An Introduction to Biological Stream Condition and Restoration, with special reference to bugs and fish in Delaware River

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THE BUG GUY

Stream Ecologist
&
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My Agenda Today

- Introduce some natural history for stream macroinvertebrates and fish
- Describe stream degradation based on current conditions in the tributaries of the Delaware River Basin
- Summarize evidence of successful or unsuccessful restoration

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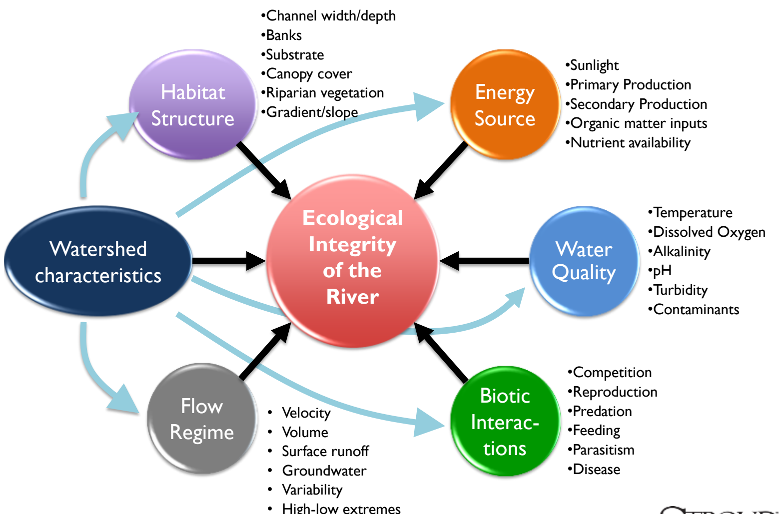

Aquatic Macroinvertebrates

Primarily aquatic insects

Mayflies

Stoneflies

Caddisflies

Aquatic Macroinvertebrates

Also non-insects

Crayfish

Mussels

Snails

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Macroinvertebrate Biodiversity

- Diversity of life in streams –
  - Breitenbach, Schlitz Germany.- Max Plank Institute (Allan 11.1, Zwick 1992)
    - **1044** species of animals over many years of collecting, **642** are insects
  - **High numbers of insects not unusual for streams**
  - Upper Three Runs in SC (about **350** species of insects)
  - White Clay Creek PA (**300** sp.)
  - Rio Tempisquito partial collections in Costa Rica **(>300 sp**.)
- In contrast, a high alpine stream in the Rockies or Alps might only have **50 species**

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White Clay Creek at Stroud Center

Over 50 years

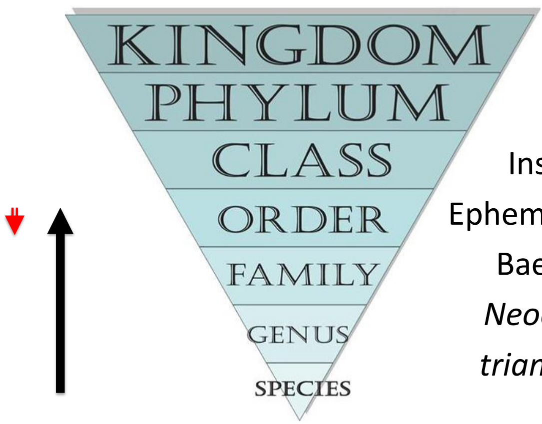
Insect Order	Species
Ephemeroptera	52
Odonata	14
Plecoptera	19
Hemiptera	9
Trichoptera	55
Megaloptera	5
Lepidoptera	1
Diptera	118
Total	298

Genus/Species

White Clay Creek, Chester Co, PA

Volunteers	≈10
Amateurs (interns)	26
Expert – genus	67
Expert – species	88
Genetics	150

Taxonomic Hierarchy



Insecta

Ephemeroptera

Baetidae

Neocloeon

triangulifer

Natural factors affecting stream macroinvertebrates

- **Temperature** – hot or cold – north vs south, high vs low elevation, summer versus winter
- **Current** – fast or slow – riffle vs pool
- **Substrate** – boulder, cobble, sand, silt
- **Food** – leaves, algae, fine particles
- **Water chemistry**
  - Dissolved oxygen
  - Alkalinity – limestone vs blackwater streams

Dynamic Fauna

Univoltine Caddisflies

1 generation/ year

Fast seasonal

Avoid summer or winter

Slow seasonal

Avoid summer

Non-seasonal

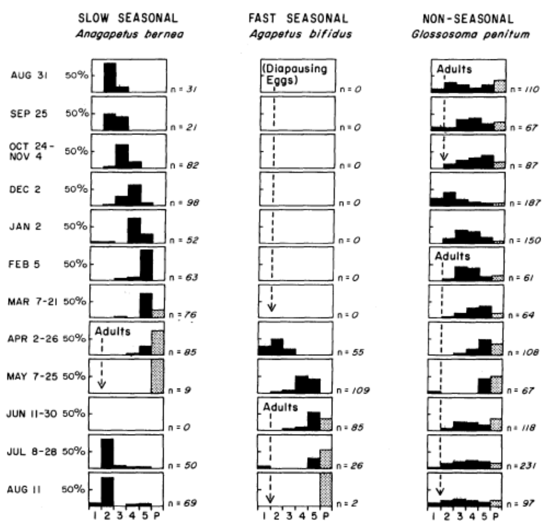
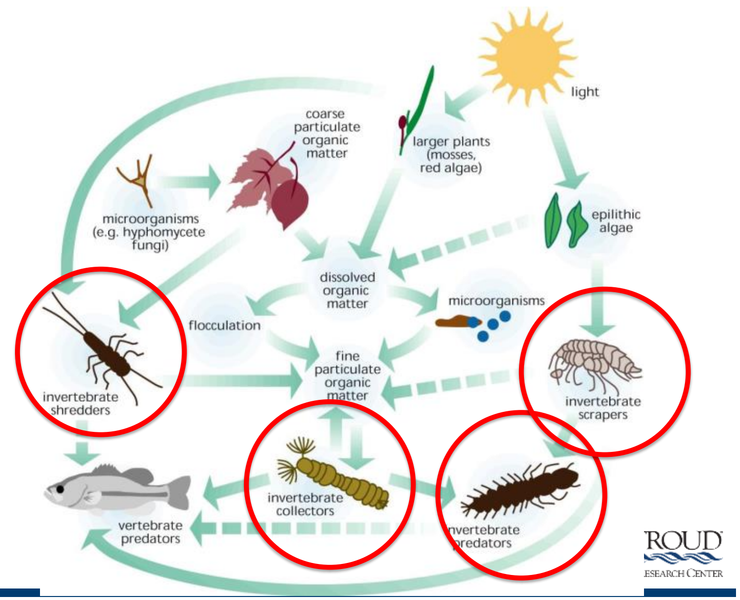
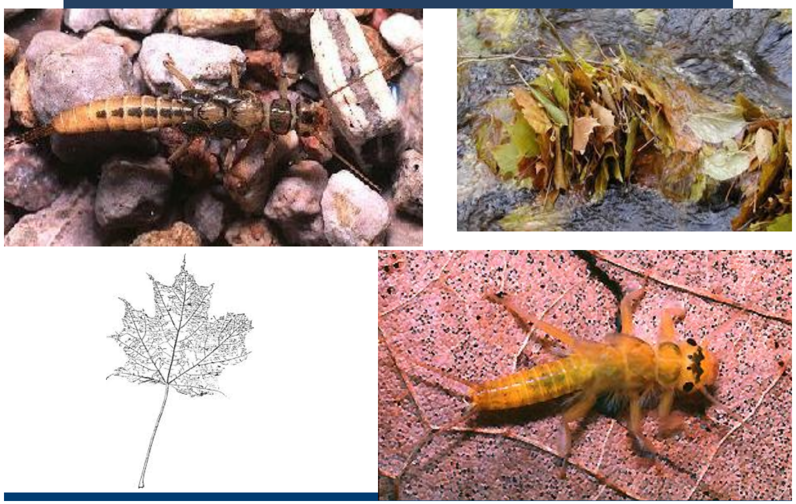


Figure 5.2. Age distribution of three glossosomatid caddisflies, illustrating life cycles. Field data are expressed as percentage composition per month for each instar. There are five larval instars; *P* = prepupa + pupa; *n* = number per sample. Flight period of adults is also indicated. (Data from Anderson and Bourne [1974].)

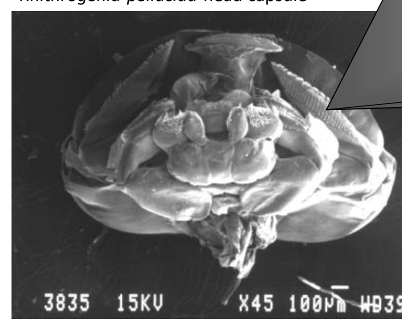


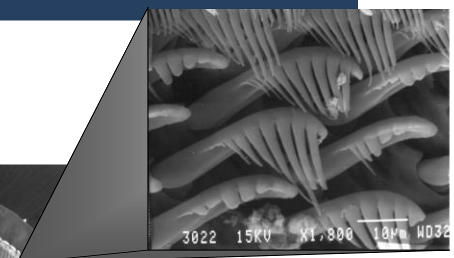
Shredders – Feed on leaves



Scraper – Algal Feeding

Rhithrogenia pellucida head capsule





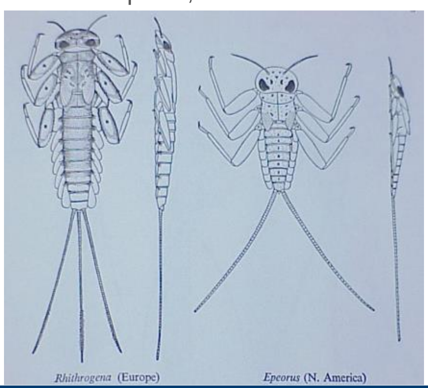
Rhithrogenia pellucida maxillary palps

Scrapers – Algal Feeding

Collector-Filterers – Fine Particles

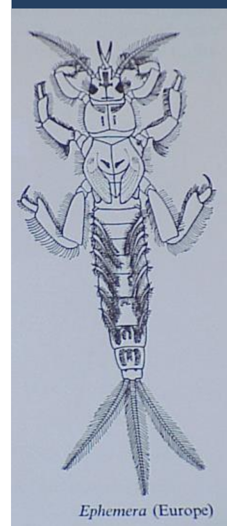
Clingers – fast water, rocky substrate

Large curved claws, dorsoventrally flattened, rheophilic, can swim if forced



Rhithrogena sp. (Ephemeroptera)

Burrowers – slow water, fine sediments



Prefer soft sediment, equipped with digging tusks, large bushy gills for O_2 poor conditions, lentic

Ephemera danica

Hynes (1970)

Air Breathers – Low Oxygen

Ranatra linearis (Hemiptera)

Nepa rubra (Hemiptera)

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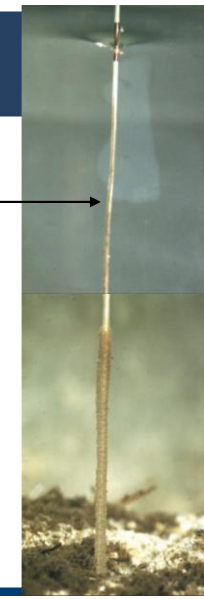
Air Breathers – Low Oxygen

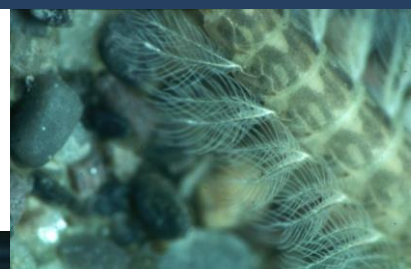
Eristalis sp. (Diptera: Syrphidae)
"Rat-tailed maggot"

Telescoping respiratory siphon extends to 6x body length



Gill Breathers – Higher Oxygen

Rhithrogena sp.
(Ephemeroptera)



Potamanthus sp.
(Ephemeroptera)

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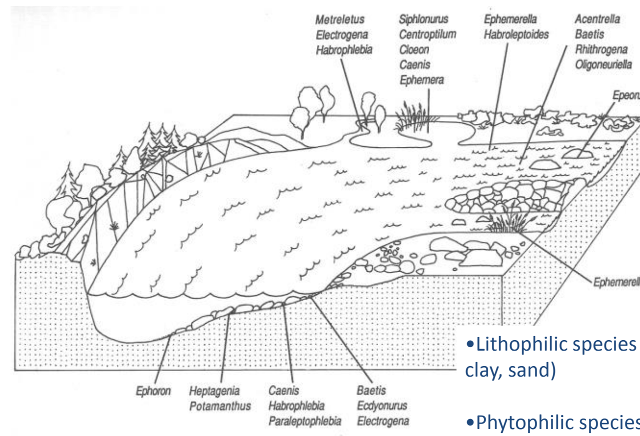
Reach-Scale Habitat for Ephemeroptera

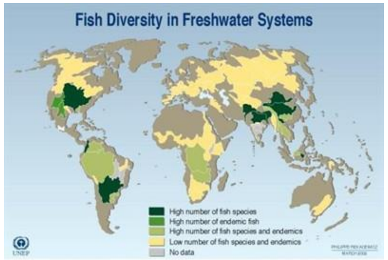
(as an example)



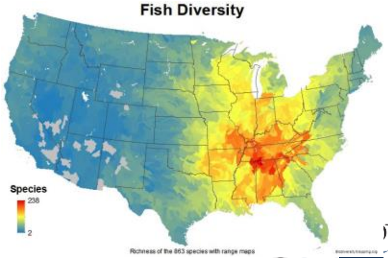
- Lithophilic species (gravel, clay, sand)
- Phytophilic species (plants & organic matter)

Fish Worldwide

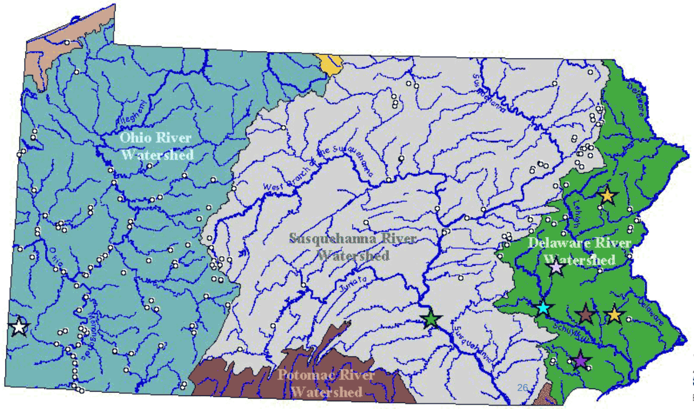
Freshwaters have disproportionately high diversity, given that there is much less freshwater habitat compared to marine habitat



Source: Revenga et al., World Resources Institute (WRI), Washington DC, 1998.



