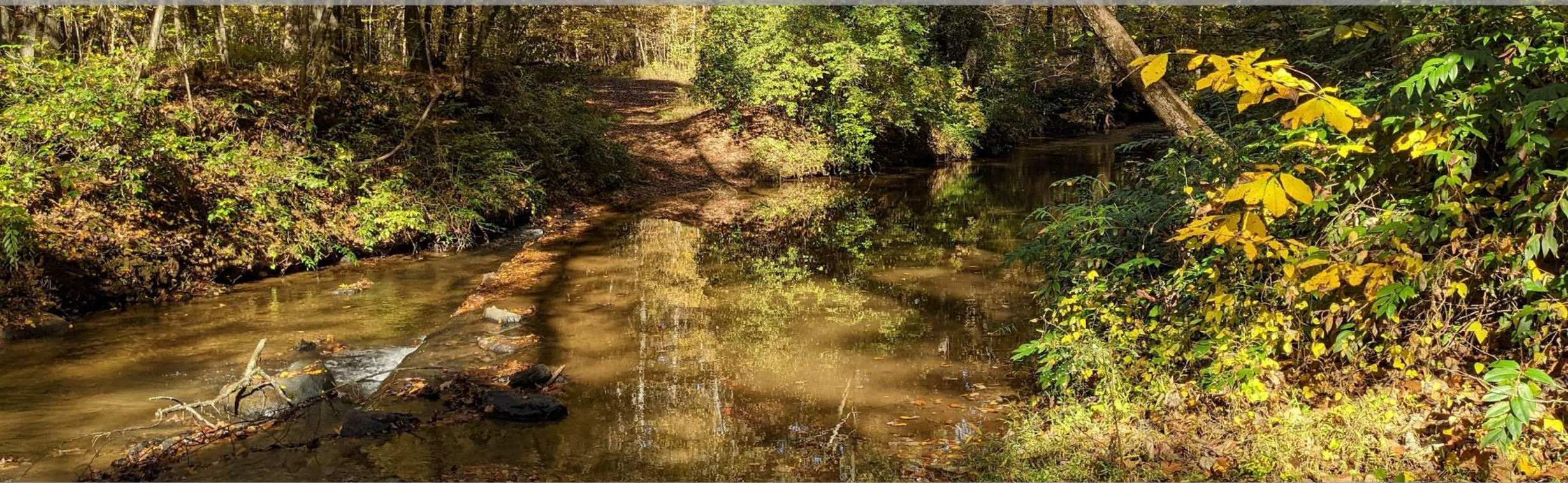
Agenda Item 4

Flow-Fish Richness Relationships

Broad River RBC, Jan 2023

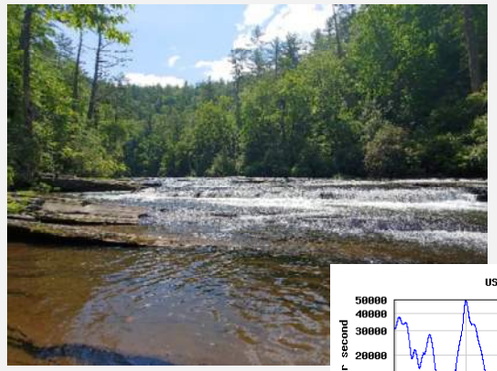


Drs. Joe Mruzek, Luke Bower and Brandon Peoples, and Eric Krueger

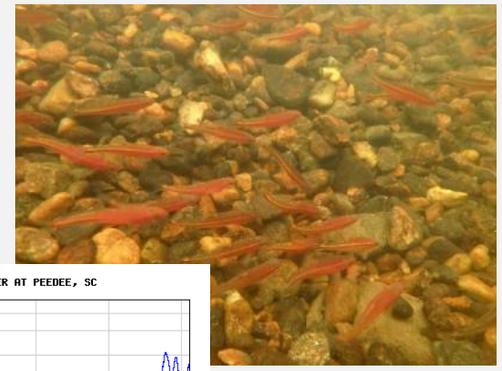
Flow-Ecology Relationships

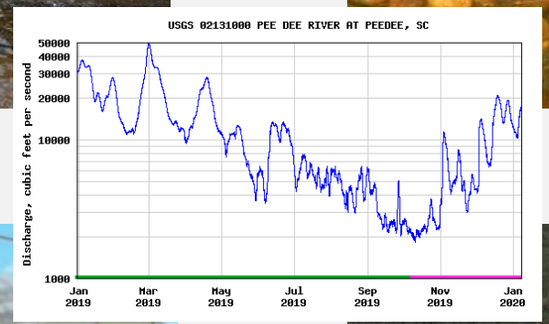
- In stream flow is critical for aquatic communities
- "Master variable"

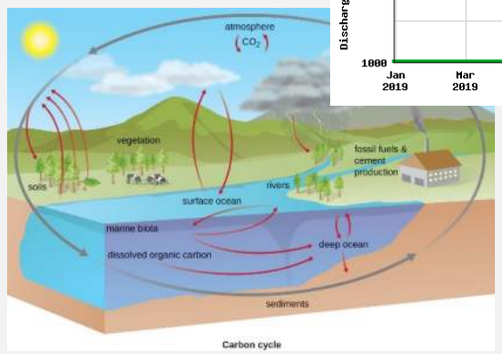
Water quality



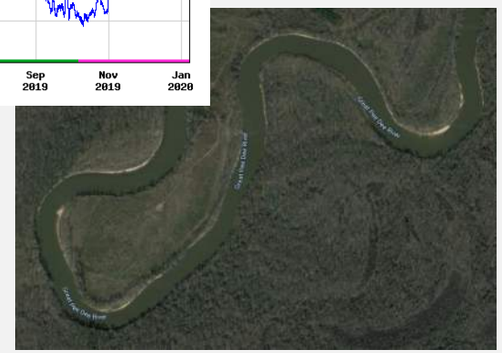
Organisms







Energy cycling



Physical habitat

Contents lists available at ScienceDirect

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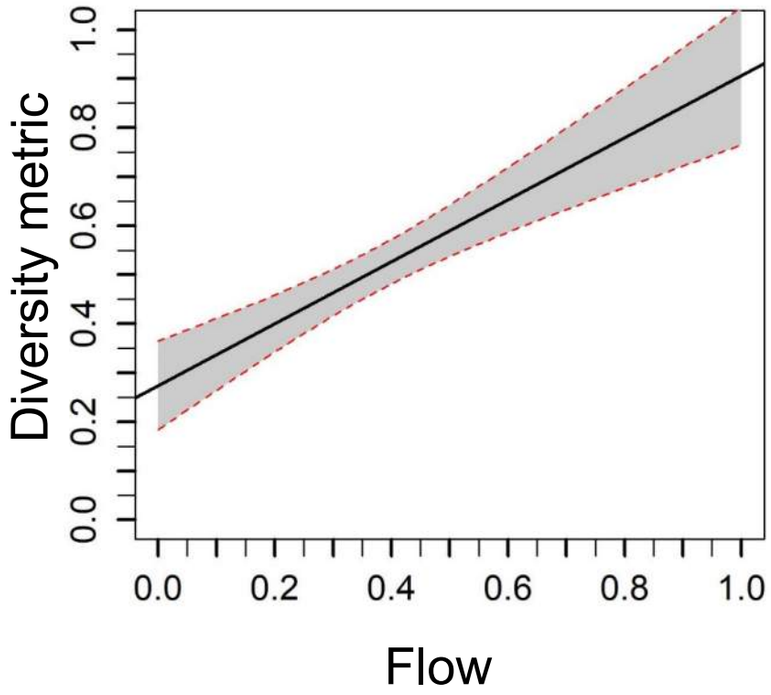
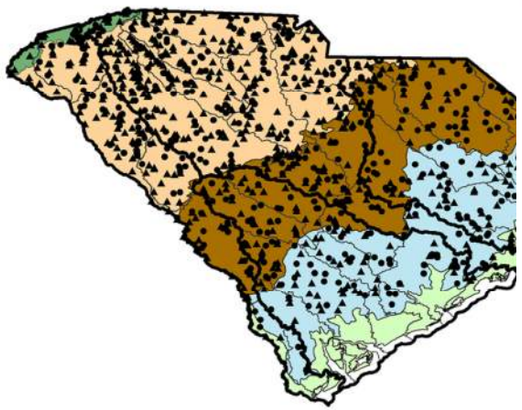
Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina

Luke M. Bower [a,*], Brandon K. Peoples [b], Michele C. Eddy [c], Mark C. Scott [d]



- Quantify relationships between key flow metrics and biotic response to better inform water flow standards throughout the state of South Carolina
  - Project changes in aquatic communities

- Provide a tool



timing, magnitude, frequency, rate of change, and duration

flow regime components
aquatic organism

2) Relationships differ across stream classes

ıips

es a flexible framework for
dard developement

Legend

Stream Class

1

3

4

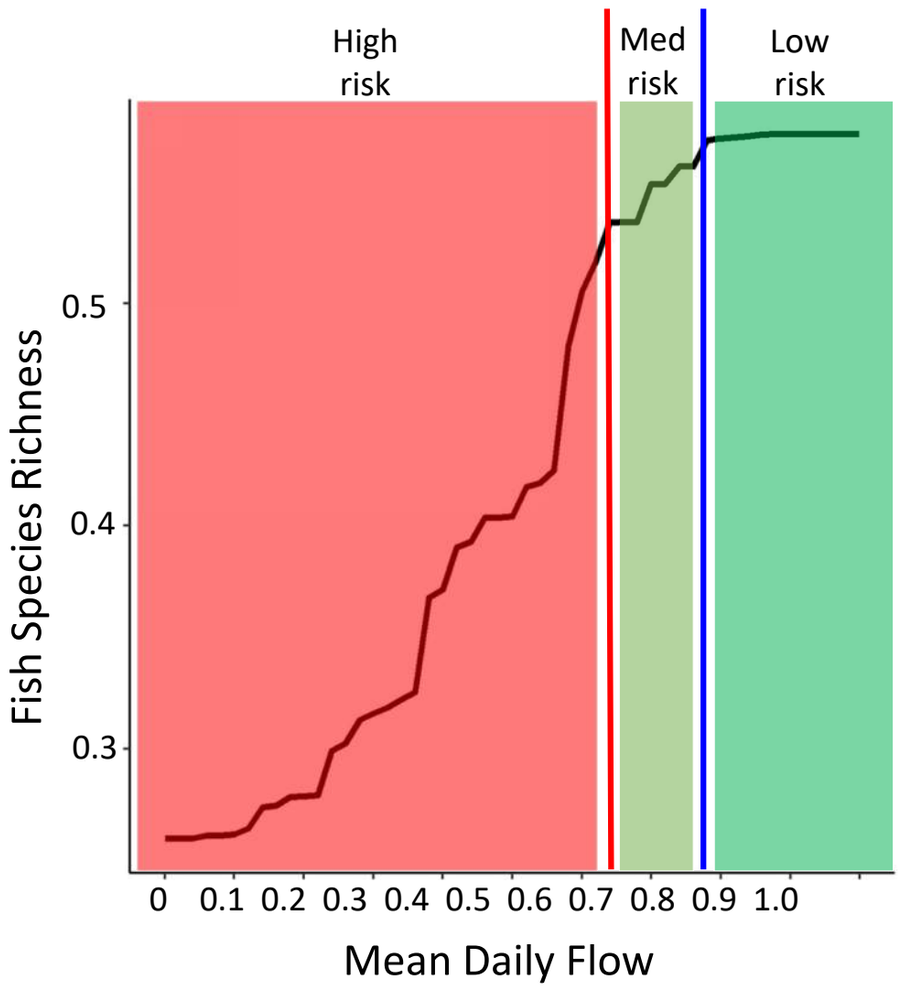
How can we use these relationships?

- Defining biological response limits
  - zones low, medium, and high change in the biological condition of streams along flow gradients
  - Searching for areas along flow gradients that induce changes in the biological metric

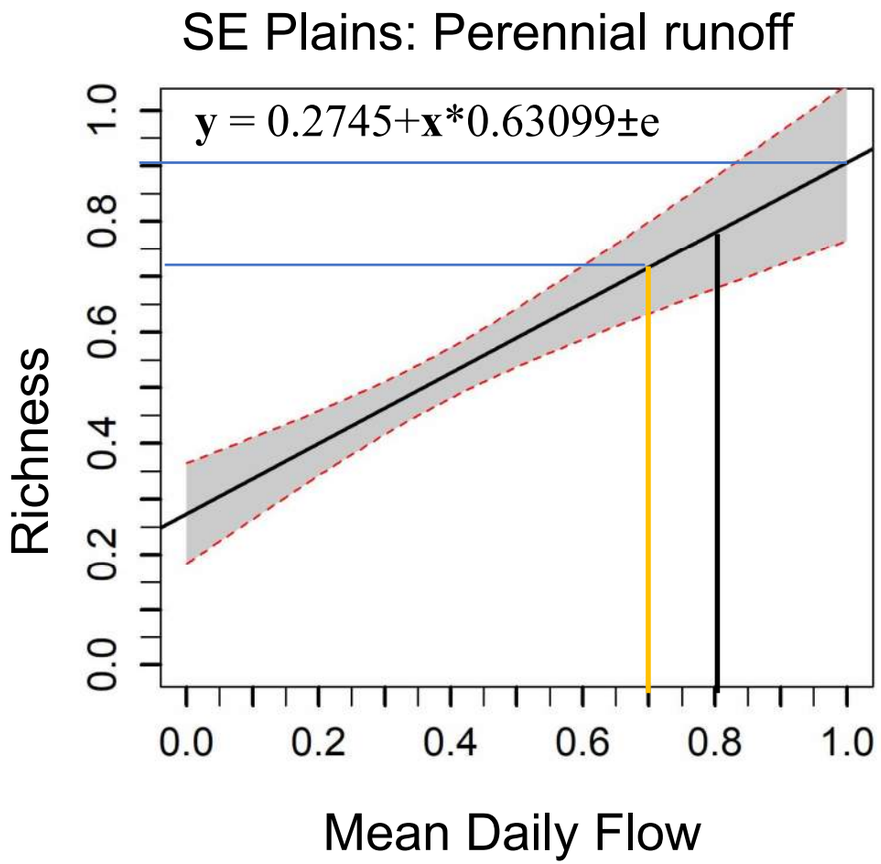
- Predicting responses
  - If we alter flow by X amount what will be the biological response?

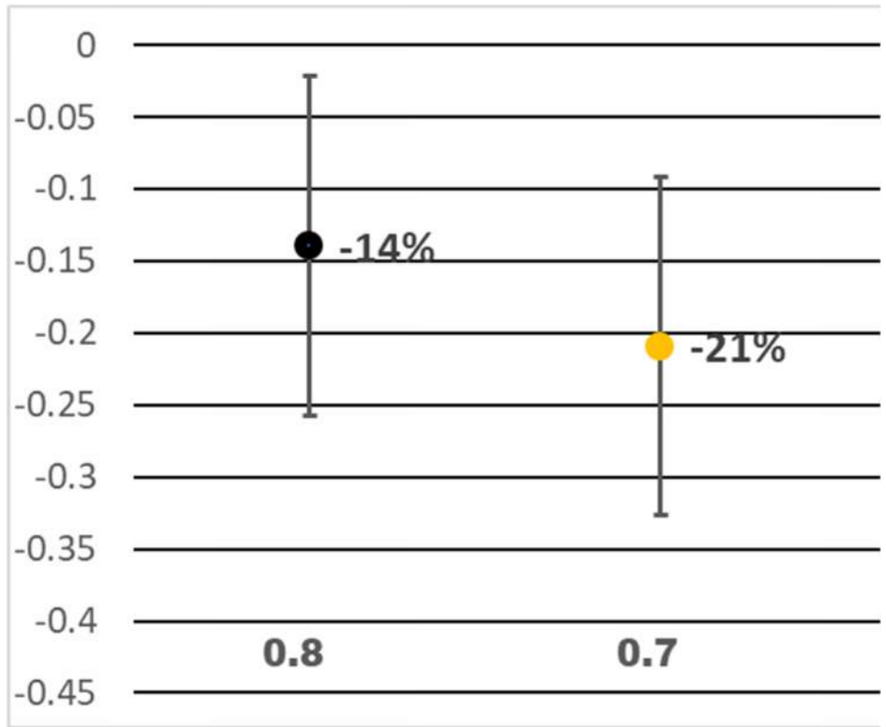
Mean daily flow (MA1): biological response limits

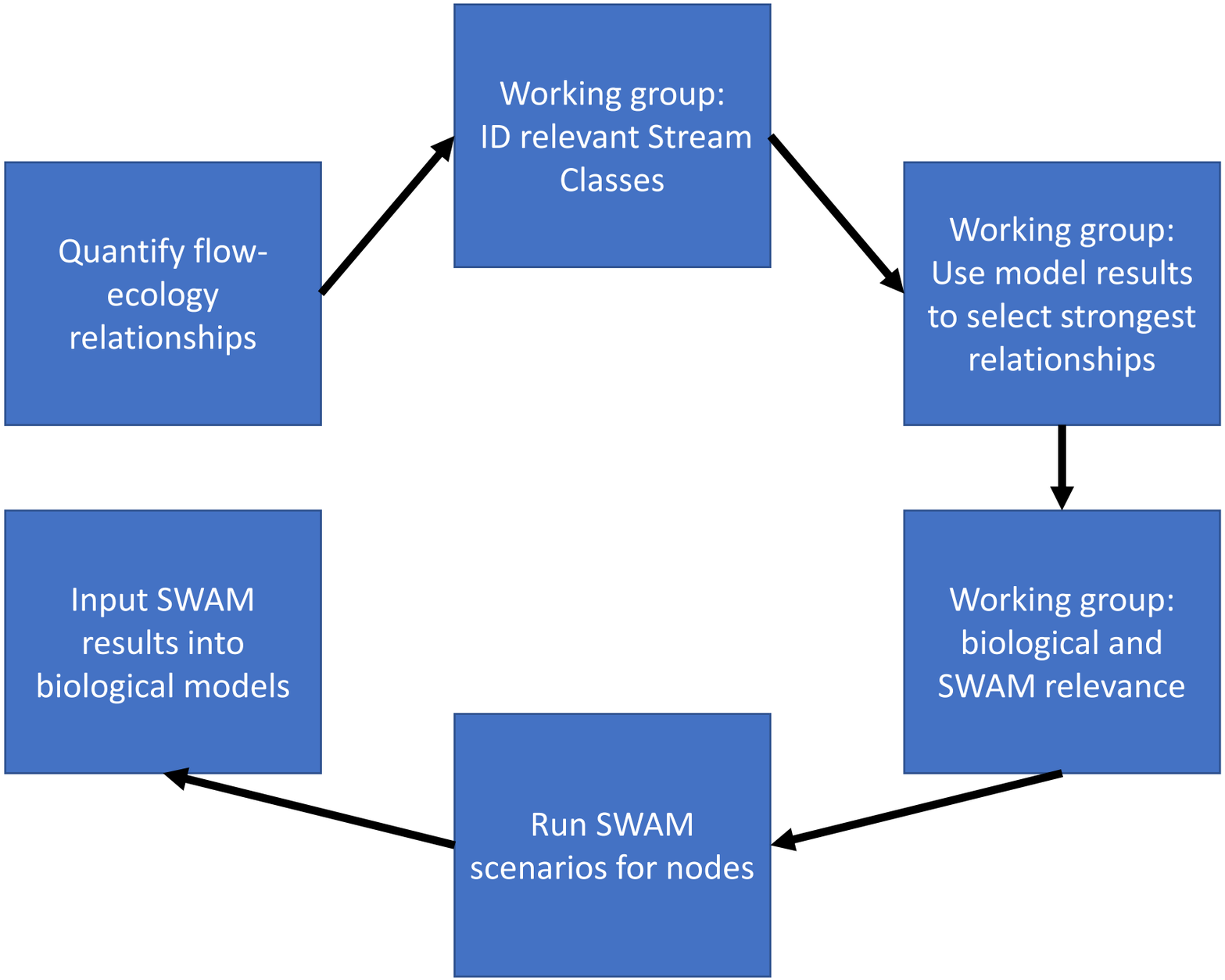
- Lines defined by working group
- Performance measure



Mean daily flow (MA1): predictions

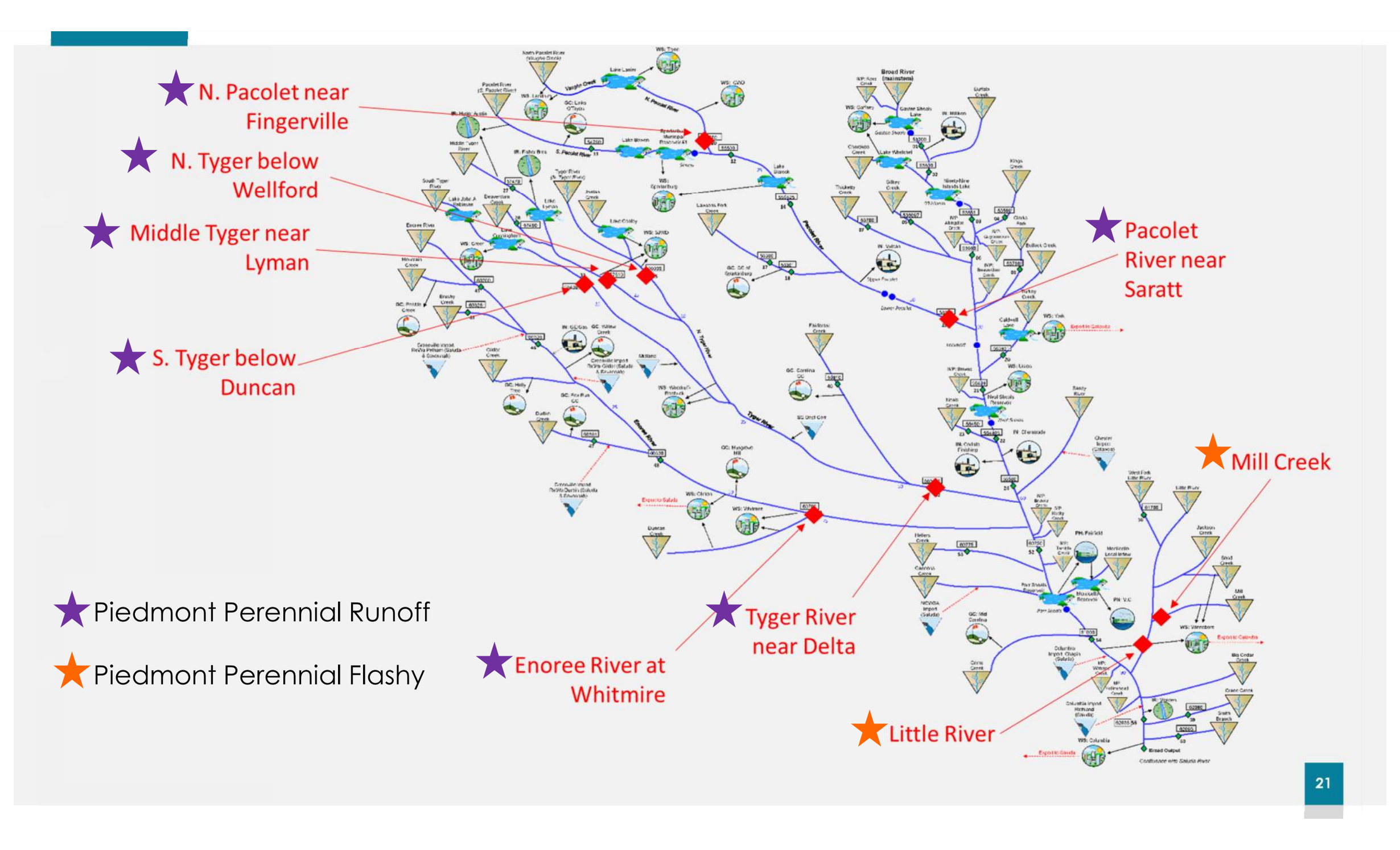





Working group: ID relevant Stream Classes
Working group: Use model results to select strongest relationships
Working group: biological and SWAM relevance
Run SWAM scenarios for nodes
Input SWAM results into biological models
Quantify flow-ecology relationships

Flow-Ecology Relationships

- Four flow-ecology metrics were considered
  - **Mean daily flow (MA1): Perennial runoff and Perennial Flashy**
  - **Timing of low flow (TL1): Perennial runoff**
  - **High flow pulse count (FH1): Perennial Flashy**
  - **High flow pulse duration (DH15): Perennial Flashy**
- These were chosen based on:
  - relevance to water withdrawal and drought management;
  - strength of relationship
  - distribution (most stream classes and basin area represented)
  - calculable from SWAM output


