CONSIDERATIONS FOR WATER RESOURCE BIOASSESSMENTS BASED ON AQUATIC MACROINVERTEBRATE COMMUNITIES: MISSISSIPPI EXPERIENCES

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INTRODUCTION

Bioassessment and Mississippi

Assessment of biological communities to evaluate water quality has received much-increased attention over the past half decade. Following the passage of the Clean Water Act in 1972, and its amendments in 1987, legislation has tightened the association between aquatic biological communities and water quality regulation in the United States. While some states developed strong bioassessment and water regulatory programs, this was the exception rather than the rule, and by year 2001, 39 states were involved in litigation related to determination of impaired waterbodies or rehabilitation plans for those thought to be impaired (http://www.epa.gov/owow/tmdl). Mississippi's inclusion in the 1998 consent decree with EPA (U.S. Environmental Protection Agency) concerning the state's impaired waterbody list brought the issues of water regulation and bioassessment to the forefront of concern to Mississippi state legislators, regulatory agencies and numerous other stakeholders involved with Mississippi water resources.

Bioassessment has become necessary to discern condition of Mississippi's waters, including identification, monitoring and TMDL supportive information associated with the 303(d) list of impaired waterbodies. It also relates to other Clean Water Act activities, including water quality assessment [305(b)] reporting, section 314 and 319 assessments, section 402 monitoring, ecological risk assessments, and section 303(c) water quality criteria and standards. Mississippi currently has time deadlines for development of new nutrient criteria for incorporation into State water quality standards to prevent promulgation of national nutrient criteria upon the state by EPA, and use of bioassessment information has been selected to play a critical part in the State's efforts to determine its own locally appropriate nutrient criteria.

Specific assessment methods must be valid; e.g., they must provide what is needed; that is, in the case of Clean Water Act requirements, a measure of the ecological condition of a waterbody to assess its "biological integrity". Biological communities suggested by EPA for use in bioassessment programs by states include macroinvertebrates, fish, and periphyton. Nationally, macroinvertebrates dominate as the community selected by states for their bioassessment programs.

While there have been many advances in our knowledge of aquatic invertebrate communities in the past few decades, many questions still remain concerning proper methods for evaluating overall community condition. Questions include: when to sample; where to sample; how to sample; what are proper methods for analysis, interpretation and reporting; what are the effects of stream size, regional conditions, sampling using artificial substrates, sampling difficult natural substrates, sub-sampling field collected material, fixed-count sub-sampling of macroinvertebrate individuals, large-rare organism sorting, level of taxonomic identification, and taxonomic instability.

These concerns escalate when researchers or agencies attempt to make comparisons over wide spatial regions (i.e. state-wide) subject to large variations in stream characteristics and conditions, and comparisons may need to be made over long periods of time (years or even decades). What are the proper methods that will give us the ability to make the right decisions? Limited amounts of resources are available to complete these large-scale bioassessment programs. We wish to not only be scientifically sound but to avoid the waste of monies and effort on failed or flawed methods.

Rapid Bioassessment

EPA recognized that simplification and greater ease were needed to allow bioassessment programs to meet required large-scale studies,

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especially where states would need to survey hundreds, and in some cases, thousands, of stream sites. In 1998, the Mississippi Department of Environmental Quality (MDEQ) stated that actual monitoring data had only been made for one third of one percent of total stream/river miles in Mississippi (about 280 of 84,000 miles) (MDEQ-OPC, 1999). The 1998 303(d) list for Mississippi included over 700 waterbodies that were in immediate need of assessment.

EPA first published rapid bioassessment protocols in 1989 (Plafkin et al.), but the suggested method had been developed primarily from research in high gradient cobble bottom streams. This 1989 protocol was also based primarily on sampling from a single habitat, the riffle, supplemented with coarse particulate organic matter (CPOM) sample. Researchers and management agencies in geographic areas that lacked high gradient cobble bottom streams and others that felt emphasis on a single habitat was insufficient to characterize the condition of a stream reach, often continued to use methods that included sampling from several habitat types, although this increased effort and expense.

Currently, for areas such as Mississippi that generally lack high-gradient cobble bottom streams, EPA (Barbour et al., 1999) promotes the use of a recently developed proportional Rapid Bioassessment Protocol (RBP'99) for sampling macroinvertebrates. This new RBP'99 for non-cobble streams involves multi-habitat composite sampling with a total pre-determined level of effort (20 "jabs" with an aquatic D-frame dip-net) apportioned between different stream aquatic habitats based on each habitat's percent of occurrence in the sampling reach. This proportional sampling methodology was developed from research by the Mid-Atlantic Coastal Streams Workgroup (1996), and has been used and proved useful for state-wide stream bioassessment programs in Florida, Massachusetts and other states.

