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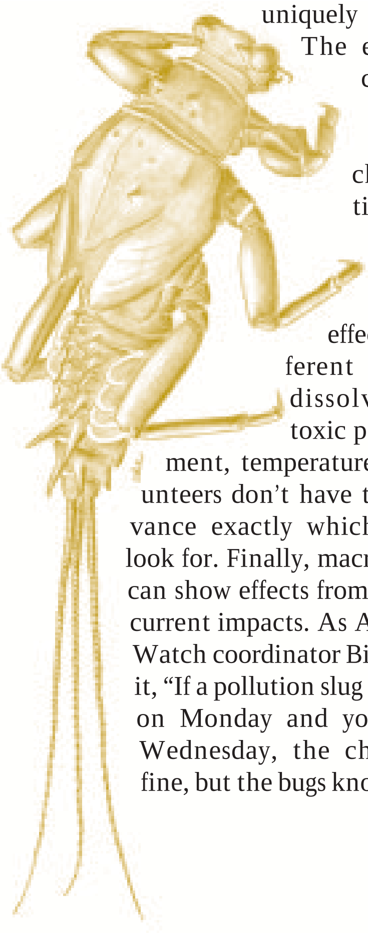
Volunteer Macroinvertebrate Monitoring
a panoramic view

by Eleanor Ely

To watch a professional taxonomist identifying preserved stream macroinvertebrates—sitting for hours at a microscope, straining to see tiny characteristics that distinguish one species of aquatic insect larva from another—you would hardly think, "This looks like a perfect activity for volunteers!"

Yet in many ways macroinvertebrate monitoring *is* perfect for citizen volunteer monitors. The insect larvae and other small invertebrates (like worms and snails) that live on stream bottoms fascinate people in a way that chemical water quality testing does not, and directly observing the effects of stream degradation on these living creatures brings home the conservation message in a uniquely powerful way. The equipment for collecting the creatures is simple and cheap. In addition, the macroinvertebrate community integrates the effects of many different stressors (low dissolved oxygen, toxic pollutants, sediment, temperature, etc.) so volunteers don't have to know in advance exactly which problems to look for. Finally, macroinvertebrates can show effects from past as well as current impacts. As Alabama Water Watch coordinator Bill Deutsch puts it, "If a pollution slug moves through on Monday and you monitor on Wednesday, the chemistry looks fine, but the bugs know better. They were there. They are mini-meters, 24/7."



For all these reasons, macroinvertebrate monitoring (in a much simplified form) was the very first type of monitoring widely used by volunteers to assess stream health, and it remains extremely popular: 76% of stream monitoring programs surveyed for the 1998 edition of the *National Directory of Volunteer Environmental Monitoring Programs* were engaged in macroinvertebrate monitoring.

The conundrum at the heart of volunteer macroinvertebrate monitoring is that the closer you get to what the professionals do, the farther you get from what most volunteer programs consider feasible or desirable. The story of the past 25 years of volunteer macroinvertebrate monitoring is largely the story of numerous creative efforts to find a workable balance between data quality and level of effort.

The protocols developed in the early 1970s by the Izaak Walton League of America (IWLA) were a far cry from professional methods, especially when it came to identifying the critters. Working right at the streamside, volunteers used simple picture keys to classify live specimens into broad groups, often corresponding to the taxonomic level of order. During the 1980s and 90s, as volunteer monitoring grew in popularity and sophistication, many programs began exploring ways to improve the usefulness of their macroinvertebrate data by bringing their methods more in line with professional protocols. They typically found that matching their state agency's collection protocols in terms of net mesh size, habitats sampled, quantification of sampling effort, and so on, was not too difficult. The main stumbling block was identification.

In this article we'll take a "tour" of U.S. volunteer monitoring programs to find out how they are resolving the difficulties associated with macroinvertebrate monitoring, particularly the problem of identification. While the programs we will visit represent just a fraction of the total, they demonstrate the astonishing variety and inventiveness of approaches used.

Categorizing the methods

To bring some order to the diversity, I grouped the different approaches into the following three broad categories, based on who identifies the organisms and to what level:

1. Streamside survey. Volunteers identify live bugs mainly to order level.

2. Family-level ID by volunteers. Volunteers identify preserved specimens to

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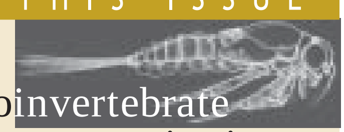

macroinvertebrate monitoring

THE
Volunteer Monitor

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Cover: Mayfly drawings (*Drunella, Isonychia*) by Peter Ode; from Harrington and Born, 2000, *Measuring the Health of California Streams and Rivers.*

Next Issue

Bacteriological monitoring will be the theme for the Winter 2006 issue. We are looking for stories on such topics as method comparisons, innovative techniques, homemade equipment, quality control, communicating results, citizen/agency bacteria-monitoring partnerships, tracking sources, and taking action to resolve problems. Please send suggestions to the editor (see information at left).

Come to the Fifth National Monitoring Conference!

May 7-11, 2006, San Jose, CA

The National Water Quality Monitoring Council's (NWQMC) national monitoring conference in San Jose, California, May 7-11, 2006, will be a great opportunity for volunteer monitoring program representatives to share ideas and experience with each other and with representatives from professional monitoring programs.

At the last NWQMC conference (Chattanooga, 2004), volunteer monitoring was highly visible. About one-fifth of presentations were volunteer-related.

Let's make volunteer monitoring an even bigger part of the 2006 event! This year's conference planners are making a special effort to encourage presentations and workshops by and for volunteer monitoring organizations, including a workshop on "getting started in volunteer monitoring." Informal networking opportunities are also being planned.

The conference will cover such topics as data comparability and sharing, evaluating the effectiveness of restoration, sustaining long-term monitoring programs, communicating data to different audiences, and translating data into action. Watch for updates on the volunteer monitoring listserv and at www.nwqmc.org, or contact the conference coordinator at NWQMC2006@tetratech-ffx.com; 410-356-8993.

PANORAMIC VIEW, continued

family level.

3. ID by professionals. Volunteers preserve samples and send them to professionals for identification.

Many programs offer participants a choice of two or more different options at different levels of rigor. Also, some of the approaches I learned about blended elements of categories 1 and 2. For these, I invented a "Category 1-1/2" (discussed below).

CATEGORY 1

Streamside Survey

Because the IWLA protocols have been so widely adopted, either "as is" or as a template that is modified to suit a group's particular purposes, it's worth taking a detailed look at how this method works. Samples are collected with a kick seine in rocky-bottom streams and a dipnet in muddy-bottom streams. The official protocols call for picking and identifying all the organisms from the net, but in practice some programs, especially those whose purpose is mainly education, do not pick all the organisms.

Critters are identified live, at streamside, with the naked eye or a hand lens. IWLA's identification guide includes drawings and descriptions of only the most commonly found organisms. As shown in the table at right, different groups are identified to different taxonomic levels. For example, non-insect groups are identified only to class, while insects in some orders (e.g., the order Diptera) are identified to family. The stoneflies, mayflies, and caddisflies are identified to order, except for one family of netspinning caddisflies, the Hydropsychidae. (Before IWLA's 2003 revision, all caddisflies were grouped together and classified as sensitive. This tended to cause stream health to be overestimated, as discussed in *The Volunteer Monitor* Winter 2003 issue, page 6.)

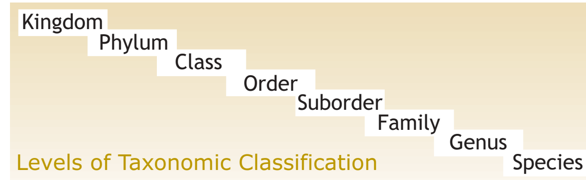
Each taxonomic group is assigned a pollution-sensitivity category, as shown. To calculate a stream health rating, the number of different sensitive groups is multiplied by three, the number of less sensitive groups by two, and the number of tolerant groups by one, and the three products are summed. Organisms are not counted. The estimated abundance of each group is recorded on the data sheet with a letter code (A = 1-9, B = 10-99, C = 100 or more). However, the abundance estimate is not used in determining the rating. Thus, the rating is based only upon presence or absence. It reflects the richness (diversity) of the sample and gives a very generalized sense of the pollution sensitivity of the organisms found, but does not incorporate information about the proportion of different groups in the sample.

Variations and refinements

Although the IWLA protocols were designed to be usable nationwide, macroinvertebrate pollution sensitivities vary from region to region. Therefore a very useful modification—recommended by IWLA and followed by a number of volunteer monitoring programs—is to consult with local biologists to tailor the sensitivity ratings for the region being studied. This is particularly important for locations outside of the mid-Atlantic region where the IWLA protocols were originally developed.

One of three macroinvertebrate monitoring options described in EPA's 1997 guidance, *Volunteer Stream Monitoring: A Methods Manual*, is a "Streamside Biosurvey" based on the IWLA method. However, the Streamside Biosurvey uses a finer-mesh net for collection, and it incorporates abundance estimates into the stream quality rating.

A few years ago, Virginia Save Our Streams (VA SOS) made several modifications to the basic IWLA protocols, including making sampling and scoring more quantitative. VA SOS volunteers must collect a minimum of 200 organisms and identify and count each of them. The level of identification is similar to that shown in the table below.



Levels of Taxonomic Classification

The "advanced" macroinvertebrate monitoring option that West Virginia SOS offers to interested volunteers calls for identifying and counting a minimum of 100 organisms, then performing "morphological sorting" in the field to approximate family-level identification. For example, characteristics such as head shape and size, location of gills, and presence or absence of "tusks" would be used to sort the mayflies in the sample into different groups.

The VA SOS and WV SOS protocols retain the advantages of streamside surveys in that collection and analysis are completed on site in a single visit and no advanced taxonomic skill is required. At the same time, these methods yield additional information—counts of individual organisms and, in the case of WV SOS, an estimate of the number of different families in the major groups—that make it possible to calculate various metrics and arrive at a somewhat more sensitive evaluation of stream health. For more details on how the developers of the VA SOS modified method tested and selected metrics, see *The Volunteer Monitor* Winter 2003 issue.

Other variations on the streamside survey are intermediate between Categories 1 and 2 because they incorporate preservation of samples and/or some family-level identification. These approaches are discussed below under the heading "Category 1-1/2."

Macroinvertebrate Sensitivity Categories, IWLA Method, Revised 2003*

Sensitive	Less Sensitive	Tolerant
Caddisflies (order Trichoptera) except netspinners	Netspinning caddisflies (order Trichoptera, family Hydropsychidae)	Aquatic worms (class Oligochaeta)
Mayflies (order Ephemeroptera)	Hellgrammites & fishflies (order Megaloptera, family Corydalidae)	Black flies (order Diptera, family Simuliidae)
Stoneflies (order Plecoptera)	Crane flies (order Diptera, family Tipulidae)	Midge flies (order Diptera, family Chironomidae)
Water snipe flies (order Diptera, family Athericidae)	Damselflies & dragonflies (order Odonata)	Leeches (class Hirudinea)
Riffle beetles (order Coleoptera, family Elmidae)	Alderflies (order Megaloptera, family Sialidae)	Lunged snails (class Gastropoda)
Water pennies (order Coleoptera, family Psephenidae)	Crayfish (two families in order Decapoda)	
Gilled snails (class Gastropoda)	Sowbugs (order Isopoda)	
	Scuds (order Amphipoda)	
	Clams & mussels (class Bivalvia)	

**Note: In IWLA's 2003 revision hellgrammites and netspinning caddisflies were moved from sensitive to less sensitive and water snipe flies from less sensitive to sensitive.*

Streamside survey: Pros and cons

The simple streamside approach is especially popular with programs that want to reach out to large numbers of people of all ages and backgrounds. As the Ohio Department of Natural Resources promises on its Stream Quality Monitoring Project web page, "Being an SQM volunteer is easy, fun, and doesn't take a large commitment of time or any prior experience."

Many large statewide programs, such as Georgia Adopt-A-Stream, Kentucky Water Watch, Ohio Stream Quality Monitoring Project, IOWATER, Missouri Stream Team, Alabama Water Watch, Virginia Save Our Streams, West Virginia Save Our Streams, Water Action Volunteers (Wisconsin), and Delaware Riverkeeper Network, use some variation of streamside biosurvey. These programs appreciate the great educational value of bringing people to local streams and allowing them to discover firsthand the relationship between stream life and water quality.

The streamside survey also yields an immediate, albeit rough, indication of stream health. In contrast, volunteers who identify preserved organisms in a lab or send their bugs off to professionals for identification often wait months for results. For many people, another

continued on next page

important advantage is that the bugs don't have to be killed. "Our groups love releasing the bugs," says Bill Deutsch.

