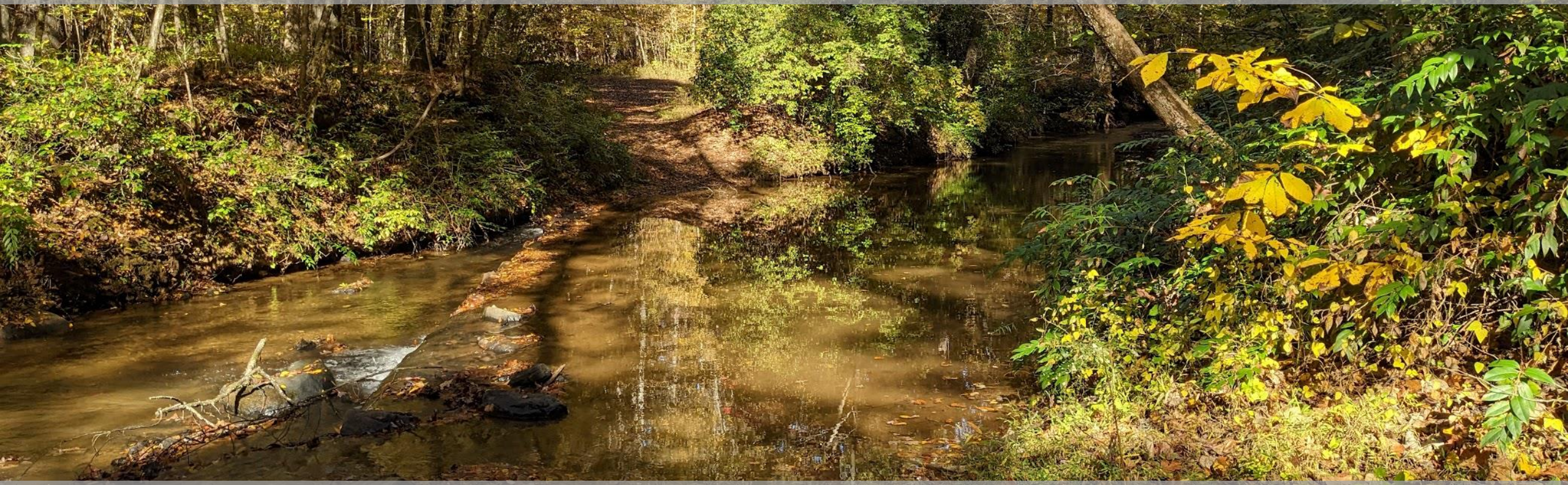
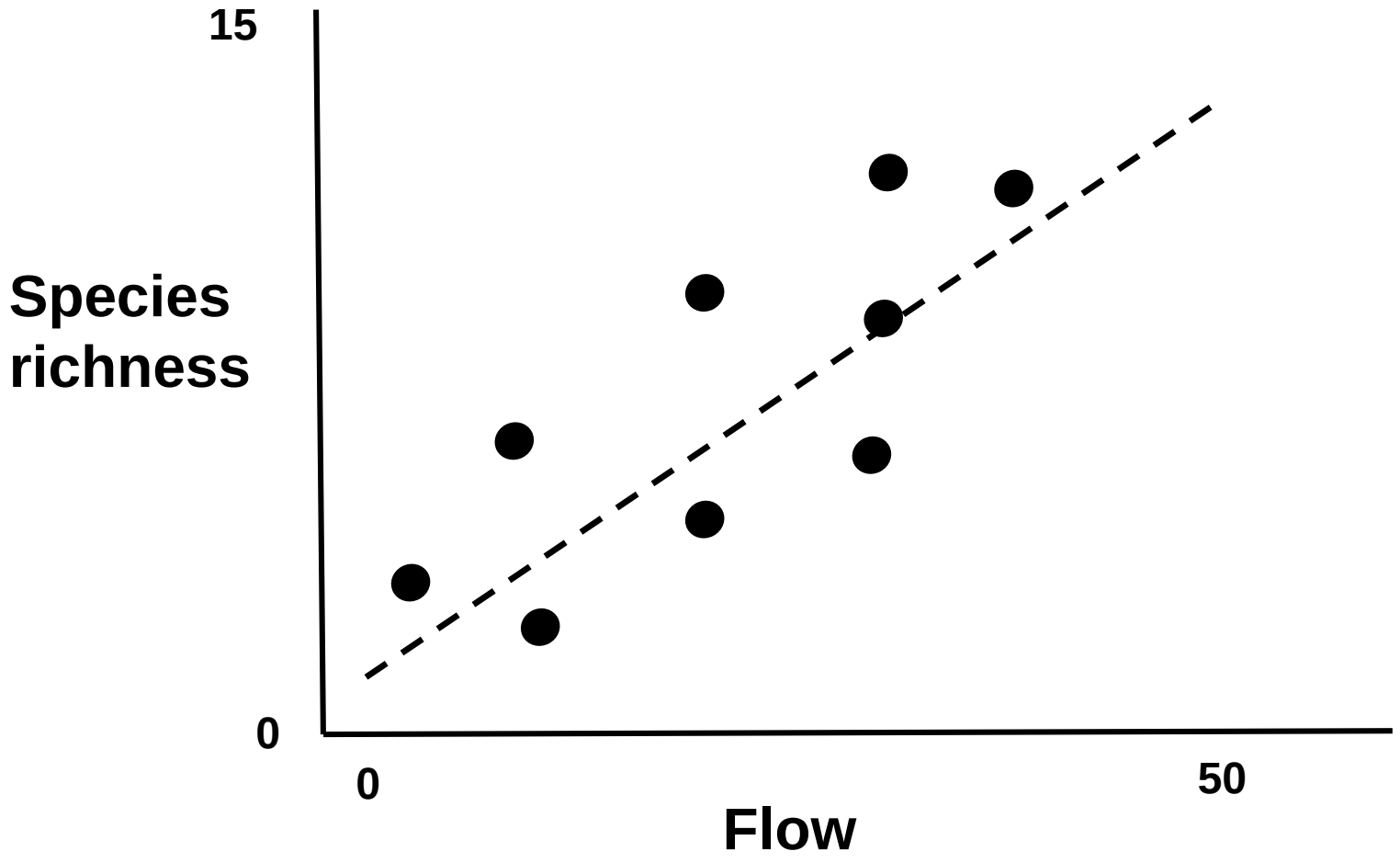
Flow-Fish Richness Relationships

Pee Dee RBC, April 25th, 2023



Drs. Luke Bower, Joe Mruzek, and Brandon Peoples

Identify relationships: some are informative



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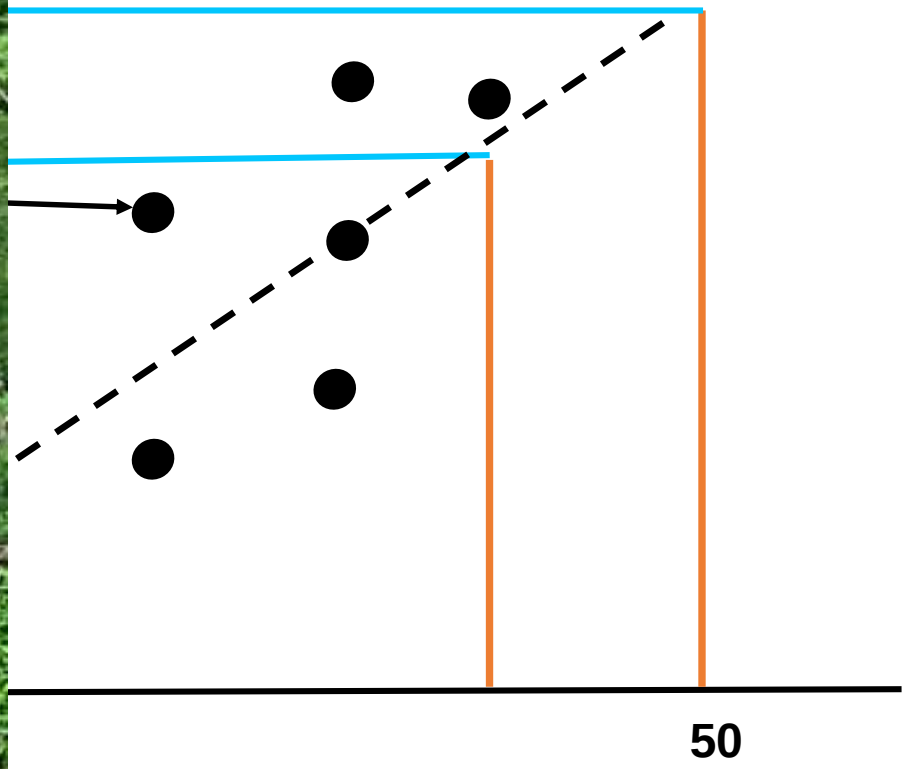
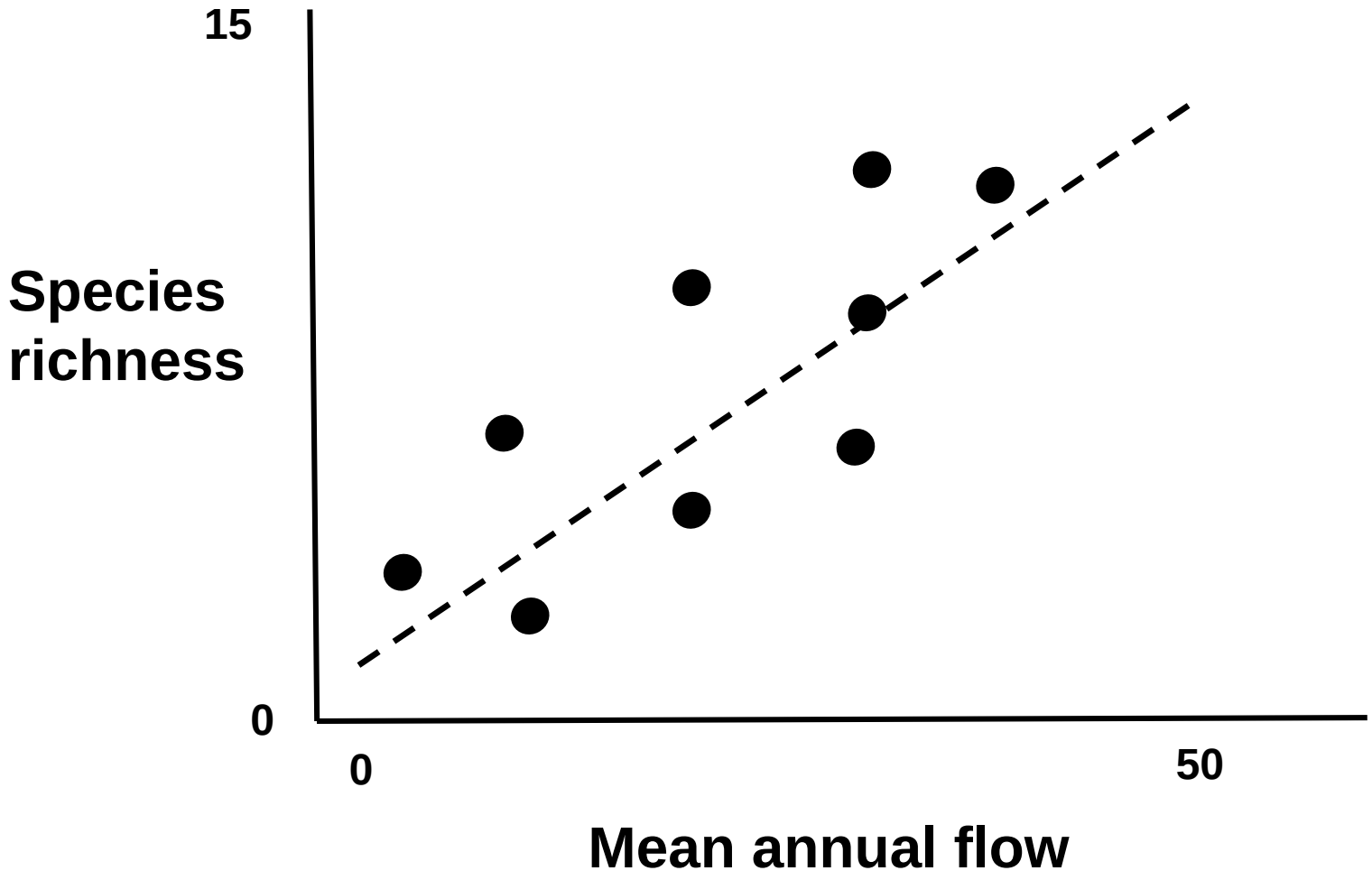
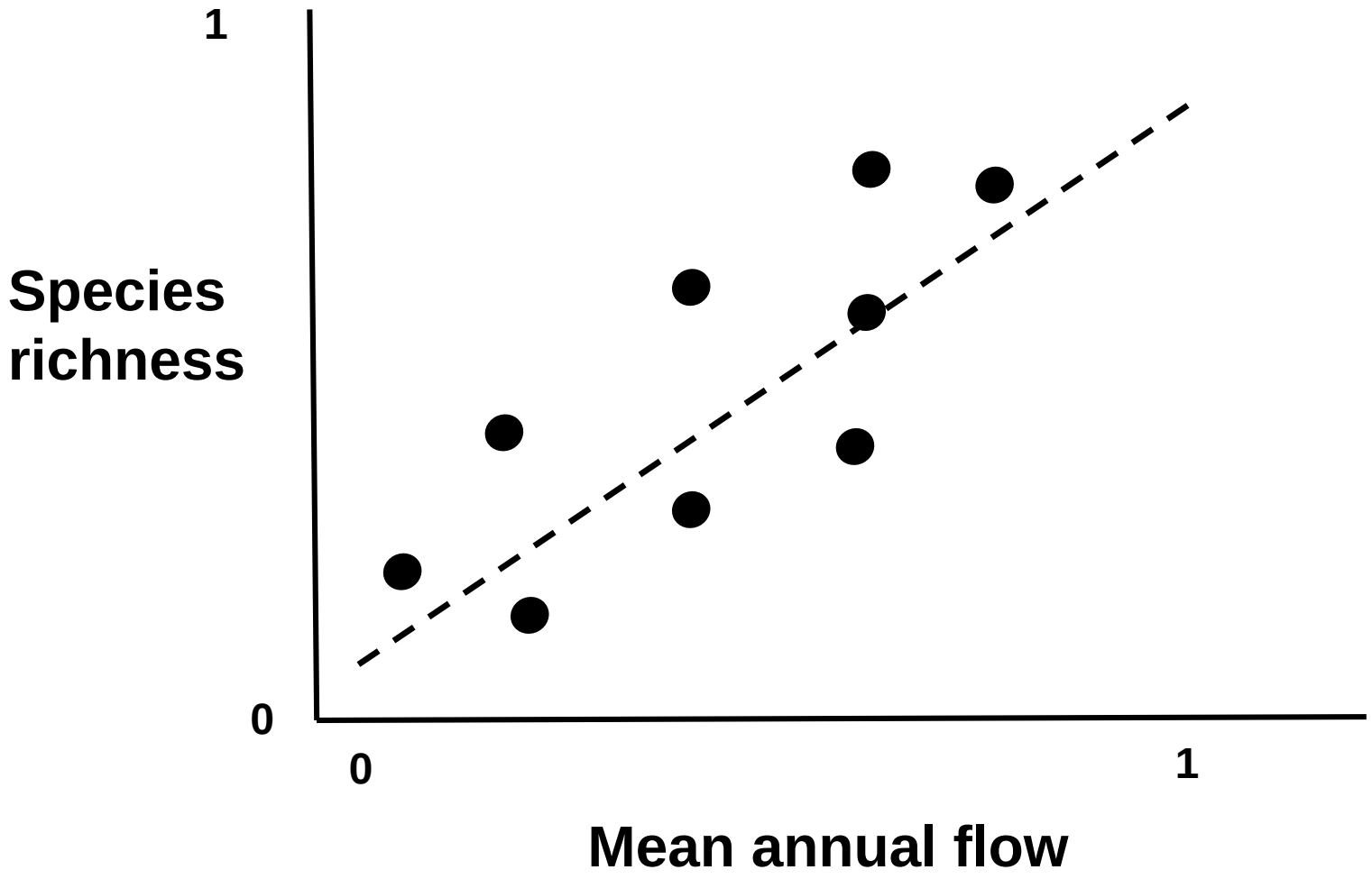
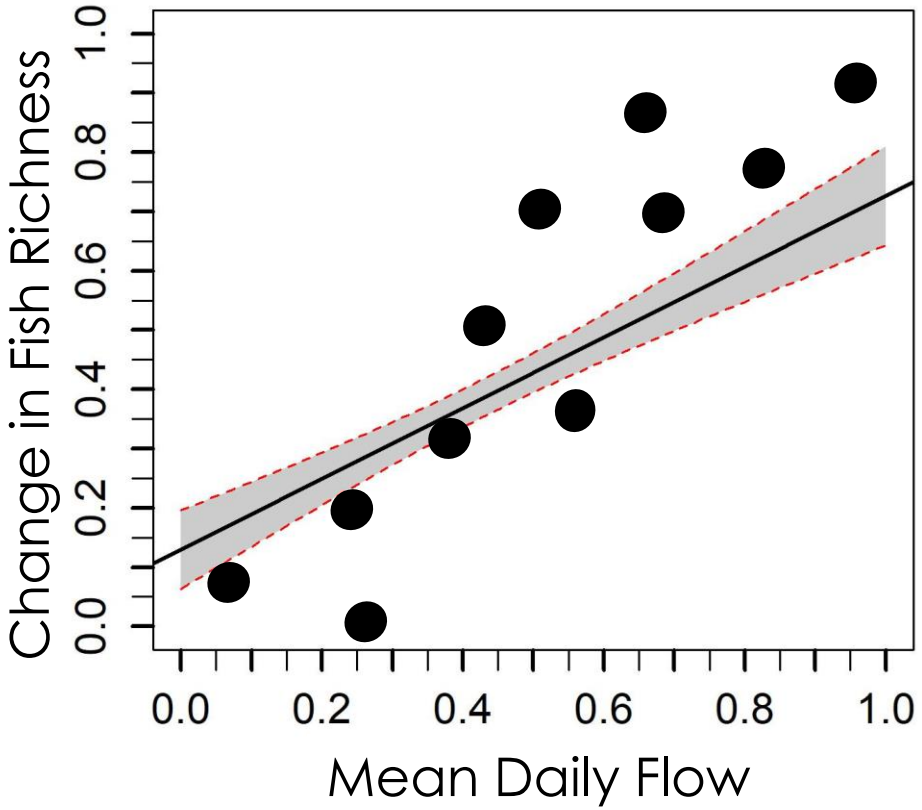
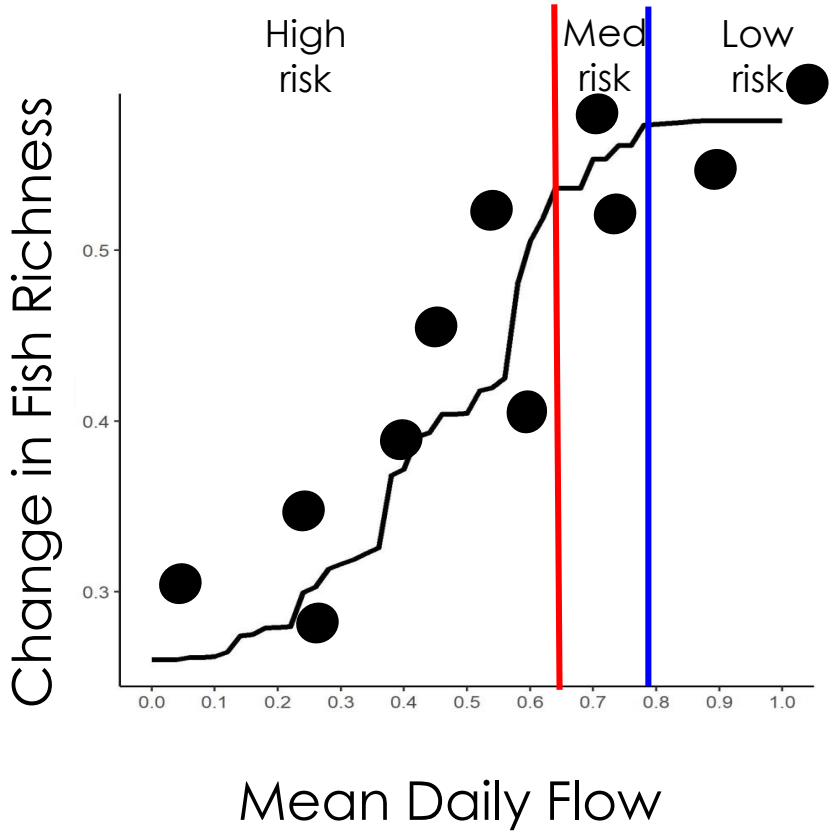


