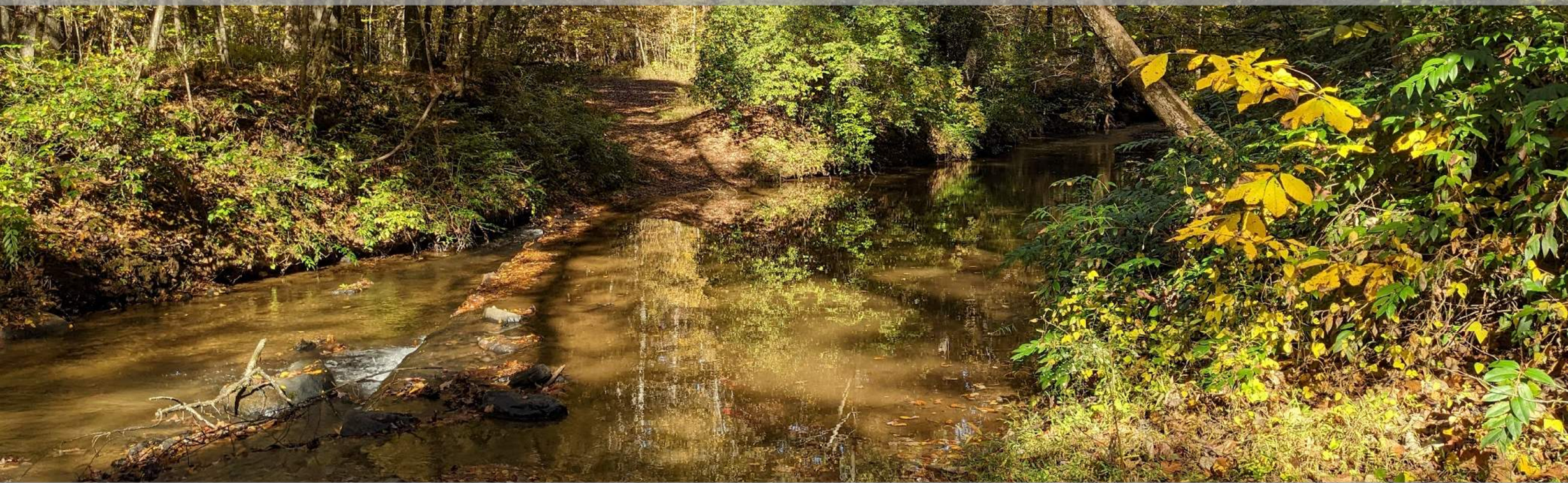
# Flow-Ecology Relationships

Upper Savannah RBC: May, 2024

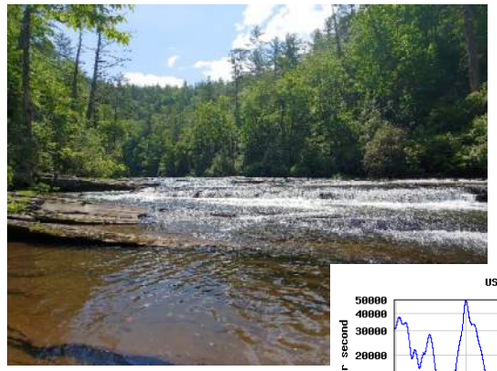


Drs. Brandon Peoples, Luke Bower, and Joe Mruzek

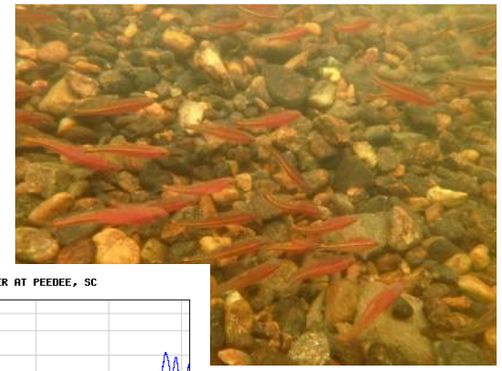
# Flow-Ecology Relationships

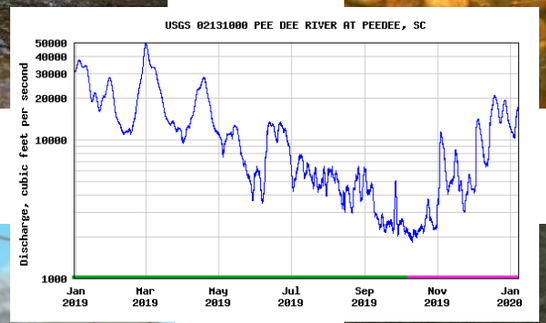
- In stream flow is critical for aquatic communities
- “Master variable”

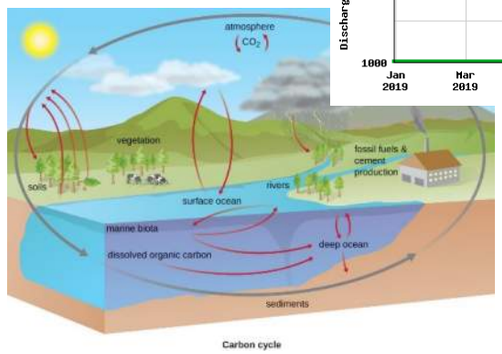
Water quality



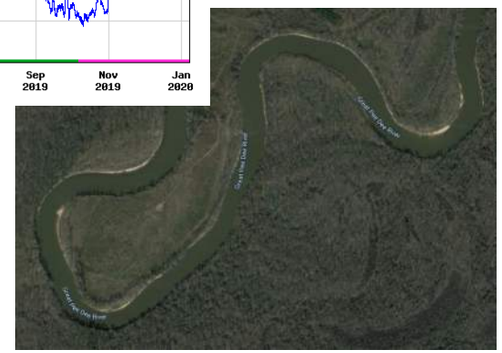
Organisms






Energy cycling



Physical habitat

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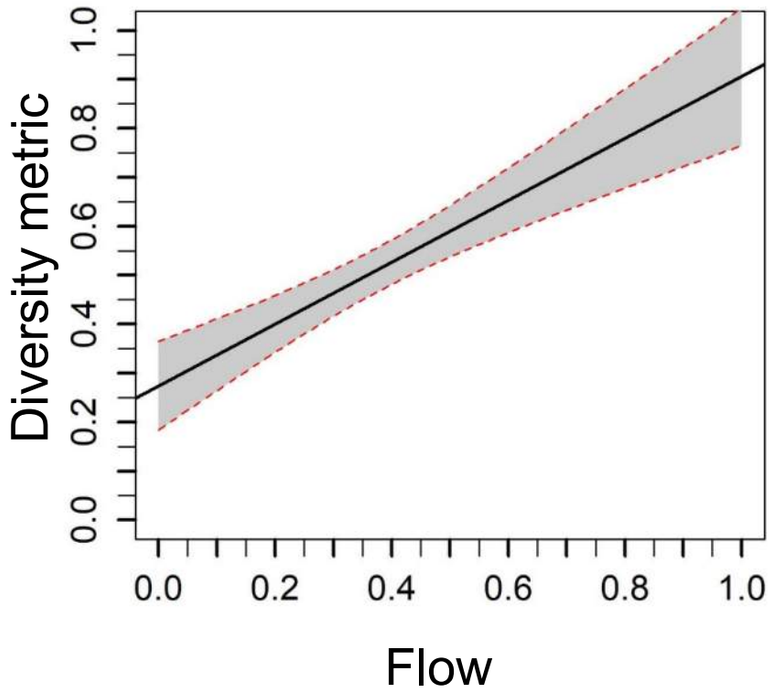
# Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina

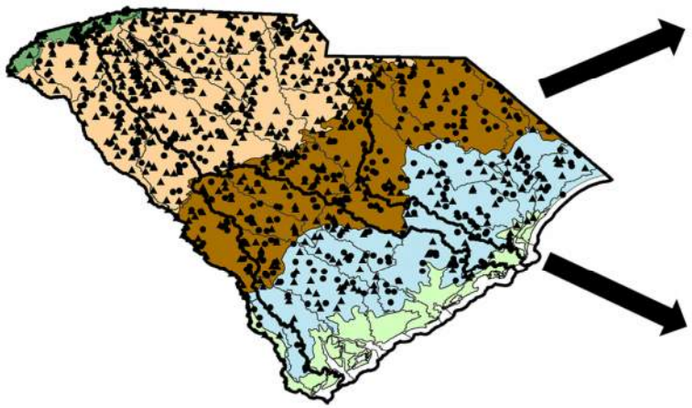
Luke M. Bower [a,*], Brandon K. Peoples [b], Michele C. Eddy [c], Mark C. Scott [d]

- Goal: to provide insight on the potential response of organisms to the alternate water withdrawal scenarios produced by SWAM.
  - We aim to put the SWAM results into a biological context in aquatic communities

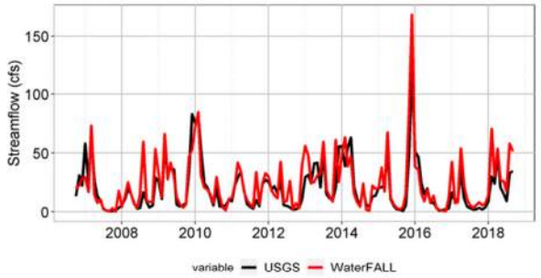


# How will this work? Step 1

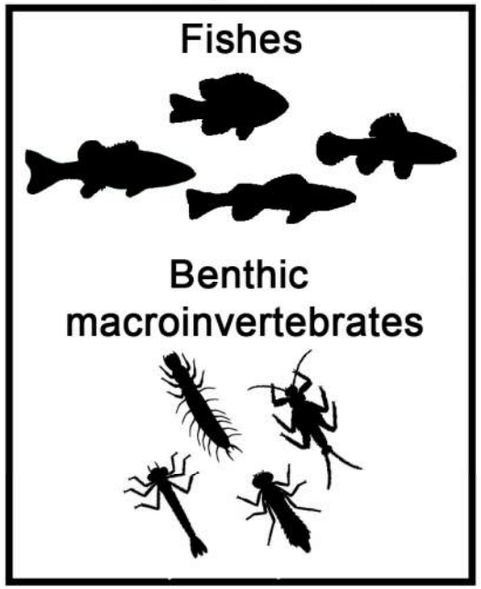
Timing, magnitude, frequency, rate of change, and duration

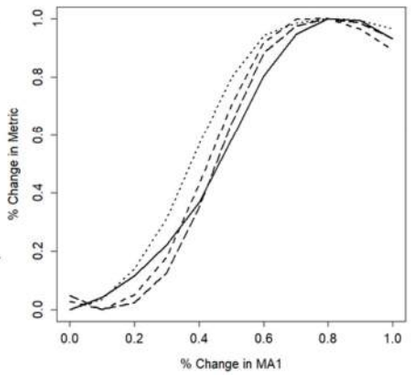


Hydrologic data




Biological data



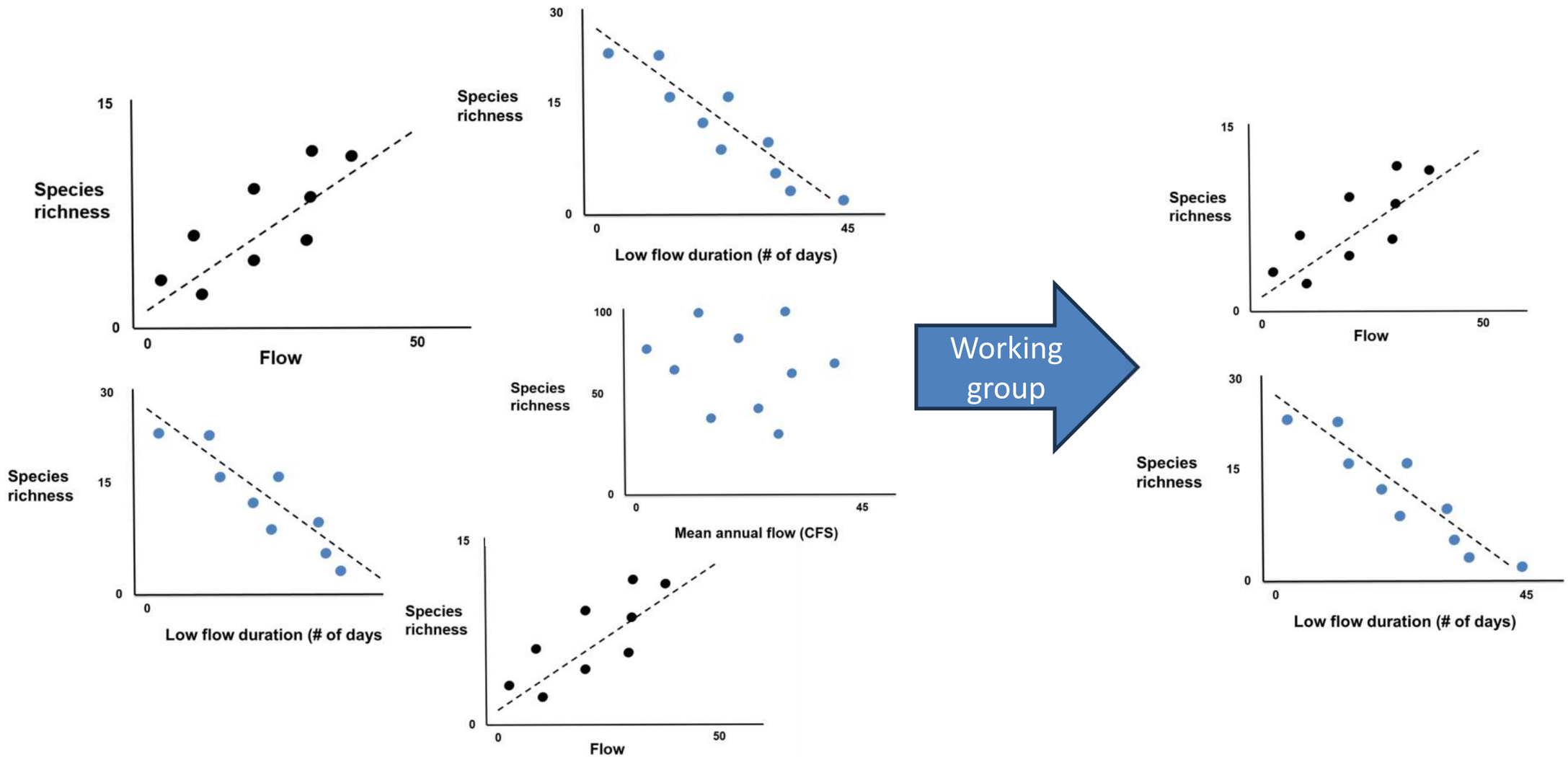




Flow-ecology relationships

1) All flow regime components affect aquatic organism

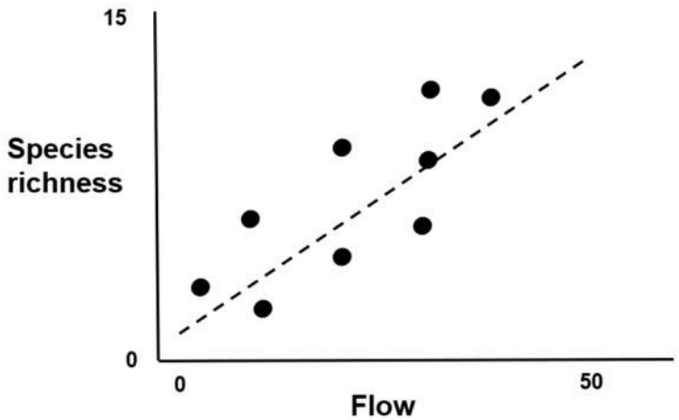
2) Relationships differ across stream classes

# How will this work? Step 2



# How will this work? Step 3

Selected relationships

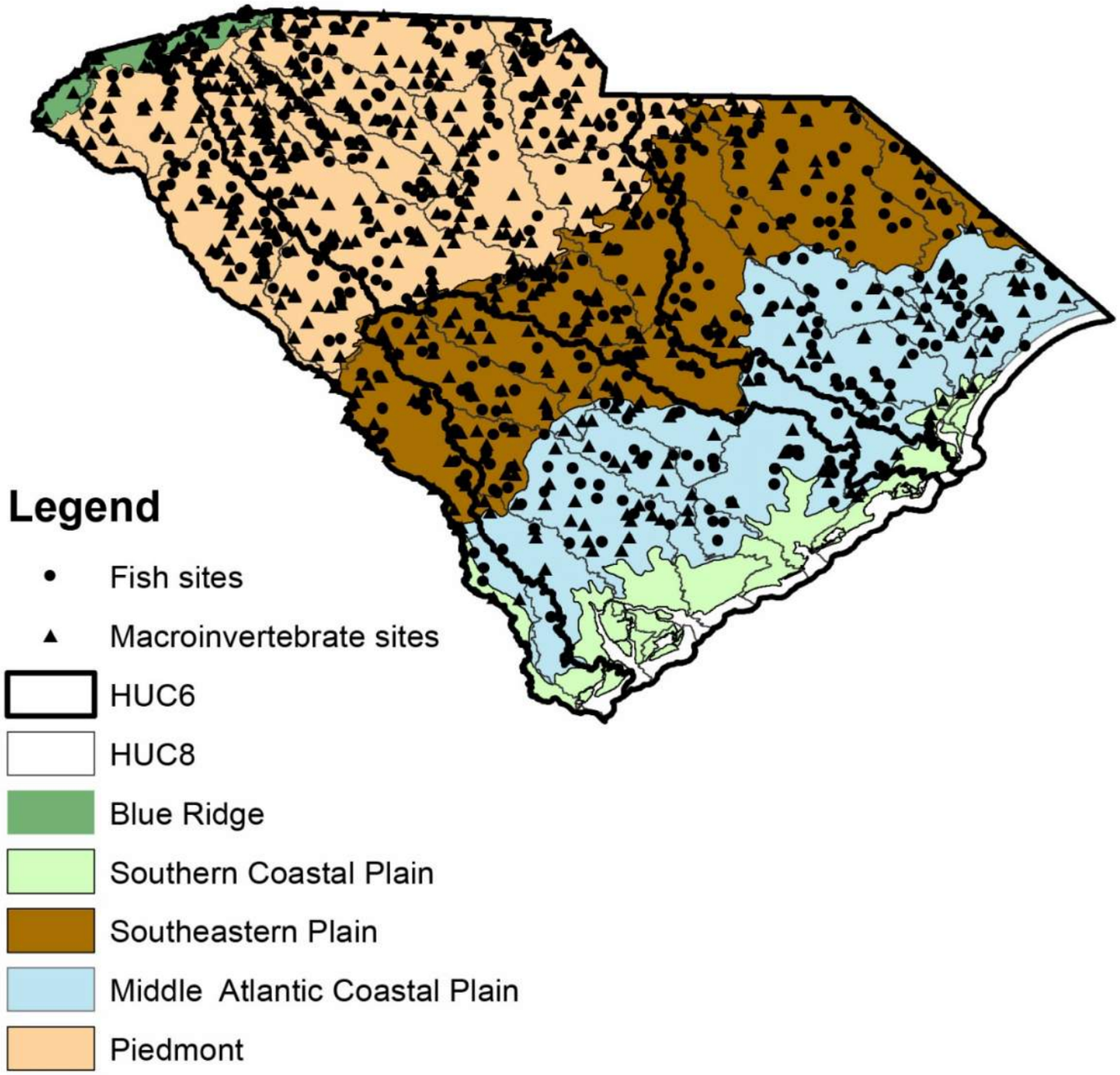



SWAM results

| Scenario | Current | Predicted | % Change |
|---|---|---|---|
| MD | 100 | 80 | 20% |
| HD | 100 | 60 | 40% |

