



## Susquehanna River Ecosystem Flow Study: Approach to Developing Flow- Ecology Relationships

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Southeast Instream Flow Network

# Susquehanna Ecosystem Flow Study

WRDA 729 study with cost share between Susquehanna River Basin Commission & USACE

SRBC with regulatory authority in basin; updating consumptive use program & passby guidance (20% ADF or PA “Trout Model”) with new desktop approach

TNC using elements of the “Savannah Process” and the ELOHA framework as contractor to SRBC

Major project elements:

- Identify flow-sensitive species, communities, and habitats through literature review
- Complete basinwide assessment of flow alteration
- Relate flow alteration to potential ecological response
- Develop ecosystem flow recommendations

March 2009 - April 2010



# Initial Process (Literature Review)

1. Orientation workshop & follow-up
2. Draft species lists (using state, federal, Natural Heritage data)
3. Focused literature review on species traits, needs, sensitivities
4. Aggregate species into groups with similar flow-sensitivities & linked to habitat classification
5. Develop hydro-ecology diagrams for major types
6. Circulate information before Flow-Ecology Workshop

# DEFINING TRAITS: FISHES

## Targeted life history traits & examined flow sensitivity:

- body size
- fecundity
- home range
- habitat associations
- feeding habit
- flow-velocity tolerances

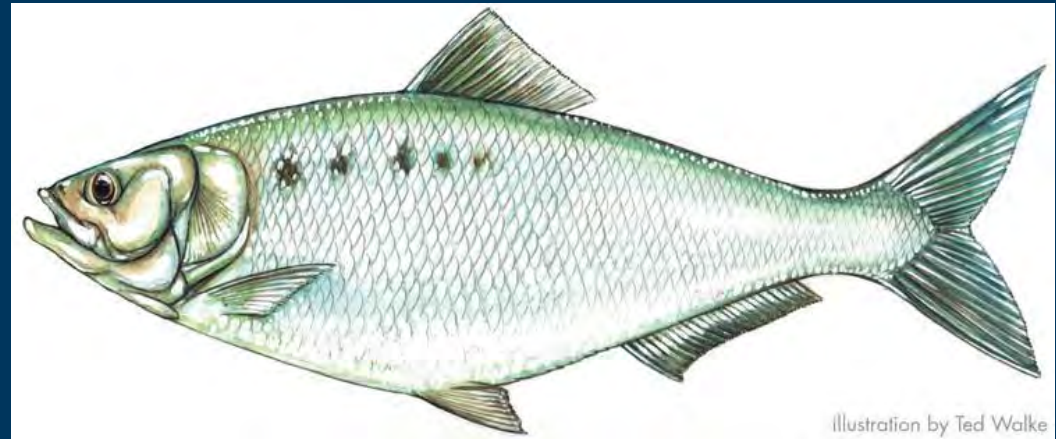


Illustration by Ted Walke

American shad, *Alosa sapidissima*



Illustration by Ted Walke

Longnose dace,  
*Rhinichthys cataractae*

Vadas and Orth 2000; Frimpong and Angermeier, in review; Walsh et al 2007

## Cold headwater – Brook trout and *Cottus spp.*

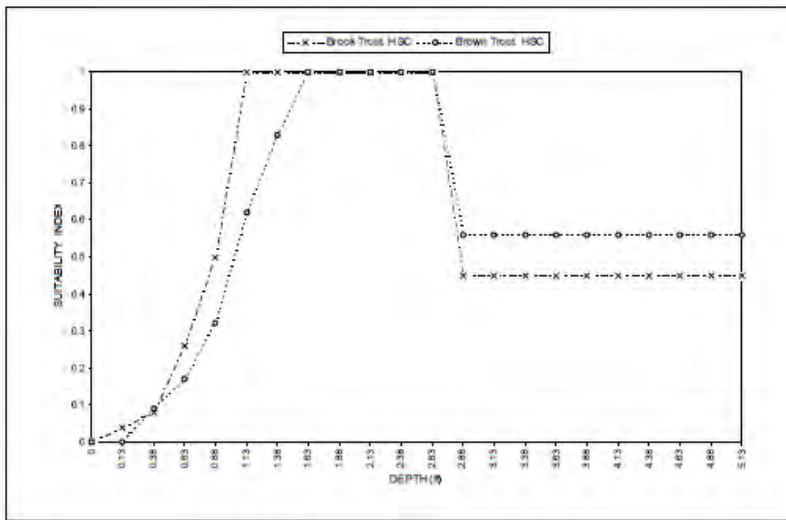


Figure 3.9. Adult Habitat Suitability Criteria for Depth

Above: Instream Flow Studies PA and MD, 1998, Pub 191

Right: Hudy et al 2005

Brook trout distribution by subwatershed

Never occurred  
 Unknown: no data or Absent: unknown history = 19%  
 Extirpated = 21%  
 Present = 60%