N. Pacolet near Fingerville
N. Tyger below Wellford
Middle Tyger near Lyman
S. Tyger below Duncan
Pacolet River near Saratt
Mill Creek
Piedmont Perennial Runoff
Piedmont Perennial Flashy
Enoree River at Whitmire
Tyger River near Delta
Little River

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)**
- Intermittent streams, classified by intermittent periods of no flow punctuated by flooding events (Class 5, 45 stream segments)

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

Standard Error

Mean daily flow (MA1): EDO10 NORTH FORK

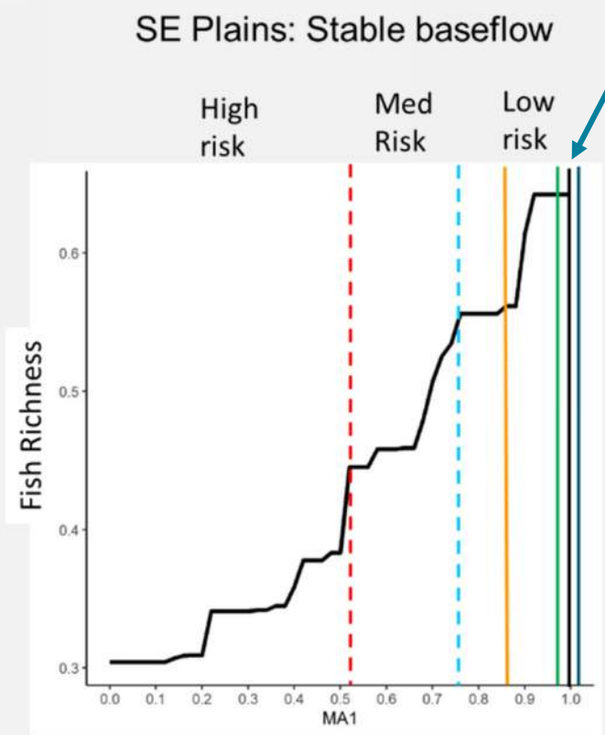
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	723.21	741.43	2.5%	Richness	1.9%	15
HD 2070	723.21	709.94	-1.8%	Richness	-1.4%	15
MD 2070	723.21	622.04	-14.0%	Richness	-10.4%	15
BAU	723.21	721.48	-0.2%	Richness	-0.2%	15

Current Use Scenario Mean Daily Flow

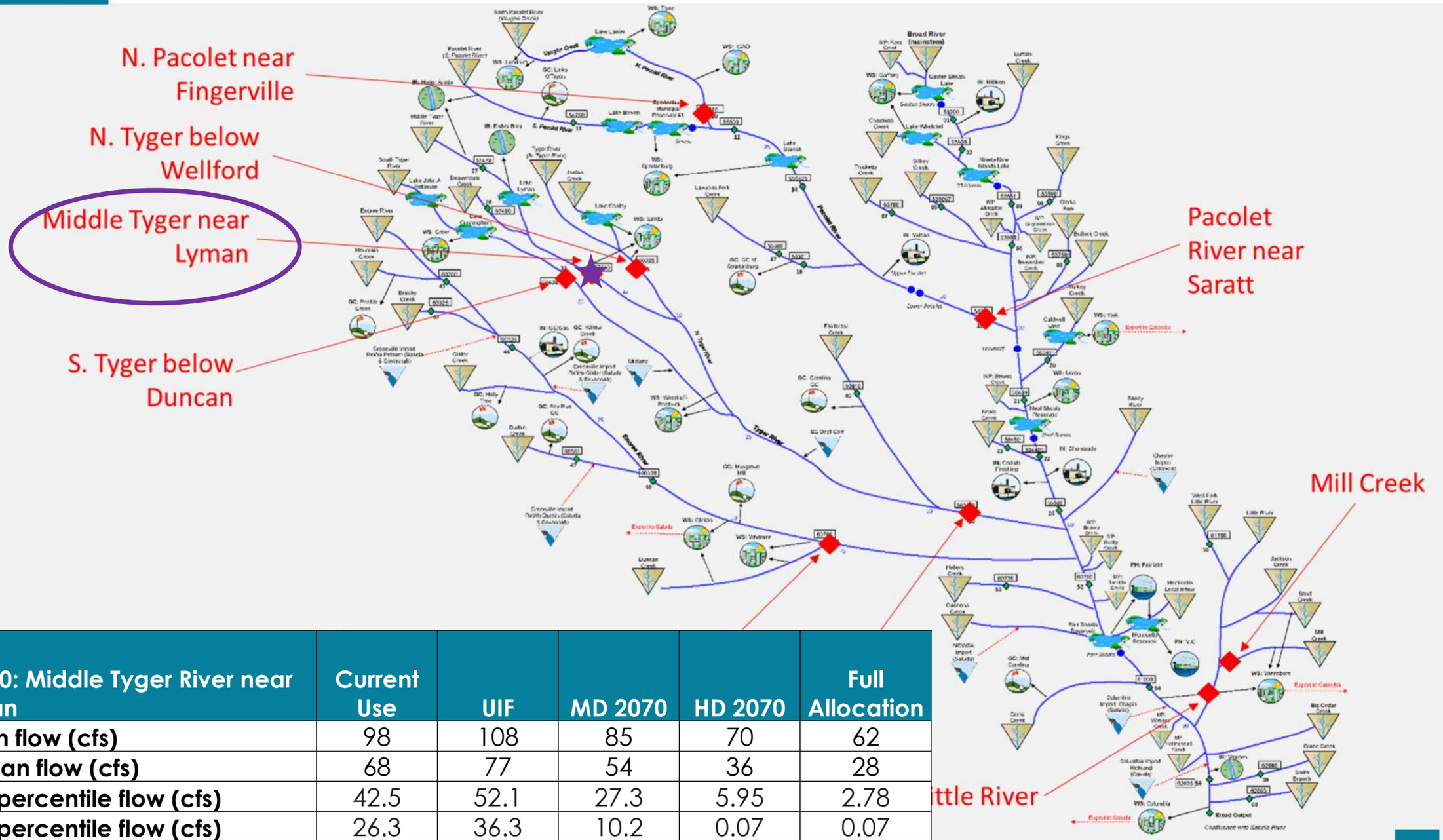
Scenario Mean Daily Flows

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

Colored lines correspond to scenario results shown in the table

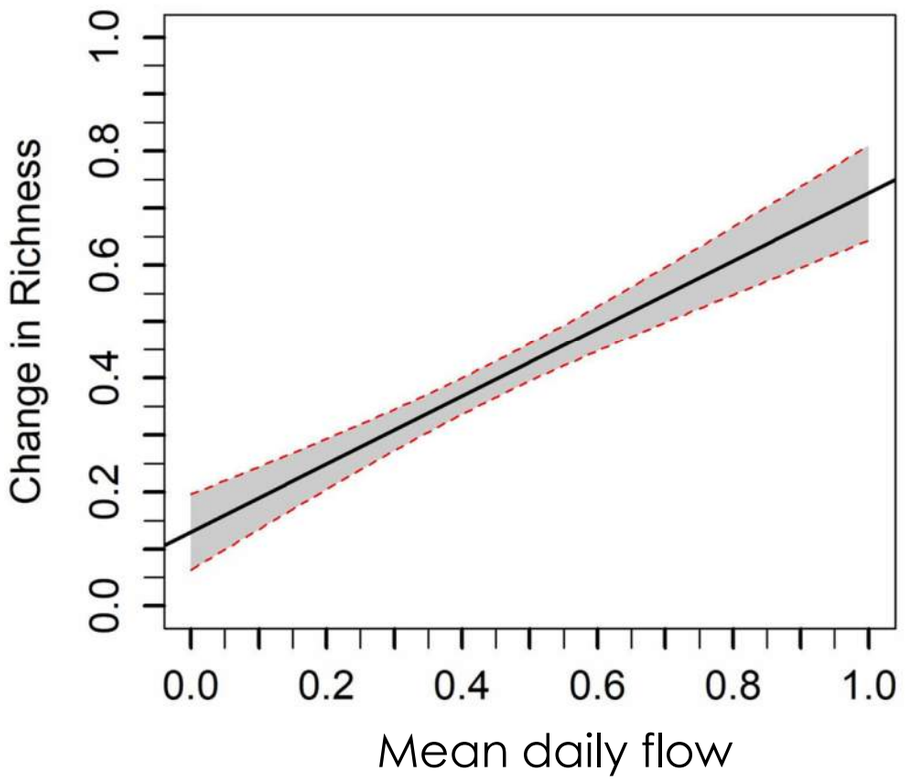


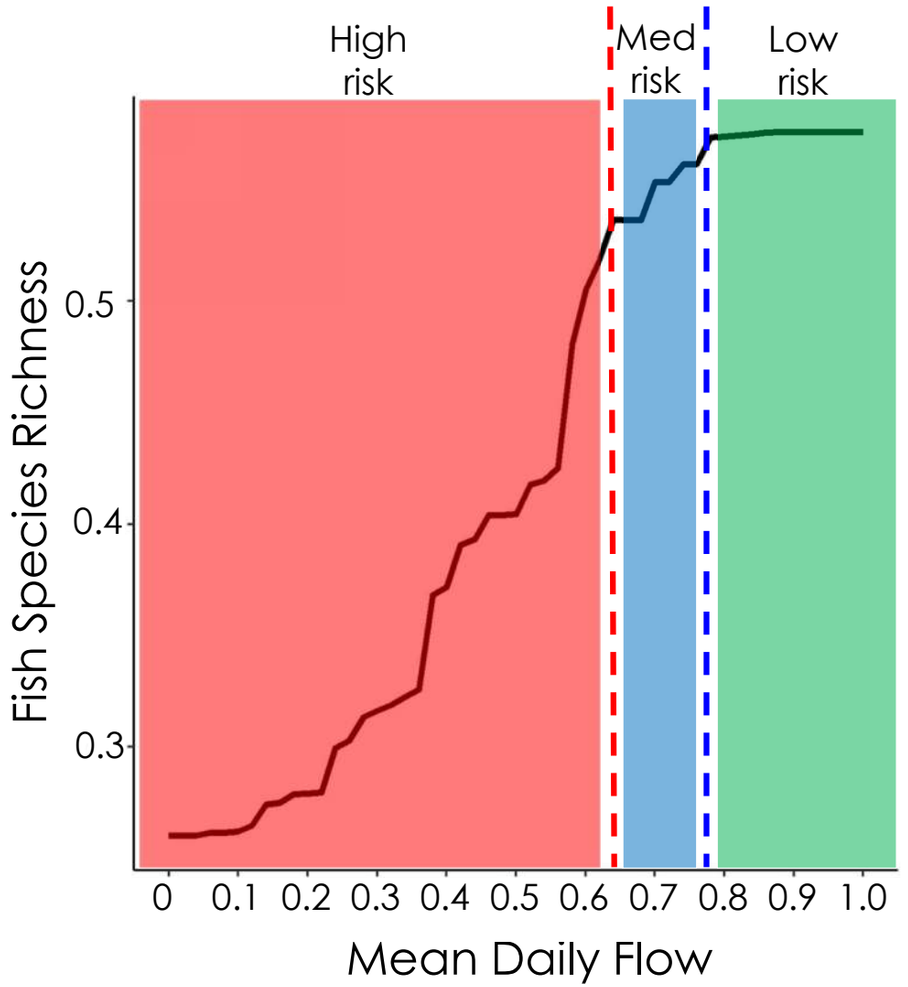
Dashed red and blue lines separate the low medium and high risk zones



BRD30: Middle Tyger River near Lyman	Current Use	UIF	MD 2070	HD 2070	Full Allocation
mean flow (cfs)	98	108	85	70	62
median flow (cfs)	68	77	54	36	28
25th percentile flow (cfs)	42.5	52.1	27.3	5.95	2.78
10th percentile flow (cfs)	26.3	36.3	10.2	0.07	0.07
5th percentile flow (cfs)	18.3	28.3	1.9	0.05	0.05

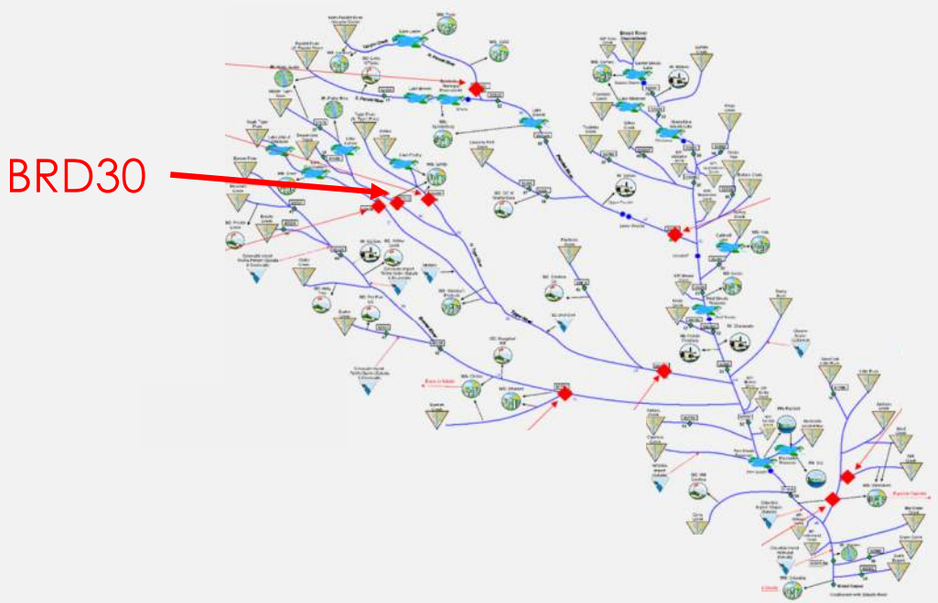
Fish Richness-MA1: Piedmont: perennial runoff

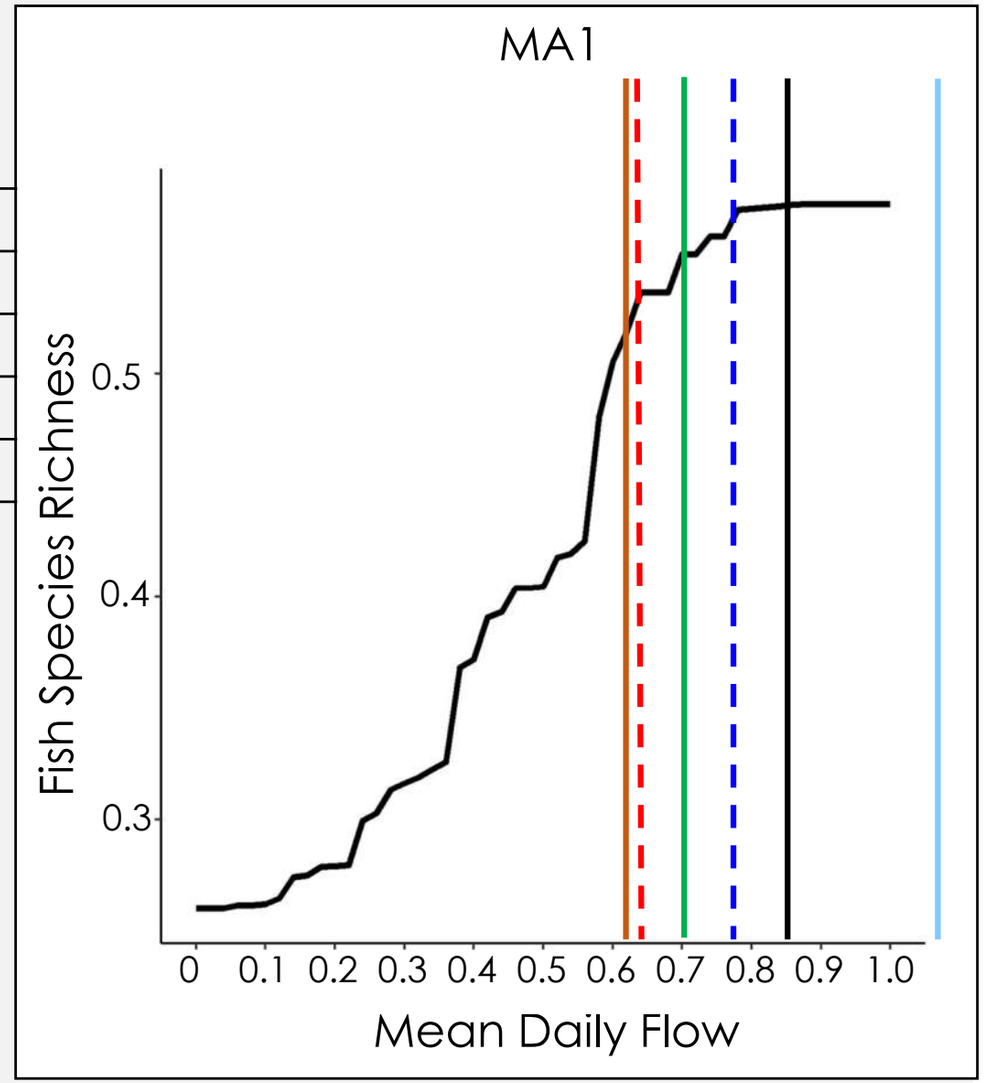




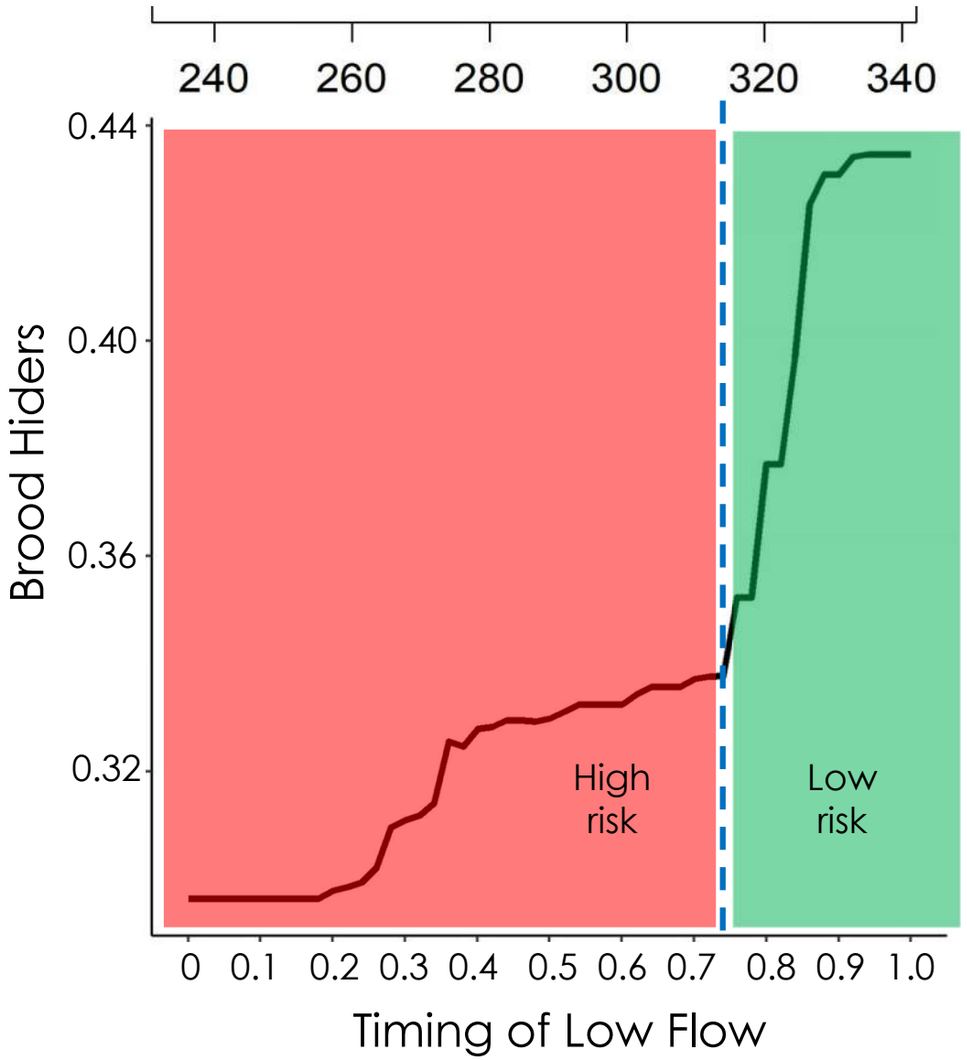
Middle Tyger River near Lyman

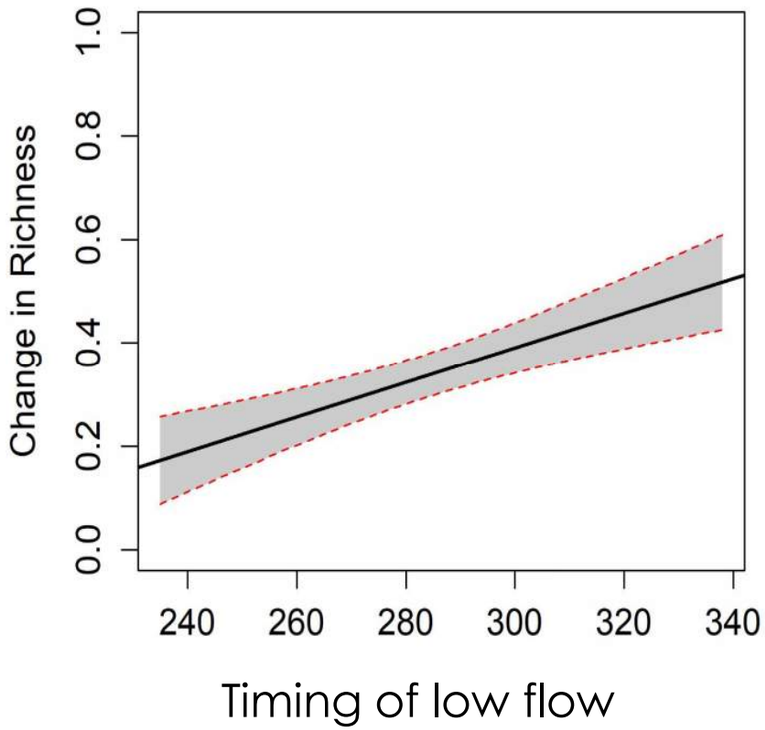
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	98.35	107.83	9.6%	Richness	7.9%	7
HD 2070	98.35	69.85	-29.0%	Richness	-23.8%	7
Full	98.35	61.68	-37.3%	Richness	-30.6%	7
MD 2070	98.35	84.57	-14.0%	Richness	-11.5%	7