The EPA RBP'99 proportional approach has not, however, been compared directly to widely-used and time-honored methods where macroinvertebrates are collected with a pre-ordained fixed number of samples from each of specifically targeted individual habitats regardless of each habitats' proportional representation within the stream reach. Fixed allocation non-proportional microhabitat sampling has typically involved use of more than one sampling device and/or method (i.e. Surber, Hess, Hester-Dendy plates, various corers, Ekman grab, Ponar Grab, Petersen Grab, Leaf Pack, basket, Kick net, D-frame net). Sampling gear combinations add to the laboriousness and complexity in collecting the requisite samples needed to complete a bioassessment.

Macroinvertebrate biological assessment of streams performed over the past decade by the USDA Agricultural Research Service's National Sedimentation Laboratory (NSL) has used a combination of collecting techniques, including fixed allocation microhabitat and, more recently, proportional EPA RBP'99 multihabitat sampling methods. These studies by the NSL provided basis for some insight into differences in site bioassessments made using these differing methods, but no direct comparison of these sampling strategies had been conducted.

In this paper, we examined NSL data collected during year 2000 and 2001 at Little Topashaw Creek (LTC), a fourth-order stream in north Mississippi, that directly compared the use of proportional multihabitat sampling (RBP'99) made with only a single gear type (D-frame aquatic dip-net) to non-proportional (fixed allocation) microhabitat sampling (MICRO) made using a variety of gear and methods.

METHODS

Little Topashaw Creek (LTC) is typical of streams in the study region that have been adversely affected by channel incision processes due to geomorphic instability and disturbance. Stream conditions resulting from channel incision at LTC have included bed degradation, massive bank failure, channel widening, loss of stable aquatic habitat structures, and loss of water depth and pool habitats resulting in a generally uniformly shallow water column over shifting sand substrate. As part of an attempt to stabilize a 2-kilometer portion of LTC, 72 large woody debris (LWD) structures were placed strategically within the channel. Constructed from over 1,100 trees, these structures theoretically would provide stream bank stabilization, increase average water depth, serve as a source of organic matter, and provide more stable habitat to the system with the overall intent of restoring better ecological condition.

Structures were inserted during August and September, 2000, prior to the first invertebrate sampling event. An on-going drought in the region prevented substantial interaction of the stream with the LWD structures during 2000. Large flow events during the spring of 2001 caused notable alteration of stream conditions to occur in the treatment sub-reaches before the second invertebrate sampling event, including increases in local water depths (~2x) adjacent to treatment structures. Untreated portions above and below the study reach remained relatively unchanged.

Collections of invertebrates were made in five 150-meter-long sub-reaches. Sampling sites included one site upstream of the region where LWD structures were emplaced (LTC4), two sites that received LWD treatment (one approximately mid-way within the structure placement region, LTC3, and one near the end of the region of LWD treatment, LTC2), and two sites below the treated region (the first beginning approximately 100m downstream of the end of treatment, LTC1, and the second beginning approximately 150m further downstream, LTC0). Samples were collected on two dates, once in October 2000, and again in June 2001.

Non-proportional Microhabitat Sampling

Large woody debris was sampled by brushing approximately 1800 cm^2 total surface area of submerged large (> 10cm diameter) logs and collecting the dislodged material and invertebrates with a standard D-frame aquatic net held down-stream. Leaf packs / CPOM (coarse particulate organic matter) were sampled by hand-grabbing from two or more accumulation areas (approximately 750 cm^3 total volume un-compacted leaf material). Stream bed substrate sand samples at each site consisted of four 929 cm^2 (1 sq. ft) samples taken to a depth of 10 cm using a Surber sampler. At the upstream non-treated site, LTC4, water depth and lack of water velocity required use of an Ekman dredge instead of Surber sampling.

Undercut bank with semi-aquatic vegetation (cutgrass – *Leersia* spp.) habitat was present in the upstream site (LTC4), and was sampled with an aquatic dip net from four 0.5-m-long areas. Due to the erosive processes affecting the stream, undercut banks were only found infrequently in the treatment and other downstream sites, and were sampled when available to the extent possible. A similar situation occurred for clay riffle habitat located in the most upstream site, LTC4, due to bed scouring nick-points; this habitat did not occur in any other (downstream) reaches. In LTC4, clay riffle habitat was sampled with an aquatic dip net from four 0.5-m-long areas. Sampling effort intended for a microhabitat that did not occur in a sampling reach was not re-allocated to other available habitat. No accumulations of gravel or aquatic macrophytes were present in sufficient quantity to be sampled separately.