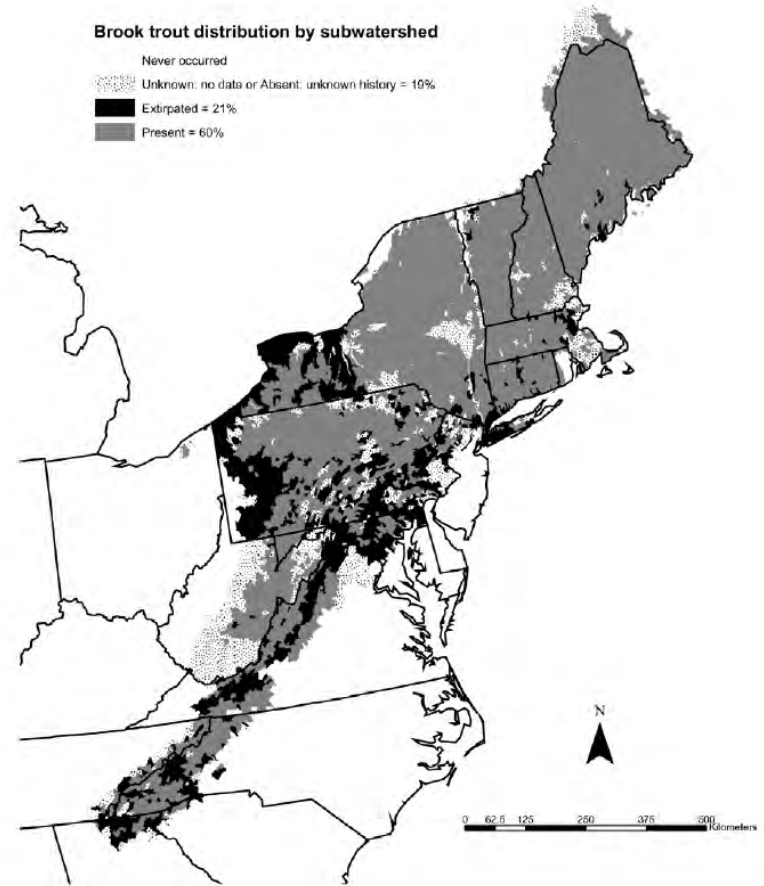
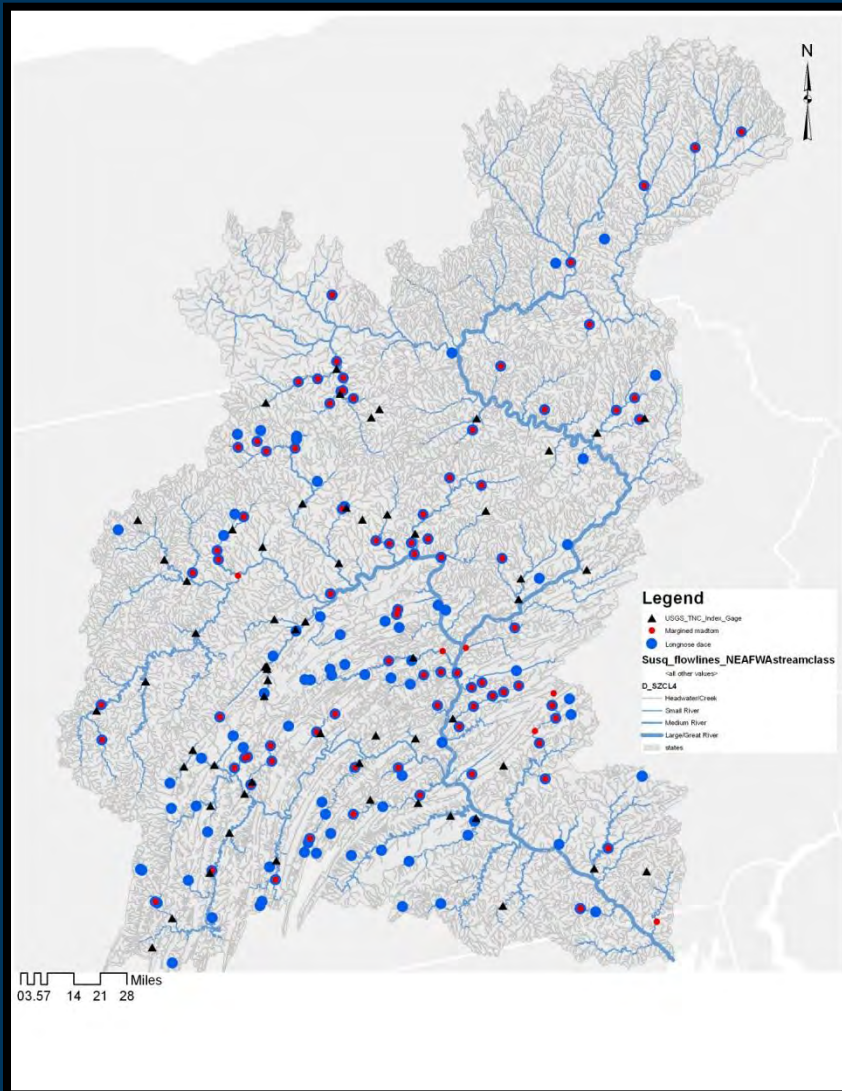
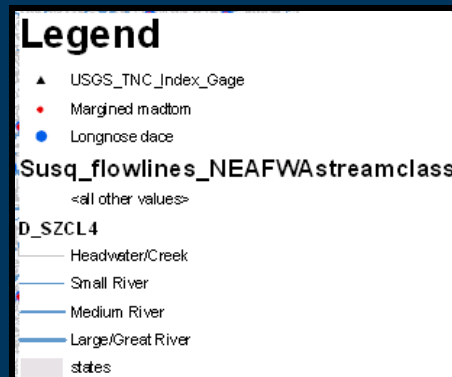


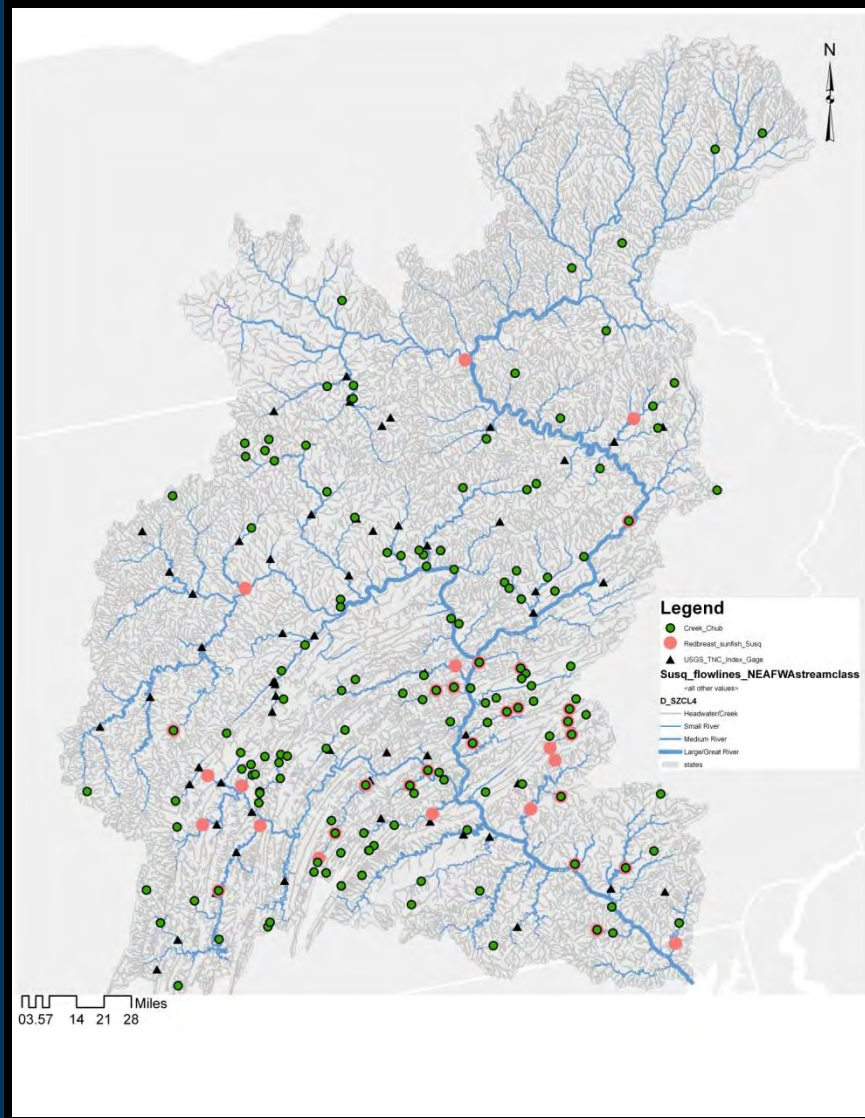
Figure 2. Distribution of subwatersheds in the eastern United States where brook trout are present (60%), extirpated (21%) or of unknown status (Unknown: no data and Absent: Unknown history) (19%). Subwatersheds classified as Never occurred are not included in the percentage calculations.