Major River Basins of Pennsylvania



Fish

19 Native species in White Clay Creek

American eel	Spotfin shiner	Creek chub
Sea lamprey	Spottail shiner	Fallfish
American brook lamprey	Swallowtail shiner	Rock bass
White sucker	Tessellated darter	
Creek chubsucker	Cutlips minnow	
Rosyside dace	Banded killifish	Brown trout
Blacknose dace	Redbreast sunfish	Rainbow trout
Longnose dace	Green sunfish	Smallmouth bass
Common shiner	Pumpkinseed	Largemouth bass
Satinfin shiner	Margined madtom	Bluegill

Fish habitat

- Water Velocity
- Water Quality
- Temperature
- Depth
- Instream-lake Cover
- Stream-lake Size
- Substrate Size
- Instream-lake Vegetation
- Riparian Vegetation
- Floodplain Habitat
- Migration Corridors

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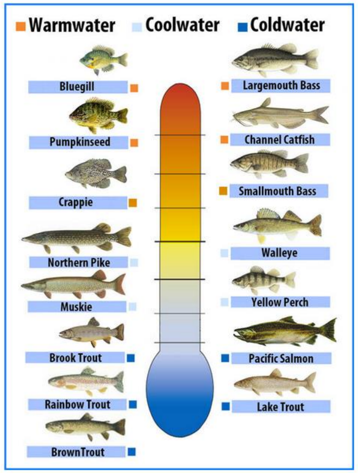
Natural factors affecting stream fish

- **Temperature** – warm or cold water fishery – north vs south, high vs low elevation
- **Current** – fast or slow – riffle vs pool
- **Substrate** – boulder, cobble, sand, silt
- **Food** – aquatic vs terrestrial, surface, drift, bottom
- **Water chemistry**
  - Dissolved oxygen
  - Alkalinity – limestone vs blackwater streams

Temperature

Defines (in part) fish community

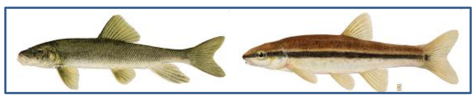


Structure within a channel unit

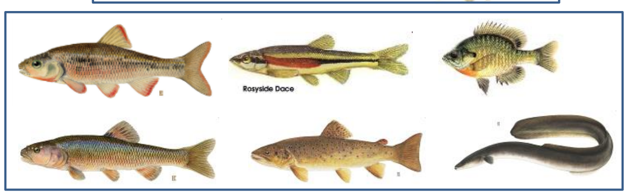
White Clay Creek
Habitat guilds

Riffle
Fast, rocky

Generalist



Pool
Slower, finer sediments



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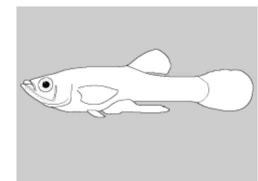
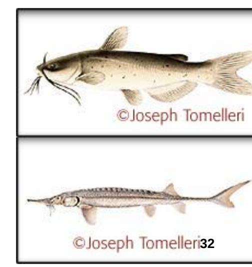
Body Shape reflects feeding behavior/location of



Feed at surface

Feed in front

Feed off bottom



32

Unfortunately, our water and waterways are rarely in a natural, pristine condition

Silent Spring 1962
Earth Day 1970

2019 is the

57th anniversary

Silent Spring

49th anniversary

Earth Day

Clean Water Act 1972
Safe Drinking Water Act 1974

2019 is the

47th anniversary

Clean Water Act

Designated Uses

Aquatic Life

Recreational Contact

Water Use
(people, animals industrial, agricultural)

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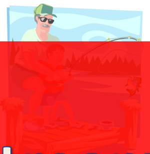
Designated Uses

Fishable

Swimmable

Drinkable

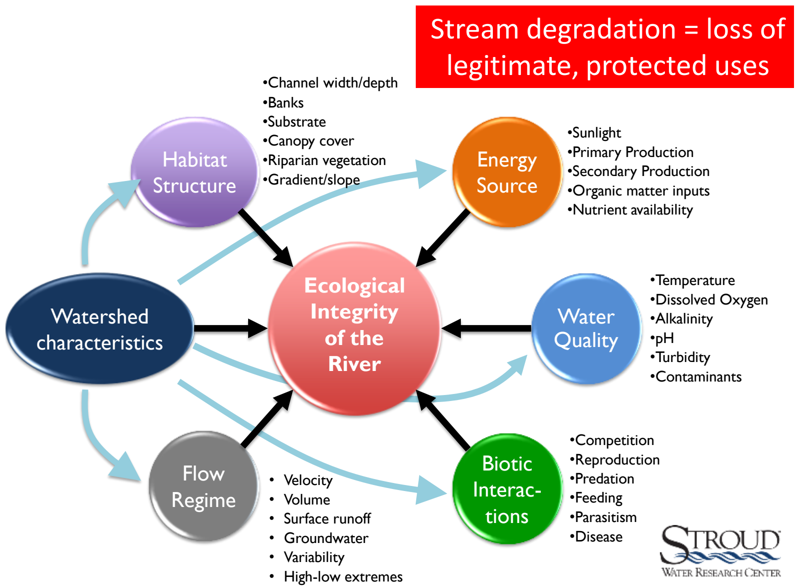


Fishable

Stream degradation = loss of legitimate, protected uses

Swimmable

Drinkable


Stream degradation = loss of legitimate, protected uses
Habitat Structure
•Channel width/depth
•Banks
•Substrate
•Canopy cover
•Riparian vegetation
•Gradient/slope
Energy Source
•Sunlight
•Primary Production
•Secondary Production
•Organic matter inputs
•Nutrient availability
Watershed characteristics
Ecological Integrity of the River
Water Quality
•Temperature
•Dissolved Oxygen
•Alkalinity
•pH
•Turbidity
•Contaminants
Flow Regime
• Velocity
• Volume
• Surface runoff
• Groundwater
• Variability
• High-low extremes
Biotic Interac-tions
•Competition
•Reproduction
•Predation
•Feeding
•Parasitism
•Disease
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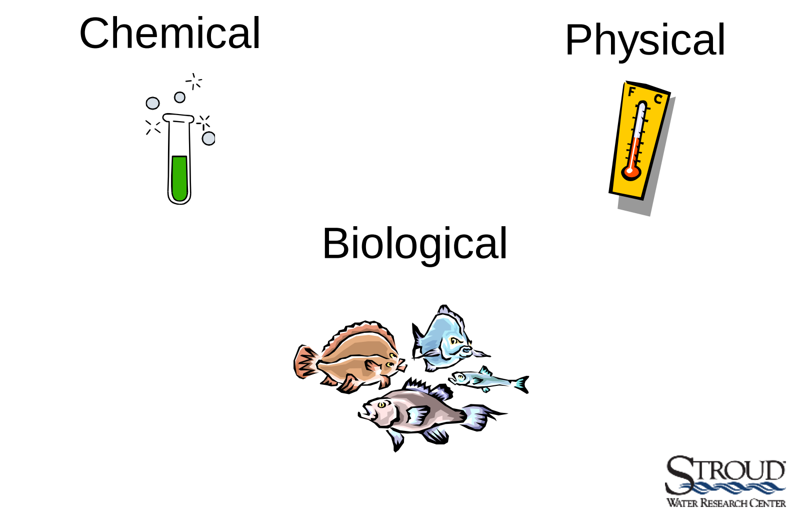
Chemical
Physical
Biological
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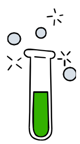
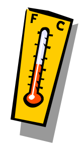
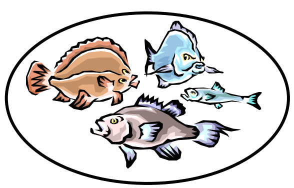
Chemical

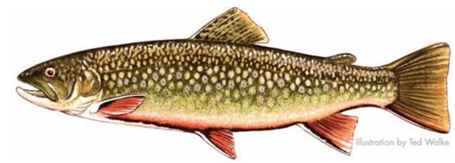


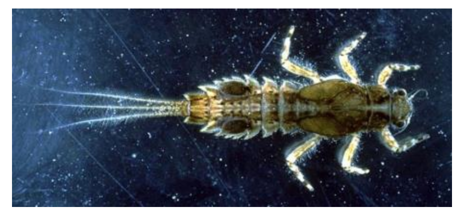
Physical



Biological





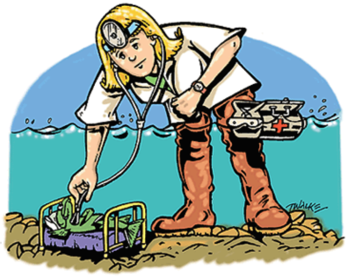


In pollution monitoring,

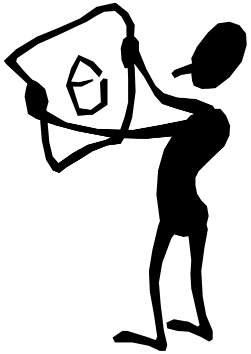
Presence tells you something

Conspicuous absence also tells you something

Use caution –
absence could reflect
natural phenomena such as
season, location, or
microhabitat



Why Monitor Aquatic Macroinvertebrates?



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Aquatic Macroinvertebrates

Primarily aquatic insects

Mayflies

Caddisflies

Stoneflies

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Aquatic Macroinvertebrates

Also non-insects

Crayfish

Snails

Mussels

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Aquatic Macroinvertebrate Monitoring

Strong public acceptance

Ecologically significant

Variable pollution response

Extends temporal perspective

Standardized monitoring protocols

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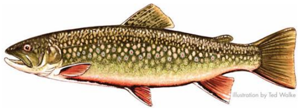
"Fish Food"



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Mayfly adult

http://upflyfishing.com/hendrickson-mayfly/

Caddisfly larva

http://flyguys.net/fly-patterns/caddis/sharks-caddis-larva

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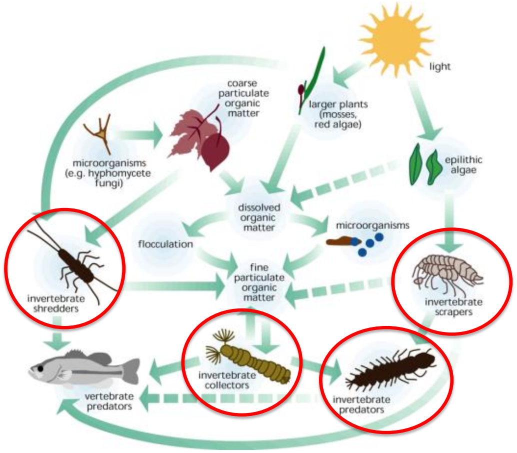

Bugs are in the middle of the food web

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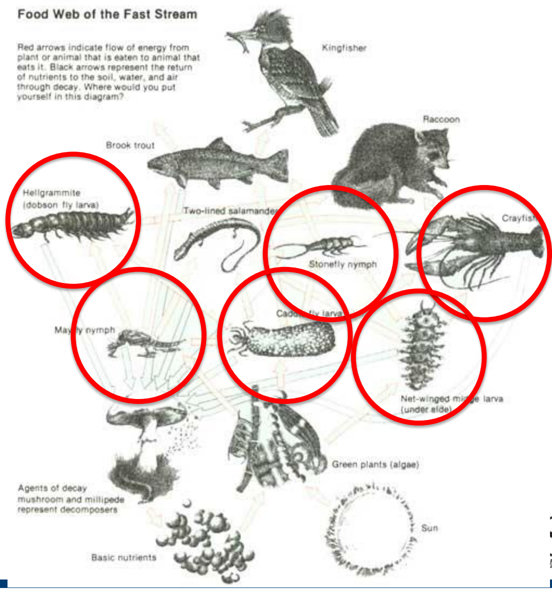


