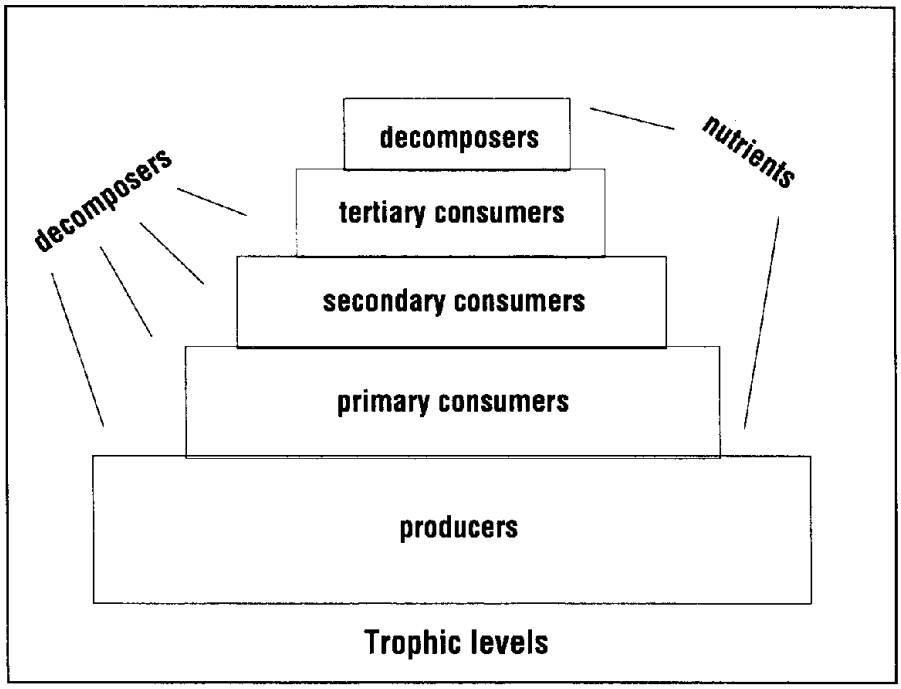
December

Aquatic Ecosystems

In order for organisms and species to survive, they must be able to meet their habitat requirements for food, water, air, space, and reproduction. The availability of good habitat determines what organisms will be able to survive in a particular environment. In December ***The Salmon Times*** takes a look at how aquatic organisms interact with each other and obtain what they need from their environments. When we study the interrelationships of organisms with each other and their environments, we are studying **ecology**.

This chapter will describe in some detail how the physical, chemical, and biological characteristics within rivers define different habitats for different organisms. It will focus specifically on how characteristic substrate (stream bottom), dissolved oxygen levels, and food sources within different reaches of streams and rivers influence the inhabitants and how macro-invertebrate inhabitants have adapted to get what they need from the environment. The April chapter will revisit macroinvertebrates in their roles as bioindicators of water quality. We will also look at how energy production and consumption balance each other within a healthy **ecosystem**.

Every natural system must have a source of energy in order to operate. The sun provides the source of energy in all but a very few unique situations. During **photosynthesis**, green plants use sunlight to change water and carbon dioxide into carbohydrate food. They also release oxygen as a byproduct during this process. Plants that can manufacture food using the energy of the sun are called **producers**. Producers play an essential role by using sunlight to "produce" chemical energy. **Primary consumers** are organisms that eat producers. **Secondary consumers** eat primary consumers and so on. When plants or animals within a system die, the chemicals that make up their bodies are broken down and released back



into the system as nutrients by **decomposers**. The major decomposers are bacteria and fungi. Decomposers even become food when they are attached to a piece of detritus that is eaten.

Organisms that obtain energy from similar sources belong to the same **trophic level** (feeding level). **Autotrophs** (plants) can make their own food. **Heterotrophs** must obtain their food from something else. As energy is transferred from trophic level to trophic level, some energy is "lost." That is because organisms cannot use all the food they consume; some is eliminated as waste. They also use energy during their own life processes and activities releasing part of that in the form of heat.

Another way of describing feeding in an ecosystem is to descibe animals by what they eat. Animals that eat plants are called **herbivores**. Animals that eat other animals are called **carnivores**. **Omnivores** eat plants or animals.

