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BRIDGES

BRIDGES is a recurring feature of J-NABS intended to provide a forum for the interchange of ideas and information between basic and applied researchers in benthic science. Articles in this series will focus on topical research areas and linkages between basic and applied aspects of research, monitoring policy, and education. Readers with ideas for topics should contact Associate Editors Nick Aumen and Marty Gurtz.

Citizen monitoring groups are an important source of data needed to assess the status of streams and rivers. Scientists and other resource management professionals are striving to increase the involvement of citizens, and to improve the quality of the data they collect. In this article, Nerbonne and Vondracek address the ability of volunteers to correctly sort and identify benthic macroinvertebrates. The authors demonstrate the effects that macroinvertebrate size and motility have on the results of volunteer efforts, and relate these results to the use of 2 different taxonomic keys available from volunteer monitoring programs. Specific recommendations are made to improve volunteer monitoring programs.

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Volunteer macroinvertebrate monitoring: assessing training needs through examining error and bias in untrained volunteers

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Public awareness of water pollution has been increasing in the United States since the 1960s. Popular philosopher John Passmore (1974) encouraged the public to reconsider traditional relationships among neighbors and recognize that protecting a common water supply is a prerequisite for respecting the rights of people to have a safe and clean environment. Since the US Federal Water Pollution Control Act of 1965, citizen awareness of water quality has grown steadily. Lathrop and Markowitz (1995) reported that, in 1995, 45 states and the District of Columbia had active citizen monitoring groups, 65% of which were formed since 1988.

During the 1990s, volunteer monitoring increased steadily. From single individuals to nationally organized networks, volunteer monitoring groups have been engaged in monitoring macroinvertebrate communities for over a decade (Lathrop and Markowitz 1995, Penrose and Call 1995, Levy 1998). Articles with titles such as ''Using bugs to bust polluters'' (Levy 1998), or ''Wanted, preferably alive'' (Beauchene 1997) encourage the lay person to pick up a net and become part of a citizen monitoring movement. The US Environmental Protection Agency (USEPA) reported that, in 1998, 76% of the volunteer monitoring groups active in streams were using benthic macroinvertebrate monitoring (USEPA 1998). Every 2 y, individual states are required to report on the quality of their water resources in the national water-quality inventory, or 305(b) report, to the US Congress. In fact, by 1995, >1/2 of the state regulatory agencies were using some form of volunteer data in their 305(b) reports (Penrose and Call 1995).

One of the first nationally recognized programs to encourage macroinvertebrate monitoring for volunteers was developed through the Izaak Walton League of America during the late 1970s. This program, called Save Our Streams

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(SOS), instructs volunteers to identify organisms to order (Firehock 1994). SOS has attempted to keep the collection and identification process simple, often focusing more on education and awareness than on quality control. Since SOS was founded, it has provided guidance for volunteer programs across the US (Stoeckel 1996).

During the 1990s, a number of programs have adopted more rigorous volunteer monitoring protocols (Beauchene and Wahle 1996, Stoeckel 1996). Hoping to produce citizen data that are comparable to professional data, the River Watch Network was one of the first national organizations to develop a family-level protocol for volunteers. More recently, the USEPA released a similar protocol in their Volunteer Stream Monitoring Methods Manual (USEPA 1997). Many programs across the country have been built using modified versions of these protocols. Is the growing popularity of volunteer macroinvertebrate monitoring helping communities to gain a better understanding of pollution in their watersheds? Some professionals are uncomfortable with putting too much faith in volunteer data (Penrose and Call 1995). Are these professionals justified? Many established and well-funded groups are aware that accurate and useful biological monitoring programs are accompanied by extensive training, but much of the rhetoric tells a different story: ''It's simple, integrative, and fun. Why not give it a try?''

Volunteer monitoring can yield useful results given the right circumstances. Engel and Voshell (2002) conducted a 2-y study in which they assessed the Virginia Save Our Streams Protocol. Initial testing revealed that volunteer results consistently overrated ecological conditions, were not significantly correlated with professional results, and did not accurately reflect the condition of a stream. Engel and Voshell (2002) then modified the volunteer metric that relied only on taxa presence, and developed a new multimetric, order-level index that was significantly correlated with professional results. In a similar study, State of Washington researchers showed that trained volunteers who were identifying organisms to family were able to assess water quality as effectively as professional resource managers (Fore et al. 2001).

In our study, we focus on the ability of beginner volunteers to perform the necessary tasks of sorting and identifying macroinvertebrates. First, we explore the ability of volunteers to sort a random subsample of organisms out of debris by comparing volunteer sorting to professional sorting. We examine the relative size and movement of organisms in volunteer vs professional samples to understand the possible source of volunteer bias. Second, we examine the types of volunteer error associated with organism identification using a SOS card and the Minnesota version of the River Watch identification key (Beauchene and Montz 1998).