Proportional Multihabitat Sampling

The RBP'99 multihabitat proportional sampling method (Barbour et al. 1999) was used with slight modification (see below). The employed technique involved sampling systematically from all available in-stream habitats in each 150-meter-long stream reach with a standard D-frame aquatic dip net to produce a single composite sample. A total of 20 "jabs" or "kicks" of effort was expended in each reach, with the number of jabs/kicks expended in each habitat being proportionate to that habitats' representation in the reach (i.e. if sandy bottom composed 50% of the reach habitat, then 10 of the 20 jabs/kicks were used in sandy bottom habitat, and the remainder of jabs/kicks apportioned to remaining habitat types).

Each jab consisted of forcefully bumping and/or sweeping the net through the habitat patch for a distance of 0.5 m. A kick was performed by stationing the net immediately downstream of a habitat patch and then forcefully disturbing the selected substrate/habitat with the foot or hand for a distance of 0.5 m upstream of the net. Our modification to the published RBP'99 macroinvertebrate sampling methods related to EPA's suggestion of not sampling a habitat type if it contributes less than 5% of available reach habitat. If a habitat was present in the reach, we allocated at least one jab or kick to sample it.

Sample Handling, Processing, and Analyses

All samples were preserved in the field in 80% ethanol with rose bengal dye and processed in the laboratory. Invertebrates were generally identified to genus with the exception of Chironomidae and most non-insects (family or higher level only). Data for all sample types taken during non-proportional microhabitat sampling were composited before computing sample indices and metrics. Macroinvertebrate community sample measures / indices calculated to allow comparison of non-proportional microhabitat sampling to proportional multihabitat sampling included taxa richness (S), Shannon Diversity (H'), Sample Evenness (E = H / ln(S)), and Simpson's Index (D). More detailed comparisons of similarities and differences were examined by comparing functional feeding group (Merritt and Cummins 1996) representations produced by the two sampling protocols. Functional feeding group categories compared included: filtering collectors, gathering collectors, parasites, predators, scrapers, shredding detritivores, and shredding herbivores.

RESULTS

A total of 21,456 invertebrates were collected in all samples types on all dates. Non-proportional microhabitat sampling yielded a total of 13,700 individuals, with 6,198 collected in year 2000, and 7,502 collected in 2001. RBP'99 sampling produced a total of 7,756 individuals in both years, with 6,351 collected in year 2000, and only 1,405 collected in year 2001 after stream adjustment to the LWD structures.

Proportional multihabitat RBP'99 sampling showed good overall agreement to non-proportional microhabitat sampling methods results in comparisons of taxa richness, Shannon Index, Evenness, and Simpson Index. The only disparate measures were seen for site LTC0 in year 2001 (Figure 1). Functional feeding group representation was similar for both proportional multihabitat RBP'99 sampling and non-proportional microhabitat sampling for some sites on some dates (year 2000, LTC1, LTC0; year 2001 LTC4, LTC3, LTC1), but dissimilar for others (Figure 2).

DISCUSSION

It is likely that addition of > 1,100 trees to the stream channel will stimulate distinct changes in the aquatic invertebrate community's functional feeding group composition over the next several years in Little Topashaw Creek. Future continued sampling with both non-proportional microhabitat and proportional multihabitat RBP'99 protocols at this research site may provide additional insight into the ability of these different sampling protocols to assess the ecological condition of streams in Mississippi. Hopefully, similar investigations in other sites and regions of the state will provide additional useful information.

Dissimilarities of Shannon, Evenness, and Simpson indices at site LTC0 are problematic. Examination of the functional feeding group representation observed at LTC0 using the different methods shows that non-proportional microhabitat sampling indicates a shift in community composition away from predators and herbivorous shredders in year 2000 toward gathering collectors in year 2001 following stream response to addition of the large woody debris structures. The proportional multihabitat RBP'99 sampling method indicates a shift away from predators, herbivorous shredders and scrapers, toward both gathering collectors and filtering collectors in year 2001.

The Mississippi Department of Environmental Quality (MDEQ), in year 2000, adopted a variation of the proportional multihabitat D-frame aquatic net method suggested by EPA (Barbour et al. 1999) to conduct a state-wide assessment of waterbodies and to develop an Index of Biotic Integrity (IBI) for future waterbody assessments. Results to date indicate that their adopted method is a valid approach to biological assessment in Mississippi (Hicks 2002). Evidence from both NSL and MDEQ data sets suggests that a proportional multihabitat sampling protocol using a single type of gear (D-frame aquatic net) can yield a high degree of certainty that accurate results are being obtained during aquatic bioassessments, and the true ecological condition of our waters is being discerned.

The obvious similarities in results observed using these two methods of sampling aquatic invertebrates appears to indicate that the easier and more cost efficient RBP'99 method may be a valid protocol for biological assessment in disturbed streams of the upper Yazoo River Basin. This study results, however, represents only one highly degraded stream system, and results in streams of other areas and / or in better ecological condition may vary.

