ADOPT a STREAM

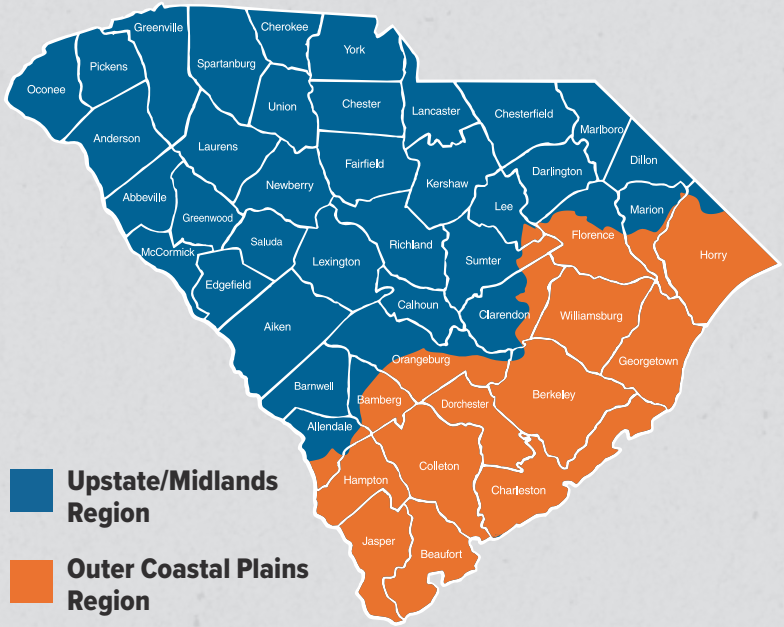
SOUTH CAROLINA ADOPT-A-STREAM

VOLUNTEER *MACROINVERTEBRATE* MONITORING

CENTER FOR WATERSHED EXCELLENCE
CLEMSON

dhec
Healthy People. Healthy Communities.

Map of South Carolina Counties and Sampling Regions



HANDBOOK CONTENTS

IDENTIFICATION GUIDE CONTENTS

Need Help?

Most questions can be answered by visiting our website:
www.scadoptastream.org

For questions about adopting a site, where to get monitoring supplies or help getting started, contact your SC Adopt-a-Stream Trainer:
www.clemson.edu/public/watershed/scaas/connect/trainers-and-staff.html

PRACTICE MACROINVERTEBRATE IDENTIFICATION

Visit macroinvertebrates.org for practice quizzes & photos.

Download Helpful Phone Apps:

Pocket Macros

- ID of all Eastern North American species
- Full color photos

Creek Critters

- Gives instant water quality score
- Out-of-state data sharing

Aqua Bugs

- Basic ID of 27 aquatic taxa

WATER QUALITY EMERGENCY?

For evidence of dangerous pollution discharges, fish kills, or public health hazards, call the 24-hour SC DHEC Hotline:

1-888-481-0125

MACROINVERTEBRATE SCHEDULE

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

1. Circle the months you plan to sample 2x per year.
   (3 months minimum between sampling events)
2. Box the month you plan to do your habitat assessment survey
   (1x per year)
3. Date you'll need to renew your certification:
   (recertify online)

MAR	JUL	NOV

(circle month)

Upstate and Midlands sample summer and winter.

Coastal plain sample winter and spring.

Introduction

WHAT ARE AQUATIC MACROINVERTEBRATES?

Aquatic macroinvertebrates are stream creatures that are big enough to see that also lack a backbone. Examples include aquatic insects, terrestrial insects in their juvenile stages, snails, crayfish, worms, and clams. Macroinvertebrates live in various stream habitats and most derive their oxygen from the water that they live in. Some macroinvertebrates spend their full life cycle in the water, while others are only found in streams as juveniles. As they mature, these young insects (larvae) change form to spend their adult stage as flying insects such as the Dragonfly, Crane Fly or Black Fly.

In many cases, aquatic macroinvertebrates are adults for a very short time. Some even hatch without mouth parts after they undergo metamorphosis. For example, many mayflies live in streams for months to years but only survive a few days as flying adult insects. During this time, they breed and lay their eggs to create the next generation.

WHY CARE ABOUT AQUATIC MACROINVERTEBRATES?

Aquatic macroinvertebrates can be found in many different aquatic habitats such as riffles, pools, vegetation, woody debris, leaf packs or the sediment. In each of these habitats, macroinvertebrates provide an important food source for fish and other predators. They are also great water quality indicators.

Different types of macroinvertebrates tolerate different levels of pollution and stream conditions. Their presence, absence, or abundance in a stream can be used to determine a water quality score, which can help indicate whether the water is clean or potentially polluted. For example,

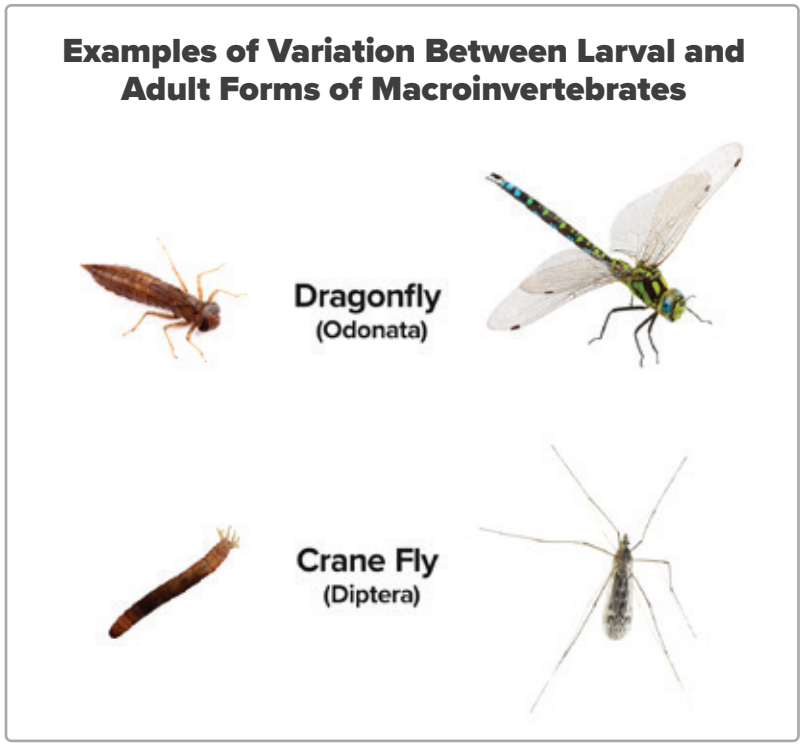


Figure 1. The larval and adult forms do not look alike, as can be seen with these examples above. However, in some ways they're quite similar. For example, dragonfly larvae and adults are both skilled predators.

most caddisfly, mayfly, and stonefly larvae cannot survive in polluted water. Finding these macroinvertebrates in abundance can show that a stream has good water quality and ample habitat. Other natural factors, such as temperature and flow, also come into play when analyzing your macroinvertebrate community found in your stream.

This handbook was created to aid SC Adopt-a-Stream (SC AAS) volunteer monitors in the field identification of macroinvertebrates. This handbook features background information, illustrations, and descriptions of some of the aquatic organisms that can be found in South Carolina's wadable freshwater streams.

MACROINVERTEBRATES AS WATER QUALITY INDICATORS

Macroinvertebrates are excellent indicators of water quality for many reasons:

- They are affected by the physical, chemical, and biological conditions of the stream.
- They are not very mobile (can't leave the area like fish can).
- They are relatively long-lived (some live 1–5 years).
- They are abundant in most streams, found statewide.
- They are a food source for many types of fish; without a food source, the food chain collapses.
- There is no chemical waste with this type of stream analysis.
- They are relatively easy to collect, view, and identify with inexpensive materials.
- Macroinvertebrates are present during all kinds of stream conditions (drought to flood).

Figure 2. List of reasons why macroinvertebrates are great water quality indicators.

In order to recognize biological trends in your stream, it is important for you to conduct monitoring events twice a year for several years. When analyzing data, be sure to compare the same seasons. The basic principle behind the study of macroinvertebrates is that some species are more sensitive to pollution than others. The abundance and diversity of macroinvertebrates found is an indication of overall stream quality. Therefore, if a stream site is inhabited by organisms that can tolerate

pollution and pollution-sensitive organisms are missing, then a pollution problem is likely. This pollution can be literal pollution or changes in other chemical and physical parameters like thermal pollution from water running off warm pavement into a cool stream.

A stream full of many different types of crawling and swimming macroinvertebrates is healthier than one without much life. Different macroinvertebrates occupy different ecological niches within the aquatic environment, so a high diversity of species generally means a healthy, balanced ecosystem.