Mean annual flow


15
Species richness
0
0
50
Mean annual flow


1
Species
richness
0
0
1
Mean annual flow


Change in Fish Richness
0.0
0.2
0.4
0.6
0.8
1.0
Mean Daily Flow


High risk
Med risk
Low risk
Change in Fish Richness
0.3
0.4
0.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Mean Daily Flow

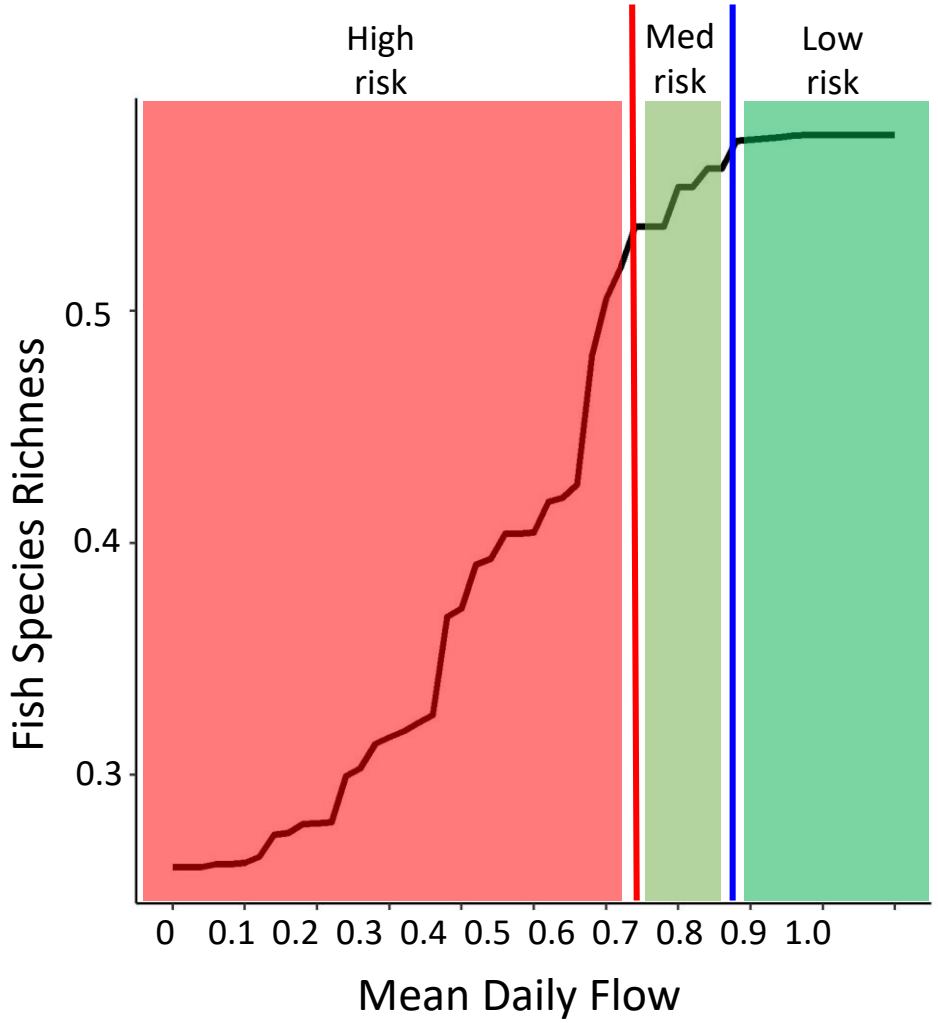
How can we use these relationships?

- Defining biological response limits
  - Searching for zones along flow gradients that induce changes in the biological metric

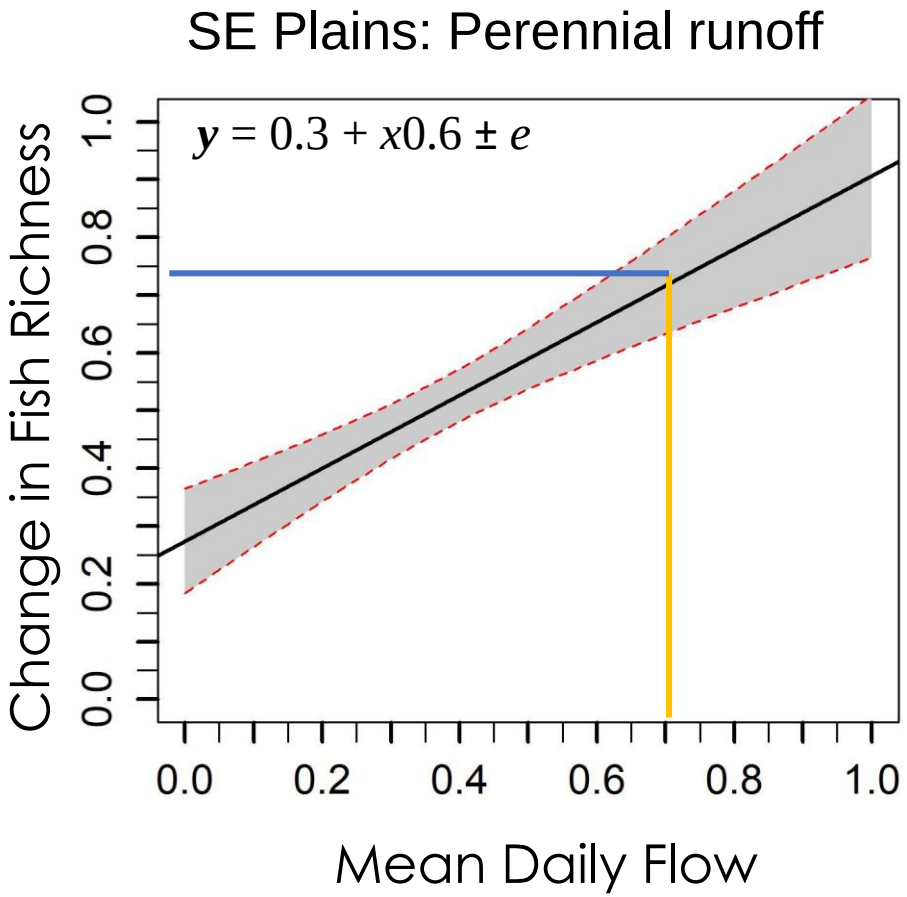
- Predicting responses
  - If we alter flow by X amount what will be the biological response?

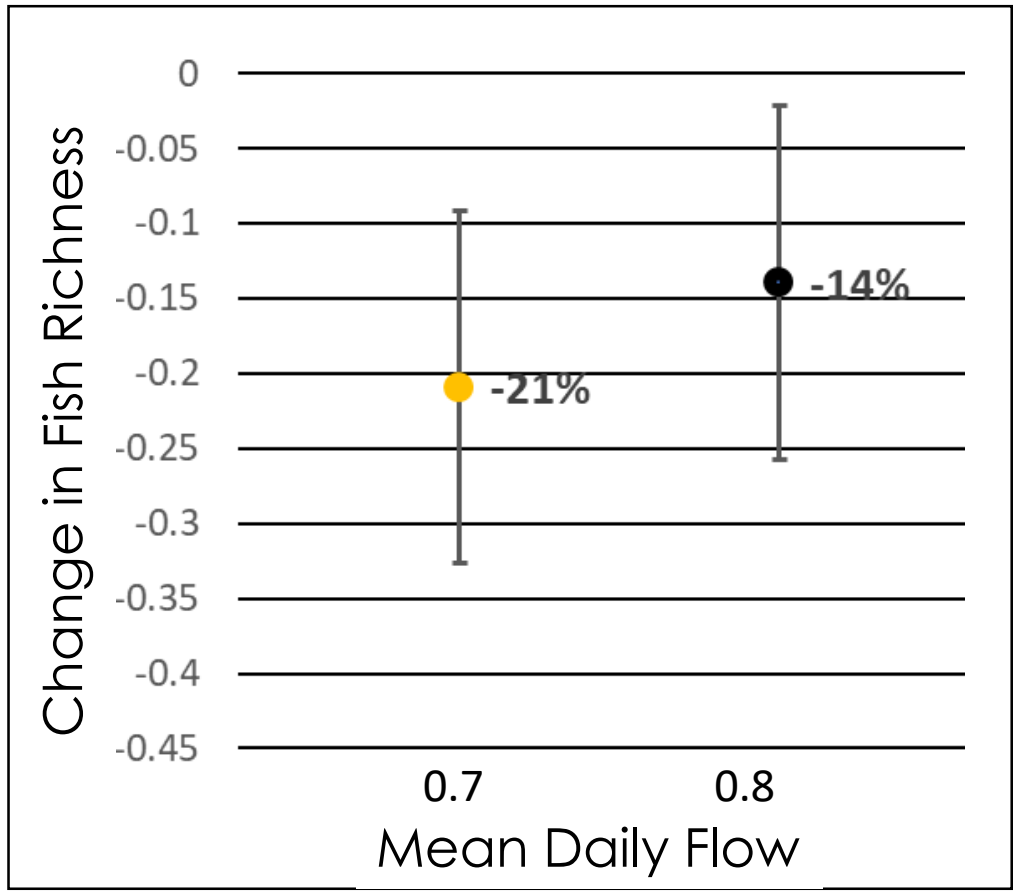
Mean daily flow (MA1): biological response limits

- Lines defined by working group
- Performance measure



Mean daily flow (MA1): predictions





SWAM: 100 cfs to 70 cfs in 2070

Stream classes

- Perennial runoff streams, characterized by moderately stabile flow and distinct seasonal extremes (Class 1, 615 stream segments)
- Stable baseflow streams: characterized by high precipitation, sustained high baseflows, and moderately high run-off (Class 3, 183 stream segments)
- Perennial flashy; characterized by moderately stabile flow with high flow variability (coefficient of variation in daily flows) (Class 4, 138 stream segments)

Key to Understanding the Results of the Surface Water Modeling Scenarios:

Mean daily flow (MA1): N. Pacolet near Fingerville

Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	320	368.91	15.4%	Richness	12.7%	7
HD 2070	320	257.78	-19.4%	Richness	-15.9%	7
Full	320	227.65	-28.8%	Richness	-23.6%	7
MD 2070	320	283.39	-11.3%	Richness	-9.3%	7

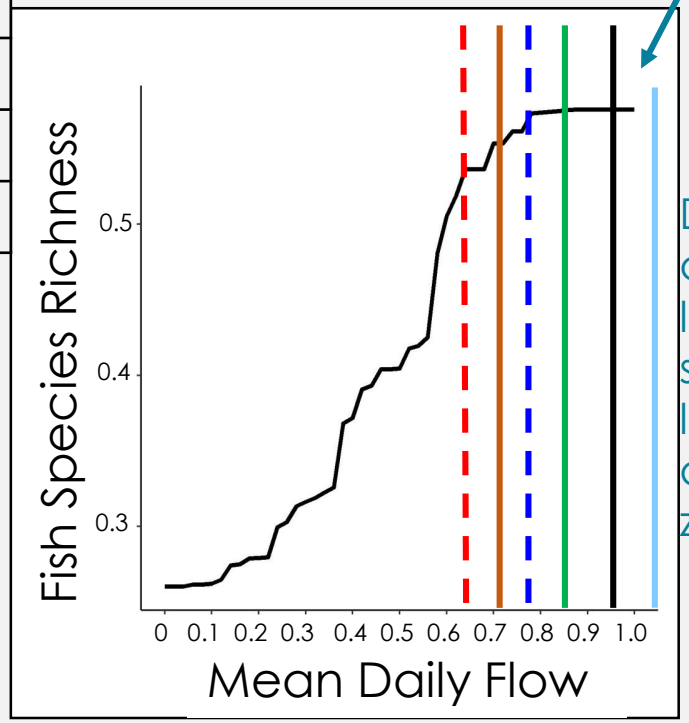
Standard Error

Current Use Scenario Mean Daily Flow

Scenario Mean Daily Flows

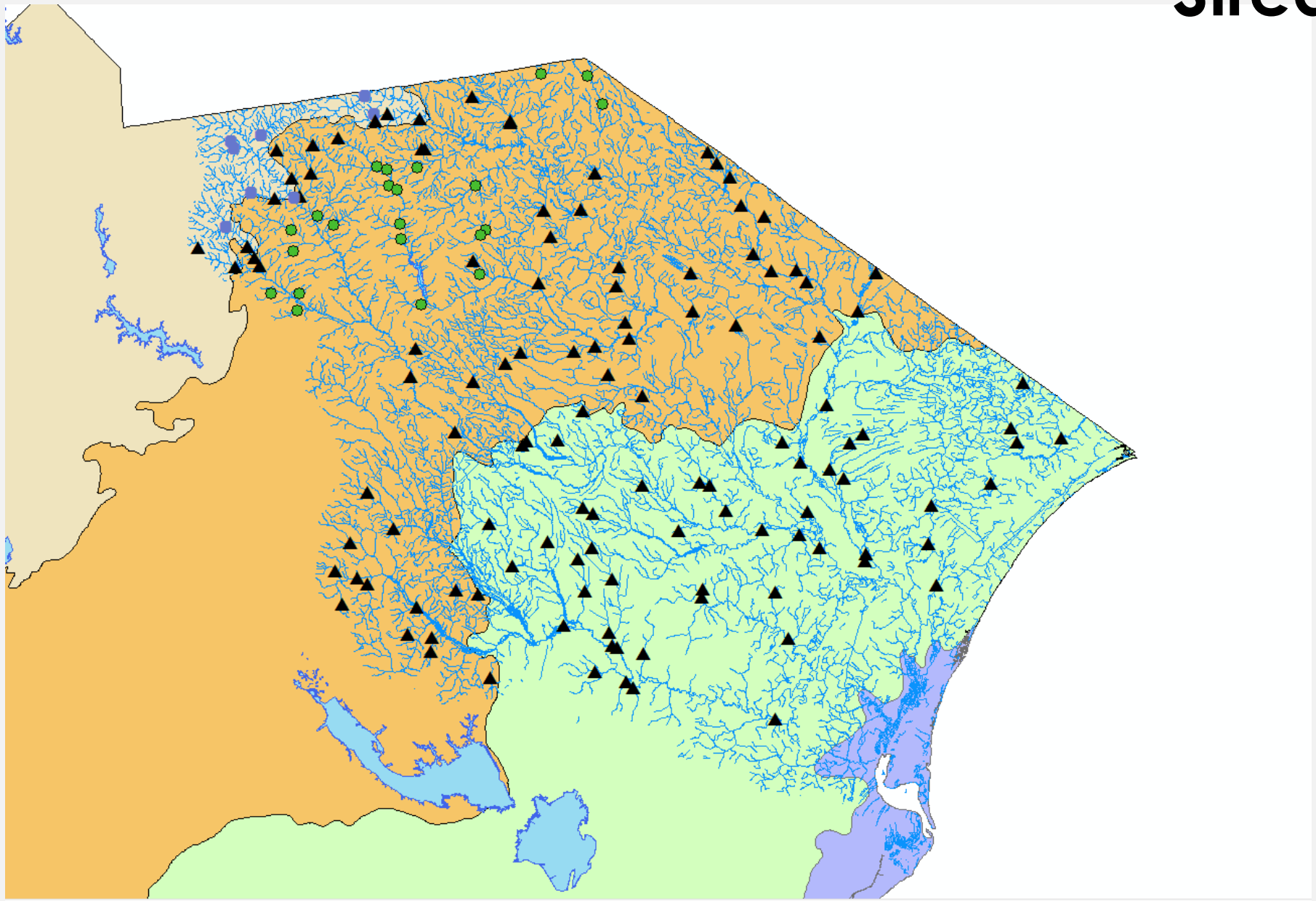
% Changes for each scenario are relative to the Current Use Scenario