Not just fish

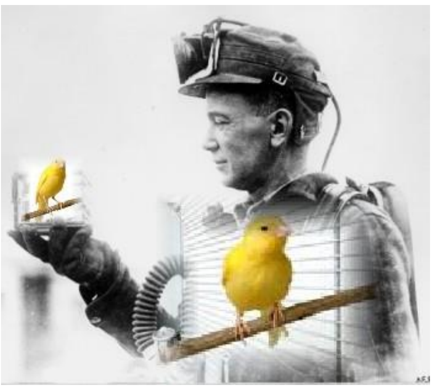
Belted Kingfisher

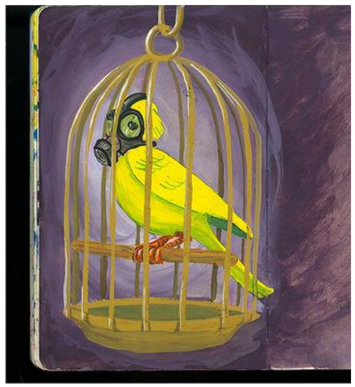
Northern Waterthrush

Northern Raccoon

Great Blue Heron

Eastern Pipistrelle





Pollution-sensitive species are our canaries in the coal mine

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Ephemeroptera
Plecoptera
Trichoptera

Pollution-sensitive

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Macroinvertebrate

Monitoring protocols well established

PA

- ✧ Freestone
- ✧ Limestone
- ✧ Multihabitat
- ✧ Semi-wadeable large river

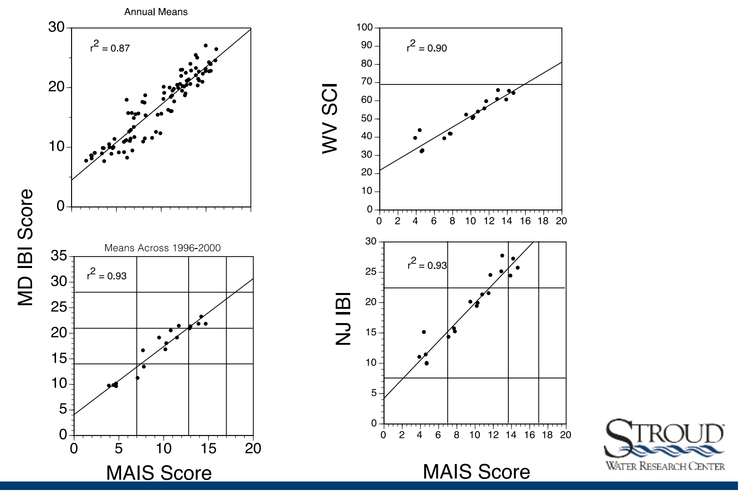
Maryland – MBSS Family and Genus

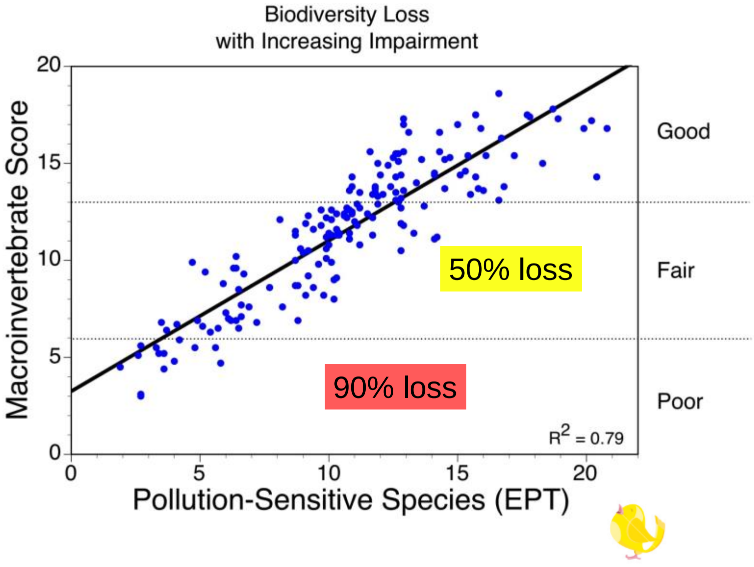
NJ, DE, NY all different

Multimetric indicies from the Mid-Atlantic Region

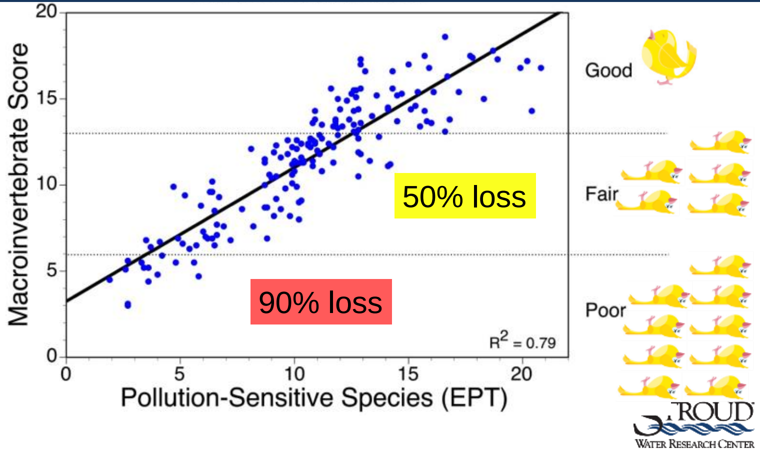
Metric	MAIS	MD	NJ	WV
Total Richness		3	3	3
EPT Richness	3	3	3	3
Mayfly Richness	**3**	**3**		
Diptera Richness		**3**		
% EPT 3		3	3	
% Ephemeroptera	3	3		
% Chironomidae				3
% Dominant 1 taxon			3	
% Dominant 2 taxa				3
% Dominant 5 taxa	3			
Simpson's Diversity	3			
Intolerant Richness	3	3		
Hilsenhoff Biotic Index	3		3	3
Beck's Biotic Index		3		
% Scrapers	3			
% Haptobenthos	3			

Different state metrics are related
(but classifications may not be)

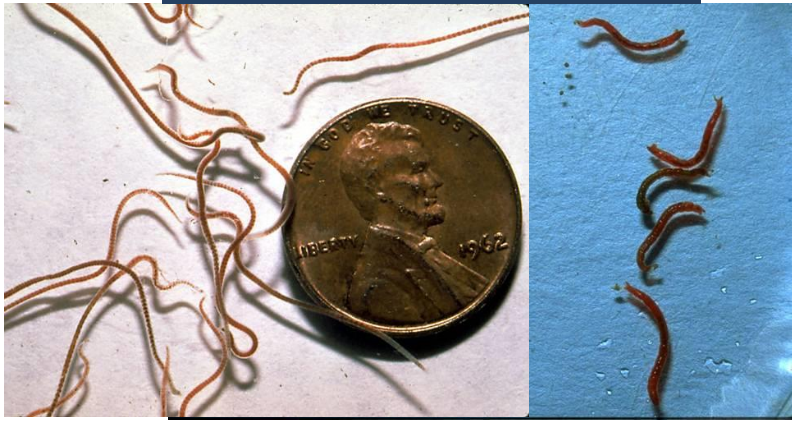




Stream degradation is a significant loss of biodiversity!



Abundance often decreases (toxins), but can increase (fertilization)



Pollution-tolerant

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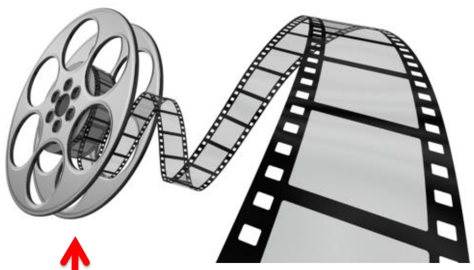
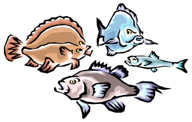
Movie versus Snapshot



Snapshot
Single
Frame

Biological

Movie



Macroinvertebrates are sampling water 24/7 for weeks or months

Macroinvertebrates Provide a Biological Perspective –

Integrating stressors

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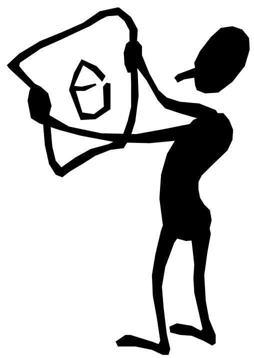
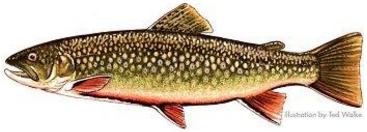
Why Monitor Stream Fish?

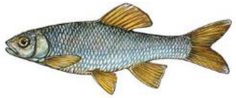


Fish

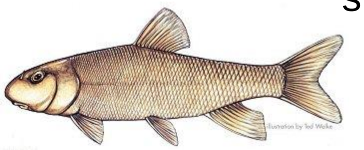
Sport & non-sport; NATIVE



Brook trout



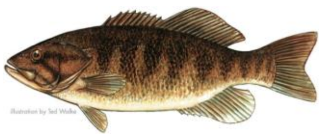
Spotfin shiner



White Sucker

Fish

Sport & non-sport; NON-NATIVE



Brown trout

Smallmouth bass

Bluegill

Stream Fish Monitoring

Strong public acceptance

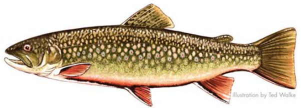
Ecologically significant

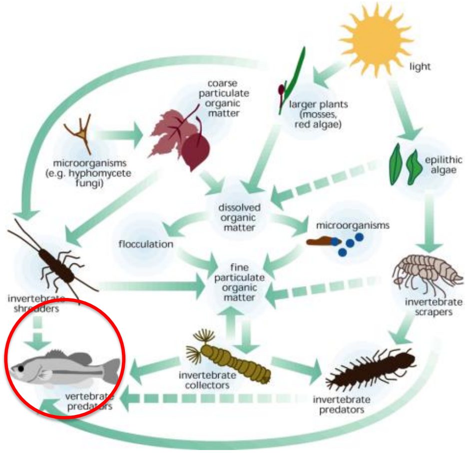
Variable pollution response

Extends temporal perspective

Standardized monitoring protocols

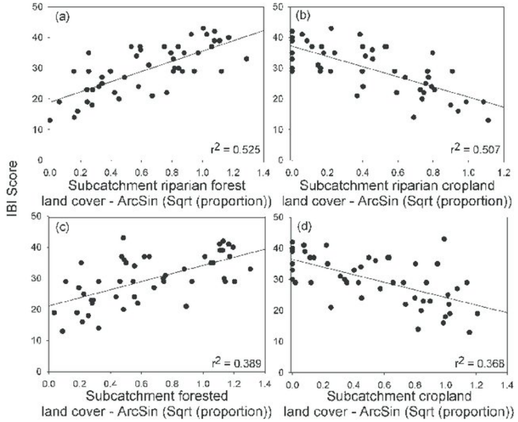
Recreational
contact
“Clean Stream”





Fish are management
targets

Fish response to watershed and riparian disturbance



https://www.researchgate.net/publication/233598362_Landscape_influences_on_stream_fish_assemblages_across_spatial_scales_in_a_northern_Great_Plains_ecoregion/figures?lo=1

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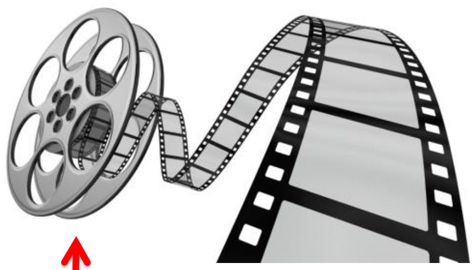
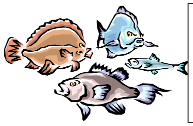
Movie versus Snapshot



Snapshot
Single
Frame

Movie

Biological



Fish are
sampling water
24/7 for weeks, months, years

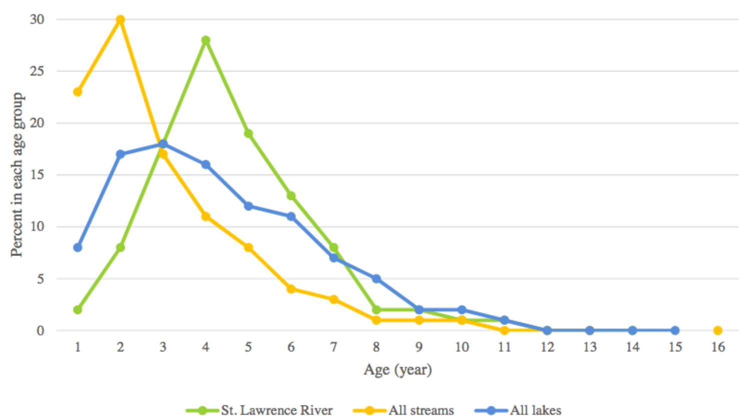


Figure 15. Percent distribution of age 1-16 smallmouth bass from streams, lakes, and the St. Lawrence River, New York, 2004-2013.

