The Nature Conservancy's Environmental Flows Project for North Carolina

Hydrogeomorphological

Kimberly Meitzen, Ph.D.

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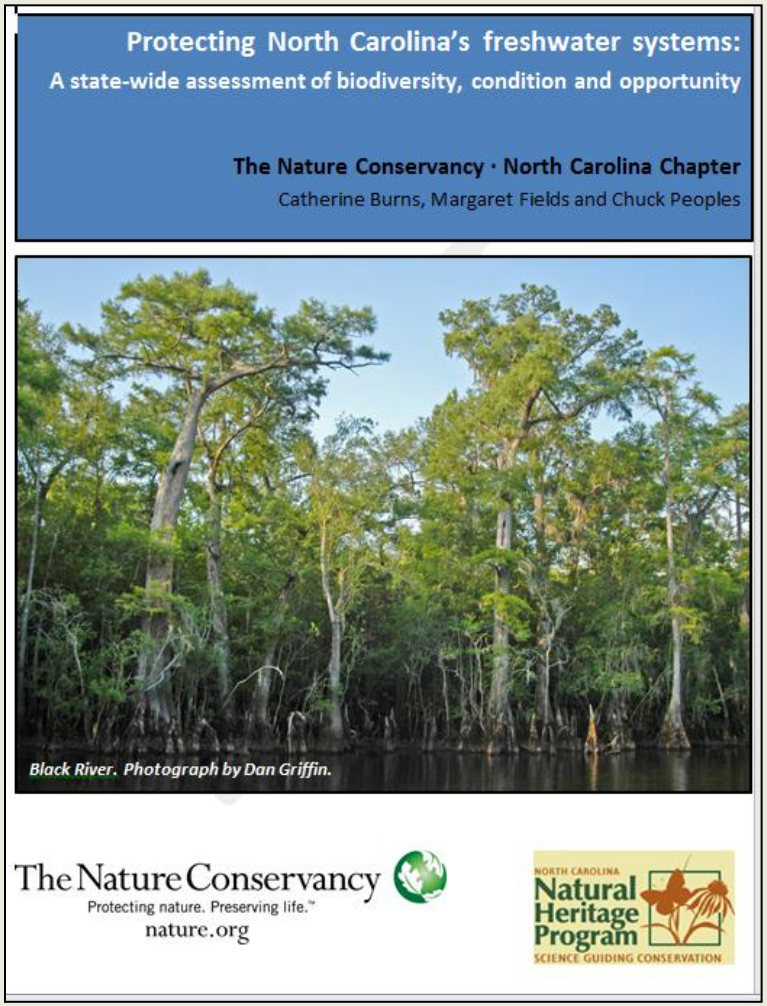
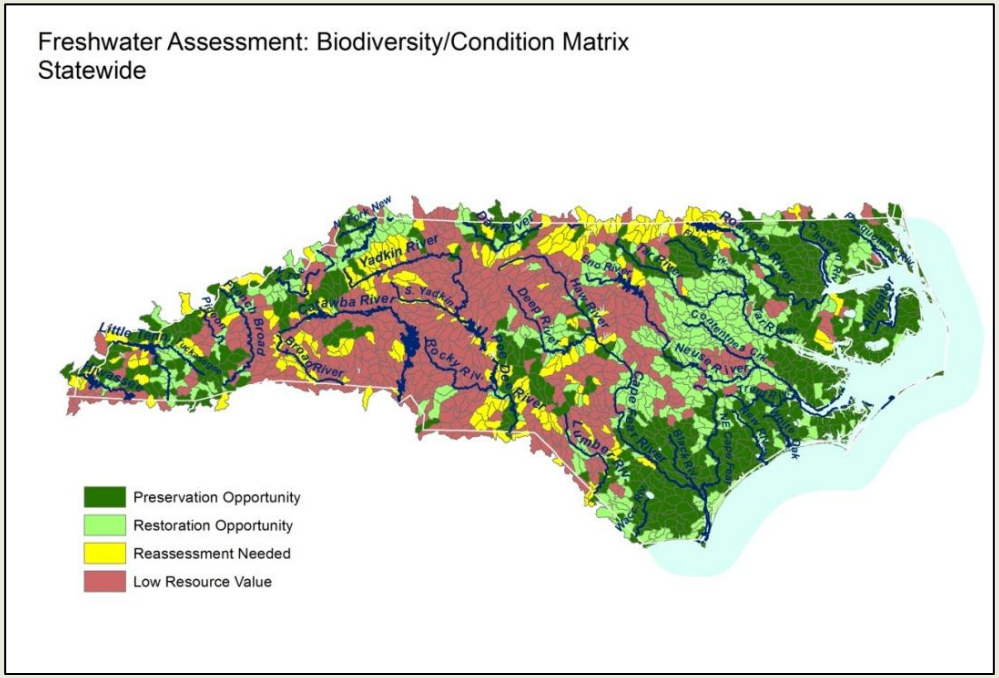
TNC Freshwater Assessment

- Cat Burns, Chuck Peoples, and Margaret Fields

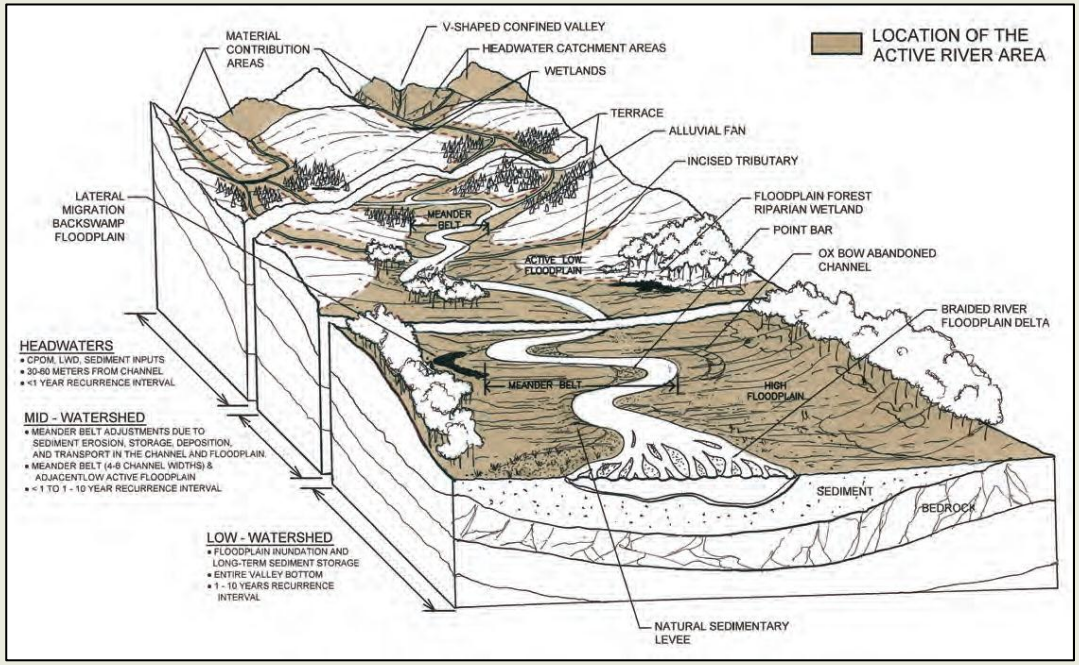


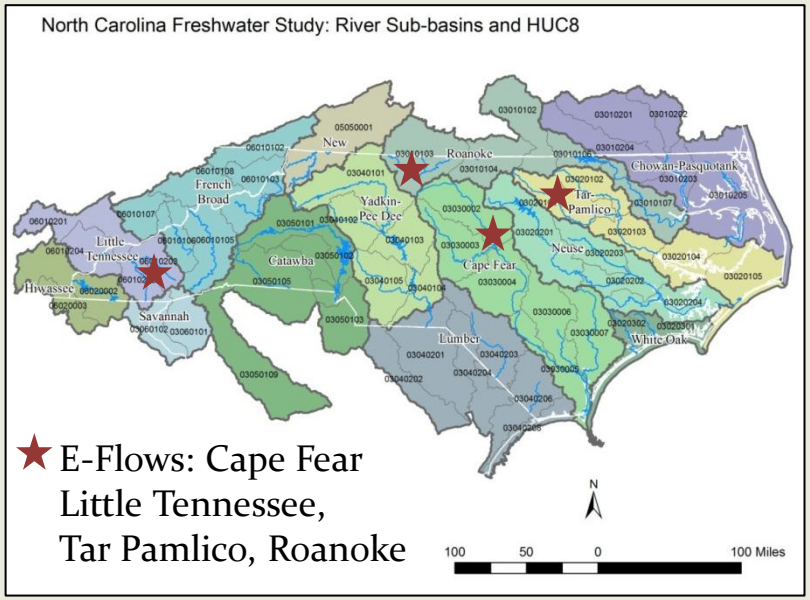
- Biodiversity and environmental condition
- Cape Fear, Tar-Pamlico, Roanoke, Little Tennessee River Basins



TNC Freshwater Resilience Project

- 1. Linear connectivity
- 2. Lateral connectivity
- 3. Water quality and land use/cover
- 4. Access to groundwater
- 5. Diversity of geophysical settings in the area
- **6. Naturally variable instream flow regime**