Fish Brood hiders-TL1: Piedmont: perennial runoff

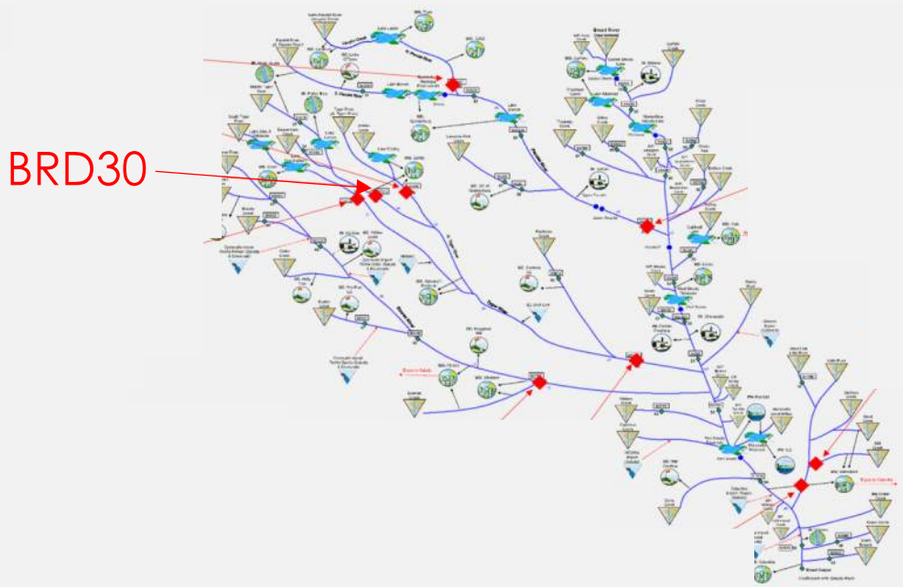


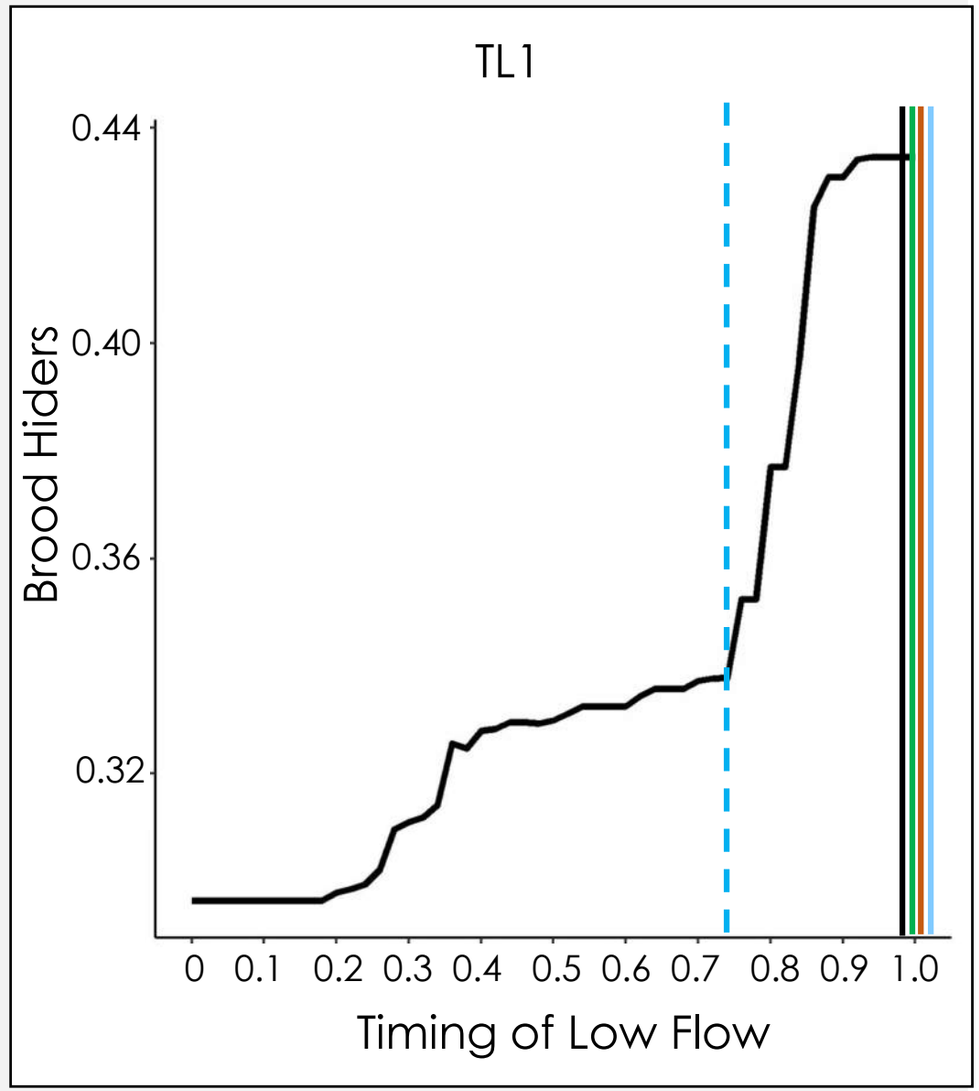


Relationship does not appear linear, so we will not forecast changes in biota

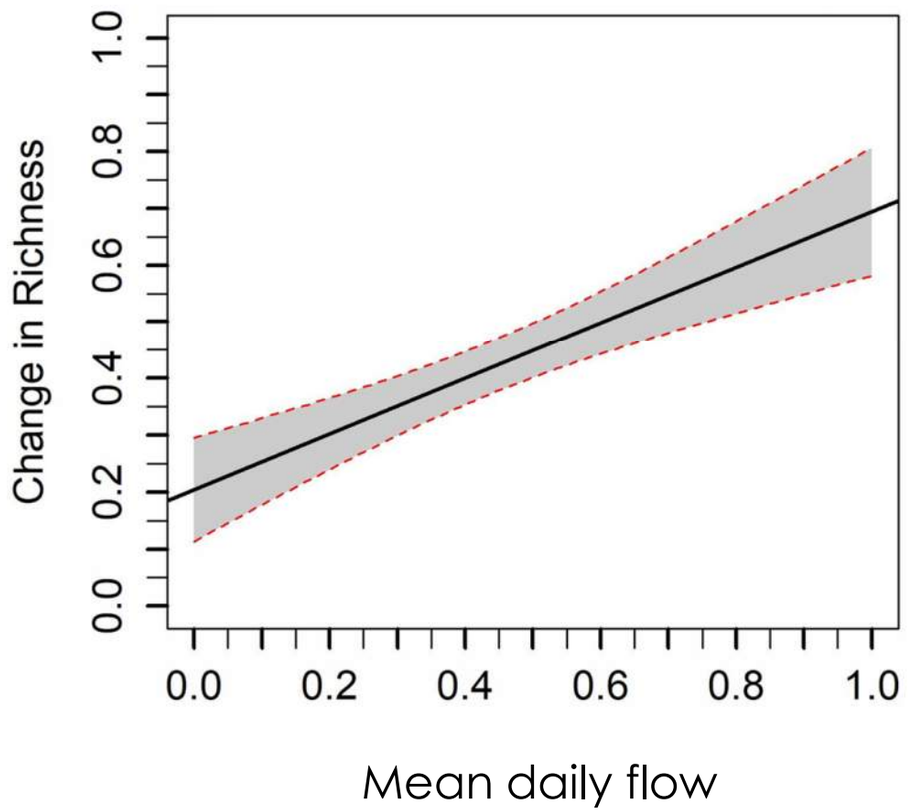
Middle Tyger River near Lyman

Scenario	Current	Predicted	% change
UIF	257	259	0.8%
HD 2070	257	256	-0.4%
Full	257	259	0.8%
MD 2070	257	254	-1.2%

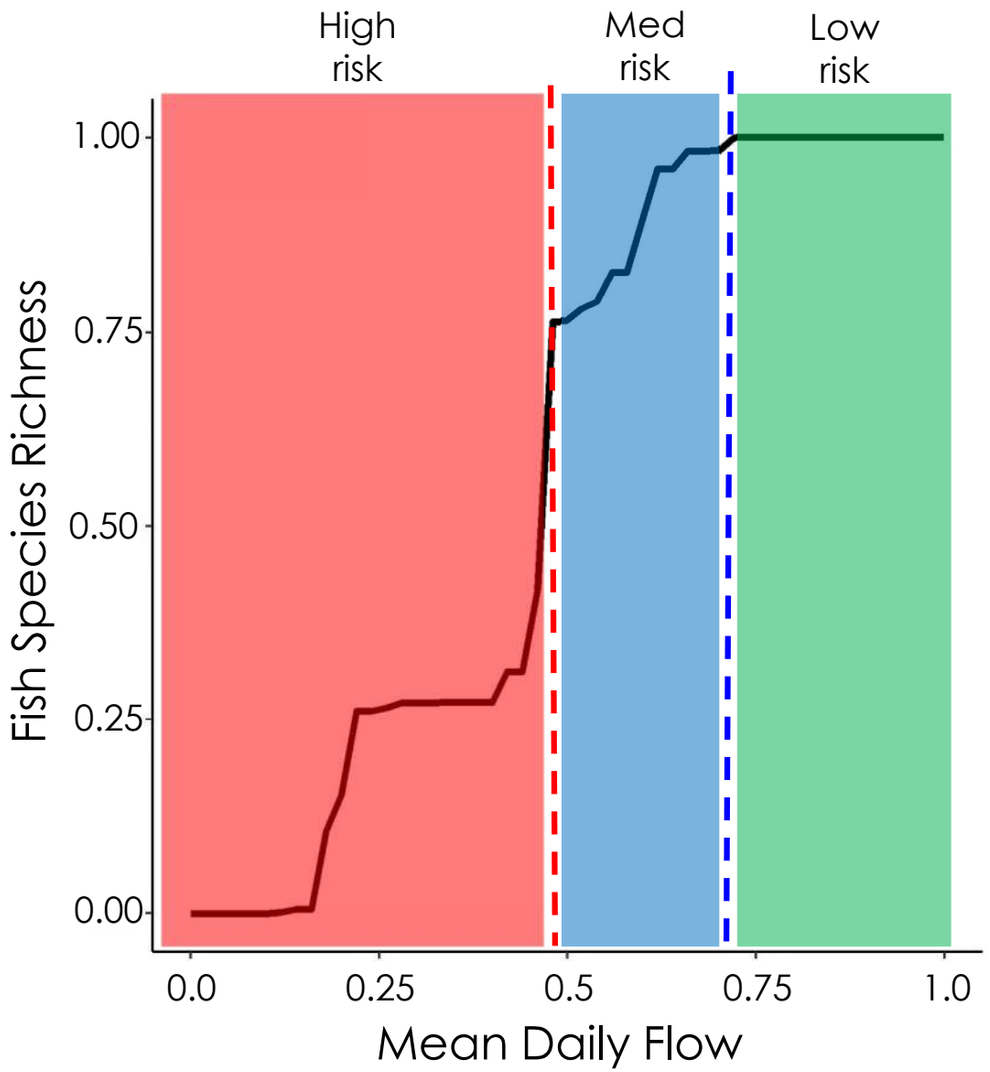




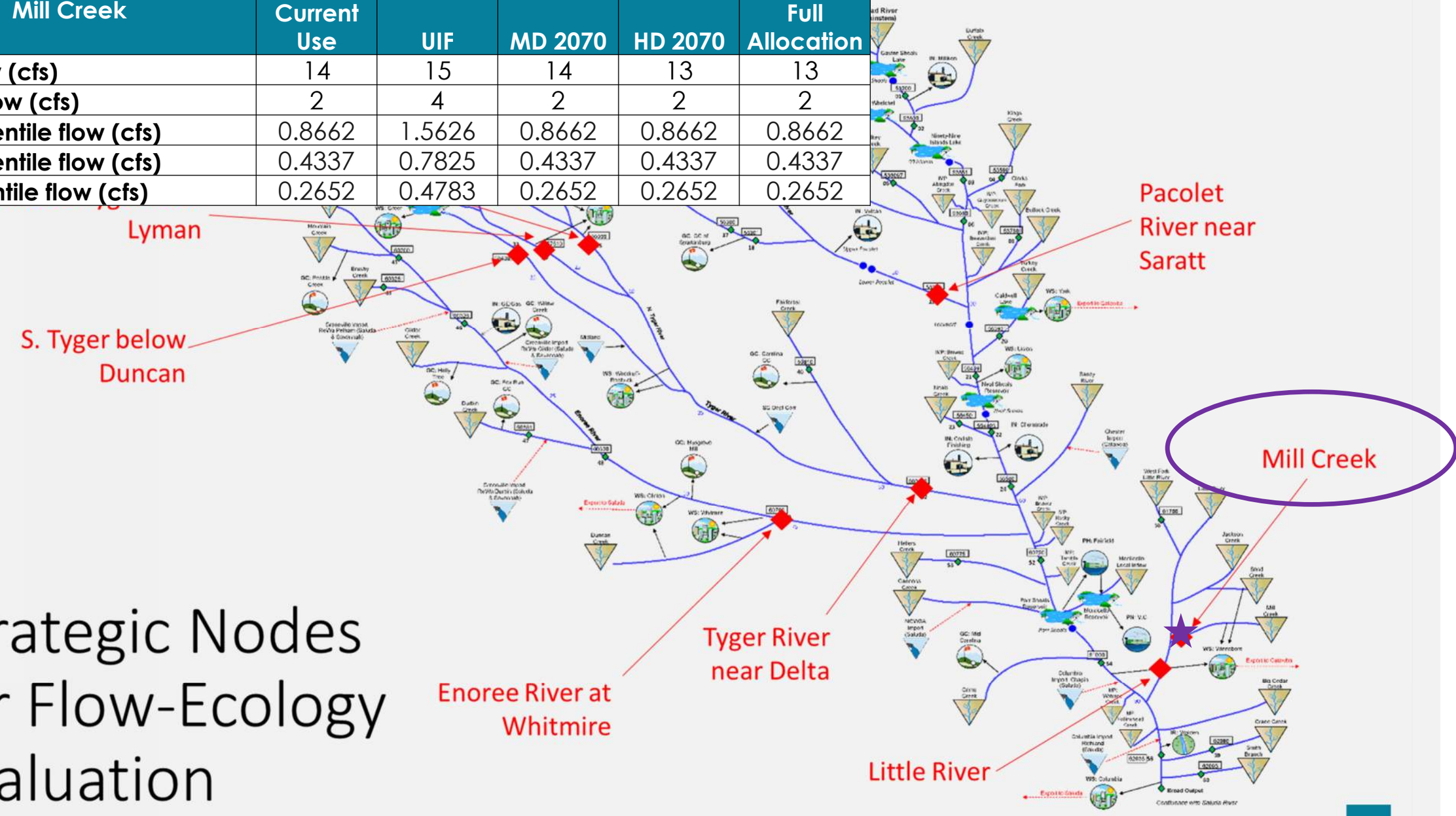
Fish Richness-MA1: Piedmont flashy



Intercept	Slope	SE	p value	R2
0.20489	0.48922	0.0905	<0.001	0.3169



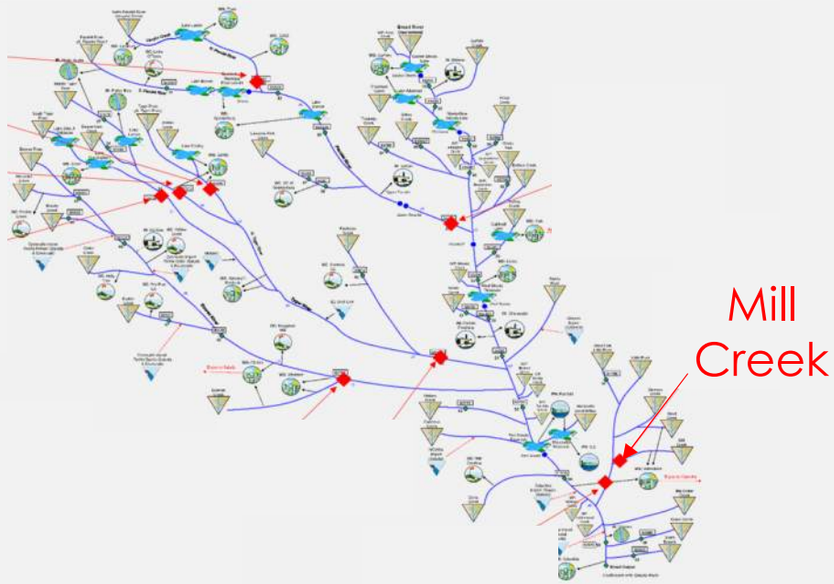
Mill Creek	Current Use	UIF	MD 2070	HD 2070	Full Allocation
mean flow (cfs)	14	15	14	13	13
median flow (cfs)	2	4	2	2	2
25th percentile flow (cfs)	0.8662	1.5626	0.8662	0.8662	0.8662
10th percentile flow (cfs)	0.4337	0.7825	0.4337	0.4337	0.4337
5th percentile flow (cfs)	0.2652	0.4783	0.2652	0.2652	0.2652

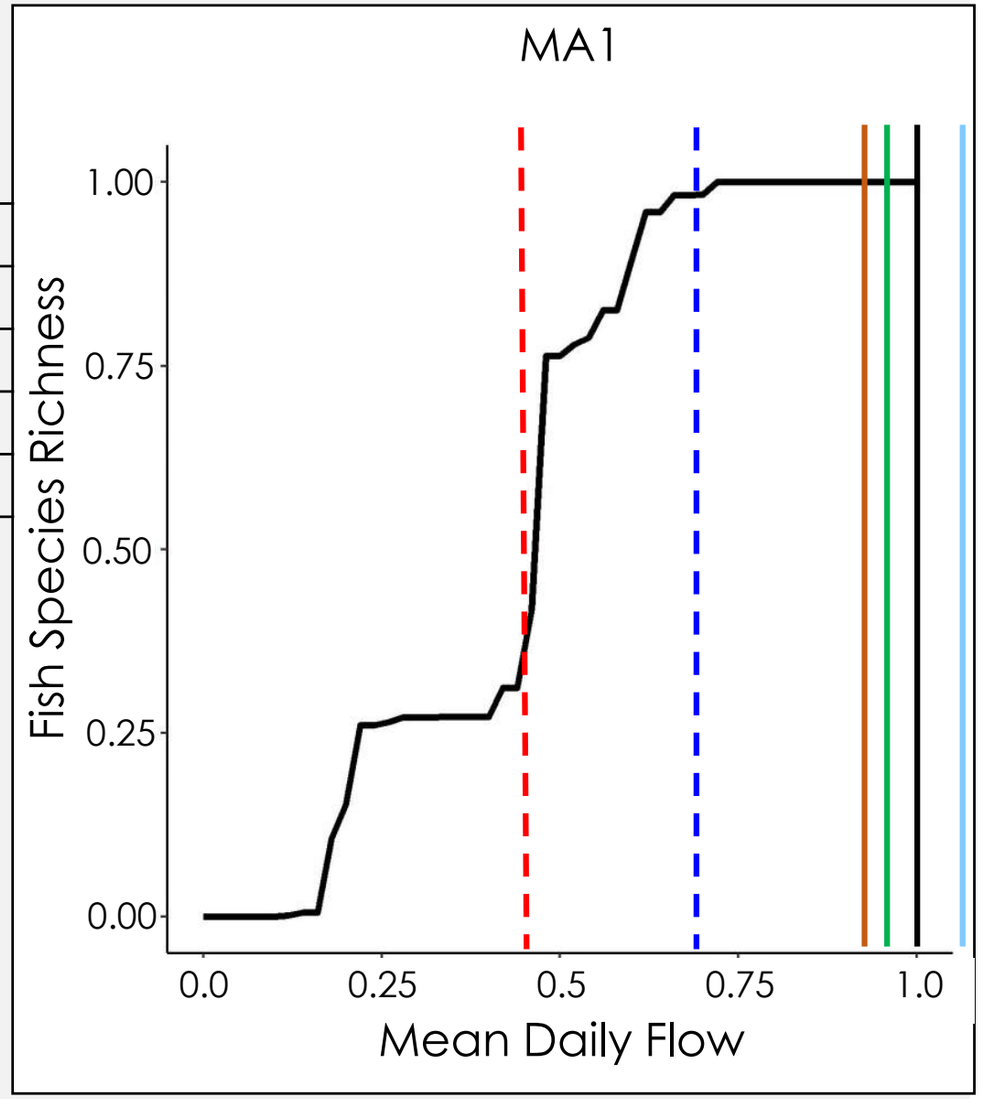


Strategic Nodes for Flow-Ecology Evaluation

Mill Creek

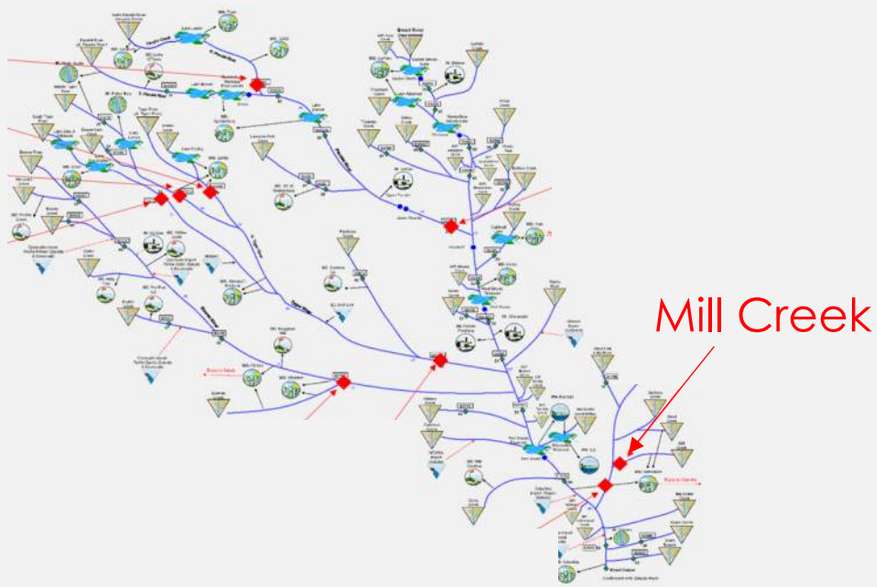
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	14.01	15.07	7.6%	Richness	5.3%	9
HD 2070	14.01	12.96	-7.5%	Richness	-5.3%	9
Full	14.01	12.65	-9.7%	Richness	-6.8%	9
MD 2070	14.01	14.10	0.7%	Richness	0.5%	9