Unfortunately, in stream assessment as in most things, "quick and easy" has its price. Streamside surveys lump together large groups of organisms, sometimes whole orders, into a single pollution-sensitivity category. While this compromise is necessary for a simple field method, it reduces the reliability of the assessment. Pollution sensitivities among mayflies, for example, run the gamut from very sensitive to very tolerant. Streamside surveys can identify high-quality sites and very degraded sites, but their resolution is generally too low to distinguish among sites of intermediate quality. Another limitation is that since samples are not preserved, the identifications cannot be verified later.

CATEGORY 2

Family ID by Volunteers

When EPA published its 1989 guidance document for state and tribes, *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*, volunteer monitoring programs took notice. One of the protocols, Rapid Bioassessment Protocol II (RBP II), was based on family-level identification in the field. Family-level identification, although challenging, seemed within the reach of trained and motivated volunteers—especially if the identification was performed in a lab, with expert assistance, rather than in the field. Here was an opportunity for volunteer monitoring programs to match an EPA-recommended method, making their macroinvertebrate data much more credible.

In 1990, volunteer monitors with Maryland Save Our Streams Project Heartbeat began following a protocol adapted from RBP II. Volunteers picked and sorted a random subsample of at least 100 macroinvertebrates in the field and preserved them. Later, they identified the organisms in the lab, with help from experts. At about the same time River Watch Network (RWN) (now River Network) developed a similar RBP II-based method, except that subsampling was performed in the lab. The "Intensive Stream Biosurvey" included in EPA's 1997 volunteer stream monitoring manual was based on the Heartbeat and River Watch Network protocols.

Hallmarks of the RBP II-inspired volunteer protocols include:

- Preserving the sample
- Identifying and counting either (a) all organisms or (b) a random subsample of at least 100
- Identifying to family level

Using more quantitative methods and family-level identifications opens the door to using more sophisticated and sensitive metrics, including the Hilsenhoff family-level biotic index, which is based on family-level pollution-tolerance values.

Two rigorous programs

For programs whose protocols are at the high end in terms of rigor, family-level identification requires a major commitment of time and effort. Take for example the Upper Merrimack Monitoring Program (UMMP) in New Hampshire. Every other Wednesday evening from January through April, about 15 volunteers show up at the UMMP lab to work on sorting, counting, and identifying macroinvertebrates collected from 10 sites the preceding summer. UMMP protocols call for spreading the sample over a 12-square grid and picking squares in a random order until a subsample of at least 100 organisms has been picked. The kicker is that the protocols also require picking—and identifying—at least 25 percent of the total sample, or three

Fun with Bugs

What keeps volunteers coming back night after night, year after year, to peer through microscopes identifying stream macroinvertebrates?

Steve Landry, Sampling Supervisor with the Upper Merrimack Monitoring Program (UMMP), has several answers to that question. He starts with the kinds of reasons you would expect: The volunteers love the river; they want to help the environment; they're interested in science; they enjoy the challenge. Then he starts using words like "quirky," "wacky," and "goofy" to describe some UMMP activities.

Take, for instance, the "Bug of the Night" prize. At the start of each Bug Night, Landry and Program Director Michele Tremblay write three bug names on the board. They might be particular families or a special bug like "lime-green caddisfly." The first volunteer to find each bug wins an entomologically themed prize like a dragonfly keychain, butterfly finger puppet, 3-D bug puzzle, or set of insect refrigerator magnets.

STEVE LANDRY

"You can burn out with the lab work because it's very repetitious," says Landry. So he and Tremblay are always thinking of new ways to keep things lively and fun.

Each year, Tremblay creates an UMMP recruitment flyer mimicking the layout of a different magazine: Rolling Stonefly, Redbug, The Insect Inquirer ("I Had a Caddisfly's Baby!"). Some contain a "personals" section ("Flexible nematode looking for companionship"). The program has also gotten some of these flyers printed on T-shirts and tote bags.

At the end of the last Bug Night, in April, the group goes out to celebrate at a local restaurant. A few weeks later, just in case they're starting to feel neglected, the volunteers get their Bug Night report cards in the mail and find out their grades on skills like "Works well with alcohol," "Respects other people's dead bugs," and "Doesn't run with dissection needles."

"We're very serious about having fun," says Landry.

squares. For a couple of the program's sites it's not uncommon to top 1,000 organisms from just three squares.

A West Coast group, Friends of Deer Creek (profiled on page 12), resembles UMMP in many ways. In both cases, a close-knit group of committed volunteers who enjoy the challenges of bug identification gather regularly at a central location where experts are always available to assist. Both programs send a portion of their samples to outside experts for quality control. One difference is that Friends of Deer Creek volunteers work on their identifications year-round rather than "only" for four months. This is partly due to the Deer Creek volunteers' determination to identify every last bug, even if mangled.

A wetland example

Macroinvertebrate monitoring is not just for streams. Since 1996, volunteers with Minnesota's Wetland Health Evaluation Program (WHEP) have performed both plant and macroinvertebrate bioassessments in wetlands. WHEP currently involves about 15 volunteer teams, each working in a different city.

BRANDON BURNS

Minnesota volunteers with the Wetland Health Evaluation Program examine their macroinvertebrate "catch."

WHEP volunteers collect macroinvertebrate samples in "bottle traps" and dipnets. All the critters in the samples are identified. Unlike the UMMP and Deer Creek volunteers, who meet at one central location to identify bugs, each WHEP team works independently. Much of the credit for the program's success goes to the team leaders, mostly high school science teachers who have access to school laboratories.

Compared to the UMMP or Deer Creek volunteers, WHEP teams are relatively speedy in their identification, spending approximately 8 "person-hours" to sort and identify all the bugs from one site. This is probably because the WHEP metrics don't require counting any groups except the Coleoptera (beetles) and Hemiptera (true bugs) and depend more on diversity than actual identifications. So while a Friends of Deer Creek volunteer could spend hours agonizing over one or two difficult bugs, a WHEP volunteer would simply note finding another type of, say, mayfly. (For more details on WHEP, including plant and macroinvertebrate bioassessment protocols, see *The Volunteer Monitor* Spring 1998 issue, page 14.)

Bug personals

Join male dobsonfly with well-developed gill tufts in my quiet riffle where I am the top predator. You are a quiet, sensitive, full-bodied invertebrate seeking protection and companionship.

Busy scraper, occasional grazer seeks similar for exploring and burrowing in oxygen-limited habitat. Must have flexible feeding habits.

Single green caddisfly with big black eye spots looking for winter companion. Chironomidae OK. No predators.

Dragonfly larva, male, seeking female for fun and games in the pool habitat before emergence. Full-figured, club-tailed species preferred.

First-year mayfly, thorax and legs proportionate, ISO same for moonlit crawls along the river bottom. Please be pollution intolerant.

—adapted from UMMP flyer designed by Michele L. Tremblay

PHOTO BY JEFF ADAMS

IOWATER: Less demanding

The protocols followed by volunteers with the IOWATER program are somewhat less demanding than those described above. IOWATER is a large statewide program coordinated by Iowa Department of Natural Resources, whose staff is not able to give volunteers the kind of one-on-one attention that staff of small local groups like UMMP or Friends of Deer Creek can give.

Since 2001, more than 2,000 volunteers have been trained in IOWATER's basic streamside survey, and about 200 of those have received an additional four hours of training in the more advanced "Benthic Macroinvertebrate Indexing" (BMI) protocol, in which volunteers identify preserved organisms to family level. Once trained, the volunteers are basically on their own, and there is no quality control of the volunteers' identifications.

Family ID by volunteers: Pros and cons

Clearly the greatest advantage of the Category 2 approach over the streamside survey is the higher resolution of the data, which in turn allows the data to be used in more ways. Since the bugs are preserved, the volunteers' identifications can be verified for quality control and specimens may be kept in case the data are challenged or there is a future need for identification to lower taxonomic levels. In addition, volunteers have the satisfaction of producing high-quality data, and some volunteers really enjoy the taxonomic work.

The downside is that family-level identification requires a lab and microscopes, extensive training, the assistance of experts, and a large investment of time

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metrics

by Geoff Dates

To make macroinvertebrate data meaningful for evaluating stream health and comparing conditions between sites, biologists summarize the information using measures called *metrics*. A metric is a characteristic of the stream biological community that changes in some predictable way relative to a stressor.

Metrics may be broadly categorized as measures of:

Richness—the number of distinct taxa in the sample, which is an indication of diversity. Richness can be evaluated at different taxonomic levels (i.e., species, genus, family, order).

Composition—the relative abundance of certain types; for example, the percentage of the total sample that consists of mayflies or shredders.

Tolerance/intolerance—the level of sensitivity or tolerance of different taxa in the sample to pollution and other stressors.

Feeding or Behavior—feeding group (e.g., scrapers, shredders, predators) or behavioral characteristics (e.g., swimming, burrowing, clinging) of taxa in the sample.

These categories, while useful, are somewhat artificial and tend to overlap. The three basic types of measure are richness, relative abundance, and absolute abundance, although in practice absolute abundance is seldom used. Richness and/or relative abundance can be calculated for different taxa, feeding groups, etc,. to yield such metrics as "% clingers" (relative abundance and behavior) or "No. intolerant taxa" (richness and intolerance).

A biotic index (not to be confused with an Index of Biotic Integrity, discussed below) is a metric that summarizes the various pollution tolerances of the taxa in the sample. The widely used Hilsenhoff Biotic Index assigns each taxon a pollution tolerance value from 0 (intolerant) to 10 (tolerant). The original Hilsenhoff Biotic Index was based on genus and species tolerance values, while the modified Hilsenhoff Biotic Index uses family-level tolerances. The tolerance values used in any biotic index should be adjusted for different ecoregions.

Several different metrics can be combined to create a multimetric index, often called an Index of Biotic Integrity (IBI), that summarizes conditions at a site with a single number or "score."

Which metrics to use

Which metrics you can calculate depends mostly on the taxonomic level to which you identify the organisms and whether you use quantitative or qualitative methods. For example, the family-level Hilsenhoff Biotic Index requires family-level identification of aquatic insects. Metrics that incorporate relative abundance (that is, any metric that is expressed as a percentage of the total sample) require that you count the organisms in either the entire sample or a subsample.

However, just because you can calculate a given metric doesn't necessarily mean you should. To decide which metrics to use in a given region, biologists test many potential metrics to find out which ones show a consistent relationship with stressors such as pollution discharges, flow modifications, or impervious surfaces.

Metrics and IBIs used by state natural resources agencies are most often based on genus- or species-level identification. Volunteer groups that identify to higher taxonomic levels sometimes work with their state agency biologists to find a set of metrics for the volunteer data that results in an overall score similar to that obtained by the professional methods.

Examples of metrics

Category	Examples	Predicted response to increasing stress
Richness measures	Total No. taxa	Decrease
	No. EPT*	Decrease
	No. mayfly taxa	Decrease
Composition measures	% mayflies	Decrease
	% EPT*	Decrease
	% midges	Increase
	% dominant taxon	Increase
Tolerance/intolerance measures	No. intolerant taxa	Decrease
	% tolerant organisms	Increase
	Hilsenhoff Biotic Index	Increase
Feeding measures	% grazers and scrapers	Decrease
	% predators	Variable
Behavior measures	% clingers	Decrease

**EPT = Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)*

Geoff Dates is River Watch Program Director for River Network and a member of *The Volunteer Monitor* editorial board.

References

Barbour, Michael T. et al. 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd Edition.* EPA 841-B-99-002. See page 21 for ordering information.

Karr, James and Ellen Chu. 1999. *Restoring Life in Running Waters: Better Biological Monitoring.* Island Press, Washington, DC.

from both volunteers and program staff. Moreover, this approach does not appeal to as broad a spectrum of volunteers as the streamside survey. It takes a certain kind of person to have the dedication and patience for family-level identification.

“CATEGORY 1^1/2”

Hybrid Approaches

This brings us to the intriguing Category 1-1/2—approaches that mix and match features of Category 1 (streamside surveys) and Category 2. These “hybrid” protocols are designed to obtain some of the benefits of the more intensive protocols without requiring such a high level of rigor.

Field ID to family

The Audubon Naturalist Society, which is active in Virginia and Maryland, was the only program I heard about that does field identification of live organisms to family level. As Cliff Fairweather of the program’s Virginia office explained, “We felt that our volunteers and members would be more supportive of a catch-and-release program where we return to the stream what we take out of it.” Volunteers receive four 2-hour training sessions—one each for the stoneflies, mayflies, and caddisflies, and one for the true flies and beetles. For convenience, preserved organisms are used in training (if live specimens were used, training would have to be offered twice a year because of the seasonal variation in which organisms are in the stream). Volunteers work on their own in the field but send any organisms they can’t identify to the program office.