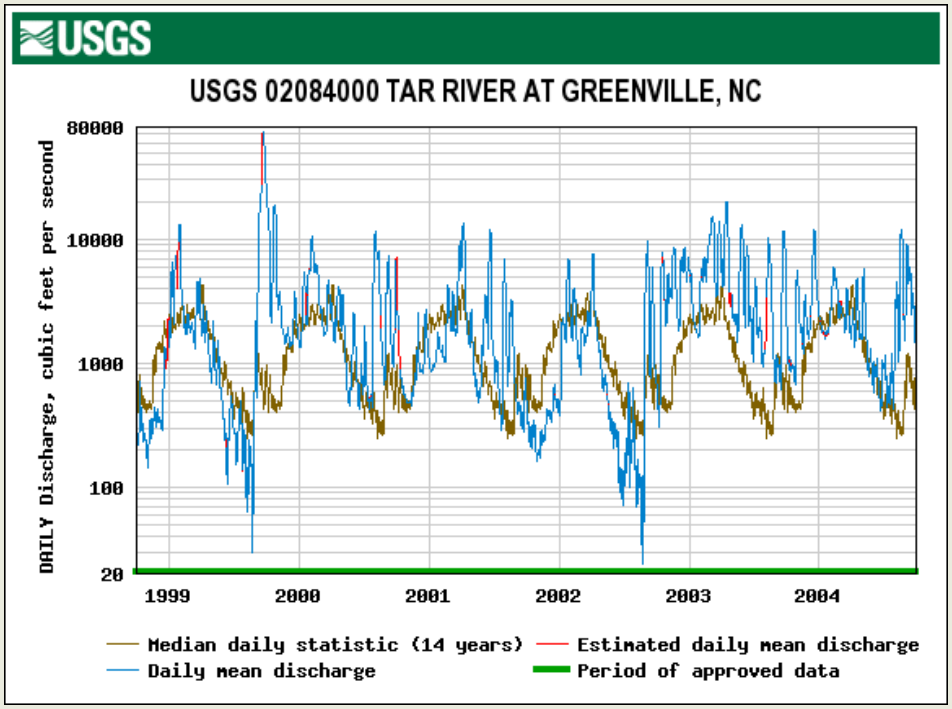


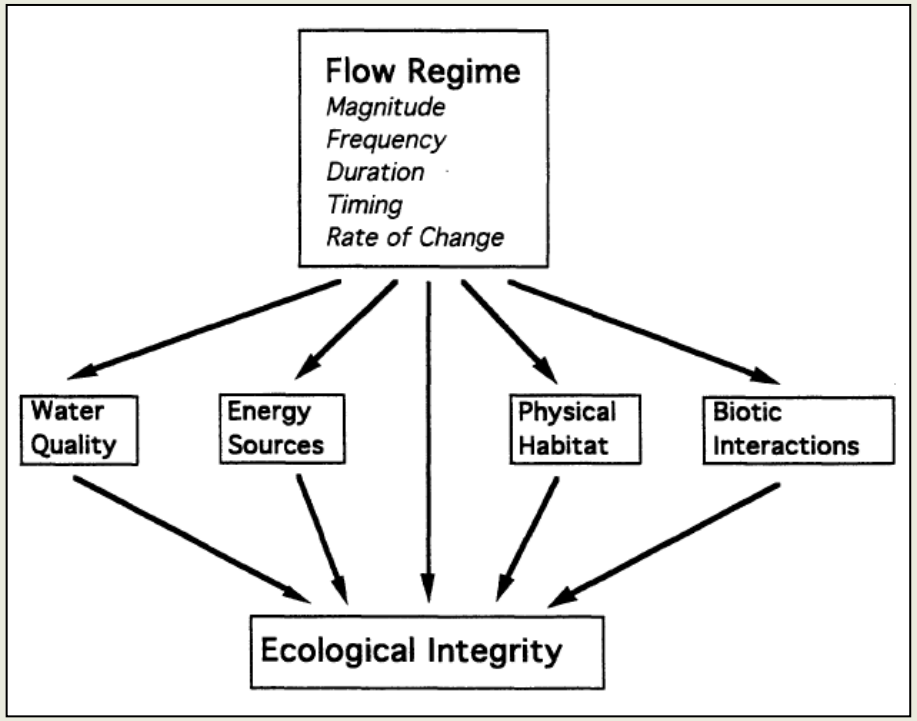
North Carolina Ecological Flows Science Advisory Board (EFSAB)

- In 2010 the North Carolina General Assembly directed the NCDENR DWR to develop hydrologic models for all 17 basins as recommended by the Environmental Review Commission (ERC)
- Models should incorporate environmental flows that are needed to maintain ecological integrity in surface waters
- Creation of an Ecological Flows Science Advisory Board (EFSAB) to assist NCDENR in assessing ecological flows
- NCDENR required to report annually to ERC on model progress
- Opportunity for TNC to apply elements of the resiliency study to help the NCDENR DWR and EFSAB meet the objectives presented by the ERC

Natural Flow Regime and Environmental Flows

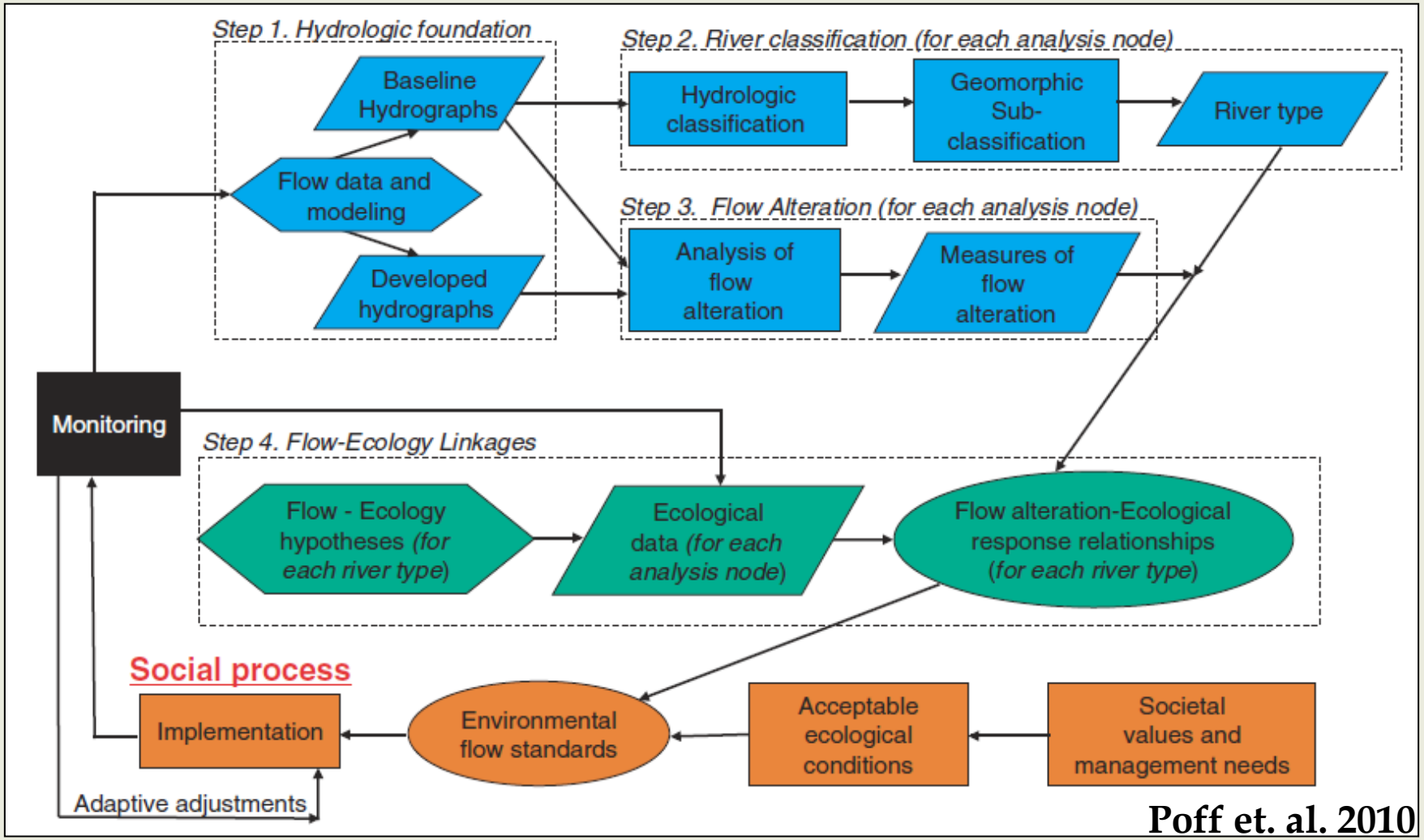
- " the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihood and well-being that depend on these ecosystems" – Brisbane Declaration, 2007
- " a naturally variable regime of flow, rather than just a minimum low flow, is required to sustain freshwater ecosystems"– Poff et al., 1997, 2010





Ecological Limits of Hydrologic Alteration

- We are applying a derivative of the 4 step ELOHA method



Poff et. al. 2010

Project Outline

1. Conduct literature review and analyze biological data to develop flow-ecology relationships

2. Model *baseline unaltered*, and *current altered* flow scenarios

3. Analyze changes in flow metrics among simulation scenarios

4. Measure and predict species responses to flow alterations.

5. Identify areas of resilience and vulnerability relative to flow alterations and environmental flow management

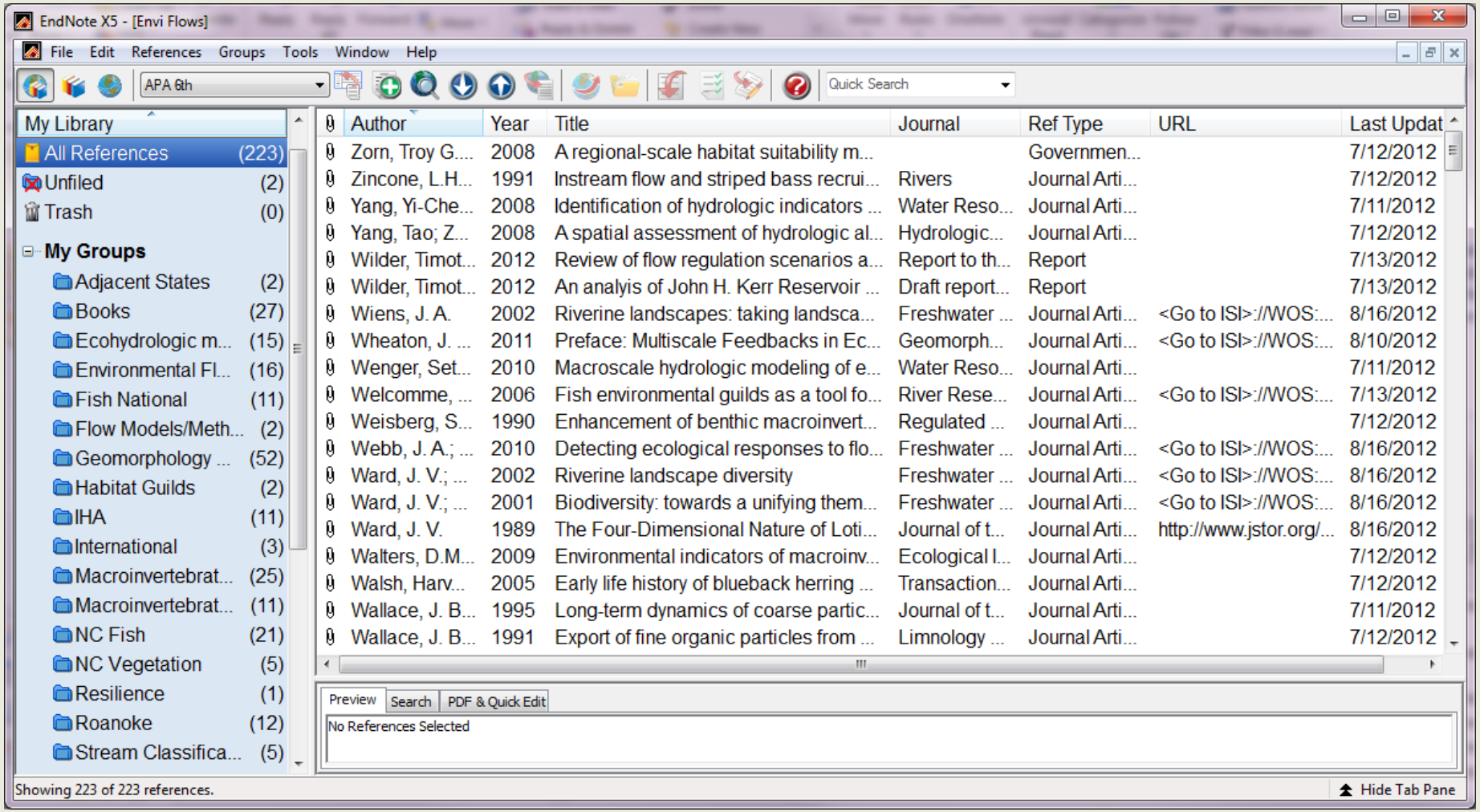
6. Provide flow recommendations to the Ecological Flows Science Advisory Board for NCDENR Division of Water Resources

Literature Review

- **Environmental Flow Projects and ELOHA Applications**
  - U.S. Nationally and Globally
- **Flow-Ecology Relationships**
  - North Carolina, adjacent states, southeastern to northeastern region
- **Flow Metrics, Statistics, and Analysis for Measuring Flow Alterations**
  - U.S. Nationally and Globally
- **Geomorphology and Environmental Flows**
  - U.S. Nationally and Globally
- * Southeastern Aquatic Resource Partnership (SARP) and South Atlantic Landscape Conservation Cooperative (SALCC) bibliographic resources and meta-analysis

Literature Review, cont.

