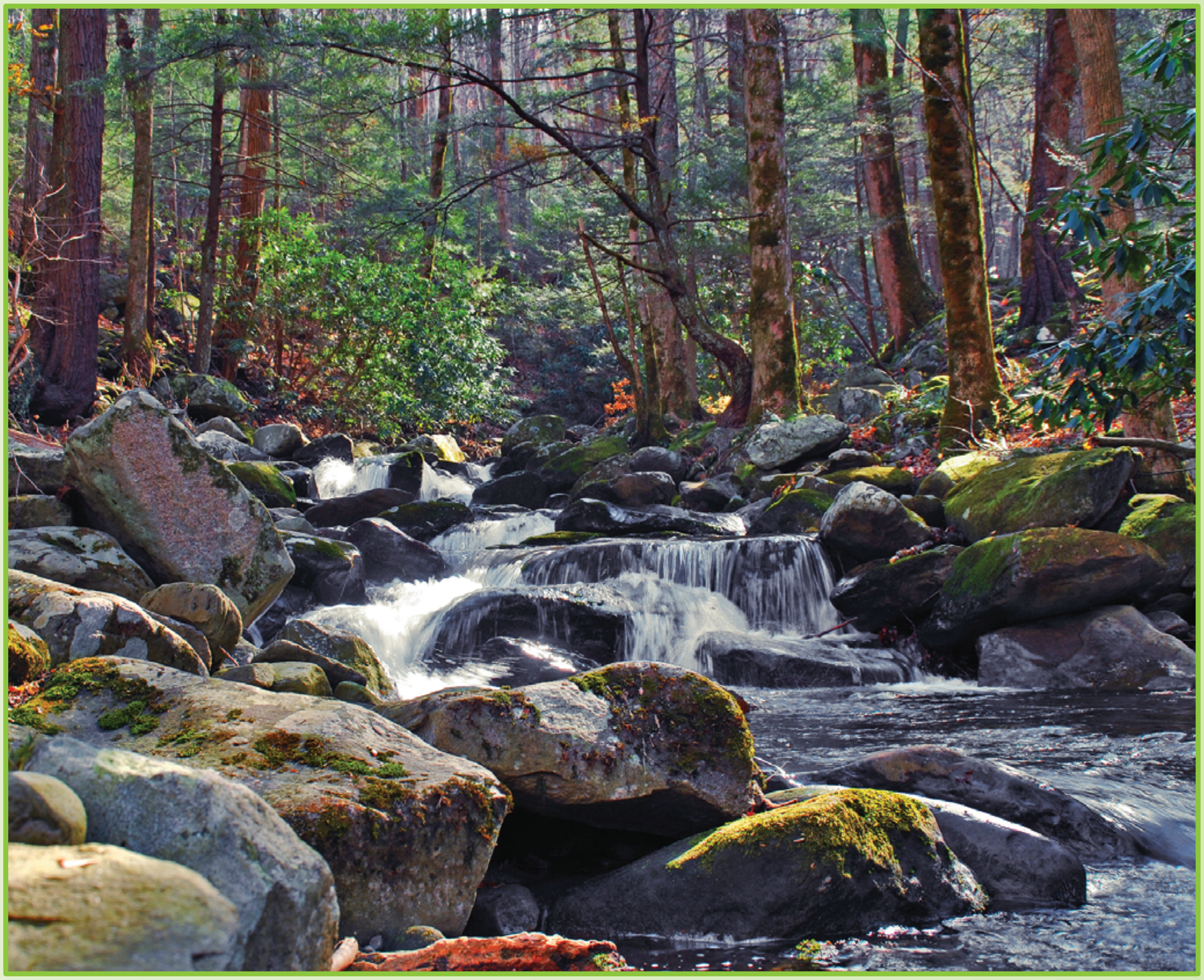
Chapter 2 Stream Ecology Primer

This chapter serves as a foundation for understanding important factors that can affect biological condition in streams—topics that are examined in subsequent chapters. Biological condition is a measure of the overall health of a stream ecosystem, defined as the degree to which the characteristics of biological communities differ from their natural state. The characteristics of biological communities can vary among different regions and environmental settings because of human activities, as well as natural factors related to hydrologic, climatic, and other watershed and stream properties.



U.S. Geological Survey photo by William Cannon.

Algal, macroinvertebrate, and fish communities provide unique and complementary information to assessments of biological condition.

Biological Communities and Water Quality

Historically, water quality in streams, lakes, and wetlands has been assessed using measures of the chemical or physical properties of water. However, a more comprehensive perspective is obtained if chemical and physical measures are integrated with assessments of resident biological communities. Guidelines to protect human health and aquatic life have been established for many physical and chemical properties of water and are useful yardsticks with which to assess water quality. Biological communities provide even more crucial information because they live within the aquatic environment and therefore integrate through time the effects of manmade changes to their surroundings. In addition, biological communities are a direct measure of the ability of a water body to support aquatic life and healthy ecosystems—which is a fundamental goal of water-quality management.

Living components of stream ecosystems include a complex and varied array of biological communities—from microscopic bacteria and algae to flowering plants, macroinvertebrates, fish, and other vertebrates. These groups of organisms interact with each other and with their ever-changing chemical and physical surroundings. Algae, macroinvertebrates, and fish are the biological communities most often evaluated in water-quality assessments by local, State, and Federal authorities. Each of these communities represents a different functional role in the ecosystem, responds in different ways to manmade environmental change, and thus provides different and complementary perspectives on water quality and stream health.

Because species within biological communities have different roles in ecosystems and widely varying traits, the most complete assessments of stream health make use of several communities, each offering complementary information. For example, algae are primary producers with short lifespans and therefore respond more rapidly than other communities to changes in chemical factors such as nutrient concentrations. Macroinvertebrates are commonly examined during water-quality assessments because they inhabit a specific stream for many months and therefore are good indicators of environmental conditions over relatively long periods of time. Fish offer advantages to those making assessments because they often migrate throughout a watershed and are therefore exposed to a wide array of environmental changes caused by human activities. In addition, many fish species are of economic importance as a food source or for recreation. Although any single biological community can provide information about water-quality conditions, assessments of two or more communities increases the potential to detect the scope of ecological change potentially caused by human activities.

Table showing the different roles of algae, macroinvertebrates, and fish in ecosystems and the traits that allow each to make a unique but complementary contribution to water-quality assessments.

Attributes	Algae	Macroinvertebrates	Fish
Primary roles in ecosystem	Primary producers; source of food for many species	Primary consumers of algae and other organic matter; source of food for many species	Primary consumers of macroinvertebrates and algae; source of food for aquatic and terrestrial species
Time scale	Lifespans of days to weeks; may respond rapidly to changes in environment	Lifespans of months to years; sensitive life stages respond quickly to environmental stress, but overall community responds more slowly	Lifespans of years; may take longer to respond to, or recover from, change
Spatial scale	Indicators of localized, site-specific conditions; organisms mostly sessile (attached to substrates)	Indicators of drainage-basin and stream-reach conditions; organisms range from mostly sessile to relatively mobile	Indicators of watershed and stream-network conditions; some are highly mobile
Sensitivity	Many species sensitive to nutrients, salinity, and other chemical factors	Sensitive to wide range of factors; may be specifically vulnerable to insecticides	Sensitive to changes in habitat such as hydrologic alteration, including manmade changes in streamflow
Societal relevance	Nuisance algal blooms, taste and odor effects on drinking water, and toxic species	Important food source for sport fisheries; high biodiversity	Economic and recreational importance