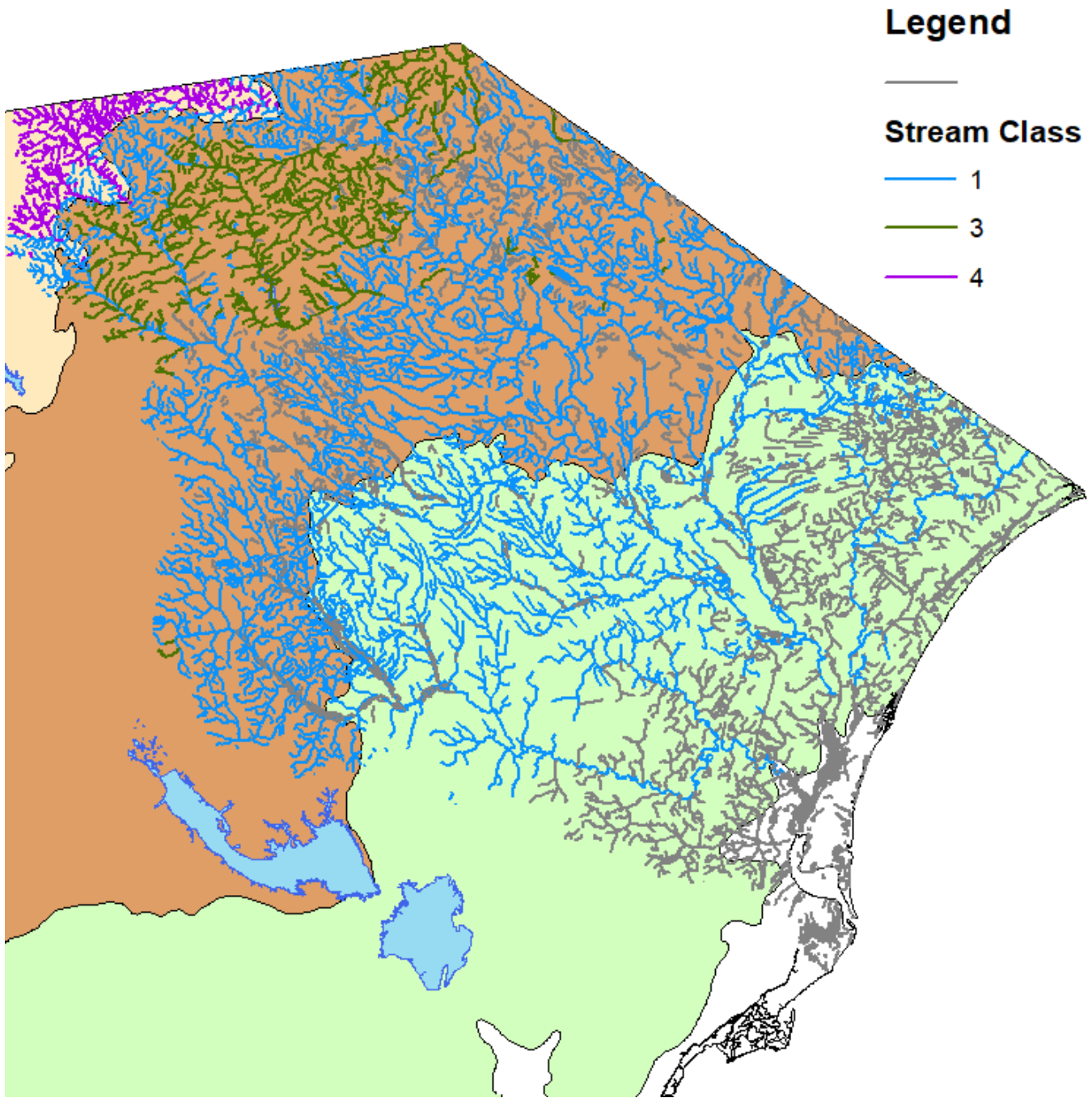
Colored lines correspond to scenario results shown in the table



Dashed red and blue lines separate the low medium and high risk zones

Stream classes





Piedmont
Southeastern Plains
Middle Atlantic Coastal Plain

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Current Use Scenario Mean Daily Flow

Scenario Mean Daily Flows

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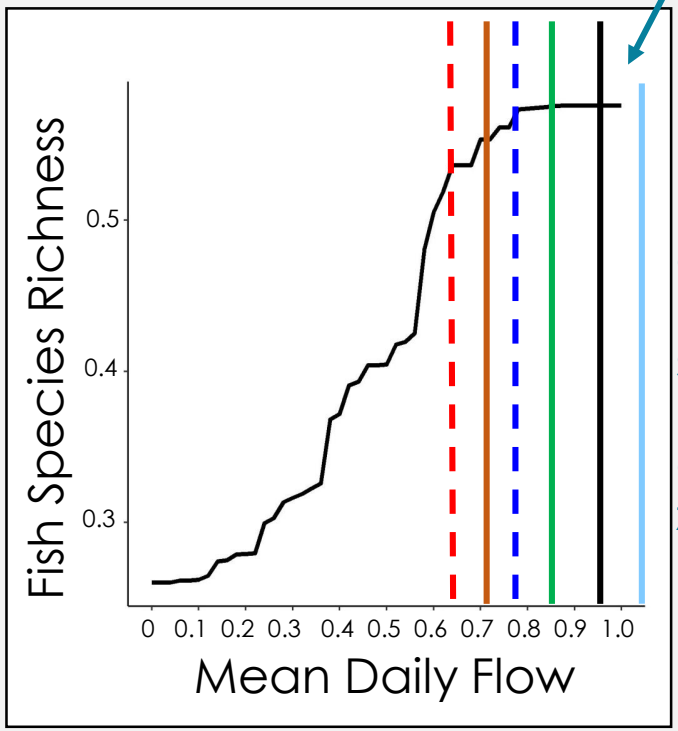

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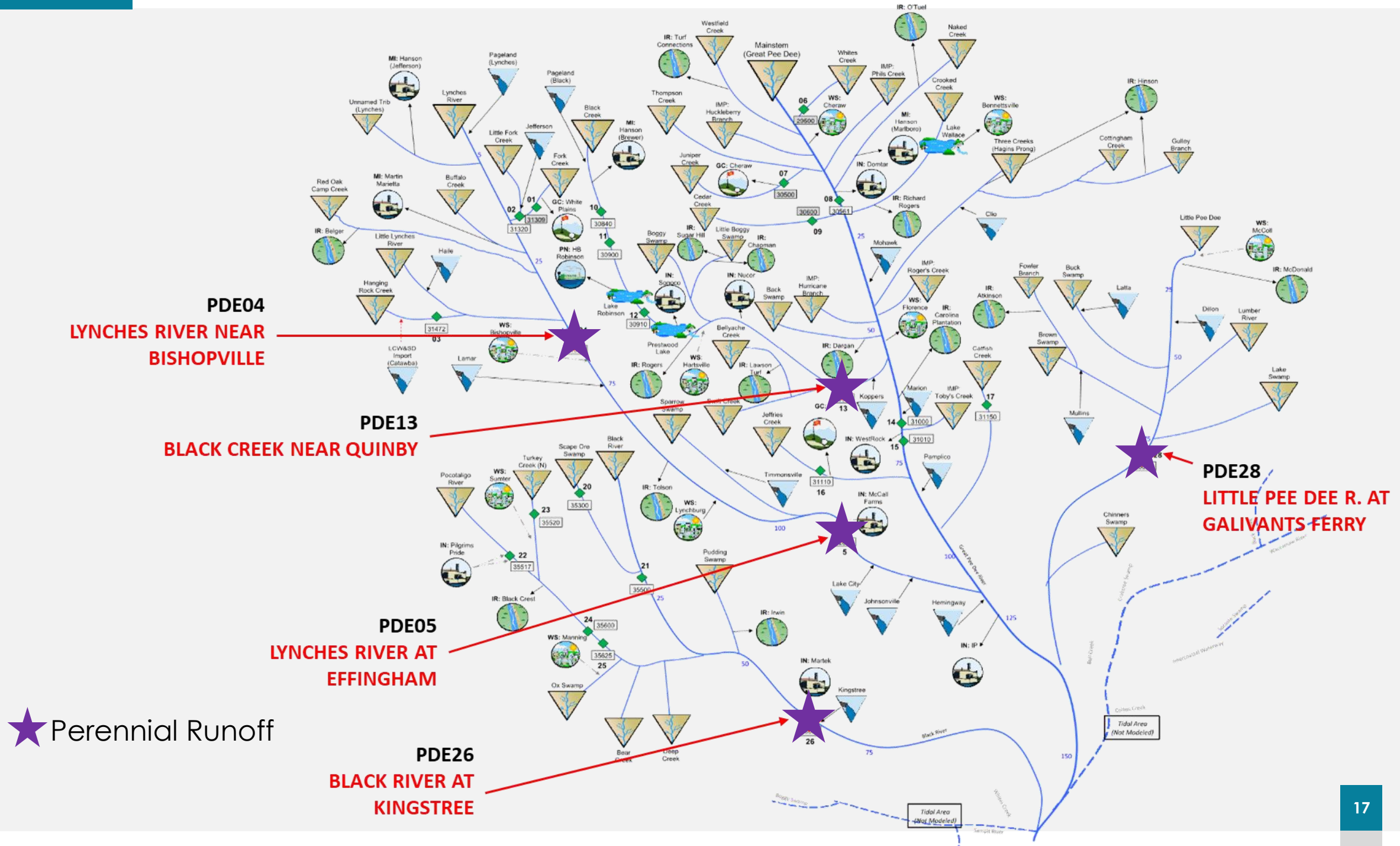
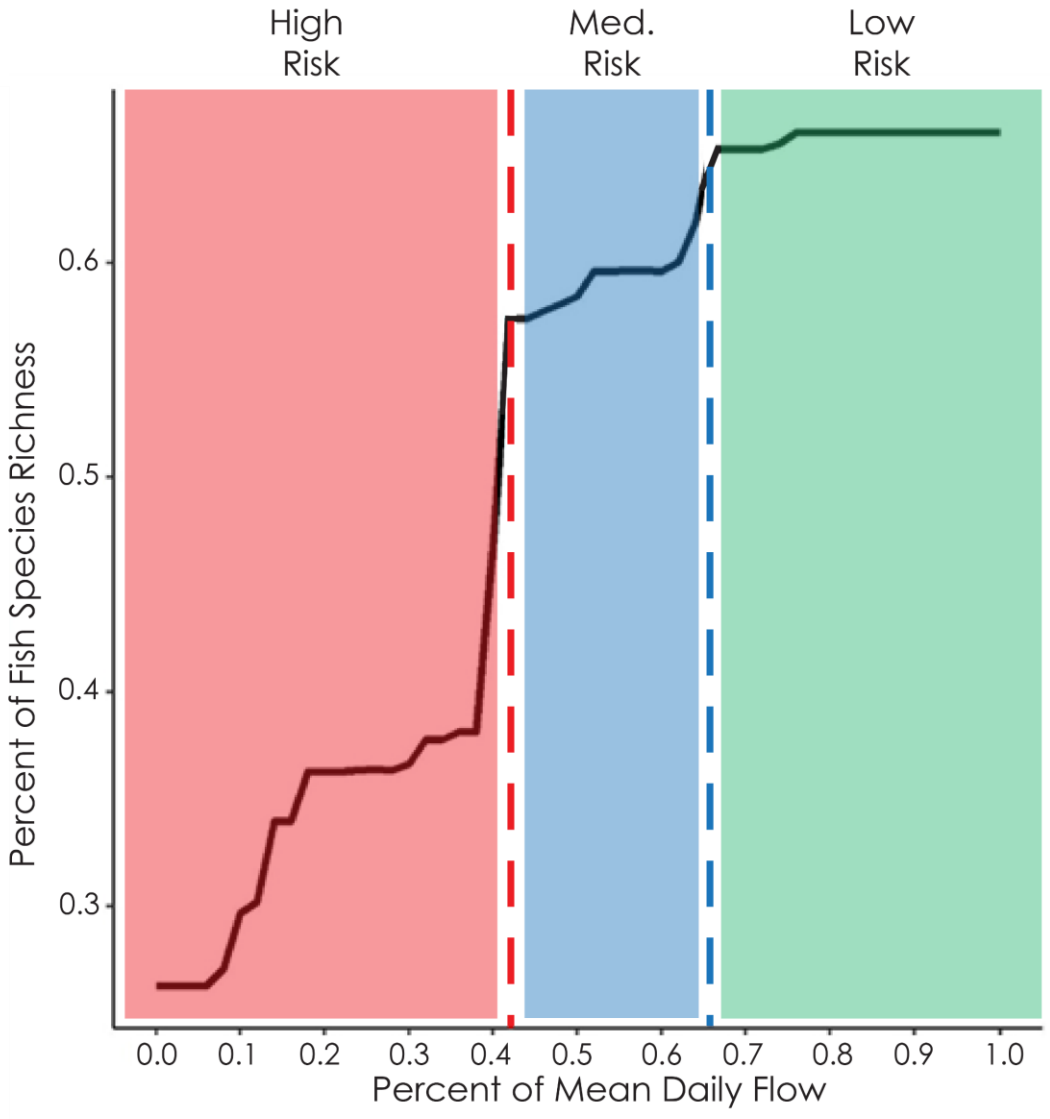
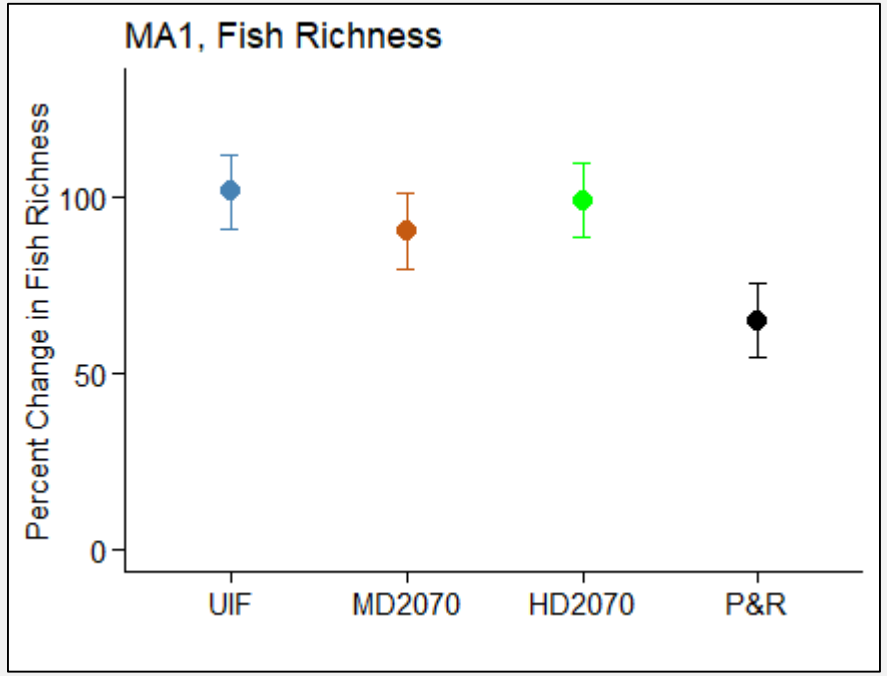

PDE04
LYNCHES RIVER NEAR BISHOPVILLE
PDE13
BLACK CREEK NEAR QUINBY
PDE05
LYNCHES RIVER AT EFFINGHAM
PDE26
BLACK RIVER AT KINGSTREE
PDE28
LITTLE PEE DEE R. AT GALIVANTS FERRY
Perennial Runoff
Tidal Area (Not Modeled)
Tidal Area (Not Modeled)

Fish Richness-MA1: SE Plains: Perennial Flashy

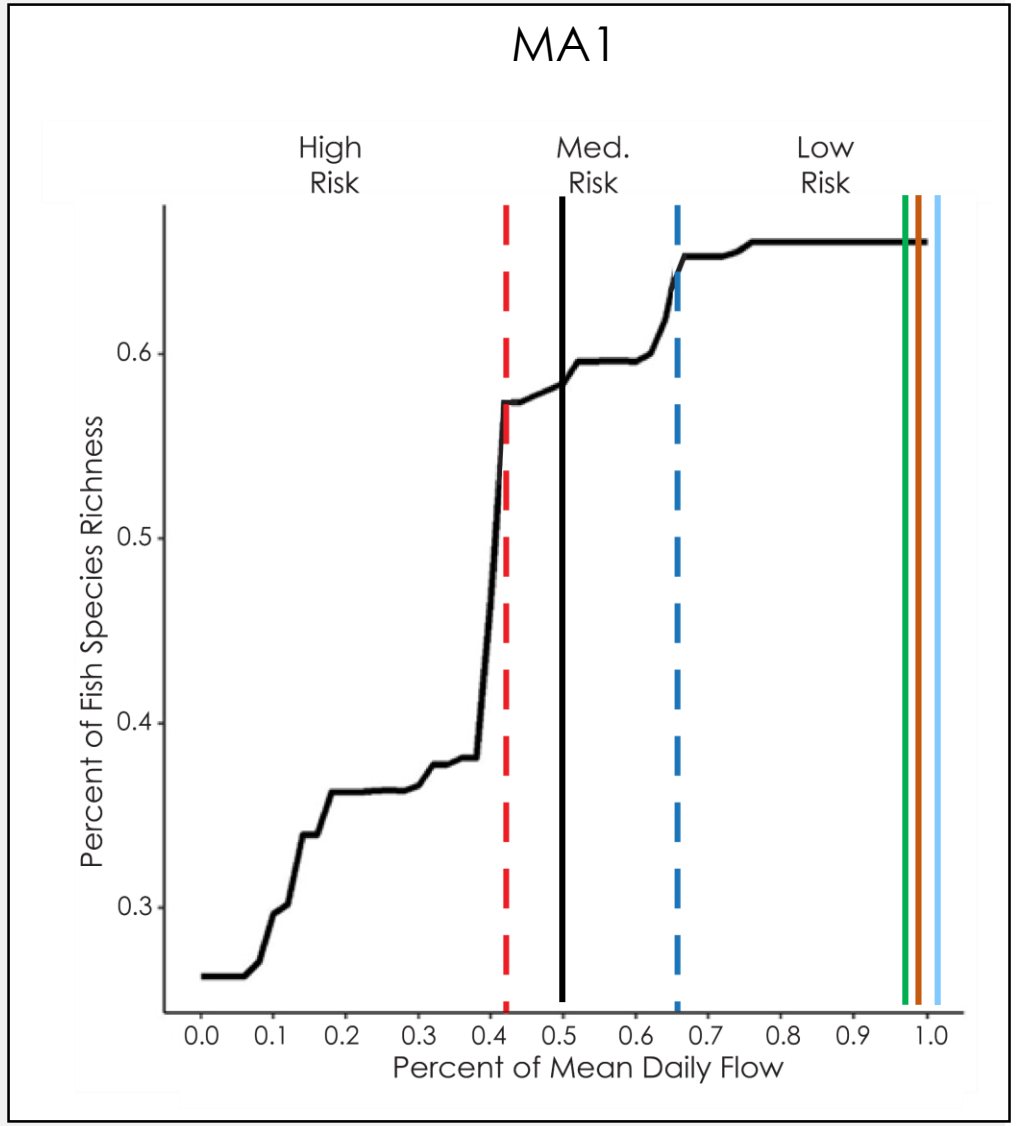
- Removal of 20% of mean daily flow is ‘low risk’
- Removal of more than 40% is ‘high risk’ to fish richness



