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Stream Ecology

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Michigan State University

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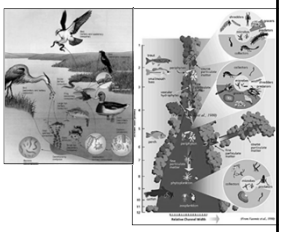
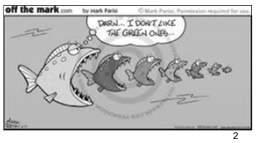
Outline



1. Links to the Landscape
   1. River Continuum Concept
2. Stream food webs
   1. Feeding Guilds
   2. Changes along the River Continuum
3. Rapid Bioassessment
   1. Types of assessment
   2. Use of metrics



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- Geomorphologist Luna Leopold once described rivers as the gutters down which flow the ruins of continents (1964)
- Rivers are strongly influenced by conditions at the land-water interface but also by the entire catchment (Allan 2004)
- Rivers have unidirectional movement of water, sediment, and other materials.

Allan, J.D. (2004) Influence of land use and landscape setting on the ecological status of rivers. Limnetica, 23 (3–4) (2004), pp. 187–198

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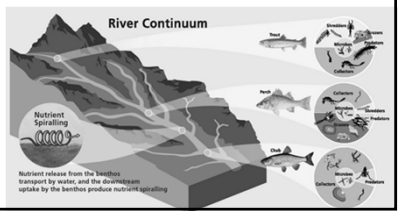
River Continuum Concept (RCC)

- Vannote et al. 1980
- Longitudinal connectivity within a watershed from headwaters to the mouth of the rivers
- Defines "sections" of the river by characteristic biota, energy dynamics, and connection with terrestrial habitat.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. (1980) The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.



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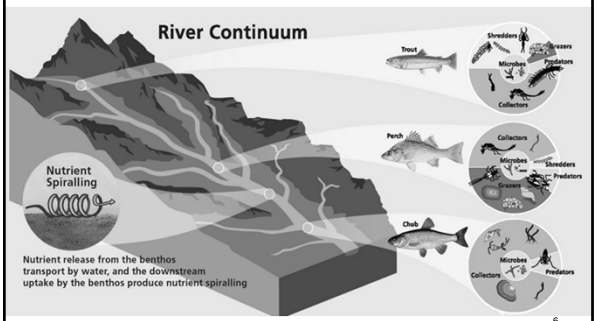
River Continuum Concept (RCC)



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Headwaters

- The headwaters of woodland streams are often shaded by overhanging trees.
  - Limits sunlight and photosynthesis.
- Energy is instead derived from terrestrial organic matter (allochthonous material), leaves and woody material that fall into the stream.
- Streams are often higher gradient and characterized by riffles and falls.
- The stream biota is dominated by aquatic insects and macroinvertebrates that specialize in utilizing the terrestrial organic material.
  - Shredders and Collectors

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Mid-reaches

- In the mid-reaches the gradient decreases and stream widens.
- The stream is too wide to remain shaded.
  - Increased primary production (autochthonous input).
- The basal food resources are a mixture of allochthonous and autochthonous production.
- There is a lower proportion of groundwater and a higher proportion of tributary inputs, so stream temperatures are warmer.
- Mid-reach streams provide more heterogeneity of habitat and energy resources.
- Often have the highest species richness of macroinvertebrates and fishes, with mixtures of most feeding guilds.

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Lower reaches

- The lower reaches of a river are very wide, often deep and the stream current is slow.
- There are no riffles and lower reaches are warm water habitats.
- The terrestrial organic matter is less important, and the food web is supported by primary production (autochthonous input) and by dissolved and ultrafine organic material drifting from upstream reaches.
- There is a loss of diversity of macroinvertebrates feeding guilds (mostly filter feeders).
- If the river is coastal, it can be tidally influenced.

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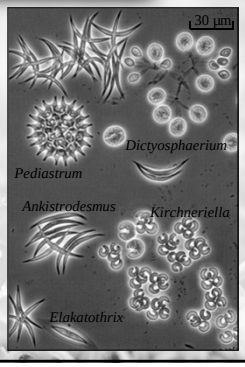
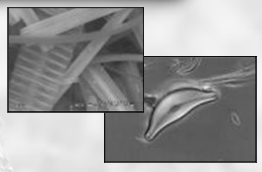
Algae (Phytoplankton): free floating

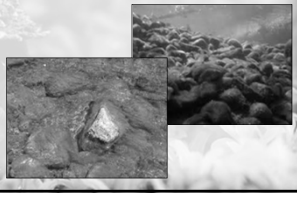
Ecological role:
- Major photosynthesizer in lakes but also found in streams
- Form the base of the foodweb
- Living form produces oxygen in water

