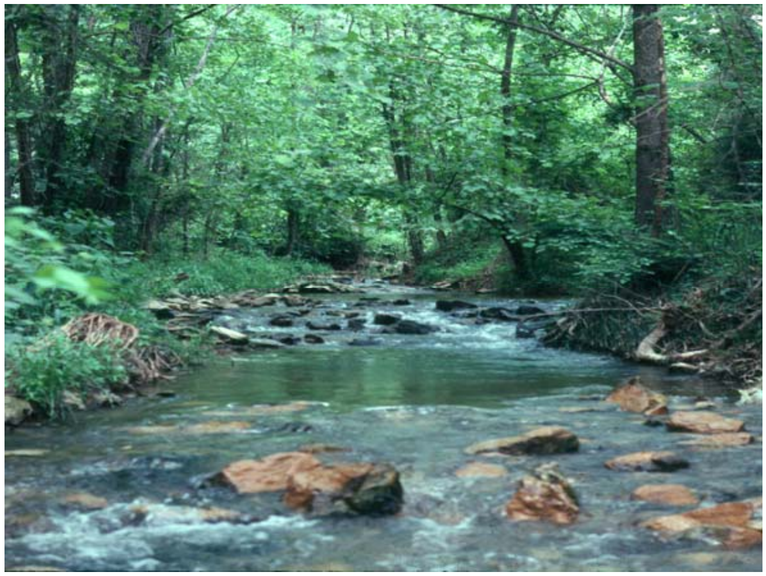
Comparison of Virginia Save Our Streams and Virginia Stream Condition Index Scores in Streams of the Eastern Piedmont of Virginia



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1.0 Executive Summary

The objective of this study was to determine if the results of stream macroinvertebrate assessments conducted by amateur volunteer monitors were appropriate for use by the Virginia Department of Environmental Quality (DEQ) in its 303 (d)/305 (b) integrated report. Rapid biological assessments of 20 wadeable stream sites in the eastern part of Virginia's Piedmont Physiographic region were conducted. The macroinvertebrate communities at the study sites were sampled and assessed using two separate protocols; the protocol of Virginia Save Our Streams (SOS), a volunteer monitoring group, and the protocol currently employed by Virginia Department of Environmental Quality (DEQ) biologists. The latter, which produces Stream Condition Index (SCI) scores, is based on EPA Rapid Bioassessment Protocols for high-gradient streams (Plafkin et al. 1989, Barbour et al. 1999) and the Virginia Stream Condition Index report (Burton and Gerristen 2003).

Pearson product-moment correlation analysis indicated a weak ($r^2 = 0.24$) but statistically significant ($p < 0.05$) correlation between SOS and SCI scores. The qualitative ratings derived from the two scoring systems were in agreement at 11 out of 16 (69 %) of the study sites. A chi-square goodness of fit test indicated that the proportion of sites receiving acceptable ratings was significantly different ($p < 0.001$) between SOS and SCI scores.

The SOS system employs a zone of uncertainty, or "grey zone," where no final judgment of ecological condition is made. Additional correlation models were constructed to determine the effect of excluding grey zone sites on the strength of the correlation between SOS and SCI scores. In these additional analyses, the range of values considered to be grey zone SOS scores was varied in an attempt to reduce variability in the data set and thus to strengthen the correlation. The correlation between SOS and SCI scores was maximized ($r^2 = 0.75$, $p < 0.05$) when a grey zone of 6-8 was employed, where all sites receiving SOS scores of 6, 7 or 8 were excluded from the correlation analysis. This increased grey zone, however caused an increase in the proportion of sites where SOS and SCI ratings were in disagreement.

Identifications of macroinvertebrates in the field by SOS personnel were determined to be generally accurate based on a re-analysis of the samples by VCU personnel. The effect of the few incorrect identifications on the results of the SOS scoring was minimal.

The results and conclusions of this study were limited by the low number of sites sampled that were categorized as being of good to excellent quality according to the SCI. In addition, the total number of sites sampled (20) was relatively low for investigations of this type. A larger sample set of eastern Piedmont streams that reflect a wider range of ecological conditions would be helpful in making a more complete evaluation of the usefulness of SOS volunteer monitoring data in DEQ water quality monitoring projects.

