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A Resource Guide for Big Hole River Communities

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BIG HOLE RIVER FOUNDATION

# ECOLOGY OF AQUATIC INSECTS

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Inside this issue:



A salmonfly (*Pteronarcys californica*) emerges on the Big Hole River, Montana. Michael A. Bias photo.

A number of conservation practices can be implemented by private landowners or managers to improve their land and water management. The Technical Guidance Series seeks to explain the ecology underlying these practices, the importance of these practices, and how to implement these practices on your property. The purpose of this issue is to give you, the reader, a basic understanding of the ecology and importance of aquatic insects to the health of the river ecosystem.

Macroinvertebrates are organisms that are large enough to be seen with the naked eye (macro) and lack a backbone (invertebrate). Most live part or most of their life cycle attached to submerged rocks, logs, and vegetation on the stream bottom, in what's known as the benthic layer. Benthic macroinvertebrates, then, are those larger invertebrates that live on the bottom, or substrate, of streams and rivers.

Benthic macroinvertebrate communities, comprise all the organisms, primarily aquatic insects, in an area of a stream. Aquatic insects, those that pass part of their life cycle in the water, can provide insight into quality of the water in which they live. Typically the immature life stages of the insect are aquatic and the adult stage is terrestrial. Ten of the 30 Orders of insects are classified as aquatic. The tremendous diversity of species comprising aquatic insect communities makes them good indicators of stream health and water quality.

Aquatic insects have important roles in food webs, acting as decomposers and consumers of aquatic plants. Many are in turn consumed by crayfish, fish, and other predators (Gratton 2012). Aquatic insects are a critically important link in stream food webs. They gather and process organic matter such as pieces of aquatic and terrestrial plants that fish cannot use, but the fish in turn feed on the insects. If aquatic macroinvertebrate populations decline or disappear, the entire food web they are a part of will suffer consequences (Cooperman 2014). Aquatic insects can also be important parts of food webs on land when they emerge from the water and fly over land to find mates. Aerial terrestrial forms can become food for predators like spiders, lizards, birds, and bats (Gratton 2012).

## AQUATIC INSECT ORDERS

There are more than a million species of animals in the world, and 95% of them are invertebrates. Within insects alone, about 900,000 species have been described. The study of organisms requires a scheme for classifying them. This scheme organizes living things into groups of similar organisms that can be distinguished from other groups of organisms. The main categories of groups used for classifying living things are Kingdom, Phylum, Class, Order, Family, Genus, and Species (Voshell 2002). Following are the major groups (Orders) of aquatic insects found in the Big Hole River, Montana.

**Ephemeroptera.** The Mayflies are well known to fly fisherman because they are one of the favorite foods of trout when they emerge as adults. Most of their lives are spent as nymphs living sometimes for several years under the water before emerging as adults to mate and lay eggs in a few hours or at most a few days. This order derives its name from the "ephemeral" nature of the insects' adult life. Mayflies are the only insects known to molt after reaching a winged form. After emerging from the water they live briefly as a winged form called a subimago (dun) which molts again to the adult form (spinner) (Klekowski and Klekowski 1997). The most common mayflies detected from surveys in the Big Hole River were blue-winged olives (*Baetis* sp.), pale morning duns (*Ephemerella* sp.), a crawler mayfly (*Heptagenia* sp.), March browns (*Rhithrogena* spp.), and tricos (*Tricorythodes* sp.) (Big Hole River Foundation (BHRF), unpublished data).

Blue-winged olive mayfly (*Baetis tricaudatus*), Jason Neuswanger photo, Troutnut.com.

**Odonata.** Odonata are the dragonflies and damselflies. They are all predators, both as nymphs and adults. Odonate nymphs have unusual mouthparts that can be extended to capture prey. These are ancient insects that have been around since before the age of the dinosaurs (Klekowski and Klekowski 1997). A snaketail dragonfly (*Ophiogomphus* sp.) has been the only Odanata detected from macroinvertebrate surveys in the Big Hole River (BHRF, unpublished data).


Dragonfly nymph (Gomphidae), Jason Neuswanger photo, Troutnut.com.

