Stream Ecology

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Cover: Cedar Creek, a rocky limestone stream in Chase County.

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Stream Ecology

by Carl Prophet

INTRODUCTION

It is well known that ecological resources essential to the maintenance of life on this planet, such as water, oxygen and carbon, are recycled again and again over time. If the movement of water through the environment is traced, its path ultimately returns to the starting point. The descriptions of this path and the main biological uses and physical processes that happen along the way are known as the water cycle.

The oceans are the main reservoirs for the world's water supply. The physical processes, evaporation and precipitation, are driving forces for this cycle. Water evaporates from the sea, and the water vapor is carried along by atmospheric currents. When the vapor condenses, precipitation in the form of rain, ice or snow takes place. Only a fraction of the total precipitation that occurs during the course of a year takes place over land, and that amount is not distributed evenly. The moisture that does not immediately soak into the soil becomes runoff to nearby streams in a given drainage basin. The water eventually flows into a major river which drains into the ocean. The journey is completed and the cycle is repeated. Numerous other events and processes are involved in the water cycle, but the focal point here is that in the water cycle, streams are the vital link between land and sea.

Historically, streams and rivers played an important and vital role in the western expansion and development of the United States. Rivers often served as highways for early explorers and adventurers entering territories previously unsettled by European colonists, and later they were used to transport commerce between the frontier settlements and the large population centers in the East. Today, huge quantities of goods and raw materials continue to be moved on many of our nation's large rivers by barge trains and even oceangoing ships. Flowing water has long been used to provide power. Before the days of steam and electricity, the force of flowing water was used to power the mills that ground our grain. Early maps often identified the locations of mills, and remnants of mill dams and races can still be found on some streams in Kansas. Today, in many parts of the United States flowing water is used to generate electricity. Dams have been constructed on some of our nation's large rivers creating giant lakes for the storage of tremendous volumes of water. The impounded water is released periodically to drive huge turbines to generate electricity. In Kansas, electricity is generated primarily by the use of nuclear and fossil fuels, but water is still necessary for the generating process.

Our rivers and streams have served other important purposes. Water is essential for life. To survive and flourish the inhabitants of an area must have a nearby dependable source of water. It is therefore not surprising that as settlers moved into new territories their towns were often established on or near streams. This was certainly true in the case of the settlement of the Kansas Territory. There were few sources of surface water on the Kansas prairie other than streams. Sadly, as some communities grew the nearby streams became used as a convenient and inexpensive way of disposing of untreated human and industrial wastes. Ultimately, such practices had a devastating impact on the ecology of the receiving streams. Such practices continued

Old mill dam at Drury, Kansas. Remnant of mill race can be seen on far side of stream.

well into the middle of the Twentieth Century until state and federal environmental laws and enforcement began to reduce the problem. While important progress has been made, the battle to improve water quality in streams continues, and each of us has a role and shares the responsibility for accomplishing this goal.

There is little doubt that our rivers and streams are an important natural resource which have many values and uses, but one value of a stream that is frequently overlooked is its aesthetic value. Is there any person who has visited a stream setting and paused long enough to take in the scene who has not been struck by the unique natural beauty and the relaxing sounds of their surrounding? Sit quietly by a stream for a few minutes. Listen. The sounds of birds singing and water trickling over a shallow rocky bottom are relaxing and peaceful. Look closely and perhaps you will see some plant or animal new to you. Is there a value to these experiences? Of course there is.

STREAM COMMUNITIES

Ecologists use the term community to designate a group of different types of organisms associated in a certain physical setting. A pond, a forest, or a decaying log is each an example of a community. Each of these examples of a community is distinguished by its physical environment and by the types of organisms which live and interact there. As one can note from these examples, the size (area or volume) of a community can be either comparatively large or small. Technically, the ecological concept of community is a bit more complex than just described, but the basic idea is clear.

Ecologists whose main interest is focused on aquatic systems divide aquatic communities into two basic categories, lotic and lentic. Although other distinctions between them can be made the simplest way to think of these two terms is that one describes standing water and the other flowing water. A lake is an example of a lentic community. The water is retained for a time

Dendritic pattern of watershed streams.

within a basin and there is little visible movement of the water other than surface waves or ripples. A stream is a lotic community. The water flows down a channel from a higher to a lower elevation. The water moving past a given point along an unobstructed stream channel continues moving downstream and never circulates past that point again.