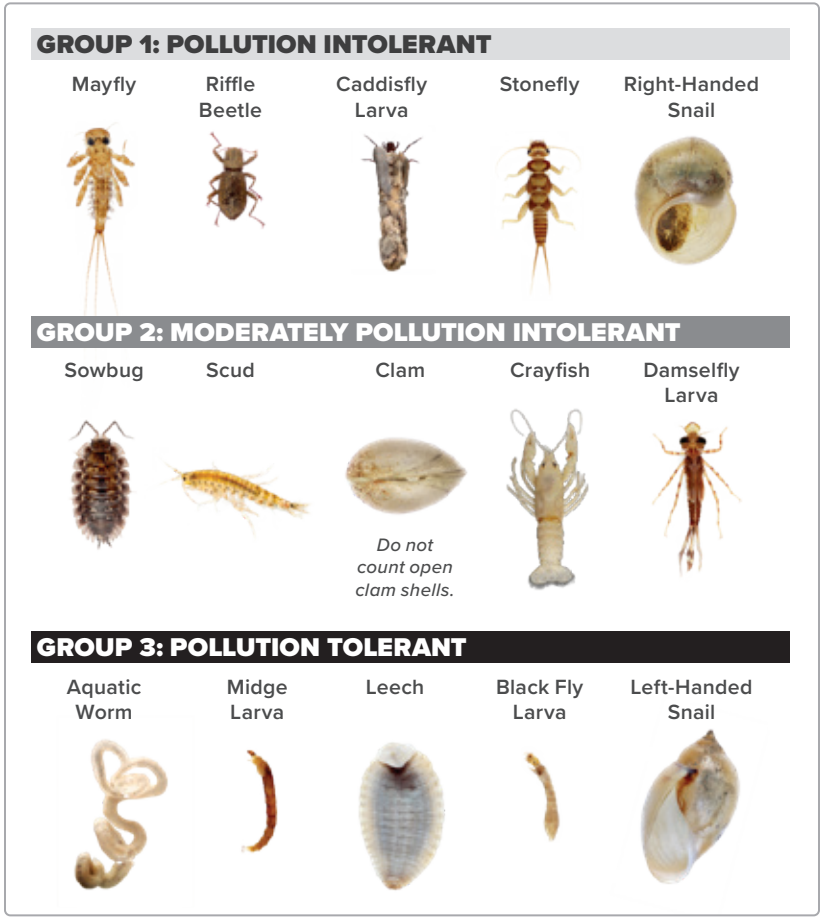
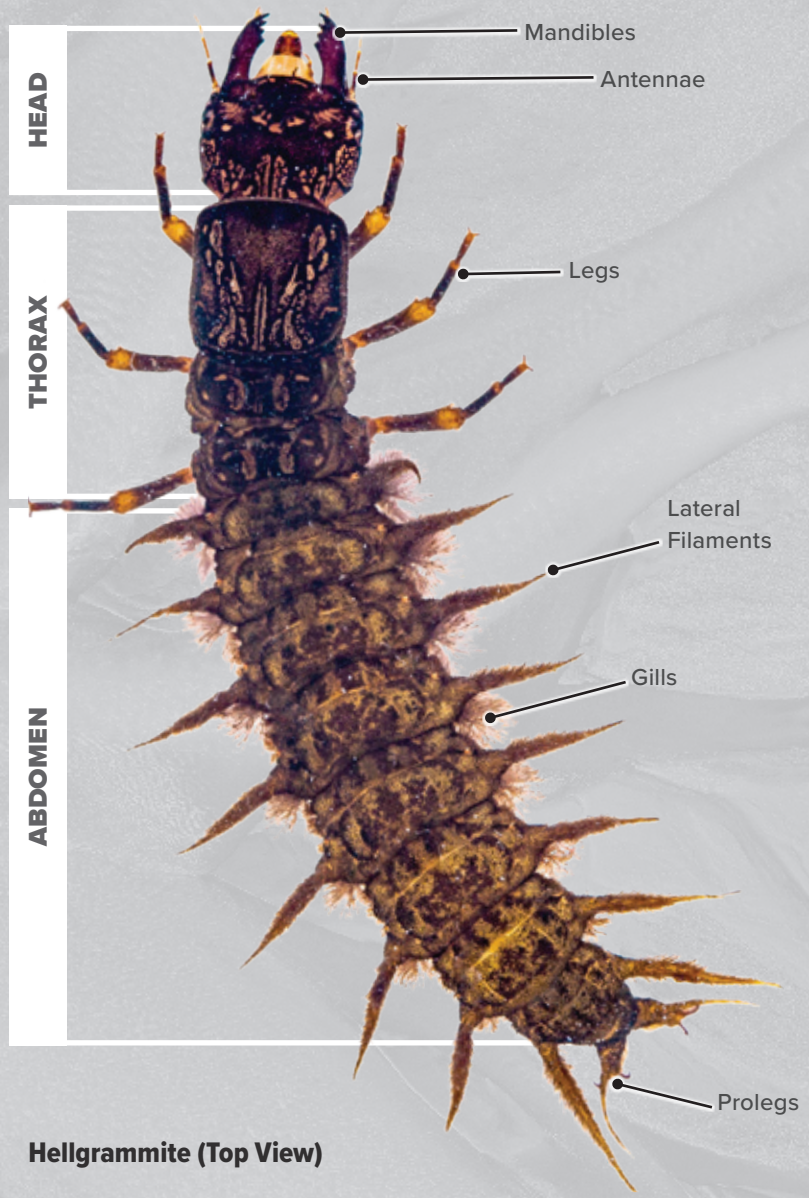
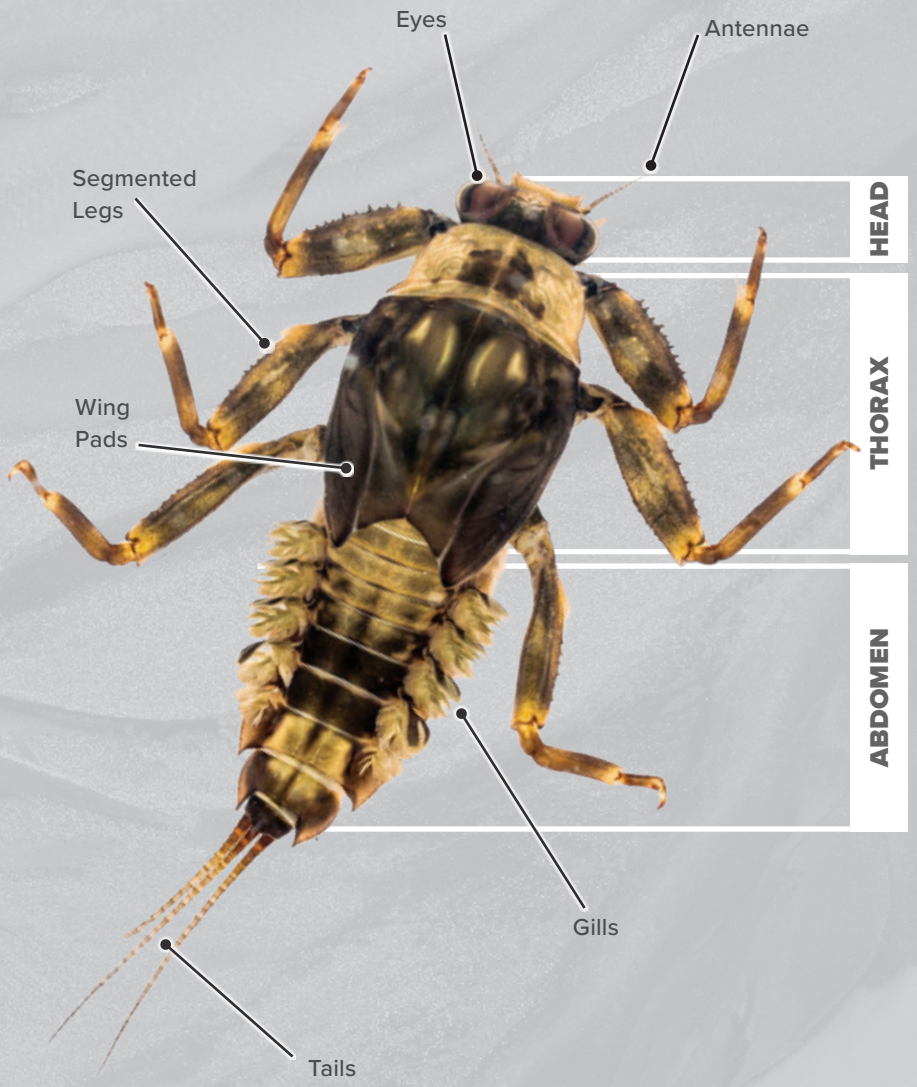


Figure 3 Some macroinvertebrates are more sensitive to pollution than others.

MACROINVERTEBRATE ANATOMY AND MORPHOLOGY



Hellgrammite (Top View)



Mayfly (Top View)

LIFE CYCLES AND METAMORPHOSIS

Life cycles of macroinvertebrates can vary depending on temperatures, levels of dissolved oxygen, day length, pesticide use, water quantity and climate changes. Aquatic insects can feed by shredding, scraping, collecting or predation.

Shredders are often found in headwaters.

Scrapers need streams filled with algae to be abundant.

Collectors can be found all over or in streams with excess sediment.

Predators can be found in a variety of habitats as well, but need other macroinvertebrates present to thrive.

Due to the variety of life cycles and desired habitat types, the more types of habitats that you collect macroinvertebrates from, the greater the diversity of organisms that you will find. Streams that have more diverse communities of macroinvertebrates receive higher water quality scores.

IMPORTANT: Always place collected material and water back where it is collected from. Do not pour it on the bank or let rocks and sticks dry out. This helps return as many macroinvertebrates back to their homes as possible.

You can find Macroinvertebrates in the following types of habitats:

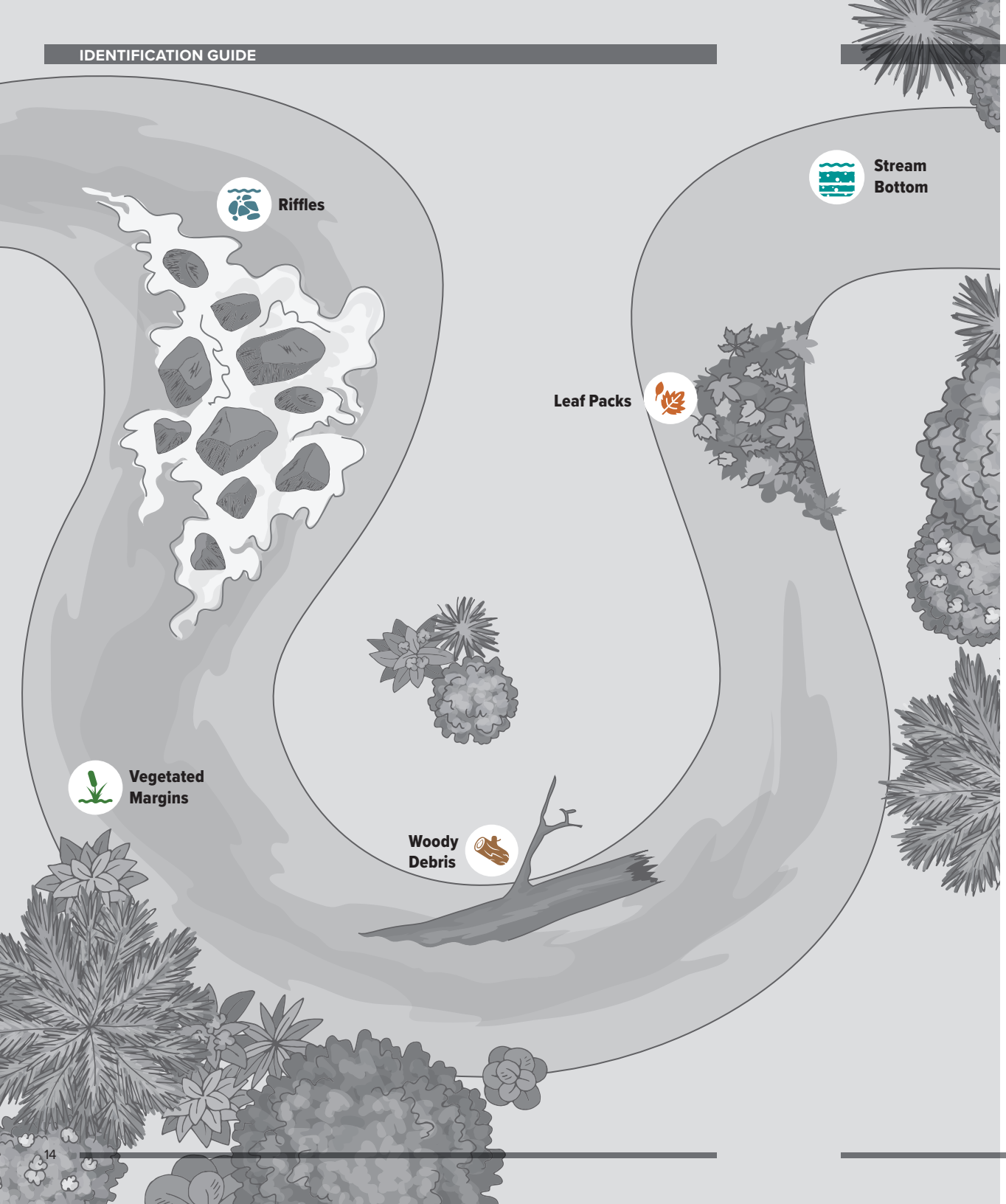
Riffles—shallow area of a stream in which water flows rapidly over a rocky or gravelly stream bed.

Leaf packs—decomposing vegetation that is submerged in the water.