**Plecoptera.** Plecoptera are the stoneflies. Another ancient order, the stoneflies prefer colder, fast-running water. The nymphs of stoneflies look very much like the adults with the exception of the wings, which are not present in the nymph (Klekowski and Klekowski 1997). Sallflies (*Suwallia* sp.), golden stoneflies (*Hesperoperla pacifica*), sallies (*Isoperla* sp.), Skwalas (*Skwala* sp.), salmonflies (*Pteronarcys californica*), and giant stoneflies (*Pteronarcella badia*) were the most common

Golden stonefly nymph (*Acroneuria* sp.), Jason Neuswanger photo, Troutnut.com.

stoneflies detected from macroinvertebrate surveys throughout the Big Hole River (BHRF, unpublished data).

**Hemiptera.** The majority of aquatic Hemipterans (backswimmers, water boatmen, and water striders) are predators. They possess raptorial forelegs and sharp piercing mouthparts. These insects usually occur where the water is slow-moving and emergent vegetation is present (Klekowski and Klekowski 1997). Water boatmen (Corixidae) were the most common Hemipterans that occurred in the Big Hole (BHRF, unpublished data).

Water boatmen (Corixidae), Jason Neuswanger photo, Troutnut.com.

**Megaloptera** and **Neuroptera.** These large insects, commonly known as alderflies or dobsonflies, can be quite striking both as larvae and as adults. The immature form of the dobsonfly is what fishermen call a "hellgramite". These fierce larvae can be over three inches long and are equipped with strong mandibles with which they can deliver quite a pinch. They are common in rocky, fast-moving areas of the river where they live by hunting down and eating other aquatic animals. When they become adults they still look formidable because many of the adult males have grossly exaggerated jaws. These however are mainly for show and cannot be used to pinch like the jaws of the larvae can (Klekowski and Klekowski 1997). These orders were uncommon in the Big Hole River samples (BHRF, unpublished data).


Hellgramite larvae (*Corydalus* sp.), Jason Neuswanger photo, Troutnut.com.

**Trichoptera.** The common name of the Trichoptera is "caddisfly," which means case-bearer. Many of these insects build protective cases from various materials they find in the river such as stones, twigs, leaves or sand (Klekowski and Klekowski 1997). The Mother's Day caddis, a humpless casemaker caddisfly (*Brachycentrus* sp.), snail-case caddisflies (*Helicopsyche* sp.), net-spinning caddisflies (*Cheumatopsyche* spp.), and little brown sedges (*Lepidostoma* sp.) were the most common caddisflies throughout the Big Hole River (BHRF, unpublished data).

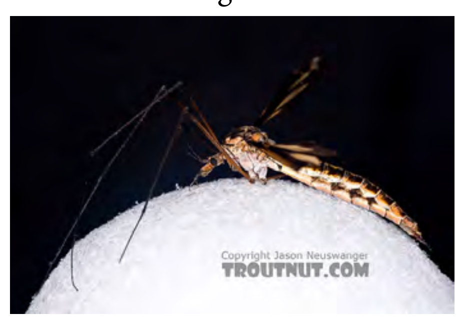
Adult Mother's Day caddis (*Brachycentrus* sp.), Jason Neuswanger photo, Troutnut.com.

**Lepidoptera.** There are only a few Lepidoptera, the butterflies and moths that are truly aquatic (Klekowski and Klekowski 1997). They are uncommon in the Big Hole River.

**Coleoptera.** Coleoptera is latin for "shield-wing." Beetles have the front wings modified into hardened covers which shield the rear wings from damage. Flying beetles use only their rear wings to fly (Klekowski and Klekowski 1997). Riffle beetles (*Optioservus* sp. and *Zaitzevia* sp.) were the most abundant beetles that occurred in the Big Hole River (BHRF, unpublished data).

Adult riffle beetle (*Zaitzevia* sp.), Bugguide.net.

**Diptera.** Diptera means "two wings" and this name refers to the true flies. These include the Tabanids, which are the horseflies and deerflies, the Culicids, or mosquitos, and the Simuliids, the biting blackflies (Klekowski and Klekowski 1997). Chironomidae (midges) and Tipulidae (craneflies) were the most common Dipterans that occurred in the Big Hole River (BHRF, unpublished data).




Adult cranefly (Tipulidae), Jason Neuswanger photo, Troutnut.com.

## LIFE HISTORY

Nearly all insects hatch from eggs and then undergo various stages as they develop into adults. The process of changing form during the life cycle is called metamorphosis, which can be either complete or incomplete.