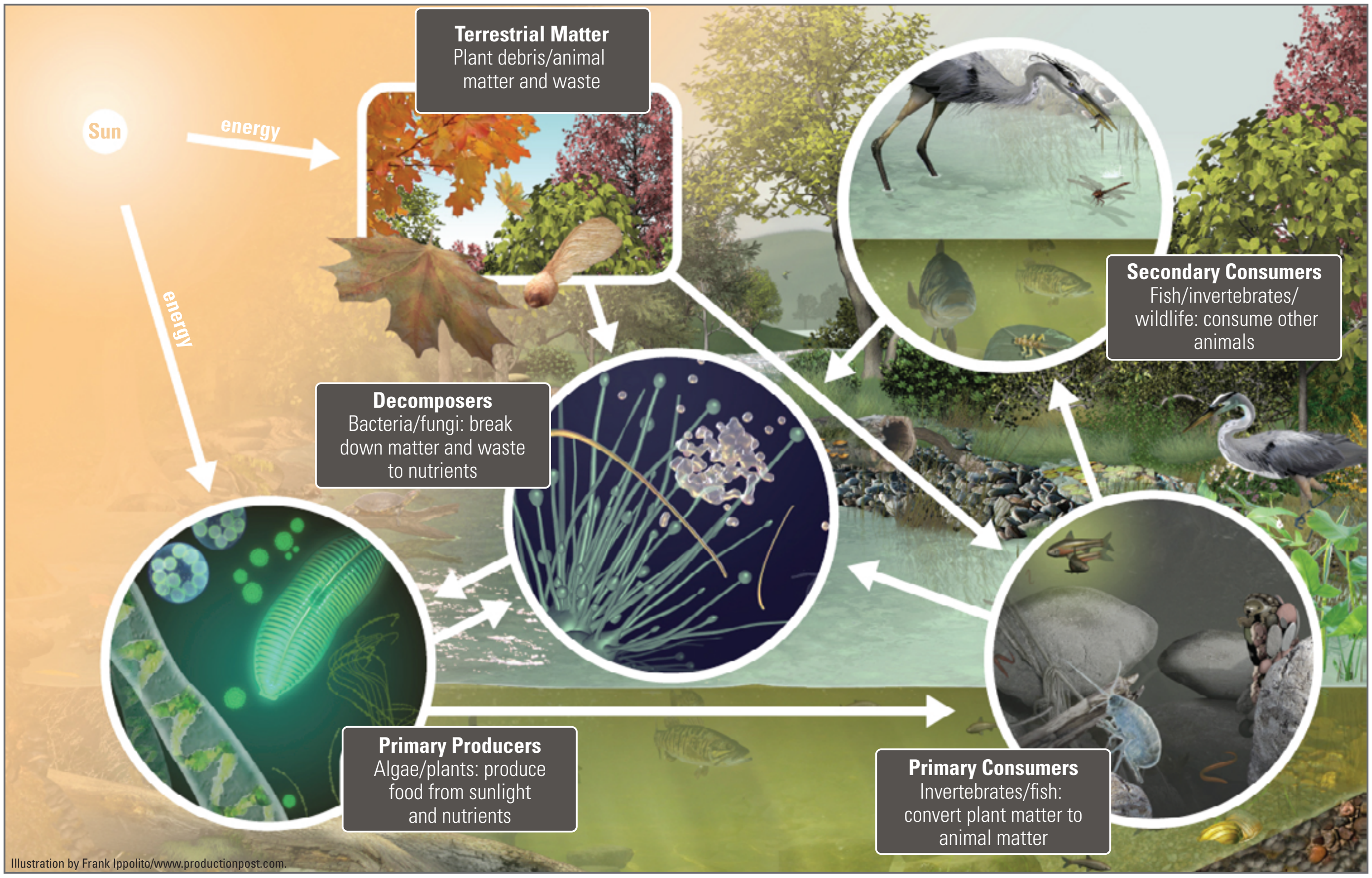


Illustration of a simplified food web in a stream ecosystem, showing the interrelations among major biological communities and their physical and chemical environment. Energy originating from sunlight and through photosynthesis in primary producers (such as algae and plants) becomes available to a wide variety of primary consumers such as insects, fish, and other animals. In turn, secondary consumers, such as fish and birds, prey on the primary consumers. Decomposers such as bacteria and fungi, are organisms that process and recycle dead and decaying organic material.

As the key living components of ecosystems, biological communities also provide an indication of ecosystem health, which is the ability of an ecosystem to support its full complement of native species and natural processes. Naturally functioning aquatic ecosystems support countless species—which adds to the Nation's biological diversity—and provide a wealth of services to society, including water purification, flood control, nutrient recycling, waste decomposition, fisheries, and aesthetics. The value to society of many of these benefits is substantial; for example, sportfishing in the United States generates an estimated annual economic output of $125 billion, including more than 1 million jobs (National Research Council, 2005; American Sportfishing Association, 2008). Another example is the maintenance of pure drinking water for the more than 8 million residents of New York City. The city invested in a long-term comprehensive watershed protection program that uses corrective and protective initiatives to ensure that watersheds and stream ecosystems retain their ability to provide high-quality water (http://www.nyc.gov/html/dep/html/watershed_protection/about.shtml, accessed January 11, 2013), which was ultimately billions of dollars less expensive than the construction and maintenance of water-purification facilities (Chichilnisky and Heal, 1998).

A stream is considered healthy if it is capable of supporting its full complement of native species and natural processes.

Algae respond rapidly to changes in water quality because of their short lifespans.

Algae

Algae are plant-like, photosynthetic aquatic organisms that range in size from single cells to giant kelps. Algal communities in rivers and streams are generally attached to hard surfaces, such as rocks and twigs, as well as to fine-grained sediments such as sand and silt. Algae are also an important food source for many aquatic organisms. Often the most abundant and diverse algal group in streams is diatoms, which are single-celled algae with elaborate silicon skeletons (see sidebar below). In general, algal populations in streams respond rapidly to changes in the environment because of their short (for example, days to weeks) lifespans and fast growth rate. As a result, algae (and diatoms in particular) are often used in biological condition assessments because they are found in streams of all sizes and are widespread.

Under certain environmental conditions, algal populations can become extremely dense. When these dense growths die and decompose, they reduce the dissolved oxygen levels in water, leading to suffocation of fish and other aquatic organisms. Some algae (cyanobacteria; sometimes called blue-green algae) produce chemicals that can cause taste-and-odor problems in drinking water, even though the organisms themselves can be removed in water-treatment processes. Some algae therefore increase the cost of water treatment or limit recreational activities.

U.S. Geological Survey photo by Nara Souza.

Under certain environmental conditions, the abundance of some species of algae, such as shown by the bands of green scum on the pond in this photograph, can reach nuisance levels that interfere with recreational, industrial, and other uses of streams and rivers.

Diatoms

Diatoms (photo at right) are a group of mostly single-celled, microscopic algae that have elaborate silica (glass) skeletons and are found in streams, rivers, lakes, and oceans. There are an estimated 100,000 living species of diatoms throughout the world. Diatoms are often the most abundant and diverse types of algae in streams and rivers.

Diatoms are photosynthetic and provide an important food source for aquatic animals such as invertebrates and fish in streams. They are therefore an important foundation of the aquatic food web. Diatoms are easily collected, and many species respond quickly and predictably to changes in water chemistry, which makes diatoms useful in water-quality assessments.

Photo from Archives of the Academy of Natural Sciences.

Macroinvertebrates

Macroinvertebrates are animals without backbones that can be seen with the unaided eye and include insects, mollusks (such as snails and clams), worms, and crustaceans (such as crabs, shrimp, and crayfish). In contrast to algae, macroinvertebrates have longer lifespans, ranging from months to years. Most macroinvertebrate species in streams are immature stages of insects that spend most of their lives in the aquatic environment and a relatively short period as terrestrial adults (see sidebar below).

Macroinvertebrates are found in a wide variety of stream habitats but primarily inhabit benthic (stream bottom) substrates such as rocks and woody debris. Macroinvertebrates are important consumers of algae (see above) and terrestrial plant material that falls into streams—especially that from seasonal leaf fall in temperate climates. Many macroinvertebrates also prey on other species, and many are an important food source for waterfowl, amphibians, and fish.

Some macroinvertebrate species can negatively affect natural ecosystems, particularly when introduced into waterways outside their native ranges or when they become unnaturally abundant in human-modified environments. For example, after colonizing the Great Lakes, populations of the zebra mussel *(Dreissena polymorpha)*—which is native to central Asia—rapidly expanded into other streams and rivers.

National Oceanic and Atmospheric Administration photo.

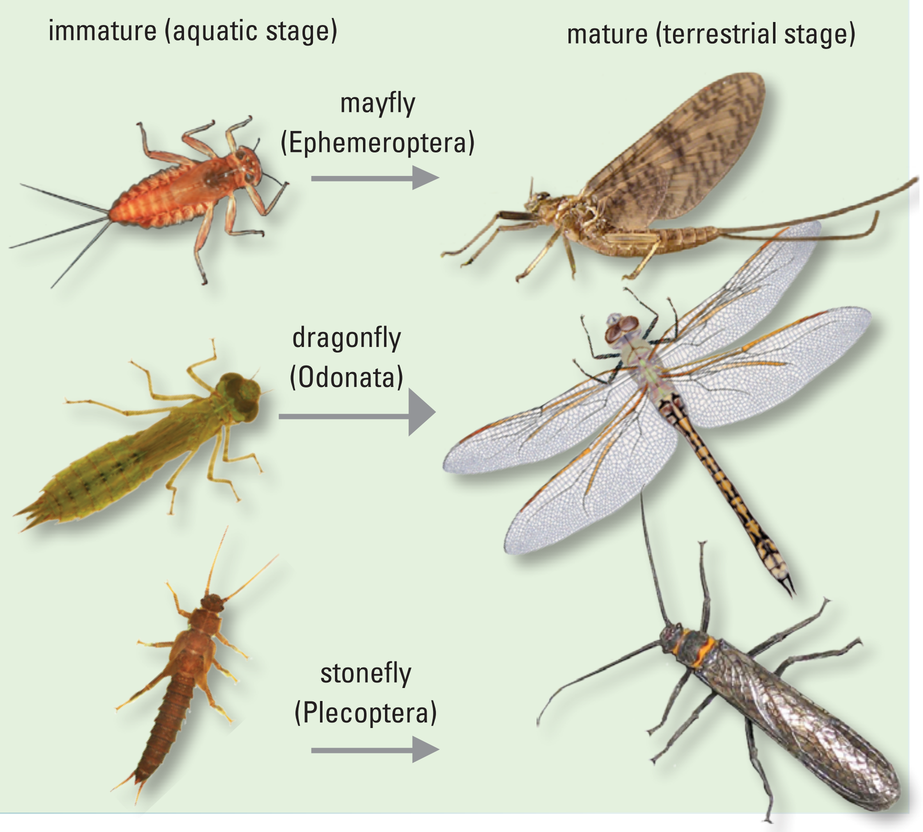
Zebra mussels attach themselves to any stable structure, as shown in this photograph. In some cases, population densities become so dense that all submerged objects are completely covered—hindering operations of water intakes, dams, and shipping.

