ASSESSING BIOLOGICAL EFFECTS OF ANIMAL PRODUCTION ON INTERMITTENT COASTAL PLAIN STREAMS

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Abstract. Biotic indices increasingly are being used by state and federal agencies to evaluate water quality. The application of existing biotic indices to intermittent Coastal Plain streams is problematic because of unique habitat and flow characteristics. Managers must field-test biotic indices before accepting them for use in this area. This study in South Georgia evaluated the appropriate sampling season for biological monitoring and tested whether existing biotic indices correlated to physical and chemical impacts. Early results showed that index scores changed drastically with season and that different indices yielded conflicting assessments of stream health in intermittent streams of the Coastal Plain. At these sites, the EPT Index (Ephemeroptera/ Plecoptera/ Trichoptera) was a better indictor of stream health than the North Carolina Biotic Index because it accurately reflected physical and chemical stream conditions.

INTRODUCTION

Animal-based agriculture is an expanding industry in the southeastern Coastal Plain of the United States, causing increasing concern regarding animal waste management. If not properly managed, nonpoint source pollution generated by animal operations can have widespread, negative impacts on stream environments through nutrient enrichment and sedimentation (Carpenter et al., 1998).

A recently initiated study aims to develop guidelines that allow for the integration of increased animal production in the southeastern Coastal Plain without compromising water quality (Vellidis et al., 1997). As part of this study, chemical, physical, and biological data are being collected in three South Georgia watersheds that are currently affected by animal production. Using a variety of biotic indices, stream assessments are being conducted to 1) identify appropriate sampling season for biological monitoring, 2) test whether existing biotic indices differentiate impacted versus reference sites, and 3) compare biotic index scores with chemical and physical evaluations of sites. Results from this project are intended to aid in the development of a biomonitoring program for similar intermittent Coastal Plain streams.

BACKGROUND

Biotic Indices

For many years, water quality was defined in chemical terms, ignoring the biological component. Chemical measurements reflect conditions at the time of collection, whereas aquatic biota are integrative indicators of long-term water quality (Loeb, 1994). The focus of water quality programs on chemical criteria does not recognize that a broad range of factors, including but not limited to chemical contamination, can cause degradation.

The Water Pollution Control Act Amendments of 1972 (PL 92-500) issued a directive to restore and maintain the "chemical, physical, and biological integrity of the nation's waters." From this mandate U.S. regulatory agencies developed bioassessment methods to evaluate the "health" of water bodies. Biotic indices are based on the idea that pollution tolerance differs among taxa. One of these methods, the EPT Index, evaluates the number of collected taxa belonging to the orders Ephemeroptera, Plecoptera, and Trichoptera--aquatic insects that are considered to be sensitive to perturbation. Thus, loss of taxa in these groups may indicate disturbance.

Other biotic indices, such as the North Carolina Biotic Index (NCBI) (Lenat, 1993) and the Family-level Biotic Index (Hilsenhoff, 1988), assign tolerance scores to macroinvertebrate taxa based on their ability to survive in a pollution-stressed environment. The total biotic index score is a weighted average of the tolerance scores of different taxa. Sites may then be compared by their index values for the relative impact of pollution.

Intermittent Coastal Plain Streams

Although the regional applicability of biotic indices has been emphasized, often they are used without confirming the accuracy of scores. In the southeastern United States, most biotic indices were developed for perennial Piedmont and Appalachian streams; these indices need field testing before they are accepted for use in intermittent Coastal Plain streams.

Intermittent streams comprise a significant portion of many drainages in the Coastal Plain. The importance of these streams to water quality is often overlooked because they flow for only a portion of the year. This oversight neither recognizes the magnitude of land that intermittent streams drain, nor considers the impacts of runoff during periods of flow.

Seasonal changes in flow have implications for the use of biotic indices in intermittent streams. Index scores may show a negative shift with seasonal dry-down due to decreases in sensitive species stressed by low dissolved oxygen and high temperatures. Coastal Plain streams also may receive lower index scores due to lower flow velocity, lower percentage of stable substrate, and higher temperatures than areas for which most indices were designed. Since few studies have examined invertebrate communities in intermittent Coastal Plain streams, it is difficult to assess whether existing biotic indices work in these streams.