https://www.dec.ny.gov/docs/fish_marine_pdf/bbstreamsassess.pdf

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Fish

Monitoring protocols still developing

New Jersey

✧NJ Headwater IBI – small watershed, northern

✧NJ Northern Fish IBI – larger watershed, northern

✧NJ Southern Fish IBI – low gradient, (pine barrens)

PA

✧ Ohio and Susquehanna done

✧ Developing for Delaware River

Maryland – MBSS done, regional

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PA Aquatic Life Uses & Special Protection Uses

EV	**Exceptional Value Waters**
HQ-CWF	**High Quality-Cold Water Fishery**
CWF	Cold Water Fishery
HQ-TSF	**High Quality - Trout Stocking**
TSF	Trout Stocking Fishery
WWF	Warm Water Fishery

Designated Uses

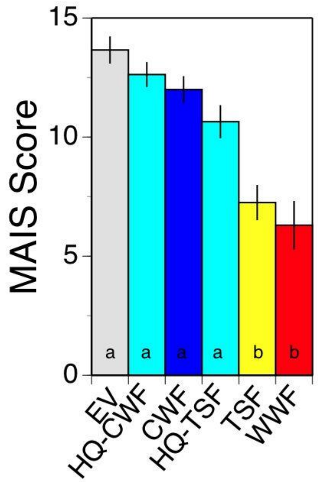
PA Code Chapter 93
https://www.pacode.com/secure/data/025/chapter93/chap93toc.html

eMapPA
http://www.depgis.state.pa.us/emappa/

Stream Impairments

eMapPA
PA Integrated Water Quality Report - 2018

EV, HQ-CWF, CWF, HQ-TSF
>TSF = WWF



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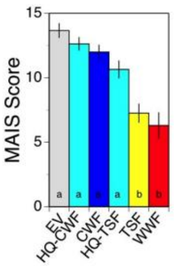
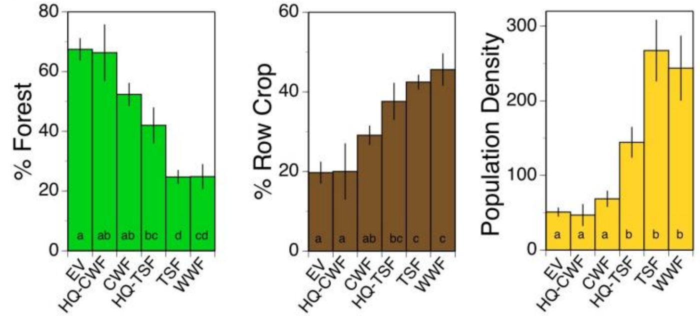
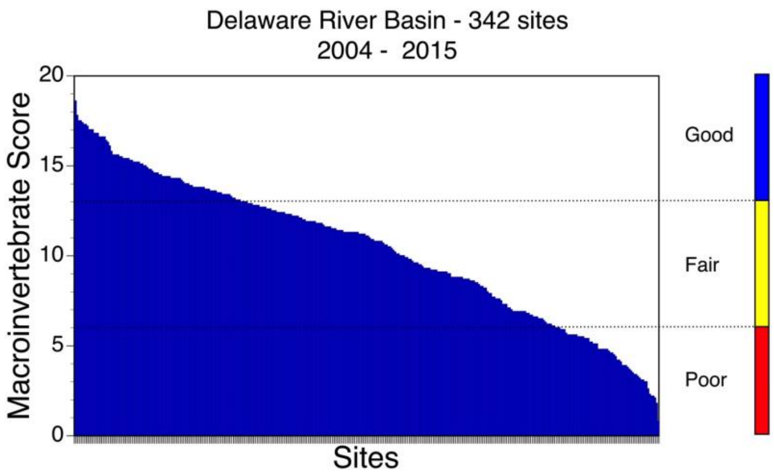


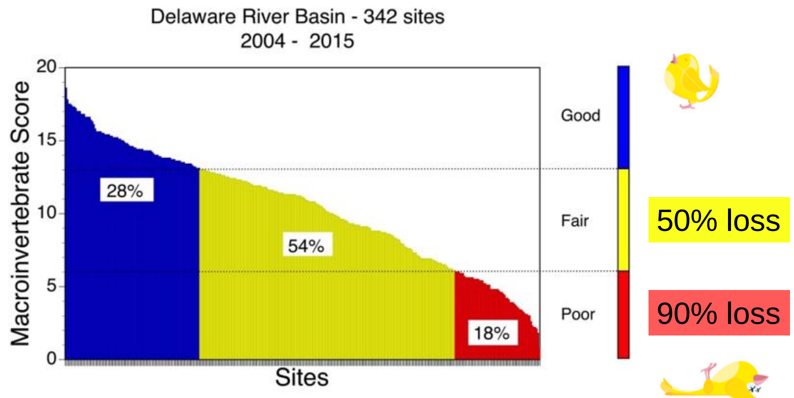
Macroinvertebrates ↓
Forest ↓
Agriculture ↑
Development ↑



Degradation is gradual



Degradation = significant loss of species



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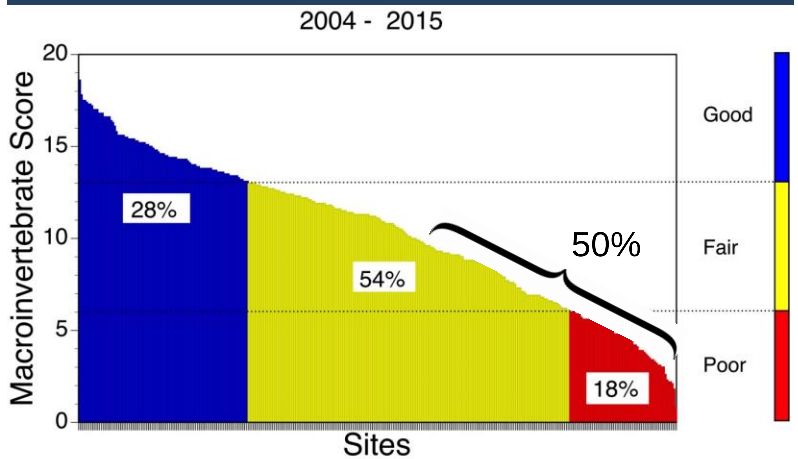
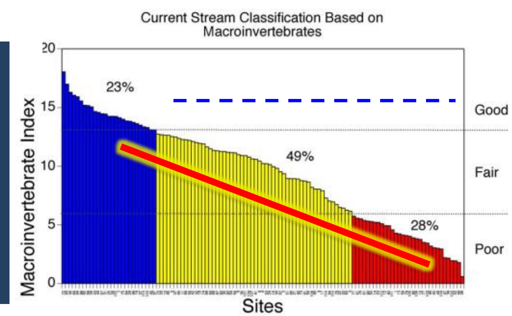
Degradation is common
≈ 50% are clearly degraded



After 47+ years, the Clean Water Act has not restored our streams.



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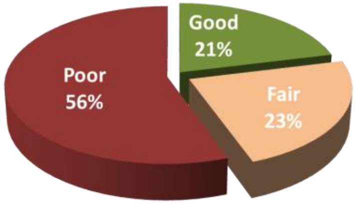
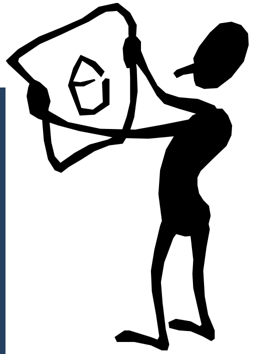
www.epa.gov/aquaticsurveys

- 56% of the nation's river and stream miles do not support healthy populations of aquatic life

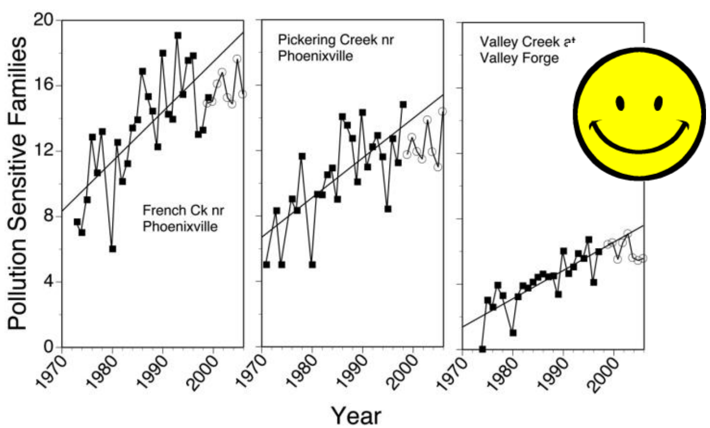


US EPA – Draft Report: National Rivers & Streams Assessment 2008-2009

Has the condition of streams of the Delaware River Basin improved or been maintained?



Stream Conditions Have Improved!



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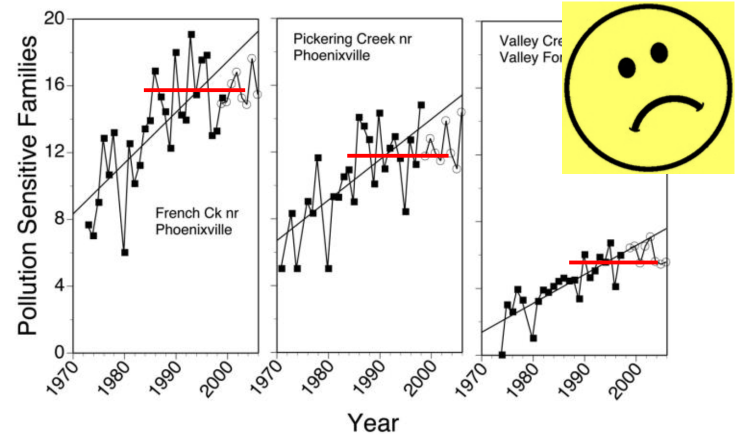
But not a lot recently



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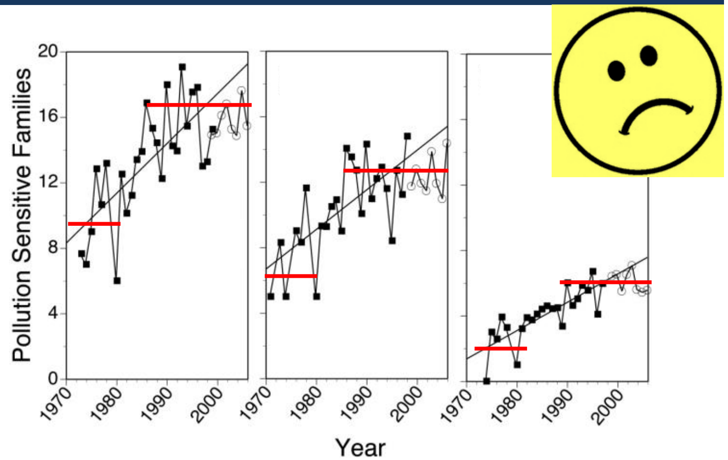
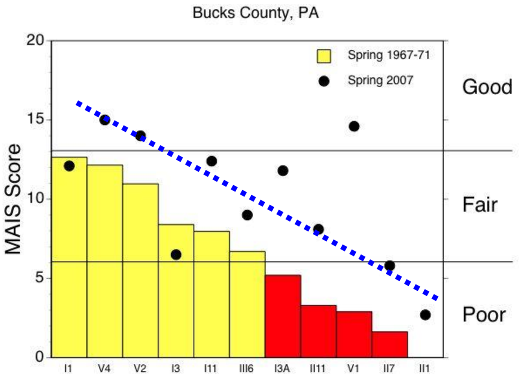
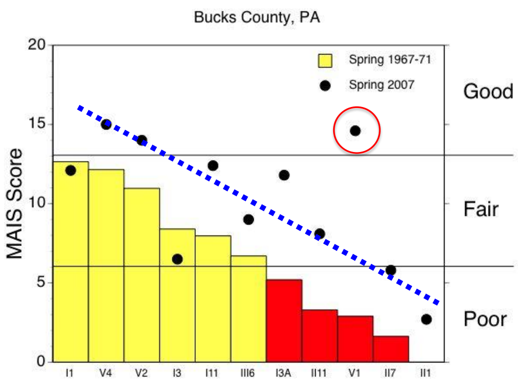
Poor streams rarely become great streams.



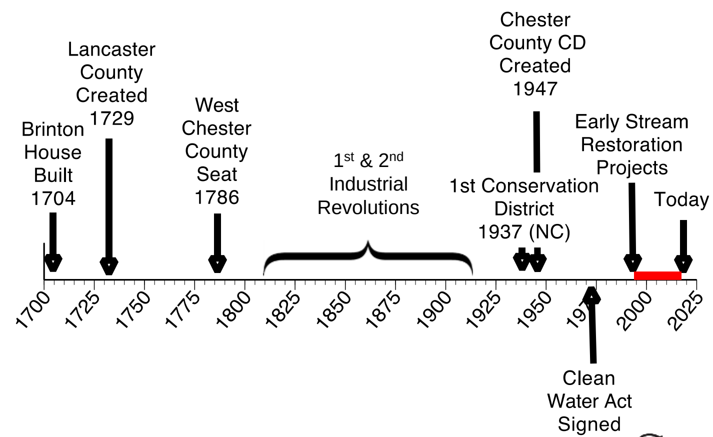


Over 40 years, stream condition generally improved or maintained



Again, poor streams rarely become great streams.