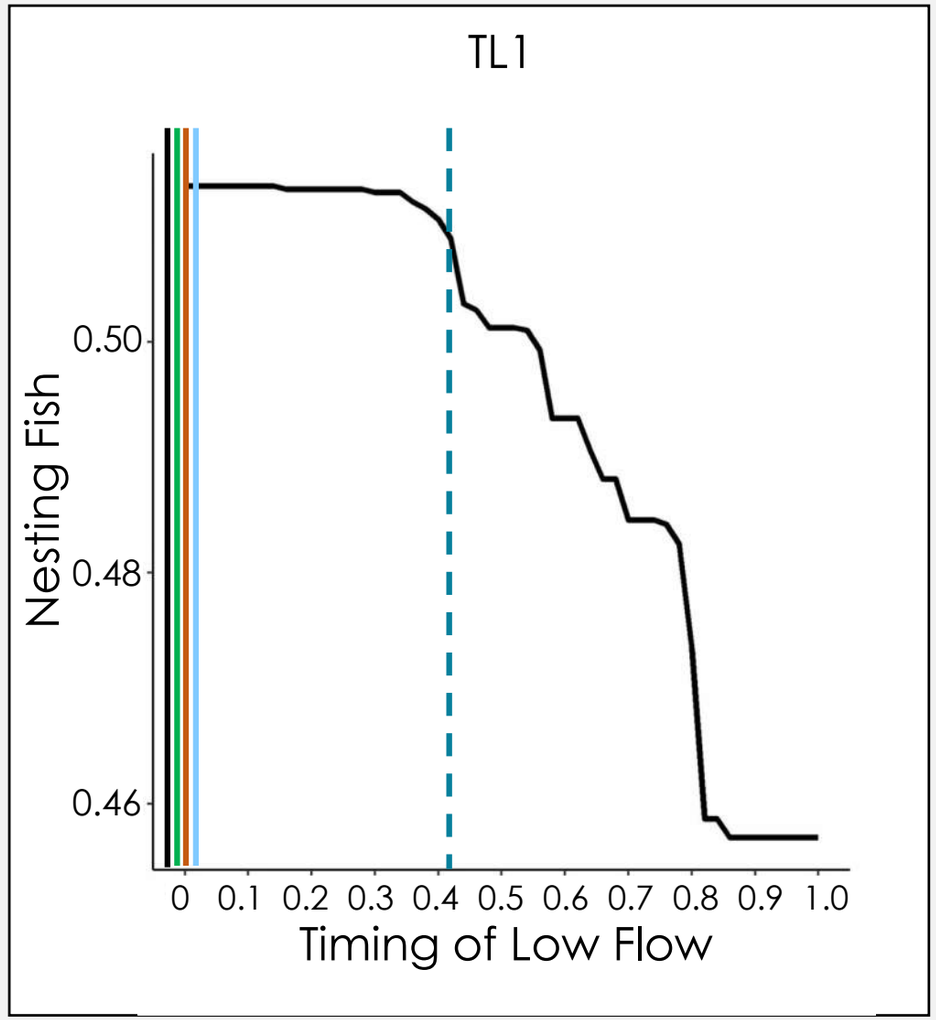




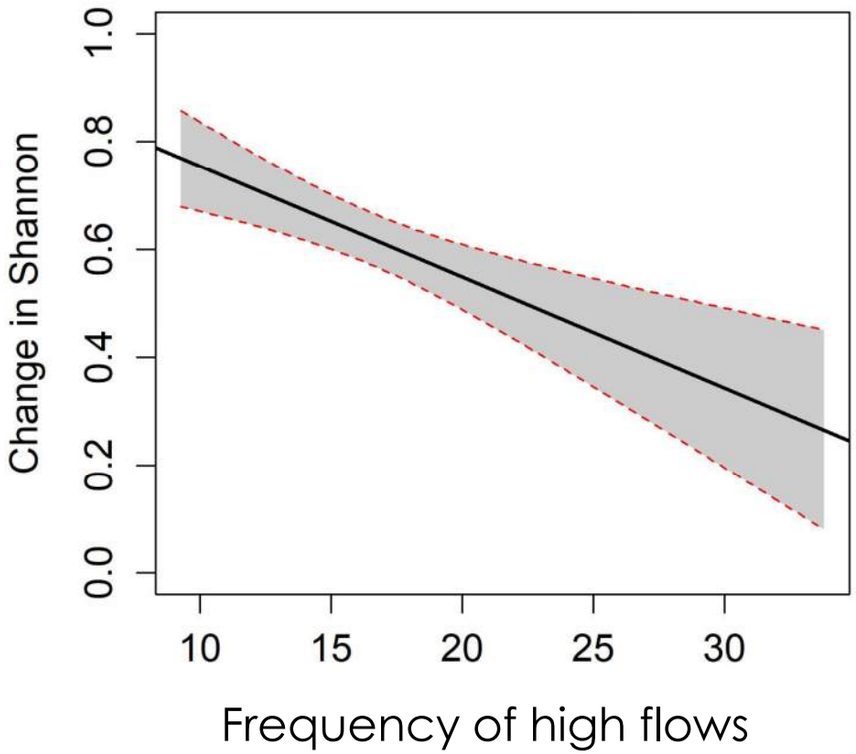
Mill Creek

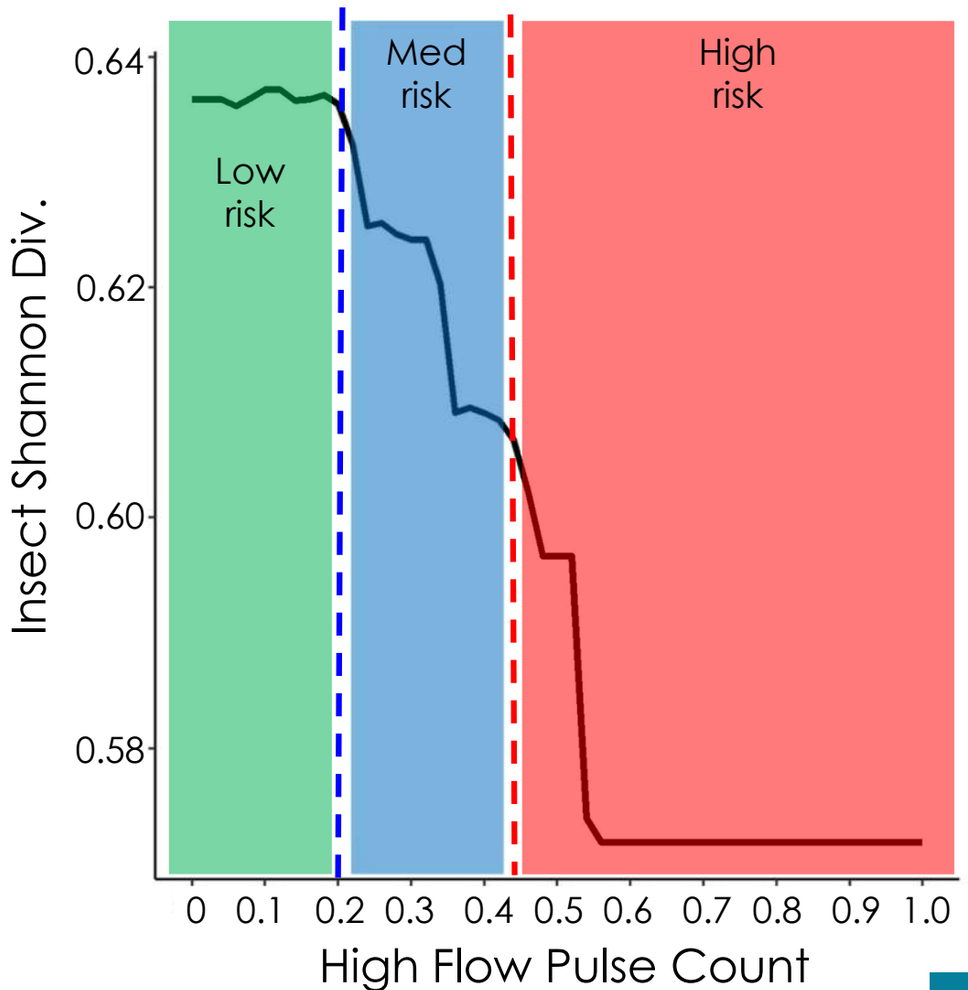
Scenario	Current	Predicted	% change
UIF	254	254	0%
HD 2070	254	254	0%
Full	254	254	0%
MD 2070	254	254	0%





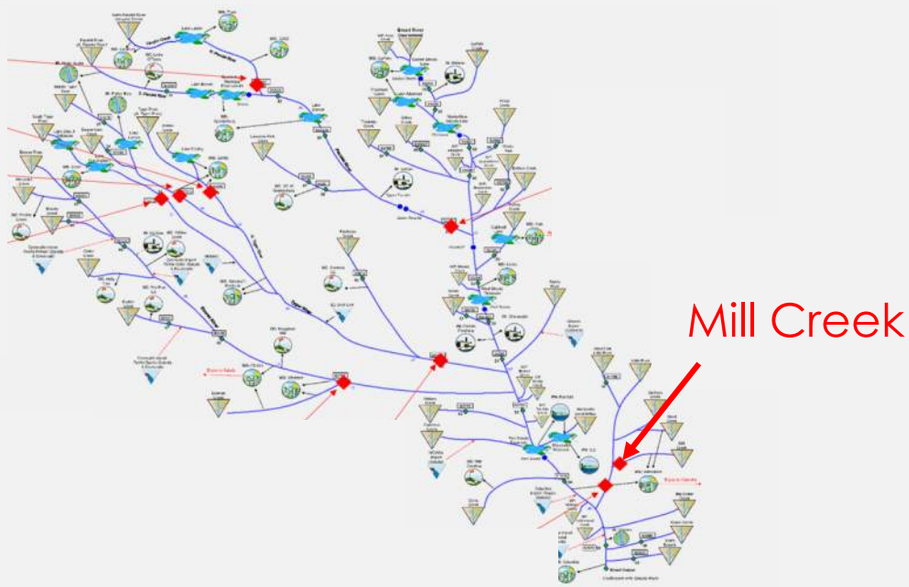
Macro Shannon-FH1 Piedmont: flashy streams

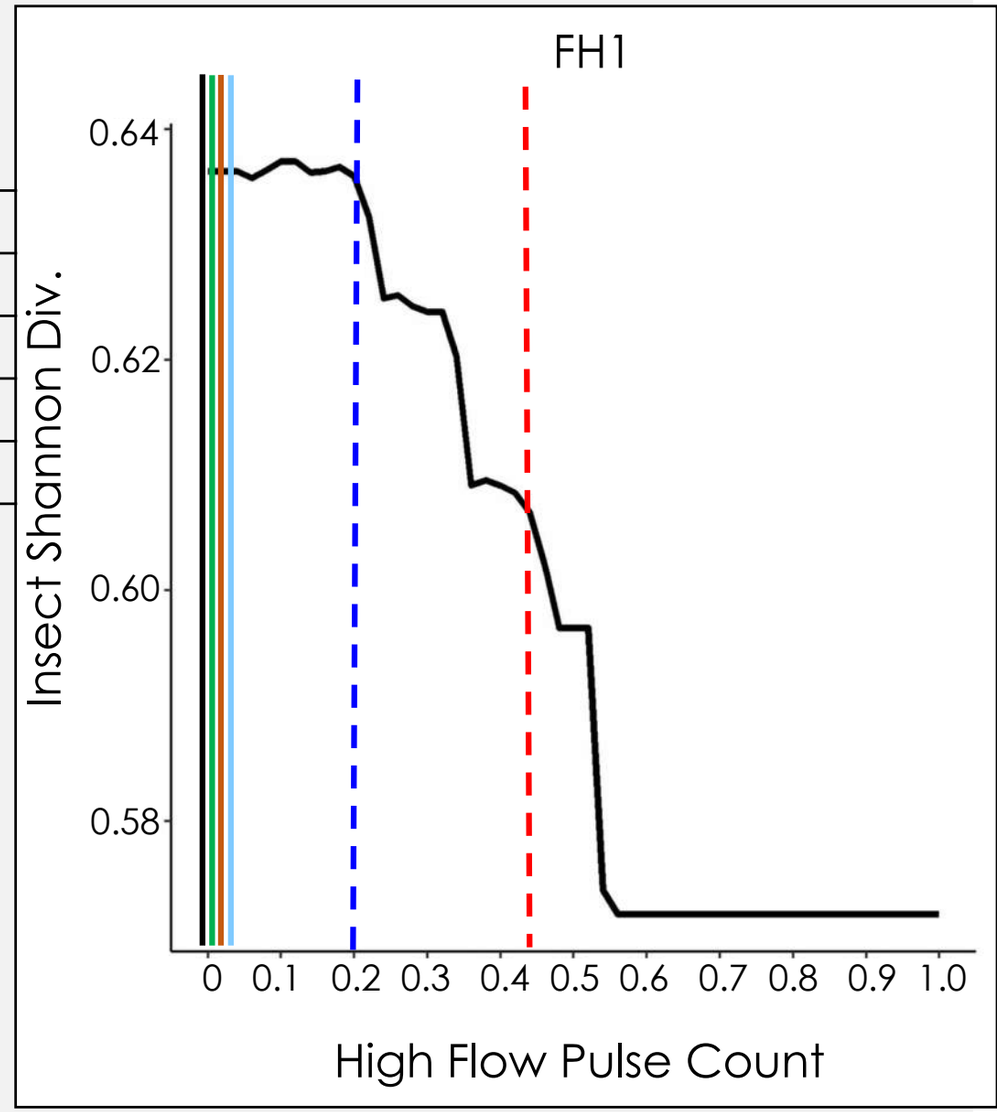




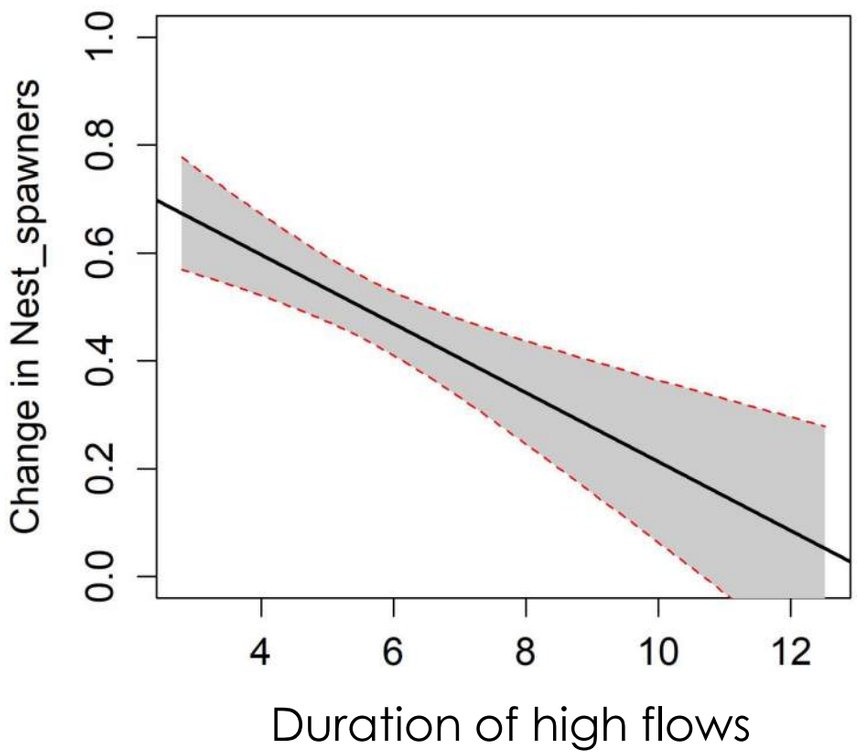
Mill Creek

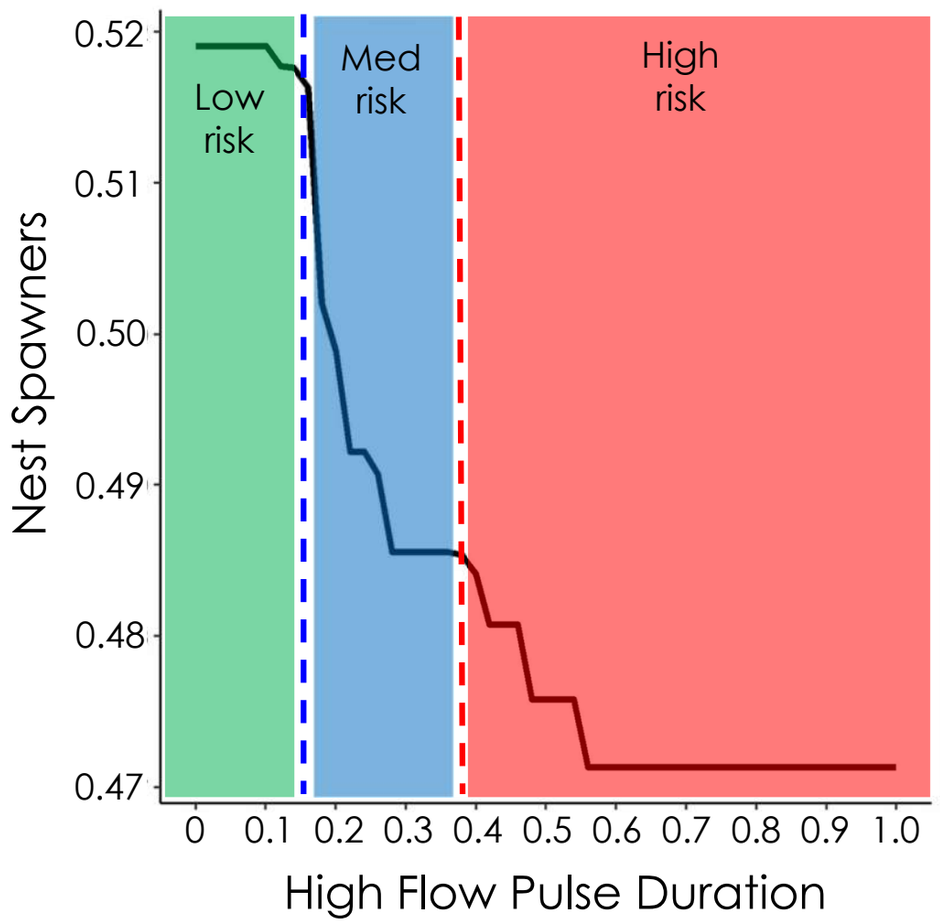
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	15.11	15.27	1.0%	Richness	-1.9%	17
HD 2070	15.11	15.29	1.2%	Richness	-2.2%	17
Full	15.11	15.27	1.0%	Richness	-1.9%	17
MD 2070	15.11	15.17	0.4%	Richness	-0.7%	17





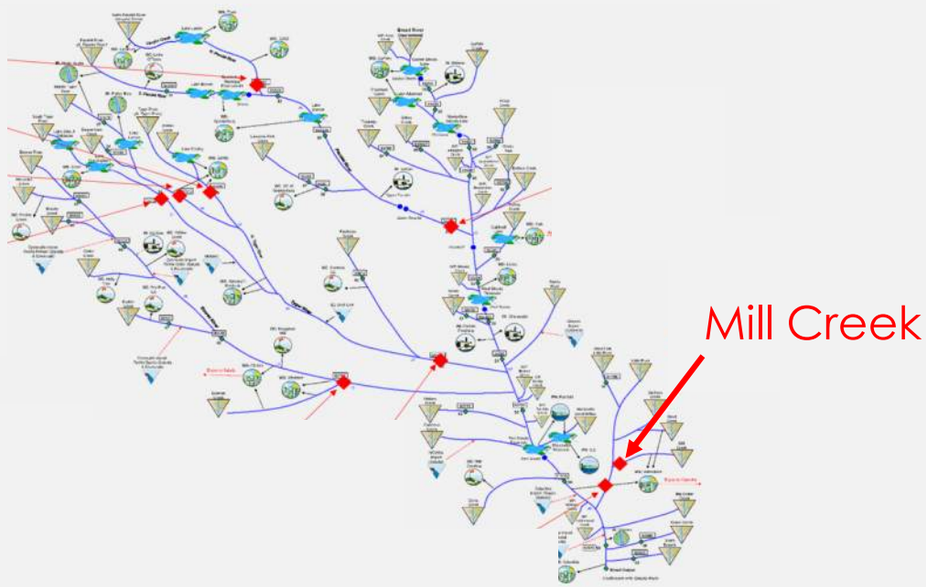
Fish Nesting-DH15: Piedmont: flashy streams

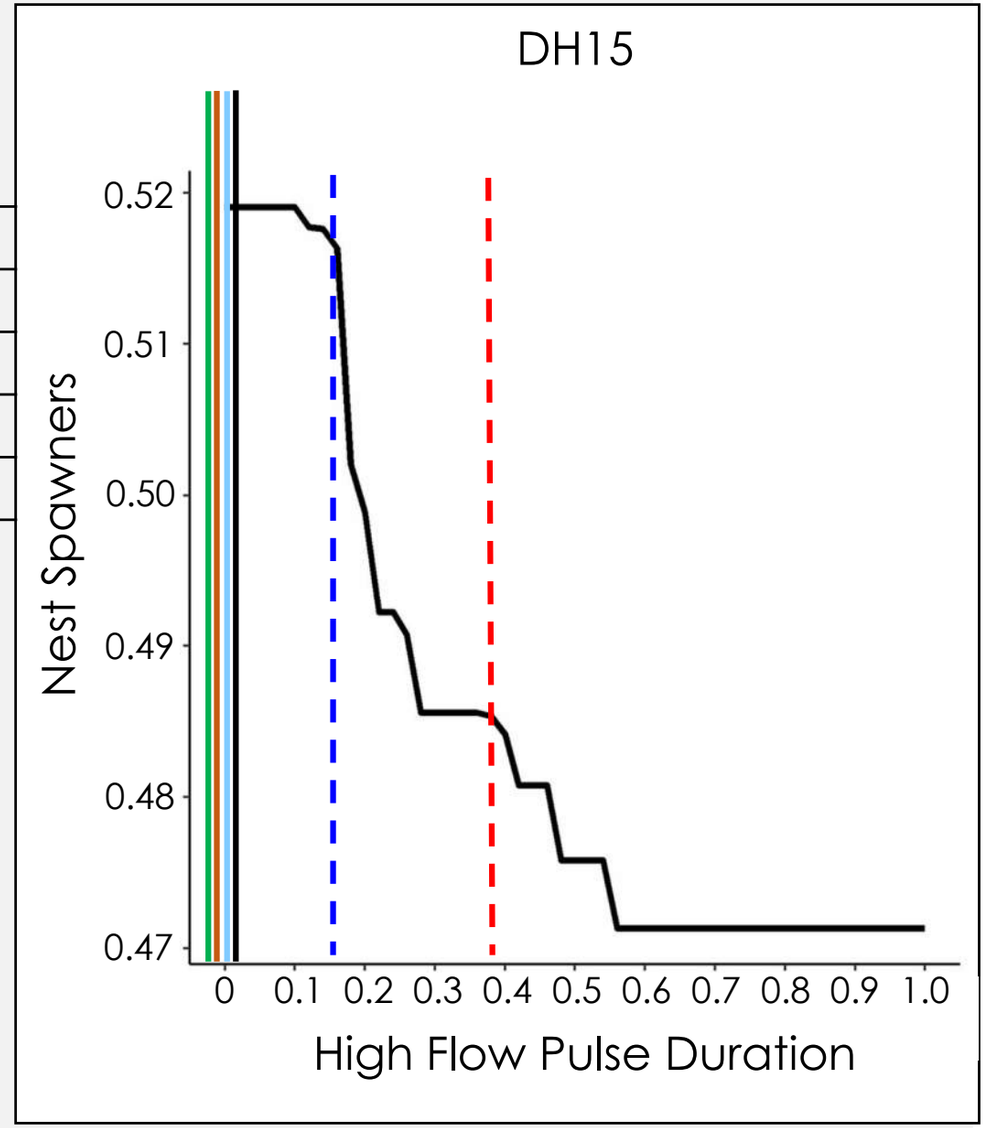




Mill Creek

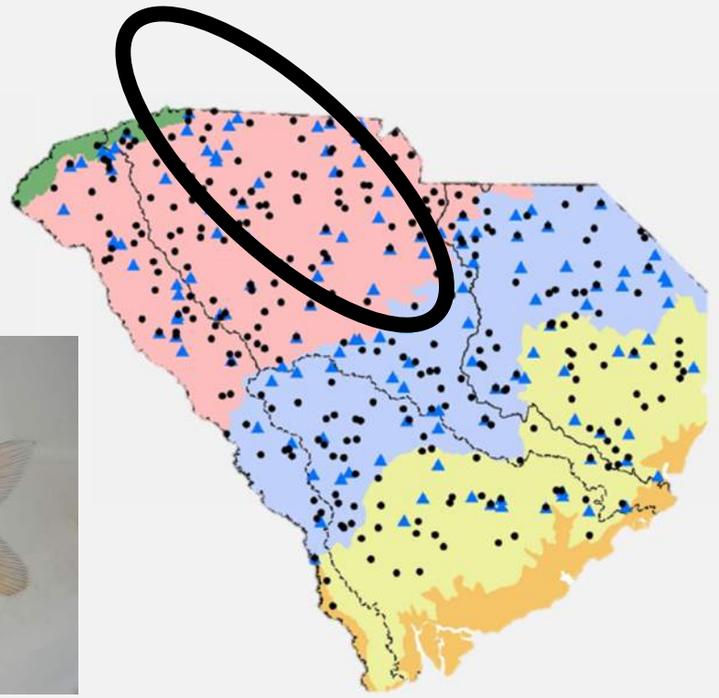
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	5.39	5.14	-4.7%	Richness	0.03%	15
HD 2070	5.39	5.14	-4.7%	Richness	0.03%	15
Full	5.39	5.14	-4.7%	Richness	0.03%	15
MD 2070	5.39	5.28	-2.0%	Richness	0.01%	15





Expected results: richness

- 35 species collected at 20 sites in upper Broad River basin
- Average 14 species per site

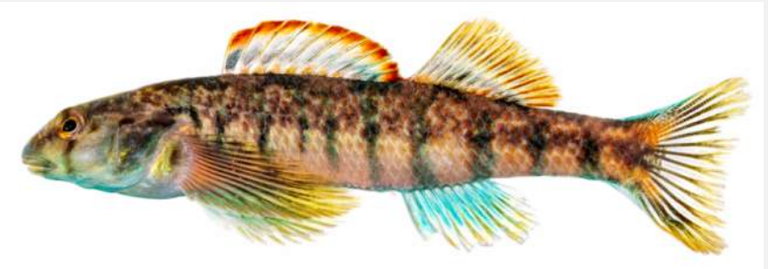


Redbreast sunfish

Notchlip redhorse

Bluehead chub

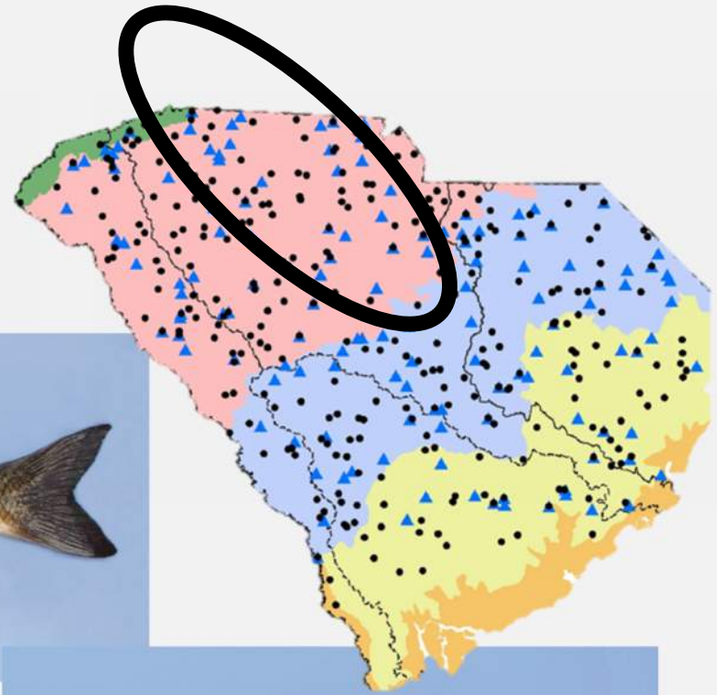
Flat Bullhead



Seagreen Darter

Expected results: richness

- Up to 50% biodiversity loss in some streams at full allocation
- Replacement by common generalists & invasives