Macroinvertebrates are sensitive indicators of changes in water quality and habitat.

Aquatic Insects

More than 90 percent of the Earth's species are invertebrates—meaning they lack backbones. The immature stages of insects are generally the most diverse group of macroinvertebrates in rivers and streams, with more than 5,000 species known in North America. Aquatic insects spend most of their lives within the stream, usually in an area of just a few square yards, then emerge from the aquatic environment and live a few days as winged terrestrial adults, as shown for mayflies, dragonflies, and stoneflies.

Aquatic macroinvertebrates are easily sampled and identified and possess a wide range of tolerances to environmental changes. Consequently, they are the most commonly used biological community in water-quality assessments.



Fish are indicative of water quality across river networks because of their long lifespans and mobility.

Fish

Fish occupy many roles in stream ecosystems. Some species are predators that eat macroinvertebrates and other fish; other species are herbivores; others feed by filtering small organisms or plant material from stream bottoms. Fish also are an important food source for wildlife, as well as for humans, and support substantial economic activity related to sport fishing. Fish communities in some geographic areas are rich in species diversity, such as in the Southeastern United States (see sidebar below), whereas the Western United States has very few native species.

Relative to macroinvertebrates and algae, fish have longer lifespans (years), and some species can migrate long distances throughout river networks. Whereas algae and macroinvertebrates are found in streams of almost any size, fish may be naturally absent from some small streams, where habitat and food resources are limited.

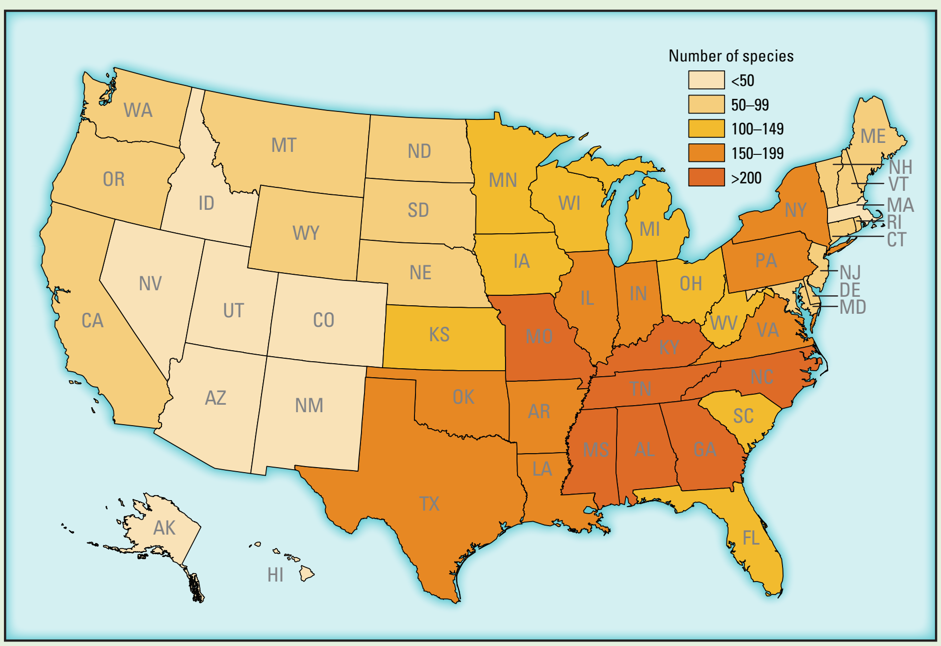
Unlike algae and macroinvertebrates, the populations of many fish species are actively managed. In fact, many species have been actively or accidentally moved to waters outside their native range, becoming invasive to resident fish communities.

Photo from asiancarp.org.

Asian carp, such as the one in this photograph, escaped from fish farms in the 1990s, spread throughout the Mississippi River, and now threaten the Great Lakes. "Asian carp" is used to refer to several species of carp (Cyprinidae) originally native to Asia; these fish are prolific and compete with native fish for food and habitat.

Fish Species Diversity

Fish are the most diverse group of vertebrates, with more than 31,000 species described throughout the world. More than 1,000 fish species are native to North America, and the Southeastern United States supports the most species (see map). Many fish species have extremely limited geographic distributions, and others have specific habitat requirements for survival and reproduction and are therefore important sentinels of manmade environmental changes. Indeed, recent estimates (Jelks and others, 2008) show that the number of imperiled North American fish species has increased from 219 to 539 since the 1980s.

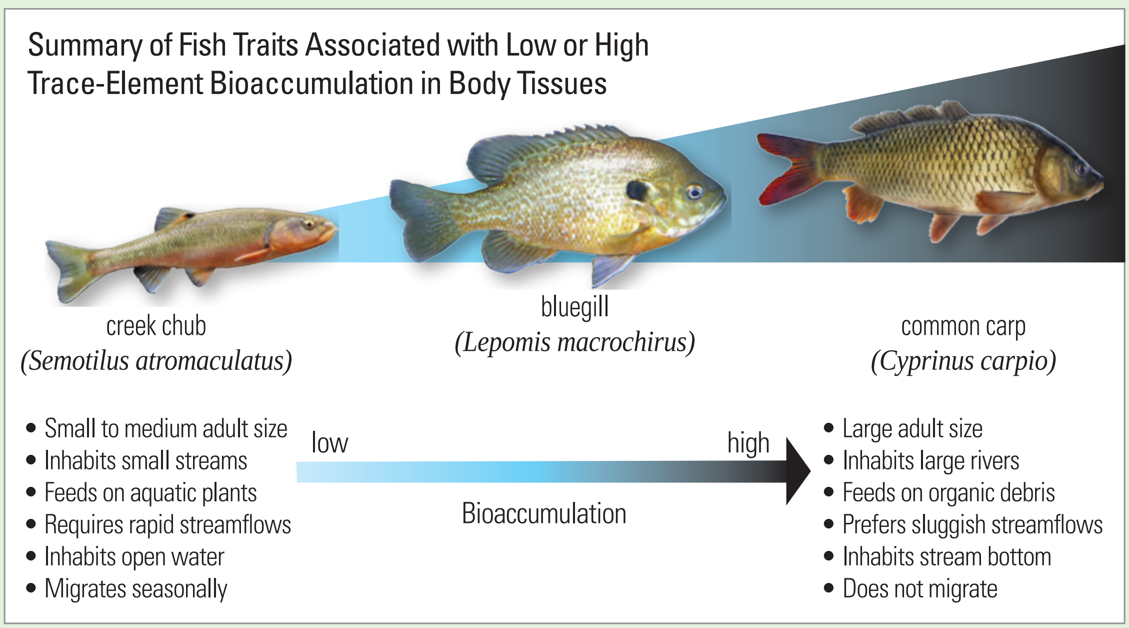


As this map shows, the natural diversity of fish species varies greatly across the United States, being lowest in the interior West and highest in the Southeast. Low species diversity in the West is thought to be a result of limited aquatic habitat in arid environments. (<, less than; >, greater than. States are identified by U.S. Postal Service abbreviations. Alaska and Hawai'i not shown to scale.)

Species Traits Influence Exposure to Chemical Contaminants

Biologists often catalogue facts on plant and animal species, organizing their traits into categories including physical appearance, habitat, behavior, and food requirements. A species' response to changes in its environment depends in large part on its traits, which influence where it can survive, grow, and successfully reproduce. Manmade changes to the environment eliminate only species that are most sensitive to those changes, whereas tolerant species may thrive. Changes in the relative abundance of different species in a community therefore provide important clues of the well-being of the ecosystem.

A species' traits also influence its exposure to chemical contaminants. Aside from the physical properties of chemical contaminants and their concentrations in the environment, an organism's exposure to contaminants depends largely on its habitat, living habits, food preferences, and other traits. This principle is illustrated in a NAWQA study evaluating the relation among the traits of fish species and the bioaccumulation of trace elements in their body tissues (Short and others, 2008). The accumulation of trace elements in body tissues varied among fish species largely due to differences in their traits. Specific trait characteristics were identified that were least and most strongly associated with trace-element bioaccumulation. For example, fish species that attain large adult body size typically had greater trace-element bioaccumulation than small-bodied species. One explanation for this pattern is that large-bodied species are typically longer lived than smaller size species (Wooton, 1998) and therefore have a longer lifetime exposure to environmental contaminants.



Streams and rivers typically undergo noticeable natural changes from headwaters to mouth.

