High School Student Success in Perennial Stream Classification

Mike K. Meyer[1] and Ryan J. Albert[2]

[1]Herndon High School, 700 Bennett Street Herndon Virginia, 20170
[2]George Mason University, 4400 University Dr. MSN 5F2, Fairfax Virginia 22030-4444

Biographical Sketches of Authors

Mike Meyer received his master's degree from Indiana University-Bloomington in Science Education. His field experience includes surveying Great Grays and Spotted owls in Oregon, surveying Mexican Spotted owls in California, and participating in a study comparing habitat preferences of various bat species in old-growth redwood forests versus younger forest ecosystems in Northern California. He currently teaches AP Biology and chemistry at Herndon High School in Herndon, Virginia and has been at the school for five years. His academic interests include working with student-scientist partnerships and bringing hands-on science into his classrooms. Ryan Albert is a PhD student in Environmental Science and Policy at George Mason University and a student of Dr. R. Chris Jones. His research examines urbanization and water quality in the rapidly developing Northern Virginia area. His field experience includes monitoring water quality in the tidal portions of the Potomac River, biomonitoring in freshwater streams, and a study examining the applicability of North Carolina's perennial stream protocol in the Northern Virginia area. He also has experience with both George Mason and part-time with TetraTech Inc. working on TMDL development.

Abstract

Qualified instructors can teach high school students the necessary skills for stream monitoring while furthering the students' education. This study examines whether data collected by high school students examining perennial and intermittent streams is valid for both research and analysis and use by policy makers. The paper also examines if students can learn from the data collection process.

The study was designed using Fairfax County's Perennial Stream Protocol. Fairfax County recently designed this protocol to map perennial streams, and to serve as a basis for reclassifying them in order to extend Resource Protection Area (RPA) protections to additional riparian habitat. Utilizing this protocol to assess two streams in Herndon Virginia, students took part in an authentic scientific project. The study has spanned two years with a modified methodology in the second year based on experiences from the first. Lesson plans were designed to teach students the basic theory and skills needed for data collection. The second year's study also included the EPA's Rapid bioassessment protocol habitat sheet; however, this was used primarily as a teaching tool. Results indicate that students do gain traditional 'academic' knowledge from the field component ($p < .01$) and that the data collected may be usable under certain circumstances.

Introduction

In September 2001, Fairfax County began a stream-mapping project to identify all perennial streams in the county. Fairfax County Storm Water division (2003) defines a perennial stream as "a body of water flowing in a natural or man-made channel year-round, except during periods of drought" whereas an intermittent stream is defined as "a body of water flowing in a natural or man-made channel that contains water for only part of the year." Classification of perennial streams was deemed necessary to comply with Virginia's modified Chesapeake Bay Preservation Area Designation and Management Regulations (Fairfax County, 2004). Previously, Fairfax County had used USGS maps to distinguish perennial streams; however, these maps did not necessarily demarcate between intermittent and perennial streams accurately. Furthermore, Fairfax County recently modified their Chesapeake Bay Preservation Ordinance, stating that all perennial streams receive a riparian buffer of 100 feet on each side of the waterway. These increased protections were implemented to protect riparian areas from development as stream quality has been shown to be negatively affected by urbanization (Jones and Holmes, 1985). The perennial stream mapping project will most likely result in more perennial stream classification which will mean an increase in total resource protection areas and protected riparian boundaries.

Due to Herndon High School's location in Fairfax County and the implication of the project for students' lives, we thought that perennial stream delineation would be a good basis for a low-budget teaching tool that could result in practical applications for future perennial stream delineation in areas where smaller county budgets prohibit large scale perennial stream reclassification. Based on previous work that shows potential benefits to students from water and watershed monitoring programs (Edelstein et al. 1998) and their experience with perennial stream classification protocols, we hypothesized that the Fairfax County stream classification protocol would also serve as a good tool to give students a broad understanding of water-feature and watershed dynamics, in addition to providing sound data based on student assessment. Students would be given opportunities to learn basic aquatic biology, basic hydrology, geomorphology, and to learn about urbanization, land use management practices, and implications to streams. We strove to expose students to issues such as the impacts of urbanization on benthic macroinvertebrate diversity (Jones and Clark, 1987) and stream hydrology (Novotny, 1991), as well as the implications of increasing resource protection areas or leaving current measures in place. We attempted to direct students' attention to conditions in local streams so that they would be made aware of these environments and become involved in stream protection, rehabilitation projects, or other conservation efforts in the future.

Fore et al. (2001) observed that citizen volunteers are interested in stream health and participating in monitoring programs. Student involvement in classification of perennial streams is akin to volunteer monitoring. The difference is that students are a captive audience who, though given the alternative to opt-out of such hands-on projects, seem to prefer the experience of gathering field data to continuous classroom instruction. Therefore, the students act as volunteers while collecting data. Volunteer monitoring is defined as the process whereby environmental data, such as water quality, is gathered by individuals who are not paid (Lathrop and Markowitz, 1995). Volunteer monitors are proving to be an important part of the data collection process. Most states have thousands of miles of streams and rivers that need to be monitored but few resources, such as money and professional staff, to gather the data on the quality of the waterways. Because of the high number of stream miles that need to be monitored, EPA states that "streams and rivers are monitored by more volunteer programs than any other waterbody type" (EPA, 1997). Using volunteers allows states to perform preliminary data collection and scientists to screen streams more broadly. The incorporation of data collected by volunteers into reports on the environmental conditions of water bodies has been allowed by the U.S. EPA (Lathrop and Markowitz 1995). However, there have been few studies comparing the results of volunteer monitoring to professional monitoring (Engel and Voshell, 2002).

Nonetheless, in one of these studies, Fore et al. (2001) found a significant correlation between professional and volunteer assessment of biomonitoring and no differences between field samples collected by professionals and volunteers. Based on Fore et al.'s assessment, we extrapolated that using students to collect data in streams should yield valid data.