Green sunfish

White sucker

Eastern mosquitofish

Yellow Bullhead

Golden Shiner

SWAP-listed fishes in upper Broad River basin

Thinlip Chub

Santee Chub

Carolina Darter

Greenfin Shiner

Seagreen Darter

Fieryblack Shiner

Highback Chub

Carolina Fantail Darter

Eastern Brook Trout

All photos from ncfishes.com

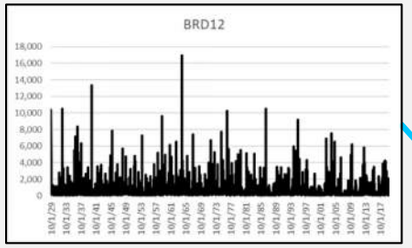
What this info *is*

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

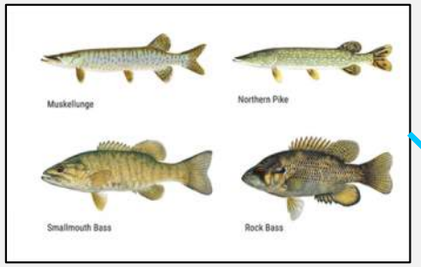
What this info *is not*

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

Flow Chart



Gauge Data

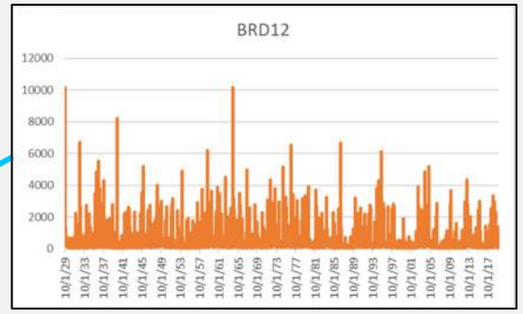


Community Data

Estimate Flow metrics

+ Uncertainty

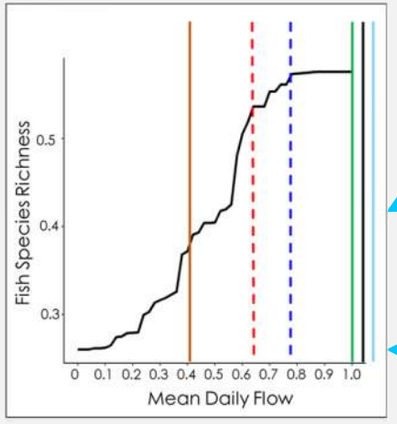
Estimate Flow-Ecology Relationships



Forecast Future Flows

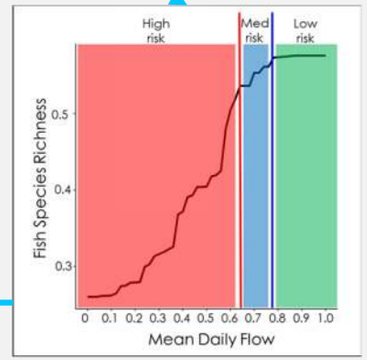
+ Uncertainty

+ 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

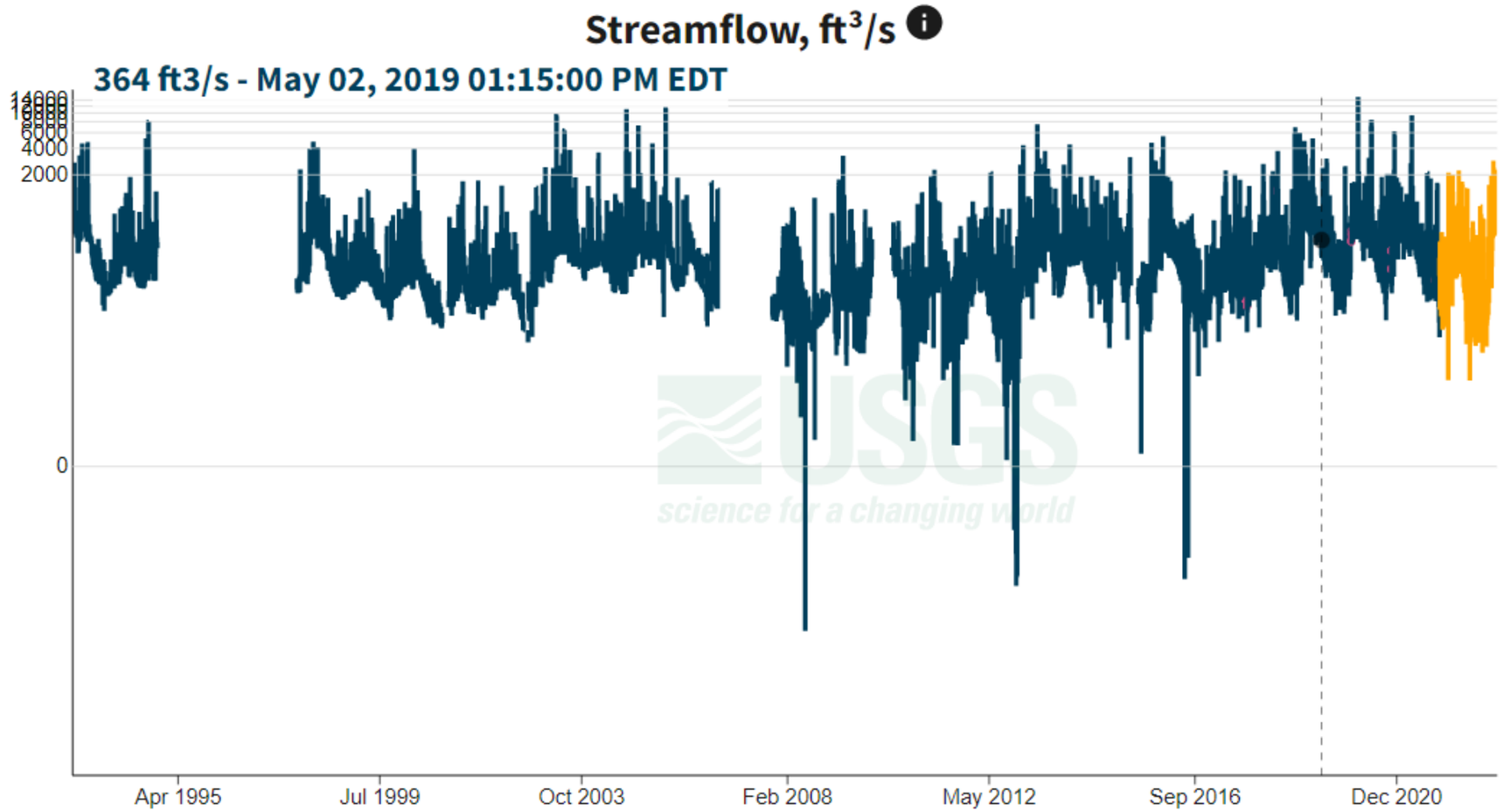
What this info *is not*

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

PACOLET RIVER NEAR FINGERVILLE, SC

IMPORTANT Legacy real-time page

Monitoring location 02155500 is associated with a STREAM in SPARTANBURG COUNTY, SOUTH CAROLINA. Current conditions of DISCHARGE, GAGE HEIGHT, MEAN WATER VELOCITY FOR DISCHARGE COMPUTATION, and MORE are available. Water data back to 1903 are available online.



What this info *is*

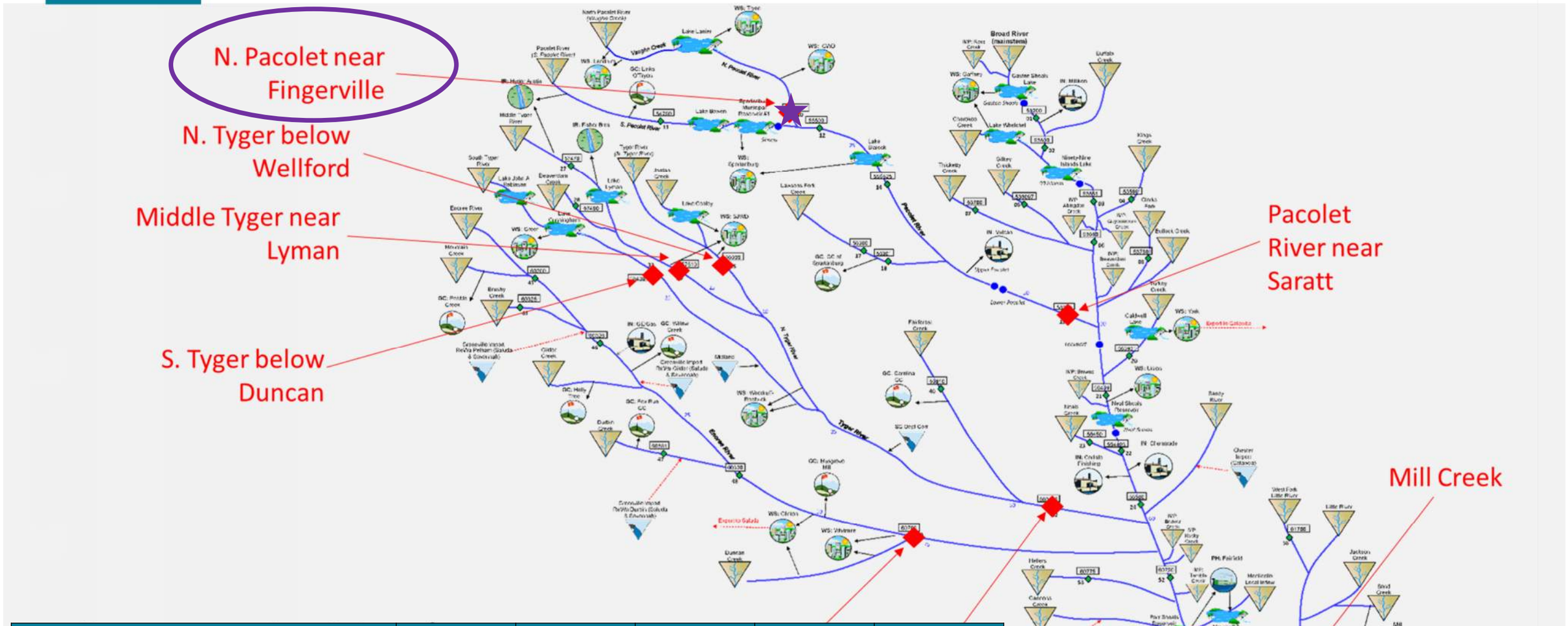
- Guidance based on best available data and analysis tools
- Based on models with compounding statistical uncertainty
- Representative of overall (30-year) flow regime characteristics
- Applicable to streams and small rivers (~86% of all SC waters)
- Relationships between organisms and flow

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.

Questions and thanks for listening

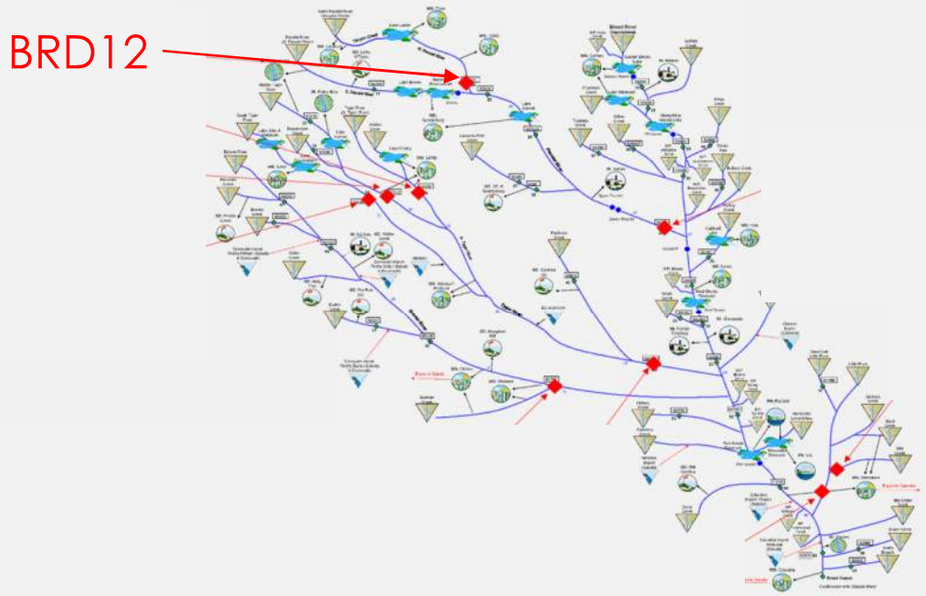
Results at additional strategic nodes are provided in the following 20 slides

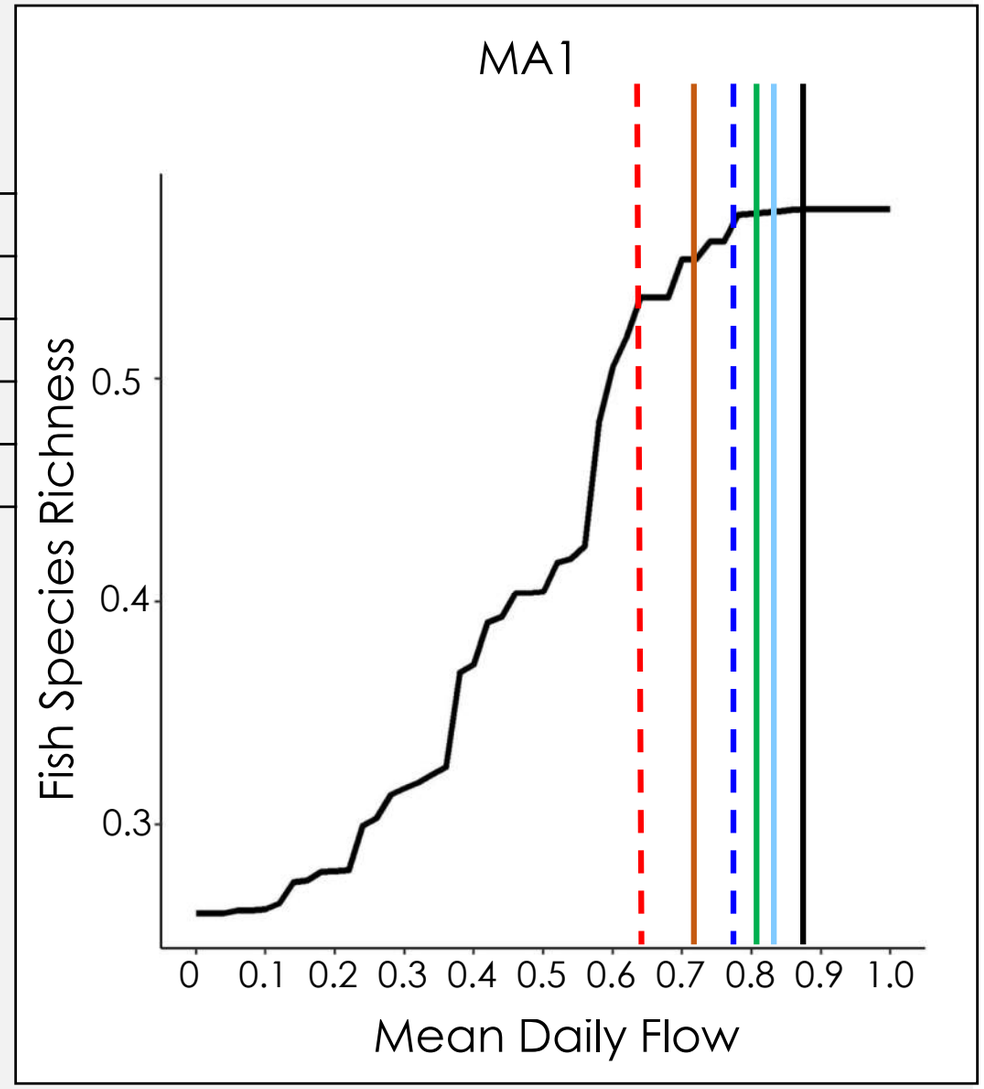


BRD12: N. Pacolet River near Fingerville	Current Use	UIF	MD 2070	HD 2070	Full Allocation
mean flow (cfs)	320	369	283	258	228
median flow (cfs)	224	274	181	150	158
25th percentile flow (cfs)	139.5	191.4	103.3	96.3	106.6
10th percentile flow (cfs)	84.2	139.1	71.0	64.8	71.9
5th percentile flow (cfs)	63.9	112.8	54.6	48.0	53.4

N. Pacolet near Fingerville

Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	319.65	368.91	15.4%	Richness	12.7%	7
HD 2070	319.65	257.78	-19.4%	Richness	-15.9%	7
Full	319.65	227.65	-28.8%	Richness	-23.6%	7
MD 2070	319.65	283.39	-11.3%	Richness	-9.3%	7

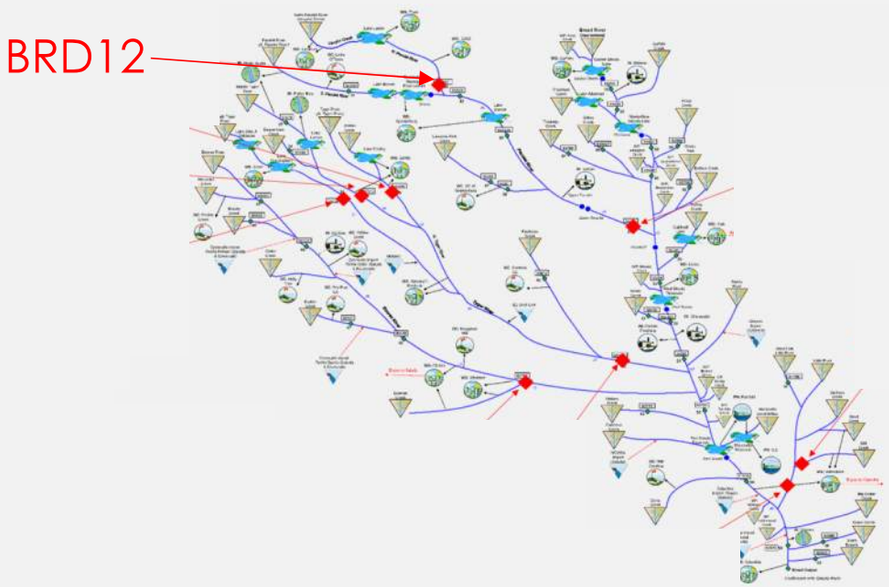


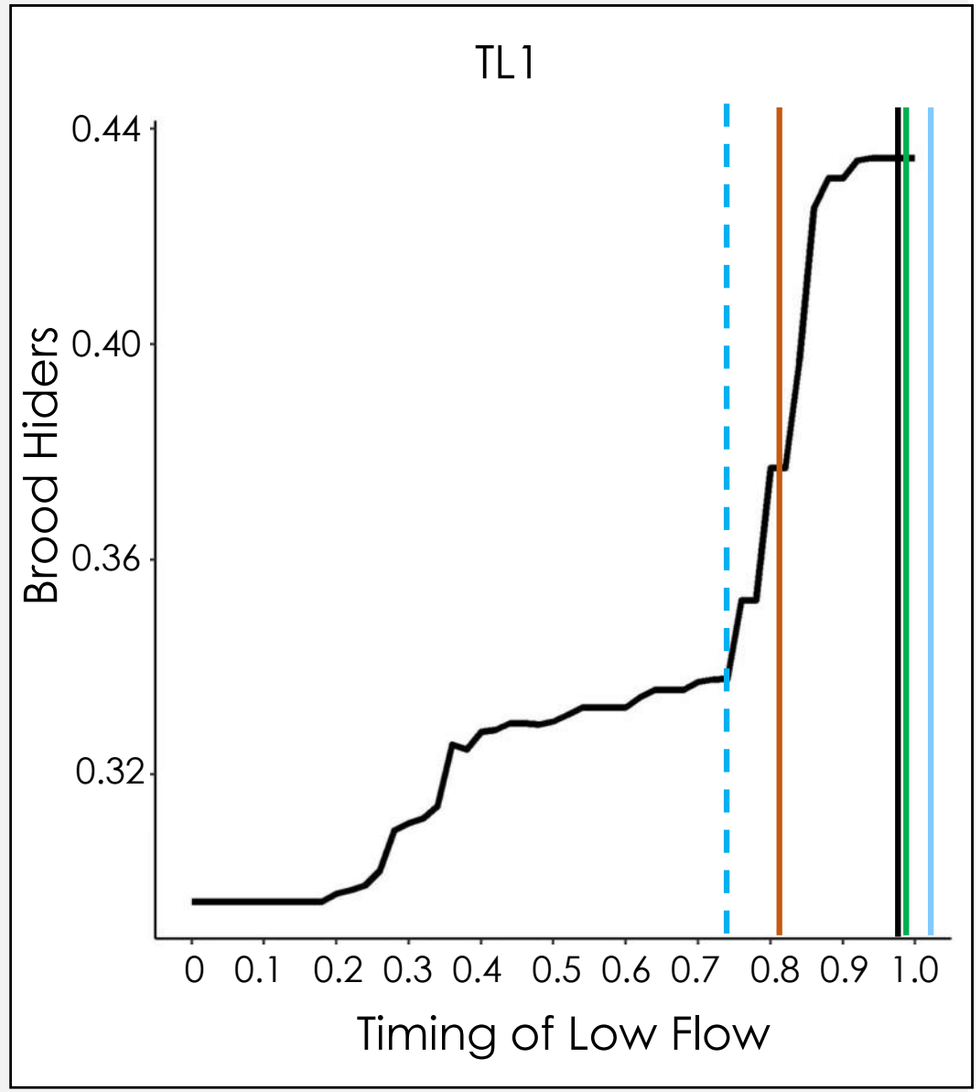


N. Pacolet near Fingerville

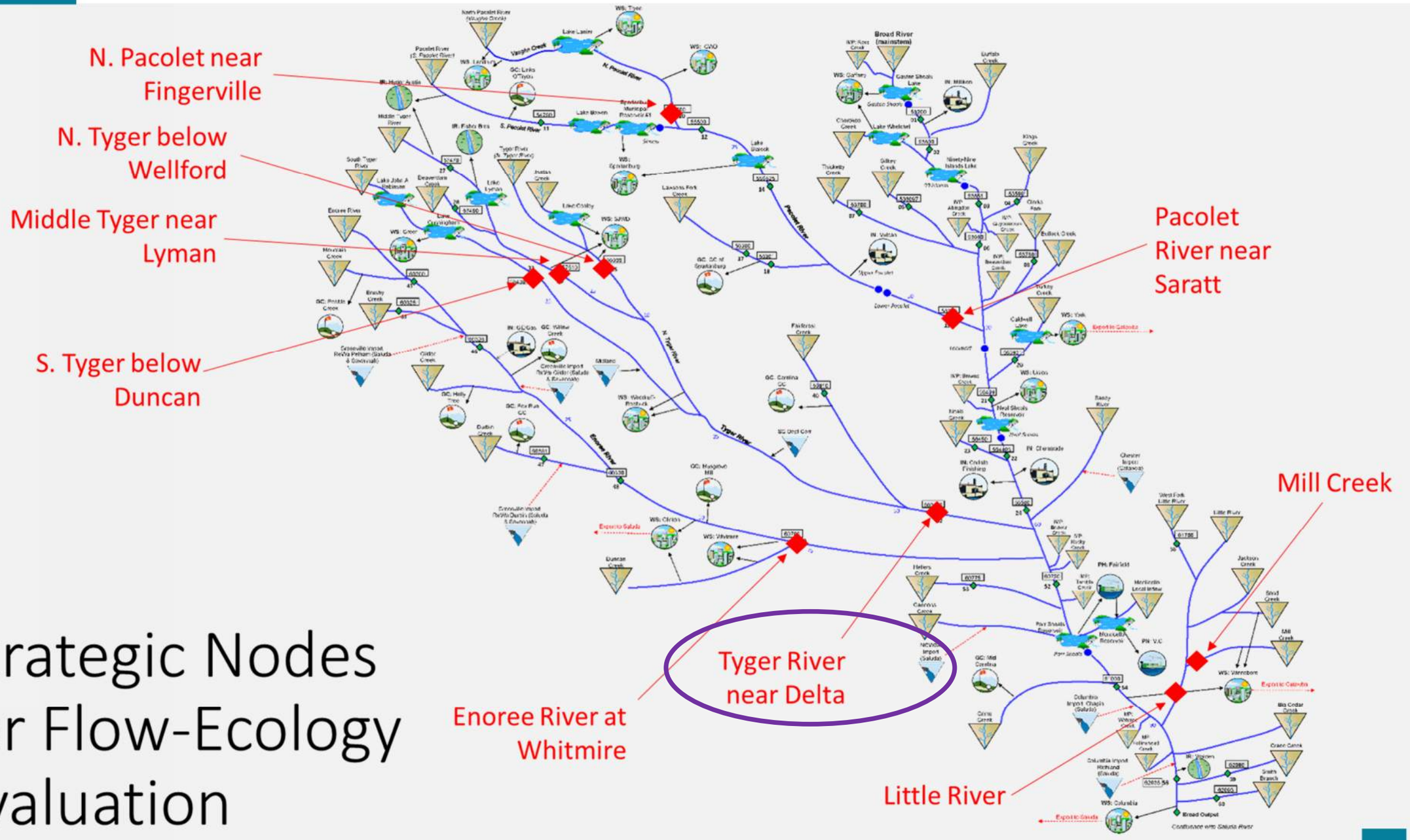
All stream class 1 strategic nodes had similar results

