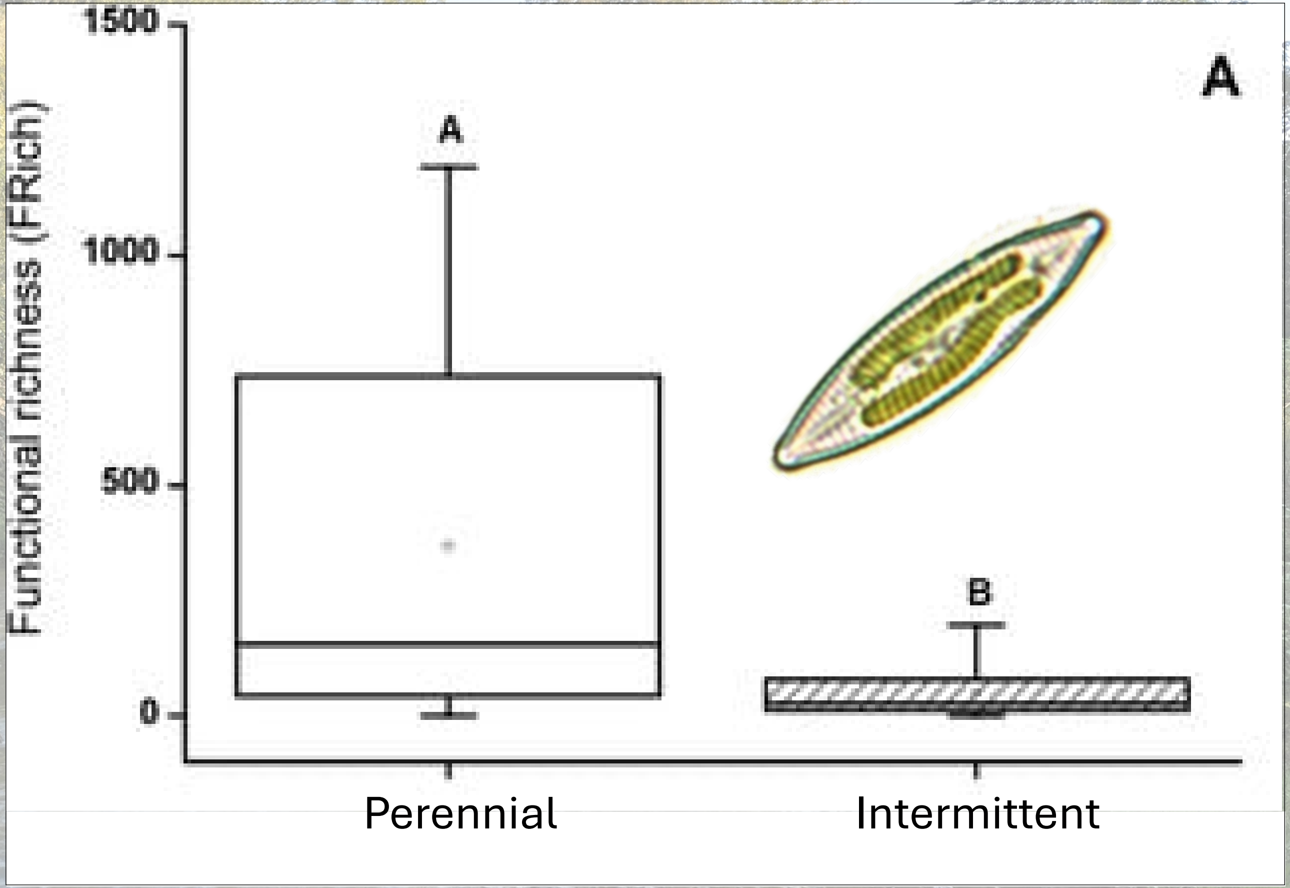


Image: B-Béres et al., 2019

[1]Stubbington et al., 2017; [2]B-Béres et al., 2019

Q1: How will the response of benthic algal assemblages to intermittency differ between riffle and pool mesohabitats?

- Riffle assemblages will be more affected than pool assemblages
  - Faster responses
  - More dynamic

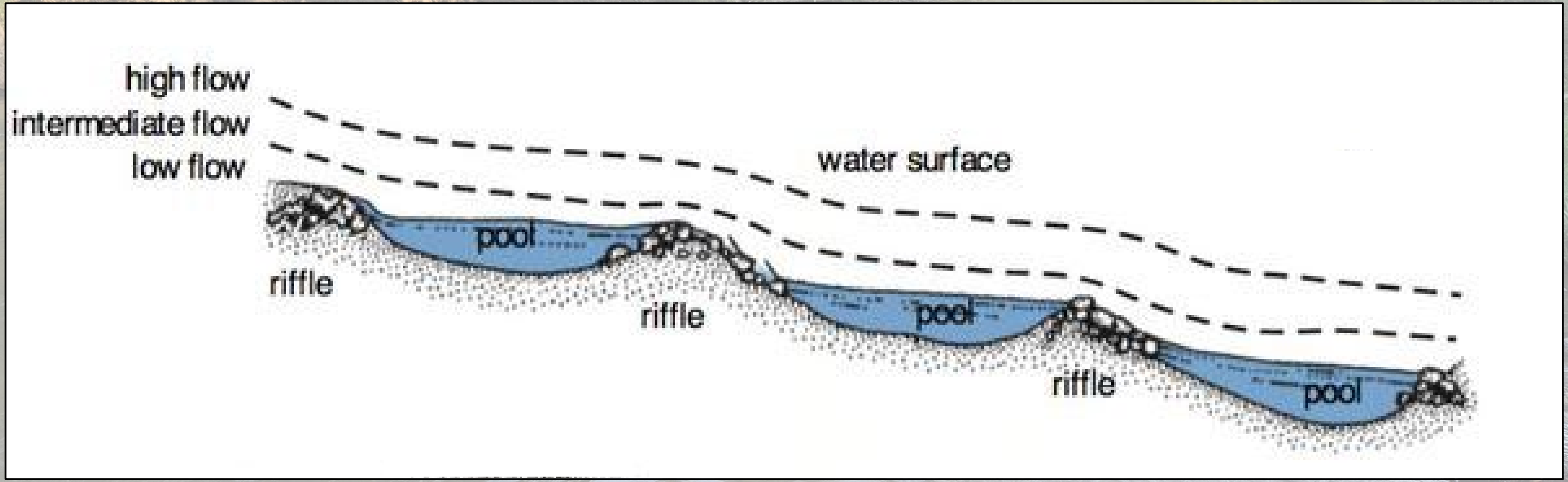
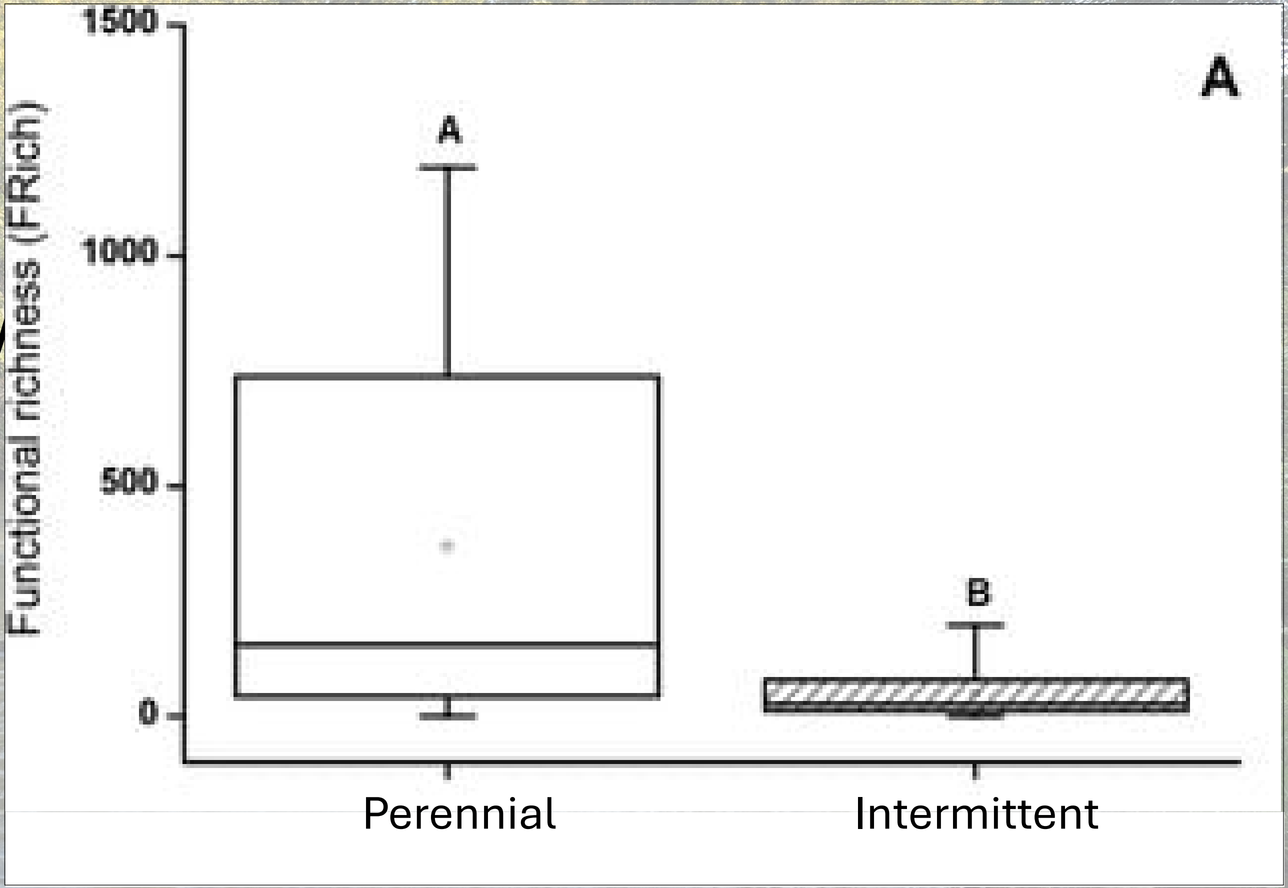


Image: Jennings & Harman, 2024

Q2: How does the functional diversity and richness of a benthic algal assemblage change in response to an intermittency gradient?

- Functional richness will
- Functional divergence w



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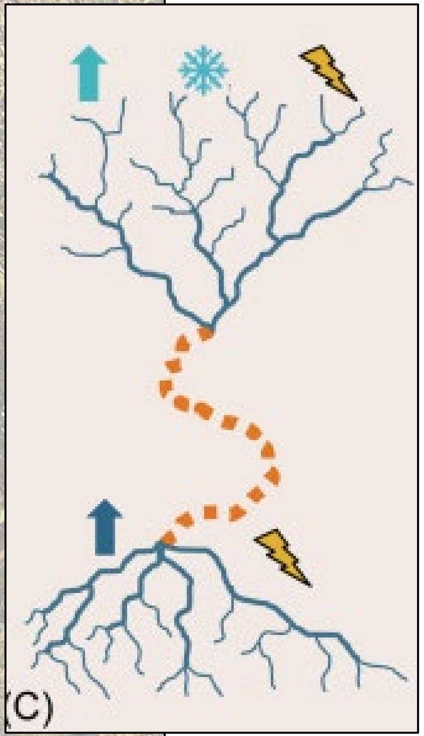


Image: Boulton et al., 2017

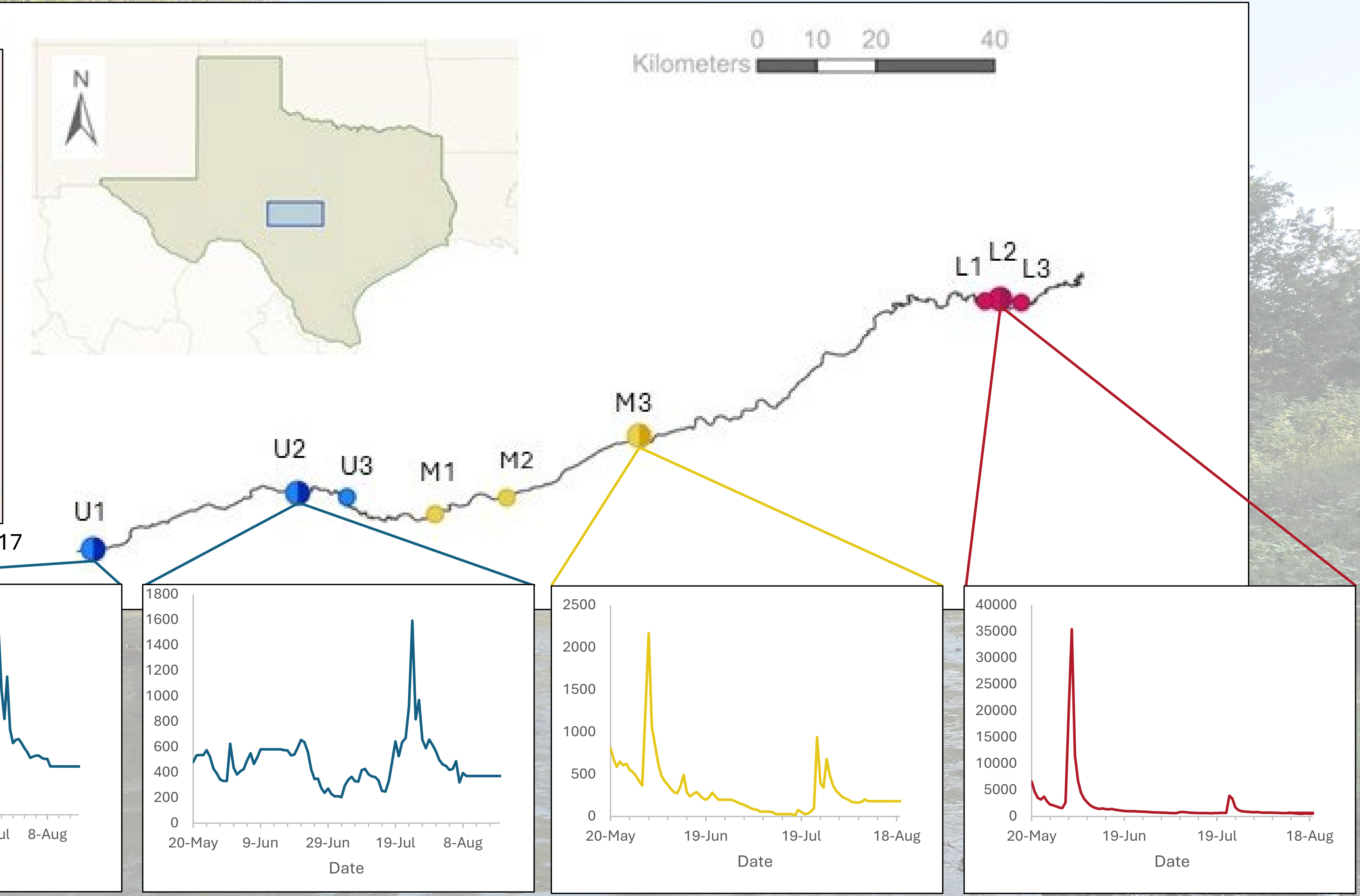


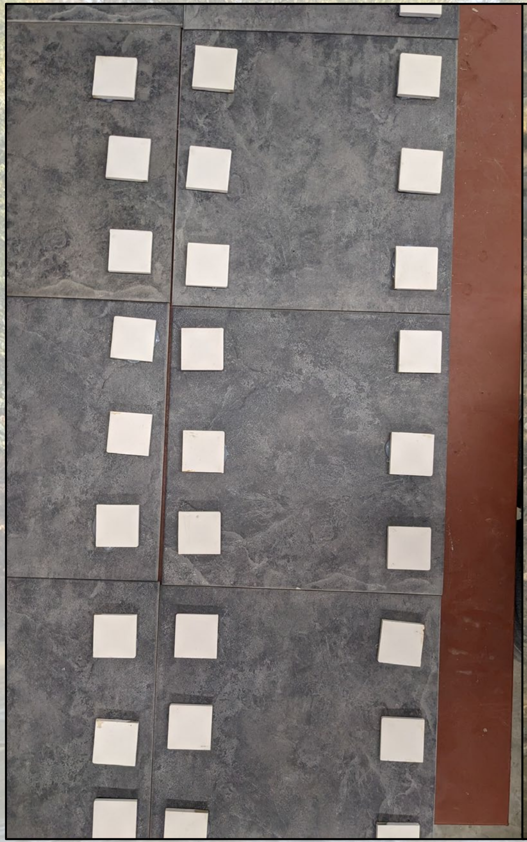
Image: Hannah Mattes

Field Sampling → Lab Processing → Statistical Analyses

- Environmental variables
  - Canopy cover, temperature, conductivity, etc.
- Water samples
- Algae samples
  - Short-term and long-term

Field Sampling → **Lab Processing** → **Statistical Analyses**

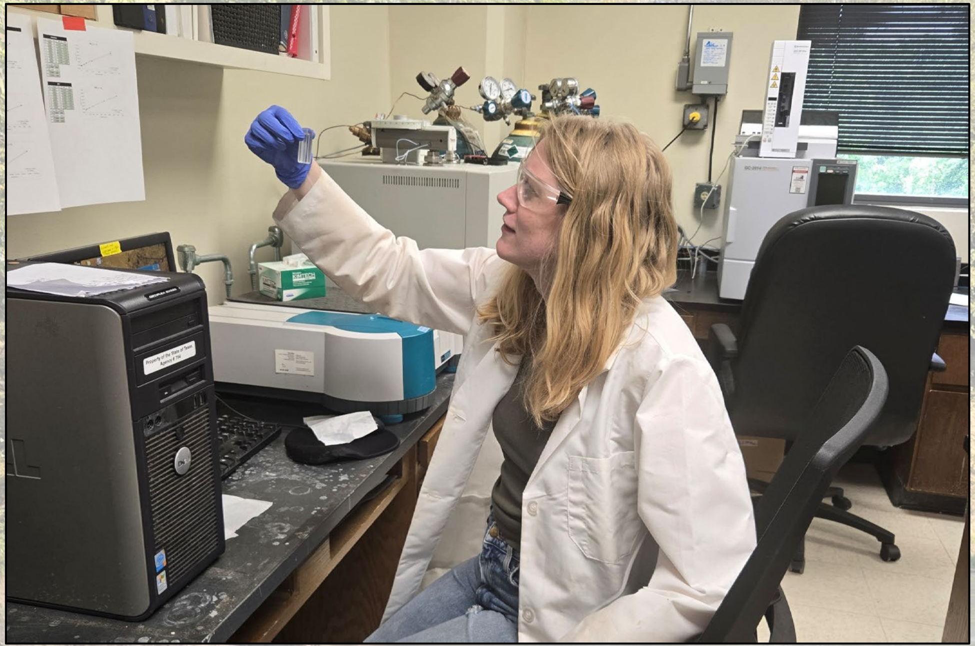
- Cut and adhered six 25 cm^2 unglazed ceramic tiles to a larger tile
- Deployed tiles in riffle and pool mesohabitats for 21-31 days
- Collected tiles and redeployed new ones

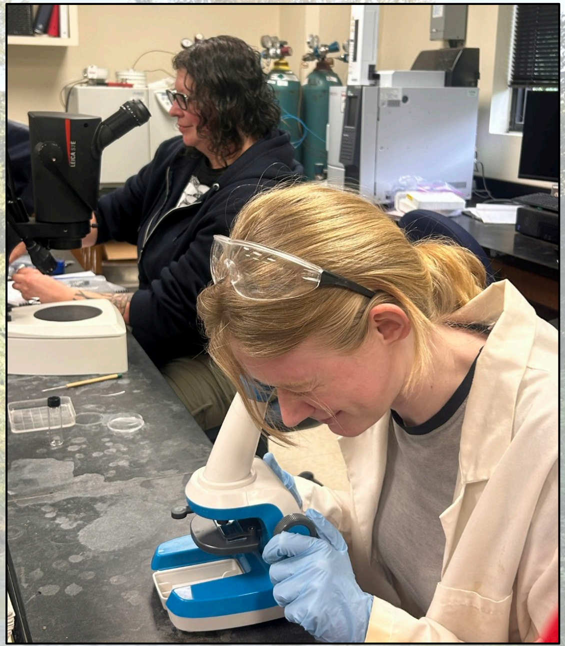


Field Sampling → Lab Processing → Statistical Analyses

- Collected limestone cobbles from both mesohabitats along same schedule as tiles

Field Sampling → **Lab Processing** → Statistical Analyses

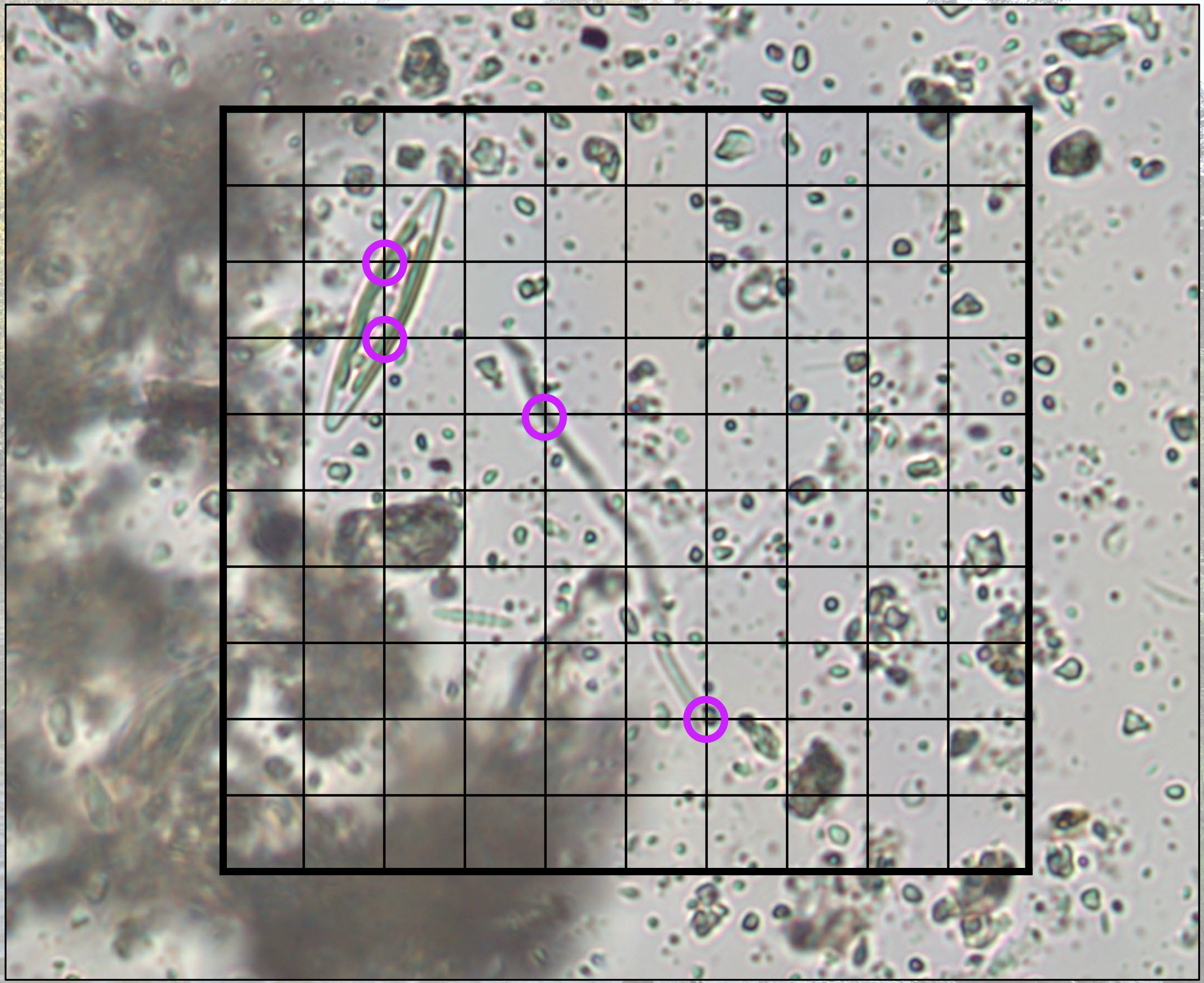




- Water samples
  - NVSS, Chl-*a*, nutrients, ions
- Benthic samples
  - AFDW, Chl-*a*, algae samples for enumeration

Field Sampling → **Lab Processing** → Statistical Analyses

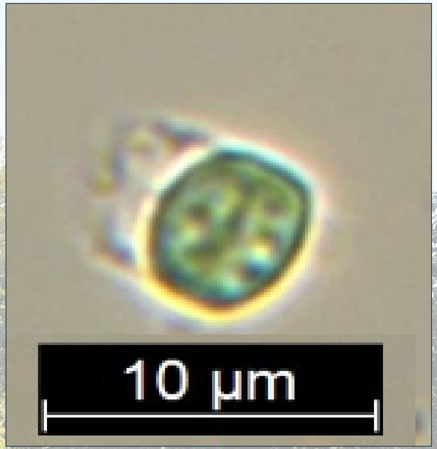
- Straight counts
    - Count cells at least half in Whipple grid
    - Filamentous cyanobacteria: 10 μm
- Biovolume estimates
    - Count Whipple grid crosshairs



Counts: 1 diatom, 6 cyano

Biovolume: 2 diatom, 2 cyano

Trait	Category
Size	Small (< 10 μm)
	Large (≥ 10 μm)
Life Form	Unicellular
	Colonial
	Filamentous
	Flagellate
Attachment	Unattached
	Attached
	Strongly attached
N-Fixation	N-Fixing
	Non-N-Fixing
Motility	Attached
	Drifting
	Gliding
Mucilage	Mucilaginous
	Non-Mucilaginous
Spore Formation	Spore Forming
	Non-Spore Forming



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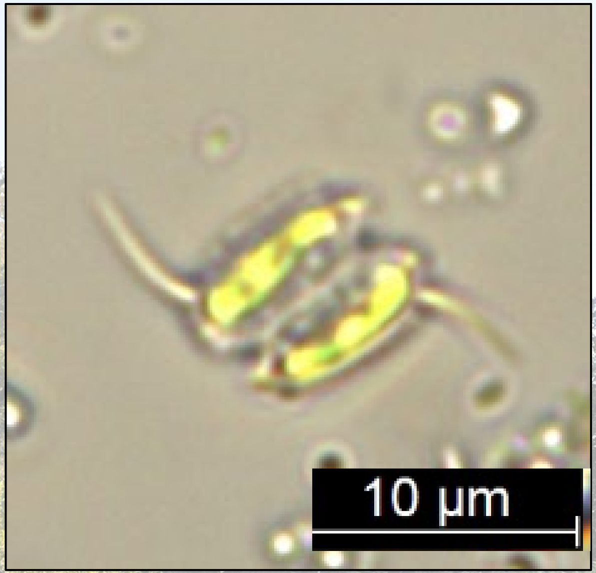

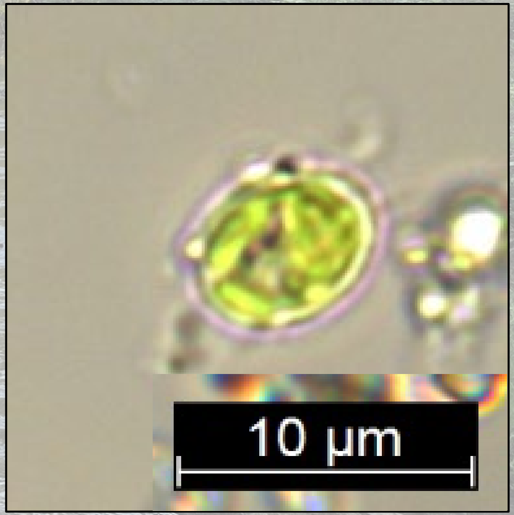

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Field Sampling → Lab Processing → **Statistical Analyses**

- Instantaneous discharge measurements
- Installed pressure transducer
- Estimated continuous discharge from gages
- Calculated suite of hydrological metrics

Field Sampling → Lab Processing → **Statistical Analyses**

Question 1:

- Assemblage composition influence by mesohabitat, river segment, and season
  - PERMANOVAs & NMDS plots
- Response of biomass
  - GLMMs

Field Sampling → Lab Processing → **Statistical Analyses**

Question 2:

- Functional diversity metrics via FD package in R
- Hydrological influences on functional diversity
  - GLMMs

