River Life: The Ecology of Flowing Water

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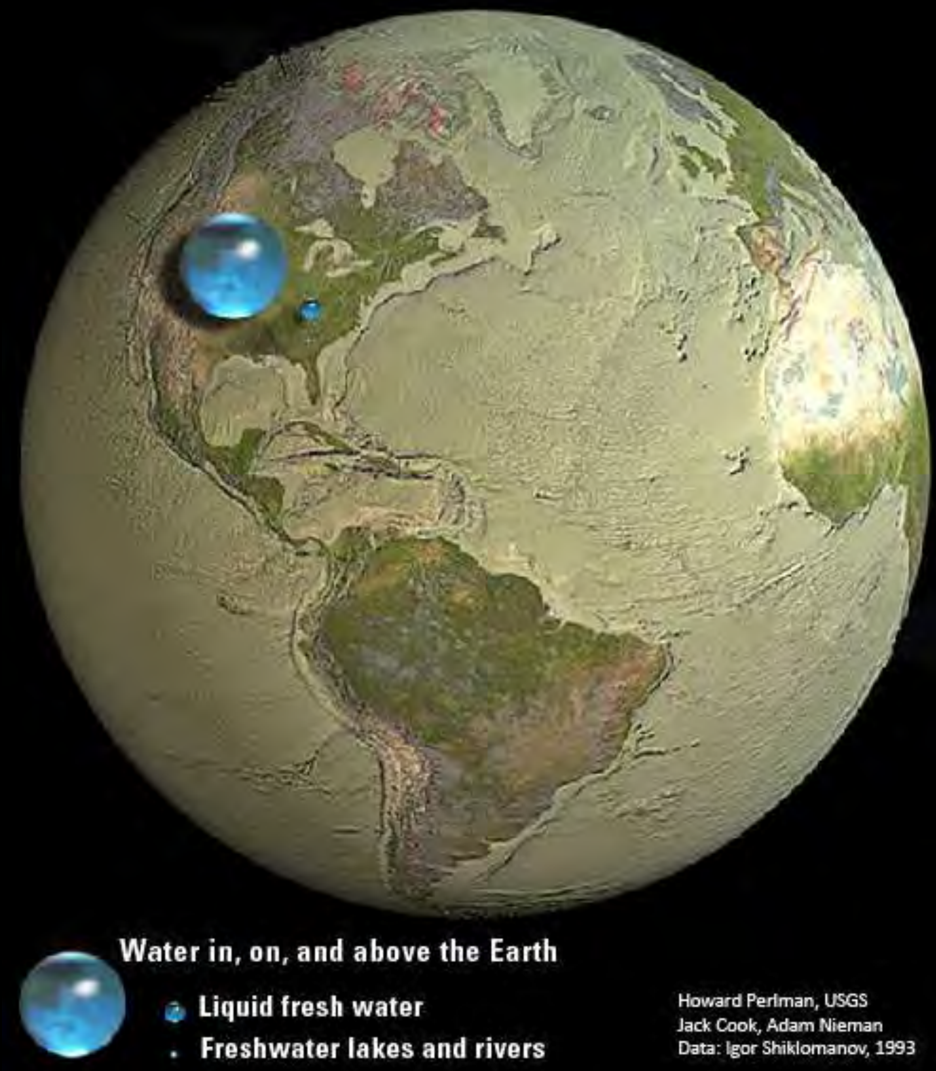
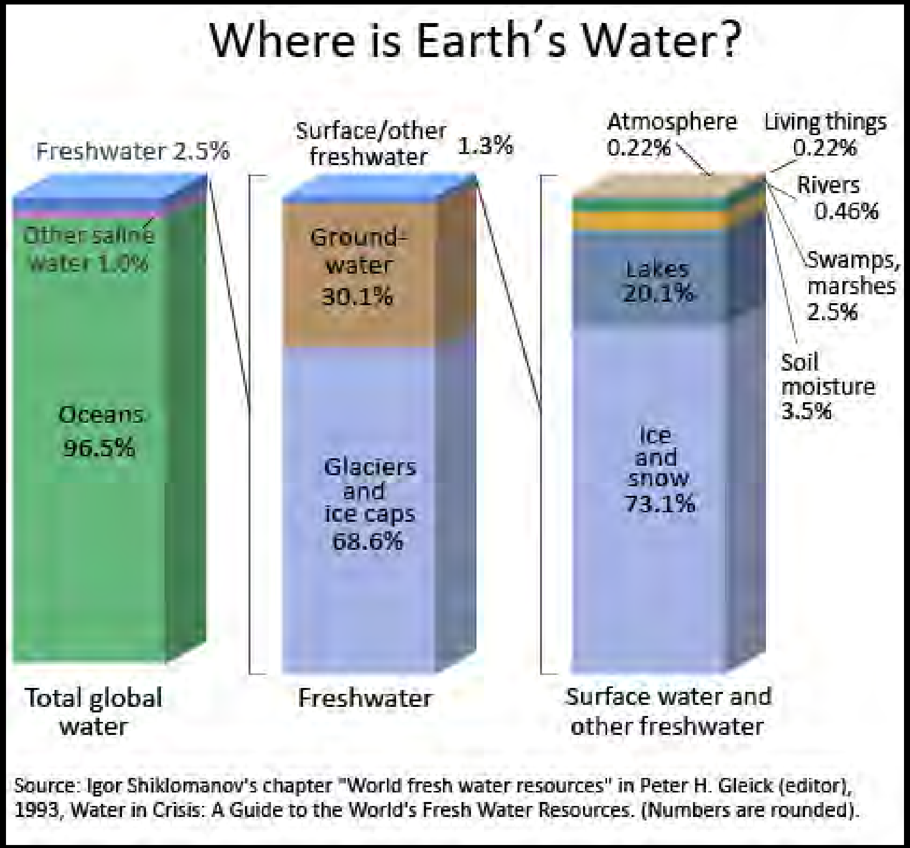




Spheres showing:
(1) All water (sphere over western U.S., 860 miles in diameter)
(2) Fresh liquid water in the ground, lakes, swamps, and rivers (sphere over Kentucky, 169.5 miles in diameter), and
(3) Fresh-water lakes and rivers (sphere over Georgia, 34.9 miles in diameter).

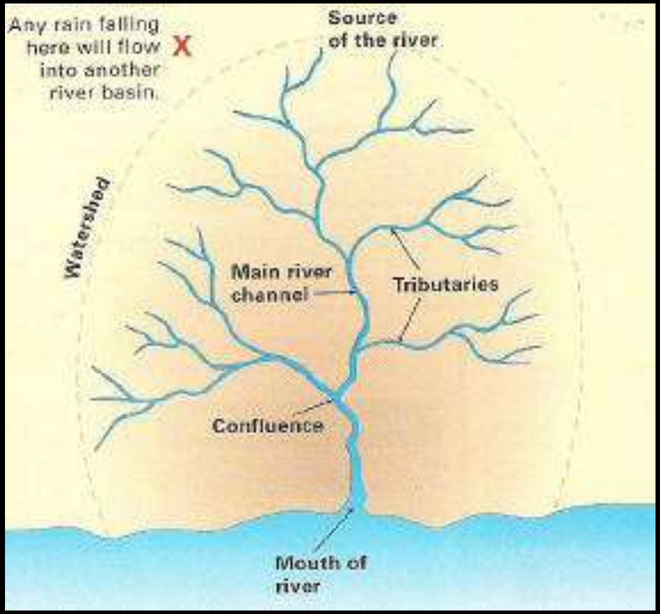
Freshwater Ecology – Lotic or Lentic

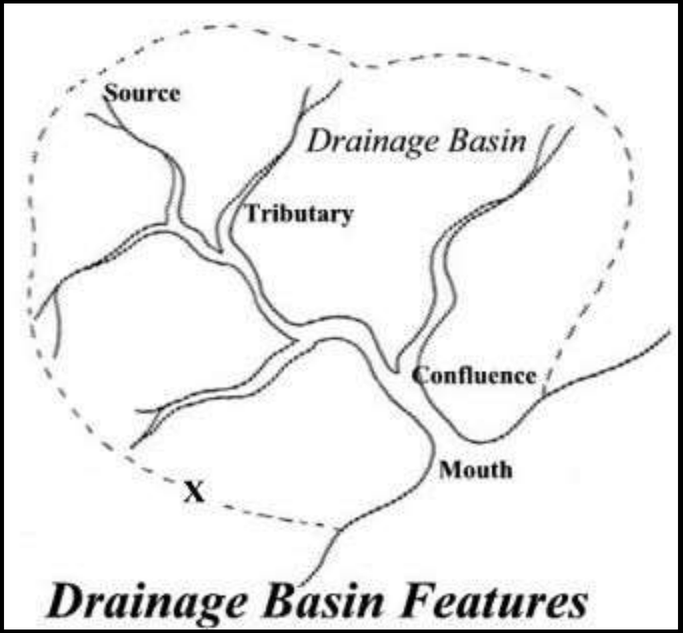
General Differences Between Streams and Lakes

Streams (Lotic)	vs	Lakes (Lentic)
One direction of flow, upstream to downstream		Various flows, no particular direction
Normally oxygen rich		Oxygen depletion exists at times in deeper water
Shallower		Deeper
Narrower and longer		Wider and shorter
Various effects from different terrestrial environments along the stream's course. The shoreline has more potential to affect water quality because a larger portion of the water body is near shore.		Terrestrial environment similar all around the lake shore. A smaller portion of the water is in close proximity to the shore.
Stream continually cuts into the channel, making it longer, wider, and deeper		Lakes become shallower over time from depositing sediments
Age progression of a stream goes from young stream, narrow and shallow, to mature stream, wider and deeper		Age progression of a lake or pond goes from lake to marsh or swamp to land
Shorter retention time for water		Longer retention time for water
Top and bottom waters generally have the same temperature		May have different temperatures from the top to bottom

The Biogeography of River Life

From source to mouth along a river course

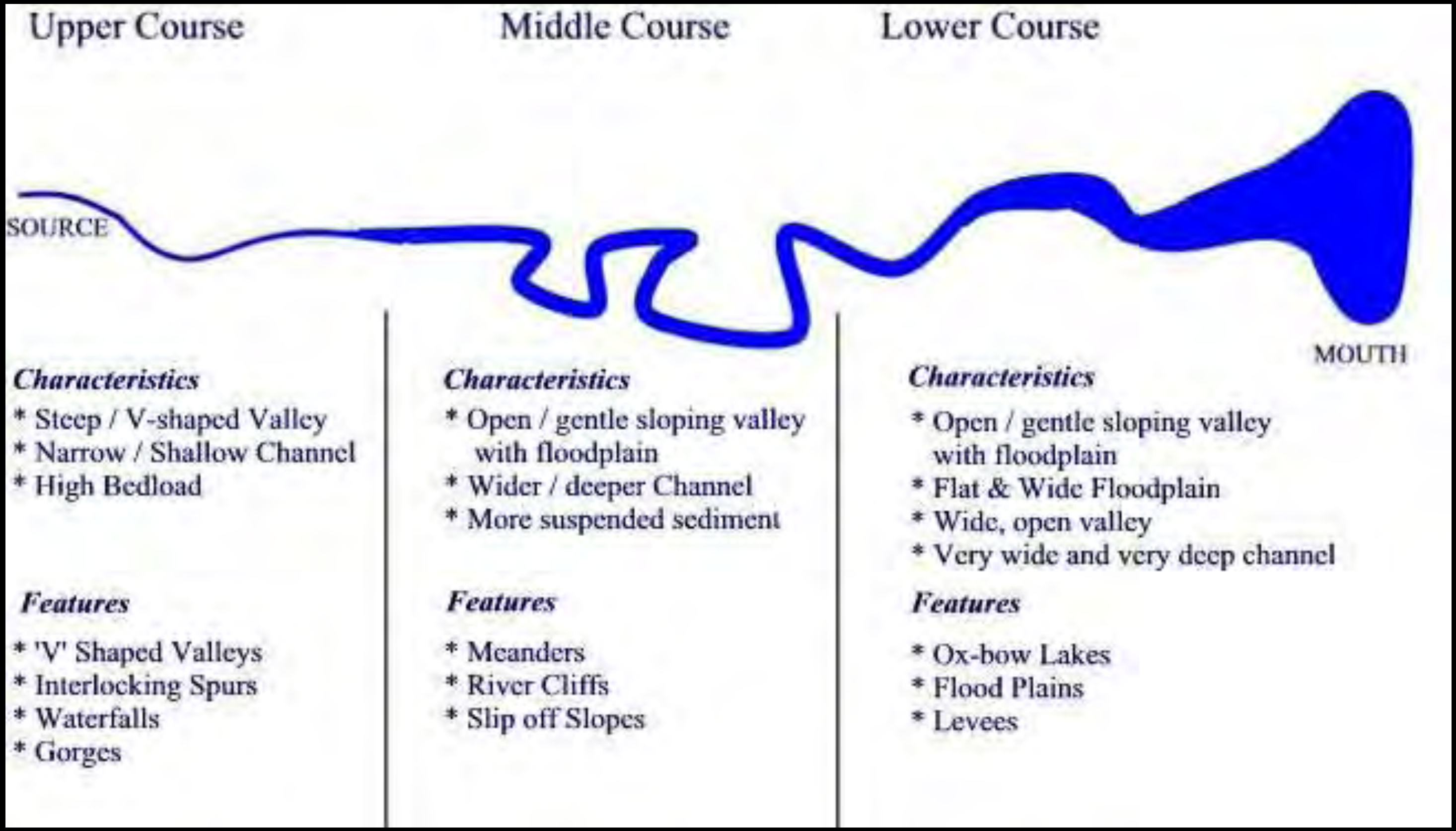




The Upper Course: Life in Rapid Waters

The Middle Course: Life in the Meander Belt

The Lower Course: From River to Sea



Freshwater Ecology - Food Webs

The pathways whereby the energy and matter produced by plants are distributed among other organisms in a habitat are known as food webs.