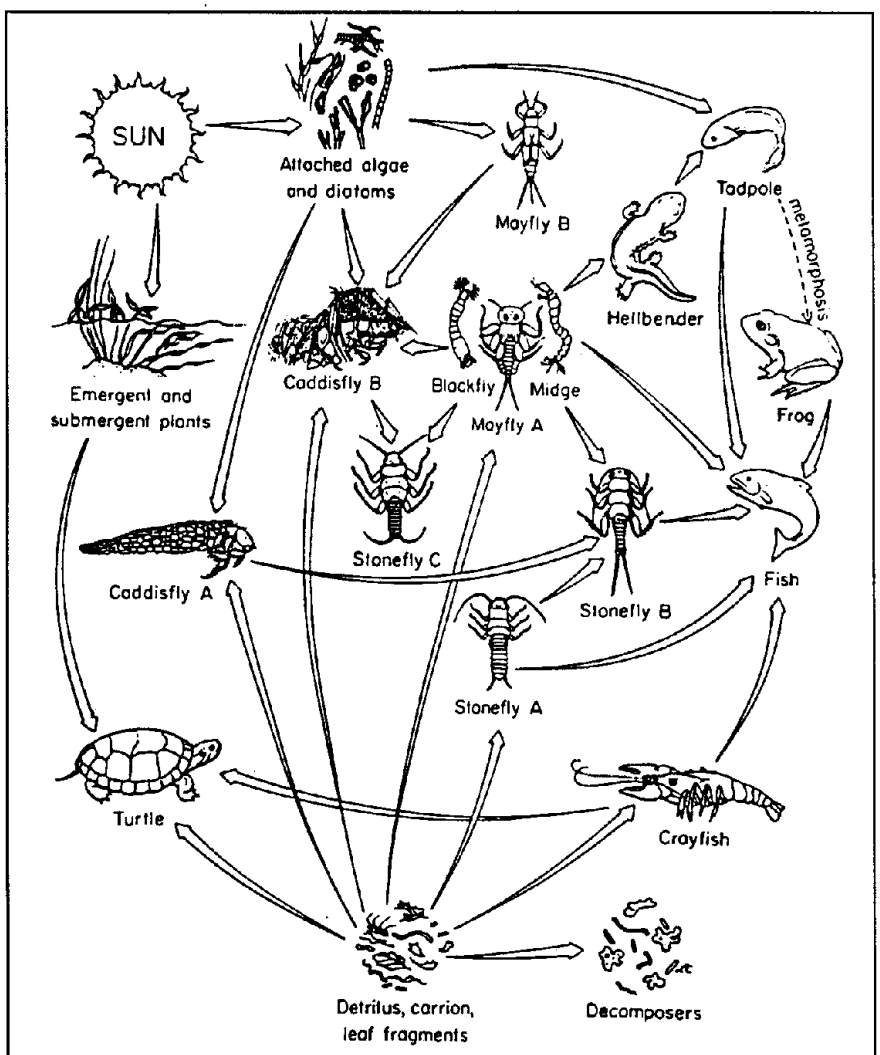
The role an organism plays in relation to other organisms within that ecosystem is its **niche.** Animals that eat other animals are called **predators**. Animals that are eaten are called **prey**. **Scavengers** eat whatever dead organic materials they can find.

Because of their ability to manufacture food, green plants are the base of **food chains**. A food chain describes the sequence of energy as it moves along from organism to organism. A food chain in a stream might look like this:

algae> mayfly> trout> osprey> bacteria

Of course, the chain does not stop there. All living organisms take up and use nutrients. They can be thought of as living nutrient warehouses. Decomposers break down dead organic materials and release nutrients into the soil or water. These nutrients renew the cycle because producers use them to grow. Most organisms are food for more than one other type of organism within the same system. A **food web** describes a number of overlapping food chains and is usually a more accurate description of feeding patterns in an ecosystem. Food webs illustrate the interconnectedness of organisms within an ecosystem.

Aquatic macroinvertebrates, such as **larval** insects, **crustaceans**, and **molluscs**, play an important role in aquatic food webs. They can be primary, secondary, or even tertiary consumers. They obtain food by shredding, grazing, filtering, gathering, and preying. One insect can have different food sources and ways of obtaining food at different stages and in different seasons of its life. Stonefly larvae



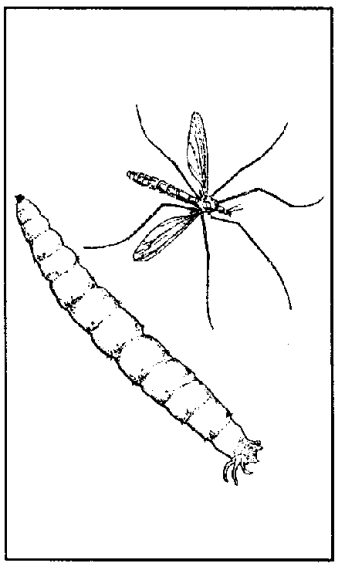
A simplified stream food web

Immature insects do not just change in size when they grow into adults. During metamorphosis, they also change form.

Some insects go through complete metamorphosis. Their form changes completely as they grow. The young are called larvae and they look very different from adults.

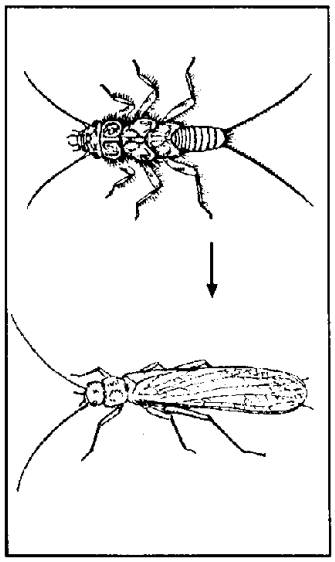
Other insects go through incomplete metamorphosis. The young are called nymphs and they look somewhat similar to the adults.