Methods

We conducted workshops and class sessions in which untrained volunteers participated in macroinvertebrate monitoring between summer 1997 and spring 1998. During the summer, we conducted two 3-h workshops with watershed groups. During the autumn and spring, we ran 14 high school class sessions (6 classes in the autumn, 8 classes in the spring). All volunteers who participated in this study received a 30-min orientation course in which they were introduced to the basic justification for using macroinvertebrates as indicators of stream water quality. At these sessions, we distributed and read aloud portions of the USEPA volunteer monitoring methods (USEPA 1997).

Organism collection

We evaluated the ability of volunteers to sort and identify macroinvertebrates collected from a stream during summer, autumn, and spring sessions. During the summer workshops, we split volunteers into groups and assigned a trained leader to each group. Volunteers collected kick samples at preselected riffles using the instructions outlined in the USEPA Volunteer Methods Manual (USEPA 1997), and available on the web at http://www.epa.gov/owow/monitoring/volunteer/stream/. Sites had been preselected to ensure abundance and diversity of organisms in the samples. To reduce sampling bias, the leader supervised all collections, and then transferred collections to buckets and into sorting trays. During autumn and spring, 5 students under researcher supervision conducted the streamside sampling according to the USEPA volunteer monitoring protocol. Sorting, preserving, and identification took place in the classroom during high school class sessions.

Sorting error and bias

In autumn 1997, we examined the ability of volunteers to sort a random subsample of macroinvertebrates out of debris by comparing volunteer sorting to professional sorting in relation to the length and movement of organisms. Students sorted 2 types of samples 1–3 h after collection: 1/2 of the samples were preserved in alcohol and 1/2 of the samples were stored in water. Students followed the protocol outlined in the USEPA volunteer manual. We provided students with magnifying glasses, pans with grids, and forceps, and instructed them to sort a 100-organism subsample from the debris by selecting all organisms from a series of randomly selected grid squares. After sorting, students placed the selected subsamples in 75% ethanol, and preserved and labeled the remaining debris. We subsequently identified student subsamples to the lowest taxonomic level possible and then returned the contents of each vial to the sampling bag to restore each sample to its original postcollection state. We then resorted each sample and identified the organisms to the lowest possible taxonomic level.

We assessed differences in composition in each sample for each organism by determining the difference in proportions between professional- and volunteer-sorted samples:

$$\text{Difference in proportion X} = \%\text{ of X in professional sample} - \%\text{ of X in volunteer sample.}$$

Length.—Some organisms were not frequently represented, so we conducted a length-bias analysis using only the 5 most abundant taxa. These 5 taxa comprised 79% of the pooled professional samples. We estimated mean length in millimeters for the specimens at each site using additional specimens collected during the same sampling events to develop length classes for these 5 taxa (Table 1). We assessed the difference in proportion among length classes using a Kruskal–Wallis test and compared the means using Tukey's Honest Significance Difference test (Statistix 4.1/1994, Analytical Software, Tallahassee, Florida).

Movement.—We categorized all organisms into 3 groups according to level of movement: fast moving (1), slow but visibly moving (2), or no visible movement (3). We used a Wilcoxon signed ranks test to compare the difference in proportion between alcohol (no movement) versus water (movement) for the 5 most abundant taxa (Statistix 4.1/1994). Only 2 of the 3 movement classes were represented in the 5 most abundant taxa, so we did a Kruskal–Wallis test using the whole water sample (Statistix 4.1/1994).

TABLE 1. Approximate mean length of each taxon, the associated length class, and movement class of the 5 most abundant organisms. Movement classes: fast moving (1), slow but visibly moving (2), or no visible movement (3). All taxa are larvae.

Taxa	Approximate length (mm)	Length class	Movement class
Chironomidae	4	1	1
Elmidae	6	2	1
Baetidae	9	2	1
Brachycentridae	10	3	2
Hydropsychidae	12	3	2

Order-level identification

We evaluated volunteer error associated with macroinvertebrate identification to order using a SOS picture card (Fig. 1) at the summer field days and high school classes in autumn 1997. We gave each volunteer 8 vials labeled as follows: caddisflies, stoneflies, mayflies, true flies, sowbugs/scuds, beetles, dobsonflies/fishflies, and other. Each vial also listed the corresponding number(s) on the SOS card. Volunteers were offered the use of magnifying glasses, but their use was not required.

Volunteers placed organisms in the prelabeled vials upon identification. Volunteers worked separately; however, some communication between individuals occurred, as would be expected during a volunteer monitoring event. When the event was finished, we transported organisms to the laboratory and reidentified them to determine volunteer accuracy.

To evaluate order-level identification, we checked each volunteer's classification and tallied their answers in a matrix corresponding to the identification they had provided. We recorded each taxon only once, regardless of how many individuals the volunteer placed in the vial, and calculated the % of volunteers with a correct identification for each taxon represented.

The SOS card only has room to display 1 to 3 families representative of each order, so we classified each family as either present or absent on the card. We used a Fisher exact test to assess whether there was a direct relationship between 1) length class (see sorting analysis), and 2) presence on card in relation to volunteer success (S Plus/Unix, Insightful, Seattle, Washington).