Freshwater ecosystems begin with the consumption of living or dead plant material

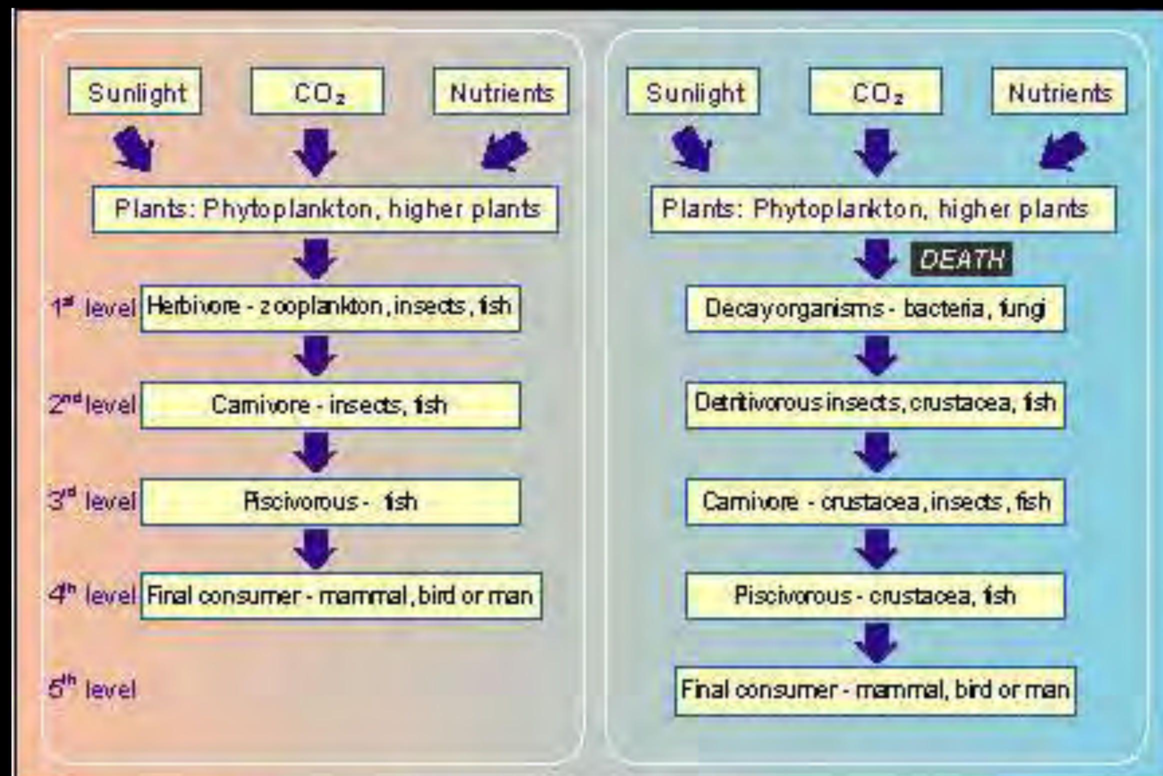


Figure: Alternative pathways for energy and nutrient flow among river organism.

Fluvial Transportation

Water, Sediment, and Organic Material

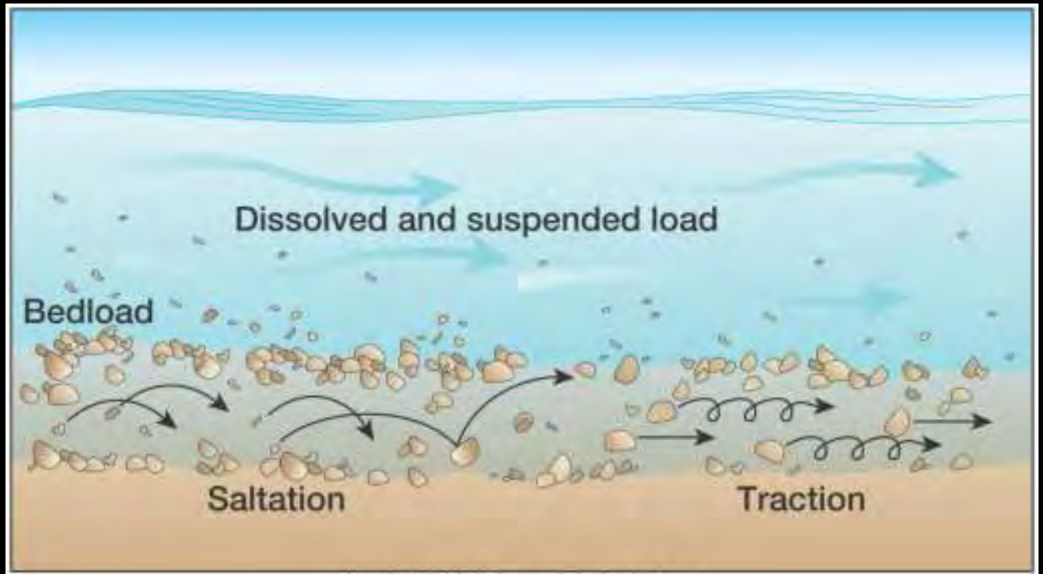
Rivers transport three main materials downstream – water, sediment, and organic material.

The abiotic components – water and sediment – most directly affect the shape of the river channel [Fluvial Geomorphology].

A change in either the flow of water or the sediment load of the river can lead to increased deposition or erosion.

For instance, above a dam, the water pools and slows and deposits much of its transported sediment, and so, below a dam, there will be increased erosion as the river looks to replace its sediment load.

The biotic components of a river's transported load range from dissolved organic matter to large woody debris.



Large Woody Debris

Tree limbs that fall into streams and rivers increase habitat heterogeneity.

Submerged woody debris persists for long periods in streams and rivers, with a calculated half-life of ~20 years.

Woody debris can stabilize river beds, modify erosion and deposition, create essential fish habitat, and help form pools that retain organic matter, extending the availability of seasonal food resources.

Experimentally manipulated woody debris was shown to increased both macroinvertebrate and fish colonization.

Dissolved Organic Matter [DOM]

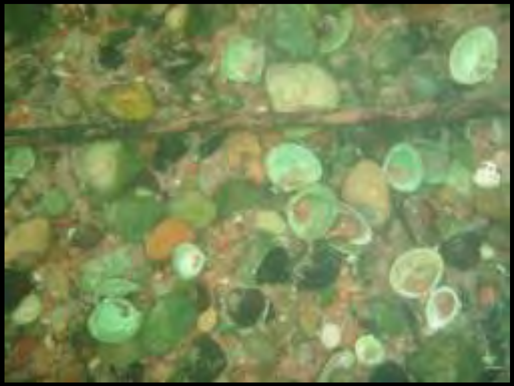
Dissolved Organic Matter (DOM; <0.5 microns in diameter) is an important component of the organic material in rivers.

Much of it enters via subsurface drainage and originates from terrestrial decomposition processes; other sources are detrital leaching, and exudates and excreta from aquatic organisms. [Everything Poops!]

DOM tends to increase in concentration downstream. The highest levels occur in blackwater rivers, especially those draining peat swamps, which are rich in humic substances that color the water.

DOM is taken up directly by microorganisms – especially bacteria – in biofilms , and can be flocculated into UFPOM or FPOM by mechanical forces such as turbulence whereupon they become available to animals.

In large rivers, DOM is absorbed onto fine particles of sediment to form organic aggregates.

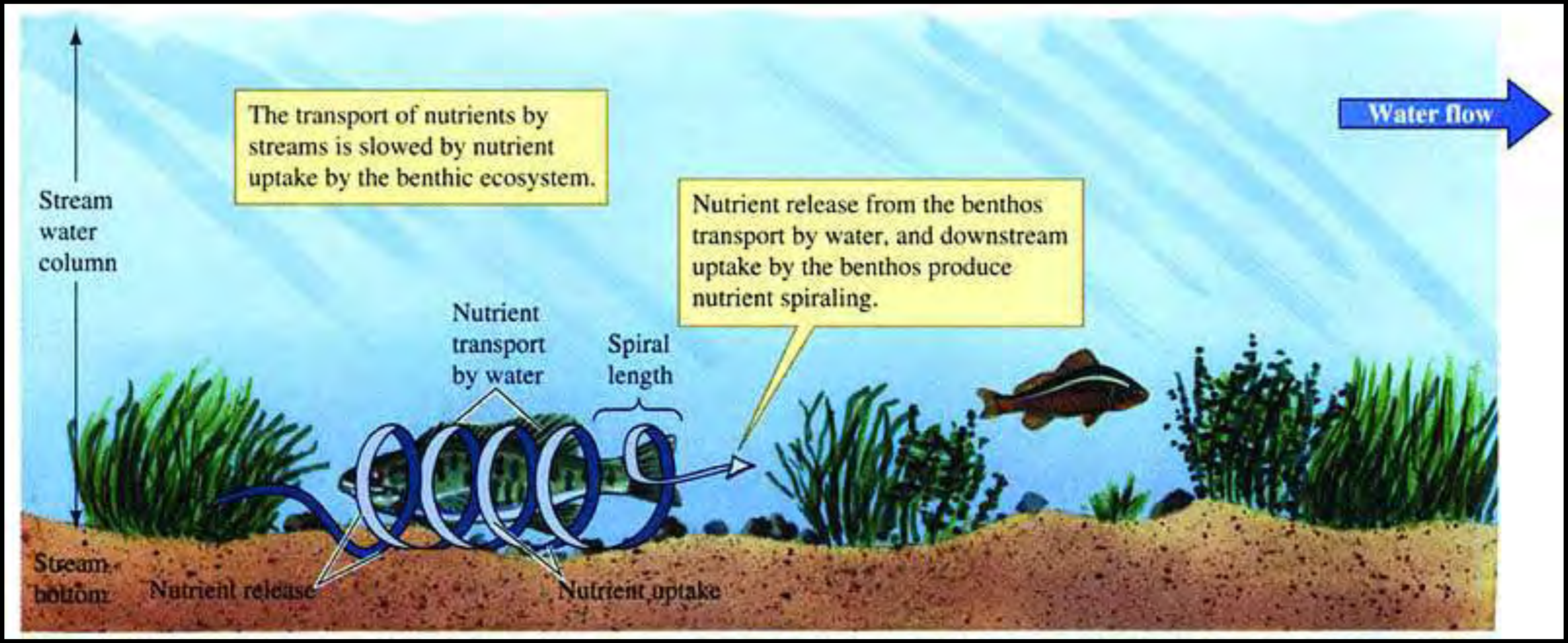

Nutrient Cycles and Nutrient Spiraling

Nutrient cycles describe changes in nutrient states through time and usually do not consider a spatial component

But water in streams have a strong spatial component.

Because these nutrient cycles occur simultaneously with downstream transport, nutrient transformations in streams are conceptualized to as nutrient "spiraling":

The spiraling length represents the distance over which the average nutrient atom travels as it completes one cycle of utilization from a dissolved available form, passes through one or more metabolic transformations and is returned to a dissolved available form.



The Hyporheic Zone

Streams exchange water, nutrients, and organisms with surrounding aquifers.

The interstitial, water-filled space beneath river beds, where most active aquifer-river water exchange occurs, is termed the hyporheic zone, and is an important habitat for a number of aquatic organisms and fish spawning.