Complete



crane fly, larva and adult

Incomplete



stonefly, nymph and adult

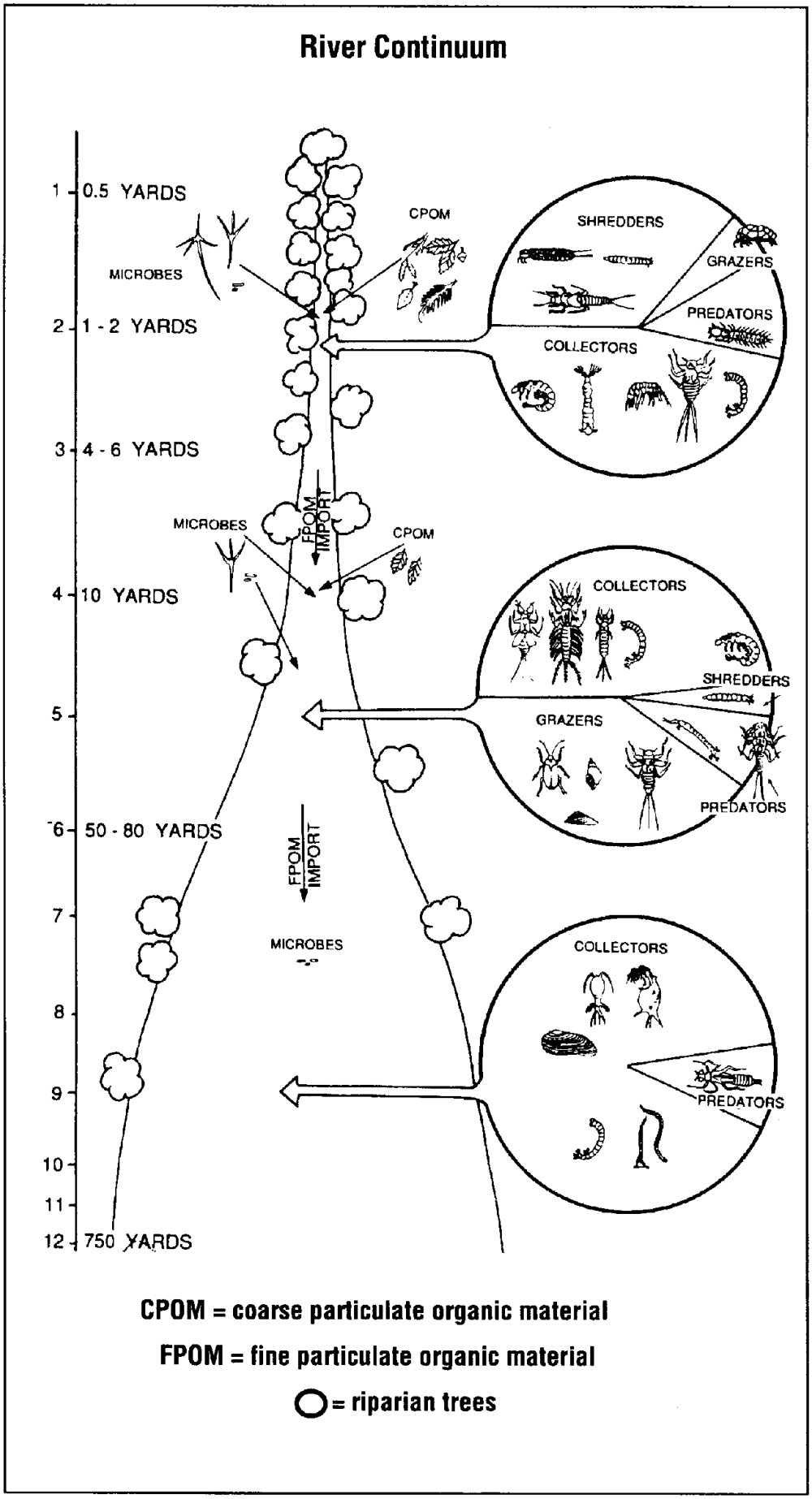
and a number of the caddis and true fly larvae are **shredders**. When they feed, they break up leaves and plant parts. Their feeding action changes large pieces into finer particles. **Collectors** gather or filter out the resulting particles or waste feces from the shredders. Some mayfly **nymphs** as well as others of the caddis and true fly larvae are collectors. **Predators**, such as the dragonfly nymph or dobsonfly larvae, eat other aquatic insects. **Grazers**, such as the water penny, scrape algae off rocks.

Streams and rivers are particularly interesting ecosystems to study because as one travels from the headwaters to their mouths, the physical and chemical characteristics influencing the ecosystems change. These changes, in turn, create changes in the **biota** (such as bacteria, algae, macroinvertebrates, and fish) living there. The notion that these changes exist and are somewhat predictable is called the **river continuum concept**.

There are many factors that influence the physical and chemical characteristics of a stream or river. Physical characteristics such as width, temperature, substrate, water velocity, and water volume are influenced by the topography and geology of the stream. Humans might change these characteristics by building dams, channelizing, affecting runoff in the area, or altering the streamside vegetation.

Chemical characteristics such as pH, buffering capacity, or dissolved oxygen and nutrient levels are also influenced by the topography and geology of the area. Land use activities such as burning fuels, farming, and managing waste can change the chemical characteristics of water bodies. These aspects of water quality will be covered in more depth in upcoming chapters.

True flies belong to the order *Diptera*. They include black flies, mosquitos, horse flies, deer flies, crane flies, and midges. The word fly is a separate word in their names. Insects belonging to other orders sometimes have the word fly attached — such as dobsonfly, dragonfly, and mayfly.



Interestingly, biological factors are not only influenced by physical and chemical characteristics, but they, in turn, can influence physical and chemical characteristics. Aquatic organisms' life processes such as obtaining nutrients, using oxygen, producing waste, and decomposing affect the physical and chemical characteristics of their water habitats.