Insects having incomplete metamorphosis pass through three distinct stages of development: egg, nymph, and adult (Figure 1). The Orders of aquatic insects with incomplete metamorphosis include mayflies (Ephemeroptera), dragonflies and damselflies (Odonata), stoneflies (Plecoptera), and water bugs (Hemiptera) (Hafele and Roederer 1995).

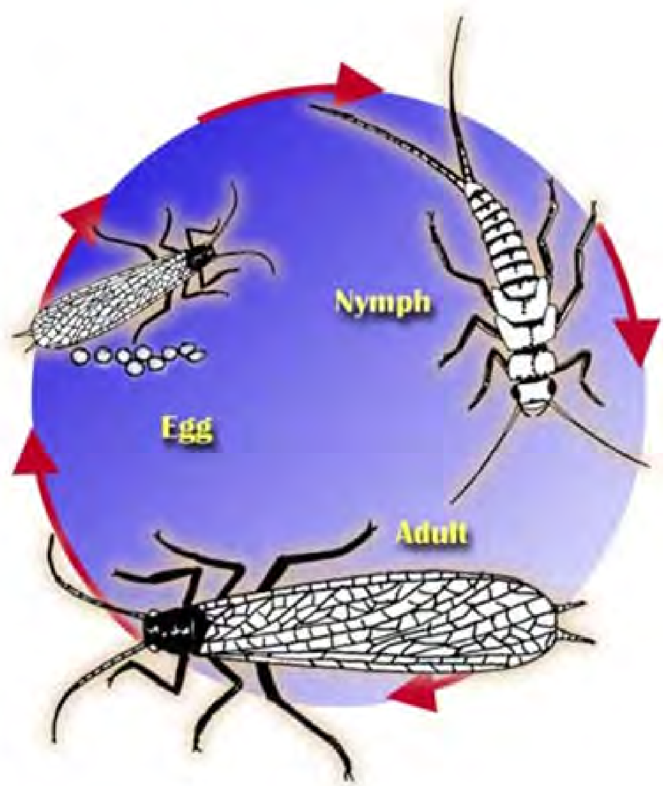



Figure 1. Stoneflies (Plecoptera) are one of the aquatic insect Orders with incomplete metamorphosis. This life history pattern has immature forms that are insect-like. Adult characteristics develop gradually through the nymphal developmental stages (instars), and wings dry in the final molt to the adult form (image from www.kidfish.bc.ca/frames.html).

Insects having complete metamorphosis pass through four distinct stages of development: egg, larva, pupa, and adult (Figure 2). Unlike nymphs, larva bear little resemblance to their adult stage. The Orders of aquatic insects having complete metamorphosis include dobsonflies and alderflies (Megaloptera), caddisflies (Tricoptera), aquatic moths (Lepidoptera), true flies (Diptera), and aquatic beetles (Coleoptera) (Hafele and Roederer 1995).

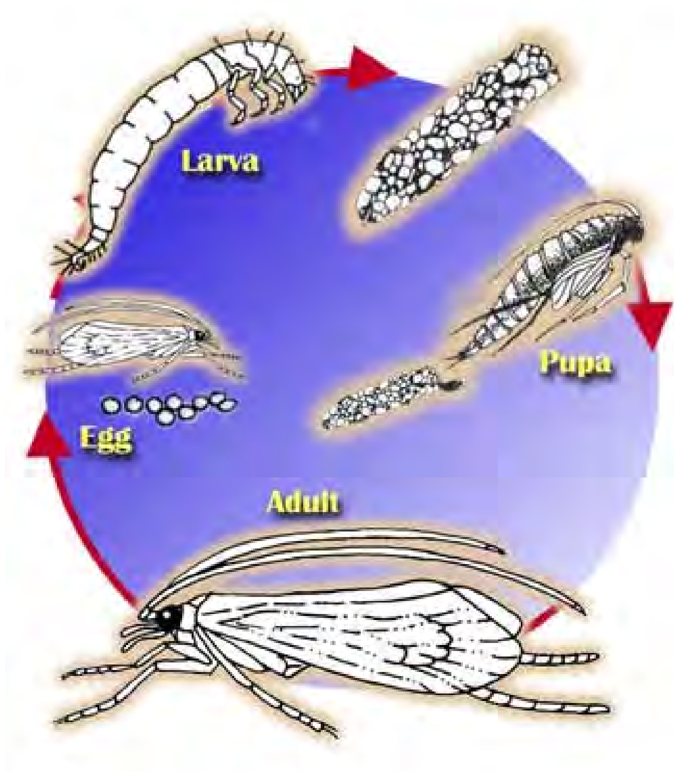



Figure 2. Caddisflies (Tricoptera) are one of the aquatic insect Orders with complete metamorphosis. This life history pattern has several larval instars that are less insect-like. Adult characteristics develop as a result of radical restructuring of the anatomy and physiology during the pupal instar stage (image from www.kidfish.bc.ca/frames.html).

