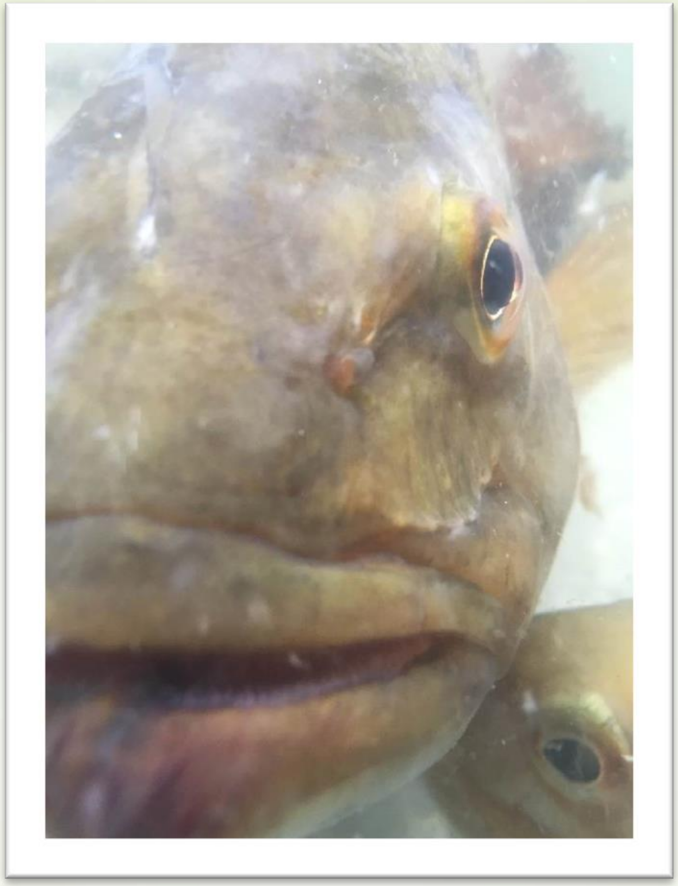
Fishes



Allison M. Stoklosa

Watershed 101

Southern Clusters

May, 2017

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Why Study Fish- What Do They Tell Us?

- Long lived and mobile – good indicators of long term and broad effects.
- Many species representing a range of trophic levels.
  - Many integrate effects of lower trophic levels, reflecting integrated environmental health
- Most species can be sorted and identified in the field by trained professionals and released unharmed.
- Life histories and environmental tolerances comparatively well known.
- Important commercially and recreationally.
- Additionally are important for human health if consumed.

From Barbour et al. 1999.

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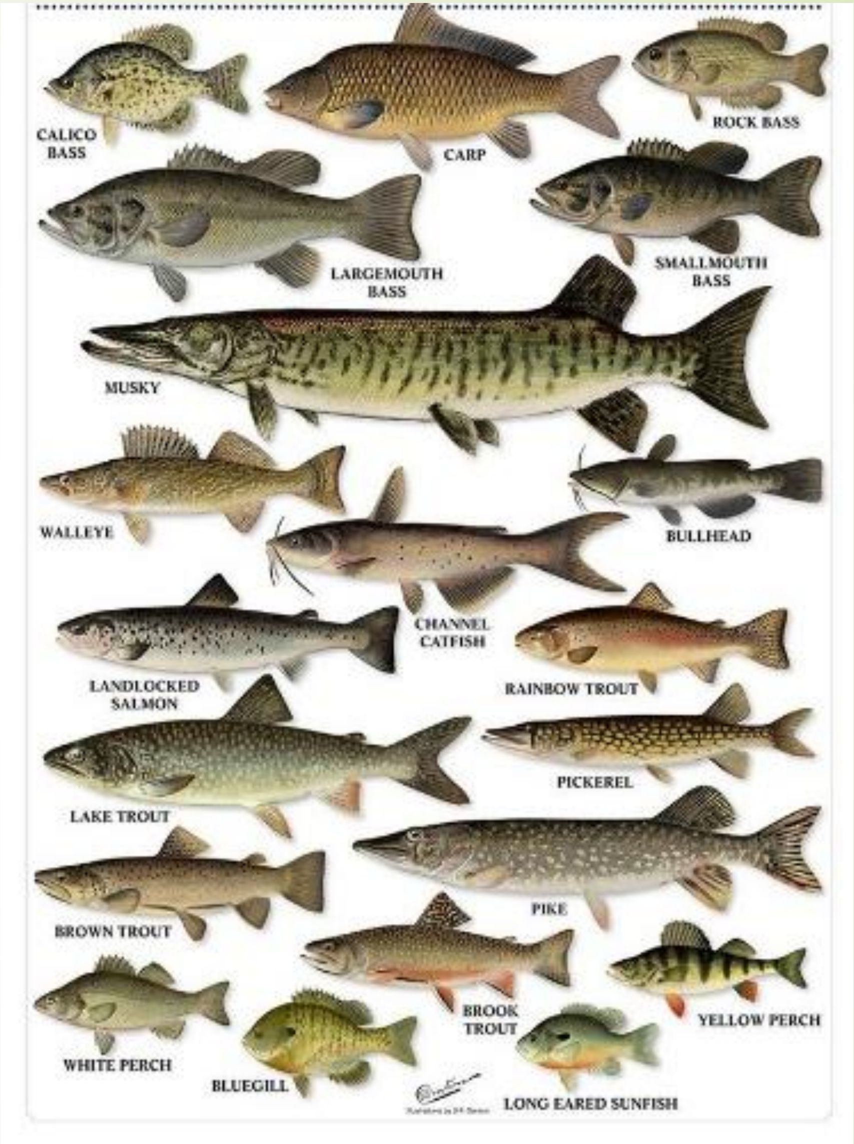
An Introduction to Freshwater Fishes