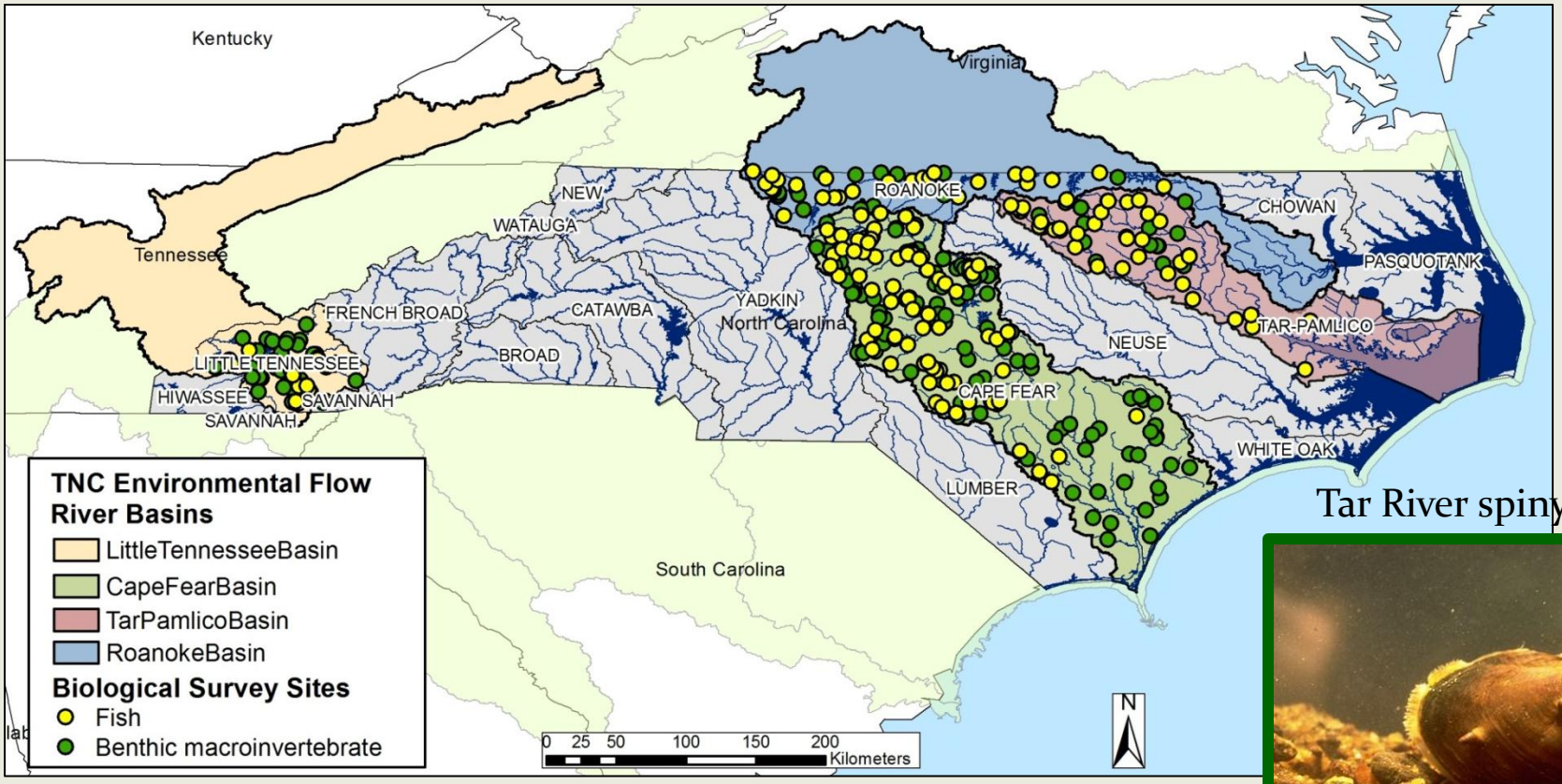
- > 223 references with linked pdfs in EndNote



Biological Data Evaluation

- **NCDWQ wadeable streams**
  - Fish ≥ 2 survey dates per site, 1990 - 2011
  - Benthos ≥ 3 survey dates per site 1982 - 2010

Creek chub sucker



Tar River spinymussel

Biological Data Evaluation

- **Fish data: sites with ≥ 2 survey samples**
- **Benthos data: sites with > 3 survey samples**

River Basin	Fish Sites	Fish Diversity	Fish Density	Benthos Sites	Benthos Diversity	Benthos Density
Roanoke	27	58	1,218	23	338	4,938
Cape Fear	69	68	2,650	136	464	28,032
Tar Pamlico	33	59	1,740	25	330	5,887
Little Tennessee	12	36	415	50	350	12,043

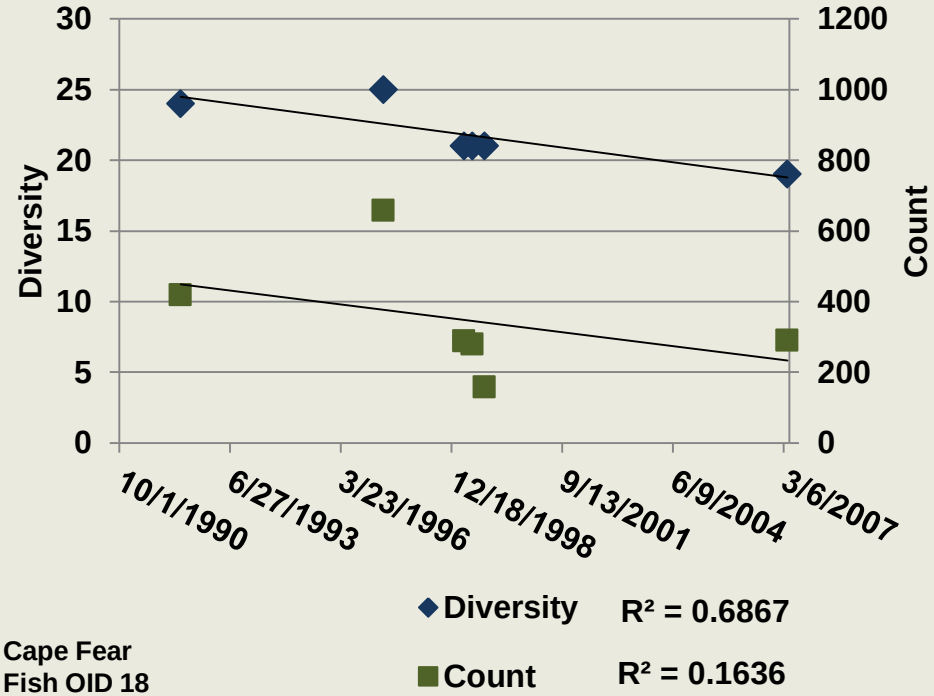
Benthos taxonomy

- **Taxonomic ambiguities resolved using the DPACs_rmO_G method**
  - (1) set the lowest taxonomic level to Genus (G),
  - (2) remove ambiguous taxa at and above the Order level (rmO)
  - (3) distribute the abundances of the ambiguous parents among the children separately for each sample (DPACs)
  - Abundance conversions: rare=1, common=3, abundant=10

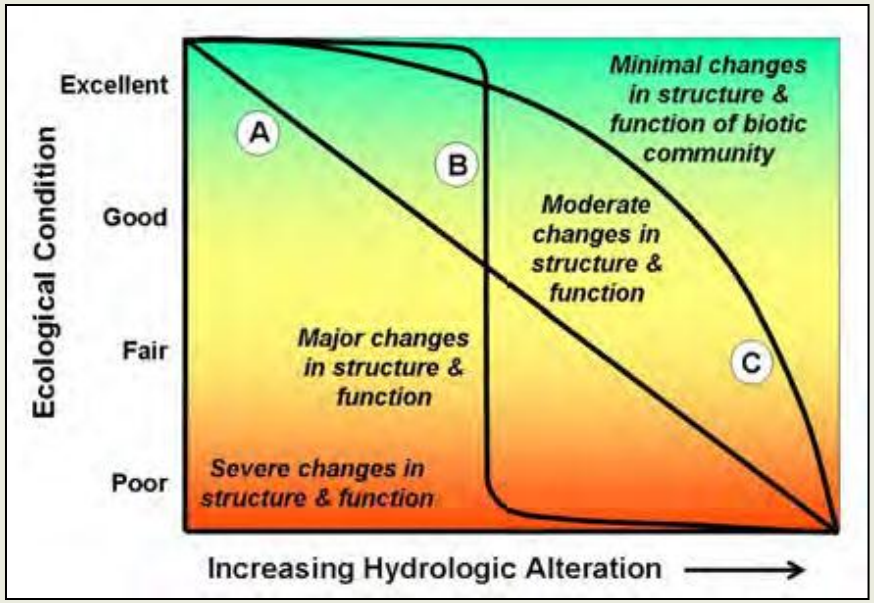
- **Resolved data was provided by Tom Cuffney, USGS**

Biotic Changes Over Time

- Fish and benthos
- Diversity and abundance changes over time
- Target species level abundance changes over time
- Community level changes in diversity and abundance