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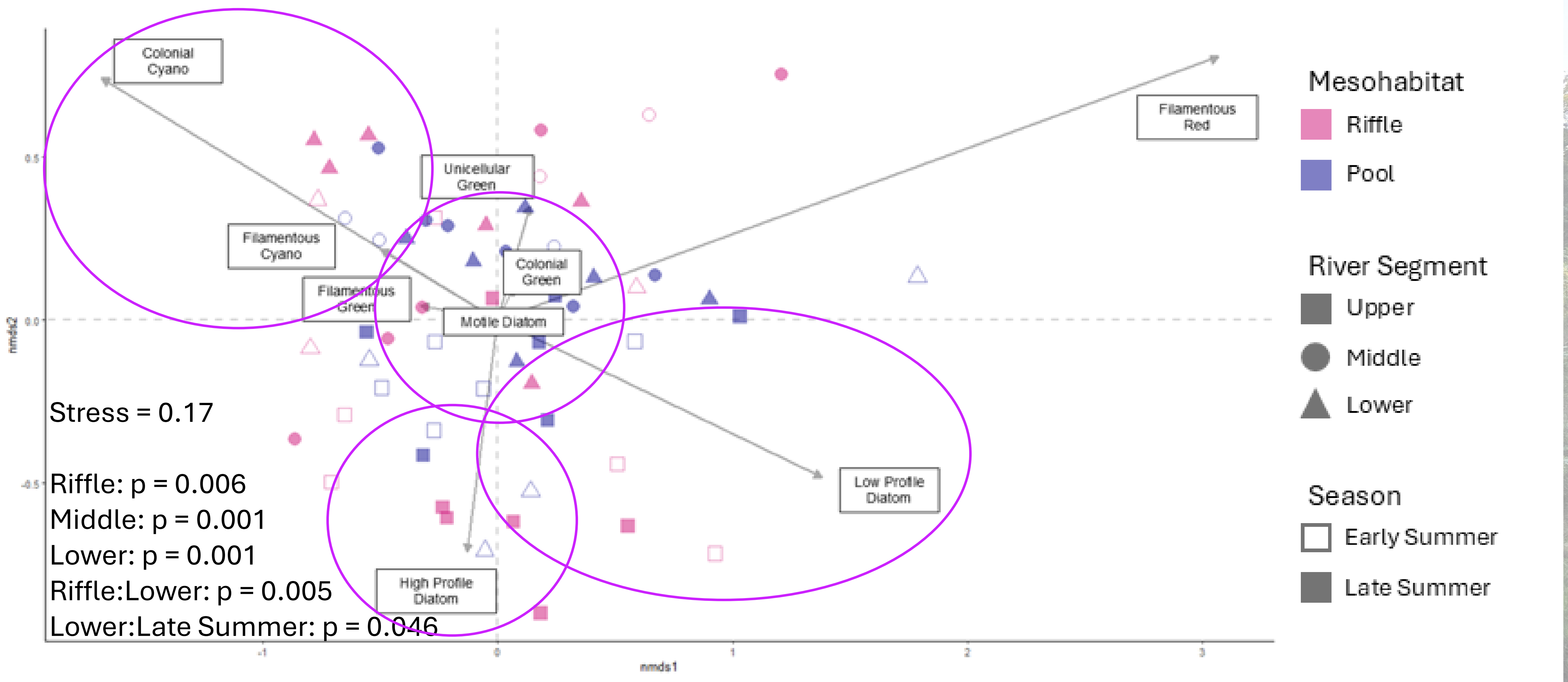
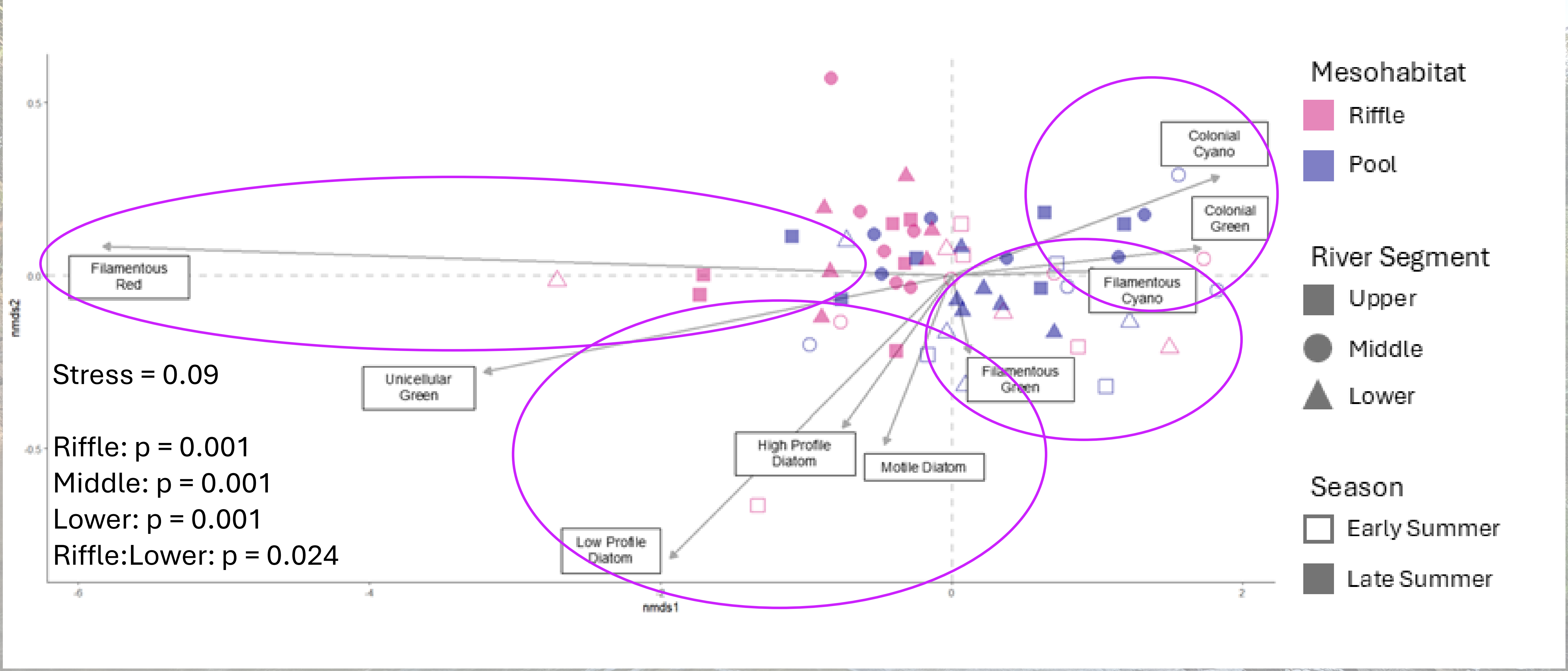
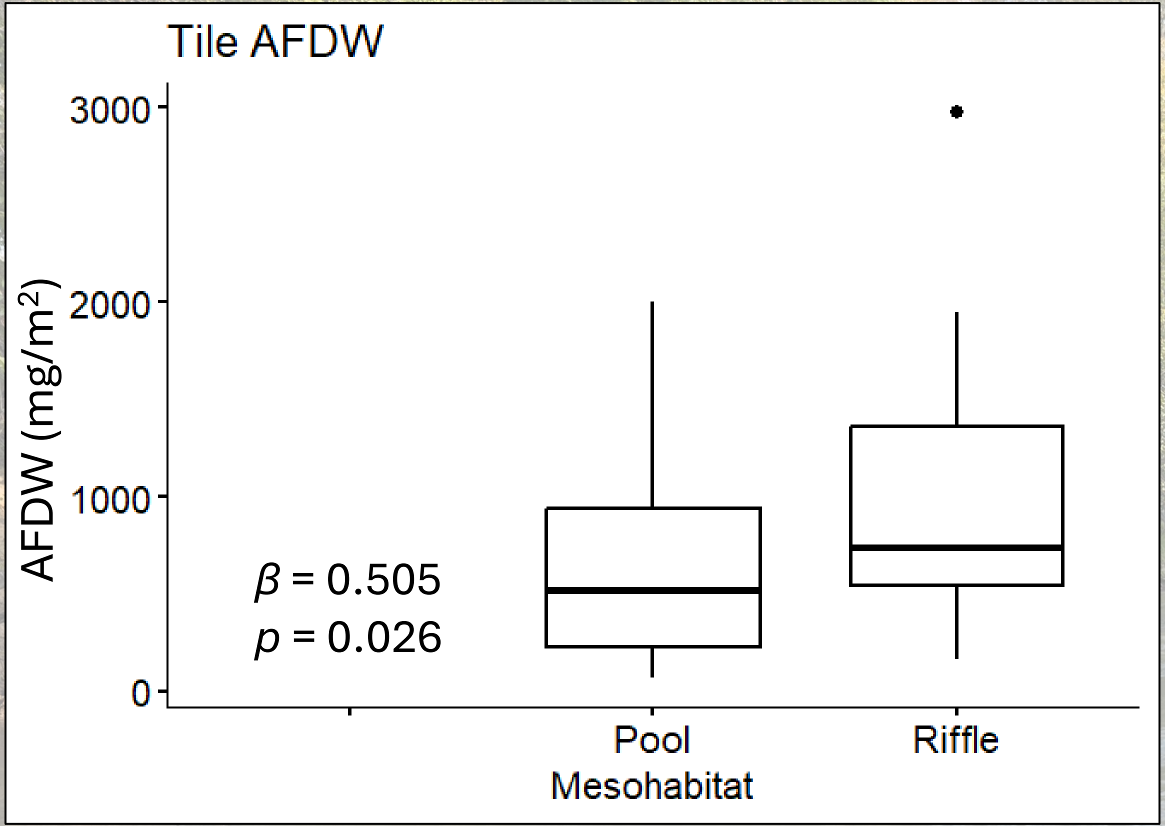
Tile Assemblage Composition

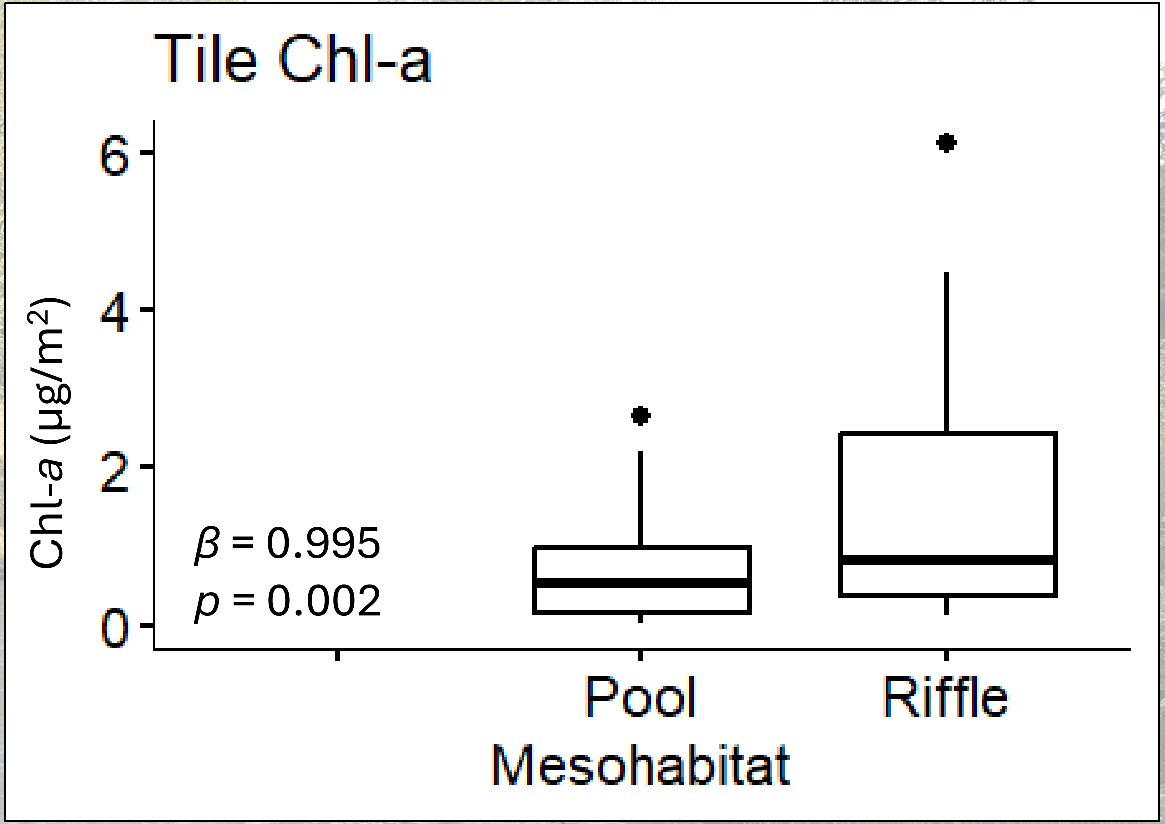


Cobble Assemblage Composition

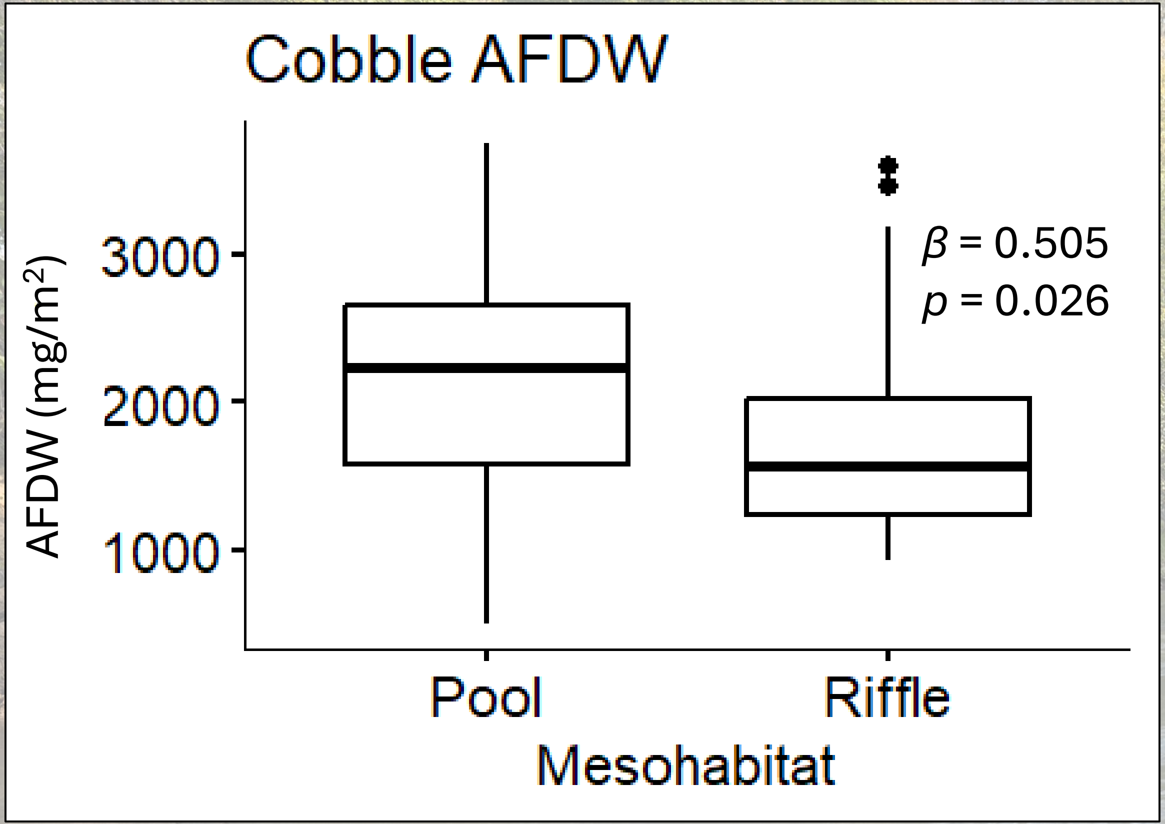


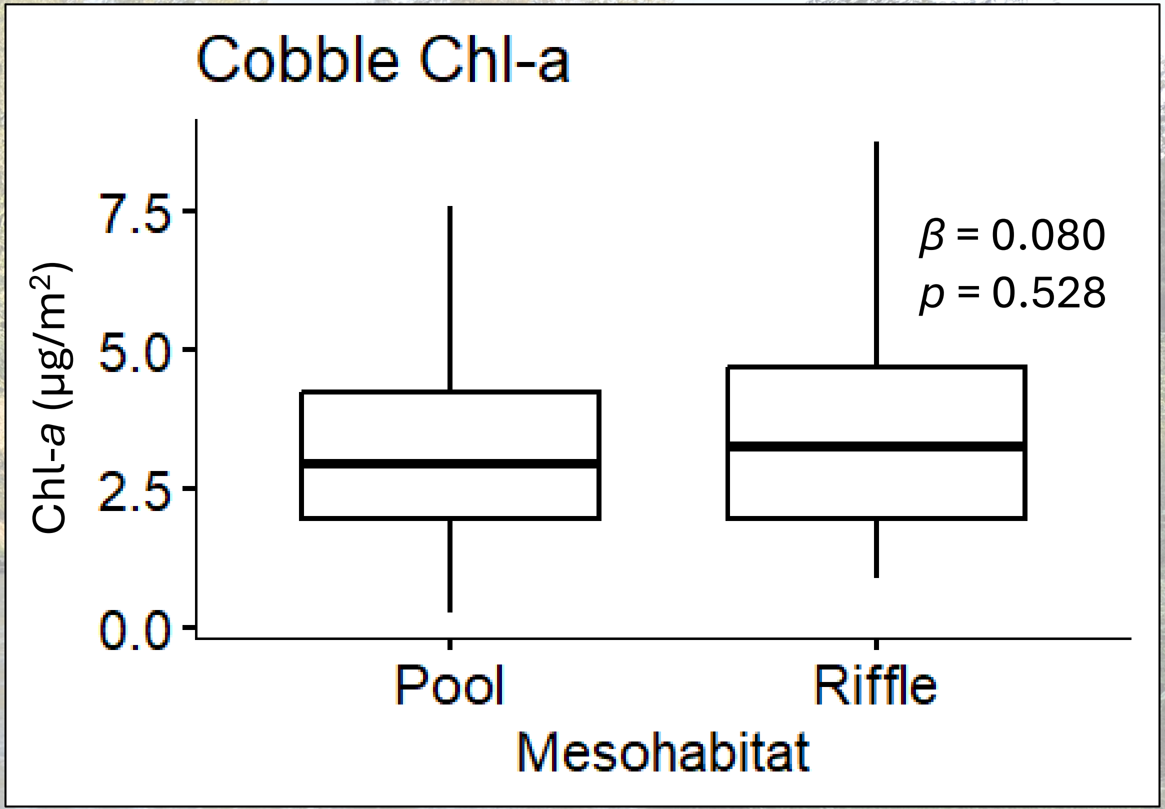
Short-Term Tile Biomass





Longer-Term Cobble Biomass





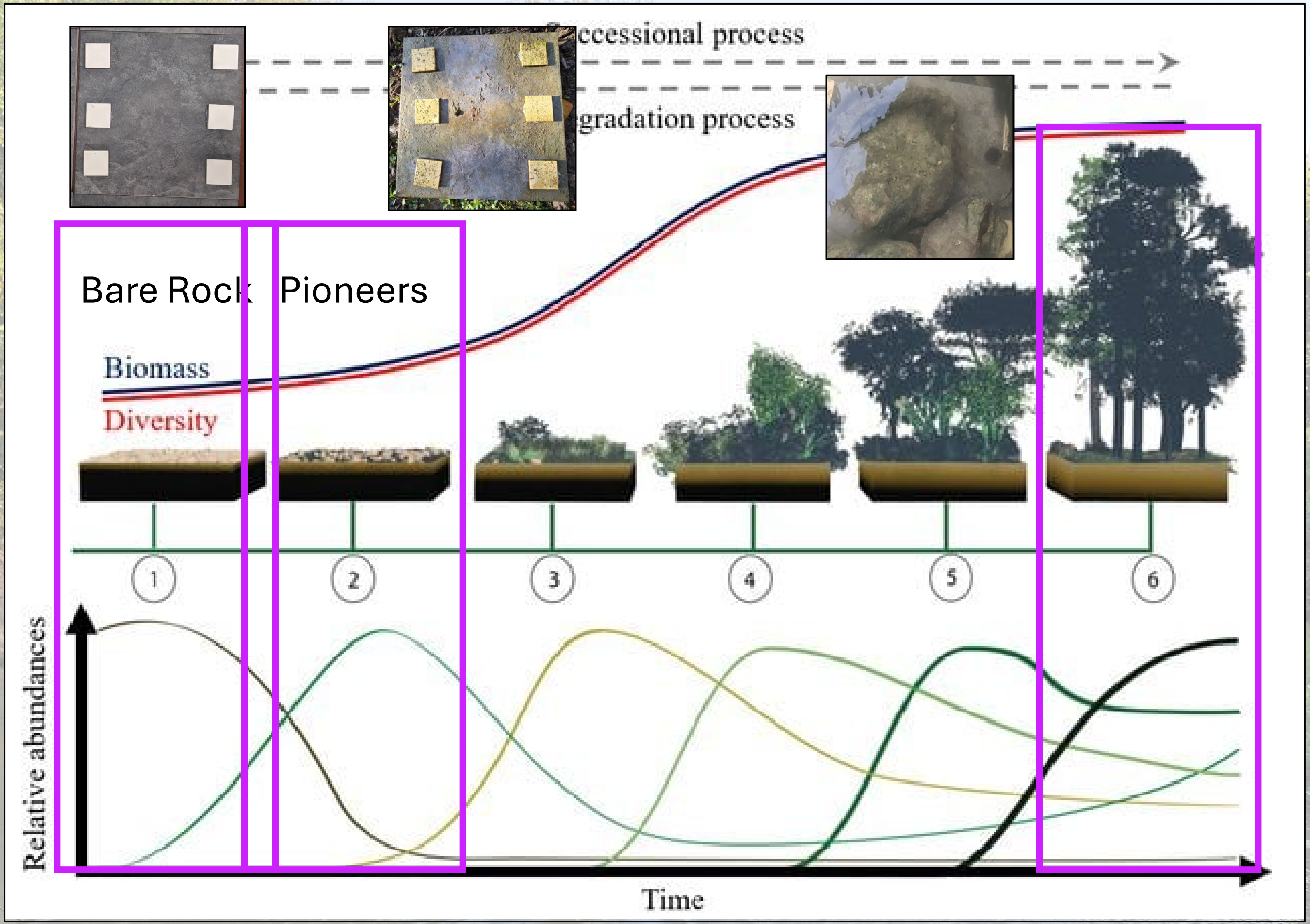
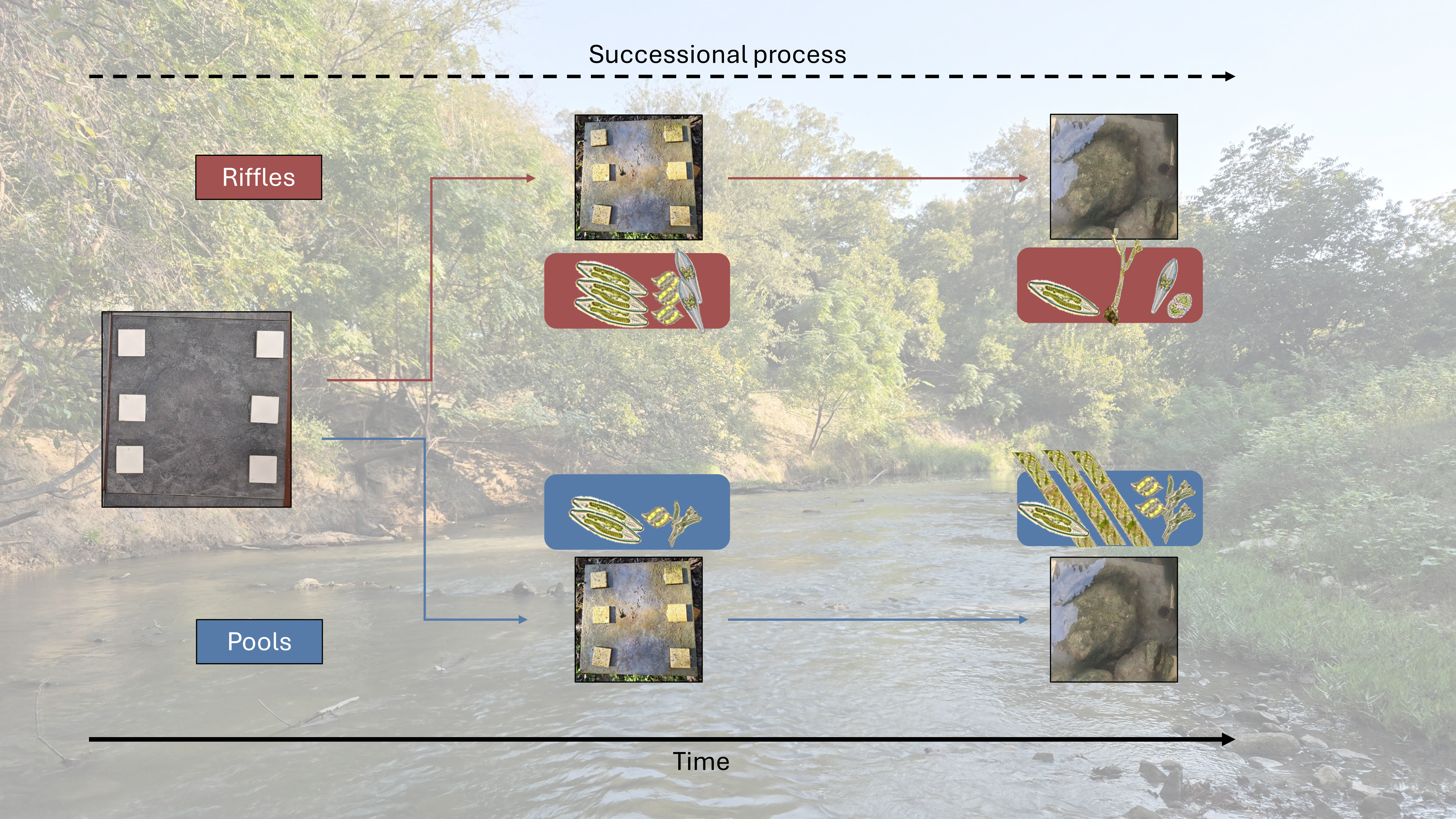


Image: Meloni et al., 2021


Successional process
Riffles
Pools
Time

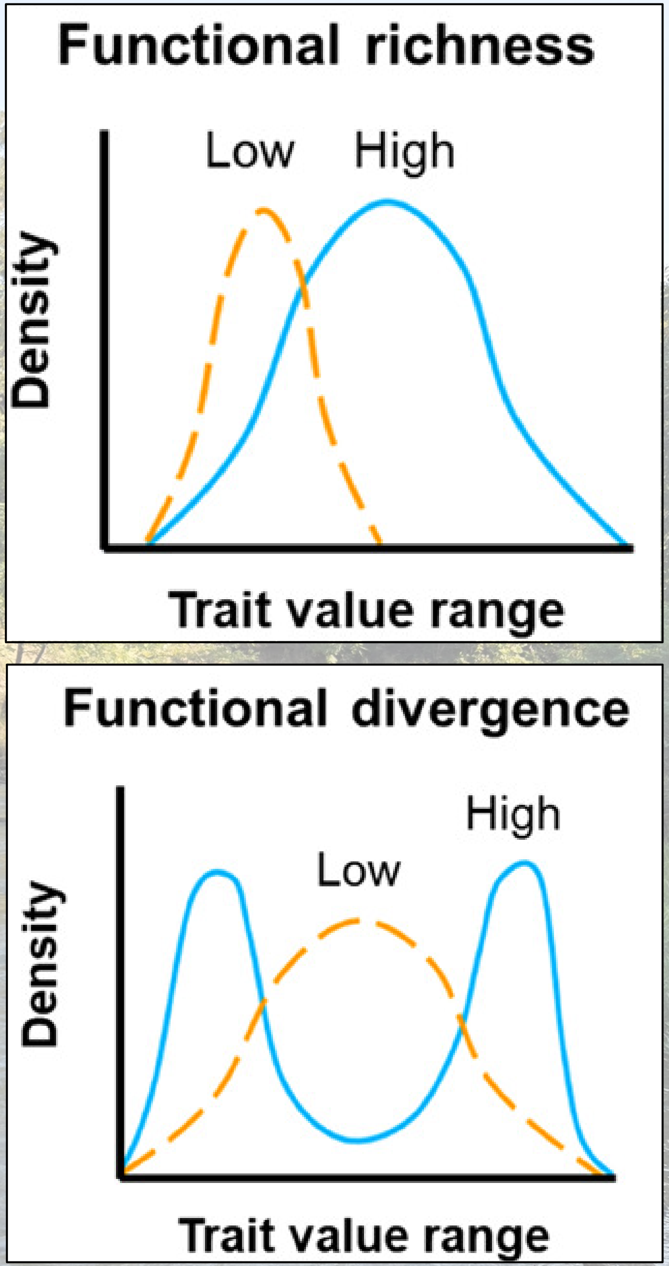
Q: How does the functional diversity and richness of a benthic algal assemblage change in response to an intermittency gradient?