Family-level identification

We evaluated family-level identification in spring 1998. We led 4 high school classes in which 83 students identified organisms to family using the Minnesota River Watch key, a dichotomous key prepared by project SEARCH in Connecticut, and modified for use in Minnesota by the Minnesota Department of Natural Resources (Beauchene and Montz 1998). We set up 14 stations at which individual taxa were displayed. Microscopes were provided at stations when the length of organism was <2 cm. We gave students all the time they needed at each station to record the order of couplets (steps) in which they progressed through the key. Students were not necessarily expected to visit all 14 stations.

We transcribed each student's success at each step in the key, for each station, to a 4-column database (student, step, station, response) to determine whether, for each organism, there were some systematic combinations of steps in which students made identification errors. We recorded the % of students successfully identifying the organism and the failure rate at each step in the process. We analyzed the results using a post-processing procedure on the database (G. Oehlert. 1999). Post-processing procedure designed for MACANOVA, Department of Applied Statistics, University of Minnesota, Minneapolis, Minnesota) in which combinations of steps and stations that did not occur were removed from the data set. We ran a logistic regression for multiple models, and selected the best model using backwards elimination (Weisberg 1985). We defined problem steps in the key as steps at which >10% and >20% of the students who attempted that station failed to advance to the next step. We performed all statistical analysis for this procedure using MACANOVA (C. Bingham and G. Oehlert 1998). MACANOVA, Department of Applied Statistics, University of Minnesota, Minneapolis, Minnesota). We used p-values of 0.05 throughout our study for significance, although movement classes were further investigated at the 0.1 significance level to see if meaningful trends were suggested.

Results

Sorting error and bias

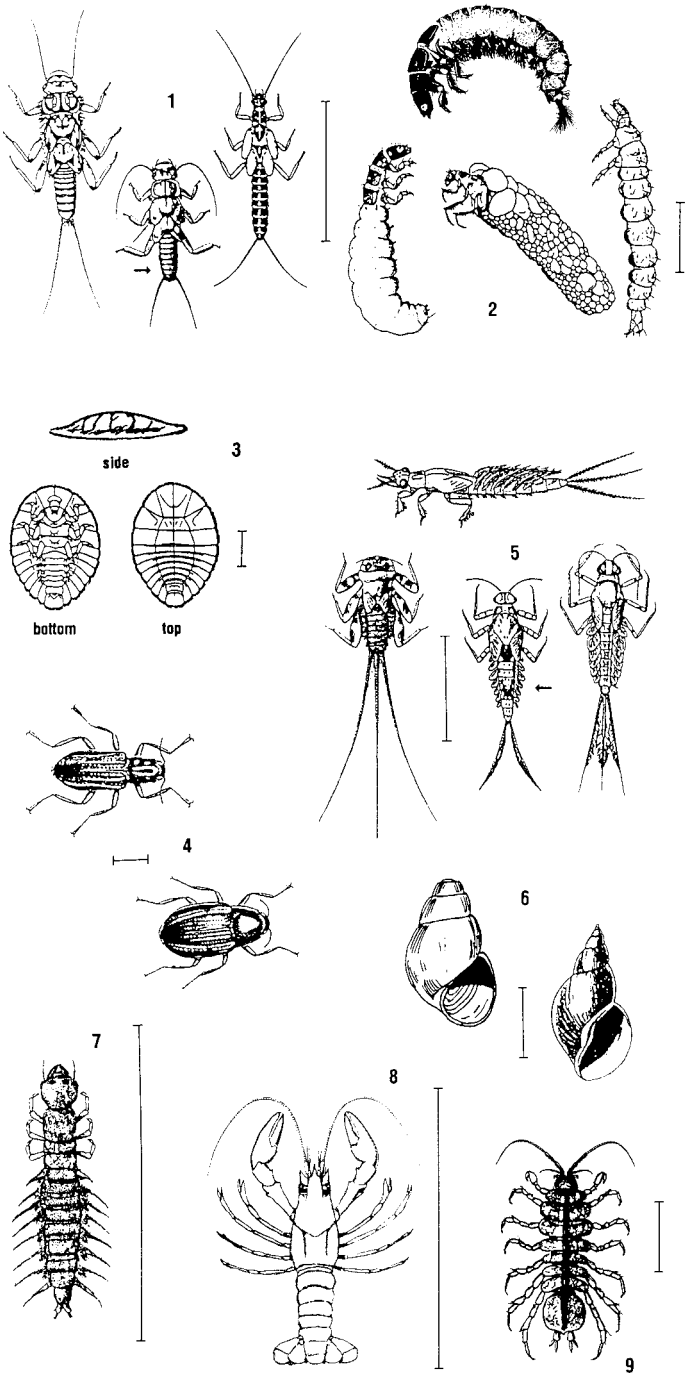
Length-class 3 organisms (Brachycentridae and Hydropsychidae) were more likely to be selected than organisms in either length-class 1 or length-class 2 (Chironomidae, Elmidae, and Baetidae) (Kruskal–Wallis test, $p < 0.001$; Table 2, Fig. 2). Only movement-classes 1 and 2 were represented in the 5 most abundant taxa, so we calculated mean difference in proportion for 3 movement classes made up of all organisms sorted from water (Table 3). There was a significant difference in selection of movement classes (Kruskal–Wallis test, $p = 0.05$), but there was no pairwise difference between classes ($p > 0.05$). At $p < 0.1$, movement-class 3 organisms (not visibly moving) were selected significantly less by volunteers than movement-class 2 organisms (slow but visibly moving) (Kruskal–Wallis test). There was no significant difference between the samples picked from water versus those from alcohol (Wilcoxon test, $p = 0.94$).