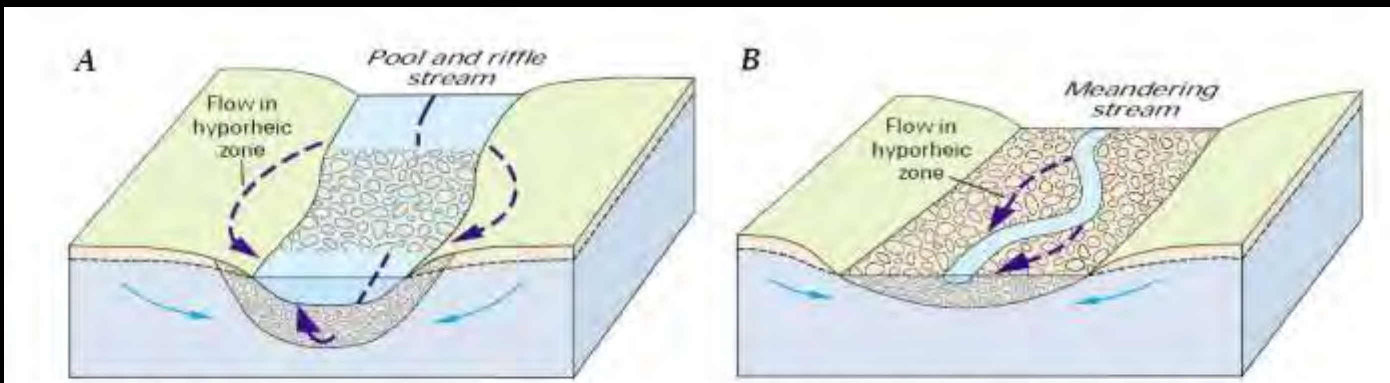
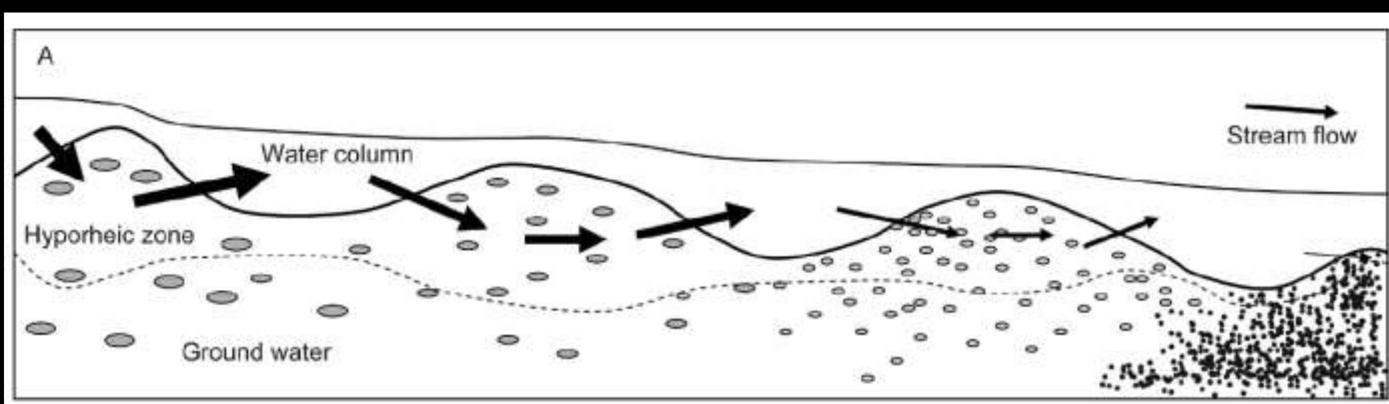
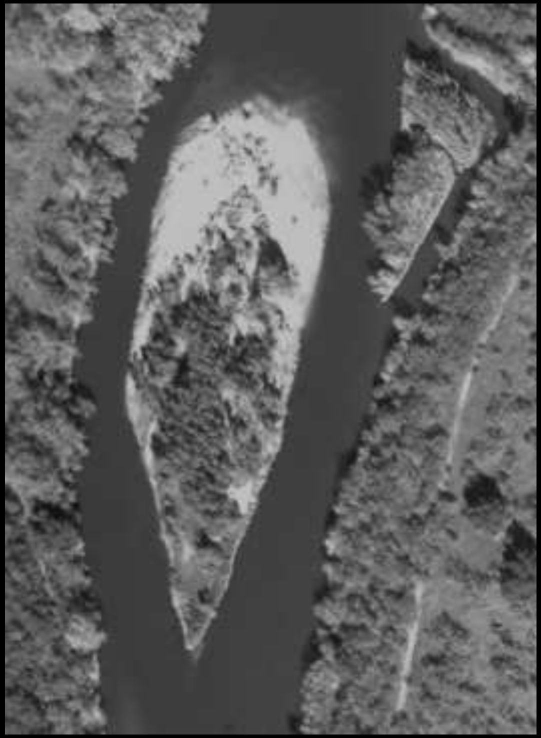
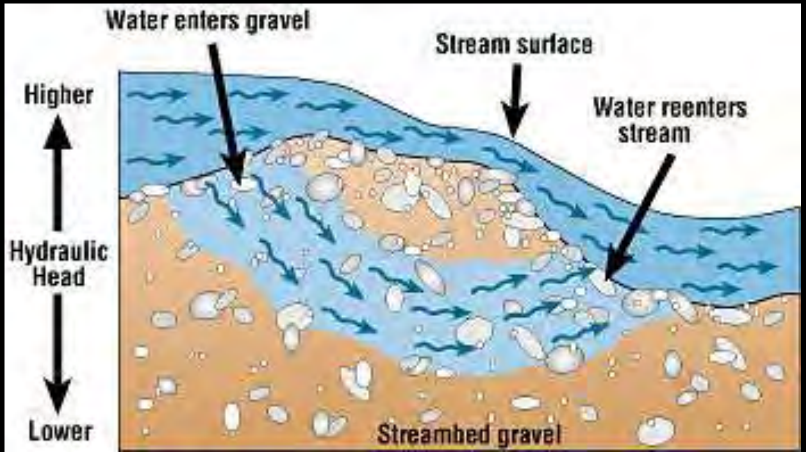


Figure 14. *Surface-water exchange with ground water in the hyporheic zone is associated with abrupt changes in streambed slope (A) and with stream meanders (B).*



The Hyporheic Zone





Stream Ecology

The River Continuum Concept [RCC]

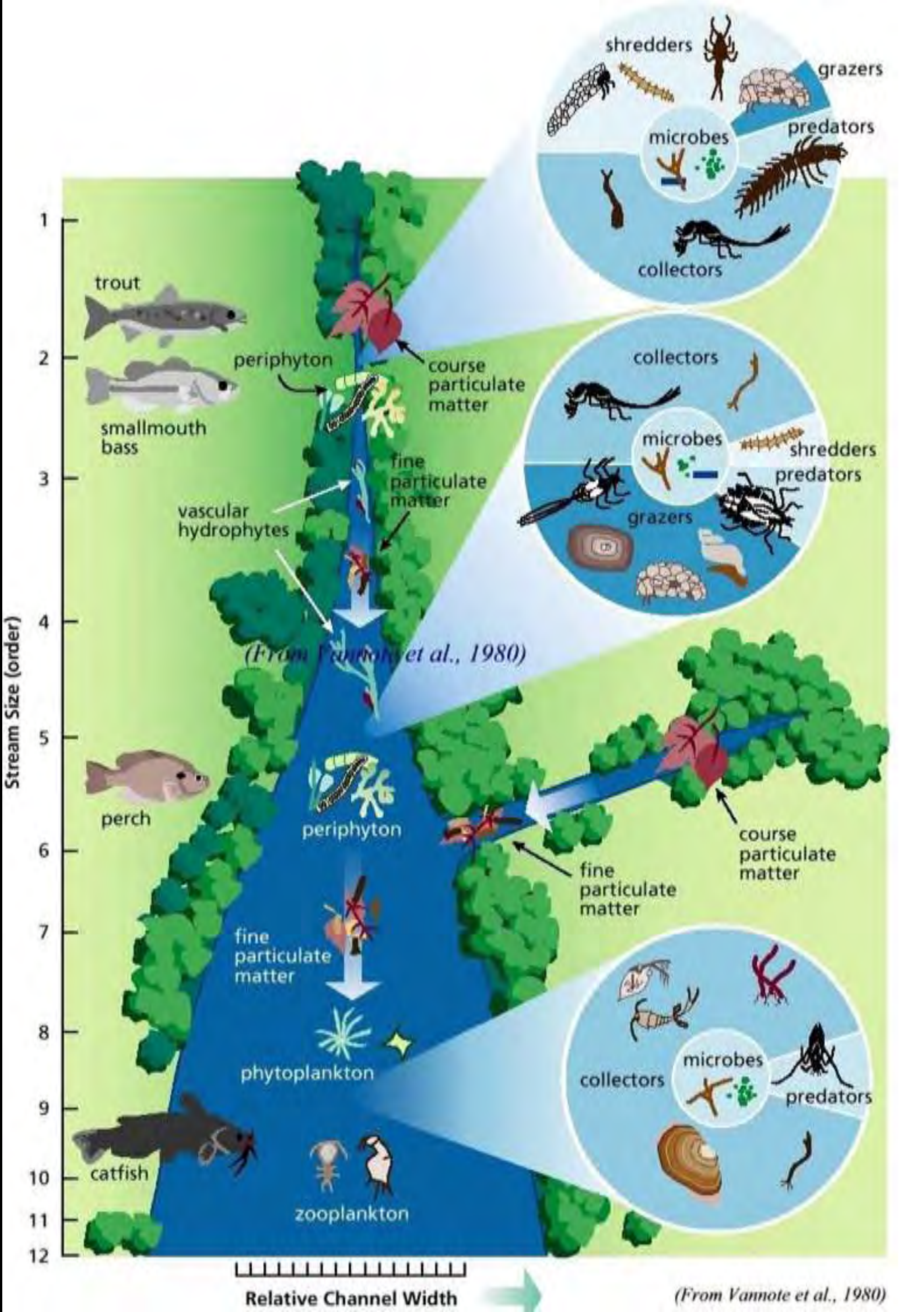
The River Continuum Concept is a model that tries to explain how the physical and biological characteristics of a river change in a downstream direction.

The foundation concept of the RCC states that rivers have physical gradients which are influenced by the surrounding environment, natural disturbance regime, local hydrology, and upstream conditions.

They in turn impact and define the biological components of the stream within the river as the river increases in size and moves downstream.

The RCC largely focuses on the interaction of stream invertebrates with their habitat and food resources.

Developed by Dr. Robin Vannote
The Stroud Water Research Center
Avondale, Pennsylvania

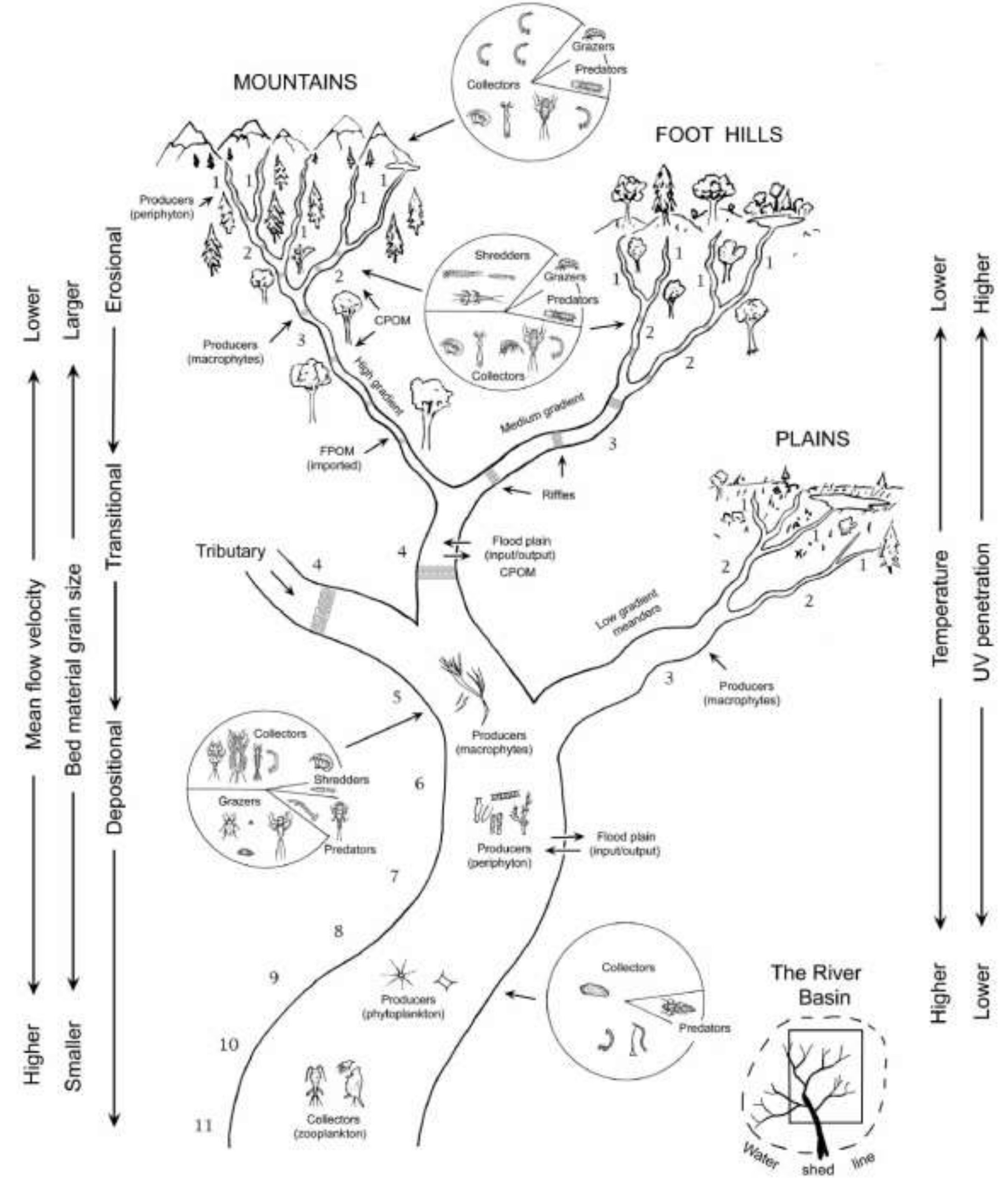


The River Continuum Concept [RCC]

Throughout the continuum of the river, the proportion of the four major organism types change

- shredders
- collectors
- grazers (scrapers)
- predators

With the exception of the predators, all these organisms feed directly from plant material



Biological Types and Food Types

Predators are organisms that eat each other and the following organisms –

Shredders are organisms that feed off of coarse particulate organic material (CPOM) such as small sections of leaves. They ingest the organic matter along with volunteer organisms (fungi, microorganisms) attached to the source. The preferred size of the CPOM is about one millimeter, therefore shredders must break it up into a finer particulate. In the process of shredding, much of the now finer particulate organic matter (FPOM) is left in the system, making its way further downstream. Some common shredders of North American waters include the Mayfly and stone fly larvae

Collectors are designated by their use of traps or other adaptive features to filter and catch organic matter.