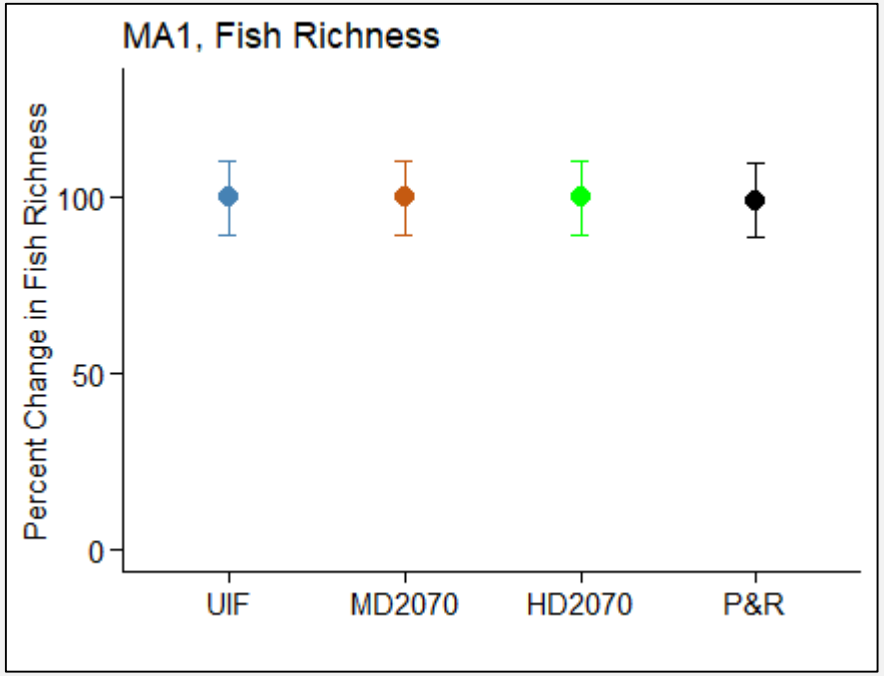
Black Creek near Quinby



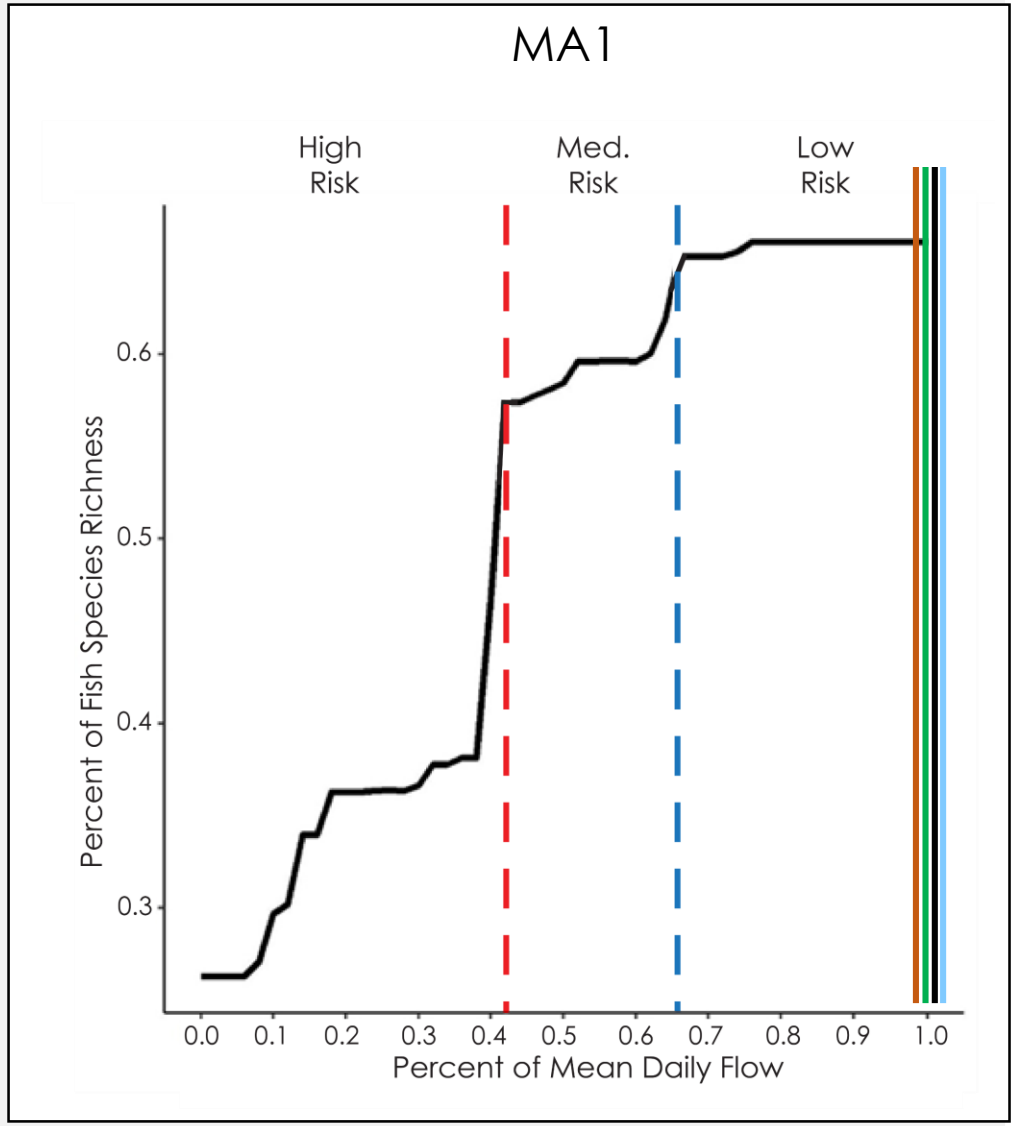
Scenario	Current	Predicted	% change	Change in Bio	SE
UIF	537	550	2.34	1.63	0.107
MD 2070	537	533	-0.82	-0.57	0.107
HD 2070	537	531	-1.16	-0.81	0.107
P & R	537	267.3	-50.23	-35.0	0.107



Lynches River near Bishopville

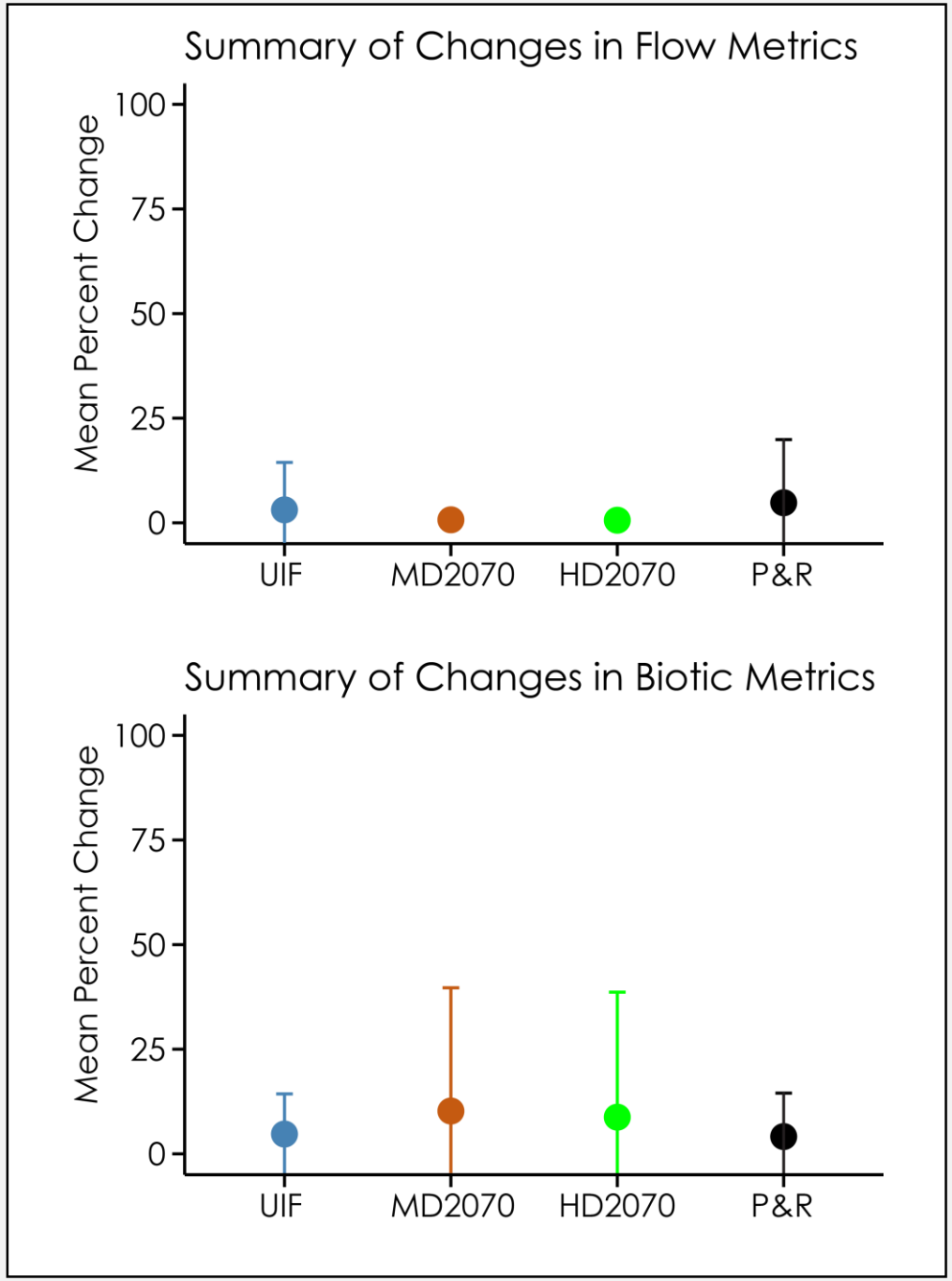


Scenario	Current	Predicted	% change	Change in Bio	SE
UIF	746	744	-0.18	-0.12	0.107
MD 2070	746	744	-0.20	-0.14	0.107
HD 2070	746	744	-0.23	-0.16	0.107
P & R	746	737	-1.16	-0.81	0.107



Summary

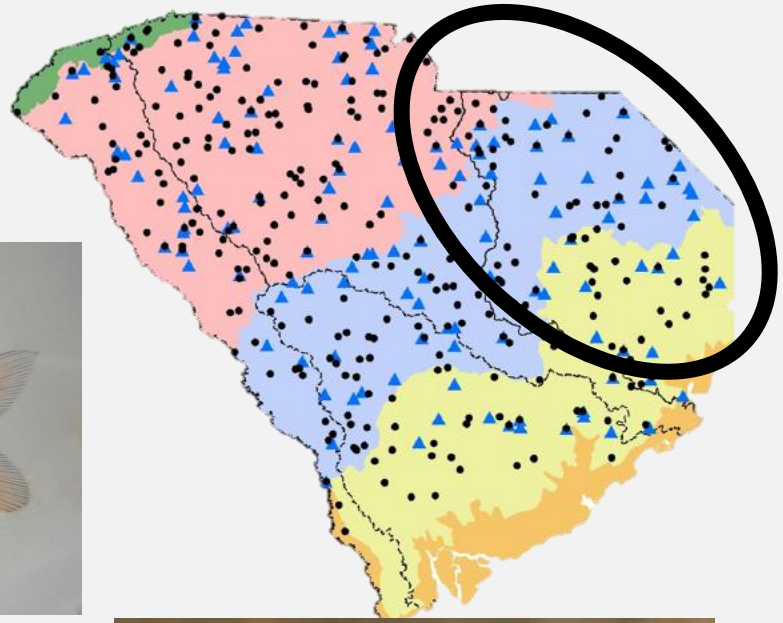
- Analyzed 4 flow metrics across 5 sites
- Analyzed 3 biotic responses
- Generally, very little change is predicted



Some implications of this work

Expected results: richness

- 65 species collected at 94 sites in Pee Dee basin
- Average 12 species per site



Redbreast sunfish

Notchlip redhorse

American Eeel

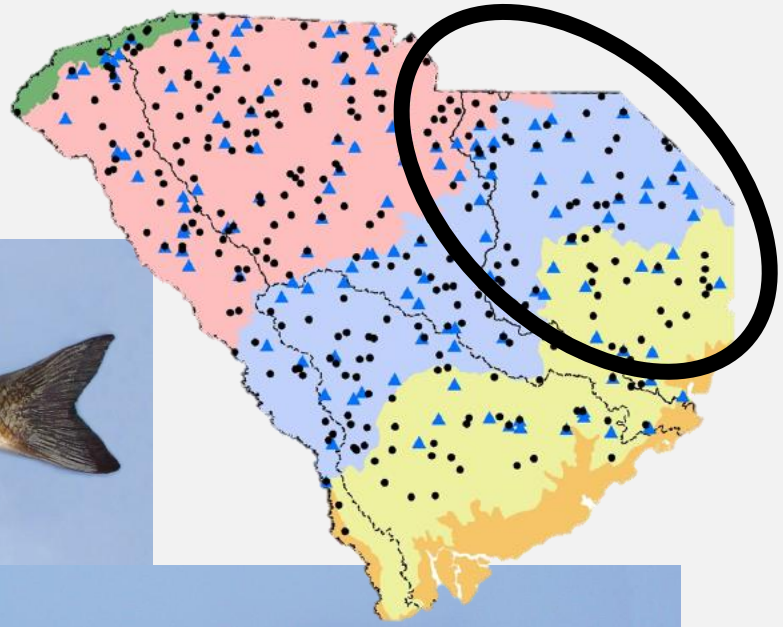
Blackbanded sunfish

Bluespotted Sunfish

Least Killifish

Expected results: richness

- Up to 39% biodiversity loss in some streams at full allocation
- Replacement by common generalists & invasives



Green sunfish

White sucker

Eastern mosquitofish

Yellow Bullhead

Golden Shiner

37 Species of Greatest Conservation Need

Thinlip Chub

Santee Chub

Carolina Darter

Pinewoods Darter

Rosyside Dace

Bluespotted Sunfish

Fieryblack Shiner

Everglades Pygmy Sunfish

Snail Bullhead

Carolina Fantail Darter

Blackbanded Sunfish

Sandhills Chub

All photos from ncfishes.com

37 Species of Greatest Conservation Need

Robust Redhorse

Shortnose Sturgeon

American Shad

Atlantic Sturgeon

Striped bass

American Eel

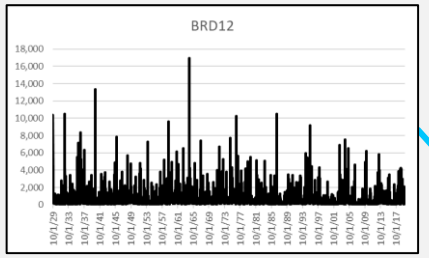
What this info *is*

- Guidance based on best available data and analysis tools
- Based on models with compounding statistical uncertainty

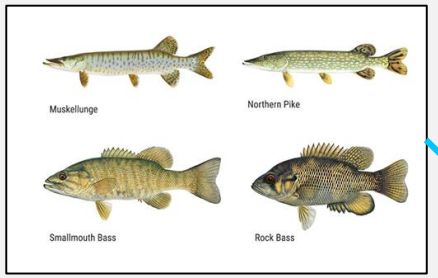
What this info *is not*

- Arbitrary recommendations from ‘expert advice’
- Perfect.
- More data = less uncertainty
- Changing climate & land cover = more uncertainty

Flow Chart



Gauge Data

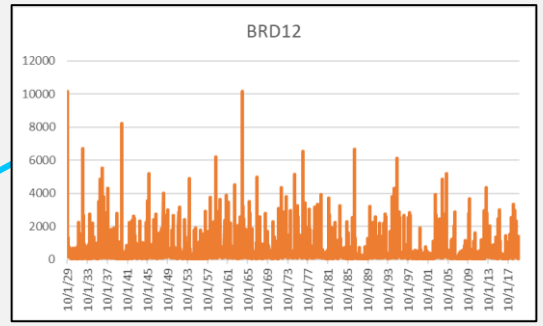


Community Data

Estimate Flow metrics

+ Uncertainty

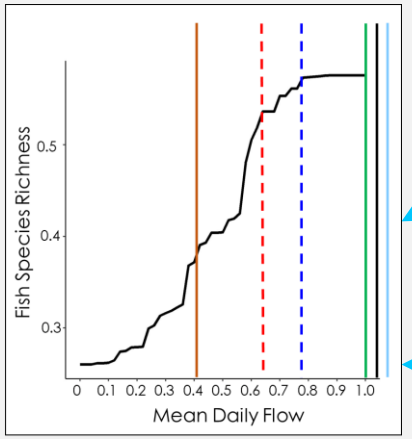
Estimate Flow-Ecology Relationships



Forecast Future Flows

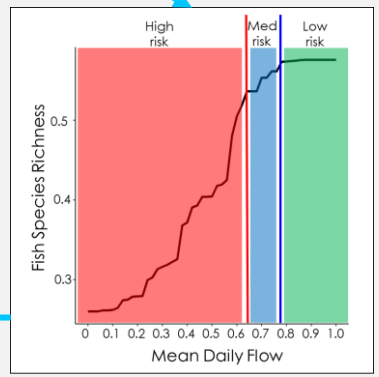
+ Uncertainty

+ Uncertainty



Forecast Changes in Biota

+ Uncertainty



Identify Thresholds

What this info *is*

- Guidance based on best available data and analysis tools
- Based on models with compounding statistical uncertainty
- Representative of overall (30-year) flow regime characteristics