Scenario	Current	Predicted	% change
UIF	258	261	1.1%
HD 2070	258	257.8	-0.8%
Full	258	227.6	-18.7%
MD 2070	258	256	-0.8%



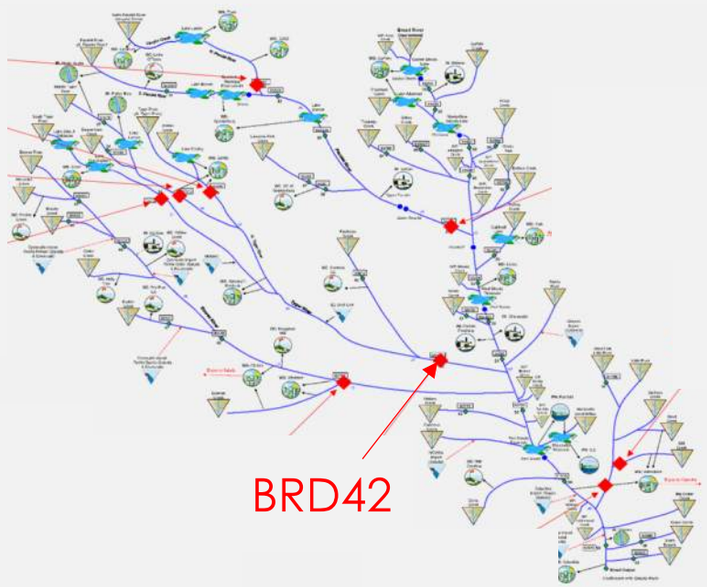


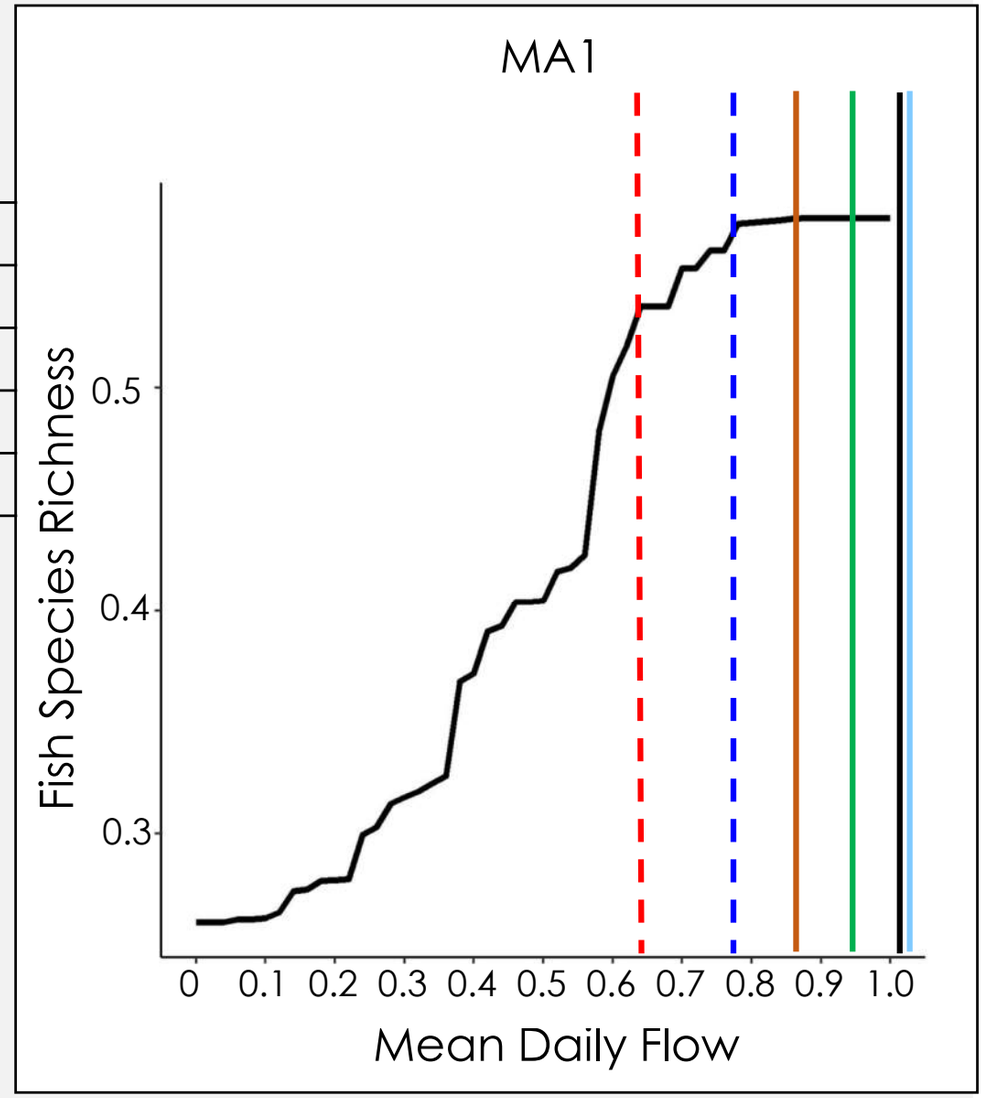
Strategic Nodes for Flow-Ecology Evaluation



Tyger River near Delta

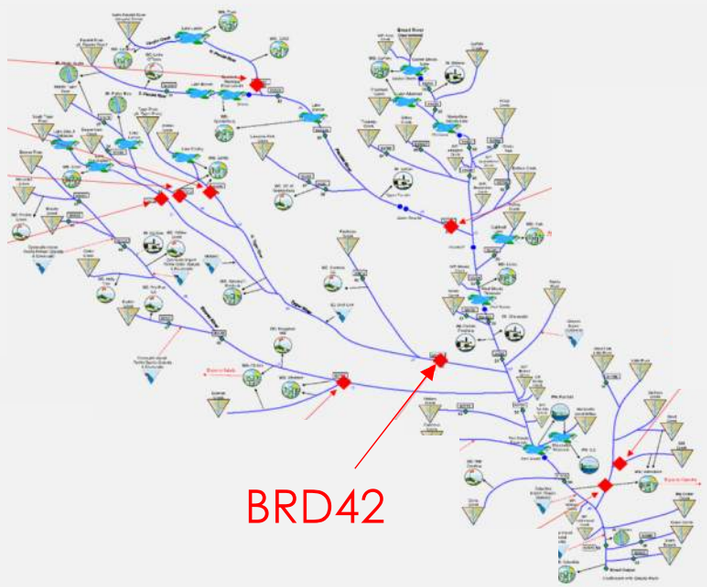
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	775.20	802.37	3.5%	Richness	2.9%	7
HD 2070	775.20	735.68	-5.1%	Richness	-4.2%	7
Full	775.20	667.73	-13.9%	Richness	-11.4%	7
MD 2070	775.20	755.98	2.5%	Richness	-2.0%	7

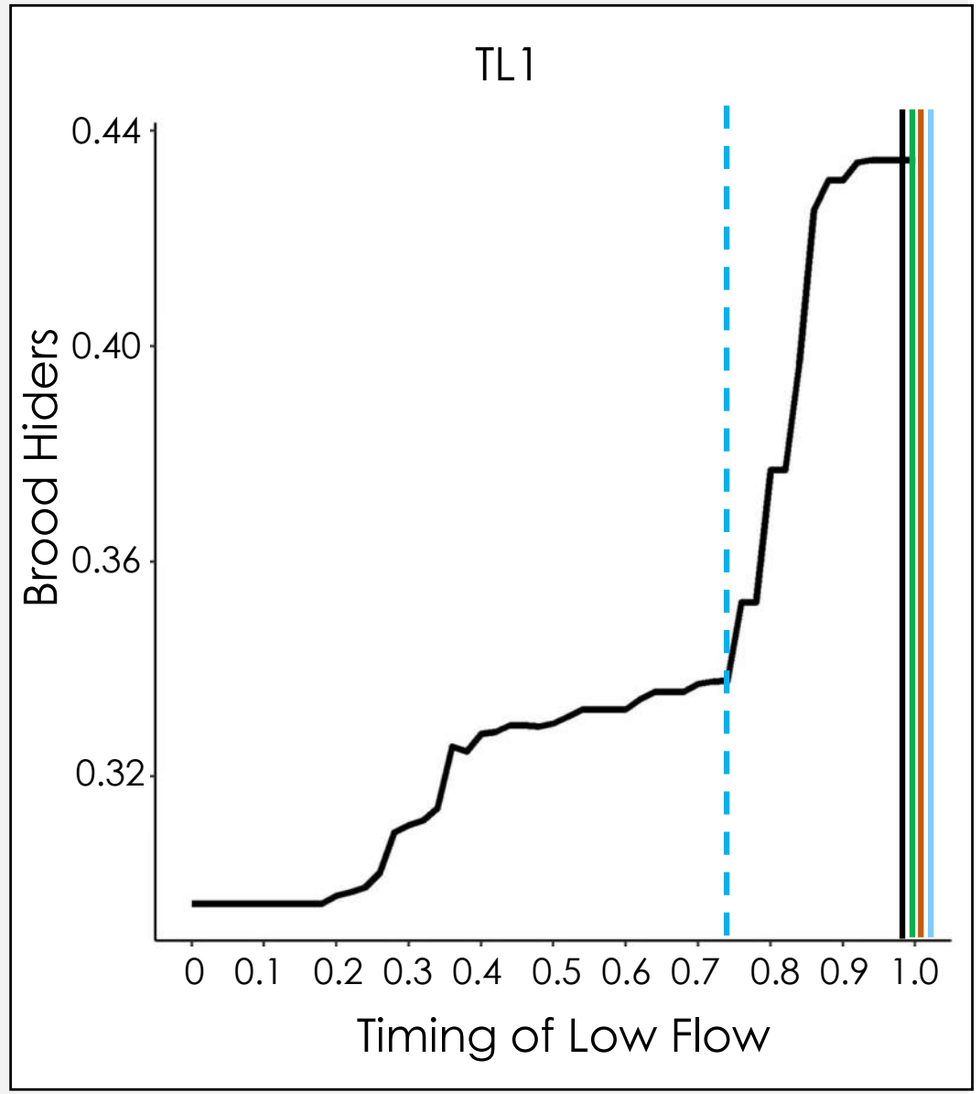




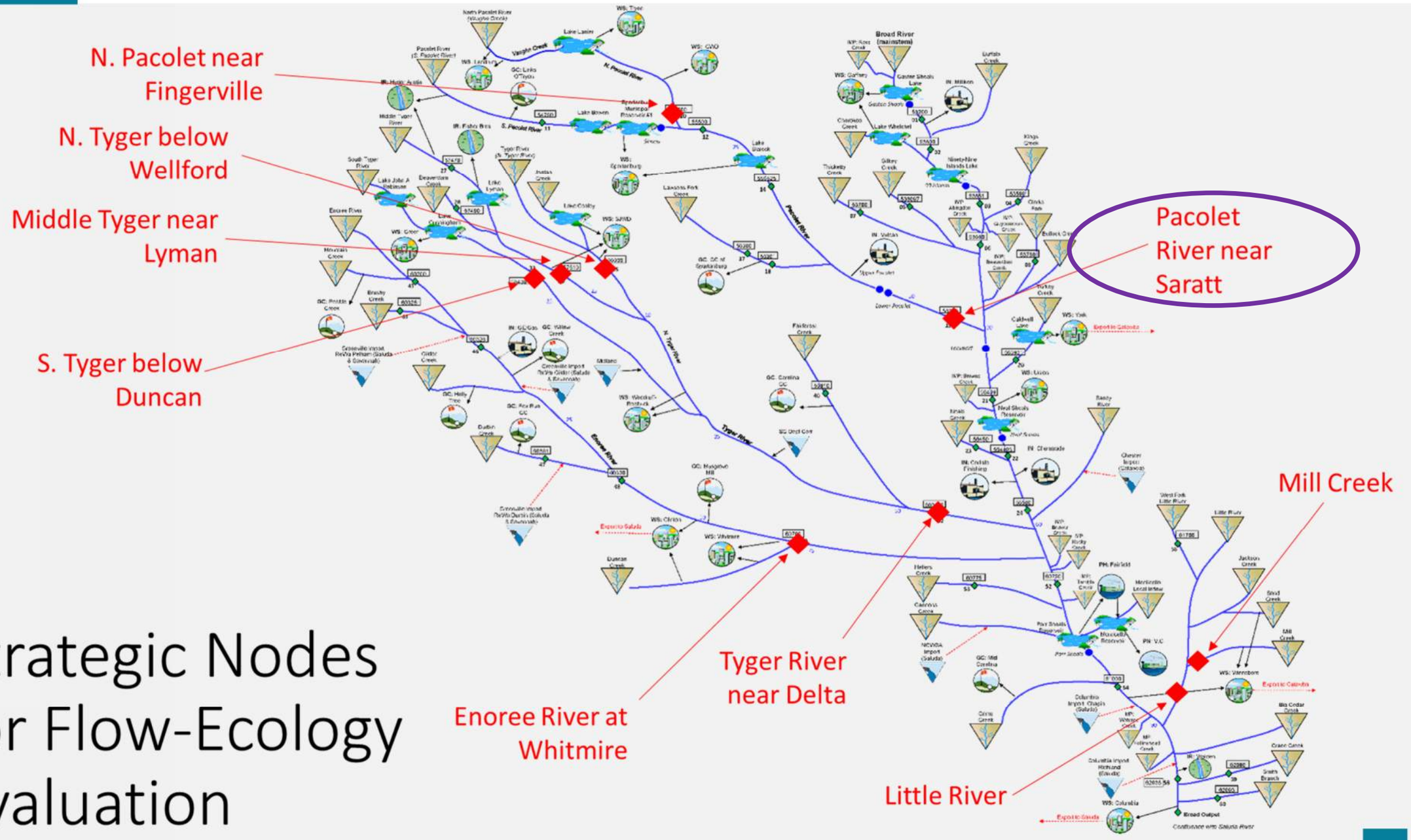
Tyger River near Delta

Scenario	Current	Predicted	% change
UIF	259	260	0.4%
HD 2070	259	260	0.4%
Full	259	260	0.4%
MD 2070	259	258	-0.4%



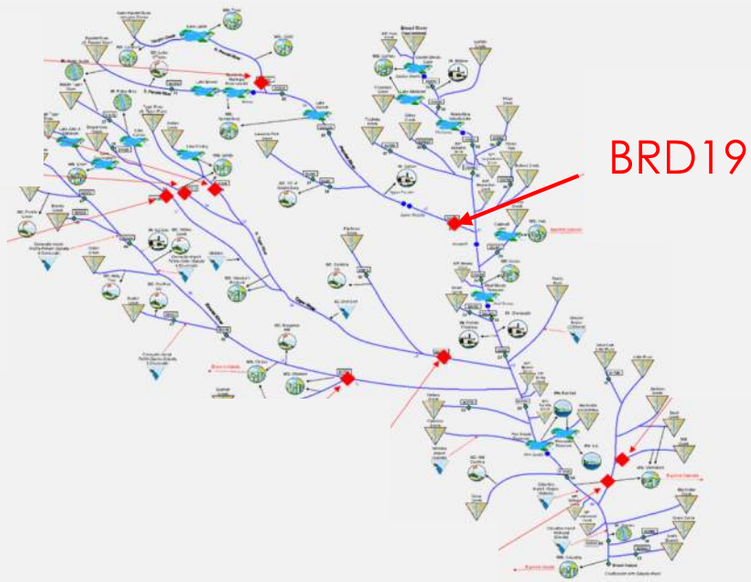


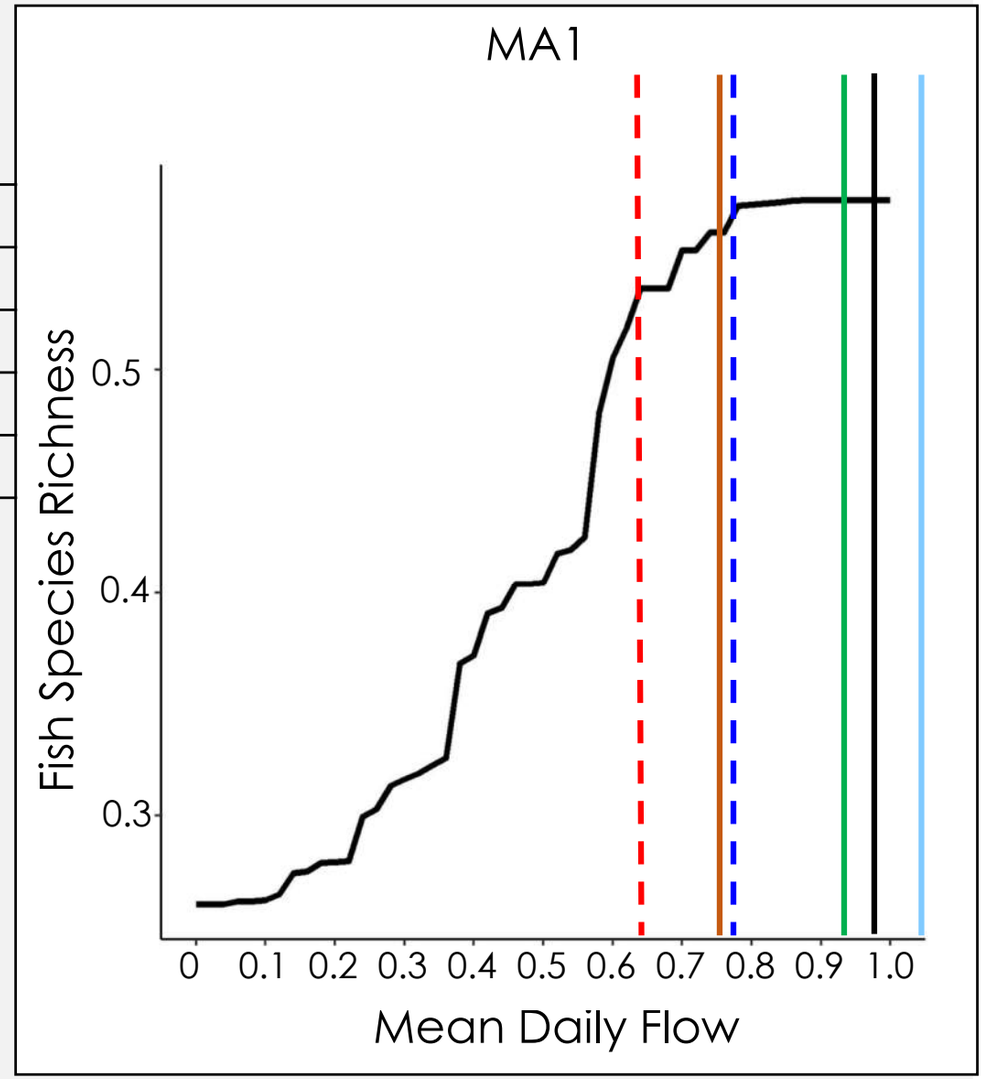
Strategic Nodes for Flow-Ecology Evaluation



Pacolet River near Saratt

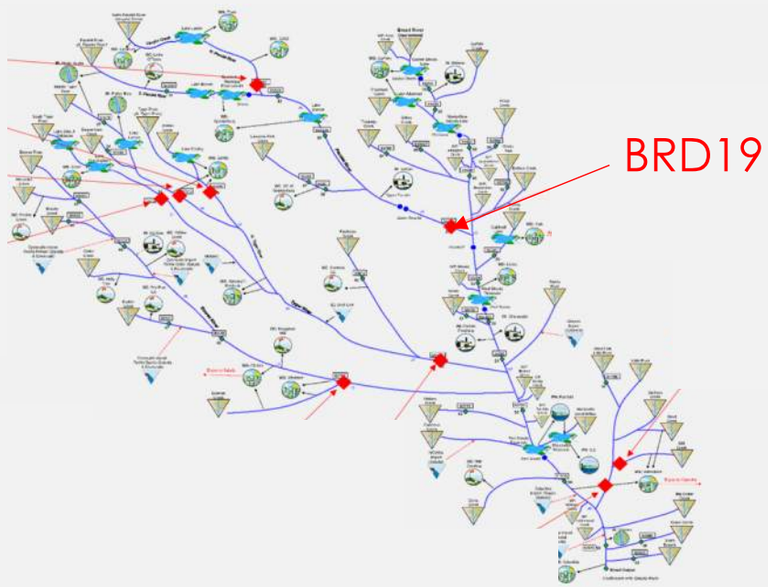
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	655.34	705.21	7.6%	Richness	6.3%	7
HD 2070	655.34	611.14	-6.7%	Richness	-5.5%	7
Full	655.34	480.85	-26.6%	Richness	-21.9%	7
MD 2070	655.34	632.96	-3.4%	Richness	-2.8%	7