Order-level identification

The likelihood of correct identification was 1.8 times greater if the family was present on the SOS card (Fig. 1) than if it was not, and the likelihood of correct identification was 2.5 times higher if the organism was large rather than small (Table 4). For example, volunteers were relatively successful at identifying Elmidae adults, which are shown on the SOS card, but not Elmidae larvae, which are not shown. Volunteers were not successful identifying Perlodidae, which are very small, but were successful with larger organisms such as Brachycentridae and Tipulidae (Table 4).

Family-level identification

Mean success rate for identifying organisms using the family-level key was 29.6%. Only Gammaridae and Elimid larvae were successfully identified >50% of the time (Table 5). Two of the 14 taxa, Baetidae and Brachycentridae,



Stream Insects & Crustaceans

GROUP ONE TAXA

Pollution sensititve organisms found in good quality water.

1 ***Stonefly: Order Plecoptera.*** 1/2" - 1 1/2", 6 legs with hooked tips, antennae, 2 hair-like tails. Smooth (no gills) on lower half of body. (See arrow.)

2 ***Caddisfly: Order Trichoptera.*** Up to 1", 6 hooked legs on upper third of body, 2 hooks at back end. May be in a stick, rock or leaf case with its head sticking out. May have fluffy gill tufts on underside.

3 ***Water Penny: Order Coleoptera.*** 1/4", flat saucer-shaped body with a raised bump on one side and 6 tiny legs and fluffy gills on the other side. Immature beetle.

4 ***Riffle Beetle: Order Coleoptera.*** 1/4", oval body covered with tiny hairs, 6 legs, antennae. Walks slowly underwater. Does not swim on surface.

5 ***Mayfly: Order Ephemeroptera.*** 1/4" - 1", brown, moving, plate-like or feathery gills on sides of lower body (see arrow), 6 large hooked legs, antennae, 2 or 3 long, hair-like tails. Tails may be webbed together.

6 ***Gilled Snail: Class Gastropoda.*** Shell opening covered by thin plate called operculum. When opening is facing you, shell usually opens on right.

7 ***Dobsonfly (Hellgrammite): Family Corydalidae.*** 3/4" - 4", dark-colored, 6 legs, large pinching jaws, eight pairs feelers on lower half of body with paired cotton-like gill tufts along underside, short antennae, 2 tails and 2 pairs of hooks at back end.

GROUP TWO TAXA

Somewhat pollution tolerant organisms can be in good or fair quality water.