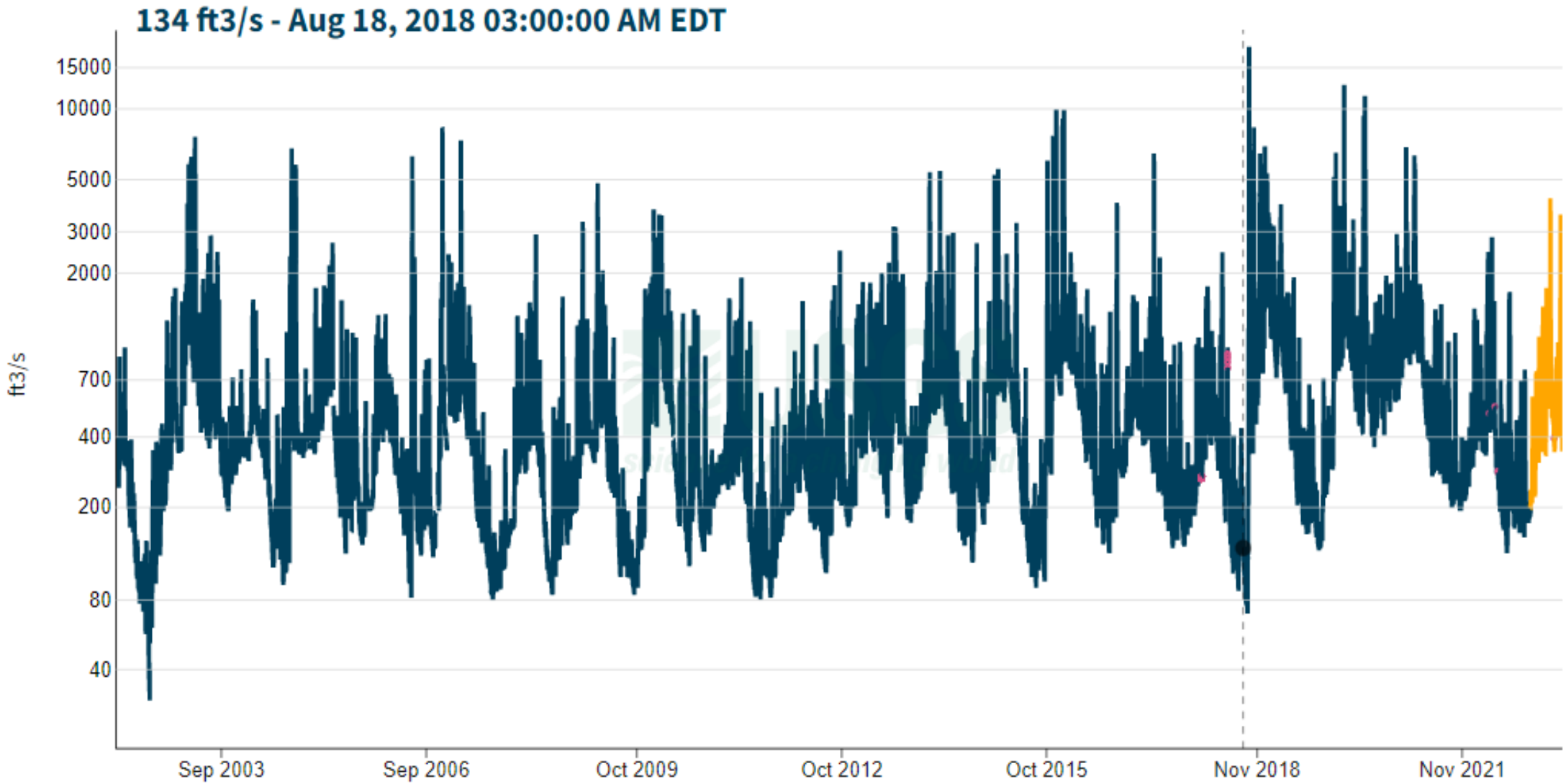
What this info *is not*

- Arbitrary recommendations from 'expert advice'
- Perfect.
- More data = less uncertainty
- Changing climate & land cover = more uncertainty
- One-time withdrawal thresholds

Lynches River Near Bishopville, SC - 02131500

February 15, 2002 - April 20, 2023

Streamflow, ft³/s



What this info *is*

- Guidance based on best available data and analysis tools
- Based on models with compounding statistical uncertainty
- Representative of overall (30-year) flow regime characteristics
- Applicable to streams and small rivers (~86% of all SC waters)
- Relationships between organisms and flow

What this info *is not*

- Arbitrary recommendations from 'expert advice'
- Perfect.
- More data = less uncertainty
- Changing climate & land cover = more uncertainty
- One-time withdrawal thresholds
- Applicable to large rivers and reservoirs
- Parsing out other factors that affect organisms
- Land use affects flow, etc.

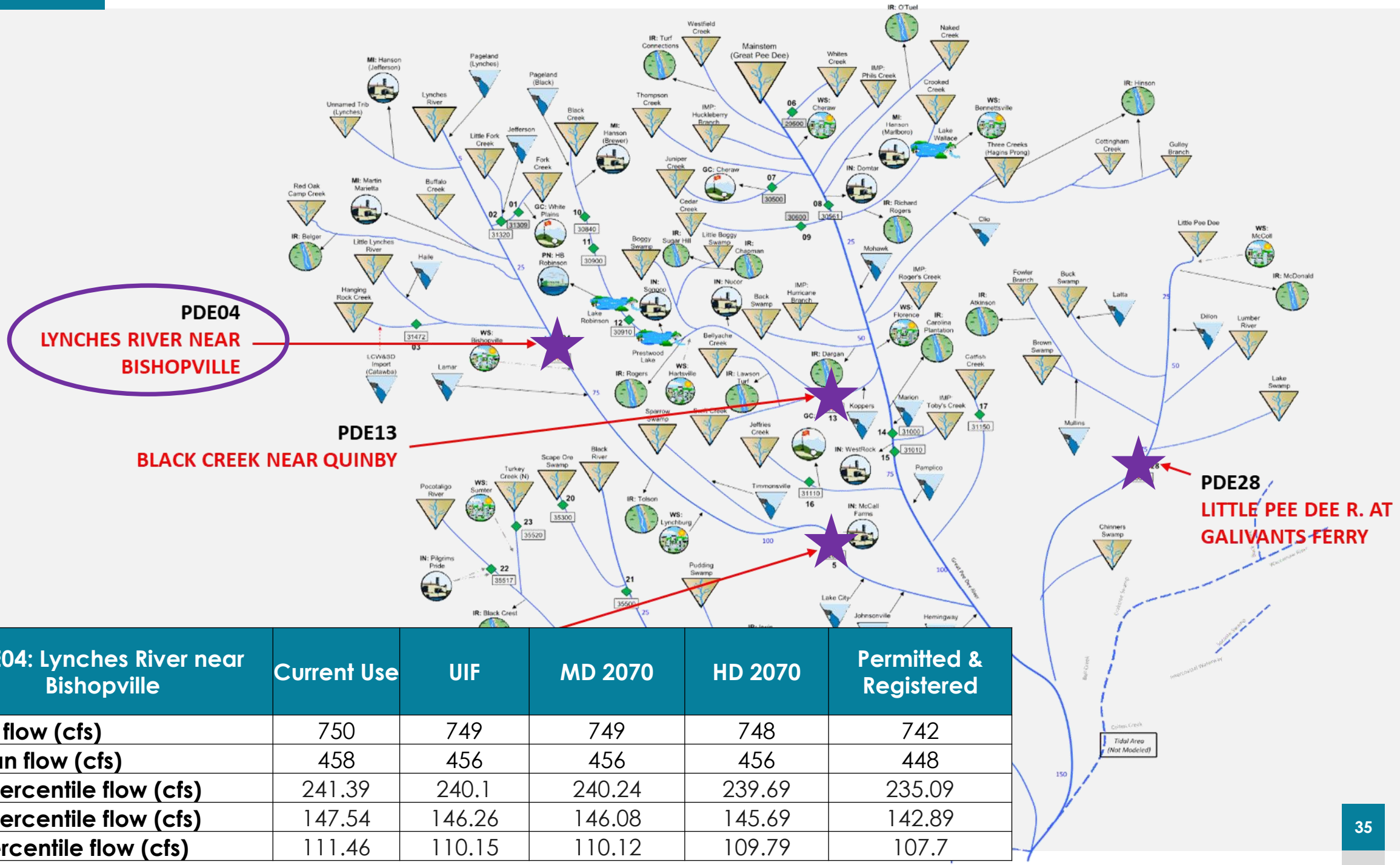
Outstanding questions

- **Parsing out multiple stressors**: Fish are affected by flow *and* other features—land use, etc.
- **Needs**: Analyses are in progress to answer this question

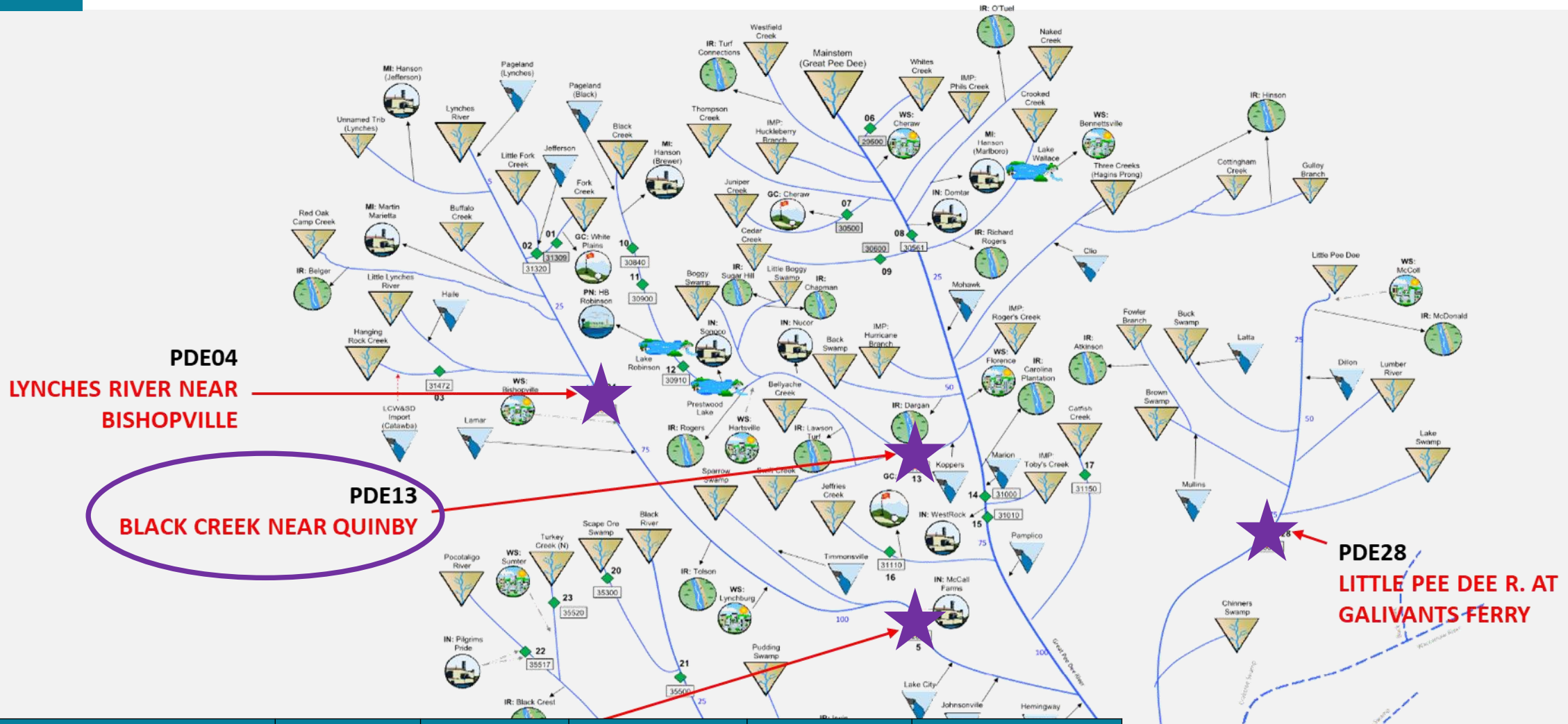
- **Future flows**: Relationships are based on 'current' flow-ecology relationships.
- **Needs:** Detailed dataset of predicted future flow. Accounting for land use, temp, & precip.

- **Large rivers & reservoirs:** Most major withdrawals occur outside our focal streams
- **Needs:** Species-level population data from these systems across the state

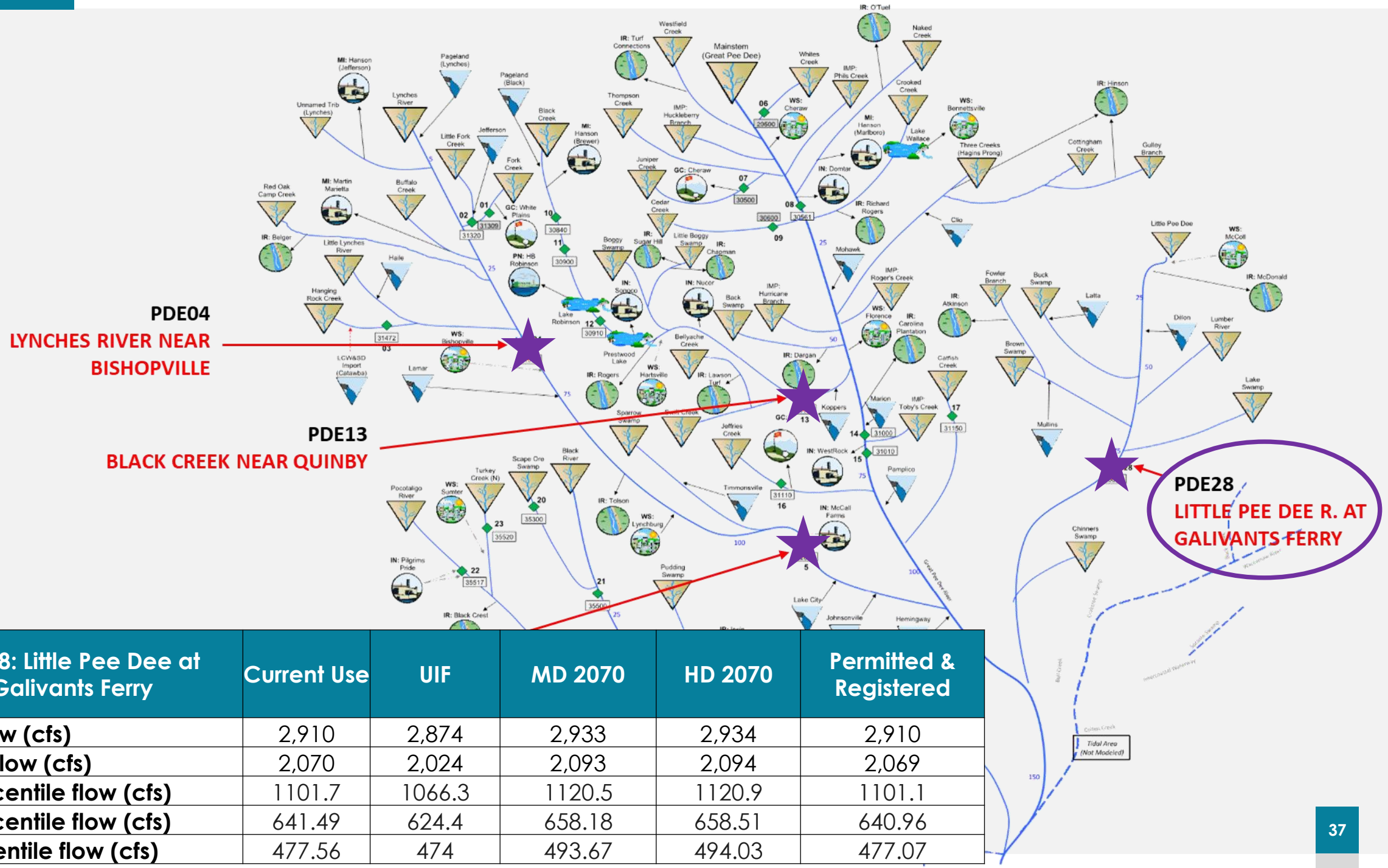
- **Flow effects on SGCNs:** Species-specific relationships can provide more detailed recommendations
- **Needs:** Personnel time.