Streams come in all sizes and types. In Kansas, when first given an officially recognized name it was customary to designate large streams as rivers and their tributaries as creeks. All would agree that major streams are properly designated as rivers, but in different parts of the United States other terms such as brook or run may be applied to the name of a small stream rather than creek.

PHYSICAL CHARACTERISTICS OF STREAMS

The ecology of a stream is influenced by numerous features. A stream is an open system. That is, a stream is not isolated from its immediate surroundings. It receives runoff from its drainage which carries both suspended and dissolved materials into the stream. The quality of the water is impacted by the dominating geology of its drainage as well as the surrounding land use. It may be said that whatever goes on within a stream's drainage may ultimately affect the ecology of that stream. Rather than existing as individual isolated channels, streams within an area merge into a stream system. If one were to view a river drainage basin from above, it would become apparent that the many drainage channels within the basin form a **dendritic pattern** in which smaller streams join to form progressively larger streams as one moves downstream.

During the 1930s Robert E. Horton introduced a system for designating the rank of individual tributaries within a river system. For example, small streams that have no tributaries are designated as first order streams. A second order stream results when

Sauble Spring in Chase County is one of the sources of Cedar Creek.

two first order streams join, and a third order stream is formed by the joining of two second order streams, and so on. A second order stream may actually have multiple first order tributaries and so too may each of the higher ranked streams have multiple lower ranked tributaries. In general, the higher the order the greater the drainage basin of a stream. The Cottonwood and Neosho rivers above their confluence a few miles southeast of Emporia are fourth order streams, and below the confluence the Neosho River becomes a fifth order stream. The Mississippi River is classed as a tenth order stream. This is the highest order reported for any North American River.

Most Kansas streams originate instate. Some streams originate from the outflow from a large spring, and while springs do contribute to the discharge of many streams, most of their discharge is derived from surface runoff. Each stream within a system will have an individual watershed from which it receives runoff. When the soils within a watershed become saturated the surplus water begins moving downslope and is eventually collected in a stream channel. The water mass flowing down a stream channel does not flow as a uniform single current but rather as a turbulent flow. Depending upon the composition of the substrate the flowing water erodes the sides and bottom of the channel and constantly changes the physical features of the channel. Depending upon the dominating geological formations in an area, the substrate of a stream can be either sand, silt, gravel, or rock and cobble and combinations thereof. The type of substrate in a stream will control, to a degree, the kinds of bottom dwelling organisms that inhabit the stream. The geology and land uses in an area will also affect the chemistry of the stream.

Many streams exhibit an alternating succession of riffles and pools. Riffles are formed along reaches of a stream channel that cut across rocky ledges that are relatively resistant to erosion or reaches where there is a buildup of rocks and gravel. Here the water depth is shallow and the velocity higher than in deeper reaches of the stream. Large rocks and cobble may be strewn throughout the riffle area which causes the flow to be visibly turbulent. Pools form below riffles in areas where the substrate is more easily eroded and the gradient is perhaps less than that along the riffle's reach. The water is deeper and velocity less. Thus, riffles and pools represent two quite different microcommunities. Some stream organisms are found primarily in riffles and others are associated mainly with pool habitats. The lengths of individual riffle and pool reaches are highly variable, but their locations along a stream tend to remain relative stable for long periods of time. This pattern of riffle-pool-riffle is repeated throughout the length of most lower order

This stream channel is gradually moving to the left as the bank on the outer part of the meander is cut away as sand is deposited along the inner curve.

streams but may be less evident or even disappear in higher order streams. The pattern may also be less evident in sluggish sandy or silty streams, but even here the deposition of sand and silt bars and snags form barriers that may create pool and riffle areas.

Besides altering the physical appearance of a stream, riffle have other impacts on the ecology of a stream. The turbulent flow of water through a riffle aerates the water increasing the dissolved oxygen content of the water in unpolluted streams to levels that are higher than levels usually found in nearby ponds and lakes. The turbulence also increases evaporation which has a cooling affect and mixes dissolved chemicals throughout the water volume. Thus, not only are streams usually well oxygenated but they tend to be cooler and less prone to developing marked seasonal differences in temperatures and dissolved chemicals between surface and bottom than conditions often found in ponds and lakes.