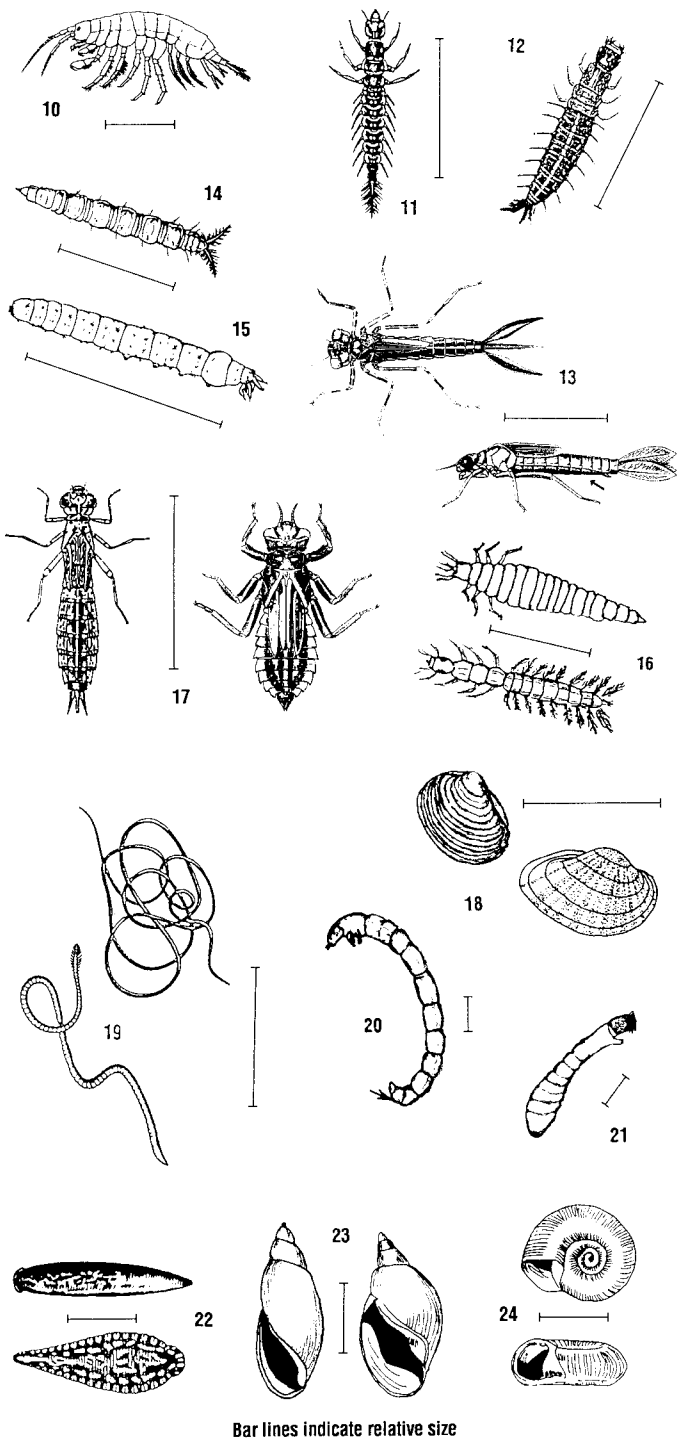
8 ***Crayfish: Order Decapoda.*** Up to 6", 2 large claws, 8 legs, resembles small lobster.

9 ***Sowbug: Order Isopoda.*** 1/4" - 3/4", gray oblong body wider than it is high, more than 6 legs, long antennae.

Save Our Streams

Izaak Walton League of America
707 Conservation Lane
Gaithersburg, MD 20878-2983
1(800)BUG-IWLA

FIG. 1. Save Our Streams organism card. (Reprinted by permission of the Izaak Walton League of America, Gaithersburg, Maryland.)



GROUP TWO TAXA CONTINUED

10 ***Scud: Order Amphipoda.*** 1/4", white to grey, body higher than it is wide, swims sideways, more than 6 legs, resembles small shrimp.

11 ***Alderfly Larva: Family Sialidae.*** 1" long. Looks like small hellgrammite but has 1 long, thin, branched tail at back end (no hooks). No gill tufts underneath.

12 ***Fishfly Larva: Family Corydalidae.*** Up to 1 1/2" long. Looks like small hellgrammite but often a lighter reddish-tan color, or with yellowish streaks. No gill tufts underneath.

13 ***Damselfly: Suborder Zygoptera.*** 1/2" - 1", large eyes, 6 thin hooked legs, 3 broad oar-shaped tails, positioned like a tripod. Smooth (no gills) on sides of lower half of body. (See arrow.)

14 ***Watersnipe Fly Larva: Family Athericidae (Atherix).*** 1/4" - 1", pale to green, tapered body, many caterpillar-like legs, conical head, feathery "horns" at back end.

15 ***Crane Fly: Suborder Nematocera.*** 1/3" - 2", milky, green, or light brown, plump caterpillar-like segmented body, 4 finger-like lobes at back end.

16 ***Beetle Larva: Order Coleoptera.*** 1/4" - 1", light-colored, 6 legs on upper half of body, feelers, antennae.

17 ***Dragon Fly: Suborder Anisoptera.*** 1/2" - 2", large eyes, 6 hooked legs. Wide oval to round abdomen.

18 ***Clam: Class Bivalvia.***

GROUP THREE TAXA

Pollution tolerant organisms can be in any quality of water.

19 ***Aquatic Worm: Class Oligochaeta.*** 1/4" - 2", can be very tiny, thin worm-like body.

20 ***Midge Fly Larva: Suborder Nematocera.*** Up to 1/4", dark head, worm-like segmented body, 2 tiny legs on each side.

21 ***Blackfly Larva: Family Simulidae.*** Up 1/4", one end of body wider. Black head, suction pad on other end.

22 ***Leech: Order Hirudinea.*** 1/4" - 2", brown, slimy body, ends with suction pads.

23 ***Pouch Snail and Pond Snails: Class Gastropoda.*** No operculum. Breathe air. When opening is facing you, shell usually opens on left.

24 ***Other Snails: Class Gastropoda.*** No operculum. Breathe air. Snail shell coils in one plane.

FIG. 1. Continued.

TABLE 2. Mean difference in proportion between professional- and volunteer-sorted samples vs length class for the 5 most abundant taxa. A positive difference in proportion indicates that volunteers sorted proportionally less of that taxa than professionals. Means with different letters indicate a significant difference ($p < 0.05$) in length class. Length classes are defined in Table 1.

