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**Subproject:** 003

**Center:** The Atlantic Slope Consortium - Developing Ecological Indicators for Aquatic Ecosystems of the Atlantic Slope Region

**Center Director:** Robert Brooks

**Title:** Integrated Assessment of Watersheds

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**Project Period:** March 1, 2001 through February 28, 2006\* (includes 1-year, no-cost, extension)

**Research Category:** Environmental Indicators

## Objective

This is the third of four subprojects under the Atlantic Slope Consortium (ASC) center. The goal of this subproject is to develop and test indicators of the biogeochemical health and integrity of watersheds, relate those indicators to environmental conditions, assess the predictability of landscape characteristics to indicator responses, and use those predictions to characterize the effects of watershed discharges on downstream riverine and estuarine health.

## Progress Summary

Several interactive teams are working on this multi-institutional subproject. Their activities in 2004 are discussed below.

### *SERC Watershed and Spatial Analysis Team*

As part of the overall objective to develop and verify geographical indicators to predict water, sediment, and nutrient losses from watersheds, this team’s primary goal is to improve existing statistical models predicting nutrient and sediment losses from geographic data. A secondary goal is to quantify the impact of wetlands and riparian conditions on watershed discharges. Our approach involves (1) exploring the efficacy of additional geographic data (beyond physiographic province and land use/land cover) in predicting nutrient concentrations, and (2) incorporating information about the spatial arrangement of landscape features, particularly source areas and riparian forests, to test hypotheses about nutrient and sediment transport.

Research activities for Year 4 included:

- Explored the effects of different land cover data sets on predictions of nutrient discharge. Results suggest that choice of landcover data has a significant impact on the relative proportions of landcover classes and resulting relationships with measured nutrient concentrations.
- Explored the relationship between soil properties and nutrient discharge, using soils data at two different levels of resolution.

- Explored the effects of improved hydrologic characterization on watershed predictions of nutrient export. A variety of geographic datasets were compiled and analyzed for this purpose.
- Evaluated the influence of wetlands in watershed predictions of nutrient discharge. We used model-based predictions of saturated area to model wetlands and predict nutrient concentrations, then compared these results to our NWI predictions.
- Developed and tested new methods for automated watershed delineation and flowpath modeling.
- Developed a novel geographic method to examine effects of stream map resolution on buffer characteristics. Stream map resolution had a highly significant impact on the areal extent of near-stream lands considered in our riparian metric analysis (and thus the measured patterns of riparian buffers), though the effect of increasing resolution differed across physiographic regions. These results have implications for indicator studies that use stream buffers as predictors.
- Developed GIS routines and a computer program for evaluating the effects of transport distance from source landscapes to streams and watershed outlets. Distance weights were found to improve assessment of biotic thresholds in watersheds, and improve nutrient discharge predictions by 22% in Coastal Plain watersheds. This technique also was applied to data developed by other ASC researchers on PCB concentrations in White Perch and Bird Integrity Index.
- Explored the effects of improved mapping/characterization of riparian buffers. Developed GIS routines for identifying and mapping contiguous riparian forests, mean buffer width, proportion of gaps, and crop loadings to specific buffers to improve accuracy of riparian buffer characterization. Refined metrics and improved analyses to illustrate patterns of riparian buffers as well as unique effects on nutrient concentrations.
- Finally, we developed a novel method for estimating subsurface connectivity among landcover, riparian areas, and stream channels for further analysis.

### *ECU Watershed Team*

Data from the three ASC watersheds in NC (60 sites) were analyzed to determine which of the measured indicators are most applicable for estimating condition of headwater ecosystems in NC. Results of the preliminary analysis were presented at the all hands ASC meeting in March 2004. In 2005, ECU took the lead in using the indicator data from the 3 NC watersheds to test the application of the data in conducting reach and watershed assessments. A paper is in its final stages of preparation, for eventual submission to Ecological Indicators (see reference list below).

During the 2004-05 project year, ECU worked with the other members of the ASC Watersheds working group in analyzing watershed data. ECU took the lead in analyzing canopy vegetation data to determine how composition varies across physiographic provinces. Ordinations have been produced and ECU is has taken the lead in writing-up the results either for the final report and/or as part of a paper to be submitted for peer review.

ECU developed a final version of an integrative riparian assessment procedure for the North Carolina Ecosystem Enhancement Program (NCEEP). The procedure was based on the ASC indicator effort and adapted for use in coastal plain watersheds. The procedure was then tested in

three NC watersheds chosen by NCEEP. We trained environmental consultants contracted by NCEEP on how to use the method before they applied the procedure in randomly chosen reaches in six watersheds. We used the collected indicator data to diagnose problems in the watersheds, compare conditions among watersheds, and determine the precision of users in scoring indicators.

