

**Atlantic Slope Consortium  
Annual Report Summary  
March 1, 2004 – February 28, 2005**

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**Center:** The Atlantic Slope Consortium

**Center Director:** Robert Brooks

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

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**Institutions:** Pennsylvania State University, Smithsonian Environmental Research Center, Virginia Institute of Marine Sciences, East Carolina University, Environmental Law Institute, FTN Associates

**EPA Project Officer:** Barbara Levinson

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

**Research Category:** Environmental Indicators

### **Objective of Research**

The goal of the Atlantic Slope Consortium (ASC) is to develop and test a set of indicators in freshwater and coastal systems that are ecologically appropriate, economically reasonable, and relevant to society. Objectives are stated in the project vision statement, developed collaboratively by the project team, as follows:

The ASC uses a universe of watersheds, covering a range of social choices (as reflected in differing land use/ land cover), and asks two questions:

1. How “good” can the environment be, given those social choices?
2. What is the intellectual model of condition within those choices, i.e., what are the causes of condition and what are the steps for improvement?

Following development and articulation of the vision statement, many of the project tasks were oriented to specific portions of this statement. This ensures that a common vision is consistently pursued throughout the project.

### **Progress Summary**

Year 4 of the ASC project included continued analysis of field data for indicator development, exploration of landscape-level indicators, conducting socioeconomic surveys and modeling, and integration of the various components of the project. Additional details can be found in the reports for individual subprojects. A one-year, no-cost extension was granted for this project by the EPA, extending the project end date to 28 February 2006.

Preparation of the final project report has begun. The report will consist of three parts: an executive summary (~4 pages) that gives a brief synopsis of the project; a synthesis report (~50 pages) that presents the project highlights; and a collection (on CD) of published articles, manuscripts, and other text, including indicator summary sheets, that provide details of the various project components.

An outline for the synthesis report is attached (Attachment 1). This report will be organized according to four “messages” that the ASC management team identified as emerging from research to date during the prior year, and that served as organizing themes for the final year and a half of the project. These messages correspond roughly to the original sub-proposal and working group structure of the ASC. The main difference is that Message 1 integrates across components of the project, and Message 2 relates to both the estuarine and optical indicators sub-proposals. Messages 3 and 4 relate to the upstream watershed indicators and socio-economic components of this project, respectively.

A list of indicators and other tools developed by the ASC is included with this summary (Attachment 2). Below is description of those indicators for which analyses are complete (or nearly complete).

#### *Message 1 - Integrating Tools*

ASC researchers have developed an indicator taxonomy to guide managers in selecting appropriate ecological indicators (see Figure 1). This taxonomy considers the land use context (e.g., urban vs. forested), the type of assessment desired (e.g., condition assessment vs. diagnosis of stressors), and the spatial and temporal resolution required (e.g., site-level vs. watershed level). Given the large number of potential indicators available, this taxonomy can help managers to choose the ones that are the most effective and efficient for their needs.

The Chesapeake Bay Program is currently using a version of the taxonomy to re-evaluate their existing suite of indicators. In addition, this tool has been presented to the Albemarle-Pamlico Sound Science Advisory Committee and EPA’s National Estuary Program, and both programs are considering its use for selecting cost-effective indicators. Since many programs are in the process of evaluating their indicators or developing new ones, the development of this taxonomy is timely.

#### *Message 2 - Estuarine Indicators*

Estuarine faunal indicators. Analyses of estuarine faunal data, and associated physical and chemical habitat, have been focused on exploring the relationships among local, watershed, and regional-scale indicators, as well as linkages between abiotic and biotic indicators. These abiotic predictors are easily measured and thus may serve as cost-effective indicators for targeting features for conservation or identifying areas that are likely to be degraded. For example, we collected data on blue crab abundance, as well as associated water quality, sediment type, physical habitat, and adjacent land use/land cover. Classification and Regression Tree (CART) analysis of these data showed that measured abiotic factors explained up to 51% of the variance

in blue crab abundance. The strongest predictors were salinity, watershed land-use and the percent cover of wetlands along the shoreline.