The preferred particle size for collectors lies between 0.5 and 50 micrometers (UPOM = Ultrafine particulate organic matter and FPOM = fine particulate organic matter). This group includes fly larvae, nematodes, and many other animal groups.

Grazers (scrapers) feed off of periphyton that accumulates on larger structures such as stones, wood or large aquatic plants. These include snails, caddisflies, and other organisms.

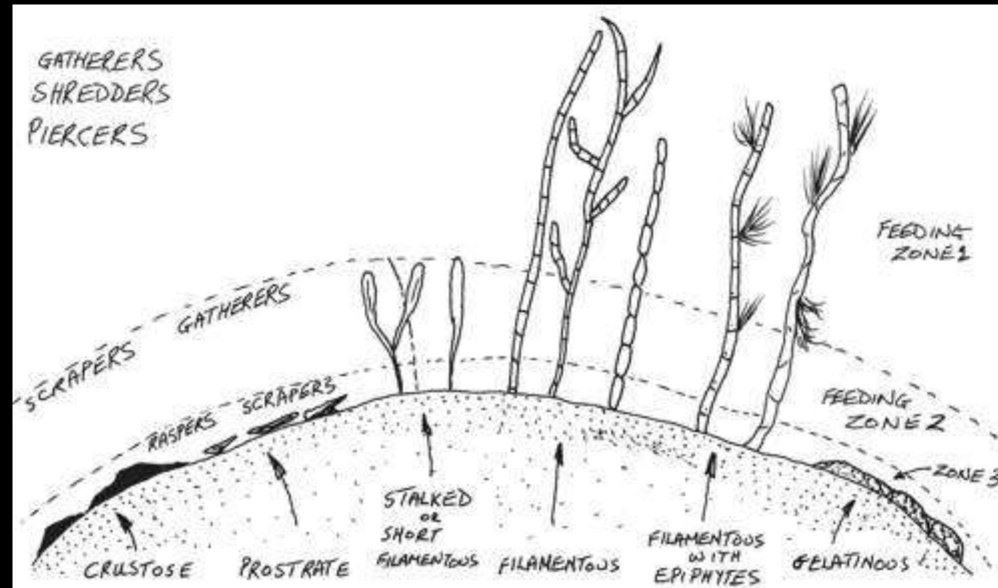
- Periphyton is a complex mixture of algae, cyanobacteria, and detritus that are attached to submerged surfaces in most aquatic ecosystems.

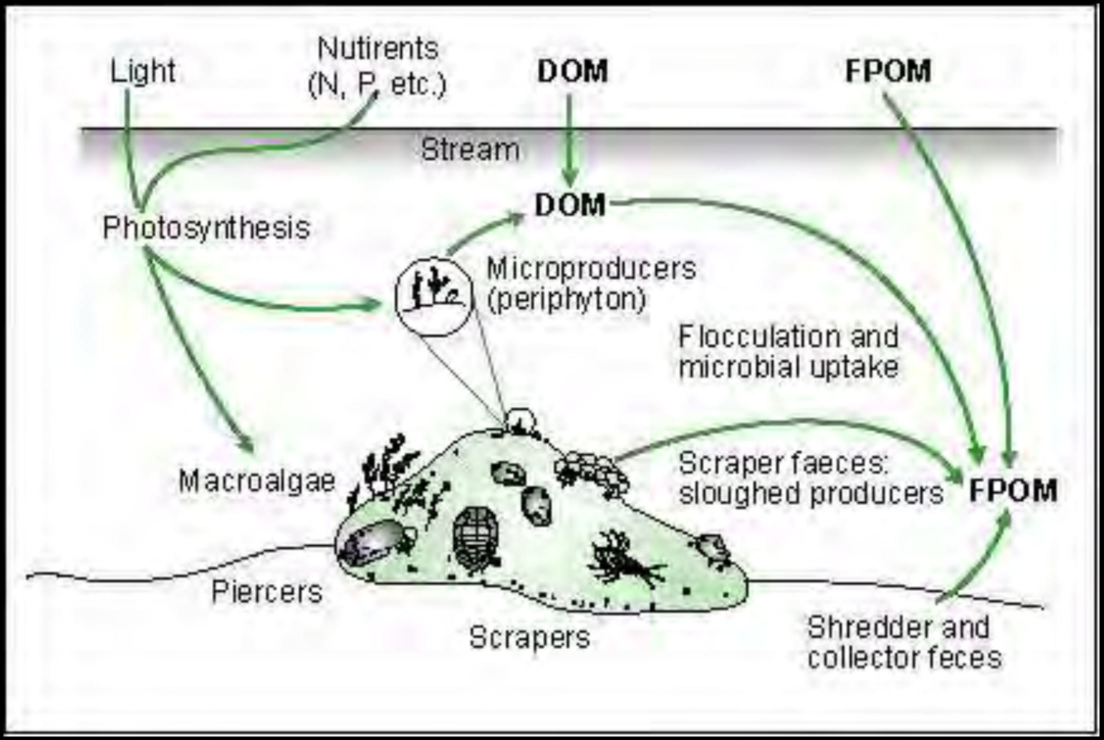



Periphyton

The three zones of Periphyton on stones.

Zones relate to the ability of the animals to consume the material

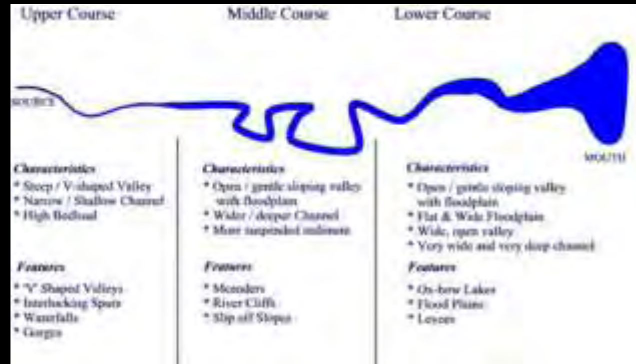




By a variety of mechanisms, the periphyton-bacteria-organic microlayer on substrate surfaces is scraped or browsed.

Diatoms are a prominent constituent of this matrix. Small Trichoptera larvae (Hydroptilitae) pierce the cell walls of macroalgea and suck out cell fluids.

Upper Course - Source



River sources are usually small and, in the case of mountain streams, steep and erosional.

In temperate environments, small streams tend to be shaded by an interlocking, overhead tree canopy.

Such conditions result in cool, well-oxygenated streams that are abundantly supplied with a food base of leaves.

Fine particles of organic matter are released as the leaves are broken down by biological communities in the streams

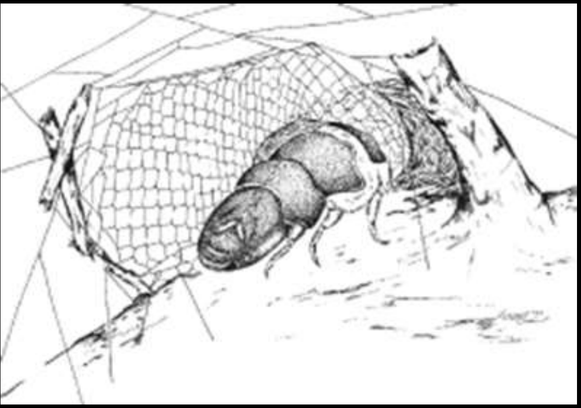
Leaves = Food

Leaf fall from the forest canopy in small streams are used by shredders .

Shredders get nutrition primarily from the fungi and bacteria that colonize the leaf surface. Craneflies, stoneflies, caddisflies and aquatic sow bugs are important members of this group.

Small fragments of leaves and feces from shredders are captured by another group of macroinvertebrates called collectors.

Netspinning caddisflies and blackflies are examples of this group.



The Leaf Pack Network (LPN) is a network of citizens, teachers, and students investigating their local stream ecosystems.

Using the Leaf Pack Experiment Kit, participants:

- Create an artificial leaf pack and place it in a stream for three to four weeks.
- Collect and examine the packs in the classroom.
- Discover aquatic insects that indicate stream health, showing the connection between trees and streams.
- Share data through the network.

Upper Course - Source

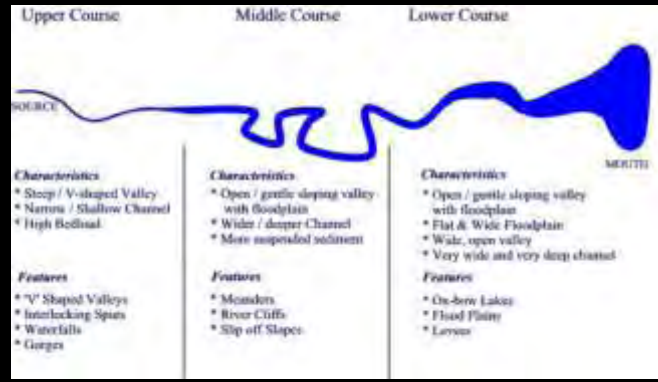
Riffle macroinvertebrate communities are typically more diverse than communities in pools.

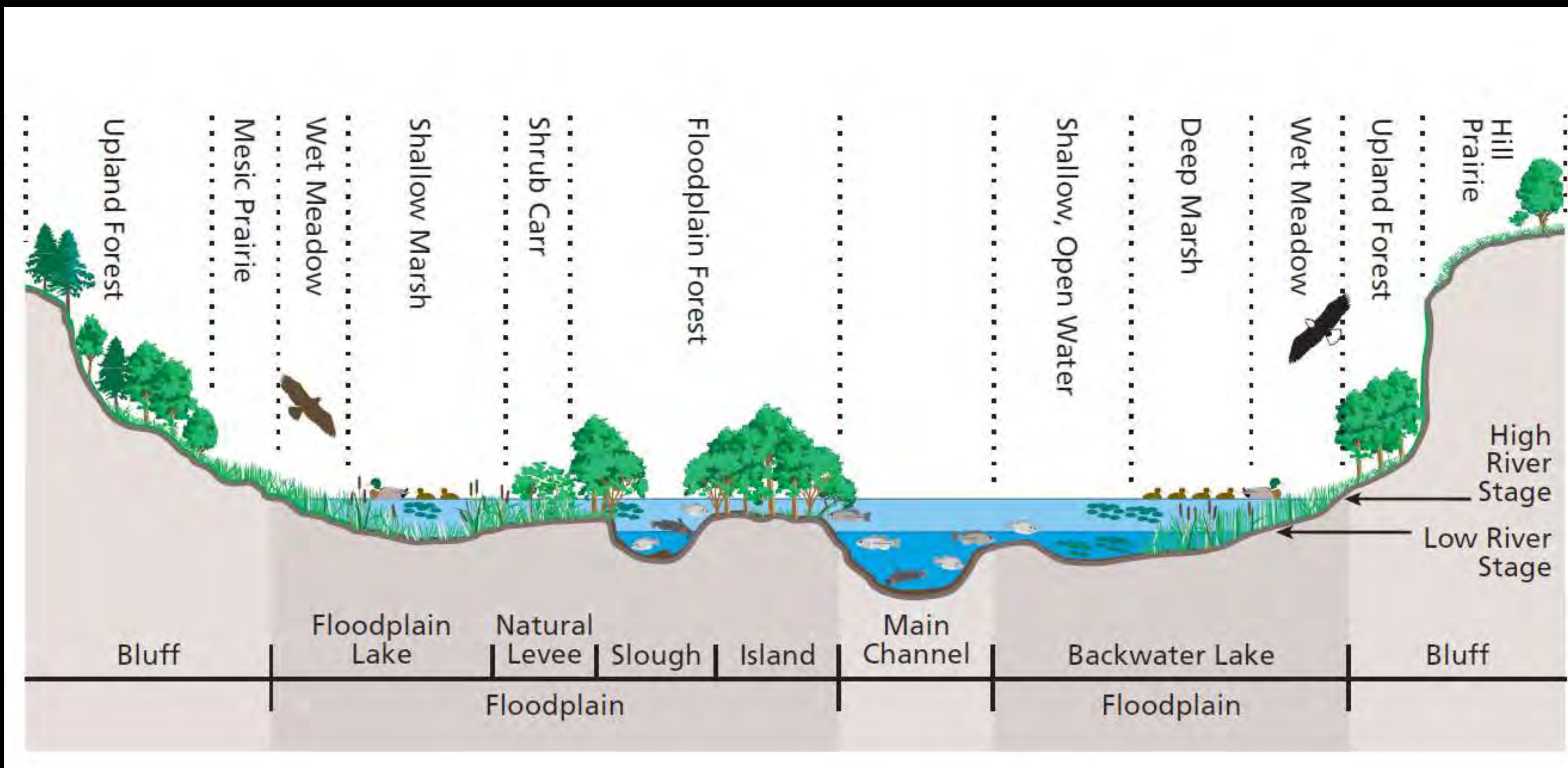
The pattern in fish communities is reversed, with pool fish communities tending to be more diverse than those in riffles.