Terrestrial biota even influence aquatic ecosystems. **Riparian forests** (streamside trees) influence many of the physical and chemical characteristics of headwater streams and play a very important role in preserving the health of a waterway:

- The roots of streamside trees and the uncompacted soils of forests help slow water down, allowing potentially harmful sediments to settle out from runoff.
- These roots also help stabilize the stream bank, reducing erosion created by fast-flowing waters.
- Trees that fall into the stream provide structure for fish and other aquatic creatures.
- Fallen trees trap detritus and serve as shelter for aquatic organisms.

Determining how much riparian forest should be preserved is not an easy task. The answer depends on what function of riparian forests is being protected. Sometimes forested buffers as small as 50 feet are helpful in stabilizing stream banks, controlling stream temperature, and protecting streams from sedimentation and excess nutrients. However, in other situations as much as 600 feet of intact riparian forest are required to maintain bird and wildlife habitat and a full diversity of native species.

• The shade from a riparian tree canopy helps maintain the cool water temperatures that give headwater streams their oxygen-carrying capability.
(Teachers: See May chapter activities if you wish to plant trees in the spring. You may be able to get trees from the state forestry office if you contact them the preceeding fall.)

Headwaters (Stream Order 1-3)

Let's follow a river along its continuum from the headwaters (first or second order) to the mouth (up to sixth order). (Although stream order is technically defined from orders one to 12, rivers beyond the sixth order are very difficult to find.) Headwater streams have a unique ecology that involves complex interactions among water, land, and living organisms.

Every natural system needs a source of energy in order to function. Algae, which are usually a major source of productivity in aquatic environments, play a very small role in headwater streams because the shade from riparian forests limits the amount of sunlight reaching the system. The major source of energy in a headwater stream is actually brought in from outside the system by wind and rain. Riparian forests supply headwater streams with energy. Fallen leaves, twigs, and tiny organisms clinging to them are the basis of the food chain in headwater streams. These organic materials fall into the water and start to decompose. Microbes and some aquatic macroinvertebrates use this coarse organic material (detritus) for energy.

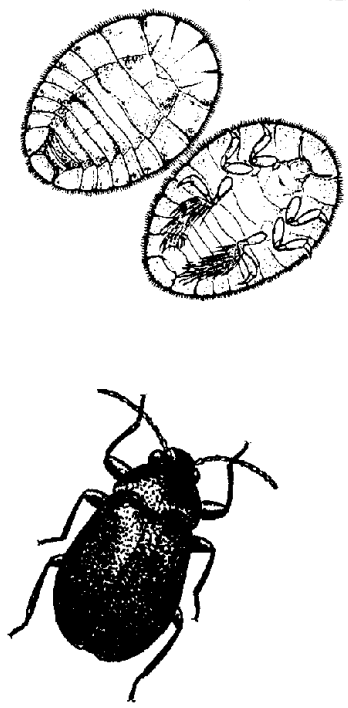
Headwater streams are typically rocky, shallow, narrow, cold, clear, fast-moving, and high in dissolved oxygen. Consequently, the primary consumers that inhabit these waters must be able to get their food from dead leaves and to tolerate shallow, fast-moving water. In addition, they usually require high levels of dissolved oxygen. Boulders, rocks, and rubble make up much of the stream bottom and create **riffles** that provide abundant habitat. Macroinvertebrates that inhabit headwater streams are also well adapted for fast-flowing water by being strong swimmers and by having streamlined bodies, structures that help them attach to rocks, or coverings that protect them.

Shredders and collectors make up the bulk of primary consumers in headwater streams. Naturally, shredders are more prevalent in these streams than along any other part of the continuum because many of the leaves falling into headwaters are still intact. The mouth parts and forelegs of shredders are adapted for chewing and breaking up these relatively big pieces.

Stonefly nymphs live in headwater streams. These aquatic macroinvertebrates are either predators or **detritivores.** Scientists believe that stoneflies that eat decaying materials are really going after the protein-rich bacteria and fungi decomposers rather than the decaying leaves themselves. Stoneflies can only survive in water with high levels of oxygen. They breathe through the surface of their skin or through tufts of gills along their sides under their legs. In lower oxygen waters, they increase the flow of oxygen over their bodies by doing "push-ups." Stonefly nymphs are a favorite food for trout. Mayflies, some caddisflies, and water pennies are examples of other aquatic invertebrates that need high levels of oxygen and are, therefore, common in headwater streams.

Hellgrammites, also known as dobsonfly nymphs, are active predators in fast-flowing waters. They are one of the larger aquatic invertebrates you might find during a survey. Hellgrammites play an important role in the

aquatic food web by eating other aquatic insects. They are also one of the few aquatic insects that might bite a person. Even so, anglers seek them out for their ability to attract fish.



water penny beetle larva

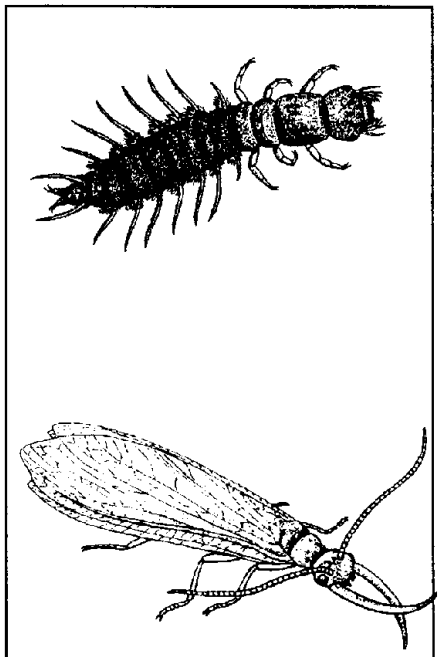
Mid-reaches (Stream Order 4-5)

Moving down from the headwaters, small streams connect to each other and grow broader and deeper. Through the stretch of third to fourth order streams, primary productivity gradually changes. Through this stretch of the river, shade trees have less influence, relatively less coarse material drops in, and fine particles of decomposing leaf litter from upstream appear. As the tree canopy starts to open and allows more sunlight to penetrate to the stream bed, additional sources of primary productivity become available. **Periphyton** (algae growing on submerged rocks) and rooted aquatic plants eventually join detritus at the base of the food chain.