Macrobenthic community indicators. Two measures of biotic integrity of macrobenthic communities were developed for the nearshore estuarine environment: (1) benthic index of biological integrity in the nearshore (B-IBI<sub>N</sub>), and (2) the W-value, a statistical measure of abundance biomass curve comparisons. The B-IBI<sub>N</sub> is comprised of several community measures specific to habitat type stratified by salinity and sediment composition; this index was applied at a site level. The W-value represents the statistical relationship between abundance and biomass at a watershed level. These indices have primarily been applied to offshore waters (> 2 m), and have not been widely tested in nearshore shallow-water systems. Macrobenthic communities and habitat condition were surveyed at five sites in each of the 23 watersheds located within the oligomesohaline portions of estuarine segments. For both of the biotic indices, the highest scores were associated with forested watersheds. Nonparametric changepoint analysis indicated a significant reduction in B-IBI<sub>N</sub> and W-value scores when the amount of developed shoreline exceeded 10 % and developed watershed exceeded 12 %, respectively.

Fish community indicators. A Fish Community Index (FCI) was developed for nearshore fish; this index was used to look for correlations with easily observed watershed and shoreline conditions. The index is comprised of seven metrics of taxonomic richness and diversity, abundance, trophic composition and nursery function. Fish community assemblages and nearshore habitat were assessed at five sites in each of the 23 watersheds located within the oligomesohaline portions of estuarine segments. Biotic responses were correlated with habitat condition in the nearshore, riparian zone and watershed. FCI scores were lower in developed and agriculture watersheds than in watersheds dominated by forests, but there were also negative impacts associated with local land use patterns and within habitat conditions. The lowest average FCI scores were found in areas with highly altered shoreline conditions and minimal subtidal habitat.

Avian indicators. An Index of Marsh Bird Community Integrity (IMBCI) and an Index of Water Bird Community Integrity (IWCI) have been developed. The IMBCI was developed to provide insight into estuarine wetland condition. Bird communities were surveyed in 96 estuarine wetlands throughout the Chesapeake Bay. IMBCI scores at the subestuary level were then compared to wetland habitat characteristics and land use coverages at various scales to identify potential stressors. A threshold response to land use disturbance was observed: when 15% of the land within 500 m of a marsh was developed there was a significant decline in IMBCI scores. The IWCI scored waterbird communities within 28 subestuaries of the Chesapeake Bay in 2002 and 2003. IWCI scores were compared to other known indicators of estuarine condition and watershed land use coverages to identify potential stressors and their pathways. Index scores showed a significant decline when 3.5% of the land within 500 m of the subestuary shoreline was developed.

Wetland vegetation indicators. We examined relationships between watershed characteristics and the abundance and concentration of nitrogen in leaves of Common Reed (*Phragmites australis*) in 26 subestuaries of Chesapeake Bay. Nitrate concentrations in *Phragmites* leaves ranged from approximately 1.5 – 3.3% and concentrations were highest (2.5-3.3%) in leaves of

plants in subestuaries that received runoff from developed watersheds. *Phragmites* was also more abundant in wetlands that were in subestuaries that were downstream of watersheds that received runoff from developed watersheds. Further research is needed to establish the relationships between water quality and disturbance and the invasion and spread of *Phragmites* in brackish wetlands.

Landscape indicators - PCBs in White Perch. Using data collected in 2002, total PCBs in white perch were related to the amount and spatial arrangement of developed land in watersheds that discharge into 14 subestuaries of Chesapeake Bay. Simple regressions were used to test for relationships between unweighted or distance-weighted developed land-use measures, including four different representations of developed land. Total PCBs ranged from < 10 to more than 600 ng/g. Based on EPA guidelines, all subestuaries with > 4% distance-weighted commercial land in their watersheds are highly likely (95% probability) to have white perch with total PCBs that would result in a consumption advisory of no more than 1 meal of white perch per month.

