# **CHAPTER 1: INTRODUCTION**



#### THE LEAF PACK STREAM ECOLOGY KIT OVERVIEW

The Leaf Pack Stream Ecology Kit is a valuable tool for establishing baseline **water quality** conditions and periodic monitoring of a local waterway. For gathering water quality data for monitoring purposes follow the procedures in Chapter 2. To use the Leaf Pack Stream Ecology Kit for learning experiences focusing on experimental design and methods, Chapter 3 will provide additional information, but regardless, each **leaf pack** study will have the same outcome:

- To provide an understanding of the structure and function of freshwater **macroinvertebrates** within a stream community.
- To relate the abundance and variety of freshwater macroinvertebrates colonizing **artificial leaf packs** to:
  - » water quality
  - » the influence of the surrounding forest/ landscape
  - » the general ecological health of the stream community

# THE LEAF PACK NETWORK®

In 1989 a scientist at Stroud Water Research Center was invited to his daughter's 9th grade classroom to conduct a lesson on streams. He thought leaf packs would be an easy way to not only bring macroinvertebrates to the classroom but to engage the students. He was right, and thus was born the Leaf Pack Network<sup>®</sup>. The network also began as a pilot project of the Stroud Center in collaboration with the Hudson Basin River Watch and the Riverkeeper Network. Support for this project came from a grant from the William Penn Foundation as well as a contract with the New York State Department of Environmental Conservation.

The Leaf Pack Network (LPN) is a network of citizens, teachers and students who are investigating their local stream ecosystems using artificial leaf packs. The monitoring methods and investigations use the Leaf Pack Stream Ecology Kit to enhance the understanding of stream ecosystems, learn scientific principles, and to demonstrate the important connection between streamside forests and the ecology of rivers and streams.

Monitoring with artificial leaf packs **replicates** the natural process of leaves forming packs in streams. In brief, artificial leaf packs (dry leaves in a mesh bag) are placed in a stream for three to four weeks, at which point they become colonized by macroinvertebrates. Participants then quantify the relative abundance and diversity of aquatic macroinvertebrates that are known to be indicators of stream health.

Through the LPN, citizens develop a connection to and greater understanding of issues facing their local **watersheds**, and can also connect and share with others that are monitoring streams with artificial leaf packs around the globe. Volunteer monitors, teachers, students, non-formal educators and conservation groups throughout the United States, as well as countries such as Kenya, Peru, Costa Rica, Guatemala, Mexico, China, and Canada have been trained in the LPN protocols. Used as a learning tool, the Leaf Pack Network will engage students in the full process of designing an experiment, conducting research, and sharing and communicating their results.

To become involved in the Leaf Pack Network, you will need:



- The User's Manual and materials that are provided with the Leaf Pack Stream Ecology Kit or the equivalent.
- Access to the internet with a computer or smart device such as a phone or tablet.
- A stream that is safely accessible

Resources on the Leaf Pack Network website [https://leafpacknetwork.org/] can be used to access the online data portal to view data from a particular stream or school, access various resources to learn about watersheds, aquatic **biodiversity** or data analysis and to explore links to interesting groups and organizations that provide information about rivers and streams.

For more specific information on how to become a part of the Leaf Pack Network or to determine the availability of a workshop in your area, contact the Leaf Pack Administrator: leafpacknetwork@stroudcenter.org.

### WHAT IS A LEAF PACK? -LINKING TREES TO STREAMS

Streams and the life in those streams evolved and developed under forested conditions. As an example, most streams in the eastern United States historically were forested. Leaf fall from the forest canopy prevailed as the dominant food resource for small streams. All ecosystems rely on a steady supply of energy. Solar energy drives photosynthesis that supplies carbon (chemical energy) for the rest of the system. In many headwater streams, however, sunlight cannot reach the water's surface due to shading of the forest canopy. Therefore, most headwater streams rely on autumn leaf fall to supply much of the carbon needed to support the stream throughout the year.

Leaves falling in or near the stream leach out organic molecules, creating a "watershed tea" that flows downstream and provides nourishment along the way. On the leaf surface, there is a diverse assemblage of microbes (fungi and bacteria) and macroinvertebrates (insect larvae, crustaceans, etc.), which "process" leaves

and facilitate the flow of energy through the system. The amount and variety of leaves that are available to the stream community are determined by the presence, health, and diversity of the surrounding streamside [**riparian**] vegetation.