2.0 Introduction

The Virginia Department of Environmental Quality (DEQ) requested that Virginia Commonwealth University (VCU) conduct a study to compare the results of citizen monitoring data, collected through the Save Our Streams (SOS) program, to DEQ bioassessment protocols and the resulting Virginia Stream Condition Index (SCI). Both programs use aquatic macroinvertebrates to assess the condition of streams in Virginia. The intent of this study thus was to determine if the ecological condition ratings of eastern Piedmont streams, as indicated by biological assessments conducted via SOS protocols, were similar to ratings derived from bioassessments conducted according to DEQ protocols. Substantial differences exist between the two protocols in terms of sampling methods, taxonomic level of macroinvertebrate identification, and data analysis. If, however, it could be shown that stream condition can be assessed by the SOS protocols accurately, consistently, and similar to the DEQ protocols, then the SOS data could be used for 305(b)/303(d) listing purposes as required of DEQ. A similar study comparing the SOS and SCI methods in mountain and western Piedmont streams in Virginia was conducted by Hiner and Voshell (2006). The general approach used here was modeled after the Hiner and Voshell study and used the current SOS protocols developed by Engel and Voshell (2002).

3.0 Methods

Field and Laboratory Investigation

Between 12 September and 12 December, 2006, personnel from VCU and SOS conducted macroinvertebrate sampling in 20 rocky-bottomed, wadeable streams in the eastern part of Virginia's Piedmont Physiographic Province. SOS personnel conducted macroinvertebrate sampling and identification and calculated SOS scores at all sites according to standard SOS protocols (original method by Firehock and West (1995) with modifications by Engel and Voshell (2002)). Personnel from VCU sampled macroinvertebrates in the same stream sections as SOS using the methods employed by DEQ regional biologists, based on EPA Rapid Bioassessment Protocols for high-gradient streams (Plafkin et al. 1989; Barbour et al. 1999). SOS monitors typically release all organisms after enumeration; however, for this study, all invertebrates collected in the field by both SOS and VCU personnel were preserved in 70 % isopropyl alcohol and transported to the laboratory. As a quality assurance measure, the SOS samples were re-identified by VCU to the taxonomic level required for SOS metric scoring (generally order- and family-level). The samples collected by VCU were sub-sampled and identified according to DEQ standard operating procedures.

Data Analysis

The macroinvertebrate data produced from the samples collected by VCU were used to calculate SCI scores for each of the 20 sites. To determine whether SOS scores could be used to accurately predict the ecological condition of the study streams, as indicated by the SCI, Pearson product-moment correlation analyses were conducted using the SOS scores as the predictor variable and the SCI scores as the response variable. The SOS system also employs a zone of uncertainty, or "grey zone", where no final judgment of ecological condition is made. Based on recommendations in a recent validation study conducted in Virginia mountain streams by Voshell and Hiner (2006), SOS scores of 8 out of a possible 12 points are assigned to this grey zone. Sites whose SOS scores were assigned to the grey zone were excluded from further analyses, as DEQ personnel indicated that grey zone scores would not be used for listing purposes. In an attempt to maximize correlations between the two scoring systems, the range of SOS score included in the grey zone, and therefore excluded from further analyses, was adjusted several times.

DEQ condition categories, called Aquatic Life Tiers, are based on a site's final SCI score and are designated as: excellent, good, stress, severe stress. The SOS ecological condition categories are: acceptable ecological condition and unacceptable ecological condition. For this study, the DEQ Aquatic Life Tiers excellent and good were considered in agreement with the acceptable SOS category and the stress and severe stress tiers were considered in agreement with the unacceptable SOS category. The chi-square goodness of fit test was used to determine whether the proportion of sites receiving acceptable ratings was significantly different between SOS and SCI scores. As noted, sites whose SOS scores placed them in the grey zone were excluded from further analysis, regardless of their SCI scores. Following each adjustment of the grey zone, an assessment was made of the proportion of sites whose SOS and SCI ecological condition ratings were in agreement with one another. The Pearson product-moment correlation analyses and chi-square test were conducted according to methods described by Zar (1999).