Third to fourth order streams are somewhat wider, warmer, sunnier, and sandier than headwaters streams. The stream bottom is likely to comprise a few boulders, more rubble and gravel, and some sand and mud. This variety of substrate provides a variety of habitats. Mid-reaches have greater **biodiversity** than either headwater streams or downstream stretches. Mid-reaches have some of the conditions and qualities of both headwater streams and downstream stretches; therefore, they can support a large variety of species. Having a wide variety of species often helps keep a natural system more stable because a catastrophe to one species will not affect as great a proportion of that system as it would if the system had only a few different species.

The primary consumers in this stretch are adapted for gathering tiny bits of organic material or algae and are dominated by collectors and periphyton grazers. The relative abundance of grazers is much greater here than in the headwater streams. Grazers are adapted for adhering to rocks and being able to scrape algae off them. Shredders decrease in abundance as less coarse material is available. Filter feeders are able to survive in stretches where there are enough small organic particles for them to eat.

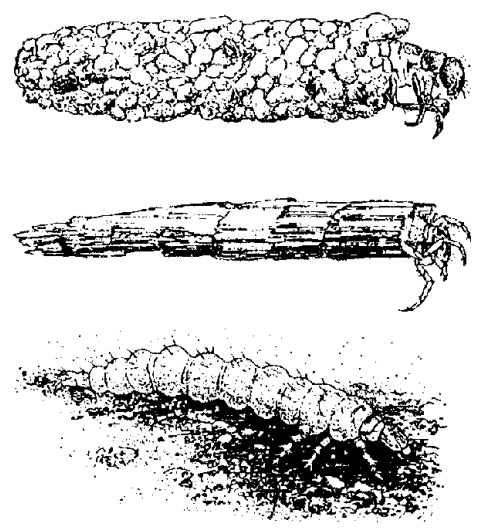
Caddisflies can be grazers, collecters, or predators. They need moderate to high levels of oxygen in order to survive. Caddisfly larvae are probably best known for the cases many build to enclose their soft bodies. They use pebbles, grass, or twigs to build tiny homes that protect them from being swept away in flowing water. Some types of caddisflies use their homes as mesh collectors to filter tiny organic particles from the stream flow.



dobsonfly larva and adult

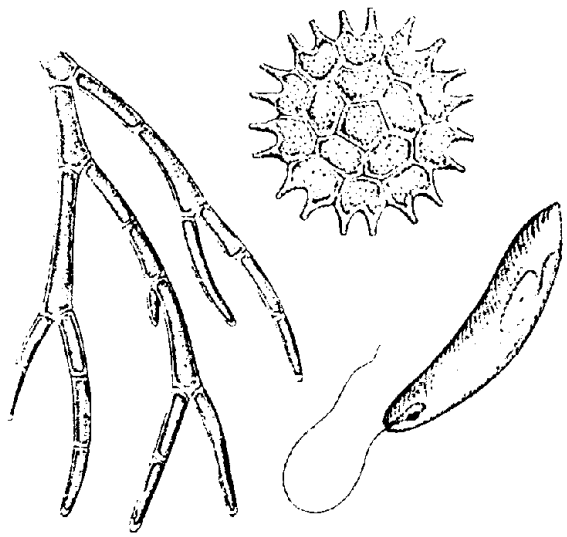
Lower Reaches (Stream Order 6 and Higher)

Moving toward the mouth, streams from the fifth to sixth orders form a river — broad, deep, sunny, and murky. Streamside vascular plants and planktonic algae, much like that found in lakes and ponds, contribute to primary productivity. Coarse particles of leaf litter are rare and an abundance of fine particles of decomposing organic materials drift in from upstream. These fine particles of decomposing plants, animals, waste, and nutrients are the primary sources of food. In other words, downstream stretches of river benefit from the inability of organisms in upstream stretches to use all the nutrients that are released there.



caddisfly larvae

River bottoms in the lower reaches are likely to have some gravel, but to be dominated by sand, sediment, silt, and mud that have been deposited. Sometimes lower reaches of the river have poor water transparency. Suspended particles cloud the water and prevent sunlight from reaching the bottom. Sediments may bring excessive phosphorus into the system. The oxygen demands of aerobic decomposition, aquatic animal respiration, and chemical oxidation reduce the amount of dissolved oxygen in water at lower reaches. Warmer temperatures and reduced aeration also affect dissolved oxygen levels.