Using students, scientists, regulators, and policy makers are presented with a great resource for collecting vast amounts of data in a relatively short amount of time. Furthermore, scientists can collect data from a wider geographical area and decrease the cost of collecting that data while educating future scientists. Volunteers' data have been used in a number of ways, including watershed planning (EPA, 2001). Hence, if students' data is

accurate, it could become a basis for establishing watershed management priorities such as which areas to set aside as riparian buffers and resource protection areas.

Due to the needs of science education, these data collecting excursions can be beneficial for both scientist and student. Current reforms in the science classroom attempt to get students involved in inquiry or research, although this goal is facing challenges (Trautmann et al. 2002).
Encouraging inquiry will present students with an understanding of scientific concepts that can be continually developed and improved, forming skills that students will use in the real world. One approach gaining interest and momentum is the development of Student/ Scientist Partnerships (SSPs) (Lawless and Rock, 1998). By working along side a teacher and a scientist, students can see how science is performed in the real world and can apply knowledge learned in the classroom to a true scientific project. By taking part in and contributing to research, students start to view science as 'a continuous process of discovery' rather than memorization of facts and figures (Trautman, 2003).

The learning experience is enhanced if students are given a real context in which they can solve problems and build knowledge (Abrams, 1998). SSPs give students an opportunity to increase scientific literacy, apply the scientific method, and develop responsibility and ownership in the contribution of data to an authentic scientific research project. Lawless and Rock (1998) stated that observations have been made showing that students presented 'with an opportunity to participate in an effort that is real and important' will work hard to produce a quality product. Those who would use these data must be concerned about the data quality and the ability of secondary students to collect quality data. Student groups can produce quality data if they are taught about the science, are well trained in the methodologies of the research, and understand the attributes of good data (Lawless and Rock, 1998). Researchers in this project set out to prove this statement in its relation to the perennial stream protocol and stream classification.

Methods

This study examines the nature of a few stream sites over the course of two years using slightly different methodology. The first year of lectures and data collection was completed in May and June of 2003 while the second year was completed in March of 2004. The study protocol was modified slightly for the second season based on experience from the first season.

In order to meet the dual goals of the project, students were given lectures so that they could adequately acquire the necessarily skills to successfully fill out the Fairfax County stream classification protocol. Lesson plans included descriptions and characteristics of various features from the Fairfax County stream identification protocol (2003), while implications for larger watershed issues were added based on textbooks (Allan, 1995; Horne and Goldman, 1994; Leopold, 1994) and our practical knowledge in order to emphasize the relevance of the characteristics to the protocol. Lessons were delivered to two separate AP Biology classes during their respective class times.

The Fairfax County stream identification protocol (2003) divides field indicators into six major groups: streamflow and hydrology, geomorphology, streambed soils, vegetation, benthic macroinvertebrates, and vertebrates. A total of twenty six indicators are listed and evaluators are asked to list each protocol as either absent, weak, moderate, or strong. Based on these rankings, and the relative importance of the indicator in determining whether a stream is perennial or intermittent, each indictor receives a score from either 0-3 or 0-1.5. Stream reaches of approximately 200 feet should be sampled to give evaluators a good impression of conditions in the area. Evaluators are asked to total these points at the end of each of the six sections and to reach a total score at the end of the sheet. The maximum score possible is 60 points. Evaluators are also asked to fill in recent weather information, riparian buffer widths and distances, and any notes. Finally, evaluators are asked to decide whether the stream is perennial (yes/no). In order to fill out the protocol accurately, students had to have an understanding of all six major indicator groups. They had to get into the stream bed, examine the substrate, look at leaf litter and patterns of deposition, examine stream morphology, take soil cores, search for benthic macroinvertebrates, search for evidence of amphibians, have a basic understanding of aquatic vegetation, and take note of the immediate riparian habitat. We instructed students that they needed to use their best judgment as to

whether a stream was perennial, but in the piedmont region of Fairfax, the cutoff score for a perennial stream is generally from approximately 25-28 (Danielle Derwin, personal communication, April 30, 2003).

The first year's study was designed to have three days in the classroom, one day teaching in the field, and then four days of field classification immediately thereafter. When selecting sites, the researchers sought both a downstream and upstream site that had considerable variation (stream 1) and a stream where the downstream and upstream site had only marginal variation (stream 2). Though the Fairfax County protocol (2003) suggests observers walk from the start of the nearest resource protection area upstream or from the start of the flow downstream until there is "a significant change in the hydrological, geomorphological, or biological conditions of the stream," we found this impractical with a full class of students during school hours due to time limitations and the logistics involved in gaining private property access on a substantially greater number of properties. Hence, we picked two downstream (generally perennial) and two upstream (generally intermittent) sites. Each downstream site was paired with an upstream site on the same creek. We were assisted in site selection by Danielle Derwin, a Fairfax County an ecologist working on the perennial stream mapping project. Sites were picked within a 3 minute drive (10 minute walk) from the high school to facilitate transportation and allow for an easy commute to the sites. Students were expected to complete one site for every 90 minute class period, including time allowed for transportation. Two weeks were budgeted to complete the eight day project, thereby allowing for postponement of data collection in the case of adverse weather conditions. However, the spring of 2003 proved to be unusually wet and due to the large amount of precipitation received, three weeks separated the time between classroom lecture and field collection. Additionally, half of the field data collection had to be eliminated due to time limitations encountered at the end of the academic year. Hence, only the upstream site and downstream site for stream 1 were sampled during the first season.

The time allowed to complete the project was expanded from eight to ten days during the second season. Four and one half days were allowed for the lecture component of the class, four days for field studies, one half day for the 'pre-field' test, and one half day for the 'post-field test.' A major modification to the second year's study included adding parts of EPA's Rapid Bioassessment Protocol. The Rapid Bioassessment Protocol habitat sheet was added due to its substantial overlap of concepts with the Fairfax County protocol, while the sheet also placed substantially more emphasis on the quality of habitat, thereby allowing the instructors to better emphasize holistic watershed issues. Also, during the second season, one of the lectures was given by Joanna Cornell, an aquatic biologist with Fairfax County, discussing benthic macroinvertebrates and their role as bioindicators. This lecture proved particularly beneficial and aided students on the section of the protocol dealing with the presence or absence of benthic macroinvertebrates and whether EPT taxa were present. During the field component, students paired up to complete the protocol and analyze whether or not they would consider the stream intermittent or perennial. Half of the class would visit the upstream site while the other half visited the downstream counterpart to allow for smaller groups and greater instructor access if the students had questions. The students were always accompanied by a science teacher from Herndon High School.