- Functional richness will decrease with intermittency
- Functional divergence will decrease with intermittency

Multiple metrics for measuring functional diversity

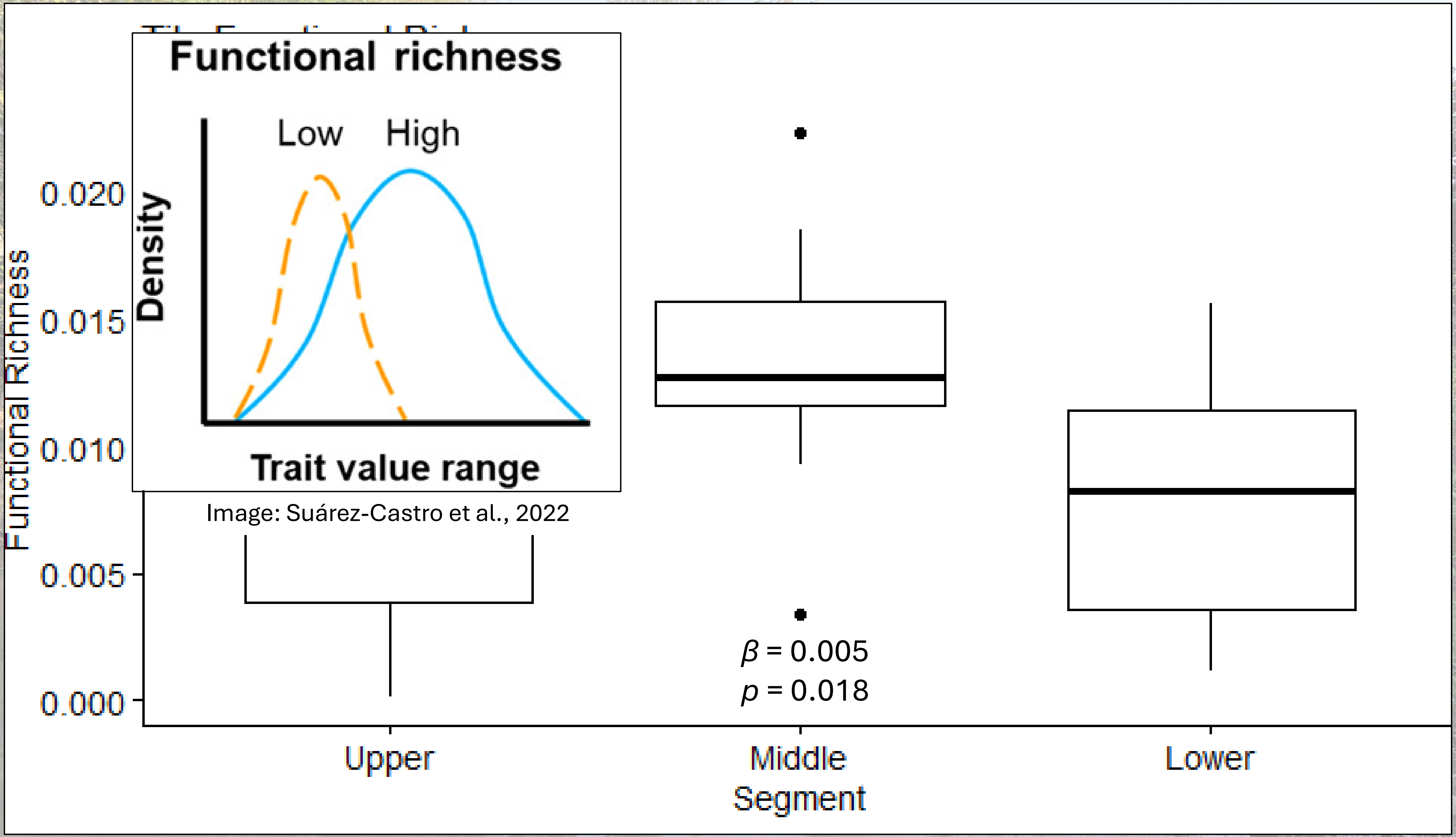
Metrics are independent of each other

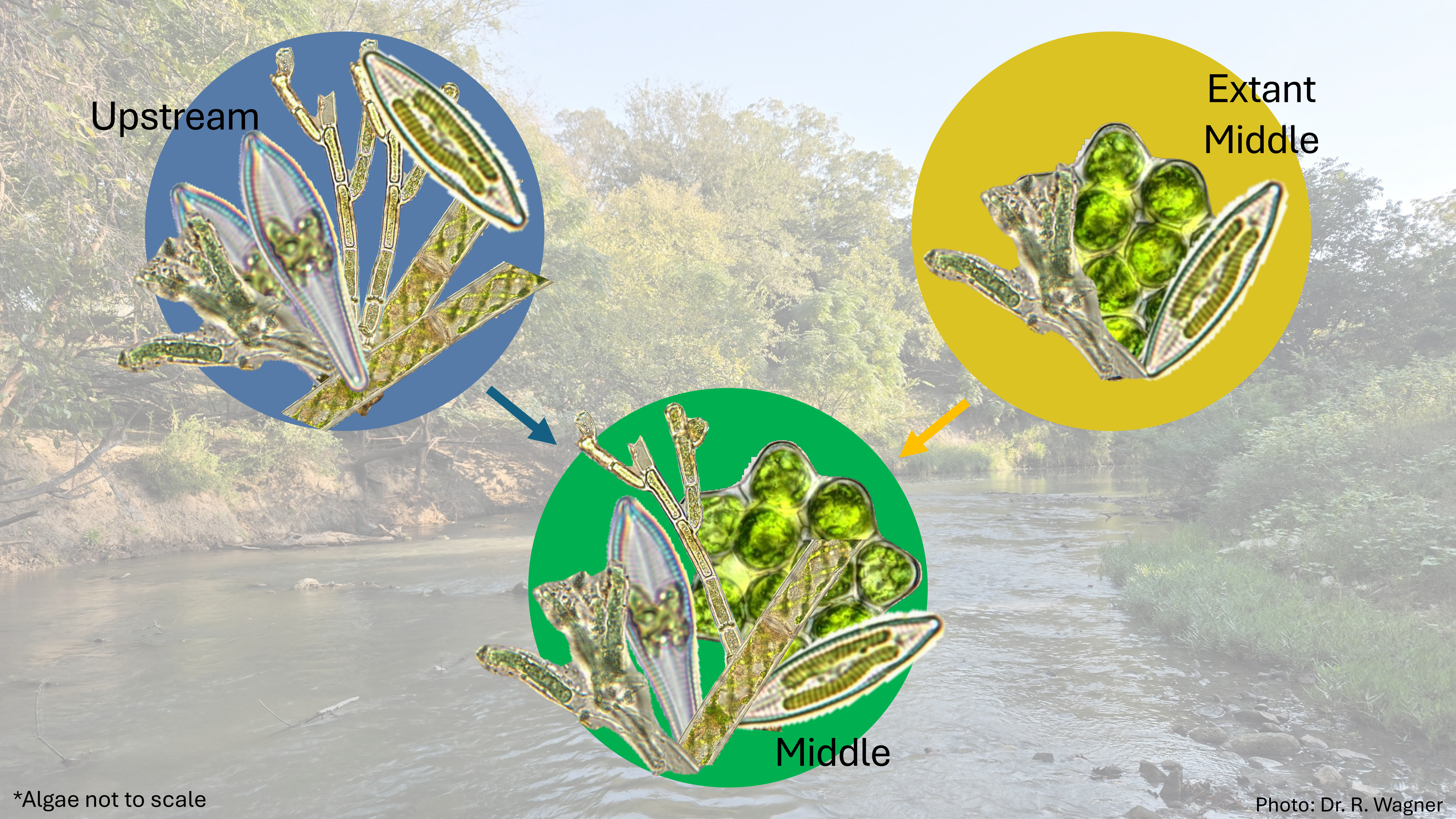
As any one metric increases, overall functional diversity increases too