Morphosorting in lab

The Huron River Watershed Council in Michigan wanted to make their macroinvertebrate monitoring program accessible to volunteers of all ages and levels of expertise. They also wanted family-level data. Their solution, described in detail in the article on page 11, is to have the volunteers sort preserved organisms into “look-alike” groups in the lab. The groups are then identified by experts who circulate around the room where the volunteers are working.

“Streamside Survey Plus”

The protocol for Massachusetts Water Watch Partnership’s “Streamside Survey Plus” resembles the simple streamside survey in that there is no subsampling and no counting (abundance is estimated as “absent,” “rare,” “common,” or “dominant”). The “Plus” is that monitors preserve one or two representatives of each different type of organism for later identification in the lab. Lab identification goes quickly because there are usually only 20 or 30 organisms to identify, and only insects are identified to family level (other types are identified to order). Program coordinator Marie Françoise Walk points out that the method is significantly simpler than the full-blown family-level protocols and kills fewer bugs, while still yielding some family-level information.

“Most Wanted” list

In the unusual approach taken by the Connecticut Department of Environmental Protection (DEP), volunteers are trained to recognize a limited suite of organisms, with greatest emphasis placed on finding and identifying the 12 “Most Wanted” bugs—those that are indicative of very high water quality. The majority of the “Most Wanted” types are actually genus-level identifications, but they have a distinctive appearance that makes them easy to recognize at streamside. Volunteers send a preserved voucher specimen of each type they identify to DEP. The agency uses the volunteer data in the state’s 305(b) report, as described in the article on page 9 of this issue.

CATEGORY 3

ID by Professionals

Use of the data by state agencies is a common goal of programs that send preserved samples to professionals for identification. In some cases (e.g., Maryland Stream Waders) volunteer programs are initiated and run by the agency expressly for the purpose of obtaining the data. In other cases, an independent group decides they want their data used by the agency. This is not to say that agency use is the only goal for the data; most programs in this category also use their data locally.

Volunteers may send the entire sample, including twigs, small rocks, and other debris, or they may do preliminary “cleaning” and separation of organisms from debris. In the Oklahoma Conservation Commission’s Blue Thumb program, volunteers (with help from program staff) sort a subsample in the lab and send that to the taxonomist.

Filling agency gaps

Maryland’s Department of Natural Resources created the Maryland Stream Waders program to fill gaps in the agency’s statewide bioassessment program. Volunteer-collected samples are identified by DNR. Identification is only to family level, mainly because the volume of volunteer samples (several hundred per year) would otherwise overwhelm agency taxonomists. In distinguishing degraded versus non-degraded sites, the volunteer results agree quite closely with results from agency-collected samples identified to genus level, as discussed in the article on page 18.

303(d) listing

Macroinvertebrate samples collected by Stream Team volunteers with Heal the Bay in Santa Monica, California, led directly to several streams being listed for sediment on the 303(d) list (list of impaired waters). The listing was based on a particular genus of Diptera, *Maruina*, whose larvae use special suckers to cling to rocks. Since the larvae are unable to cling to rocks that are coated with fine sediment, this genus was used as an indicator of sediment pollution.

Stream Team samples are identified by professional taxonomists to the lowest possible taxon. Mark Abramson, Stream Team Manager, points out that identification to a higher taxonomic level—even to family—would not have identified the indicator organism. He adds that the robust identification provided by the professional taxonomists allows Stream Team data to be “plugged into” the same metrics and indices used by the state, making the data easy for decision makers to understand and use.

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Contributing to biocriteria development

For Rivers of Colorado Water Watch Network, a major goal is to help the state in developing biocriteria (water quality standards based on biological characteristics), which Colorado currently does not have. Macroinvertebrate samples collected by volunteers, both high school students and adults, are identified by the same professional taxonomist who is contracted by the state health department. The data are being used to build a "taxonomic library" and species lists for different ecoregions in Colorado, which will be very useful for establishing biocriteria.

Sample ID by professionals: Pros and cons

Having samples identified by professional taxonomists is the surest road to agency use of the data for such purposes as developing biocriteria, listing waters on the 303(d) list, or writing TMDL plans. (A TMDL—the acronym stands for "total maximum daily load"—is a pollution budget and cleanup plan for restoring an impaired water body.)

This approach is also easy on the volunteers. But at the same time, volunteers may find it less fulfilling than approaches that bring them face to face with the bugs to do their own identification and interpretation. "It feels as if the volunteers are left wanting something else," says Cheryl Cheadle, coordinator of Oklahoma's Blue Thumb program. "It's as if we read 10 chapters of an 11-chapter book."

Another potential drawback is the cost—although several program coordinators told me they considered it more cost-effective to send their samples to professionals than to train and support volunteer monitors to do family-level identification. Mark Abramson feels that the Stream Team program's investment in professional identification (approximately $200 per sample) pays for itself because the data's value to resource agencies has helped the program obtain funding. The cost equation will differ from program to program. For example, in small programs like UMMP and Friends of Deer Creek much of the technical training and assistance is provided by volunteers.

There are also ways to lower the cost. Rivers of Colorado Water Watch Network got a "price break" by (a) having volunteers separate organisms from debris before sending the sample; (b) not requiring a fast turnaround (so the taxonomist can do the work in the winter when she doesn't have other work); and (c) requiring only family-level identification for chironomids (midges), even though other insects are identified to genus or species. This last is a big timesaver because many chironomids must be dissected and mounted on a slide for genus/species identification.

Dragonfly (family Gomphidae)

PHIL EMMLING

The Big Picture

On our tour through the world of volunteer macroinvertebrate monitoring, we've seen a lot of vignettes. Do the individual stories add up to a larger story? Although the "evidence" is largely anecdotal, some trends and patterns can be discerned.

Informal survey

I began my research for this article by posting a short informal questionnaire on the volunteer monitoring listserv. Of the 25 respondents to the survey, 16 reported using the streamside survey method exclusively or predominantly. There were five programs (including two school programs) whose participants identify organisms to family, and six that send specimens to professionals for identification. (The total adds up to 27 because two of the responses were counted in two categories.)

Obviously the survey sample was not random. Still, the large number of programs that reported using the streamside survey attests to the enduring popularity of this simple, inexpensive approach.

Indicators You May Be an Adopt-A-Stream-aholic

You have done a Google search for "hellgrammite earrings."

You threw out your spare tire to make room for your 5-gallon bucket.

You have a giant stonefly tattoo.

You named your firstborn after Izaak Walton, even though she's a girl.

You have the Hach and LaMotte toll-free numbers on speed dial.

—Ed Griffin, GA Adopt-A-Stream volunteer (adapted from GA Adopt-A-Stream newsletter, August 2005)

East/West differences

The survey responses also showed an East/West pattern that I had not expected. Of the six programs that reported sending samples to professionals for identification, five were in western states (California, Washington, Oregon, and Colorado). Several people I consulted who have worked extensively with West Coast volunteer monitoring groups all agreed that sending samples to professionals is more common in the West than in other regions. A possible reason is that state agencies in the West generally follow more rigorous protocols, including sorting a larger subsample (see article on page 22) and identifying specimens to the lowest possible taxonomic level. Volunteer groups in the West who want to approximate their state agency protocols have a higher hurdle to jump, so may be more inclined to get help from professional taxonomists.

Decline in intensive approach

Conversations with numerous volunteer program coordinators and other longtime observers of the volunteer monitoring scene confirmed my impression that over the past decade there has been a movement away from having volunteers identify organisms to family level (i.e., Category 2). Geoff Dates, who trained some two dozen mostly Northeastern volunteer groups in RWN's intensive method during the mid-1990s, and Jim Harrington, who trained numerous California programs in similar

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Case Study

Connecticut's "Most Wanted": Simple Method, Usable Data

by Mike Beauchene

In a previous article for this newsletter (Spring 1997 issue), I wrote about creating a list of "Most Wanted" macroinvertebrates that were (a) easy to identify and (b) highly sensitive to pollution. Students participating in Connecticut's Project SEARCH used the Most Wanted types as a "reality check" for the metrics they calculated based on family-level identification of preserved samples. If the metrics indicated poor water quality but several of the Most Wanted were found in the sample, students were alerted to suspect a problem with their collection, sorting, or identification.

Fast forward to 1998, when I was fortunate to move to a position with the Connecticut Department of Environmental Protection (DEP) Bureau of Water Management, Ambient Monitoring Program. One of my roles in this position is to encourage and facilitate the generation of usable water quality data by volunteer monitoring programs across the state.

When I began my new job, several existing citizen programs were interested in providing DEP with accurate macroinvertebrate assessment data. I began offering training sessions using the same protocols and support materials developed for Project SEARCH—but soon got the message that "THIS IS TOO MUCH LIKE WORK!" The family-level assessments that had worked smoothly with a captive audience like a high school biology class were not going over well with busy adults. In fact, the demanding protocols were pushing volunteer groups away from monitoring. If this trend were to continue, my first performance evaluation for DEP was looking fairly bleak.

Obviously, I needed to revise my strategy. I knew the volunteers wanted a simple, quick, and exciting method. At the same time, the results needed to be robust enough to provide useful information to DEP and answer the volunteers' own questions. The last kind of feedback any volunteer monitor wants to receive is: "Dear Volunteer, Thank you for your time and substantial effort. Unfortunately the data you have provided does not meet our data quality objectives …"

Considering the options

I looked at several simple national protocols—for example, the Izaak Walton League's Save Our Streams program—that were attractive in many ways (streamside identification, inexpensive equipment, short training). However, the weakness for DEP was the lumping together of all mayflies, stoneflies, and caddisflies as "very sensitive."* Within each of these orders the different families and genera form a pollution-tolerance continuum. The range in sensitivity is the narrowest in the stoneflies (not a problem) but can be very wide in the mayflies and caddisflies (problem). With this type of approach, a sample dominated by hydropsychid caddisflies or baetid mayflies could be falsely interpreted as indicating good to excellent water quality.

Most Wanted revisited

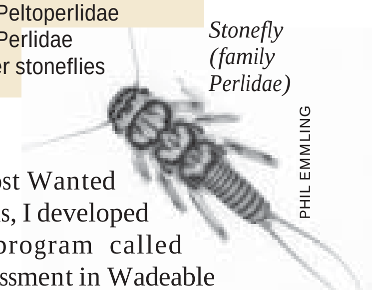
I am not sure where or when I was asked for the umpteenth time, "What is it about a macroinvertebrate sample that would make you consider it outstanding?" It finally hit home. I needed a complete paradigm shift. The new protocol would abandon the community-based approach and instead target an elite group, the crème de la crème: the Project SEARCH Most Wanted list. When these organisms were present in a sample it really stood out—outstanding!

With the advice of DEP aquatic entomologist Guy Hoffman, whom I had consulted on the original Most Wanted list, I came up with a new set of Most Wanted (see box). All of these organisms satisfy three criteria: statewide distribution, a requirement for very high-quality environmental conditions, and the possession of some unique behavior or morphological characteristic easily recognized by volunteers. In addition to the Most Wanted, we thought it would be a good idea to include several other commonly found types of macroinvertebrates, which we assigned to the Moderately Wanted or Least Wanted categories. These types do not provide definitive water quality information but do provide additional choices to volunteers trying to correctly identify an organism.

*Recently, the Izaak Walton League made several revisions to its method, including moving the hydropsychid caddisflies into the "less sensitive" category.

RBV Program "Most Wanted" List

- Order Ephemeroptera (mayflies)
  - Genus Drunella
  - Genus Isonychia
  - Genus Epeorus
- Order Trichoptera (caddisflies)
  - Genus Glossosoma
  - Genus Apatania
  - Genus Rhyacophila
  - Genus Brachycentrus
  - Genus Lepidostoma
- Order Plecoptera (stoneflies)
  - Genus Pteronarcys
  - Family Peltoperlidae
  - Family Perlidae
  - All other stoneflies



Stonefly (family Perlidae)

PHIL EMMLING

"RBV day"

Using the Most Wanted list as the basis, I developed a one-day program called Rapid Bioassessment in Wadeable Streams and Rivers by Volunteer Monitors—RBV for short. Any interested volunteer group that can assemble six or more adults is eligible to receive free RBV training. For me, this means devoting most of my fall Saturdays to hosting "RBV days" for different groups around the state. After two or three years, groups are ready to metamorphose and "hatch" out on their own.