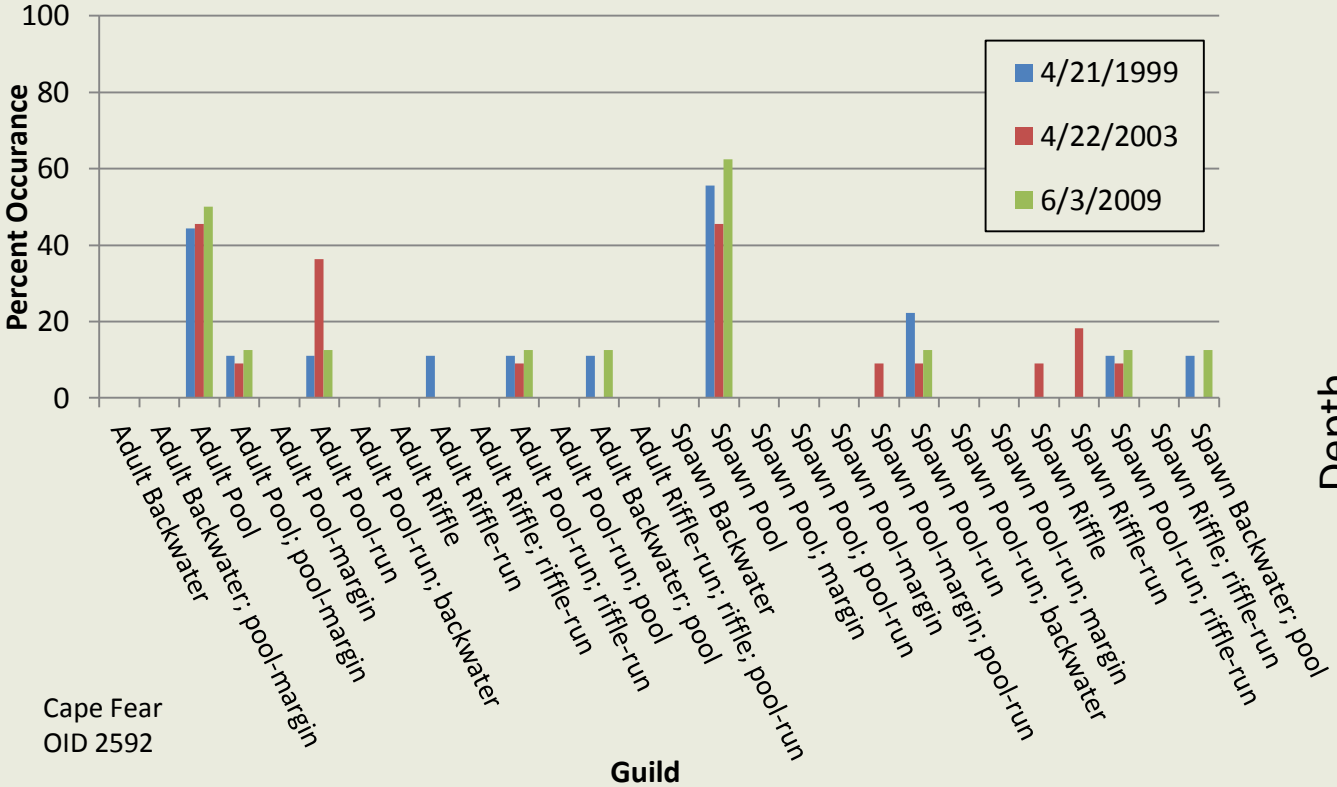


Cape Fear
Fish OID 18

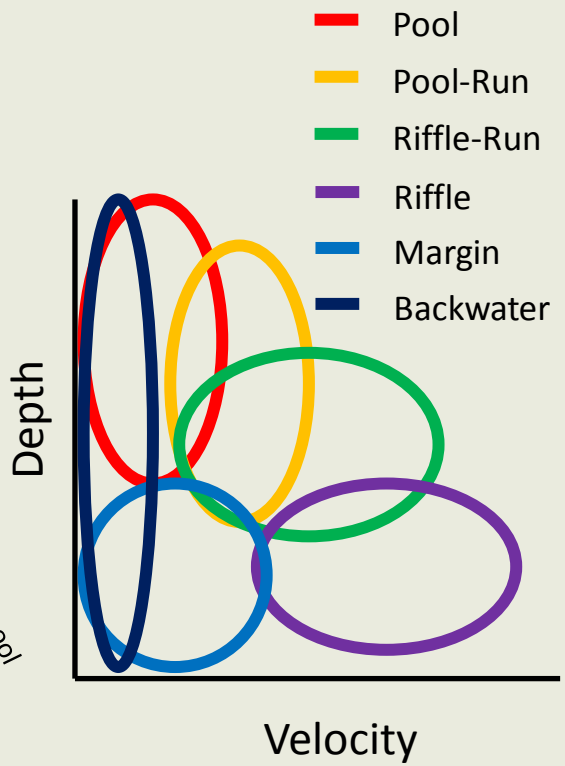


Habitat-Guild Analysis

- What is the percent occupancy by guild type at each survey site and each survey date?
- Is guild composition and percent distribution at a site consistent?
  - Possible controls on variation: Flow alteration, combined flow and habitat changes, seasonality, life stage characteristics…



Cape Fear
OID 2592



Flow-Ecology Relationships

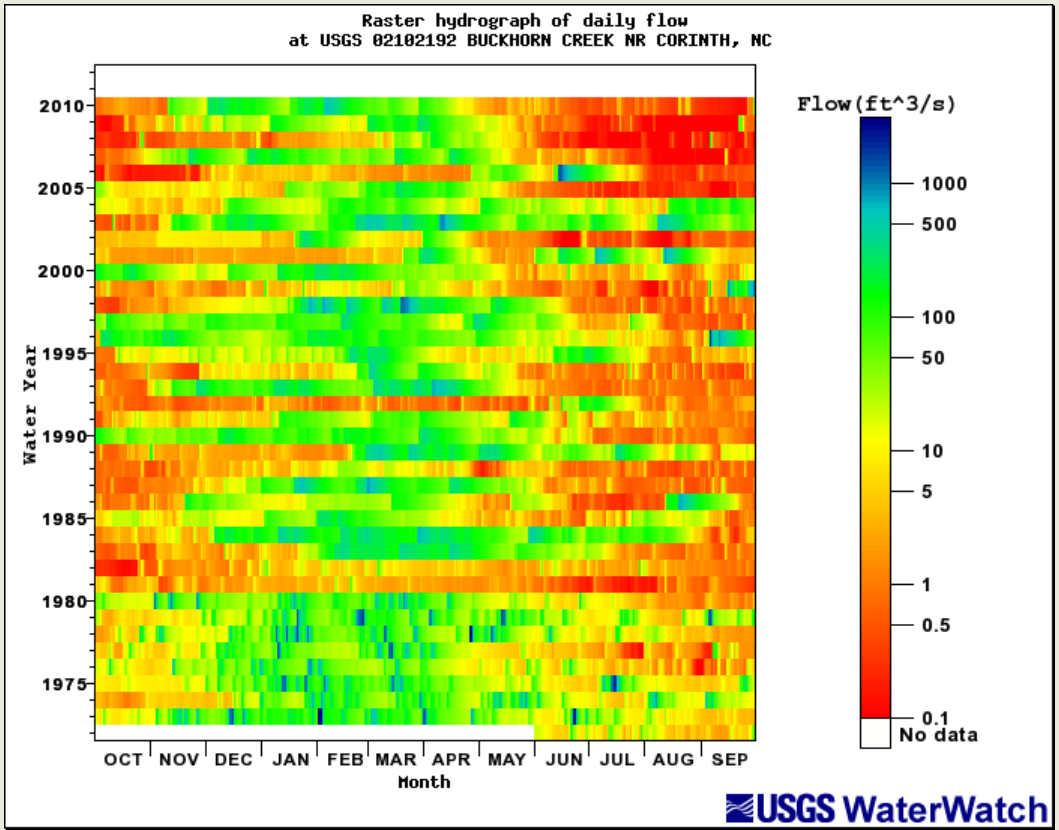
- How do biota (abundance and diversity) respond to changes in flow?

- 1. Analysis of USGS gage data in proximity to biological survey sites to measure effect of inter-annual flow variability on biota
  - Previous 1-4 years of data from gages sites in closest proximity to biological survey locations
    - Example 1: Site with samples from 1994, 1998, 2005 (gage data for 4 years prior to sample)
    - Examples 2: Sites with samples from 2008, 2009 (gage data for 1 year prior to sample)
  - IHA comparisons of flow metrics between flow periods

- 2. Analysis using simulated altered and unaltered flows, RTI WaterFALL

USGS gage data

- How does the hydrology in year(s) proceeding surveys compare to longer-term patterns?
- What inter-annual flow conditions support healthier communities?
  - Select gages with closes proximity to biological survey and 35 year record
  - 30 year statistics and inter-annual statistics relative to survey dates

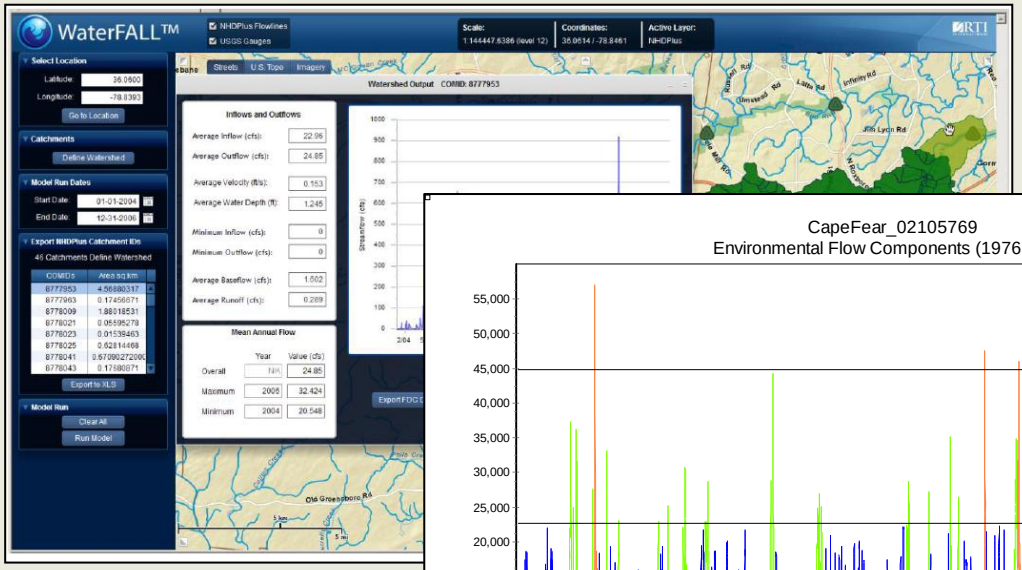


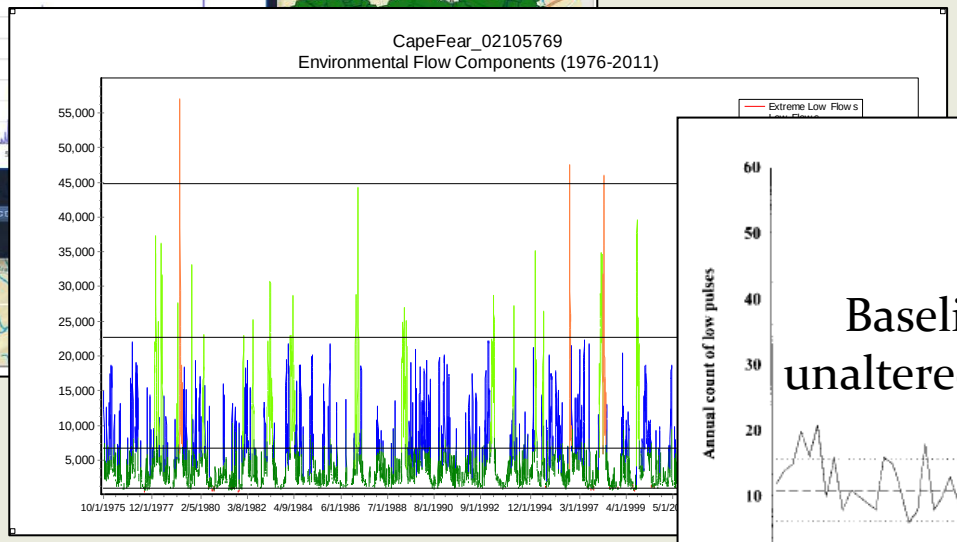
- Example 1:
- Site with samples from 1994, 1998, 2005
- gage data for 4 years prior to sample

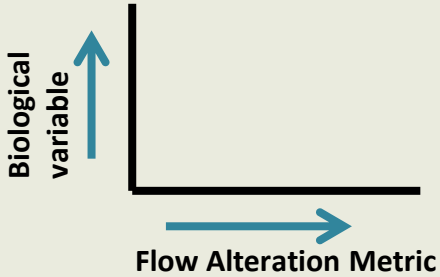
- Example 2:
- Sites with samples from 2008, 2009
- gage data for 1 year prior to sample