Three types of stream channels are recognized: **straight**, **braided**, and **meandering**. Stream channels are rarely straight for long distances. In general, hydrologists consider a stream channel straight between two points if the distance the stream flows does not exceed 1.2 times the direct line distance. A straight channel will usually occur along reaches where the stream banks consist of erosion-resistant rock and/or where the gradient is extreme. A braided channel develops in areas where the channel becomes shallow and wide and the water velocity slows such that the sediment load can no longer be carried. The sediment is deposited in long narrow parallel bars that become cross-cut to form a network of intertwined channels. This type of channel is most likely to form in sandy or silty bottom streams. Most streams will exhibit a meandering channel in which it bends first in one direction and next in the opposite direction. Where the channel bends the velocity of the water flowing on the inside

Deepest part of channel (Thalweg) shifts from side to side as evidenced by this series of sand/gravel bars that were exposed along the Neosho River at Emporia during low discharge.

of the curve is lower compared to the outside of the bend. Because the lower the velocity the less suspended materials the water can carry, material is deposited on the inner curve creating a silt/sand or gravel bar. The higher velocity next to the outer bank undercuts that side of the channel resulting in the bend becoming more exaggerated. Eventually, the channel may loop back on itself and cut a new connecting channel. If the ends of the old meander become sealed by the deposition of silt and accumulation of detritus the result is an oxbow lake.

Hydrologists have learned that it is the nature of streams to form meandering channels over time. The water flowing down a stream channel does not flow as a linear, uniform current. Friction between the channel substrate and the water moving over it causes a sort of spiraling helical current. In fact the velocity of the very thin layer of water in contact with the substrate, the boundary layer, is virtually zero. Little or no current along the bottom is extremely important to many benthic organisms because they are not subjected to the effects of turbulence. Rather than moving downstream in a straight line the helical current moves in a serpentine fashion. As one moves downstream the deepest part of the channel, the thalweg, moves from side to side rather than staying in the middle of the channel. This flow pattern is often revealed along a relatively straight reach of a stream during periods of low discharge by the appearance of sand or gravel bars seemingly evenly spaced and alternating from side to side of the channel. It is clear that a stream is a dynamic system.

The flow in most of the major streams in Kansas has been interrupted by the construction of large dams and reservoirs. Most of these structures were created for flood control purposes. Gradual drawdown of the impounded water helps maintain downstream flow during periods of low runoff. Even with these dams in place the annual discharge in Kansas streams tends to be highly variable. Runoff following storm events may result in bank-full to flood conditions. Such storm discharges greatly alter the stream community. The force of the storm discharge can move even large rocks down the channel and sweep away many of the stream organisms. However, the disrupted populations soon recover. Surface flow may cease in some small streams during periods of little or no precipitation with only a chain of isolated pools remaining along the channel. Although the stream bottom between pools may appear to be dry there may be water a few centimeters below the surface. Some organisms survive by burrowing down to the saturated substrate. If there is no input from springs and the period of drought long, small streams may become completely dry and the organisms inhabiting them perish. Obviously, organisms inhabiting a stream community face many challenges.

Chikaskia River is mostly a sand/silt bottom stream in Sumner County.

BIOLOGICAL FEATURES OF STREAMS

If anyone were asked to name some examples of animals that could be found in a Kansas stream, it is highly probable that the examples given would include fish, frog, turtle, crayfish or clam in some manner or the other. Certainly, each of these groups of animals is well represented among the stream **macrofauna**, but they represent only a fraction of the many diverse organisms present which play an important role in the ecology of a stream. If noticed at all, many other types of animals commonly found in a stream are often dismissed as some kind of worm or bug and therefore of little value. Yet, when carefully studied, each creature reveals something about how it meets the challenges of its environment and where it fits in the web of life in a stream.

Ecologists have a term for everything. To draw attention to differences in their spatial distributions and modes of life the various organisms inhabiting an aquatic community may be grouped into one of several categories Large aquatic animals such as fish that can orient and actively swim against the water currents are collectively termed **nekton**. Conversely, microscopic organisms with relatively limited or no powers of locomotion and which are suspended in the water column are known as plankton. Plankton may be further divided into either **phytoplankton** or **zooplankton**. In general, plankton is less diverse and less abundant in lotic systems than in lentic systems. This condition is especially noticeable in low order streams. Organisms that are associated with the substrate in an aquatic habitat are known as **benthos**. Invertebrates which are found on the bottom of a stream and which are visible with the naked eye are collectively known as **benthic macroinvertebrates**. The **neuston** consists of organisms which move about on or just below the surface of the water.