In a nutshell (or caddis case), RBV day consists of a presentation followed by macroinvertebrate collection and identification at the stream sites. Participants divide into small groups that each visit a different site. They collect kick-net samples from six different locations within a riffle, then dump the net contents into white-bottomed trays and

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CONNECTICUT, continued

proceed to engage in a sort of scavenger hunt, looking for as many different Most Wanted types as they can find. To help the volunteers with identification, I created field identification cards with sketches of the critters and a checklist of key features, including distinctive swimming, crawling, clinging, or hiding behaviors that may be observed on the net or in the tray.

While each group is busily sorting Most, Moderate, and Least Wanted organisms and placing them into ice-cube trays, I make the rounds of all the sites to offer assistance and answer questions. Volunteers record their results on the RBV data sheet and then place one or two representatives of each different kind of macroinvertebrate they found into a vial with alcohol. Both the voucher collection and the data sheet are sent to DEP for verification.

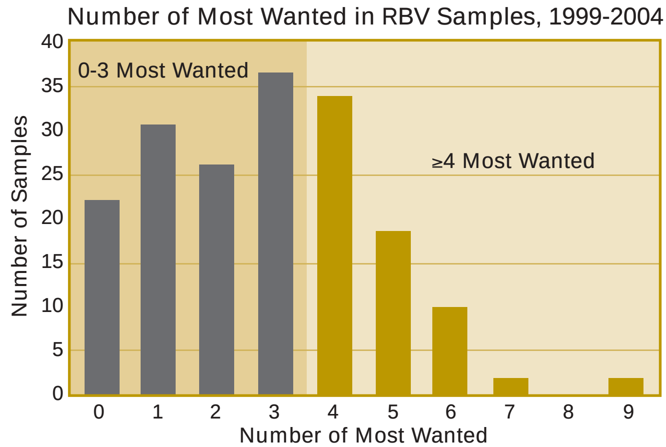
Value to volunteer programs

The number of programs submitting RBV data to DEP has increased every year. In 1999, just five volunteer groups in Connecticut were attempting family-level macroinvertebrate work, and of those most were planning on taking a sabbatical in 2000. During fall 2004, 20 programs completed the RBV protocol at 54 sites. These groups have used their RBV data to document upstream/downstream conditions, establish baseline information for sites with no previous monitoring data, prioritize locations for preservation efforts, support local land-use decisions, and educate citizens about water quality.

Clearly the RBV program is a hit with the volunteers. What about DEP's data needs?

Value to DEP

Like all states, Connecticut must submit to Congress a summary of the water quality within its boundaries. In this summary, a.k.a. the 305(b) report, waterbodies are categorized as "fully supporting," "partially supporting," or "not supporting" for certain designated uses. In Connecticut, macroinvertebrate data are the primary tool for determining the level of support for the "aquatic life" designated use.



Of 183 RBV samples collected between 1999 and 2004, a total of 66 (36%) contained four or more Most Wanted types, qualifying those stream segments as "fully supporting" for aquatic life use.

I calibrated the RBV method against water quality conditions by determining the number of Most Wanted types present in 256 macroinvertebrate samples collected and analyzed by DEP. This analysis showed that samples with four or more Most Wanted types could reliably be assessed by DEP as "fully supporting" for aquatic life.

From DEP's perspective, the RBV protocol is essentially foolproof since DEP biologists recheck the volunteers' voucher specimens to confirm the identifications (this takes about 10 minutes per sample). As Ernest Pizzuto, the supervisor of DEP's monitoring program, points out, "There is little or no likelihood of a false positive, so we feel confident using the data in the 305(b) report."

To further increase the probability of usable data, DEP encourages volunteers to monitor small to midsize streams, especially those expected to have high water quality. These are the streams that unfortunately receive little DEP attention, since our limited resources must be focused on monitoring major waste-receiving streams, permitted discharges, and TMDL projects.

To date, RBV data have contributed to 48 waterbodies being assessed in the 305(b) report. Without the RBV program the water quality in these waterbodies would be based upon assumptions and not actual data.

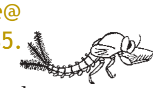
Finding fewer than four Most Wanted does not automatically condemn the stream. Organisms can be missed for any number of reasons, including high flows at the time of sampling, sampling from suboptimal areas, inadequate collection effort, or failure to find all the Most Wanted types that were collected. Therefore DEP does not list sites as "partially supporting" or "not supporting" in the 305(b) report based solely on RBV data. However, volunteer results indicating degraded conditions may trigger follow-up monitoring by DEP.

Strengths and limitations of RBV

The RBV method is in no way a substitute for professional monitoring. It works well at either extreme of the water quality continuum but not in the middle; for example, it cannot add clarity to the fuzziness between fully supporting and partially supporting. Also, the method is designed for use in riffle habitats only.

But within its limitations, the RBV is very effective. For high-quality streams, it provides reliable data that DEP can use with confidence in the 305(b) report. At the same time, the method is very appealing for citizen groups. It is simple and inexpensive, requires a commitment of only one day each year, and gives volunteers hands-on experience with collecting and identifying macroinvertebrates.

Mike Beauchene is CT DEP's volunteer monitoring coordinator. He may be reached at mike.beauchene@po.state.ct.us; 860-424-4185.



RBV materials including manuals, reports, field identification cards, and an EPA-approved QAPP are available at http://dep.state.ct.us/wtr/volunmon/volopp.htm.

Project SEARCH curriculum guides and other materials are available at http://www.sciencecenterct.org/projectsearch/.

Case Study

Huron River Watershed Council: Family-Friendly

by Joan Martin

Reaching out to our whole community has always been a primary mission for the Huron River Watershed Council (HRWC) in Ann Arbor, Michigan. Obtaining reliable data is equally important.

When we began our Adopt-A-Stream program in 1992, our advisor, University of Michigan professor Mike Wiley, suggested that macroinvertebrate monitoring with family-level ID would provide us with the type of information we needed to characterize the condition of our 900-square-mile Huron River system. At our first "ID Day" we provided the volunteers with picture keys and asked them to key out their preserved organisms to family level. A valiant effort was made, but the volunteers found the work quite difficult, and when we checked the identifications we found too many errors to continue in that fashion.

Over the next couple of years we evolved our identification event into its current form, which provides macroinvertebrate identification to the level of family without placing undue stress on the human families who participate.

River RoundUp

We have designed our macroinvertebrate monitoring program so that both collection and identification are one-day group events in which anyone can take part, even young children (as long as each one is with an adult).

On a single Saturday in the fall, and again in the spring, volunteer teams visit many of our 73 study sites to collect macroinvertebrates. Each team visits two sites. This five-hour event, called River RoundUp, typically attracts about 150 people and is something of a party. There is a terrific excitement in the room as the teams meet and prepare to set off. Participants are likely to make new friends since they work in small teams of about five people.

At their sites, the teams collect samples using a D-frame net. Everyone helps pick the macroinvertebrates out of the debris. About 100 organisms—including at least one representative of all the different kinds present in the sample—are preserved in a jar of alcohol. Even new volunteers with no special training or background can be very useful since they work on a team with two trained leaders (also volunteers). There is only one requirement for leadership training: River RoundUp experience. We have no age minimum for leaders—12 is the youngest so far.

ID Day

ID Day is held two weeks after the RoundUp. Usually about 40 volunteers show up. With the help of magnifying glasses, dissecting microscopes (borrowed from a local high school), and pictures of some of the macroinvertebrates they are likely to see, they sort their collection into "look-alike" groups based on whatever looks different to them. They place the groups into trays with multiple compartments individually marked with a letter code. Those who are new to this

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Event I: River RoundUp


JOHN CRAMER

Each fall and spring, over 100 volunteers assemble for a brief orientation and training, then gear up and head out in small teams to their sampling sites.


JOHN CRAMER

At the stream site, team members pick bugs out of the debris and preserve about 100 organisms.

Event II: ID Day


HERB ALVORD

Two weeks after the RoundUp, volunteers sort the preserved samples into "look-alike" groups of bugs.


AL WOOLL

Experts identify the sorted macroinvertebrates to family level while team members record the information.

activity work at a table with experienced volunteers. Program staff members help the sorters notice subtle differences and ignore differences that are only in size. Interested children can be helpful, usually working with an adult.

The crucial ingredient that makes ID Day work is the participation of local experts. We are usually able to recruit seven or eight people, including staff from agencies or consulting firms, graduate students, and a few of our volunteers who have become experts. HRWC's own in-house expert, Jo Latimore, also participates. HRWC provides two research-quality microscopes for the experts' use.

When a group of volunteers is finished sorting their sample, one of the experts sits with them to identify each family while the volunteers record the letter code for each compartment in their tray next to the corresponding family name on the data sheet. Following the expert's work, the volunteers count the number of bugs in each family, record the data, and place all the bugs into a labeled jar of fresh alcohol for storage. Thus, the people who do all the work except the actual ID need no training in macroinvertebrate identification.

Using this method, we are able to identify macroinvertebrates from over 50 samples of approximately 100 bugs each in a single afternoon. To speed things up, bugs that are especially challenging can be placed in a "mystery jar" attached to the sample jar. Later, Latimore, who has a Ph.D. in fisheries and wildlife and eight years of experience with macroinvertebrate identification, identifies these "mystery bugs." She also spends 8-12 hours rechecking all the samples, focusing especially on verifying the identification of any rare or hard-to-identify organisms noted on the data sheet.

Interpreting and using the data

Our data are not quantitative because we don't use a quantitative method to collect and sort the sample, but we do have a high degree of confidence in our identifications. In interpreting the data, we mainly look at the diversity of the macroinvertebrate community and pollution sensitivity of the insect families. We maintain our preserved specimens permanently, so we can always go back later and check if questions arise.

Because we are able to monitor more frequently, and at more sites, than our state agencies, we are often the major or only source of information, especially for the smaller tributaries. Citizen groups, counties, and consultants request our data when planning development, mapping floodplains, and planning stream restoration projects.

Thanks to our large number of attentive volunteers, we have been able to provide the community with reliable data and with an opportunity to protect our precious water resources.

Joan Martin is HRWC's Adopt-A-Stream Program Director. She may be reached at jmartin@hrwc.org; 734-769-5971.

Case Study

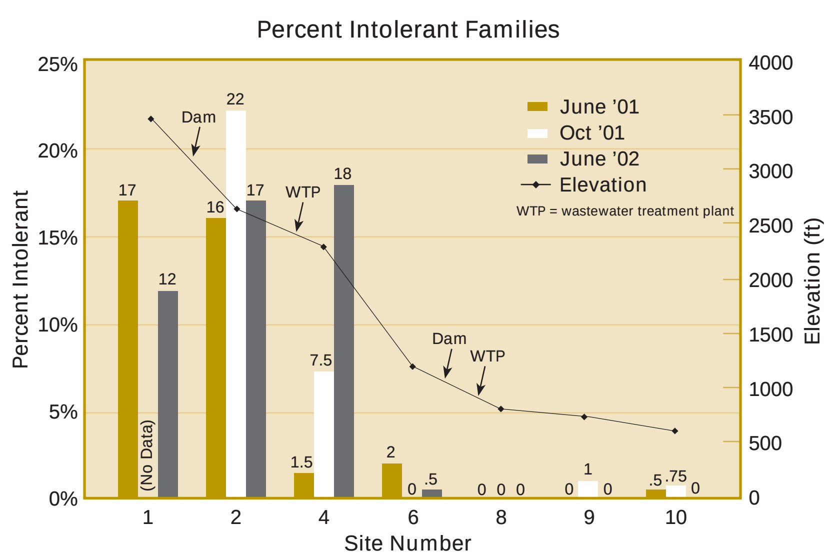
Friends of Deer Creek: Rigorous Science, Remarkable Volunteers

by Eleanor Ely

Joanne Hild is used to being greeted with incredulity when she describes the macroinvertebrate monitoring carried out by Friends of Deer Creek in Nevada City, California. Here are some of the things that astonish people: (1) Every other Wednesday evening, year-round, a group of 10 to 15 volunteers shows up at the program office to identify preserved organisms. (2) Some of these folks come in even more often. (3) About 10 of the volunteers have been doing this work for over five years. (4) For each sample, 500 organisms are identified to family level. (5) Some volunteers have begun doing some genus-level work. (6) One of the volunteers is a professional taxonomist who comes to every session.

This level of effort and commitment would be extraordinary anywhere in the United States, but it's even more unusual in California, where most volunteer programs ship preserved samples off to professional taxonomists for identification. This may be partly because West Coast environmental agencies subsample and identify 300 to 500 organisms per sample, as compared with the 100-organism subsample often used in other regions of the country (see page 22). The prospect of identifying 500 bugs from every sample would be intimidating for most volunteer programs, but not Friends of Deer Creek.