Human interest in algae:
- Algae can reach "nuisance" levels
- Abundance of living algae can be a problem (i.e., "green paint," diseases)
- Decay of dead algae can lead to deoxygenation
- Contributes to eutrophication



Algae (Periphyton): attached



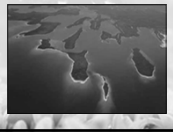


Ecological role:
Equivalent to phytoplankton, more common in streams but are present in some lakes and wetlands

Macrophytes: rooted aquatic plants

Ecological Role:
- Photosynthesis
- Stabilize sediments
- Provide critical habitat for inverts and fish (sometimes key for survival of juvenile species)

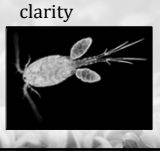
Human interest in macrophytes:
- Can impede recreation, aestheics
- Provide habitat for key fisheries



Zooplankton

Ecological role:
- Major consumers of phytoplankton
- Important food source for fish

Human interest in zooplankton:
- An abundance of algae (i.e., Daphnia) can reduce numbers of algae, leading to greater water clarity



***Copepods* (herbivorous and predaceous)**

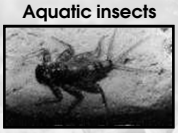
***Daphnia* spp. (herbivorous)**

Macroinvertebrates

Ecological role:
- Numerous feeding guilds in lakes and streams
- Important food source for fish

Human interest in macroinvertebrates:
- Food for fish
- Indicator organisms for water quality
- Nutrient cycling

Aquatic insects

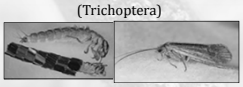


Crustaceans

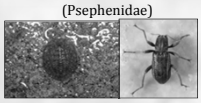
Mollusks

Macroinvertebrates

Collectors
Caddisflies (Trichoptera)

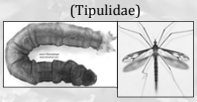


Scrapers
Water penny/ Riffle beetle (Psephenidae)

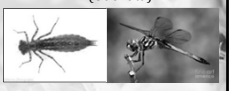


Filters
Freshwater mussels (Unionids)

Shredders
Crane fly (Tipulidae)



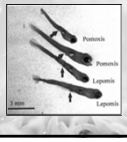
Predators
Dragonfly nymphs (Odonata)



Fishes

Ecological role:
- Specialize on different food types
- Some are major predators in lakes
- Important nutrient recyclers

Human interest in freshwater fish:
- Fisheries (recreational and commercial)
- Influence water quality, depending on feeding guild (i.e., predators, herbivores)



Fish feeding guilds

Carnivore: Flathead catfish

Invertivore: Rainbow darter

Planktivore: Lake whitefish

Detritivore: Common white sucker

Herbivore: Grass carp

A special case of a parasitic fish

- *Vandellia cirrhosa* "Vampire fish."
- Native to Amazon Basin
- Swims into a larger fish's gill using the out current as a guide.
- Has backward-pointing spines on the gill covers to wedge self into gills.
- Although Vampire fish attacks on humans abound, very few cases have been verified



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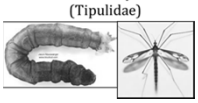
Headwaters

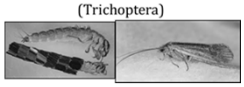
Insectivore Fishes

Predators
Dragonfly nymphs (Odonata)

Shredder
Crane fly (Tipulidae)



Collectors
Caddisflies (Trichoptera)



Allochthonous material

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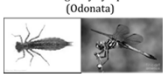
Mid-reaches

Piscivore Fishes

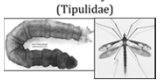
Insectivore Fishes

Predators
Dragonfly nymphs (Odonata)

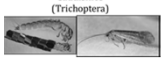


Omnivore Fishes

Shredder
Crane fly (Tipulidae)

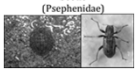


Collectors
Caddisflies (Trichoptera)



Herbivore Fishes

Scraper
Water penny/ Riffle beetle (Psephenidae)



Allochthonous material

Autochthonous material

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Lower reaches

Piscivore Fishes

Insectivore Fishes

Predators
Dragonfly nymphs (Odonata)

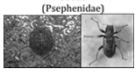
Omnivore Fishes

Filters
Freshwater mussels (Unionids)

Planktivore Fishes

Herbivore Fishes

Scraper
Water penny/ Riffle beetle (Psephenidae)



Phytoplankton

Dissolved and ultrafine organic material

Autochthonous material

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Top-down and Bottom-up Alteration of Food Webs

- Top-down alteration occurs when top consumers are lost, or energy exchange is changed through new species introductions.
  - Trophic cascades occur when predators limit the density and/or behavior of their prey and thereby enhance survival of the next lower trophic level.
- Bottom-up alteration is based on changes in basal resources
  - Nutrient enrichment or depletion

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Lake Erie

Round goby (*Neogobius melanostomus*)

quagga mussel (*Dreissena bugensis*)

- Watershed land use alteration leading to increased amount of nutrients from point and non-point sources.
  - 90% watershed is in anthropogenic land use.
- Introduced non-native fauna (Zebra mussels, quagga mussel, round goby, and zooplankton species) altered food web dynamics and water quality.