The Middle Course: Life in the Meander Belt





The Middle Course

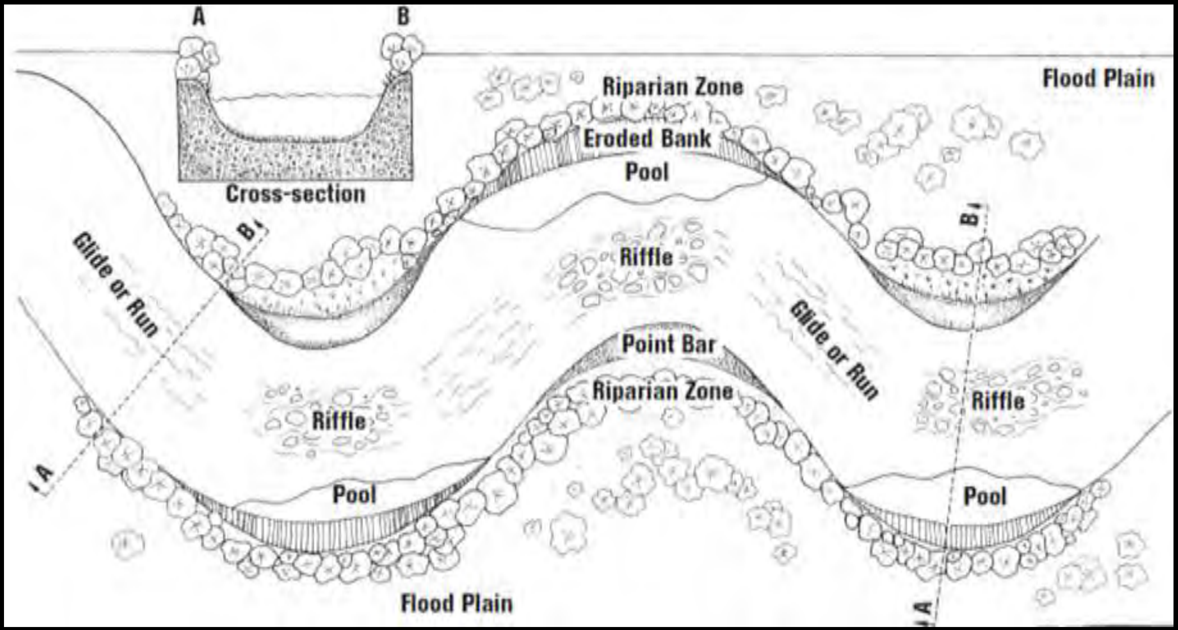
At some point along their path to the sea, rivers have typically gained enough water and width to preclude interlocking tree canopies.

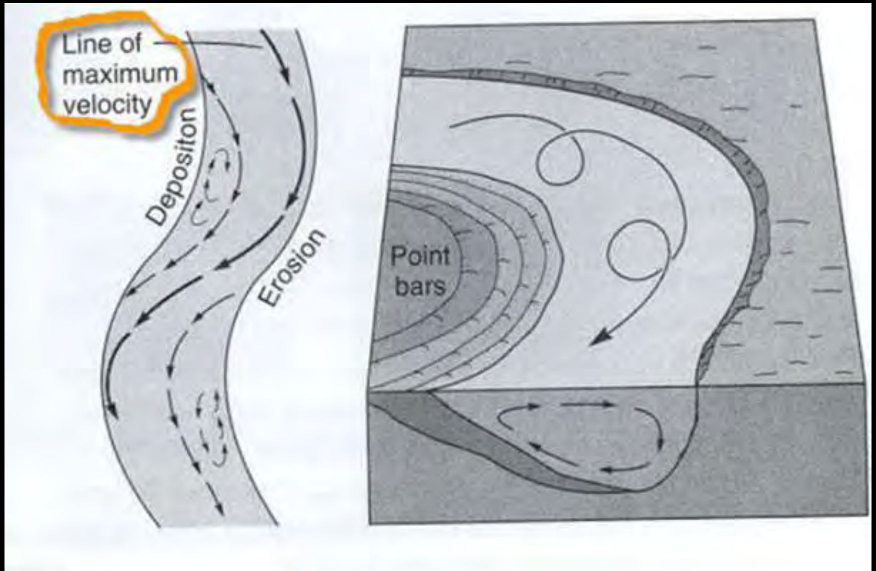
This open-canopy state frequently coincides with somewhat lower gradient landscapes.

Streams at this point are warmer and less abundantly supplied with leaves than was the case upstream.

Open canopy, and fairly shallow water, means that light can reach the river benthos, increasing in-stream primary productivity.

Aquatic Life Worlds: Erosional Zone and Depositional Zone





Helical flow in a meander.

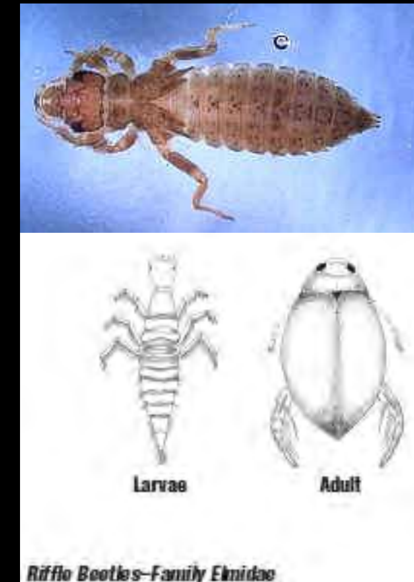
Erosional Zone – Riffles, Runs, Glides

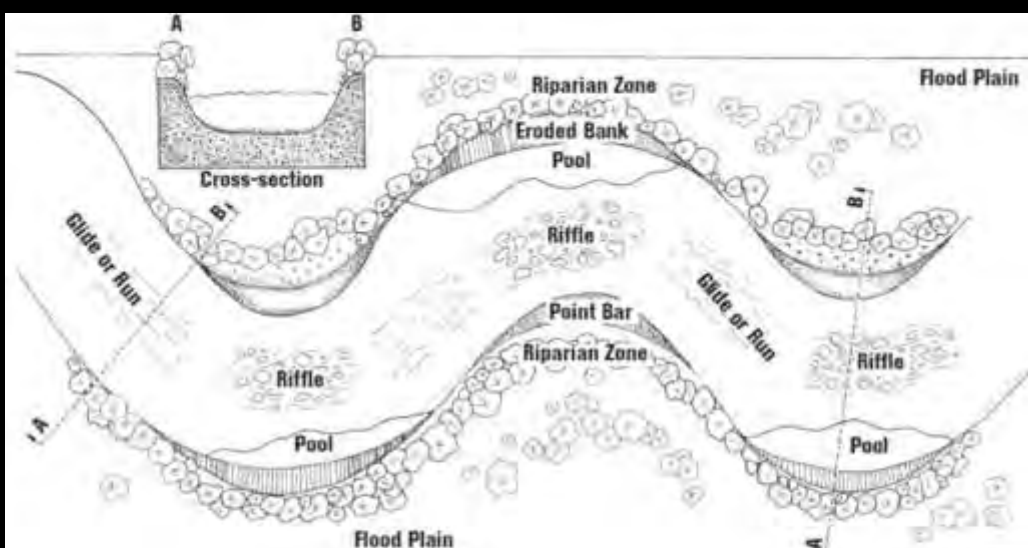
The erosional zone of a stream is the outer bank where flow velocities and bank erosion are high.

Riffles are the shallow portions of a stream characterized by relatively fast-moving, turbulent water with bottom materials composed of cobble, gravel, or bedrock. Riffle areas of streams are important habitats for many aquatic insects and small fish that require flowing water for feeding and high oxygen levels.

Few plants grow in the fast-moving water of a stream, but some may be adapted for living in the current of smaller streams.

Riffle areas commonly support those organisms adapted to life in fast-moving waters, such as algae, plants, and invertebrates (mayflies, caddisflies, riffle beetles, water pennies) that can anchor themselves to rocks, logs, and other stream debris.





Erosional Zone – Riffles, Runs, Glides

Some fish prefer the fastest part of a stream (darters). Many fish spawn in the riffles of streams.

Glides and runs are intermediate habitat types that fall between riffles and pools.

A glide is an area where the flow is characterized by slow-moving, nonturbulent flow referred to as laminar, similar to that in a shallow canal. A glide is too shallow to be a pool, but the water velocity is too slow to be a run.

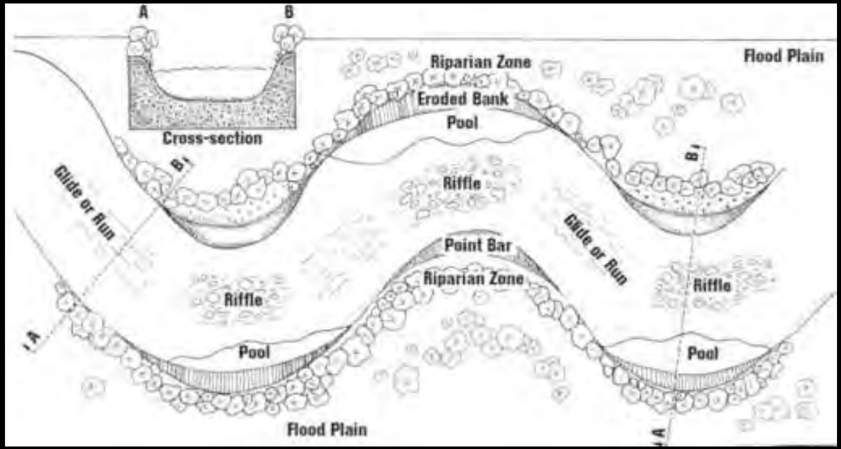
A run is a relatively shallow portion of a stream characterized by relatively fast-moving, nonturbulent flow.

Depositional Zone – Bars, Pools, Eddies

The depositional zone refers to the inner bank of a stream where velocity is at a minimum.

The slower velocities allow for the deposition of suspended sediment and bed materials (gravel, pebbles), which form bars.

These bars often support emergent aquatic vegetation.



Depositional Zone – Bars, Pools, Eddies

A pool is relatively deep and wide with slow-moving water compared to riffle, run, or glide areas.

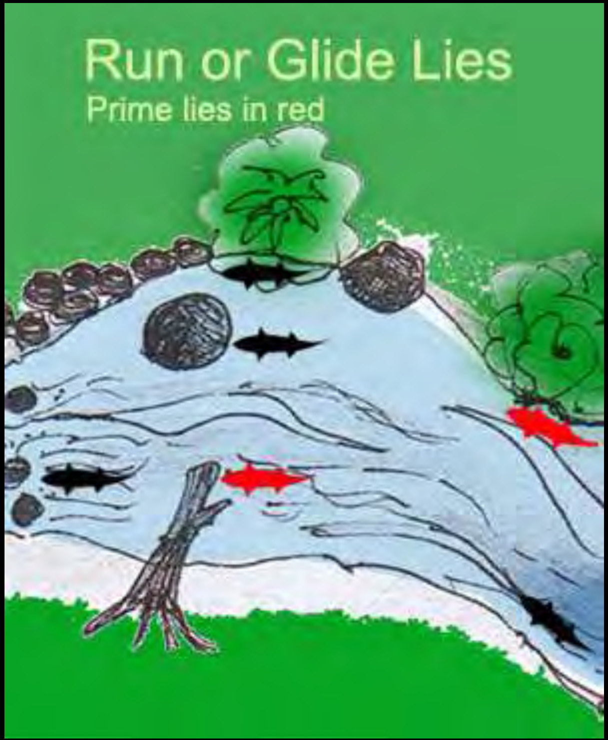
Pools often contain large eddies with widely varying directions of flow compared to riffles, glides, and runs, where flow is nearly all downstream.