Environmental Factors that Influence Stream Biological Communities

The abundance and types of species in streams are influenced by many factors, including streamflow, water and sediment chemistry, and physical habitats. Many of these factors are influenced by the properties of the watershed, a geographic area where rainfall and (or) snowmelt drain into a common body of water. Most of these factors change naturally from a river's headwaters to its mouth; this continuum of change influences the numbers and types of species present in biological communities, as well as the ecological processes that these species control. In addition, these factors vary naturally among geographic regions (see sidebar on opposite page). Land- and water-management practices in a watershed can modify these factors outside their natural ranges or to levels that affect the growth, survival, and reproduction of individual species. The fundamental principles of these changes are described on this page and shown later in this chapter in the two-page sidebar "Natural River/Altered River."

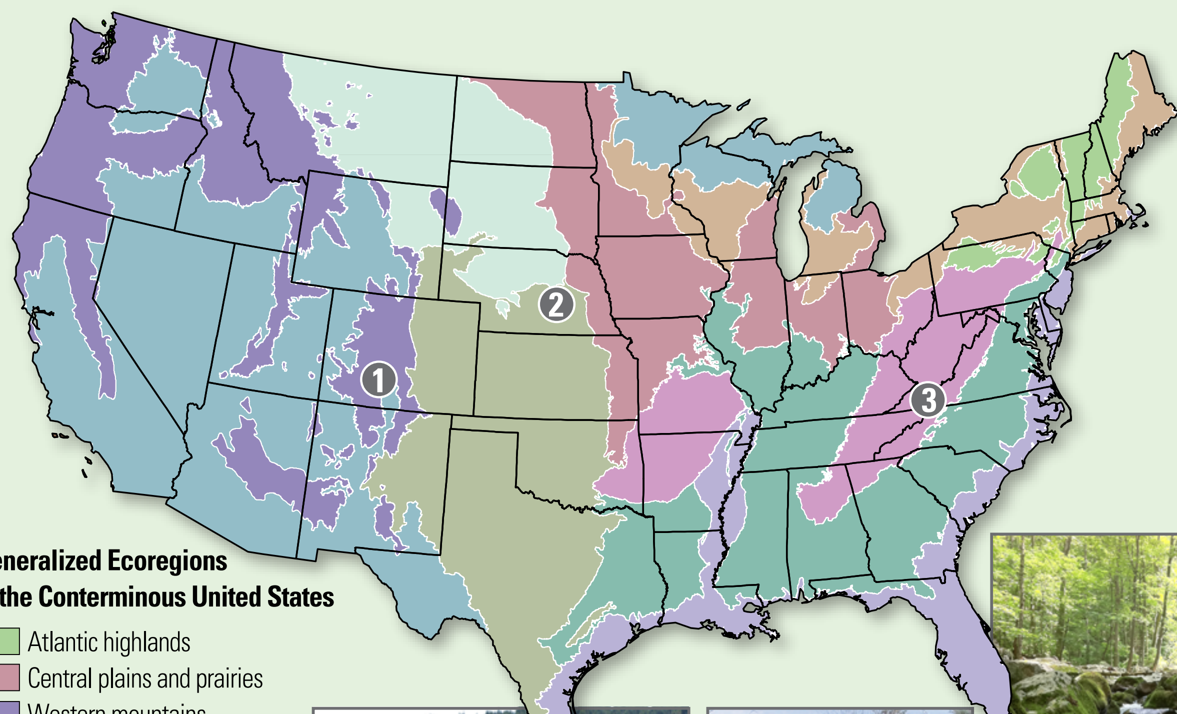
Streams and rivers typically undergo noticeable natural changes from headwaters to their mouths (see Natural River). Headwater streams are typically small and shaded by streamside vegetation, which influences water temperature and other physical characteristics. Food webs in headwater streams are often supported by decaying organic matter rather than through direct sunlight. As streams increase in size they become wider, more open to sunlight, and slower moving. In addition, suspended particles in the water column prevent sunlight from reaching the streambed. Slow currents enable free-living algae to thrive; these algae, together with imported organic materials from upstream, are the base of the food web.

Land and water use in watersheds are often superimposed on the natural changes in streams and rivers (see Altered River). Water temperatures and sunlight increase in headwater streams that are influenced by land management—such as logging—that removes trees and shrubs from the hillslopes and along stream channels. Agricultural or urban land uses can influence the hydrology, chemistry, and physical habitat of streams. Water-management strategies such as diversions and storage reservoirs, which often are used on mid-sized rivers, can dramatically alter the hydrologic characteristics and consequently the biological communities both upstream and downstream. Large-scale industrial activities that typically occur on large rivers can alter the water and sediment chemistry and physical habitat. In addition, the physical and chemical factors of large rivers can be influenced by the cumulative effects of human activities far upstream and throughout the watershed.

Streams Differ Across the Nation due to Natural Variation in Environmental Settings

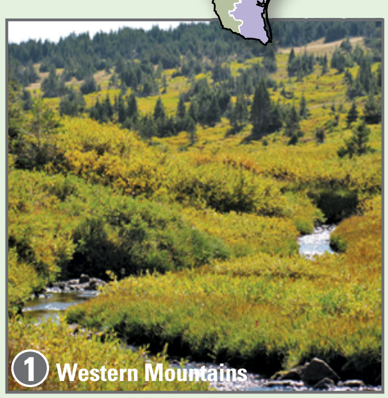
Differences in environmental settings (sometimes referred to as ecoregions; see map below), including geology, soils, topography, and climate, lead to natural geographic changes in the chemical and physical factors of streams. For example, headwater streams in mountainous areas are typically cold, fast flowing, and highly dilute—that is, have extremely low concentrations of chemical substances. In contrast, headwater streams in the Central Plains are typically warm, slow flowing, and contain high concentrations of natural substances such as nutrients or dissolved organic matter.

Natural variation in the chemical and physical characteristics of streams and rivers influences the abundance of aquatic species and must therefore be considered in all biological assessments, whether they are local, regional, or national in scale. It is impossible to attribute changes in biological communities to manmade factors without adjusting for the variation in biological communities caused by natural factors. A variety of design considerations and analysis tools are used in biological assessments to account for natural variability. For example, statistical models use the climatic, topographic, and geographic characteristics of a stream to predict the assemblage of species that are expected to occur if the stream were undisturbed by human activities (chapter 3). Understanding the natural variability in streams requires the sampling of physical, chemical, and biological characteristics of a relatively large number of least-disturbed or reference sites (chapter 3).



Generalized Ecoregions of the Conterminous United States

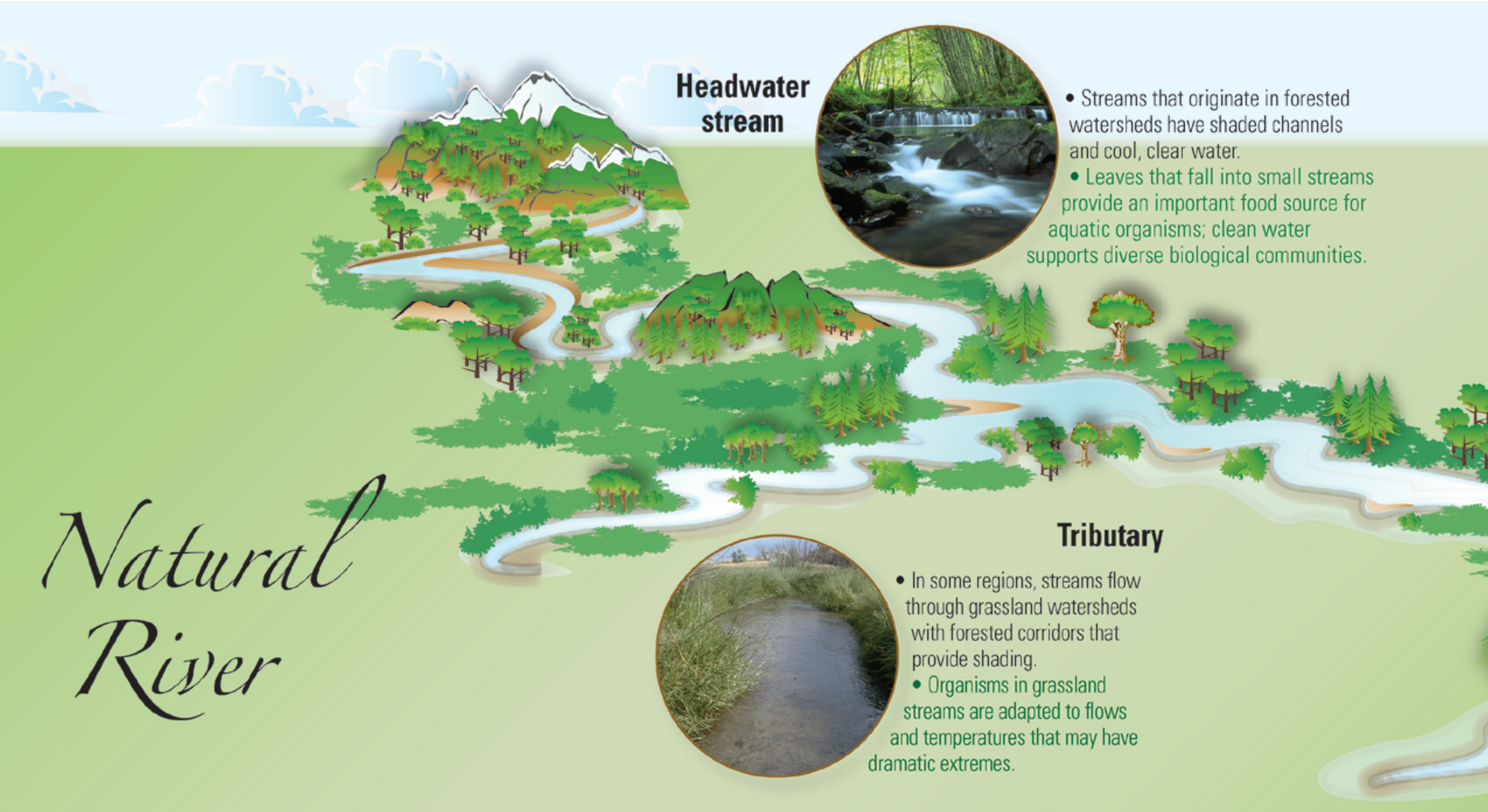
- Atlantic highlands
- Central plains and prairies
- Western mountains
- Mississippi alluvial and Southeast coastal plains
- Mixed wood plains
- Mixed wood shield
- Ozark-Appalachian forests
- South-central semiarid prairies
- Southeastern plains
- Mediterranean California and Western desert
- Temperate and west-central semiarid prairies