The relative success of the two goals was analyzed independently. The first goal, whether students learned from their field experience, was analyzed by giving a "pre-field" test and a "post-field" test. Tests were a combination of mostly multiple choice questions with some true false questions included. The tests were designed in this manner to remove the subjectivity that might be associated in grading other question types such as short answer or essay questions. Probability dictates that uninformed students would score an average of 8.8/35 on the first year's test and 11.15 out of 45 on the second years test. Unfortunately, due to relatively low number of students in the two classes, we felt that we would be unable to establish a 'control' giving both a field group and a non field group the same test while still getting enough quality field data on the protocol for analysis. During the first season, several versions of the same test were given, effectively resulting in no control. During the second season, we tried to counter the absence of a control by using a crossover study and creating two separate tests (Test A and Test B). One class was given test A as a pre-field test while the other was given Test B. The class that took test A as a pre-field test was then given Test B as a post field test and vice versa for the other class. The authors acknowledge that this methodology is not as good as establishing a control; however, we believe that this provided a fairly independent method of performing the analysis. Student test results were analyzed in three ways: first, we looked at the absolute number of students who improved versus those who did the same or did worse. Secondly, due to the high likelihood of non-normality in the test results, we ran the Wilcoxin Sign Rank Test, a non-parametric statistical test, to test for a treatment effect and determine the

statistical significance of these results. Finally, we examined both the absolute and relative changes in the pre and post test descriptive statistics to see if the change in scores was meaningful.

The results from the Fairfax County stream classification protocol were analyzed by seeing if students identified a stream reach as perennial, intermittent, or if they were unsure. These results were explored using a $\chi 2$ test. The total scores were then analyzed to look at the relative degree of variance in the students' scoring of the streams. Scores were looked at for both variations in the site scores and also to check if there was substantial variation amongst groups. Results from various indicators of the protocol were examined to determine those points where students were the most consistent and those where students were the most different. Those areas where students were the most variant were assumed to be those where students were having the most problems clearly identifying the necessary characteristics needed to complete the protocol. We assumed the variation indicated lack of understanding of the given indicator. Lastly, we also independently completed protocols and students results were compared to our protocols. A table was created examining means, standard deviation, and whether streams were deemed perennial. Our answers were not considered absolute as there was variation between the two of us; however, we used these answers to see if students' results were in the same range as ours.

Findings

Results show that students generally scored perennial streams higher than intermittent streams for the upstream and downstream sites on Stream 1 for both years of the study (figures 1 and 2). In 2003, 13 of 14 matched student groups scored the downstream site higher than they scored the upstream. In 2004, 20 of 22 student pairs scored the downstream site higher, 1 scored it the same, and 1 scored it lower (by .5 points). With the exception of upstream site 1, students' scores fell into the range of our total scores, indicating that these figures are reliable when taken as a whole (table 1). However, there was substantial standard deviation in some of the total scores, indicating that one group evaluation in itself may not be reliable. Furthermore, students tended to score upstream sites higher than our scores. Examining the data, we speculate that this is due to a general reluctance of the students to give parameters extreme scores: i.e. far more 1s (weak) and 2s (moderate) were given than 0s (absent) and 3s(strong). We also believe that it is difficult for students to relate an indicator as weak or moderate when they have little experience on which to compare their ratings.

In the first year of the study, students' answer to the question whether the reach was perennial often agreed with our analysis with 11 student groups stating yes, 1 group stating no, and 4 groups electing not to answer on the datasheet. These results were calculated to be statistically significant with the $\chi 2$ at 5.04 and $p \leq .025$. For the upstream 1 site, 10 students said no to the question and 8 students elected not to answer. With an α test of .05, these results were also statistically significant with a $\chi 2$ of 4.81 and a $p \leq .05$. Results for the second year were slightly more ambiguous, with 11 yes answers and 11 students not answering the question for the downstream site ($\chi 2$ of 7.33, $p \leq .01$) and 7 yes, 16 no, and 1 with no answer on the upstream site ($\chi 2$ of 1.83, $p \leq .20$). The increased numbers of yeses in the upstream site could be a result of increased flow after two consecutive wet seasons.

The results for stream 2, the sites picked due to their belonging in a 'grey area' of classification between intermittent and perennial streams, were less conclusive. Students scored the downstream site higher 15 times, scored the sites the same 1 time, and scored the upstream site higher 5 times (figure 3). For the question of whether the stream was perennial, results were not statistically significant at an α of .05. At the upstream site, there were 4 yes, 12 no, and 3 who didn't answer ($\chi 2$ of 2.133, $p \leq .20$) and 4 yes, 7 no, and 11 who elected not to answer for the downstream site ($\chi 2$ of 0.42, $p \leq 1$). Scores seemed to be artificially inflated at the upstream site, primarily due to many students claiming a high presence of aquatic macrophytes. However, these students confused a substantial quantity of algae with aquatic plants as there were no aquatic macrophytes in the stream bed. As a result, the total scores were inflated and masked some of the students' ability to differentiate between an upstream 'grey-zone' intermittent site and a downstream 'grey-zone' perennial site.

Based on the variance in evaluating the approximately thirty criteria, students understood some of the biological and geological indicators better than others. In general, students fared quite well in the benthic macroinvertebrate and vertebrate sections and fared reasonably well in the geomorphology and streamflow and hydrology sections. In addition to variation amongst student groups, there were occasional variations between

class subgroups, for example, at downstream site two, students in two of the subgroups scored mostly .5/1.5 for presence of amphibians whereas other subgroups scored mostly 1.5. This variance was either due to an increased perception in what students viewed as a weak versus strong presence of amphibians or the second group actually encountered greater numbers of amphibians. Students' results were the most consistent when there was a yes/no type of answer rather than a relative degree of a characteristic. For example, due to the general absence of bivalves in our study sites, 122 out of 125 student sheets scored a 0 to the presence of bivalves. However, when characteristics were in various degrees, standard deviations of the scores increased.