**View SWAM results in a biological context**

| Scenario | Loss of species | Risk |
|---|---|---|
| MD | 15% | Med |
| HD | 25% | High |

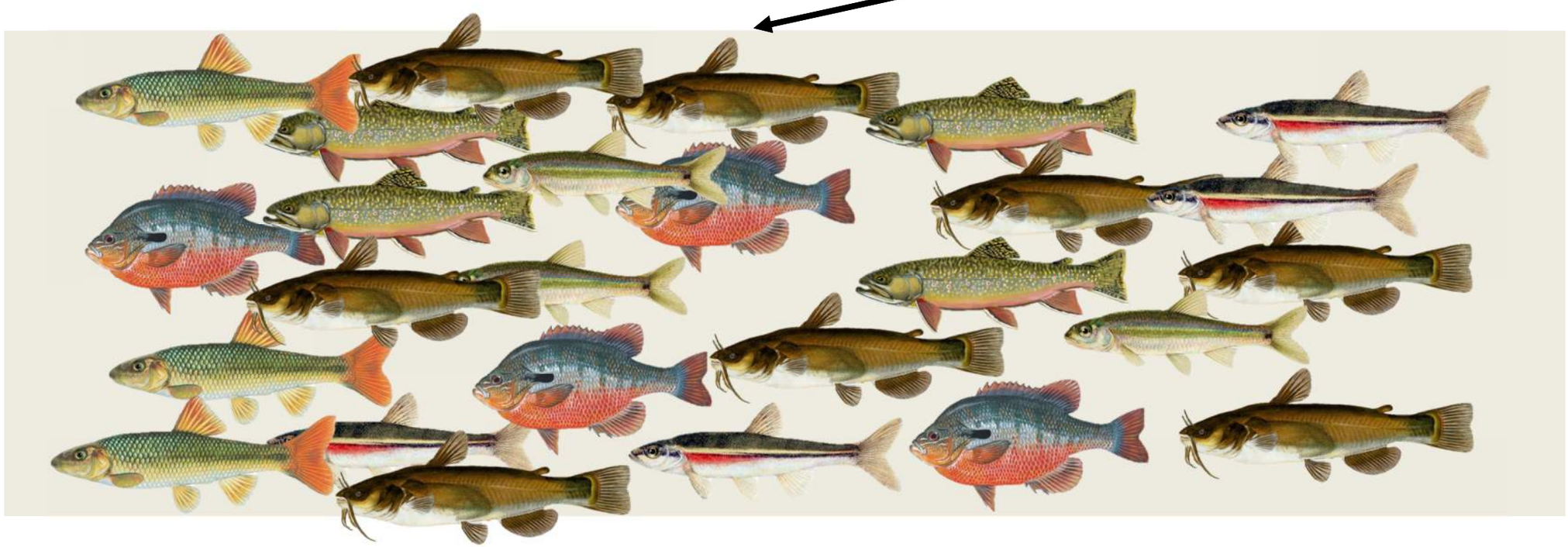



# Biological Data:

- 492 Fish sites (streams & rivers)
  - DNR
  - 8 biological response metrics
- 530 aquatic insect sites
  - DHEC
  - 6 biological response metrics

# Characterizing aquatic diversity

- **Species richness:** number of species
- **Shannon's Diversity:** Accounts for <u>percentages</u>




Diverse biota = healthy ecosystem

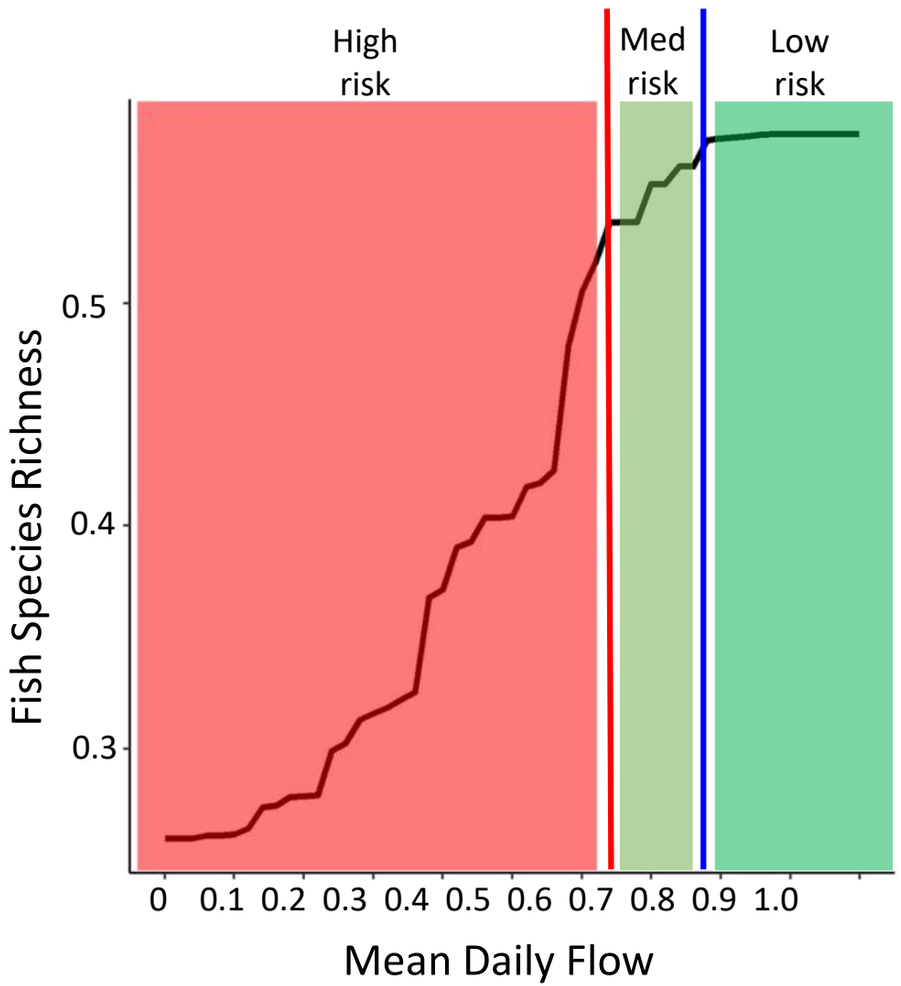
# How can we use these relationships?

- 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

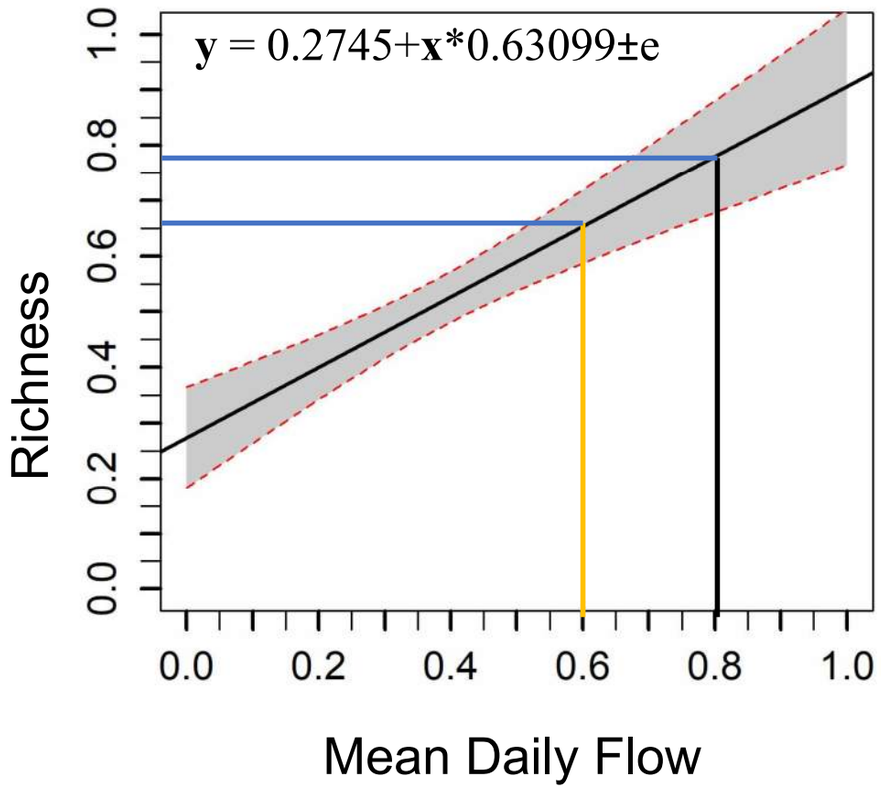
- Predicting responses
  - If we alter flow by X amount what will be the biological response?

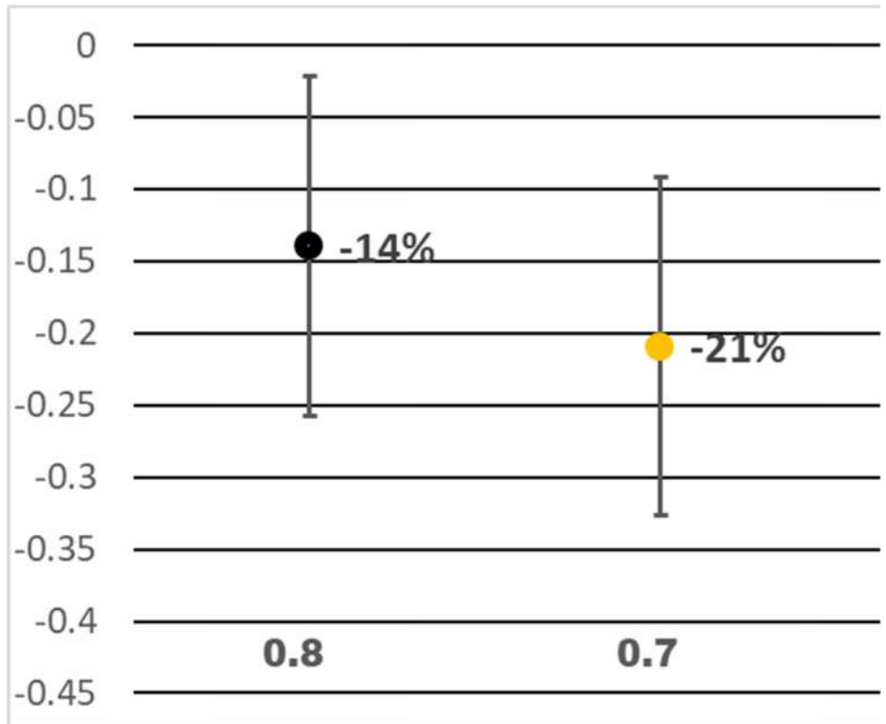
# Mean daily flow (MA1): biological response limits

- Lines defined by working group
- Performance measure



# Mean daily flow (MA1): predictions




| Scenario | Current | Predicted | % Change |
|---|---|---|---|
| MD | 100 | 80 | 20% |
| HD | 100 | 60 | 40% |

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

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

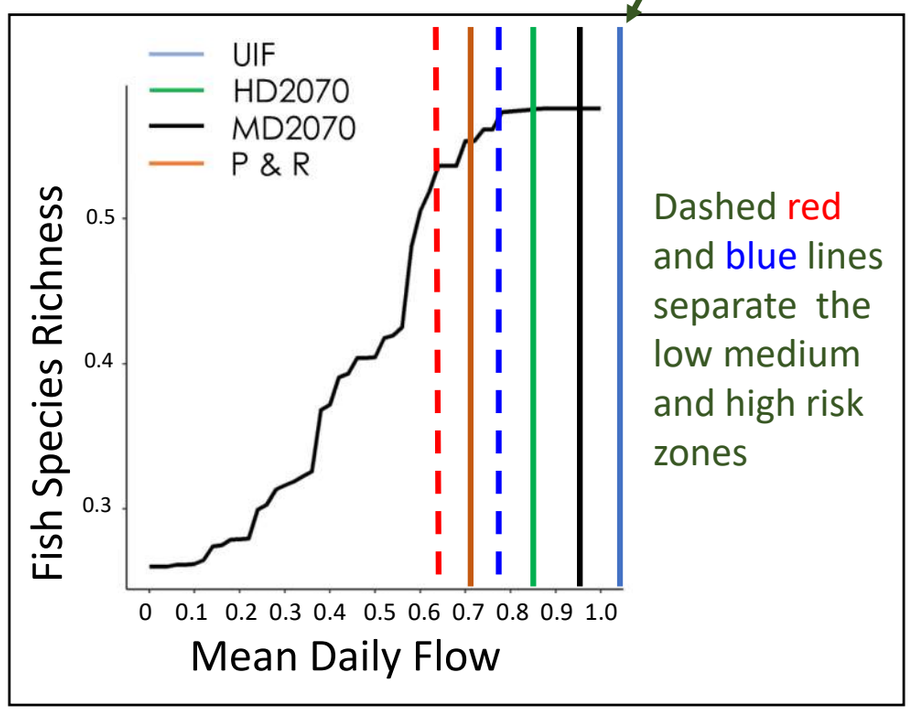
| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 320 | 368.91 | 15.4% | Richness | Low |
| MD 2070 | 320 | 283.39 | -11.3% | Richness | Low |
| HD 2070 | 320 | 257.78 | -19.4% | Richness | Low |
| P&R | 320 | 227.65 | -28.8% | Richness | Med |

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

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

95% Confidence Interval

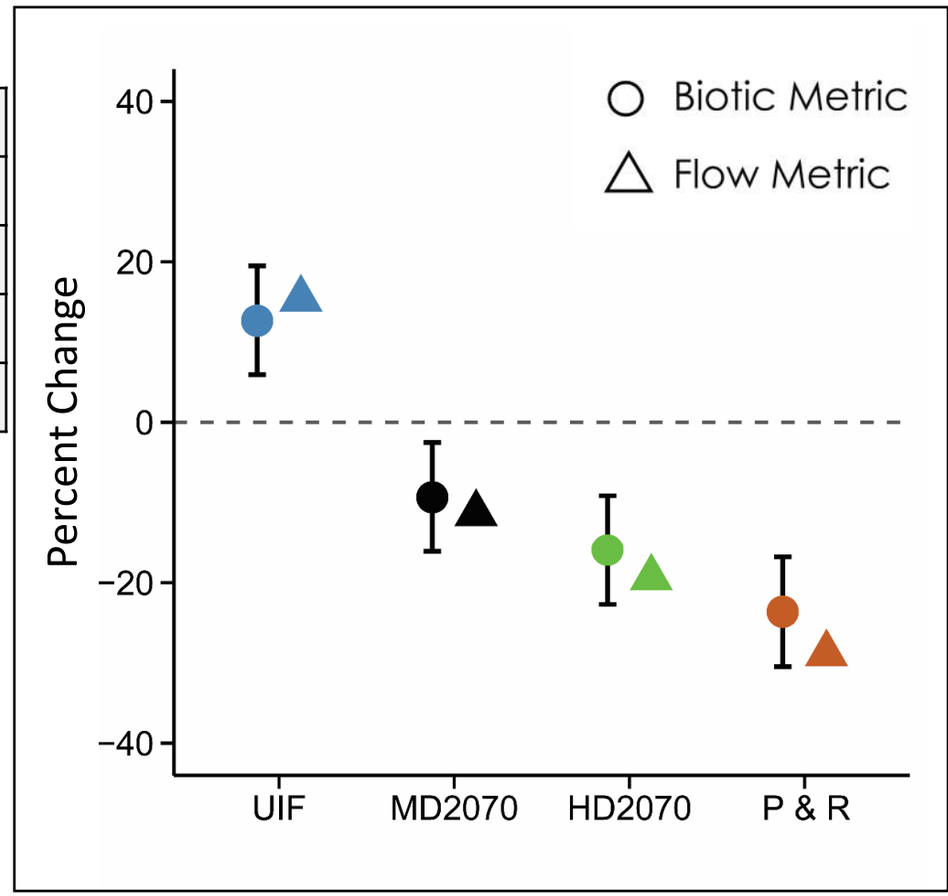
**Mean daily flow (MA1): N. Pacolet near Fingerville**

| Scenario | Current | Predicted | % change | Bio Metric | Change in Bio | 95ci |
|---|---|---|---|---|---|---|
| UIF | 320 | 368.91 | 15.4% | Richness | 12.7% | 7 |
| MD 2070 | 320 | 283.39 | -11.3% | Richness | -9.3% | 7 |
| HD 2070 | 320 | 257.78 | -19.4% | Richness | -15.9% | 7 |
| P&R | 320 | 227.65 | -28.8% | Richness | -23.6% | 7 |