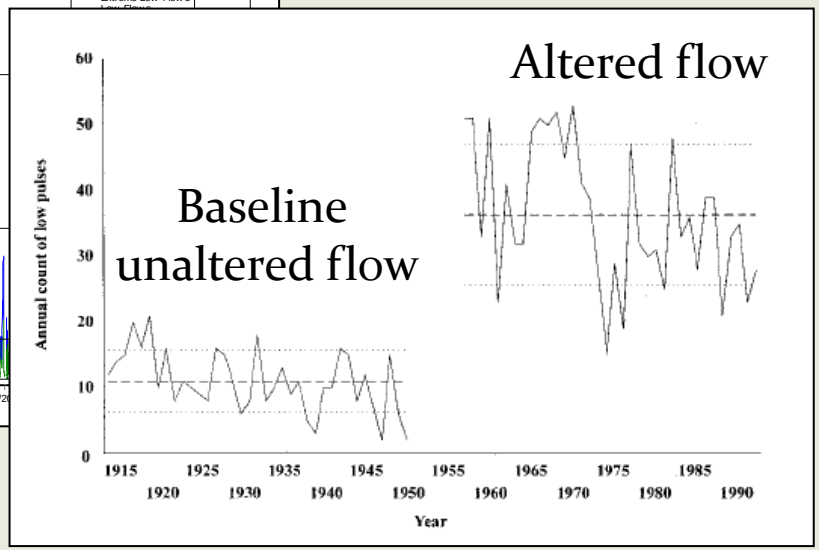
Hydrologic Modeling and Flow Analysis

- Research Triangle Institute (RTI) Water Flow and ALLocation model (WaterFALL)
  - Model baseline unaltered flows and current altered flows scenarios
  - Make comparisons using TNC's Indicator of Hydrologic Alteration (IHA)

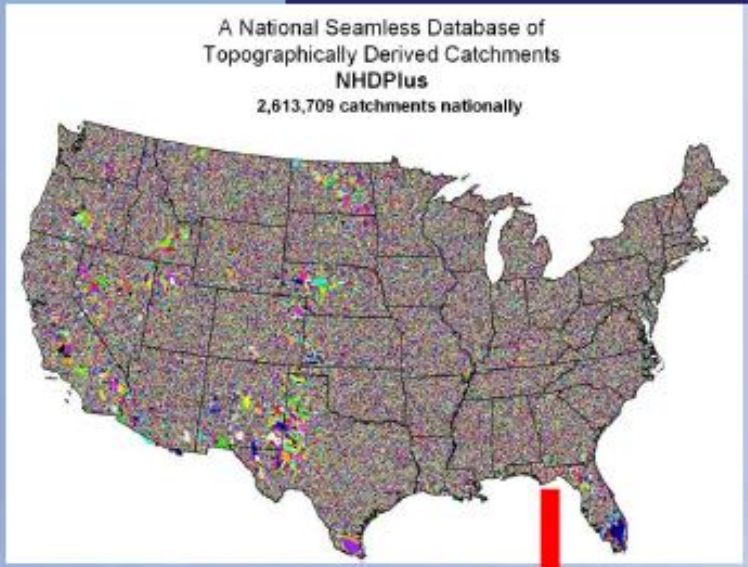




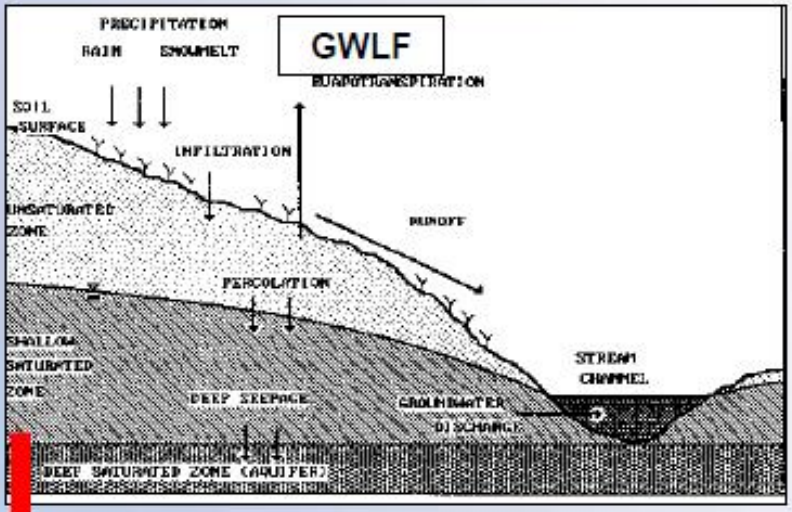




WaterFALL: Watershed Flow and ALLocation Model



Source: http://www.horizon-systems.com/nhdplus/documentation.php



Source: GWLF User Manual Version, Haith et al., 1996

Headwater reaches – flows generated with GWLF

Reach receives inflow from upstream and flows generated with GWLF

Outflow from catchment after inflow + GWLF flow subjected to routing method

Watershed outlet

Simulations of Baseline and Altered Flows

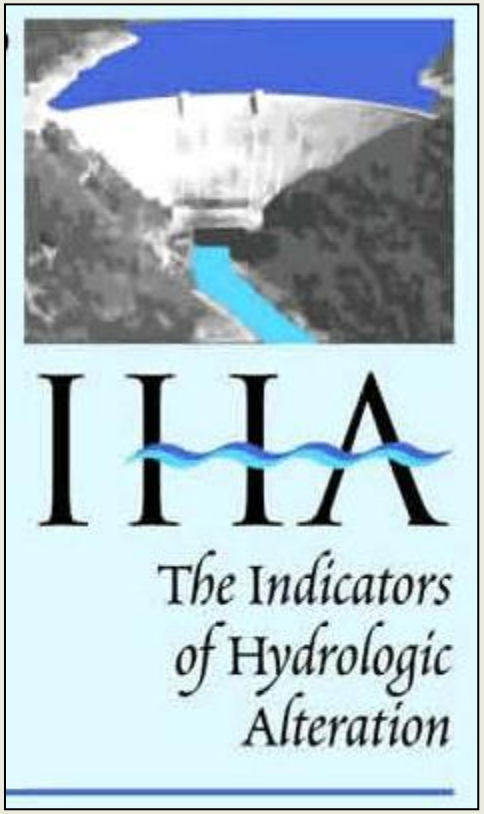
- **RTI's Water Flow and ALLocation model (WaterFALL)**
- **1. Baseline Flows:**
  - mid-1970's land cover and no flow alterations
- **2. Altered Flows:**
  - 2006 land cover, scenarios with flow alterations (dams, withdrawals/returns)
- **Model flows for the entire basin and compare flow alterations at multiple points through the basin**
  - Locations of biological surveys
  - Mainstem river channels

Quantitative analysis and comparison of flow metrics among simulation scenarios

- Indicators of Hydrologic Alteration (IHA)
- Compare IHA flow metrics among simulation scenarios
  - 1. At the location of the biological survey to examine at a site flow alterations
  - 2. Along the river network from headwaters to the relevant drainage point to examine basin-scale patterns of flow alterations
- Hydrologic metrics that are:
  - 1. Most representative, unique, and useful for flow-ecology relationships
  - 2. Provide useful indicators for measuring responses to flow alteration
  - 3. Amenable to management

Indicators of Hydrologic Alteration IHA

- Software for understanding hydrologic changes in ecologically relevant terms
- Developed by TNC to quantify flow patterns and flow alteration
- Metrics for Magnitude, Duration, Frequency, Timing, Rate of Change
  - 33 Metrics calculated for the period of record
  - 34 Environmental Flow Component (EFC) Metrics calculated for 5 discrete groups: Extreme Low Flows, Low Flows, High Flows, Small Floods, Large Floods
- Applied in numerous e-flow studies nationwide



Version 7.1

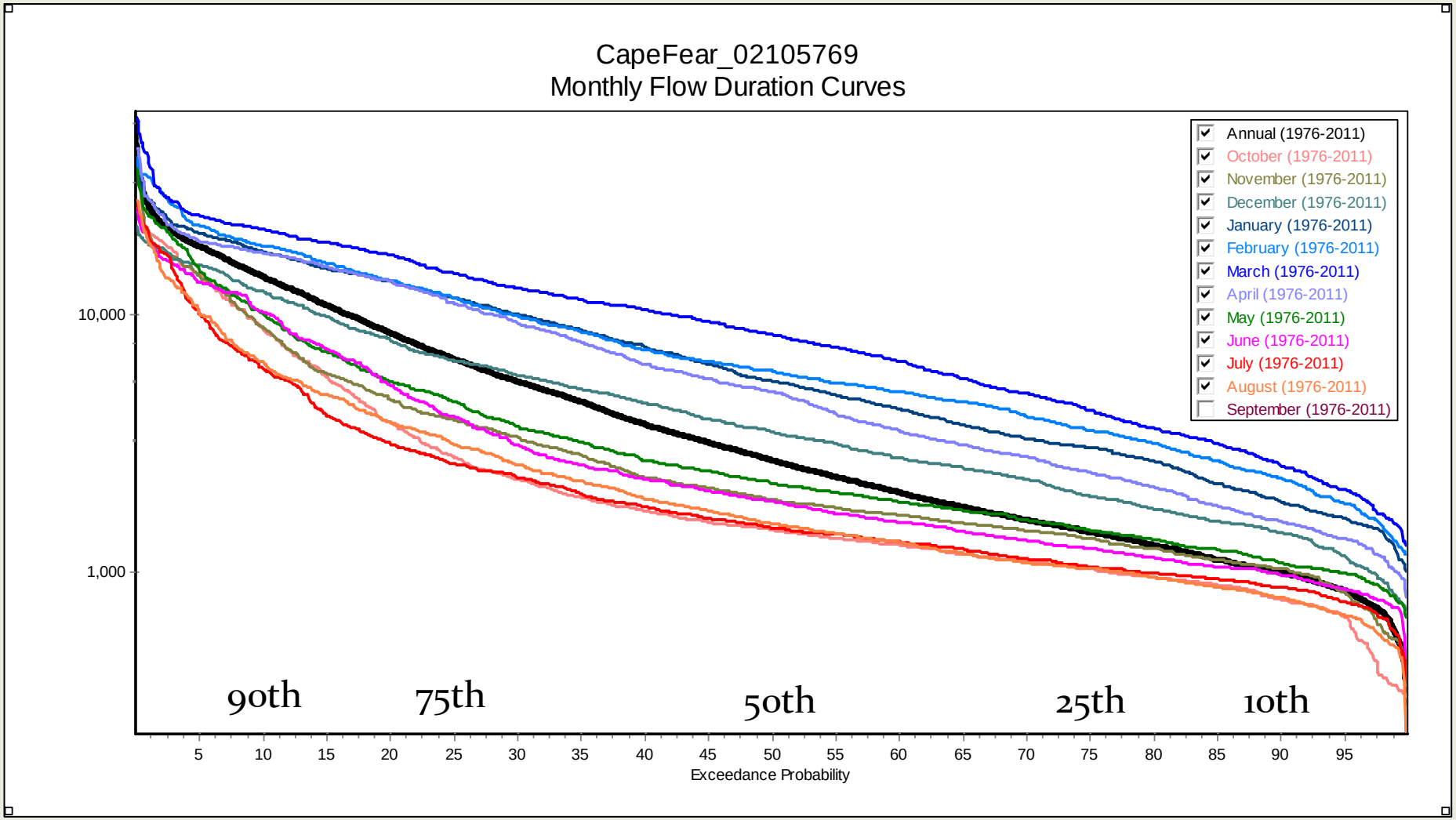
IHA software download:
http://conserveonline.org/workspaces/iha/documents/index/view.html

IHA metrics for quantifying flow alteration between baseline and altered conditions

- **Standard metrics**
  - 3, 7, 30, and 90 day minimums and maximums
  - Low pulse count, low pulse duration
  - High pulse count, high pulse duration
  - Monthly metrics for the 10th, 25th, 50th, 75th, and 90th
- **Environmental Flow Component Metrics**
  - Extreme low flow peak, duration, frequency, and timing: calculated for 2 periods (1) July 1st –Sept. 30th and (2) Oct. 1st-June 30th
  - High flow peak duration, frequency, and timing
  - Small flood peak, duration, timing, and frequency
  - Large flood peak, duration, timing, and frequency
  - Extreme low flow, low flow, and high flow thresholds
  - Small flood and large flood minimum peak flow