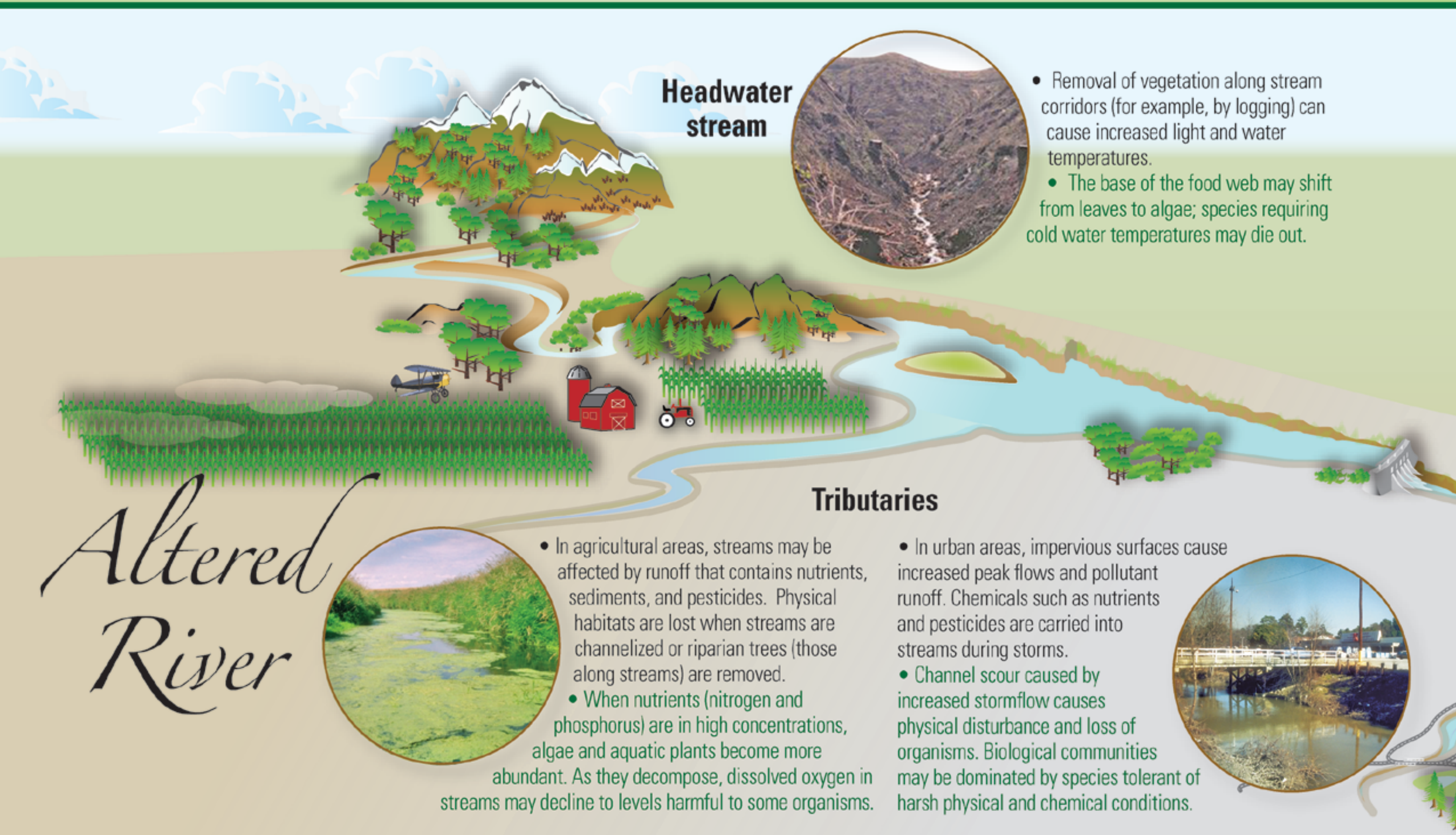
U.S. Geological Survey photo by Daren Carlisle.

Central Plains Center for Bioassessment photo.

U.S. Geological Survey photo by Daren Carlisle.



Left to right: Central Plains Center for BioAssessment photo; U.S. Geological Survey photo by Dennis Wentz; photo reprinted from Stanford and others (2005), used with permission; and National Park Service photo.



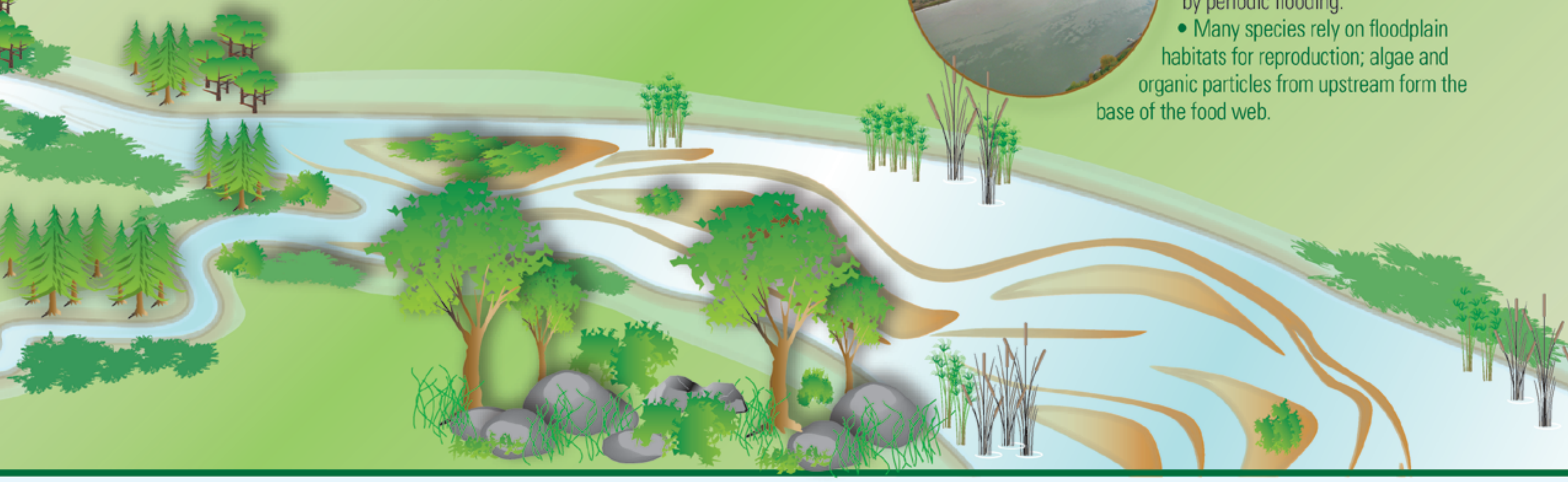
Left to right: U.S. Geological Survey photos by Dennis Wentz; Friends of Elk River photo by Elizabeth Feryl; U.S. Geological Survey photo by Alan Cressler; U.S. Army Corps of Engineers photo; and U.S. Geological Survey photo.

Mid-sized river

- As streams get larger in size, the influence of riparian trees (those along streams) decreases, water velocities decline, and the stream bottom has larger amounts of fine sediments.
- Photosynthetic organisms, such as algae and aquatic plants, become more abundant in response to increased light reaching the stream bottom; aquatic animals that rely on these food sources also increase in abundance.