To determine whether SOS personnel accurately identified macroinvertebrates in the field, the percent similarity between the data from the original, in-the-field SOS identifications and the data from the VCU re-identifications of the SOS samples was calculated for each site. In addition, the SOS metrics were re-calculated, based on the VCU re-identifications and compared to the original SOS metric scores.

4.0 Results

Most of the study sites received unacceptable ratings by both assessment methods. Scores based on the SCI method ranged from 15 to 60 out of a possible 100 points. Scores based on the SOS method ranged from 3 to 12 out of a possible 12 points (SOS and SCI scores and condition ratings are included in Table 1). The chi-square goodness of fit test indicated that the proportion of sites rated acceptable was significantly different between SOS and SCI scores ($X^2 = 16.84$; $p < 0.001$). In all cases where disagreements occurred between the condition ratings assigned to sites based on the two methods, sites were rated acceptable based on the SOS method but unacceptable based on the SCI method. Only one site was rated acceptable according to the SCI score; this site was eliminated from the analysis when the grey zone was employed since it received an SOS score of 8. Therefore, no other statistical comparisons of the proportions of acceptable versus unacceptable ratings between the SCI and SOS methods were warranted.

All Pearson product-moment correlation analyses indicated statistically significant ($p < 0.05$), positive correlations between SOS and SCI scores. When no grey zone was employed (that is, when all 20 sites were included in the analysis), the r^2 value for the regression of SCI scores against SOS scores was 0.24, indicating that 24 % of the variation in the SCI scores could be explained by the variation in the SOS scores. Figure 1 provides a scatter plot of the SOS and SCI scores with all 20 sites included.

When a grey zone of 8 was employed, as recommended by Voshell and Hiner (2006) when using the SOS method in mountain streams, the correlation between SOS and SCI scores was improved slightly ($r^2 = 0.38$; Fig. 2). With this grey zone of 8, four sites were excluded from the analyses and the two scoring systems were in agreement at 11 out of 16 (69 %) of the study sites.

The correlation between SOS and SCI scores was maximized ($r^2=0.75$) when a grey zone of 6-8 was employed, where all sites receiving SOS scores of 6, 7 or 8 were excluded from the correlation analysis (Fig. 3). With this 6-8 grey zone, 11 out of 20 sites were excluded from the analysis and only 4 of the remaining 9 sites (44 %) had SOS and SCI condition ratings that were in agreement with each other.

Macroinvertebrate identifications made in the field by SOS personnel were generally accurate. The mean percent similarity between the field identifications produced by SOS personnel and the results of the VCU re-identifications of the samples was 95 % (range: 89 – 98 %). The SOS scores calculated from the SOS identifications and VCU re-identifications were identical at 14 out of 20 sites, and only differed by one to two points at the remaining sites. All condition ratings applied to the scores were in agreement, except for one site where the original SOS score was 7 and assigned an unacceptable rating and the score from the VCU re-identification was 8 and assigned to the grey zone. This result occurred due to an error in the score for the Percent Beetle metric. Five individual beetles from the sample were misidentified as some other taxon by SOS personnel. Upon re-examination of the sample, it was determined that these likely were small members of the family Elmidae.

Table 1: Total SCI and SOS scores and ecological condition ratings of 20 Piedmont stream sites