Length class	Mean difference in proportion (SD)	*n*
1	0.107 (0.074)[a]	17
2	0.080 (0.121)[a]	34
3	−0.149 (0.176)[b]	34

were never correctly identified. There was no correlation between the number of steps and the % of students who correctly identified the organisms (logistic regression). Steps at which volunteers failed 10 to 20% and >20% of the time are listed in Table 6. When asked if the organism had a ''visible head and segmented legs'', 28% of the students failed to see the legs of the Bracycentridae, and 25% thought that there were legs on an Athericidae; 70% of the students failed to identify segments on a relatively small Hirudinea (10 mm); and 35% of students believed that Chironomidae had ''suction discs on both ends''. When asked if the organism had a ''visible head'', 30% of the volunteers failed to see a head on Athericidae, 42% failed to see it on a Tipulidae (*Antocha*), and 39% on a Tipulidae (*Tipula*). Students had trouble seeing distinct legs on smaller organisms such as the Ephemerellidae (6 mm), so 23% of the volunteers wrongly selected Ephemerellidae as an organism that had ''more than 3 pairs of segmented legs and 2 pairs of antennae''. When asked to positively identify a labium, or a ''large structure covering its mouth'', 23% saw such a structure on an Elmidae adult, 21% on a Hydropsychidae, and 20% on a Perlodidae. Last, students had trouble understanding the difference between the thorax and the abdomen, as illustrated by the fact that 50% of students identified ''2 distinct spine-like appendages on each

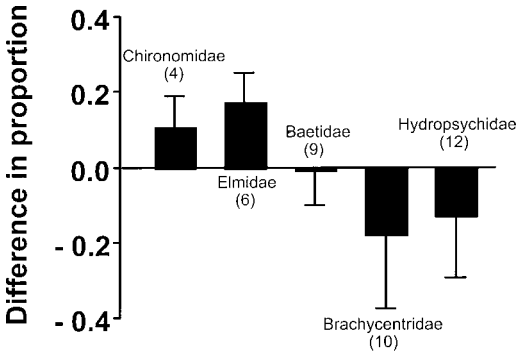


FIG. 2. Taxa (mean length in mm) vs average difference in proportion between professional and volunteer samples. A negative difference in proportion indicates that volunteers picked a higher proportion of that taxon than professionals. Error bars = + or −1 SD. All taxa are larvae.

TABLE 3. Mean difference in proportion between professional- and volunteer-sorted samples vs movement class for all organisms sorted from water. Means with different letters indicate a significant difference ($p < 0.1$) in movement class. Movement classes are defined in Table 1.

Movement class	Mean difference in proportion (SD)	*n*
1	−0.015 (0.085)[a,b]	60
2	0.022 (0.077)[a]	50
3	0.034 (0.154)[b]	60

TABLE 4. Percentage of correct order-level identifications, represented on the Save Our Streams picture card, and length class. Y = yes, N = no. Length classes are defined in Table 1, except for 4, which is >14 mm. All taxa of insects are larvae, unless otherwise noted.

Taxa	% correct	On card?	Length class
Baetidae	40	Y	2
Emphemerellidae	20	Y	2
Perlodidae	0	N	1
Hydropsychidae	50	Y	3
Brachycentridae	83	N	3
Chironomidae	34	Y	1
Athericidae	57	Y	3
Tipulidae	73	Y	4
Elmidae	15	N	2
Elmidae adults	94	Y	2
Gammarus	95	Y	3
Physidae	100	Y	4
Sphaeriidae	100	Y	4
Oligochaeta	86	Y	2
Hirudinea	92	Y	3

TABLE 5. Identification success using the Minnesota River Watch family-level key, and number of steps to correctly identify organisms. All taxa of insects are larvae, unless otherwise noted.

Family	Success rate (% correct)	Number of steps
Tipulidae (*Tipula*)	14	8
Tipulidae (*Antocha*)	26	8
Chironomidae	29	7
Hydropsychidae	46	9
Gammaridae	75	5
Elmidae	69	13
Elmidae adults	48	14
Pteronarycidae	43	9
Brachycentridae	0	16
Baetidae	0	16
Athericidae	21	8
Aphemerellidae	6	14
Perlodidae	17	10
Hirudinea	20	4

section of the abdomen'' in Baetidae and 24% saw it in a Pteronarycidae.

Discussion

Many proponents of volunteer monitoring have noted that the education of citizens about water quality is the most important outcome of these programs. We recognize the power of involvement and the profound need to foster awareness of environmental quality among citizens, but we did not design this study to evaluate these benefits. Instead, we examined the potential for these programs to supply useful and accurate information using data processed by untrained volunteers. Our study showed that untrained volunteers were biased in sorting organisms from debris, and were unable to correctly identify most organisms in a sample. Our data lead us to make a number of recommendations.