Vegetated margins—submerged aquatic plant areas in the stream. Do not pull the vegetation from the bank; however, it's good to collect any parts of the plants that break free with your sample. **Watch out for poison ivy.**

Woody debris—dead or living trees, roots, limbs, or other submerged organic matter. Watch out for fishhooks, wear gloves and use a brush if you choose to sample individual pieces of wood.

Stream bottom—use this habitat type as a last resort for sampling. It is common for this sampling to collect a lot of sediment, mud, and debris, which will make picking macros out hard.



Macroinvertebrate movement style can help you determine which types may be found in different habitats:

Climbers—Many macroinvertebrates climb vegetation to molt and fly away as adults. Dragonfly nymphs are often found in submerged aquatic vegetation.

Crawlers—These macroinvertebrates "walk" or "crawl" across the bottom of the stream, usually in sandy or leaf-packed areas.

Swimmer—Some mayflies are extremely good swimmers, like fish, which is likely where "Minnow Mayflies" get their common name.

Burrowers—Some species of mussels and clams won't be seen until the steam substrate is disturbed. Sandy and silty substrates can often have more burrowing macros in them. Midges are often found in substrate.

Clingers—Individuals typically have visible claws and exposed gills for holding on in areas of fast current such as a riffle habitat. The Net-Spinning Caddisfly is a great example.

Figure 6 Macroinvertebrates can be found in different types of aquatic habitats. However, some habitat is better to sample than others. There is often more diversity in species in riffles and leaf packs and typically fewer individuals found in sandy stream substrate.

IMPORTANT NOTE: Not all streams have all habitat types and some macroinvertebrate groups have individual species that fit multiple movement types as listed above.

Macroinvertebrate Collection Protocol

At its most basic level, macroinvertebrate monitoring is merely turning rocks over, collecting leaves and kicking up the streambed to dislodge macroinvertebrates into a net. Then they are sorted by similar characteristics like number of tails, presence of gills, color, or overall size. Unlike other sampling protocols, we return the macroinvertebrates back into the stream instead of harvesting them for lab identification.

Although there are many methods of collecting, SC AAS uses a time-based model similar to state agency monitoring. Macroinvertebrate collection involves **spending a full hour** collecting from a variety of habitats, then picking and sorting macroinvertebrates for identification. **Take as much time as you need to identify what you find** outside of the hour spent collecting. The type of net used for collection depends on the type of habitat you are sampling.

If you sample with a partner, you should each collect macroinvertebrates for 30 minutes (for a total of 1 hour combined). You can also break up the hour as long as you keep track of how long you have sampled for. Sample a stretch of at least 100 ft up to 300ft, making sure there are no factors impacting your sampling reach like pipes, land use changes or tributaries.

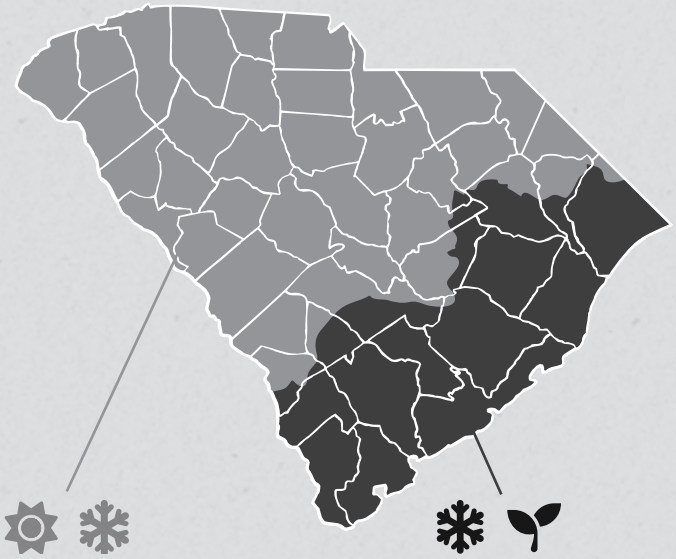
There are 7000+ species of macroinvertebrates in North America. We can get a general idea of our Stream Score just by looking at a handful of them. SC AAS volunteers are taught to identify (20) groups of macroinvertebrates.

IMPORTANT: ALWAYS WORK IN AN UPSTREAM DIRECTION so habitat is not disturbed prior to collection. If you choose to put macroinvertebrates back before your hour of collecting is finished, put them downstream of where you are going to sample next.

FREQUENCY OF MONITORING

In order to recognize biological trends in your stream, it is important for you to conduct monitoring events twice a year for several years. When analyzing data, be sure to compare the same seasons. Wadable freshwater streams in the Upstate and Midlands should be sampled summer and winter. Volunteers with adopted sites in the Outer Coastal Plain should sample winter and spring. When sampling in spring, wait until after the last snow. Always avoid times with significant storm events or periods of extreme floods or droughts. Wait for flow to return to normal before sampling after rain events.

When to Sample in Upstate/Midlands and Outer Coastal Plains Regions



Upstate and Midlands sample summer and winter.

June	December
July	January
August	February

Outer Coastal Plain sample winter and spring.

December	March
January	April
February	May

NET TYPE BY HABITAT TYPE

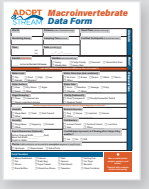
Try to adopt streams that have multiple types of habitats to monitor. When sampling, always work in an upstream direction. You do not want to walk through areas or disturb places that you plan to sample.

1. The best place to sample is in flowing riffles using a **3x3 kick net**. This net type requires 2 people to use.
2. **"D-Frame" nets** can also be used in slower moving streams, to collect leaf packs or under vegetated margins.
3. As a last resort, a **bucket with a sieve (fine mesh)** can be used to sample fine sediment along the stream bottom.

Once collected, place your macroinvertebrates in a white sorting pan or plastic tray. Separate creatures that look similar into groups in an ice cube tray. Use identification keys such as the Macroinvertebrate Identification Guide included in the back of this book, phone apps like "Pocket Macros," or websites like www.macroinvertebrates.org to classify the macroinvertebrates and numbers of each type.

RARE. COMMON. DOMINANT.

You will need to note how often you identify each macroinvertebrate as **Rare** (1-9), **Common** (10-99), or **Dominant** (100+). As you sort through your collection, remember each stream will have different types and numbers of macroinvertebrates. Calculate the score for your stream using the index on the Macroinvertebrate Data Form: https://www.clemson.edu/public/watershed/scaas/resources/materials.html. Macroinvertebrates found in the sensitive category receive the highest scores. The higher the score, the better your water quality and/or stream habitat.

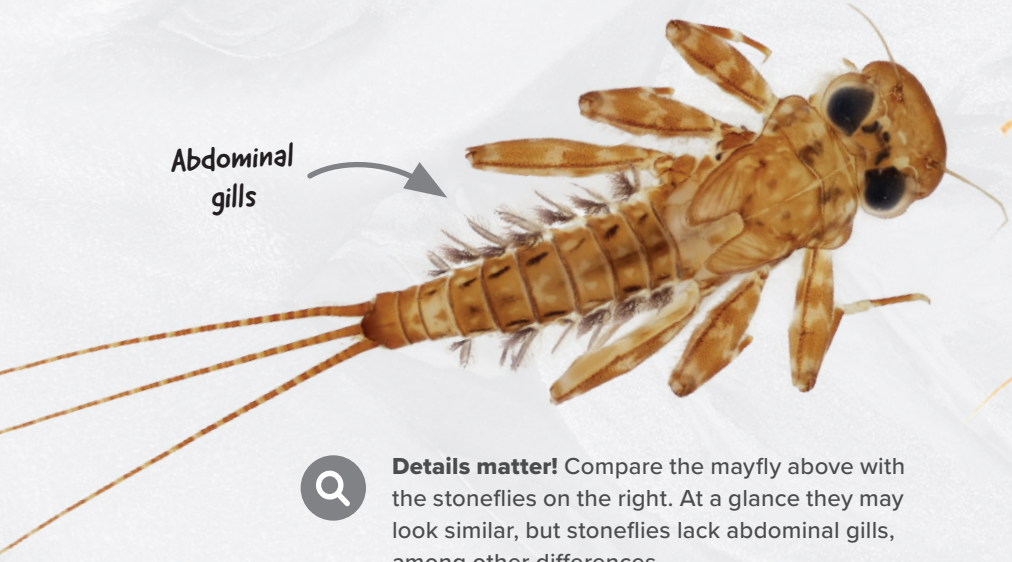


Need the Data Form?

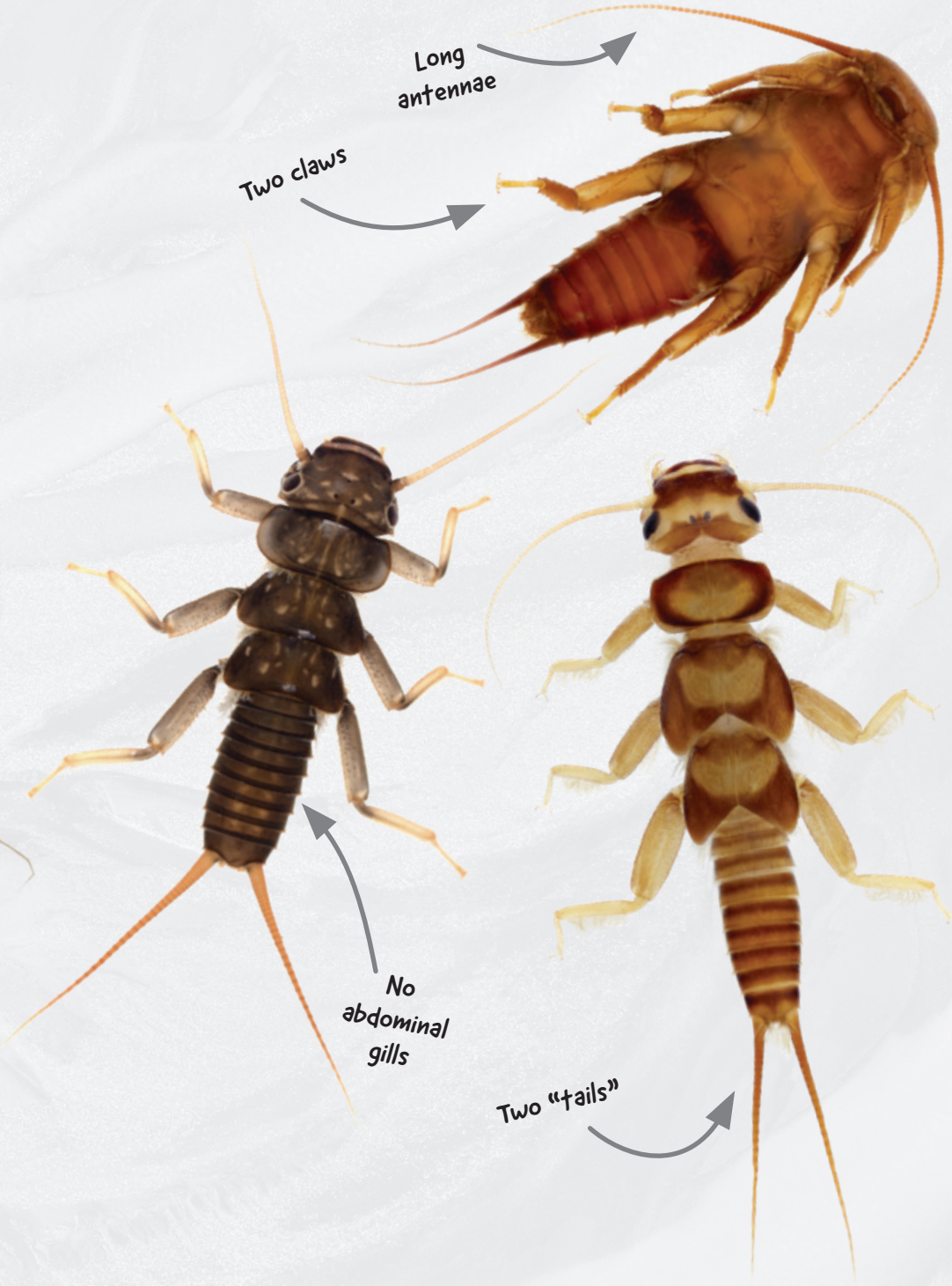
You can view the full-size form by scanning **this QR code** with your phone camera!