# LEAF PACKS AS HABITAT

Many leaves that fall or are blown into a stream float downstream until they land on a rock within a **riffle**. Riffles are areas in a stream where the bottom is rocky and the water is fast flowing. The leaves accumulate behind the rocks forming natural leaf packs. The artificial leaf packs created in the Leaf Pack Stream Ecology Kit mimic these natural leaf packs. In natural and artificial leaf packs, after a few weeks of submersion, the leaves become slimy with the colonization of fungus and bacteria and, in time, are colonized by macroinvertebrates.



Figure 1. Natural Leaf Packs. The leaves that fall into streams accumulate in packs behind branches, rocks, and other obstructions in the stream, forming natural leaf packs.

Leaf packs provide important **habitat** for macroinvertebrates in healthy streams. The

physical features of the stream itself offer many different types of habitats, which in turn support specialized macroinvertebrates that occupy certain niches in each of those different habitats. For example, riffles [fast-flowing, rocky areas] characteristically offer diverse environments and the fast-flowing water offers a continuous supply of oxygen and food to macroinvertebrates. Slow-flowing, muddy-bottomed habitats, such as **pools**, facilitate a very different habitat; they support macroinvertebrates dapted to these specific conditions and contain different species compared to the macroinvertebrates found in riffles. Other stream habitats that can be investigated include sandy/silty bottoms, areas near vegetated **banks**, and areas having an accumulation of woody debris. Each type of habitat will offer a unique assemblage of macroinvertebrate species.

Streams are naturally dynamic environments, often exhibiting marked variation in conditions such as stream flow (e.g., floods or drought), temperature (e.g., warm versus cold), and food quality or quantity (e.g., autumn leaf fall or summer algal blooms). This variation in conditions occurs annually, seasonally, and daily, and contributes significantly to the variety and abundance of macroinvertebrates in streams.

#### FRESHWATER MACROINVERTEBRATES

Once a leaf pack has been submerged in a stream for several weeks, bacteria and aquatic fungi [**decomposers**] will begin to colonize the surface of the leaves. Leaf **detritus** colonized by these microbes feels "slimy." As the fungi and bacteria break down the leaves, benthic freshwater **macroinvertebrates** enter the leaf pack and begin their function of further breaking down the leaves. Benthic freshwater macroinvertebrates can be defined as the following:



Benthic	=	inhabit bottom areas/substrates
Freshwater	=	streams, rivers, lakes, ponds
Macro	=	relatively "large" (> 0.2-0.5mm)
Invertebrate	=	animal without vertebrae



These macroinvertebrates play important roles in the food webs of the stream ecosystem. Leaves can be difficult for macroinvertebrates to digest and often contain nutrients that are hard to absorb. The aquatic fungi and bacteria that colonize leaves as a first step in the decomposition process provide an essential component to the macroinvertebrate diet. Research indicates that different leaf types offer different levels of nutrition for freshwater macroinvertebrates. Experimenting with different types of tree leaves may yield a better understanding as to which leaf type certain macroinvertebrates prefer.

# LIFE CYCLES OF AQUATIC INSECTS

Many macroinvertebrates are aquatic insects, that go through several stages from eqq to adult. The number of stages depends on the type of metamorphosis or series of developmental changes that are followed. Insects that undergo incomplete metamorphosis follow three stages. They begin as eggs that hatch into nymphs, which then grow into adults. The immature period is called the nymphal stage. Examples of insects that undergo incomplete metamorphosis are mayflies, dragonflies, damselflies, stoneflies, and true bugs. Many of the insects that undergo incomplete metamorphosis are aquatic only during the egg and nymphal stages. The winged adults do not live in the water. Dragonflies, for example, can often be seen in the adult form flying along streams and rivers in the summer.