Sorting

Beginner volunteers randomly sorted organisms from debris in a biased fashion. Because our results showed that volunteers were more likely to select larger organisms than smaller organisms, we recommend that program organizers and trainers stress the importance of both lighting and magnification of a sample. When sorting live specimens, volunteers were biased towards organisms that moved but were not fast enough to prevent capture. For example, volunteers might be apt to select a slow, but obviously moving, Brachycentridae before a fast-moving Gammaridae. Stopping organism movement through preserving them in alcohol (or possibly slowing them down using CO_2) might help to alleviate this problem.

In some volunteer programs, coordinators only ask citizens to collect and sort the samples. Coordinators then send the sorted samples to a professional laboratory for identification. These programs have great potential for generating accurate data only if they are able to teach volunteers to overcome sorting bias. Having volunteers work in teams so that they can check the quality of each other's samples can provide an important safeguard against such biases.

Identification

Beginner volunteers had trouble identifying organisms both to order, using a SOS card, and to family, using the Minnesota River Watch key. The SOS card provides volunteers with a limited number of drawings to examine when classifying organisms, which posed a problem when a family that a volunteer was attempting to identify was not represented. Volunteers were 1.8 times more likely to succeed if the family they were identifying was depicted on the card than if it was not. For example, Elmidae larvae are not represented on the SOS card among the ''beetle larvae.'' In this case, volunteers were more likely to place Elmidae with caddisflies than with beetles. Large size also positively affected the order-level identification success rate of volunteers.

In addition, certain steps on the family-level key, such as the step that asks volunteers to identify the presence or absence of a labium on an Odonata, were difficult for those who have never seen such a structure. Creating a program that trains volunteers in the nuances of insect morphology will help them to avoid common errors such as this one. (Other suggestions appear in *Training volunteers to use the family-level key,* below.)

Modifying the order-level card.—The SOS card is only one of many order-level identification cards that have been created for volunteers in the United States. Many states use the basic ap-

TABLE 6. Selected questions on the key where students had either a <10% failure rate, 10 to 20% failure rate, or >20% failure rate. All taxa of insects are larvae, unless otherwise noted.

Question on key: Does the organism have . . . Or Is the organism . . .	Number of stations that used this step	Organisms in which <10% of the students failed because of this step	Organisms in which 10%–20% of the students failed because of this step	Organisms in which ≥20% or more of the students failed because of this step
both a visible head and segmented legs?	14	Baetidae Elmidae Ephemerellidae Gammaridae Hirudinea Hydropsychidae Perlodidae Pteronarycidae	Chironomidae Tipulidae (*Antocha*)	Athericidae Brachycentridae
divided into segments?	5	Athericidae Chironomidae Tipulidae (*Antocha*) Tipulidae (*Tipula*)		Hirudinea
a suction disc at both ends?	5	Athericidae Tipulidae (*Antocha*) Tipulidae (*Tipula*) Hirudinea		Chironomidae
a visible head?	4		Chironomidae	Athericidae Tipulidae (*Antocha*) Tipulidae (*Tipula*)
more than 3 pairs of segmented legs and 2 pairs of antennae?	9	Baetidae Elmidae adults Elmidae Gammaridae Hydropsychidae	Brachycentridae Perlodidae Pteronarycidae	Ephemerellidae
a large structure covering its mouth?	8	Baetidae Elmidae	Brachycentridae Ephemerellidae Pteronarycidae	Elmidae adults Hydropsychidae Perlodidae
2 distinct spine-like appendages on each section of the abdomen, following the 3 pairs of legs?	8	Brachycentridae Elmidae adults Elmidae Ephemerellidae Hydropsychidae Perlodidae		Baetide Pteronarycidae

proach offered by SOS, but they have also developed their own identification tools (e.g., see the card created by IOWATER, a cooperative effort for volunteer water-quality monitoring in Iowa: http://www.iowater.net/benthickey.htm).

The SOS card only has space to represent a maximum of 3 different drawings for each order (Fig. 1). The problem of misidentifying organisms not on the SOS card could be remedied if program leaders created a watershed-specific card that describes the life history and approximate emergence dates of known species in the watershed. We subsequently provided a 5-page document with drawings and descriptions of the life history of common benthic organisms to one citizen group that we worked with, and this tool reduced their confusion about organisms present on the SOS card but not found in their watershed. This approach also afforded an opportunity for the group to consider whether the nationally published tolerance values were appropriate in their region. Professional biologists have been encouraged by Karr and Chu (1999) to create metrics specific to ecoregions (sensu Omernik 1995), an approach that should not be ignored in volunteer programs. The North American Benthological Society (NABS) might be well suited to offer a web-based picture library of invertebrates to aid program leaders in creating watershed-specific cards with ecoregion-specific tolerance values.