When the analysis of the students are pooled, upstream stream site 1 has the lowest score, followed by stream 2 upstream, stream 2 downstream, and stream 1 downstream (figure 4). For all sites, at least 50% of scores fell within a 10 point range, although maximum and minimum scores varied by up to 20 points per site. There was also considerable variation between how each of the groups scored each site as well as variation between 2003 and 2004 data (figure 5). When overall averages for all sites were examined based on group, considerable variation was noted in how groups scored, with median scores ranging from about 21 for group 4B to about 28 for group 4D. There was also greater variation within groups in the 2003 groups than in the 2004 groups. These variations may be due, in part, to the differing times of year that data was collected (June versus March).

Students' test scores show statistically significant improvement after the field experience. During the second year of the study, class 1 scored an average of 31/45 on test A while class II scored an average of 31.5/45 on Test B. The post test saw an average score increase to 32.6 for Class I, test B while Class II scored 34.3 on test A. Due to the proximity in test scores of the classes on the two tests on the pre-field test component, we concluded that the difference in the difficulty of the tests was minor compared to the effect of the field work, and consequently assumed test A and test B to be virtually identical in statistical analysis. Of 47 students who took both tests, 32 students improved, 10 students scored the same, and 5 students fared worse after the field component (figure 6). The mean improvement for class A was 1.59 points while the mean improvement for class B was 2.84 points. Using the Wilcoxin sign rank test to check for a treatment effect, we calculated p to be $< .00001$, showing clear statistical significance. We would also argue that the improvement is meaningful, as students' relative scores increased by 5.4% and 9.0% respectively. This evidence is supported by the first year of the experiment, where the mean score was 24.6/35 on the first test and 28.0/35 on the second, an absolute improvement of 9.7% and a relative improvement of 13.8%. Of the 28 students who took both exams, 21 students fared better on the second exam, 3 scored the same, and 4 did worse. Using a Wilcoxin Sign rank test to test for treatment effect, these results were found to be statistically significant at $p = .001$. We feel the results from the first year, though not sufficient on their own due to lack of independence of the samples, support the evidence from the second year's study and that student's are benefiting academically from their field experience.

Discussion

Students appear quite capable to take useful data when there is enough variation in site conditions to discern noticeable patterns. However, these data have enough variations amongst students that they should only be used in a generalized fashion. Therefore , it seems acceptable to note that the majority of student groups considered a stream perennial or that most student groups scored 2 out of 3 on the presence of a braided channel (moderately braided), with only a few scoring ones (weakly braided) or threes (strongly braided). However, it does not seem reasonable to assume that student data is absolutely accurate or that there will be insignificant variation amongst scores. Researchers should expect a greater degree of outliers than would be found with professional quality data. We found, however, that averages of student results tended to conform to those data taken by experts.

Students in the first year appear more able to distinguish between intermittent and perennial sites. This is generally a result of them scoring the upstream site 1 quite low. They may have been able to make this distinction because the day spent teaching in the field taught them important skills in the practical aspect of examining lower flow streams. An alternate hypothesis is that habitat improved in the interim year due to increased, consistent flow or more environmentally friendly land use practices in the riparian area. A third hypothesis is that they were better able to distinguish between perennial and intermittent streams later in the season. However, a conflicting

indication is that there is greater variation with scoring some parameters in the 2003 groups versus the 2004 groups. We believe this indicates a decreased understanding of some of the more challenging questions. We hypothesize that the second year group was more consistent because of the added days in the classroom, particularly the day discussing benthic macroinvertebrates and their importance as indicator species of watershed processes. An alternate hypothesis is that the 2003 students simply forgot much of their necessary skills in the long 'rain-out' period between the classroom component of the class and the field component.

A large number of student groups also did not complete the final question on the protocol answering whether the stream was perennial. Though we outlined the goals of the project, students may have lost the importance of this final question after examining the 26 field indicators on the protocol. Based on the design of the protocol, students may have not seen the question and forgotten to answer it. Others may have thought that the score was sufficient as to interpret their answers. Some students may have also felt uncomfortable or unqualified to clearly identify the stream as perennial or intermittent. If this project is continued for the next year, it must be emphasized to students that the goal of the project is to see if they think the stream is perennial or intermittent, and so they must answer the final question. When students did complete this question, their results conformed to our expectations. Student groups gave the highest percentage of yes answers to the most perennial site (DS1) and the greatest number of no answers at the most intermittent site (US1). At the two sites (US2 and DS2) picked due to their mixture of intermittent and perennial characteristics, students' answers were mixed. These answers were somewhat expected as the transition from an intermittent stream to a perennial stream is gradual. We consider it likely that professional researchers also have a hard time drawing a clear line when such a line does not necessarily exist. Furthermore, based on one week's experience, it should be expected that students will make varying determinations on where to place the cut-off of a perennial versus an intermittent stream.

Students' academic knowledge clearly benefits from the four days spent in the field: however, we are unable to comment as to if the students would learn more traditional 'test' knowledge if those four days were spent in the classroom. Due to the absence of a control group, we cannot say that field work is better or worse than classroom work. Based on improving test scores, however, we can say that field work is a nice complement to classroom work and does add to a knowledge base created in the classroom. We can also state that students gained experience in participating in 'field' science and showed themselves to be reasonably competent in their analysis. For many students, this was their first experience being in their local streams, and simply walking a stream reach taught them anecdotal knowledge of stream ecology. For these students, who are unlikely to become scientists or ecologists, this simple education will give them a better understanding of their natural surroundings and an introduction into how human processes interact with the aquatic environment. This education will certainly aid future conservation and clean up efforts, and as adults the students will be more likely to support environmentally sound policies. Furthermore, there is a greater likelihood that they personally will become involved in stream conservation or restoration projects, and that they will personally minimize actions that damage watershed health. We believe that giving students a connection to their local ecosystem through data collection will instill an attitude of professionalism and responsibility on the part of students.