Insects that undergo **complete metamorphosis** have four stages: egg, larva, pupa, and adult. They begin as eggs that hatch into tiny larvae; these larvae grow and eventually enter a **pupal stage** in which the insects are transformed into an adult (in a similar way that a caterpillar once in the chrysalis is transformed into a butterfly]. The immature period is called the **larval stage**. Examples of aquatic insects that go through complete metamorphosis are true flies, beetles, caddisflies, and dobsonflies.



Figure 2. Incomplete Metamorphosis and Complete Metamorphosis. Aquatic macroinvertebrates go through several stages from egg to adult.

Many insects that undergo complete metamorphosis are aquatic during the egg, larval, and pupal stages, but not as adults. Some insects like the whirligig beetle and predaceous diving beetle pupate out of the water in overhanging tree branches and return to the water as adults.

The majority of insects found in leaf packs will be in the nymphal or larval stage. The total life cycle of macroinvertebrates ranges from less than two weeks for some true flies (midges and mosquitoes), to two years or longer for some stoneflies, dragonflies, and dobsonflies.

### WATER QUALITY INDICATORS

The ability of freshwater macroinvertebrates to flourish not only depends upon optimal physical factors but also on chemical factors in their environment. Many macroinvertebrates require a specific range of aquatic chemical parameters (pH, dissolved oxygen, temperature, alkalinity, etc.) to survive. The presence or absence of



these organisms in a stream can be used to reveal the overall ecological quality of the water. Generally, unpolluted waters support a greater variety of freshwater macroinvertebrates than polluted waters. There are some macroinvertebrates, however, that can tolerate polluted waters, and these may be found in a greater abundance in polluted waters than in unpolluted waters. As "canaries of the stream," these organisms are exposed to all of the pollutants coming into the stream and serve as living barometers that can indicate changes in water quality. Therefore, macroinvertebrates can act as **bioindicator organisms** to estimate the water quality and the overall health of the stream community.

Since streams are a complex ecosystem, when introducing artificial leaf packs to a particular stream environment, it may also be informative to collect chemical and physical data using a variety of field test kits and visual surveys to provide the most comprehensive assessment of the stream.

#### **FUNCTIONAL FEEDING GROUPS**

Macroinvertebrates can be classified not only by traditional **taxonomy** but also by how they function in the ecosystem (Figure 3). This method of classification based on feeding adaptations and/ or food preferences is known as **functional feeding groups**.

In a simplified view of the food web, these groups process leaf detritus in a stepwise fashion. Large detrital pieces and their associated microorganisms (fungi and bacteria) are eaten by certain, highly specialized macroinvertebrates. This process yields smaller particles (feces and leaf fragments, similar to crumbs created after eating crackers, for example), providing food for other functional feeding groups further downstream. These macroinvertebrates, in turn, are an important food source for **predators**. Ecologically, macroinvertebrates are a primary link between the base of the food web (algae, detritus, and



#### Figure 3. Food Web in Small Streams.

Macroinvertebrates can be classified by how they function in an ecosystem. Image provided by "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)." microorganisms) and larger animals near the top of the food web such as fish.

There are a number of feeding strategies (Figure 4.) including the **shredders** which break down leaves. Shredders (which include crane flies, some caddisflies and stoneflies, sowbugs, and scuds) break the leaves down into fine particles by eating them. Drifting downstream, the fine particles become food for another group of detritus feeders, the **collectors**.

Collectors use various methods to filter or gather the fine particles. Filtering collectors such as the black fly use fanlike filaments near the mouth to capture food particles. Other filtering collectors, such as the net-spinning caddisflies, construct web-like nets. Gathering collectors include some mayflies and midges.

The **grazers** (also known as **scrapers**) are another group of freshwater macroinvertebrates present in the stream community, however these organisms feed on the algae that grow on the surface of rocks. They include some caddisflies, the water penny (a beetle), and certain midges and mayflies.

The shredders, collectors, and grazers are food sources for predators, which include other macroinvertebrates such as dobsonflies and the dragonflies. Predators have large, powerful mouthparts used for grasping prey. All macroinvertebrates, in turn, are food for fish and birds.

Feeding Strategy	Food Category
I. Shredders	dead leaves/live macrophytes
II. Collectors	fine organic particles (live/dead)
Filter feeders	particles in water column
Miners	buried particles
Browsers	bottom surface deposits
III. Scrapers	live benthic algae (diatoms)
IV. Piercers	live filamentous algae
V. Predators	other invertebrates + small fish

Figure 4. Functional Feeding Groups. Macroinvertebrates are classified based on feeding adaptations and/or food preferences.