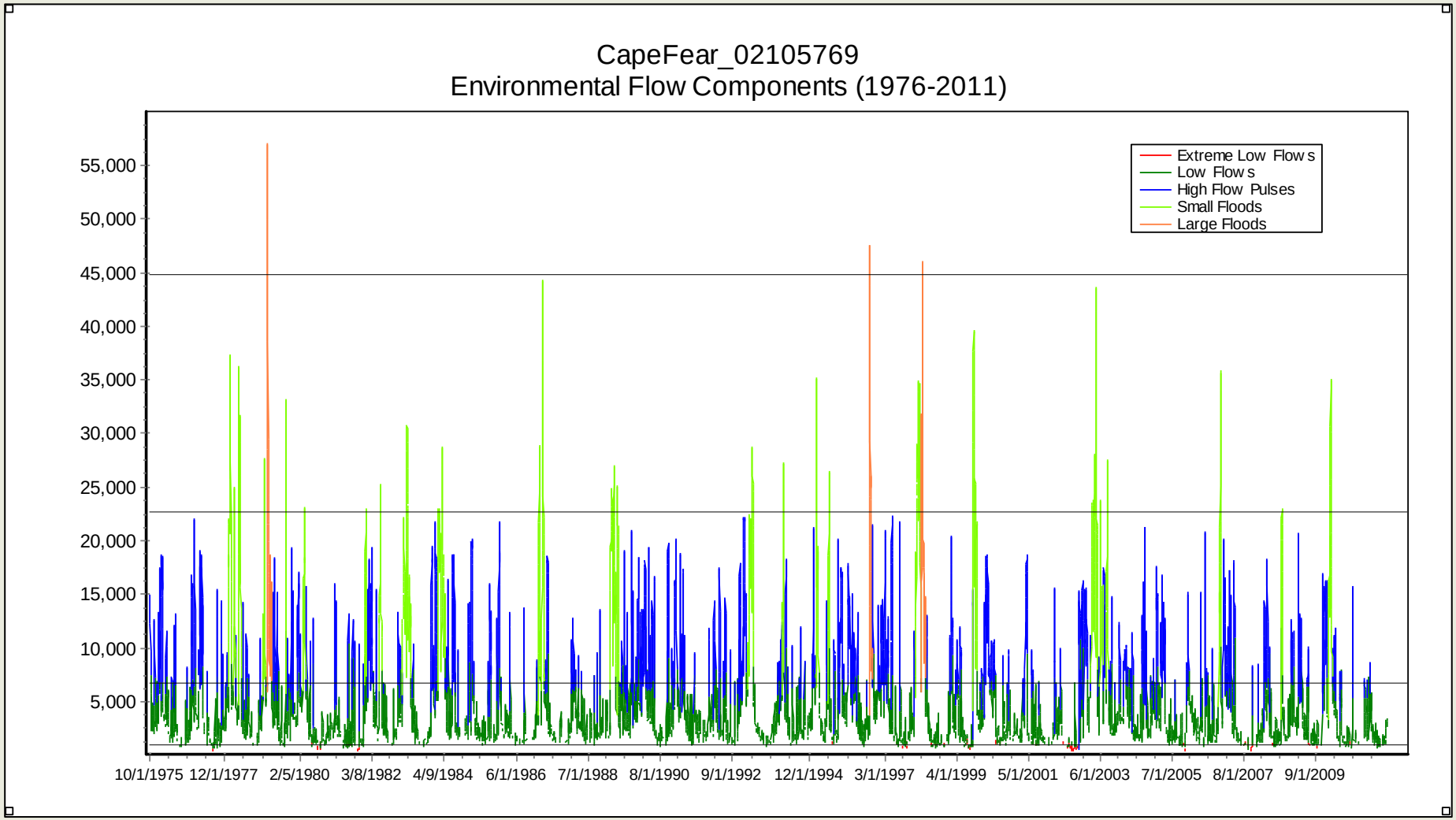
IHA Monthly Flow Duration Curves

- 10th, 25th, 50th, 75th, 90th percentile flows for each month



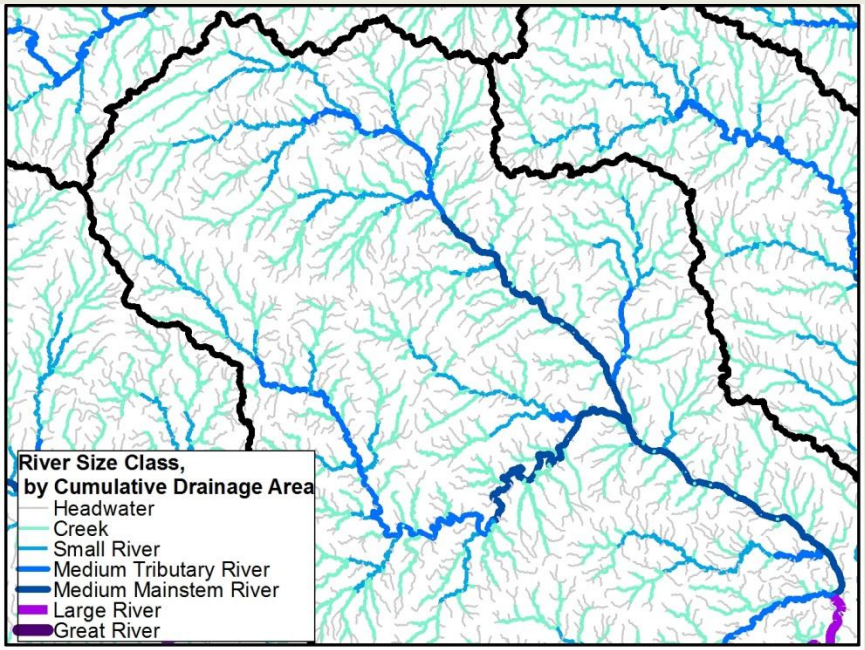
IHA Environmental Flow Components

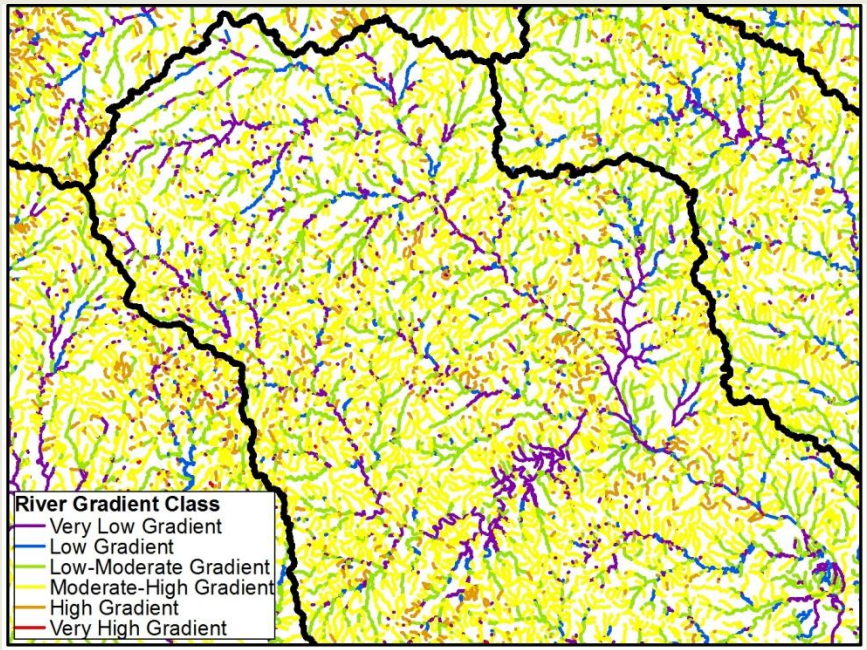
- Extreme low flows, low flows, high flow pulses, small floods, large floods



Environmental Variables

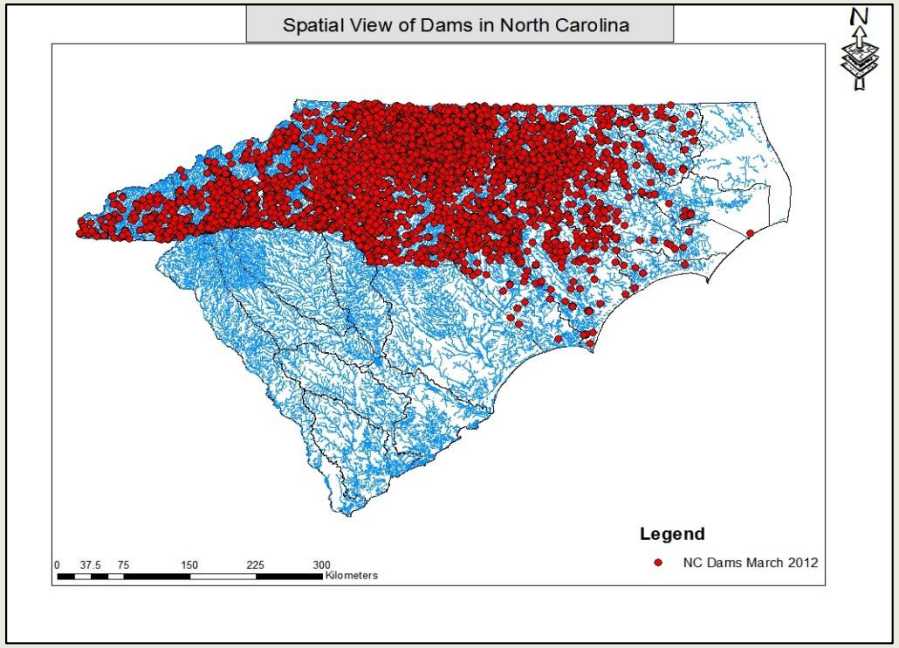
- Stream size by cumulative drainage area
- Stream gradient, continuous values and categorical (6 classes)
- % Natural land cover within active river area
- Connectivity and amount of accessible river network