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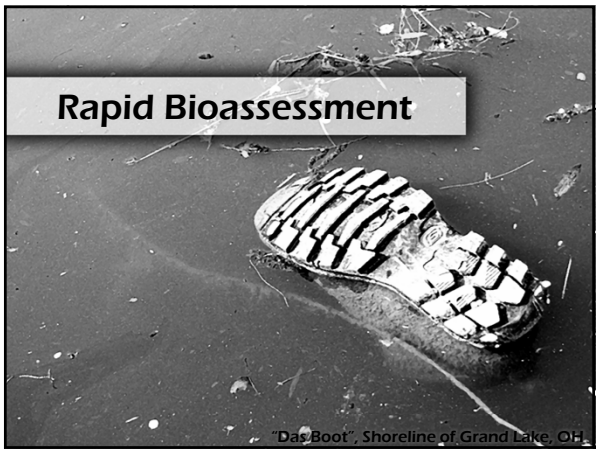

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Use of Rapid Bioassessments

- Assessment to evaluate the structure of the biological assemblage to infer water and habitat quality.
- Why is this better than water quality assessments?
  - Relatively less expensive then testing for many types of toxins.
  - Biological communities integrate the effects of different stressors and thus provide a broad measure of their aggregate impact.
  - Water quality often only provides a pass/fail threshold assessment.

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Relative condition assessment

- Need a baseline (reference condition)
- Used for interpretation of biological surveys
  - Regional reference streams determined by professional judgment or established state criteria
  - Best available based on perceived amounts of disturbance
  - Historical condition
  - Pre-disturbance condition (site specific)

Wang, L., Brenden, T., Seelbach, P., Cooper, A., Allan, D., Clark Jr, R., & Wiley, M. (2008). Landscape based identification of human disturbance gradients and reference conditions for Michigan streams. Environmental Monitoring and assessment, 141(1-3), 1-17.

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Types of Rapid Bioassessments

- Water Quality Assessment
- Index of Biotic Integrity (IBI)
  - Fish and Benthic Macroinvertebrates
- EPT Index
  - Ephemeroptera (mayflies)
  - Plecoptera (stoneflies)
  - Trichoptera (caddisflies)

- Diatom and Periphyton Assessment
- Tier Aquatic Life Unit (TALU)
  - Newer hybrid bioassessment

http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm

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Why Fish?

- Fish are sensitive to a wide array of stresses.
- Fish are long-lived; their populations show effects of reproductive failure and mortality in many age groups and, therefore, provide a long-term record of environmental stressors.
- Fish are highly mobile and can move away from disturbance.
- Fish are relatively easy to collect and identify as well as having high social and cultural value .

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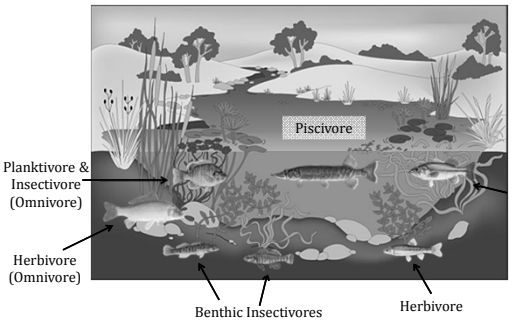
Feeding guilds



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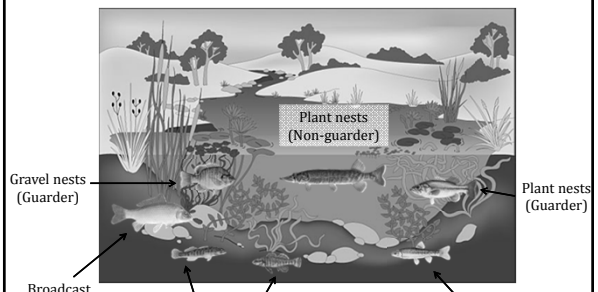
Breeding guilds



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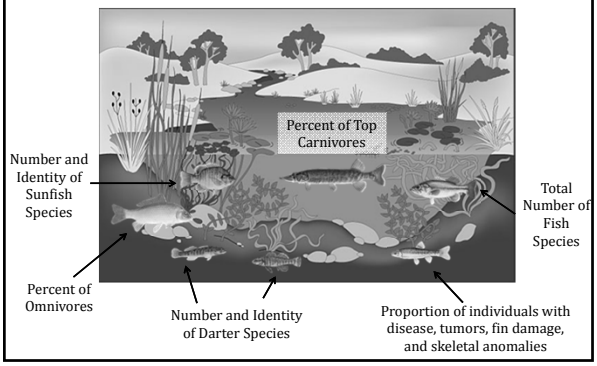
Karr 1986 IBI Metrics