The Friends' quality control procedures are just as rigorous as everything else they do. Every sample is rechecked by the professional taxonomist, Susan McCormick, and 20 percent of samples are sent to the California Department of



As elevation decreases and development increases, pollution-intolerant macroinvertebrates all but disappear from Deer Creek.

Fish and Game for professional analysis. (These analyses are paid for through a contract between Fish and Game and the California State Water Resources Control Board.) In addition, taxonomist Wayne Fields, whom Hild describes as "the guru of Sierra Nevada macroinvertebrates," regularly stops by to help identify the most difficult organisms and give special training sessions.

"Secrets" of success

How is all this possible? Hild, the program's Executive Director, gives a lot of credit to the local community in Nevada City, a town of a few thousand people located in the foothills of the Sierra Nevada. "Our town is crawling with very dedicated people, people who are incredible community givers," she says. For example, just as the bioassessment program was getting started, a local woman with a lifelong passion for aquatic insects walked in the door. She has been an invaluable participant and trainer ever since.

Another critical ingredient is McCormick's ongoing involvement. "Without her, this project would have been nearly impossible," says Hild. "Identifying bugs is a very technical, detailed science, and volunteers get frustrated if there is no one there to answer their questions."

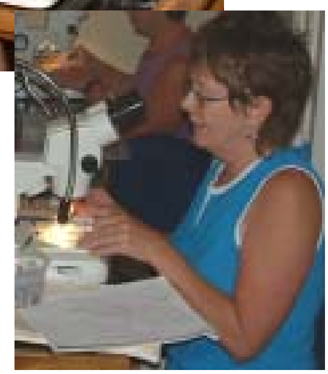
Then there's the fun factor—the group spirit. By this time, most of the volunteers have gotten quite good at identification. Hild says, "We get together and we laugh and we get excited about the bugs."

Hild's own enthusiasm (she's a biologist) and her commitment to high scientific standards surely play an important part in the program's success. And, as she points out, success builds on success. The program continually attracts new sources of help. A year and a half ago, a former aquatic entomologist joined up; she now helps with quality control and training.

The bugs' story

The macroinvertebrates that live in Deer Creek have a story to tell. As shown in the graph at left, the upper reaches of the creek yield a diverse community of organisms, including many pollution-intolerant families, but at the downstream sites few or no intolerant families are found.

THOMAS SPELLMAN



THOMAS SPELLMAN

A Friends of Deer Creek volunteer transformed part of the program office into this lab space, where volunteers identify macroinvertebrates with assistance from taxonomist Susan McCormick (below).

What's going on? Moving downstream, development increases so more nutrients and other pollutants enter the stream via runoff and wastewater treatment plants. Meanwhile, water is removed for irrigation at numerous places, so the amount of dilution steadily decreases the farther downstream you go. Also, the water gets warmer as the riparian plant cover decreases. All these factors add up to algae blooms. Dissolved oxygen levels near the creek bottom drop, and so do the populations of intolerant macroinvertebrates.

Using the data

The point of all the hard work is, of course, to protect and improve Deer Creek. Before the Friends began monitoring, there was no baseline data on macroinvertebrates in the creek (and not much on Sierra creeks in general), so one important goal is simply to collect that baseline data. The data are also being used to pinpoint areas for restoration, and to monitor the success of current restoration efforts on a portion of a tributary that is encased in cement and covered with non-native vegetation.

Recently, the Friends succeeded in getting a segment of Deer Creek listed for pH on the state 303(d) list (list of impaired waters). The listing was based on a combination of the volunteers' chemistry and macroinvertebrate data. "Our macroinvertebrate data really demonstrated the impacts on aquatic life," says Hild. "We were able to show a drastic difference in macroinvertebrate community diversity and numbers above and below the treatment plant."

As if they're not busy enough already, the Friends have several exciting new projects in the works. One involves analyzing mercury levels in certain families of predatory macroinvertebrates as part of a research study on how mercury moves through the food chain. Mercury is a major contaminant in Sierra streams because Gold Rush miners used it to amalgamate gold. The group is also planning a comparison study of family-level metrics versus metrics obtained from professional labs. Finally, they are in the process of developing a "Bug Book" for family-level identification in Sierra streams, which they will use to help train other watershed groups.

Friends of Deer Creek's highly rigorous approach is obviously not for everyone. It takes a special combination of ingredients to maintain this level of enthusiasm for aquatic macroinvertebrate taxonomy. But their work stands as an inspiring example of what a tightly knit group of dedicated volunteers is capable of achieving.

For more information, contact Joanne Hild, Friends of Deer Creek, jshild@sbcglobal.net; 530-265-6090.

Catch-and-Release Bioassessment

by Patrick Edwards

Can we collect meaningful biomonitoring data without harming insects and other invertebrates? This is an important question because many volunteer bioassessment programs have a dual purpose: to generate high quality data and to inspire environmental stewardship of streams and rivers. But are these goals mutually exclusive? By refining current biomonitoring protocols to reflect a catch-and-release ethos it may be possible to collect high quality bioassessment data while simultaneously modeling environmental sensitivity.

I teach a general education course at Portland State University called Water in the Environment, in which students carry out a family-level biomonitoring study on a local stream. One of the major insights I've had in teaching this course is that once students learn that macroinvertebrates are a critical component of stream ecology, they don't want to preserve and kill them. Over the last five years, I have developed several tools to help my students conduct accurate, family-level biomonitoring research using a catch-and-release approach. These include a live subsampling procedure, handling techniques that ensure maximum insect survival, and a family-level field guide that features photographs of live specimens and descriptions of live identification characteristics.

The techniques I have developed for my course may also be useful for those seeking to conduct environmentally sensitive volunteer-based biomonitoring. Some of these methods have not yet been scientifically validated. They are presented as a departure point for developing and testing catch-and-release protocols.

Identifying live insects

When I first began teaching Water in the Environment, we used traditional field guides and dichotomous keys. But these did not provide enough information for live, streamside identification. Then I tried creating reference sets of preserved specimens that students could take into the field with them. This did not work either; preserved insects often look very different from their live counterparts. The bottom line was that my students were not identifying macroinvertebrates accurately enough to distinguish between impacted and non-impacted streams.

I conducted a simple study with my students in which one group used nothing but a traditional field guide for identification, a second group also received instruction in key live-identification characteristics, and a third group was given a reference tray of live insects in addition to the field guide and instruction. The group using only the field guide correctly identified an average of 45 percent of the time. The average accuracy for the second group was 80 percent, and for the third group it was 89 percent. These results show that beginners, when given the appropriate resources, can identify live insects relatively accurately.

PATRICK EDWARDS

Student pours sample into compartmentalized tray for subsampling of live organisms.

In fact, it can actually be easier to identify live specimens than preserved ones—if you know what to look for. Live traits such as swimming or other movements can be better key identification characteristics than gills, antennae, and other small features that can only be seen with a dissecting scope and are often destroyed in the process of preservation. A person who is familiar with basic movements and swimming characteristics can accurately identify many insect families without any magnification at all. For example, flatheaded mayflies (Heptageniidae) move around a collection tray in an odd flopping swim that is easily recognized. Midges (Chironomidae) swim with a very distinctive looping twist, and pronggill mayflies (Leptophlebiidae) pulse their hairlike gills when respiring.

Subsampling live insects

The sheer number and diversity of invertebrates collected in a sample make streamside sorting, counting, and identifying difficult and time-consuming. A single "kick sample" may turn up hundreds of insects. Arbitrarily choosing a portion of the organisms for analysis will introduce selection bias into the study. To resolve this problem, researchers often take a random subsample by pouring the sample into a shallow tub or tray with numbered squares painted on the

PATRICK EDWARDS

A field guide that includes photos of insects in ice cube trays gives students a sense of scale (for more information on the guide, see page 20).

bottom. The sample is evenly spread across the bottom of the tray and a random process is used to select particular squares for sampling. The rest of the sample is disregarded.

Most subsampling procedures call for the use of preserved specimens. While a few do suggest pouring live insects into a subsampling tray, I found that insects move around far too much for this to be effective. So I devised another plan. For live, streamside subsampling, I use a compartmentalized storage case available at most large general-merchandise stores. It is made of durable plastic and has a watertight lid that prevents water and insects from spilling out. The bottom part, which serves as the subsampling tray, is divided into 18 compartments or cells that are 1.5 inches square with 1.5-inch-high "walls" that prevent critters from moving from cell to cell.

My students place their samples into a large tub, swirl the contents to evenly distribute organisms and debris, and then pour the contents of the tub into the subsampling tray. They use a random number sheet to select five cells from which to collect a minimum of 30 insects. (These 30 insects make up one of at least six samples from the study stream. This means that a typical study is based on at least 100 randomly selected insects.) Organisms from the selected cells are placed in an ice cube tray and the rest of the sample is immediately returned to the stream. If it's necessary to preserve and keep the selected insects for later identification and archiving, at least the others are returned alive.

In a preliminary study, I found that when students used the above method their data showed less variability than when they picked organisms randomly. More research is needed to investigate how representative a subsample this procedure yields.

Handling and release

While many insects are quite sensitive to handling and temporary holding, I have found that by taking a few precautions it is possible to capture, identify, and release them with minimal deaths. Insects should be handled gently and as little as possible, using a turkey baster or no-crush entomology forceps. Most important is keeping them cool.

When possible, my students and I subsample at the streamside. Otherwise we put the entire sample in jars with stream water, which are placed in a cooler for transport. We choose a shaded location for our work, and we keep the insects in the sorting tubs and ice cube trays cool by placing ice in the water. Because insects are sensitive to the diurnal cycle, it's a good idea to keep the lid off the cooler so that natural sunlight can reach the insects. This is particularly important if you plan to keep specimens overnight.

When we are finished with identification, the macroinvertebrates and water are poured back into the jars, which are transported in the cooler back to the spot from which the sample was taken. When I release the organisms, I'm sure to acclimate them to stream temperature. I do this by dumping out all the jars into a large tub and then gradually adding stream water until the water in the tub reaches the same temperature as the stream.

I believe that by adopting more sensitive biomonitoring procedures volunteer monitors can attain their goals for both data quality and stewardship and avoid the paradox of "loving the stream to death." A side benefit is that sometimes landowners are more willing to let you conduct bioassessments if they know you are using live-identification techniques.

When I return insects to the stream, I often watch as they scurry under rocks or swim away. It's a good feeling to know that you've learned something about a stream without harming its residents.

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Ode to a Biological Stream Monitor

by Jonathan Pearson

I kick the riffle with hope to see
the wondrous Hydropsychidae
with ventral gills and forelegs three;
I curse the heavens should there not be.

But wait! Upon the seine I spy
my quest, for 'tis a caddisfly!

The riffle explodes as I hope and pray
to find a Siphlonuridae.
Tails are three, but claws are one;
I question my faith should I find none.

Gadzooks! Do I believe my eyes?
Upon the net, two huge mayflies!

My angst-driven legs begin to feel weak
"Plecoptera!" I shout, "It is you I must seek!"
Body of armor, displaying two claws;
I offer my soul for a stream without flaws.

Huzzah! Could it be?? An illusion?? Oh My!
'Tis not! For I see the seductive stonefly!

I fall to my knees, I crawl to the net.
My face fills with glee; I don't care that I'm wet.
There's crayfish and beetles, a sowbug, a midge;
a disgusting black crane fly, as large as a bridge.

I fill up my sample, relaxed and relieved
For biodiversity has been achieved.

PHIL EMMLING

Caddisfly (family Limnephilidae)

Jonathan Pearson wrote this poem while on staff with Maryland Save Our Streams.

THE LEAF-STREAM CONNECTION

by Kristen Travers

When we ask participants at Stroud Water Research Center workshops to sort through slimy, decomposing clumps of leaves, the activity is at first greeted with odd or downright dirty looks. However, the connection between the slimy leaves, the trees they come from, and healthy streams is an important story that is central to the protection and restoration of stream ecosystems. It is also a story of which the majority of the public is unaware.

Historically, streams in eastern North America, as in much of the world, were forested, but most of our riparian areas were disturbed or destroyed many years ago. Deforestation has altered streams in many ways. For example, the loss of the forest canopy and the shade it provides raises water temperatures, potentially by several degrees. While this may not sound like much, our research in the Piedmont region of North America has revealed that an annual water temperature increase of 4˚C (about 7˚F) is equivalent thermally to shifting the latitude of the stream about 425 miles south.

Deforestation also removes an important food source for macroinvertebrates. Leaves that fall into small or medium-sized streams typically do not travel far before accumulating in packs behind branches, rocks, and other obstructions. Certain macroinvertebrate species that are adapted to feeding on leaves get nutrients primarily from the rich diversity of microbes (fungi and bacteria) that colonize the leaf surface and create the slimy effect. These leaf-eating macroinvertebrates, called shredders, include some types of stoneflies, crane flies, caddisflies, and sowbugs.