Chester County History



Are current environmental laws protecting our streams and rivers?

Yes

Good evidence many streams are cleaner

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Are current environmental laws protecting our streams and rivers?

No

Good evidence many streams are still polluted, and not improving

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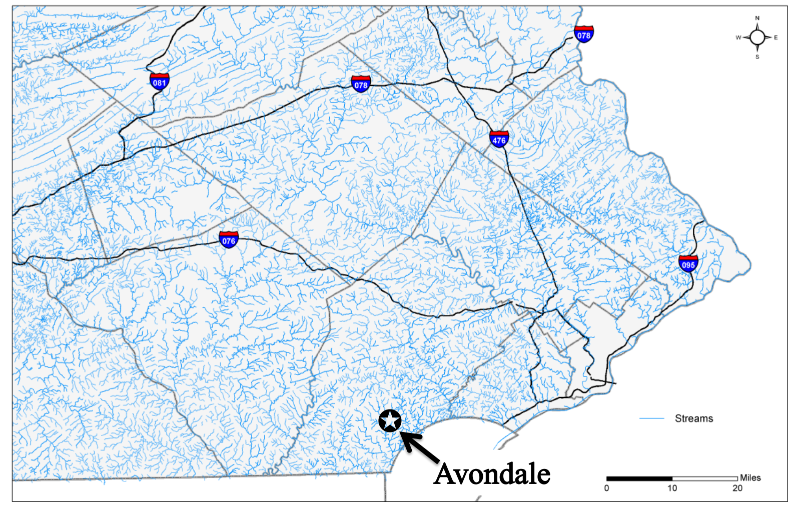

We live in a wet world

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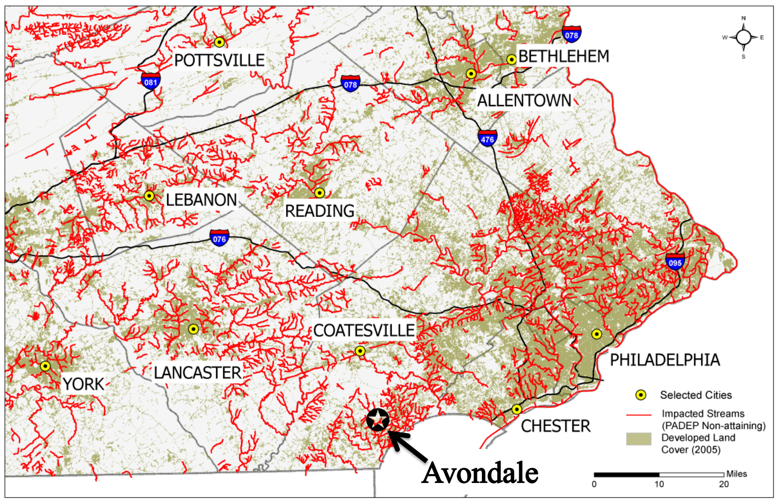

With a lot of polluted streams

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How big is Chester County's polluted stream challenge?

Chester County, PA

957 miles impaired

5,052,960 feet impaired

5,053 projects if 1000 feet long

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Addressing 100 ft here and 1000 ft there, leaves us much more to do!

Lancaster County, PA

824 miles impaired

4,350,720 feet impaired

4,350 projects if 1000 feet long

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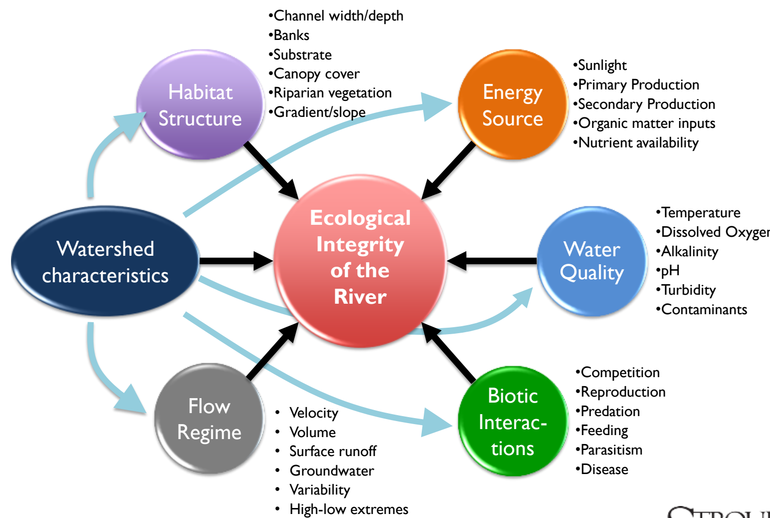

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Anthropogenic factors affecting stream macroinvertebrates

- **Temperature** – hot ➔ cold or cold ➔ hot (thermal pollution from power plants, dams, stormwater, climate change)
- **Current** – fast ➔ slow – dams and diversions, hydropeaking (wet/dry, armoring)
- **Substrate** – boulder & cobble ➔ sand & silt (field and channel erosion, but also armoring)
- **Food** – leaves ➔ algae or fine particles (deforestation, grass buffers, organic waste)

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Anthropogenic factors affecting stream macroinvertebrates

- **Water chemistry**
  - Dissolved oxygen sag (sewage or other high Biological or Chemical Oxygen Demand)
  - pH/Alkalinity – acid mine drainage, acid rain
  - Petroleum Oils (mosquito control)
  - Toxins (metals, pesticides, pharmaceuticals, personal care products)

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Human modification of streams (targets of restoration)

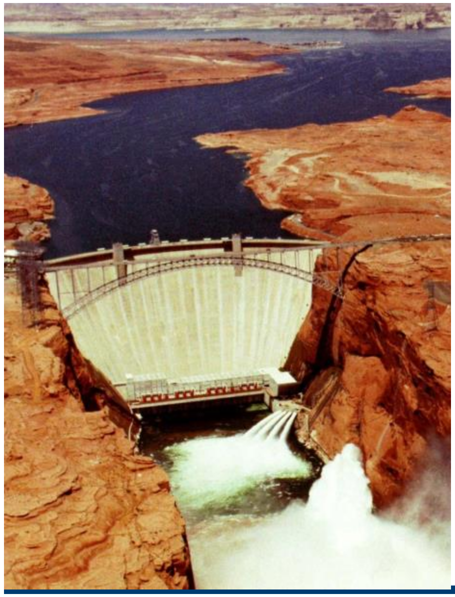
1 – Modifications of Natural Flow Regimes

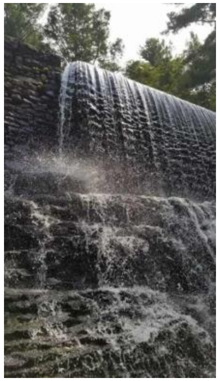
2 – Watershed Modifications

3 – Pollution

4 – Non-native Species

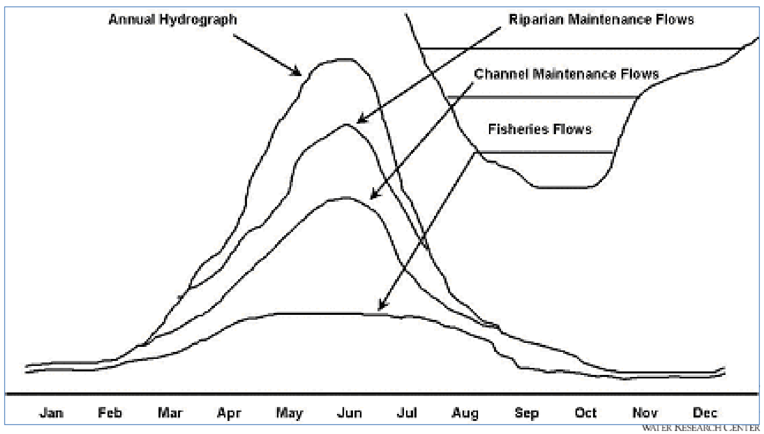
5 – Global Change



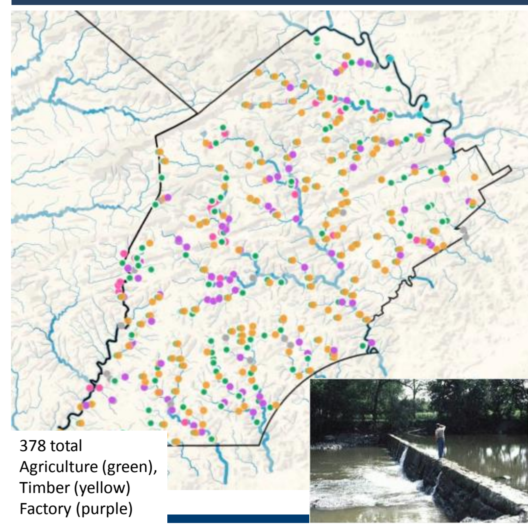


Environmentally Significant Flows

But also temperature, oxygen, food, substrate



Mill Dams in Chester County - 1847

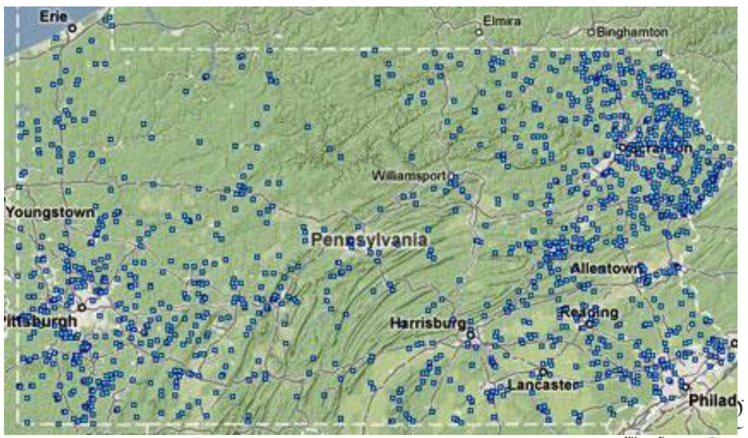


378 total
Agriculture (green),
Timber (yellow)
Factory (purple)

Alewife, Blueback, Herring, Hickory Shad, American Shad

Dams in Pennsylvania

Barriers to movement



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Channelization and constrainment

Kankakee River

Indiana & Illinois

1 – Modifications of Natural Flow Regimes

2 – Watershed Modifications

3 – Pollution - the presence in or introduction into the environment of a substance or thing that has harmful or poisonous effects

4 – Non-native Species

5 – Global Change

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2–Watershed modifications from changes in land use during human settlement

Rural - forest removal, agriculture, excessive grazing in former forests or grasslands

Urban - increased impervious surfaces from roads, houses, buildings (storm runoff)

Both - riparian integrity (presence?, size, age, able to function as a buffer or part of stream?)

All of the above (**dams and diversions, channelization and constrainment, watershed modifications)** equal **habitat modification and loss**

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Common Landscape Predictors of Stream Degradation

- % Forest
- % Agriculture
  - Row Crop vs Pasture
  - Livestock (density, barnyards)
- % Urban
  - Population Density (individuals per sq km)
  - % Developed (high, medium, low intensity)
  - % Impervious Cover

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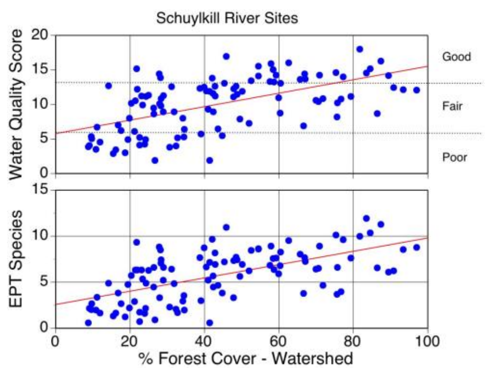
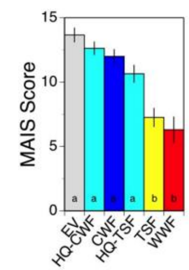
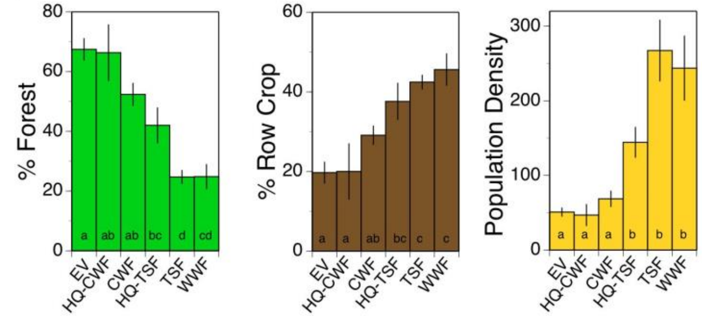
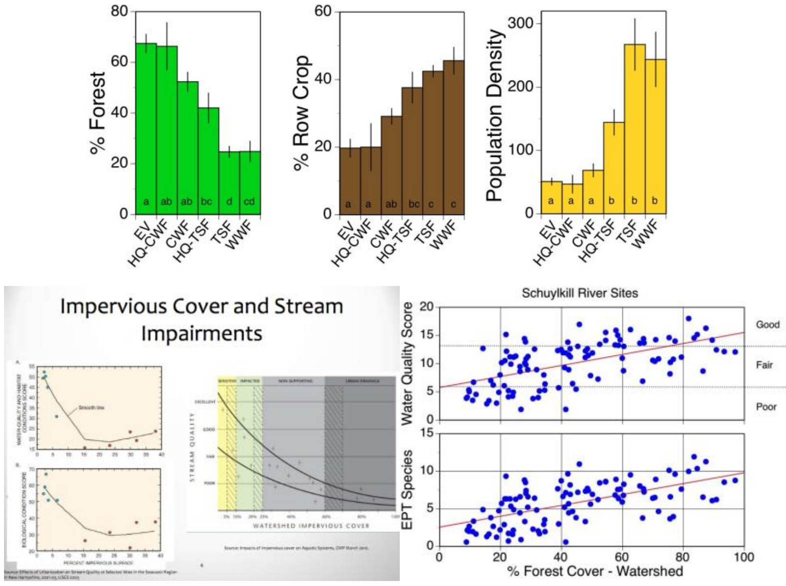
Better stream condition associated with greater forest cover.