- There are ~80 species of fish in the DRB
- Most fishes found in the DRB are teleosts, or, ray-finned, jawed, bony fishes
- With the exception of lamprey, which lack a jaw and belong to the order Petromyzontiformes



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Common Local Freshwater Fish Families

- Anguillidae -American Eel
- Centrarchidae -Sunfish, Bass, Crappies
- Clupeidae -Herrings
- Cottidae -Slimy Sculpin
- Cyprinidae -Carps and Minnows
- Esocidae - Pike, Pickerel
- Fundulidae -Killifishes
- Ictaluridae -Catfish, Bullheads, Madtoms
- Percidae -Perch, Darters
- Salmonidae -Trout

Basic Fish Life History

- Egg: variable in size and number; few to millions
  - Hatching time days (many) to months (e.g., Brook Trout)

- Larvae: defined as stage until attains adult structures

- Juvenile: adult morphology, but pre-breeding

- Adult: mature months (Mosquitofish) to many years (e.g., Sturgeon)
  - Growth usually indeterminate, though slower with age
  - A few (e.g., Mosquitofish) have determinate male size
  - Some always die after spawning (lampreys, Pacific salmon); some sometimes die (American Shad)

What Types of Questions Can Be Answered with Fish

- Is this stream impaired?
- What are the long term effects of pollution and/or habitat changes in streams, rivers, and lakes?
- Do these fish pose a threat to wildlife or people eating them?
- How are different species distributed among habitats, streams, drainages, regions?
- What is the effect of non-native species? Of stocked fish?
- What can I catch here? How could I catch more or bigger fish?
- What is the effect of fracking, dams, or pollution?
- How do fish affect macroinvertebrates? Food webs?

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When to Use Fish in Your Projects

- After you determine what stressor(s) your project will address
  - How will the physiochemical and biotic environments change in response?
- Choose the best monitoring tool(s) for the job
  - No silver bullet
  - Prioritize monitoring options by the measures that are most likely to respond to the stressors your project will address
- Use fish measures when aspects of their biology and ecology are:
  - the most likely parameter to respond to a change in the identified stressor (as caused by your project)

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What Are The Stressors For Fish That Your Project Could Involve?

- Physical habitat in stream
- Water chemistry
- Toxins, pollution, disease
- Breaks in connectivity
- Invasives

Physical Habitat and Fish

- Functional Morphology: Form to Function
  - Full range displayed from shallow streams to deep sea ocean, but differences are evident even in microhabitats within small areas.

- Where does it live?
  - Swimming in current
  - Swimming in open
  - On bottom
  - Hiding in vegetation
  - Hiding in crevices

Why does this matter?
Physical habitat is important and dictates which species a stream can support.

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Examples of Physical Habitat Preferences

- Fast Current (Riffles)
  - Streamlining
  - Often small scales
- Slow current (Pools)
  - Deep bodies
- Benthic (bottom-dwellers)
  - Fins for support, some without swim bladder

I live in riffles

Rhinichthys cataractae – Longnose Dace

I live in pools

Lepomis cyanellus– Green Sunfish

I live on the bottom

Cottus cognatus– Slimy Sculpin

- Log/snag piles, undercut banks, live roots, boulders, submerged aquatic vegetation, filamentous algae.
  - Provides hiding places, spawning habitat, may even act as food sources

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Vegetation in Rivers and Streams

- Slow currents, low sediment

- Common in many Coastal Plain streams, less common on Piedmont (at least now)
  - Some Minnows, Pickerels, Mudminnow, Dwarf Sunfishes, Chubsucker, Swamp Darter

Umbra pygmaea– Eastern Mudminnow

Esox niger– Chain Pickerel

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Vegetation in Ponds and Small Lakes

- Potentially contain (or contained) subset of stream and river species
- Introduced predators and others shift assemblage
  - Fewer minnows
  - Bass, sunfishes
  - Yellow Perch

Micropterus dolomieu– Smallmouth Bass

Lepomis cyanellus– Green Sunfish

Perca flavescens– Yellow Perch

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Habitat Assessment of Streams and Rivers

- Many protocols for habitat assessment
  - Rapid protocols (fast, easy, and not very accurate)
  - Detailed (useful, may take as much or more time than fish sampling)
- Different scales
  - Reach level (sinuosity, gradient, riffle/pool structure, etc.)
  - Mesohabitat (pools, runs, etc.)
- Will go over in more detail on Day 3

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Ways to Use Habitat in Projects

- Goal: Improving catch rates vs. improving biotic integrity?