#### *Penn State Watershed Team and Multi-Institutional Activities*

Development of a Stream, Wetland, Riparian (SWR) Index: Data were collected the previous year using a rapid assessment protocol for sampling Streams – Wetlands – and Riparian areas (“SWR” protocol) that was developed as part of this project. In Year 4 these data were used to create a composite assessment of condition (the “SWR Index”) for these three interrelated components of aquatic ecosystems. Steps in index development included extraction of metrics by summarizing measurement data, selection of a subset of metrics, conversion of each metric to a scale of 0 to 1, refinement of a conceptual model of how these components of the stream system relate to each other, and combining the metrics into an index based on the conceptual model.

Values of the Index were then compared with Index of Biotic Integrity (IBI) values collected as part of the Maryland Biological Stream Survey for fish and benthic macro-invertebrates in selected watersheds of the study region. For the most part, the SWR Index agreed well with these more labor-intensive biotic indices when compared on a site-to-site basis.

The SWR Index was also compared with two landscape-level (GIS-based) indices of condition: the first based on landscape characteristics in a 1-km radius circle around each SWR sample point, and the second based on landscape in the entire HUC-14 watershed. Agreement was better for the former than the latter. In cases where there was disagreement between the two indices, specific components of the indices were examined to diagnose the causes of degraded condition and to reconcile differences. Work continues to develop better methods for scaling the SWR index from the site to the watershed level.

Contributions to EaGLE’s Data Committee: The ASC has been working with the EaGLes data committee to develop protocols for long-term storage of data, data organization, data catalogues, metadata creation, and backup of this system. The ASC is in the process of compiling metadata (data about data) describing each of the datasets developed over the course of the project. The datasets and associated metadata will be archived in a central location along with that from other EaGLes projects, and made accessible to future researchers at an appropriate point in time. The target date for compilation of this information is October 1, 2005.

#### **Future Activities**

All three teams that comprise this sub-project will be working together to improve integration of the various components. Specific analyses will include integration of distance-weighted landscape measures developed by the SERC team with the landscape metrics used in the SWR component of the study; and comparison of these combined measures with biotic indices (IBIs) and the SWR Index. We will also be exploring an alternative method for ranking watersheds

according to condition, that takes into account the degree of agreement (or disagreement) of metric scores and expresses this as an uncertainty measure.

The SERC Watershed and Spatial Analysis team will be testing the effect of additional watershed descriptors such as impervious surface, septic density, and population density, and using improved statistical models to provide expectations for the estuarine sub-project.

Members of all three teams will be making presentations and working on additional publications, as well as contributing to the final project report.

## **Publications and Presentations**

### *Publications*

Baker, M.E., D. E. Weller, and T. E. Jordan. 2005. Mapping watershed boundaries using digital elevation data: implications for land cover analysis of nutrient discharge. *Photogrammetric Engineering & Remote Sensing (In press)*.

Baker, M.E., D. E. Weller, and T. E. Jordan. Improved methods for quantifying regional patterns of riparian buffers. *Landscape Ecology. (In review.)*

Baker, M.E., D. E. Weller, and T. E. Jordan. Effects of stream map resolution on riparian metrics. *Landscape Ecology. (In prep.)*

Baker, M.E., D. E. Weller, R.S. King, and T. E. Jordan. Quantifying effects of land cover arrangement using distance weighting. *Landscape Ecology. (In prep.)*

Baker, M.E., D. E. Weller, and T. E. Jordan. Evaluating measures of riparian buffer configuration in geographic predictions of nutrient discharge. *Ecological Applications. (In prep.)*

Brinson, M., R.P. Brooks, R. Rheinhardt, M. McKenney-Easterling. Stream and riparian condition of Atlantic Slope watersheds, USA. *(In prep.)*

Brooks, R.P., M.M. Brinson, K.J. Havens, C.H. Hershner, R.D. Rheinhardt, D.H. Wardrop, D. Whigham, A.D. Jacobs, and J. Rubbo. Proposed hydrogeomorphic classification for wetlands and deepwater habitats of the Mid-Atlantic region, USA. *(In prep.)*

Brooks, R.P., M. Brinson, R. Rheinhardt, M. McKenney-Easterling. Selection of indicators for assessing stream and riparian conditions of Atlantic Slope watersheds, USA. *(In prep.)*

Rheinhardt, R., M. Brinson, M. McKenney-Easterling, J. Rubbro, R. Brooks, J. Hight, and B. Armstrong. Applying indicators of riparian condition to reach and watershed assessments: a case study of three coastal plain watersheds in North Carolina. Paper in internal ASC review for eventual submission to *Ecological Indicators*.

