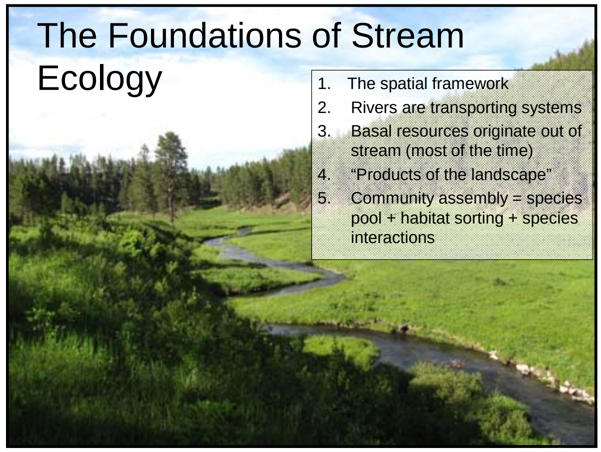
The Causes & Consequences of River/Stream Diversity

Broad patterns structure habitats, energy pathways, and assemblages

As managers, we need to understand how rivers function and how common principles are expressed across spatial scales to be effective

The Foundations of Stream Ecology



1. The spatial framework
2. Rivers are transporting systems
3. Basal resources originate out of stream (most of the time)
4. "Products of the landscape"
5. Community assembly = species pool + habitat sorting + species interactions

"Lotic" Ecosystem Diversity

- Stream and river systems are diverse
  - Continuous, open systems
  - Very structured environmental and biotic patterns
  - Important lateral, longitudinal, and vertical connections
  - Products of their position on the landscape
  - Disturbance
- Vast majority of river length in the world?
- Nomenclature:
  - What is the difference between a river and stream and creek and a brook …?
  - "Great rivers" – Mekong, Amazon, Mississippi rivers

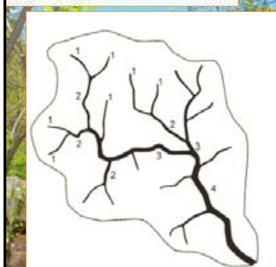
TABLE 1.1 Number and lengths of river channels of various sizes in the United States (excluding tributaries of smaller order). (From Leopold et al. 1964.)

Order	Number	Average length (km)	Total length (km)	Mean drainage area (km^2)
1	1,570,000	1.6	2,510,000	2.6
2	350,000	3.7	1,300,000	12.2
3	80,000	8.8	670,000	67
4	18,000	19	350,000	282
5	4,200	45	190,000	1,340
6	950	102	98,000	6,370
7	200	235	48,000	30,300
8	41	540	22,999	144,000
9	8	1,240	9,900	684,000
10	1	2,880	2,880	3,240,000

River Science & Management

Catalog the diversity among lotic systems → Reveal underlying processes that are responsible for patterns → Manage processes that create and maintain diversity

Nested Subsets within a Stream Network

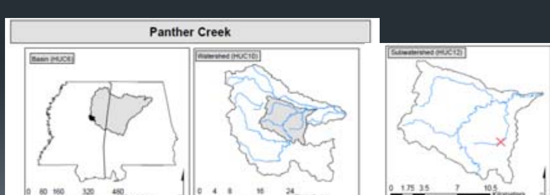


Characterizing Streams

- Numerous different classifications – none overarching
  - Discharge, "flow", assemblages, stream order
  - Communicate natural patterns of variation
- Stalher stream order – quick description of a river system
  - ~ stream size, drainage area, discharge & channel dimensions
- "Flow" is a dirty word in stream ecology
  - Discharge = volume of water per unit time
  - Velocity = current; speed of water
  - Flow = Discharge? Velocity? Both?