- In-stream restoration
  - Plantings
  - In-stream structures
  - Increasing sinuosity and depth/current variety
  - Many of these geared more towards improving catch rates

- Out of stream restoration
  - Riparian improvement
  - Bank stabilization
  - Reconnecting floodplain to stream

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Water Chemistry and Fish

- Dissolved oxygen
  - Low DO suffocates fish.
- Temperature (often related to DO)
  - Different species with distinct tolerances
- pH
  - Low pH can make Al and Pb more toxic and can increase concentrations of NH_3
- Hardness-Salinity
  - In fresh water, fish need to keep salts in and water out.
  - Hard water (Mg + Ca salts) reduces metal toxicity and form insoluble carbonates and is a better buffer.
  - Carbonates also affect gill exchange and reduce metal uptake.
- Suspended Solids (Turbidity)
  - Decrease DO, form unsuitable substrates, smother fish eggs and nurseries, abrade gills, and increase disease.

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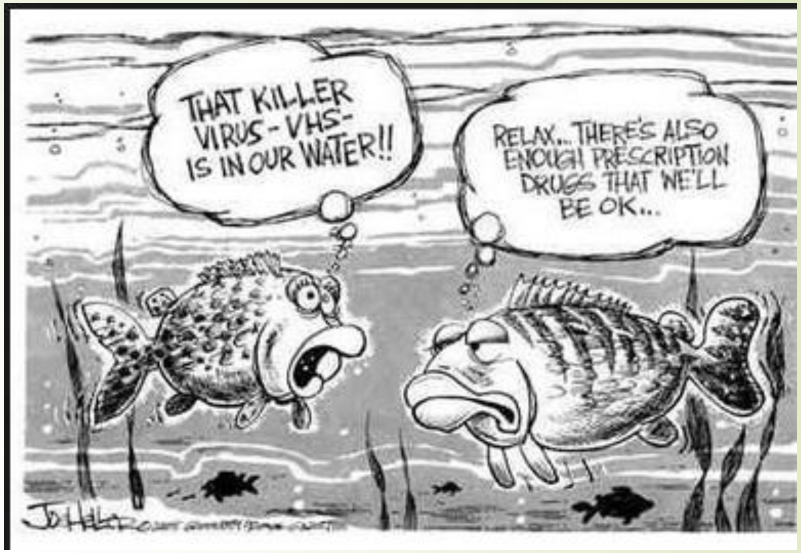
Toxicity, Pollution, and Fish

- Range of toxicity of variety of chemicals
  - Can be physical (siltation, oils, heat, radiation),
  - Biological (pathogens, parasites, introduced species),
  - Or chemical (inorganic or organic)
- Nitrates, Nitrites, and Ammonia
  - High pH increases ammonia.
  - High nitrite concentrations interfere with O_2 transport by hemoglobin.



- PAH & PCB
  - Polycholorinated hydrocarbons (hydraulic fluid)
  - Polychlorinated biphenyls (transformers).
  - Bioaccumulate and biomagnify.
  - Carcinogenic.
- EDC
  - Endocrine disrupting chemicals (pesticides, additives, birth control).
  - Produces intersex.
- Aluminum
  - Inorganic acid water, can be toxic.
- Chlorine
  - Periodic fish kills when people empty swimming pools or water main breaks.

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Monitoring of Water Chemistry and Toxins in Fish Projects

- Similar to monitoring for any other project for streamside chemistry monitoring
  - YSI Multimeter- pH, DO, Conductivity
  - Taken to set our electrofishing gear and to use as variables in analyses

- Tissue analysis for contaminates
  - Filet or whole fish

- Gonad analysis for EDC
- Otolith Microchemistry

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Fish Passage and Stream Connectivity

- Lateral Connectivity
  - Floodplains, backwaters, oxbows, etc.
- Longitudinal Connectivity
  - Upstream and downstream passage
- Blockages
  - Natural (waterfalls) or man-made (dams)

Lateral Connectivity

- Floodplains important to river function
- Nutrient transport
- Backwaters
- Oxbow lakes
- Small ponds
- Varying degree and frequency of connection to river
- These can provide important habitats for breeding and spawning