SITE DESCRIPTION AND METHODS

The study site is located in the 390 km^2 Piscola Creek watershed in South Georgia. Many smaller tributaries are intermittent, drying in summer and fall. Cattle, goats, and over 60,000 swine are raised in this watershed, and many streams receive runoff from animal agriculture.

Table 1. Impacts and riparian vegetation at sites.

Site	Impacts	Riparian Vegetation
Reference	No livestock production	20 m Forested
Best Management Practices (BMP)	Confinement with lagoons Manure land applied Swine rotated on pasture	10 m Forested
Runoff	Runoff from swine No access to stream	8 m Forested
Cattle Access	Runoff from swine Cattle access stream	Scattered Trees

At four sites within the watershed (Table 1), invertebrates were collected monthly (March to May 1998). Three composite macroinvertebrate samples were collected at each site with a D-net, then preserved in ethanol for sorting and identification in the lab.

Substrate and depth were recorded at 20 cm intervals along three transects across the stream. Width and incision (measure of erosion) were also recorded. An ongoing study (Vellidis et al., 1997) provided NO_3-N, NH_4-N, and PO_4-P water quality data. Bioassessments were made using the EPT Index and a combination of the North Carolina Biotic Index (NCBI) (Lenat, 1993) and the Family-level Biotic Index (Hilsenhoff, 1988).

RESULTS

Nitrate-N, NH_4-N, and PO_4-P concentrations were higher at the three impacted sites (BMP, runoff, and cattle access) than concentrations at the reference site (Table 2). EPT scores were much higher at the reference site--suggesting better water quality-- than the three impacted sites. The NCBI rated the reference site in poorest condition and the cattle access site in best condition. EPT scores changed from March to May, drastically decreasing at the reference and BMP sites and increasing slightly at the cattle access site, while the NCBI scores did not change significantly with month (Figs. 1a,b).

Width and depth were greatest at the reference and runoff sites, and were lowest at the BMP and cattle access sites. Width decreased from March to May in all streams except at the runoff site (Table 3). Depth also decreased at all sites from March to May. Incision was greatest at the cattle access and runoff sites, and was least at the reference and BMP sites. Percent wood and leaves was substantially lower at the cattle access site than the three other sites.

Table 2. Mean nutrient concentrations, EPT scores, and NCBI ratings for study sites.

Site	NO_3-N (mg/l)	PO_4-P (mg/l)	NH_4-N (mg/l)	EPT	NCBI
Reference	0.09	0.03	0.09	14	Poor
BMP	0.90	0.49	0.55	1	Fair
Runoff	3.00	0.21	0.31	0	Fair
Cattle Access	0.67	0.12	0.21	1	Good

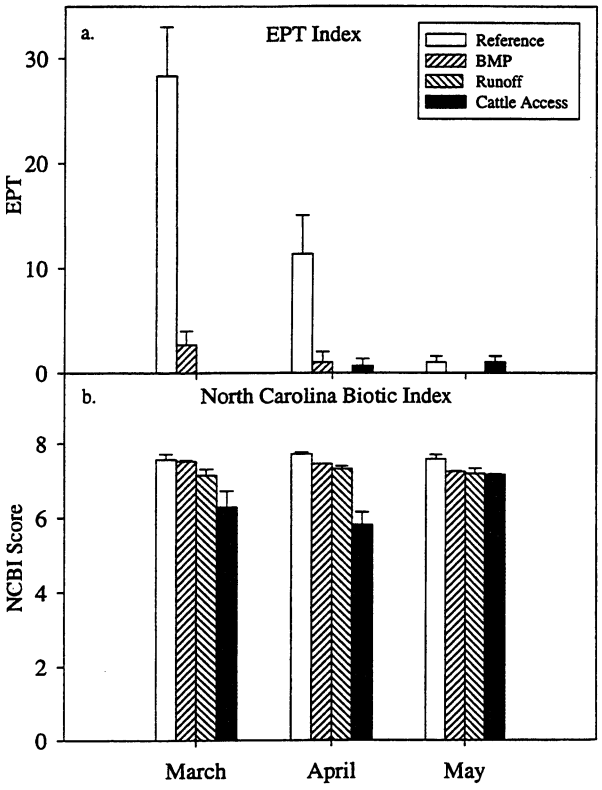

Figure 1. Mean EPT (a) and mean NCBI (b) scores (+1 S.E.) for March – May 1998, at four study sites.