If the exclusive goals of the class are to teach students about watershed health and field work, the lesson plan should consist of at least three to four days classroom lecture discussing basic aquatic ecology, watershed ecology, land use impacts, and what various indicators on the protocol represent and how to identify them. These lectures should be followed by a day of teaching in the field where students are shown the field indicators in various degrees. Students should then be allowed at least two days to complete protocols and independently study field indicators. However, if the goals of the class are to also collect data for other uses, then extra time should be allotted for the collection of data. We believe that use of student data for stream classification would be usable under certain circumstances. One possible scenario might be to give students the same amount of training as we have for this project and have student 'volunteers' participate in either after-school sampling or weekend programs. Using this methodology will still allow all students to gain some field experience and learn important information about stream and watershed characteristics, while also allowing those who are most interested to continue sampling data. A project such as this would likely appeal to many students in an AP biology class who are interested in college admissions and would like some official research experience. This methodology would most likely eliminate many of the extreme outliers that are submitted by the less interested or unmotivated student. A second option would be to use the data collected by students as a pre-screen for deciding where to

send professional staff. Additionally, we speculate that the data quality will improve if students have slightly more field training. Hence, a third years' study should better clarify if students' data is of high enough quality to be used in its own right or what limitations must be placed on the data's use.

Conclusions

Like previous research in SSPs, we believe that students worked harder when they thought that their efforts were a part of a genuine scientific effort. The range of field indicators on the protocol allowed students to participate in such an effort while students could learn about numerous components of watershed ecology and conservation. In the context of an AP Biology class, the broad background information needed to address the Fairfax County stream classification protocol will help prepare students for their AP exam and a college curriculum. Additionally, the specificity of working in the field, exploring the stream ecosystem, and interpreting and analyzing components and indicators of streams makes students excited about science. As an added bonus, if students are trained well, we found that their recorded data is usable in a generalized fashion by scientists and can give policy makers an idea of the general nature of streams at specific points so that professionals can pre-screen sites. In the context of limited resources, this could be a good tool for financially constrained localities as they can then decide where resources most likely need to be allocated and then send professionals to fine-tune the results for establishing policies and regulations. For the next field season, we plan on offering student volunteers the opportunity to sample either after school or on the weekend in addition to some in class sampling. This extra curricular sampling would be scheduled after completion of in class sampling. Our goals will be to see if data collected by students outside the classroom exceeds the quality of data collected in the classroom. We will also modify our curriculum slightly to focus more on a goal-oriented approach and emphasize that we are interested in students' final evaluation. We hope that these modification will result in data quality increasing, decreasing standard variation, and increasing the ability of students to decipher those sites that are clearly perennial versus intermittent.

Acknowledgements

We would like to thank the following people for their help in carrying out this project: Danielle Derwin, Joanna Cornell, Dr. Clifton Sutton, Dr. R. Chris Jones, Dr. Ronald Stewart, Elizabeth Fine, Megan Draheim, Maynard Heins, Arlene Danby, Anthony Petras, Melissa Quigley, and finally the students who participated in the project.

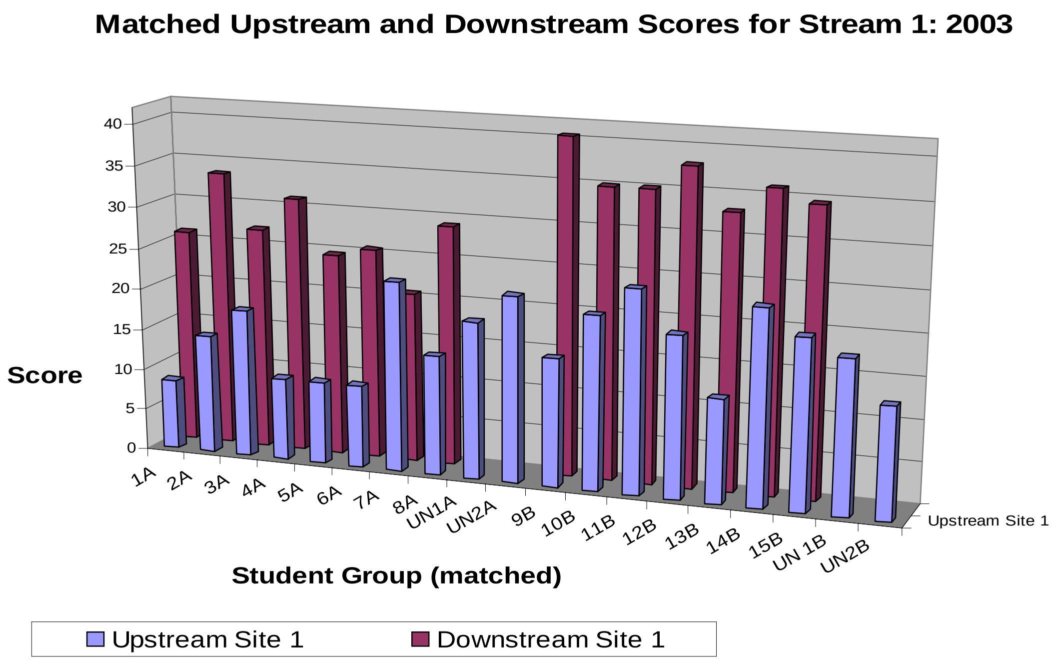

Figure 1 shows that the majority of student groups in 2003 were more inclined to give downstream site 1 higher scores, and hence, more likely to consider it as perennial, than upstream site 1. Each student group was assigned a number and each class received a letter: i.e. group 1A is a student group in class A. Note that for reasons of attendance, groups starting with UN (unmatched) did not complete a protocol for the downstream site.