Many kinds of benthic invertebrates can be found on the surfaces of large rocks taken from a riffle in a limestone stream.

Depending on behavior and life cycle stage some aquatic organisms may fit into more than one of the above described categories at different times. It is also possible to recognize additional subdivisions, but greater detail is unnecessary for our purposes. The point of interest here is to emphasize that each member of the biota occupies a specific physical position within the community that in turn enables it to utilize the ecological resources in varying ways. The end result is a more diverse and efficient biological community. Because there are distinct differences in the physical conditions between lentic and lotic communities there are some distinct differences in the diversity and relative abundance of the organisms in each of these categories.

It was previously mentioned that, to a large extent, the physical features of a stream greatly influence the types of organisms which inhabit them. For example, there are some obvious differences between the species composition of fishes and benthos inhabiting a sandy stream and those found in a rocky limestone stream. Mussel populations in a limestone stream tend to be more diverse and more abundant than in either a sandy or silty stream. Macroinvertebrates dominate the benthos in limestone streams while microscopic burrowing forms are abundant in silty streams. If a sample of the substrate from a sandy stream is examined microscopically, an abundance of tiny animals may be found which live in the spaces between the sand grains. Aquatic ecologists term these types of organisms psammon. Most people are probably unaware that such creatures exist.

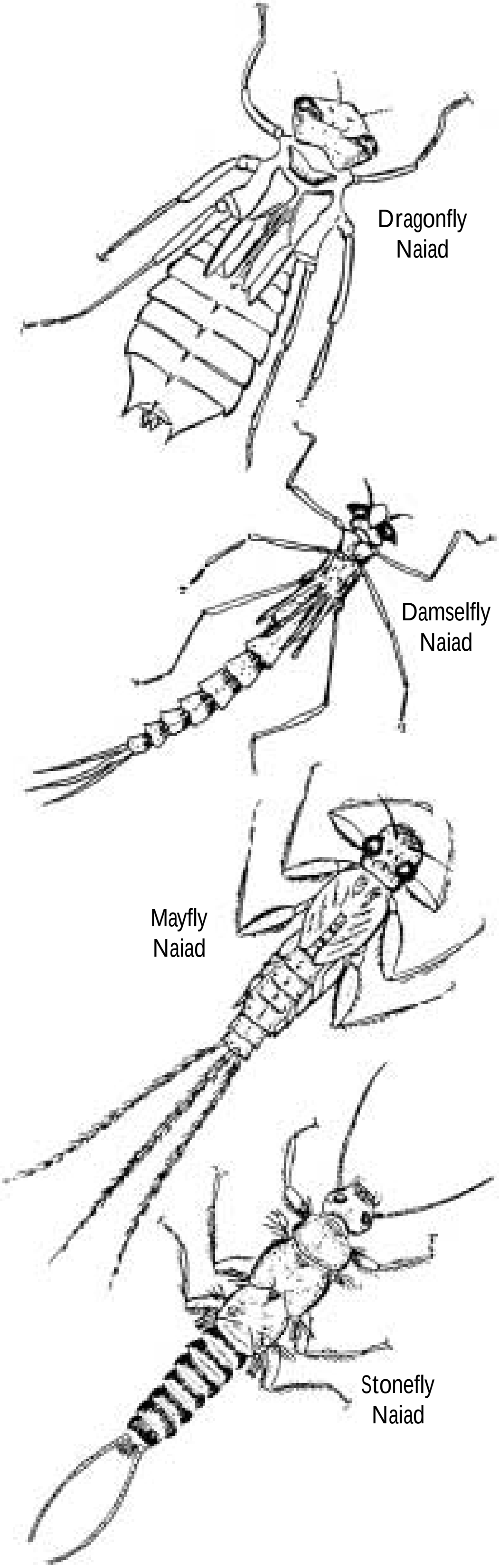
Benthic organisms are vital links in stream food webs, the complex pathways whereby energy is passed from lower to higher levels in an energy pyramid. Some species filter or strain tiny suspended organic particles from the water thereby converting some of this potential energy into their bodies. When a filter feeder is eaten by a predator some of the energy represented by the suspended organic material is transferred to the next level, and so on. A significant part of the total energy moving through a stream is derived from allochthonous (outside) sources. In other words, it enters as organic material washed into the stream from its watershed and as leaf fall from bordering riparian woods. Some aquatic ecologists have shown that the breakdown of a leaf is brought about by the combined efforts of many different micro-organisms and benthic macroinvertebrates. Feeding as shredders and scrapers, many of the macroinvertebrates help reduce big pieces of organic matter into smaller and smaller particles which, in turn, may be utilized by collector (filter and strainer) feeders and which can be more rapidly reduced by decomposer microbes.