Optical indicators. Activities in 2004 focused on analysis of data collected and refinement of the optical indicator developed during the prior two years. The indicator utilizes concentrations of optically active water quality parameters to determine whether sufficient light penetrates the water column for growth of SAV. Differences in indicator values between vegetated and non-vegetated sites were found to be attributable both to differences in water quality concentrations and to site-specific differences in mass-specific optical properties of the suspended particulate matter. Sites classified as developed watersheds consistently exhibited lower indicator scores, while forested and agricultural watersheds showed only minor differences. Due to the inferential design of the study, there are no clear ways to determine the mechanisms by which development alters the optical properties of the particulate matter. Predictions of the optical indicator were found to be consistent with the depth limits of the *Zostera* bed at Middle Marsh, as determined by investigators with the ACE-INC EaGLes center.

Nutrient indicators. Water quality data were analyzed to evaluate the relationships between the dominant type of watershed land-use and nutrient concentrations in water samples collected at multiple sites in each of 26 subestuaries of Chesapeake Bay. Watersheds that discharged into the subestuaries were classified, based on land-use composition, as being dominated by forests, agriculture, development, mixed-agriculture or mixed-development. In years with below (2002) and above (2003) normal precipitation, nutrient concentrations, especially nitrate and Total N were higher in subestuaries with watersheds dominated by development. Nutrient concentrations were low in all other subestuaries in the dry year. In the year with above average precipitation, subestuaries that received runoff from watersheds dominated by agriculture had higher nutrient concentrations also.

Stream indicators. We examined relationships between watershed characteristics and macroinvertebrate assemblages in the freshwater portion of estuarine segments in Maryland, using existing and new data collected in collaboration with the Maryland Biological Stream Survey. Stream biota was related to land-cover using an extension of the partial Mantel test and the spatial arrangement between land-cover and streams was analyzed with several techniques. Stream biota were found to be influenced directly and indirectly by many factors, especially watershed development. Biotic assemblages changed markedly between 21 and 32% watershed

development, and beyond 32% the probability was almost 100% that all streams would be biologically impaired. This number dropped to 18-23% when development near the stream was emphasized by using distance weights. The study demonstrated the complexity of relationships between land-use and their arrangement and stream biota. A threshold analysis showed that it takes relatively little development to drastically alter the species composition of stream macroinvertebrates.

### *Message 3 - Upstream Watershed Indicators*

Physical habitat/ landscape indicators. In Year 4, data collected in prior years using a new protocol for sampling streams, adjacent wetlands, and riparian areas – known as the “SWR protocol” - were used to create a composite assessment of condition for these three interrelated components of aquatic ecosystems. Values of the resulting “SWR Index” were then compared with Index of Biotic Integrity (IBI) values collected as part of the Maryland Biological Stream Survey for fish and benthic macroinvertebrates 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.

Physical habitat/ landscape indicators – NC variant. ASC researchers at East Carolina University developed a version of an integrative riparian assessment procedure for the North Carolina Ecosystem Enhancement Program (NCEEP). The procedure was based on the SWR protocol described above, and adapted for use in coastal plain watersheds. The procedure was tested in three NC watersheds, then applied by NCEEP in randomly chosen reaches of six watersheds. The data collected were used to diagnose problems in the watersheds, compare conditions among watersheds, and determine the precision of users in scoring indicators. Results are described in a report prepared for NCEEP.

Landscape indicators – nutrient discharge. An existing nutrient discharge model and GIS were used to explore the efficacy of geographic data (beyond physiographic province and land use/land cover) in predicting nutrient discharges. Factors considered include the spatial arrangement of landscape features, particularly source areas and riparian forests; the effects of improved hydrologic characterization; and the influence of wetlands.

At least one indicator – “percent source to buffer” - has evolved from this work thus far. This landscape indicator estimates the effective percentage of a source land cover type (e.g., cropland or developed land) in the watershed draining to a stream response point. It is calculated from digital land cover, elevation, and stream maps using a geographic information system (GIS). Within a watershed, all surface flow paths leading downhill from source areas to a stream are identified. Then, the area of uphill source area loading onto each flow path is divided by the length of riparian buffer that the flow path crosses. These effective areas are summed across all

flow paths, and then divided by total watershed area to yield an effective source area percentage. The percent source to buffer indicator was developed and tested for 503 small watersheds within 4 major physiographic provinces of the Chesapeake Bay drainage. Values of the metric were compared with more traditional riparian buffer measures, such as the percentage of forest within 100 m of a stream. Percent source to buffer was a stronger and more interpretable predictor of measured nitrate concentrations in streams than simple land cover proportion or traditional buffer measures, especially in the Coastal Plain physiographic province.