Current Use Scenario Mean Daily Flow

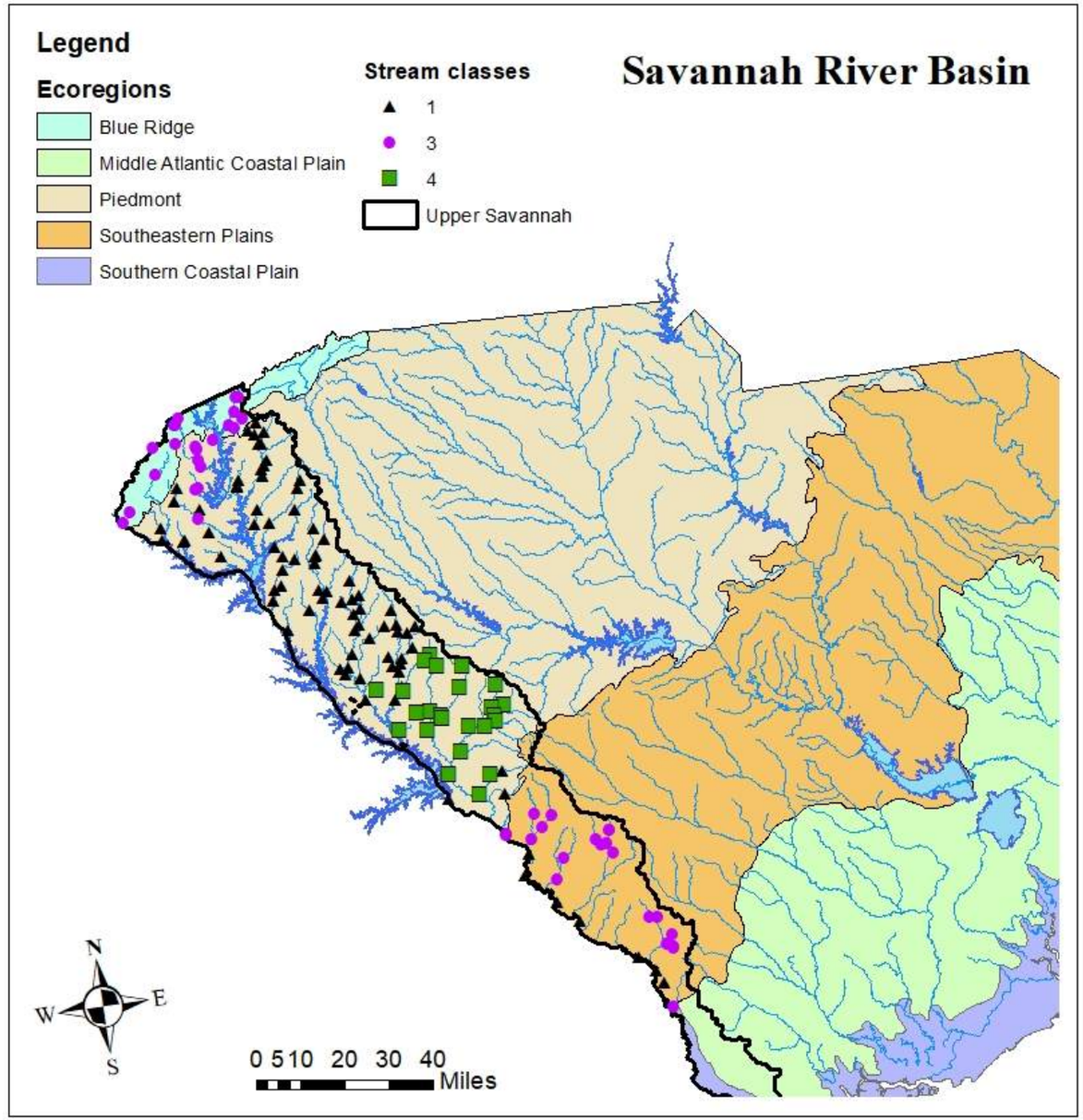
Scenario Mean Daily Flows

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



# Ecoregions

- ~~Blue Ridge: Mountainous~~
- Piedmont: Rolling hills
- ~~Southeastern plains: Flatter, well drained sandy soils~~

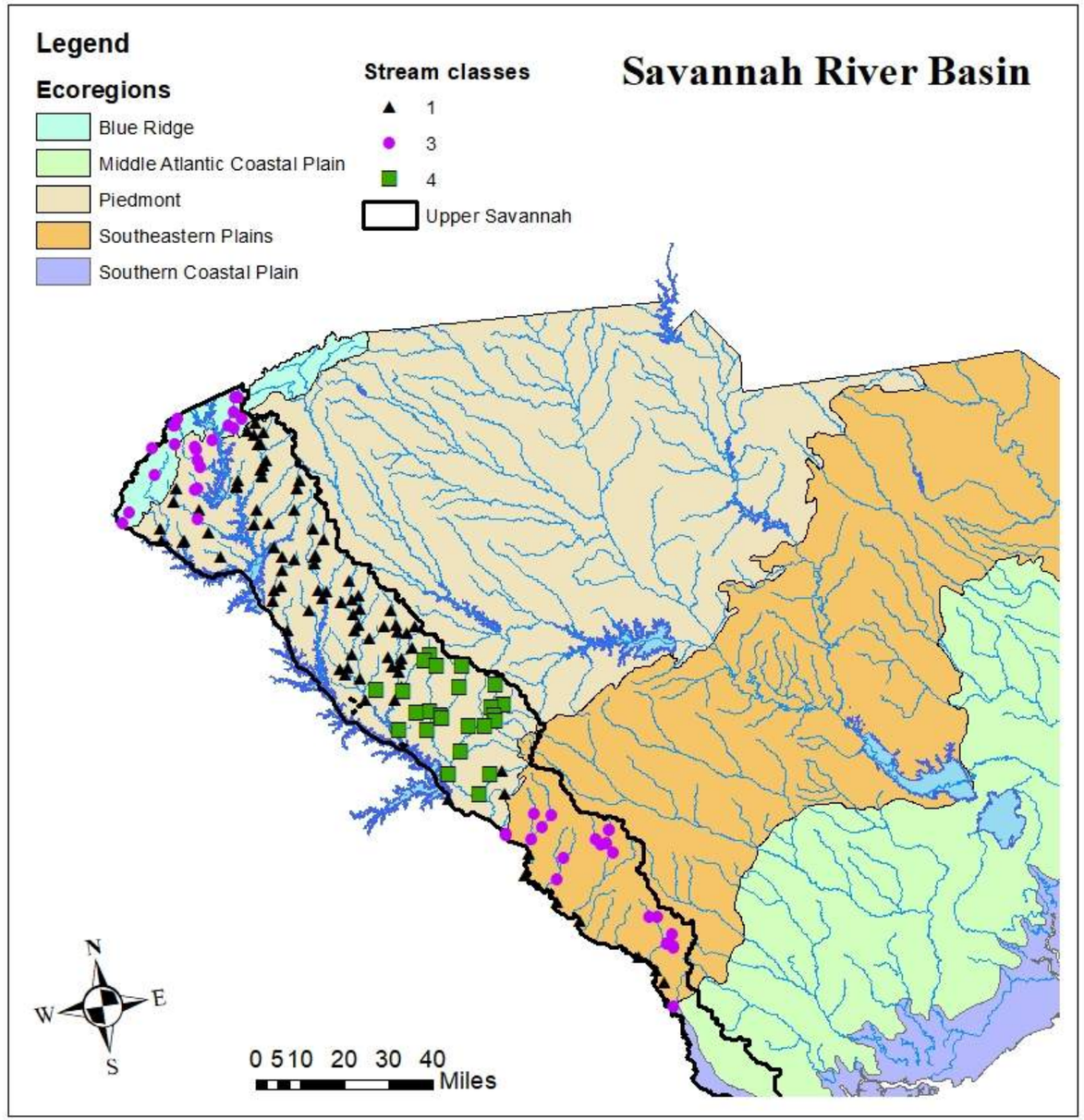


# Stream Classes

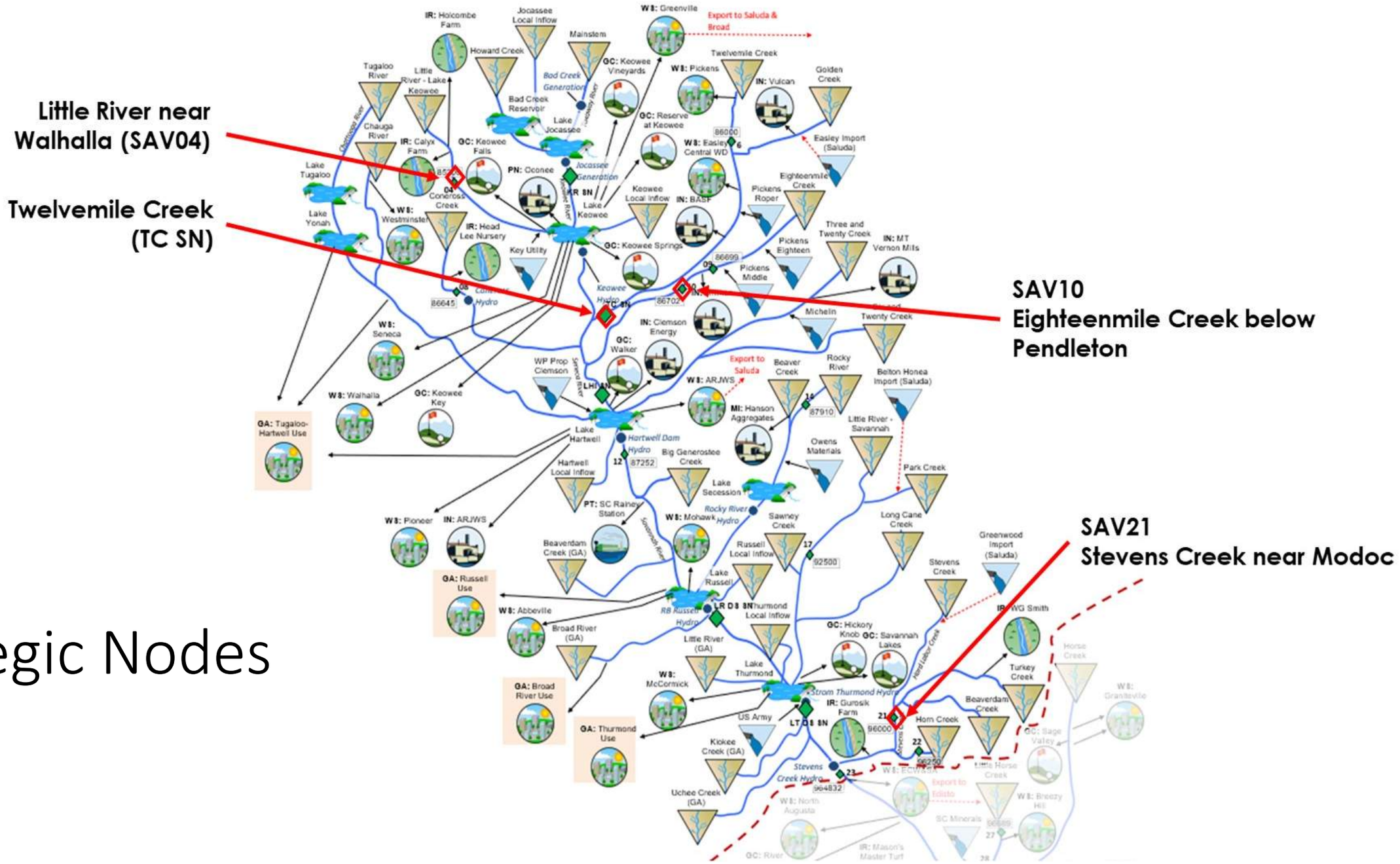
- 1: Perennial runoff: moderately stabile flow and distinct seasonal extremes

- ~~3: Stable baseflow: high precipitation, sustained high baseflows, and moderately high run-off~~

- 4: Perennial flashy: moderately stabile flow with high flow variability



# Strategic Nodes



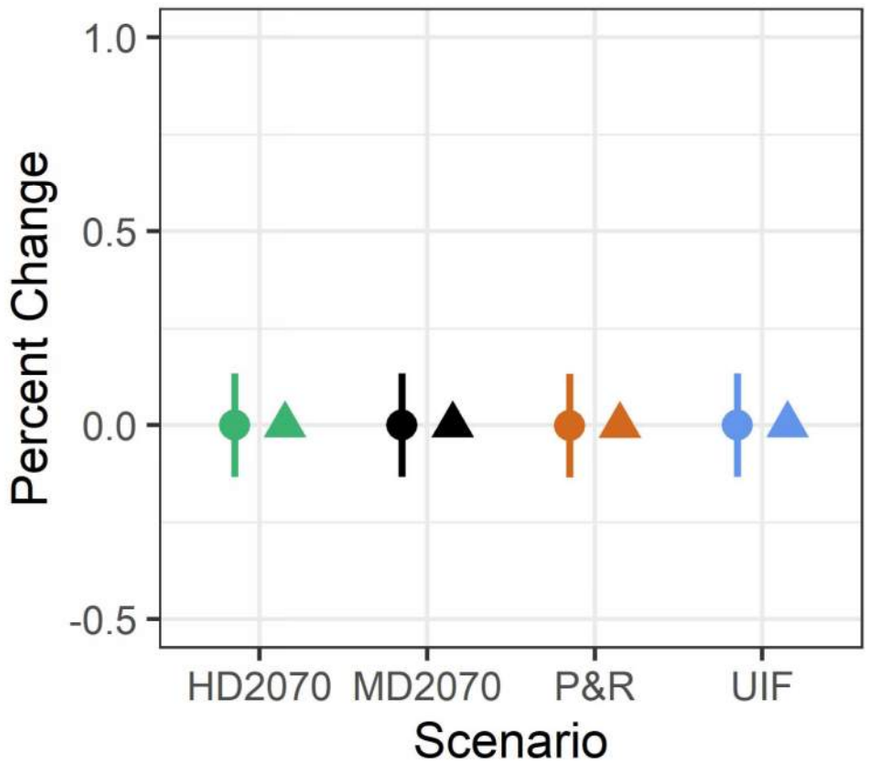
# Selected Metrics

| | Performance Recommendations and Risk Ranges | | | | | |
|---|---|---|---|---|---|---|
| **Stream Type:** | **Piedmont Perennial** | | | **Piedmont Flashy** | | |
| | **Low** | **Med** | **High** | **Low** | **Med** | **High** |
| **Flow Metric** | | | | | | |
| **Mean Daily Flow (FR)** | >0.66 | 0.42-0.66 | <0.42 | >0.71 | 0.49-0.71 | <0.49 |
| **Mean Daily Flow (FS)** | >0.78 | 0.46-0.78 | <0.46 | | | |

*FR=Fish Species Richness: The number of fish species found in a stream or river reach*

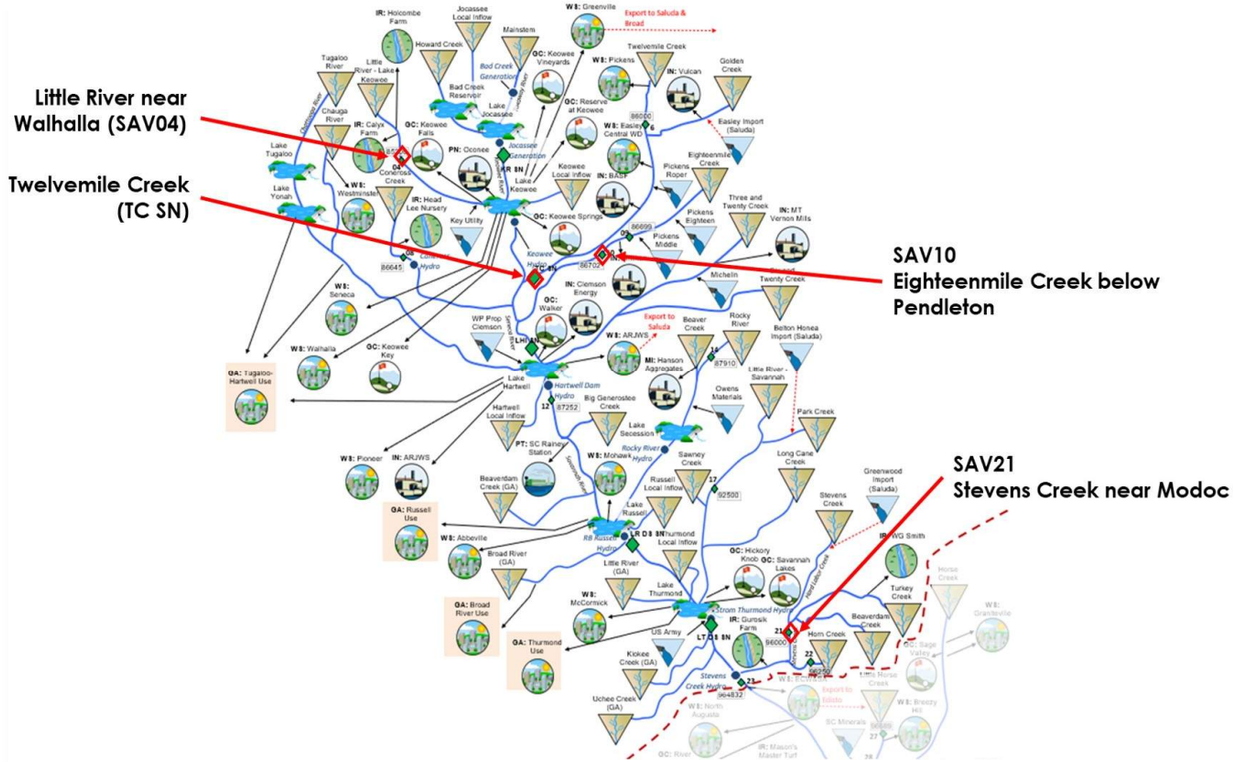
*FS=Fish Species Shannon's diversity: The evenness of fish species found in a stream or river reach*