STROUD WATER RESEARCH CENTER

New York State teachers fill an onion bag with dried leaves found at their stream site.

Leaf pack experiments

How can we convey these concepts to the public, to help people understand and appreciate the benefits of riparian forests? At the Stroud Center we have found that one of the best ways is through direct, hands-on investigation. To do that, we adapted a technique long used by researchers to study macroinvertebrate communities and monitor changes in a stream. The basic process is simple—put a bunch of leaves in a mesh bag, with a mesh size small enough to contain the leaves yet large enough to allow macroinvertebrates to enter, and submerge the bag in the stream for three to four weeks. Then remove the bag and sort through the leaves to discover the different macroinvertebrates in the stream.

Using leaf packs, you can design a variety of experiments to investigate how a particular stream uses leaf litter. For example, you can compare the numbers and types of macroinvertebrates found in riffles versus pools or in a forest stream versus a meadow stream. Or you can study the effects of using different types of leaves—native versus non-native species, deciduous versus coniferous, green versus dried. You can also vary the length of time the leaf packs are left in the stream.

Leaf pack kit: "One-stop shopping"

While it's possible to conduct leaf pack experiments using common household items such as the mesh bags in which onions are sold, zipper-top plastic bags, kitchen strainers, and so on, to make things easier for busy teachers we designed a Leaf Pack Experiment Kit for "one-stop shopping." The kit, which is now commercially available from LaMotte Company (www.lamotte.com), contains mesh bags, strainer, sorting trays, Petri dishes, magnifiers, zipper-top bags, waterproof illustrated sorting sheets, color photos of macroinvertebrates, tree-finder booklet, instructor's manual, and other materials—everything needed for a class of 30.

STROUD WATER RESEARCH CENTER

Teachers at a Stroud Center workshop use macroinvertebrate sorting sheets and other items from the Leaf Pack Experiment Kit.

The sorting sheets (available separately) are an especially big hit with teachers and watershed groups. They are designed so that the Petri dishes containing the different organisms can be placed on the sheet right next to the corresponding illustration.

Logistics

In our experience smaller streams work best for leaf pack experiments, as larger streams are prone to floods that can wash away the packs. The packs can be attached to rocks in the stream or to bricks. We have found that the best method is to lash the leaf pack to a construction brick (one with holes) using strong fishing line, then place the brick in the stream with its long axis parallel to the direction of the water flow. Because of their weight and placement, bricks rarely flip over, even in fairly heavy storms. They can also be "staked" through the holes into the stream bottom to provide more stability.

As they sit on the stream bottom, the leaf packs gradually become camouflaged by sediment and algae. Finding them several weeks later can therefore become an aquatic version of "Where's Waldo" unless you have made a detailed sketch of the location. We don't recommend marking the location by placing stakes or flags along the streambank because some groups who tried that method have found their leaf packs thrown high and dry on the banks. Whether this was the result of vandalism or someone mistaking the leaf packs for trash is hard to determine, but in any case we recommend not drawing attention to the packs.

Leaf pack experiments required two visits to the stream, which is difficult for many school classes to manage. Some teachers have the students make and place the packs during a field trip and then the teacher or a volunteer takes care of subsequent retrieval. Usually the students sort through the leaf packs and identify the macroinvertebrates in the classroom.

Online network

In 2000 we created the Web-based Leaf Pack Network (www.stroudcenter.org/lpn) to provide support and resources to schools using leaf packs. Students can enter not only their macroinvertebrate data but also habitat and physical data (such as flow and temperature), and can upload photos and reports. Anyone can visit the site and view the data and resources.

As community-based monitors are well aware, monitoring involves more than collecting data—it requires interpreting and communicating the results. The Leaf Pack Network lets students engage in the full scientific process of designing an experiment, conducting research, and sharing the results. The ability to compare their data with other datasets is especially valuable in helping students interpret their results.

Leaf pack vs. traditional macroinvertebrate monitoring

Although we have observed that results from leaf packs indicate similar water-quality trends as traditional macroinvertebrate monitoring methods, the use of leaf packs for monitoring has not been firmly established. To determine the leaf pack's efficacy as a monitoring tool, we are currently placing the packs at existing research sites being sampled by quantitative methods. Preliminary results show a strong correlation with water quality results from Surber samplers. The results will be posted soon on the Leaf Pack Network website.

As an educational tool, leaf packs are uniquely suited to demonstrating the direct link between stream quality and riparian areas. They allow students to observe firsthand the dependence of macroinvertebrate communities on leaves for food and habitat. In addition, as students sort through the packs to separate the macroinvertebrates from the leaves, they often notice the amount of sediment that has accumulated—a potential indicator of poorly designed upstream development or suboptimal agricultural practices. Leaf packs may be particularly appropriate for schools or environmental centers that work with large numbers of students, because repeated kick sampling may damage the stream habitat.

So if you are looking for a new way to investigate streams and at the same time help people make the connection between the terrestrial and aquatic environments, give leaf packs a try.

STROUD WATER RESEARCH CENTER

Philadelphia students use the Leaf Pack Experiment Kit to sort macroinvertebrates from leaf packs.

To become involved in the Leaf Pack Network visit www.stroudcenter.org/lpn or contact the Leaf Pack Administrator at leafpacknetwork@stroudcenter.org or 610-268-2153 ext. 258.

homemade sieves

A sieve comes in handy for helping separate macroinvertebrates from debris in the field or lab, but the standard brass type is expensive. Volunteer monitoring programs have devised a number of homemade versions, two of which are described below. Either mesh netting or metal screening (more durable) may be used. Whatever the material, the sieve mesh size should be no larger than the mesh size of the collection net.

Some California volunteer programs saw 6- to 8-inch-diameter PVC (white) or ABS (black) pipe into 2-inch "slices," then glue on 500-micron Nitex mesh netting. Arleen Feng of the Alameda County Public Works Agency reports having good results with pipe at least 1/8 inch thick, GOOP adhesive, and one or more hose clamps for extra security. She cautions, "If you use a power saw be careful not to burn or melt the pipe, and avoid breathing the fumes. Also be sure to have adequate ventilation for fumes from the adhesive."

The sieve used by West Virginia Save Our Streams volunteers is made from a modern style of embroidery hoop called a Q-snap frame (shown above). Program coordinator Tim Craddock got the idea for the design while looking through his wife's embroidery catalogs. Nitex mesh or stainless steel screen is simply snapped into the frame; no glue required. The frames are available in different sizes and the sieve can be easily disassembled for convenient transport.

For further information on these designs contact Arleen Feng at arleen@acpwa.org or Tim Craddock at tcraddock@wvdep.org.

Volunteer vs. Professional Macroinvertebrate Data

Maryland Stream Waders

by Dan Boward

Since 2000, the Maryland Department of Natural Resources (DNR) has operated a statewide volunteer stream monitoring program, Maryland Stream Waders. The volunteers collect macroinvertebrate samples which are then identified by DNR. Stream Waders data are used to support the state's professional program, the Maryland Biological Stream Survey (MBSS), by "filling the gaps."

Stream Waders is nearly seamless with the MBSS because in both programs (1) samples are collected during the same March-April index period, (2) the same equipment (D nets) and field protocols are used, (3) the same watersheds are sampled, and (4) the same experienced DNR taxonomists identify the organisms using the same subsampling procedures and identification keys.

However, there are two important differences. First, whereas MBSS samples are identified to genus level, Stream Waders samples are identified only to family. DNR typically gets two to four times as many Stream Waders samples as MBSS samples each year, and does not have enough staff to identify so many samples to genus level. Second, most MBSS sites are chosen randomly, while Stream Waders sites are chosen nonrandomly either by the volunteers themselves or by DNR, local governments, or watershed organizations.

Developing IBIs

In 1999, when DNR developed its genus-level benthic macroinvertebrate index of biotic integrity (IBI), it had the foresight to develop a comparable family-level IBI that could be used by volunteer programs and schools. The two IBIs were developed separately, based on the same physical, chemical, and land-use criteria for defining reference and degraded sites. (For example, degraded sites met such criteria as dissolved oxygen ≤2 ppm, urban land use >50% of upstream catchment area, poor instream habitat, and others.) Both IBIs produce a stream health rating from 1 to 5, with any site scoring less than 3 classified as degraded (i.e., stream health rating of "Poor").

In piedmont and highlands streams, the classification efficiency (percentage of reference and degraded sites that were classified correctly) for both indices was 88%. In coastal-plain streams, the family-level IBI did not do quite as well—it was 71 % efficient, compared to 88% for the genus-level IBI. Details of DNR's IBI development can be found at www.dnr.state.md.us/streams/pubs/1998_benthic_ibi.pdf.

Assessing Maryland's streams

Between 2000 and 2004, both MBSS and Stream Waders completed a statewide sampling of Maryland's 1st- through 4th-order streams. DNR biologists collected 1,336 MBSS samples, of which 16% were rated Good (IBI 4-5), 35% Fair (IBI 3-3.9), and 49% poor (IBI <3), using the genus IBI. Meanwhile, about 700 Stream Waders volunteers collected 2,877 samples, which were identified to family by DNR biologists. Using the family IBI, 14% of the Stream Waders sites were rated Good, 26% Fair, and 60% Poor.

Assessing the Stream Waders data

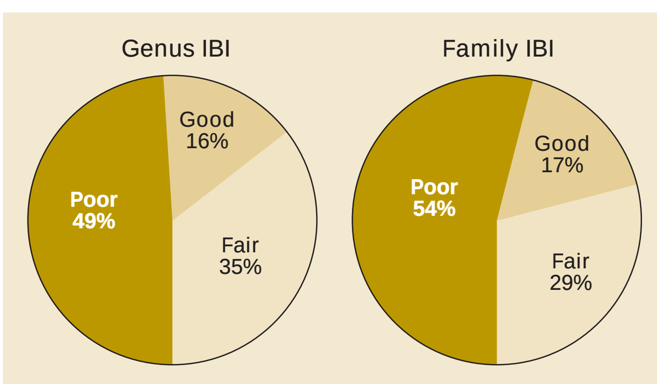
But here's the $1,000,000 question … how good are the Stream Waders data? Put another way, does the larger percentage of Poor ratings for Stream Waders sites reflect real differences in stream health? That is possible, especially since Stream Waders sites are more often near road crossings, which could be impacting the stream. But other factors may also be at play, including differences in the two IBIs and differences between volunteer and professional sample-collection techniques. The comparisons presented below shed at least some light on these questions.

Comparing the two IBIs

The first comparison was designed to see how the two IBIs differ when calculated from the same dataset. Using the taxa and abundance data from the 1,336 MBSS samples (no volunteer data), we conducted a "desktop study" by backing up the identifications to family level, then applying the family IBI. The two IBIs were closely correlated ($r = 0.84$), but the genus IBIs tended to be higher (mean difference 0.12) than the family IBIs.

In terms of stream health rating, the genus IBI rated 16% of the sites as Good, 35% as Fair, and 49% as Poor, as compared to the family IBI ratings of 17%, 29%, and 54%, respectively (see Figure 1). This suggests that the larger percentage of Poor ratings seen in the Stream Waders data may be at least partially attributable to the use of the family IBI. In the future, we plan to examine individual metrics within both IBIs to tease out reasons for these differences.

Figure 1
Genus and family IBIs calculated from the same dataset (MBSS data, 2000-2004)



Within-program repeatability

To look at repeatability within each program, we identified instances where two or more sites within the same stream reach (i.e., the length of a stream be-

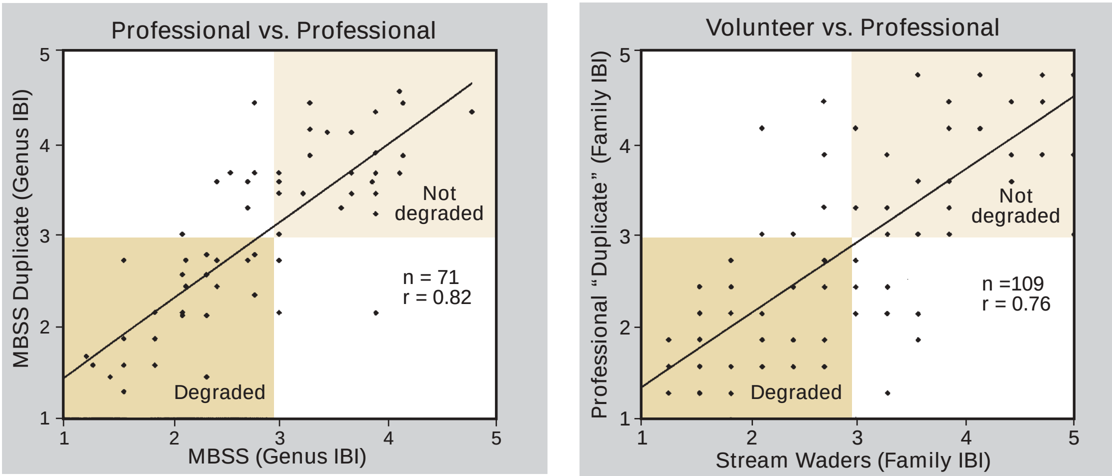


Figure 2
Validation study

tween two confluences) were sampled by the same program. We found 172 "stream-reach pairs" for the Stream Waders and 118 for MBSS. Among the Stream Waders pairs the overall mean difference in IBIs was 0.74, while for the MBSS pairs it was 0.53. Based on this evaluation, MBSS results are slightly "closer" at the reach scale.