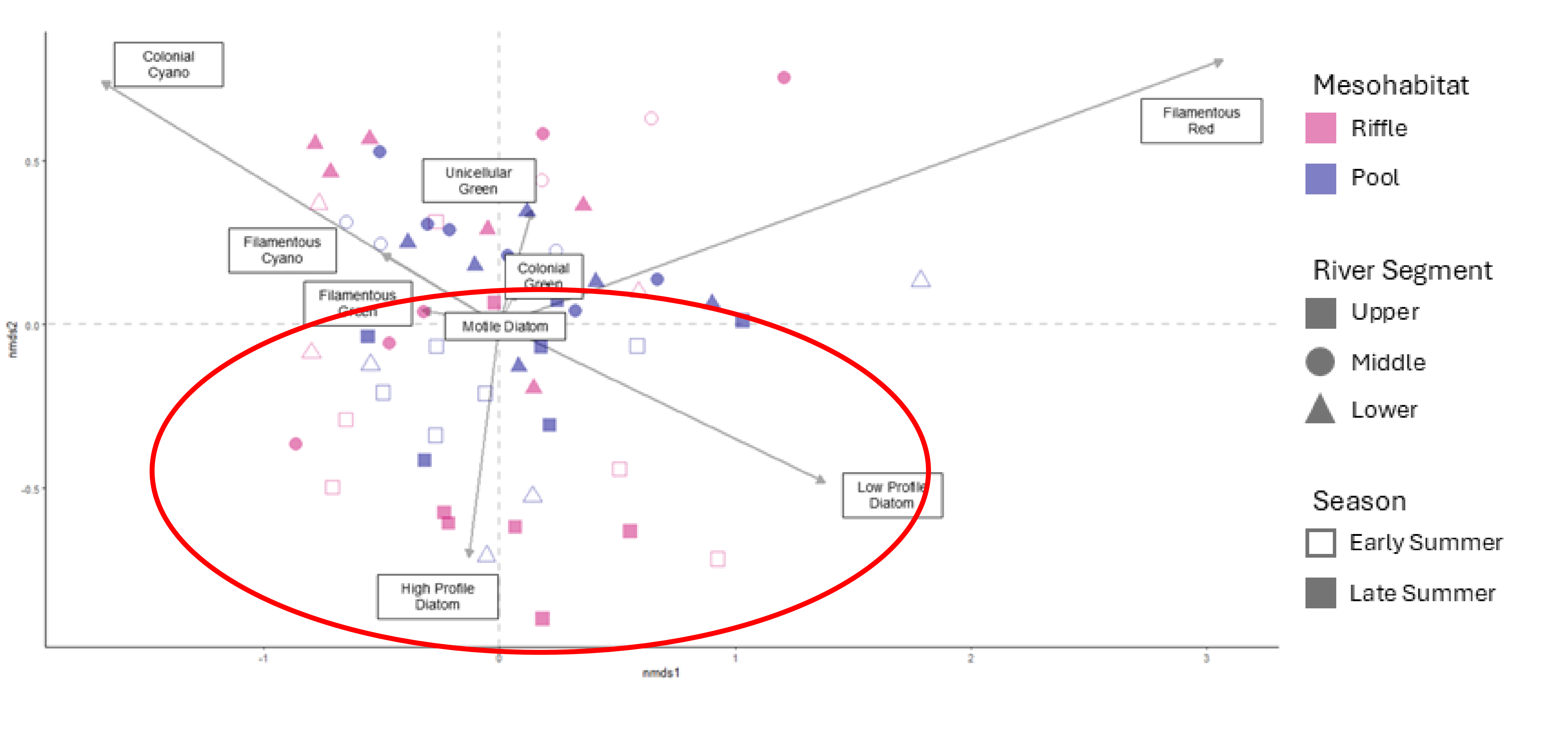
Images: Suárez-Castro et al., 2022

Tile Functional Richness

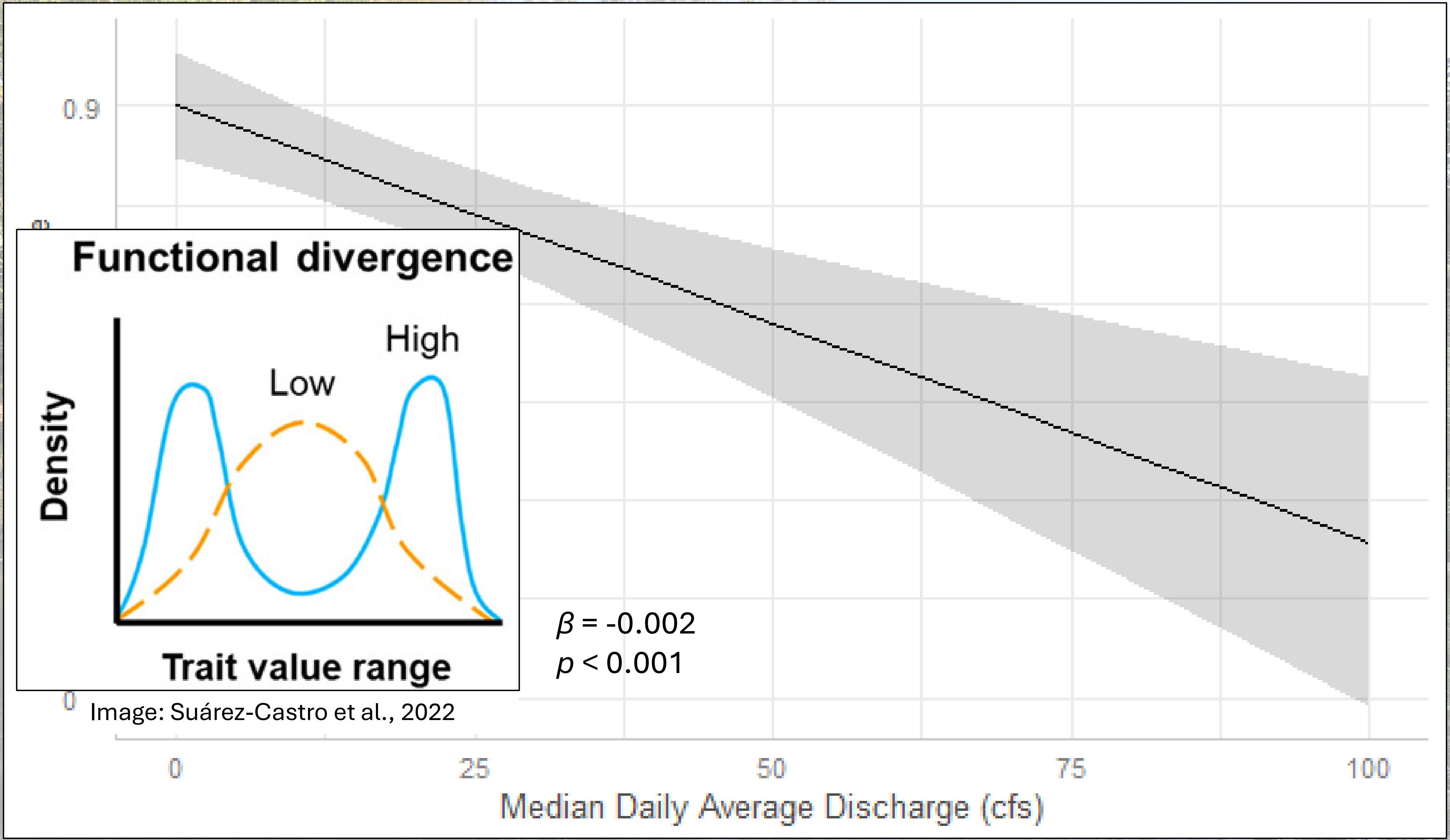



Upstream
Extant
Middle
Middle
*Algae not to scale
Photo: Dr. R. Wagner

Tile Assemblage Composition



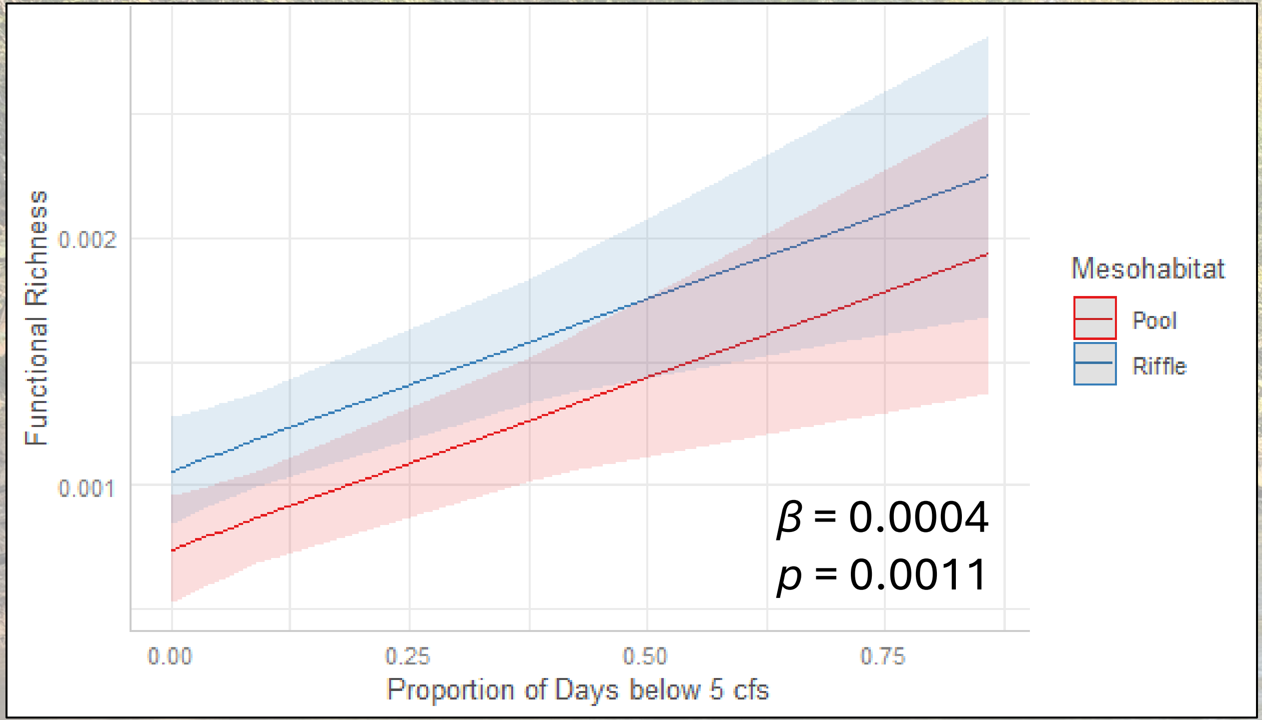
Tile Functional Divergence

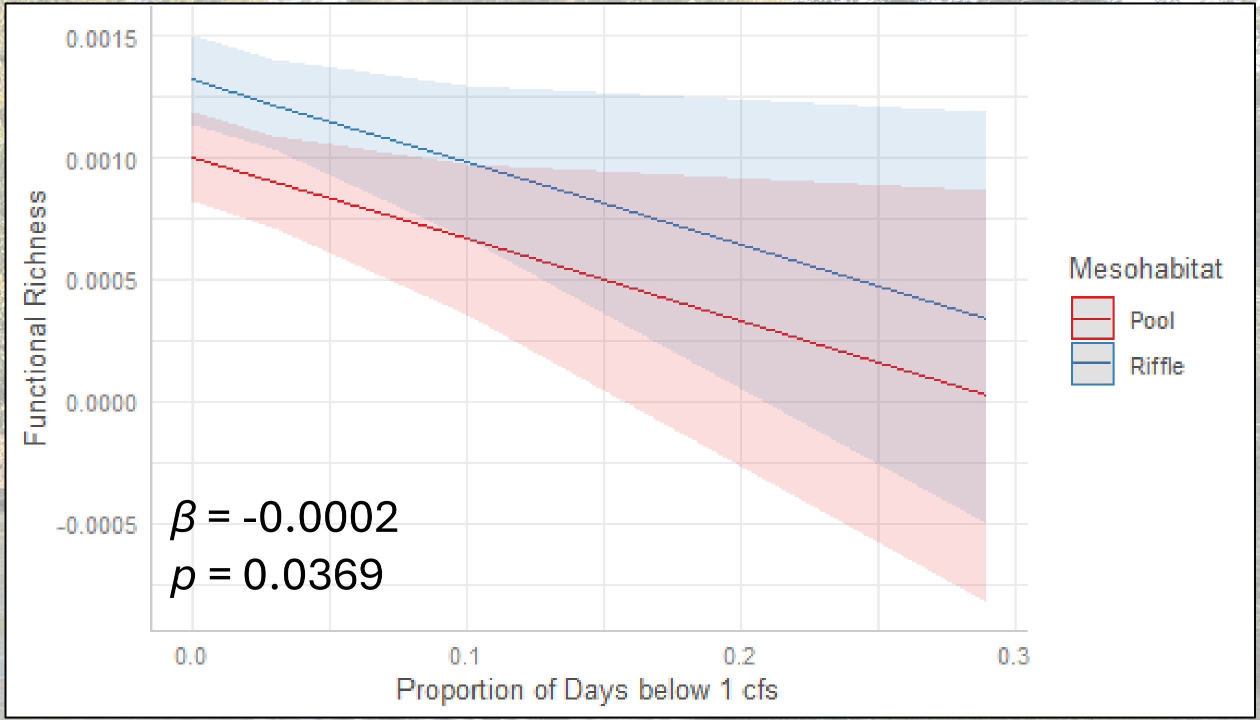


$\beta = -0.002$
$p < 0.001$

Image: Suárez-Castro et al., 2022

Cobble Functional Richness





Mesohabitat (Riffle):
β = 0.0003
p = 0.0219

Ecological Threshold → Environmental filtering

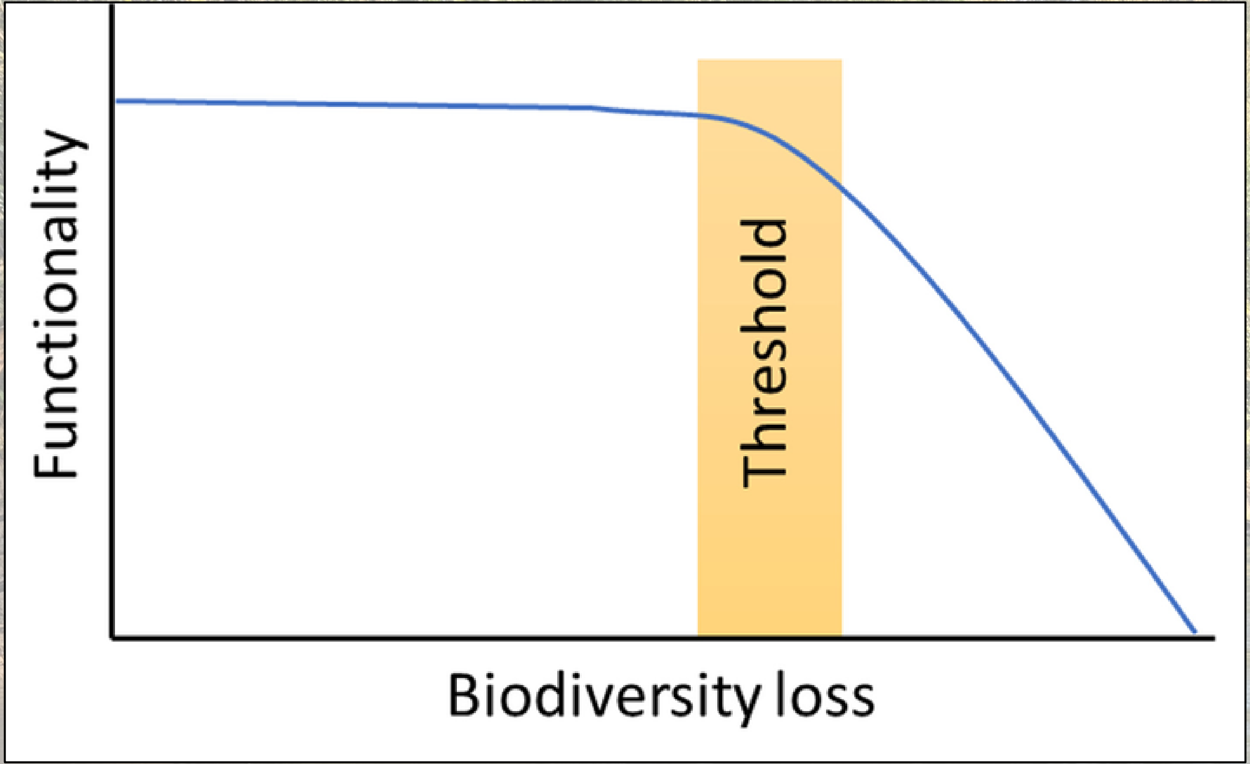


Image: Hillebrand et al., 2023

Intermediate Disturbance Hypothesis

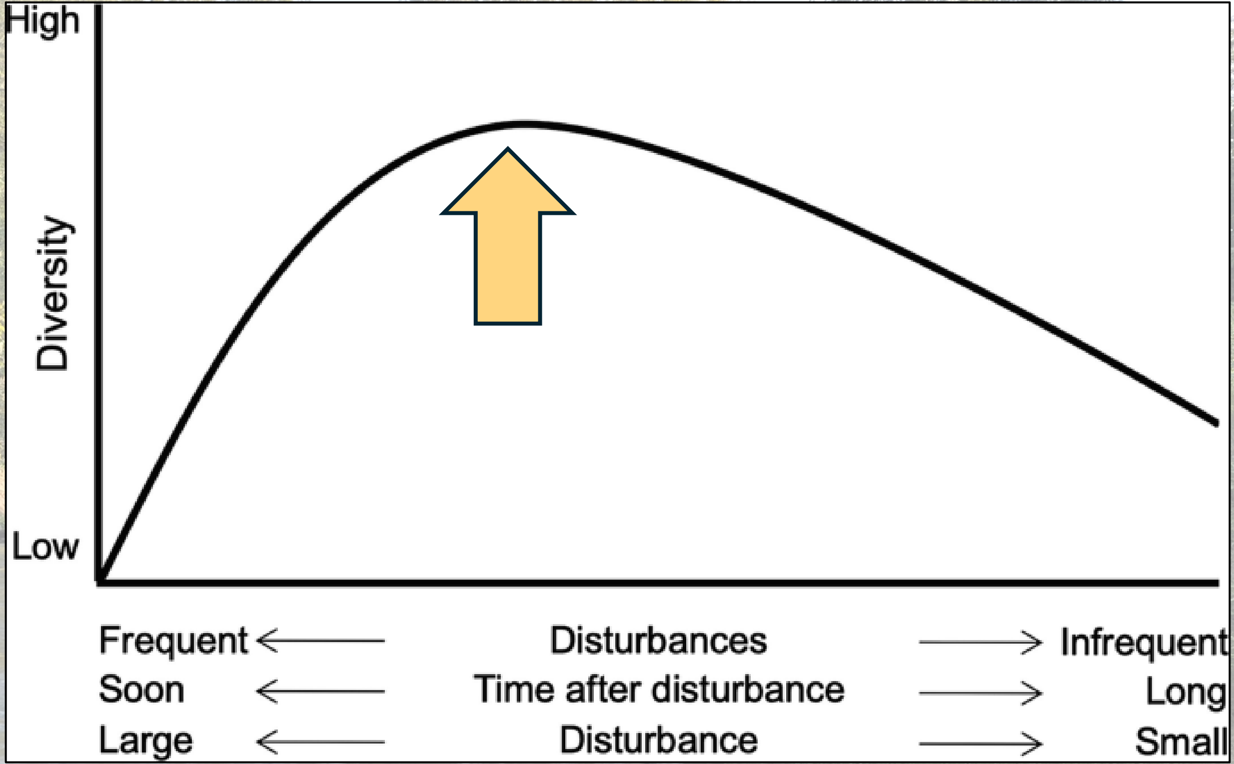
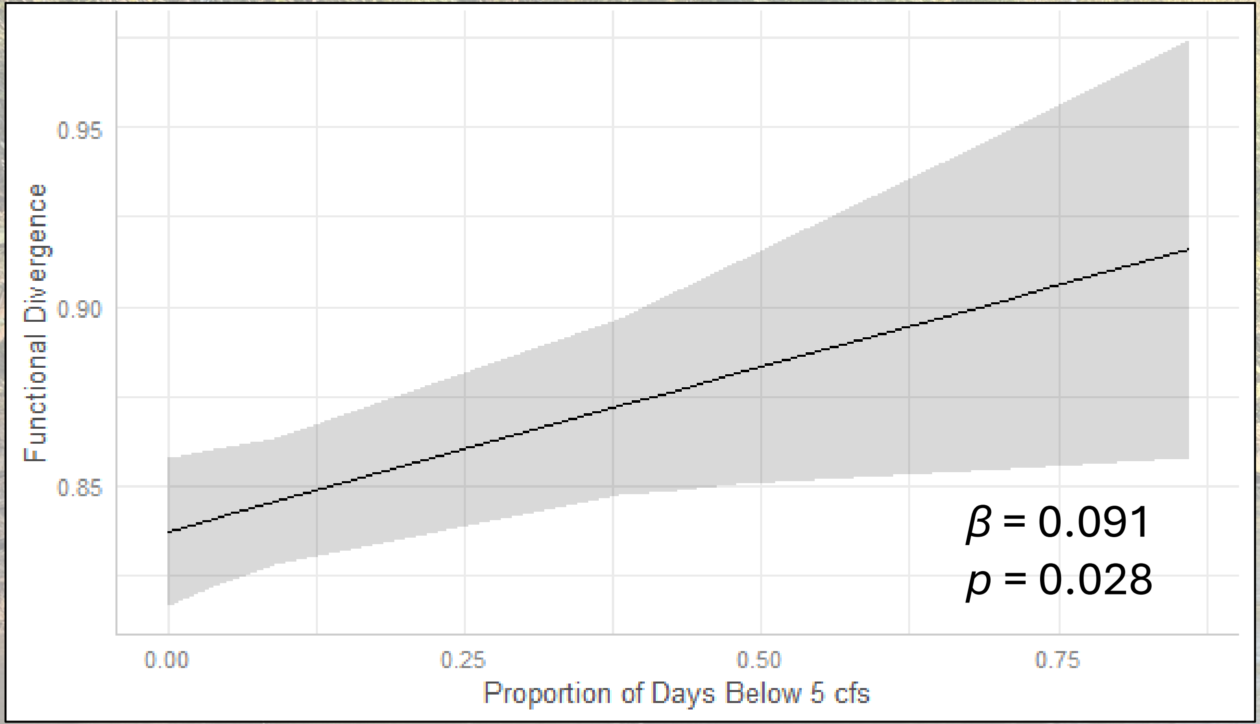
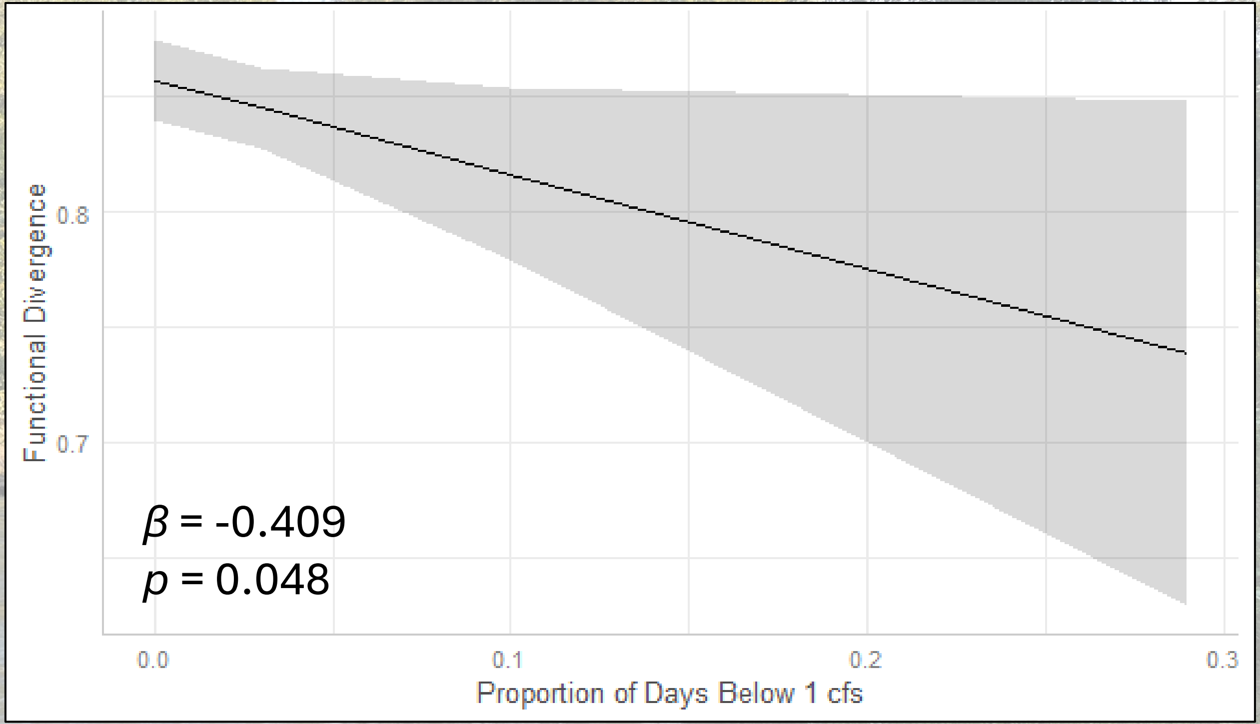


Image: Seidl et al., 2022

Cobble Functional Divergence





- River segment explains more variation in algal assemblages than mesohabitat
- Flow conditions influenced functional diversity
- Resistance and resilience traits responded to declining flows

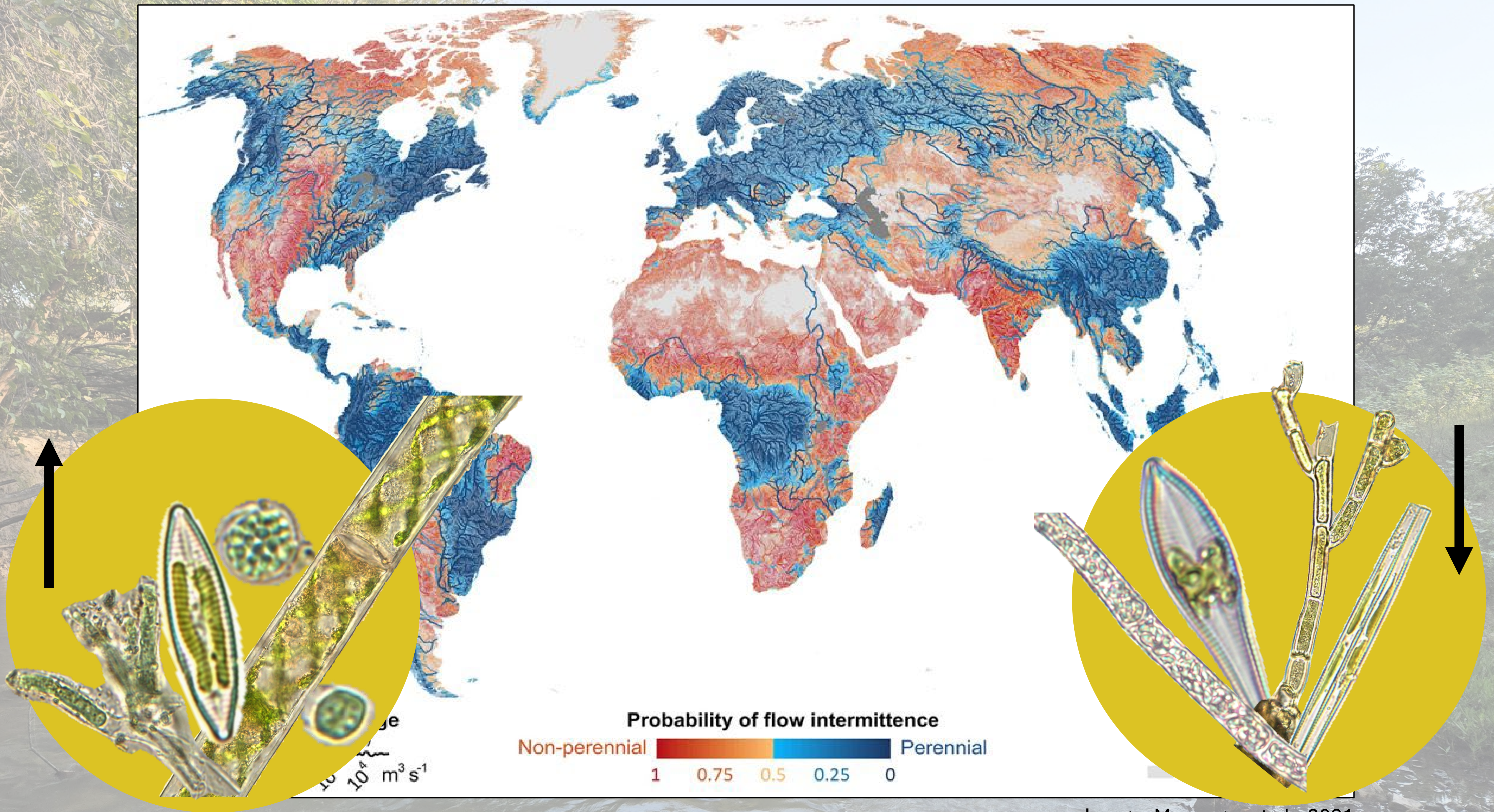


Image: Messager et al., 2021

Thank you to Ashley Casarez, Jered Davenport, Steve Guntli, Derreck Harris, Rachel Hill, Jess Kittridge, Hannah Madler, Hannah Mattes, Parvathi Nair, Jasmine Rodriguez, Incy Rojas Pina, Miranda Sams, Matthew Stehle, and Waverly Wadsworth

Thank you to the landowners who allowed us access to their property in the name of science

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Thank you to my committee members:
Dr. Paula Furey
Dr. Candice Piercy
Dr. Jason Martina

Thanks Steve!

Food Webs in Flow: Spatiotemporal Variation in Diversity and Food Web Structure in an Intermittent River

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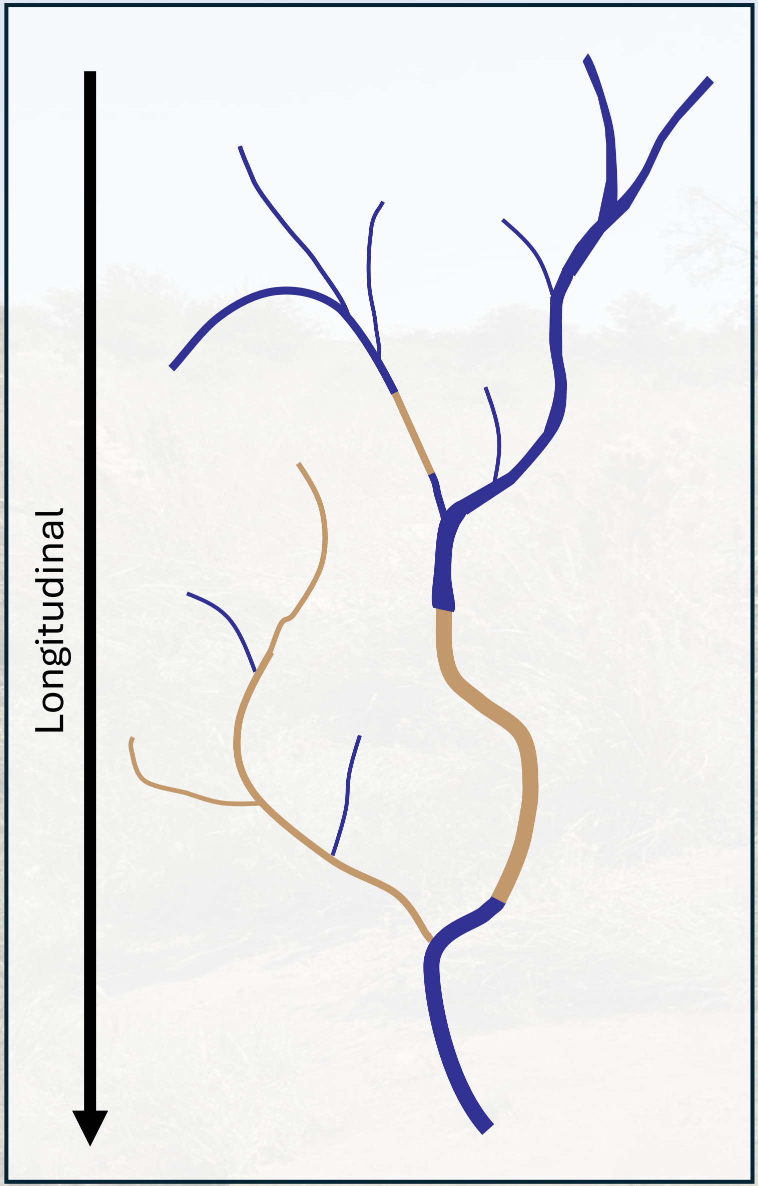
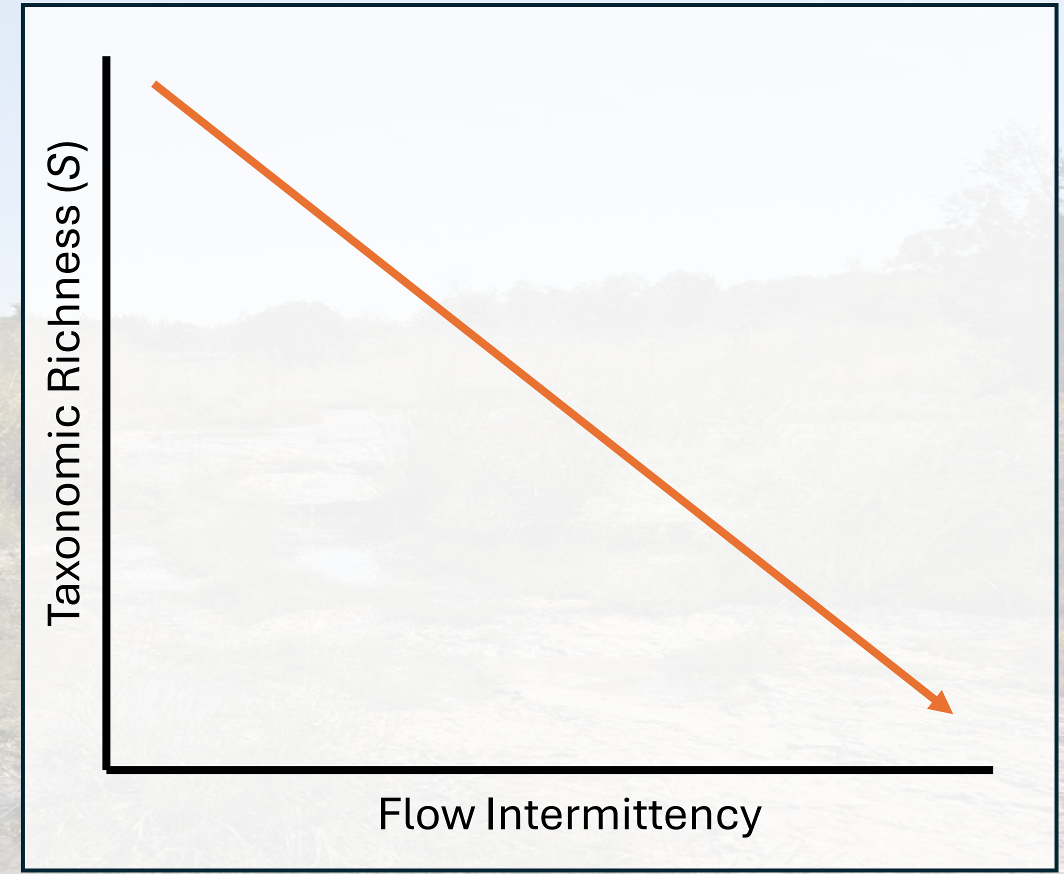
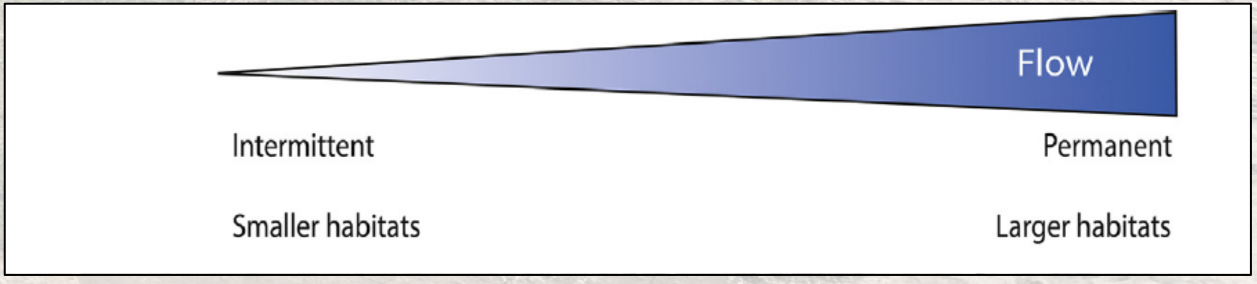
Dr. Weston Nowlin[1], Dr. Todd Swannack[1], Dr. Ben Hutchins[2]

[1]Texas State University Department of Biology,
[2]Edwards Aquifer Research and Data Center

Community Assemblages – Taxonomic Richness (*S*)

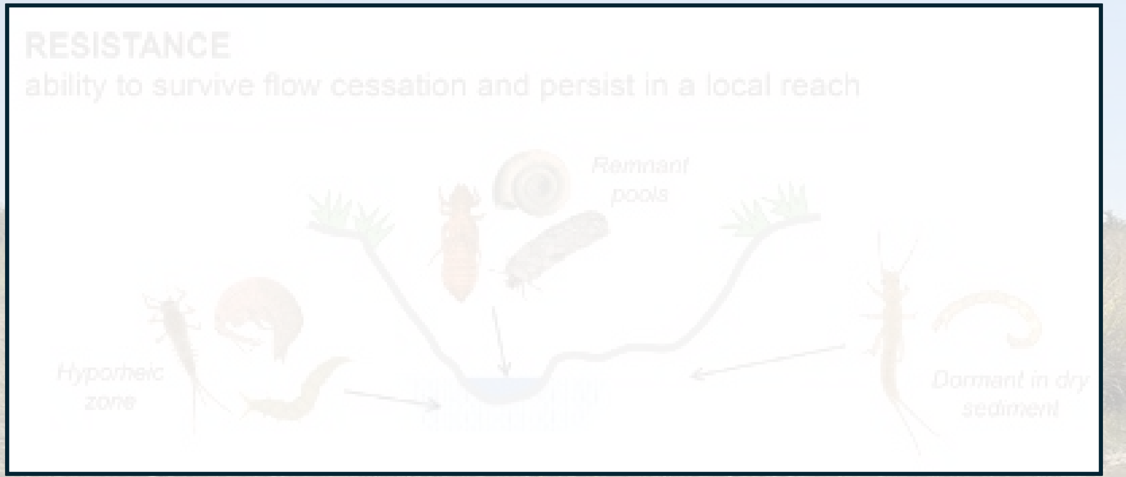


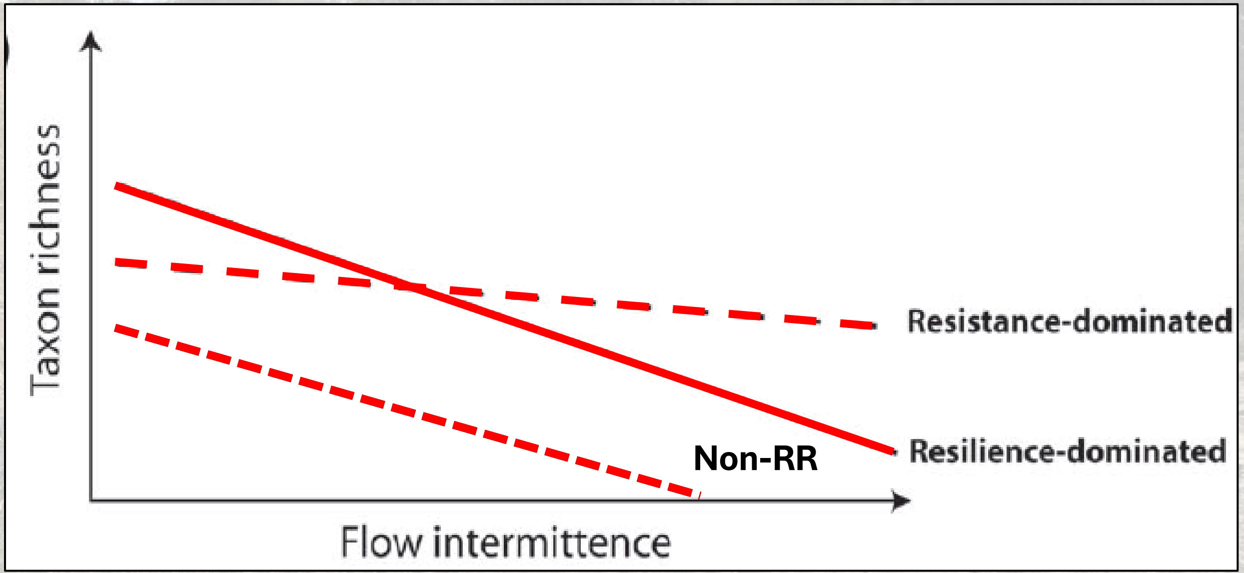




Datry et al, (2011). *Freshwater Biology;* Fritz and Dodds (2004). *Hydrobiologia*

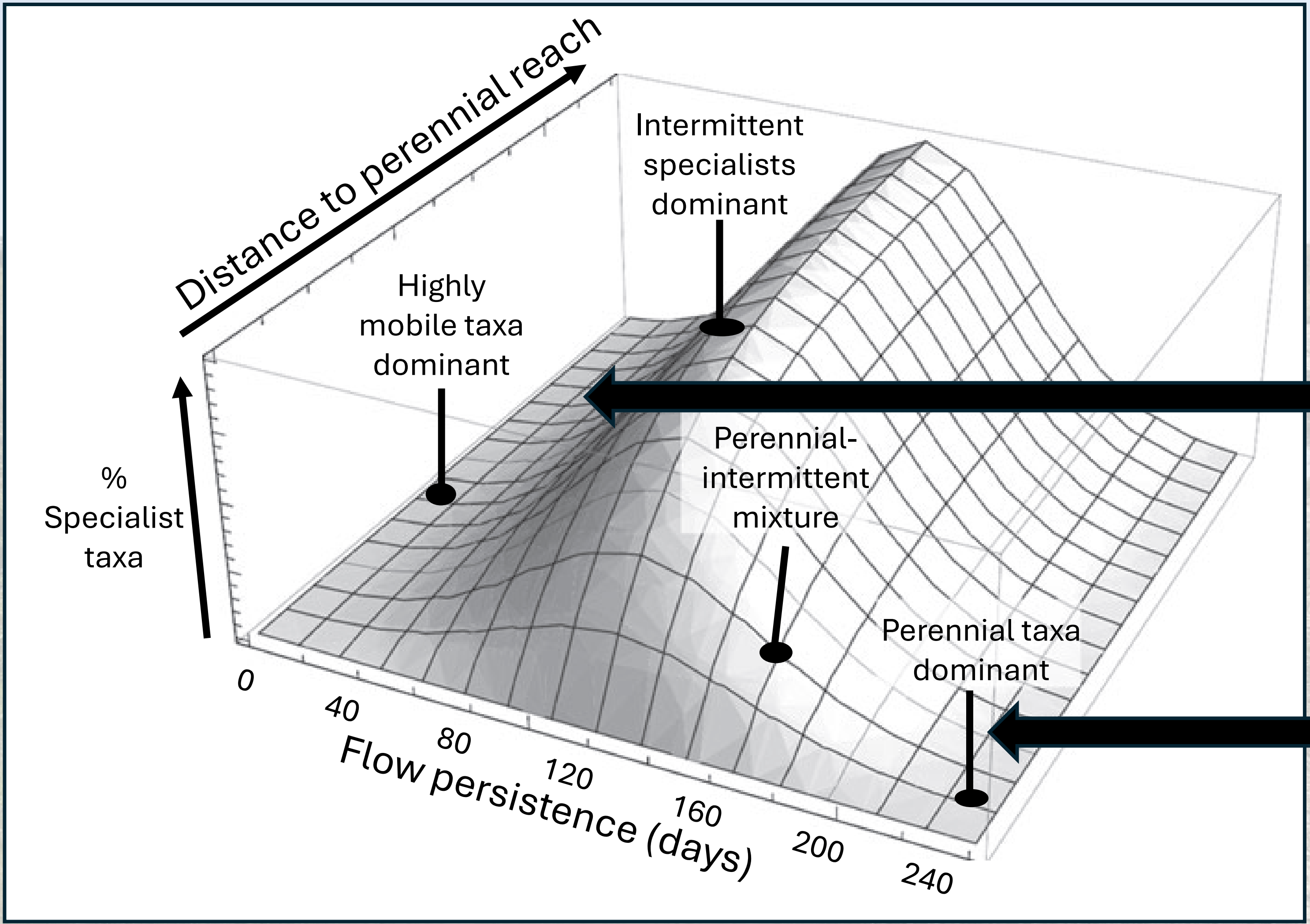
Traits in Community Assemblages





Bogan et al, (2017). *Intermittent Rivers and Ephemeral Streams;* Datry et al, (2013) *Ecography*

Community Assemblages



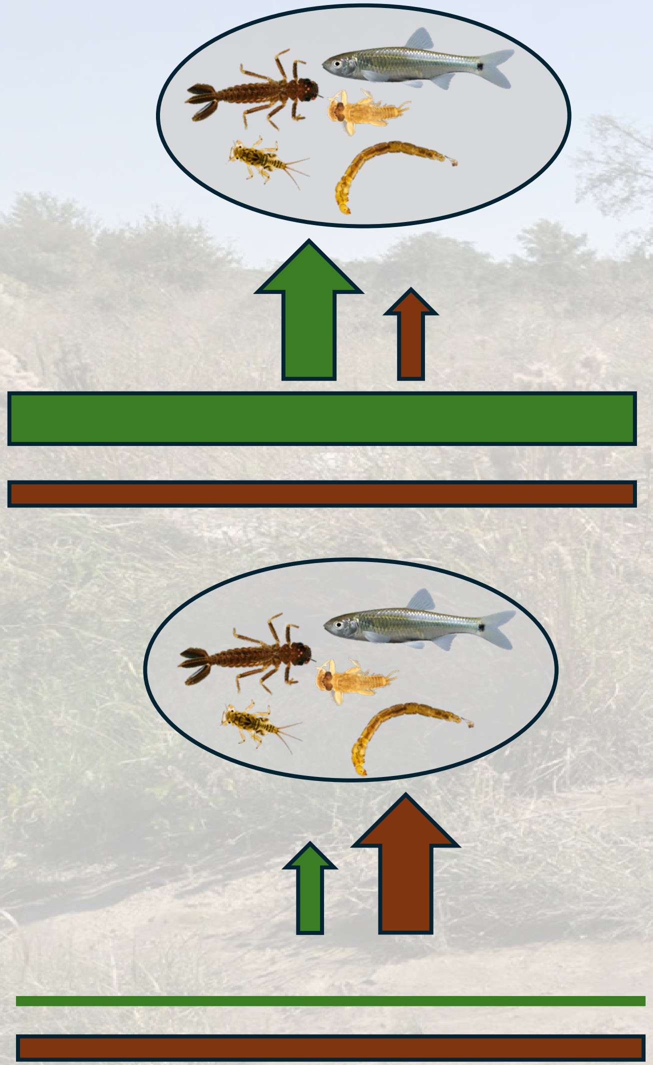
- Environmental filters lead to selected taxa (i.e. functional traits)
- “Goldilocks” disturbance = increased specialist taxa