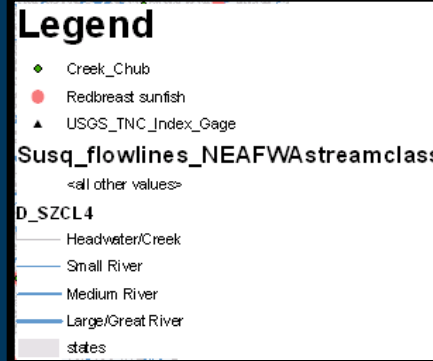
**Riffle-obligates –**  
 Margined madtom, longnose dace, central stoneroller, northern hog sucker, fantail darter

**Riffle-associates –** White sucker, shorthead redhorse

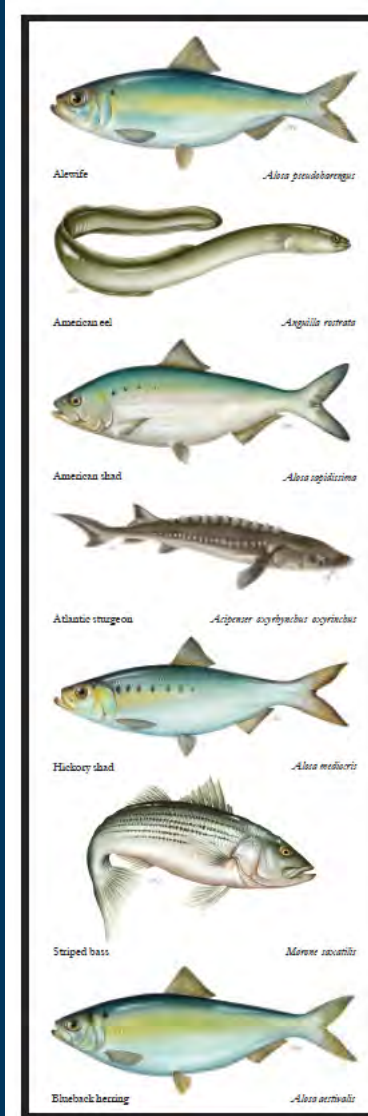




**Nest-builders** – Fallfish, creek chub, river chub, redbreast sunfish, smallmouth bass



## Migratory – American shad, alewife, American eel



### Atlantic States Marine Fisheries Commission

*Atlantic Coast Diadromous Fish Habitat:  
A Review of Utilization,  
Threats, Recommendations  
for Conservation, and  
Research Needs*

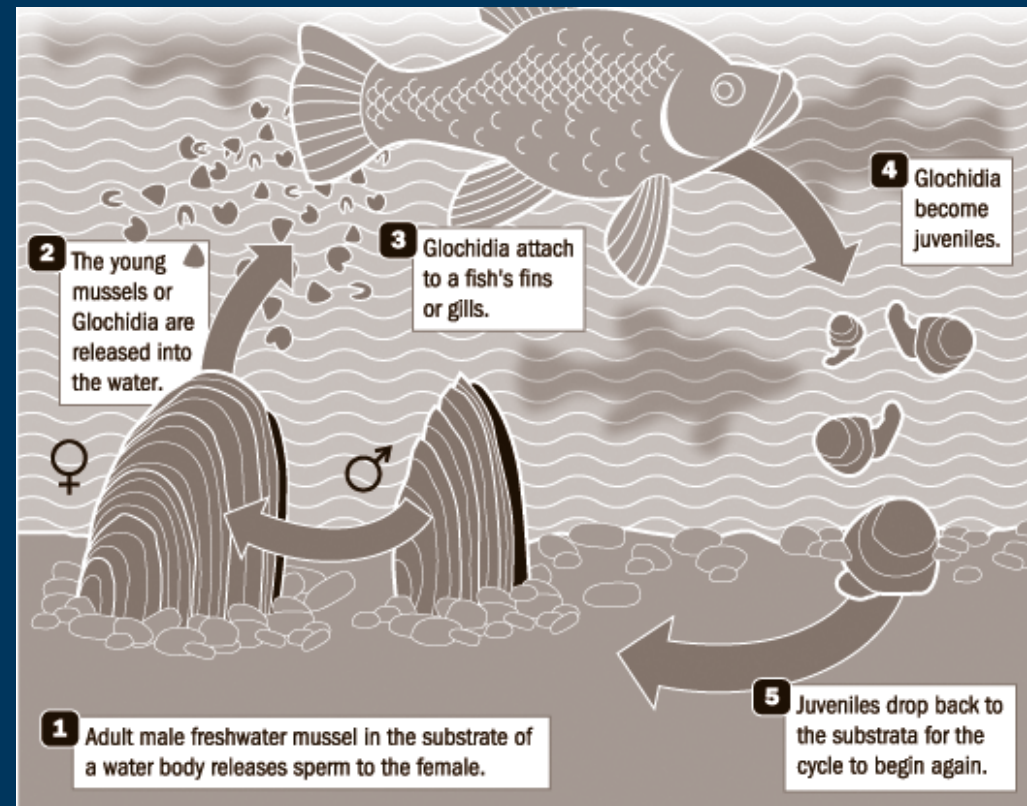


Habitat Management Series #9  
January 2009

*Working towards healthy, self-sustaining populations of all Atlantic coast fish species or successful restoration well in progress by the year 2015*

## Targeted life history traits:

- host-specificity
- longevity
- habitat associations
- velocity associations
- reproductive traits
  - spawning,
  - glochidia release
  - brooding length