"Duplicate" samples

The most direct way to evaluate the Stream Waders data would be to have professionals accompany volunteers to their sites and collect side-by-side samples at the same time and location. Although we have not done this, we did perform a validation study in which MBSS crews visited Stream Waders sites after the volunteers' sampling. The samples they collected were approximate rather than true duplicates because (a) MBSS crews estimated the Stream Waders sample locations using coordinates provided by the volunteers and (b) at least two weeks passed between the volunteer and professional sampling, to allow for recolonization. MBSS personnel collected such "duplicate" samples at 109 Stream Waders sites between 2000 and 2004. These samples were analyzed in the same way as the Stream Waders samples, using the family IBI. During the same time period, MBSS crews performed their own internal audit by collecting duplicate samples (same site, same day, same sampler) at 71 MBSS sites.

Results from the validation study are quite encouraging (see Figure 2). In the Stream Waders-versus-professional comparison, family IBIs were well correlated (r = 0.76), with 83% of sample pairs agreeing on site degradation. This level of agreement was nearly identical to that seen in the MBSS internal audit (r = 0.82, with 84% of pairs agreeing on site degradation). These results are especially impressive considering that the study design introduced extra variability into the Stream Waders/professional comparison ("duplicate" samples were taken at different times and probably not at exactly the same locations).

Summary

In summary, samples collected by Stream Waders volunteers and analyzed by DNR staff using a family IBI compared well with MBSS samples collected and assessed by DNR staff using a genus IBI. When it comes to identifying degraded sites, the volunteer results were virtually identical to the professional results.

Factors responsible for the observed differences between volunteer and professional stream ratings probably include differences in: (1) the family and genus IBIs; (2) site location (Stream Waders sites are more often close to road crossings); and (3) field technique (Stream Waders may be less able to identify the most productive habitats and less thorough in collecting samples).

Currently, DNR and our cooperators (watershed organizations and local governments) use Stream Waders data to support MBSS data in characterizing watersheds, targeting restoration and protection efforts, and evaluating the effects of management activities. The studies reported here suggest that Stream Waders data are of high enough quality that they could also provide valuable support for compiling the state's 305(b) report and 303(d) list, formulating antidegradation policy, and developing biocriteria for wadeable streams.

Dan Boward is Assistant Program Chief of MD DNR's Ecological Assessment Program and also manages the Stream Waders program. He may be reached at dboward@dnr.state.md.us; 410-260-8605.

For more information on Stream Waders and the MBSS, visit www.dnr.state.md.us/streams/mbss/mbss_volun.html.

DAN BOWARD

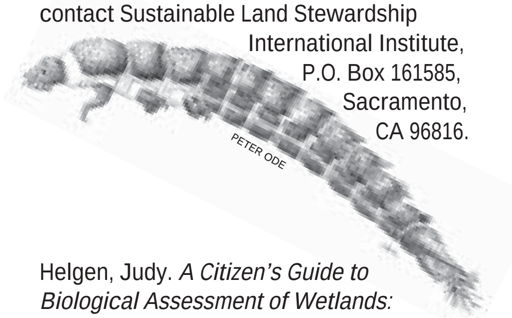
University students at training session for Maryland Stream Waders.

Macroinvertebrate Resources

Methods manuals (volunteer-oriented)

Dates, Geoff. *Living Waters: Using Benthic Macroinvertebrates and Habitat to Assess Your River's Health.* 2000. Thorough, how-to guidance for habitat assessment, streamside surveys, and intensive bioassessments. Detailed discussion of sampling methods (including artificial substrates) and data interpretation; also includes several keys. 200 pages. $25 from River Network, 503-241-3506, 800-423-6747, www.rivernetwork.org.

Harrington, Jim and Monique Born. *Measuring the Health of California Streams and Rivers: A Methods Manual for Water Research Professionals, Citizen Monitors, and Natural Resources Students, 2nd Edition.* 2000. Comprehensive manual; includes protocols for collection and processing. Nearly half is devoted to a family-level field guide and key with exceptionally detailed drawings and descriptions. 286 pages plus appendices. $35; see http://www.slsii.org/ or contact Sustainable Land Stewardship International Institute, P.O. Box 161585, Sacramento, CA 96816.



Helgen, Judy. *A Citizen's Guide to Biological Assessment of Wetlands: The Macroinvertebrate Index of Biological Integrity (IBI).* 2002. Collection procedures (including bottle-trap method), identification key, and metrics for wetland bioassessment using macroinvertebrates. Designed for use by volunteers with Minnesota's Wetland Health Evaluation Program. 51 pages. Single copies (no charge) available from Mark Gernes, Minnesota Pollution Control Agency, 651-297-3363. ALSO AVAILABLE: Companion manual, *A Citizen's Guide to Biological Assessment of Wetlands: The Vegetation Index of Biological Integrity (IBI)*, by Michael Bourdaghs and Mark Gernes, 2005. 84 pages. Download PDF from www.pca.state.mn.us/water/biomonitoring/bio-citizenmonitoring.html.

Murdoch, Tom and Martha Cheo. *Streamkeeper's Field Guide: Watershed Inventory and Stream Monitoring Methods.* 1999. Guidance on physical, chemical, and biological stream monitoring; includes simple macroinvertebrate key. 300 pages. $29.95 from Adopt-A-Stream Foundation, www.streamkeeper.org/catalog, aasf.streamkeeper.org, 425-316-8592.

U.S. EPA. *Volunteer Stream Monitoring: A Methods Manual.* 1997. Step-by-step instructions for habitat assessments and three levels of macroinvertebrate survey, as well as some chemical and physical water quality tests. No keys. 210 pages. Free from National Service Center for Environmental Publications (NSCEP), 800-490-9198, ncepimal@one.net, www.epa.gov/ncepihom/index.htm (order # EPA 841-B-97-003), or download PDF from www.epa.gov/owow/monitoring/volunteer/stream/.

National field guides (volunteer-oriented)

Izaak Walton League of America. *A Volunteer Monitor's Field Guide to Aquatic Macroinvertebrates.* 2003. Four-panel foldable laminated brochure with drawings, descriptions, and IWLA sensitivity ratings for major groups of macroinvertebrates. $4.95 from McDonald & Woodward Publishing Co., 800-233-8787, mwpubco@mwpubco.com, www.mwpubco.com. Also available from McDonald & Woodward: IWLA's "Watershed Stewardship Action Kit" with instructions for conducting streamside surveys, plus other resources; $10.95. For IWLA macroinvertebrate data forms see www.iwla.org/sos.

McCafferty, W. Patrick. *Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives*. 1998. Extremely comprehensive; includes biology, identification keys, and more than 1,000 highly detailed illustrations (drawings and color plates). 448 pages. $82.95 from Jones and Bartlett Publishers, www.jbpub.com, 800-832-0034.

Voshell, J. Reese, Jr. *A Guide to Common Freshwater Invertebrates of North America.* 2002. Designed for teachers, volunteer monitors, and other nonprofessionals. Family-level identification guide with over 100 color illustrations and detailed descriptions, plus extensive information on life histories and ecology. 454 pages. $32.95. Order from McDonald & Woodward Publishing Co., 800-233-8787, mwpubco@mwpubco.com, www.mwpubco.com.

Regional guides and keys

Bouchard, R.W. *Guide to Aquatic Invertebrates of the Upper Midwest.* 2004. Family-level guide and key with line drawings and descriptions. Available online or in hardcopy (spiral-bound, $25.) For ordering information or to download PDF, see http://wrc.coafes.umn.edu/VSMP/education.htm.

Jessup, B. K., et al. *Family-Level Key to the Stream Invertebrates of Maryland and Surrounding Areas, 3rd Edition.* 2003. Dichotomous family-level key with many drawings and photographs. 98 pages. Download PDF from www.dnr.state.md.us/streams/pubs/ea99-2rev2003.pdf.

Regional pocket guides

Adams, Jeff and Mace Vaughn. *Macroinvertebrates of the Pacific Northwest: A Field Guide.* 2003. Includes color photos of 64 Pacific Northwest macroinvertebrate groups (mostly families). Companion to CD-ROM (see below). 16 pages. $9 from the Xerces Society; see www.xerces.org.

Macroinvertebrate-related articles in past issues of *The Volunteer Monitor:*

Spring 1997. How a "Most Wanted" macroinvertebrate list helped Connecticut high school students improve data interpretation.

Spring 1998. Several articles on wetland bioassessment using macroinvertebrates and other assemblages.

Spring 2000. Macroinvertebrate methods overview and trends; comparison of volunteer vs. professional results; other related articles.

Summer 2002. Local uses of macroinvertebrate data by Huron River Watershed Council.

Winter 2003. Development of Virginia Save Our Streams modified method for streamside survey.

Summer 2004. Using rock baskets to collect macroinvertebrates.

Edwards, Patrick. *Aquatic Macroinvertebrate Field Guide and Biomonitoring Reference Manual for the Willamette Valley.* 2005. Geared toward live identification; features photos of live specimens, including photos of organisms in ice cube trays for scale perspective. 38 pages. $20 from Patrick Edwards, Portland State University, 503-725-8303; psu22536@pdx.edu.

Hafele, Rick and Steve Hinton. *Guide to Pacific Northwest Aquatic Invertebrates, 2nd Edition.* 2003. Color photographs and descriptions of the 45 most common Pacific Northwest macroinvertebrates. 45 pages. $16.95 from Oregon Trout, www.ortrout.org/, info@ortrout.org, 503-222-9091 ext. 14.

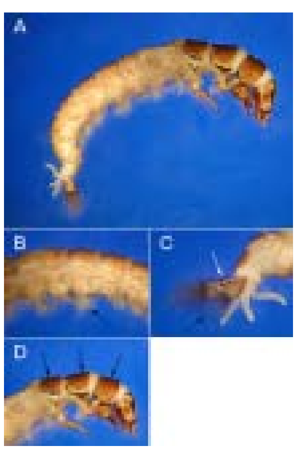
Digital field guides and keys

CD-ROM:

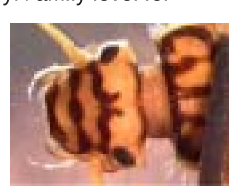
Adams, Jeff. *Stream Bugs as Biomonitors: A Guide to Pacific Northwest Macroinvertebrate Monitoring and Identification.* 2004. Covers nearly 500 organisms, most at genus or species level. Over 5,000 images (mostly color photos), detailed descriptions, even some mini-movies (to show characteristic movements). Also instructions on sample collection, data interpretation, and more. $8 from the Xerces Society; see www.xerces.org.

Websites:

Digital Key to Aquatic Insects of North Dakota. www.waterbugkey.vcsu.edu/. Very comprehensive. Family- and genus-level photo keys including many close-up photos of distinguishing features, plus detailed descriptions.



New York State DEC Key to Aquatic Macroinvertebrates. www.dec.state.ny.us/website/dow/stream/. Photo key. Family level for mayflies, stoneflies, caddisflies; order level for most others. Not much text.



Other Resources

Plant Recognition Guides

Two laminated fold-out guides from the University of Florida's Center for Aquatic and Invasive Plants help students and professionals identify plants in the field. One guide features freshwater plants of the Southeast and the other includes non-native and invasive plants. $11.95 each. See http://plants.ifas.ufl.edu or call 800-226-1764.

Volunteer Monitoring Listserv

EPA's volunteer monitoring listserv is a forum for announcements, questions, and discussion. To subscribe, send a blank message to volmonitor-subscribe@ lists.epa.gov.