For a more detailed look at functional feeding groups and their relationship to their location in a stream, visit https://www.leafpacknetwork.org/learn/linking-trees-streams.

# STREAM SIZE AND THE MACROINVERTEBRATE COMMUNITY

Leaf fall from the forest canopy in small streams is a valuable food source for shredders (Figure 5), the macroinvertebrates that get nutrition primarily from the fungi and bacteria that colonize the leaf surface. Crane flies, stoneflies, caddisflies and aquatic sow bugs are all important members of this group.



Leaves accumulate in leaf packs which become food for shredders.

Figure 5. Small Streams. Shredders and collectors form the major portion of stream macroinvertebrates.

As the stream widens, trees do not overhang as much of the water surface so it is exposed to sunlight and instream photosynthesis plays a more important role in the aquatic food web. The amount of leaf litter reaching the stream decreases and algae, due to the increased sunlight, becomes more abundant. As the food base shifts, so does the type of invertebrates. Grazers/scrapers that utilize the abundant algal resource increase while shredders decrease (Figure 6). Snails, limpets, certain mayflies and case-building caddisflies are adapted to feeding on the algae growing on rock surfaces.



Figure 6. Mid-Sized Streams. Collectors gather or filter plant fragments, feces, and plankton. Grazers, also known as scrapers, browse on algae.

Further downstream, the river channel widens and deepens. Trees shade only the water's edge, and sunlight, although abundant, does not penetrate to the river bottom due to turbidity caused by runoff from the land. The food base is dominated by phytoplankton and fine suspended organic particles generated farther upstream and from the river's floodplain. Filtering collectors (Figure 7) such as mussels and clams are adapted to filtering these fine particles from the water column. To complete the food web ecology, a diverse group of predators are found throughout the entire stream length feeding on all other feeding groups.



Large River

Figure 7. Large Rivers. Filtering collectors such as mussels are found in greater abundance in larger streams.

### A CONTINUUM OF LIFE

The Stroud Center's first director had an innovative idea of studying the entire watershed as opposed to only studying sections of a stream as had been done in the past. Physical conditions vary greatly in small headwater streams compared to large rivers. For example, a river's width, depth, velocity and temperature change constantly as the water flows downstream. More importantly, those changes are interrelated — and because a change in one factor affects all the others, a river's pattern is predictable and a continuum (Figure 8). Not only does a stream change physically as it flows downstream, it also changes biologically.



#### Figure 8. River Continuum Concept. Physical and biological characteristics change along the length of a river.

[Source: Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences, 32, 130-137. Reprinted with permission from NRC Research Press. Image provided by "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by the Federal Interagency Stream Restoration Working Group (FISRWG)."

# LINKING THE LEAF PACK NETWORK TO STREAM ECOLOGY

The **River Continuum Concept** (Figure 8) correlates the continuum of physical changes with biological changes throughout a river system. A river is a single continuum that flows ceaselessly from its source to the sea, and to understand a river, what is happening upstream and what is entering it from the watershed must be understood. This became the first unified hypothesis about how streams and their watersheds work. Today, the River Continuum Concept is still the most widely cited study in the field of stream ecology and continues to provide a conceptual model to compare with stream systems throughout the world.

Early research conducted for the River Continuum laid the foundation for more recent studies linking streamside forests and stream ecosystems. It has been well known that streamside forests can function as filters for pollution. Ongoing research has determined that in addition to acting as buffers for pollution, streamside forests are an integral and essential part of the stream ecosystem that affect the physical, chemical and biological aspect of streams.

Stroud Center scientists have used leaf packs to better understand the stream ecosystem. In Costa Rica, for example, leaf packs have been used to study how tropical streams differ from temperate streams. Leaf packs in the Flint River, Georgia, were used to assess effects of industrial effluents. Leaf packs have also been used by scientists to study the effects of streamside forest efforts. Wherever you are in the world, leaf packs can paint valuable portraits of macroinvertebrate communities, water quality and watershed health.

