COMPARISON OF BIOASSESSMENT METHODS OF ECOLOGICAL CONDITION USING AQUATIC MACROINVERTEBRATE ASSEMBLAGES IN SOUTHWEST GEORGIA HEADWATER STREAMS

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Abstract. Despite their importance, most biomonitoring programs ignore headwater streams, and focus their usually limited resources on larger streams. This study compared aquatic macroinvertebrate assemblages using Georgia Department of Natural Resources' (DNR) Georgia Bioassessment Protocol (GBP) and Georgia Adopt-A-Stream's (AAS) assessment protocol for four relatively undisturbed headwater streams. The rating of ecological condition/water quality of study streams by the GBP and AAS index differed slightly with a greater percentage of samples rated excellent or poor by the AAS index when compared to GBP results. The AAS index detected differences between sampling periods and streams that agreed with commonly used metrics such as Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. Study results do not suggest that one assessment method is better at describing streams than the other, but they do suggest that the coarser taxonomic resolution employed by the AAS index is adequate to conduct assessments.

INTRODUCTION

This study compared aquatic macroinvertebrate assemblages in four relatively undisturbed headwater streams to determine their ecological condition before forest harvesting in two of the watersheds. Many metrics and indices were used to assess the condition of study streams and tested for their usefulness in describing the fauna of headwater streams of southeastern Georgia. However, results from two indices of interest to resource managers in Georgia, GBP and AAS index, are presented here.

The GBP includes ecoregional scoring criteria and associated ecological condition categories to determine if waterbodies meet their designated use. The Georgia AAS volunteer monitoring program has one set of scoring criteria for the state to evaluate general water quality categories. Both bioassessment programs were intended for broad application in the state of Georgia geographically, but it is not clear if these methods adequately assess the condition of small headwater streams.

BACKGROUND

First and second order streams comprise approximately 95% of all streams and represent 73% of total channel length in North America (Leopold et al. 1992). Headwater streams have a high perimeter to area ratio (e.g., stream to watershed) compared to larger rivers, and as such, are more influenced by their stream-land interface (Polis et al. 1997). Headwater streams also perform numerous functions important to downstream systems (Meyer et al. 2003).

The southeastern United States harbors a rich and diverse aquatic fauna especially in the Gulf Coastal plain (Felley 1992). However, in the Apalachicola-Chattahoochee-Flint (ACF) river basin, there is limited information on the number and distribution of invertebrate species (Couch et al. 1996). Generally, researchers and government agencies have given little attention to wadeable streams of the coastal plain (Maxted et al. 2000). Therefore, additional information is needed to build on the work previously conducted in southwestern Georgia (Muenz 2004, Davis et al. 2003, Gregory 1996) and further characterize the unique aquatic macroinvertebrate assemblages of headwater streams.

In Georgia, the GBP and the AAS index provide important information on the condition of waterbodies. The former is used for regulatory decisions and the latter by citizens to assess general water quality and if necessary, report problems to regulators. Currently, data collected by Georgia AAS volunteers are not used by the Georgia Environmental Protection Division in regulatory decisions, but these data have been used to justify additional monitoring by DNR (K. Sanford, personal communication).

METHODS

Study Site

The study was conducted in southwestern Georgia approximately 16 km south of Bainbridge in the Coastal Plain physiographic province (Figure 1). The study site is located in the Dry Creek watershed, which discharges to the Flint River approximately 22.5 km upstream of the Jim Woodruff Dam of Lake Seminole. The study streams were first order, perennial, groundwater-influenced, low to medium gradient, with a sand-dominated substrate. In-stream habitat included coarse woody debris, undercut banks, leaf packs, and fine roots. The four study watersheds averaged 39 ha, 1.5 L/s in average annual discharge, and 457 m channel length (Summer et al. 2003 and Summer unpublished data). Watersheds A and B had gentle slopes and broader, meandering channels, whereas watersheds C and D had steeper slopes with well defined stream channels (Figure 1).