# SAV04 Little River: MA1-Richness




Scenario
- HD2070
- MD2070
- P&R
- UIF

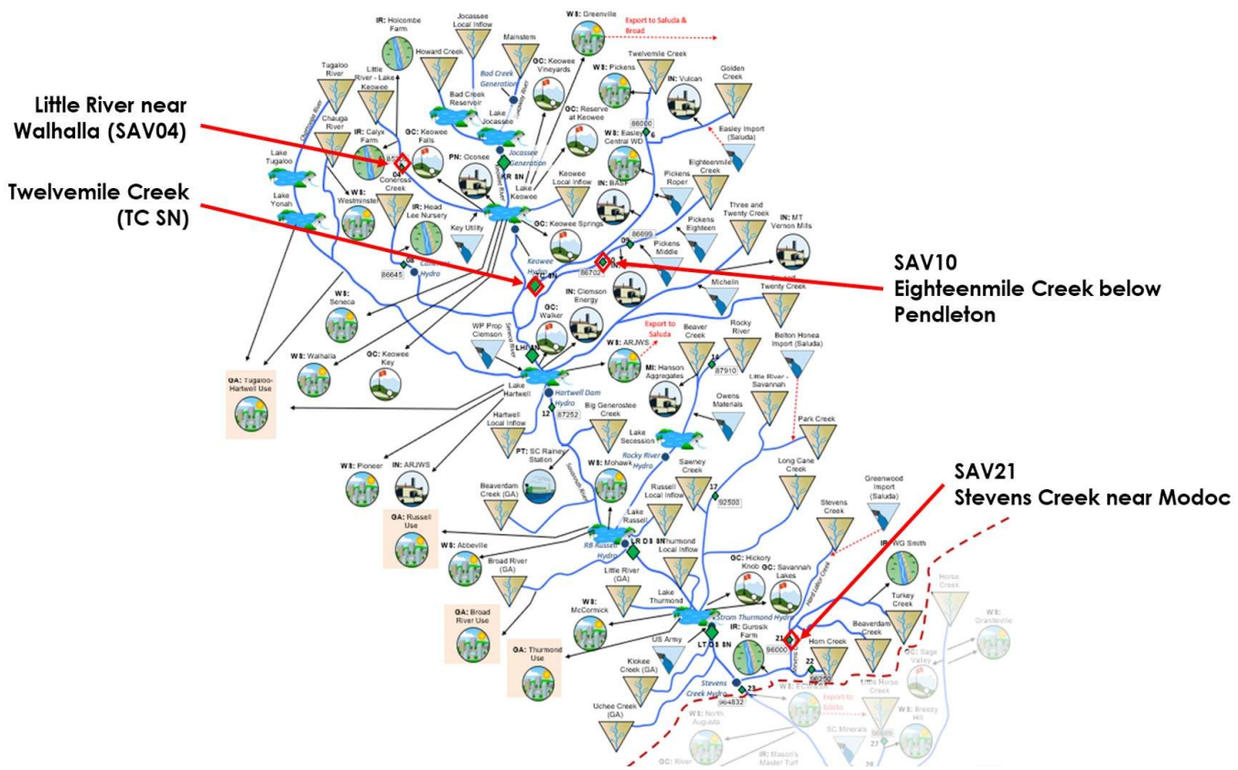
Metric
- Bio
- Flow

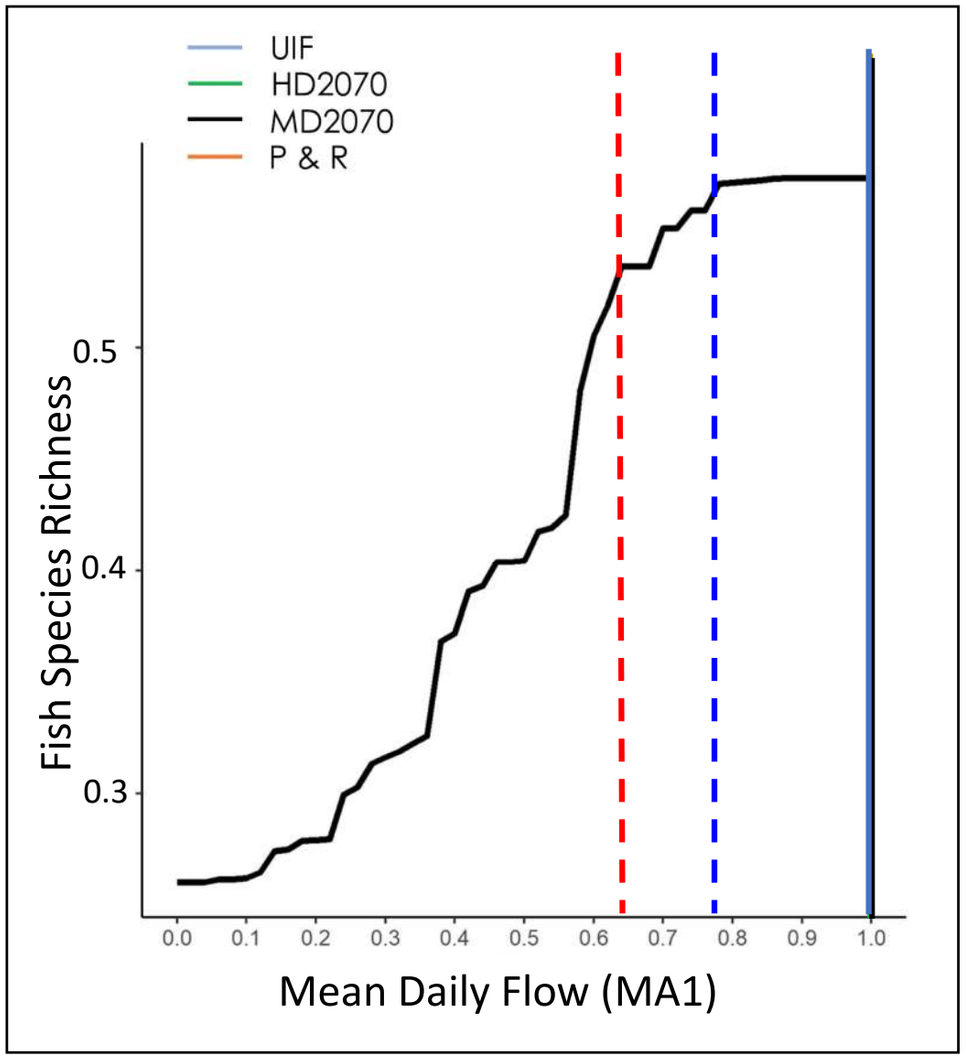



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 168.20 | 168.22 | 0% | Richness | 0% | 6.8 | 13.4 |
| MD 2070 | 168.20 | 168.21 | 0% | Richness | 0% | 6.8 | 13.4 |
| HD 2070 | 168.20 | 168.14 | 0% | Richness | 0% | 6.8 | 13.4 |
| P&R | 168.20 | 167.86 | -0.002% | Richness | 0% | 6.8 | 13.4 |

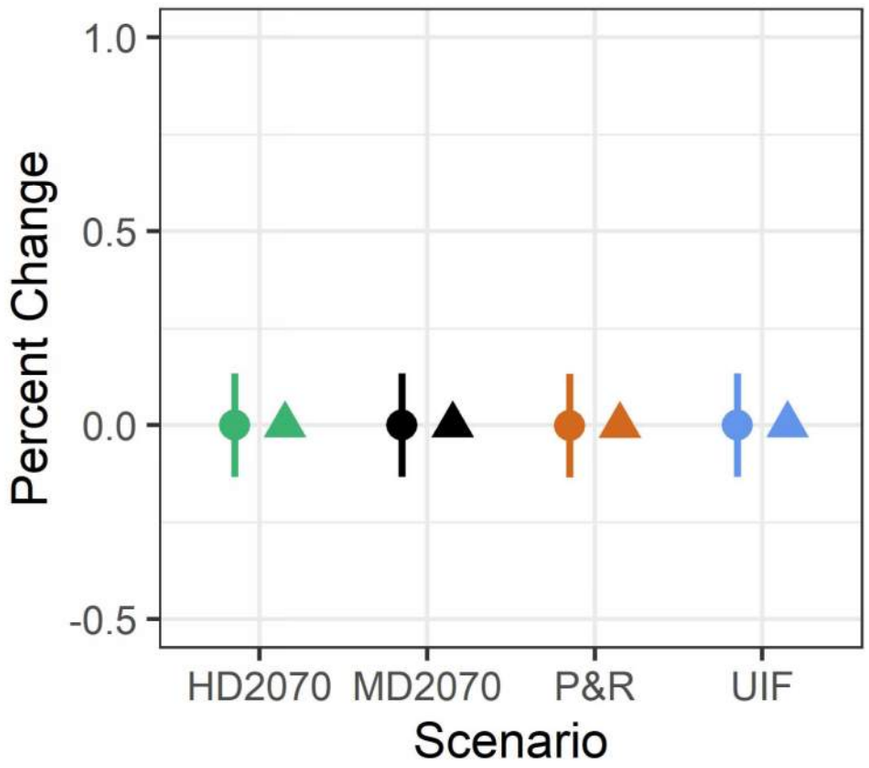
# SAV04 Little River: MA1-Richness

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 168.20 | 168.22 | 0% | Richness | Low |
| MD 2070 | 168.20 | 168.21 | 0% | Richness | Low |
| HD 2070 | 168.20 | 168.14 | 0% | Richness | Low |
| P&R | 168.20 | 167.86 | -0.002% | Richness | Low |



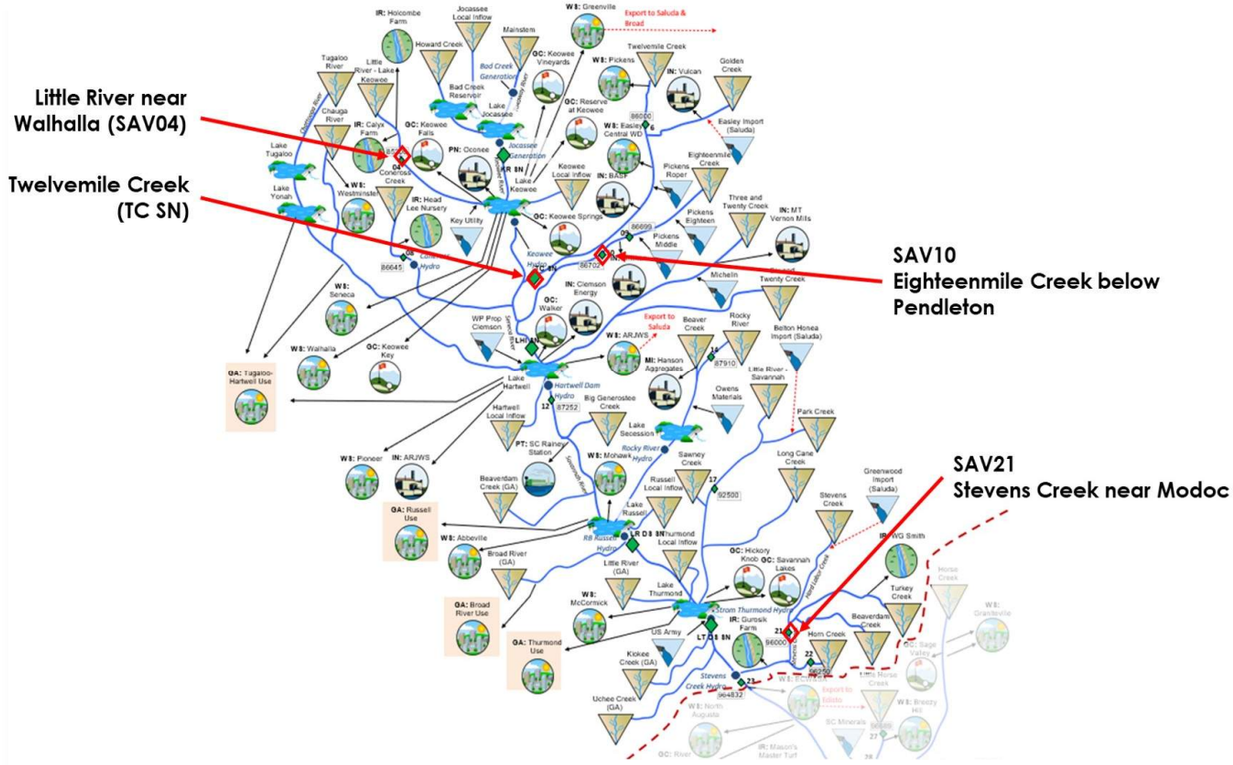



# SAV04 Little River: MA1-Shannon




Scenario
- HD2070
- MD2070
- P&R
- UIF

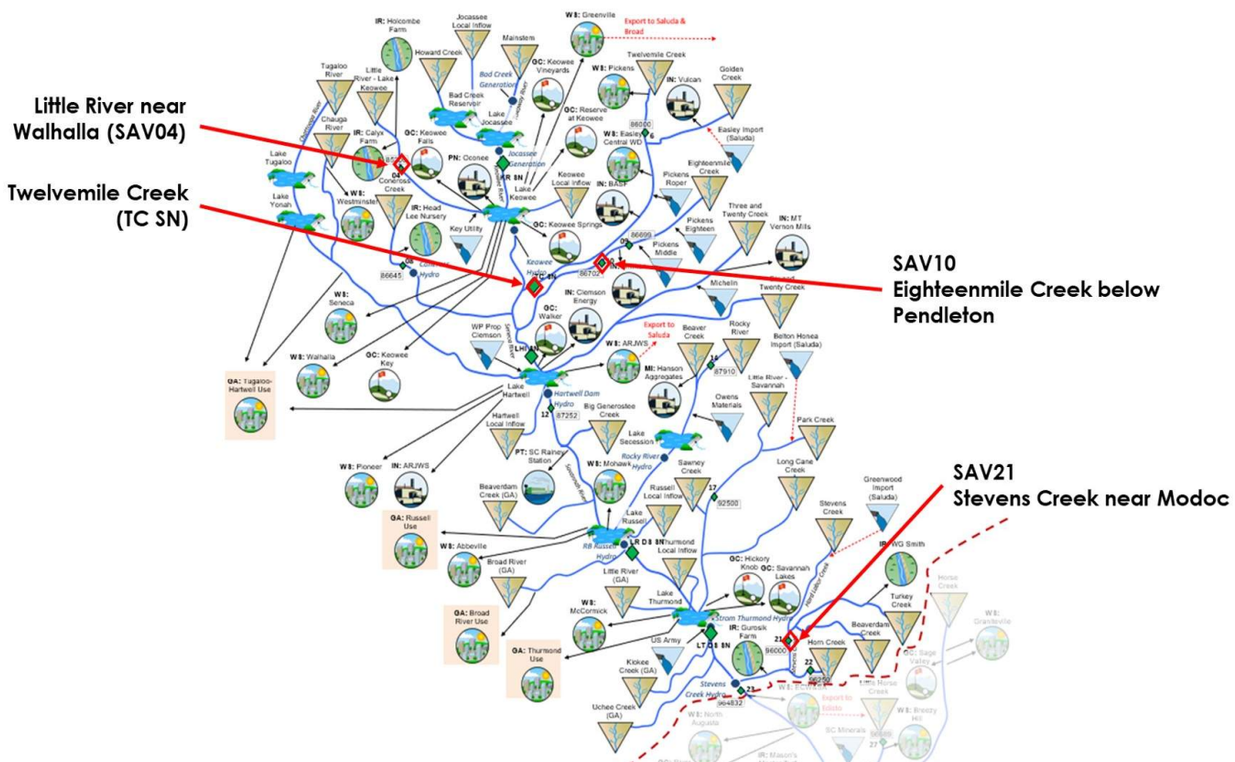
Metric
- Bio
- Flow

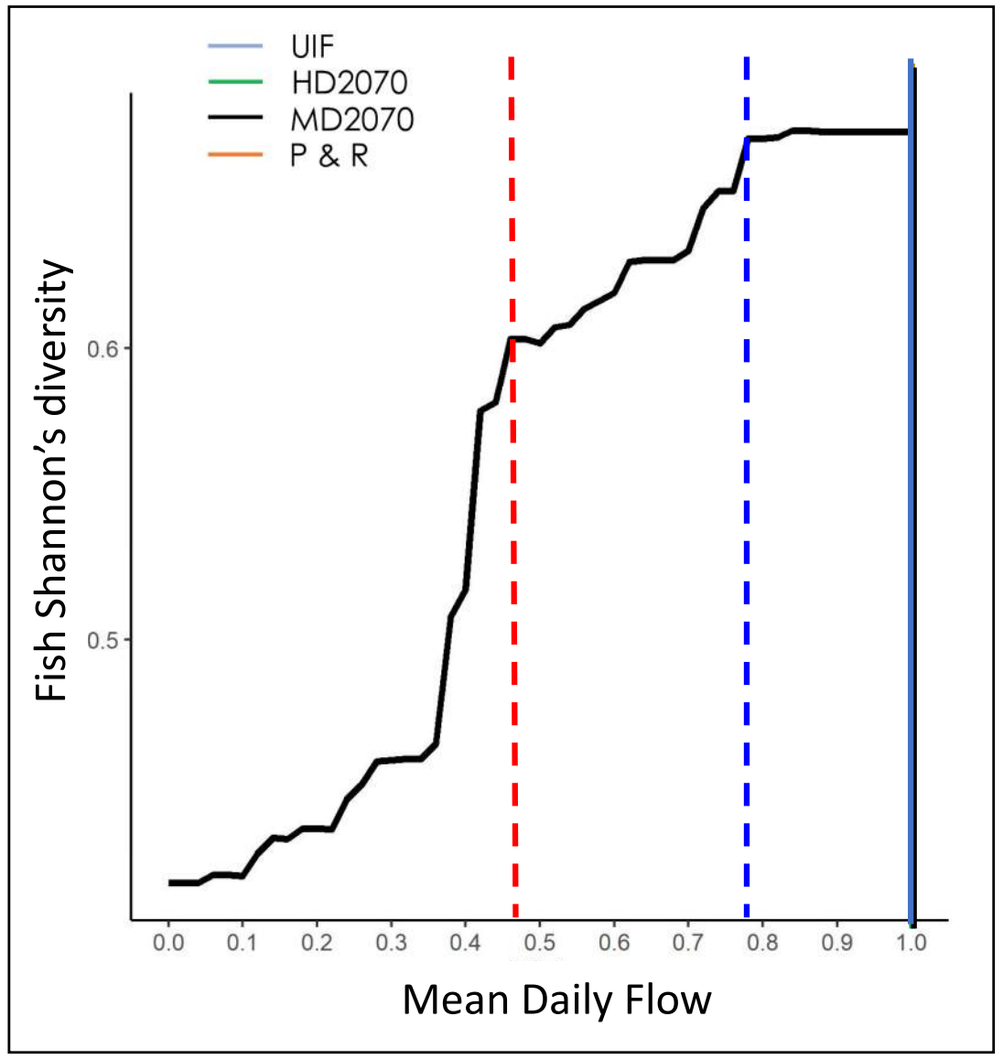



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 168.20 | 168.22 | 0% | Shannon | 0% | 7.8 | 15.5 |
| MD 2070 | 168.20 | 168.21 | 0% | Shannon | 0% | 7.8 | 15.5 |
| HD 2070 | 168.20 | 168.14 | 0% | Shannon | 0% | 7.8 | 15.5 |
| P&R | 168.20 | 167.86 | -0.002% | Shannon | 0% | 7.8 | 15.5 |