IMPORTANT TIPS

- Pay close attention to the size, shape, color, movement, and presence of notable features like gills, tails, claws, etc.
- 2 people are needed for handling kick nets
- Place large rocks on bottom of kick net to prevent anything from moving underneath
- Put everything that you collected back in the stream (bugs, leaves, rocks)
- Clean sampling equipment and your apparel to prevent the spread of invasives
- Leave site cleaner than it was found (make sure to pick up litter)
- Try to focus on finding all types present in your nets and not capturing 100+ of the same organism
- Contact a SC AAS trainer or SC AAS staff member for help with unknown ID.



Details matter! Compare the mayfly above with the stoneflies on the right. At a glance they may look similar, but stoneflies lack abdominal gills, among other differences.



STREAM SCORE... NOW WHAT?

The macroinvertebrate water quality score is informative for environmental impacts, fisheries resources, aquatic pests, sport fishing, and more. The macroinvertebrate community in a stream reflects both short-term and long-term water quality impairments.

This type of monitoring is indicative of long-term water quality conditions and habitat health. It is also important to keep in mind that a diverse macroinvertebrate community indicates a healthier stream than one with an abundance of only a few types of organisms. Examples of this can be seen on the next page.

POOR SCORE?

- Email SC AAS trainer or SC AAS Staff
- Keep sampling regularly
- Note observed changes in the comments box of the SC AAS database
- Adopt additional sites below or above where you sample to compare

Once a problem is identified, the next step is to actively study the watershed or to determine a source of pollution. Identification of water quality concerns can lead to grants and/or implementation of best management practices to help restore the waterbody.

Analyzing Macroinvertebrate Score

Observation		Analysis
	high diversity, lots of stoneflies, mayflies, and caddisflies	no problem, good water quality
	low diversity, high density, lots of scrapers and collectors	Possible organic pollution (nutrient enrichment) or sedimentation likely present; lots of algal growth from nutrient enrichment
	only 1 or 2 taxa groups, high number of collectors	Possible severe organic pollution or sedimentation
	low diversity, low density, but the stream appears clean	Possible toxic pollution (e.g. chlorine, acids, heavy metals, oil, pesticides), or naturally unproductive due to limited light or nutrients (small, high altitude streams)

Get Ready to Get Involved!

(What to expect as a volunteer)

Through this program, it is our GOAL to help citizen scientists increase their knowledge, provide more information about stream health statewide, encourage improved water use habits, and provide opportunities for watershed stewardship.

PROGRAM GOALS

Please keep in mind the purpose of data collected with SC AAS: education, determining baseline conditions, and screening for issues. Though important for these purposes, data collected through this program is NOT regulatory in nature. The data is not to be used to target individuals, organizations or businesses. Therefore, follow up from collected data should and does happen at the local government level all the way up to SC DHEC and is aided by the SC AAS program coordinators.

Most volunteers borrow monitoring supplies from their SC AAS trainer or a local SC AAS Hub, have a local business sponsor a kit, or invest in their own supplies. Monitoring for macroinvertebrates is best done in pairs or small groups. You can sample with non-certified volunteers as long as you continue to follow protocol and report the data to the SC AAS Database at www.scadoptastream.org.

IMPORTANT NOTE:

Water quality concerns are rarely solved with just a few data points like those generated from macroinvertebrate monitoring. Therefore, consider why you want to become a SC AAS Volunteer Monitor to help determine what protocols (biannual macroinvertebrate, annual habitat and/or monthly chemical/bacteria monitoring) may be the most suitable for your objectives.

WHAT DOES ADOPT ACTUALLY MEAN IN SOUTH CAROLINA ADOPT-A-STREAM?

The “ADOPT” in Adopt-a-Stream outlines the program’s objectives.

ADOPT a STREAM

South Carolina Adopt-a-Stream was launched in 2017 as a freshwater quality monitoring program for citizen scientists. It is co-led by South Carolina Department of Health and Environmental Control and Clemson University’s Center for Watershed Excellence. Together, with other local program partners, these groups help keep the program running and growing.

Trainers are SC AAS Volunteers that have been actively monitoring for at least a year and have successfully completed the SC AAS Trainer Certification Workshop. You, our volunteers, are integral to data collection and stream stewardship. After attending this training workshop, you will be a certified citizen scientist. You have the chance to positively impact water

A

ACTIVE
Volunteers are actively monitoring across the state

D

DATA
Baseline data is collected and stored for public use

O

OUTDOORS
Monitoring is a good excuse to get outdoors

P

PROTECT
Data helps the protection of streams

T

TOGETHER
Monitoring helps improve waters together

quality in your community by providing valuable data about streams that you care about. Others can also get involved by becoming hubs (a location that stores or loans monitoring kits, helps promote workshops and actively shares data) or sponsors (help with kit purchases, handbook printing, or donate awards for top volunteers).

USE OF DATA

The protocols selected to collect volunteer monitoring data follow an EPA approved Quality Assurance Project Plan (QAPP). Although this helps ensure the data is high quality, it cannot be used for regulatory purposes by agencies. A QAPP ensures consistency of data collection, trainings, protocols, policies and procedures. This QAPP was approved by US Environmental Protection Agency (EPA) Region 4 and SC DHEC in April 2018, updated in 2022 and is available at www.scadoptastream.org.

While the screening level data generated by the program method does not meet the rigorous data quality requirements for SC DHEC regulatory decisions, it provides many benefits. Data collected by SC AAS Volunteer Monitors will be used to establish baseline conditions for determining stream health based on chemical, physical, biological and habitat parameters. Volunteer monitor data is useful in screening waterbodies for water quality problems and in assessing the overall health of a watershed. This data may also be used to:

- Identify waters in need of more detailed monitoring or restoration
- Assist decision-makers at local and regional watershed levels
- Encourage community involvement in their local watershed
- Prioritize or assess areas for Best Management Practices/319 Grants
- Identify potential pollution events
- Provide educational and involvement opportunities

WATER QUALITY IN SOUTH CAROLINA

South Carolina's waterways, their health and vitality, are the cornerstone to all things South Carolina. Our waterways power our industries and homes, with power generation utilizing the greatest volumes of water in our permitting system. Our state's largest industry, agriculture, uses surface and groundwater to put food on our table and feed the growing local food movement. The state's population and tourists paddle, swim, fish, and boat from our mountain streams to the coast. Ample rainfall, groundwater replenishment, and clean water help maintain a healthy South Carolina. In the past two centuries, human activities have had a significant effect on South Carolina's water quality. Point and nonpoint source pollution contribute to water quality problems.

Point Source Pollution (regulated discharges) has been the focus of regulatory oversight for decades. Attention to point source problems has resulted in significant improvement in water quality. Point source pollution is where you can see or point to the source, such as industrial discharges and municipal sewage treatment plants. This type of pollution is regulated by SC DHEC. Industries, business, cities, and counties must go through a lengthy permitting process.

What makes Nonpoint Source Pollution?

Erosion & Sediment Runoff

Fertilizers & Pesticides

Animal Waste

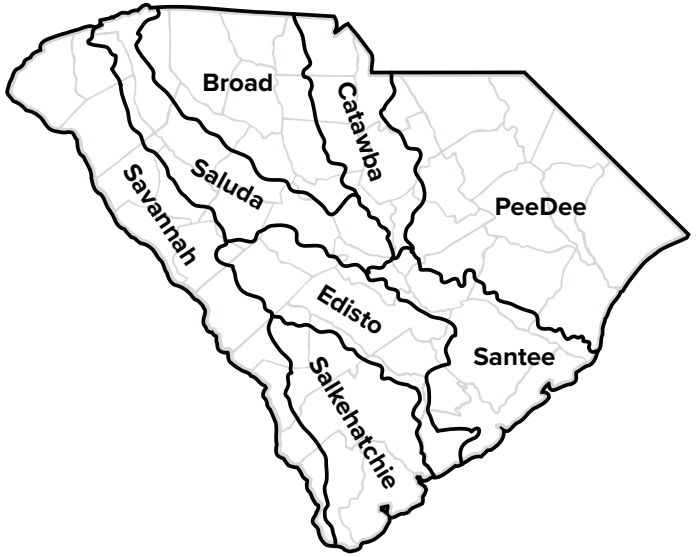
Illegal Dumping

Paved Surfaces

Septic Leaks

Nonpoint Source Pollution is now the #1 threat to water quality for South Carolina. Nonpoint source pollution is where an individual source cannot be easily identified. SC AAS volunteers can play an important role in tracking and monitoring water quality and sharing data, which helps us learn more about sources of nonpoint source pollution. Examples of nonpoint source pollution include erosion/sediment runoff, fertilizers, pesticides, animal wastes, runoff from roads and parking lots, illicit spills, illegal dumping and leaking septic systems. This type of pollution is the leading cause of water quality problems in SC.

Many “pollutants” in a stream are naturally occurring and are only considered a pollutant when their presence is altering a waterway’s ability to maintain aquatic life or poses a potential threat to humans.



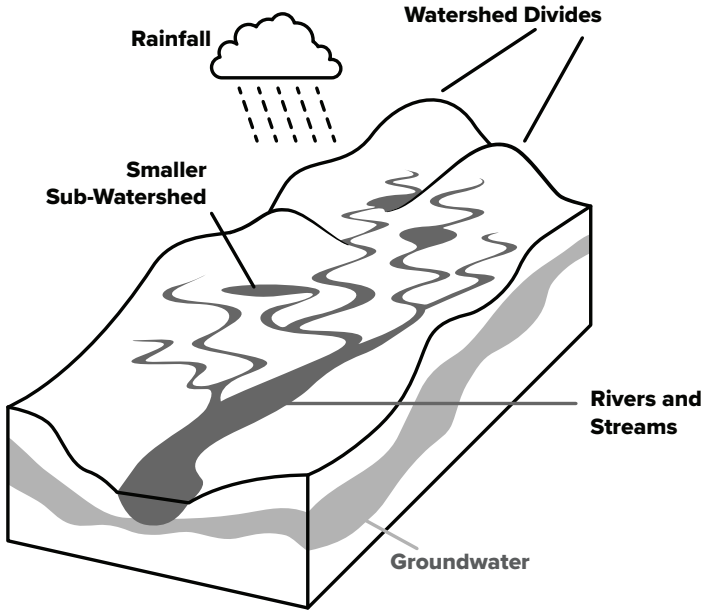
South Carolina Watershed Water Quality Management Basins

WATERSHEDS

South Carolina is divided into 8 very large "watersheds" or river basins. They are called the: Savannah, Saluda, Broad, Catawba, Pee Dee, Edisto, Santee, and Salkehatchie.