Source: Texas Parks and Wildlife

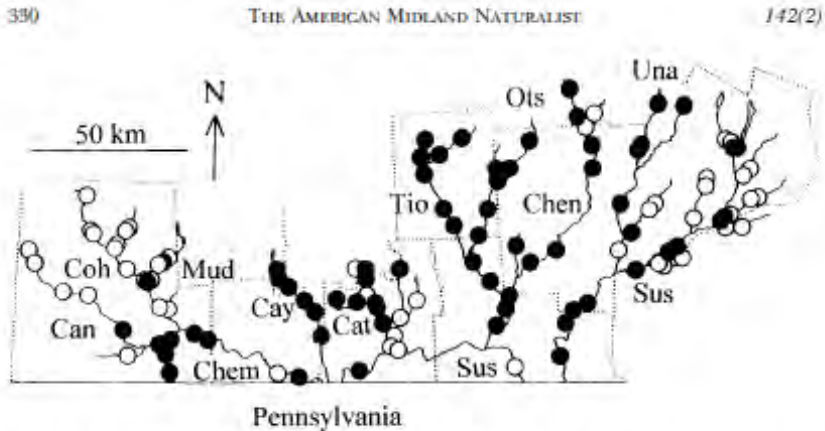


FIG. 1.—Sites in the upper Susquehanna basin surveyed for mussels in 1996–1997. Black circles show resurveys of historical sites; white circles show surveys of previously unsurveyed sites. Major streams are: Can = Canisteo River, Cat = Catatank Creek, Cay = Cayuta Creek, Chem = Chemung River, Chen = Chenango River, Coh = Cohocton River, Mud = Mud Creek, Ots = Otselic River, Sus = Susquehanna River, Tio = Troughnioga River, Una = Unadilla River. Dotted lines are county boundaries and the solid line is the Pennsylvania–New York border

Strayer, D.L. and A.R. Fetterman. 1999 Changes in the Distribution of Mussels in the Upper Susquehanna River Basin

**Primarily riverine** – Green floater, elktoe, brook floater, creeper

**Facultative riverine** – Yellow lampmussel, triangle floater, eastern lampmussel, eastern elliptio

**Primarily lentic** – White heelsplitter, eastern floater, cylindrical papershell

# AQUATIC INSECTS

Habitat	Collector-gatherer	Collector-filterer	Herbivore	Predator	Shredder
	Riffle	●	●	●	●
Pool & Riffle	●	●	●	●	●
Pool	●	●	●	●	●

● - Present in habitat; ● - Common in habitat; ● - Abundant in habitat



Ephemeroptera- *Isonychiidae*



Trichoptera- *Glossosomatidae*



Odonata- *Gomphidae*

## Emergent bed

water willow  
lizard's tail

## Herbaceous

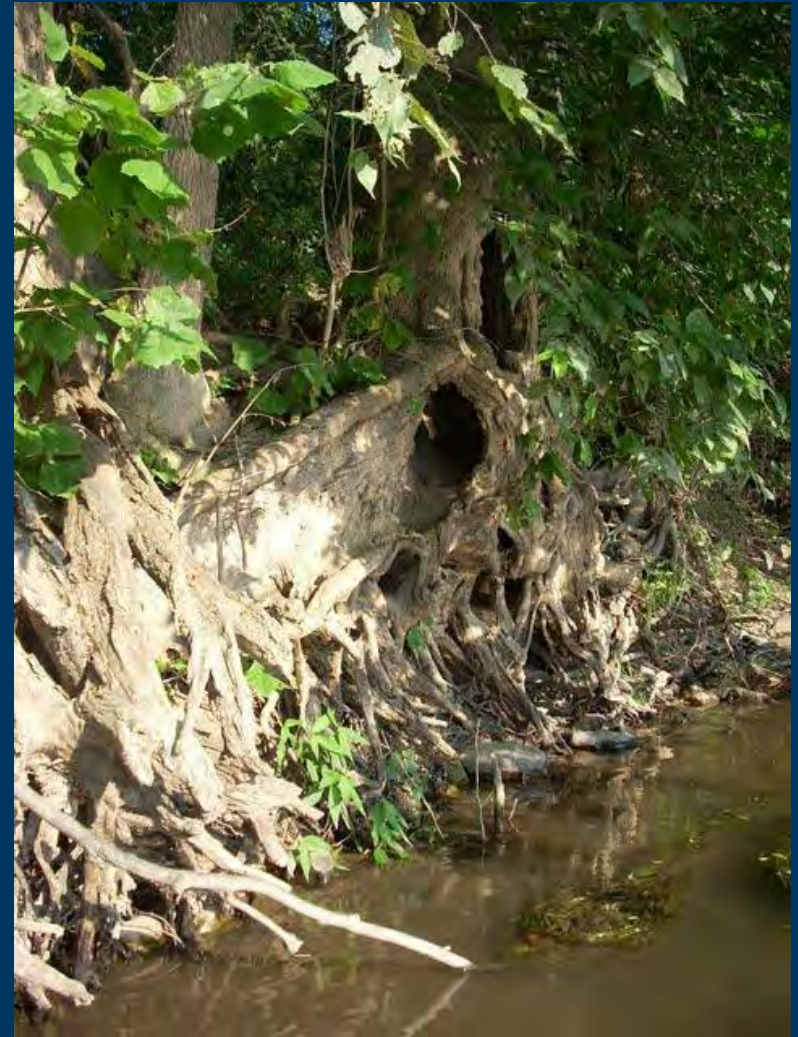
willow-indian grass

## Scrub/shrub

speckled alder riverine shrubland  
sycamore-mixed hardwood riverine shrubland  
river birch-mixed hardwood riverine shrubland  
silver maple-mixed hardwood riverine shrubland  
black willow-mixed hardwood riverine shrubland