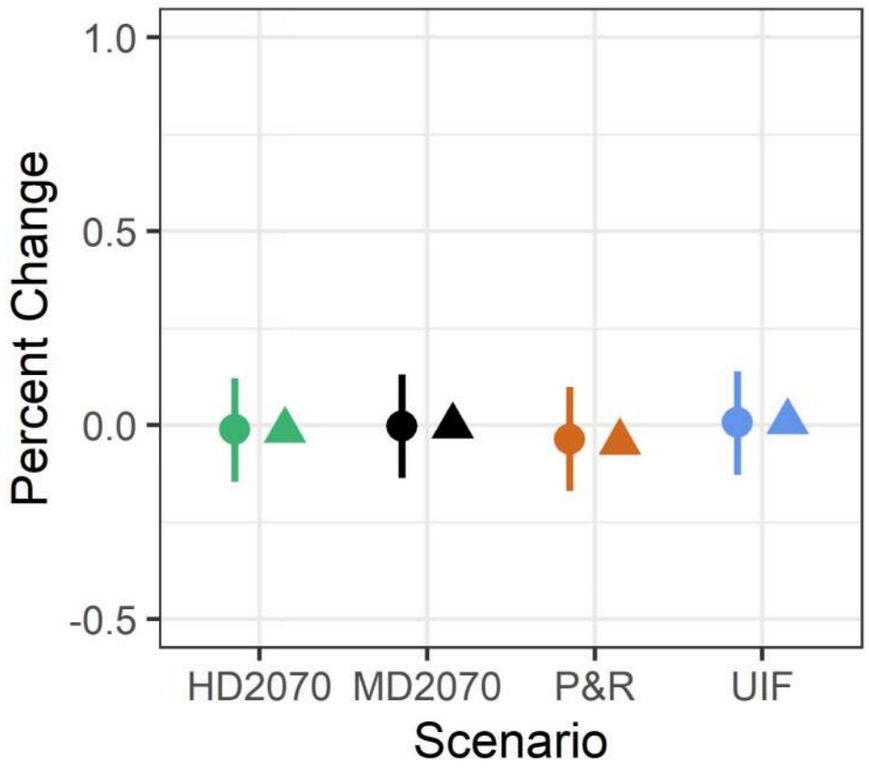
# SAV04 Little River: MA1-Shannon

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 168.20 | 168.22 | 0% | Shannon | Low |
| MD 2070 | 168.20 | 168.21 | 0% | Shannon | Low |
| HD 2070 | 168.20 | 168.14 | 0% | Shannon | Low |
| P&R | 168.20 | 167.86 | -0.002% | Shannon | Low |



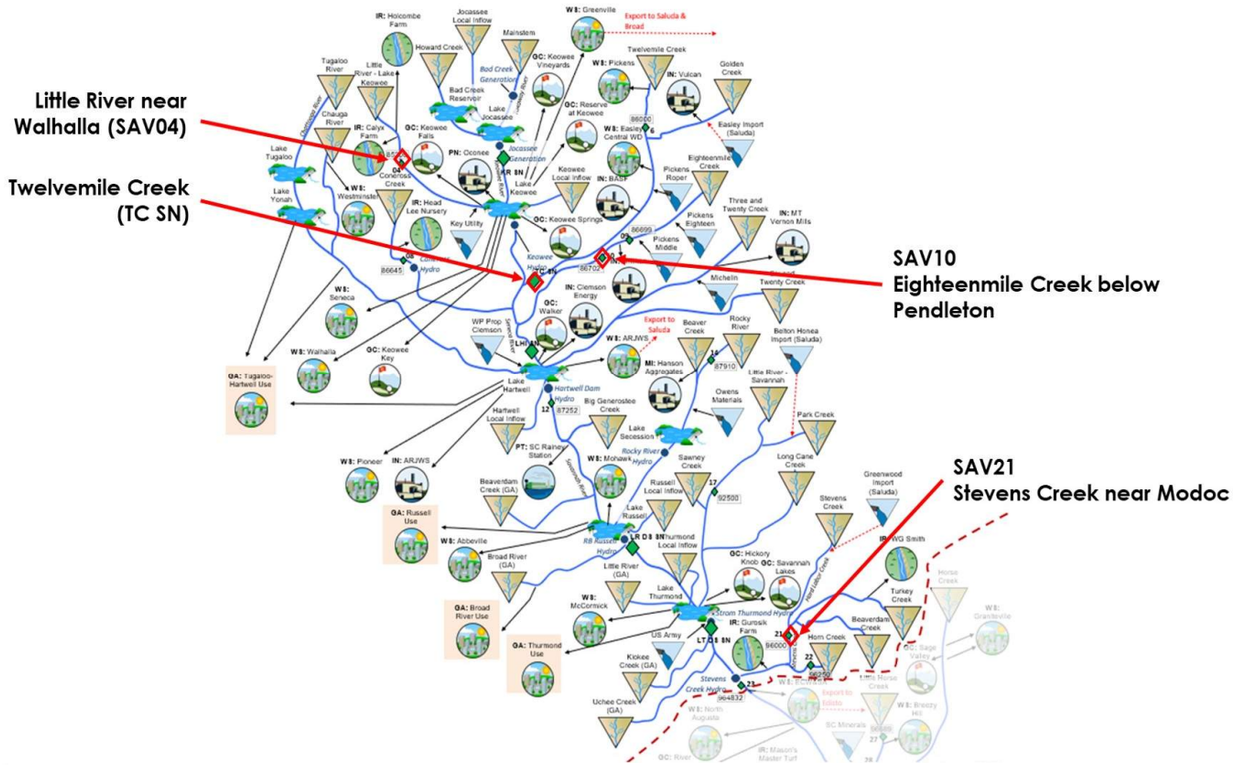



# TC SN Twelvemile Creek: MA1-Richness




Scenario
- HD2070
- MD2070
- P&R
- UIF

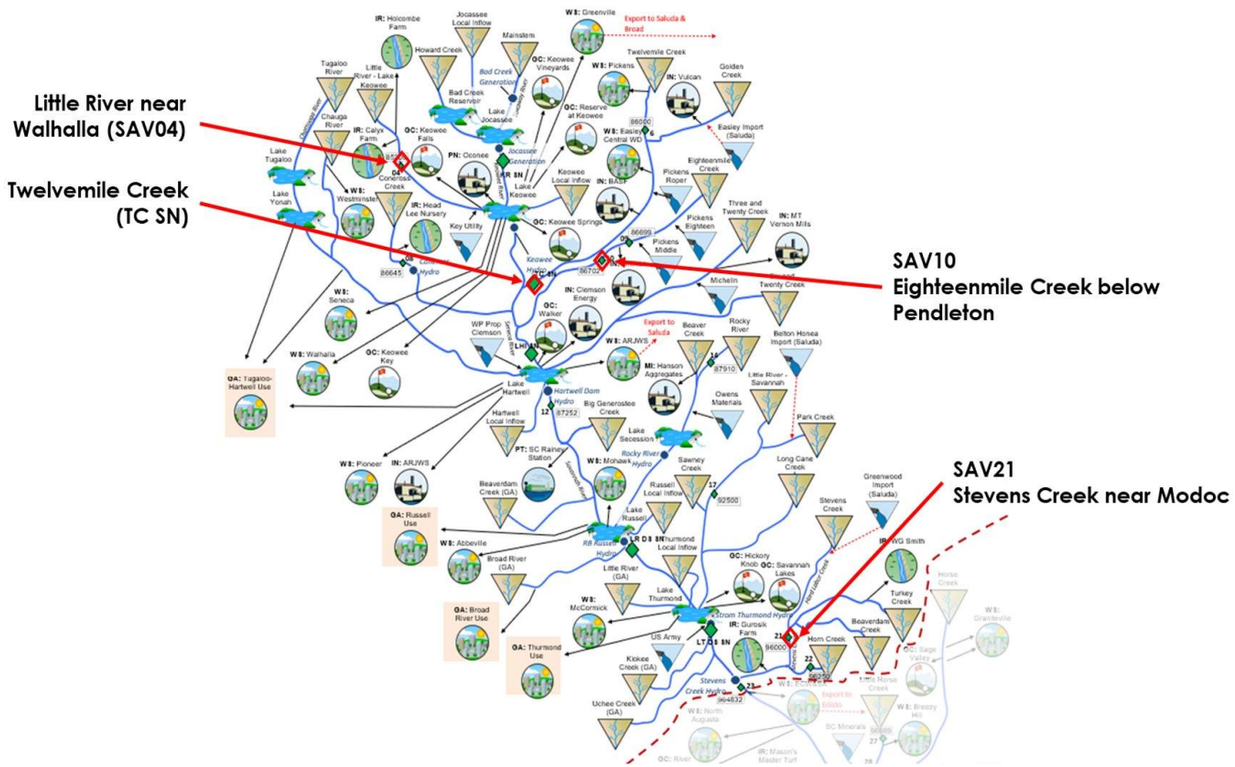
Metric
- Bio
- Flow

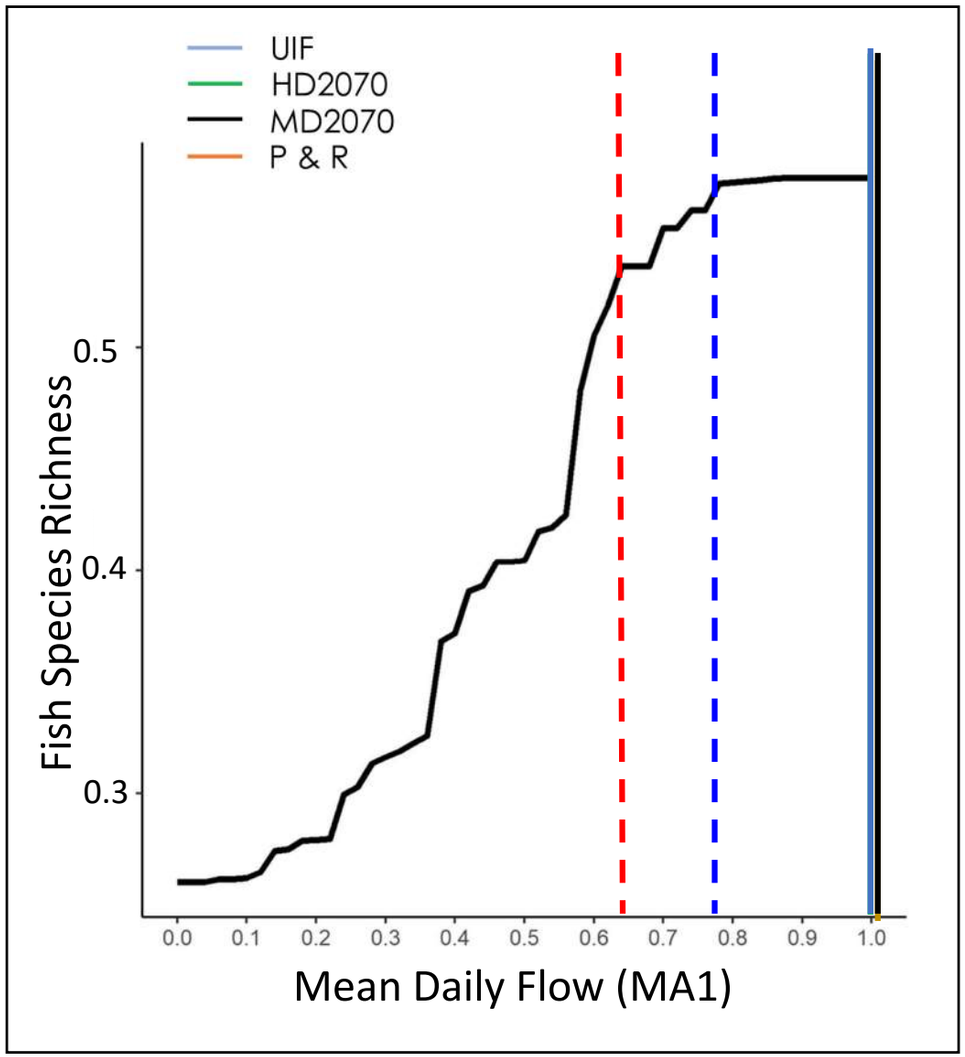



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 263.60 | 265.58 | 0.008% | Richness | 0.01% | 6.8 | 13.4 |
| MD 2070 | 263.60 | 262.64 | -0.004% | Richness | 0% | 6.8 | 13.4 |
| HD 2070 | 263.60 | 259.79 | -0.014% | Richness | -0.01% | 6.8 | 13.4 |
| P&R | 263.60 | 251.94 | -0.044% | Richness | -0.04% | 6.8 | 13.4 |

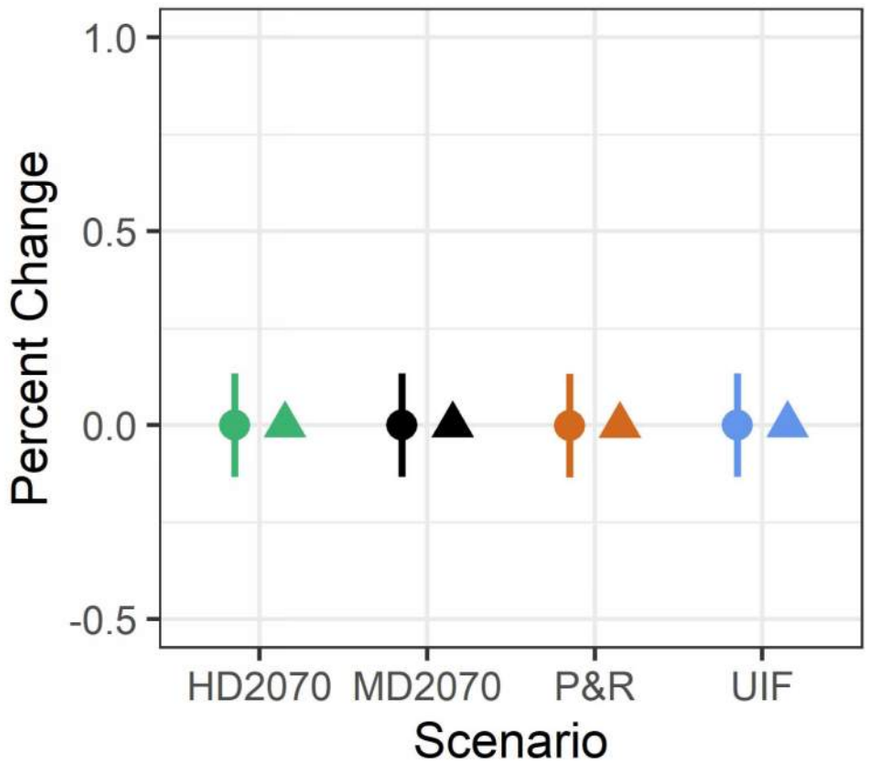
# TC SN Twelvemile Creek : MA1-Richness

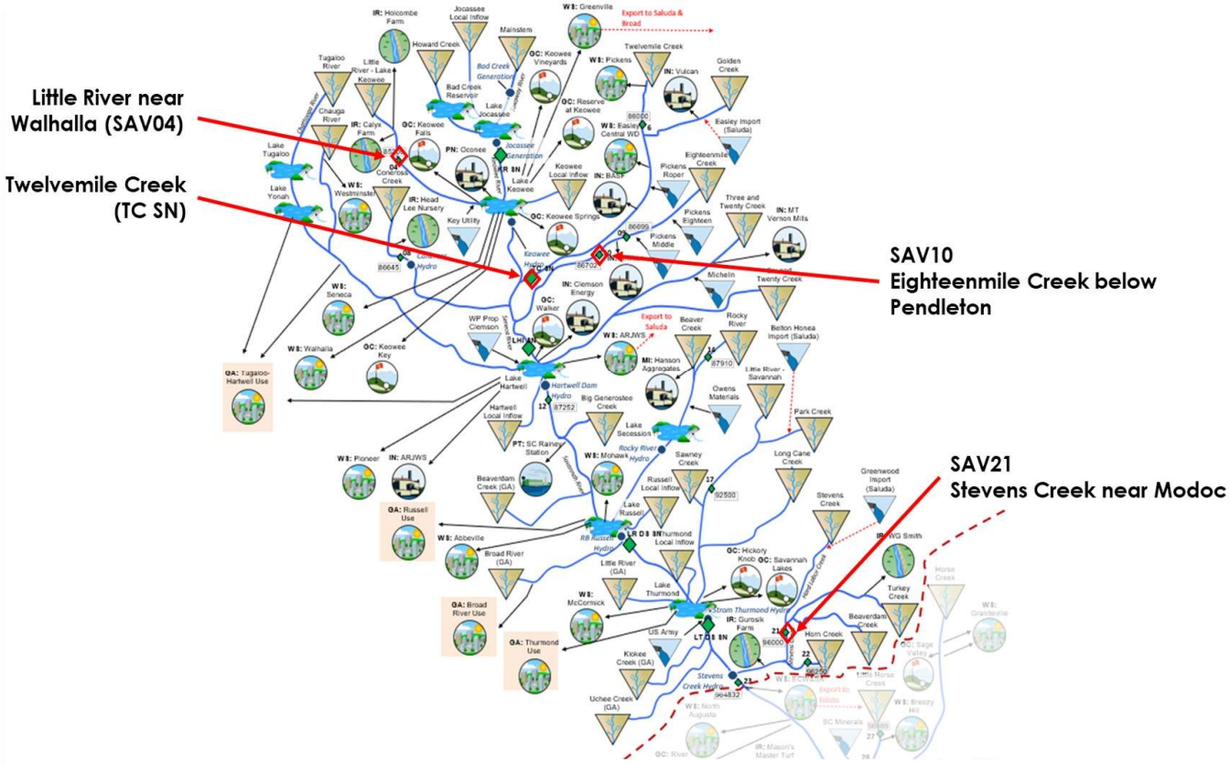
| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 263.60 | 265.58 | 0.008% | Richness | Low |
| MD 2070 | 263.60 | 262.64 | -0.004% | Richness | Low |
| HD 2070 | 263.60 | 259.79 | -0.014% | Richness | Low |
| P&R | 263.60 | 251.94 | -0.044% | Richness | Low |