Virtually all aquatic insects have a terrestrial adult phase. Mating usually occurs outside of the aquatic environment, and most species lay eggs on or in the water. Typically, the aquatic stage dominates the life cycle of aquatic insects; the adult stage is very short. However, the winged terrestrial adult phase is often important for dispersal and provides for re-populating upstream locations and for reaching new watersheds. Larval insects also can move substantial distances via drifting with the current or other means (Hershey et. al. 2010).

**Habitat.** Freshwater aquatic insects occupy very diverse habitats, although not all species of aquatic insects live in all types of freshwater habitats. The most favorable habitats are the edges of ponds and lakes and in the riffle sections of streams. In both standing and flowing freshwater habitats, the greatest diversity of aquatic insects is found in water less than three feet deep (Voshell 2009).

Because aquatic insects are small and highly specialized, they are often found in small areas with similar features, called microhabitats. Microhabitats include cobble (rocks about the size of your fist); gravel; sand; muck; accumulations of dead leaves and twigs; live plants; and grasses and tree roots that extend into the water from land. Different microhabitats, with different aquatic insects living in them, can occur in close proximity to each other (Voshell 2009).

Eight categories of aquatic insects have been recognized based primarily on the substrate or microhabitat they occupy (see Figure 3). The first four groups remain associated with the substrate for most of their lives. *Burrowers* and *crawlers* inhabit fine sediments where they either tunnel into or remain on top of the sediments, respectively. *Climbers* move along the stems of aquatic plants or pieces of detritus. *Clingers* attach themselves to the surfaces of substrate exposed to moving water, such as rocks in streams or wave-swept lakeshores. The final four groups spend part, or most, of their lives moving through or on the water. *Swimmers* periodically propel themselves through the water to change location, although they mostly remain attached to a substrate. *Divers* divide their time between swimming to the surface and then returning to the substrate, and clinging to submerged objects. *Skaters* live on the water surface, where they use hydrophobic (i.e., water-repelling) body parts to move over the water. *Planktonic* forms drift or swim about in open water (Hershey et. al. 2010).

Aquatic insects can live in temporary habitats, such as small streams or ponds that dry up in the summer. If they are adults, they can simply fly to anoth-


Jason Neuswanger photo, Troutnut.com.

Robert Newell photo, Troutnut.com.


Jason Neuswanger photo, Troutnut.com.


Jason Neuswanger photo, Troutnut.com.

Figure 3. Four of the eight catagories of living among the substrate and in water are well-represented in the nymphs of mayflies (Ephemeroptera). Body forms of Ephemeroptera nymphs have adapted specifically for living among these various substrates. *Baetis* sp. (top left) are swimming nymphs and have developed a fusiform shape and paddle-like tail for swimming. The robust shape of the western green drake (*Drunella grandis*, top right) is perfectly suited for crawling along the bottom. All mayfly clingers, represented by the March brown (*Rhithrogena* sp., bottom left), belong to the Family Heptageniidae. Clinger nymphs, adapted for living in fast riffles, are flattened dorso-ventrally, possess prominent eyes on top of a broad flat head, and have relatively large plate-like gills. Although uncommon in Montana, burrowers are the largest mayflies in North America. Brown drakes (*Ephemera simulans*, bottom right) possess tusk-like mandibles, large digging forelegs, and large feather-like gills (Hafele and Roederer 1995).

er place with water. Some immature aquatic insects will burrow into the bottom where it is damp and go into an inactive state, something like animals hibernating over winter. However, most aquatic insects that live in temporary habitats are "programmed" to stay in their eggs, where they are protected, until the time of year when water is present (Voshell 2009).

**What do they eat?** The foods of aquatic insects are as diverse as the habitats in which they live. Although individual species of aquatic insects may only eat one type of food, all organic material in the water, living and dead, is a food source for some aquatic insect. Scientists categorize aquatic insects according to the method by which they obtain their food. The categories are called functional feeding groups, or FFGs (Voshell 2009).