COMMON GROUPS OF STREAM ORGANISMS

It is impossible in the limited space available here to discuss all of the organisms that inhabit streams. The groups of organisms that are described here were selected for several reasons. First, they tend to be common and abundant in many streams. Next, they can easily be collected and recognized by the novice; and finally, they show special features that enable them to live in specific microhabitats within a stream community. Also, their presence or absence tells us something about the quality of the stream environment. Many types of aquatic organisms were omitted or mentioned only briefly because they require special equipment to collect and/or identify. Others, like fishes and freshwater mussels, were omitted because they have either been the subject of past issues of *The Kansas School Naturalist* or will be covered in future issues.

About half of the fifteen orders of insects includes some species which spend a part of their life cycles in an aquatic environment. The Odonata (damselflies and dragonflies), Ephemeroptera (mayflies), Trichoptera (caddisflies) and Plecoptera (stoneflies) are aquatic for all but the adult stage of their life cycles. These four orders of insects are well represented in the benthic macroinvertebrate community of most streams. Mayflies, dragonflies, damselflies, and stoneflies exhibit many similarities in life cycles. The egg hatches as a feeding and growth stage which in these three orders is known as a naiad. Each naiad passes though numerous instars (individual growth stages) and gradually becomes more and more adultlike. The final instar is the adult. This pattern of development is known as gradual metamorphosis.

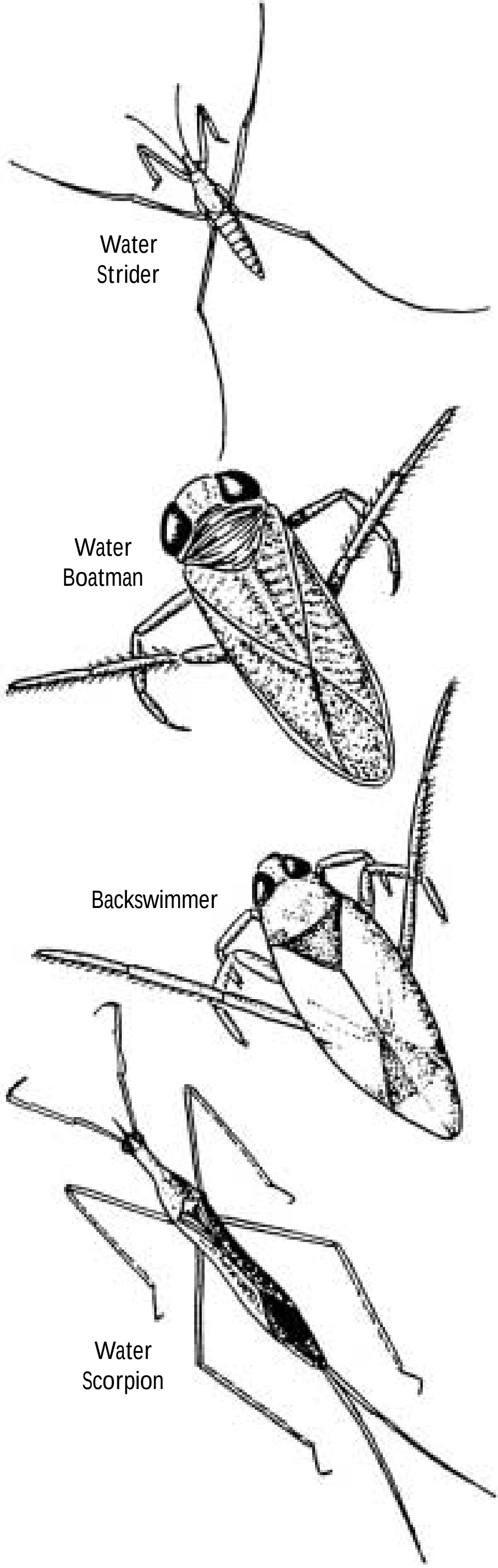
Naiads of stoneflies, mayflies and damselflies have elongated bodies which are divided into three general regions, the head, thorax, and abdomen. Mouthparts are adapted for chewing. Mayflies are thought to be mainly herbaceous and stoneflies and damselflies are predaceous. In addition, a pair of compound eyes and a pair of antennae are conspicuous on the head. Wing buds are usually absent during the early instars but develop on the dorsal surface of the thorax in later instars. Three pairs of jointed slender legs which are adapted for clinging and crawling are attached ventrally to the thorax. The elongated abdomen is divided into numerous segments. In the stoneflies and mayflies the most distal or caudal abdominal segment usually bears two (stonefly) or three (mayfly) filaments; in damselflies these caudal appendages are modified into three leaf-like tracheal gills. Except for the last two or three segments, the mayfly naiad bears a pair of lateral gills on each segment of the abdomen. In stoneflies, a tuft of gills is present at the base of each of the thoracic legs. Naiads of some species of mayfly dig into soft sediments, but instars of all three orders can be picked from the surfaces of large rocks and other submerged objects in riffles. The flattened bodies of most species enable them to occupy the boundary layer thus preventing them from being washed away by the turbulent flow.