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Longitudinal Connectivity

- Important for nutrient transport, etc.
- Important for movement of anadromous, catadromous and other migratory fish
- Important for recolonization of upstream
- Affected by
  - Natural blocks: waterfalls (at least one way)
  - Dams

Catadromous = spawn in saltwater, mature in freshwater.
Examples: American eel, European eel

Anadromous = spawn in freshwater, mature in ocean.
Examples: salmon, smelt, American shad, striped bass, lamprey

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Upstream Passage Solutions

- Fish ladders
  - Special designs
    - Lampreys: can climb vertical walls using disc for suction
    - Eels: can get up simple structures with some complexity for traction

- Other approaches
  - Lifts
  - Trucking

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Dam Removal

Elwha River, Washington

Manatawny

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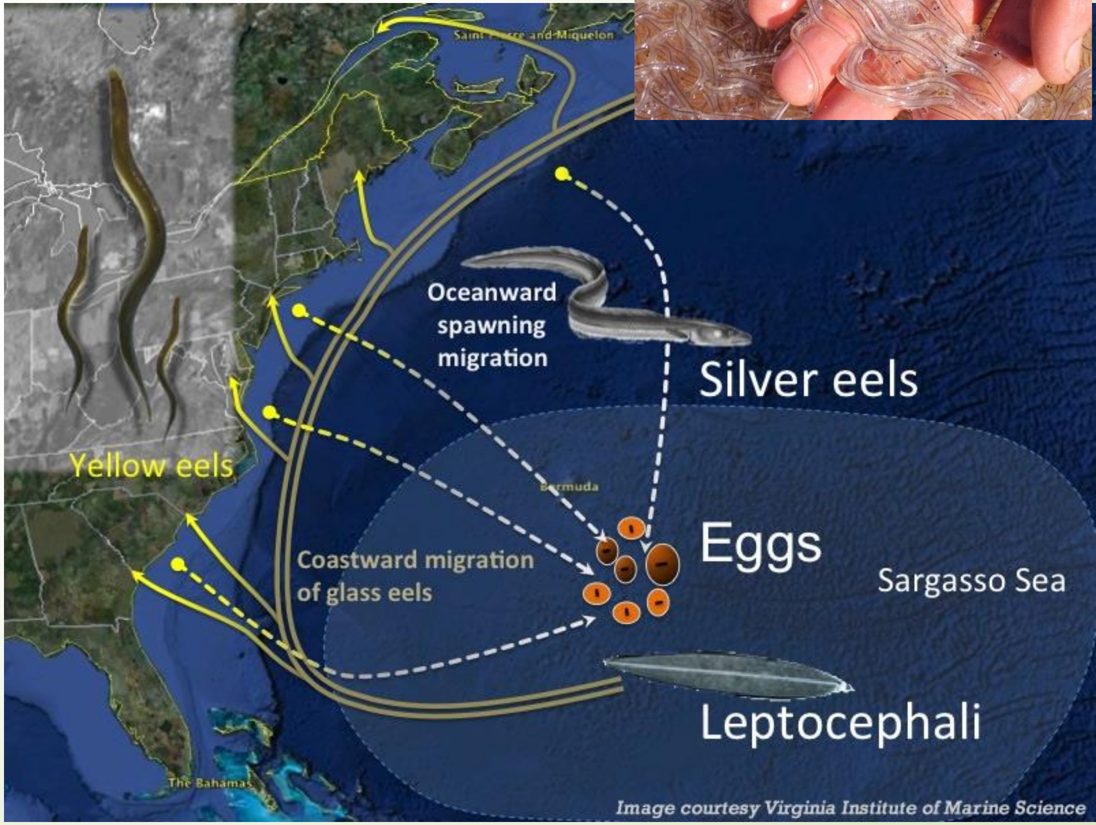
Species Affected by Dams: Sea Lamprey

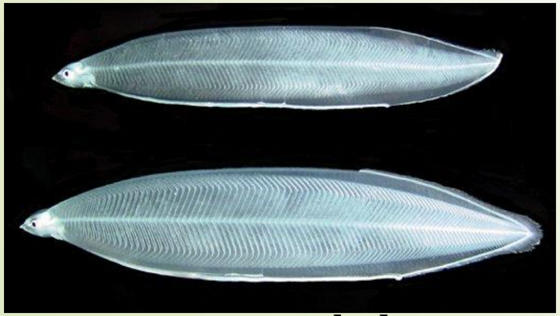
- Anadromous
- Adults die after spawning
- Larvae (called "ammocoetes") are blind and lack teeth.
  - Filter-feeders
  - Live in sand and silt
  - In this stage for 3-10 years
- Eventually, transform and develop eyes and suction disc mouth
- Juveniles and adults are parasitic

Species Affected by Dams : American Eel

- Considered as the fish having the broadest diversity of habitat of any fish species.
- Migrates to Sargasso Sea each winter to reproduce (marine stage) and die.