Clean Water Act Manual, 2nd Edition

River Network's popular *The Clean Water Act: An Owner's Manual* is now available in an expanded and updated second edition. This indispensable guide helps citizens understand and use the Clean Water Act—the nation's most important legislation for protecting and restoring water quality. Water quality standards, designated uses, NPDES permits, impaired waters listing, TMDLs, and more are demystified with clear explanations and real-world examples of how citizens have used these provisions to protect their watersheds. 212 pages. $40 from River Network, www.rivernetwork.org/; or call 503-542-8387.

Coastal Restoration Monitoring

The National Oceanic and Atmospheric Administration's (NOAA) *Science-Based Restoration Monitoring of Coastal Habitats, Volume Two: Tools for Monitoring Coastal Habitats* is designed to help scientists, managers, and citizens plan and conduct restoration monitoring efforts in coastal habitats. For more information visit www.noaa.gov.

Videos

Benthic Macroinvertebrate Monitoring. New England Regional Monitoring Collaborative, 1999. Demonstrates collection, identification, and interpretation for both a simple streamside survey and an intensive assessment. (Based on approaches described in *Living Waters*—see above.) 24 min. $25 from Massachusetts Water Watch Partnership, 413-545-5531, mfwalk@tei.umass.edu.

Fresh Waters Flowing and *Biological Monitoring Protocol.* Cedar Films, 1998. Two videos based on the work of James Karr. The first discusses the rationale for biomonitoring and the second provides step-by-step instructions. $16 each from Adopt-A-Stream Foundation, www.streamkeeper.org/catalog, aasf.streamkeeper.org, 425-316-8592.

S.O.S. for America's Streams—A Guide to Water Quality Monitoring. Izaak Walton League of America, 1990. Demonstrates the IWLA method for macroinvertebrate monitoring. 28 min. $19.95. Order from McDonald & Woodward Publishing Co., 800-233-8787, mwpubco@mwpubco.com., www.mwpubco.com.

Professional-oriented resources

Barbour, Michael T. et al. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd Edition.* 1999. Guidance document from the U.S. Environmental Protection Agency that outlines various bioassessment approaches and protocols. Extensive bibliography; tolerance values for macroinvertebrates and fish. Not a field guide; no keys. 339 pages. Free from NSCEP, 800-490-9198, ncepimal@one.net (order # EPA 841-B-99-002), or download PDF from www.epa.gov/owow/monitoring/bioassess.html.

Merritt, Richard W. and Kenneth W. Cummins, eds. *An Introduction to the Aquatic Insects of North America, 3rd Edition*. 1996. Hundreds of detailed illustrations; comprehensive coverage of ecology and biomonitoring. Does not cover non-insect aquatic macroinvertebrates. 876 pages. $77.95 from Kendall/Hunt Publishing Co., www.kendallhunt.com, orders@kendallhunt.com, 800-228-0810.

Agency Macroinvertebrate Methods

a very mixed bag

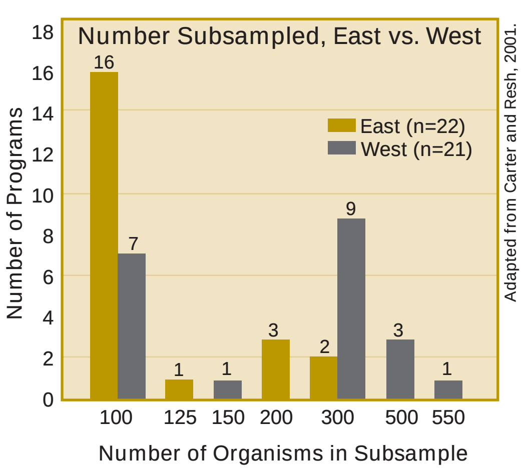
by Eleanor Ely

As evidenced by numerous examples in this newsletter, volunteer programs vary tremendously in their macroinvertebrate monitoring methods. But guess what—a recent nationwide survey of state agency biologists shows that the volunteers are not alone in this regard. Granted, the variability found among the state agency protocols was not quite as great as that among volunteer protocols—for example, all the survey respondents identified insects at least to family level, whereas some volunteer programs use order-level identification. Still, the collection, field processing, and laboratory processing protocols followed by state agencies were pretty much all over the map.

The survey was conducted by James Carter, an aquatic ecologist with the U.S. Geological Survey, and Vincent Resh, a professor of entomology at the University of California, Berkeley. The questionnaire they mailed out contained detailed questions on such topics as sampling device, compositing of samples, sorting and subsampling, and taxonomic level to which organisms are identified. Ninety responses were received from 48 states (states that followed more than one protocol filled out a separate questionnaire for each protocol). According to Carter, no previous study has examined the bioassessment methods used by state agencies at this level of detail.

Carter points out that some differences in protocol are to be expected, for reasons of both history (programs began at different times) and geography (methods used in one ecoregion may not be applicable in another). On the other hand, the monitoring community's current interest in data sharing and comparability makes it desirable to reduce at least some of the variability. Carter and Resh realized that obtaining comprehensive data on the different bioassessment methods currently in use was a necessary first step to assessing the comparability of these methods.

East of the Mississippi, most programs that sorted a subsample in the lab sorted 100 organisms, whereas west of the Mississippi the majority sorted 300 or more organisms.



Below are a few highlights of Carter and Resh's findings, based on their 2001 article in the *Journal of the North American Benthological Society*. (Note that the word "program" denotes a distinct protocol for which a separate survey questionnaire was completed. Thus, some states have more than one program.)

- *Net mesh size:* Mesh size varied from 350 to 1200 um, with 80.2% of programs (65/81) using a mesh size between 500 and 600 um.
- *Placement of sampling device:* In deciding where to place the sampling device (net, artificial substrate, etc.), 70.6% (60/85) used "expert opinion" and only 4.7% used a random technique.
- *Field sorting and processing:* 22.9% (19/83) sorted organisms from debris in the field. There was considerable variability in the number of organisms sorted. Just six programs subsampled in the field.
- *Subsampling in lab:* Of 72 programs that processed samples in the lab, 19 (26.3%) sorted all the organisms while the rest (73.6%) sorted a subsample. The number of organisms subsampled ranged from 100 to 550, with 100 being the most common.
- *Magnification:* The magnification used for sorting organisms in the lab ranged from none to 30X. About 1/5 of programs used no magnification.
- *Level of identification:* Many programs used different levels of identification for different groups of organisms—e.g., mollusks and oligochaetes (aquatic worms) were often identified at higher taxonomic levels than were insects. A survey question that asked, "If you were asked to what taxonomic level you typically identified macroinvertebrates—what would you respond?" elicited the following responses: family, 16.4%; genus, 41%; genus and species, 24.7%; species, 17.8%.

Trends and patterns

In comparing their survey results with earlier studies, Carter and Resh noted several trends. The area sampled has become larger and compositing (combining two or more discrete samples) has become more common. Perhaps as a result of these changes, which lead to larger samples, subsampling has also become more common.

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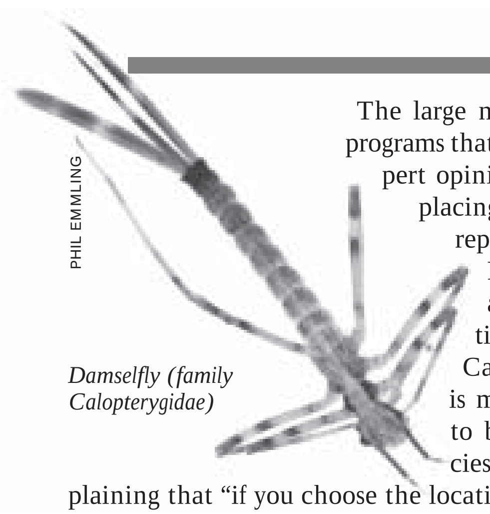

PHIL EMMLING

Damselfly (family Calopterygidae)

The large number of state agency programs that reported relying on expert opinion to choose spots for placing the sampling device represents, as Carter and Resh wrote, "certainly a departure from traditional random sampling." Carter says that this trend is motivated by the desire to best represent the species present at the site, explaining that "if you choose the locations randomly and only take a few small samples you can misrepresent the site. On the other hand, if you randomly take many different grabs and composite them, you can probably represent the site without using expert opinion."

States east of the Mississippi differed from those to the west in several respects. Kick-nets were more popular in the east, fixed-quadrat samplers (such as Surber or Hess) were used only in the west, and net mesh sizes were larger in the east.

Perhaps the most significant east/west difference from the perspective of volunteer monitoring groups was the difference in number of organisms sorted from the sample (see graph at left). Of programs that used a fixed-count method to subsample in the lab, east of the Mississippi the majority (72.7%) sorted 100 organisms. Only 9.1% of programs in the east sorted 300, and none sorted more than 300. In contrast, in states west of the Mississippi just one-third of programs sorted 100 organisms, while 42.9% sorted 300 and 19.1% sorted 500 or 550. The implication for volunteer monitoring programs is that volunteer groups in the west who want to emulate their state agency procedures will have to identify a lot more organisms than their counterparts in the east.

Do the differences matter?

How much do all these differences in protocol really affect the ability to detect changes in benthic macroinvertebrate community composition? Carter suspects that "only a few key procedures significantly influence the estimation of either an individual metric or a constructed biotic index." This is an area ripe for further investigation. Carter says that the effect of subsampling different numbers of organisms, in particular, has not been sufficiently addressed in the literature. He points out that the number subsampled affects different metrics differently, with percent composition metrics being little affected while measures based on the number of different taxa (i.e., richness) are very sensitive to the number of organisms in the sample. Carter and Resh's article proposes 12 questions (graduate students take notice!) that they consider particularly appropriate for future research.

For further information, contact James L. Carter, U.S. Geological Survey, 345 Middlefield Rd. MS465, Menlo Park, CA 94025; jcarter@usgs.gov; 650-329-4439.

Reference

Carter, James L. and Vincent H. Resh. 2001. After site selection and before data analysis: Sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. *Journal of the North American Benthological Society* 20(4):658-682. Reprints available from James Carter (see contact information above).

Photo page 22: Caddisfly (family Hydropsychidae) by Phil Emmling

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Stonefly (family Pteronarcyidae)

PANORAMIC VIEW, continued from page 8

protocols during the later 1990s, used almost the same words in describing their experience. Both initially expected that volunteers would love the taxonomic work, and indeed people were very excited during training, but ultimately most of the groups they trained could not maintain that level of effort. It was just too demanding. Some of the programs that moved away from the full-blown intensive biosurvey devised hybrid approaches like the ones described in the "Category 1-1/2" section above, while others started sending their samples to professionals for identification.

Data uses

How do the different macroinvertebrate monitoring approaches, especially the different levels of identification, relate to data use? Rigorous protocols that include preservation of specimens and identification to lower taxonomic levels are usually required in order for the data to be used by state natural resources agencies in carrying out Clean Water Act-mandated activities like setting water quality standards, placing water bodies on the 303(d) list, and developing TMDLs for water bodies on the 303(d) list. Since these activities are subject to close scrutiny and legal challenges, naturally agencies want to make sure they can back up their decisions with scientifically defensible data. Having samples identified by professional taxonomists is probably the best bet for volunteer groups that want their data used in these ways.

However, state agency use is hardly the be-all and end-all for volunteer monitoring data. Most volunteer programs are more focused on local uses of the data, of which there are many. Often volunteers collect data on small streams that no one else is monitoring. Just having this baseline data can be very useful in case, for example, the water quality declines or a large development is proposed in the watershed.

Some situations don't require the most rigorous methods. WV SOS program coordinator Tim Craddock points out that some West Virginia volunteers do macroinvertebrate monitoring at acid mine drainage remediation sites, where it doesn't take a high level of sophistication to determine whether the stream is still essentially dead or is coming back to life. Even streamside surveys, especially those that include refinements like counting the organisms and using regional pollution-sensitivity ratings, can be very effective in identifying high-quality and degraded sites.

Volunteer macroinvertebrate monitoring is often used in conjunction with local restoration projects, for everything from prioritizing sites to supporting funding applications to assessing the results after projects are completed. Several Pennsylvania citizen groups have used volunteer-collected macroinvertebrate data to support petitions for state redesignation of streams as "High Quality" or "Exceptional Value."

Local jurisdictions and watershed associations frequently use volunteer monitoring data, including macroinvertebrate data, in watershed planning and for local regulations. In Minnesota, several cities have used WHEP wetland bioassessment data for establishing ordinances related to wetland buffer widths and use of pesticides.

Citizen macroinvertebrate monitoring also offers countless opportunities for community education. The results can be publicized through local media and used in outreach materials like the watershed "report card" that a Maryland County created, based in part on Maryland Stream Waders macroinvertebrate data.

Finally, as noted at the beginning of this article, there's nothing quite like a close acquaintance with a stream's living inhabitants for turning citizens into advocates for water quality protection.

Special thanks to James Carter for assistance with this article.