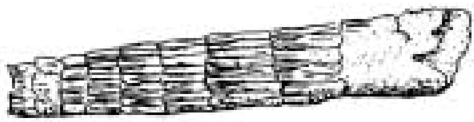
Dragonfly naiads can be distinguished from other types of naiads by the absence of external gills plus, with few exceptions, their more square-shaped body. There are no caudal filaments or gills. Gills are present in a special gill chamber within the modified rectum. The labium of both dragonflies and damselflies covers the other mouth parts when folded; extended it may approach a quarter of total body length or more. Dragonfly naiads often hide in the bottom detritus and sediments but, like the other naiads may also be found crawling on submerged objects. Some species of each of these orders of insects require more than one year to complete their life cycles. Adults of the Odonata and Plecoptera are carnivorous and are relatively long-lived. Conversely, mayfly adults usually survive only a few days, or just long enough to reproduce. The presence of a diversity and abundance of the naiads of these three orders in a stream is a good indication of relatively clean water conditions.

Water striders, water scorpions, water boatmen, backswimmers, and giant water bugs are examples of Hemiptera (True Bugs) associated with aquatic habitats. In streams these hemipterans are most commonly found in pools and other areas of quiet water. The Hemiptera undergo gradual metamorphosis but, unlike the mayfly, the egg hatches into a nymph which resembles the adult except for its body size and the absence of wings. Nymphs have the same feeding habitats as the adults. Water striders run across the water surface on three pairs of long, spider-like legs. They feed on small insects that fall in the water and may even leap from the surface to capture prey. Water boatmen and backswimmers look somewhat alike. Their hind legs are enlarged and adapted for swimming in a rowing fashion. Backswimmers tend to be larger than the boatmen and as the name implies they swim through the water on their backs. Backswimmers use their piercing mouth parts to feed on small animals; and you can get your fingers stabbed if you hold them for long in your closed fist. Water boatmen are more darkly colored than backswimmers and swim upright. They feed on the bottom ooze. Both periodically swim to the surface for air and then dart back to the bottom. Giant water bugs (toe-biters) are active predators and will feed on any small animal that can be captured. The female deposits the eggs on the dorsal surface of the male where they stay until hatched. As their name implies, these bugs are large, sometimes approaching 5 cm in length. Water scorpions will usually be found just below the water surface clinging to submerged objects by the hind two pairs of legs and quietly awaiting for prey to come within reach. The first pair of legs are raptorial and extend forward. The body is slender and ends in a tube structure which when extended above the surface is used for air exchange. They resemble the better known walking stick.