Site name	Total SCI score	SCI condition rating	Total SOS score	SOS condition rating	Agree/Disagree
Byrd Creek	60	Good	8	Grey zone	N/A
South Anna River	42	Severe stress	9	Acceptable	Disagree
Unnamed trib. of Edens Creek	26	Severe stress	6	Unacceptable	Agree
Mountain Run (south) 1	46	Stress	9	Acceptable	Disagree
Mountain Run (south) 2	50	Stress	10	Acceptable	Disagree
Plentiful Creek	37	Severe stress	10	Acceptable	Disagree
Pleasant Run	46	Stress	8	Grey zone	N/A
Upham Brook (Spring Hill Park)	20	Severe stress	7	Unacceptable	Agree
Upham Brook (Byrd Hill)	20	Severe stress	7	Unacceptable	Agree
North Run	15	Severe stress	8	Grey zone	N/A
Pocoshock Creek	49	Stress	8	Grey zone	N/A
Black Walnut Run	45	Stress	6	Unacceptable	Agree
Massaponax Creek	35	Severe stress	5	Unacceptable	Agree
Rocky Branch	25	Severe stress	3	Unacceptable	Agree
Third Branch	53	Stress	12	Acceptable	Disagree
Clairborne Run	34	Severe stress	3	Unacceptable	Agree
Mountain Run (north) 1	27	Severe stress	5	Unacceptable	Agree
Mountain Run (north) 2	31	Severe stress	7	Unacceptable	Agree
Summerduck Run	35	Severe stress	7	Unacceptable	Agree
Unnamed trib. of Rappahannock River	43	Stress	7	Unacceptable	Agree

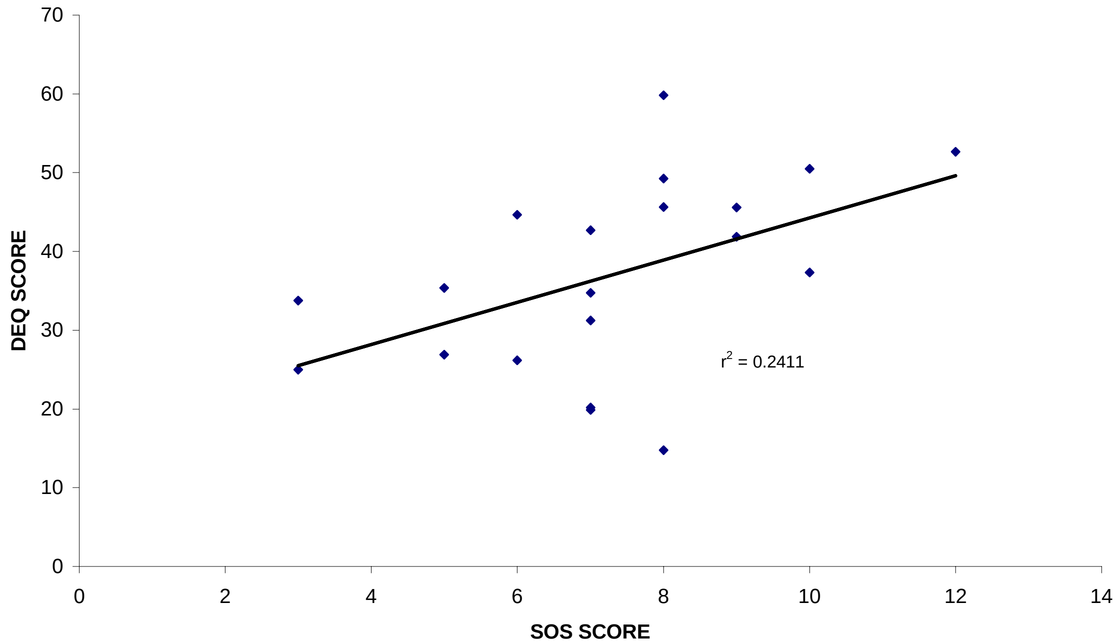

Figure 1: Scatterplot of SCI and SOS scores with all 20 study sites included.