These river basins are then further broken up into smaller watersheds. A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. Rain and runoff from these watershed divides (hills, ridges, mountains) drains to the streams in the watershed, as shown on the next page.

All the land and water that drains water to the outflow point is the watershed for that outflow location. Understanding the boundaries of your watershed and how it is affected by the smaller watersheds provides you insights on how land use, permitting, and other occurrences in the watershed may result in changes in your data and observations at your site(s).



Pollution and other impacts found in watersheds that directly affect macroinvertebrates:

Dissolved Oxygen—Macroinvertebrates breathe oxygen that is dissolved in the water. In the immature stage, many species require high levels of dissolved oxygen in order to survive. Some breathe through gills (mayflies) while others inhale oxygen through their posterior end (dragonflies). Warm, slow-moving, water holds less oxygen than cool, fast-moving, water. As streams receive more sediment, they also become more shallow, tend to widen, slow down, and warm.

pH—Discharges from industries or mining can lower pH (making water more acidic). Low pH can weaken shells and exoskeletons and kill macroinvertebrates.

Vegetation—Removal of riparian vegetation (plants along the streambank) takes away important food sources and breeding grounds for macroinvertebrates. It also allows for the banks to erode altering the channel and covering up habitat with sediment.

Seasons—Shredders can be most abundant in the fall when streams are rich with organic matter (nutrients). Scrapers can be hard to find in shaded areas during the summer when algal growth is limited due to reduced sunlight. Scrapers that feed on algae are most abundant in the summer when algae production is at its highest. In some streams, many species of stonefly nymphs will be found in the winter, but will not be as evident in the summer.

Sediment—A stream naturally carries sediment, with high volume waterways carrying greater loads of sediment. Too great of a load of sediment is considered a pollutant and can lead to significant damage. Sediment sources include streambank erosion and soil loss from construction site runoff, agricultural runoff, streets, yards, and damaging stormwater flows. When sediment fills in the spaces between rocks and substrate, this is called "embedded" sediment. Sediment also carries with it adsorbed nutrients (nutrients attached to the surface of sediments) and metals which can cause eutrophication or toxicity.

Nutrients—Nutrients, such as nitrogen and phosphorus and their various forms, are natural and needed for plant growth. Nutrients come from many sources, such as leachate from septic systems or as fertilizer runoff from agriculture, golf courses, and commercial and residential properties. Excess nutrients can create a chain of events that decreases water quality and can harm the species that live in these waters. This is evidenced by rapid growth of algae. When large amounts of algae die, bacteria that decomposes plant materials consumes the oxygen in-stream, causing hypoxia (low oxygen condition). The abnormal, often sudden, depletion of oxygen is a stressor for fish and other aquatic animals and can even result in a macroinvertebrate or fish kill.

Temperature—Temperature is an important measure of the health of a stream. Water temperature has significant effects on its inhabitants. Certain species, like trout, require cold water to reproduce. Warmer temperatures may increase fish vulnerability to disease and can be a factor in ammonia toxicity. Groundwater seepage and natural springs provide cold water to streams. Alternatively, where tree canopy and riparian buffers have been reduced, or stormwater runs off from paved urban areas, this runoff becomes a thermal pollutant.

Site Selection

Be prepared to sample the same location, at the same time of day, two times a year. The safety of volunteers is the highest priority in this program. Never sample if conditions are too dangerous! The ideal stream to sample is “wrist-deep” to “hip-deep” during normal conditions. Do not adopt sites that run dry regularly or that become stagnant during the summer.

Remember not to collect from disturbed areas. Always collect upstream of structures and remember to select the same habitat/stream segment each time to sample. It’s best to work in upstream direction. Never sample at outfalls.

THINGS TO CONSIDER OR EXPLORE BEFORE ADOPTING A SITE

Access/Permission

Identify a site with easy access for you to carry equipment and with a stable, clear location to setup and sample. Sample upstream of any bridge or road crossings when possible. Consider where to safely park and if there is a flat space to work near the stream. Always get permission to sample on private property.

SC AAS provides a Landowner Permission Form to encourage good relationships between volunteers and land owners: https://www.clemson.edu/public/watershed/scaas/files/landowner-permission.pdf

Existing Data

- Proximity of Existing Sites—adopt sites no closer than 100 yards (football field) from existing sites.

- Explore the SC DHEC Watershed Atlas to learn where state monitoring already exists: https://gis.dhec.sc.gov/watersheds

Stream Type

It is best to select a site that has a well-mixed area of flowing water. Remember to only sample during NORMAL flow conditions. Your adopted stream must flow year-round and be deep enough to sample. Flowing water helps push the macroinvertebrates into the net when sampling. Note: heavy rain in areas with a high percentage of impervious surface (most urban areas) can cause flash floods that may carry macroinvertebrates downstream. This protocol is not intended for sampling use in large rivers, lakes or swamps. Ideal streams to sample should be wrist-deep to waist-deep.

Seasons

Some macroinvertebrates are easier to find when leaf packs are present in the stream. Other macroinvertebrates may have periodic hatches during portions of the year where they may not be present in the stream or be too tiny to identify.

THINGS TO CONSIDER OR EXPLORE AFTER ADOPTING A SITE

Watershed Tour

Get to know your watershed by taking a driving tour. Record notes (as a passenger or invite a friend) on anything that can affect your waters. This could be land use change, floods, droughts, sediment sources, discharges, withdrawals, mining, agriculture, etc.

Stream Walk (only walk where you have permission)

- Litter—consider bringing a reusable trash bag to help keep your stream clean. If an organized clean-up is needed, select that option in our SC AAS database or email SC AAS staff.

- Take pictures of anything unusual.
- Take note of any nearby tributaries, pipe outlets, or crossings.

Mapping/Data sharing

- All data from the SC AAS database can be copied and pasted or exported from it.
- Maps can be made using the SC Watershed Atlas. View recorded webinars demonstrating this process in the Videos section of the Resources & Materials page at www.scadoptastream.org.

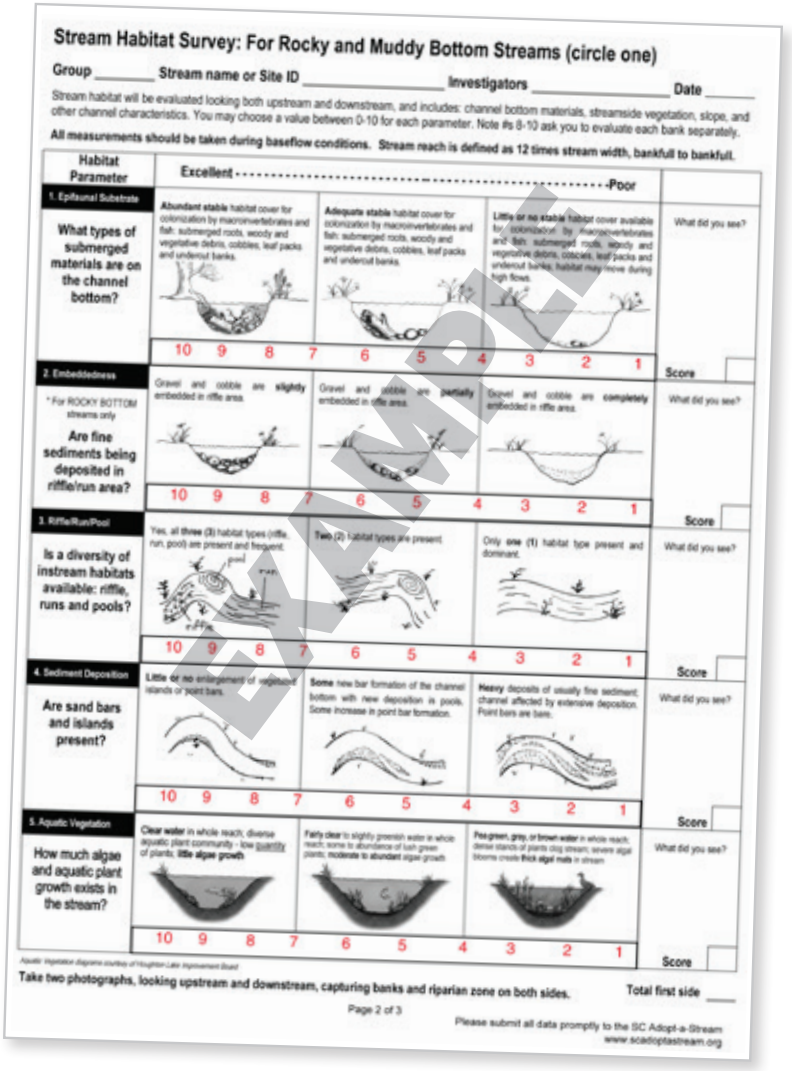
SAFETY

It is always best to sample with someone, even if they are not a certified volunteer. However, if you must sample without someone, let a friend know where you'll be and what time you plan on leaving and returning. Never sample during a storm. Wait until a storm has stopped AND high-water flow has subsided. Keep in mind, your site may be contaminated even if the water is clear or has no odor. Always wear boots and gloves and wash hands after sampling. Lastly, if there is evidence of criminal activity, leave the area immediately and call local law enforcement. Make sure you have permission to sample on private lands each time you sample at that site.

HABITAT ASSESSMENT

Score your site using the Stream Habitat Assessment once per year. This tool can be used to quantify changes in your stream over time.

Watch the **"Stream Habitat Assessment"** video on the Resources & Materials page of our website, www.scadoptastream.org to learn more.


Stream Habitat Survey: For Rocky and Muddy Bottom Streams (circle one)

Group _____ Stream name or Site ID _____ Investigators _____ Date _____

Stream habitat will be evaluated looking both upstream and downstream, and includes: channel bottom materials, streamside vegetation, slope, and other channel characteristics. You may choose a value between 0-10 for each parameter. Note #s 8-10 ask you to evaluate each bank separately.

All measurements should be taken during baseflow conditions. Stream reach is defined as 12 times stream width, bankfull to bankfull.

