Ecological Indicators 43 (2014) 19–28

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Short communication

Bank erosion hazard index as an indicator of near-bank aquatic habitat and community structure in a southeastern Piedmont stream

Aiden Simpson[a,*], Ian Turner[b], Eve Brantley[b], Brian Helms[c]

[a] Department of Biology, Clarion University, 840 Wood St., Clarion, PA 16214, USA
[b] Department of Crop, Soil, and Environmental Sciences, Auburn University, Auburn, AL 36849, USA
[c] Auburn University Museum of Natural History, Department of Biological Sciences, Auburn University, Auburn, AL 36849, USA

ARTICLE INFO

Article history:
Received 17 September 2013
Received in revised form
10 December 2013
Accepted 2 February 2014

Keywords:
Macroinvertebrates
Sedimentation
Bank erosion
Restoration
Convex hull

ABSTRACT

Streams in the southeastern Piedmont region display varying degrees of bank erosion, which in turn can influence multiple physical and biological processes. In efforts to assess and predict bank erosion, the multi-metric tool Bank Erosion Hazard Index (BEHI) is often calculated. As designed, the BEHI takes into consideration many physical phenomena and scores stream banks categorically from very low to extreme bank erosion hazard; however the power of this index to directly predict in-stream biological conditions is unknown. The predictive ability of BEHI was evaluated on near-bank aquatic biota and organic matter (OM) retention in an AL Piedmont stream with a range of bank conditions. Fifteen banks were characterized using the BEHI and subsequently, macroinvertebrates, crayfishes, fishes and organic matter associated with each bank were quantified. Results suggest increased macroinvertebrate richness and OM retention with low BEHI score. Multivariate analyses suggest functional similarity in macroinvertebrate assemblages associated with low BEHI banks and greater variation in assemblages as BEHI increased. Crayfish were more abundant at banks with high BEHI, a pattern attributed to increases in a generalist species in more-degraded habitats. Fish response showed no discernible pattern in relationship to BEHI score. These results suggest that BEHI may have applications as an informative ecological evaluation tool integrating physical and biological conditions in streams.

1. Introduction

Streams in the southeastern United States display a wide range of physical conditions, with many systems being significantly degraded, a scenario often attributable to the long history of agricultural land use coupled with erosion in the area (Wear and Bolstad, 1998; Trimble, 2008; Nagy et al., 2011). The southeastern US was cultivated extensively during the period after European settlement until the early 20th century and has undergone extensive transition with row crops being replaced by forest, pasture, and urbanization (Trimble et al., 1987; Wear and Bolstad, 1998). However, many of the physical effects associated with agricultural land use (e.g., increased erosion, sedimentation, and altered channel morphology) often remain after watershed reforestation (Galay, 1983; Scott et al., 2002).

Deforestation and agricultural land use patterns have been shown to influence stream bank erosion and channel instability (Lyell, 1830; Simon, 1989; Rosgen, 2001; Shields et al., 2010). Mukundan et al., (2010) concluded that bank erosion was by far the greatest contributor of suspended stream sediment in typical Southeastern Piedmont streams. Bank erosion and subsequent sedimentation as environmental factors are drivers for a variety of in-stream effects that can reduce the physical and biological function of streams (Allan, 2004). The often wider and steeper channels of incised streams also confine flow discharge to the channel during high water events, leading to a flashier channel with reduced hydraulic retention (Shields and Cooper, 1994). Often coupled with increased channel incision is a reduction or altogether loss of stream – floodplain connectivity (Rosgen, 2001). The subsequent in-stream scouring that occurs when peak discharge is confined within the channel can lead to a reduction in pool, riffle, run sequences (i.e., homogenization), woody debris and organic matter retention, and stable substrate (Allan, 2004; Shields et al., 2010).

Land use alterations in upland areas can exert a strong influence on the biotic assemblages of receiving waters (Allan, 2004; Fausch et al., 2002; Townsend et al., 2003). Although stream communities can be particularly resilient to individual disturbance

* Corresponding author. Tel.: +1 7178777327.
E-mail address: a.r.simpson@eagle.clarion.edu (A. Simpson).

http://dx.doi.org/10.1016/j.ecolind.2014.02.002
1470-160X/

events (Fisher et al., 1982; Reice, 1985; Johnson and Vaughn, 1995; Matthaei et al., 1996), sustained anthropogenic stressors such as land use alterations can drastically change aquatic communities with effects often persisting long after activities have been abandoned (Harding et al., 1998; Maloney et al., 2008). Communities within chronically stressed ecosystems shift in structure toward a community dominated by more small bodied, rapidly reproducing, opportunistic or generalist species, and subsequently, undergo a general reduction in diversity (Odum, 1985; Rapport et al., 1985; Rapport and Whitford, 1999). These trends have been documented in both terrestrial and aquatic ecosystems, including stream systems that have been altered via agricultural and urban land use practices (Wang et al., 2000; Sullivan et al., 2004). The reduction in quality habitat associated with incised streams has been shown to cause a shift from longer-lived, large bodied predator fishes in favor of smaller, opportunistic species (Shields et al., 1994), whereas suspended sediment can reduce the reproductive success of benthic spawning fishes (Burkhead and Jelks, 2001; Sutherland and Meyer, 2007). Other studies have shown that land use changes influence a similar shift in macroinvertebrate assemblages with mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) being replaced by chironimid midges (Diptera) in streams flowing through lands converted for agriculture (Quinn et al., 1997; Dudgeon, 1994). Thus the decrease in quality habitat and increase in sediment due to bank erosion associated with land use change clearly alter the macroinvertebrate and fish assemblages of receiving streams. Identifying predictable responses of biotic assemblages to habitat quality reduction due to bank erosion at a more local scale (e.g., riffle/pool sequence) would be highly informative from a management and restoration perspective.