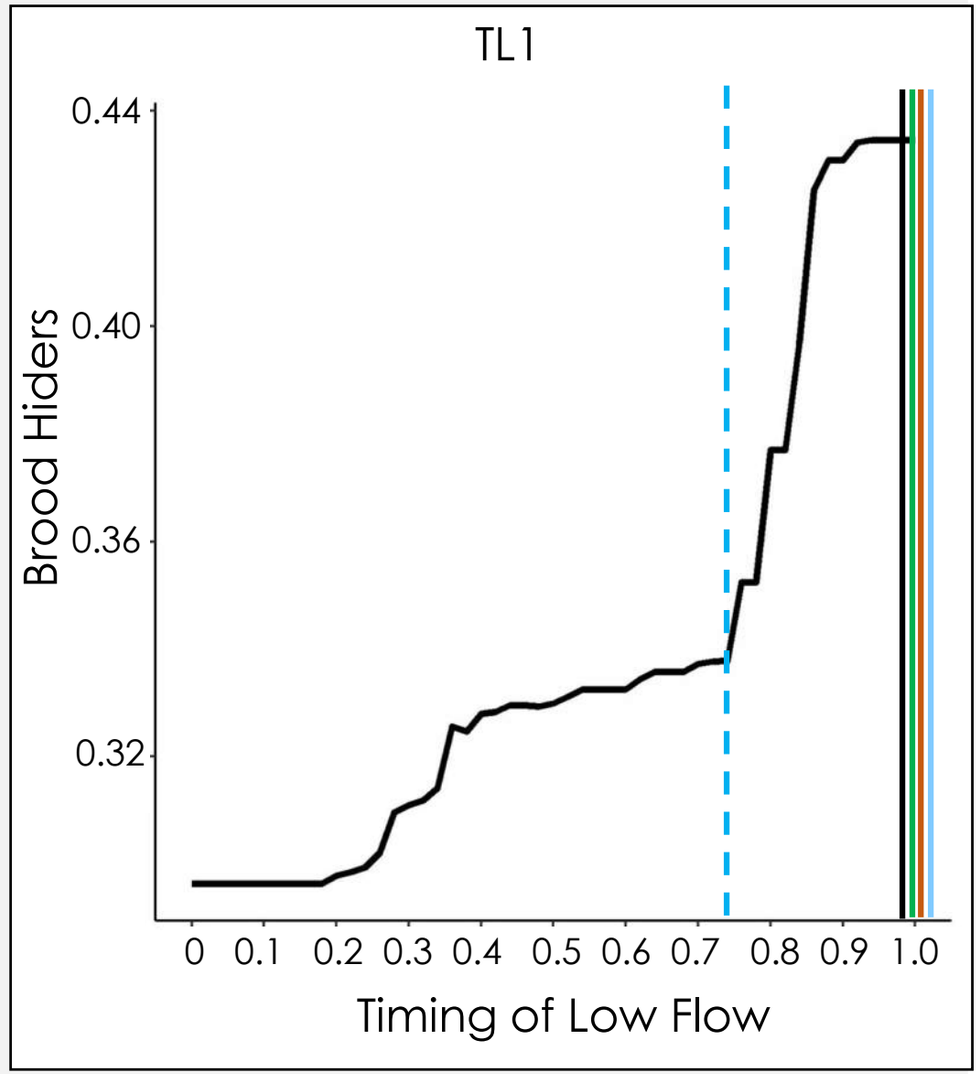




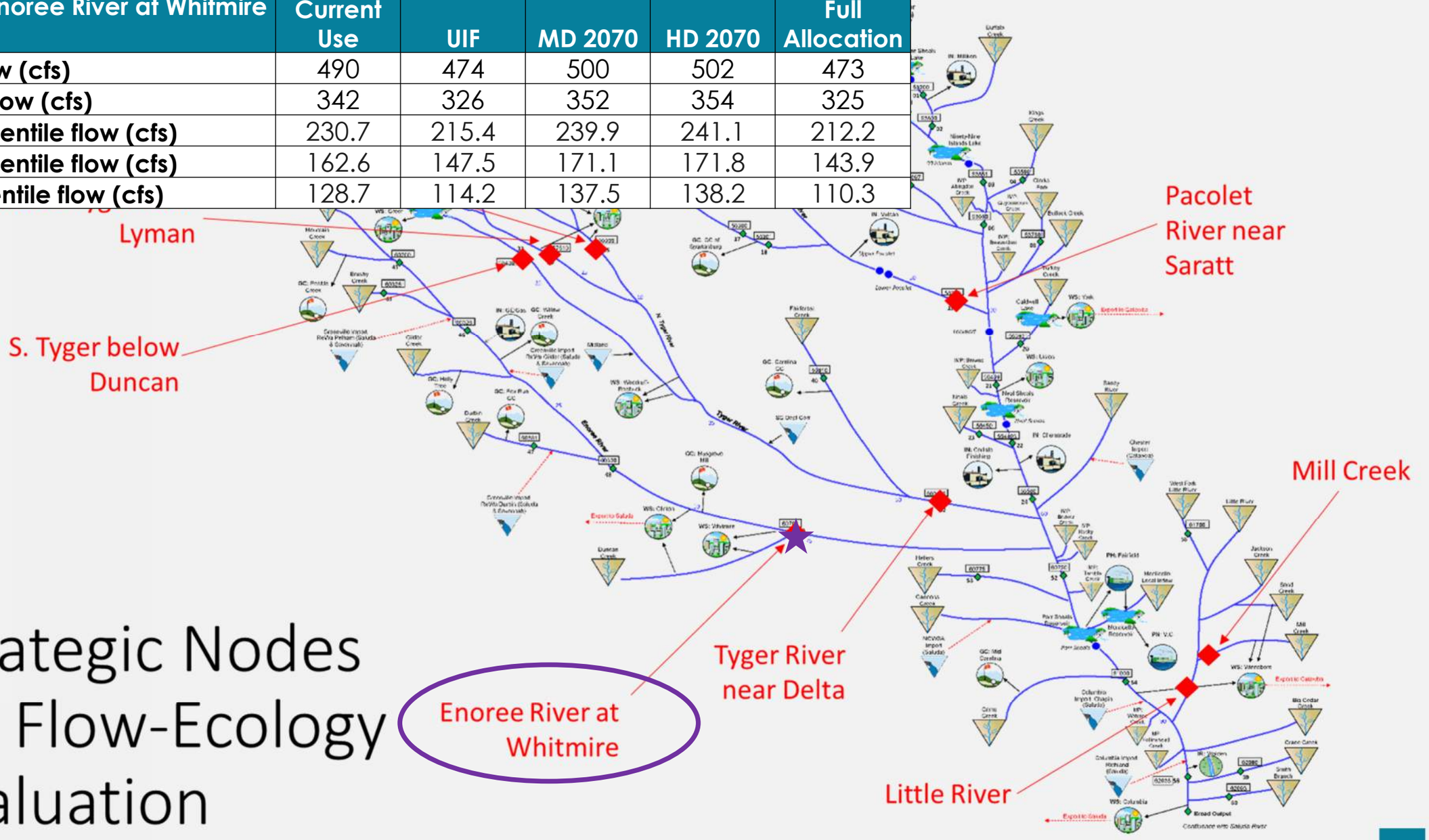
Pacolet River near Saratt

Scenario	Current	Predicted	% change
UIF	258	257	-0.4%
HD 2070	258	261	1.1%
Full	258	257	-0.4%
MD 2070	258	259	0.4%





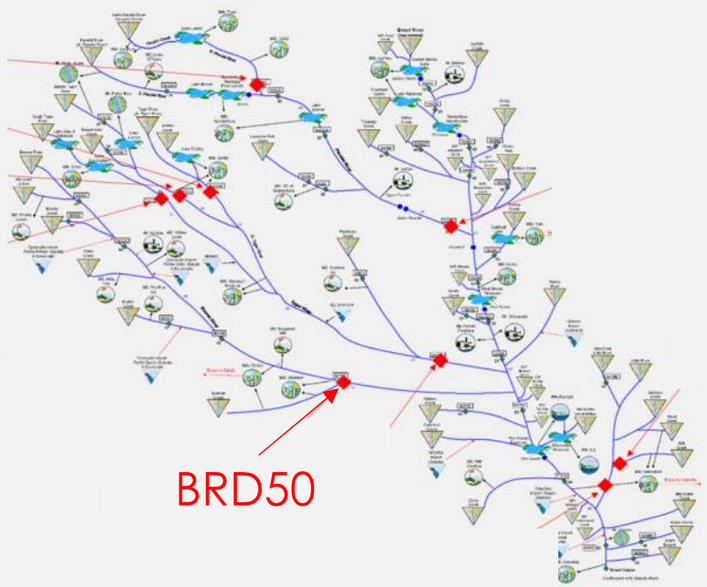
BRD50: Enoree River at Whitmire	Current Use	UIF	MD 2070	HD 2070	Full Allocation
mean flow (cfs)	490	474	500	502	473
median flow (cfs)	342	326	352	354	325
25th percentile flow (cfs)	230.7	215.4	239.9	241.1	212.2
10th percentile flow (cfs)	162.6	147.5	171.1	171.8	143.9
5th percentile flow (cfs)	128.7	114.2	137.5	138.2	110.3

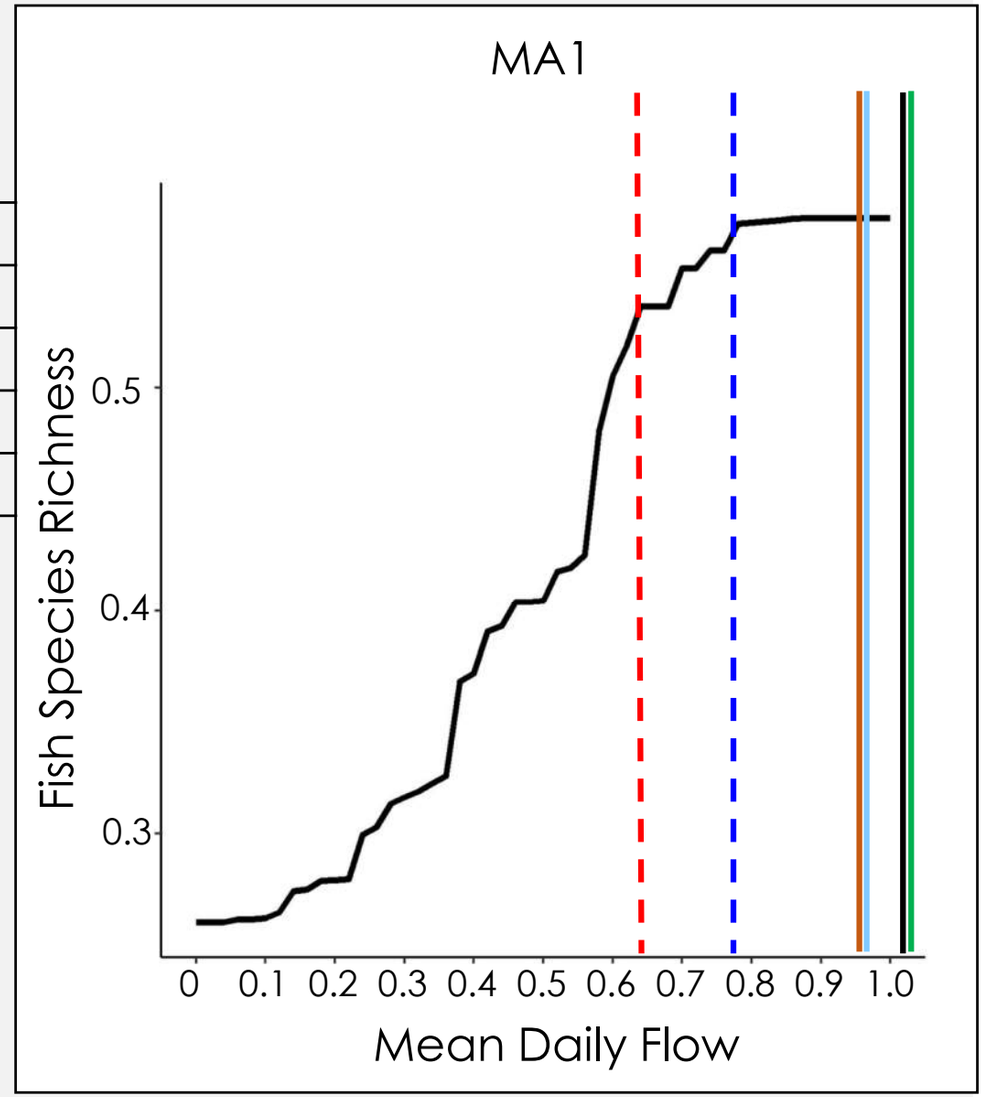


Strategic Nodes for Flow-Ecology Evaluation

Enoree River at Whitmire

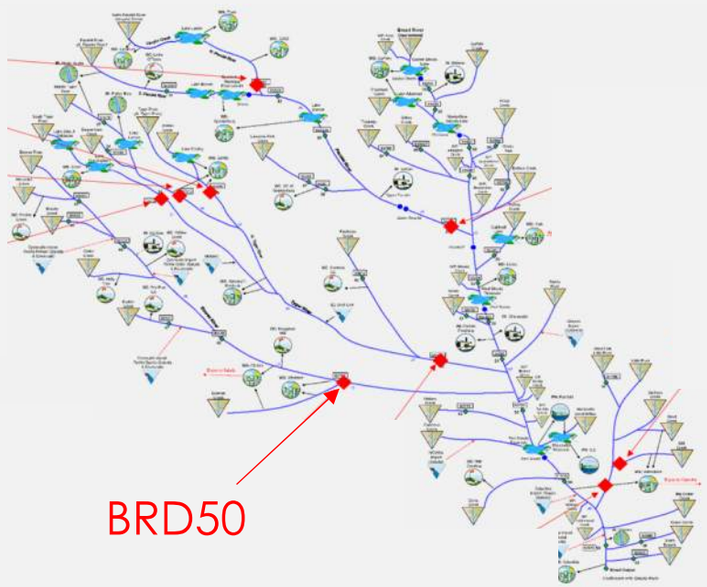
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	490.52	474.68	-3.2%	Richness	-2.7%	7
HD 2070	490.52	501.80	2.3%	Richness	1.9%	7
Full	490.52	473.26	-3.5%	Richness	-2.9%	7
MD 2070	490.52	500.12	1.9%	Richness	1.6%	7

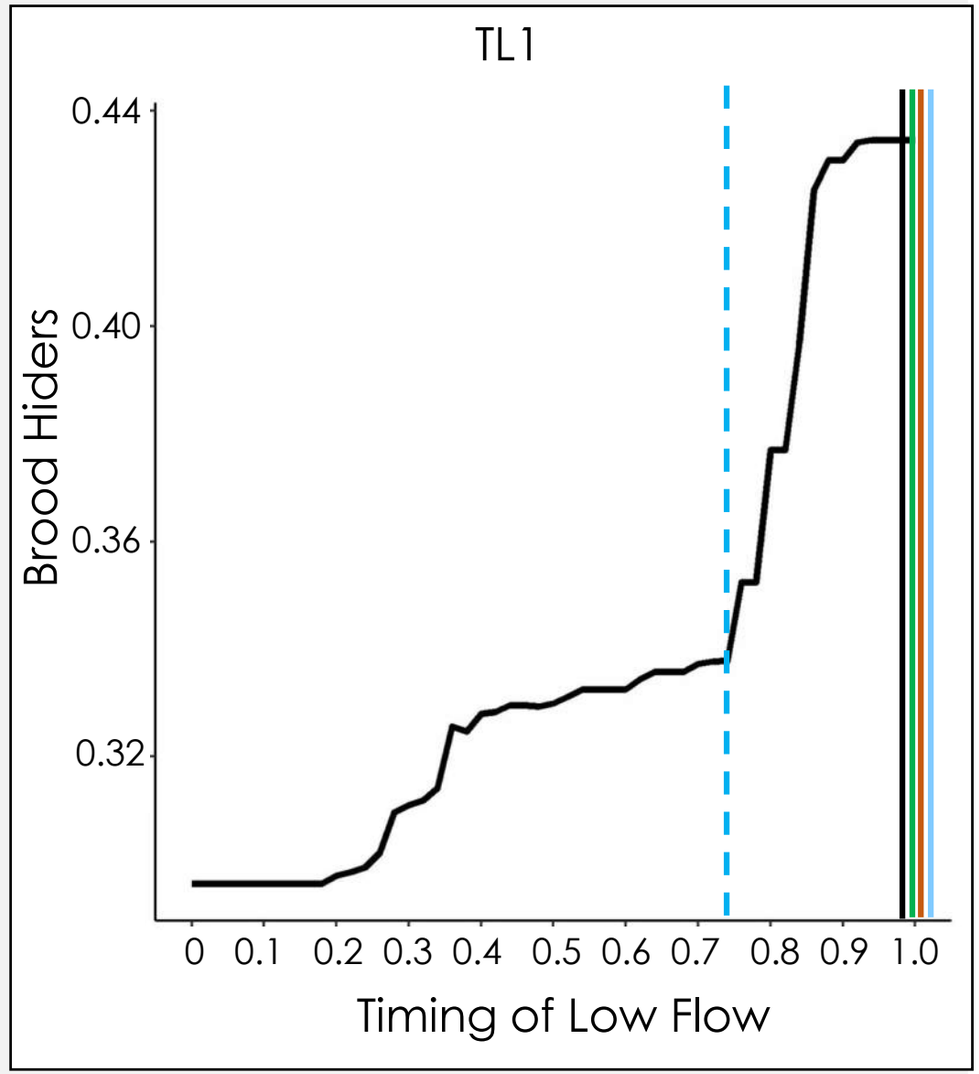




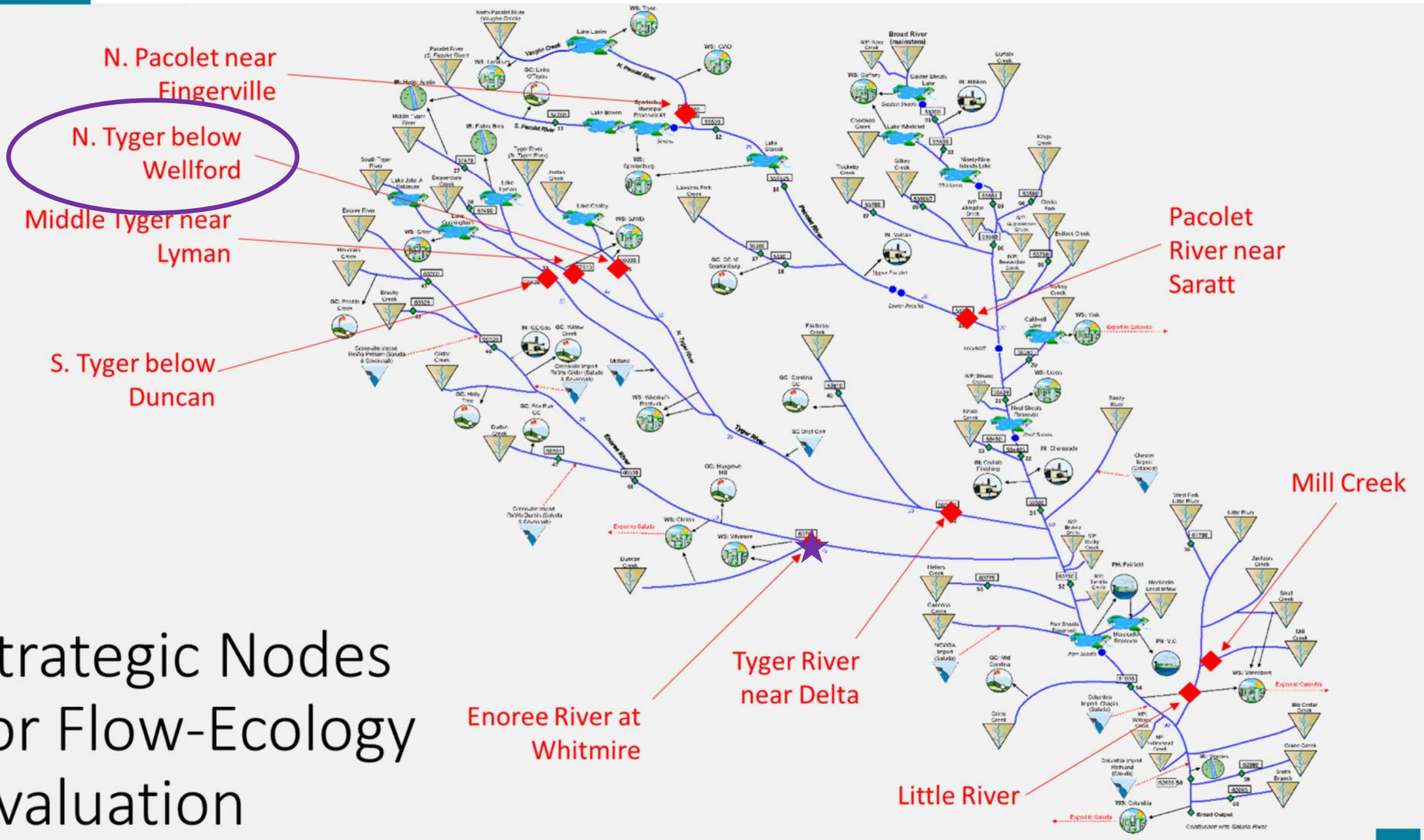
Enoree River at Whitmire

Scenario	Current	Predicted	% change
UIF	256	257	0.4%
HD 2070	256	257	0.4%
Full	256	257	0.4%
MD 2070	256	256	0%



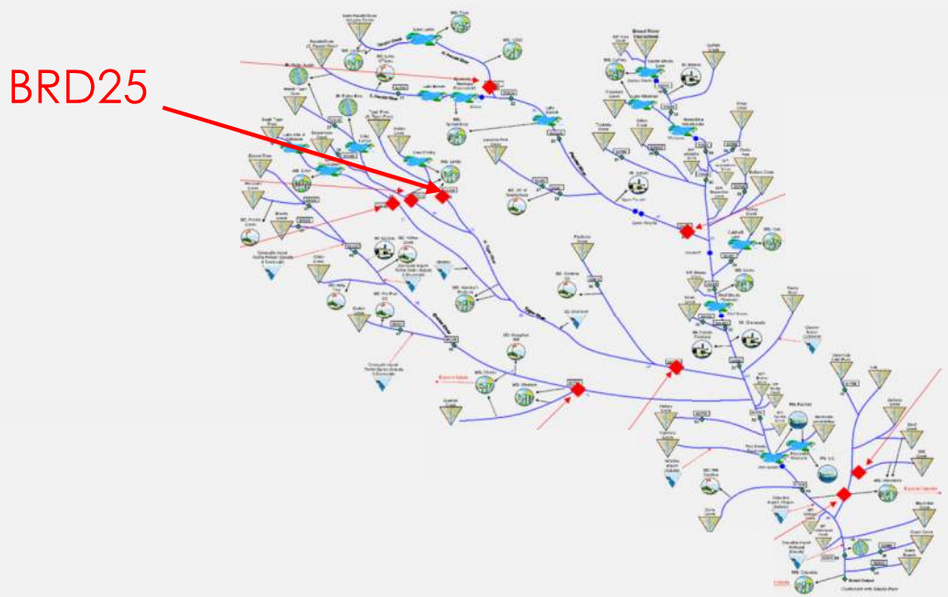


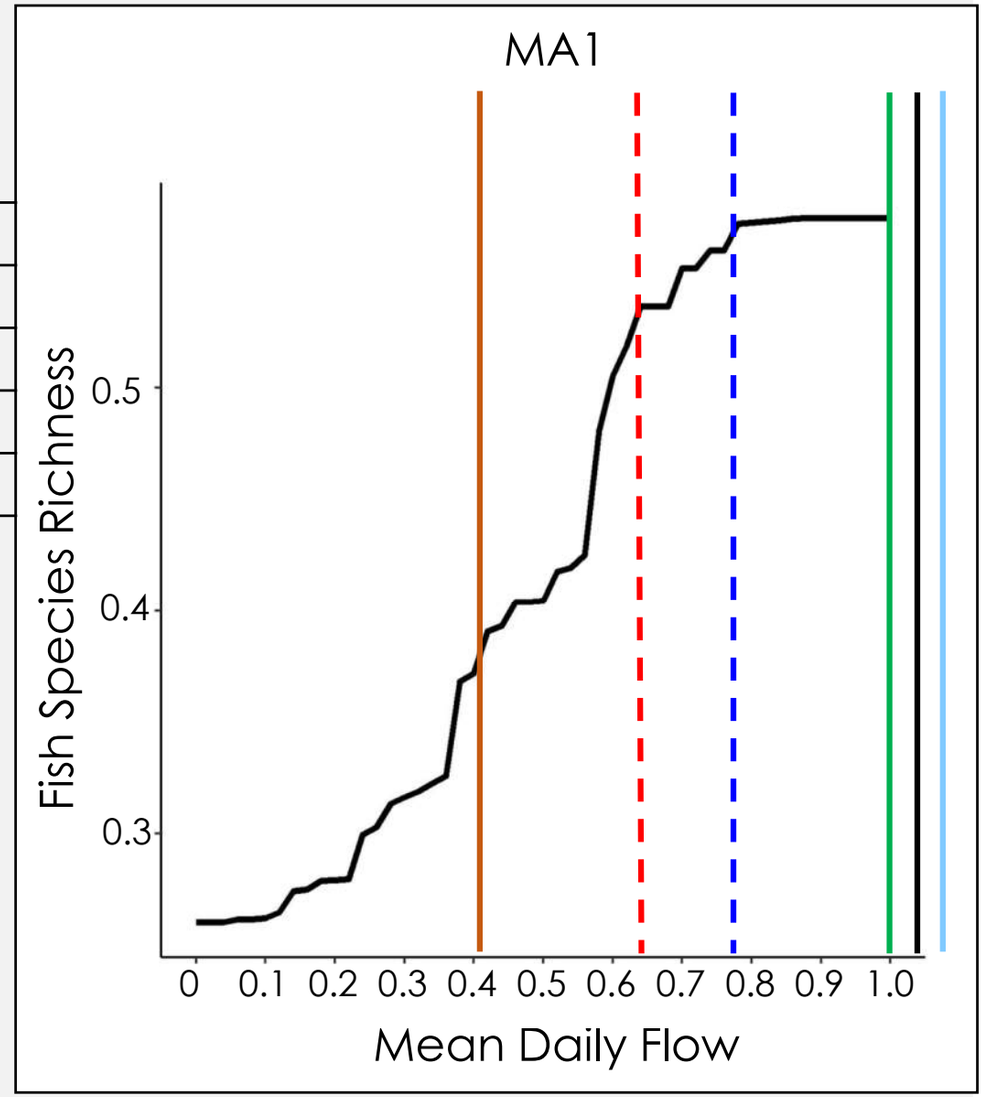
Strategic Nodes for Flow-Ecology Evaluation