Training volunteers to use the family-level key.—Our study found systematic errors made during the application of the Minnesota River Watch key. This key is only one of a variety of different ones available to help identify organisms to order (e.g., http://www.people.virginia.edu/~sos-iwla; http://osf1.gmu.edu/~avia/page1.htm) or to family (http://www.dec.state.ny.us/website/dow/stream/). Table 6 indicates some specific steps from the Minnesota River Watch key at which students had limited success, and can help to focus the attention of trainers on general problems that can arise when untrained volunteers use a variety of different keys. Our study showed that >20% of students failed to correctly identify a head on Tipulidae and Athericidae larvae. This situation could be remedied by either replacing this characteristic with others, or by including some explanation of what a head looks like in these common organisms. A guide for trainers could be included with volunteer keys, pointing out common errors and suggesting some simple demonstrations that might help volunteers avoid common pitfalls. For example, a set of overheads or slides, provided through the NABS web site, could illustrate differences between organisms that go through complete and incomplete metamorphosis. These visual aids could clarify different body parts for each taxon. A trainer might also take this opportunity to point out specific features such as prolegs, and help volunteers distinguish prolegs from gills on the abdomen, and from real legs on the thorax. The State of New York Department of Natural Resources now has a picture key of macroinvertebrate families (http://dnr.state.il.us/orep/inrin/ecowatch/RIVER/NewKeyWeb_.pdf). Such keys could help volunteers check their answers and/or provide real photographs to aid in taxa recognition.

Attracting committed and cooperative volunteers

Volunteer program leaders should focus on attracting individuals who are interested and willing to do the monitoring. During summer field days, for example, we observed that not every member of the watershed partnerships we worked with was really committed to staying for a 3-h event. Because they wanted to be helpful, they hurried through the process. Likewise, high school students can provide a guaranteed work force, but one should not count on every student putting in sufficient effort. Students who are excited about the opportunity to participate should be targeted and rewarded for their interest, whereas other less-interested individuals should be encouraged to do other jobs so they do not detract from the monitoring tasks.

Volunteers should be encouraged to check the quality of each other's results. Errors might be minimized if students or volunteers reviewed another person's pan to verify that all organisms have been sorted, or if several volunteers independently identify an organism. Little Falls Aqua-Tech founder, and former teacher from Little Falls, Minnesota, Wayne Pikal, set up a successful program using this approach. He always relies on teams of individuals to complete each step of the protocol.

Training

Our project evaluated the performance of untrained beginner volunteers. It is critical that

these data be evaluated in context and not be used to characterize all volunteer efforts. Successful programs are emerging to train volunteers around the United States. For example, project SEARCH, in Connecticut, requires participating teachers to receive 144 h of training before their results can be incorporated into state and national databases. Teachers felt that the high-quality training and onsite field assistance was crucial to their success (Beauchene and Wahle 1996).

In Minnesota, the Hennepin Conservation District macroinvertebrate monitoring program has established a slightly less demanding, but nevertheless still rigorous, training program for teachers participating in a county-wide program. A 6-h training session is conducted twice yearly, and teachers are encouraged to attend, regardless of their skill level. The program is set up to be realistic, and advises program leaders to be sensitive to a participant's learning curve; thus, program staff check all samples for the quality of identifications (Fortin 1996). Other programs throughout Minnesota have begun to follow this model. Because training takes time and money, program coordinators should budget for this investment. Likewise, volunteers must have a real desire and commitment to learn the skills that make extensive training worth the effort.

Choosing the appropriate goals

Macroinvertebrate monitoring is difficult for volunteers. It is therefore critical that the goals and objectives of individual groups are assessed when choosing an appropriate protocol. The USEPA volunteer monitoring protocol provides 3 levels of sampling for groups with a variety of interests (USEPA 1997). Other organizations, such as the Volunteer Stream Monitoring Partnership in Minnesota, encourage volunteers to consider both the level of investment and the monitoring objective of a particular group, and provide a matrix that identifies a range of different goal-appropriate activities for a group (Volunteer Stream Monitoring Partnership 2002). It may be helpful for citizen groups to seek help when developing goals. Hiring a graduate student, or contacting a natural-resource professional to do an initial inventory in particular streams, can be invaluable. This inventory can be used for training purposes, to create a voucher collection, or to create an identification card that is watershed specific.

Final thoughts

It is critical to remember that the benefits of macroinvertebrate monitoring go far beyond collecting accurate data. The SOS program does not try to market their protocol to groups interested in regulatory quality data. Instead, they advocate macroinvertebrate monitoring as an educational experience (Firehock and West 1995). Many volunteer leaders agree that the most important outcome of volunteer monitoring is that the public has an opportunity to glimpse the lives of aquatic insects. In the course of taking >200 people out to streams, we have repeatedly observed this enthusiasm.

Although education may be the most valuable product of these efforts, we are hesitant to rely solely on generating awareness and enthusiasm. Accurate assessment is part of the stated goal of most programs, so generating protocols designed to enhance only awareness, rather than accurate data, undermines the potential for citizens to make a contribution to better understanding local pollution problems. Few volunteers will continue to provide their time on the basis of receiving an education. Rather, we believe that high-quality results are the foundation of lasting programs.

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