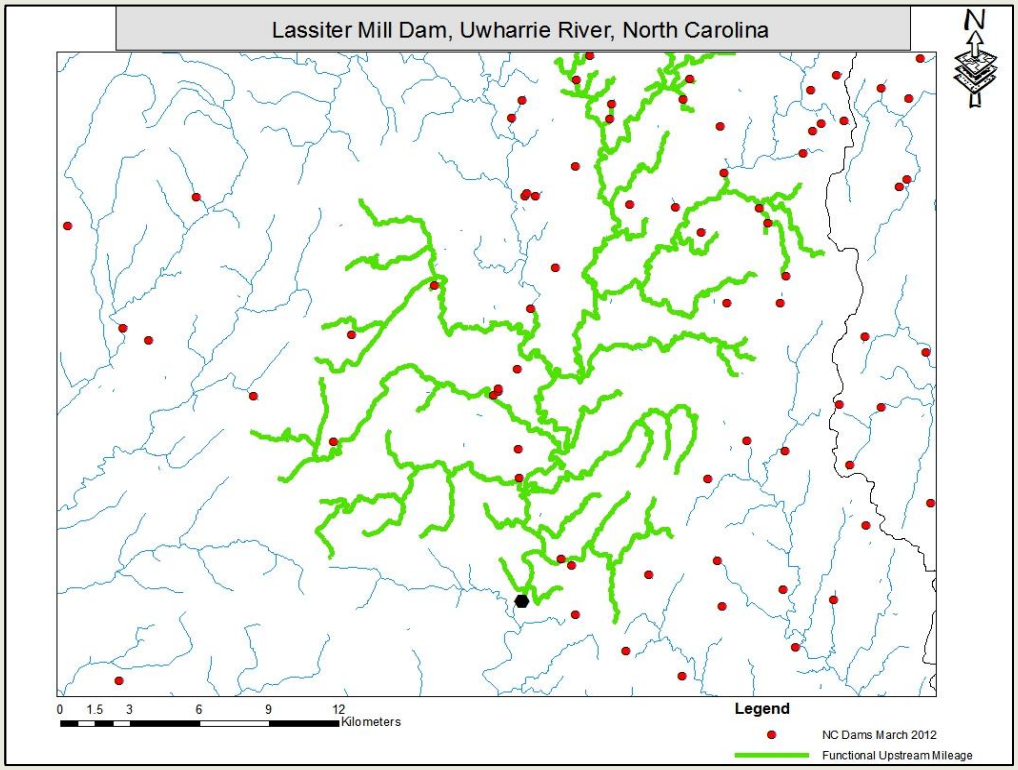




Linear Connectivity Analysis

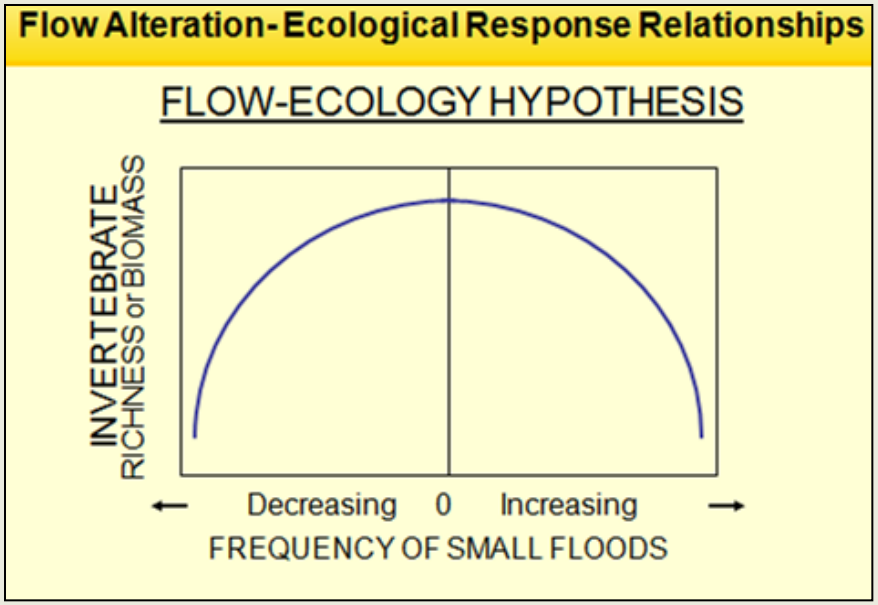
- Comprehensive barrier data for state
- Upstream functional river network length calculated from dam to dam





Re-examination of flow ecology relationships in context of simulated flows and IHA metrics

- Can we make predictions regarding organism responses to different flow scenarios, and what are these predictions?
- Which metrics best inform these flow-ecology response relationships?
- Is there an effect from the other environmental variables?
- How much confidence do we have in these F-E relationships and predicted responses?



Providing flow recommendations to the EFSAB

- For TNC's project, our goal is to include recommendations for all components of the natural flow regime relevant to the organisms and ecological interests we focus on.

- For the EFSAB however we will provide a set of recommendations targeted to moderate and low flow conditions with the intention of identifying critical thresholds where regulatory water management and allocation is a necessary action.

Schedule: 18 month timeline

Methods	Literature Review	Select Priority Basins from Freshwater Assessment	Biological Data Evaluation	Flow-Ecology Relationships (from literature review)	Flow Analysis of USGS data and Baseline and Altered Flows using IHA	Quantifying Flow Metrics and Flow-Ecology Relationships
	January – September 2012	March 2012	April – September 2012	April – September 2012	August – November 2012	October – December 2012
Reporting Milestones	Present project methodology to NC's Ecological Flows Science Advisory Group (EFSAB) and solicit input for how TNC's project can help them meet their needs: August 28th, 2012					
	Compile report of flow recommendations for the NCDENR DWR EFSAB December-March 2013					
	Draft report and distribution for comments: March – April 2013					
	Project Completion: June 2013					

Thank you !

Acknowledgements:

Cat Burns, Eloise Kendy, Kat Hoenke, and Alex Cohn, *TNC*

Martin Doyle, *Duke*

Jim Mead and Fred Tarver, *NCDENR*

Bob Dykes, Michelle Cutrofello, and Jen Phelan, *RTI*

Sam Pearsall, *EDF*

Chris Goudreau, *NCWRC*

Tom Cuffney, *USGS*

Mary Davis, *SARP*

Discussion Questions:

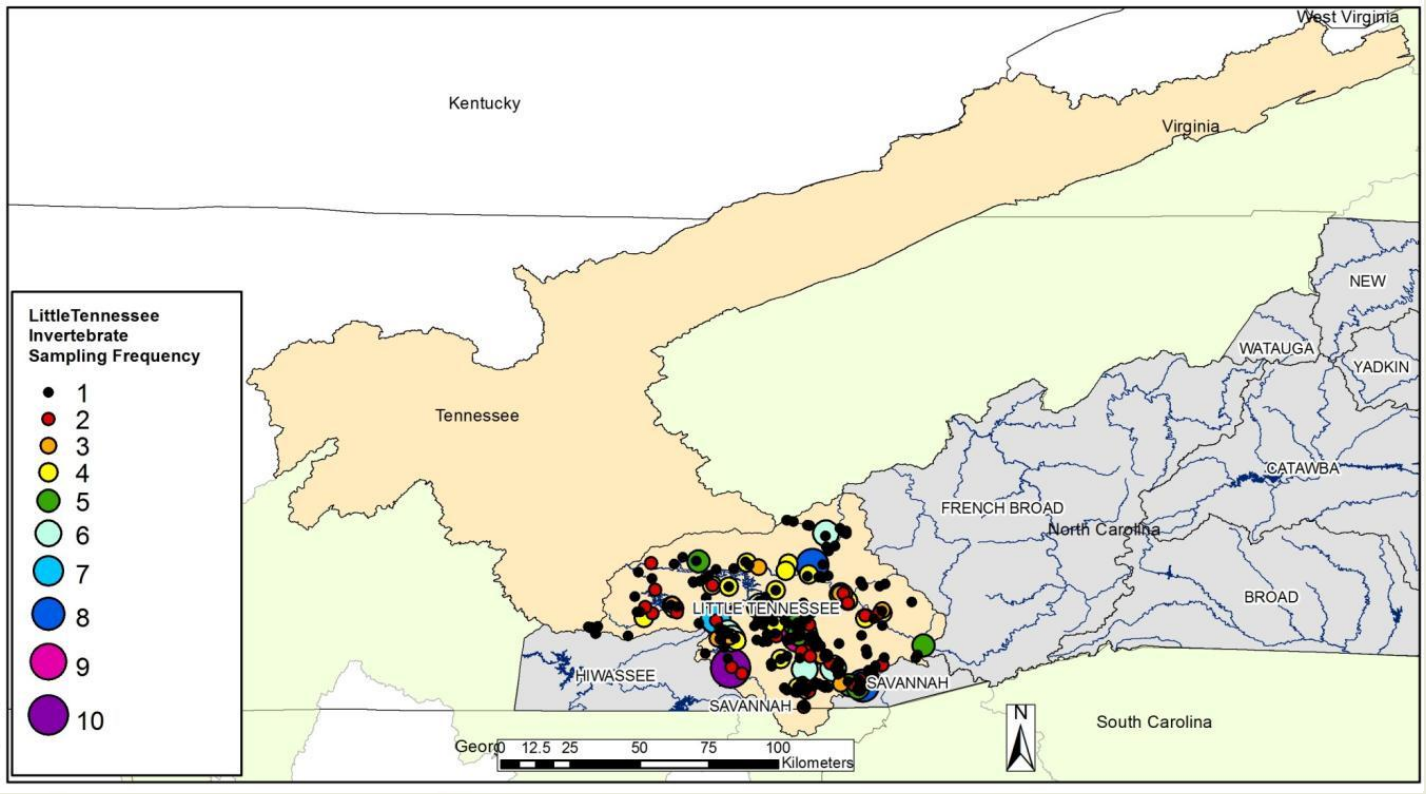
- What are the implications of these evaluations for EFSAB's work?
- What information from TNC's proposed project do the board members anticipate will be most useful for the EFSAB management objectives?
- How can TNC better accommodate and assist with meeting the objectives of the EFSAB and ERC?

Little Tennessee River Basin

- 1,797 square miles in North Carolina
- 89% land cover is forested
- 74 native fish species, 21 non-native fish species
- Cullasaja, Nantahala, Tuckasegee, Cheoh major tributaries
  - Tuckasegee, Panthertown Valley, contains over 20 miles of native brook-trout streams classified as "Outstanding Resource Waters" by NCDENR
  - Nantahala National Forest
  - Great Smoky Mountains National Park
  - Joyce Kilmer Memorial Forest
- 10 dams in NC
  - Fontana, Santeetlah, Nantahala, Glenville, Emory
  - Unimpounded Little Tennessee and Tuckasegee above Fontana support one of the most biodiverse aquatic communities in the Blue Ridge
  - Cheoh and Santeetlah dam is already a focus for environmental flows (Alcoa, 2004)
- Conservation Activities: U.S. Fish and Wildlife Service, Wildlife Resource Commission, Priority Area for TNC

NCDENR, 2012

Little Tennessee River



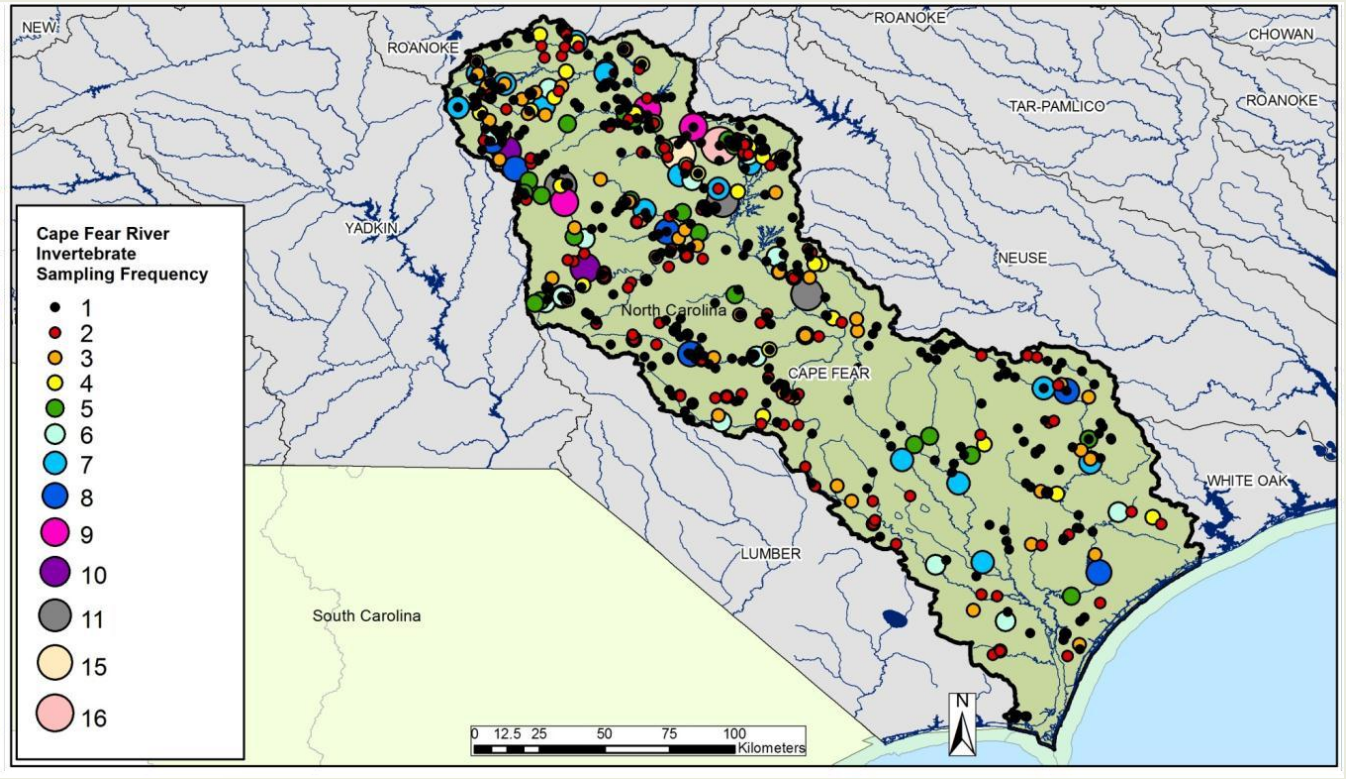
Little Tennessee Basin	Number of sites with specified sampling frequency										
Frequency of sampling	1	2	3	4	5	6	7	8	9	10	Total
Fish	39	11	1	0	0	0	0	0	0	0	51
Invertebrates	172	32	14	18	7	6	1	2	1	1	254