Rheinhardt, R., M. Brinson, R. Christian, K. Miller, G. Meyer, C. Bason, and E. Hardison. 2005. Development of Ecological Assessments for Planning Coastal Plain Stream Restoration in Coastal North Carolina. Report presented to the North Carolina Ecosystem Enhancement Program.

Wardrop, D.H., J.A. Bishop, M. Easterling, K. Hychka, W.L. Myers, G.P. Patil, and C. Taille. 2005. Use of landscape and land use parameters for classification and characterization of watersheds in the Mid-Atlantic across five physiographic provinces. *Environmental and Ecological Statistics* 12 (2): 209-223.

### *Presentations*

Baker, M.E., D.E. Weller, and T.E. Jordan. 2005. Transport-distance effects in regional predictions of nitrate discharge: implications for nitrogen transformation. NABS/AGU Joint Session, New Orleans, LA, June 2005.

Baker, M., R. King, D. Whigham, D. Weller, W. DeLuca, P. Marra, A. Hines, and T. Jordan. 2005. Identifying linkages between watersheds, wetlands, and shallow sub-estuaries. All-Hands meeting, Chesapeake Bay Program Headquarters, Annapolis, MD, May 2005.

Baker, M., R. King, D. Whigham, D. Weller, W. DeLuca, P. Marra, A. Hines, and T. Jordan. . 2005. Identifying linkages between watersheds, wetlands, and shallow sub-estuaries. Public Presentation to the South River Federation, Chesapeake Bay Foundation Headquarters, Annapolis, MD, December 2004.

Baker, M.E., D.E. Weller, R.S. King, and T.E. Jordan. 2004. Effects of within-watershed land cover arrangement on nutrient discharge. Presented at the North American Benthological Society Meetings, Vancouver, BC. June 6-10, 2004.

Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Explicit measures of riparian configuration as watershed indicators and landscape metrics. America's Clean Water Foundation World Water Monitoring Day. Edgewater, MD. October 18, 2004.

Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Advances in watershed delineation: do automated methods affect watershed indicators? ALL-EaGLes meetings, Duluth, MN. October 20, 2004.

Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Explicit measures of riparian configuration as watershed indicators and landscape metrics. ALL-EaGLes meetings, Duluth, MN. October 20, 2004.

Baker, M.E. 2004. Where's the Buffer? Spatial Factors Influencing Riparian Ecosystem Structure and Function. Invited seminar, Utah State University, Logan UT. November 30, 2004.

- Baker, M.E. 2005. Where's the Buffer? Spatial Factors Influencing Riparian Ecosystem Structure and Function. Invited seminar, Western Washington University, Bellingham, WA. January 14, 2005.
- Baker, M.E., D.E. Weller, and T.E. Jordan. 2005. Land Cover Proportion and Arrangement: Spatial Analysis at SERC. National Association of Science Writers workshop, Edgewater, MD. February 15, 2005.
- Baker, M.E., D.E. Weller, and T.E. Jordan. 2005. Quantifying Regional Patterns of Riparian Buffers: new landscape metrics and effects of stream map resolution. Presented at the 20th Annual Meeting of the U.S. Chapter of the International Association for Landscape Ecology (IALE), Syracuse, NY. March 12-16, 2005
- Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Landscape-Level Effects of Riparian Buffers: Considering Configuration and Routing in Geographic Predictions of Nutrient Discharge. Presented at the 19th Annual Meeting of the U.S. Chapter of the International Association for Landscape Ecology (IALE), Las Vegas, NV. March 30-April 2, 2004.
- Baker, M.E., R.S. King, D.F. Whigham, D.E. Weller, W.V. DeLuca, P.P. Marra, A.H. Hines, and T.E. Jordan. 2005. Indicators of Linkages Between Watersheds and Shallow Estuarine Habitats. Invited Plenary, Chesapeake Bay Program, Annapolis, MD. May 9, 2005.
- Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Explicit measures of riparian configuration as watershed indicators and landscape metrics. Presented at US- EPA/CVI Workshop: Sharing Methods for Prioritizing Conservation and Restoration. Harpers Ferry, WV. September 28, 2005.
- Baker, M.E., D.E. Weller, and T.E. Jordan. 2004. Advances in watershed delineation: do automated methods affect watershed indicators? Presented at US-EPA/CVI Workshop: Sharing Methods for Prioritizing Conservation and Restoration. Harpers Ferry, WV. September 28, 2005.
- Baker, M.E. 2004. Chesapeake Bay 101: Land Use Nutrients and Bay Ecology. National Council of Churches: Environmental Clergy Training Plenary. Annapolis, MD. June 19, 2004.
- Brooks, R.P., M.M. Brinson, R. D. Rheinhardt, M. McKenney-Easterling, D. L. O'Brien, and J. M. Rubbo. 2004. Simultaneous Monitoring of Stream, Wetland, and Riparian Components of Watersheds – Development of an Assessment Protocol. Poster presentation at ALL-EaGLes meeting, Duluth, MN, October 2004.
- Rheinhardt, R.D., M.M. Brinson, R.R. Christian, K.H. Miller, G.F. Meyer, J.E. O'Neal. Developing and calibrating an indicator for biogeochemical condition of headwater riparian ecosystems. Poster presented at the North Carolina Water Resource Research Institute conference in Raleigh, NC: Watershed Assessment and Restoration: Lessons Learned and Future Directions, March 2004.