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Fish Index of Biotic Integrity

- Fish assemblage's taxonomic, trophic composition, abundance and condition of fishes provides insight into the quality of the stream's water and habitat.
- Metrics based on:
  - Taxonomic groups
  - Feeding guilds
  - Habitat use
  - Breeding guilds
  - Tolerance
  - Species of Greatest Conservation Need (SGCN)
  - Native vs. Non-native

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. (1986) Assessing biological integrity in running waters: A method and its rationale. Special publication 5. Illinois Natural History Survey.

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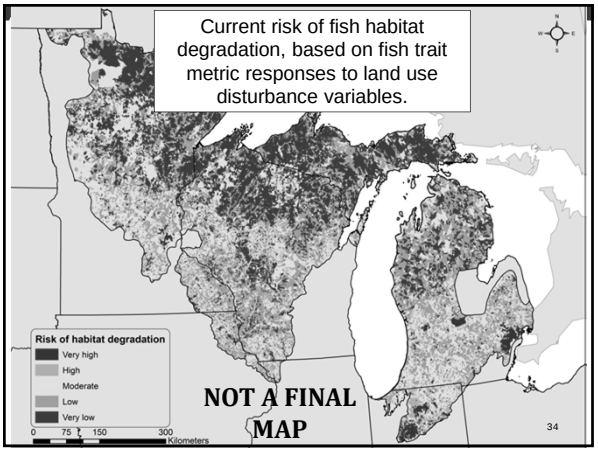

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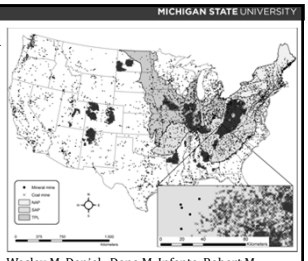
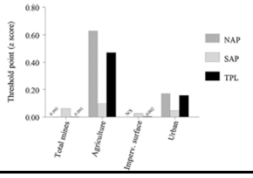
- Response of multiple fish metrics to amounts of
  - Mines
  - Impervious surface
  - Agricultural land use
  - Urban land use
- Varied by ecoregion and metric type



Wesley M. Daniel, Dana M. Infante, Robert M. Hughes, Peter C. Esselman, Yin-Phan Tsang, Daniel Wieferich, Kyle Herreman, Arthur R. Cooper, Lizhu Wang, William W. Taylor. 2014. Characterizing coal and mineral mines as a regional source of stress to stream fish assemblages. Ecological Indicators 50:50-61.



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Kentucky Index of Biotic Integrity (Fish)

- Wadeable streams (outside headwaters)
- The reference dataset (i.e. minimally impacted stream reaches) within each of the state's 6 Level III "Ichthyoecoregions" was used to calibrate each metric
  - Native Richness
  - Darter, Madtom, and Sculpin Richness
  - Intolerant Richness
  - Simple Lithophilic Spawners
  - Relative Abundance of Insectivorous Individuals, excluding Tolerant Individuals
  - Relative Abundance of Tolerant Individuals

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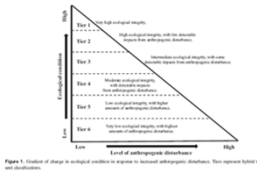
Tier Aquatic Life Unit (TALU)

- Combines land use, water chemistry and biotic variables to represent a site's integrity.
- A tiered category system uses a hierarchy of classes (tiers) to represent ecological integrity along a gradient of anthropogenic disturbance.

Davies S.P. & Jackson S.K. (2006) The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16, 1251–1266.

Wesley M. Daniel, Kenneth M. Brown, & Michael Kaller. 2014. A tiered aquatic life unit bioassessment model for Gulf of Mexico coastal streams. Fisheries Management & Ecology 21:491-502.



From: Daniel et al. 2014

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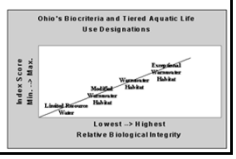
Tier Aquatic Life Unit (TALU)

- A reflection of the whole ecosystem –based on representative ecological attributes
- Assigned to water bodies based on the protection and restoration of ecological potential
- Recognizes gradients of biological responses
- Ohio used a TALU assessment since 1980s.



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TALU in Michigan?

Michigan DNR has 9 aquatic designated uses

- Total body contact recreation
- Partial body contact recreation
- Navigation
- Industrial water supply
- Warm water fishery
- Cold water fishery
- Fish consumption
- Agriculture
- Other indigenous Aquatic life and wildlife

From: Daniel et al. 2014

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Questions?