Habitat Parameter	Excellent ---------- Poor			
1. Epifaunal Substrate What types of submerged materials are on the channel bottom?	Abundant stable habitat cover for colonization by macroinvertebrates and fish: submerged rocks, woody and vegetative debris, cobbles, leaf packs and undercut banks.	Adequate stable habitat cover for colonization by macroinvertebrates and fish: submerged rocks, woody and vegetative debris, cobbles, leaf packs and undercut banks.	Little or no stable habitat cover available for colonization by macroinvertebrates and fish: submerged rocks, woody and vegetative debris, cobbles, leaf packs and undercut banks; habitat may recive during high flows.	What did you see?
	10 9 8 7 6 5 4 3 2 1			Score
2. Embeddedness * For ROCKY BOTTOM streams only Are fine sediments being deposited in riffle/run area?	Gravel and cobble are slightly embedded in riffle area.	Gravel and cobble are partially embedded in riffle area.	Gravel and cobble are completely embedded in riffle area.	What did you see?
	10 9 8 7 6 5 4 3 2 1			Score
3. Riffle/Run/Pool Is a diversity of instream habitats available: riffle, runs and pools?	Yes, all three (3) habitat types (riffle, run, pool) are present and frequent.	Two (2) habitat types are present.	Only one (1) habitat type present and dominant.	What did you see?
	10 9 8 7 6 5 4 3 2 1			Score
4. Sediment Deposition Are sand bars and islands present?	Little or no enlargement of sediment islands or point bars.	Some new bar formation of the channel bottom with new deposition in pools. Some increase in point bar formation.	Heavy deposits of usually fine sediment; channel affected by extensive deposition. Point bars are bare.	What did you see?
	10 9 8 7 6 5 4 3 2 1			Score
5. Aquatic Vegetation How much algae and aquatic plant growth exists in the stream?	Clear water in whole reach; diverse aquatic plant community - low quantity of plants; little algae growth	Fairly clear to slightly greenish water in whole reach; some to abundance of lush green plants; moderate to abundant algae growth	Pea-green, gray, or brown water in whole reach; dense stands of plants clog stream; severe algal blooms create thick algal mats in stream	What did you see?
	10 9 8 7 6 5 4 3 2 1			Score

Aquatic Vegetation diagrams courtesy of Houghton Lake Improvement Board

Take two photographs, looking upstream and downstream, capturing banks and riparian zone on both sides. Total first side ____

Page 2 of 3

Please submit all data promptly to the SC Adopt-a-Stream www.scadoptastream.org

EXAMPLE

Need the Habitat Assessment Form?

You can view the full-size form by scanning **this QR code** with your phone camera!

Macroinvertebrate Identification Guide

HOW TO READ THIS ID GUIDE

This guide is divided according to macroinvertebrate pollution tolerance:

- Section 1: Sensitive
- Section 2: Somewhat Tolerant
- Section 3: Pollution Tolerant

Each section includes examples from various taxa. Use the Indicators for ID to help you sort and tally.

INDICATORS for ID

This section will list out any prominent features or characteristics that you can use to help in your identification efforts.

SIMILAR TO

This section will list out the other macroinvertebrates or aquatic insects that may be visually similar to the one you are attempting to identify.

SIZE

A ruler helps visualize the average minimum and maximum (if applicable) sizes of each macroinvertebrate.

DISTRIBUTION

This section lists out where in the state you are most likely to find the macroinvertebrates listed.

FEEDING

 Predators

 Collectors

 Scrapers

 Shredders

MOVEMENT

 Climbers

 Burrowers

 Crawlers

 Clingers

 Swimmer

HABITAT

 Riffles

 Woody debris

 Leaf packs

 Stream bottom

 Vegetated margins

SC AAS Macro Key

START HERE

SHELLS

DO NOT COUNT empty or opened shells.

ONE SHELL

Lunged Snail
opens on left

Gilled Snail
opens on right

TWO SHELLS

Clams and Mussels

NO SHELLS

LEGS

10+ LEGS

Crayfish
lobster-like

Scud
shrimp-like, swims on side, side-to-side flat

Aquatic Sowbug
walks on bottom, top-to-bottom flat

3 PAIRS OF LEGS

NOT BEETLE-LIKE

NO OBVIOUS "TAILS"

Water Penny
tiny, suction cup-like

Dragonfly Larva
large body, hinged mouth

Casebuilder/Free Swimmer Caddisfly Larva
lives in a case or has hook-like tails

ONE OR TWO "TAILS"

Net-Spinning Caddisfly Larva
two brush-like tails, plates, gills on abdomen

Helgrammite/ Dobsonfly, Fishfly, Alderfly Larva
large mouth parts, "spines" on side

Stonefly Larva
2 tails, long & stiff, long antennas

MORE THAN TWO "TAILS"

Mayfly Larva
3 long tails, gills on abdomen

Damselfly Larva
no gills on abdomen, oar-shaped "tails"

BEETLE-LIKE

Riffle Beetle (Adult)
small, crawls on bottom

NO LEGS

WITH TENTACLES, BRUSHES, OR "TAILS"

Aquatic Snipe Fly Larva
pointy head, two tails

Crane Fly Larva
large, with tentacles

Black Fly Larva
bowling pin shape

WORM-LIKE

Leech
suckers, expands and contracts

Aquatic Worm
segmented body

Midge Larva
distinct head, soft

Riffle Beetle Larva
dark and "crunchy"

Plecoptera

Stonefly

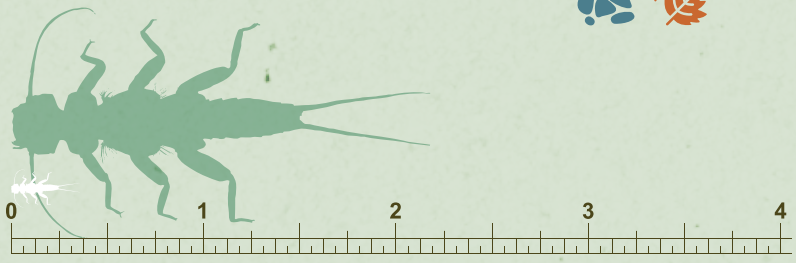
- Stonefly nymphs do pushups to get oxygen through gills under their legs to breathe.
- Their streamlined, flattened bodies enable them to move about the rocky streambed in rapid currents.

INDICATORS for ID

- Two tails, prominent antennae, and two claws at the end of each leg. They will rarely have gills on their abdomen.
- 2 sets of wing pads
- Many, but not all, have branched gills between legs on underside of body, “hairy armpits”
- Yellow to dark brown

SIMILAR TO

- Mayfly



SIZE: 0.25–1.5 inches *(excluding tails)*

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Ephemeroptera

Mayflies

- Mayflies can be narrow like a minnow or flattened top to bottom.
- Mayflies flap gills on their abdomen to breathe.

INDICATORS for ID

- Slender, normally short, antennae
- One claw per leg
- Usually 3 tails
- Gills on abdomen

SIMILAR TO

- Stonefly

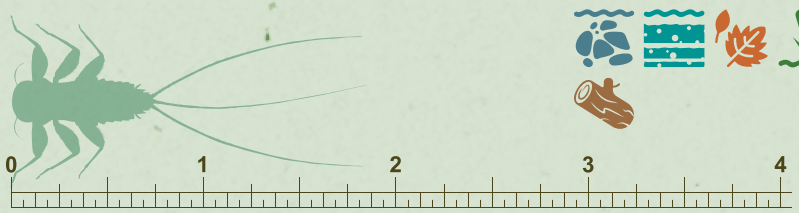
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: Up to ¾ inch *(excluding tails)*

Trichoptera

Case-building/Free-swimming Caddisfly

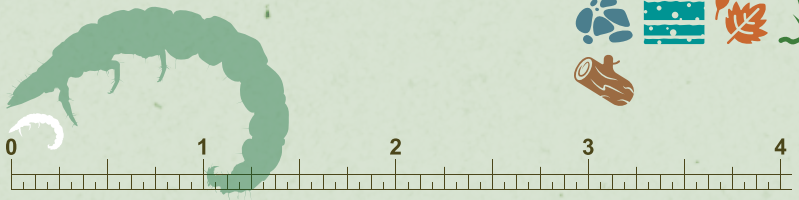
- Caddisfly larva are unique because some build distinctive cases made of sticks, rocks, sand, plant material and/or other debris.

INDICATORS for ID

- "C" Shaped
- Some have cases
- Claw-bearing prolegs at end of abdomen
- 3 pairs of legs

SIMILAR TO

- Riffle Beetle (crunchy and dark)
- Net-Spinning Caddisfly (gills on abdomen)
- Midge (tiny)



SIZE: 0.25 to 1.5 inches

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Diptera

Aquatic Snipe Fly

- All snipe flies have piercing mouth parts that allow them to subdue and consume prey species.

INDICATORS for ID

- Pale to brown-green color
- Caterpillar-like
- Two stout tails (short)
- Pointed head
- 8 Segments

SIMILAR TO

- Crane Fly
- Midge

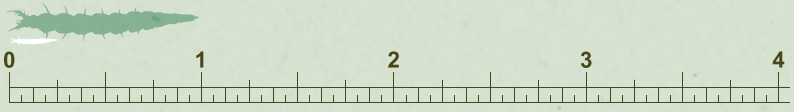
DISTRIBUTION

Upstate and Midlands

FEEDING

MOVEMENT

HABITAT



SIZE: ¼ to 1 inch

Coleoptera

Water Penny

- Water pennies are beetle larvae that cling to rocks and look like tiny pennies.

INDICATORS for ID

- Flat and copper colored
- Has gills on abdomen
- Disk or shield-like body
- 6 legs

SIMILAR TO

- Crane Fly
- Midge

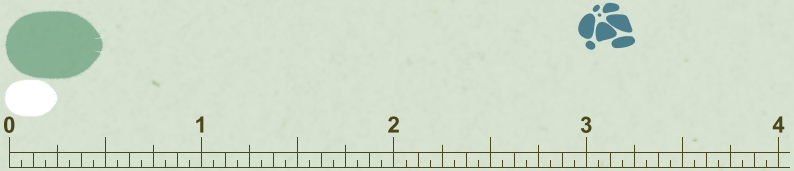
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ¼ to ½ inch

Gastropoda

Gilled Snail

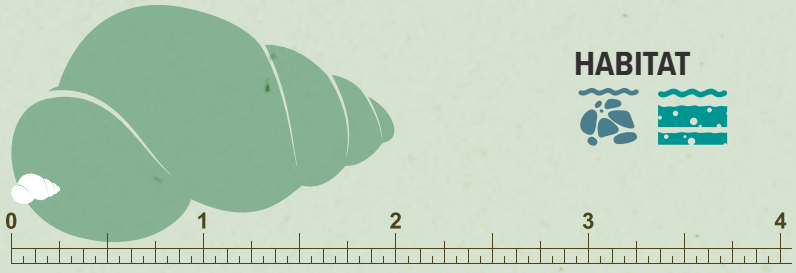
Gilled snails have a door (called an operculum) that helps protect them. The door is not always present if the shell is empty.

INDICATORS for ID

- Shell open to right
- Living organisms have a “trap door”
- **DO NOT COUNT** empty shells

SIMILAR TO

- Lunged Snail



SIZE: ⅛ inch to 2 inches

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Coleoptera

Riffle Beetle

- Riffle beetles live in the water as a larva, then pupate on land, and finally return back to the water as an adult.