Rheinhardt, R.D., M.M. Brinson, R.R. Christian, K.H. Miller, and G.F. Meyer. Developing and calibrating an indicator for biogeochemical condition of headwater riparian ecosystems. Oral presentation at the EPA EMAP Symposium in Newport, RI: Integrated monitoring and assessment for effective water quality management, May 2004.

Rheinhardt, R.D., M.M. Brinson, R.R. Christian, K.H. Miller, and G.F. Meyer. Developing and calibrating an indicator for biogeochemical condition of headwater riparian ecosystems. Oral presentation at the Society of Wetland Scientists meeting in Seattle, WA: Charting the future, a quarter of a century of lessons learned, July 2004.

Rheinhardt, R.D., M.M. Brinson, R.R. Christian, K.H. Miller, and G.F. Meyer. Developing and calibrating an indicator for biogeochemical condition of headwater riparian ecosystems. Poster presented at the EaGLes meeting in Duluth, MN, December 2004.

Rheinhardt, R.D., M.M. Brinson, R.R. Christian, K.H. Miller, and G.F. Meyer. Using indicators of riparian condition to assess water quality of stream reaches and watersheds. Abstract for oral presentation accepted for the Estuarine Research Federation annual conference in Norfolk, VA: Biological-physical feedbacks and adaptations, October 2005.

Weller, D. E., M.E. Baker, and T.E. Jordan. 2004. Considering the amount and location of land cover within watersheds: integrative landscape indicators. America's Clean Water Foundation World Water Monitoring Day. Edgewater, MD. October 18, 2004.

Weller, D. E., T.E. Jordan, D.L. Correll, and Z-J. Liu. March 2004. Effects of land use and land use change on nutrient discharges from the Patuxent River watershed. Invited presentation at the Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, VA. March 22, 2004.

Weller, D.E., M.E. Baker, R.S. King, and T.E. Jordan. 2005. Improved distance-weighting methods for predicting stream responses from watershed land cover. Presented at the 20th Annual Meeting of the U.S. Chapter of the International Association for Landscape Ecology (IALE), Syracuse, NY, March 12-16, 2005.

Weller, D. E., T.E. Jordan, D.L. Correll, and Z-J. Liu. March 2004. Effects of land use and land use change on nutrient discharges from the Patuxent River watershed. Invited presentation at Horn Point Laboratory (HPL), University of Maryland Center for Environmental Science, Cambridge, MD. March 24, 2004.

Weller, D.E., D.F. Whigham, and T.E. Jordan. 2004. Landscape indicators of wetland condition in the Nanticoke River Watershed. Invited presentation at the Mid-Atlantic Wetlands Working Group, State College, PA. June 14, 2004.

Weller, D.E., M.E. Baker, and T.E. Jordan. 2004. Considering the amount and location of land cover within watersheds: integrative landscape indicators. Presented at EPA/CVI Worskshop: Sharing Methods for Prioritizing Conservation and Restoration. Harpers Ferry, WV. September 28, 2005.

Weller, D.E., M.E. Baker, and T.E. Jordan. 2004. Considering the amount and location of land cover within watersheds: integrative landscape indicators. ALL-EaGLes meetings, Duluth, MN. October 20, 2005