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Figure 1. Comparison of community indices produced from composited non-proportional microhabitat sampling (Green Squares, dark line) and proportional multihabitat RBP'99 sampling (Yellow Triangles, red line). Indices represent sample data taken from collections at five sites, LTC4 through LTC0, taken on two dates (October 2000 and June 2001) in Little Topashaw Creek in north central Mississippi. LTC4 is the most upstream site.

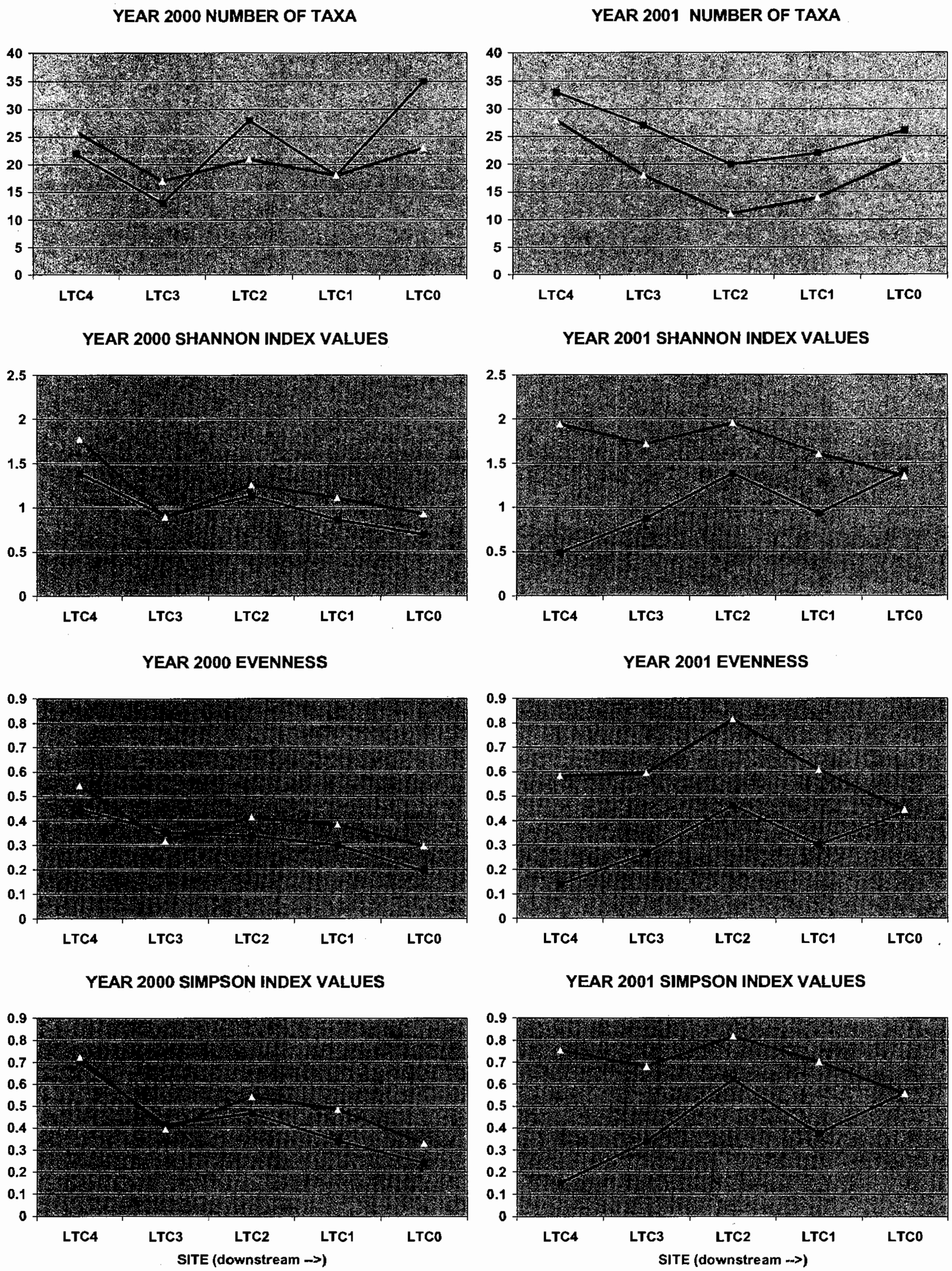

Figure 2. Comparison of functional feeding group percentage representation from composited non-proportional microhabitat sampling (Blue Bars) and proportional multihabitat RBP'99 sampling (Yellow Bars). Graphs represent sample data taken from collections at five sites, LTC4 through LTC0, taken on two dates (October 2000 and June 2001) in Little Topashaw Creek in north central Mississippi. LTC4 is the most upstream site. Functional feeding group categories are: CF= filtering collector, CG= gathering collector, PA= parasite, PH= piercing herbivore, PR= predator, SC= scraper, SD= shredding detritivore, SH= shredding herbivore.