- Larvae (leptocephalus) transported by oceans current from Greenland to Venezuela (9 to 12 months)



Leptocephali

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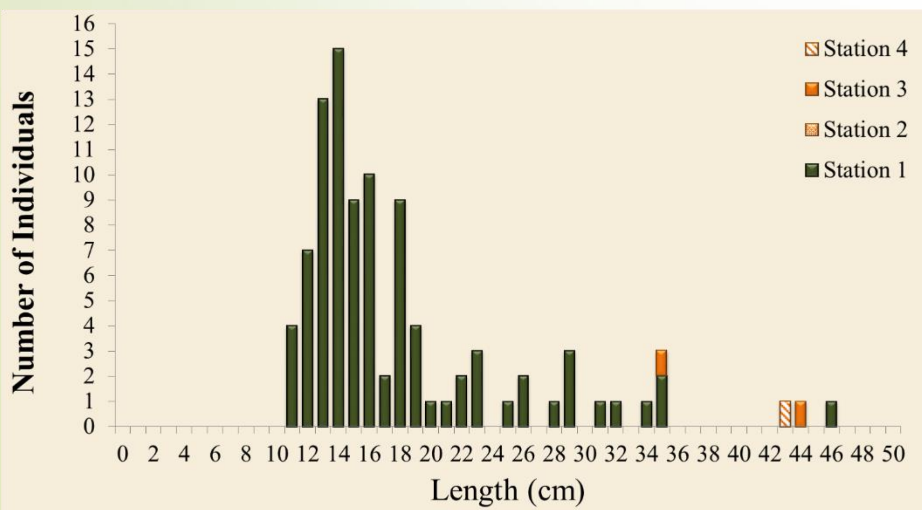
Local Example: The Paulinskill

- Block migratory fish passage
- May have unintended effects on crayfish populations, especially non-natives
- Changes habitats



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Monitoring and Projects for Connectivity and Fish

- Dam Removal
  - Sampling US and DS to determine impacts

- Restore and protect floodplains and backwaters and stream sinuosity
  - Increase fish nurseries and habitat

Invasive Species and Fish

- Difficult to make distinction between "invasive", "non-native", "introduced", and "naturalized"
  - As per Merriam-Webster:
  - Invasive - tending to spread; especially : tending to infringe
  - Non-native - of an animal or plant : living or growing in a place that is not the region where it naturally lives and grows
  - Introduced - to lead or bring in especially for the first time
  - Naturalized - to cause to become established as if native

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Invasive Species and Fish

- Aquatic species banned in Pennsylvania (sale, barter, possession or transportation) by PA Fish and Boat Comission
  - Bighead carp, Black carp, European rudd, Quagga mussel, Round goby, Ruffe, Rusty crayfish, Silver carp, Snakehead, Tubenose goby, Zebra mussel, Flathead Catfish, Common Carp, Goldfish, Grass Carp, Talapia
- The following are listed as "Potentially dangerous fish" by NJ Fish and Game
  - Asian Swamp Eel, Bighead Carp, Brook Stickleback , Flathead Catfish , Grass Carp, Green Sunfish , Snakeheads, Oriental Weatherfish, Silver Carp, Warmouth
- Naturalized
  - Brown trout – Europe
  - Rainbow Trout – Pacific North American and Asia
  - Smallmouth and Largemouth Bass - upper and middle Mississippi River basin, Great Lakes system, and Hudson Bay basin

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Invasive Spotlight: Flathead Catfish

- Native to Mississippi and Gulf drainages
- Found in large rivers, streams, and lakes with deeper water
- Piscivorous and feed only on live prey, known to reduce native populations, especially native Bullheads and sunfishes
- Can live up to 28 years and can lay up to 100,000 eggs/year

Invasive Spotlight: Grass Carp

- Native to eastern Asia
- Alters food web and trophic structures
- Significantly reduces aquatic vegetation
- Increase phytoplankton and zooplankton
- Reduce habitat, increases predation
- In extreme cases, can lead to algal blooms

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Invasive Spotlight: Snakeheads

- Native to Asia
- Voraciously predatory
- Obligate air breathers
- Can lay 1300-1500 eggs up to 5 times per year
- Can survive 4 days out of water
- Can travel short distances overland as juveniles
- Can NOT "walk" with its fins
- Reaches 33inches in length (2.75 feet)

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Monitoring and Projects for Invasives

- Removal
  - Rarely successful once introduced
- Prevention
  - Education
  - Ban Sales/Bait Bucket

So…Should Fish Be Inluded?