Large river

- Large rivers often support highly varied habitats such as sandbars, islands, and backwaters and have broad floodplains that are nourished by periodic flooding.
- Many species rely on floodplain habitats for reproduction; algae and organic particles from upstream form the base of the food web.



Mid-sized river

- Dams modify the timing, magnitude, and frequency of high and low flows. Flows can also be reduced by diversions or withdrawals for domestic or agricultural water use.
- Changes to natural flow patterns affect survival and reproductive success of aquatic species whose migration or reproduction are tied to specific streamflow cues. Reduced flooding "starves" the river and floodplain of sediment and woody debris.

Large river

- Water quality in large rivers is influenced by the cumulative effects of human activities nearby, such as channelization, as well as the impacts of land use and water management upstream throughout the watershed.
- Aquatic communities are often dominated by non-native species that thrive in artificial channels or modified environments, such as reservoirs.

Environmental Factors Influenced by Agriculture and Urban Land Use

In addition to natural variation, many hydrological, chemical, and physical factors in streams are influenced by land- and water-use activities in watersheds. The effects of land and water management on stream ecosystems are briefly described below and illustrated at left. More detail is given later in this chapter in three two-page sidebars—Dynamics of a Natural Stream Ecosystem, Dynamics of an Agricultural Stream Ecosystem, and Dynamics of an Urban Stream Ecosystem.

Natural Stream Ecosystem

Agricultural Stream Ecosystem

Urban Stream Ecosystem

Illustrations by Frank Ippolito/www.productionpost.com.

Hydrology

The natural timing, variability, and magnitudes of streamflow influence many of the key physical, chemical, and biological characteristics and processes of streams (Natural Stream). For example, recurring high flows from seasonal rainfall or snowmelt shape the basic structure of a river and its physical habitats, which in turn influences the types of aquatic organisms that can thrive. For many aquatic organisms, low flows impose basic constraints on the availability and suitability of habitat, such as the amount of the stream bottom that is actually submerged. The life cycles of many aquatic organisms are highly synchronized with the variation and timing of natural streamflows. For example, the reproductive period of some species is triggered by the onset of spring runoff.

Human activities that change the natural flow regime of streams and rivers include (1) withdrawals of water for public supply, industrial uses, and thermoelectric power and (2) dams and reservoirs for flood control, water storage (sometimes involving transfers between basins), hydropower, and navigation. In agricultural areas (Agricultural Stream), tile drains, used to drain subsurface water, route seepage directly to the stream channel rather than allowing gradual infiltration through soils. Water withdrawal for irrigation and channelization can also change the natural flow regime. In urban areas (Urban Stream) impervious surfaces, such as pavement, lead to increased storm runoff and higher and more variable peak streamflows, which scour the streambed and degrade the stream channel; reduced infiltration to groundwater may also lead to diminished streamflows during dry periods when groundwater is the main source of streamflow.

Water Chemistry

The unique water chemistry requirements and tolerances of aquatic species help to define their natural abundance in a given stream, as well as their geographic distribution. Many naturally occurring chemical substances in streams and rivers are necessary for normal growth, development, and reproduction of biological communities (Natural Stream). For example, sufficient dissolved oxygen in water is necessary for normal respiration. Dissolved oxygen concentrations in streams and rivers is determined, in part, by physical aeration processes that are influenced by the slope and depth of the stream, as well as the water temperature. Similarly, small amounts of nutrients (nitrogen, phosphorus, and silica) and trace elements dissolved from the weathering of soils and rocks and from the atmosphere are necessary for normal growth of aquatic plants.

Human activities often contribute additional amounts of these naturally occurring substances, as well as other synthetic (manmade) chemicals to streams from point and nonpoint sources. Runoff from agricultural lands (Agricultural Stream) may contain (1) sediment from soil erosion on tilled lands; (2) nutrients from the application of fertilizer and manure; (3) chloride and other salts from irrigation return flows; (4) pesticides used in the past and present to control insects, weeds, rodents, bacteria, or other unwanted organisms; and (5) other synthetic compounds used for varying purposes along with their degradates. Runoff from urban lands (Urban Stream) may contain (1) sediment from construction activities; (2) nutrients and pesticides applied to lawns and recreational areas; and (3) petroleum compounds, trace metals, and de-icing salts from roads and parking lots. Point sources include municipal and industrial wastewater effluent that, depending on the sources of wastewater and level of treatment, may contain different amounts of nutrients and other contaminants.

Physical Habitat

Physical habitat includes factors such as streambed substrates, water temperature, and large debris from streamside vegetation. Streambed substrates include the rocks, sediments, and submerged woody material in a stream (Natural Stream). Streambed sediments may range in size and composition from large rocks to sand and silt that reflect the local geology. These substrates are important because they provide living space for many stream organisms. Stable substrates, such as cobbles and boulders, protect organisms from being washed downstream during high flows and, thus, generally support greater biological diversity than do less stable substrates, such as sand and silt. Water temperature is crucial to aquatic organisms because it directly influences their metabolism, respiration, feeding rate, growth, and reproduction. Most aquatic species have an optimal temperature range for growth and reproduction. Thus, their natural spatial and temporal distributions are largely determined by regional differences in climate and elevation along with more local effects from riparian (stream corridor) shading and groundwater influence. Water temperature also influences many chemical processes, such as the solubility of oxygen in water. The riparian zone is the land adjacent to the stream inhabited by plant and animal communities that rely on periodic or continual nourishment from the stream. The size and character of riparian zones are important to biological communities because these have a major influence on the amount of shelter and food available to aquatic organisms and the amount of sunlight reaching the stream through the tree canopy, which influences water temperature and the amount of energy available for photosynthesis. Riparian zones also influence the amount and quality of runoff that reaches the stream.

Land uses that affect streamflow, sediment availability, or riparian vegetation can alter physical habitats in streams. Some agricultural practices (Agricultural Stream), such as conventional tillage near streambanks and drainage modifications, lead to increased sediment erosion, channelization, or removal of riparian vegetation. Increased sediment from erosion can fill crevices between rocks, which reduces living space for many stream organisms. As watersheds urbanize (Urban Stream), some segments of streams are cleared, ditched, and straightened to facilitate drainage and the movement of floodwaters. These modifications increase stream velocity during storms, which can transport large amounts of sediment, scour stream channels, and remove woody debris and other natural structures that provide habitats for stream organisms. In addition, culverts and ditches can be barriers to aquatic organisms that need to migrate throughout the stream network. Humans can alter natural stream temperature through changes in the amount and density of the canopy provided by riparian trees. In some extreme cases, streams through urban areas are routed through conduits and completely buried.

Dynamics of

Hydrology: Water connects the watershed to the stream. In an undisturbed ecosystem, precipitation (rain and snow) reaches a stream gradually by flowing over the vegetated land surface into the stream and by infiltrating the soil and flowing underground (as groundwater) toward the stream. Natural seasonal patterns of streamflow serve as life-cycle cues to aquatic organisms.

Water chemistry: Nutrients such as nitrogen, phosphorus, and carbon are required for all stream life. Nutrients are incorporated into algae that are then consumed by other organisms, introducing the nutrients into the stream’s food web. Oxygen dissolved in water is essential for most aquatic organisms because they respire through their skin or gills.