#### *Message 4 - Socioeconomic and Institutional Research*

Human Dimensions of Ecological Indicators. To gain a basic understanding of how ecological indicators are differentially perceived and labeled by policy makers, ecological scientists, and the general public, we conducted facilitated interviews with each of these groups over the course of this project. We interviewed 46 policy makers (primarily state and federal officials involved in water quality decision-making), and found that properties of useful indicators vary by what they are being used for: setting priorities, regulatory enforcement, monitoring and assessment, or communication to stakeholder groups.

We also conducted focus groups with ecological scientists to gain an understanding of their terminology, their assessments of ecological quality, and the data they utilize to create these assessments. To this end we conducted focus groups with ecologists at PSU, VIMS, ECU, and SERC.

Further, to help us understand watershed specific environmental quality, threats to current conditions, use patterns, and terminology, we conducted focus groups with the general public in six watersheds across the region (a subsample of those selected to subsequently receive a mail survey). These watersheds represent a broad range of ecological and socioeconomic conditions. A total of 53 members of the general public participated in these groups. We found that water quality is recognized as generally important to quality of life, but that there is low public awareness of “conventional” indicator terminology and relatively poor recognition of interconnections between land use and water quality.

These focus groups provided the basis and “ground-truthing” for developing a mail survey that helped us to understand quality of life and how it relates to use and perceived ecological quality of local watershed conditions, as well as how watershed quality is valued economically and potentially threatened by multiple factors. This survey was developed and pilot tested in 2004, and is currently being implemented in eight watersheds in the Atlantic Slope Region. Several of these (Spring Creek, n=550 and Clearfield Creek, n=435) are nearing completion. Several others (Ware River, n=392 and Chickahominy River, n=560) are just underway, with mailings in 4 other watersheds still to be implemented during the summer of 2005. Data from these surveys will be compiled and analyzed in fall 2005.

Institutional Issues and Water Quality Indicators. During 2004, a final focal area for the Socioeconomic and Institutional Research working group has been an examination of the role of federal and state laws and institutions in shaping the choice and use of indicators. A paper

describing the results of this research has recently been accepted for publication in the Columbia Journal of Environmental Law.

### **Future Activities**

The final year of the project will be devoted to completion of remaining analyses, continued preparation and submittal of manuscripts, research presentations at conferences, and preparation of 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.)

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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.)

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Bilkovic, D.M., C.H. Hershner, M.R. Berman, K.J. Havens and D.M. Stanhope. 2004. Evaluating Nearshore Communities as Indicators of Ecosystem Health, *In Estuarine Indicators*, Stephen Bortone, ed., CRC Press, Inc., p. 365-379. <http://ccrm.vims.edu/eagles/estuarineindicators.html>

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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.)

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Gallegos, C.L., Jordan, T.E., Hines, A.H., Weller, D.E., 2005. Temporal variability of optical properties in a shallow, eutrophic estuary: Seasonal and interannual variability. *Estuarine, Coastal and Shelf Science* in press.

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Hershner, C., K. Havens, D.H. Wardrop and D.M. Bilkovic. December 2004. A Practical Concept for Developing Indicators of Aquatic Ecosystem Health. *Submitted to EcoHealth*

Jamro, E, R. Stedman, J. Shortle and others. Correspondences between perceived and measured environmental condition and environmental stressors. (in prep.)

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### *Presentations*

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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.

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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.

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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.

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Bilkovic, D.M., C.H. Hershner, M.R. Berman, K.J. Havens, D.M. Stanhope and L.Varnell. September 30 - October 01, 2004. Evaluating Estuarine Indicators of Ecosystem Condition in the Nearshore of Chesapeake Bay. 4<sup>th</sup> Annual Estuarine and Great Lakes Indicator Development (EAGLE) meeting in Duluth, MN.

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Unit within the Coastal Plain of Virginia, USA. ECSA37-ERF2004. Ballina, New South Wales, Australia. June 20-25, 2004.