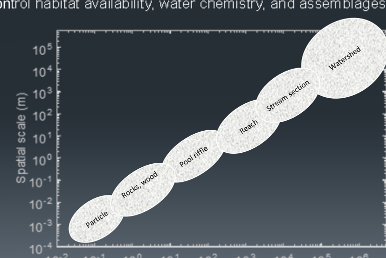
Drainage Networks - Basins

- Streams drain areas proportional to its size
  - Topographically determined
  - Catch all the water that ends up in that stream system
  - Like rivers and streams, lots of overlapping terms are used
    - Basins generally = large areas
    - Watersheds/ catchments = smaller areas

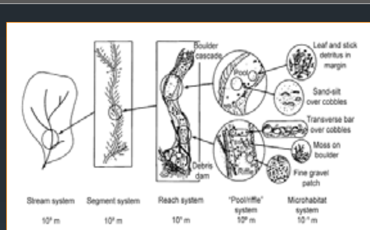


Drainage and River Networks

- A powerful framework to understand patterns and processes at multiple scales
- Processes at upper levels control how features are expressed at lower levels
  - Generally not vice versa (management implications)
  - Control habitat availability, water chemistry, and assemblages



Multi-Scale Perspectives



Controlling Regional Processes

Cascading Nature of Lotic Systems

Local climate, geology, landscape, sediment supply

Riparian vegetation, substrate, terrestrial inputs

Three Dimensional Interactions

- Local stream conditions are resultant of multi-dimensional exchanges

1. Longitudinal – open systems, connections to upstream and downstream areas
2. Vertical - subsurface water exchanges
3. Lateral – exchanges with adjacent landscape can control expression of largescale features

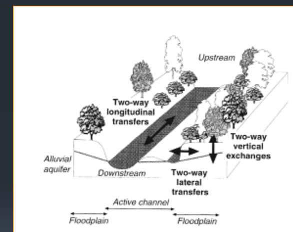
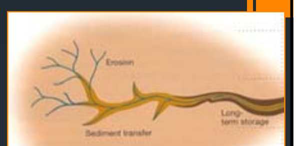
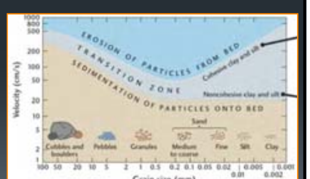


FIGURE 1.1 The fluvial ecosystem with its three major axes: upstream/downstream, channel/margins, and surficial/underground environments. (Reproduced from Piégay and Schumm 2003.)

Linear Patterns

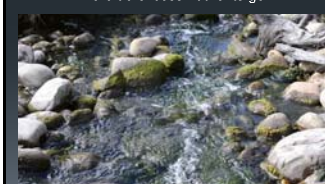
- Streams are an important agent of landscape modification and erosion
- Three river zones based on sediment load:
  1. Erosional
  2. Transfer
  3. Depositional
- Sediment sorting machines
- Processing and transport of materials to the sea
  - Energy flow through food webs, cycling of carbon, nitrogen, and phosphorus

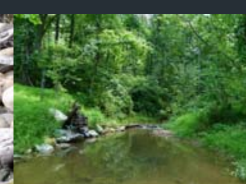




Energy Sources

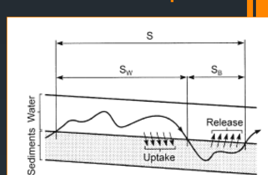
- Primary production originates either instream or along its banks
  - **Small streams**
    - Algae & diatoms found on stones, wood, and other structures
    - Organic matter from the surrounding land – leaf fall, plant and animal detritus
    - Depends on the riparian vegetation and connectivity with its floodplain
  - **Rivers**
    - Receive processed organic matter from upstream (some laterally)
  - Where do excess nutrients go?

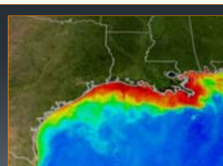




Linear Patterns - Linear Nutrient Spirals

- The uptake of a nutrient and its incorporation into biological tissue
  - Then - resides in tissues → passes through other consumers → eventually remineralized
- In running waters, downstream transport also occurs
- Uptake distance is a useful measure of biologically availability and demand
- ~25% (up to 50%) of total N inputs are exported at the river mouth
  - Nutrient enrichment has harmed fisheries over a large region