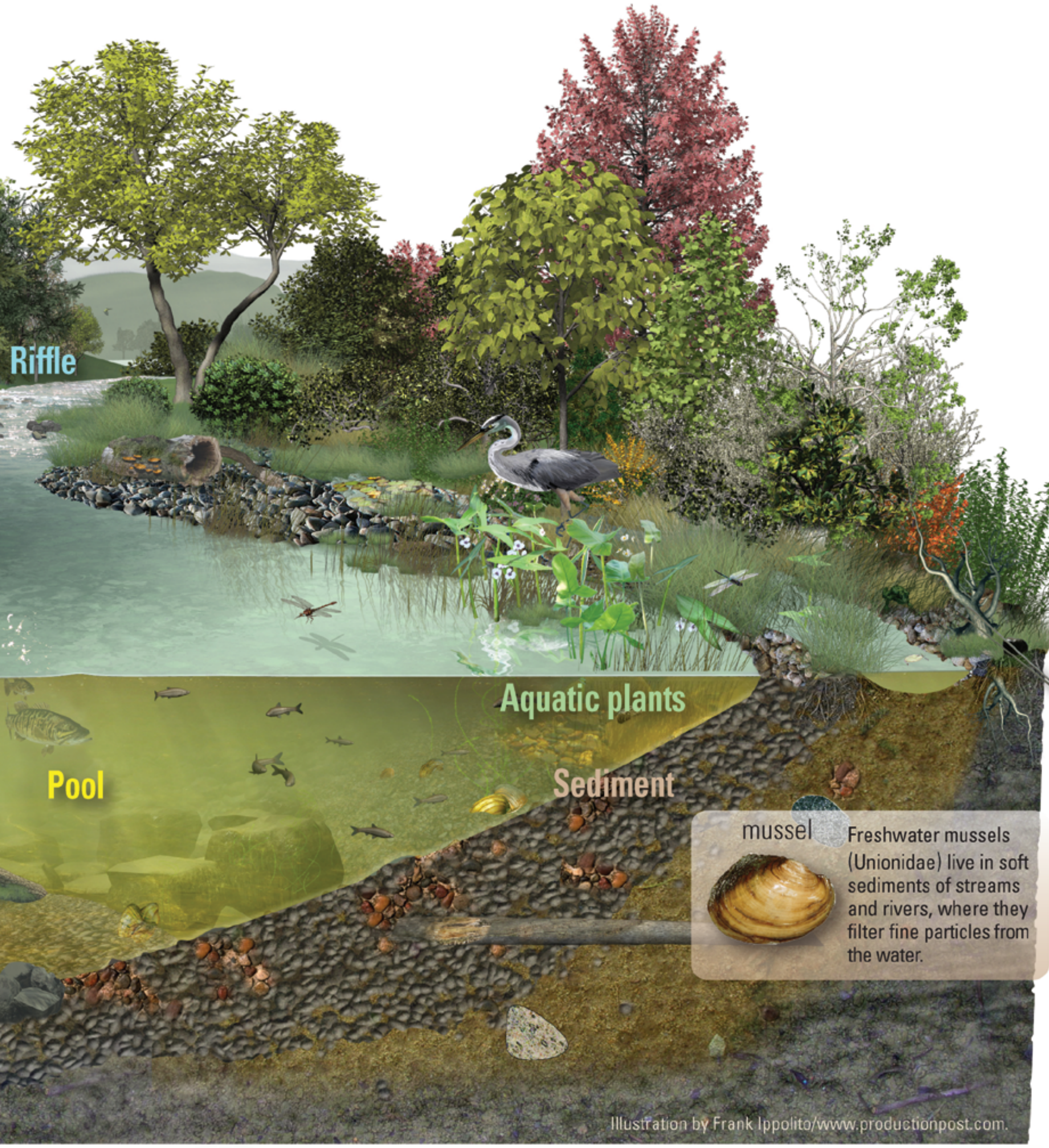
Physical habitat: The physical living space of aquatic organisms includes the water in the stream—whether in pools or faster flowing riffles—as well as the rocks and sediment in the stream bottom and along the banks, submerged leaves and wood, and aquatic plants. A stream with more diverse physical habitats will generally have more diverse kinds of organisms.

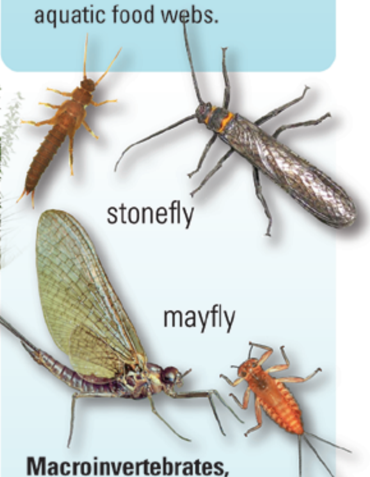
U.S. Geological Survey photos by Daren Carlisle.

a Natural Stream Ecosystem

Healthy stream ecosystems support diverse communities of aquatic organisms.

Algae have short life cycles of days to weeks and can respond relatively rapidly to changes in water chemistry. The most common algae found in natural streams of small to moderate size are diatoms, which attach to underwater surfaces such as rocks and aquatic plants. The diatom genus *Cymbella* can be found in riffles, either as solitary cells or at the ends of branched stalks on rocks and other surfaces. The diatom genus *Epithemia* is commonly found on the surfaces of submerged aquatic plants. Algae are the foundation of most aquatic food webs.





Macroinvertebrates, including these aquatic insects, have complex life cycles that occur over time spans of weeks to months. Most aquatic insects spend nearly all their life in the water as eggs and larvae and then leave the water and develop wings as adults. Many mayflies (Ephemeroptera) crawl on the surfaces of rocks in riffle areas and feed by gathering fine particles of organic matter or scraping algae. Some stoneflies (Plecoptera) feed by shredding submerged leaves that have been colonized by bacteria and fungi.

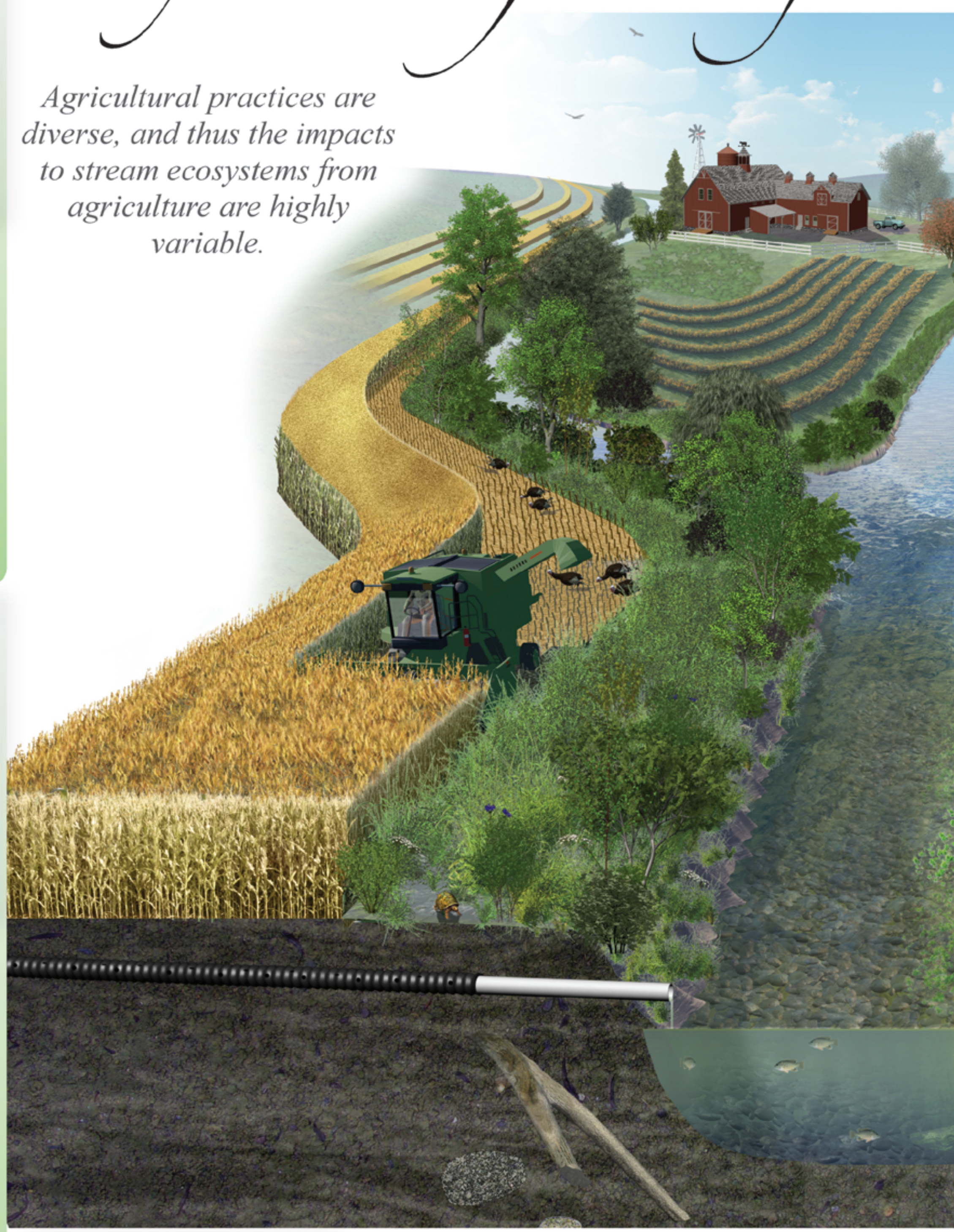
Fish have life cycles that span years. Because they are more mobile than algae or macroinvertebrates, they are affected by conditions that extend upstream and downstream within the river network. Smallmouth bass *(Micropterus dolomieu)* may hide under logs or undercut banks along stream edges or in pools, emerging to feed on invertebrates and small fish. Greenside darters *(Etheostoma blennioides)* live in riffle habitats of streams, where they feed on aquatic insects such as mayflies.

Dynamics of an Agricu

Agricultural practices are diverse, and thus the impacts to stream ecosystems from agriculture are highly variable.

Hydrology: Agricultural practices can alter the movement of water in a watershed through (1) subsurface drains, which lower the water table and quickly route water to nearby streams; (2) ditches and straightening of headwater streams; and (3) irrigation, which supplements available water for crops. These changes can result in more rapid runoff, reduced streamflows during dry periods, and increased transport of sediments and chemicals.