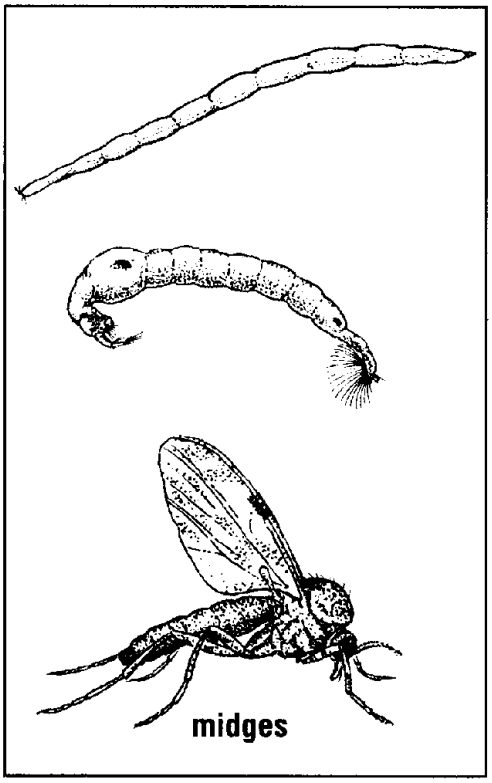


plankton magnified

In the lowest reaches of the river, filter-feeding macroinvertebrates dominate the scene as primary consumers. Most of these creatures burrow in the sand and silt and use fringed body parts to help them filter food, nutrients, and oxygen from the water. **Zooplankton** (microscopic floating animals) that cannot withstand the flowing waters of upper reaches are found downstream in quiet, still waters. They feed off phytoplankton throughout the water column. The aquatic macroinvertebrates that need coarse organic material to eat and cool, clear, highly oxygenated water to breathe cannot survive here. The species that can burrow, filter food, and tolerate lower oxygen conditions survive best in lower reaches.

In addition to the characteristic conditions of lower reaches, there may be land use impacts from upstream and along the river that affect the water quality of this section. Because lower stretches of the river are subject to all that happens in upper stretches and within the whole watershed, they tend to have physical and chemical conditions that create habitat which limits the amount and variety of species that can survive there. Pollution tolerant and hardy types of aquatic invertebrates can live anywhere along the continuum, but they are likely to be more prevalent in the lower reaches than their pollution intolerant relatives.

Some macroinvertebrates are adaptable to a wide range of habitat conditions. Midges are interesting aquatic larvae that can survive in a huge variety of habitats from marine waters to arctic bogs. They live everywhere from clear, deep lakes to heavily polluted waters. Midge larvae live in sediments and take in oxygen through their body surfaces. They have a substance in their blood that holds oxygen. The oxygenated blood makes some of them red. This blood substance helps them survive in low oxygen conditions. They can be predators, herbivores, or omnivores and are important prey for fish.



Midges also play an important role in sewage treatment ponds. During daylight, algae in sewage ponds release oxygen that is used by aerobic decomposers. However, the accumulation of dead algae creates problems for the operation of the pond. Midges help to reduce this accumulation by consuming the collected algae.

The river continuum concept describes how abiotic and biotic factors in stream and river ecosystems influence each other. It also illustrates how changes in energy production and consumption through different portions of a river network help keep the whole system in balance. What do you think could knock this system out of balance? It should be noted that coastal rivers don't necessarily follow the continuum concept as described here, because they might not have headwaters at high elevation. Also, the mouth of the river is likely to be an estuary and thus have very different conditions. Coastal rivers do exhibit changes along their lengths; however, the degree of change may be less than that described in this chapter. Next month's readings describe how Atlantic salmon need healthy headwater streams and open ocean in order to survive.

Word Power

*adaptation
*biodiversity
*camouflage
*conservation
*consumers
*decomposers
*drought
*ecosystems
*energy cycle
*erosion
*flat water
*food chain
*food web
*herbivore
*invertebrates
*larva(e)
*nutrients
*nymph
*photosynthesis
*predators
*producers
*omnivore
*rapids
*riffles
*scavenger
*surface runoff
*survey
*terrestrial
autotroph
biota
carnivores
collectors
crustacean
detritivores
grazers
heterotroph
microbe
mollusc
niche
periphyton
prey
primary consumers
riparian forest
river continuum concept
secondary consumers
shredders
trophic level
zooplankton

Go Buggy!

Concepts: Form relates to function.
Observable differences and similarities help identify organisms.

Objectives:
1. Students will observe insect body parts.
2. Students will hypothesize function based on form.
3. Students will classify insects based on observations.

Materials:

In the Field
- shallow stream
- aquatic mesh net - Contact UNH Cooperative Extension Water Resources
- hip boots or waders
- long sleeve rubber gloves
- wide mouth glass or plastic jars with lids

In the Classroom
- shallow white enamel or plastic trays
- Petri dishes
- forceps or tweezers
- hand lens or magnifying boxes

For Preserving Specimens
- 8 ounce jars with screw caps, half-filled with 70% ethyl alcohol - CAUTION: ETHYL ALCOHOL (available at most hardware stores) IS TOXIC IF INGESTED. EMPHASIZE THIS FACT TO STUDENTS. MAKE SURE ROOM IS WELL VENTILATED.
- empty 8-ounce containers with lids
- Petri dishes
- small sample vials with covers
- identification labels for vials

Subjects: Science, Art

Preparation and Procedure:

Because of the complications inclement weather may pose for some students in December, it is recommended that teachers collect specimens to bring back to the classroom for observation. Yes, you will be able to find aquatic insects through the winter! We will revisit this topic during the spring when we look at aquatic invertebrates as bioindicators of water quality. Spring may be a better time to have students participate in collecting. On the other hand, high waters may complicate collecting in the spring. Determine which time is better for your situation and adapt the materials list and procedure accordingly. BE SURE TO REQUEST PERMISSION FROM LANDOWNERS IF YOU ARE GOING TO BE ON PRIVATE PROPERTY. DO NOT SAMPLE MORE THAN ONCE A QUARTER FROM THE SAME SITE. TRY TO SAMPLE FROM A VARIETY OF PLACES.You will need to make a decision to either observe the animals alive and return them to the stream or to preserve them for observation.