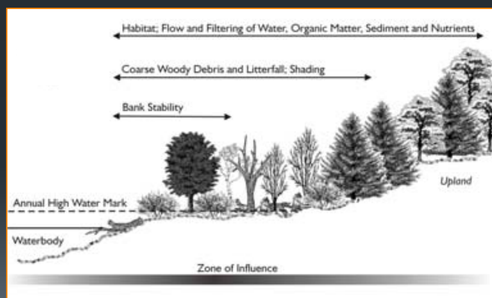




Important Lateral Connections

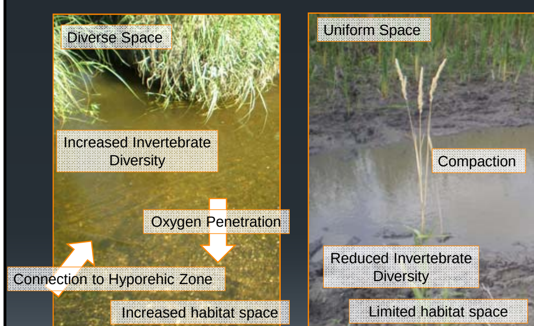
- "In every respect, the valley rules the [local] stream" (Hynes 1975)
- Geology, slope, and vegetation impact the movement of water
  - Complicated by human land-use
  - "Runoff" - precipitation that moves over surfaces
    - Transport sediments, organic matter, and nutrients
    - Threats?
- "Riparian zone" – transition between terrestrial and river environment
  - Floodplain in locations where the river frequently overflows its banks
  - Influence of the stream margin and vegetation
  - Can override hierarchical controls in local stream environments

Lateral Connection to Terrestrial Systems



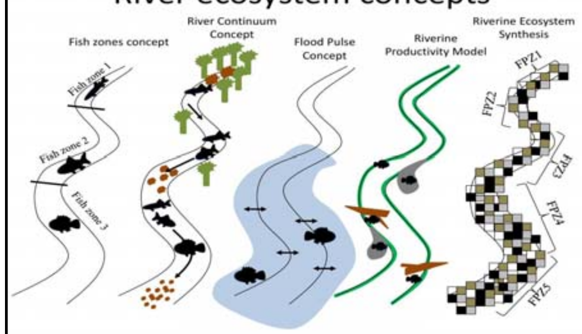
Intact Riparian Areas Maintain Instream Habitats

Vertical Dimension



- Impacts disturbance magnitude (floods and drought)
- Important connections to groundwater

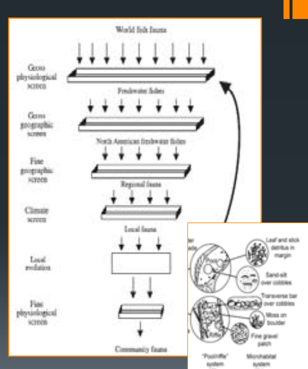
River ecosystem concepts



- Combine multi-dimensional processes to model stream ecosystems

Filtering Biological Communities

- A series of hierarchically nested environmental factors influence species assemblages
  - Similar to the way that river habitats are structured
- Progressively smaller scales: refined match of species adaptations to physical habitats, food resources & specific temperature and flow conditions
- Last filter, interactions among species
  - Competitive displacement, predation



Grand Challenges – Rivers & Streams

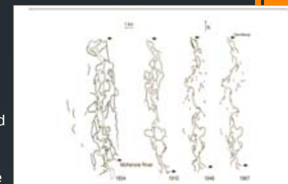
- Influence of people – rivers are magnets for human settlement
- River ecosystems provide benefits to human kind
  - Drinking water, agriculture, harvestable resources, transportation, waster disposal & hydropower
  - Almost all running water today have been modified for human activities
- Diversity of freshwater ecosystems in greater decline than a majority of terrestrial ecosystems
- Conflicting demands on freshwater & changing land- use
  - Most human activities that harm river ecosystems are becoming more severe
  - Pollution has declined

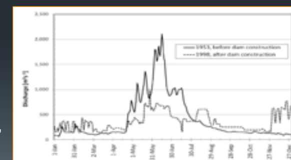
Biodiversity Crisis in Freshwater

- Multiple interacting threats:
  - All interrupt physical processes, hierarchies, and the biota respond
  - **Habitat degradation is pervasive**
    - Instream alterations like dams, dredging, and channelization, destabilized banks, changes in land use that affect hydrology
  - **Widespread pollution**
    - Better in developed nations, but sewage spills & aging infrastructure are concerning
  - **Invasive species spread by accident or design**
    - Predation, competition, habitat alteration, and disease spread
  - **Overexploitation of some species in some regions**
  - **Climate change**
    - Changing temperature & hydrologic regimes
    - Altered precipitation patterns impact lotic ecosystem function