*Scrapers* possess specialized mouthparts that remove algae growing on the surface of rocks or other solid objects. These mouthparts work like a sharp blade to remove the outermost layer of algae, which is very nutritious for those insects equipped to remove it (Voshell 2009).

*Collectors* acquire small pieces of decaying plant material, called detritus. Some use long hairs on their head or legs or silk nets to filter these small particles out of the water. Other collectors use their mouthparts to gather fine particles lying on the stream bottom (Voshell 2009).

*Shredders* have mouthparts that are designed to nibble off pieces of vegetation and grind up the material. Most aquatic insects shred decaying vegetation that has dropped off plants, primarily from riparian trees and shrubs growing at the edge of the water. Few aquatic insects feed on parts of live plants that grow under the water (Voshell 2009).

*Predators* feed on other living animals, primarily invertebrates, but some, like dragonfly nymphs, are large and strong enough to catch small vertebrates, such as fish and tadpoles. Predators often have special structures for catching and subduing their prey, such as strong jaws and sharp teeth, or a sharp beak, or spiny legs (Voshell 2009).

**Physical Environment.** The physical environment of aquatic ecosystems exerts substantial control over population abundances and hence community composition of insects. Within these habitats, important physical factors to aquatic insects include: dissolved oxygen concentration, water temperature, and type of substrate and water flow (hydrodynamics) (Hershey et. al. 2010).

*Oxygen.* All insects must obtain sufficient oxygen to drive their metabolic machinery. This presents a particular challenge for aquatic insects because water, even when saturated, contains much less oxygen than terrestrial environments (a maximum of about 15 parts per million (ppm) oxygen in water compared to over 200,000 ppm in the air). Seasonal and spatial variation in oxygen concentration greatly restricts the types and diversity of insects found in aquatic environments. Dissolved oxygen concentrations are highly variable over time and space, and oxygen may be totally lacking from some aquatic habitats (anoxic). Oxygen solubility is also temperature dependent, warmer water holds less oxygen than cold water (Figure 4). In most unimpacted streams, dissolved oxygen concentrations generally are near saturation and thus oxygen rarely limits insect diversity (Hershey et. al. 2010).

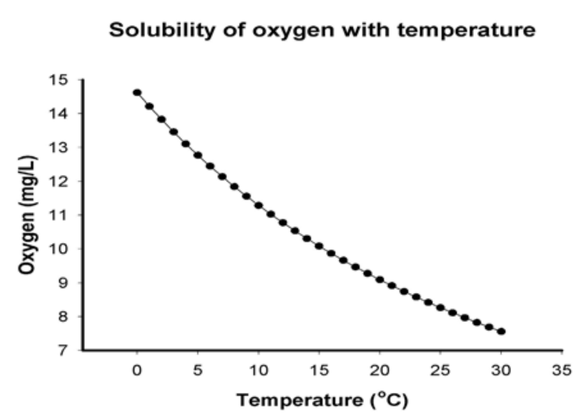



Figure 4. Relationship of oxygen solubility to water temperature.

Most representatives of the aquatic insect orders (e.g., Ephemeroptera, Plecoptera, and Trichoptera) possess gills in the immature aquatic life stages and achieve their highest diversity in flowing waters (Figure 5). Gills, however, rely on abundant dissolved oxygen for diffusion into the body, and thus gilled immature life stages can experience stress at low oxygen concentrations. Exposure to low oxygen


Figure 5. Thoracic gills on the nymph of *Pteronarcys biloba*, a stonefly (top) and abdominal gills on the nymph *Isonychia bicolor*, a mayfly (bottom) (Jason Neuswanger photos, Troutnut.com).

can occur in larger rivers with low turbulence (and therefore low aeration), especially at night when photosynthesis in plants stops. In these situations, the aquatic insect fauna will more closely mimic that found in oxygen-poor standing waters (many dipterans, for example). Some behavioral adaptations allow insects to survive periods of low oxygen in flowing water. For example, perlid stoneflies perform "push-ups" when oxygen declines, presumably to move more oxygenated water across their ventral thoracic gills. Burrowing mayflies of the genus *Hexagenia* undulate their body to draw water, and thus food and oxygen, through their burrows (Hershey et. al. 2010). And, nymphs of crawler mayflies, such as the western green drake (*Drunella grandis*), rhythmically pulse their abdominal gills.