STREAM COLLECTING:

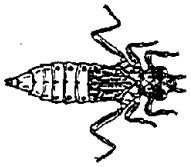
You will need a partner to help hold the net in the stream. Plan to sample from a number of stream habitats. Riffles are usually productive areas. Try pools and muddy bottoms as well. Place the net in the stream against

Adapted from *Pond and Stream Safari: A Guide to the Ecology of Aquatic Invertebrates*, by Karen Edelstein and illustrated by Tamara Sayre for Cornell Cooperative Extension, 1993.

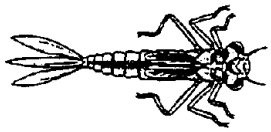
Checklist of Common Aquatic Invertebrates

Aquatic Organism

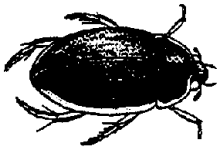
Dragonfly nymph



Damselfly nymph

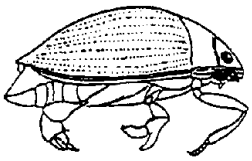


Water scavenger beetle adult

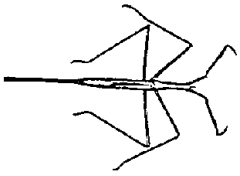


Whirligig beetle larva

Whirligig beetle adult



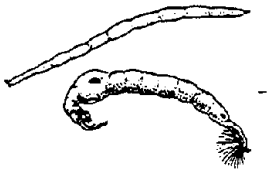
Water scorpion (adult)



Black fly larva

Aquatic Organism

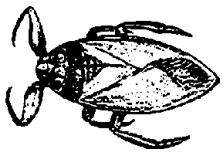
Midge larvae



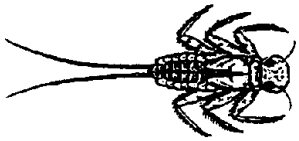
Water boatman (adult)

Backswimmer (adult)

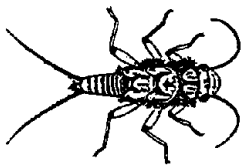
Giant water bug (adult)



Mayfly nymph



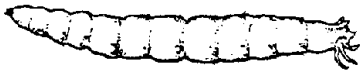
Stonefly nymph



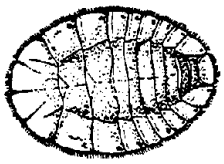
Caddisfly larva

Aquatic Organism

Crane fly larva

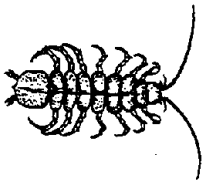


Water penny (beetle larva)