N. Tyger River below Wellford

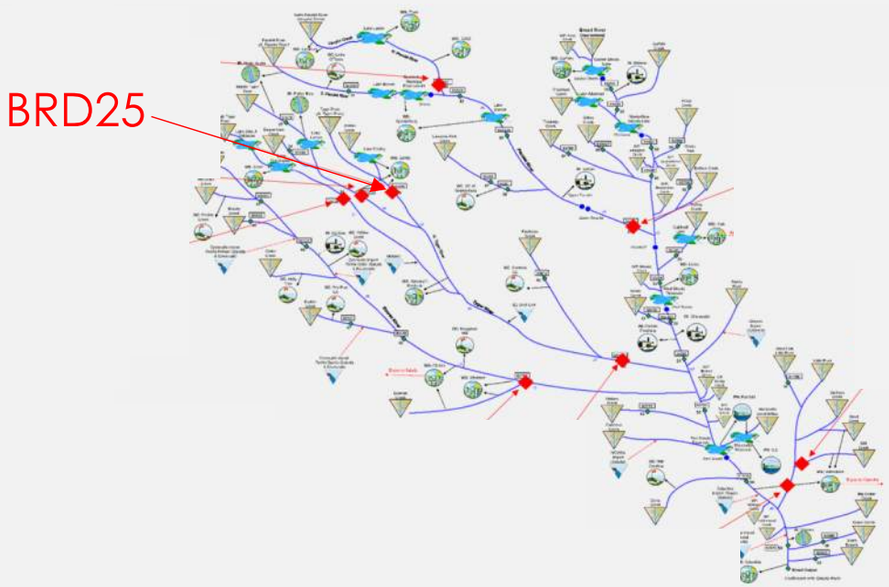
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	47.12	51.45	9.2%	Richness	7.6%	7
HD 2070	47.12	47.24	0.3%	Richness	0.2%	7
Full	47.12	18.29	-61.2%	Richness	-50.3%	7
MD 2070	47.12	49.84	5.8%	Richness	4.7%	7

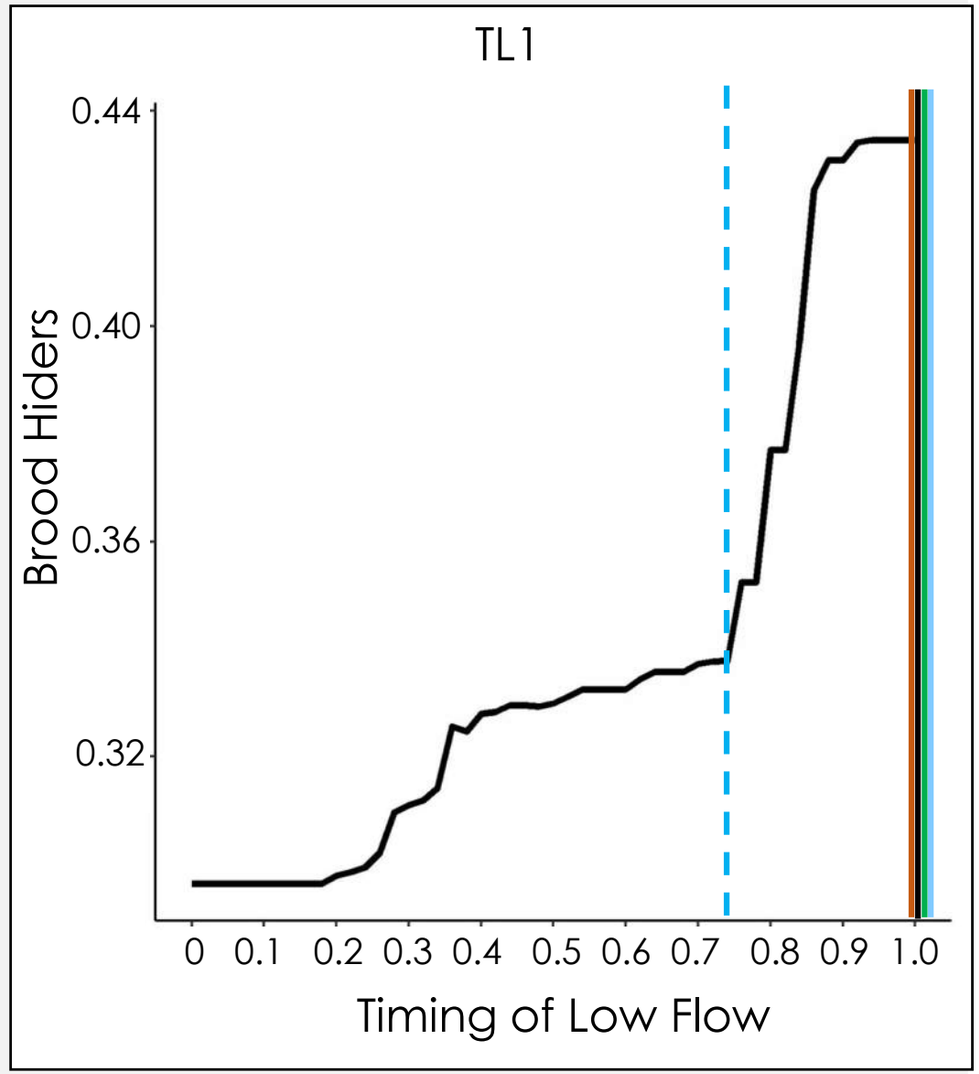


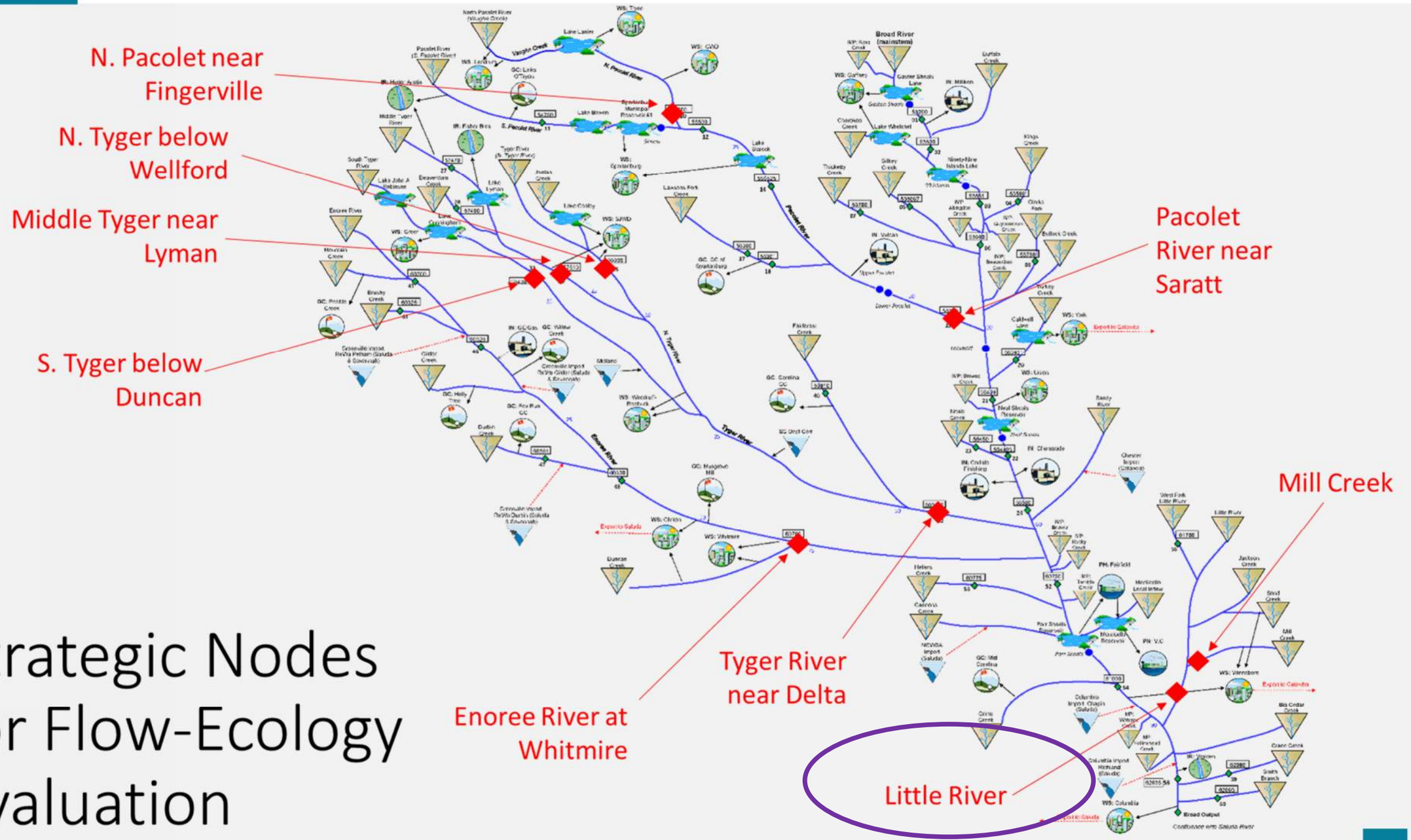


N. Tyger River below Wellford

Scenario	Current	Predicted	% change
UIF	253	257	1.6%
HD 2070	253	256	1.2%
Full	253	255	0.8%
MD 2070	253	254	0.4%



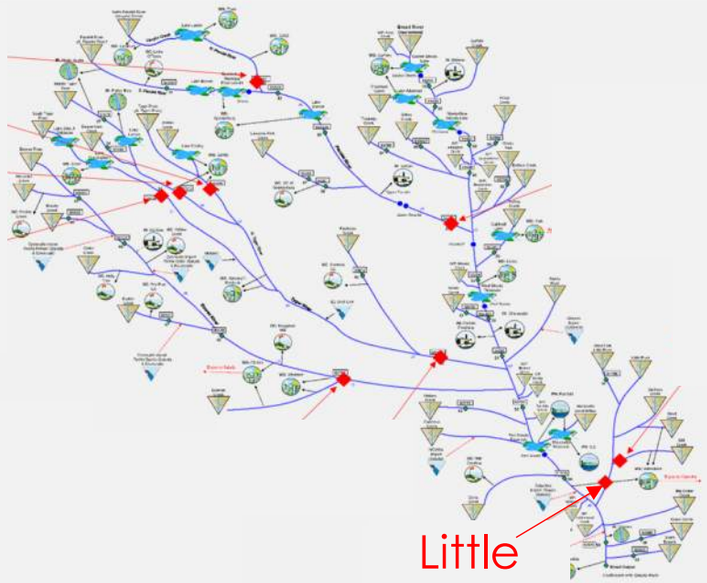


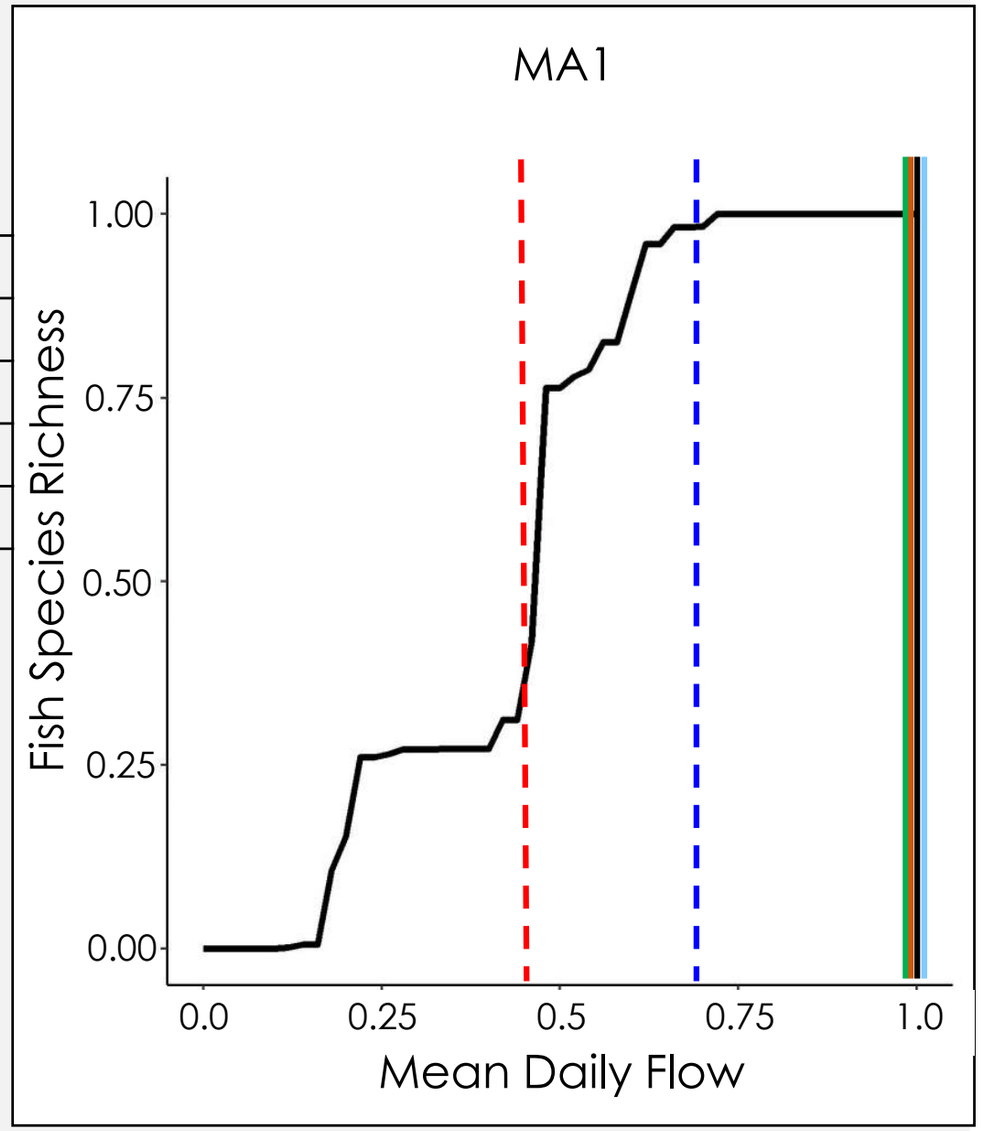


Strategic Nodes for Flow-Ecology Evaluation

Little River

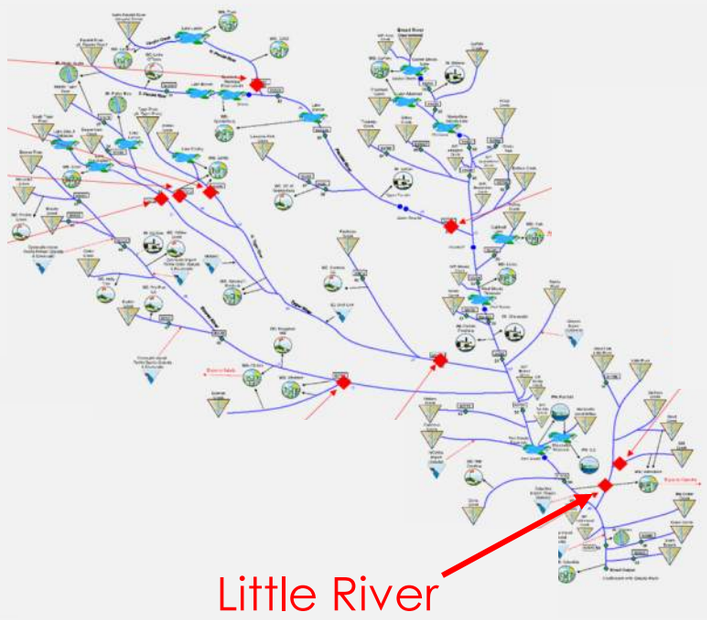
Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	236.41	238.41	0.7%	Richness	0.5%	9
HD 2070	236.41	235.82	-0.4%	Richness	-0.3%	9
Full	236.41	236.12	-0.3%	Richness	-0.2%	9
MD 2070	236.41	236.85	0.1%	Richness	0.0%	9

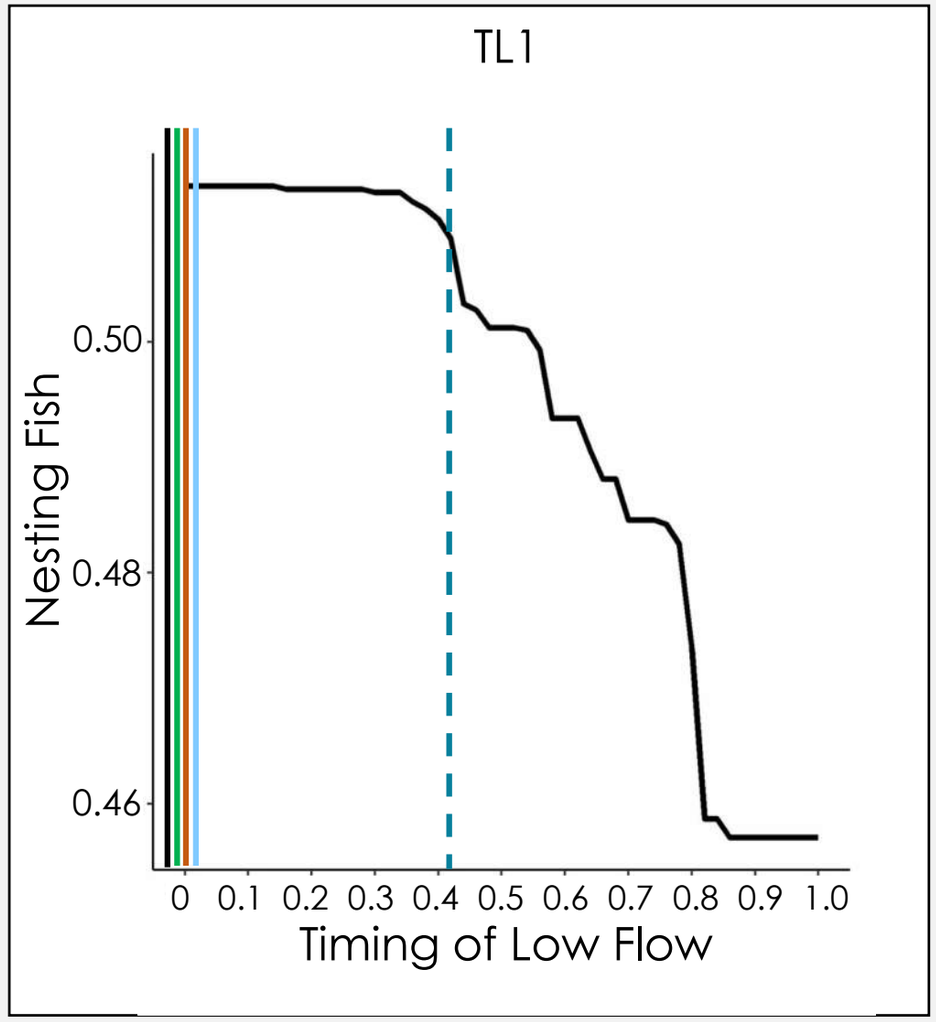




Little River

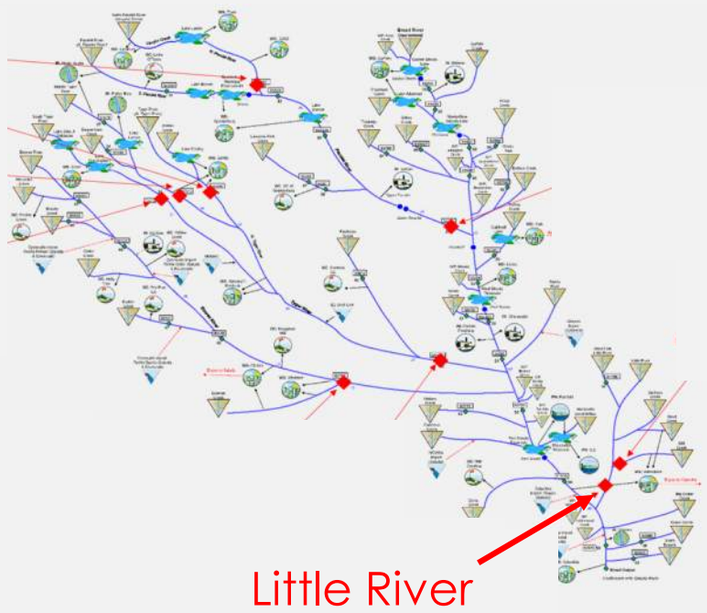
Scenario	Current	Predicted	% change
UIF	254	254	0%
HD 2070	254	253	-0.4%
Full	254	253	-0.4%
MD 2070	254	254	0%

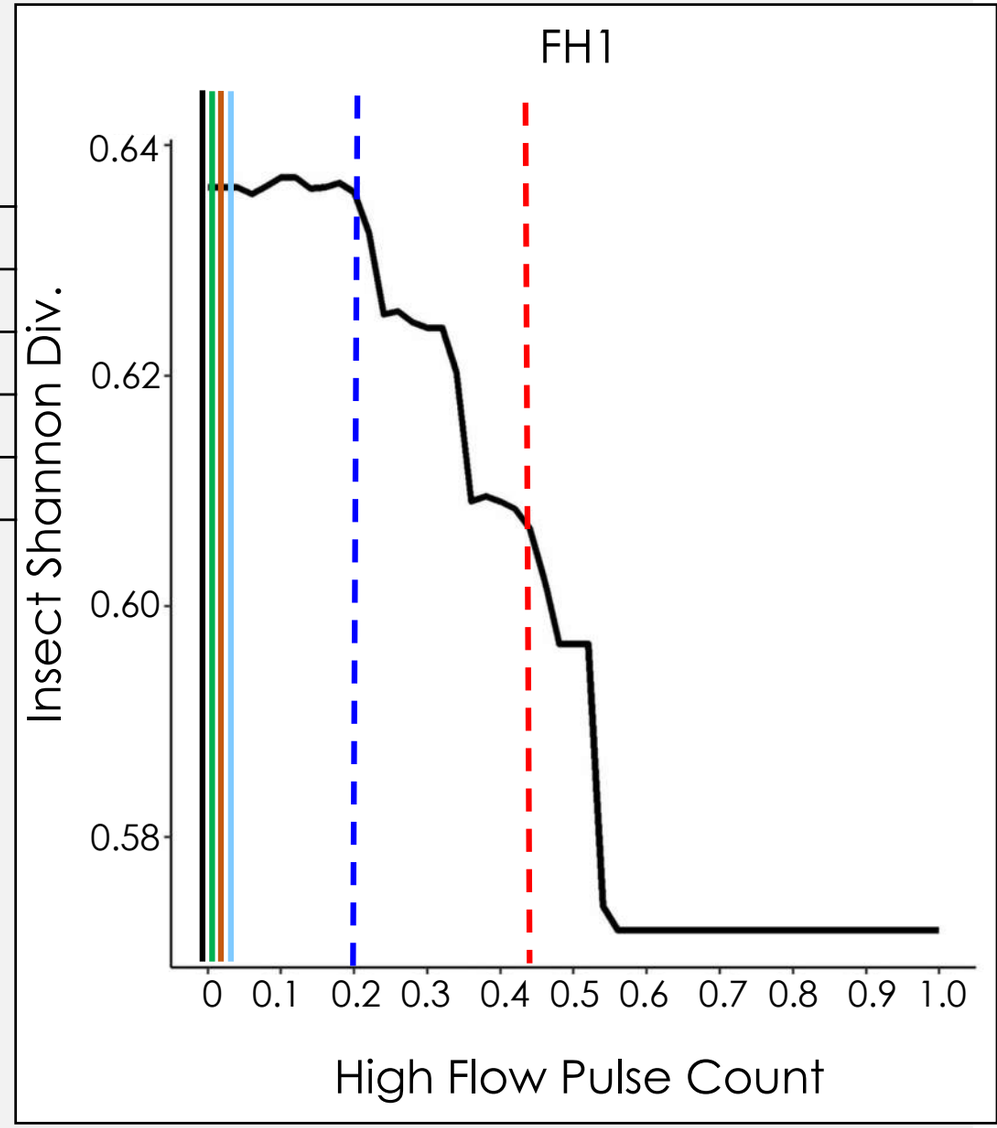




Little River

Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	16.1	16.1	-0.1%	Insect Shan.	0.04%	17
HD 2070	16.1	16.0	-0.4%	Insect Shan.	0.23%	17
Full	16.1	16.1	-0.1%	Insect Shan.	0.13%	17
MD 2070	16.1	16.1	-0.1%	Insect Shan.	0.04%	17





Little River

Scenario	Current	Predicted	% change	Bio Metric	Change in Bio	SE
UIF	4.6	4.6	0.0%	Nest Spawn	0.0%	15
HD 2070	4.6	4.4	-0.04%	Nest Spawn	4.5%	15
Full	4.6	4.4	-0.04%	Nest Spawn	4.5%	15
MD 2070	4.6	4.6	0.0%	Nest Spawn	0.0%	15