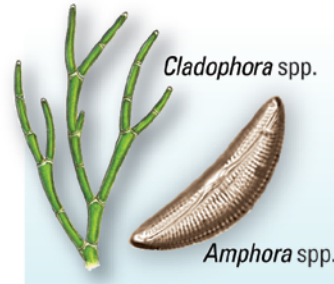
Water chemistry: Agricultural chemicals applied to fields can move to streams and groundwater; other sources of chemicals include irrigation water or waste from animal feeding operations. Nutrients—primarily nitrogen and phosphorus—in streams can exceed natural levels when fertilizer infiltrates through the soil or runs off the surface of the ground. Excess nutrients can cause nuisance growths of algae and aquatic plants, which when they die and decompose lead to low oxygen levels downstream. Pesticides are applied to control insect damage and growth of weeds or fungus but can also harm aquatic organisms.



Physical habitat: Some agricultural practices reduce the quality of stream habitats and have negative effects on organisms. Straightening and dredging headwater streams removes living spaces for aquatic organisms. Removal of riparian trees and shrubs results in more sunlight and warmer water temperatures. Soil disturbances from conventional tilling of the soil or overgrazing can cause erosion, resulting in buildup of sediment in the stream channel.

U.S. Fish and Wildlife Service photo by Scott Roth (top) , USDA Natural Resources Conservation Service photo by Jeff Vanuga (middle), and photo by Eric Caldwell, North Carolina State University (bottom).

ltural Stream Ecosystem



Algae may proliferate in agricultural streams with high nutrient concentrations and available sunlight. *Cladophora* (a genus of green algae that grows in long filaments) and *Amphora* (a diatom genus) are examples of algae that can reach nuisance levels, occurring as large clumps or floating mats. As these mats are transported downstream and decompose, they can contribute to low levels of dissolved oxygen in the water that are harmful to other aquatic life.

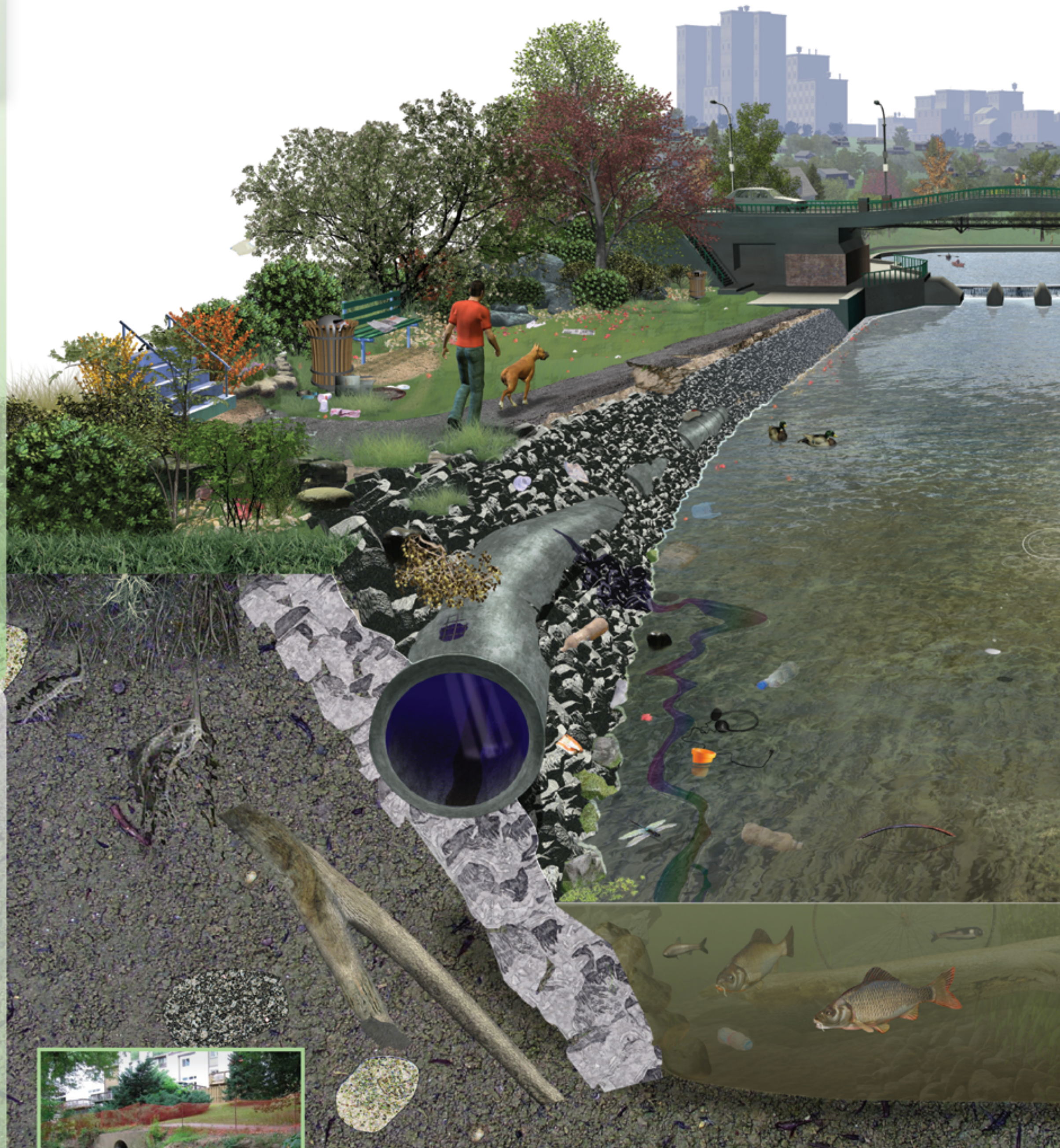
Macroinvertebrates that consume algae or organic-matter particles can thrive in some agricultural streams, whereas those that are sensitive to high silt inputs may decline. Net-spinning caddisflies of the family Hydropsychidae are filter feeders that collect and ingest organic particles that are suspended in the water; these particles may originate from crop residues, animal wastes, or algae as they gradually decompose. The triangular gill covers of this mayfly (*Tricorythodes* sp.) protect the sensitive oxygen-gathering gills from silt in sediment-laden streams.

Fish communities in agricultural streams may be dominated by species—such as the central stoneroller *(Campostoma anomalum)*—that graze on algae attached to rocks and other submerged surfaces. Green sunfish *(Lepomis cyanellus)* are tolerant to high turbidity (water cloudiness), deposition of silt, and temperature.

Dynamics of an Urban Stream

Urban development may have significant impacts on stream ecosystems that are often obvious to the casual observer.

Hydrology: Urban development alters the movement of water through a watershed. Impervious surfaces (for example, roads, parking lots, and buildings) restrict the infiltration of precipitation into the groundwater system, and the construction of artificial drainage systems (for example, storm drains) quickly moves runoff to the stream. Rapid runoff and high streamflow increase the power or energy of the water flowing in the stream, which can deepen or widen stream channels and cause streambank erosion.

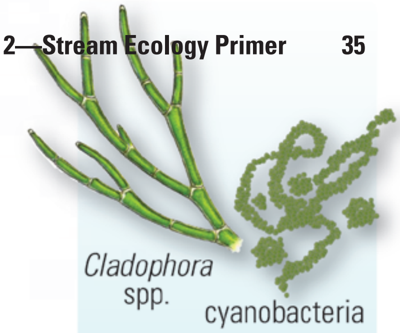


Water chemistry: Urban development may increase the inputs of complex chemical mixtures typically found in runoff from impervious surfaces in industrial and suburban areas. These mixtures may include pesticides, nutrients, and hydrocarbons that are known to have harmful biological effects.

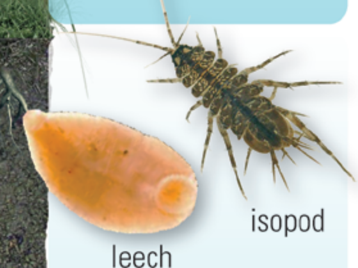
Physical habitat: Urban development can lead to removal of vegetation near a stream, which increases the amount of light reaching the stream and increases the water temperature. Streamflow modification associated with urban development drives changes in stream habitat, including excessive flow velocities that erode the streambanks and scour the streambed.

U.S. Geological Survey photos by Martin Gurtz (top and middle) and Wetland Studies and Solutions, Inc., photo (bottom).

Ecosystem



Algae that are tolerant of pollution may increase in abundance with increased urban development. Diatom algae tend to decrease and nondiatom algae tend to increase with urbanization. Some algae-like bacteria and nondiatom algae, such as cyanobacteria or the green algae genus *Cladophora*, may increase in abundance to nuisance levels in the sunlight- and nutrient-rich conditions of many urban streams. These can be seen as long bands or strands of green slime on the surface of water and rocks.



Macroinvertebrates that are sensitive to pollution may be lost as a watershed becomes urbanized. More-tolerant organisms—such as leeches and isopods—may increase in abundance. Leeches, such as the North American freshwater leech *Macrobdella decora*, are most common in warm, protected shallows where there is little disturbance from currents. Isopods (Isopoda) are tolerant of relatively low dissolved oxygen levels.

Native fish communities generally become less diverse with increased urban development. Common carp *(Cyprinus carpio)*, a non-native species, prefer large bodies of slow or standing water and soft sediment. The fathead minnow *(Pimephales promelas)* is tolerant of cloudy, low-oxygen water.