Several other insect orders also include species that can be found in streams. In general, these types of insects undergo complete metamorphosis. The egg hatches as a larva. This type of feeding stage in no way resembles an adult. There is no trace of wings and compound eyes are absent. The body shape is variable but may generally be described as wormlike. The body is usually soft or weakly sclerotized. Legs and/or prolegs may be present or absent. Mouth parts are variously adapted for chewing, shredding, filtering or sucking. The final larval instar forms a pupa by constructing a protective covering or case. During the pupal stage the individual is transformed into an adult.



Larvae of the Order Trichoptera (Caddisflies) are a common and abundant example of stream benthos which undergo complete metamorphosis. Trichopteran larvae often coat the surfaces of large rocks in riffles as well as other submerged objects. Many types of these larvae are master builders, using a variety of materials to construct cases in which the individuals live. Grains of sand or pieces of plant material and detritus are cemented together to form the case. The size and shape of the case as well as the kind of construction material used to build the case are characteristic of different families of caddisflies. Not all caddisflies build a case. Some types build rather elaborate funnel-shaped nets of silk which strain food particles from the flowing water, and other types are free-living. Feeding habits vary from carnivorous to herbivorous.



A hellgrammite is the larva of the Dobson fly (Order Neuroptera). These larvae are often 4-6 cm in length and can be found under large rocks in riffles. They are carnivores as evidenced by the large opposing mandibles which can give a hard pinch if your fingers get in the way. Prey is small invertebrates. The body is heavily sclerotized and three pairs of large legs are present on the thorax. The last abdominal segment bears a pair of large recurved hooks or anal legs which help hold the individual in place. The other abdominal segments exhibit a lateral unbranched appendage on each side. These larvae are sometimes used as fish bait.

Larvae of several families of the Order Diptera (flies) are common in some streams. Two groups will be mentioned, midges and black flies. Like caddisflies the dipterans undergo complete metamorphosis. Adult midges are often mistaken for mosquitoes, but unlike the latter, do not bite. Emergence is synchronized so that swarms of adults can be observed around aquatic habitats throughout much of the year. The small adult black fly is also known as a buffalo gnat, and the female can deliver a painful bite. The larval stages of these dipterans are aquatic. Black fly larvae are about 5-10 mm in length, dark colored, and the distal abdominal segments are distinctly swollen. These larvae attach to the substrate by a sucker-like disc on the last abdominal segment. They mostly inhabit clear streams and are most likely found on rocks in riffles or other reaches of relatively fast flowing water. Sometimes the larvae and/or pupae are so numerous that they appear to carpet the bottom. Two other features can be noted. There is an anterior pair of prolegs and a fan-like process on each side of the mouth strains or diverts small food particles towards the mouth. Midge larvae have an elongated body that is of uniform thickness from end to end. Prolegs are usually present, an anterior pair and a posterior pair. Many species spin silky tubes which are attached to submerged objects. The larva lives inside the tube and

Caddisfly cases attached to sides of a floating log.

extends the anterior part of the body to feed. Some species burrow into the soft sediment, some are red colored due to the presence of hemoglobin and are called blood worms.

Whirligig beetles are familiar to almost anyone who has spent much time around streams or ponds. In streams, the adult whirligig beetles are found in groups on the surface in areas of slow currents. They have a shiny black body and rapidly "swim" about on the surface of the water in an erratic pattern yet avoid slamming into each other. Netting the adults is a challenge. The larvae which are predaceous actively move about on and within bottom detritus. The adult predaceous diving beetle, or dytiscid, is semi-aquatic, which means it is not adapted for obtaining oxygen directly from the water. The adult must periodically swim to the surface to replenish its air supply. Its dark colored body has a yellowish stripe along the edge of the wing covers. The body length may reach 2 cm. The larval diving beetle is an actively hunting larva that is sometimes called a water tiger. These are but two of the many types of beetles that as either adult or larva inhabit our streams.

The examples described here just scratch the surface of the myriad organisms that inhabit Kansas streams. Many interesting discoveries await any person curious enough to wade into a stream, pick up a submerged rock or other object and carefully look at what is there. You will surely be amazed at what you see.

Planet Earth: Rivers and Lakes. Time-Life Books, Alexandria, VA.

How to Know the Immature Insects. Wm. C. Brown Co., Dubuque, IA.

Freshwater Benthos. *The Kansas School Naturalist*, 24(3)

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