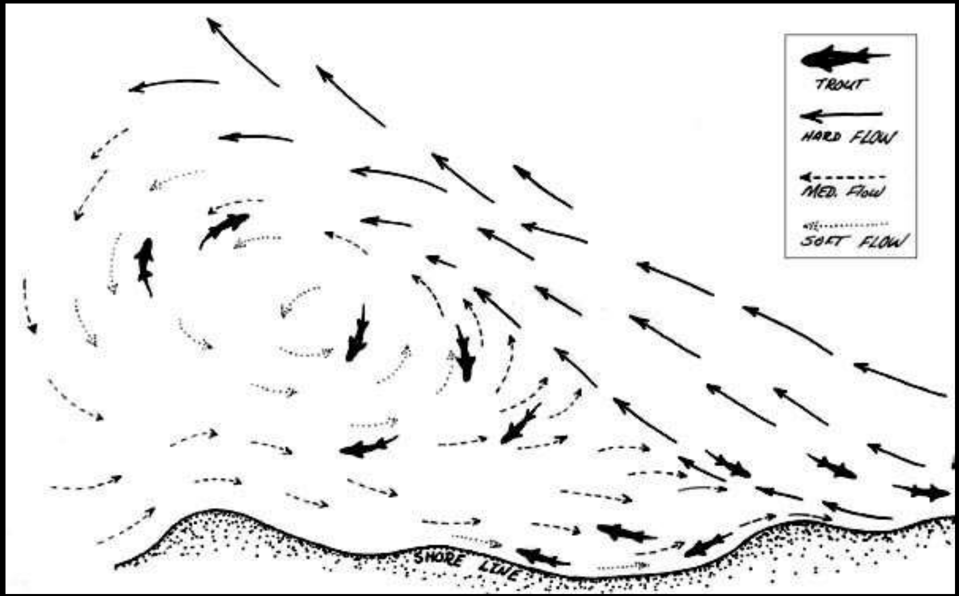
Eddies are currents that move in a direction other than downstream, usually in a circular motion.

Pool areas support fish, aquatic invertebrates, and aquatic plants .

Sediment in most pooled areas of streams and rivers is composed of sand, silt, clay, and organic matter, compared to the coarser sediment of riffles, runs, and glides.

Reduced velocity allows suspended materials to settle to the bottom. The slower-moving water supports organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders).


Run or Glide Lies
Prime lies in red

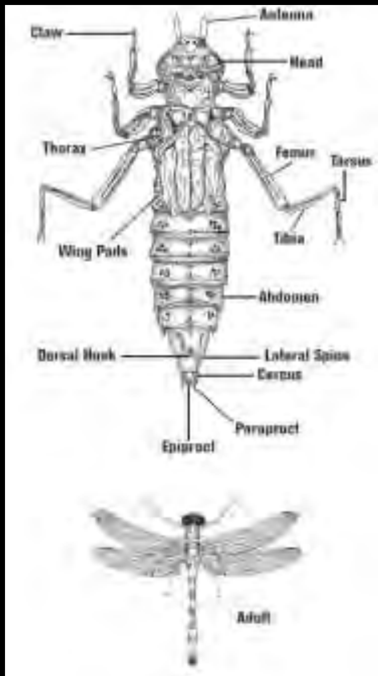

TROUT
HARD FLOW
MED. FLOW
SOFT FLOW
SHORE LINE

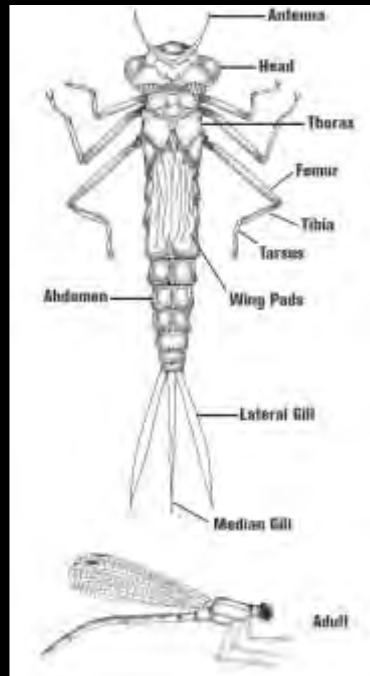
Aquatic Stream Habitats

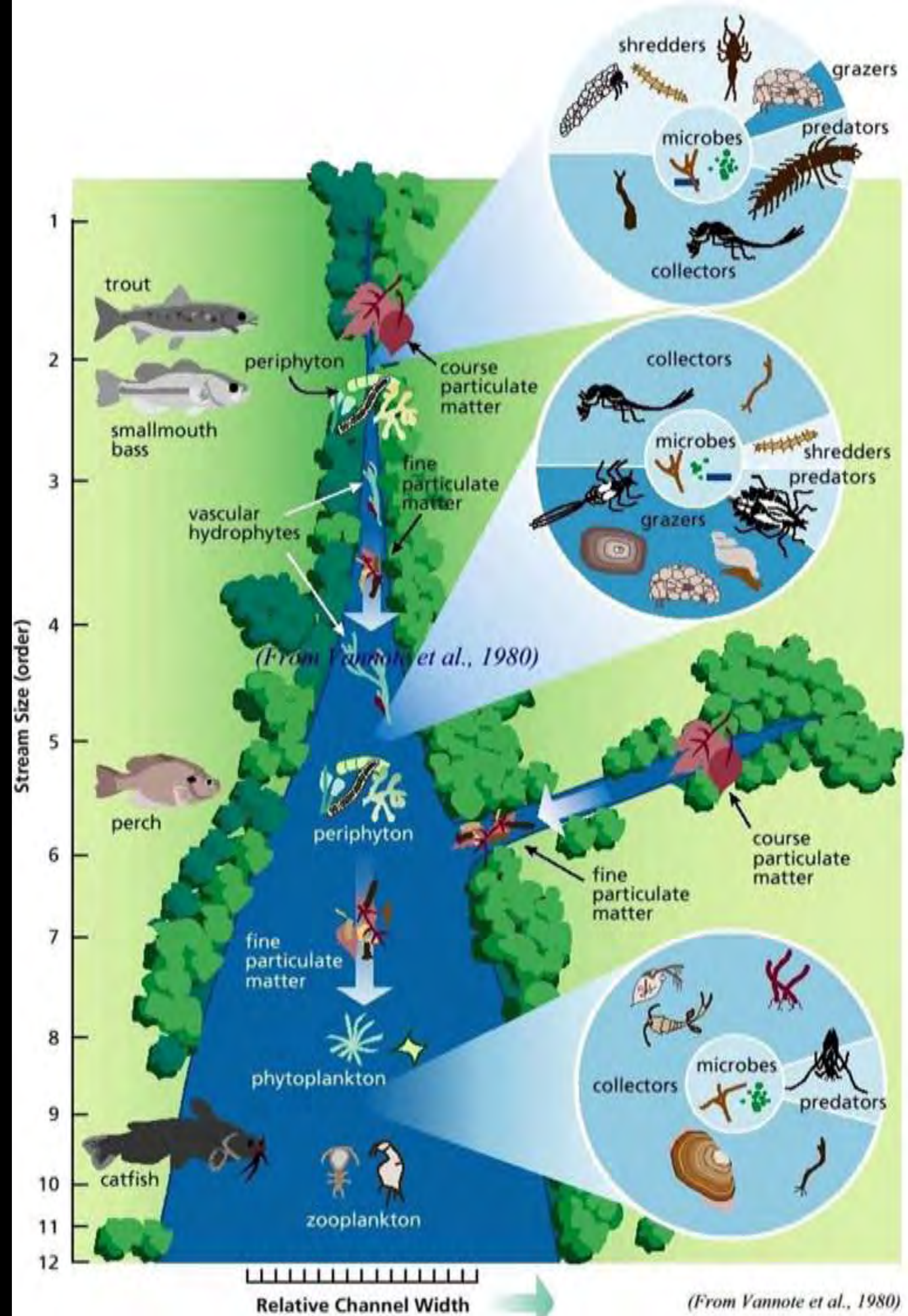
General Aquatic Habitat Types	Characteristics	Description
Lotic–erosional	Flow	Relatively shallow area of a stream. Three areas defined by flow: Riffle–fast-moving, turbulent water Run–fast-moving, nonturbulent water Glide–slow-moving water
	Sediment	Coarse sediment comprised of cobble, pebble, and gravel
	Aquatic plants (macrophytes)	Plants typically grow on or in coarse sediment (pondweed)
	Aquatic animals	Aquatic insects and small fish that require high oxygen levels, flowing water for feeding, and are adapted to living in swift water through the ability to swim or cling to rocks in riffle areas
	Organic materials (detritus)	Comprised of leaf litter, twigs, and other coarse particulate matter, usually trapped in stream riffles behind large rocks or logs; also known as *leaf packs*
Lotic–depositional	Flow	Relatively deep and wide with slow moving water compared to riffles, runs, or glides
	Sediment	• Primarily found in pools and backwater areas of streams • Fine sediment comprised of sand and silt
	Aquatic plants (macrophytes)	Submergent vegetation growing in fine sediment *(Hydrilla, Potamogeton)*
	Aquatic animals	• Organisms similar to those found in lakes and pond systems (dragonflies, damselflies, water striders) • Many fish use the deeper water of the pools and areas along the banks for cover and find food easier to catch in slower moving water
	Organic materials (detritus)	Comprised of leaf litter and other particulate matter found at the bottom of pools and backwater areas of streams

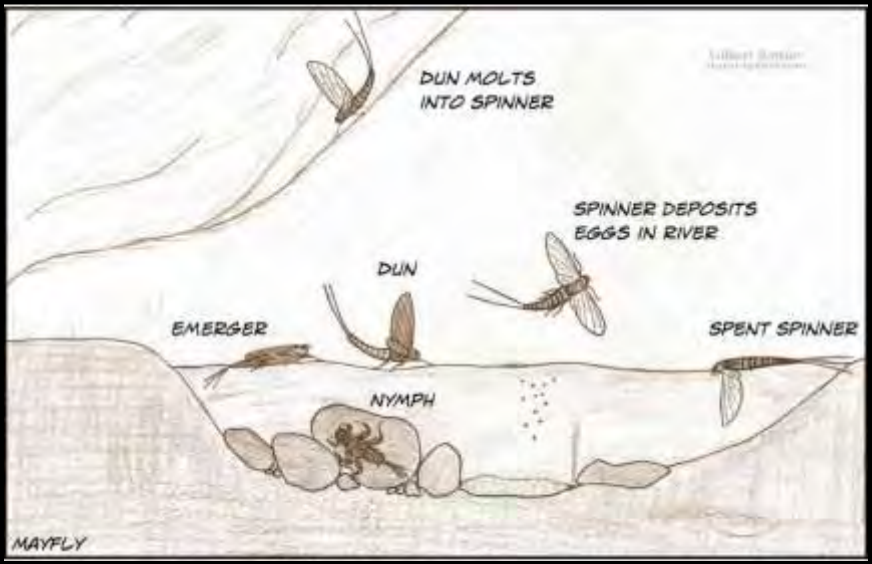
Adapted from Merritt and Cummins, 1995.