Scud

Aquatic sowbug



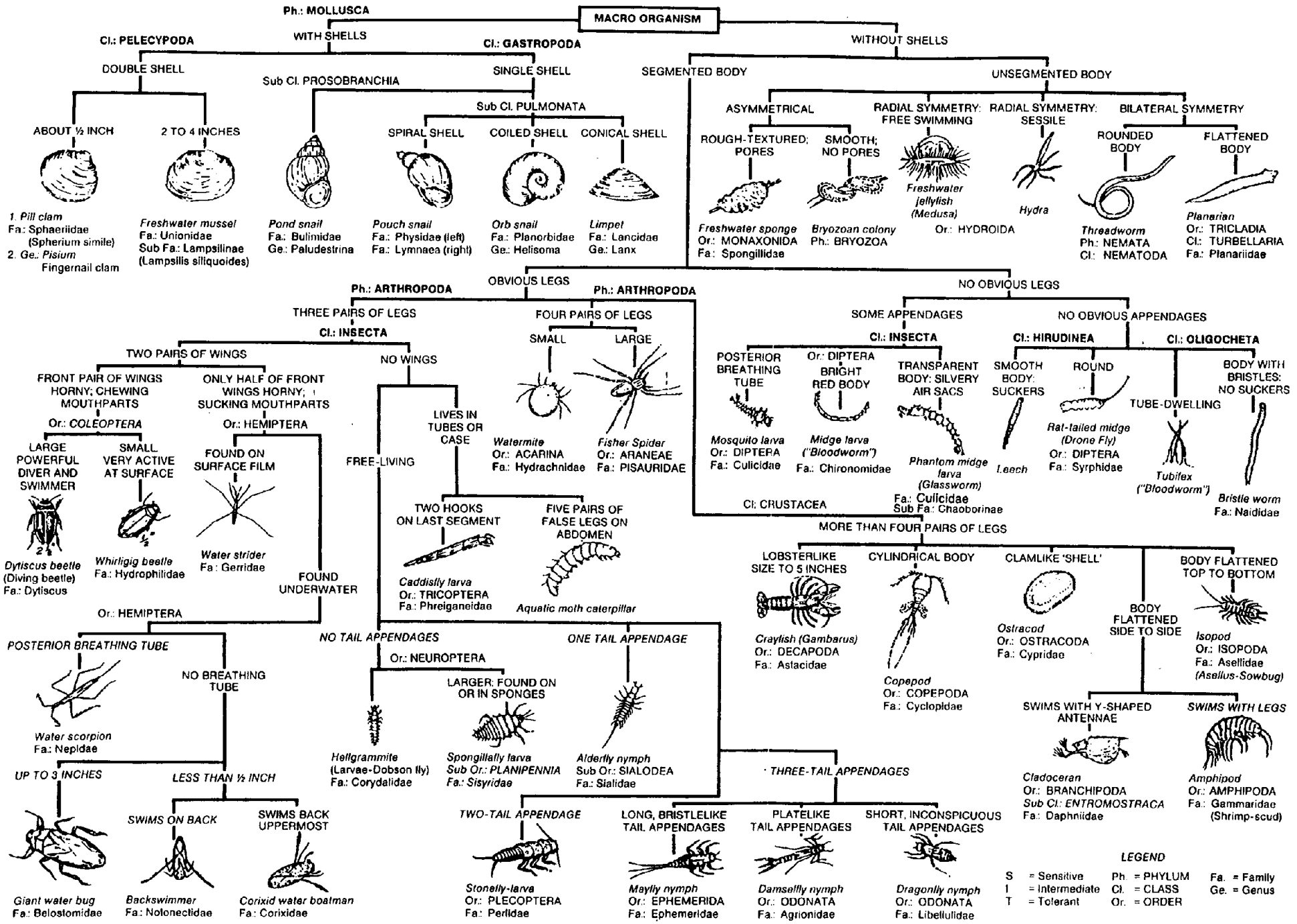
Mosquito larva

Water strider (adult)

Dobsonfly larva (hellgrammite)

Figure B-11

Key to the Major Invertebrate Species of Stream Zones.



USDA - Soil Conservation Service 4-28-75

Stream Web

Concepts: Living things within a stream are linked to each other through the transfer of energy (food) from one organism to another.
This interconnectedness helps maintain balance in a system.
Loss of one part of the system will impact other parts of the system.
Many connections at each level help minimize the impact of loss.

Objectives:
1. Students will identify organisms at the base of the food web.
2. Students will determine connections between organisms according to predator/prey relationships.
3. Students will hypothesize the impacts when part of the web is removed.

Materials:
- natural history information about aquatic life (See References and Resources)
- markers
- large index cards
- tape
- chalkboard and chalk - WEB I
- a ball of yarn or string - WEB II

Subjects: Science, Social Studies

Preparation and Procedure:

There are a number of ways to conduct this activity. Two of them are outlined here.
Write each of the following words on a large index card.

Organism/Energy Cards
SUN
BACTERIA & FUNGI
NUTRIENTS (optional depending on student's understanding.)
PHYTOPLANKTON
"SLIMY" ALGAE
WATER CRESS
DETRITUS
ZOOPLANKTON
MAYFLY NYMPH - can be scrapers or gathering collectors
STONEFLY NYMPH - can be shredders or predators
CADDISFLY LARVA - can be shredder, scraper, or predator
BLACKFLY LARVA - filtering collector
SCAVENGER BEETLE
DRAGONFLY NYMPH - predator
MIDGE - gathering collector
FROG
JUVENILE TROUT
TURTLE
CRAYFISH
MUSSEL
ATLANTIC SALMON
KINGFISHER
OSPREY

Event Cards
FLOOD
DROUGHT
STREAMBANK EROSION
DAM
PESTICIDES
EXCESSIVE FERTILIZERS
STREAMSIDE TREE REMOVAL
OVERHARVESTING

WEB I - Start the activity with a discussion of producers, consumers, and decomposers in streams and rivers. Then, have each sudent select an organism/energy card. Provide a number of resources for them to determine where their organism lives, what it eats, and what eats it. Once they have found out the information, start with the sun, follow with producers, and so on. Then have each student attach their card to the board. Then have them draw an arrow to it from any of its energy sources. After every card is placed try adding an event card, discuss potential impacts, and adjust the organism cards accordingly. What are the results of a small variety of organisms at each level on the web overall? How about a wide variety?

WEB II - Start the activity with a discussion of producers, consumers, and decomposers. Have each student select an organism/energy card and sit in a circle so all cards are visible. Start by asking students which organisms rely directly on the sun for their energy. The student holding the sun card starts by holding the end of a ball of yarn or string that is passed to each producer. From each producer, pass the ball of yarn to each organism that relies on that producer. Once all the producers have been identified, continue with the next level of organisms. Use the event cards to discuss possible changes and their impacts, have impacted organisms let go of the yarn. Do the remaining connections still hold or do they fall apart as well? What are the results of a small variety of organisms at each level on the web overall? How about a wide variety?

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To borrow Stream Study Kits or obtain information on buying or making equipment, contact:

UNH Cooperative Extension - Water Resources
Pettee Hall
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(603) 862 - 1029

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Complete and Incomplete metamorphosis
Sayre, Tamara. *Pond and Stream Safari: A Guide to the Ecology of Aquatic Invertebrates.* Ithaca: Cornell University Cooperative Extension, 1993

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River Continuum Concept
Cummins, Ken. *"From Headwater Streams to Rivers", The American Biology Teacher, May 1977, p. 306.*

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Water penny beetle larva and adult, Dobsonfly larva and adult, Midges
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Caddisfly larvae
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