*Water Temperature.* Water temperature also imposes constraints on aquatic insects. Temperature directly regulates their metabolic rates and thus development from egg to adult, and indirectly, by influencing such things as oxygen content in the water and how fast plants grow. Water temperature fluctuates both spatially and temporally. For example, lakes and deep pools in rivers can show marked temperature gradients from top to bottom, while rivers can show gradients in temperature from bank to bank and from the headwaters to the lower reaches. Streams also may exhibit pronounced daily temperature fluctuations, especially on sunny days. Shallow unshaded wetlands and stream reaches also exhibit large daily temperature fluctuations, ranging from subfreezing to tepid in northern wetlands (Hershey et. al. 2010). This is why in cold water fisheries, such as Rocky Mountain trout streams, stream or river channel width to depth ratio (W:D) is a powerful indicator of stream condition. Channels that are relatively deep and narrow have less surface area exposed to sunlight than those that are wide and shallow and therefore experience less solar heating (Cooperman 2014).

*Substrate and Water Flow.* At the microhabitat scale, substrate and hydrodynamics are probably the most important factors determining the types and abundance of aquatic insects present. Most aquatic insects spend at least part, if not most, of their life cycle associated with the substrate, and hydrodynamic forces interact strongly with substrate type to define the habitat available to the insect fauna (Hershey et. al. 2010).

## ENVIRONMENTAL STRESS

There are different types of disturbance that can occur in freshwater environments. Some are caused by human activities, while others are the result of the forces of nature. Pollution is the term most often associated with human-caused disturbances, but its meaning is restricted to substances or energy (heat) released into water that bring about undesirable changes. Environmental stress is a broader term that describes any action that brings about an undesirable change. Examples of environmental stress that do not fit the strict definition of pollution are reducing water supply, whether for irrigation or municipal supply; impounding a stream; and, vegetation removal, which eliminates shade and leaf fall. This broad concept of environmental stress is not limited to human activities; natural events such as floods and fires disturb aquatic environments (Voshell 2002).

Disturbance has been defined as any discrete event that disrupts population, community, or ecosystem structure, usually by changing resource abundance or the physical environment. Many types of natural and human-induced disturbances can disrupt the habitat, resources, or population densities and community structure of aquatic insects. Large-scale natural disturbances that can affect insects include: (1) floods, ice, or wave action that scour or remove substrates; (2) droughts that lead to drying of aquatic habitats; (3) watershed disturbances, such as wildfire and timber harvest, that can disrupt water, nutrient, and sediment inputs to streams and lakes for decades; and (4) seasonal events, such as summer or winter oxygen depletion. Many small-scale disturbances can also affect local insect populations. Human-related disturbances of aquatic insect habitats are at least as important and include: (1) point and nonpoint source pollutants that enter aquatic ecosystems from the land, connected water, or the atmosphere; (2) water withdrawal, diversion, and storage; (3) modifications of stream or river channel geomorphology and destruction of wetlands; (4) watershed disruptions, such as incorrectly implemented logging, unmanaged grazing, and other land uses; and (5) introduction and establishment of exotic species (Hershey et. al. 2010).

All these mechanisms, singly and in combination, can alter population densities and community structure of insects, sometimes for decades or centuries as in the case of watershed land use change. In general, however, natural disturbances tend to be episodic, and, if the habitat returns to its original state, insect communities recover quickly (Hershey et. al. 2010). Indeed, some amount of natural disturbance is needed for maintenance of habitat quality and diversity. For example, without periodic floods there would be no exporting of accumulated materials such as fine sediments and woody debris, and eventually these materials could choke a stream and degrade habitat quality. Floods also deliver sediments to a stream, thereby replenishing the abundance of spawning size gravel (Cooperman 2014). Human disturbance, by contrast, tends to be chronic and thus insect communities may not recover until the disturbance ceases or the habitat is restored. In response to the recognition that both structure and function of aquatic ecosystems have suffered greatly because of human-induced disturbance, there has been considerable recent interest in ecosystem restoration, especially restoration of wetland and stream ecosystems (Hershey et. al. 2010).