- Determine what stressor(s) your project will address
  - Ex. Habitat, chemistry, pollutants, blockages, invasives, etc.
- Choose the best monitoring tool(s) for the job
  - No silver bullet
  - Prioritize monitoring options by the measures that are most likely to respond to the stressors your project will address
- Use fish measures when aspects of their biology and ecology are:
  - likely to respond to a change in the identified stressor (as caused by your project)
  - Consult with a fisheries biologist

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So….How Do I Survey the Fish?

- Need to consider:
  - Purpose of sample, sampling design, possible impact on population, possible impact on habitat, safety, time, and cost
- Match technique to purpose
  - Provide best estimate of species assemblage
    - Want technique which has nearly equal probability of capturing each individual
  - Obtain desired specimen for subsequent analysis
    - Want technique which has high probability of capturing desired specimen; lower probability of capturing other specimens reduces process time and sampling impacts
  - These goals are opposite: no single technique will always be best

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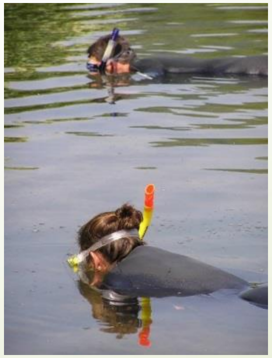
Fisheries Techniques

- Electrofishing
  - Stuns fish

- Seines

- Visual (SCUBA, snorkel, bankside)
- Gill nets, Traps and Hoop nets
- Dip nets, cast nets, archery, angling
- Trawls
- Hydroacoustic
- eDNA



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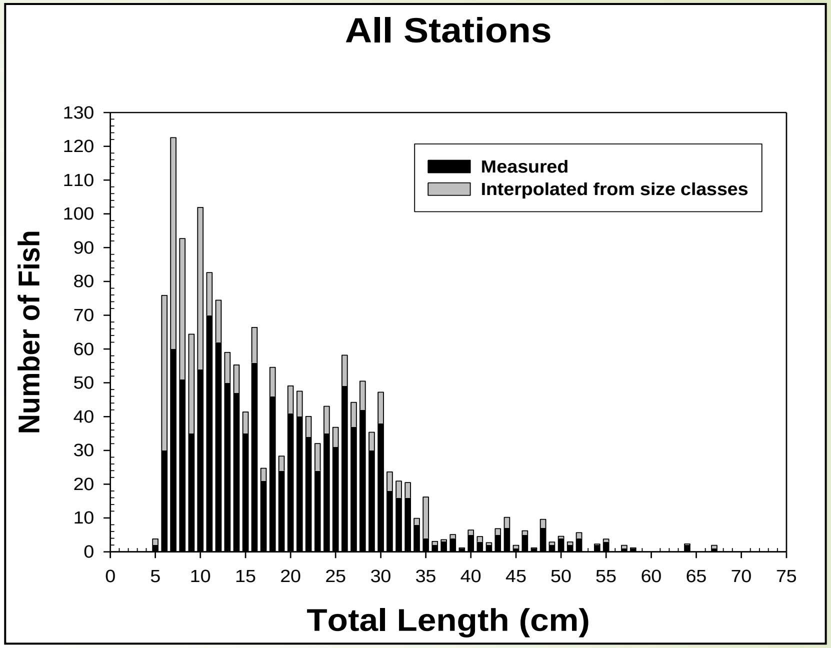
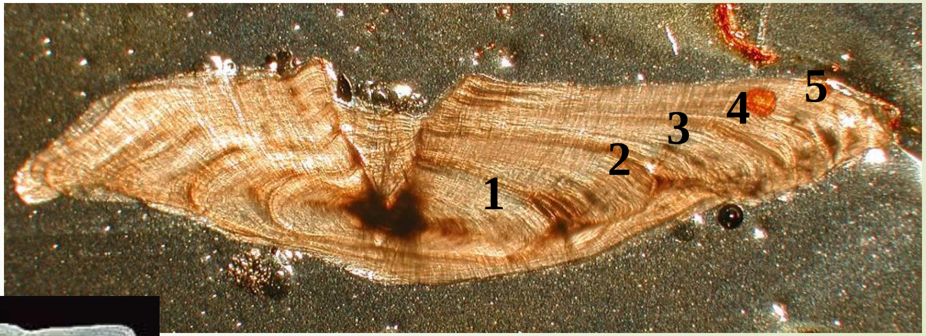
Other Fisheries Technique: Age and Growth Rates

- Modes of size distribution
  - Simple
  - Often subjective or requires knowledge of number of modes
- Look for annual rings on Otoliths
  - Produced in seasonal environments
- Scales
  - Simple, non-lethal, but often inaccurate on older fish





Other Fisheries Technique: Physiology, Body Conditions, and DELTs

- Hormones
- Reproductive condition
- DELTs = Deformities, erosion, lesions, and tumors.

