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Development of a reference-based method for identifying and scoring indicators of condition for coastal plain riparian reaches

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Abstract

Indicators of riparian ecosystem condition for headwater coastal plain streams were identified from data obtained from a reference population of reaches ranging widely in ecological condition. Each indicator was associated with some facet of hydrologic, biogeochemical, and/or habitat functioning and to channel condition, riparian zone condition, or both. Variation in the condition of the indicators among reference reaches provided a framework for developing narratives that could be used to partition and score the condition of the indicators from 0 (severely altered) to 100 (relatively unaltered). The developed narratives were the basis for creating a scoring approach for assessing stream condition at the reach scale (100-m long × 60-m wide segment). This approach was designed to be a rapid, field-based assessment method (<1 h/site) that could be applied by resource professionals with several days of training in the method. Although most alterations to riparian reaches usually affect both channels and riparian zones together, the ability to score channel and riparian zone condition separately is useful for diagnosing problems and suggesting viable restoration options at the reach scale. The assessment method is also useful for comparing the condition of reaches relative to one another, thus offering guidance for prioritizing restoration efforts at a watershed scale.
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1. Introduction

1.1. Background

Since enactment of the U.S. Clean Water Act §101(a), which calls for restoring and maintaining the chemical, physical, and biological integrity of the

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nation's waters, there has been a demand for scientifically defensible procedures for diagnosing problems and providing solutions for improving aquatic health (Kurtz et al., 2001; Bernhardt et al., 2005). For streams, almost all effort has been devoted to perennial streams with some minimum base flow, usually more than 5 ft^3/s. This is partly because high base flow is required to conduct fish and invertebrate Index of Biological Integrity (IBI) assessments. As a consequence, the condition of headwater (intermittent first to third order) streams, and particularly the intermittent ones, have been received scant attention. Also, unless there are extensive wetlands associated with the riparian zones being assessed or monitored, the condition of streamside habitat is seldom considered, except where riparian zones are explicitly and separately assessed (Bjorkland et al., 2001; Munné et al., 2002). At any rate, stream condition and wetland condition are almost always evaluated by different groups with different expertise, and although riparian condition affects stream condition and visa versa (especially in headwater reaches), assessments that evaluate both stream and riparian zone have seldom been integrated.

Although headwater reaches have received scant attention in water quality studies, their condition is particularly important to aquatic health because they disproportionately affect water quality in downstream rivers and estuaries (Brinson, 1993). This is because headwater reaches are in closest contact with sources of non-point-source pollution and they constitute 70–85% of total stream length in any given watershed (Rheinhardt et al., 1999, 2005). Non-point-source pollution is the major factor affecting poor water quality in most streams and rivers in the agricultural landscape of the southeastern U.S. coastal plain (Lowrance et al., 1997).

The Atlantic Slope Consortium (ASC), a collaboration of 30 scientists from 6 research institutions, engaged in developing and testing ecological and socioeconomic indicators of aquatic health over a wide geographic region of the Atlantic Seaboard (http://www.asc.psu.edu/overview.asp). One of the ASC's four working groups, the Watershed Working Group, developed and tested a suite of biophysical and socioeconomic indicators that could be used to assess condition of headwater riparian ecosystems at spatial scales ranging from reach (site) to watershed to ecoregion. The ultimate goal was to provide end users (e.g., resource managers, policymakers, assessment protocol developers, etc.) with guidance on choosing appropriate indicators and information on the inherent sensitivity of those indicators.

The study area of ASC's Watershed Working Group encompassed the drainage basins of the three major estuaries of the mid-Atlantic coast of the U.S.: Delaware Bay, Chesapeake Bay, and Albemarle-Pamlico Sound (http://www.asc.psu.edu). This is an enormous, ecologically and culturally diverse area covering 280,479 km^2 across eight states, five physiographic provinces, and at least six ecoregions (depending on authority) (Fig. 1). Potential indicators of riparian condition were initially identified for this entire study region, with the caveat that some indicators would not be appropriate for all regions, that further refinement and calibration would likely be required even for those indicators that are appropriate, and that additional indicators would be identified in the course of field studies. The focus of this study is to illustrate how one can go about using results of research and published scientific studies to identify and calibrate indicators that can be used by resource managers to rapidly assess the condition of headwater riparian ecosystems. The foundation of the approach taken is that scoring of an indicator's condition is reference-based, i.e., scoring is based on variation in condition among real sites (reference sites). Therefore, before an indicator can be identified and its potential variation in condition defined, it is critical to anchor the method in reality by defining the reference framework as narrowly as practical.