Habitat Alteration

- Damming and water diversions
  - Abiotic: Loss of natural discharge variability, severing upstream and downstream linkages
  - Biotic: Reduced dispersal and migration, changes to water quality and assemblage composition
- Channelization
  - Abiotic: Reduced habitat and substrate complexity
  - Biotic: Favors highly tolerant species
- Land-use Change
  - Abiotic: Altered energy inputs, more sediments & contaminants, flashier systems
  - Biotic: Changed assemblage composition, altered trophic dynamics, facilitates invasions



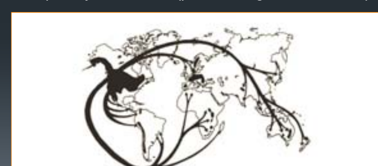


Land-use Change

- Sedimentation
  - Increases turbidity, reduces overall substrate size and diversity, decreases primary production, reduces stream depth
- Nutrient Enrichment
  - Proliferation of filamentous algae, decrease in dissolved oxygen
  - Shift from sensitive to tolerant or nonnative species
- Contaminants
  - Increased heavy metals associated with sediments
  - Decreases growth and survival of fishes
- Hydrologic Alteration
  - Increased flood magnitude and frequency, lowers base flow, altered channel dynamics
  - Impervious and compacted surfaces
- Riparian clearing
  - Reduces shading (higher temperatures), more plant growth, decreases bank stability and inputs of organic materials, no interception of sediments and nutrients, alters trophic structure
- Loss of woody debris
  - Reduces feeding and cover substrate, limits sediment and organic material storage
  - Reduces bank stability
  - Influences invertebrate and fish diversity

Invasions of Nonnative Species

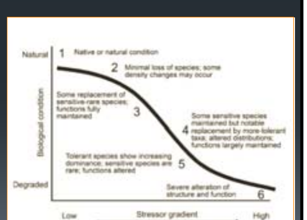
- Most permanent form of "pollution"
  - All aquatic systems can be invaded
    - Invaders are more likely to become established in disturbed, less variable systems
  - Most invaders fail to establish
    - Generalist species are more likely
  - Most successful invaders have no realized impacts
    - Hard to quantify interactions (positive, negative, or neutral)



River Management - Good News

1. Rivers have enormous restorative powers
2. Public awareness and concern are growing

- Monitoring the status and trends of freshwater biota and ecosystems
  - Evaluate the effectiveness of management actions
- Emphasis is placed on maintaining and restoring physical & biological processes that create healthy ecosystems
  - Degraded systems can be improved and restored
  - Site-specific improvements within a whole catchment context (my PhD)
    - Inadequately assessed and reported (~15%)



Monitoring and Assessment - IBI

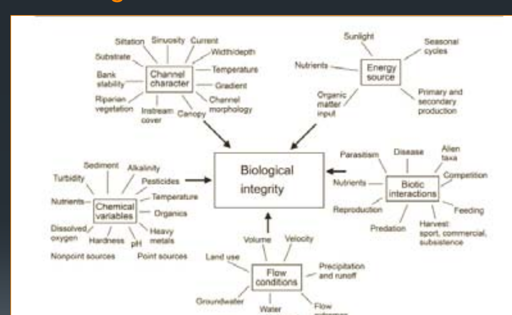


FIGURE 13.16 The Index of Biotic Integrity measures changes to stream health in response to human alterations to physical, chemical, and biological components of the five principal factors depicted. (Reproduced from Karr and Chu 2000.)

Managing Biological Diversity

- **Kind of a new thing**
  - The totality of genetic, species, and ecosystem variability within a particular region
  - The ecological complexes of which they are part
- Increasing appreciation for biodiversity
- Recognition of the unique ecological “value” of diverse species
  - Ecosystem goods and services