# TC SN Twelvemile Creek : MA1-Shannon

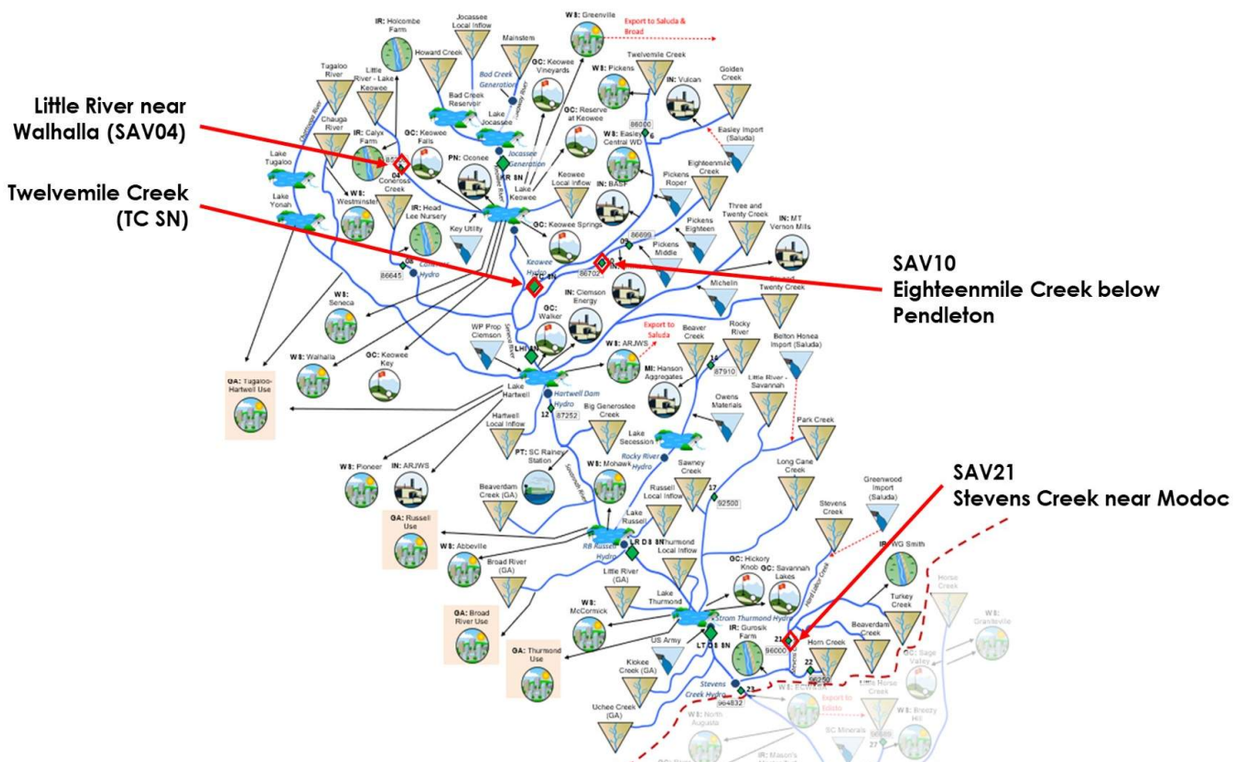


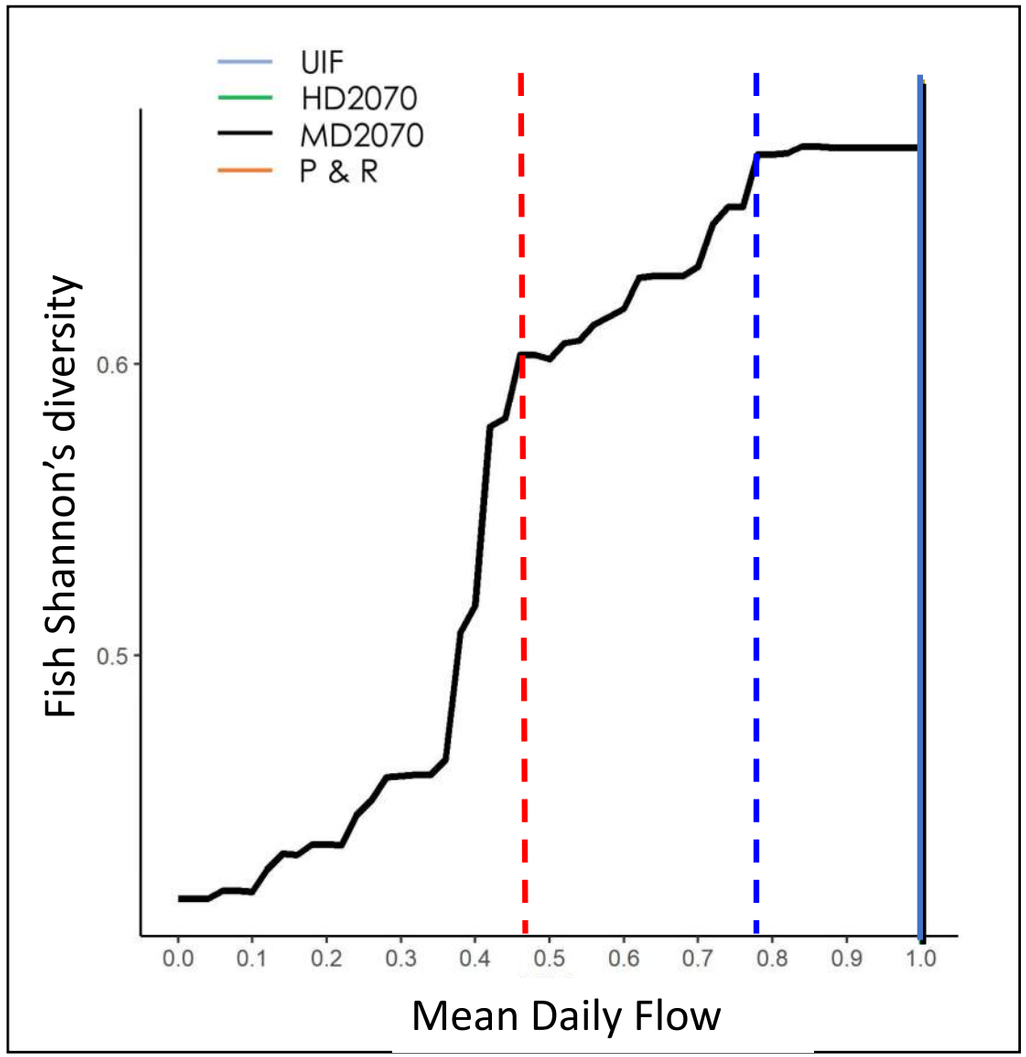




| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 263.60 | 265.58 | 0.008% | Shannon | 0% | 7.8 | 15.5 |
| MD 2070 | 263.60 | 262.64 | -0.004% | Shannon | 0% | 7.8 | 15.5 |
| HD 2070 | 263.60 | 259.79 | -0.014% | Shannon | -0.01% | 7.8 | 15.5 |
| P&R | 263.60 | 251.94 | -0.044% | Shannon | -0.03% | 7.8 | 15.5 |

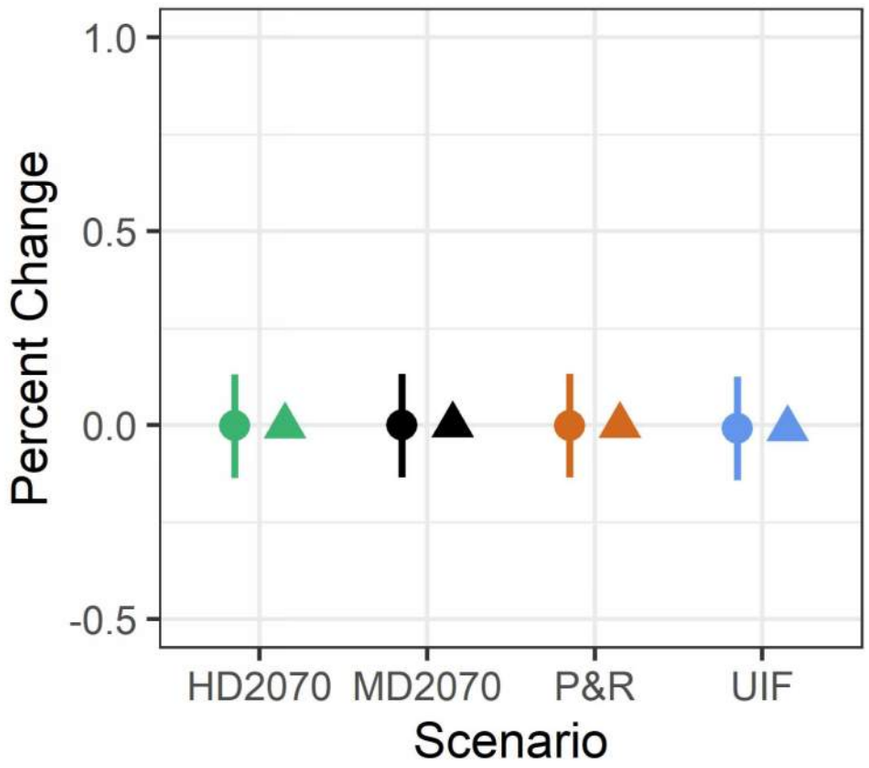
# TC SN Twelvemile Creek : MA1-Shannon

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 263.60 | 265.58 | 0.008% | Shannon | Low |
| MD 2070 | 263.60 | 262.64 | -0.004% | Shannon | Low |
| HD 2070 | 263.60 | 259.79 | -0.014% | Shannon | Low |
| P&R | 263.60 | 251.94 | -0.044% | Shannon | Low |

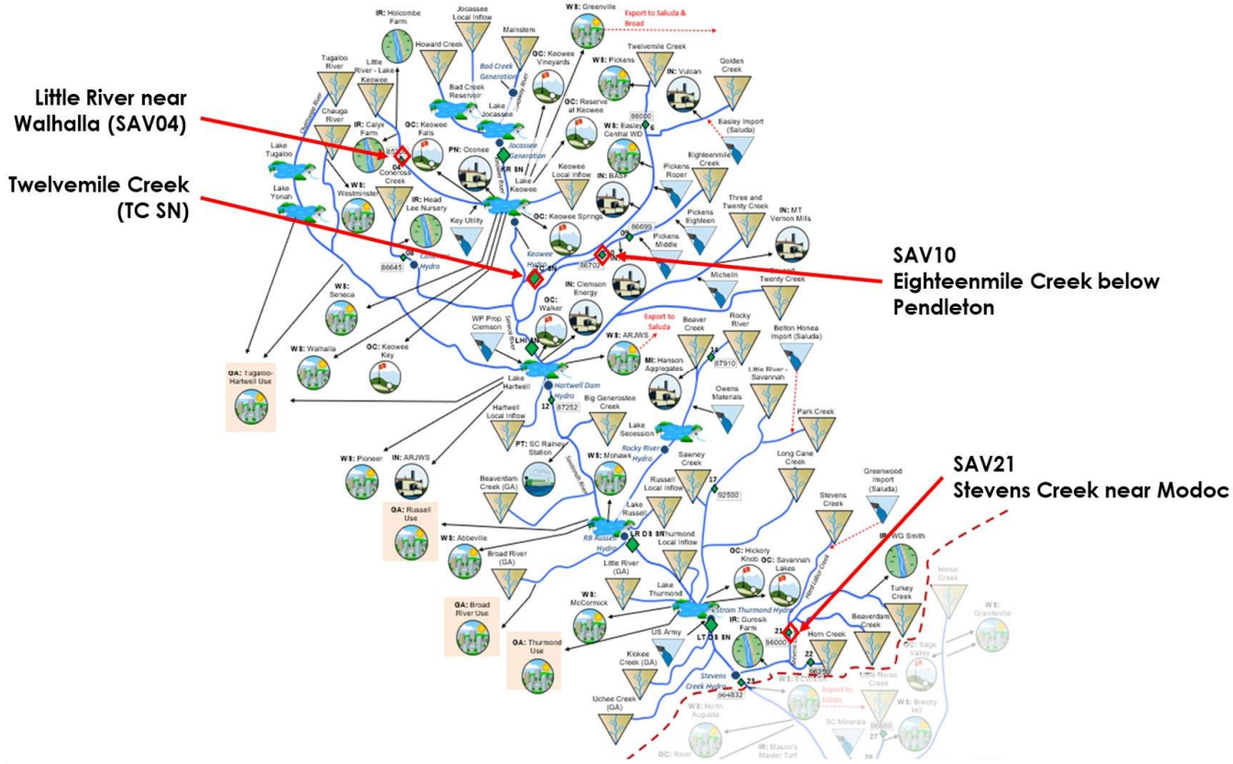


# SAV10 Eighteenmile Creek: MA1-Richness



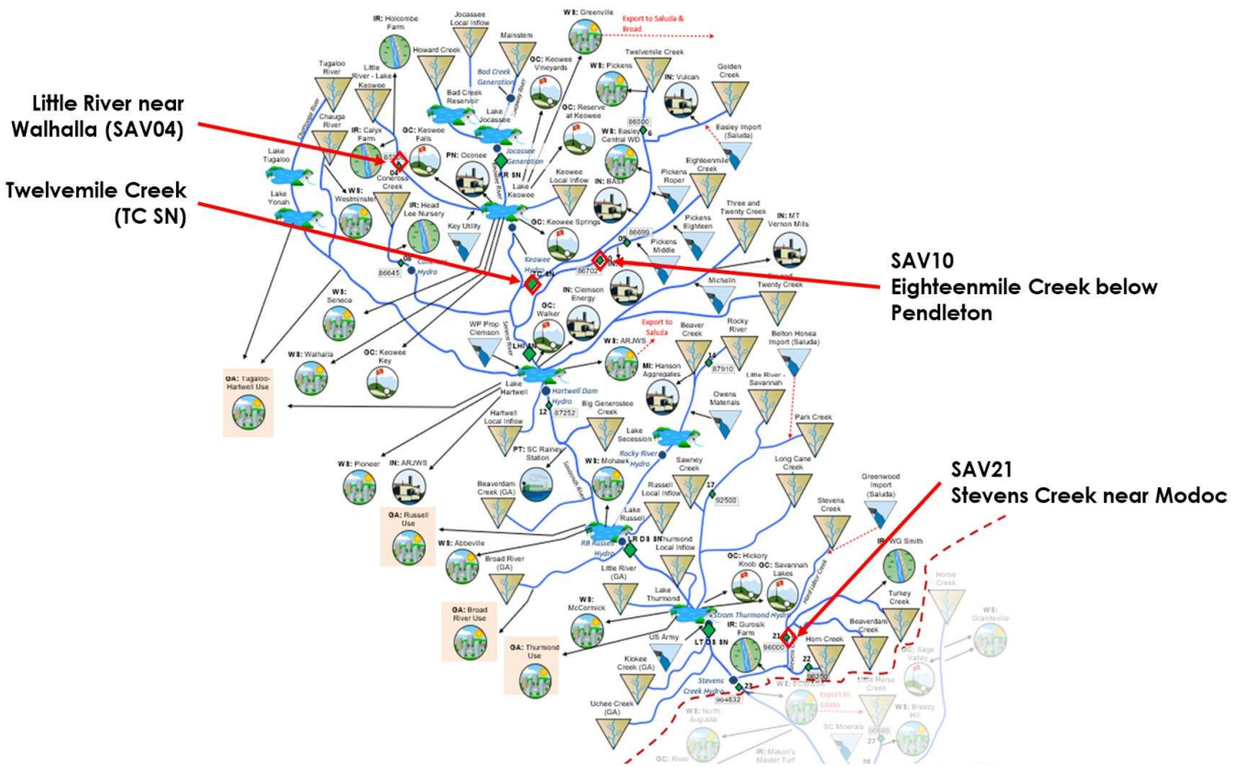


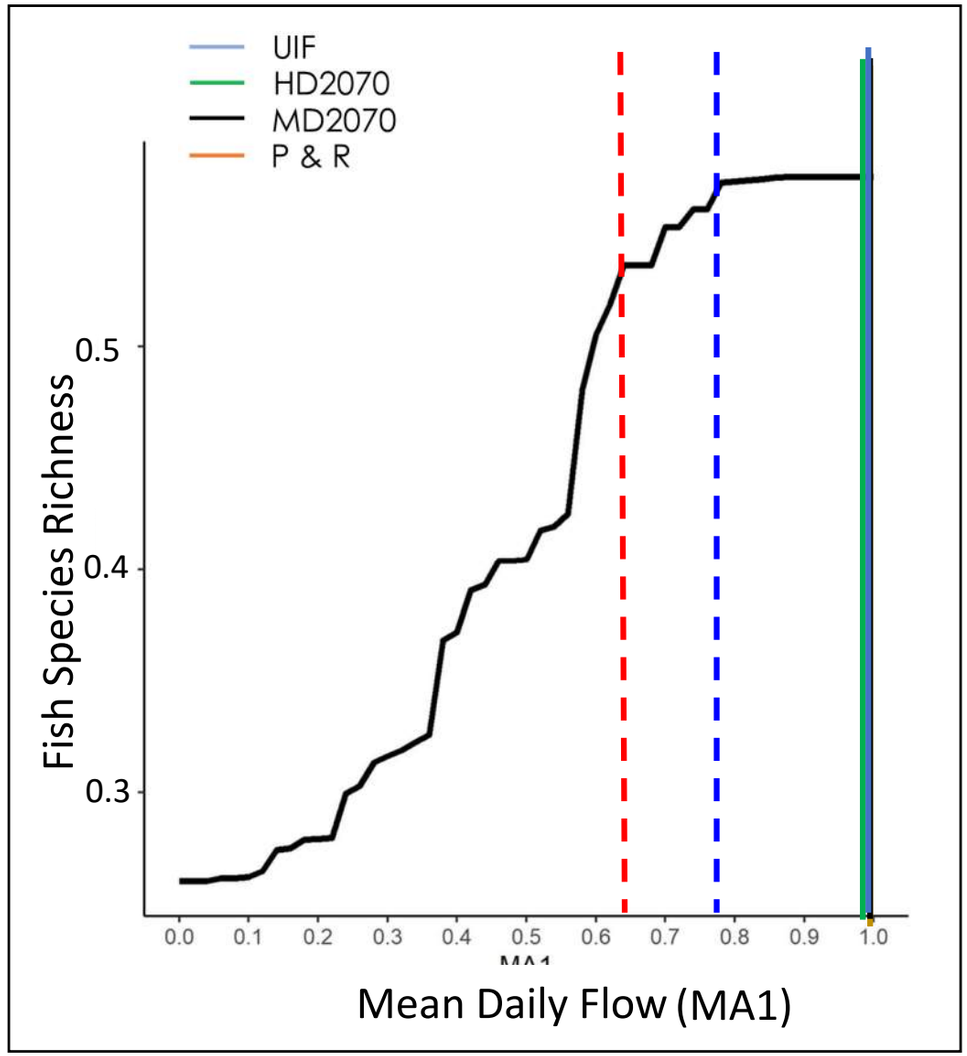



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 72.77 | 72.01 | -0.01% | Richness | -0.001% | 6.8 | 13.4 |
| MD 2070 | 72.77 | 72.70 | -0.001% | Richness | 0% | 6.8 | 13.4 |
| HD 2070 | 72.77 | 72.55 | -0.003% | Richness | 0% | 6.8 | 13.4 |
| P&R | 72.77 | 72.67 | -0.001% | Richness | 0% | 6.8 | 13.4 |