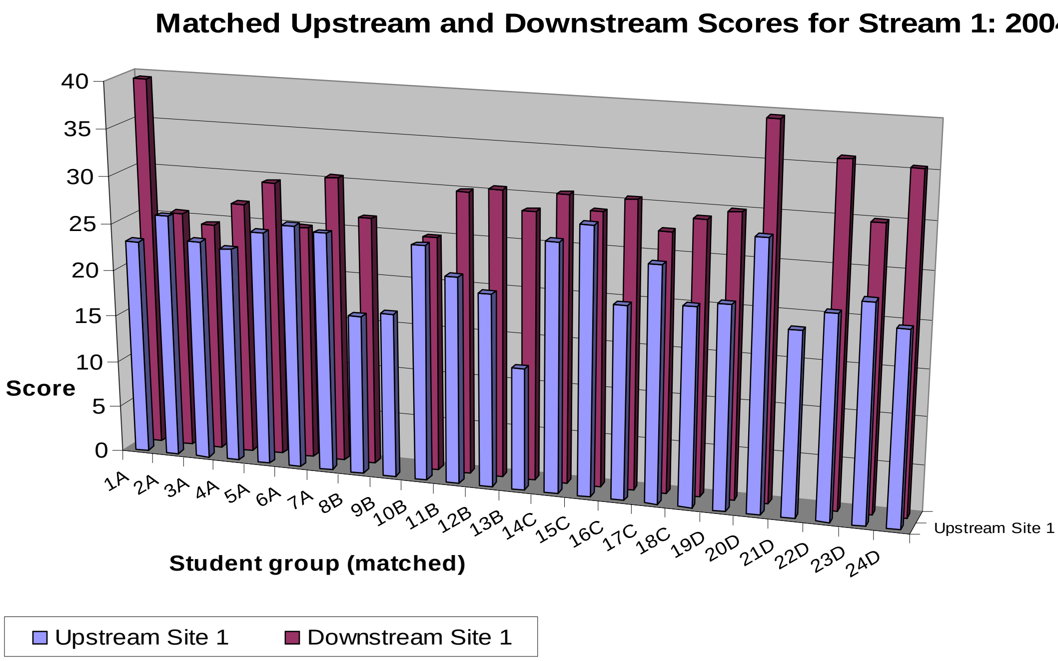

Figure 2. In 2004, Students were also more inclined to give the downstream (perennial) site a higher score than its upstream counterpart. Group notation is the same as in figure 1 except classes were split into two working groups each, giving 4 total groups.

Table 1. Summary statistics of data collected by students versus data collected by researchers

Site (year)	group	n	mean	SD	Perennial (Y/N/No answer)
US1(04)	students	24	23.3	3.69	7/16/1
	researchers	2	17.0	0.71	0/2/0
DS1 (04)	students	22	30.0	4.26	11/0/11
	researchers	2	28.8	1.06	2/0/0
US2 (04)	students	23	22.2	5.41	4/12/3
	researchers	2	19.3	1.77	0/2/0
DS2 (04)	students	22	23.8	5.49	4/7/11
	researchers	2	26.8	2.47	2/0/0
US1 (03)	students	19	16.8	5.64	0/10/8
DS1 (03)	students	15	31.3	5.12	11/1/4

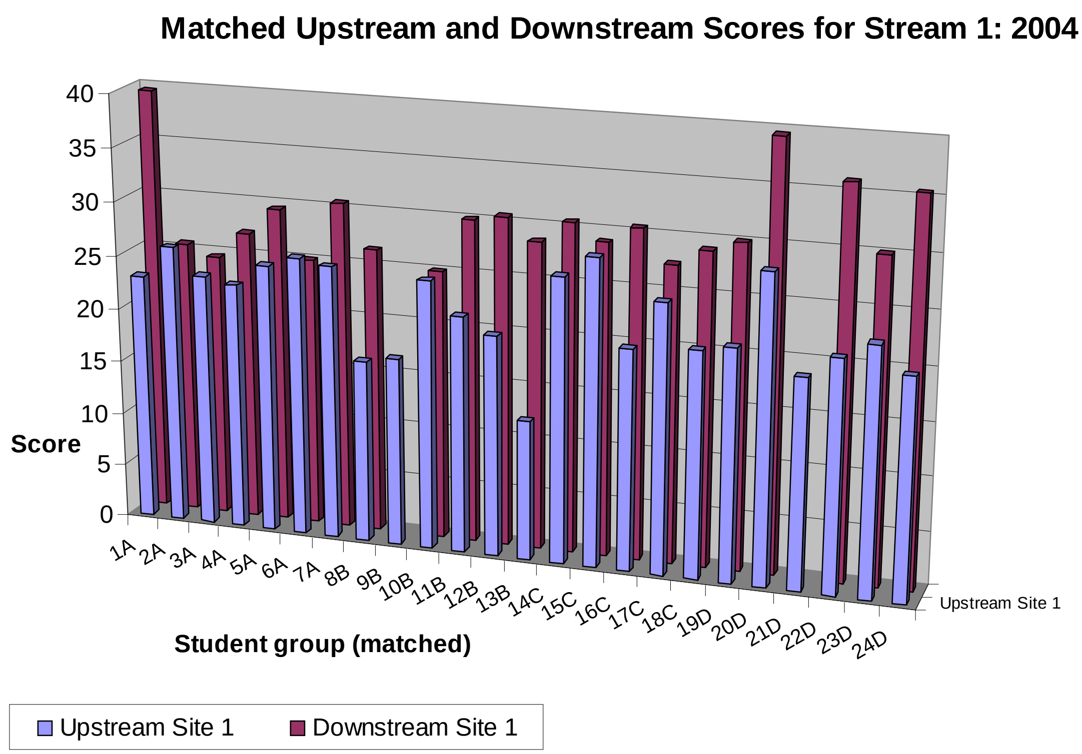

Figure 3. Students differentiated less for the upstream site and downstream site for stream 2 than stream 1. Some students did, however, notice the subtle shift toward perenniality in the downstream site. Reasons for confusion between some students is speculated upon in the discussion.