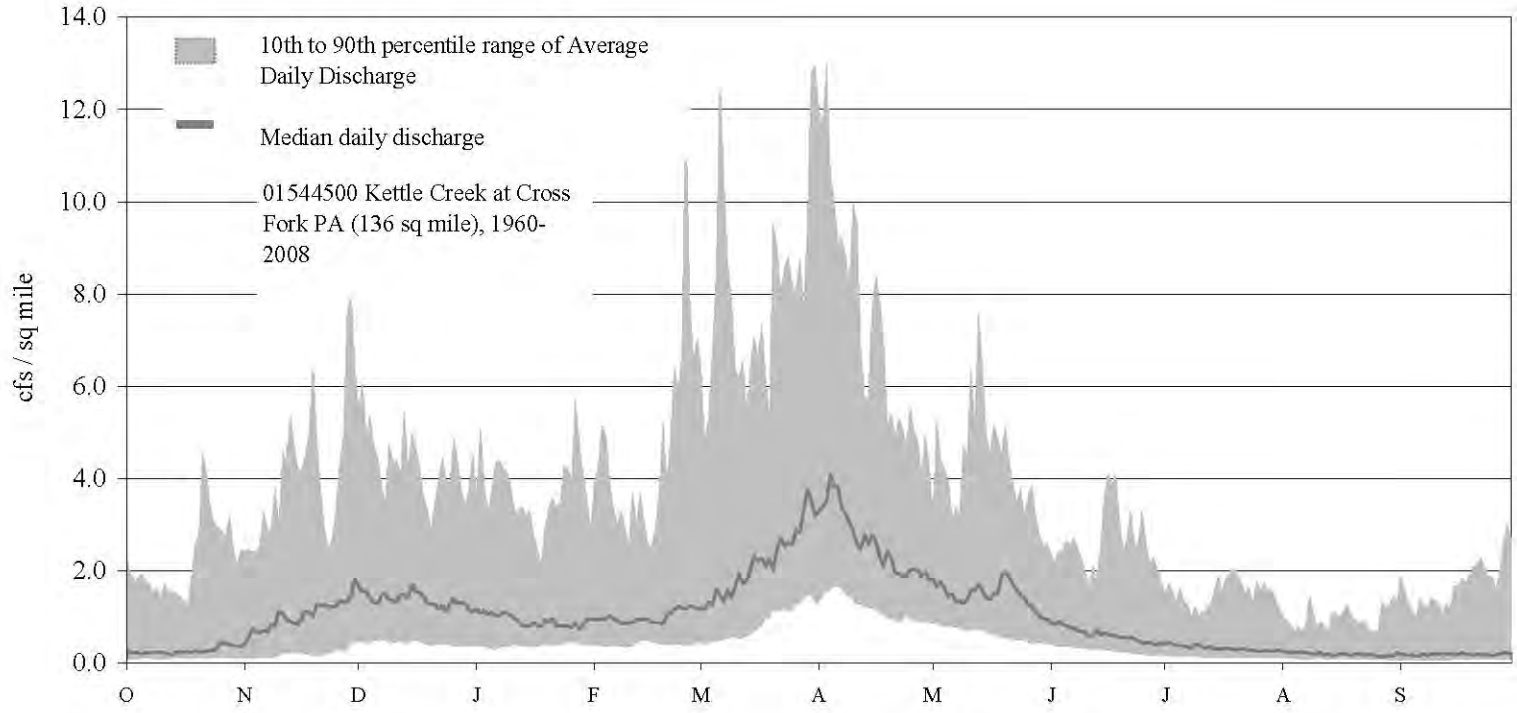
## Floodplain forest

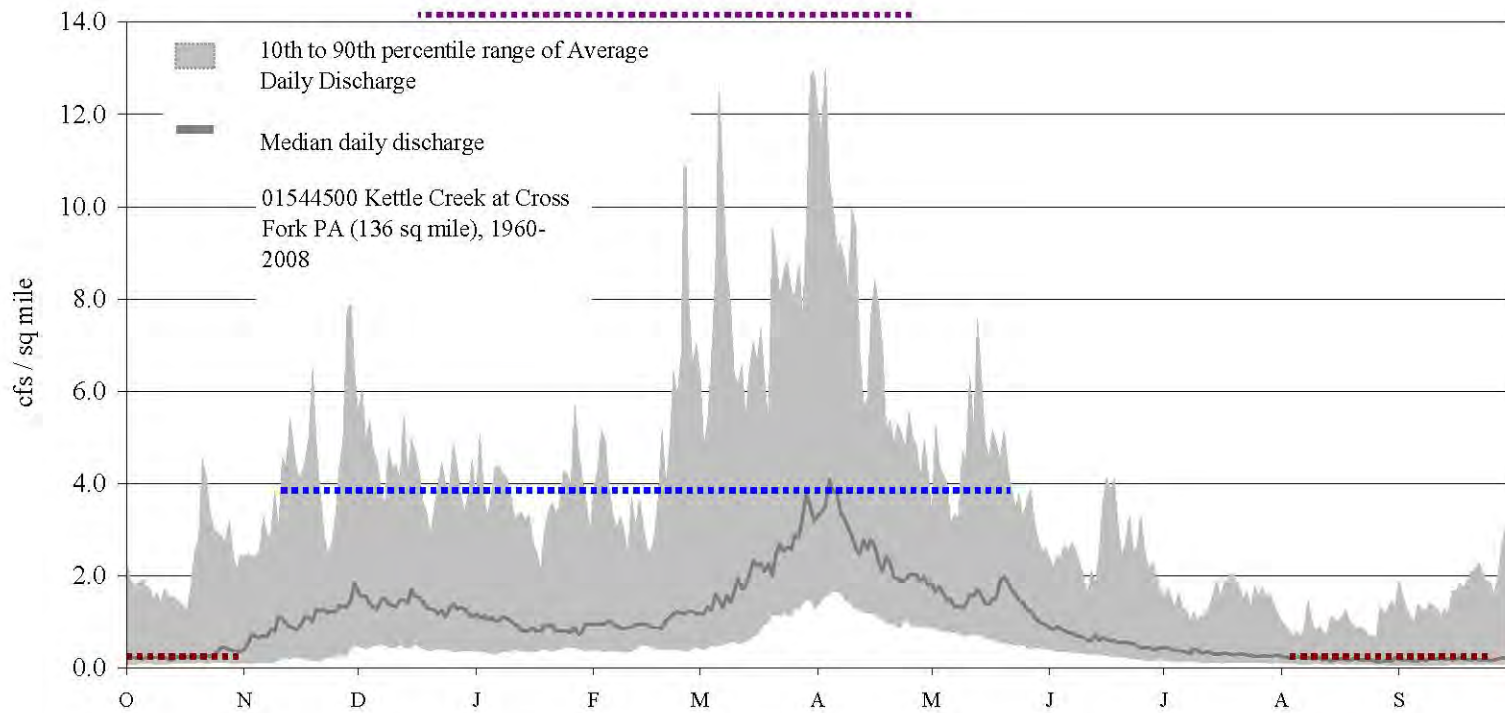
sycamore,  
sycamore-mixed hardwood,  
silver maple,  
silver maple-mixed hardwood,  
green ash-mixed hardwood



# Flow-Ecology Diagrams:

- Illustration of relationship between species life stages and seasonal hydrologic conditions, including seasonal & inter-annual variability