Data Collection and Analysis

Benthic macroinvertebrates were collected within eight sample reaches (two per stream) with a 500-µm-mesh D-frame net (0.3 m wide) in December 2001, February and December 2002, and February 2003 using a multi- habitat sampling procedure (Barbour et al. 1999). Macroinvertebrates were identified to the lowest practical taxonomic level. Verification and identification to genus and species were made by expert taxonomists. For GBP, values for metrics describing taxa richness, abundance, and composition calculated from genus and species level data were used to calculate an overall score, which was compared to an ecoregional reference stream (Southeastern Plains Ecoregion, Tifton Upland sub-ecoregion) for a determination of ecological condition (GA DNR, 2002). For Georgia AAS, the presence/absence of aquatic taxa (order level) and their associated tolerance or sensitivity to pollution were used to calculate a water quality index value (GA DNR 2000).

Repeated measures ANOVA (SPSS Inc.) was used to determine any significant effect due to position (upstream versus downstream), time (Dec. 01, Feb. 02, Dec. 02, Feb. 03), or interaction of position and time for index values. When significant ($P<0.05$) differences were detected due to time, repeated contrasts (i.e. comparison of adjacent levels) was used to compare time periods. A second repeated measures ANOVA was run when position was insignificant ($P>0.05$) for determining effects due to time, stream (A, B, C, D,) or the interaction of time and stream. The power of this analysis was limited because the sample size for each stream was two. When ANOVA resulted in significant ($P<0.05$) differences between means, a pairwise multiple comparison test (Tukey's honestly significant difference test, alpha = 0.05) was made between means of a factor.

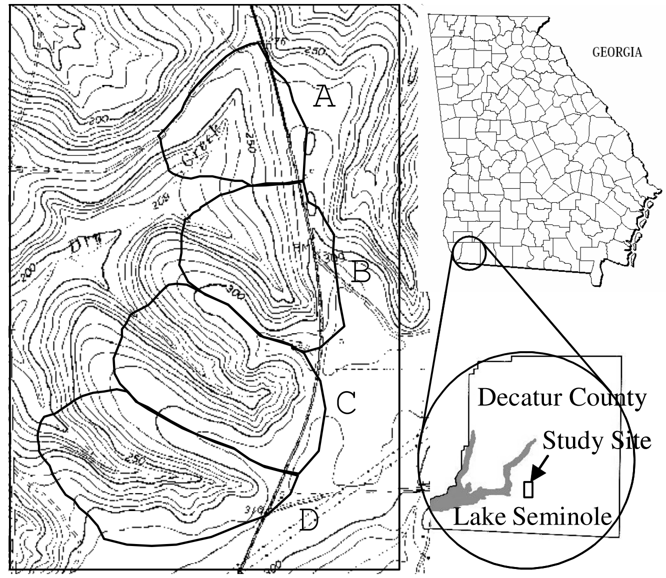

Figure 1. Study site (left) and study location (right).

RESULTS

GBP scored 15.6% of samples Very Good, 56.2% Good, 18.8% Fair, 6.2% Poor, and 3.1% Very Poor when compared to the reference stream (Figure 2). The GBP scored C1 the highest and A1 the lowest across all sampling periods.

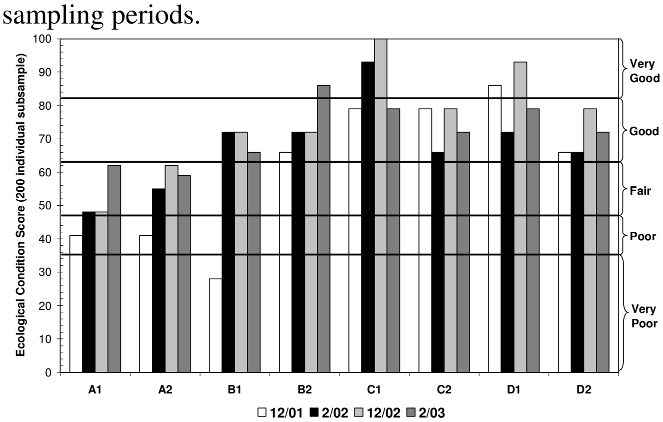

Figure 2. GBP scores for downstream (1) and upstream (2) sites of each stream (A-D) over the entire study period.

Repeated measures ANOVA detected significant differences due to time for GBP scores ($P=0.04$). December 2002 had significantly ($P=0.04$) higher scores than February 2002, with no significant differences between the remaining time periods. No differences were detected due to position. A marginally significant difference ($P=0.08$) was found between streams. Stream A had lower average scores than stream C.