PDE04: Lynches River near Bishopville	Current Use	UIF	MD 2070	HD 2070	Permitted & Registered
mean flow (cfs)	750	749	749	748	742
median flow (cfs)	458	456	456	456	448
25th percentile flow (cfs)	241.39	240.1	240.24	239.69	235.09
10th percentile flow (cfs)	147.54	146.26	146.08	145.69	142.89
5th percentile flow (cfs)	111.46	110.15	110.12	109.79	107.7

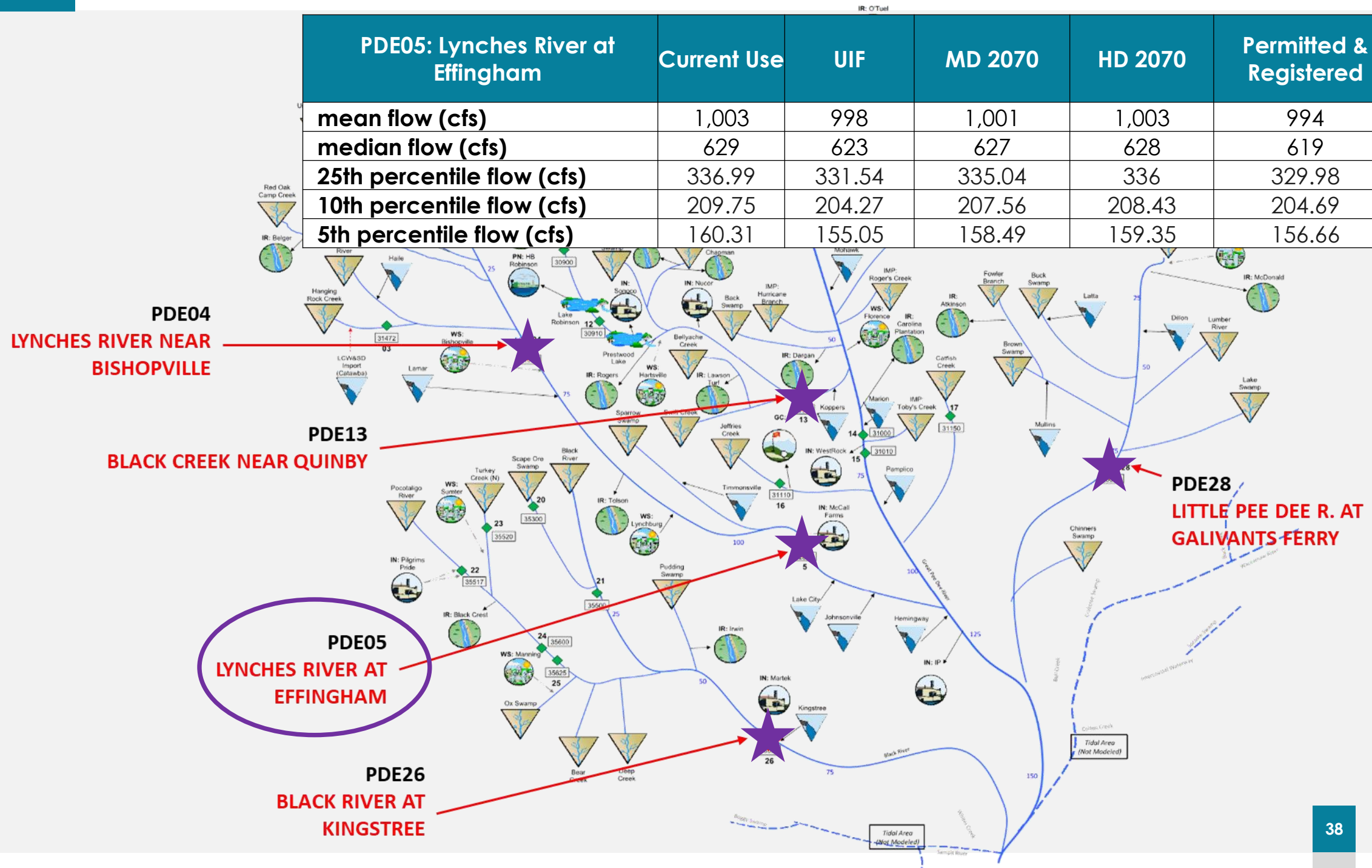


PDE13: Black Creek near Quinby	Current Use	UIF	MD 2070	HD 2070	Permitted & Registered
mean flow (cfs)	540	553	536	534	270
median flow (cfs)	426	437	421	418	115
25th percentile flow (cfs)	252.96	267.03	248.35	245.79	10.659
10th percentile flow (cfs)	163.79	179.66	158.64	156.38	6.9219
5th percentile flow (cfs)	127.51	144.84	121.83	128.3	5.4387

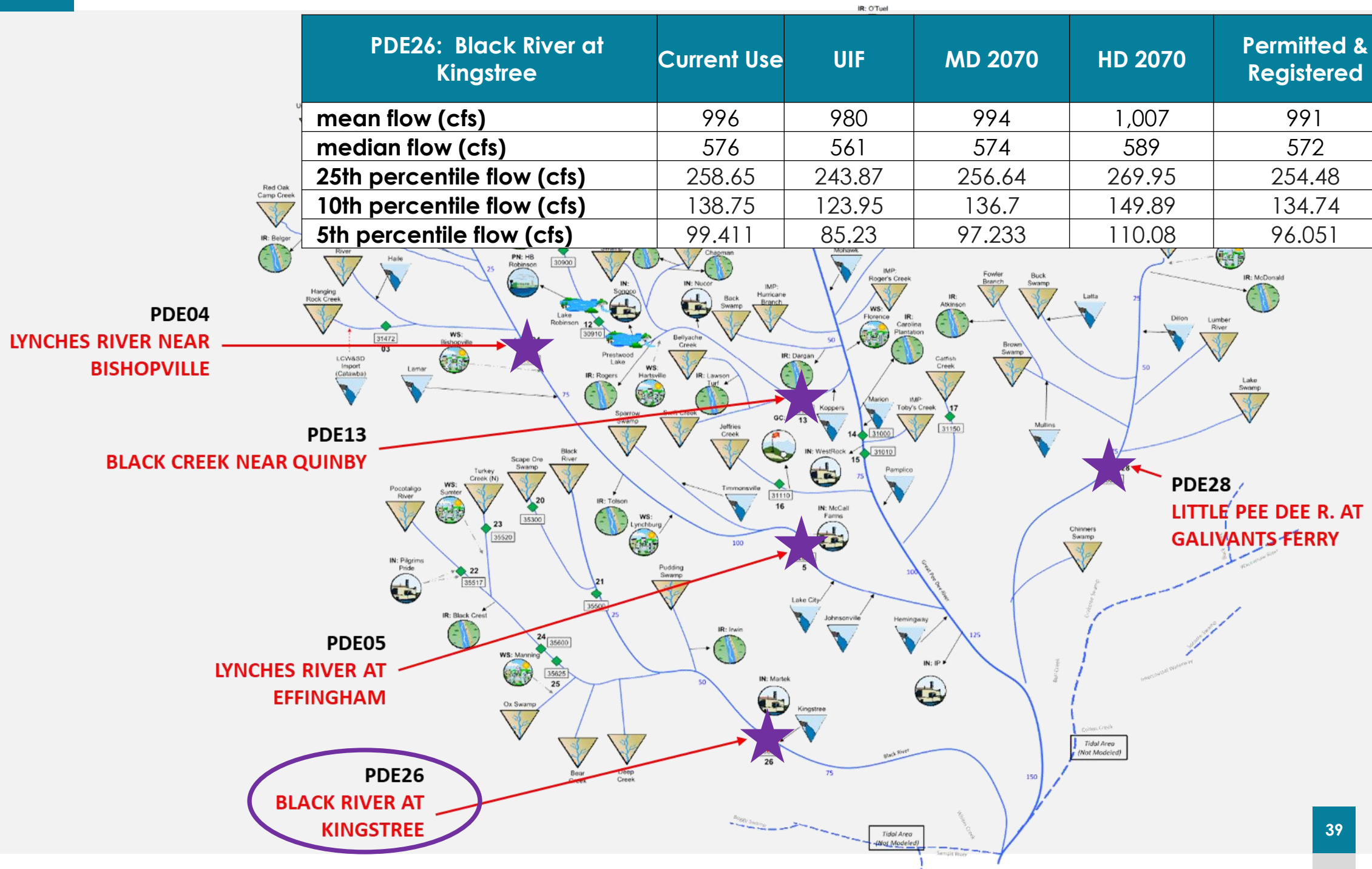


PDE28: Little Pee Dee at Galivants Ferry	Current Use	UIF	MD 2070	HD 2070	Permitted & Registered
mean flow (cfs)	2,910	2,874	2,933	2,934	2,910
median flow (cfs)	2,070	2,024	2,093	2,094	2,069
25th percentile flow (cfs)	1101.7	1066.3	1120.5	1120.9	1101.1
10th percentile flow (cfs)	641.49	624.4	658.18	658.51	640.96
5th percentile flow (cfs)	477.56	474	493.67	494.03	477.07

PDE05: Lynches River at Effingham	Current Use	UIF	MD 2070	HD 2070	Permitted & Registered
mean flow (cfs)	1,003	998	1,001	1,003	994
median flow (cfs)	629	623	627	628	619
25th percentile flow (cfs)	336.99	331.54	335.04	336	329.98
10th percentile flow (cfs)	209.75	204.27	207.56	208.43	204.69
5th percentile flow (cfs)	160.31	155.05	158.49	159.35	156.66

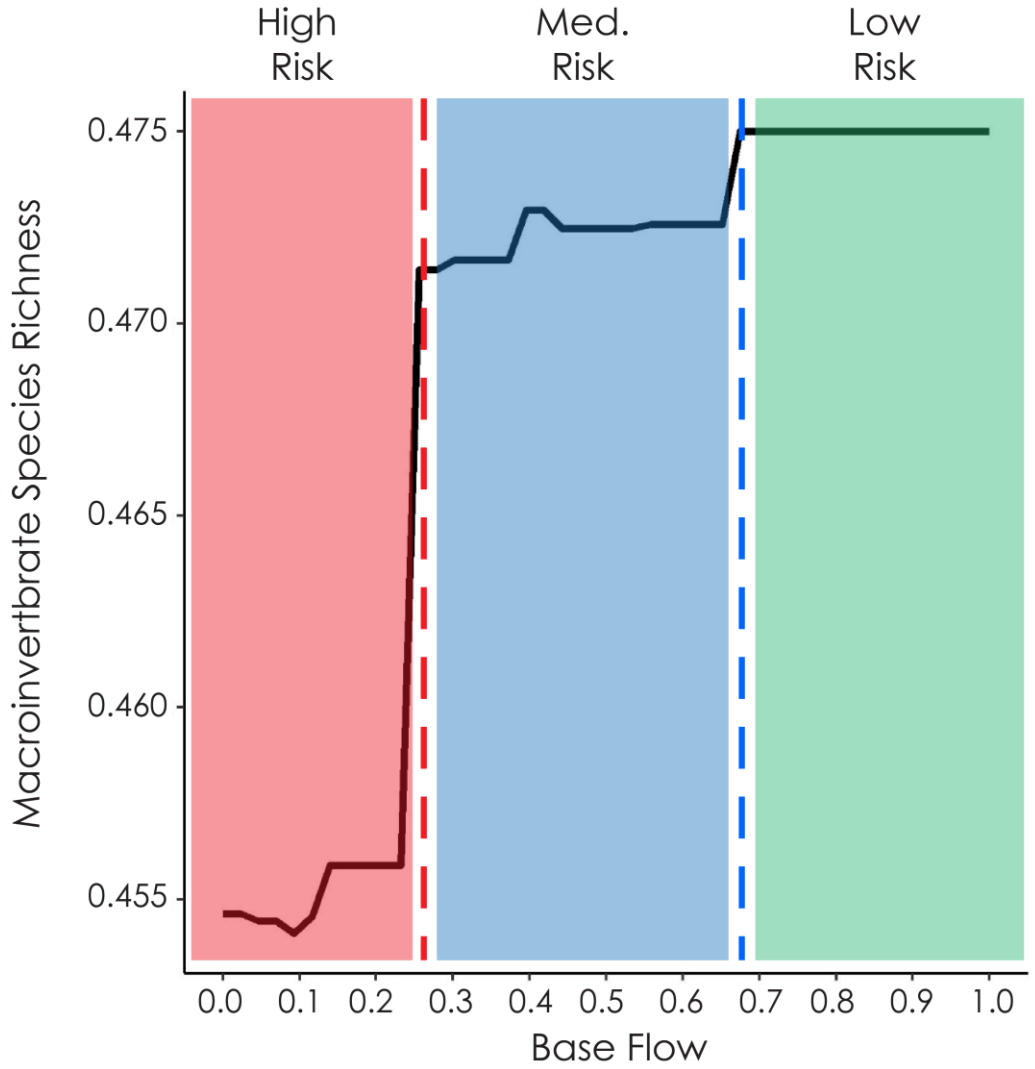


PDE26: Black River at Kingstree	Current Use	UIF	MD 2070	HD 2070	Permitted & Registered
mean flow (cfs)	996	980	994	1,007	991
median flow (cfs)	576	561	574	589	572
25th percentile flow (cfs)	258.65	243.87	256.64	269.95	254.48
10th percentile flow (cfs)	138.75	123.95	136.7	149.89	134.74
5th percentile flow (cfs)	99.411	85.23	97.233	110.08	96.051

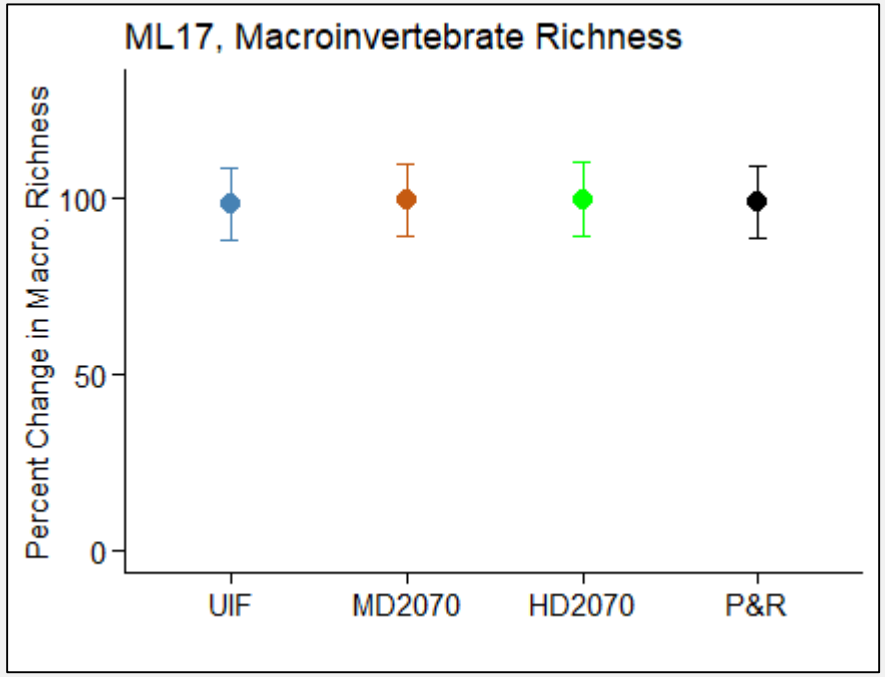


Macroinvertebrate Richness-ML17: Mid-Atlantic Coastal Plains: Perennial Flashy

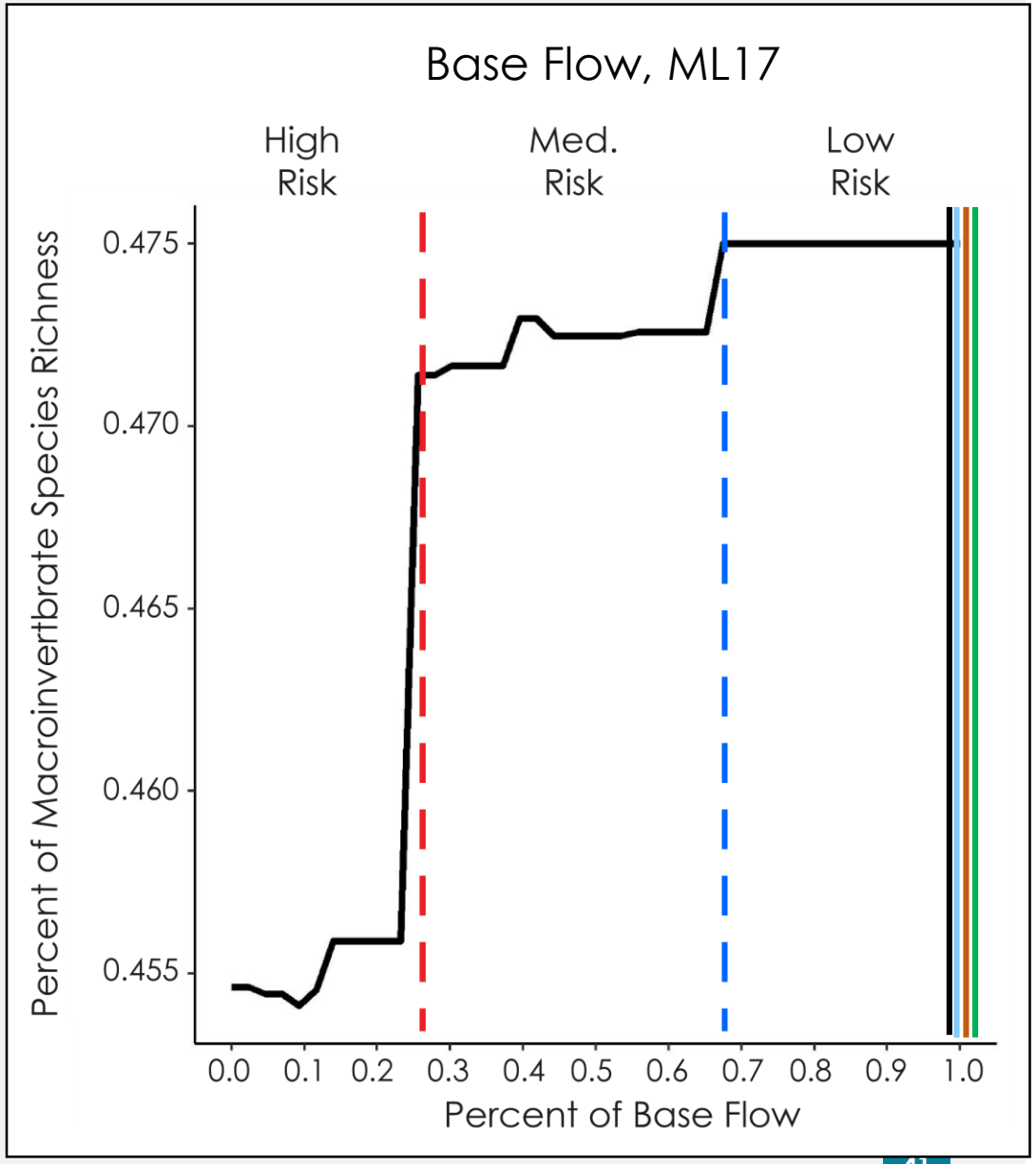
- Removal of 30% of base flow is ‘low risk’
- Removal of more than 70% of base flow is ‘high risk’ top macroinvertebrate richness