INDICATORS for ID

Larvae

- Dark and "Crunchy"
- "C" Shaped
- 6 legs
- "Trapdoor" with gills at end of abdomen

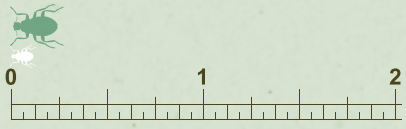
Adult

- Long Legs
- No Gills
- Slender Antennae
- Walks underwater on bottom of the substrate

SIMILAR TO

- **Larvae**—Caddisfly or Midge
- **Adult**—Diving Beetles, Whirligig Beetles, Water Scavenger Beetles *(All not scored with SC AAS)*

LARVA SIZE: 1⁄16 to 1⁄4 inch



ADULT SIZE: 1⁄16 to 1⁄4 inch

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Trichoptera

Common Net-Spinning Caddisfly

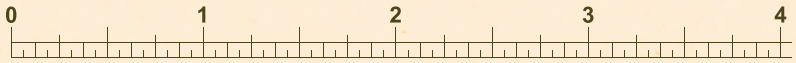
- Larvae build stationary retreats of silk, detritus, and rock fragments. A part of the entrance of the retreat often has a circular silken net woven to its upstream end, protruding across the current to filter bits of suspended food from the water.

INDICATORS for ID

- "C" Shaped
- Dark plates near head, "crunchy and creamy"
- Gills on abdomen
- Fluffy "Tails" (gills)

SIMILAR TO

- Riffle Beetle
- Non Net-Spinning Caddisfly



SIZE: ¼ to ¾ inch

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Megaloptera

Dobsonfly (Hellgrammite), Alderfly and Fishfly

- Fishfly larvae can breathe through gill tubes along the body.

INDICATORS for ID

- Flattened body
- Short antennae
- 2 claws on each leg
- 8 pairs of lateral filaments
- Pinchers
- May have gills under lateral filaments
- **Caution!** Can deliver a painful bite.

SIMILAR TO

- Riffle Beetle
- Non Net-Spinning Caddisfly

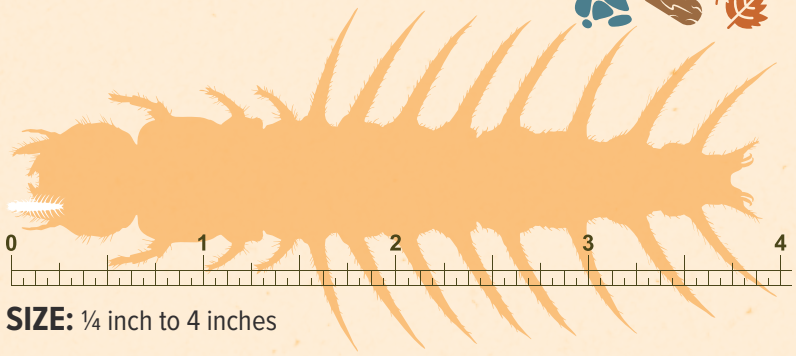
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ¼ inch to 4 inches

Odonata

Dragonfly and Damselfly

Dragonfly

Damselfly

Damselfly

Dragonfly

Dragonfly

- Damselfly nymphs breathe through paddle-like gills on their backsides, making them bum-breathers.

INDICATORS for ID

Dragonfly

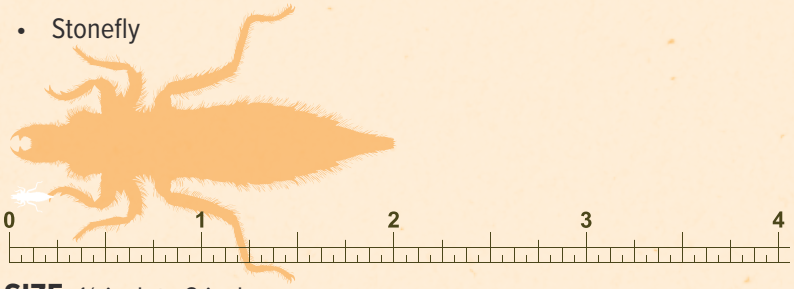
- Two pairs of wing pads
- Large round or oval abdomen
- No tails, No gills
- Big eyes and jaws

Damselfly

- Very slender bodied
- 3 oar-like tails (gills)

SIMILAR TO

- Mayfly
- Stonefly



SIZE: ¼ inch to 2 inches

DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT

Diptera

Crane Fly

- Crane fly adults look like giant mosquitos but cannot eat or bite.

INDICATORS for ID

- Plump and caterpillar-like
- Segmented Body
- Milky green to brown color
- Finger-like gills at end of abdomen

SIMILAR TO

- Midge
- Black fly
- Aquatic snipe fly

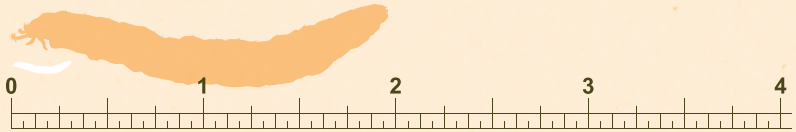
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ⅓ inch to 2 inches

Crustacea

Crayfish

IMPORTANT NOTE:

Crayfish can be many different colors.

- Crayfish are better at swimming backward than forward.

INDICATORS for ID

- Lobster-like
- Large Pinchers
- 10 legs

SIMILAR TO

- Scud
- Sowbug

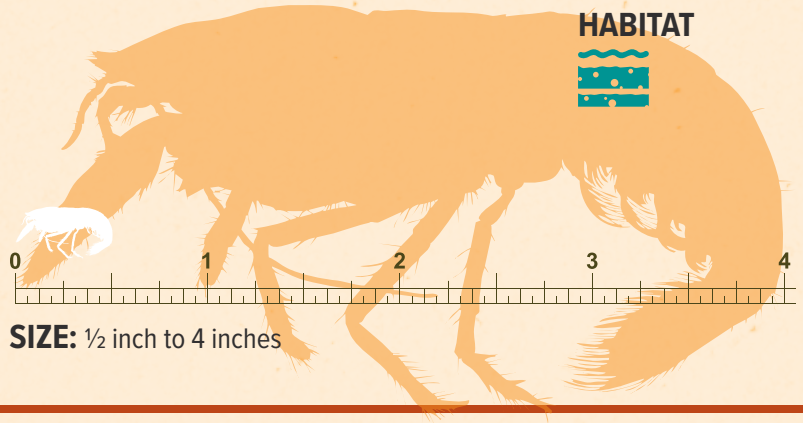
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ½ inch to 4 inches

Crustacea

Sowbug

- Sowbugs are the aquatic relatives of roly polies.

INDICATORS for ID

- Light grey to clear in color
- Flattened top to bottom
- 14 legs

SIMILAR TO

- Scud

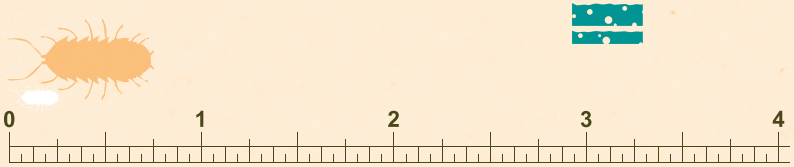
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ¼ inch to ¾ inch

Crustacea

Scud

- Scuds are called sideswimmers.

INDICATORS for ID

- Clear to pink in color
- Flattened side to side
- 14 legs

SIMILAR TO

- Sowbug

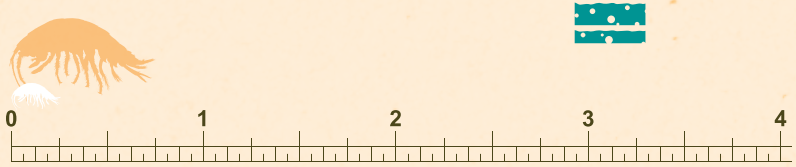
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: less than ¼ inch to ¾ inch

Bivalvia

Clams and Mussels

IMPORTANT NOTE:

When counting clams and mussels, **DO NOT COUNT** empty shells.

- Freshwater mussel larvae disperse by attaching to fish gills or fins (often for several weeks or months) before dropping off and settling to the bottom. Because of this life cycle, mussel conservation is directly linked to fish conservation.

INDICATORS for ID

- Fleshy body between 2 shells
- Shells shut when alive
- **DO NOT COUNT** empty shells

SIMILAR TO

- Snails

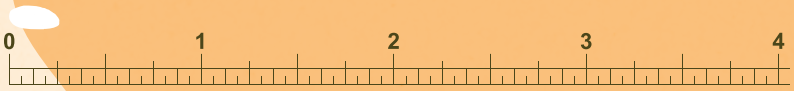
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: less than ¼ inch to 6 inches

Diptera

Midge

- Even though some species of midges are called “biting-midges” they don’t bite in larval form.

INDICATORS for ID

- Small curved body
- Variety of colors

SIMILAR TO

- Worms
- Caddisfly

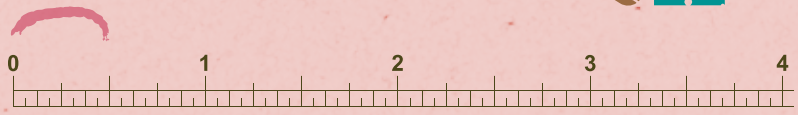
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: Up to ½ inch

Diptera

Black Fly

- Black fly larvae use hooks and silk to hold on tight to the bottom of a stream.

INDICATORS for ID

- Bowling pin shape
- Sticks to surfaces at base of abdomen

SIMILAR TO

- Worms
- Midge

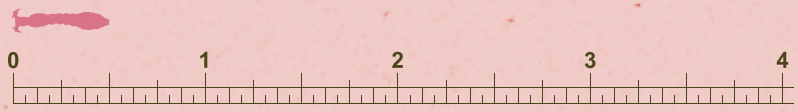
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: Up to ½ inch

Annelida

Leech

- Some leeches are parasitic, but many are not.

INDICATORS for ID

- Flattened top to bottom
- Sticks to surfaces at base of abdomen
- 2 suckers on opposite ends

SIMILAR TO

- Worms

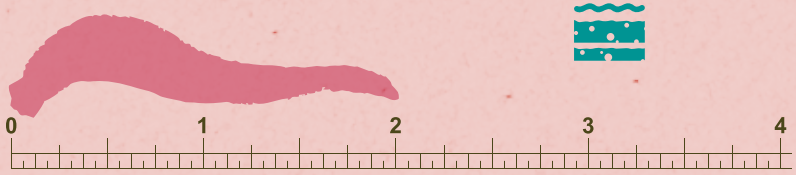
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: Up to 2 inches

Annelida

Aquatic Worms

- Aquatic worms all breathe through their skin.

INDICATORS for ID

- White or pink in color
- Segmented body
- No eyes, legs or gills

SIMILAR TO

- Earth Worms

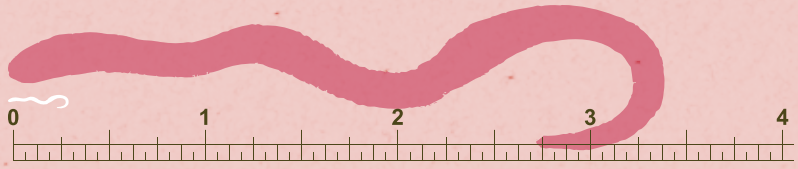
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ⅛ inch to over 3.5 inches

Gastropoda

Lunged Snails

- Aquatic snails can trap a bubble of air inside their shells to breathe while under water.