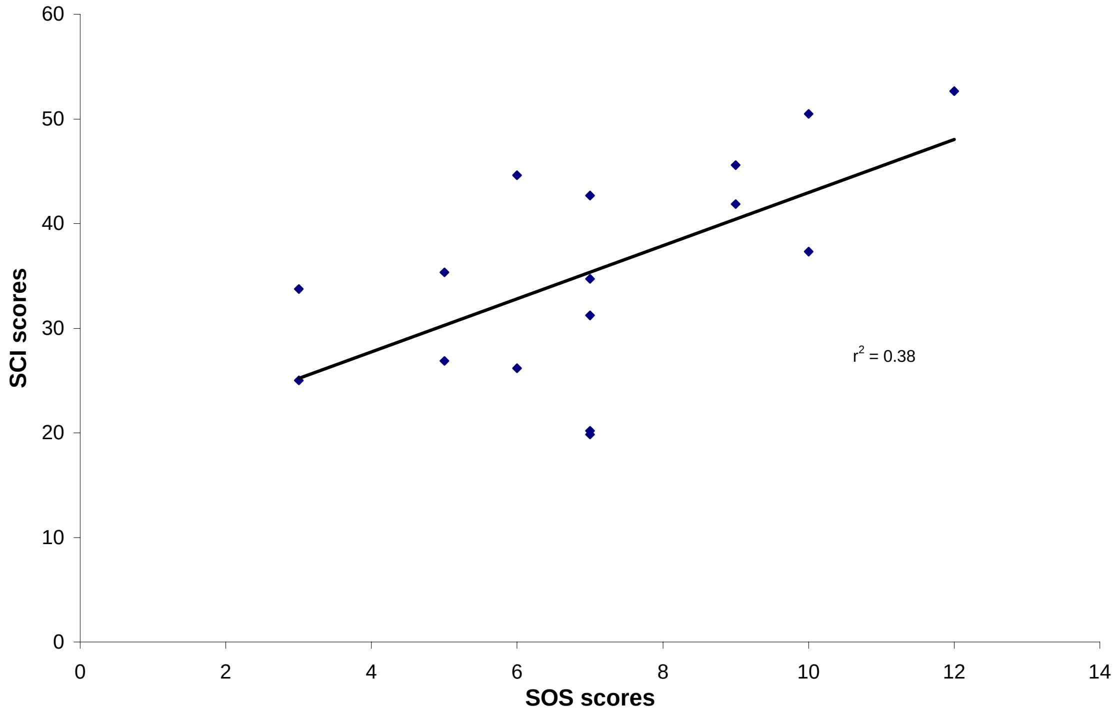

Figure 2: Scatterplot of SCI and SOS scores with sites receiving an SOS score of 8 excluded.