Studies on the effects of bank erosion on total sediment contribution to watersheds led to the development of the Bank Erosion Hazard Index (BEHI, Rosgen, 2001). BEHI is a semi-quantitative multimetric index for estimating bank erosion potential in streams and is comprised of estimates and/or direct measurements of the ratio of bank height/bankfull discharge height (i.e., maximum height of water at bankfull discharge), the ratio of rooting depth/bank height, root density, bank angle, and the percent of surface protected by vegetation (Rosgen, 2001). Other metrics exist, such as the rapid bioassessment protocol (RBP) estimates for high and low gradient streams, which are a qualitative cumulative score of the habitat features structured by channel substrates and morphology, streambed and bank characteristics, and riparian vegetation (Lazorchak et al., 1998; Barbour et al., 1999). While RBP scores for high and low gradient streams are meant to characterize a sampled reach, the BEHI is an index applied to individual banks to estimate their rate of erosion. While the BEHI has been shown to be an effective tool for evaluating stream bank condition in the context of ecological condition and restoration (e.g., Tullos et al., 2009), its specific ability to predict biotic habitat and subsequently, aquatic community composition, have yet to be specifically tested. The scale at which the BEHI is applied (i.e., individual banks within a reach) and the assumed associations between high levels of bank erosion and degradation of instream habitat suggest that this index may be useful in predicting biotic conditions of individual stream banks.

The goal of this study was to explore the effects of bank condition, measured by the BEHI, on near bank aquatic community structure in a stream reach with variable bank conditions. Bank condition was measured in order to examine if BEHI is directly related to near bank aquatic community structure along an extended stream segment. Specifically, this study was focused on comparing the biota of the pools and pool-like features adjacent to fifteen consecutive banks of this stream segment.

2. Methods

2.1. Study site

This study was conducted in Osborn Creek, a third order tributary in the Middle Tallapoosa River drainage in the Piedmont of Alabama, USA (Fig. 1). The riparian zone and associated flood plain of Osborn Creek is mature deciduous woodland, characterized by canopy species typical of Piedmont bottomlands (e.g., *Quercus* spp.) and an understory composed of floodplain-adapted ferns (e.g., *Woodwardia*), forbs (e.g., *Impatiens*), and graminoids (e.g., *Arundinaria*). Osborn Creek was selected as the study stream based on it containing an apparent wide range of observed bank stability conditions.

2.2. Site assessment and sampling

Osborn Creek was visited in June 2011 and 15 sample reaches (hereafter 'sites') were identified within a 200 m representative reach. Each site within the reach was approximately 10 m in length and contained stream banks of differing stability. Sites were preliminarily categorized as being low, moderate, or extreme in terms of observed bank erodibilty based on estimates of top-of-bank height, bank angle, and vegetation cover. After categorizing and marking 15 sites, bank condition, associated instream habitat, and aquatic macroinvertebrates were assessed. The same sites were revisited in August 2011 for fish and crayfish sampling.

2.3. Habitat and bank condition assessment

At every site, physical habitat variables were measured using the BEHI to assess bank stability. BEHI is a cumulative score of five discrete variables that are directly measured or estimated (Rosgen, 2001). Directly measured variables include the ratio of bank height to bank-full height (i.e., the maximum elevation of the active floodplain), the ratio of average root depth to bank height, and bank angle. Estimated variables include percentage of root density and percentage of surface protection (percent of bank covered by vegetation, woody debris, etc.). Each measurement is then relativized to an existing 1–10 index scale; all index scores are summed and then adjusted for underlying bank material to give a final BEHI score. The erosion hazard is then interpreted as categories based on the final score (Table 1; Rosgen, 2001).

Length, average depth, and current velocity were measured at each site. Current velocity calculations were based on 3 measurements taken with an electromagnetic velocity meter (Marsh-McBirney Flo-Mate 2000) at each macroinvertebrate sample location (see below). Habitat was further characterized by measuring dissolved oxygen (DO) and temperature (YSI Model 55, YSI, Inc.), and by quantifying benthic organic matter (BOM). To quantify BOM, organic material trapped in a D-frame dip net (see Section 2.4) from each sample bank was dried for 48 h at 60 °C, weighed, ashed at 500 °C for 3 h, and re-weighed to determine ash-free dry mass (AFDM). To calculate BEHI each bank was scored on the five contributing components of the index (Table 1). Each component was scored by the same individual unaware of our initial bank categorization and summed to produce a BEHI score of 0–50.

2.4. Benthic macroinvertebrates

Benthic macroinvertebrates were collected following general procedures outlined in EPA rapid bioassessment protocol (RBP) for vegetated banks (Barbour et al., 1999). Using a D-frame dip net (500 μm mesh), macroinvertebrates were sampled along the