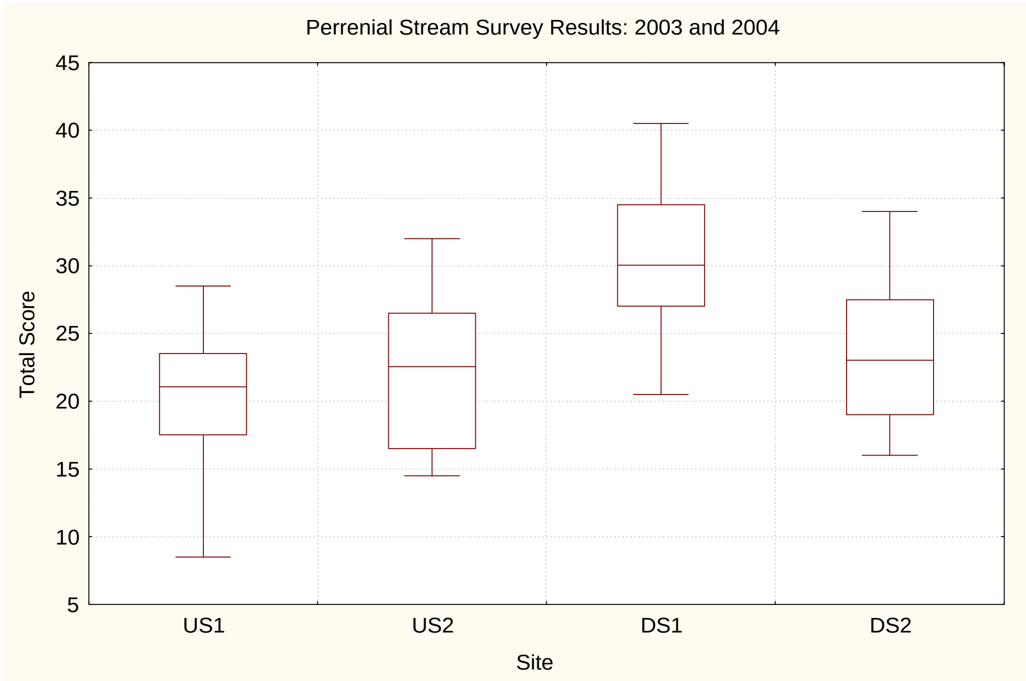

Figure 4. Boxplots showing total scores given by students at all four sites (Upstream stream 1 (US1), Upstream stream 2 (US2), Downstream stream 1 (DS1) and Downstream stream 2 (DS2).

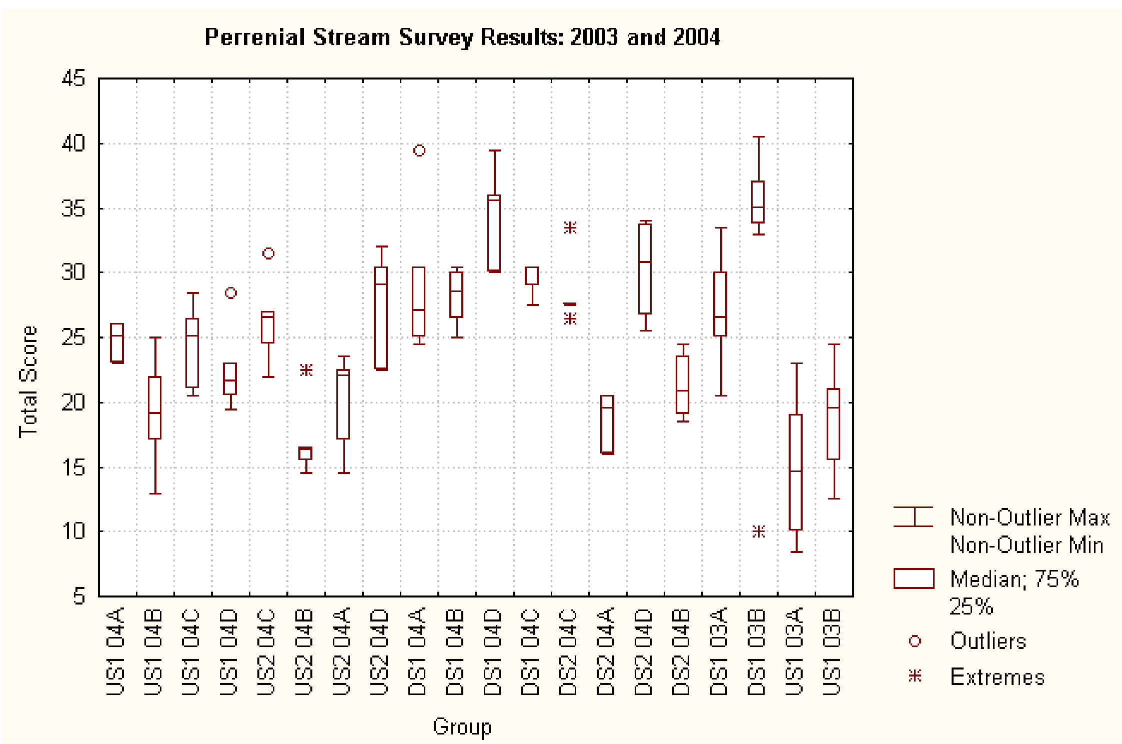

Figure 5. Boxplots showing group evaluations at each site (DS or US) per group (A, B, C, D). Note 2003 data at the far right of the graph compared to data from 2004. 2003 students much more clearly identified characteristics common in intermittent vs. perennial streams.