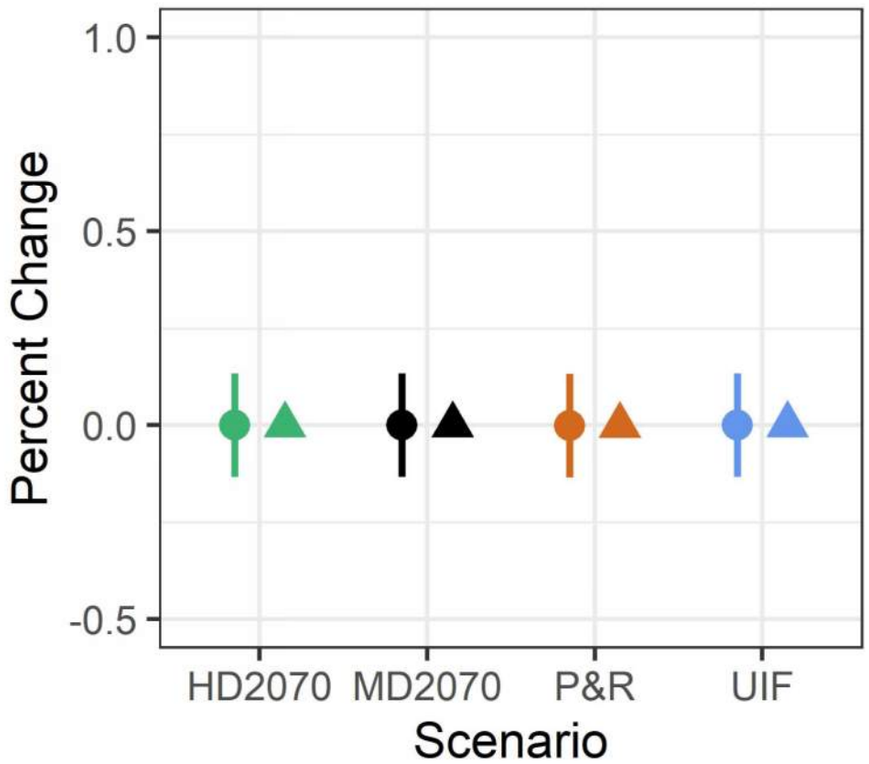
# SAV10 Eighteenmile Creek: MA1-Richness

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 72.77 | 72.01 | -0.01% | Richness | Low |
| MD 2070 | 72.77 | 72.70 | -0.001% | Richness | Low |
| HD 2070 | 72.77 | 72.55 | -0.003% | Richness | Low |
| P&R | 72.77 | 72.67 | -0.001% | Richness | Low |

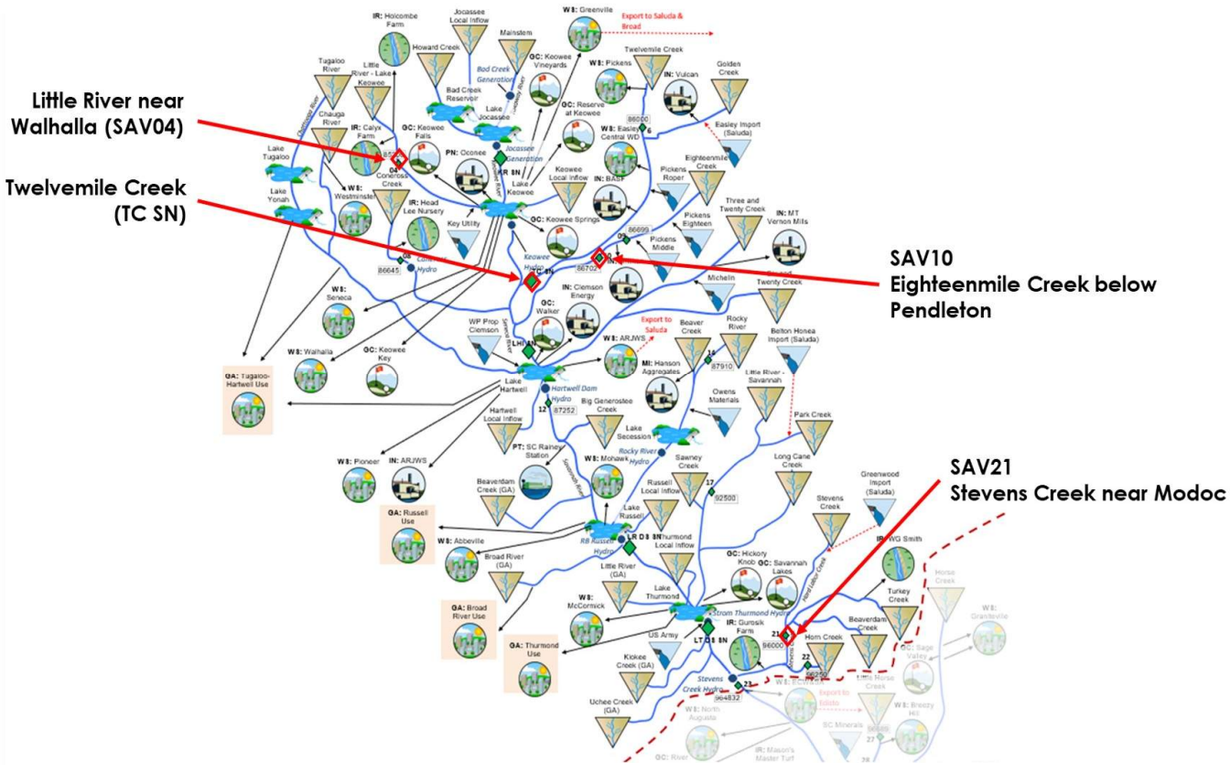


# SAV10 Eighteenmile Creek: MA1-Shannon



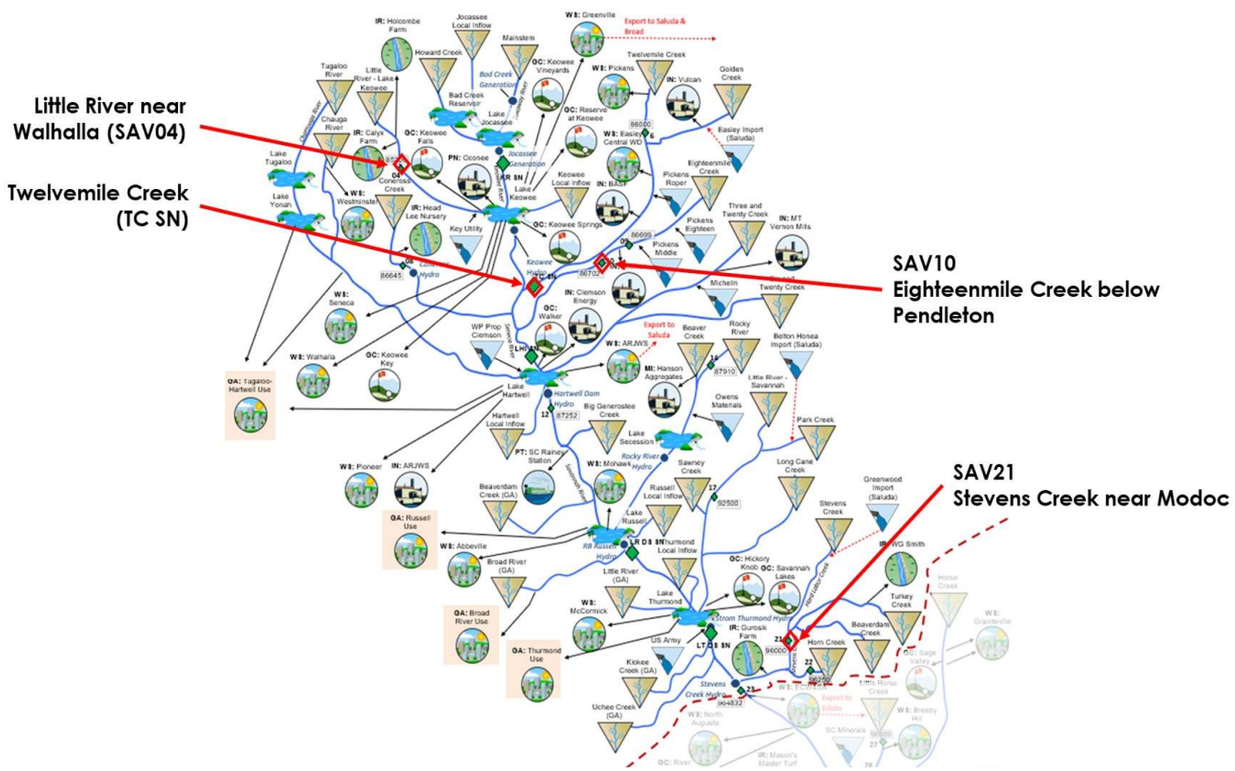


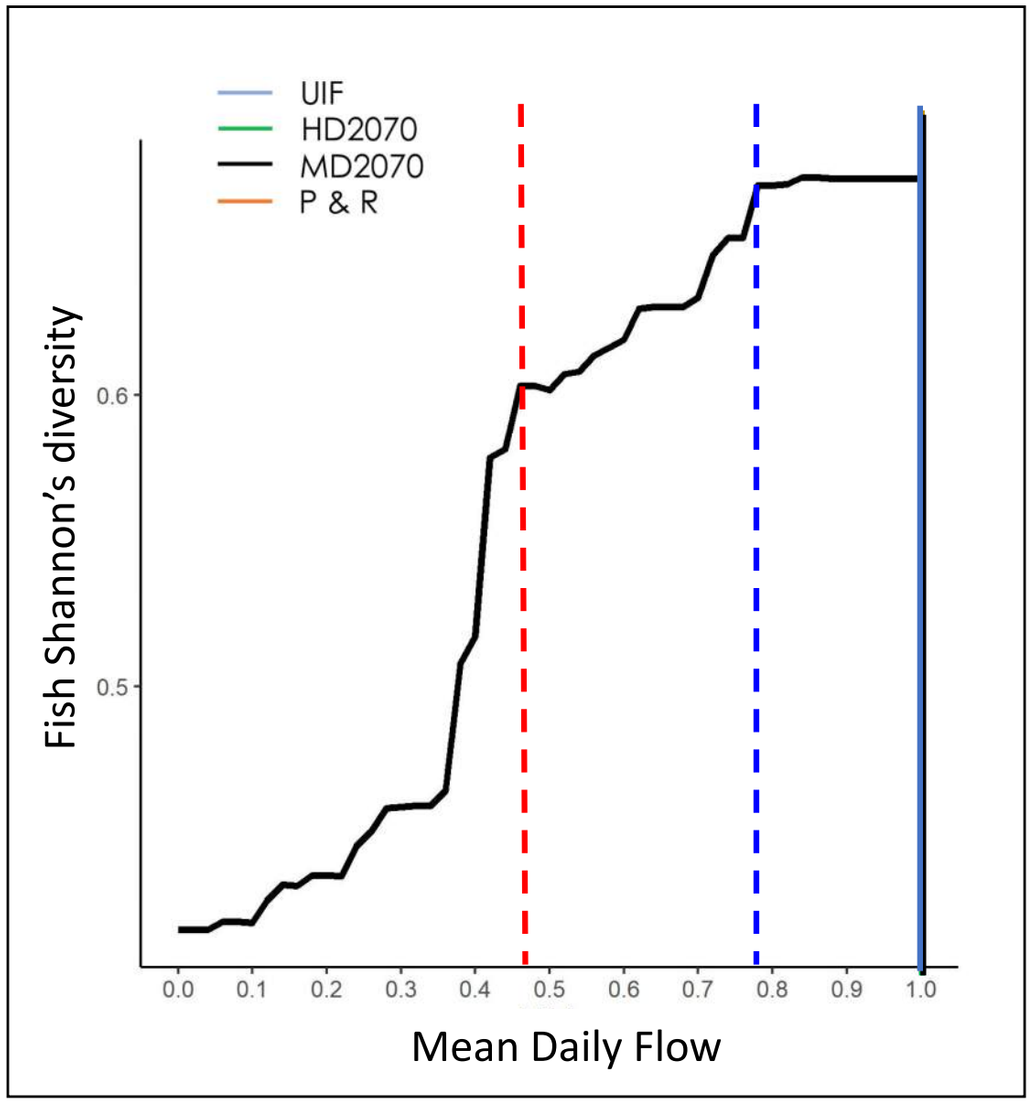



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 72.77 | 72.01 | -0.01% | Richness | -0.01% | 7.8 | 15.5 |
| MD 2070 | 72.77 | 72.70 | -0.001% | Richness | 0% | 7.8 | 15.5 |
| HD 2070 | 72.77 | 72.55 | -0.003% | Richness | 0% | 7.8 | 15.5 |
| P&R | 72.77 | 72.67 | -0.001% | Richness | 0% | 7.8 | 15.5 |

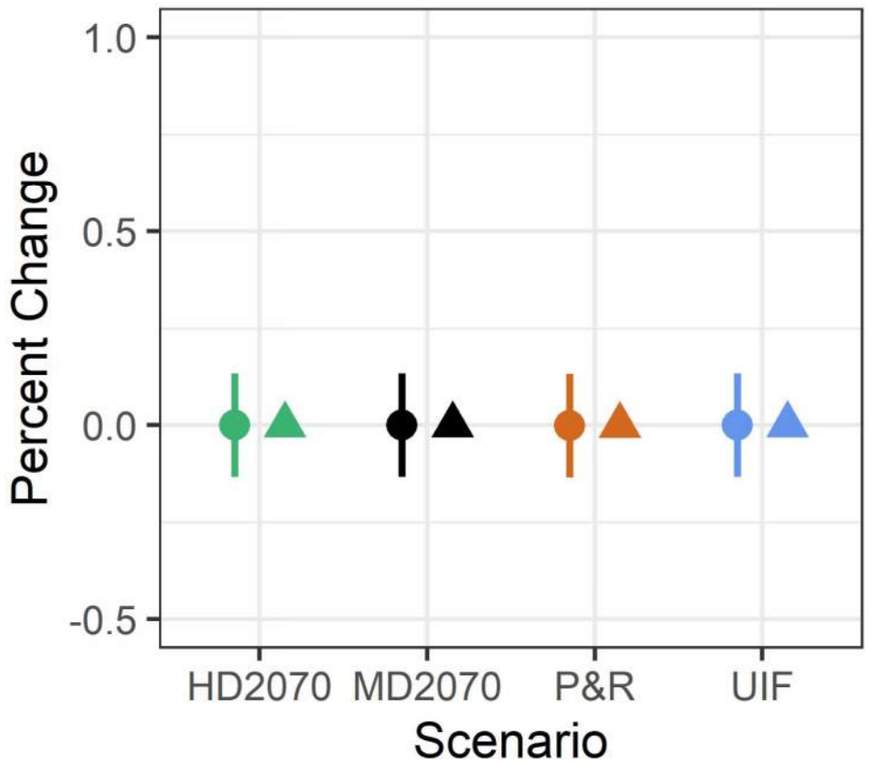
# SAV10 Eighteenmile Creek: MA1-Shannon

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 72.77 | 72.01 | -0.01% | Richness | Low |
| MD 2070 | 72.77 | 72.70 | -0.001% | Richness | Low |
| HD 2070 | 72.77 | 72.55 | -0.003% | Richness | Low |
| P&R | 72.77 | 72.67 | -0.001% | Richness | Low |