- Body Condition
  - Relative index of weight at length
  - Concept is that healthier fish are heavier at size
  - Different growth allocation
  - Loss of weight

OK, So I've Decided to Survey Fish… What Species Can I Expect?

- Differ by stream order
  - Rivers vs streams
- Differ by geography
- Differ in cold water streams
- Assemblages shift in response to :
  - Deforestation
  - Impairment

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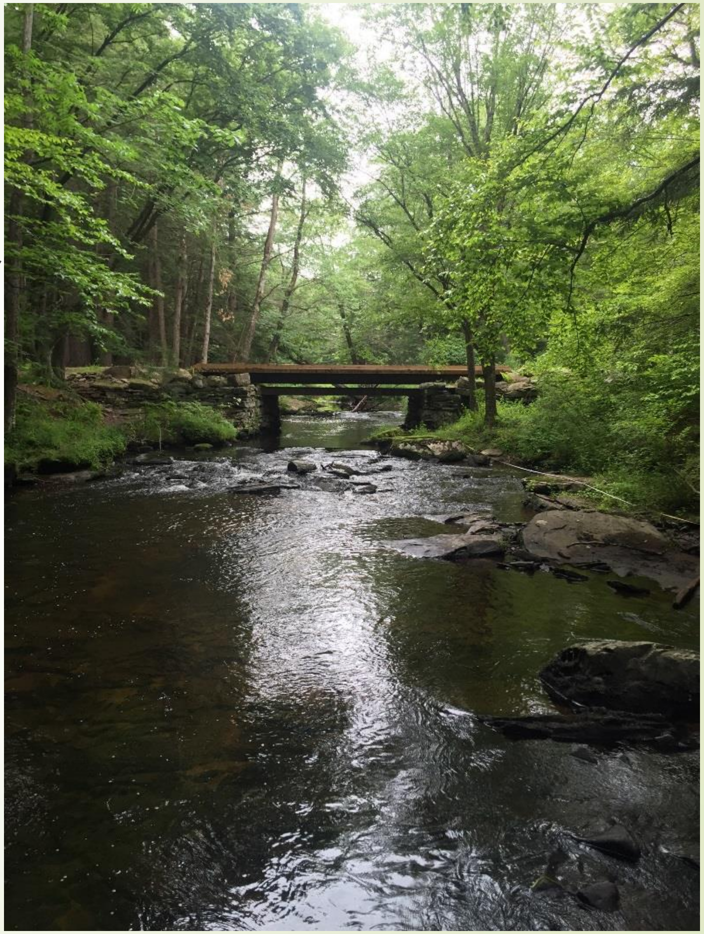
Fish Assemblages in Main Rivers

- Some stream-small river species still common
  - Minnows, Suckers, Darters
- Addition of other species
  - Large suckers and catfishes
- Some reproductive types
- Migratory species, including anadromous
- Many introduced species (most of local sport fishes)
- Estuarine species at lower ends

Fish Assemblages in Larger Streams and Small Rivers

- Warmer temperatures, usually riffle-pool habitats
- Range of species, many found over range of stream size, temperature, etc.
- American Eel, Lampreys
- Minnows, Suckers, Catfishes
- Darters, Sunfish
- Others depending on size, temperature, location



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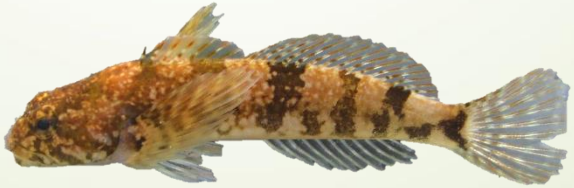
Cold Water Fish Assemblage

- Most typical members:
  - Brook Trout
  - Sculpins (several regional species)
- Introduced species
  - Brown Trout
  - Occasionally Rainbow Trout

Salvelinus fontinalis -Brook Trout

- Often small numbers of individuals of typical small stream species
- Might confuse IBI scores



Cottus cognatus- Slimy Sculpin

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Fish Assemblage: Deforestation

- Especially riparian

- Fish assemblage responds to warmer water, changed habitat and primary productivity
  - Lose trout (early)
  - Lose sensitive species, especially
    - Lampreys
    - Other intolerant species (many minnows)

- Often increase fine sediment, decrease vegetation
  - Lose several vegetation-associated species

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Fish Assemblage: Impairment

- Mainly at high levels of disturbance
- Omnivores increase, including introduced species
  - Fathead Minnow
  - Banded Killifish
- Tolerant species increase
  - Eel
  - Mummichog (normally estuarine)
  - Brown bullhead
  - Green Sunfish (introduced)

Ok, Great, I Got My Assemblage Data…Now What?