## MANAGEMENT OF RIPARIAN ZONES

Most adult aquatic insects that emerge from streams live briefly in the nearby riparian zone. Adult activities, such as mating, dispersal, and feeding, influence their distribution in the terrestrial habitat. Numbers and biomass of adult aquatic insects tend to be greatest in the near-stream vegetation. Because adult aquatic insects are abundant, they represent a primary food resource for many riparian insectivores. Therefore, modifications of the riparian zone can directly affect adult aquatic insects by interfering with the reproductive activities of adults (e.g., swarm or oviposition markers are lost), or by changing abiotic (e.g., air temperature) or biotic (e.g., insectivore density) conditions that adults are exposed to in the riparian zone. Indirect effects can include changes in the survival and growth of the immature stages of aquatic insects (i.e., those that occur in the stream), which in turn affects the abundance of adult aquatic insects in the riparian zone (Jackson and Resh 1989).

This array of direct and indirect effects increases the complexity of management decisions. For example, opening the stream canopy can increase the production of the immature stages of aquatic insects in the stream. As a result, immatures would be more available as prey for stream insectivores, such as trout, and adults would be more available as prey for riparian insectivores, such as birds and bats. However, such a modification of the riparian zone may actually have a negative effect on stream biota because other essential stream parameters (e.g., water temperature) would also change. Birds and bats may be adversely affected as well if the survival and reproductive success of adult aquatic insects decrease (and consequently numbers in subsequent generations decrease) because of modification of the riparian zone (Jackson and Resh 1989).

## RESTORATION

Ecological restoration can be defined as assisting the recovery of a degraded, damaged, or destroyed ecosystem. Perhaps the most prominent human-induced disturbances are chemical pollutants, physical habitat modification, invasive species, and land-use changes, all of which can have adverse impacts on aquatic insect communities. Restoration efforts likely are the key to aquatic insect recovery to pre-disturbance conditions (Hershey et. al. 2010).

Stream restoration projects typically involve some combination of approaches such as increasing the sinuosity of straightened channels, increasing the complexity to the channel through additions of large woody debris, addition of engineered structures, and stabilization of riparian zones (Hershey et. al. 2010). The Big Hole River Foundation and other entities are currently implementing many of those restoration methods, as well as other methods, such as riparian planting throughout the Big Hole River watershed.

The effectiveness of such restoration efforts on aquatic insects has been poorly known because most projects do not involve pre- or post-restoration monitoring (Cooperman et. al. 2007; Hershey et. al. 2010). However, recently more and more restoration projects are implementing pre- and post-restoration monitoring.

**BIOMONITORING**

Freshwater invertebrates vary widely in their ability to cope with environmental stress, and monitoring benthic macroinvertebrate communities takes advantage of this situation to assess stream health. If benthic macroinvertebrate samples contain many kinds of organisms that are known to be sensitive to stress, then that indicates a healthy environment. If samples reveal just a few kinds or organisms, all known to be tolerant of stress, that indicates an unhealthy environment. There are many intermediate conditions between these two extremes in which samples contain a mix of tolerant and sensitive organisms (Voshell 2002).

Two methods commonly used for evaluating water quality are *indicator organisms* and *diversity*. The indicator organisms method is based on the fact that every species has a certain range of physical and chemical conditions in which it can survive. Examples of intolerant organisms are mayflies, stoneflies, and some caddisflies (members of the

Sampling for benthic macroinvertebrates in the Big Hole River, Montana, using a D-frame sampling net. Michael A. Bias photo.

Ephemeroptera, Plecoptera, and Trichoptera orders, respectively). Examples of some tolerant organisms include leeches, aquatic worms, and some midge (Diptera) larva. Water quality is evaluated by comparing the number of tolerant organisms to the number of intolerant organisms. A large number of pollution-tolerant organisms and few intolerant organisms may indicate poor water or habitat quality. However, remember that pollution-tolerant organisms can also be found in a wide range of conditions, including pollution-free environments (Maryland State Envirothon 2014).

Diversity refers to the number of different species found in a biological community. In general, communities with high diversity are more stable. Environmental stress or frequent habitat disturbances can eliminate intolerant species, and therefore reduce diversity. So if an area becomes environmentally stressed, the total number of organisms may stay the same, but diversity may decrease, highlighting the stress on the stream (Maryland State Envirothon 2014).