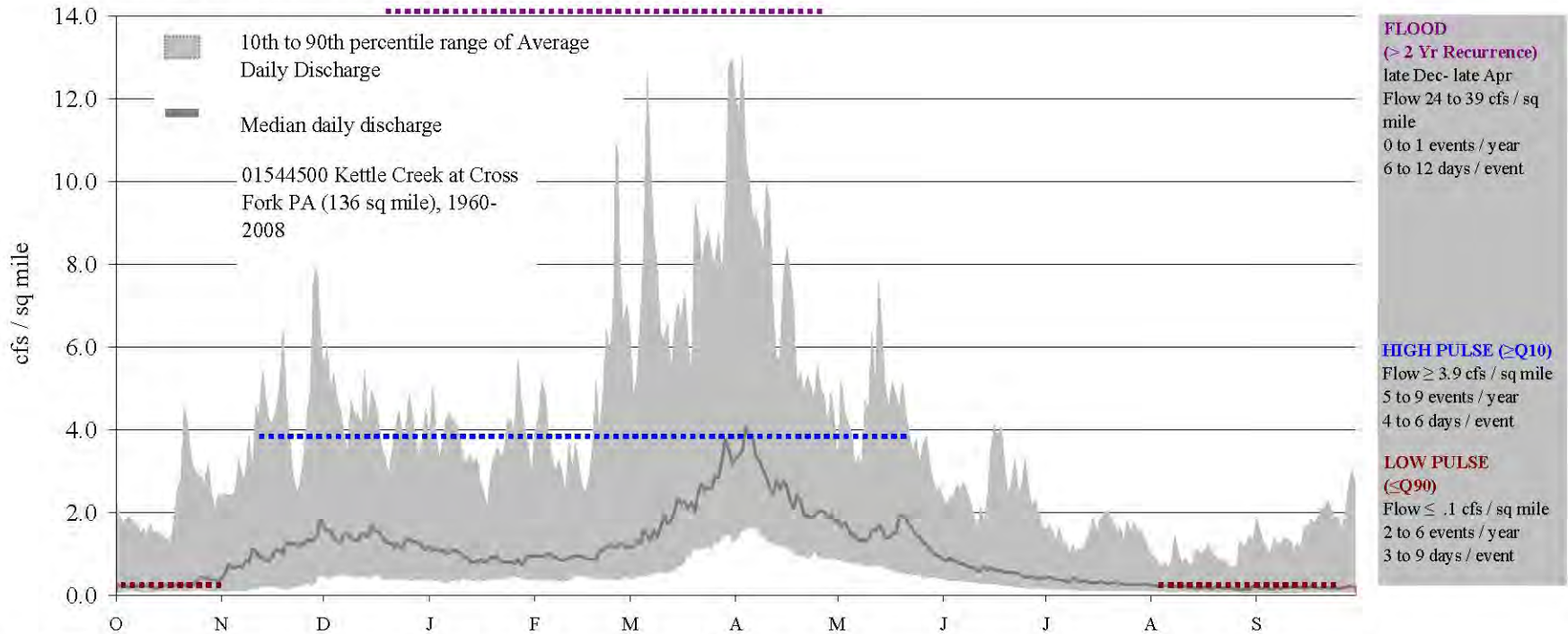


**FLOOD**  
( $\geq 2$  Yr Recurrence)  
late Dec- late Apr  
Flow 24 to 39 cfs / sq mile  
0 to 1 events / year  
6 to 12 days / event

**HIGH PULSE** ( $\geq Q10$ )  
Flow  $\geq 3.9$  cfs / sq mile  
5 to 9 events / year  
4 to 6 days / event

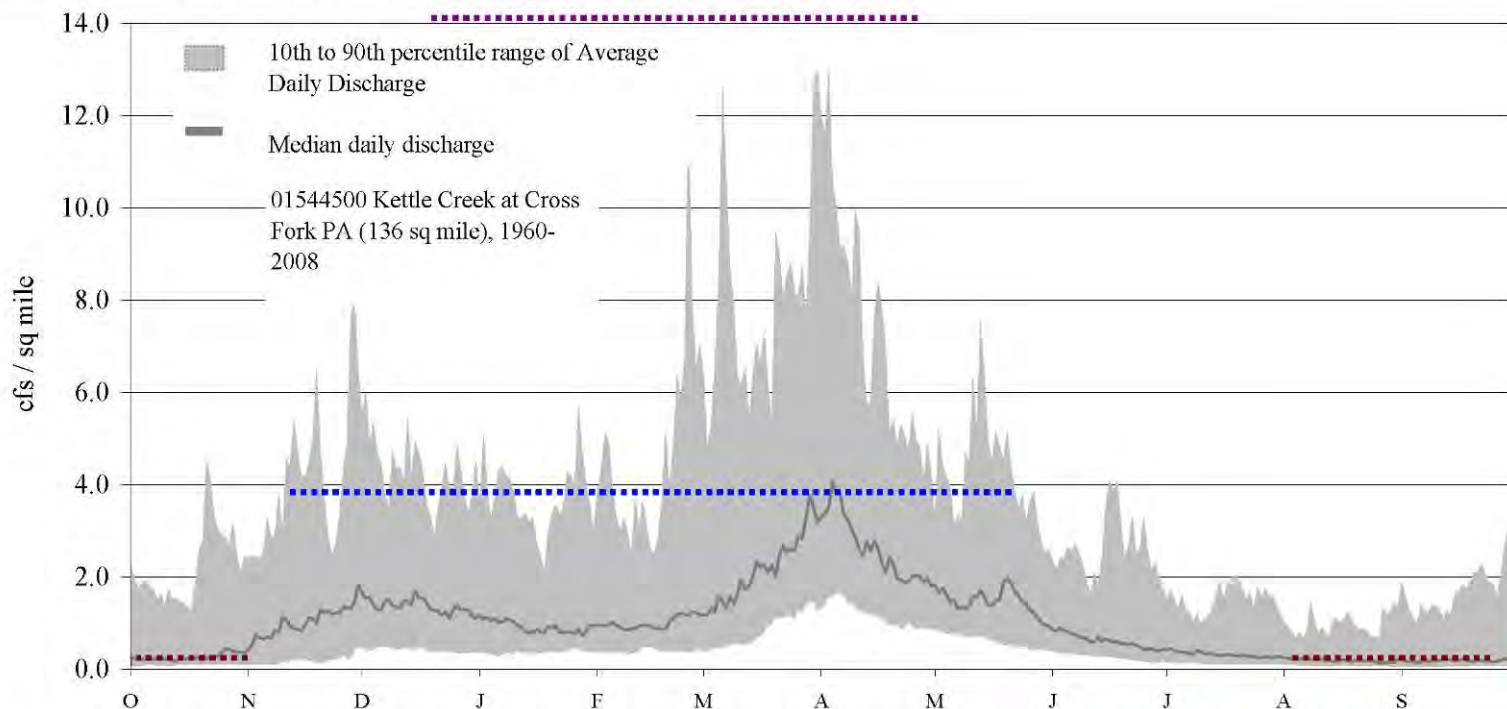
**LOW PULSE**  
( $\leq Q90$ )  
Flow  $\leq .1$  cfs / sq mile  
2 to 6 events / year  
3 to 9 days / event

# Fishes: Riffle-Obligates - Margined madtom (*Noturus insignis*), Longnose dace (*Rhinichthys cataractae*), Central Stoneroller (*Camptostoma anomalum*), Northern hog sucker (*Hypentelium nigricans*), Fantail Darter (*Etheostoma flabellare*)



Margined madtom	
Longnose dace	
Central stoneroller	
Northern hog sucker	
Fantail darter	