- Indices of Biotic Integrity (IBIs)
  - Use set of metrics, each measuring some aspect of assemblage structure, fish health, density
  - Designed for relatively rapid assessment
- Trout abundance
- Predict species which should be present, and calculate difference
- Measure difference between stream and reference condition
- Quantify aspects of flow variation and modification (IHA)
- **More on Day 3**

A bit more on IBI's

- Region/State specific
- Not always super informative/appropriate for fish
  - E.g., headwater streams are healthy but only have trout and sculpin, so IBI score lowered
- Has limitations
  - Very specific to region/stream order/etc.
  - Takes a lot of data to adjust other IBI metrics to your region
  - Some IBI metrics from adjacent regions may not be best for yours
  - Many factors affect fish assemblage and an IBI tries to simplify a complex system, may give false information
  - For DRWI, we use Daniels IBI for Mid-Atlantic and New Jersey IBI
    - Sometimes yield different results

Daniels IBI

- Metrics:
  - Total Number of Fish Species
  - Number of benthic insectivorous species
  - Number of water column species
  - Number of terete (cylindrical body) minnow species
  - % Dominant species
  - % White Suckers
  - % Generalists
  - % Insectivores
  - % Top carnivores
  - Fish per sample
  - % in two size classes
  - % with DELTS

Daniels IBI Continued

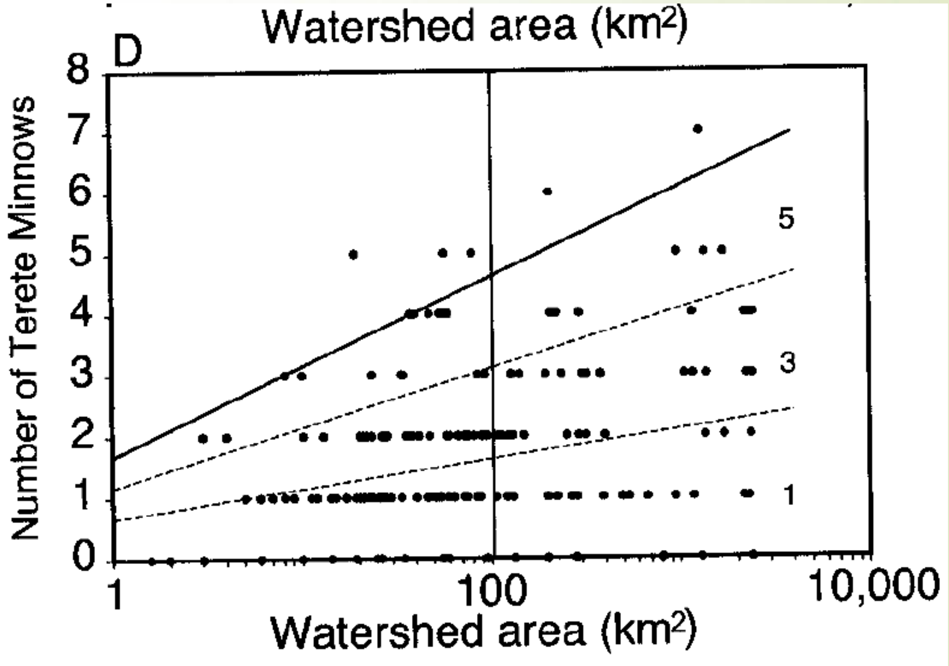
- Scoring:

1	3	5
Bad	Moderate	Good

  - Some scores dependent on stream size (Total number species, benthic insectivores, water column species, terete minnows)
    - Use maximum species richness lines
  - Others based upon %

- Totals:

45-50	Excellent
37-44	Good
29-36	Fair
10-28	Poor



Take Home Messages

- Fish can tell us a variety of things based on our questions that other organisms might not
  - Especially true for studies on energetics, contaminants, and long-term changes.
- ~80 species of fish in the Delaware River Basin
  - Important to note that species richness and diversity do not always equate to stream quality as they do with other organisms, but it is much more project, site, and scenario specific which is why our goals and questions must be clearly defined.
- Physical habitat, water chemistry, pollution, invasives, and stream connectivity all affect fish and are reflected in individuals and assemblages.
- Project goals drive both restoration and monitoring
  - Remember: electrofishing requires training and additional permits, and without such is illegal and dangerous
  - **BUT- if you are interested in including fish in your study design, let's have a discussion about ways we could work with you to incorporate a fish component.**
- Please bring any specific questions you may have on incorporating fish into your projects to Day 3!!

Questions?

Allison Stoklosa
Fisheries Scientist
ams844@Drexel.edu
215-299-1159

Richard Horwitz
Fisheries Section Leader
rjh78@Drexel.edu

David Keller
DRWI Fisheries Project Coordinator
dhk44@Drexel.edu
215-299-1150

Paul Overbeck
Fisheries Scientist
pfo23@Drexel.edu

- Question about fish sampling? Found a fish and want to know what it is? Want to incorporate fish into your monitoring? Got a general fish question? Don't hesitate to reach out and ask!

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