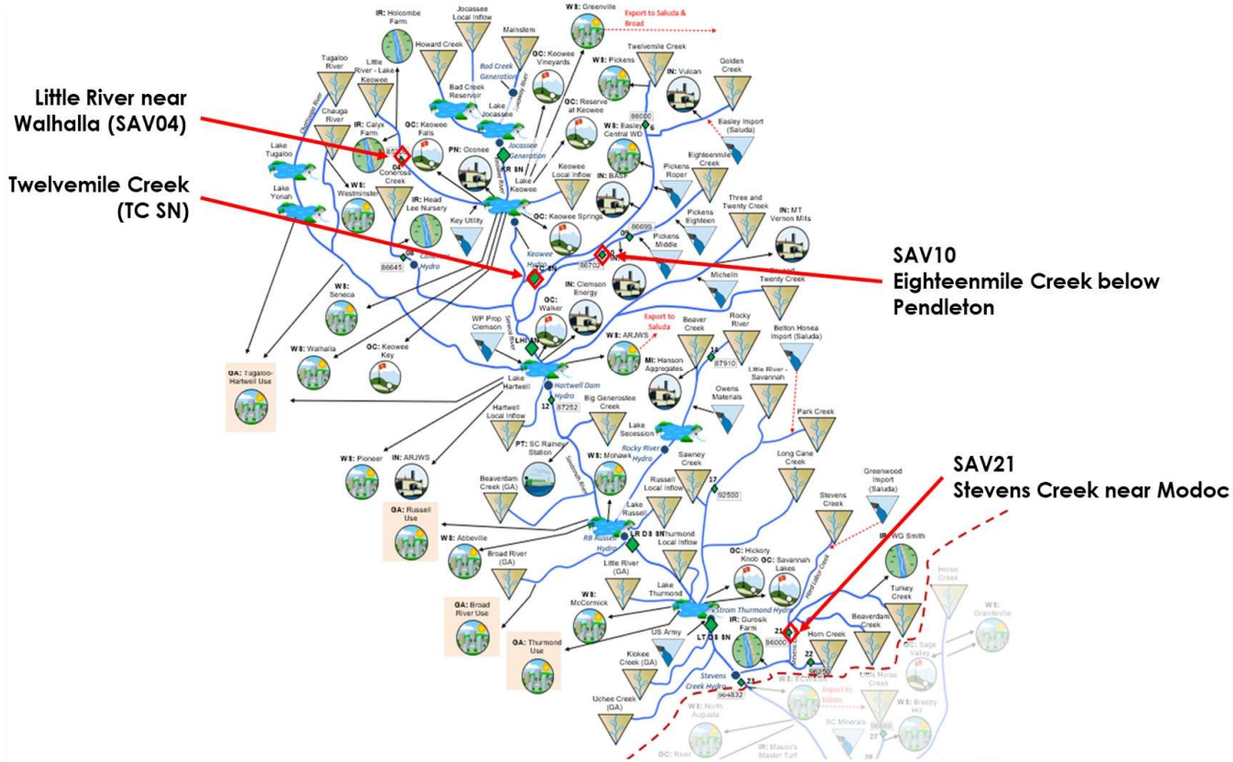



# SAV21 Stevens Creek : MA1-Richness




Scenario
- HD2070
- MD2070
- P&R
- UIF

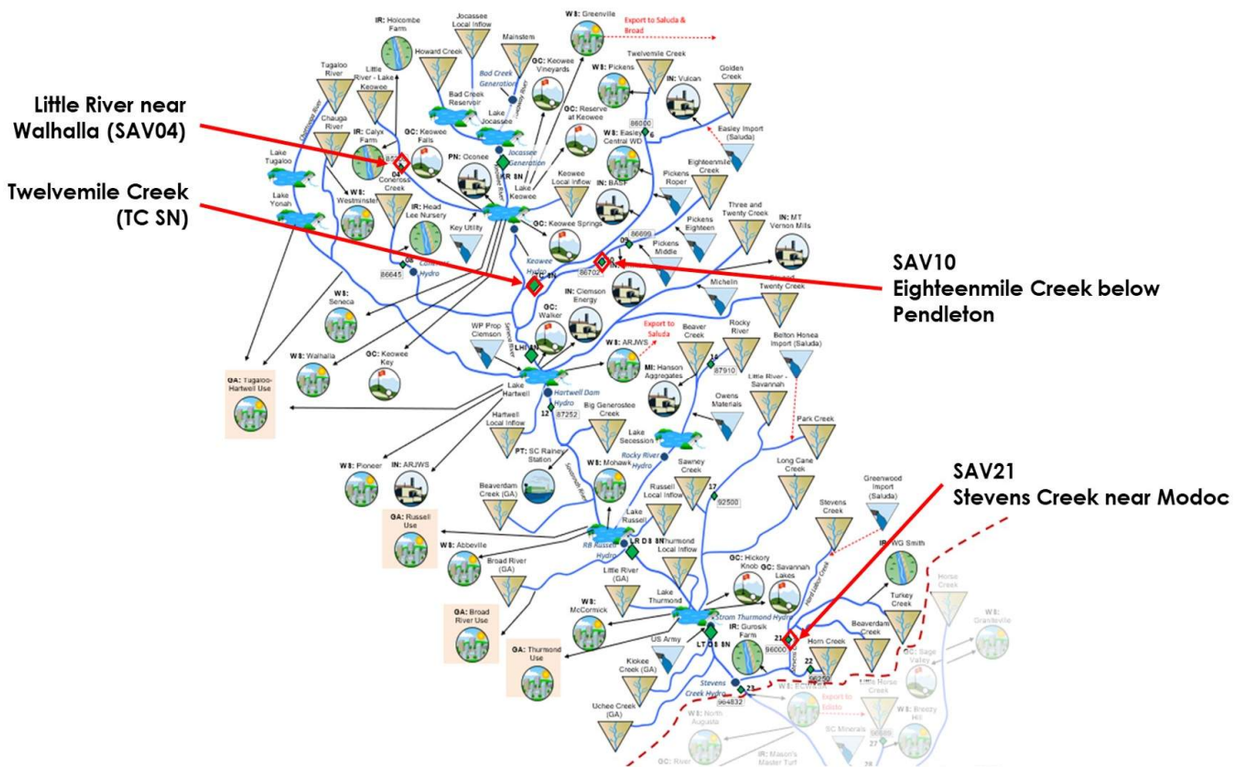
Metric
- Bio
- Flow

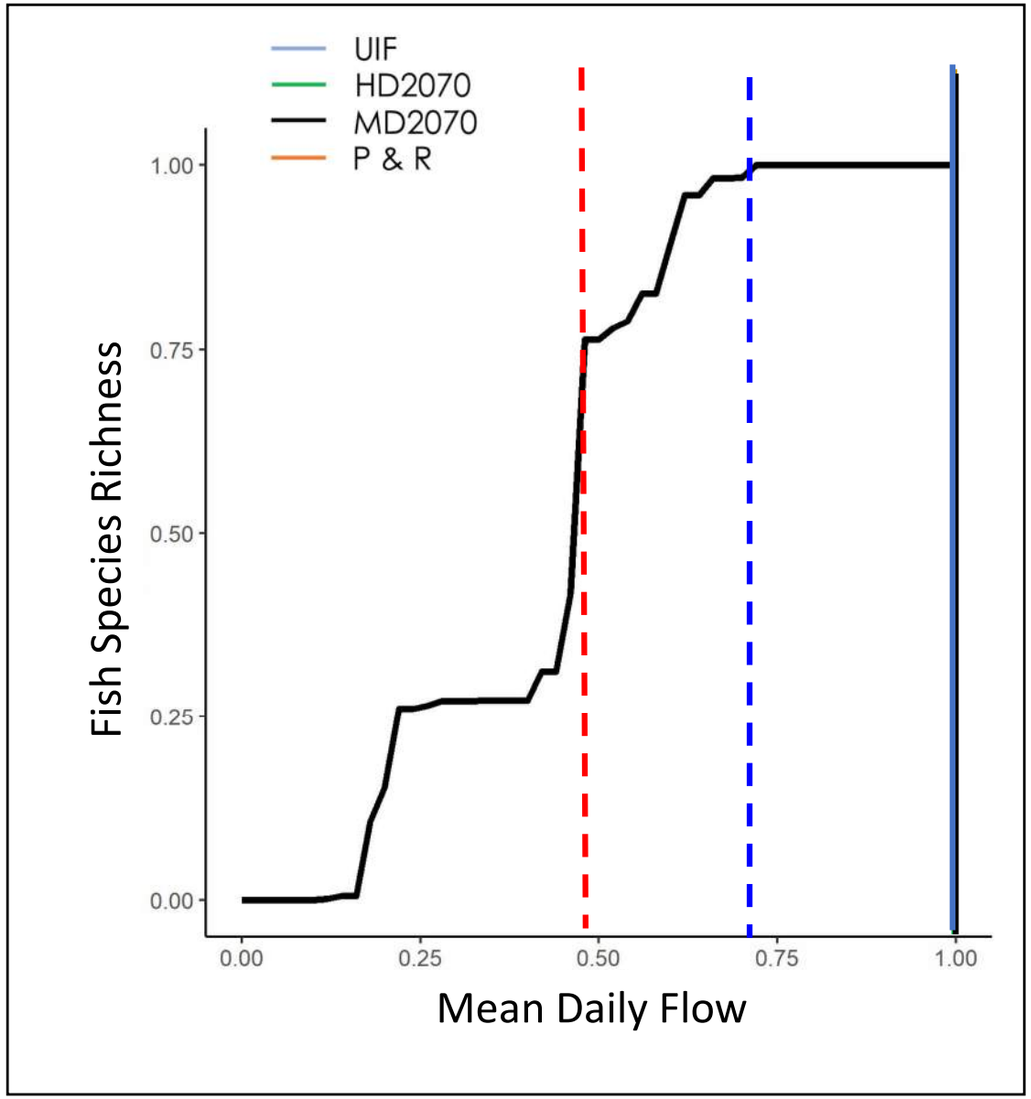



| Scenario | Current | Predicted | % Flow | Bio Metric | % Bio | SE | 95% |
|---|---|---|---|---|---|---|---|
| UIF | 388.34 | 387.81 | -0.001% | Richness | 0% | 9 | 17.7 |
| MD 2070 | 388.34 | 387.81 | -0.001% | Richness | 0% | 9 | 17.7 |
| HD 2070 | 388.34 | 389.72 | 0.004% | Richness | 0% | 9 | 17.7 |
| P&R | 388.34 | 391.79 | 0.009% | Richness | 0% | 9 | 17.7 |

# SAV21 Stevens Creek : MA1-Richness

| Scenario | Current | Predicted | % change | Bio Metric | Risk |
|---|---|---|---|---|---|
| UIF | 388.34 | 387.81 | -0.001% | Richness | Low |
| MD 2070 | 388.34 | 387.81 | -0.001% | Richness | Low |
| HD 2070 | 388.34 | 389.72 | 0.004% | Richness | Low |
| P&R | 388.34 | 391.79 | 0.009% | Richness | Low |

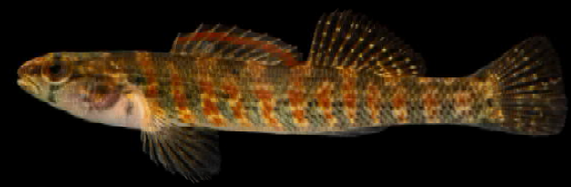


# SWAP-listed fishes in Savannah River Basin

V-LIP REDHORSE

Bartram's Bass



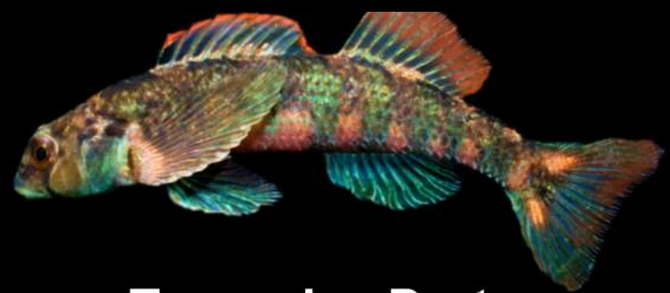
Christmas Darter

Savannah Darter

Rosyside Dace

Rosyface Chub

Highback Chub



Turquoise Darter

Eastern Brook Trout

All photos from ncfishes.com

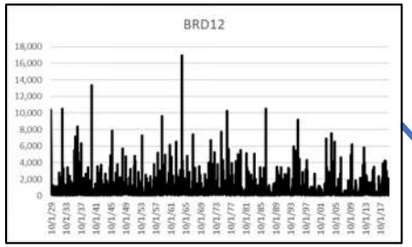
# What this info *is*

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

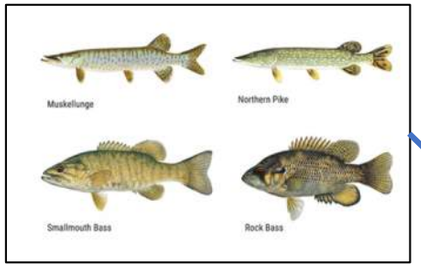
# What this info *is not*

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

# Flow Chart




Gauge Data

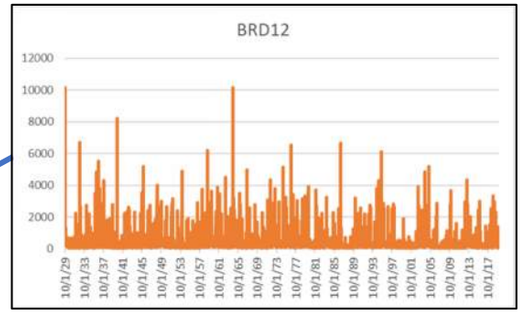



Community Data

Estimate Flow metrics

+ Uncertainty

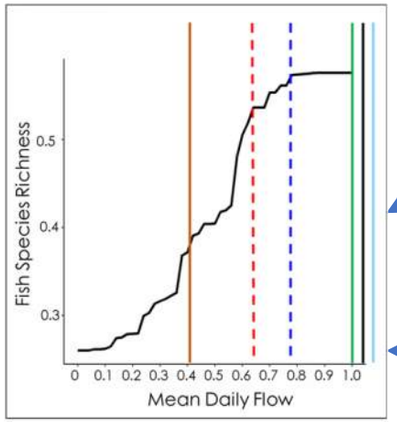
Estimate Flow-Ecology Relationships




Forecast Future Flows

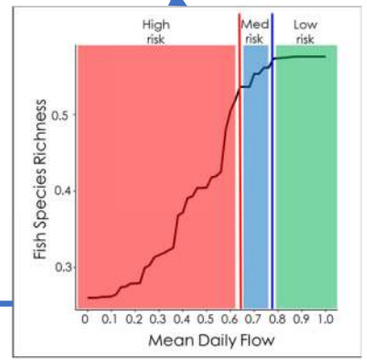
+ Uncertainty

+ 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**

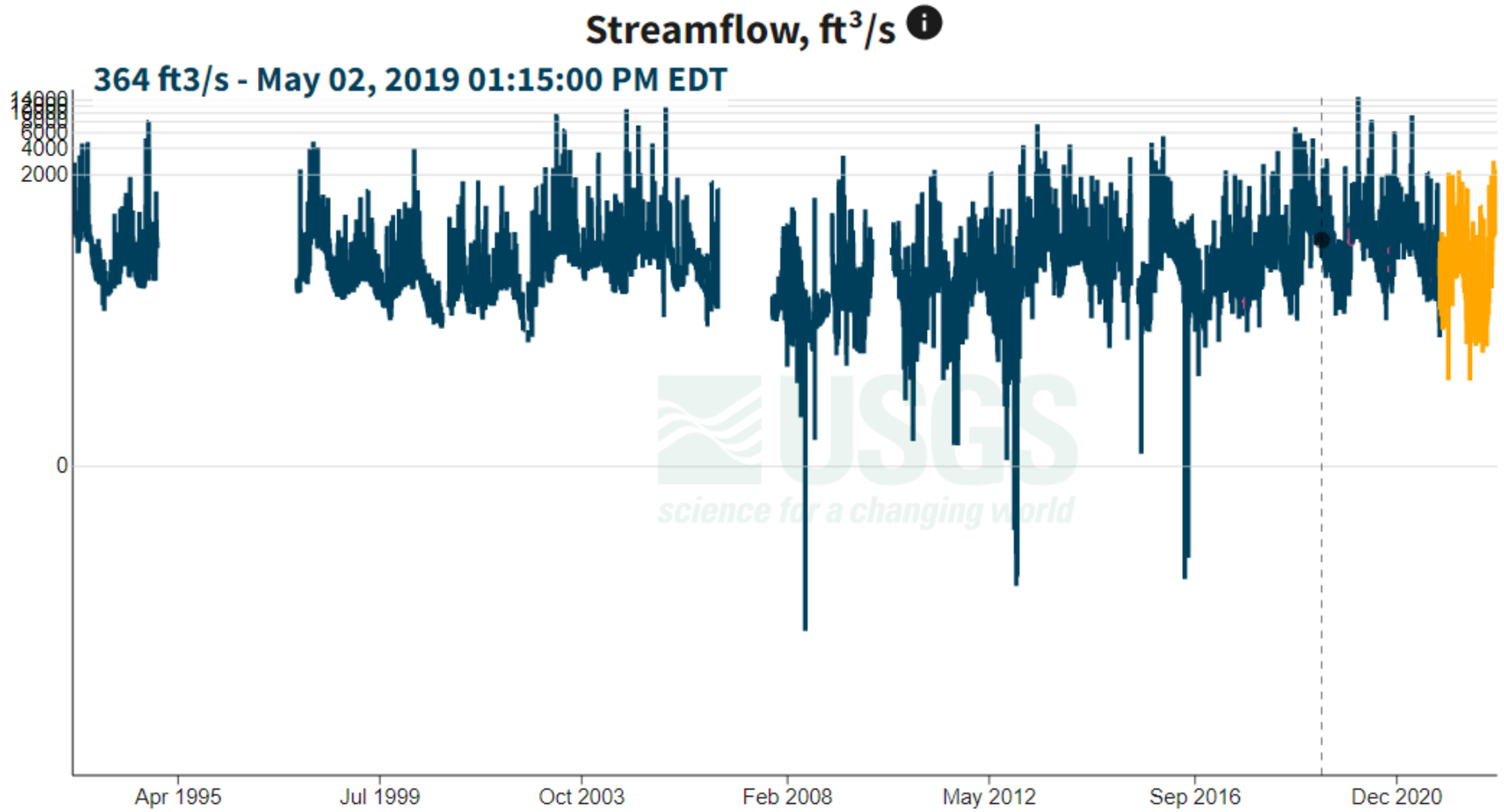
# What this info *is not*

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

# Results summer

- All scenarios showed little to no change for fish Richness and Shannon’s diversity

- Report to follow

# Questions

**Email: lmbower@clemson.edu**