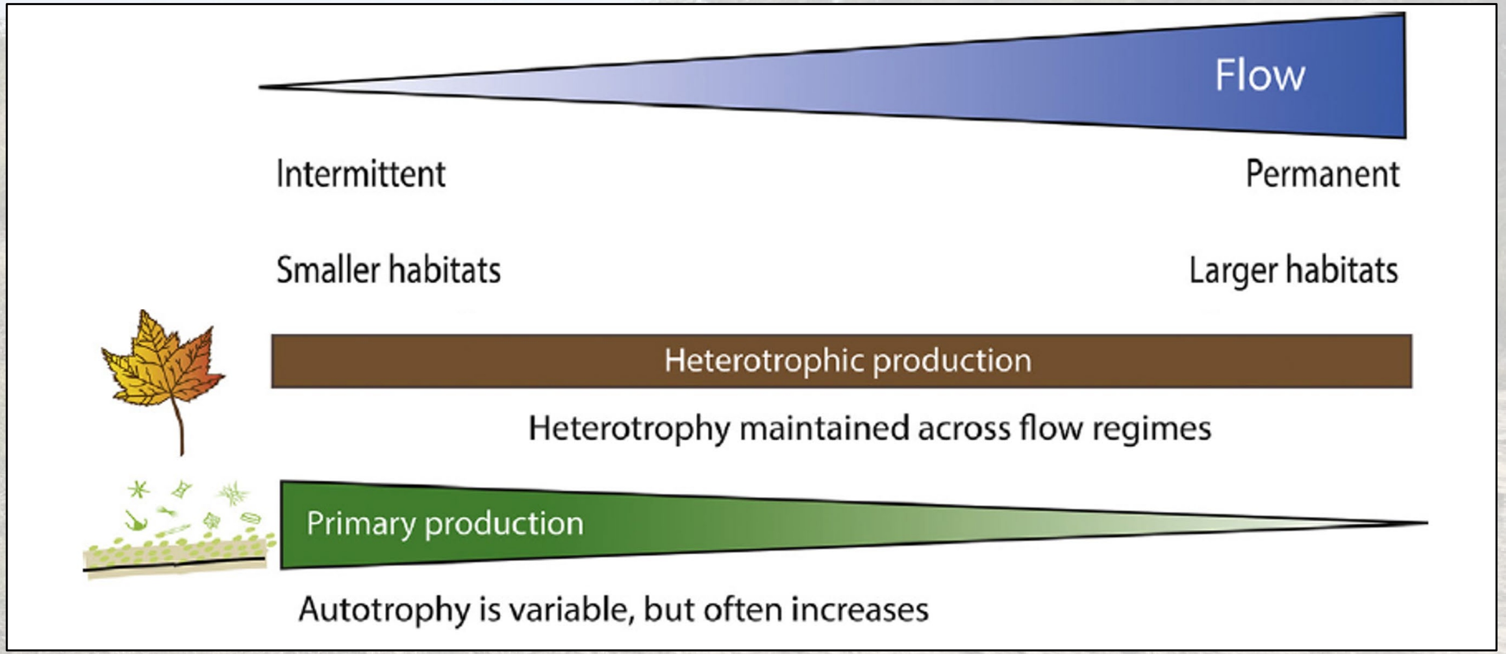
Smaller bodied consumers, more lentic taxa

Larger bodied consumers, more lotic taxa

Bogan et al, (2013) . *Freshwater Biology;* Carpenter-Bundhoo et al, (2022). *Freshwater Biology;* Kerezsy et al, (2017). *Intermittent Rivers and Ephemeral Streams*

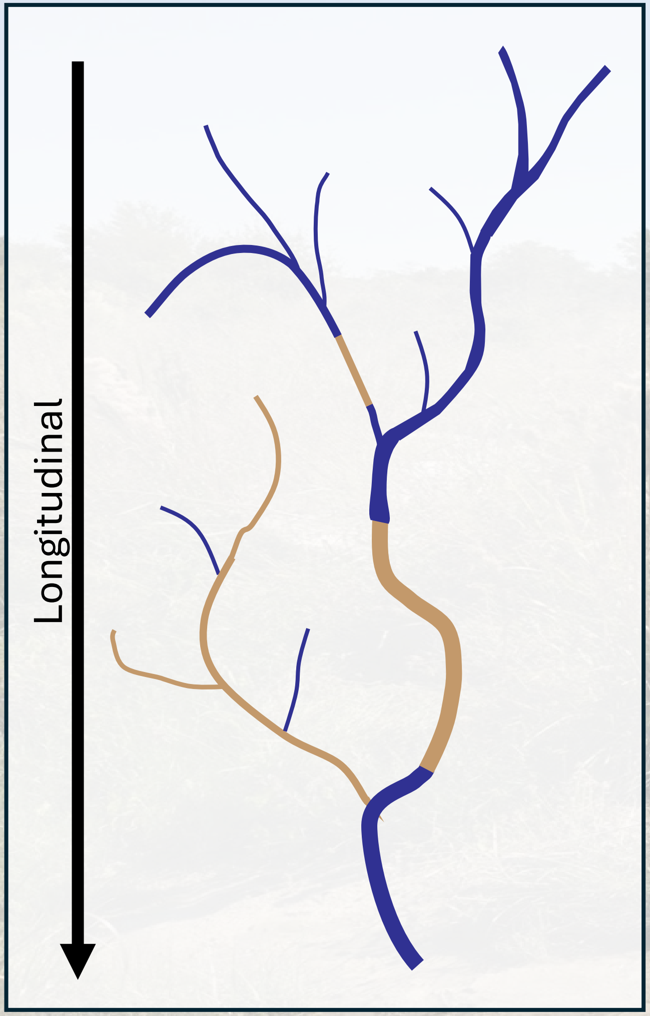
Organic Matter Interactions

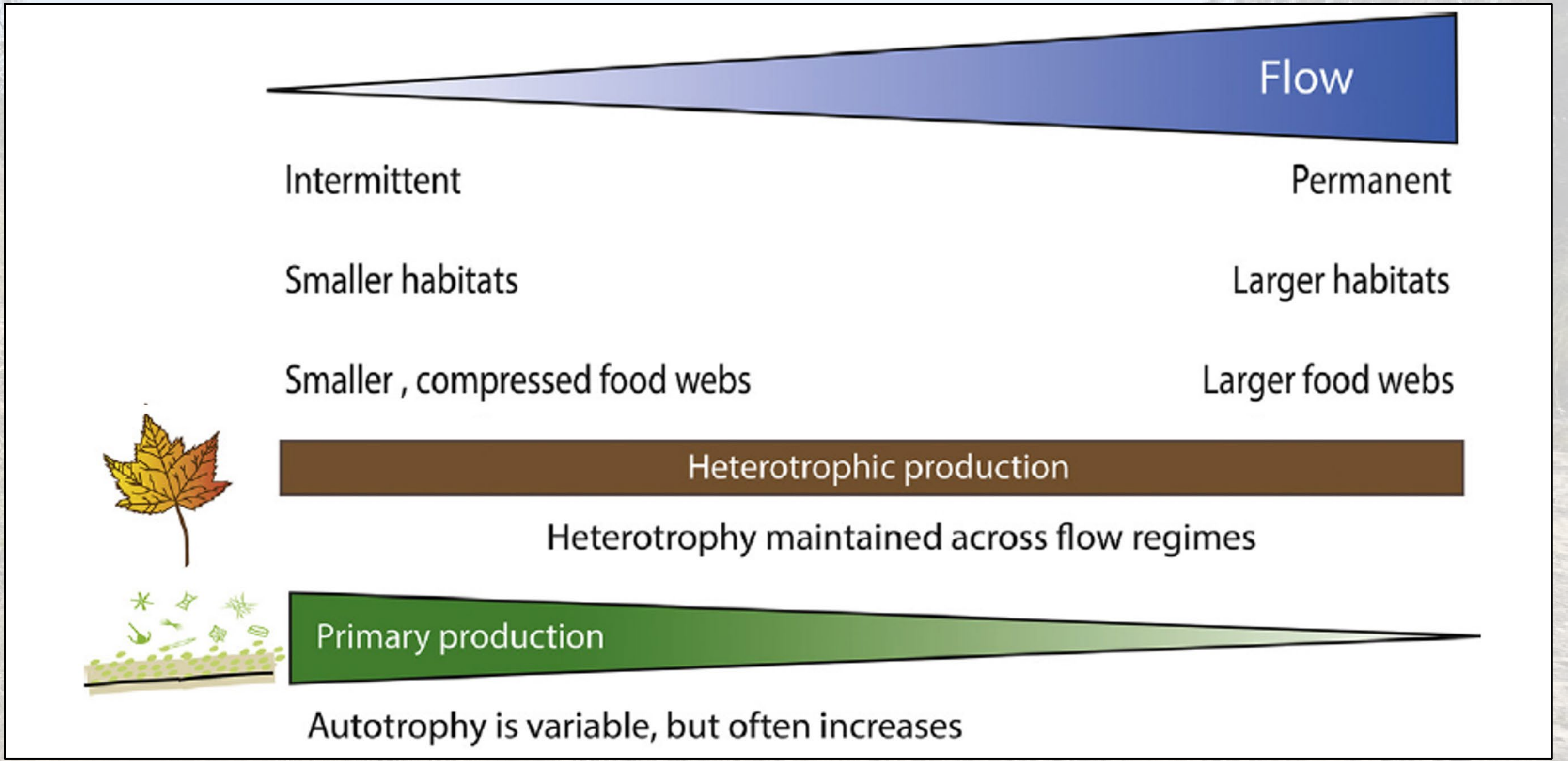




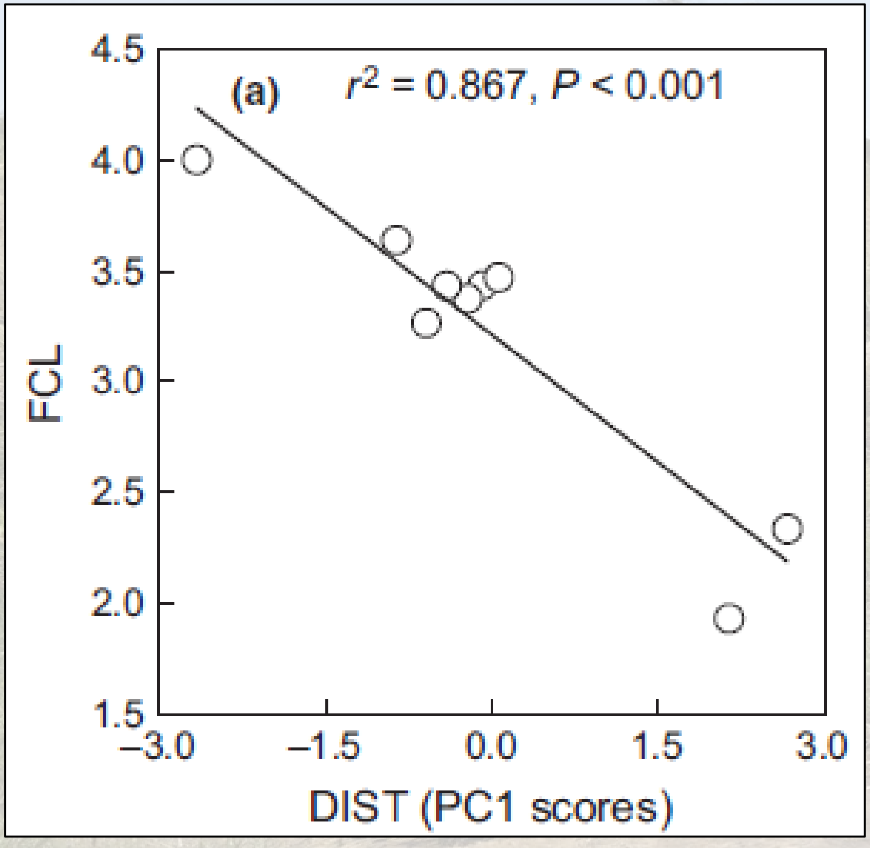
McIntosh et al, (2017). *Intermittent Rivers and Ephemeral Streams*

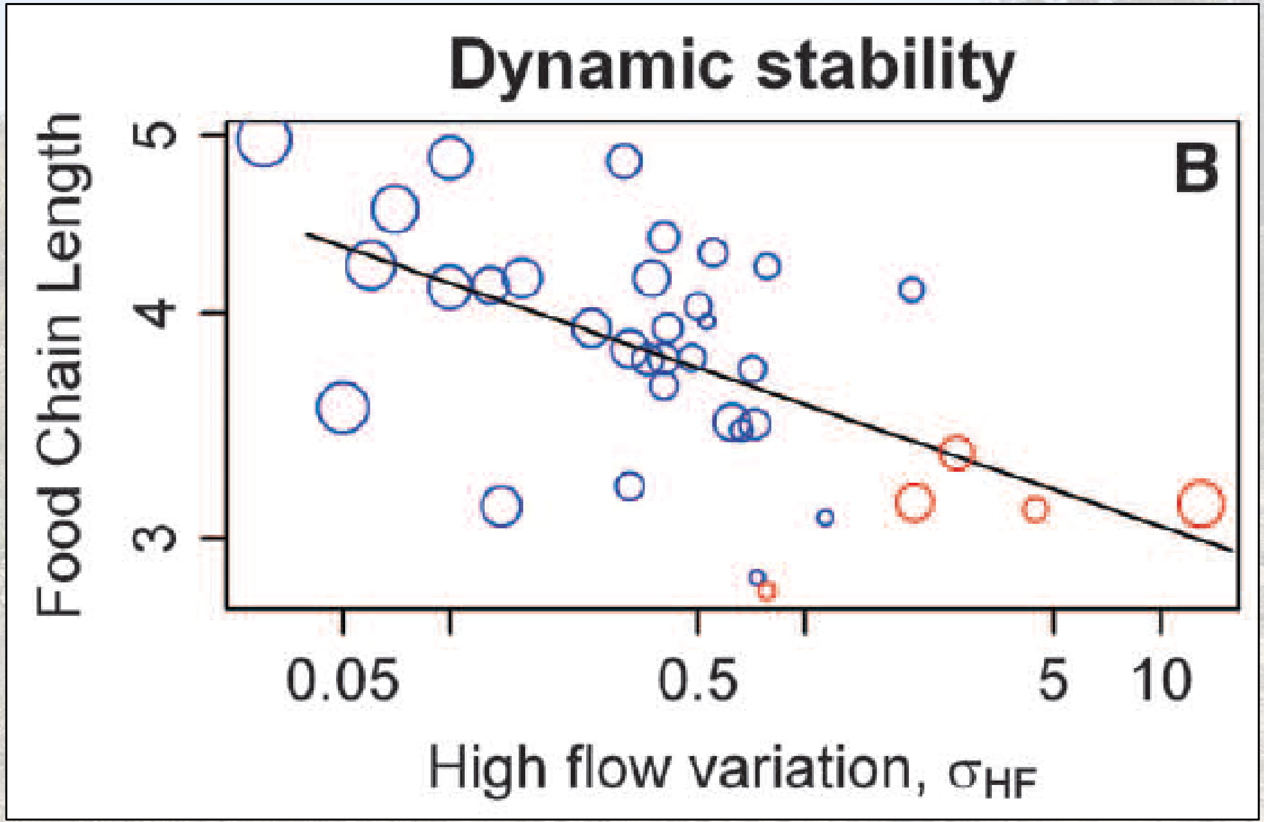
Disturbance and Food Chain Length





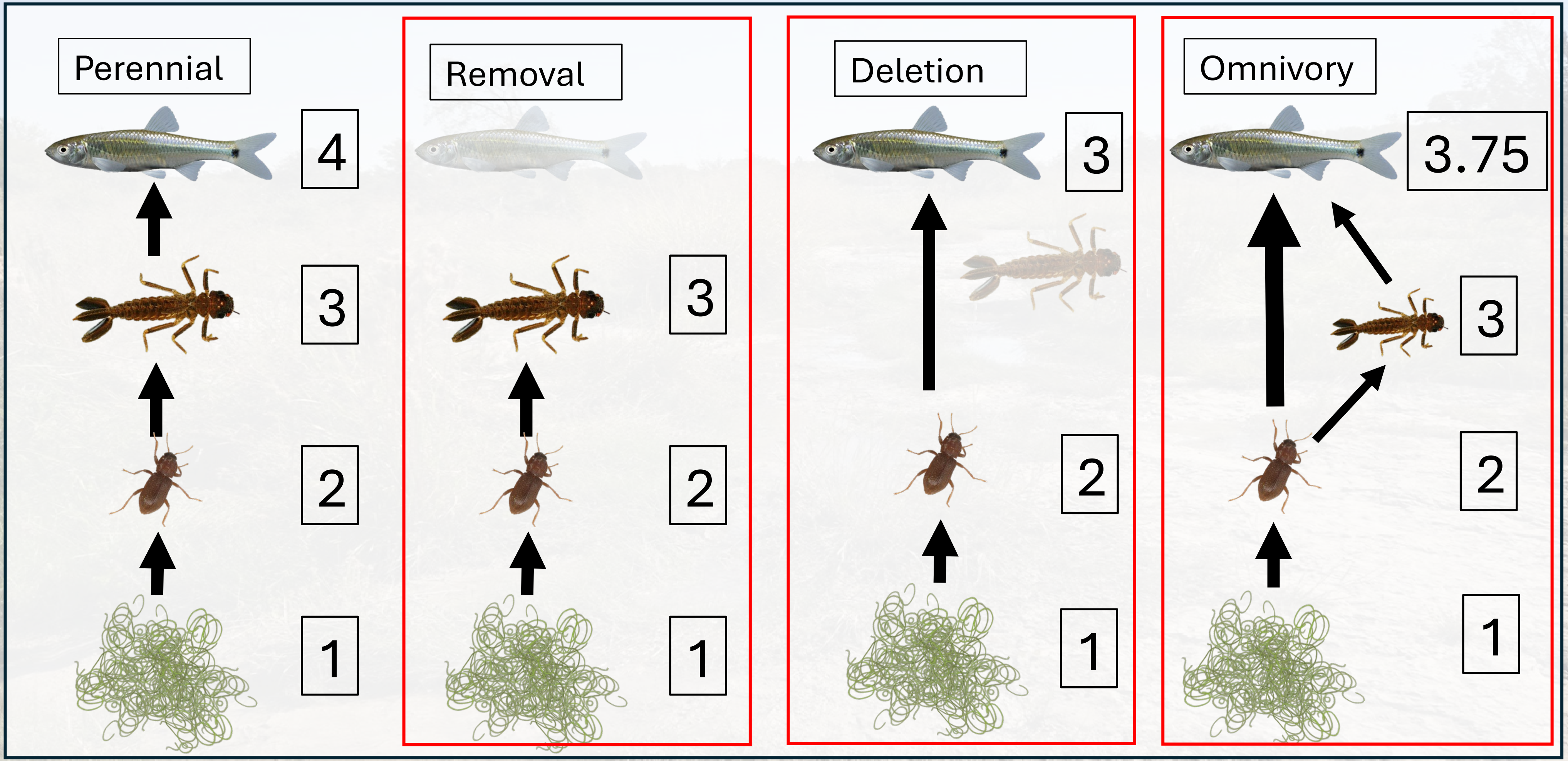
Disturbance and Food Chain Length



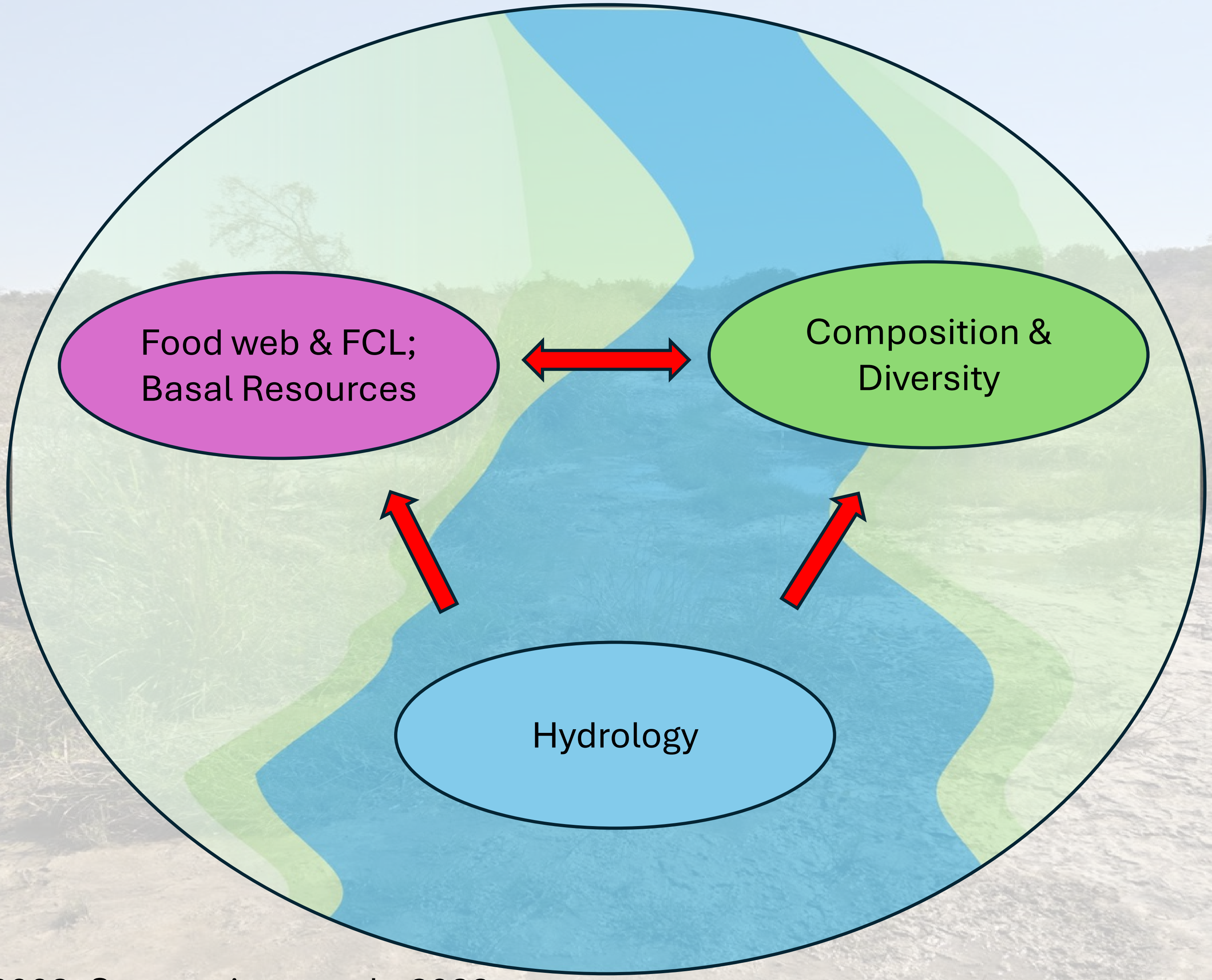


Sabo et al, (2010). *Science;* Ruhí et al, (2016). *Freshwater Biology*

Disturbance and Food Chain Length - Mechanisms



Post & Takimoto (2007). *Oikos*

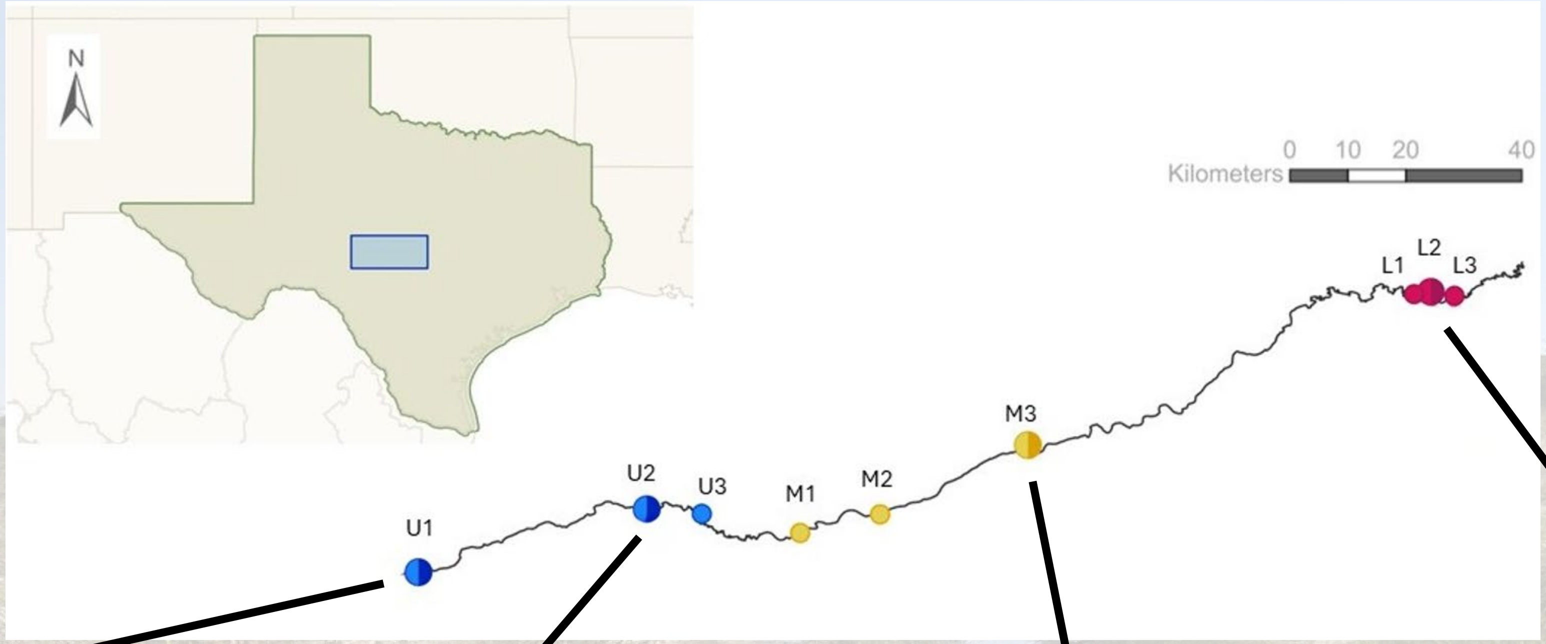


Sabo et al., 2010; Post, 2002; Sarremejane et al., 2022

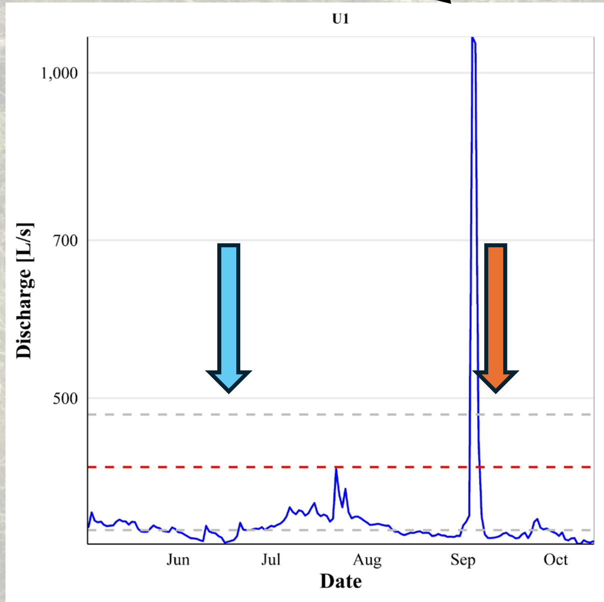
Questions

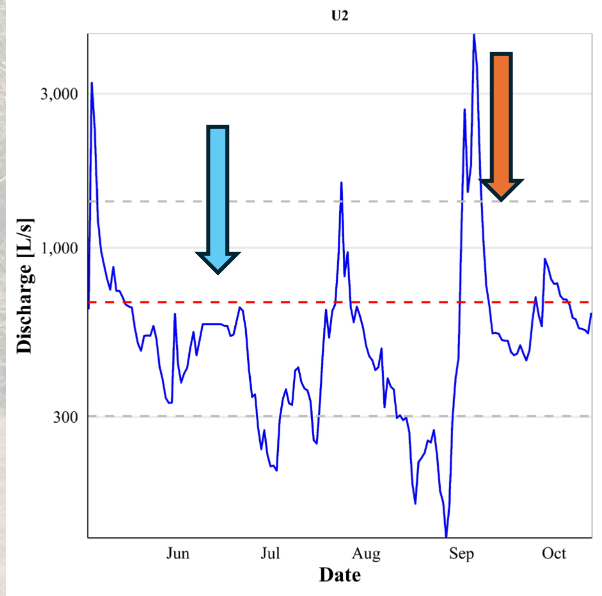
1. How do macroinvertebrates and fish in intermittent segments differ in their taxonomic richness (*S*) and community composition?
2. How does flow intermittency affect the estimated trophic positions of target consumers found at sites throughout study reaches?
3. How does intermittency along stream network positions affect the relative proportion of basal diet proportions of same target consumers?