1.2. Defining the reference framework

This study describes how we began with the initial suite of indicators and stressors measured in reaches sampled in the ASC study region, identified those that seemed to be relevant to the inner coastal plain of North Carolina, adapted them to fit biophysical conditions inherent there, and calibrated the adapted indicators to the range of conditions typically encountered in the southeastern coastal plain. We then developed, field-tested, and refined the assessment protocols with input and feedback from resource practitioners who would be the end-users of the protocols in North Carolina: North Carolina Ecosystem Enhancement Program (NCEEP) personnel and environmental consultants

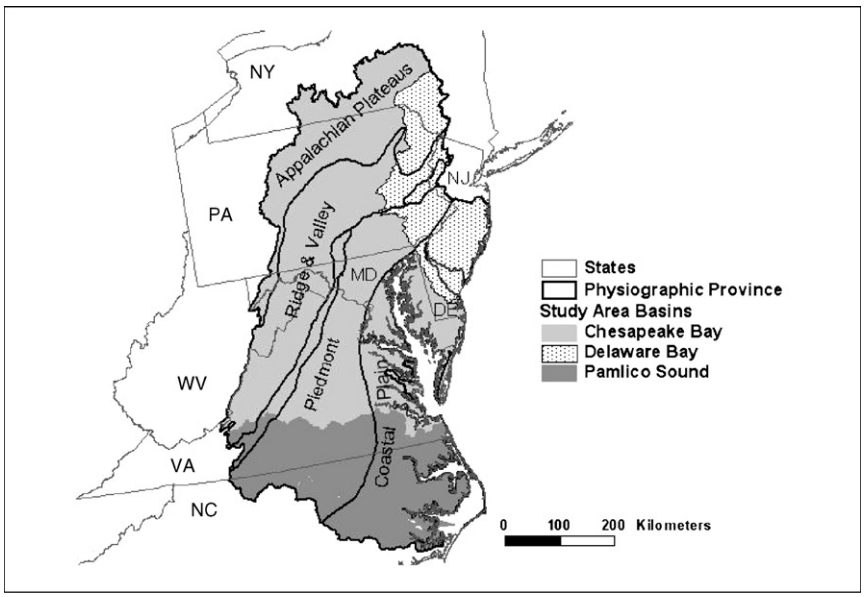

Fig. 1. Study region of the Atlantic Slope Consortium.

who contract with NCEEP in watershed planning (Rheinhardt et al., 2005; Brinson et al., 2006).

Reaches were assessed in three watersheds in North Carolina as part of the ASC watershed characterization effort: Contentnea, Grindle, and Ahoskie (Fig. 2). In all three watersheds, mixed hardwood forests or managed pine plantations tend to occupy the flat inter-stream divides and floodplains of high order streams, while agriculture dominates the better-drained landscape between the divides and larger streams. The majority of stream length occurs in this agriculturally dominated landscape position in the better-drained middle region.

From previous studies (Rheinhardt et al., 1998, 1999), we knew that low and high order coastal plain streams differ in structure and function (except when channelized). Low order streams have intermittent flow that is primarily driven by groundwater discharge while higher order streams are intermittent to perennial that generate sufficient peak flows to put them in regular contact with their floodplains. Therefore, pre-classifying streams as high or low order was an important prerequisite for developing a reference-based framework for evaluating riparian condition. Differences between low and high order streams in hydrodynamics are responsible for differences in biogeochemical and habitat functioning as well. In unaltered low order streams, nutrient transformations occur when surficial groundwater passes through organic-rich surface soils and root zones before entering channels (Bohlke and Denver, 1995); in higher order streams, nutrient transformations are also associated with flooding events when aerobic and anaerobic conditions in close proximity provide ideal conditions for denitrification (Clement et al., 2002). Forest composition is also affected by hydrologic differences between low and high order systems, with more flood-tolerant species dominating riparian zones of higher order streams (Rheinhardt et al., 1998). These differences underscore the importance of pre-classifying stream types and creating a reference framework of field sites that represent the range of ecological conditions for each class (Rheinhardt et al., 1999).