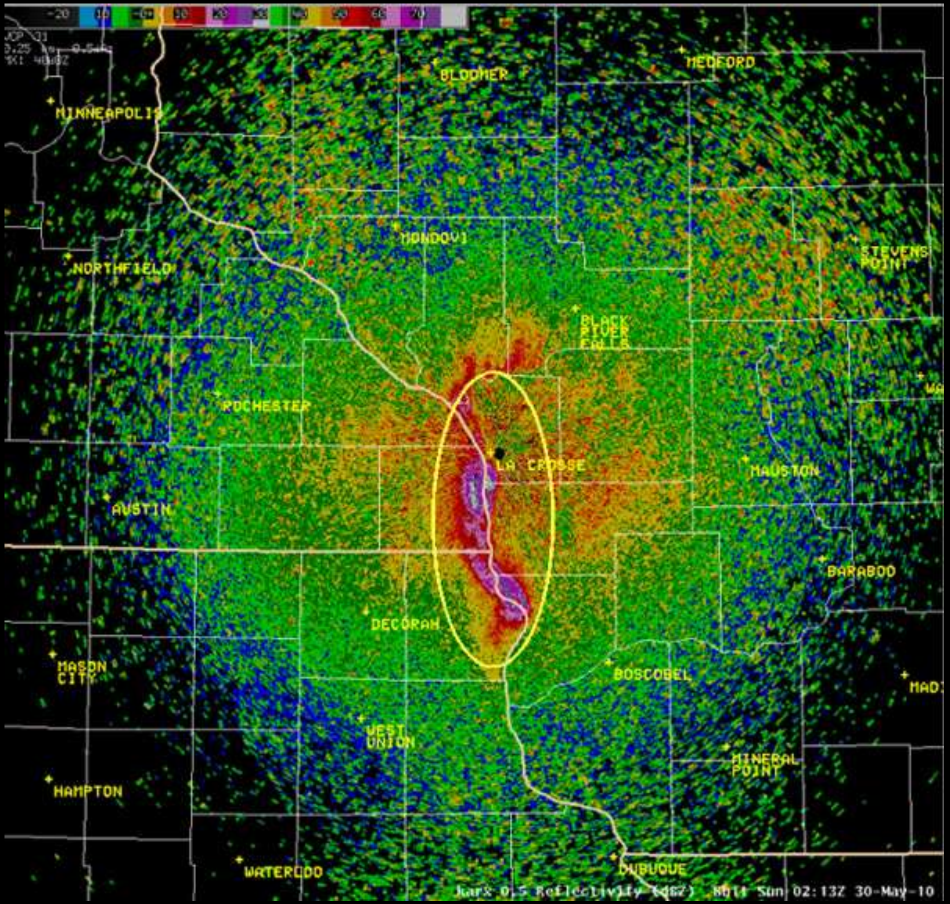
Diversity of Life in The Middle Course











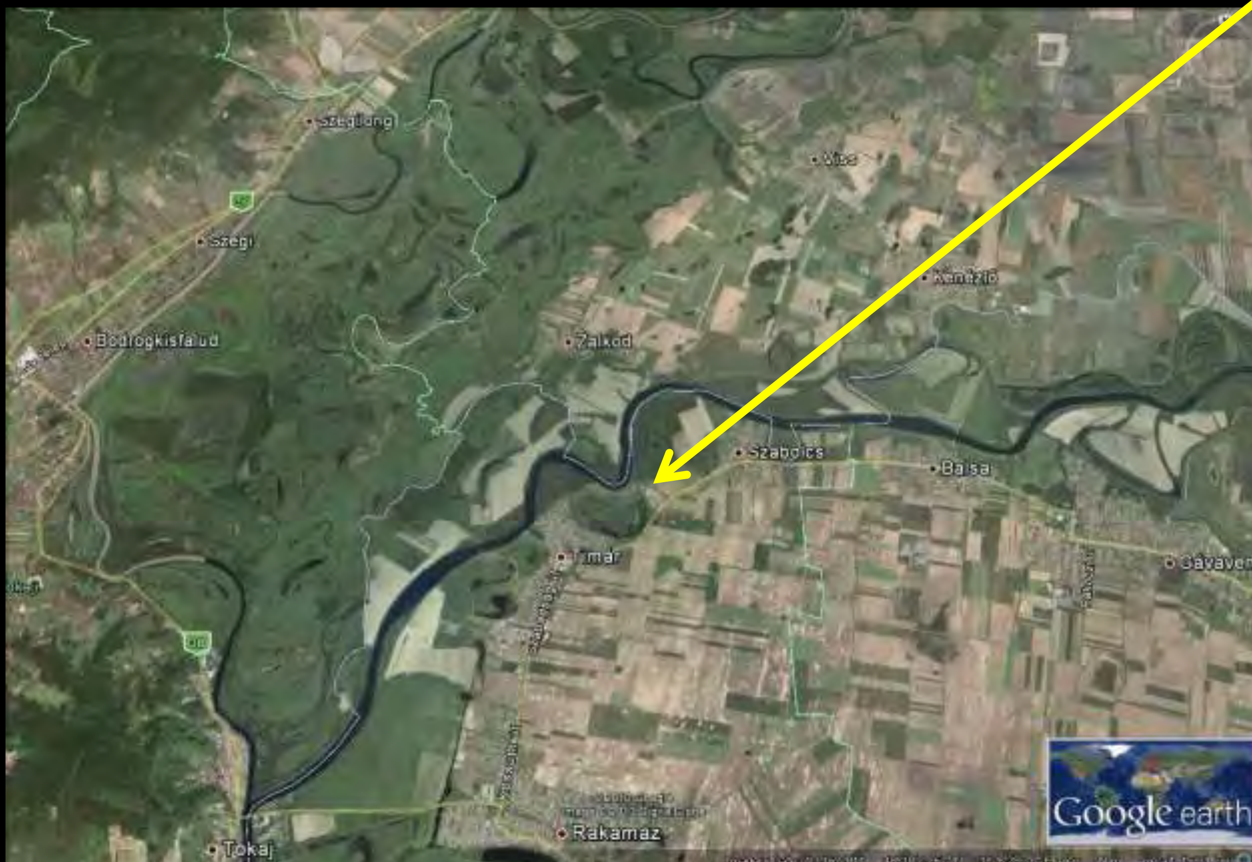
A mayfly mass emergence or hatch from the Mississippi river captured by the National Weather Service Doppler radar in La Crosse Wisconsin (USA) in May 2010

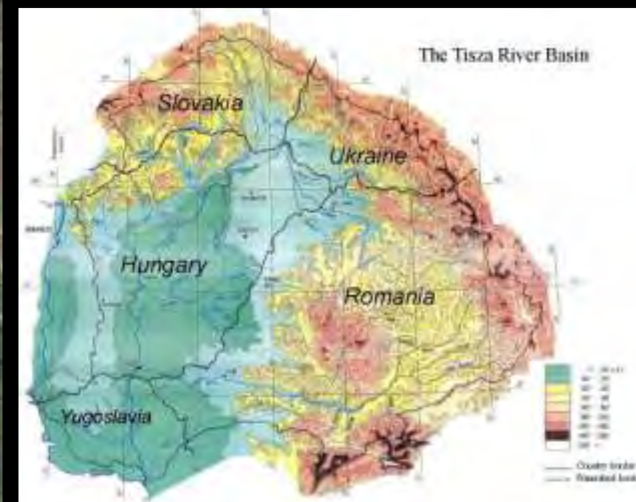
The adult mayflies in flight are represented by the bright pink, purple, and white.

Oxbow Lake

An oxbow lake is a crescent -shaped lake formed on a river when a meander has been cut through and abandoned.

When a river meanders in very big loops, the outer bank is so rapidly eroded that the river cuts through the narrow neck of the meander. The river then flows straight through the channel. When deposition seals off the cut-off from the river channel, an oxbow lake is formed. It may silt up and eventually dry up.





The Bodrogköz lowland region between the Bodrog and Tisza rivers is separated from the area up north by yet another river called Latorca. The southern part belongs to Hungary and the upper Bodrogköz is on the other side of the border in Slovakia. Now a cross-border UN Ramsar Wetland of International Importance

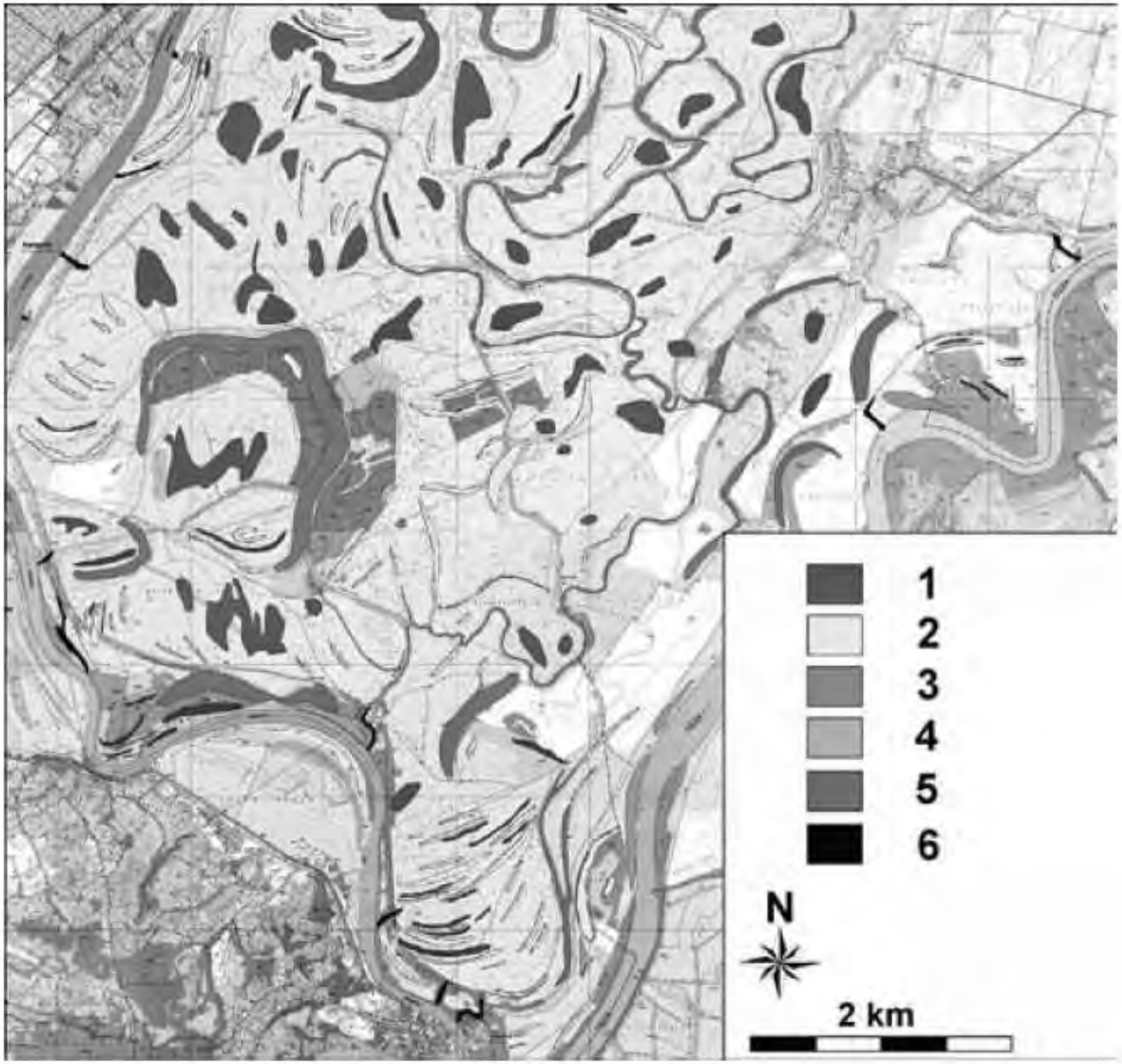


FIG. 2 - Landforms of the SW Bodrogköz (In: Szabó & *alii*, 2004). 1: fluvial ridge, 2: swale, 3: abandoned cut-offs, 4: present natural levee, 5: backswamps, 6: (remnants of) one-time flood-plain ditches.

The Lower Course: From River to Sea

Very large rivers are usually low gradient and very wide, resulting in negligible influence of riparian canopy in terms of shading and leaf-litter input.

Water currents keep fine solids in suspension, reducing light penetration to the benthos.

Organic matter in suspension is by far the largest food base in these very large rivers.

Larger alluvial rivers in their natural state are diverse habitats with side channels, sand and gravel bars, and islands that are formed and reformed on a regular basis.

Delta

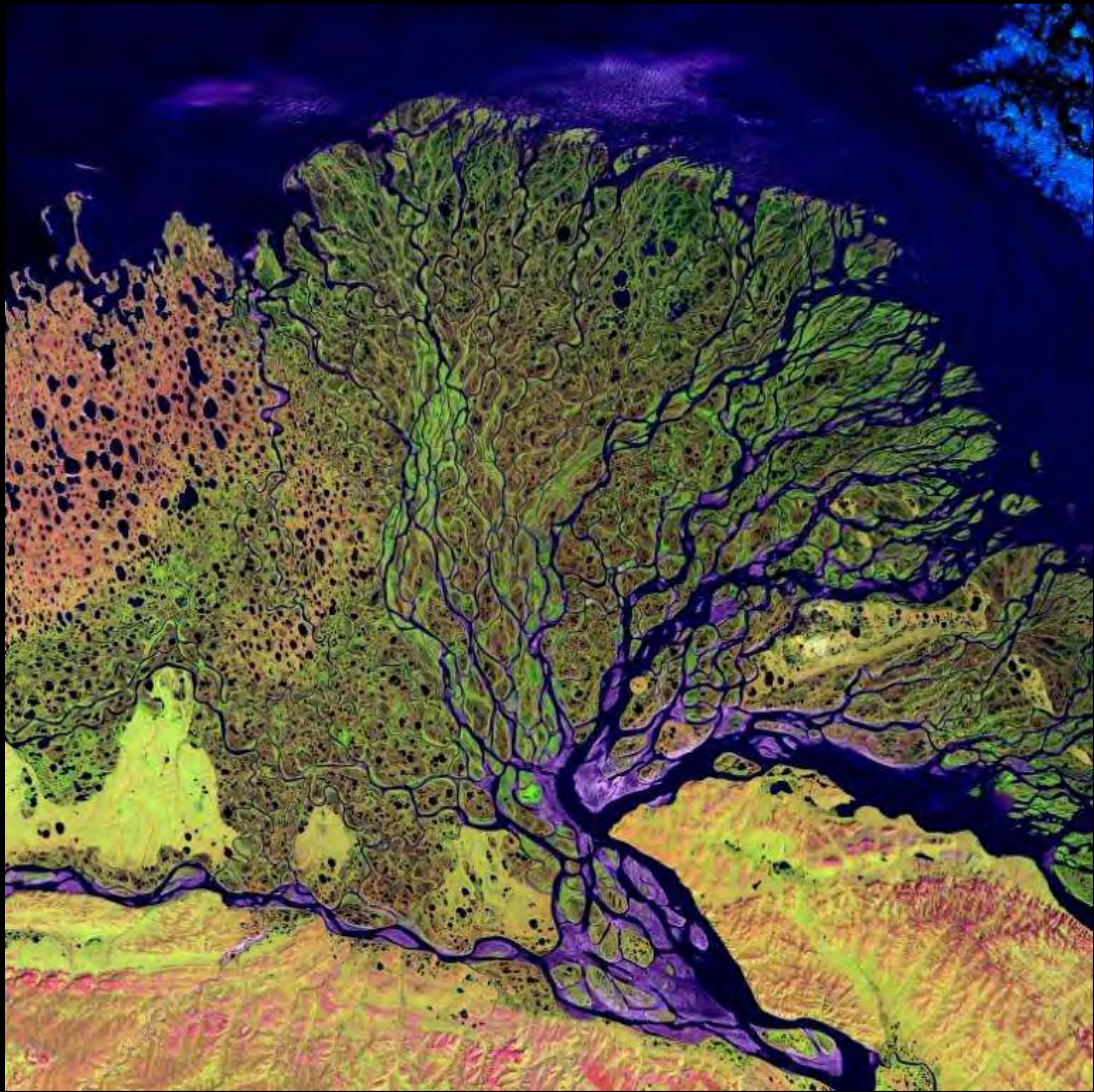
River deltas form at the mouth of the river or inland on the approach to lakes.