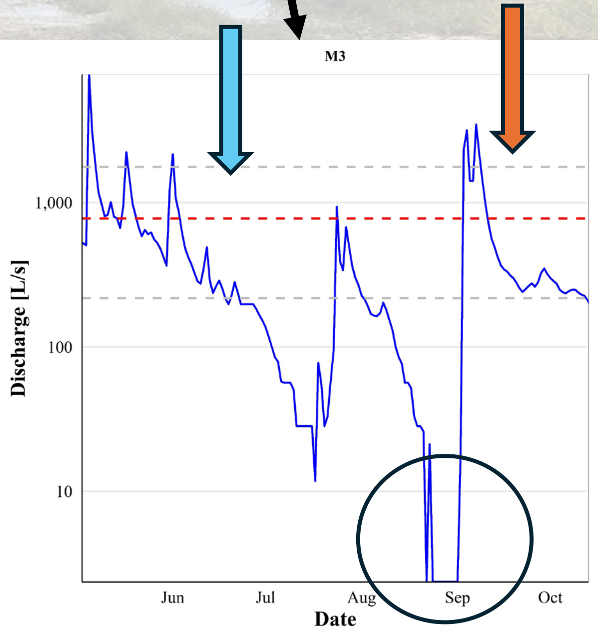
Study Design & Methods

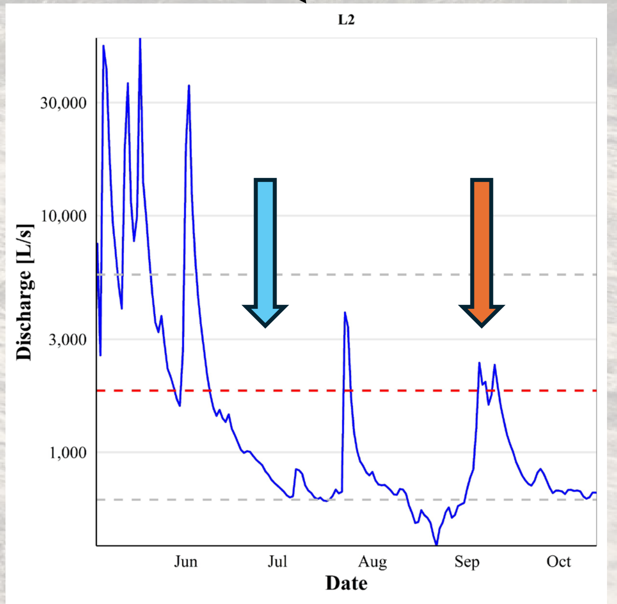


Two sampling periods
- June (peak flows)
- September (low flows)









Study Design & Methods

Reach M1

Pictures taken by Ailish Collins and Hannah Mattes

Study Design & Methods

Field Collections

- Collected fish (seine *n* =10; enumerated and identified to lowest feasible taxonomic level); macroinvertebrates from riffle (Hess *n* = 3; 500-μm mesh, 860 cm^2 mesh) and shallow pool (Lang *n* = 5; 10 x 10 cm, 500-μm mesh)
- Nalgene water grabs (*n* = 2)
- C_3 allochthonous leaf litter (*n* > 6); Riffle (*n* = 3), and Pool (*n* = 3) periphyton
- Environmental conditions – Canopy Cover, wetted width, pH, conductivity, substrate
- Manual discharge (*Q*) measurements during baseflows at each reach (n ≥ 5)

Lab work:

- Fish measured for total length; dorsal muscle tissue extracted
- Invertebrate enumeration to lowest feasible taxonomic level

Stable Isotope Methods – UT Marine Science Institute:

- Periphyton & water column Chl*a* – filtered, dried, fumed (removal of inorganic C)
- Terrestrial C_3 – Identified, dried, ground, packaged
- "Target" Fish & Invertebrates – Dried, ground, packaged (1-15 individuals; $n \geq 3$)

Hexacylloepus & *Stenelmis*
Algivorous scrapers/grazers

Tricorythodes & *Thraulodes*
Collector Gatherers

Chironominae
Collector

Corbicula fluminea
Filterers

Argia
Predator

Cyprinella venusta
Predator

Data analyses

R platform

- Taxonomic richness (*S*) among mesohabitats, segments, and season were tested using GLMs
- Community Composition among mesohabitats, segments, and season were assessed using PERMANOVA and SIMPER *(vegan)*
- Trait proportions among macroinvertebrate communities – GLMM (*glmmTMB*)

Trait (~Datry et al., 2013)						Classification
Resilient	Long adult lifespan	High fecundity	Strong swimming ability	Common occurrence in drift	Strong flying ability	1
Resistant	Body armoring	Desiccation resistant forms	Plastron/Spiracle respiration	Low rheophily		2

Co-dominant R&R: 3

Non-R&R: 0

- Trophic position of each target consumer at each reach was estimated using the *trps* package
- Proportion of autochthony in consumer diet was estimated using MixSIAR

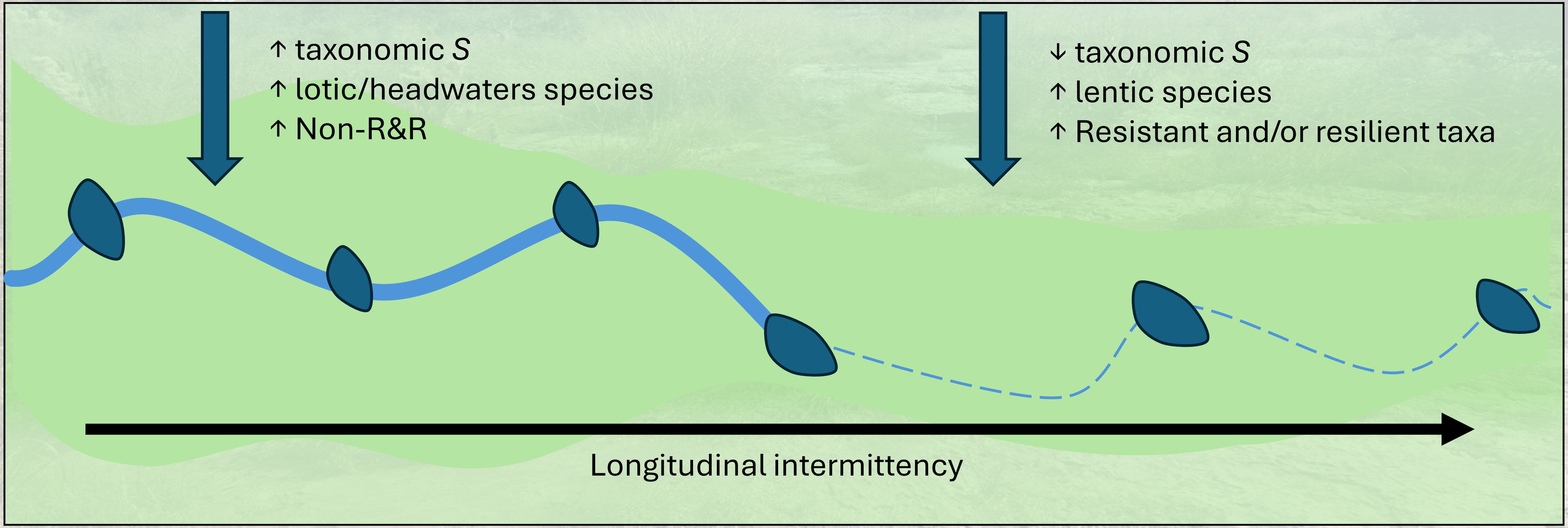
Anderson (2014). *Wiley statsref: statistics reference online*; Arbizu (2020). *R package version*; Clarke (1993). *Australian journal of ecology*; Oksanen et al (2026). *Community ecology package*

Questions

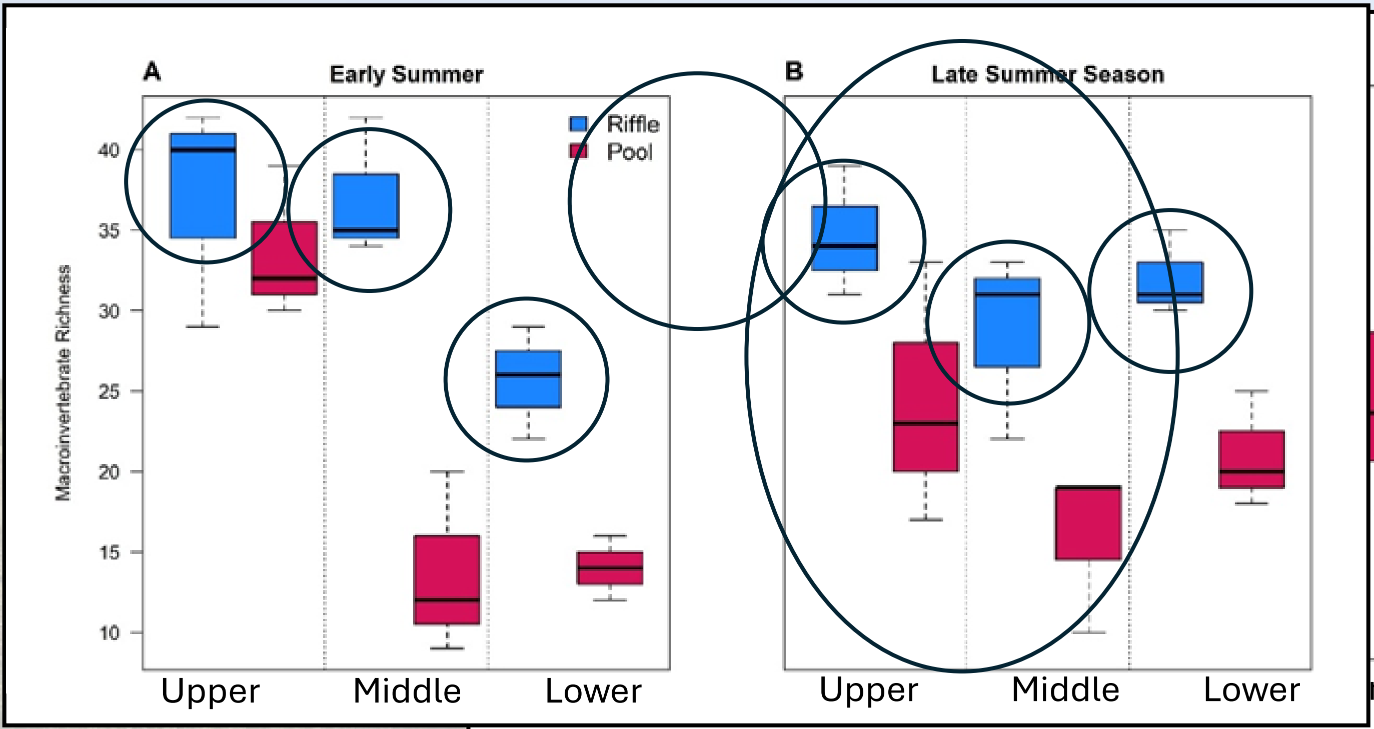
1. How do macroinvertebrates and fish in intermittent segments differ in their taxonomic richness (*S*) and community composition?
2. How does flow intermittency affect the estimated trophic positions of target consumers found at sites throughout study reaches?
3. How does intermittency along stream network positions affect the relative proportion of basal diet proportions of same target consumers?

Research Question 1:

Macroinvertebrate and fish communities in intermittent reaches will have lower taxonomic richness and have a greater proportion of taxa associated with intermittency compared to perennial reaches.



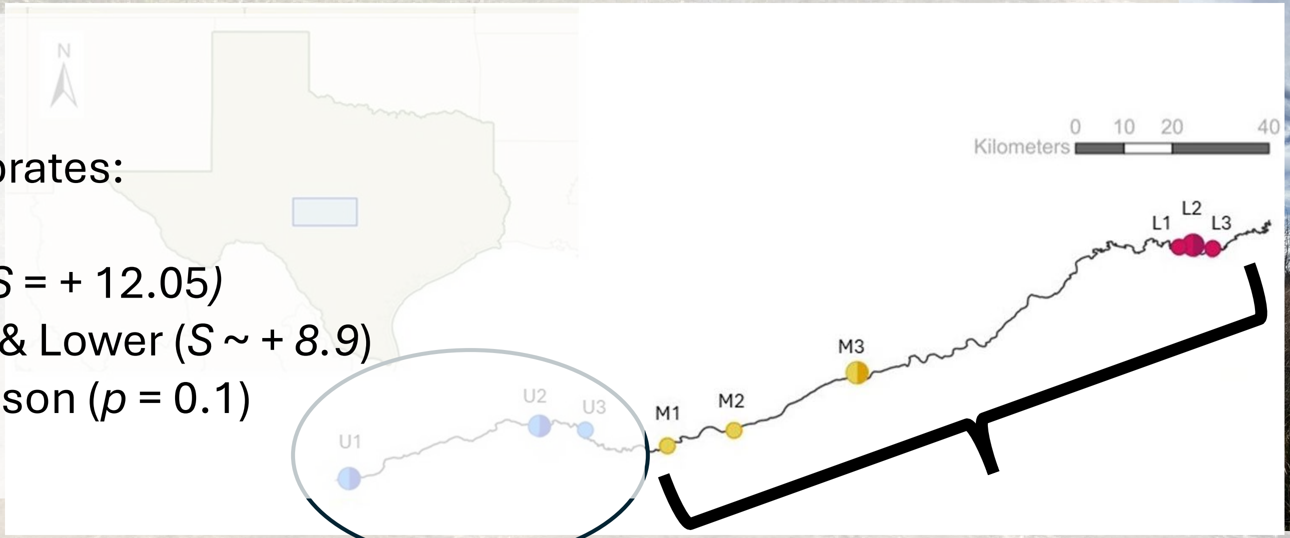
Results – Taxonomic Richness

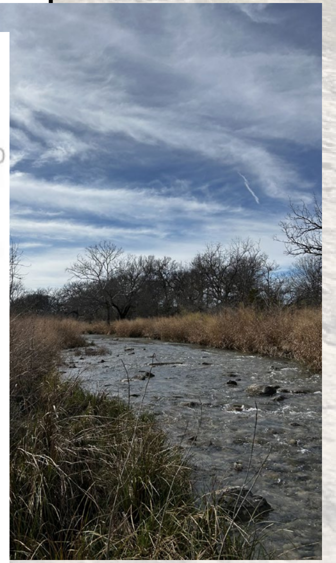


Taxonomic Richness

Macroinvertebrates:

- Riffles > Pools (S = + 12.05)
- Upper > Middle & Lower (S ~ + *8.9*)
- No effect of Season (p = 0.1)

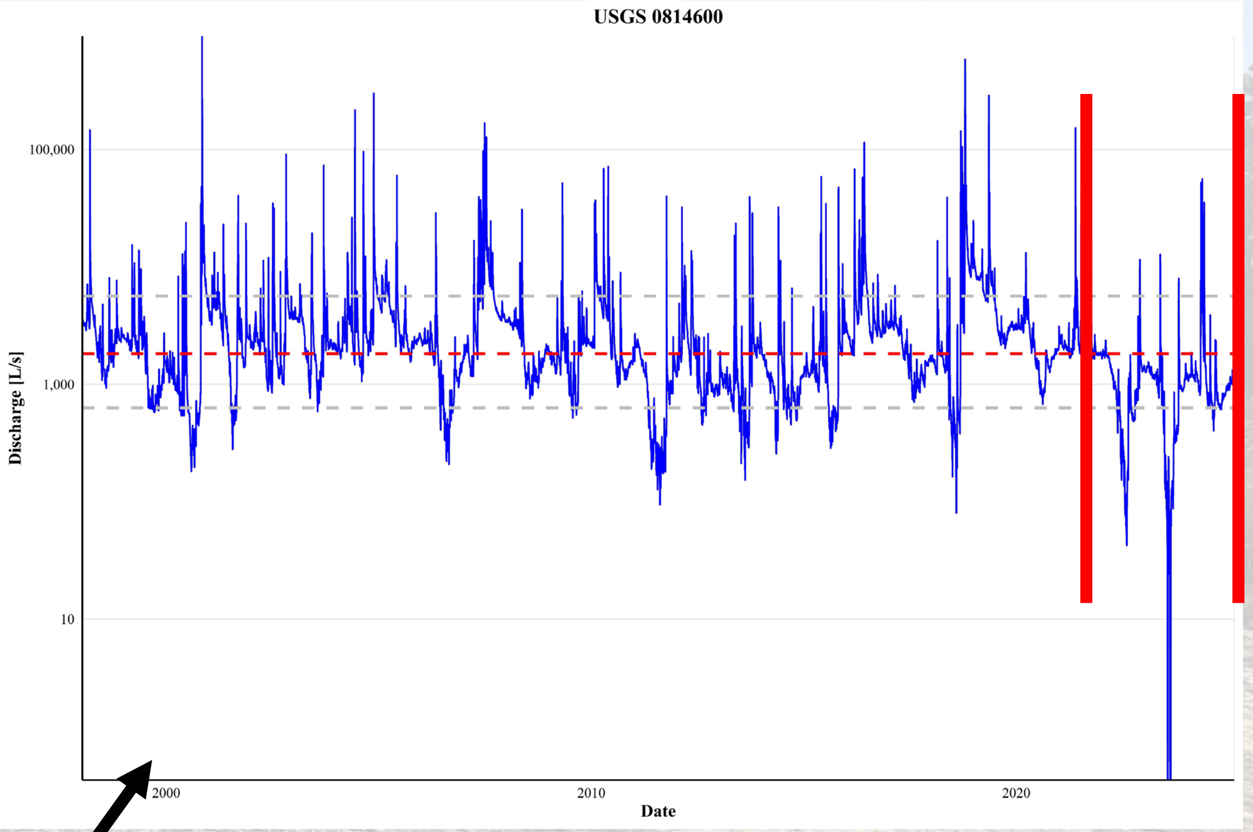




Discussion – Taxonomic Richness

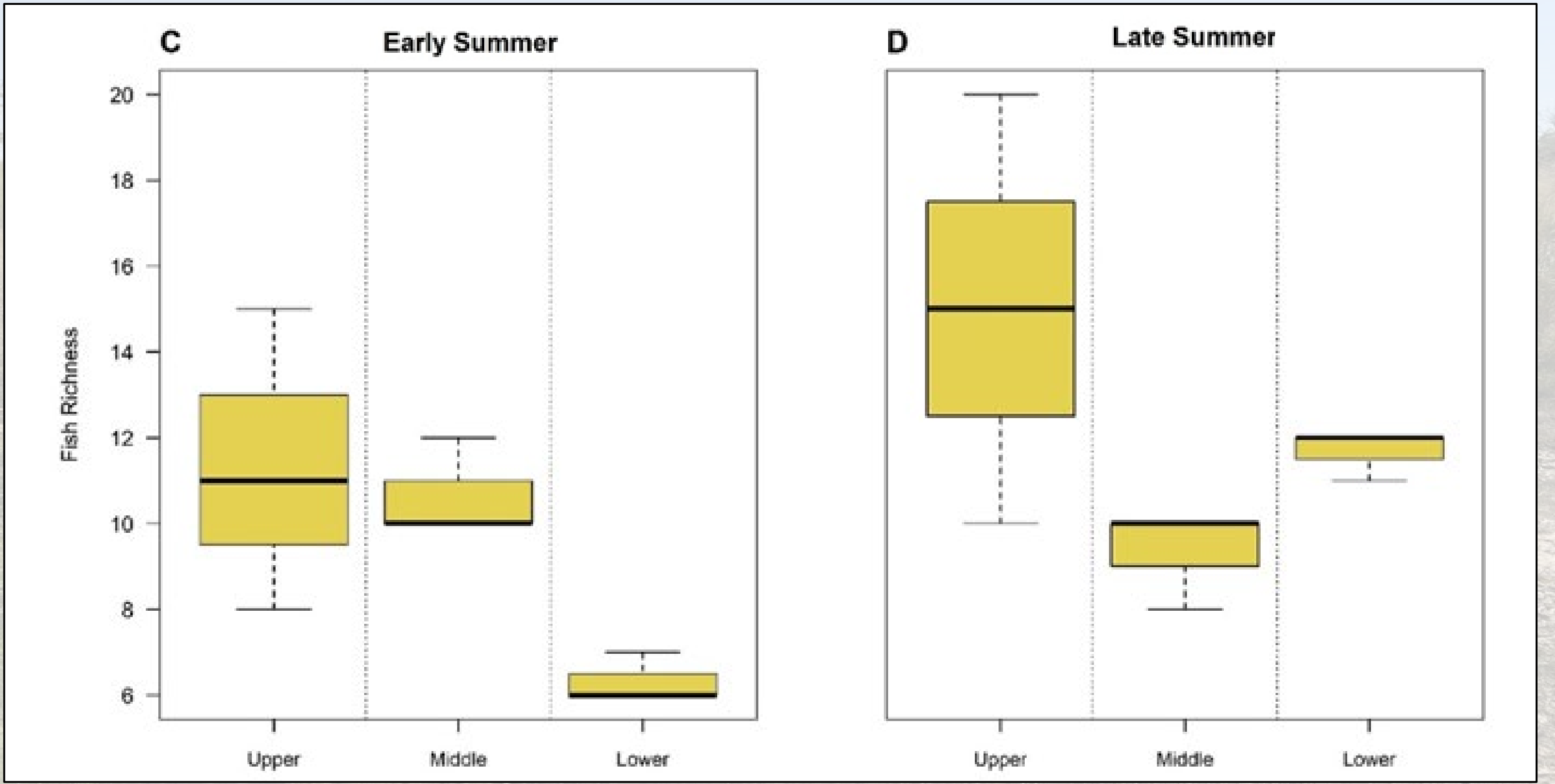
M3

L2



- Subject to variations in timing of flow/connectivity
- Annual to interannual no-flow conditions along a longitudinal gradient
- High flow variability

Results – Taxonomic Richness

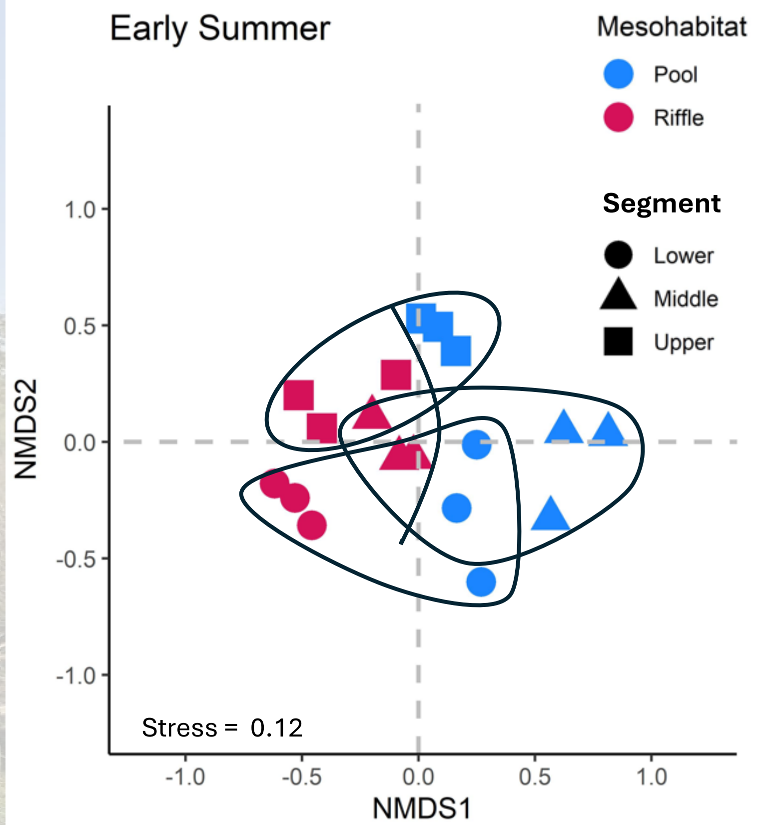


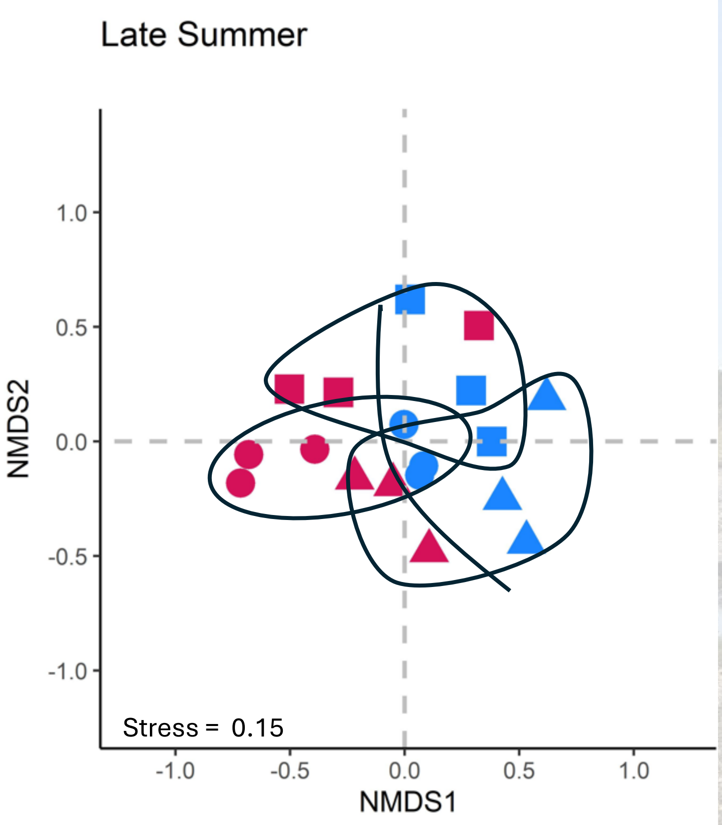
Taxonomic Richness

Fish:

- No effect of Segment or Season (p =0.18; p = 0.07)

Results – Macroinvertebrate Community Composition

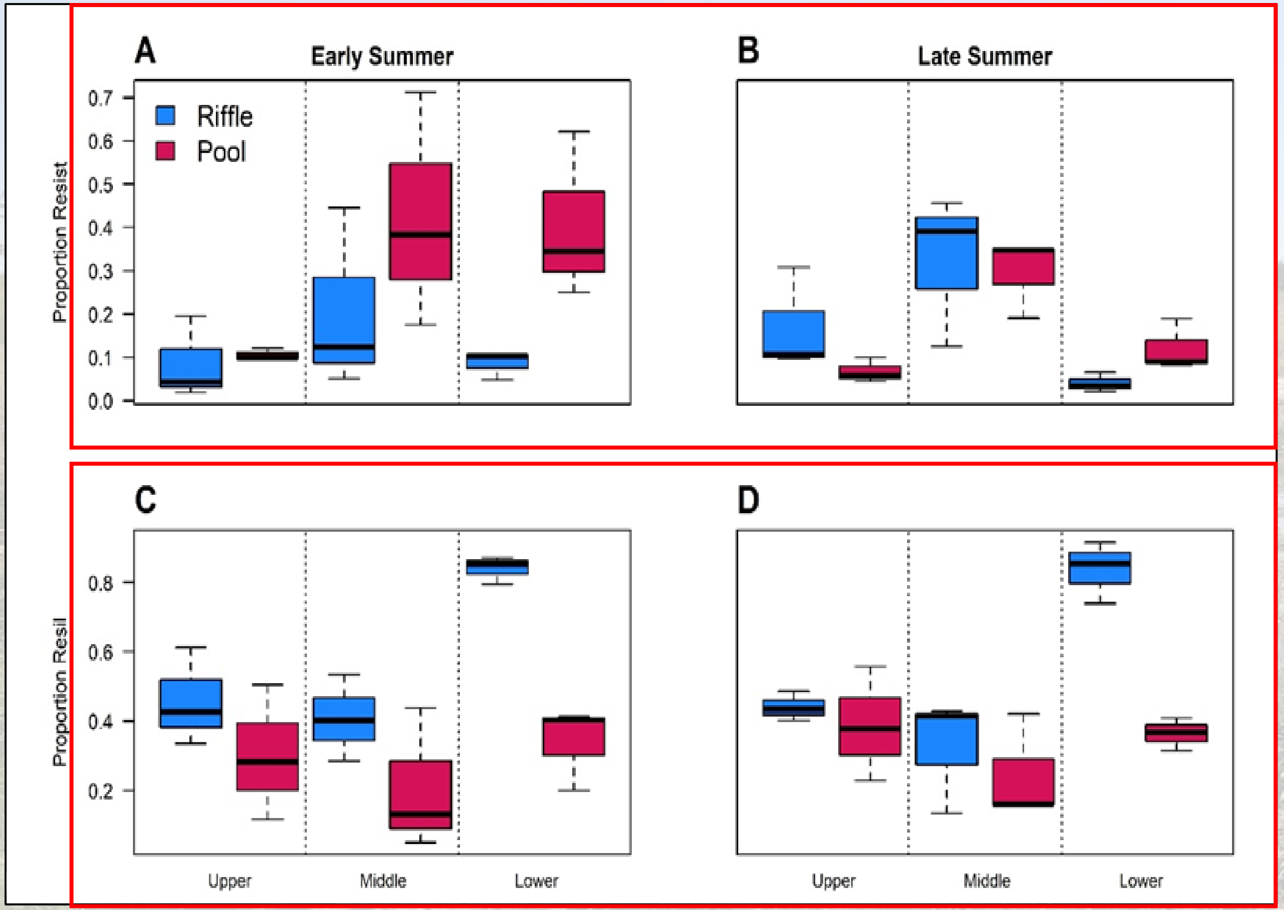




- Mesohabitat – partial R^2 = 0.18, $p < 0.001$
  - Riffle = greatest variation in mesohabitat communities
- Segment - partial R^2 = 0.22, p = 0.001
  - All segments differed
- Season – partial R^2 = 0.05, p = 0.005