2. Methods

2.1. Data collected at the reach scale

Reach-level data were collected on 14 pages of Stream–Wetland–Riparian (SWR) field data forms (the 4 pages most pertinent to this paper are provided in Appendix A). Some of those data were specifically intended to help identify potentially useful indicators

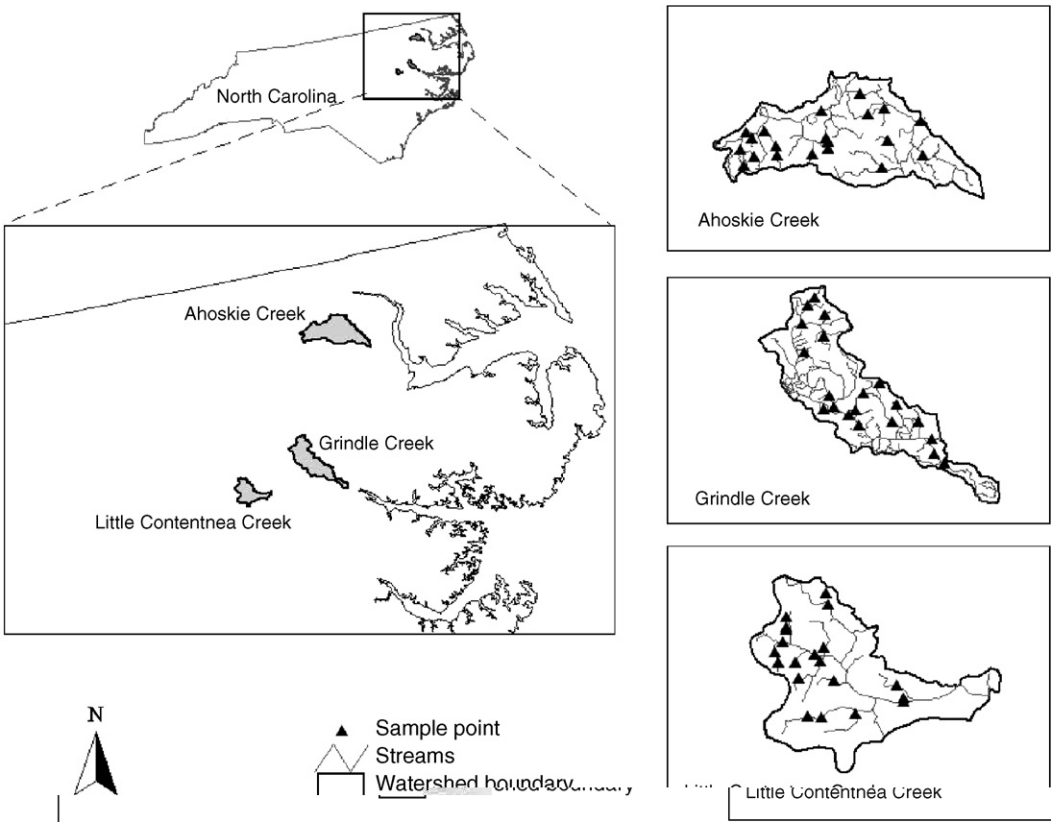

Fig. 2. Three study watersheds in coastal plain North Carolina.

for assessing riparian condition. In testing the applicability of the SWR data forms in North Carolina, we found that the pages initially prepared for Stream Habitat Assessments (SHA) did not reflect conditions in coastal plain streams, especially headwater reaches. The SHA data forms were originally developed by EPA (Barbour et al., 1999) to assess stream habitat condition based on reference conditions of perennial streams in regions other than the coastal plain. It was clear from the scoring protocol on the forms that the reference streams had naturally rocky substrate and moderate sinuosity.

North Carolina coastal plain streams are neither rocky nor sinuous and headwater reaches often have intermittent flow. In fact, SHA reference conditions were so different (off reference) in coastal plain streams that many of the EPA descriptors were meaningless. For descriptors that could be applied, the EPA protocol scored some of the least altered coastal plain streams very low and some of the most severely altered very high. Therefore, to avoid acquiring inappropriate data, we developed an alternative protocol that better reflected conditions inherent to coastal plain streams, but maintained the four-tiered condition approach developed by Barbour et al. (1999). However, to account for differences in reference conditions between low and high order reaches, indicators identified for the two stream types were calibrated separately.

3. Results and discussion

3.1. Summary of ASC data for sampled North Carolina watersheds

The presence of environmental stressors (both on and off sites) was recorded for both the stream channel and the riparian zone in each reach sampled (see field data sheets in Appendix A for list). A summary of stressor categories by watershed and stressor type confirmed that some classes of stressors rarely or