INDICATORS for ID

- Shell usually opens left
- **DO NOT COUNT** empty shells
- Includes “rams horn” shaped snails

SIMILAR TO

- Gilled Snail

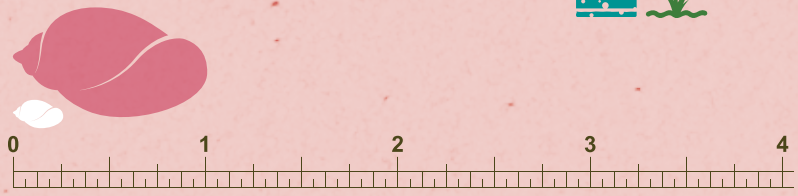
DISTRIBUTION

Widespread

FEEDING

MOVEMENT

HABITAT



SIZE: ¼ inches up to 1 inch

Other Critters You Might See

Although you may find these neighbors while surveying, they are not included in the SC AAS macroinvertebrate assessment for water quality scores.


Freshwater Shrimp


Water Mites


Water Measurer


Water Scorpion


Backswimmer


Giant Water Bugs


Water Striders


Predaceous Diving Beetle


Whirligig Beetle


Crawling Water Beetle


Water Scavenger Beetle


Horsehair Worm

Monitoring Kit Information

Monitoring kits can be borrowed from several SC AAS Hubs, Trainers, and Kit Loan locations around the state. View our Kit and Hub Maps at www.scadoptastream.org to find one near you. Pre-made kits are also available for purchase through the USC Upstate Watershed Ecology Center. Monitoring for macroinvertebrates is best done in pairs or small groups. Certified volunteers who have attended a macroinvertebrate workshop can sample with non-certified volunteers as long as you continue to follow protocol and report data at www.scadoptastream.org. Only certified volunteers can upload data and be entered into the database.

Macroinvertebrate Kit Loan Locations as of March 2023:

ANDERSON COUNTY

Anderson County Soil and Water Conservation District
1521 Pearman Dairy Road
Anderson, SC 29625
Anaston Porter
anaston.porter@andersonswcd.org
864-844-8224

CU Center for Watershed Excellence
509 Westinghouse Road
Pendleton, SC 29670
Emily Anderson
esa2@clemson.edu
864-651-0819

CHARLESTON COUNTY

Clemson Extension
259 Meeting St,
Charleston, SC, 29401
Samantha Porzelt
sporzel@clemson.edu
843-722-5940

GREENVILLE COUNTY

City of Greer*
113A Berry Ave,
Greer, SC 29651
Adam Vidalis
avidalis@cityofgreer.org
864-479-0972

Friends of the Reedy River
564 Mauldin Road,
Greenville, SC 29607
Josie Newton
Josie@FriendsOfTheReedyRiver.org

Sustaining Way
60 Baxter St,
Greenville, SC 29607
Sophi Christian
sophia.christian@sustainingway.com
651-325-7570

OCONEE COUNTY

Clemson Extension
301C W S Broad Street,
Walhalla, SC 29609
Mallory Maher
mallord@clemson.edu
864-638-5889

PICKENS COUNTY

City of Easley Public Works
801 Pope Field Road
Easley, SC 29642
Darya Cowick
dcowick@cityofeasley.com
864-810-4132

RICHLAND COUNTY

Richland Soil and Water Conservation District
2020 Hampton Street, Rm. 3063A,
Columbia, SC 29204
Chanda Cooper
cooperc@rcgov.us
803-576-2084

SC DHEC
2600 Bull Street,
Columbia, SC 29201,
scaas@dhec.sc.gov
803-898-4168

SPARTANBURG COUNTY

City of Greer*
113A Berry Ave,
Greer, SC 29651
Adam Vidalis
avidalis@cityofgreer.org
864-479-0972

USC Upstate Watershed Ecology Center
800 University Way,
Spartanburg, SC 29303
Beth Button or Jack Turner
aas_wec@uscupstate.edu
864-503-5728

**The city of Greer is co-located in both Greenville and Spartanburg counties. The contact information is the same for both entries.*

Have a macroinvertebrate kit to share?
Add it to our kit list:
www.clemson.edu/public/watershed/scaas/resources/kit-map.html

FIELD CHECKLIST

- ☐ **Macroinvertebrate Data Form**
  Found under “Resources” at www.scadoptastream.org
- ☐ **Kick-net, D-Frame, Sieve Bucket**
  (Either or both net types, sieve optional).
- ☐ **Toolkit**
  - ○ spoons
  - ○ forceps
  - ○ hand lenses
  - ○ petri dishes
  - ○ sorting pans
  - ○ ice trays
  - ○ bucket(s)
  - ○ paintbrushes
  - ○ small mesh nets
  - ○ disposable pipettes
- ☐ **Pitcher or jug**
  For rinsing out macros from nets into sorting pans
- ☐ **Clear container or Whirl-pak® bag**
  For the visual color/clarity observations
- ☐ **Pens/pencils**
- ☐ **Clipboard**
- ☐ **Trash bag to pick up litter**
- ☐ **First Aid Kit**
- ☐ **Waders, boots, or old tennis shoes**
- ☐ **Rubber gloves for rubbing rocks**

Photo Attribution

All photography not otherwise cited below is licensed via Getty Images.

Macroinvertebrates.org

Images licensed from Macroinvertebrates.org appear on the following pages:

- Page 7 (cranefly larva)
- Page 9 (mayfly larva, riffle beetle, caddisfly larva, stonefly larva, right-handed snail, clam, crayfish, damselfly larva, midge larva, leech, black fly larva, left-handed snail)
- Page 20 (mayfly larva)
- Page 21 (stonefly larvae)
- Pages 40 & 41 (lunged snail, gilled snail, clam, aquatic snipe fly larva, crane fly larva, black fly larva, leech, midge larva, riffle beetle larva, crayfish, aquatic sowbug, riffle beetle adult, water penny, dragonfly larva, casebuilder caddisfly larva, net-spinning caddisfly larva, stonefly larva, mayfly larva, damselfly larva)
- Page 42 (stonefly larvae)
- Page 44 (mayfly larvae)
- Page 46 (case-building caddisfly larvae, free-swimming caddisfly larvae)
- Page 48 (aquatic snipe fly larva)
- Page 50 (water penny larva)
- Page 52 (gilled snail)
- Page 54 (riffle beetle larva, riffle beetle adult)
- Page 56 (common net-spinning caddisfly larva)
- Page 58 (alderfly larva, fishfly larva)
- Page 60 (dragonfly larvae, damselfly larvae)
- Page 62 (cranefly larvae)
- Page 64 (crayfish)
- Page 66 (aquatic sowbug)
- Page 68 (scud)
- Page 70 (fingernail clam, Asian clam, freshwater mussel)
- Page 72 (midge larva)
- Page 74 (black fly larva)
- Page 76 (leech)
- Page 80 (lunged snails)

Morse, J., Broomall, M., Wenzel, J., Kautz, A., Louw, M. (Eds) (2020) *The Atlas of Common Freshwater Macroinvertebrates of Eastern North America*. Available from https://www.macroinvertebrates.org/ (April 2023)

Materials developed for the *Atlas of Common Freshwater Macroinvertebrates of Eastern North America* by Macroinvertebrates.org is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

This material is based upon work supported by the National Science Foundation under Grant #1623969.

SC DHEC

Images owned by SC DHEC appear on the following pages:

- Page 9 (aquatic worm)
- Page 19
- Page 27
- Page 29
- Page 41 (aquatic worm)
- Page 49 (aquatic snipe fly larva)
- Page 55 (riffle beetle larva, riffle beetle adult)
- Page 69 (scud)
- Page 78 (aquatic worm)
- Page 82 (water mite

iNaturalist.org Contributors

Images obtained from iNaturalist.org are licensed under various Creative Commons licenses, and have their own specific requirements. They are listed below, by page.

- Page 49
  Adult snipe fly
  Photo 194912064, © Hilda Flamholtz, some rights reserved (CC BY-NC)
- Page 51
  Water penny larva
  Photo 10199594, © Robby Deans, some rights reserved (CC BY-NC)
  Water penny adult
  Photo 83156746, © Jeremy Collison, some rights reserved (CC BY-NC)
- Page 53
  Gilled snail
  Photo 8606729, © Alex Bairstow, some rights reserved (CC BY-NC)

- Page 57
  Caddisfly larva
  Photo 168792754, © joanescobetcasals, some rights reserved (CC BY-NC)
  Caddisfly
  Photo 243756466, © odonataChR, some rights reserved (CC BY-NC)
- Page 59
  Dobsonfly larva
  Photo 103538894, © Gustav Paulay, some rights reserved (CC BY-NC)
- Page 61
  Damselfly
  97588321, © Hilda Flamholtz, some rights reserved (CC BY-NC)
  Dragonfly
  76788302, © Linda Gilbert, some rights reserved (CC BY-NC)
  Dragonfly larva
  Photo 114737285, © Joe Girgente, some rights reserved (CC BY-NC)
- Page 63
  Crane fly
  Photo 818855, © hennda, some rights reserved (CC BY-NC)
  Crane fly larva
  Photo233159810, © oyermm, some rights reserved (CC BY-NC)
- Page 65
  Crayfish
  Photo 34529462, © alocastro, some rights reserved (CC BY-NC)
- Page 67
  Aquatic sowbug
  Photo 62007464, © Matthew L. Niemiller, some rights reserved (CC BY-NC)
- Page 71
  Freshwater mussel
  Photo 214465731, © chris buelow, some rights reserved (CC BY-NC)
- Page 73
  Midge larva
  Photo 71976099, © Sonorabee, some rights reserved (CC BY-NC)
  Midge
  Photo 105687023, © Luke Armstrong, some rights reserved (CC BY-NC)
- Page 75
  Black fly larvae
  Photo 62529902, © joycp89, some rights reserved (CC BY-NC)
- Page 77
  Leech
  Photo 183955822, © matthew_wills, some rights reserved (CC BY-NC)
- Page 79
  Aquatic worm
  Photo 54239425, © Alex Field, some rights reserved (CC BY-NC)
- Page 81
  Lunged snail
  Photo 229915608, © alex_shure, some rights reserved (CC BY-NC)
- Page 82
  Freshwater Shrimp
  Photo 35292358, © Ikirk, some rights reserved (CC BY-NC)
  Water Measurer
  Photo 6612332, © Robby Deans, some rights reserved (CC BY-NC)
  Water Scorpion
  Photo 123600314, © ocharlop, some rights reserved (CC BY-NC)
  Backswimmer
  Photo 8615887, © Jean-François Roch, some rights reserved (CC BY-NC)
  Giant Water Bug
  Photo 194258837, © Laura Gaudette, some rights reserved (CC BY)
  Water Strider
  Photo 47397578, © Phillip Harpootlian, some rights reserved (CC BY-NC)
  Predaceous Diving Beetle
  Photo 178118735, © Clara Dandridge, some rights reserved (CC BY)
  Whirligig Beetle
  Photo 115997416, © Emilio Concari, some rights reserved (CC BY-NC)
  Crawling Water Beetle
  Photo 144152113, © Mike Quinn, Austin, TX, some rights reserved (CC BY-NC)
  Water Scavenger Beetle
  Photo 204487233, © Sydney Penner, some rights reserved (CC BY-NC)
  Horsehair Worm
  Photo 110913751, © Joseph McPhail, some rights reserved (CC BY)

Funding for the development of this handbook has been provided by a US EPA Region 4 Wetland Program Development Grant.

CR-013727 5/23