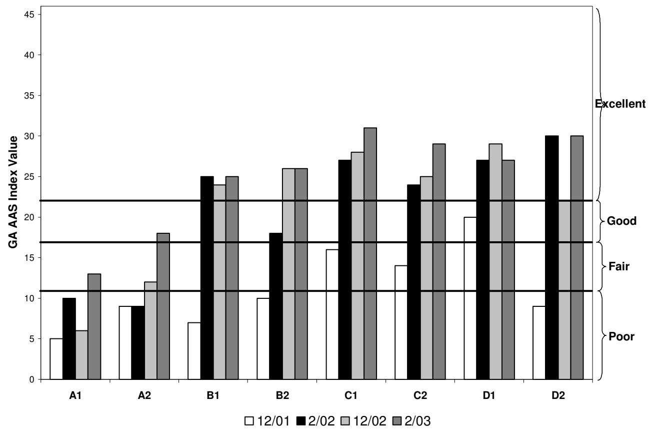

Figure 4. Georgia AAS scores for downstream (1) and upstream (2) sites of each stream (A-D) over the entire study period.

AAS water quality ratings were excellent for 50% of samples, good for 12.5%, fair for 12.5%, and poor for 25%. Five of eight sites for December 2001 were rated as poor water quality (Figure 3). Repeated measures ANOVA found significant differences due to time ($P<0.001$) and stream ($P=0.005$), but not for position. December 2001 samples had significantly ($P=0.008$) lower scores than February 2002. February 2003 samples had significantly higher scores when compared to December 2002 ($P=0.03$). Scores from stream A were significantly lower than scores for stream B ($P=0.02$), C ($P=0.006$), and D ($P=0.006$).

DISCUSSION

The effectiveness of each index in describing the streams varied. The GBP and AAS index scored most stream samples Good or Excellent, respectively, but the AAS index scored more samples Poor. Significant differences associated with time and stream were detected for AAS index and GBP values. However, comparisons between time for AAS and GBP varied, with December 2002 and February 2003 having the highest average GBP and AAS index value, respectively. AAS results agreed with those for other commonly used metrics such as EPT taxa, total taxa, and abundance, whereas GBP results did not. The GBP combines information from the following metrics: taxa richness, number of EPT taxa, number of Chironomidae taxa, percent contribution of dominant taxon, percent Diptera, Florida Index, and percent filterers into a final score. It is not clear what metric(s) caused GBP scores to decrease in February 2003. For differences among streams, AAS index and GBP had results similar to EPT taxa with stream A having lower values than C.

There are similarities and inherent differences between these indices. GBP combines results from selected metrics that are weighted based on regional differences and summed to provide a final score, which is compared to a regional reference stream score and converted into a final assessment of ecological condition. The average area of watersheds in the study was 0.40 km^2 compared to 38.4 km^2 for the reference watershed. The number of species is generally thought to increase from headwaters to mid-order streams, then decrease in larger rivers (Vannote et al. 1980, Allan 1995). Overall, GBP scores might improve if compared to a reference stream closer in size to the study streams.

The AAS index is calculated as presence/absence of invertebrates at the order level versus genus and species levels used in calculation of GBP. Genus or species level taxonomy can yield the greatest benefits for biological monitoring studies, especially when results could influence management decisions (Lenat and Resh 2001). However, studies utilizing higher taxonomic levels (e.g., family, order) can discriminate among ecoregions (Feminella 2000) and describe community patterns (Bowman and Bailey 1997) as well as lower taxonomic levels (e.g., genus, species). One argument against using lower taxonomic levels is that genus and species information increases the cost and ecological noise of bioassessment (Bailey et al. 2001). Feminella (2000) also proposed that coarser taxonomic levels may provide adequate resolution between sites even for relatively unimpaired streams that may only differ due to natural within-catchment variation.

CONCLUSIONS AND RECOMMENDATIONS

Study results do not suggest that one assessment method is better at describing streams in this study than the other, but they do suggest that the coarser taxonomic resolution employed by the AAS protocol is adequate to conduct assessments. AAS volunteer monitoring data could be used to focus DNR monitoring efforts where problems have already been identified by AAS volunteers.

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