Cape Fear River Basin

- 9,164 square miles
- Deep and Haw rivers form the headwaters, other major tributaries include the Black and Northeast Cape Fear rivers
- 108 native fish species, 22 non-native fish species
- 42 Rare, threatened, and endangered
  - Shortnose sturgeon, Cape Fear shiner
- Several Large Reservoirs
  - B. Everett Jordan Reservoir 46,768 acres
  - Three major lock and dam structures have potential for removal or restoration of fish passage
- 1/5th the states population resides in the basin among Greensboro-Burlington-High Point, Durham-Chapel Hill, Fayetteville, and Wilmington
- Contains nearly 60% states swine livestock populations

NCDENR, 2012

Cape Fear River



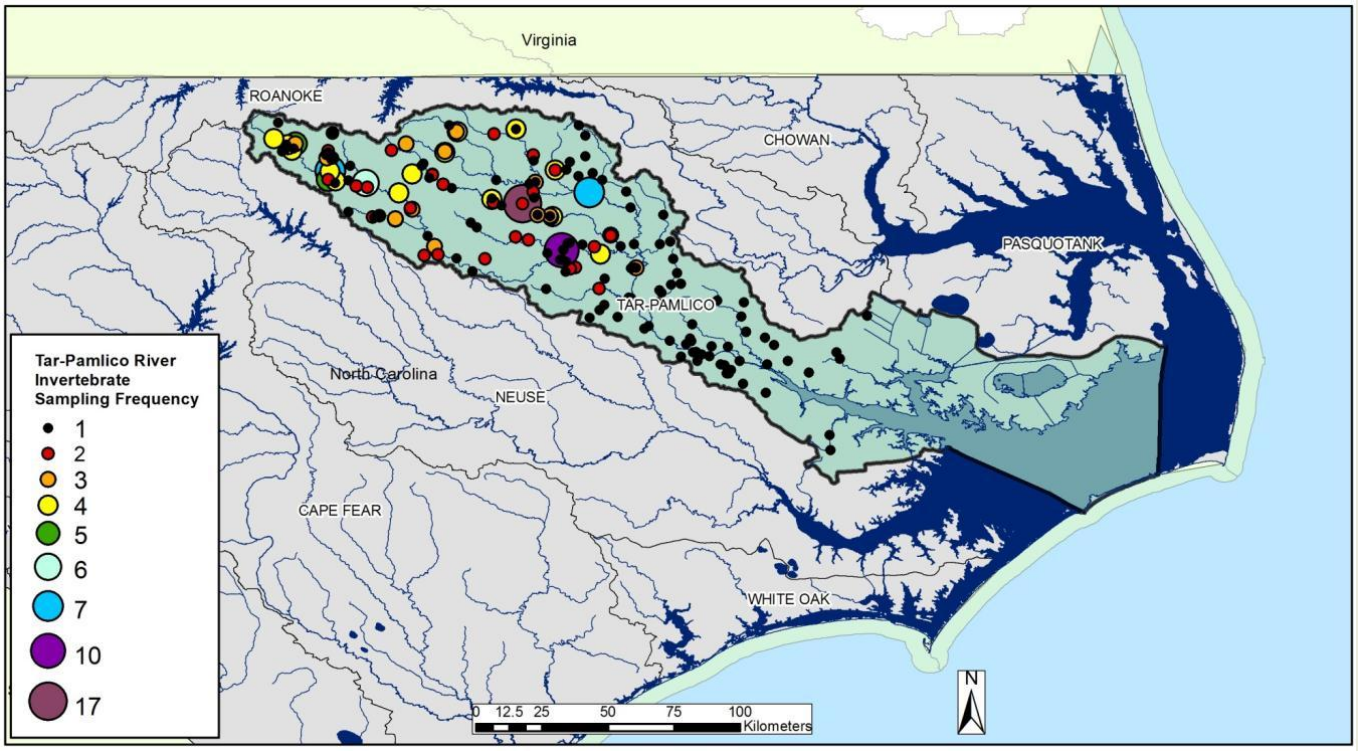
Cape Fear River Basin																	
	Number of sites with specified sampling frequency																
Frequency of visits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Fish	49	31	22	8	4	1	0	2	0	1	0	0	0	0	0	0	118
Invertebrates	320	121	63	32	24	16	18	6	3	2	3	0	0	0	1	1	610

Tar-Pamlico River Basin

- 6,148 square miles
- Tar River 3,750 square miles
  - Swift, Fishing, and Tranters tributaries
- 89 native fish species, 10 non-native fish species
- Recreational sport fish
- 17 rare freshwater mussels
  - Tar River spinymussel, Dwarf wedgemussel
- No Major Reservoirs
- Floodplain habitat in Coastal Plain

NCDENR, 2012

Tar Pamlico River



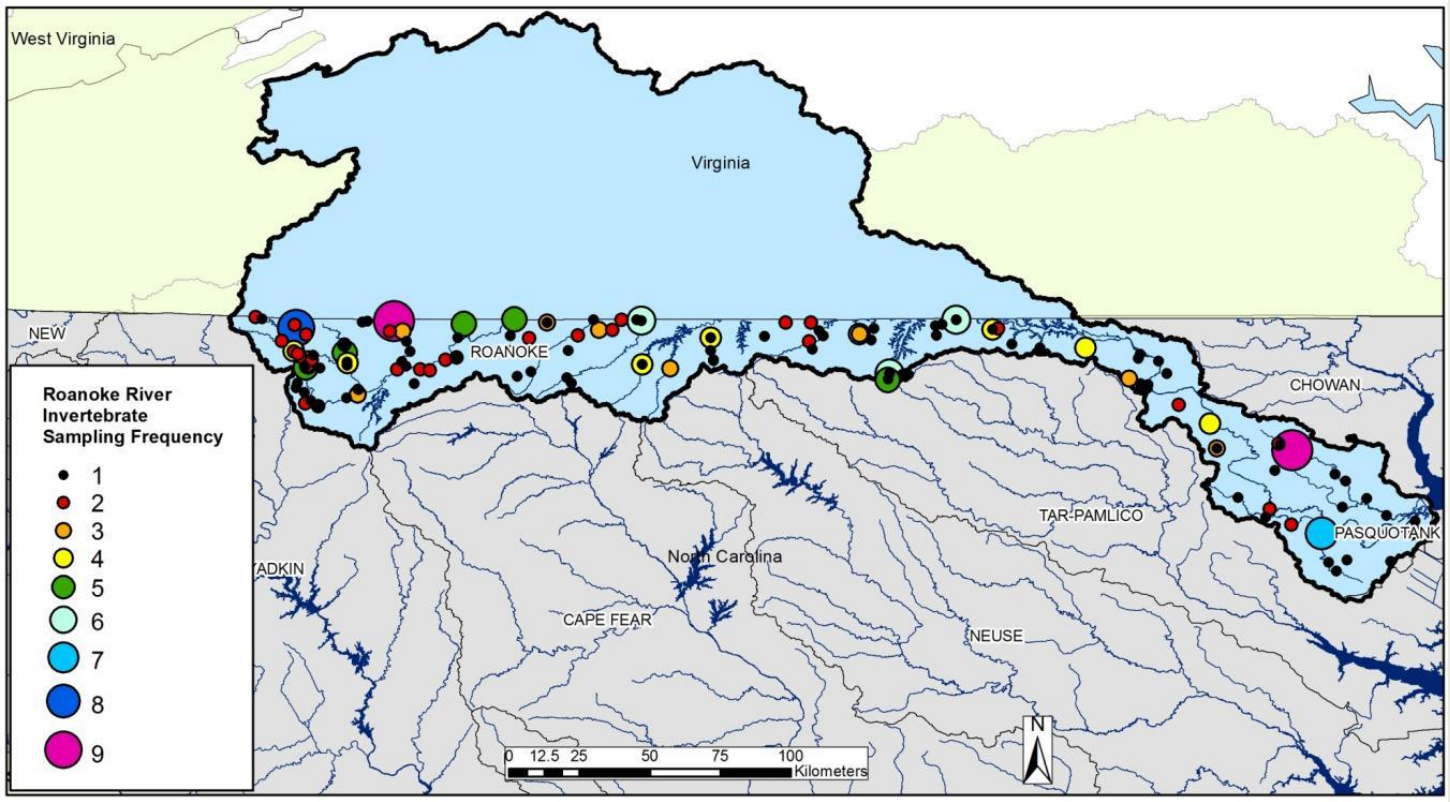
Tar-Pamlico Basin	Number of sites with specified sampling frequency																	
Frequency of sampling	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Fish	34	19	3	9	1	1	0	0	0	0	0	0	0	0	0	0	0	67
Invertebrates	256	29	15	14	2	1	2	0	0	1	0	0	0	0	0	0	1	321

Roanoke River Basin

- 9,680 square miles (3,493 in North Carolina)
- 100,000 acre area protected by TNC, USFWS, NC WRC, private conservation easements, Georgia Pacific Corporation
  - 21,000 acres Roanoke River National Wildlife Refuge
  - > 235 square miles of intact hardwood and cypress-tupelo bottomland forest
  - 137 mile of corridor of riparian habitat
- USACE 1953 John H. Kerr Dam, 1955 Lake Gaston, 1963 Roanoke Rapids Lake and Dam
  - Flood control, hydroelectric, recreation
- 113 native fish species, 24 non-native fish species
- Floodplain habitat
- TNC has existing involvement with environmental flows and the Corps (USACE)

NCDENR, 2012

Roanoke River



Roanoke River Basin	Number of sites with specified sampling frequency									
Frequency of sampling	1	2	3	4	5	6	7	8	9	Total
Fish	17	22	3	2	0	0	0	0	0	44
Invertebrates	96	30	10	9	5	3	1	1	2	157