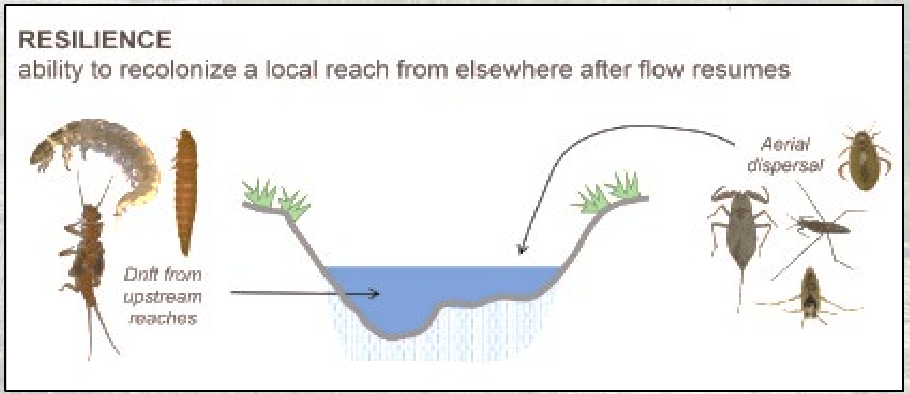
- 12 taxa account for ~50% of dissimilarity among groupings.
- *Chironominae* more abundant in middle segment & riffle mesohabitats (5.1-11.0%)
- *Hyalella* found only in the Upper reaches

Results – Macroinvertebrate Traits

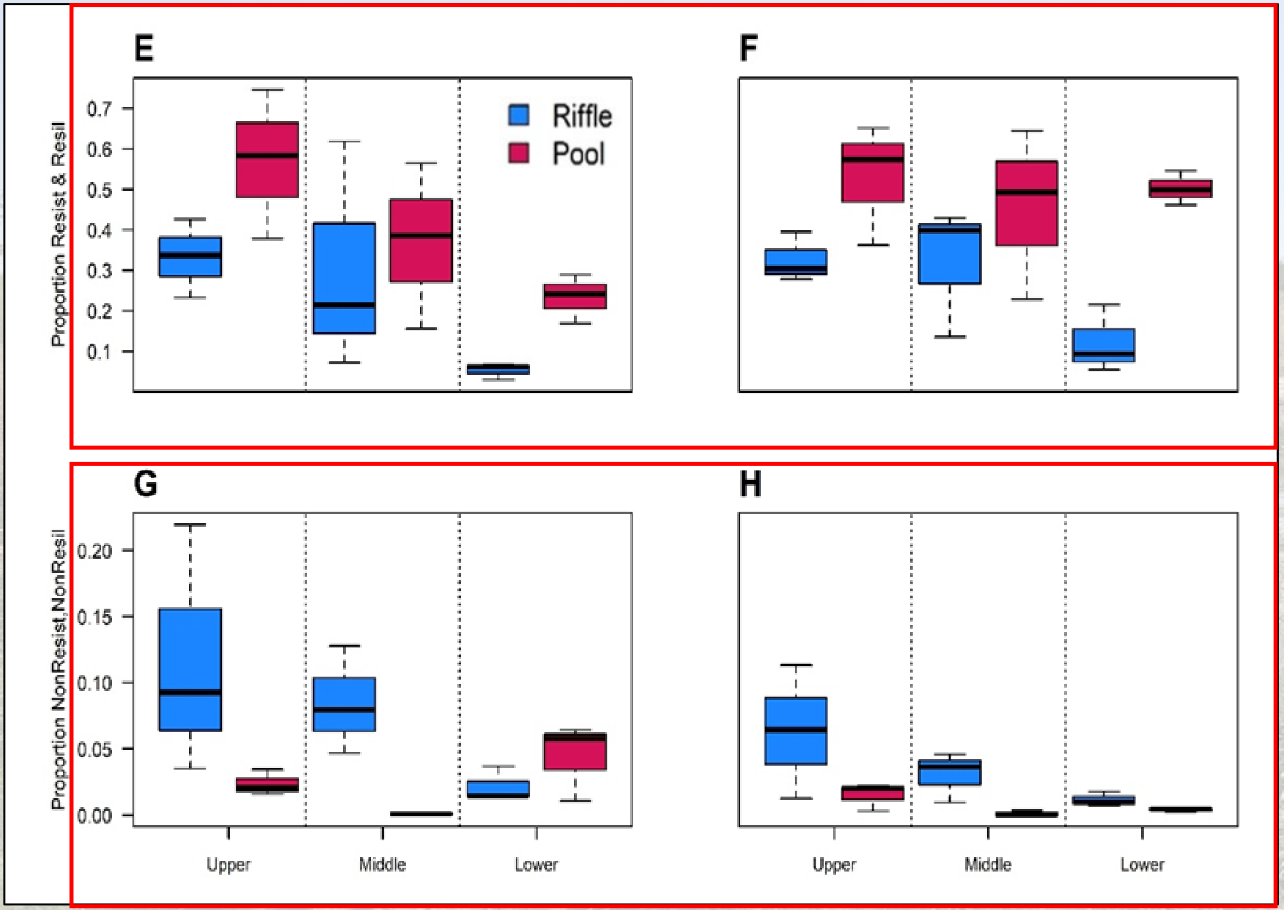


Resistant (~19% overall; n= 14)

Resilient (~43% overall; n = 29)

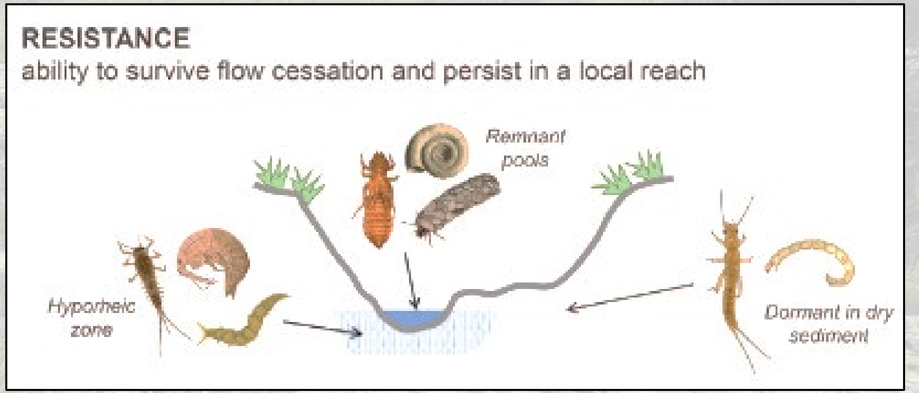


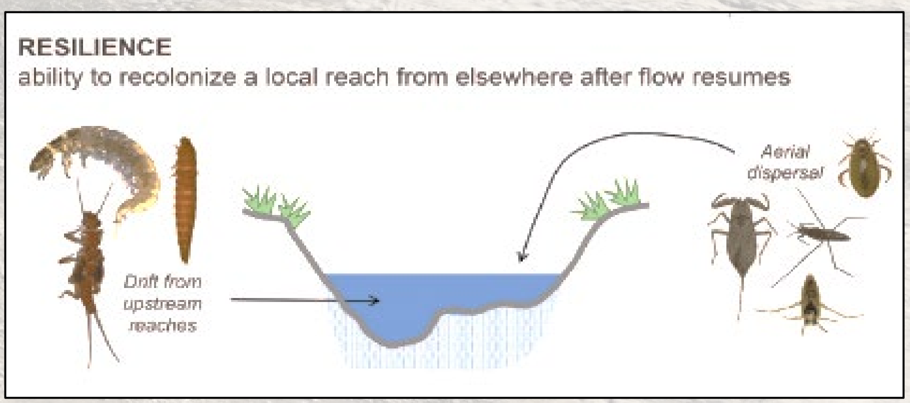
Results – Macroinvertebrate Traits



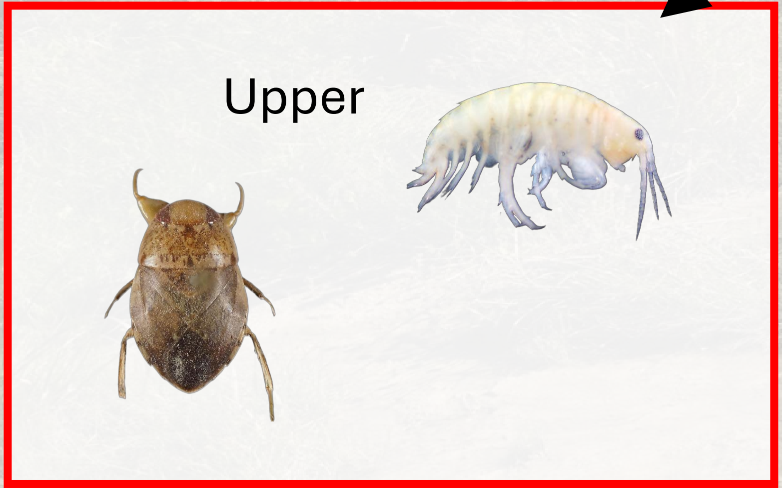
Resistant & resilient (R&R; ~34% overall; n = 29)

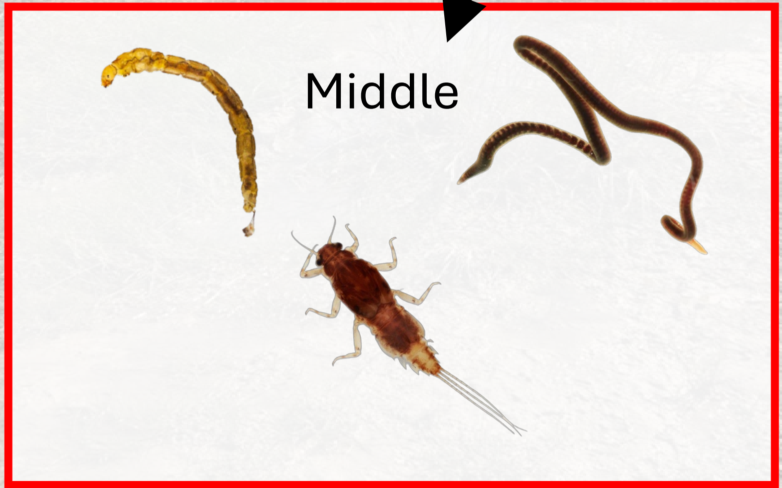
Non-R&R (~3% overall; n = 7)

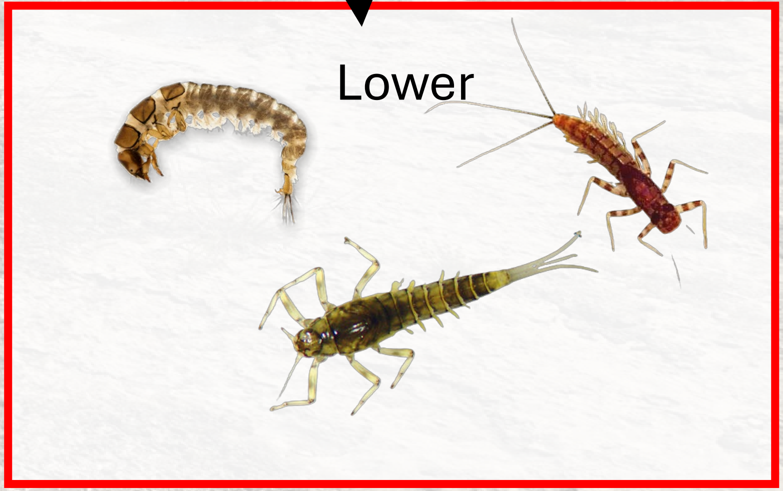




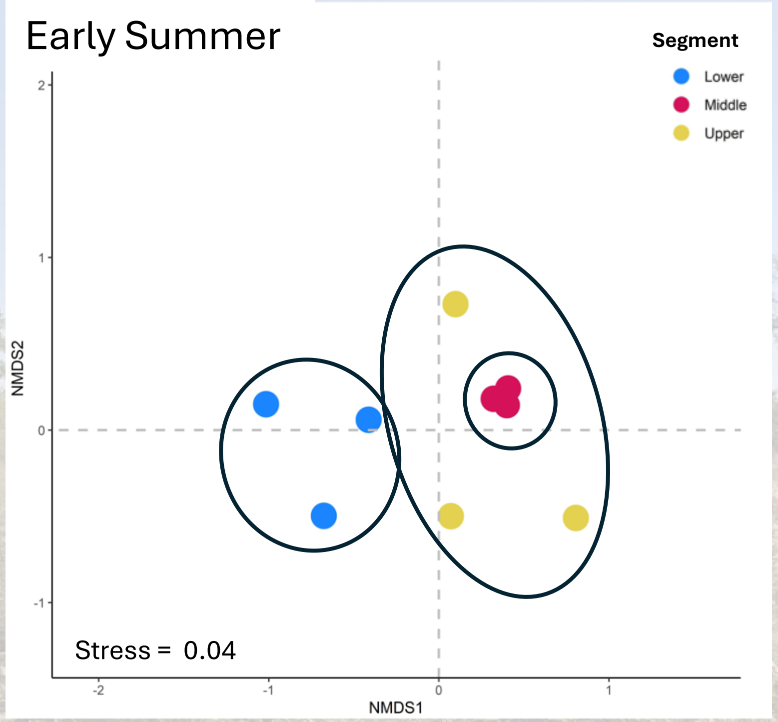
Discussion – Taxonomic Richness

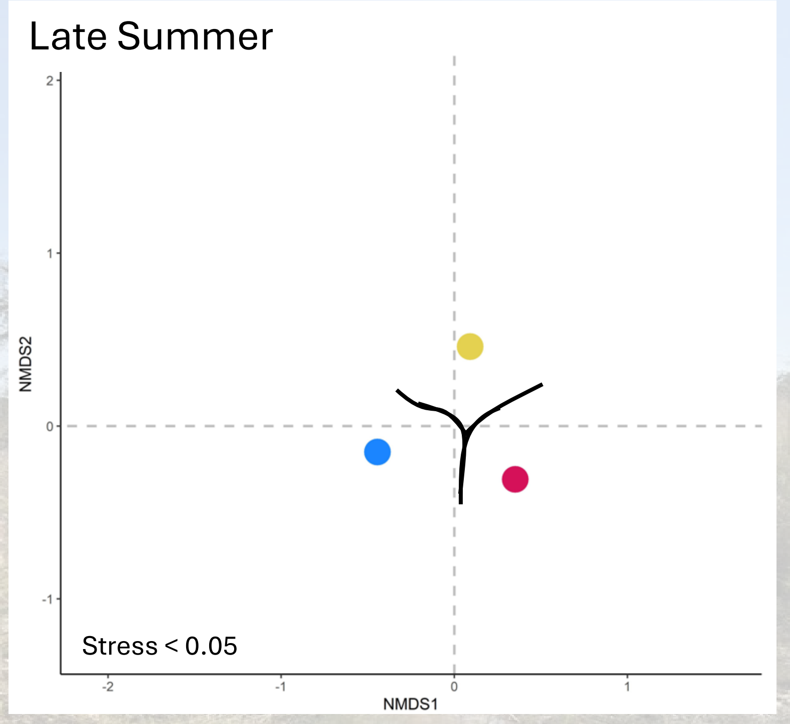






Results – Fish Community Composition

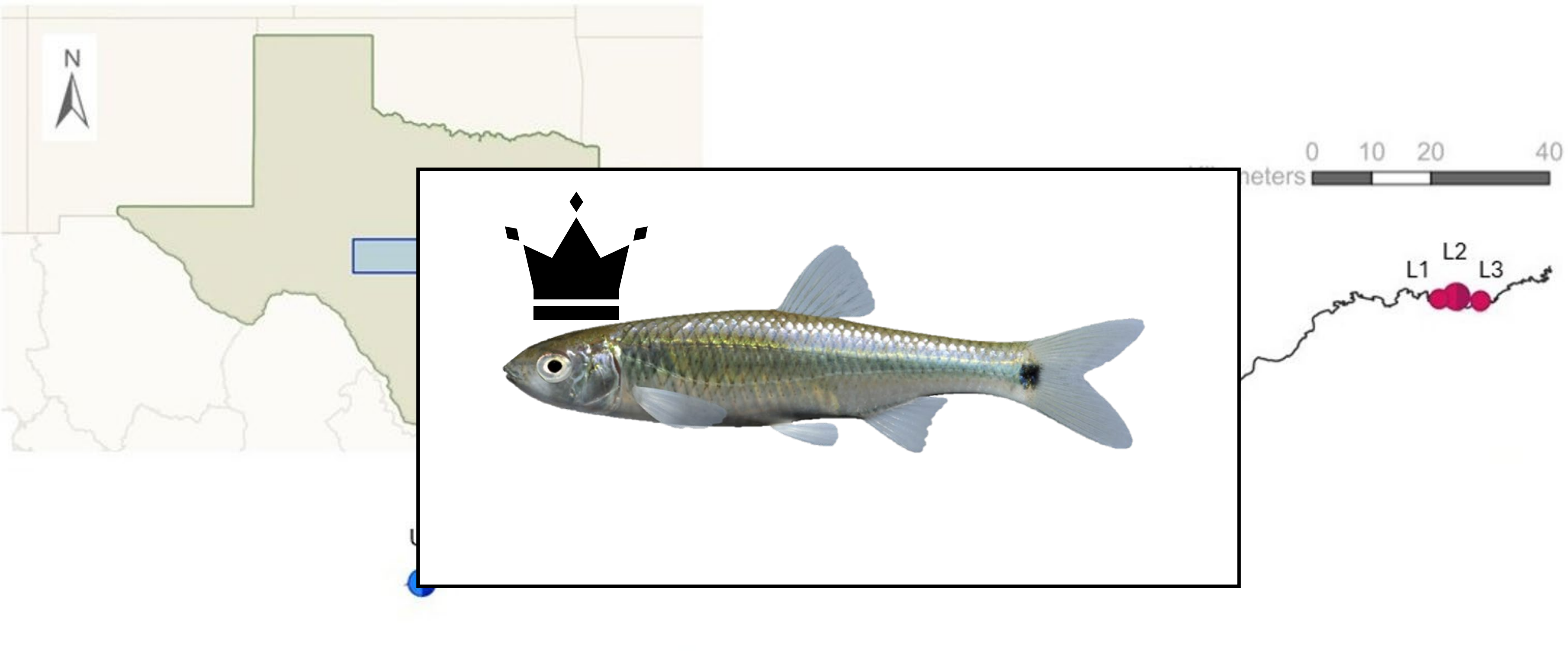


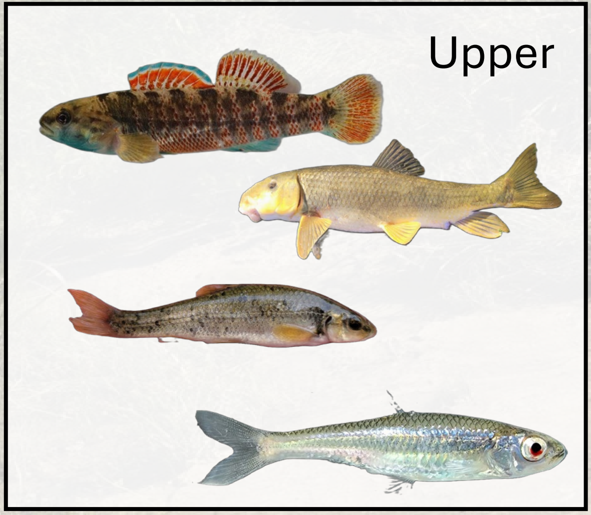


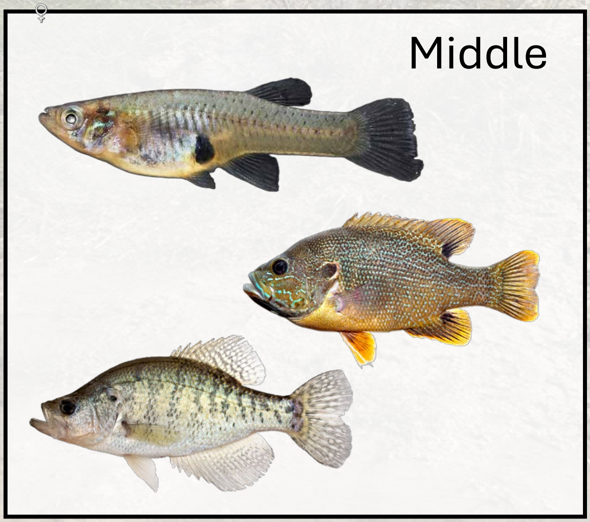
- Global Model: $F_{5,30} = 8.09$, $R^2 = 0.46$, $p < 0.001$
- Segment partial $R^2 = 0.39$, $p < 0.001$
- Season partial $R^2 = 0.03$, $p = 0.09$

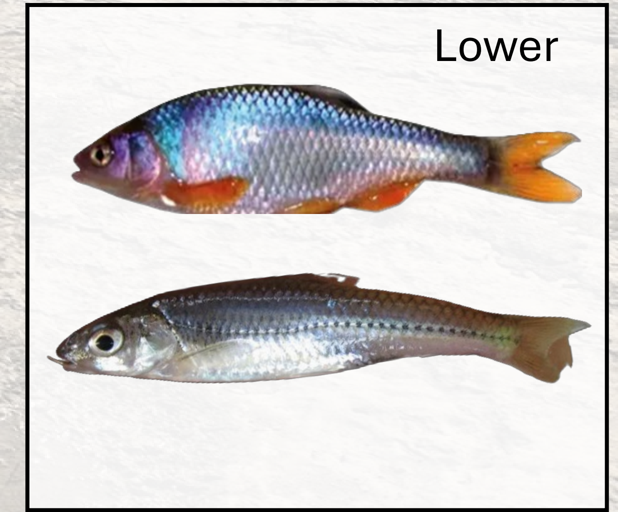
- Top 5 taxa make up >78% of community dissimilarity
- *C. venusta contributed the most dissimilarity* (26%-48%)

Discussion – Taxonomic Richness









Questions

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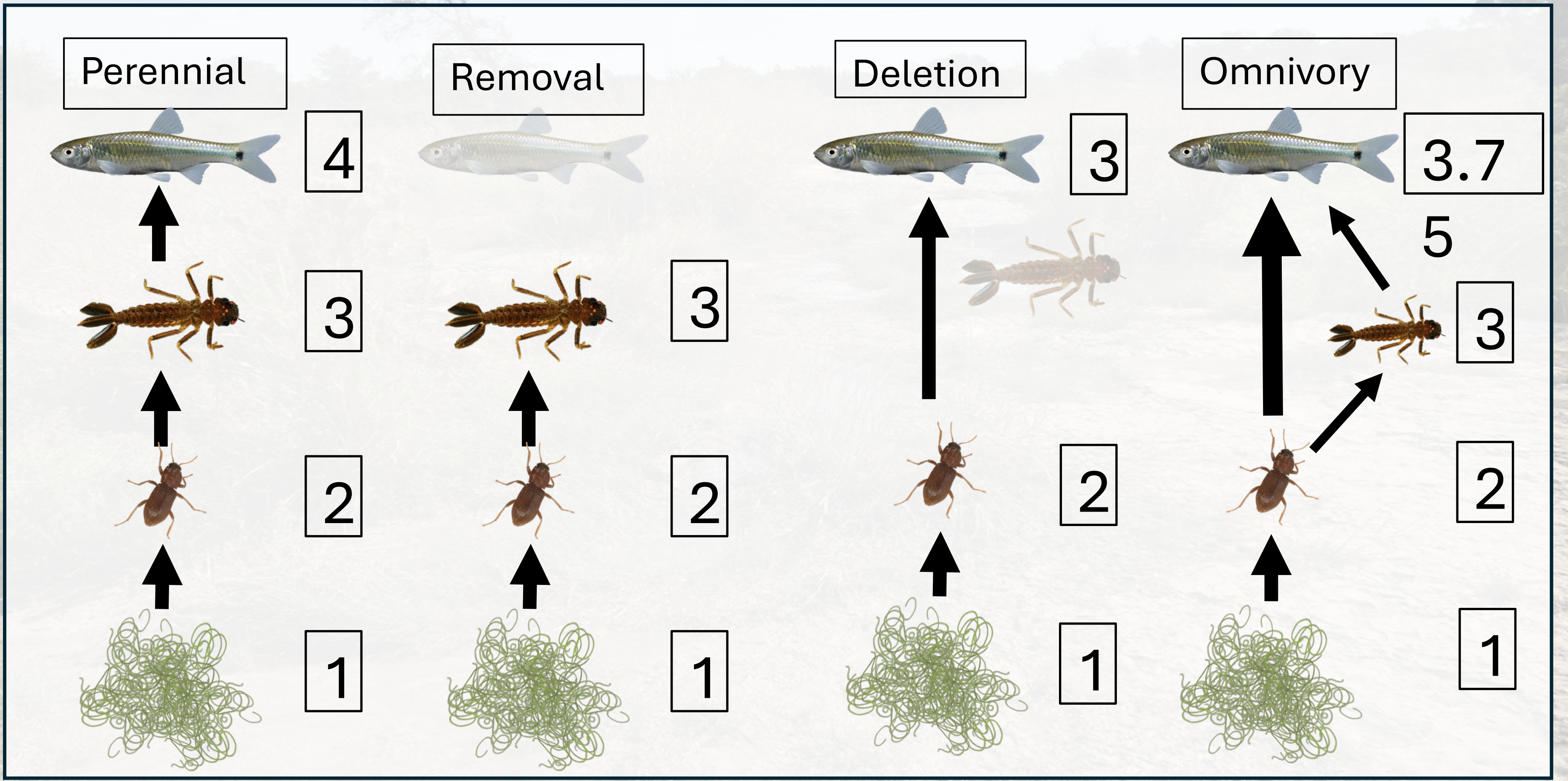
2. How does flow intermittency affect the estimated trophic positions of target consumers found at sites throughout study reaches?

3. How does intermittency along stream network positions affect the relative proportion of basal diet proportions of same target consumers?

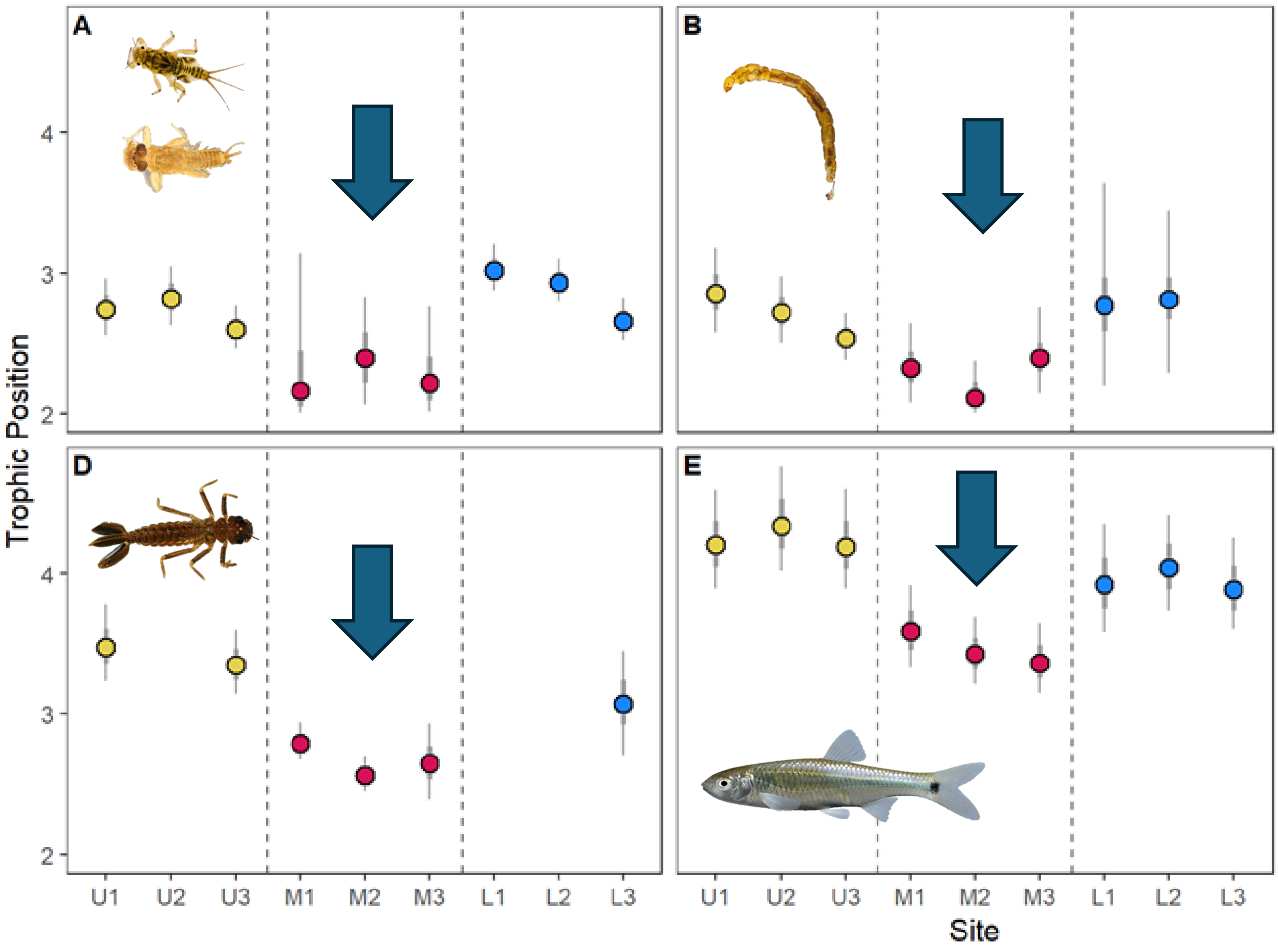
Research Question 2:

Consumers at intermittent reaches will have reduced trophic positions compared to those in perennial reaches.