DISCUSSION

Physical Stream Condition

As is normal for this region, the streams dried down between the months of March and May, with accompanying decreases in stream depth and width at all study sites. Although stream depth at the runoff site did decrease with month, width at this site was constant. This stream was deeply incised from erosion, such that as water level decreased, width remained constant because the sides of the stream channel were nearly perpendicular to the bed of the stream.

Incision and riparian vegetation are important determinants of invertebrate habitat, and thus influence the composition of invertebrate communities. The cattle access and runoff sites had high incision depths and sparse riparian zones, and received the lowest EPT scores. Reference and BMP streams had larger riparian buffers, lower incision depths, and higher EPT Index scores than streams at the other two sites.

Indices in the Coastal Plain

Most biotic indices for the East Coast were designed for perennial Piedmont and Appalachian streams that support high total and EPT taxa richness. Due to environmental stresses such as limited stable substrate, low dissolved oxygen, and warm temperatures, even pristine Coastal Plain streams will likely have fewer EPT and lower invertebrate diversity than higher gradient streams (Lenat, 1988). This lower diversity may result in decreases in biotic index scores, as shown in this study. In recognition of the differences between Coastal Plain streams versus Piedmont and Appalachian streams, Lenat (1993) developed a NCBI seasonal correction factor for Coastal Plain streams, but some indices have not been modified to increase their utility. These regional differences in species diversity must be considered when comparing Coastal Plain index scores to other regions.

Table 3. Change in width and depth (March to May 1998) and average incision and percent wood/ leaves at the four study sites.

Site	Δ Width (cm) (Mar-May)	Δ Depth (cm) (Mar-May)	Incision (cm)	Wood/ Leaves (%)
Reference	-100	-11	44	33
BMP	-85	-4	17	32
Runoff	-7	-7	72	25
Cattle Access	-47	-4	87	10

Indices in Intermittent Streams

Fluctuation in instream flow also influences invertebrate assemblages, thereby affecting index scores. Invertebrate communities in intermittent streams have intrinsically low species richness relative to the regional species pool, and abiotic factors (e.g., temperature and dissolved oxygen) dominate community structure (Poff and Ward, 1989). As abiotic conditions change with flow, so does the invertebrate community.

Because taxa richness (EPT and total) is positively correlated with flow permanence (Feminella, 1996), intermittent streams typically have lower biotic index scores than perennial streams. Low dissolved oxygen and warm temperatures in intermittent streams during the summer may select for a stress-tolerant assemblage of invertebrates. Index scores drop as flow decreases because the sensitive taxa usually are the first to disappear as the stream environment becomes harsher.

The invertebrates that remain in intermittent streams during dry-down may further shift biotic index values towards an impaired rating, even at reference sites,

because of their ability to tolerate low dissolved oxygen. Concurrent with dry-down, EPT scores dramatically decreased from winter to spring at both the reference and BMP sites. This change indicates that flow at time of sampling affected index scores, and must be considered when evaluating the health of intermittent streams.

Choosing a Biotic Index

NCBI rankings were poor predictors of stream health in the intermittent streams of this study. At these sites, the EPT Index was a better indicator of stream health than the NCBI because it accurately identified sites with physical and chemical degradation. Although the reference site had lower nutrient concentrations and higher EPT scores, the reference stream was rated in poorer condition than the three impacted sites by the NCBI. Gregory (1996) found similar results for other intermittent South Georgia streams. In his study, EPT was generally higher in reference streams than in streams without riparian buffers, but NCBI scores were consistently higher (indicating poorer water quality) at reference sites relative to no-buffer sites.

Based on Gregory's (1996) findings and results from this study, the North Carolina Biotic Index does not correctly classify intermittent streams in South Georgia. The EPT Index appears to accurately identify impacted streams provided that reference streams are available for comparison. EPT should only be used, however, in the winter months when the most diverse assemblage of taxa is present. Future work will also test the Stream Condition Index for Florida (Barbour et al., 1996).

SUMMARY

Biotic indices are based on the premise that stressed invertebrate communities differ from unstressed communities. In addition to human impacts, invertebrates living in intermittent Coastal Plain streams also are subjected to the natural stresses of seasonal dry-down, low dissolved oxygen, warm temperatures, and limited stable substrate. These factors must be considered when using indices in this region. It may be necessary to create a new, modified index specifically for these streams if studies continue to yield conflicting results.

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