Monitoring benthic macroinvertebrate communities through time or among stream reaches is a reliable, cost effective, method of assessing environmental conditions and factors limiting biological integrity. Benthic macroinvertebrates are good indicators of localized conditions; as such, they are particularly well-suited for assessing site-specific impacts as they respond rapidly to the effects of short-term environmental variations. Benthic macroinvertebrate communities can provide biologically robust information for interpreting cumulative effects or differences across stream sections or differences among streams (McGuire 2003).

## MONITORING IN THE BIG HOLE RIVER

Bias (2012, 2014), of the Big Hole River Foundation, monitored and evaluated benthic macroinvertebrate communities in the Big Hole River and important tributaries from 2002 through 2012 to assess baseline river health and determine whether implemented conservation measures improved stream biological health (McGuire 2003, Bias 2012, Bias 2014). Techniques used to collect, process, and analyze macroinvertebrate samples followed guidelines

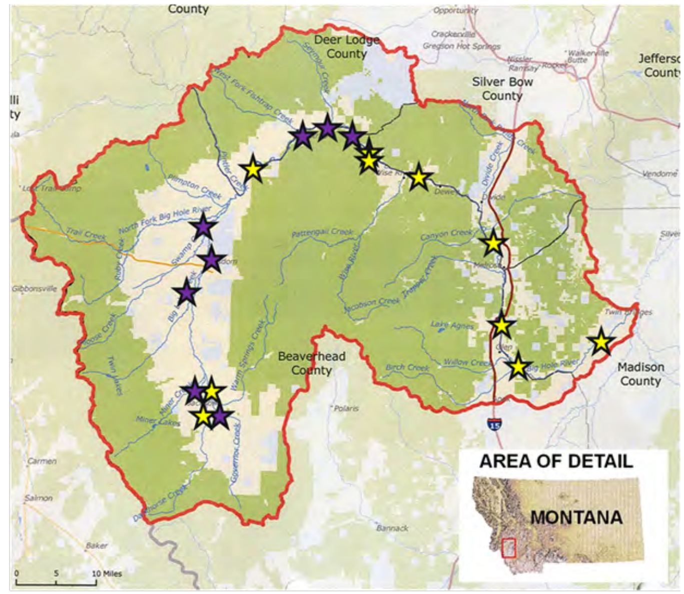



Figure 6. Benthic macroinvertebrate sampling locations along the Big Hole River and tributaries. Yellow stars depict mainstem and purple stars depict tributary sampling sites (from Bias 2014).

established in the Montana Rapid Bioassessment Protocols. Invertebrate sampling occurred three times per year (April, June, and September) from at least 19 locations, 14 mainstem and 5 tributary (Figure 6). Although not significantly, Ephemeroptera, Plecoptera, and Trichoptera (EPT) relative abundance steadily increased across all years (Figure 7). EPT relative abundance for all the years sampled

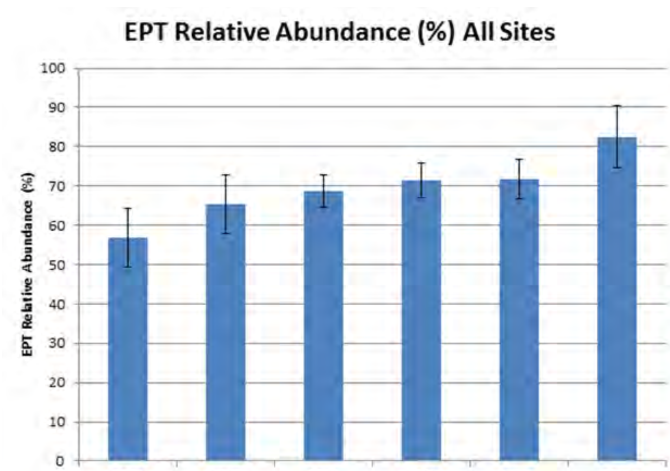



Figure 7. Mean EPT relative abundance (±standard error), or percentage of sample composed of Ephemeroptera, Plecoptera, and Trichoptera, by year for all locations sampled along the Big Hole River, Montana. The steadily increasing EPT relative abundance revealed improving stream biological health (Bias 2014).

for every site was greatest during 2012. The steadily increasing EPT relative abundance revealed improving stream biological health. However, he could not determine from this project whether increasing macroinvertebrate metrics were a result of site-specific implemented conservation measures or steadily improving snowpack and water conditions over this time. Continued site-specific monitoring will be conducted in the future to specifically determine the contribution of conservation management practices to improved stream health (Bias 2014).

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