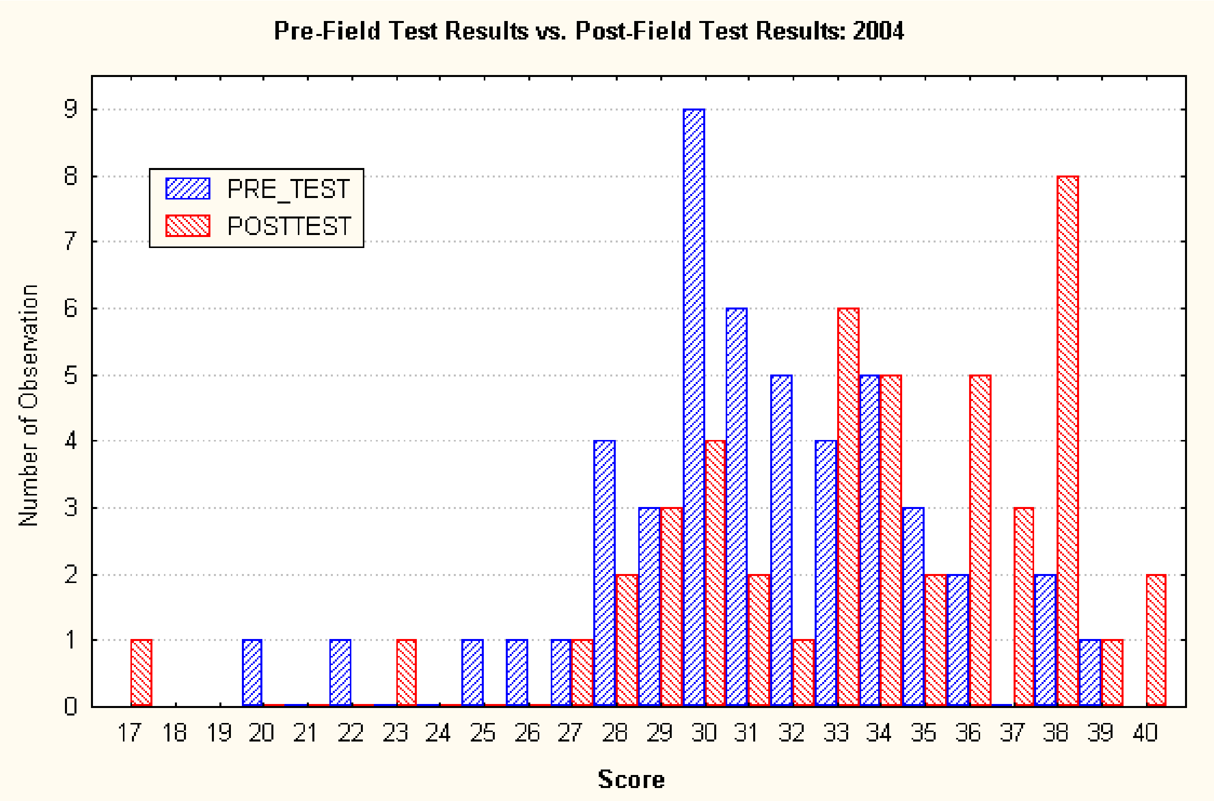

Figure 6. The total score on a test for students in 2004 versus the number of times scored. With the exception of one outlier, the post field test scores shift to the right considerably. Note that the post test data is skewed and would weaken the power of any parametric statistical test.

References

Abrams, E. 1998. Talking and doing science: important elements in a teaching-for-understanding approach. In J.J. Minstrel, J.S. Wandersee and J.D. Novak. Teaching Science for Understanding: A Human Constructivist Approach: 307 – 323. San Francisco: Academic Press.

Allan, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman & Hall.

Engel, Sarah R. and Voshell Jr., J. Reese. 2002. Volunteer biological monitoring: can it accurately assess the ecological condition of streams? American Entomologist, 48 (3): 164-177.

Edelstein, Karen, Trautman, Nancy, and Krasny, Marianne. 1998. Watershed science for educators. Cornell cooperative extension: 215 pp.

EPA. 1997. Volunteer stream monitoring: a methods manual. Available at: http://www.epa.gov/volunteer/stream/index.html

EPA. 2001. Volunteer wetland monitoring: an introduction and resource guide. Available at: http://www.epa.gov/owow/wetlands/monitor/volmonitor.pdf

Fairfax County Stormwater Planning Division. 2003. Perennial Streams Field Identification Protocol. Available at: http://www.fairfaxcounty.gov/dpwes/watersheds/ps_protocols.pdf

Fairfax County. 2004. Perennial Stream Mapping Project. Available at: http://www.fairfaxcounty.gov/dpwes/watersheds/perennial.htm

Fore, Leska S., Paulsen, Kit, and O'laughlin, Kate. 2001. Assessing the performance of volunteers in monitoring. Freshwater Biology 46: 109-123.

Horne, A.J. and G.R. Goldman. 1994. Limnology. 2nd Ed. McGraw-Hill.

Jones, R. Chris and Clark, C.C. 1987. Impact of watershed urbanization on stream insect communities. Water Resources Bulletin 23: 1047-1055.

Jones, R. Christian and Holmes, Beatrice H. 1985. Effects of Land Use Practices on Water Resources in Virginia. Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University: Bulletin 144.

Lawless, James G. and Rock, Barrett N. 1998. Student Scientist Partnerships and Data Quality. Journal of Science Education and Technology 7(1): 5-13.

Lathrop, Joyce E. and Markowitz, Abby. 1995. Biological assessment and criteria pg. 303-314. (W.s. Davis and T.P. Simon (eds.), Biological and Assessment and Criteria. Lewis, Boca Raton, FL.)

Leopold, L.B. 1994. A View of the River. Harvard University Press.

Novotny, Vladimir. 1991. Urban diffuse pollution: sources and abatement. Water Environment and Technology 3(12): 60-65.

StatSoft, Inc. 1999. STATISTICA for Windows [Computer program manual]. Tulsa, OK: StatSoft Inc. 2300 East 14th Street, Tulsa OK, 74104.

Trautmann, N. M., L. M.Avery, M. E. Krasny, and C. M. Cunningham. 2002. University science students as facilitators of high school inquiry-based learning. Poster paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA, April 7-10.

Trautmann, Nancy. 2003. What can university scientists offer to K-12 schools? The Volunteer Monitor. 15(1): 12-13.