The Danube Delta is the second largest river delta in Europe, after the Volga Delta.

The greater part of the Danube Delta lies in Romania, while its northern part, on the left bank of the Chilia arm, is situated in Ukraine.

The approximate surface is 4,152 km², of which 3,446 km² are in Romania.

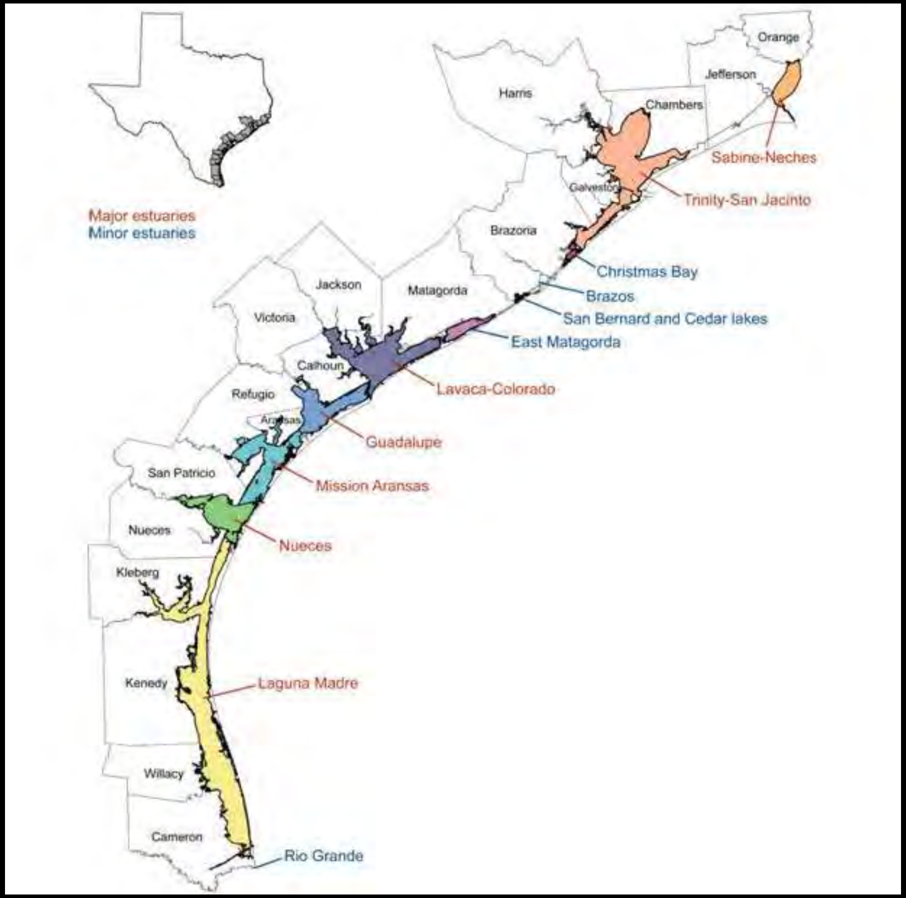
The Lena River, some 2,800 miles (4,400 km) long, is one of the largest rivers in the world. At the end of the Lena River there is a large delta that extends 100 km into the Laptev Sea and is about 400 km (250 mi) wide. The delta is frozen tundra for about 7 months of the year, but in May transforms the region into a lush wetland for the next few months.The Lena Delta Reserve is the most extensive protected wilderness area in Russia. It is an important refuge and breeding ground for many species of Siberian wildlife.



Estuary

An estuary is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea.

Estuaries form a transition zone between river environments and maritime environments and are subject to both marine influences, such as tides, waves, and the influx of saline water; and riverine influences, such as flows of fresh water and sediment. The inflows of both sea water and fresh water provide high levels of nutrients in both the water column and sediment, making estuaries among the most productive natural habitats in the world.



The Serial Discontinuity Concept

The RCC is a model that might apply to pristine rivers, but few rivers remain unchanged or unaffected by human activities.

Dams are certain to have an impact on the organization of aquatic communities, since the flow is blocked and the longitudinal transition of conditions along the river is altered.

The dam creates a 'serial discontinuity' in the river because the gradual downstream transition in conditions is disrupted, and the longitudinal transfer of material is prevented.

Suspended sediments are deposited behind the dam.

Water released from the dam will pick up a 'normal' sediment load downstream where it may erode the riverbed and banks.

The Serial Discontinuity Concept

The main effects of dams, in relation to the River Continuum Concept, are as follows:

- Discontinuity in flow conditions is introduced: i.e., standing water behind a dam in what was formerly a flowing-water habitat.

- Movement of aquatic animals is impeded or prevented and populations are fragmented.

- Organic matter transported by the river is deposited in the impoundment behind the dam. The availability of food downstream is therefore reduced.

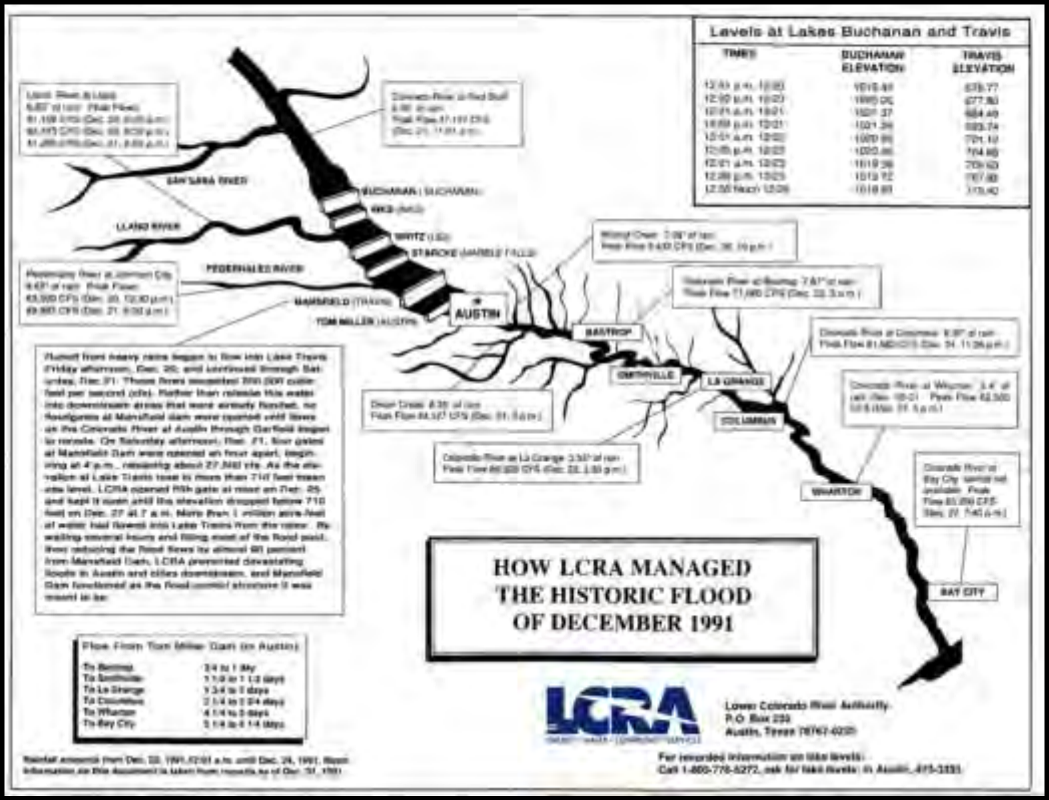
• The downstream transition of water temperature is altered, and water released from the dam may be either warmer (if it is taken from the surface) or cooler (if it is taken from the depths) than natural conditions. Concentrations of dissolved oxygen may be changed also.

• Phytoplankton that develops behind the dam may be released downstream providing a food resource for filter-feeders that would be unavailable under natural conditions.

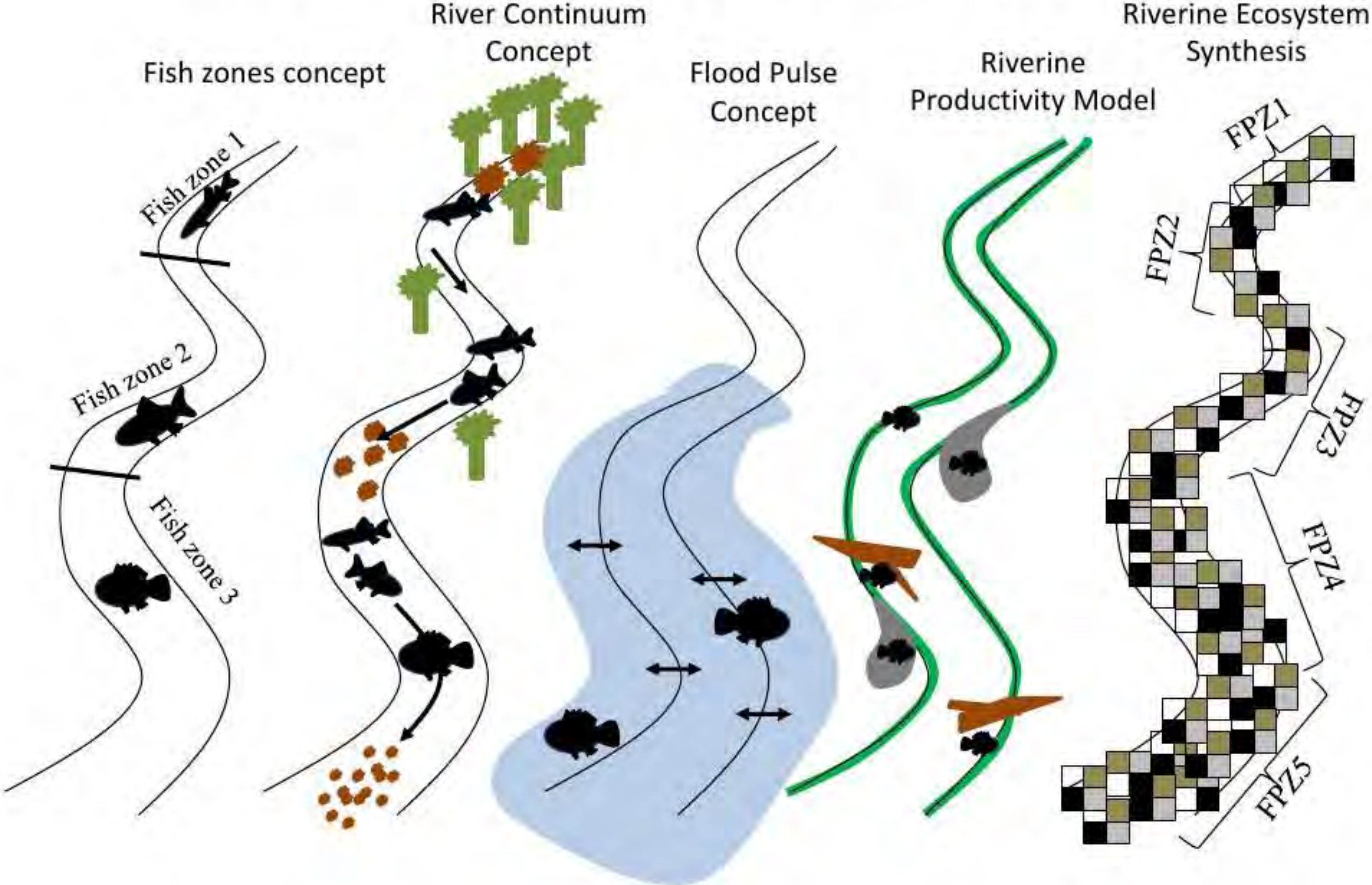
• The seasonal patterns of flow will be altered, especially if the function of the dam is to provide water for irrigation (in which case dry-season flows downstream will be reduced) or to control flooding (in which case wet-season flows and floodplain inundation will change).

The consequences of the introduction of a serial discontinuity depend on its position on the river.

Clearly a dam on the river main stream will have a greater impact than one on a minor tributary. If the discontinuity is far upstream, then the river will be able to recover from the loss of inputs if it passes through forest further downstream. However, if the discontinuity is in the middle course of the river, it will have a dramatic effect on the transport of material to downstream reaches, and may affect the flood pulse.



River ecosystem concepts



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