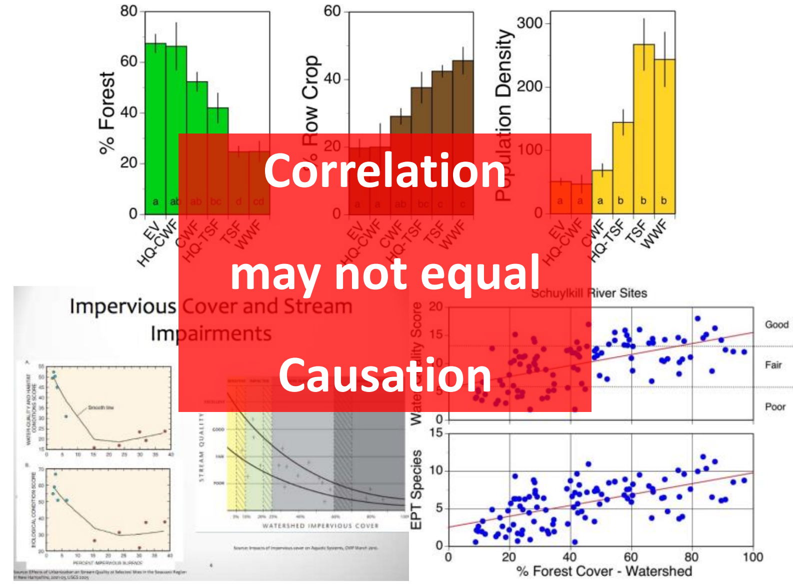




Macroinvertebrates ↓
Forest ↓
Agriculture ↑
Development ↑




% Forest
% Row Crop
Population Density
EV
HQ-CWF
CWF
HQ-TSF
TSF
WWF
Impervious Cover and Stream Impairments
Schuylkill River Sites
Water Quality Score
Good
Fair
Poor
EPT Species
% Forest Cover - Watershed


Correlation
may not equal
Causation
% Forest
% Row Crop
Population Density
Impervious Cover and Stream Impairments
Schuylkill River Sites
Good
Fair
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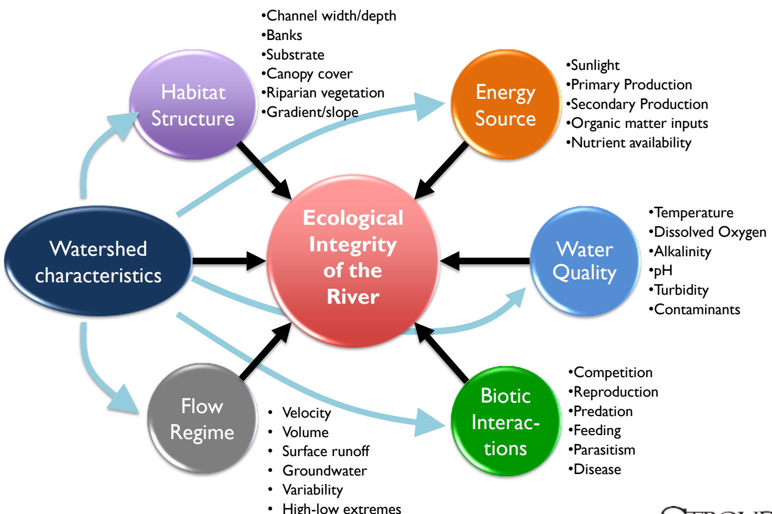

All of the above (**dams and diversions, channelization and constrainment, watershed modifications)** equal **<u>habitat modification and loss</u>**

1 – Modifications of Natural Flow Regimes

2 – Watershed Modifications

3 – Pollution - the presence in or introduction into the environment of a substance or thing that has harmful or poisonous

4 – Non-native Species

5 – Global Change

Pollution

3. Pollution
   - introduction into the environment by humans of something (substance, energy, land use practice) that is likely to interfere with the natural process of that environment and or the legitimate uses of the environment

•History of water pollution
   - began with the change from migratory to sessile state of man
     - cut down forests, farmed land (upland areas)
     - population densities increase, accumulation of human wastes and need for disposal
     - water sources affected by both of these, and was an easy answer to disposal (out of sight)

Pollution
point source - at the pipe;
non-point source - diffuse points of entry

1. **Pathogen** (human health issues-fecal coliform, cryptosporidium, giardia)
2. **Poisons** (industrial wastes, pesticides, herbicides, urban runoff, oil)
3. **Organic** (dissolved and particulate residues ie untreated sewage, farm and manufacturing waste)
4. **Nutrient** (fertilizers, treated sewage, farm, manufacturing effluent, aerial deposition)
5. **Physical** (sediment, habitat change, temperature) – see #1 and 2 above for physical changes

Impact of pollution
- In all cases of poisons, organics, nutrients, and physical
  - **loss of species** (unless only a minor nutrient increase that might support a few more species)
- In some cases
  - **increase abundance** (fertilization effect exploited by survivors)
- In most cases
  - **decrease abundance** (depends if tolerant taxa can exploit conditions)

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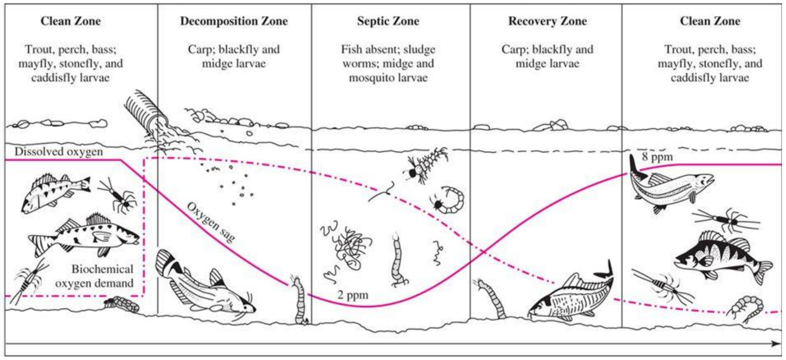
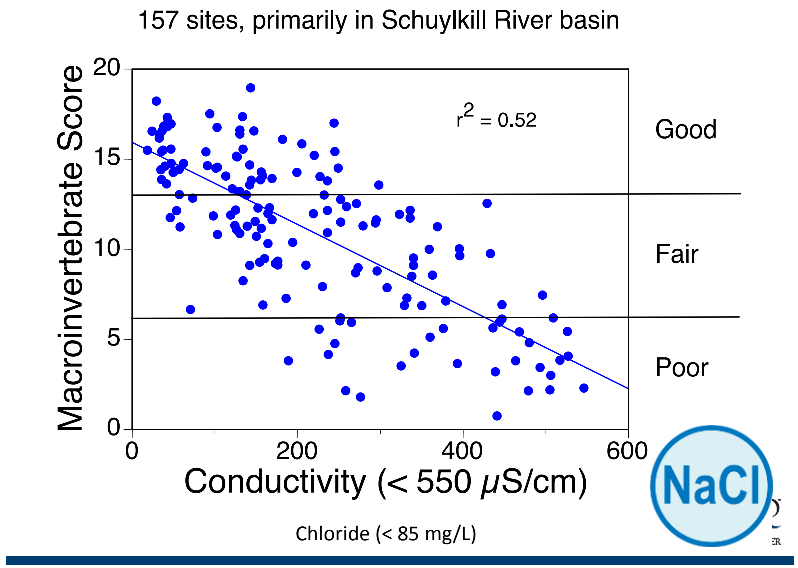
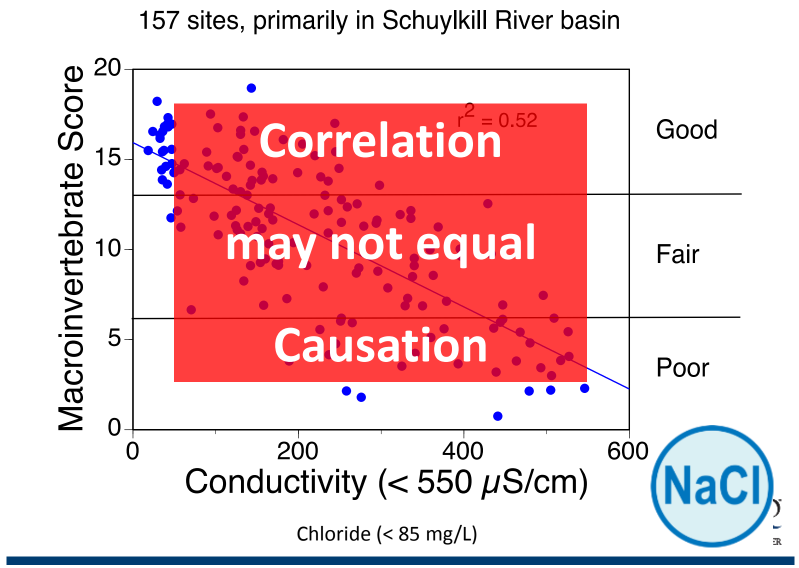
Dissolved Oxygen Stress
Common pre-Clean Water Act
Not common now

DO Sag Curves




157 sites, primarily in Schuylkill River basin
Macroinvertebrate Score
20
15
10
5
0
0
200
400
600
r^2 = 0.52
Good
Fair
Poor
Conductivity (< 550 μS/cm)
Chloride (< 85 mg/L)
NaCl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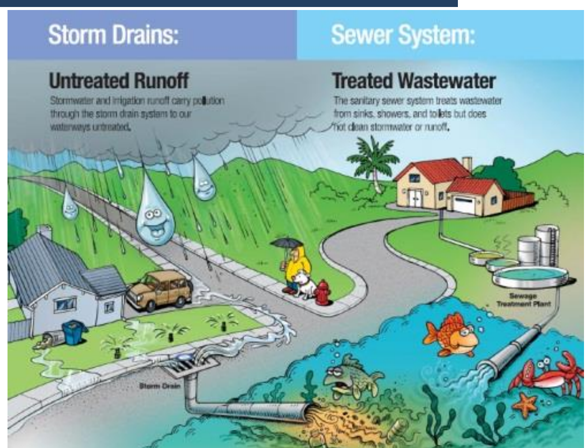
NaCl

Salt Illustrates Land/People Connection to Water:

Toxins:
Salt
Oils
Metals
Sealants
Herbicides
Insecticides
Soaps

Drugs
Personal Care
Fertilizers



Salt Illustrates Land/People Connection to Water:

Toxins:
Salt
Oils
Metals
Sealants
Herbicides
Insecticides
Soaps

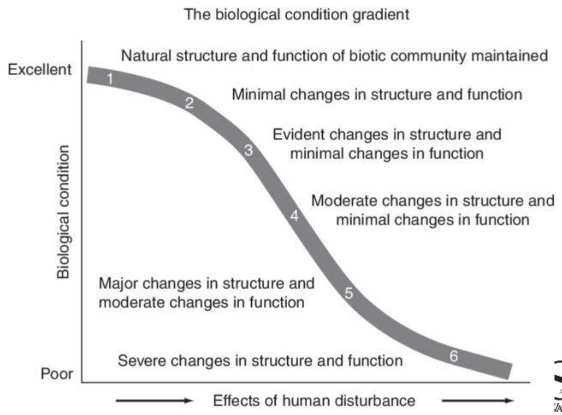
Drugs
Personal Care
Fertilizers

"Chemical Cocktail" in storm water

Freshwater Salinization Syndrome

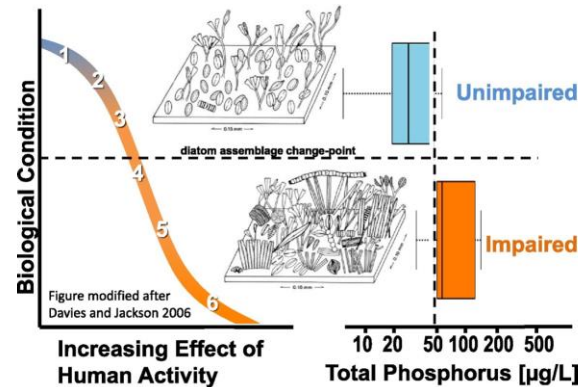
Kaushal et al. 2018

Building from Stream Degradation Curve – a Dose Response Curve

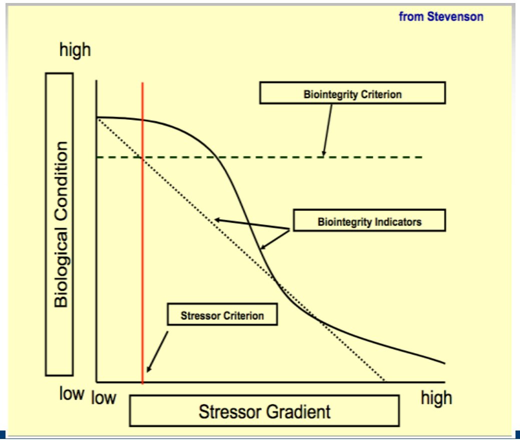


Courtesy of Susan Davies Maine Department of Environmental Protection

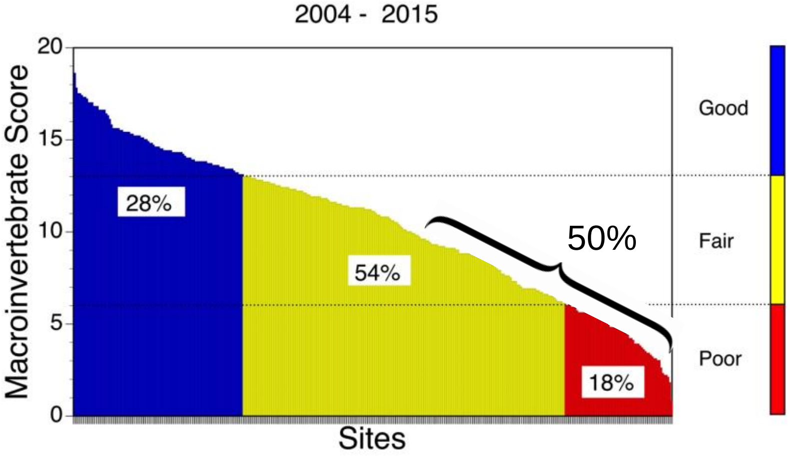
Stream Degradation Curve – Contributes to Definition of Impaired



Stream Degradation – the shape of the degradation curve is key



Degradation is common
≈ 50% are clearly degraded



Why are we not seeing streams delisted, or at least larger improvements?

1. Not Enough Time?
2. Not Enough Intensity?
3. Wrong Prescription?
4. Missed Something?

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Case Studies – Evidence of Success

Streams Impacted by Acid Mine Drainage

Urban Streams

Agricultural Streams

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Case Study – Acid Mine Drainage

Acid
Metals (Fe, Al)
Sulfate

STROUD Water Research Center

Ecological Applications, 22(8), 2012, pp. 2144–2163

Abandoned coal mine drainage and its remediation: impacts on stream ecosystem structure and function

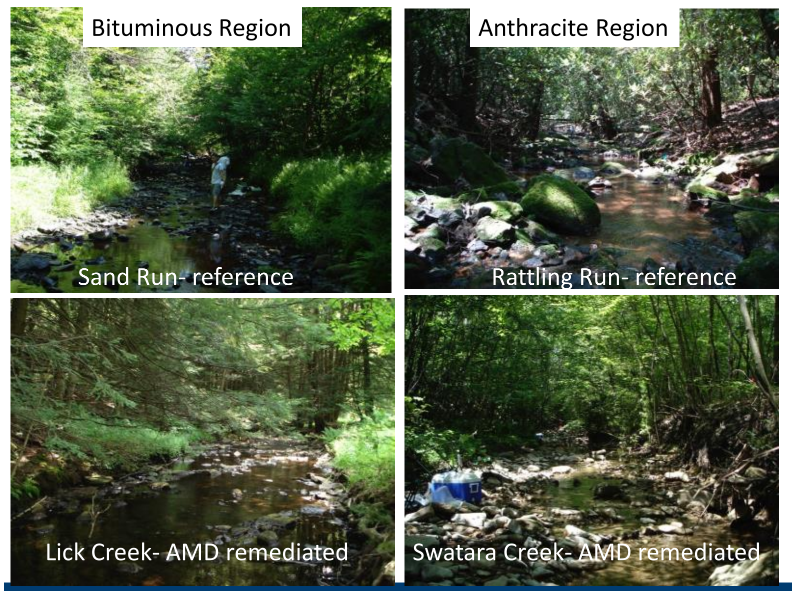
Thomas L. Bott,[1,4] John K. Jackson,[1] Matthew E. McTammany,[2] J. Denis Newbold,[1] Steven T. Rier,[3] Bernard W. Sweeney,[1] and Juliann M. Battle[1]

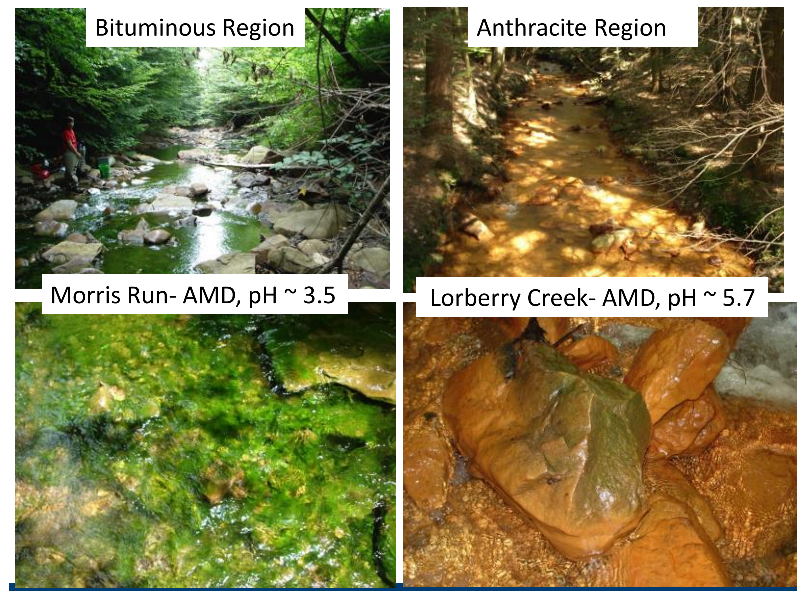
[1]*Stroud Water Research Center, Avondale, Pennsylvania 19311 USA*
[2]*Department of Biology, Bucknell University, Lewisburg, Pennsylvania 17837 USA*
[3]*Department of Biological and Allied Health Science, Bloomsburg University, Bloomsburg, Pennsylvania 17815-1301 USA*

Reference, remediated, and AMD impacted streams draining watersheds with either historic bituminous or anthracite coal mining

Lick Creek - AMD remediated using limestone diversion wells, vertical flow wetlands, and settling ponds for metal precipitates

Upper Swatara – AMD remediated using limestone diversion wells and reclamation of mine-waste-laden land adjacent to study reach


Bituminous Region
Anthracite Region
Sand Run- reference
Rattling Run- reference
Lick Creek- AMD remediated
Swatara Creek- AMD remediated


Bituminous Region
Anthracite Region
Morris Run- AMD, pH ~ 3.5
Lorberry Creek- AMD, pH ~ 5.7

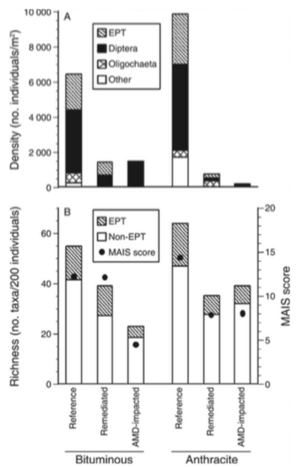


Fig. 2. (A) Total macroinvertebrate densities shown by major group in reference, remediated, and abandoned mine drainage (AMD)-impacted streams in the bituminous and anthracite coal fields of Pennsylvania. EPT stands for Ephemeroptera, Plecoptera, and Trichoptera. (B) Non-EPT macroinvertebrate richness, EPT taxa richness, and macroinvertebrate aggregated index for stream scores for each study stream.

Table 2. Results of Tukey's test comparing densities and community structure measures from reference (Ref), remediated (Remed), and AMD-impacted (AMD) sites within bituminous and anthracite regions.

	Bituminous			Anthracite		
Parameter	Ref	Remed	AMD	Ref	Remed	AMD
Total density	a	b	b	a	b	c
EPT density	a	a	b	a	b	c
Diptera density	a	b	ab	a	b	b
Oligochaeta density	a	b	ab	a	a	b
Other density	a	a	a	a	b	b
Total richness	a	ab	b	a	b	ab
EPT richness	a	ab	b	a	b	b
MAIS score	a	a	b	a	b	b

Notes: Sites sharing the same letter (a, b, c) did not differ statistically ($P > 0.05$). EPT are taxa in Ephemeroptera, Plecoptera, and Trichoptera. The MAIS score is the macroinvertebrate aggregated index for streams score (Smith and Voshell 1997).

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Case Study – Agricultural Stream

Agricultural runoff – fields, barnyards, roads…

Volume
Sediment
Manure
Fertilizer
Pesticides

http://www.crawfordconservation.com/portfolio/barn-roof-water-runoff/

https://www.usda.gov/media/blog/2013/04/25/water-quality-index-agricultural-runoff-streamlined-and-accessible

https://projectsafeplanet.weebly.com/rural-runoff.html

Agricultural Stream Syndrome

	Impact	Remediation
Hydrology	↑ Volume ↑ Peak depth ↑ Flood frequency ↓ Baseflow	Some improvements possible with better field management and added Infrastructure
Geomorphology	↓ (or ↑) Width ↑ (or ↓) Depth ↓ Channel complexity	Some natural improvements possible, Natural Stream Design
Temperature	↑ Temperature	Shade from riparian forest
Chemistry	↑ Nutrients ↑ Toxins ↑ Sediments	Some possible with field and barnyard treatment, ↓ Non-point sources
Biology	↓ Sensitive species	Not common yet

"Before" for a Lancaster Co. Conservation District buffer

Photo courtesy of Lancaster Co. Conservation District

Before
&
After

Before
&
After

•Improved water quality: nutrient, sediment, pesticide, and bacteria reductions

•Improved watershed/stream structure & function

Can we measure improvements?

Valley Creek
near Atglen, PA
10 km ^{2}
3.5 km of stream

Apr 1999

Aug 2016

Valley Creek
near Atglen, PA
10 km ^{2}
3.5 km of stream

Apr 1999

Aug 2016

Valley Creek
near Atglen, PA
10 km ^{2}
3.5 km of stream

Apr 1992

Aug 2016

We need a <u>streamside forest</u> (not just a few trees) next to a small stream if we want the ecosystem to be natural and healthy

Flow

Erosion

Morphology

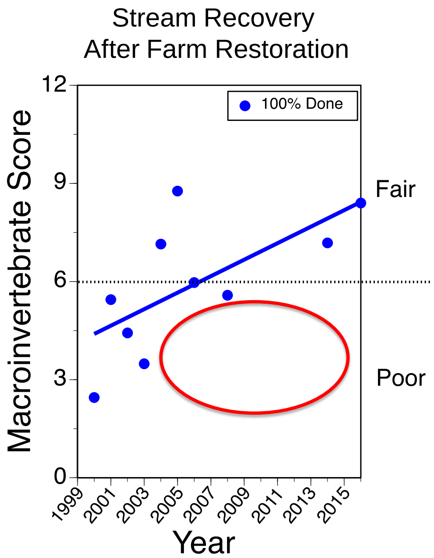
Temperature

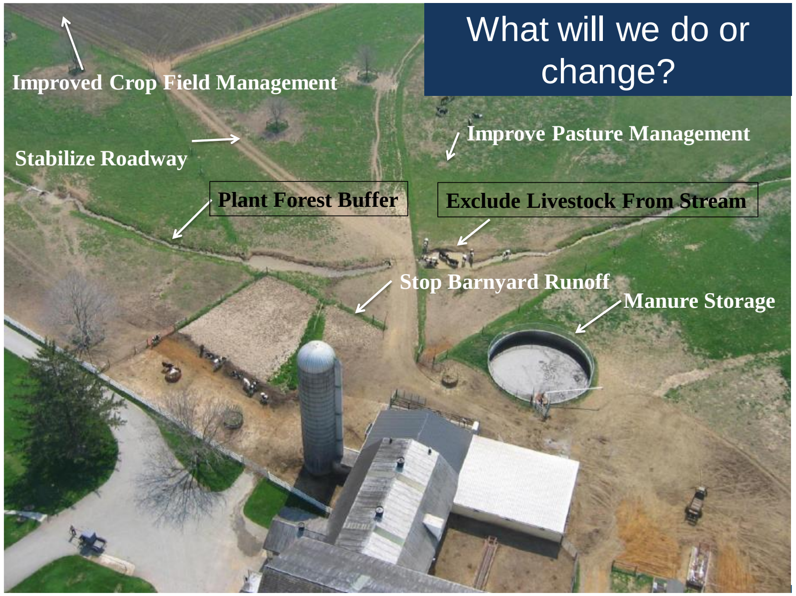
Food Resources

Nutrient Processing

Organic Matter Processing

Comparison of stream condition 2000 versus 2016





Case Study – Urban Stream

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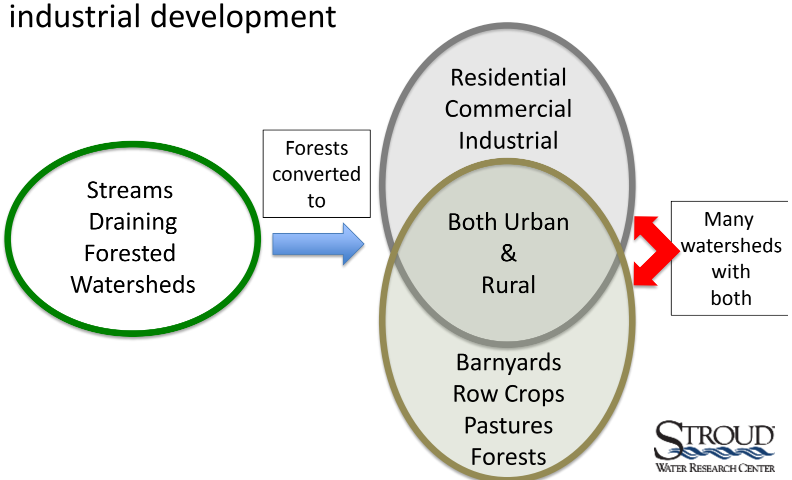
Urban Streams – drain watersheds with significant (but maybe not entirely) residential, commercial, and industrial development