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## FLOOD

(> 2 Yr Recurrence)

late Dec- late Apr  
Flow 24 to 39 cfs / sq mile  
0 to 1 events / year  
6 to 12 days / event

## HIGH PULSE (≥Q10)

Flow ≥ 3.9 cfs / sq mile  
5 to 9 events / year  
4 to 6 days / event

## LOW PULSE (≤Q90)

Flow ≤ .1 cfs / sq mile  
2 to 6 events / year  
3 to 9 days / event

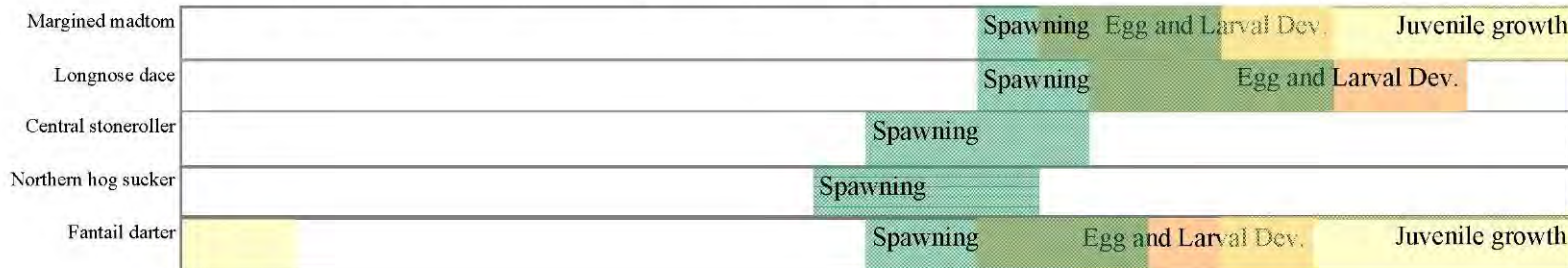


Table 2 includes a summary of life history information for each species



# Life History Summaries for Flow Workshop

Table 2 Riffle-obligate fishes life history summary

Life Stage	Timing		Cue	Substrate	Habitat		Q or Velocity	Hydro-Ecology Relationships		Comments
	Months				Temp	DO		Depth	Hydraulic Habitat Unit	
<b>Margined Madtom</b> <i>Noturus marginatus</i>	<b>Egg and Larval development</b>	Late May to August, 1 to 3 weeks from spawning	Incubation 7-10 days at 15.6 C; yolk sac absorbed 7 days after hatch							
	<b>Juvenile Growth</b>	Most growth occurs in July, August and September after spawning has occurred								
	<b>Adult Growth</b>		Mature by age 2, live up to 4 years	sand or gravel bottom	warm water		moderate current	riffles		
	<b>Spawning</b>	May to June		nests beneath flat rocks			moderate current			
<b>Longnose dace</b> <i>Etheostichus caeruleus</i>	<b>Egg and Larval development</b>	June and Aug. (three weeks after fertilization)					within 6 weeks of age (at 30 mm TL), move to swift water areas in streams > 45 cm/s	< 3 m rarely > 1 m	dry abundant in protected margins of quiet shallow water, riffles	juveniles and adults are adapted to high velocity areas
	<b>Juvenile Growth</b>						v > 45 cm/s			
	<b>Adult Growth</b>		mature at age 2, live up to 5 years temperature dependent, when daily maximum temp exceeds 15 C (Barnik 1970)	gravel and rock smaller than Optimum 14-19 20 cm diameter			v = 45 to 60 cm/s, observed living as high as 182 cm/s	< 3 m rarely > 1 m	swift flowing, steep gradient headwater streams (1.9 to 19.7 m/km) of larger river systems, shelter from current must be present	small home range, most recaptures in same reach, average distance 13.4 m
	<b>Spawning</b>	As early as May, Late as August, peak from June to early July						< 3 m rarely > 1 m		
<b>Central Stoneweller</b> <i>Campestenoma anomalum</i>	<b>Egg and Larval development</b>			in a depression of gravel or gravel and sand						
	<b>Juvenile Growth</b>									
	<b>Adult Growth</b>		Mature in 1 to 5 years	hard bottomed streams					runs and riffles, males commonly school over Noemius nests	
	<b>Spawning</b>	April to May		males dig pits in shallow-gravel bottomed areas, may maintain spawning pits in close proximity			slow to moderate			
<b>Northern Hog sucker</b> <i>Hypentelium nigricans</i>	<b>Egg and Larval development</b>	April through late May - estimated 2 weeks to hatch another 1 to 2 for yolk sac absorption	Hatch in 10 days at mean temp 17.4 C.							eggs and small young predated by other fish.
	<b>Juvenile Growth</b>									
	<b>Adult Growth</b>		Mature at age 2-4	gravelly/stony streams					feeds and rests in very shallow riffles	they also disturb bottom sediment, synergistic relationship with fish following to take advantage of drift
	<b>Spawning</b>	late March through early May		gravel, gravel and sand	60 F		fast-flowing	shallow	move from larger streams to smaller headwaters to spawn, over riffles, like other suckers	
<b>Fanail darter</b> <i>Etheostoma flabellare</i>	<b>Egg and Larval development</b>	May-July: Hatch one month behind spawning (30 to 33 days at 17-20 C)	14-16 days at 23 C							
	<b>Juvenile Growth</b>	Mid July-November: Juvenile development								pools and slackwater areas downstream of riffles
	<b>Adult Growth</b>		Mature at age 1 or 2	particularly abundant in streams with slab of limestone or shale; many stones and rocks for cover	cool and warm streams		temp 15 to 24 C	shallow to very shallow	riffles or along the shallow banks	runs and slow riffles including shallows
	<b>Spawning</b>	April to Mid June	correlated with temperature							

**References**

Buyak G.L. and H.W. Mohr. 1978. Larval Development of the Northern Hog Sucker (*Hypentelium nigricans*), from the Susquehanna River. *Transactions of the American Fisheries Society*. 107(4): 595-599.

Cooper, E.L. 1983. *Fishes of Pennsylvania and the Northeastern United States*. Pennsylvania State University Press, University Park, PA. 243 pp.

Cooper, J.E. 1980. Egg, Larval and Juvenile Development of Longnose Dace, *Rhinichthys cataractae*, and River Chub, *Noemius micropogon*, with Notes on Their Hybridization. *Copeia*. 1980(3): 469-478.

Edwards, E.A., H. Li, and C.B. Schreck. 1983. Habitat suitability index models: Longnose dace. U.S. Department of the Interior, Fish Wildlife Service. FWS/O-83-22/10.33. 13 pp.