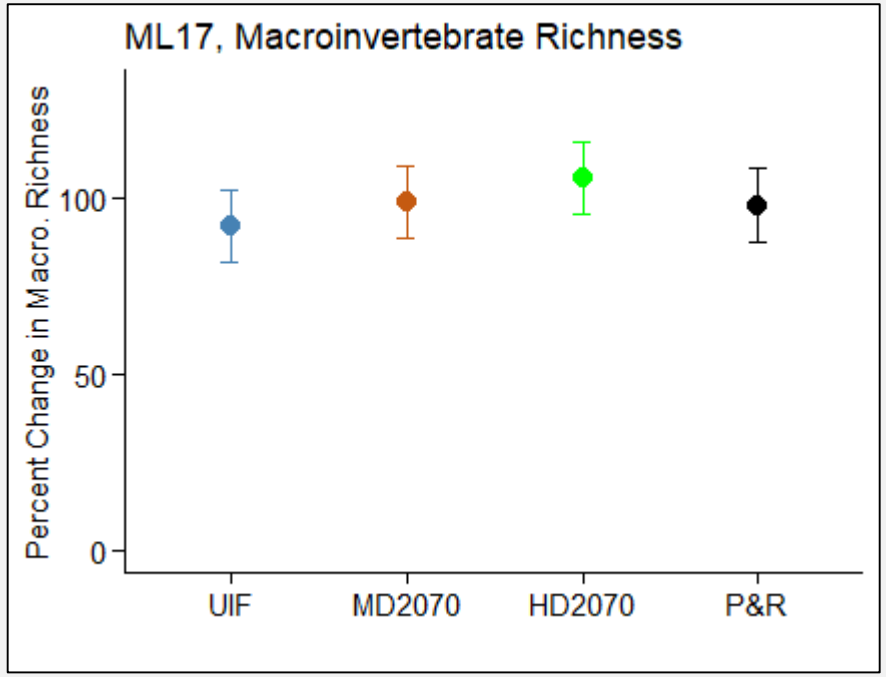
Lynches River at Effingham



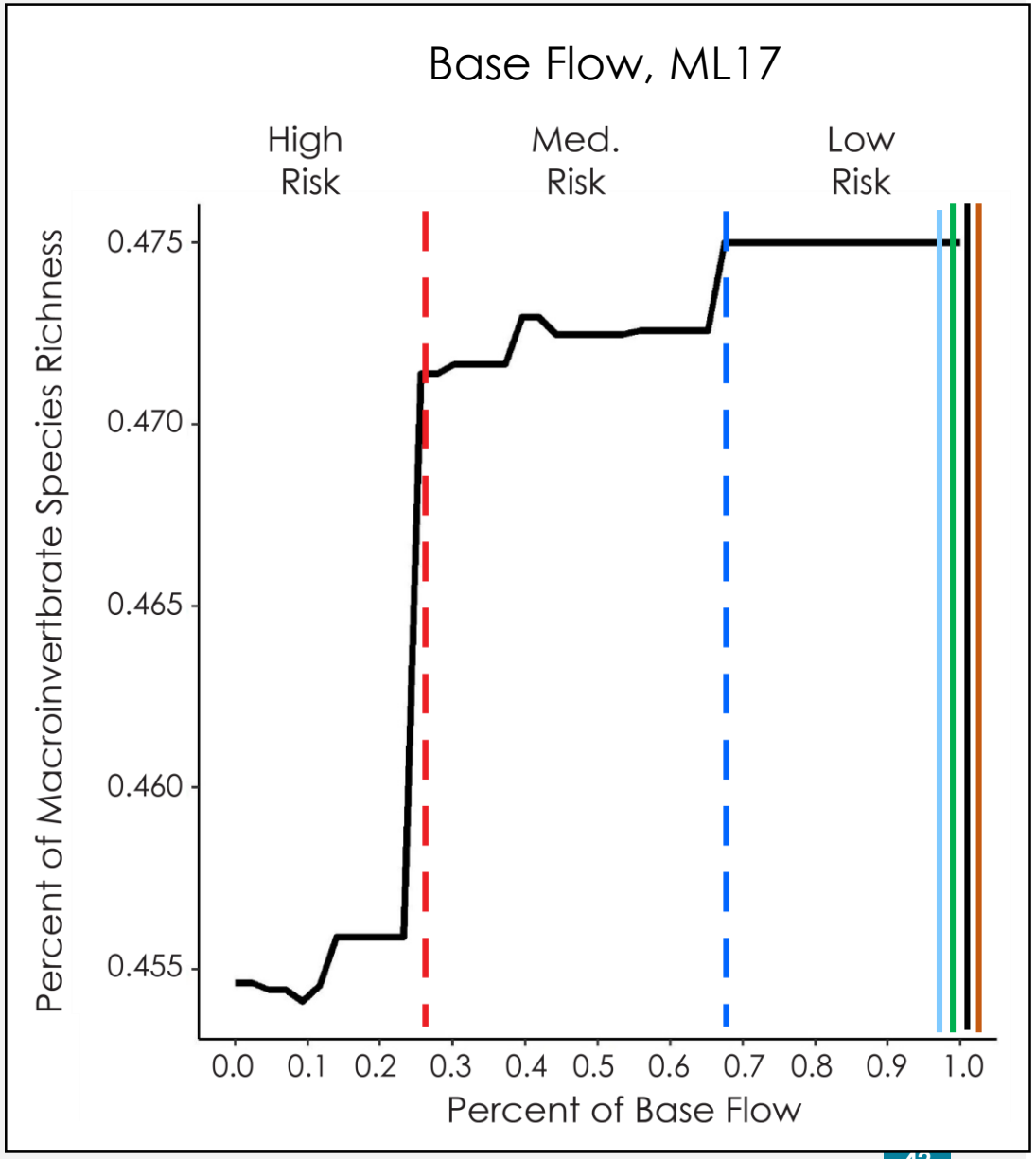
Scenario	Current	Predicted	% change	Change in Bio	SE
UIF	0.19	0.18	-2.65	-1.58	0.104
MD 2070	0.19	0.19	-1.01	-0.63	0.104
HD 2070	0.19	0.19	-0.53	-0.32	0.104
P & R	0.19	0.19	-1.59	-0.95	0.104



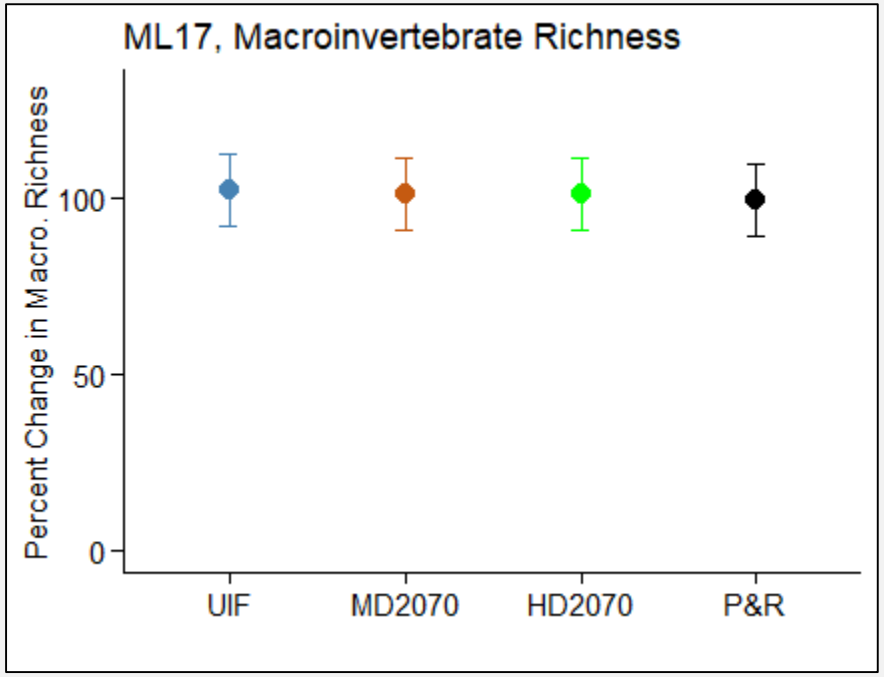
Black River at Kingstree



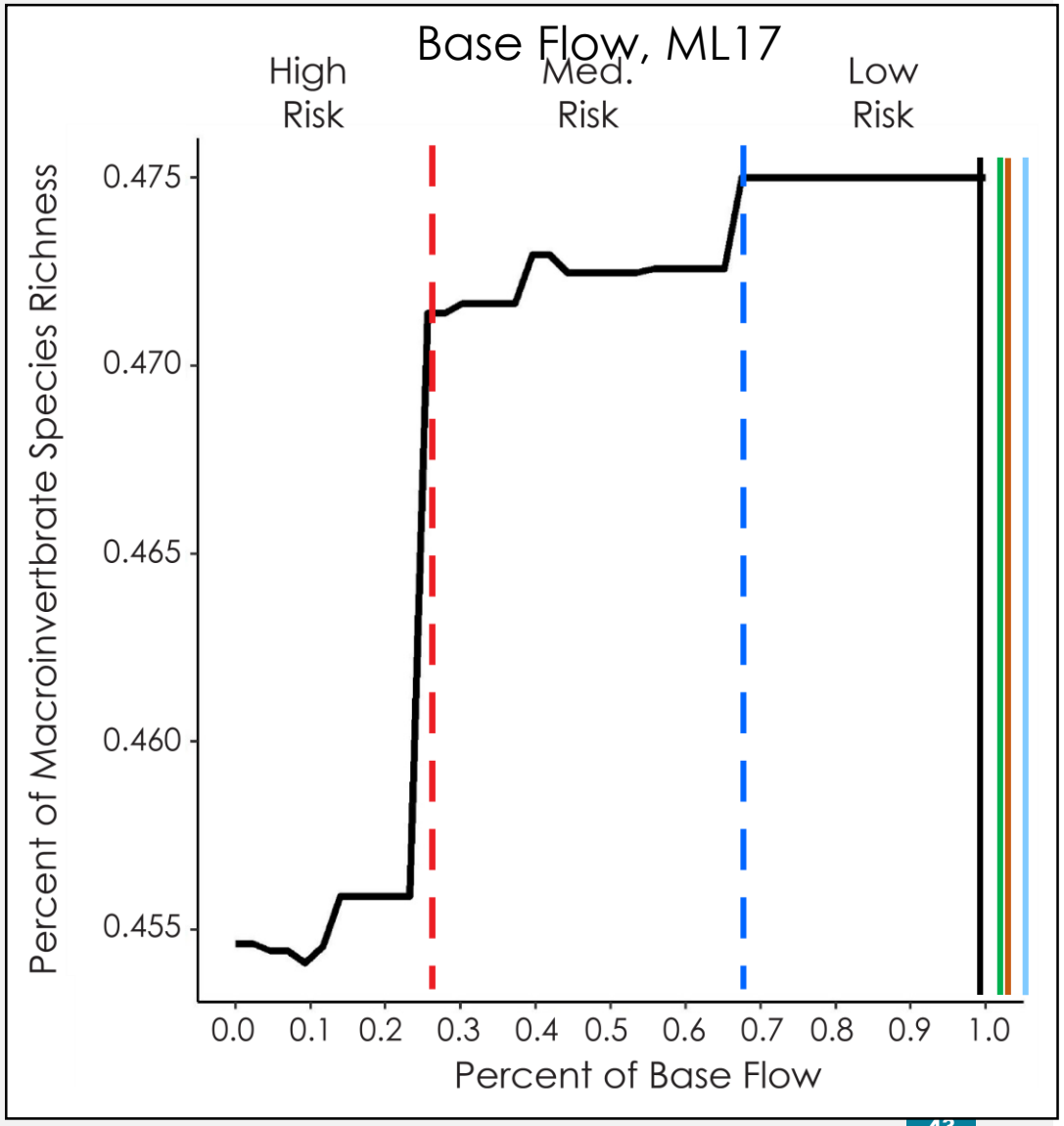
Scenario	Current	Predicted	% change	Change in Bio	SE
UIF	0.12	0.11	0.87	-7.81	0.104
MD 2070	0.12	0.12	0.98	-0.98	0.104
HD 2070	0.12	0.13	1.10	5.86	0.104
P & R	0.12	0.12	0.97	-1.95	0.104



Little Pee Dee R. At Galivants Ferry

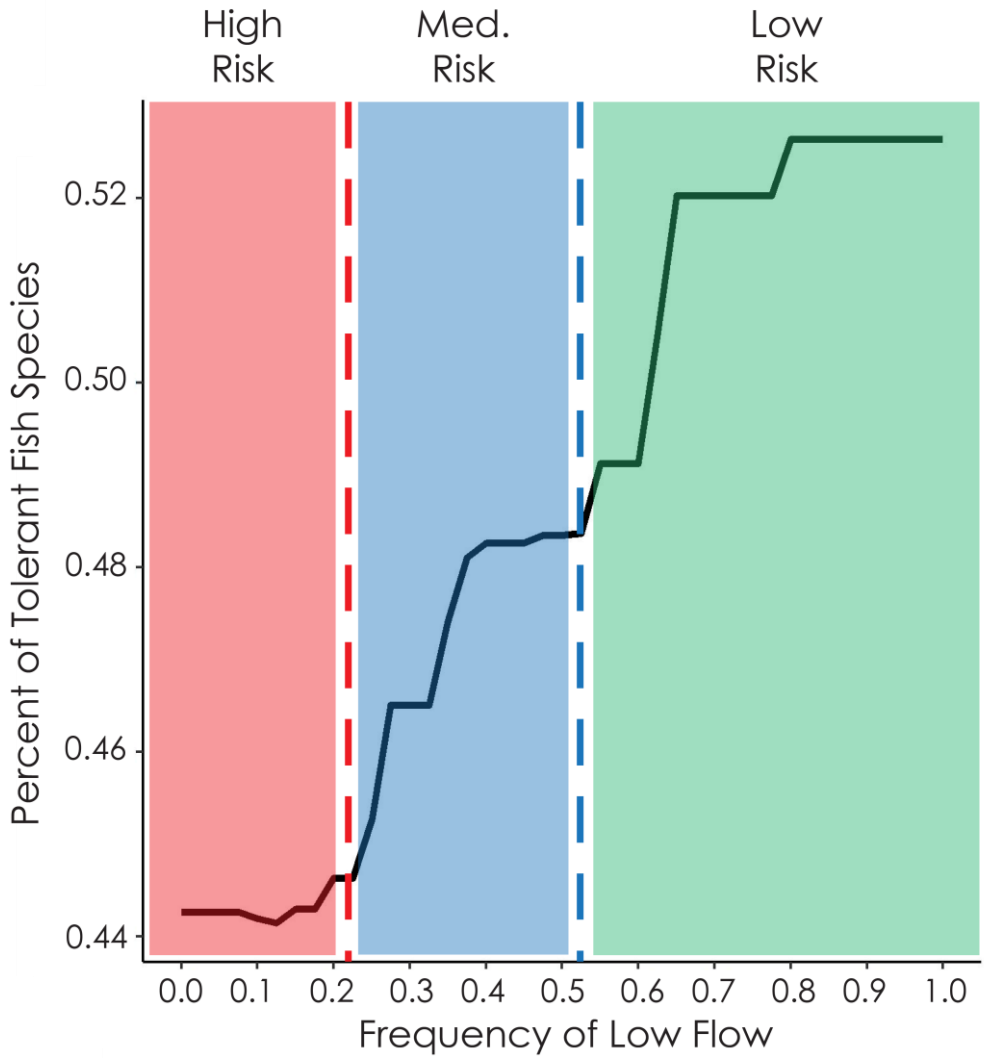


Scenario	Current	Predicted	% change	Change in Bio	SE
UIF	0.18	0.18	4.00	2.38	0.104
MD 2070	0.18	0.18	2.29	1.36	0.104
HD 2070	0.18	0.18	2.29	1.36	0.104
P & R	0.18	0.17	-0.57	-0.34	0.104



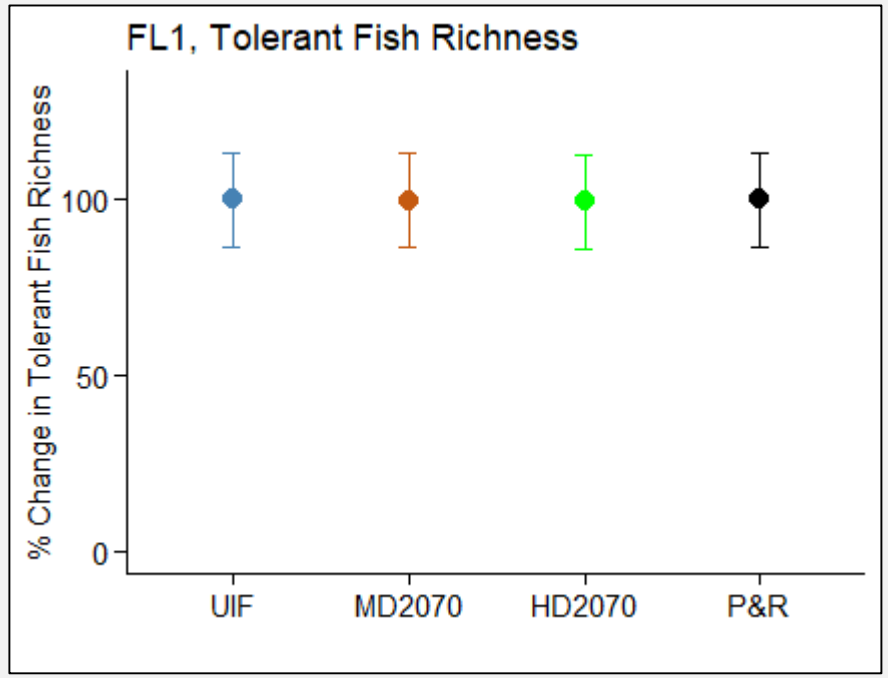
Percent Tolerant Fish-FL1: Mid-Atlantic Coastal Plains: Perennial Flashy

- Less than 50% change in frequency of low flow is ‘low risk’
- Greater than 20% change in the frequency of low flow is ‘high risk’