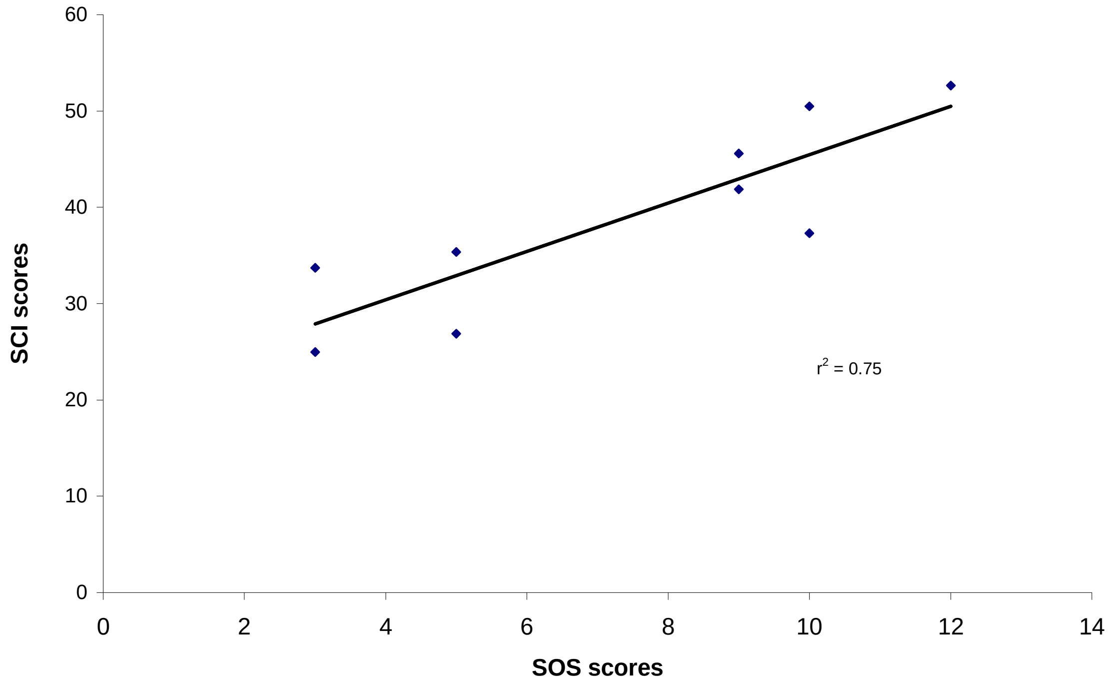

Figure 3: Scatterplot of SCI and SOS scores with sites recieving SOS scores of 6-8 excluded.

5.0 Conclusions and Recommendations

Results of this study were consistent with similar studies conducted by Engel and Voshell (2002) and Voshell and Hiner (2006). Macroinvertebrate identifications made by SOS personnel were generally correct. Significant, positive correlations were observed between SOS scores and scores derived from professional bioassessment surveys. When disagreements occurred between ecological condition ratings derived from SOS scores and those derived from professional bioassessments, the SOS method tended to overrate ecological condition.

The grey zone currently employed in SOS assessments encompasses only sites receiving a score of 8 out of a possible 12 points (that is, sites that receive a score of 7 or lower are given an unacceptable ecological condition rating and those that receive a score of 9 or higher are given an acceptable rating). When this grey zone was applied to the data set, a weak but statistically significant correlation between SOS and SCI scores was observed. The correlation could be increased by adjusting the grey zone, but such adjustments actually increased the relative frequency of qualitative disagreements between SOS assessment results and those from assessments conducted according to current DEQ standard operating procedures. Thus, results of this study suggest that adjusting the zone of uncertainty in SOS scores provides no real benefit for improving congruence between SOS and SCI scores.

Assuming that the ratings derived from SCI scores accurately reflected the ecological condition of the study sites, SOS bioassessment results were accurate in assessing ecological condition at 69 % of the sites. We believe that this level of accuracy is not sufficient for using SOS data for 305(b)/303(d) listing of streams. Misidentifications of macroinvertebrates or other methodological errors by SOS personnel did not appear to be major causes of the observed disagreements between SOS and SCI ecological condition ratings. The strength of the correlations observed between SOS and SCI scores is an indication that the SOS score of a study site can serve as a general indicator of the ecological condition at the site. Although not appropriate for 305(b)/303(d) listing purposes, the SOS method is a useful tool for prioritizing sites for professional monitoring, and, moreover, is an excellent means of encouraging volunteer involvement in water quality monitoring and fostering environmental stewardship by citizens of Virginia.

The major limitations of this study were the small number of sampling sites and the lack of sites that reflected a high level of biological integrity. Improvement in the level of agreement between SOS and SCI scores would most probably require a much more detailed comparison of the two indices, including assessments of individual metrics, based on data from a larger sample set of eastern Piedmont stream sites that included minimally-impaired sites with high SCI scores.

References

Barbour, M.T., Gerristen, J., Snyder, B.D. and Stribling, J.B. 1999 Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-003. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Burton, J. and Gerristen, J. 2003 A stream condition index for Virginia non-coastal streams. Tetra Tech, Inc. Owing Mills, MD. Report prepared for USEPA Office of Science and Technology, Office of Water, Washington, DC; USEPA Region 3 Environmental Services Division, Wheeling, WV; Virginia Department of Environmental Quality, Richmond, VA.

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

Firehock, K. and J. West. 1995. A brief history of volunteer biological water monitoring using macroinvertebrates. Journal of the North American Benthological Society 14:197-202.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. EPA 444/4-89-001. U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, Washington, D.C.

Voshell, J.R. Jr. and Hiner, S.W. 2006. Validation of the modified Virginia Save Our Streams protocol. Virginia Tech. Blacksburg, VA. Report Prepared for Virginia Save Our Streams.

Zar, J.H. 1999. Biostatistical Analysis, 4th Edition. Prentice Hall, Upper Saddle River, New Jersey. 663 pages.