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Urban Stream Syndrome

	Impact	Remediation
Hydrology	↑ Volume ↑ Peak depth ↑ Flood frequency ↓ Baseflow	Some improvements possible with Green Infrastructure
Geomorphology	↑ Width ↑ Depth ↓ Channel complexity	Some improvements possible with Natural Stream Designs
Temperature	↑ Temperature	Shade Reduced retention
Chemistry	↑ Nutrients ↑ Toxins	Some possible with wastewater treatment, ↓ Non-point sources
Biology	↓ Sensitive species	Not common yet

Watershed-Scale Evaluation of a System of Storm Water Detention Basins

Clay H. Emerson, M. ASCE[1]; Claire Welty[2]; and Robert G. Traver, M. ASCE[3]

Abstract: The effectiveness of an existing system of storm water detention basins operating at the watershed scale is evaluated. Data utilized in the study were collected from Valley Creek watershed in Chester County, Pa., which has undergone rapid development from the westward spread of suburban Philadelphia. Since the late 1970s, more than 100 storm water detention basins have been constructed in this 62 km^2 (24 mi^2) watershed, each designed on a site-by-site basis. The design objective of these detention basins is to limit a site's postconstruction peak flow rate to or below its predevelopment level for 2- through 100-year storms. To evaluate the watershed-wide

Results from modeling six measured storm events show that the detention basins reduce watershed-wide peak storm flows by an average of only 0.3%, and can potentially increase peak flow rates.

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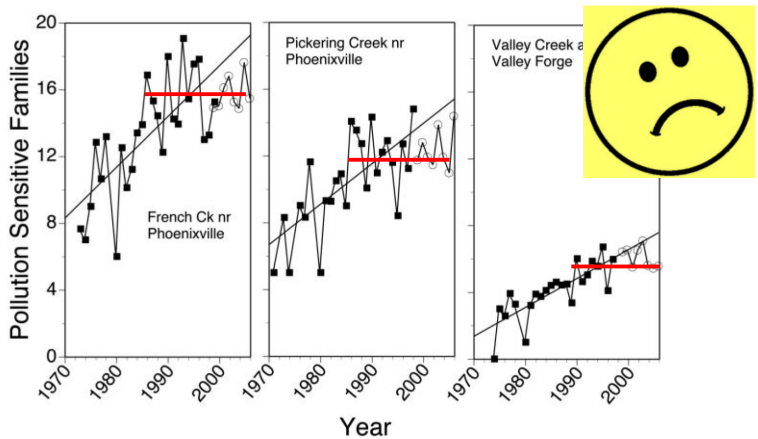
But not a lot recently



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Ecological Applications, 0(0), 2017, pp. 1–11

Metacommunity theory meets restoration: isolation may mediate how ecological communities respond to stream restoration

Christopher M. Swan[1,2,4] and Bryan L. Brown[3]

13 streams studied (near Baltimore MD)
13-41% impervious cover

Each with restored reach and adjacent unrestored reach
(up- or downstream of restored reach)
Tree planting, bank stabilization, in-channel manipulations

5 headwater streams (1st order)
8 mainstem streams (headwater, 3rd and 4th orders)

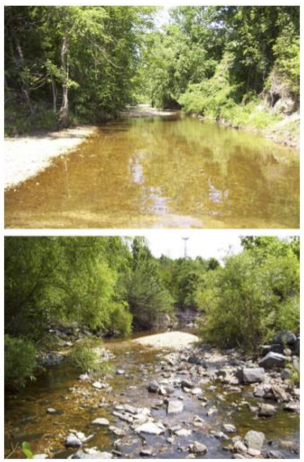


Fig. 1. Image of Site 19 taken during the invertebrate sampling. The image was taken at the upstream point in the stream where the restoration project started. Habitat in the adjacent, unrestored, upstream reach (top) exhibited a much more homogeneous distribution of substrate sizes compared with the restored reach (bottom). There is a clear addition of larger substrates in the restored reach.

Increase light (temperature?)
Increased cobble
Maybe reduced bedrock

No change in macroinvertebrates

Assumption was that restoration reduced stressors – but maybe not appropriate or adequate.

Also suggested regional pool of potential recolonists may be lacking.

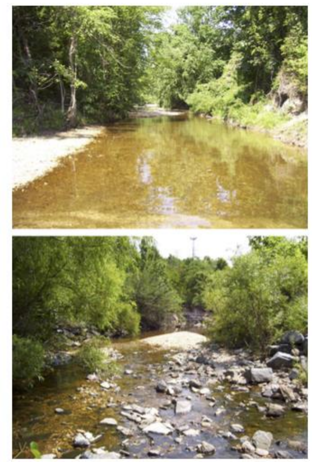


Fig. 1. Image of Site 19 taken during the invertebrate sampling. The image was taken at the upstream point in the stream where the restoration project started. Habitat in the adjacent, unrestored, upstream reach (top) exhibited a much more homogeneous distribution of substrate sizes compared with the restored reach (bottom). There is a clear addition of larger substrates in the restored reach.

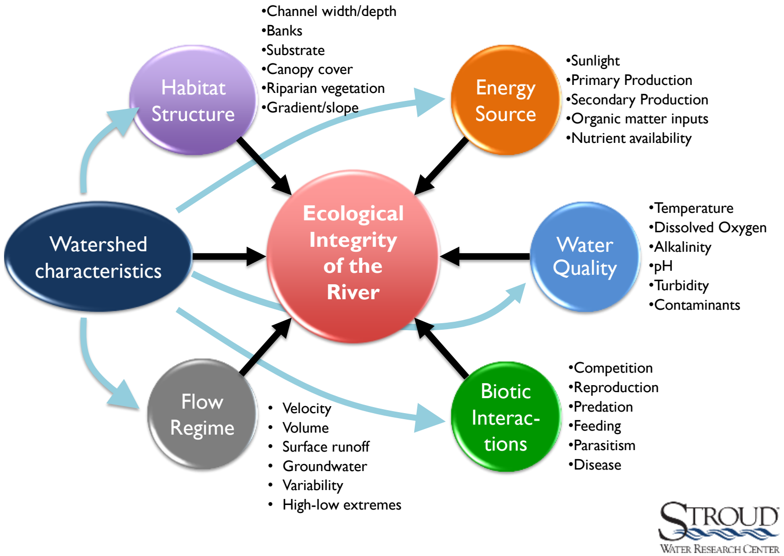
Swan and Brown 2017, 2018
Murray-Stoker 2019

… taxon richness was generally low throughout the experiment, a mean of <12 taxa per collection, despite genus-level resolution, indicating that these streams were likely heavily impaired regardless of network position or restoration state. Pg 8

Healthy Watersheds = Healthy Streams

- Identify ecosystems (stream, wetland, groundwater) to be protected and **set targets**
- Mimic **predevelopment water balance**
- Implement stormwater control measures that deliver **filtered** flows
- Implement stormwater control measures with **capacity** to store rain events that would produce disturbance to stream biota
- Apply stormwater control measures to **all impervious surface** in the catchment

Walsh, C.J., et al. 2016. Principles for urban stormwater management to protect stream ecosystems." Freshwater Science 35: 398-411.



My Agenda Today

- Introduce some natural history for stream macroinvertebrates and fish
- Describe stream degradation based on current conditions in the tributaries of the Delaware River Basin
- Summarize evidence of successful or unsuccessful restoration

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Issues I addressed today:

1) Natural factors that affect the distribution and abundance of aquatic macroinvertebrates and fish?
2) Why monitor aquatic macroinvertebrates and fish?
3) What are current conditions in the tributaries of the Delaware River?
4) What are the major factors that contribute to stream degradation?
5) What do case studies show us about the success or failure of stream restoration efforts?

Issues I addressed today:

1) Natural factors that affect the distribution and abundance of aquatic macroinvertebrates and fish?
   - Temperature
   - Current
   - Substrate
   - Food
   - Water chemistry

2) Why monitor aquatic macroinvertebrates and fish?
   - Public acceptance
   - Ecologically significant
   - Variable pollution response
   - Temporal perspective
   - Established protocols

3) What are current conditions in the tributaries of the Delaware River?
   - Fair – half show evidence of degradation
   - Improving over time
   - But not much recently

4) What are the major factors that contribute to stream degradation?
   - Flow regulation/modification
   - Watershed modifications
   - Pollution

5) What do case studies show us about the success or failure of stream restoration efforts?
   - Not enough time
   - Insufficient intensity
   - Wrong prescription
   - Unknown/unrecognized stressors

How do we see more improvements?

1) Do more, try new things.
   - Research

2) Be vigilant.
   - Monitor

1) Change regulations and recommendations.
   - Demand for clean water will increase

Stream
pollution & degradation
reflect choices

We need to help the **<u>public</u>** understand pollution they cannot see

… our problems are not a single pollutant or polluter

On a farm

In a neighborhood

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… our problems are not a single pollutant or polluter

Inside house

Outside house

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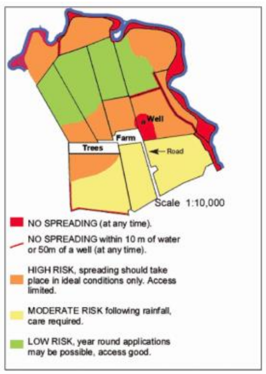
We need the public to prioritize pollution prevention

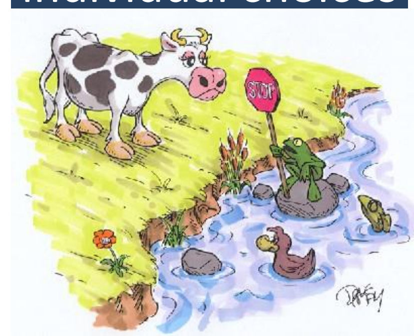
Conservation swale



Fertilizer management plan

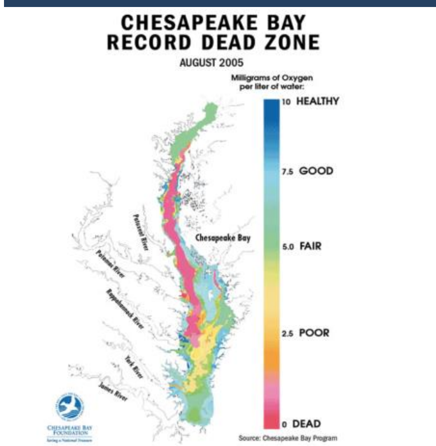
No-till field with cover crop

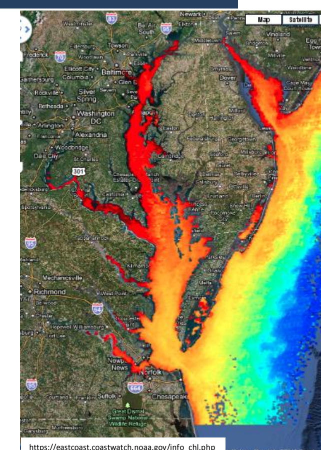
Pollution prevention starts as individual choices



Individual choices translate into local & regional choices

Local & regional choices translate into national choices





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How do we see more improvements?

1) Do more, try new things.
   - Whole watershed efforts, include research
2) Be vigilant.
   - Monitor
1) Change regulations and recommendations.
   - Demand for clean water will increase

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THROUGH RESEARCH, EDUCATION, AND RESTORATION