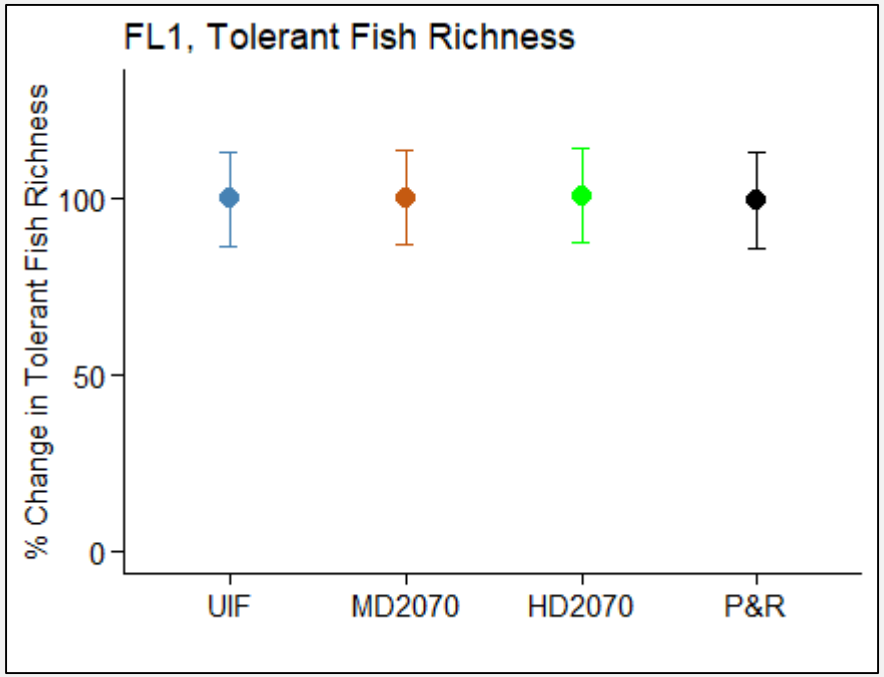
Lynches River at Effingham

Scenario	Current	Predicted	% change	Change in Tolerant	SE
UIF	6.12	6.11	-0.20	-0.15	0.135
MD 2070	6.12	6.10	-0.38	-0.30	0.135
HD 2070	6.12	6.10	-0.73	-0.58	0.135
P & R	6.12	6.11	-0.20	-0.15	0.135



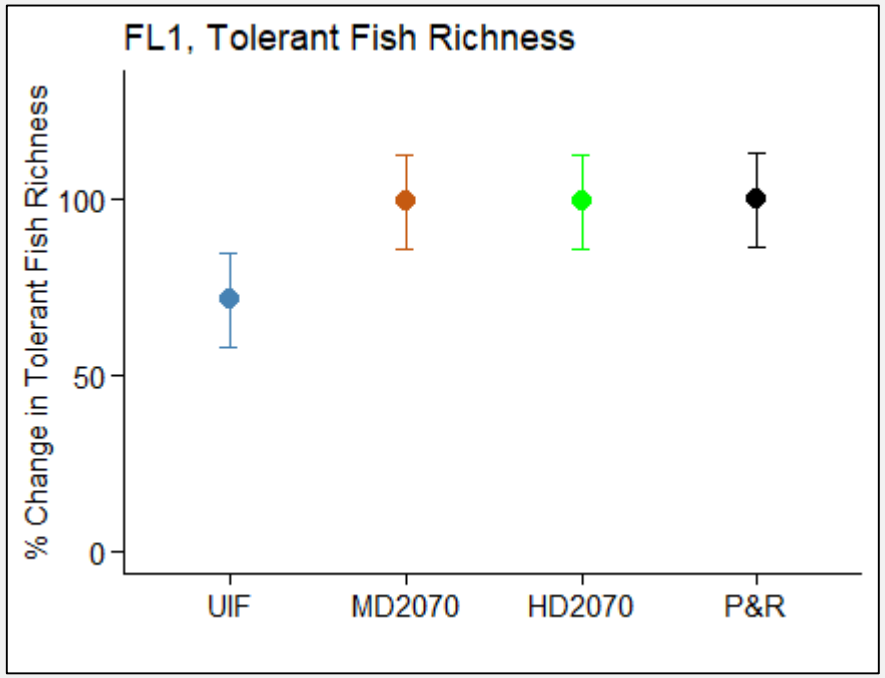
Black River at Kingstree

Scenario	Current	Predicted	% change	Change in Tolerant	SE
UIF	5.81	5.80	-0.19	-0.15	0.135
MD 2070	5.81	5.83	0.38	0.30	0.135
HD 2070	5.81	5.84	0.96	0.76	0.135
P & R	5.81	5.78	-0.59	-0.46	0.135



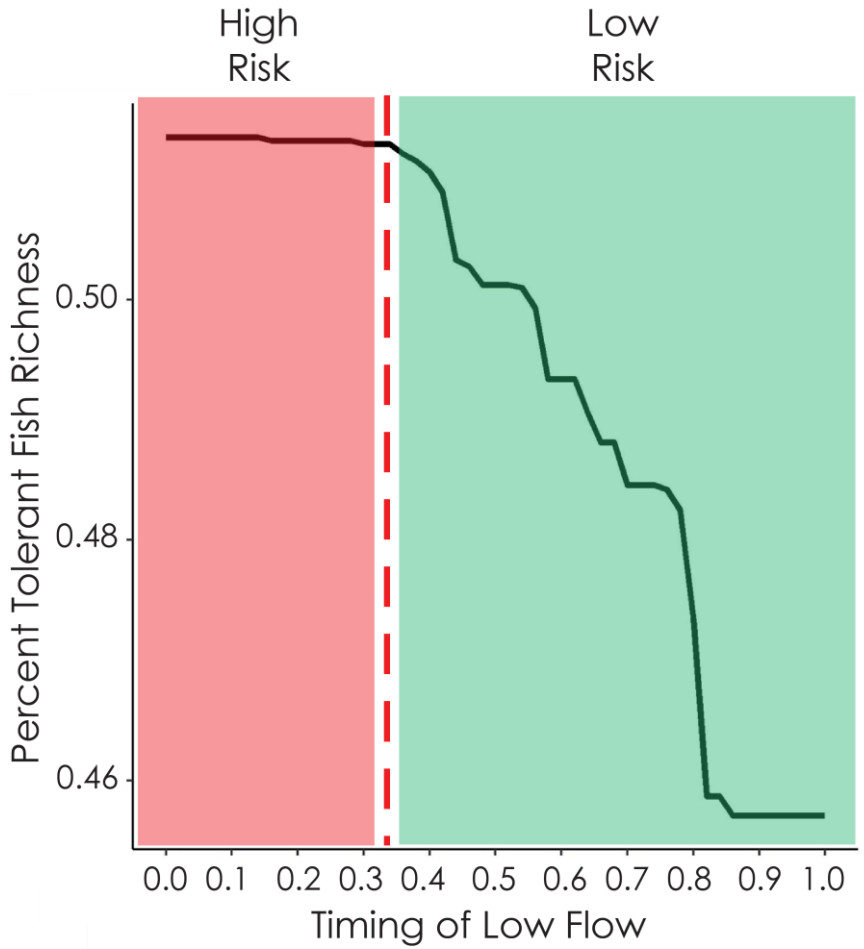
Little Pee Dee R. At Galivants Ferry

Scenario	Current	Predicted	% change	Change in Tolerant	SE
UIF	6.84	4.37	-36.12	-28.52	0.135
MD 2070	6.84	6.79	-0.82	-0.65	0.135
HD 2070	6.84	6.79	-0.82	-0.65	0.135
P & R	6.84	6.84	0.00	0.00	0.135

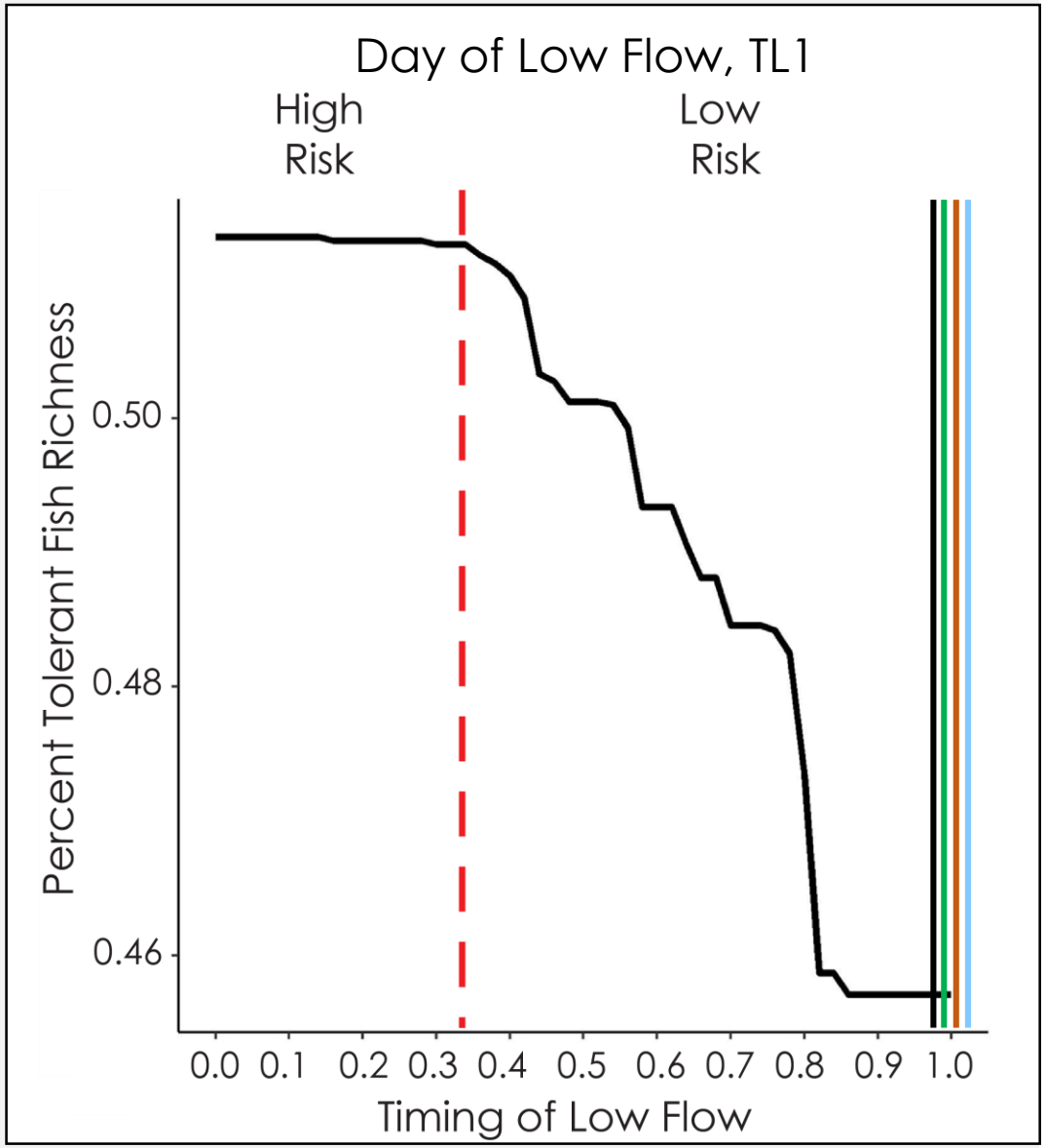


Percent Tolerant Fish-TL1: Mid-Atlantic Coastal Plains: Perennial Flashy

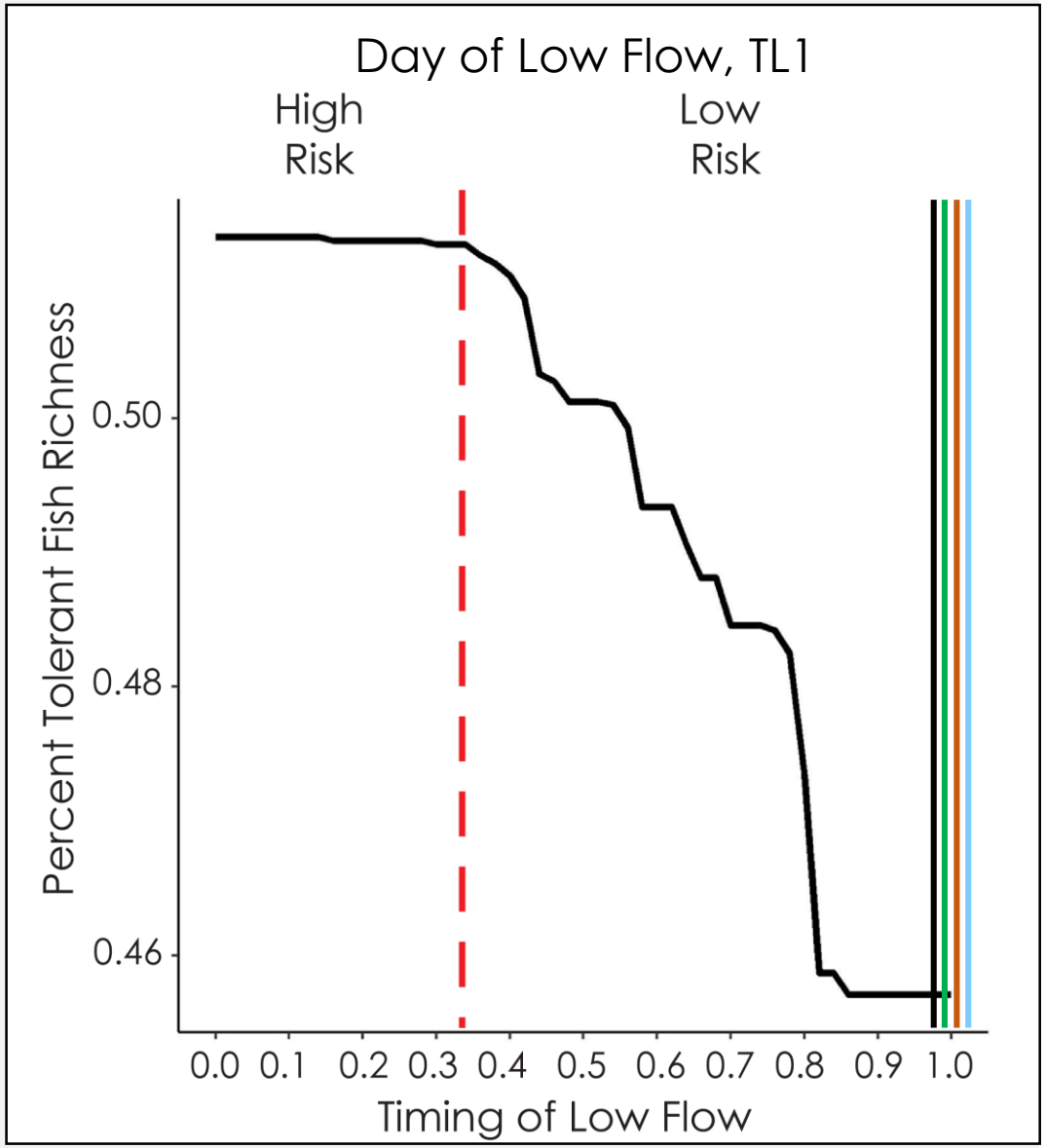
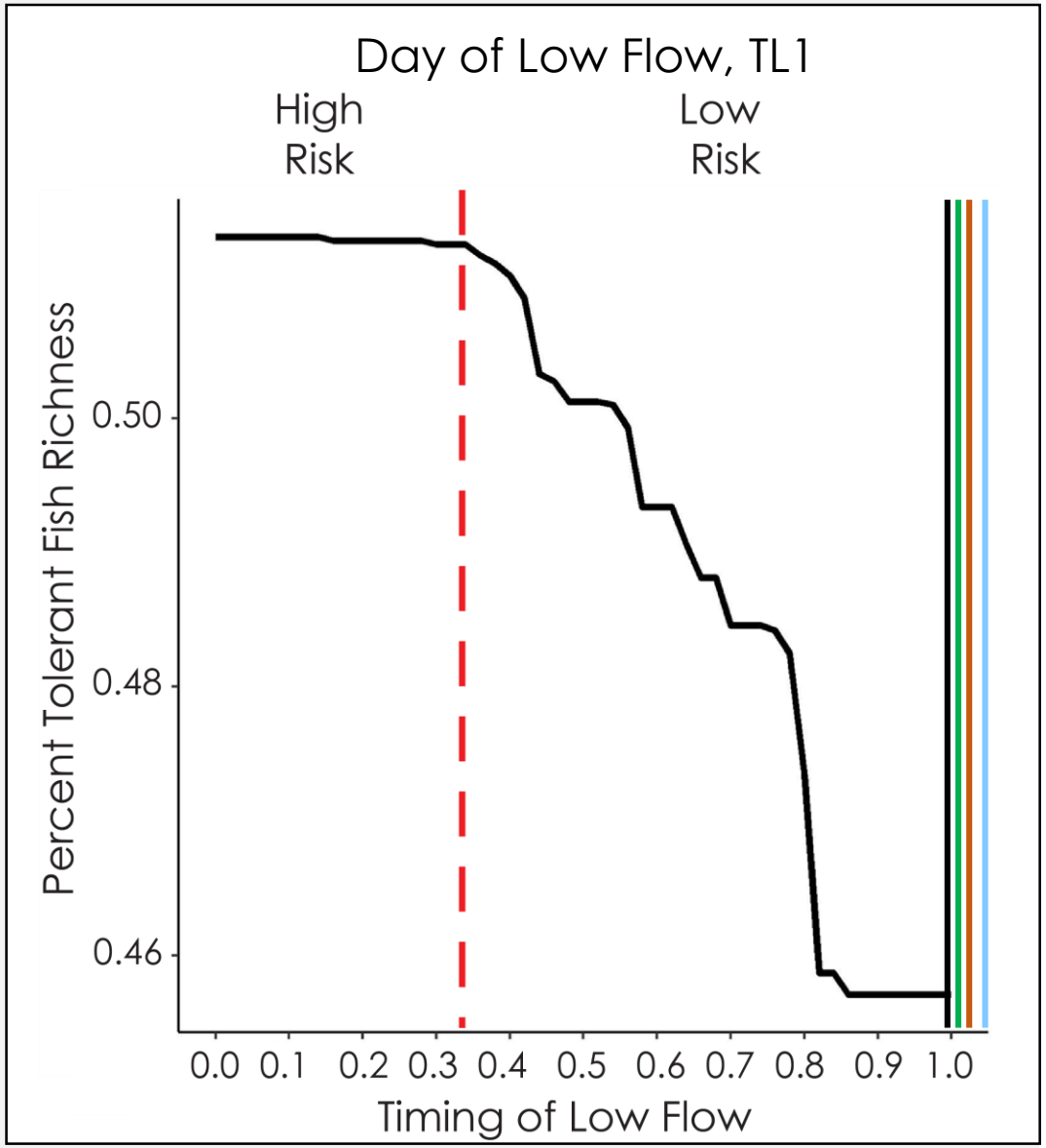
- Change less than 65% in timing of low flow is 'low risk'



Lynches River at Effingham



Black River at Kingstree



Little Pee Dee R. At Galivants Ferry