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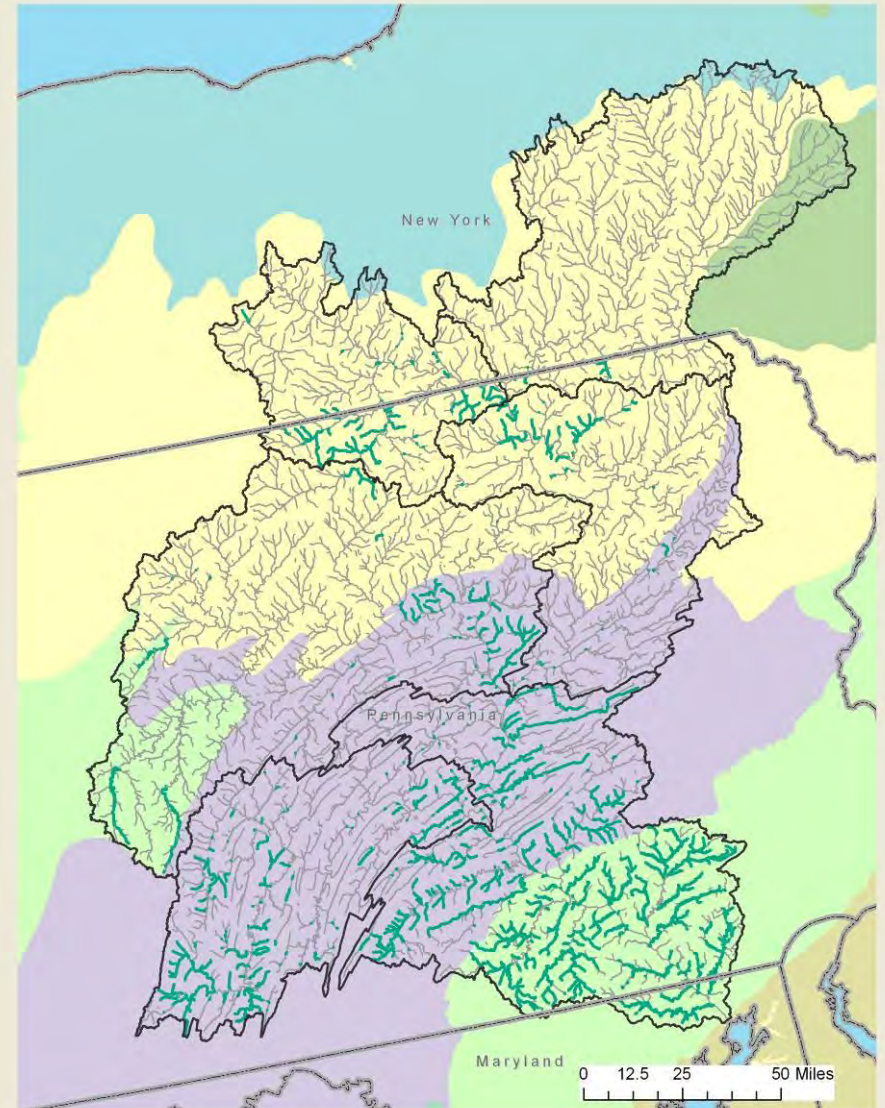
Gutowski, M.I. and B. Stuyffer. 1993. *Salvelinus bairdianus*, the Nature museum in the Delaware River. *American Midland Naturalist* 126(2): 308-312.

## Fishes

- Riffle obligate
- Riffle associate (spawning)
- Nest builders
- Migratory – Eels (juvenile)

## Mussels

## Aquatic insects



	Headwaters and small streams ( $< 200$ square miles)			Major tributaries ( $>200$ square miles)		Mainstem	
	Cold headwater and small streams	Calcareous headwaters and small streams	Warm headwaters and small streams	Upper Susquehanna and Chemung	West Branch and Juniata	Middle mainstem	Lower Mainstem
<b>Fishes</b>							
Cold headwater	X	X					
Riffle obligate	X	X	X	X	X	X	X
Riffle associate	X	X	X	X	X	X	X
Nest builders	X	X	X	X	X	X	X
Migratory					X	X	X
<b>Mussels</b>							
Primarily riverine	X	X	X	X	X	X	X
Facultative riverine	X	X	X	X	X	X	X
Primarily lentic				X	X	X	X
<b>Aquatic vegetation</b>							
Emergent					X	X	X
Herbaceous					X	X	X
Scrub/shrub					X	X	X
Floodplain forest					X	X	X
<b>Aquatic insects</b>							
Pool					X	X	X
Pool-riffle	X	X	X	X	X	X	X
Riffle	X	X	X	X	X	X	X

## Goals:

- draft hypotheses about the relationships between flow and the **most sensitive** species, ecosystems, and physical processes in the Susquehanna River watershed using professional experience and workshop materials
- prioritize additional information to include in a draft summary report
- identify analyses that would support development of flow recommendations

33 participants, 2 day, facilitated process

Goal: to develop quantitative flow recommendations that include:

- Specific location
  - Time period
  - Flow magnitude (range)
  - Frequency and duration of event
  - Related ecosystem function
- 
- Focus on species of particular sensitivity to flow alteration across species groups
  - Ensure representation of flow components (low flows, floods, etc)
  - Ensure representation of seasons

# Elements of a flow hypothesis from Workshop

Goal: to develop quantitative flow recommendations that include:

Who	Species or group of species
What	Flow magnitude or event
When	Month or season
Where	Habitat type
Why / how	Ecological response

## Example hypothesis

During the summer months, central stoneroller, margined madtom, northern hog sucker, and fantail darter require flows that maintain swift to moderate current riffle/run habitats.

If the magnitude of summer flows is reduced, available riffle habitat may be reduced limiting juvenile and adult growth.

## Example hypothesis

During the **summer months**, **central stoneroller**, **margined madtom**, **northern hog sucker**, and **fantail darter** require flows that maintain swift to moderate current riffle/run habitats.

If the **magnitude of summer flows is reduced**, available **riffle habitat** may be reduced **limiting juvenile and adult growth**.

Who

What

When

Where

Why/How



## **Confirming and finalizing hypotheses –**

- Data does not exist to “test” all hypotheses, yet several types of information sources will be used to confirm that these hypotheses reflect the needs of aquatic species in the Basin.
- Will provide as much basis as possible to support each hypothesis, indicate gaps, and confirm/revise at final workshop

## **Draft flow recommendations –**

- Use qualitative flow hypotheses to develop draft flow recommendations that include the range of flows needed to sustain species and communities within the basin
- Will draft recommendations that include acceptable ranges of values of a series of flow statistics representing flow magnitude and the frequency, duration, and rate of change of flow conditions. Review & refinement at next workshop.

## **Complete Summary Report -**

- Documents results of literature review and workshops and is reviewed by participants

## **Deliver to SRBC for use in regulatory program**