Post & Takimoto (2007). *Oikos*

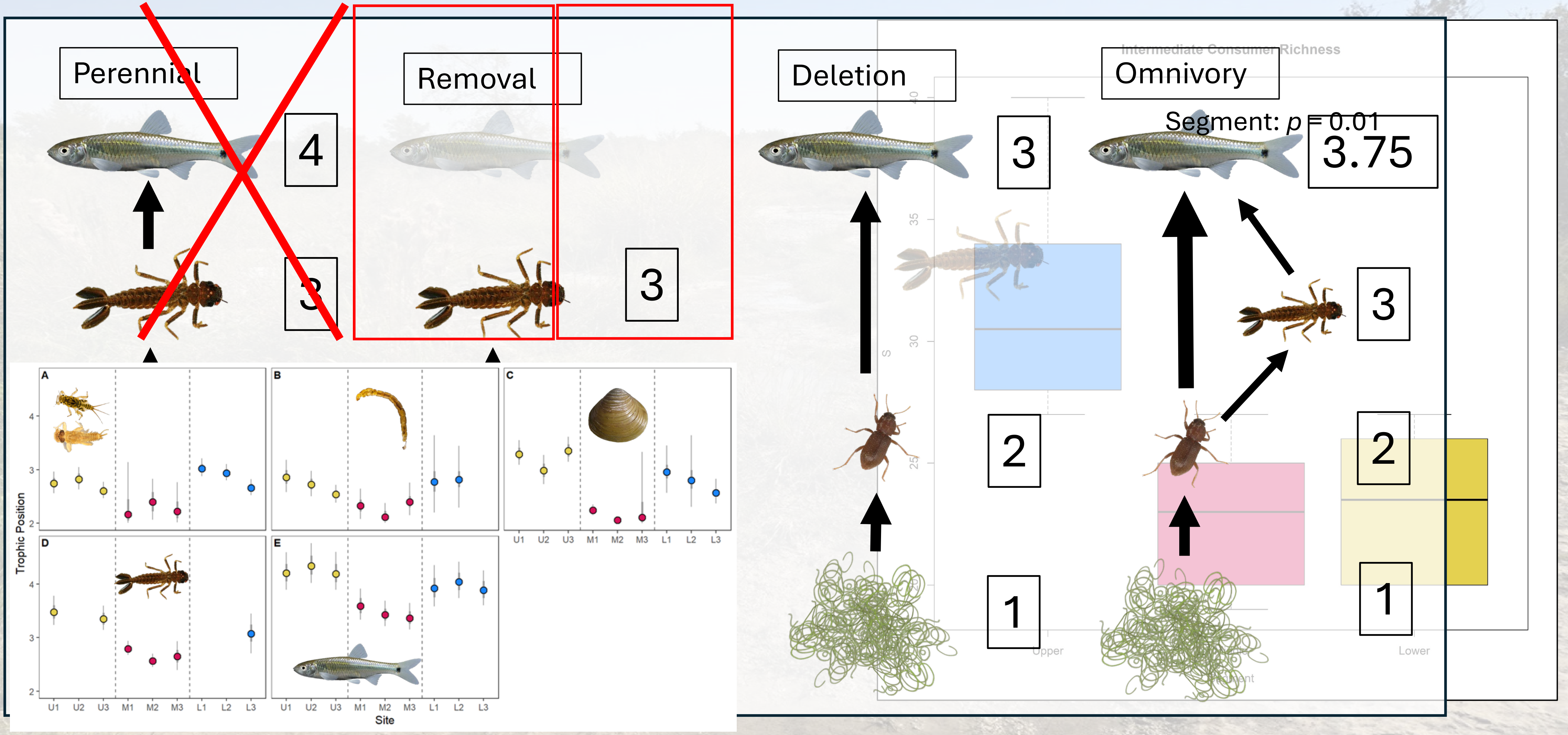
Results – Target Consumer Trophic Position



A – Ephemeroptera
B – Chironominae
C – *C. fluminea*
D – *Argia*
E – *C. venusta*

~ 0.5 trophic positions lower

Discussion – Target Consumer Trophic Position



Questions

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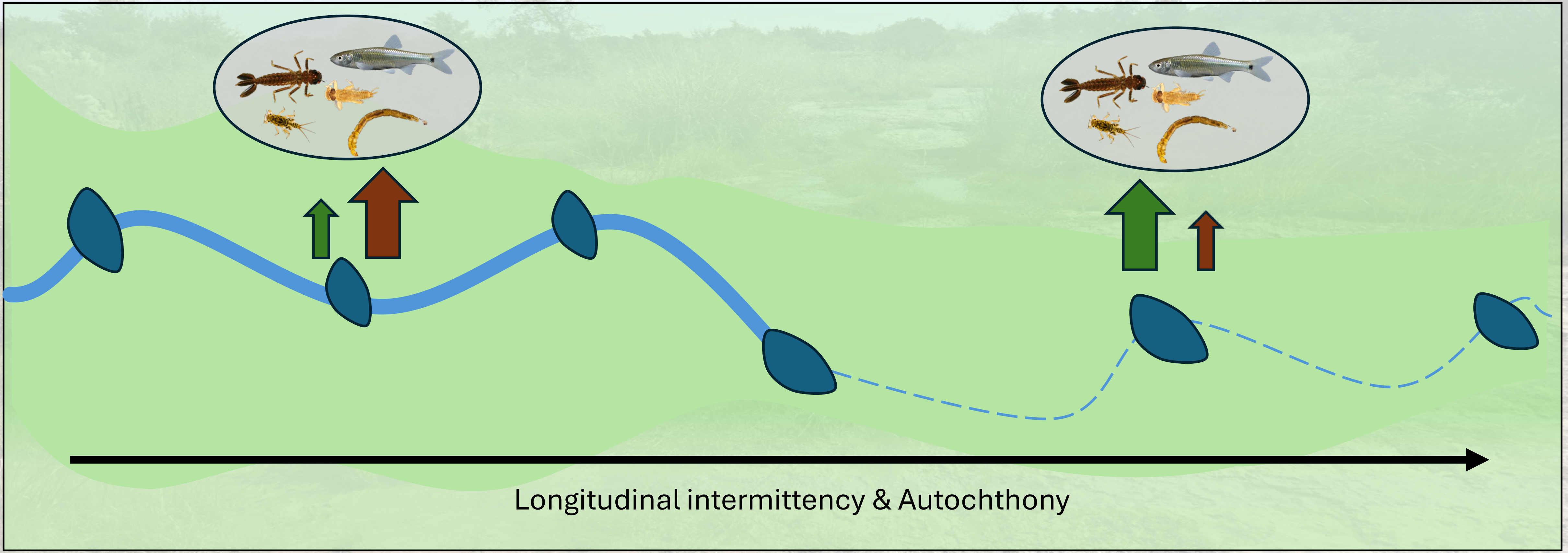
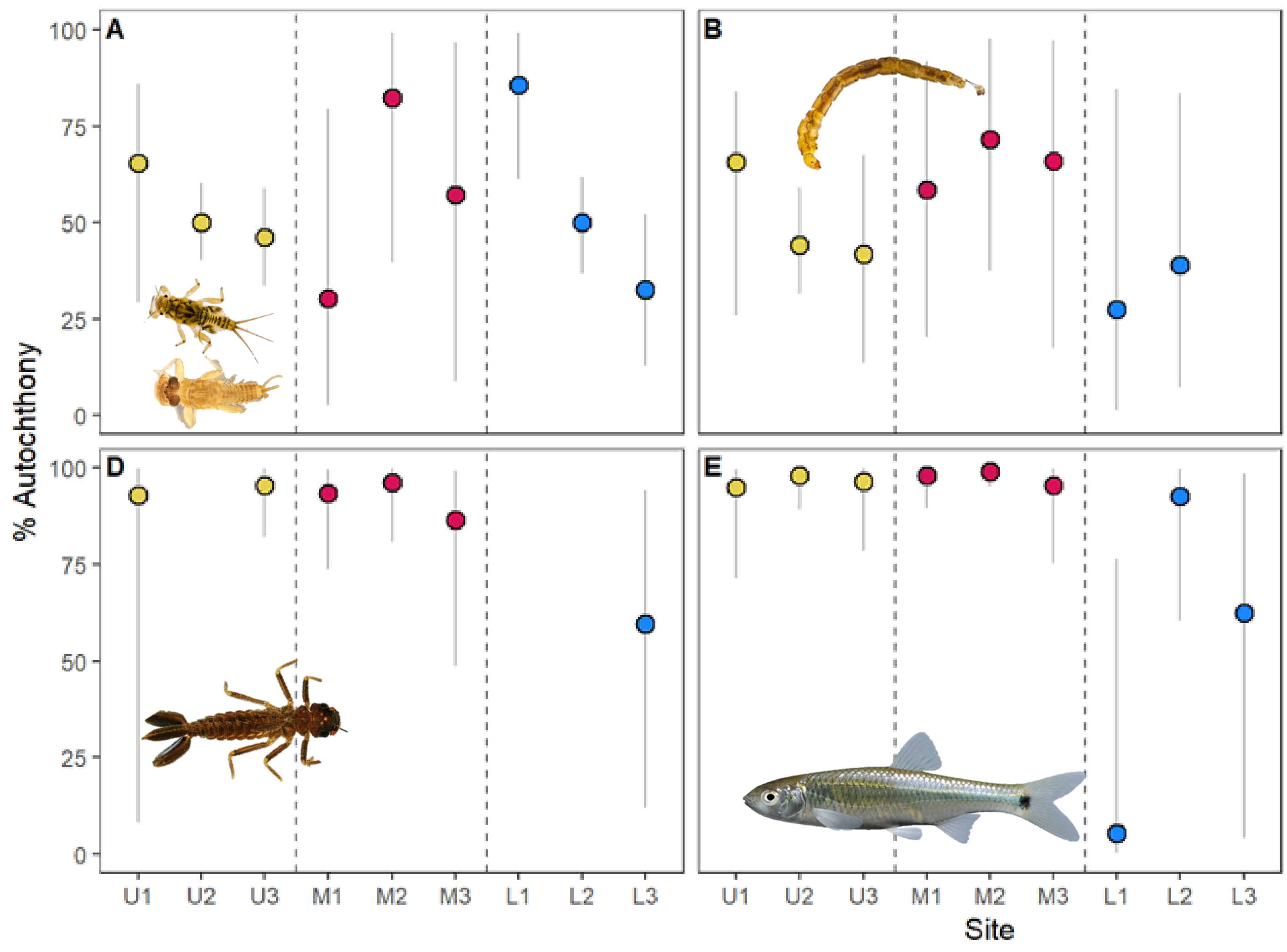
3. How does intermittency along stream network positions affect the relative proportion of basal diet proportions of same target consumers?

Research Question 3:

Prediction: As flows decrease, consumer diet proportions would be estimated to primarily be autochthonous



Results – Target Consumer Basal Resource Use

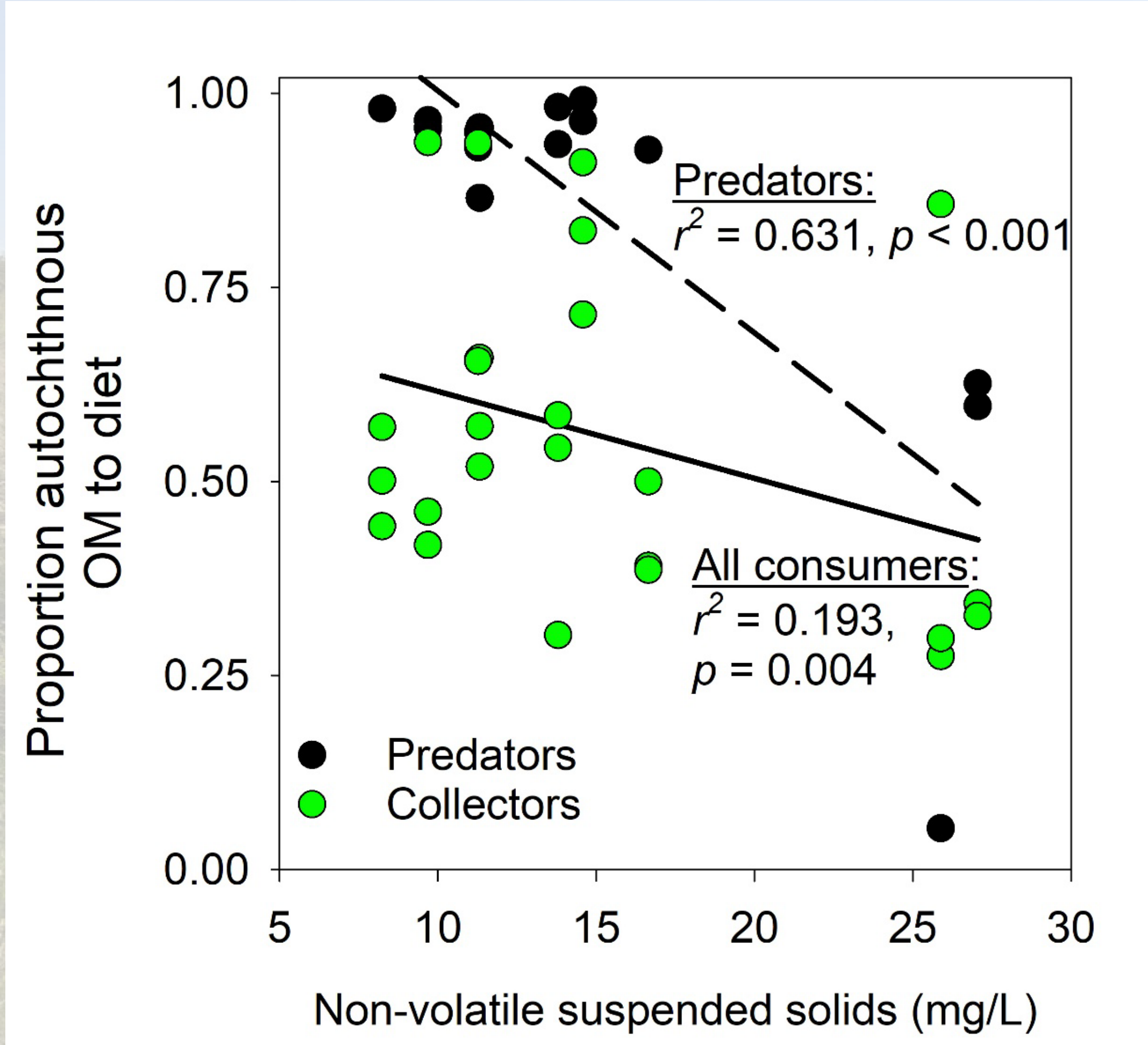


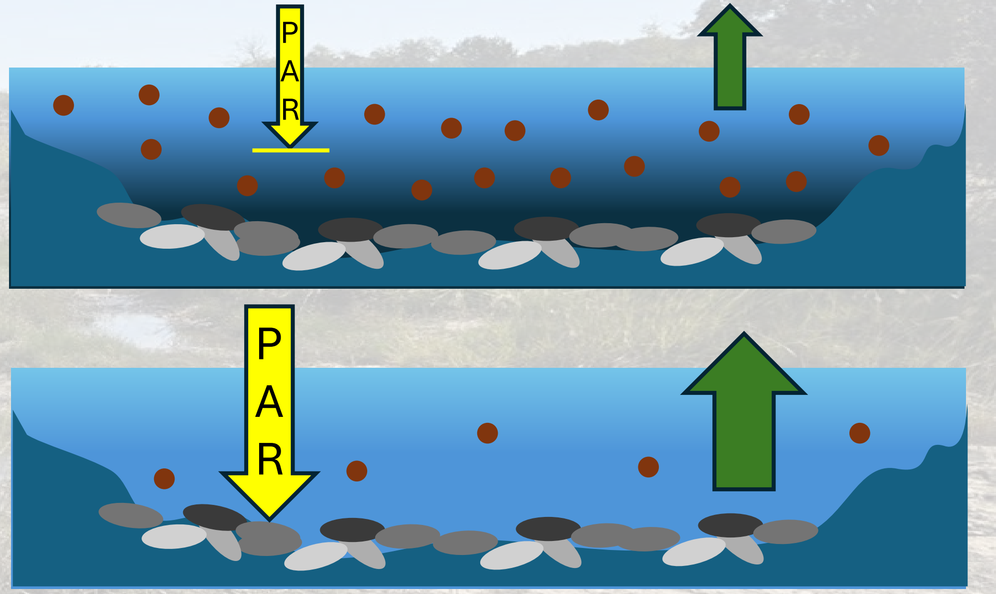
A – Ephemeroptera
B – Chironominae
C – *C. fluminea*
D – *Argia*
E – *C. venusta*

Intermediate Consumers: ~ 50%

Argia & *C. venusta*: > 85% *

Discussion – Target Consumer Basal Resource Use





Questions

1. How do macroinvertebrates and fish in intermittent segments differ in their taxonomic richness (*S*) and community composition?

   - Mesohabitat & Segment (hydrological regime/history)

2. How does flow intermittency affect the estimated trophic positions of target consumers found at sites throughout study reaches?

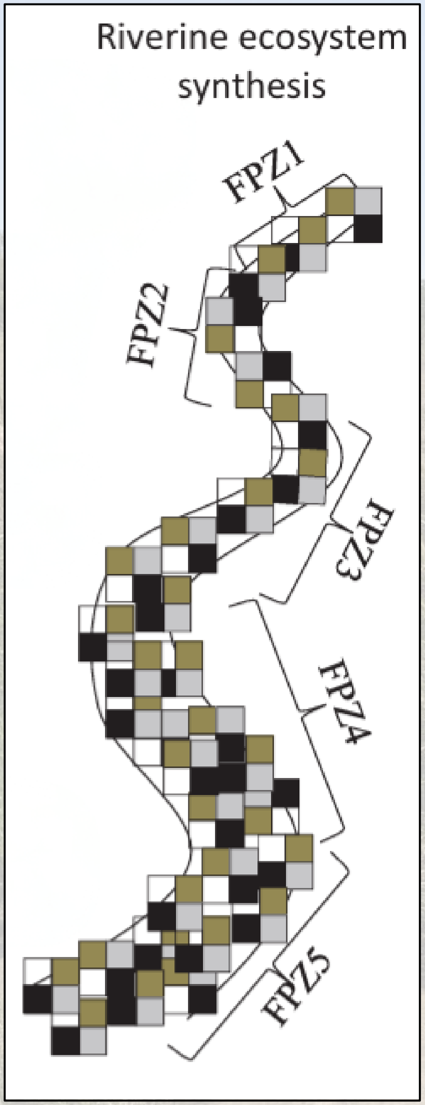
   - Segment (hydrological regime)

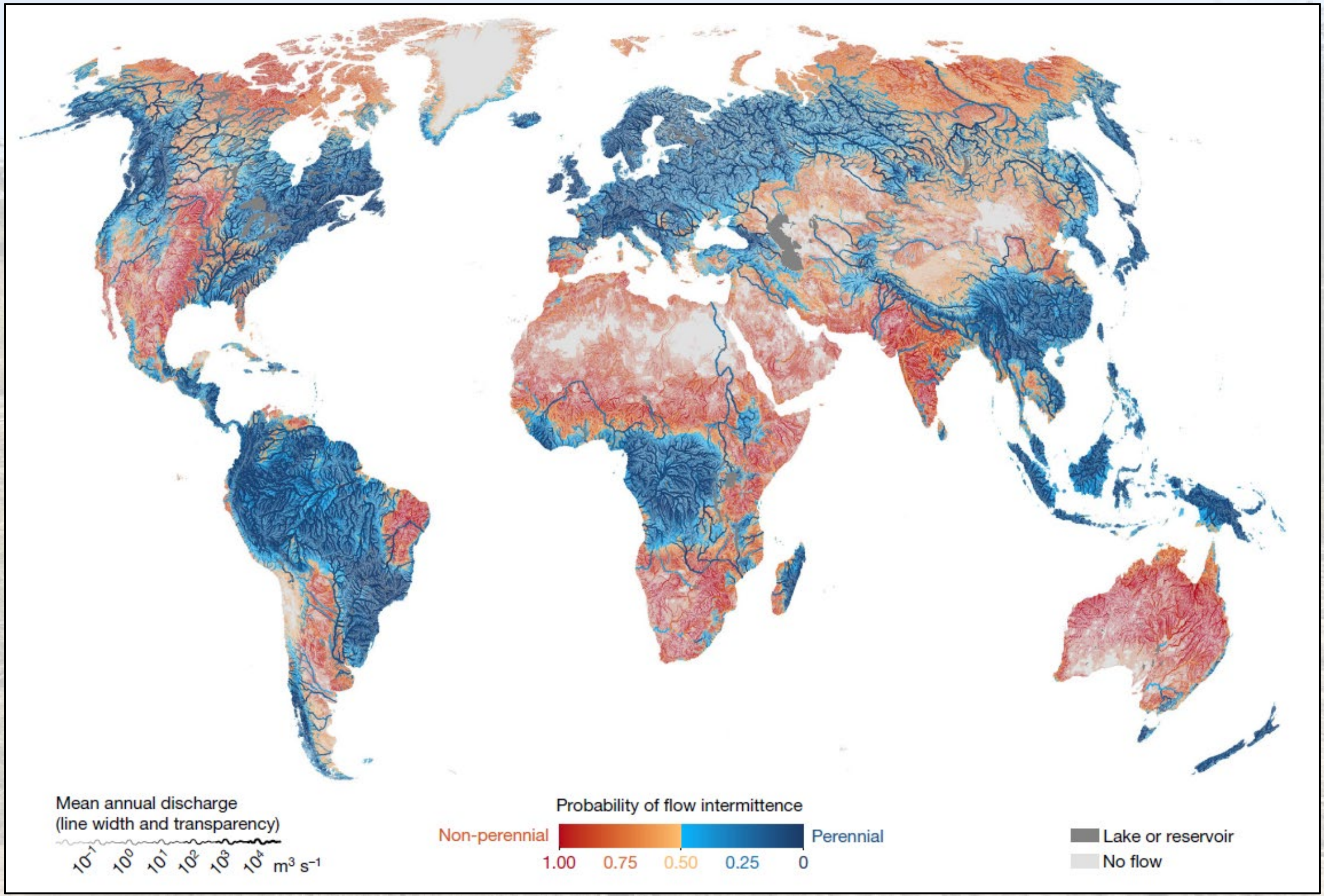
   - Removal of non-algivorous, non-predatory consumers

3. How does intermittency along stream netwok positions affect the relative proportion of basal diet proportions of same target consumers?

   -Local environmental conditions

Conclusion





Thorp et al (2006). *River Research and Applications;* Messager et al, (2021). *Nature;* Dhungel et al, (2016). *River Research and Applications.*

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Nowlin Aquatic Ecology Lab - Parvathi Nair, Jess Kittridge, Rachel Hill, Hannah Mattes, Ailish Collins, Jasmine Rodriguez, Spencer Sliter, Andrew San-Miguel, Hannah Bates, Matthew Stehle, Chloe Harrell, Al Wilson, Waverly Wadsworth, Orion Hovsepian, Ashley Casarez, Derreck Harris, Meranda Goodwin
and thank you to the landowners that allowed us to access their property

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>33,000 **

TRIAGE

US Army Corps of Engineers ®

Big thank you to my committee members: Dr. Weston Nowlin, Dr. Ben Hutchins, and Dr. Todd Swannack

Funding was provided by the US Army Corps of Engineers - Aquatic Nuisance Species Research Program

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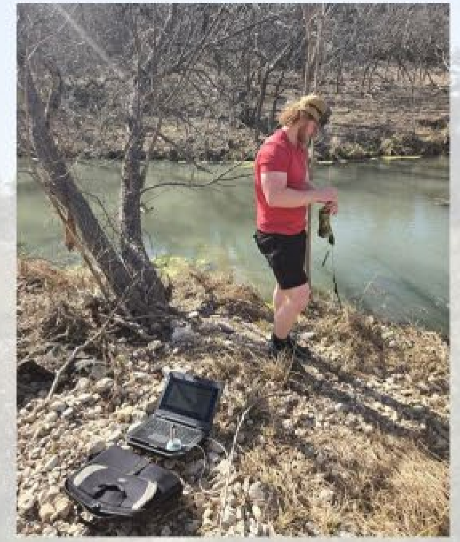

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Thank you!

Dnf44@txstate.edu

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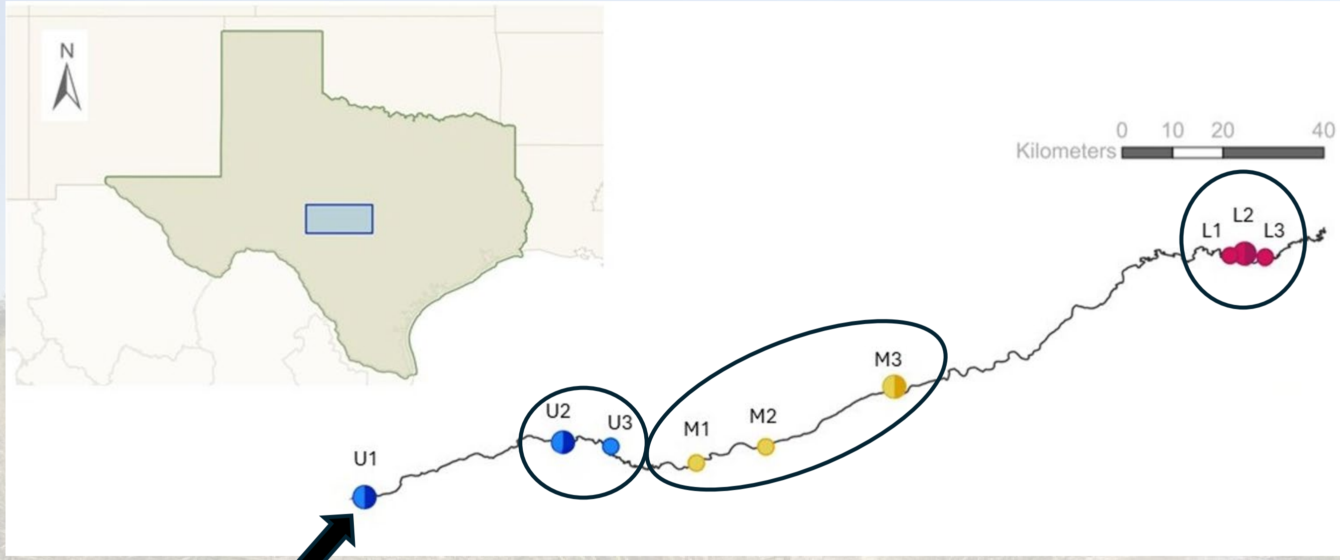
Supplemental

Data analyses – Hydrology Estimations



- USGS water depth sensor
- Submersible & barometric pressure transducers

- 4 historical *Q* gaging stations (USGS or LCRA)
    - 1 water depth sensor (U1)
    - Manual *Q* + deployed logger data → rating curve → continuous *Q* estimates
- Continuous *Q* for ungauged reaches were related to nearest gaging station within same segment
    1. Q_{MM} were compared with concurrent gage records to calculate % difference
    2. 5,000 BCa distribution → median % difference
    3. Median % difference used as a proportional correction → continuous Q_{est}

	Pre-sampling period (90 days)				Inter-sampling period			
Reach	Qavg	# days = 0 L/s	Prop. Days = 0 L/s	QCV	Qavg	# days = 0 L/s	Prop. Days = 0 L/s	QCV
U1	380.12	0	0	1.35	381.56	0	0	26.99
U2	736.63	0	0	53.24	391.97	0	0	114.45
U3	570.65	0	0	36	303.18	0	0	113.41
M1	290.92	0	0	138.97	111.71	9	0.12	177.05
M2	490.29	0	0	135.92	177.94	9	0.11	179.85
M3	494.36	0	0	123.01	130.97	9	0.1	187.39
L1	1166.14	0	0	193.71	657.89	0	0	63.74
L2	1293.36	0	0	191.92	725.97	0	0	62.55
L3	934.51	0	0	193.03	534.93	0	0	63.31