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Whigham, D.F., R.S. King, W.V. DeLuca, D.M. Bilkovic, P.P. Marra, A.H. Hines, D.E. Weller, M.E. Baker, T.E. Jordan and C.L. Gallegos. 2005. Linking catchment land-use patterns to estuarine condition. U.S.D.A. Continuing Education Course, SERC, Edgewater, MD. April, 2005.

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Whigham, D.F., R.S. King, W. DeLuca, and P.P. Marra. 2005. *Phragmites australis* in Chesapeake Bay estuarine wetlands – linkages to past and present watershed activities. INTECOL-ESA meeting. Montreal, Canada. August 2005.

**Supplemental Keywords:** indicators, integrated assessment, aquatic ecosystem, wetland, stream, estuary, watershed, biological integrity, landscape ecology, scaling, socio-economic, decision-making, GIS, Mid-Atlantic.

**Relevant Web Site:** [www.asc.psu.edu](http://www.asc.psu.edu)

Attachment 1.

## **Atlantic Slope Consortium Synthesis Report Outline**

**Title:** Ecological and Socioeconomic Indicators of Condition for Estuaries and Watersheds of the Atlantic Slope

### **ASC Executive Summary**

Premise

Concept Framework

Formulating Indicators

Completing the Vision

### **Synthesis Report – Management Team**

Introduction - **Denice**

- EPA EaGLE STAR Program
- Atlantic Slope Consortium

Premise - **Denice**

- Project/Team Vision
- Ah Ha!
  - Multiple reference benchmarks needed
  - Indicators needed at multiple scales because are multiple management, manager scales
  - Humans part of, not apart from, the environment
  - Condition is multifaceted (not just ecological indicators)
  - Coastal systems are not independent of their watersheds
- Describe and define Social Choice/Societal Desires
- KEY – Tell A Story

Message 1 – **Carl & Denice**

- Framework and Building Blocks
- Taxonomy Development
- Criteria for Populating the Frame
- Application and “Proof of Concept”

Message 2 – **Dennis (w/ Denice)**

- Extract from Dennis’ Frontiers in Ecology
- Extract from Donna
- Extract from Chuck

Message 3 – **Rob & Mark**

- SWR Index

- Groundbased Level II
- Landscape Level I
- Don/Matt Modeling
- Fills critical need – Links Aggregate Social Choices with Societal Desired Uses

Message 4 – **Kent & Jim**

- Indicators Useful To Managers
- Frontier Analysis
- Watershed Resident Survey

Next Steps - **Kent**

- Linking Watersheds to Estuaries Through Large Rivers
- Moving Toward Adaptive Management
- Managing Sustainably

**Technical Reports (as enclosed CD) – Mary (compilation)**

Compilation of PI Publications

One-pagers of indicators summaries (see attached template)

Attachment 2.

LIST OF ASC INDICATORS

1. Nitrate concentrations in streams on the Coastal Plain of Chesapeake Bay
2. Macroinvertebrate assemblages in streams
3. Bio-optical model for determining habitat suitability for submerged aquatic vegetation (SAV) in estuarine segments of Chesapeake Bay
4. Abundance of Common Reed
5. Polychlorinated biphenyls (PCBs) in White Perch
6. Index of Marsh Bird Community Integrity (IMBCI)
7. Blue crab (*Callinectes sapidus*) abundance
8. Nitrate, Total N and Total P concentrations in subestuaries of Chesapeake Bay
9. Percent source to buffer (riparian buffer metric)
10. Index of Waterbird Community Integrity (IWCI)
11. Stream – Wetland – Riparian (SWR) Index
12. Landscape-level Riparian Index
13. NC Variant of SWR Index
14. Fish Community Index (FCI)
15. Macrobenthic Community Indices (B-IBI, W-value)
16. Shoreline Survey of Estuary
17. Impervious Cover
18. Marshbird Community Index
19. Socio-economic Distance Indicator
20. Environmental Quality of Life Indicator
21. Economic Quality of Life Indicator

ADDITIONAL TOOLS and METHODOLOGIES

1. Indicator Taxonomy
2. Geographic models (SERC)
3. Statistical models (PSU)
4. Frontier analysis/ Data Envelope Analysis
5. Stream-Wetland-Riparian assessment - 3 levels

Figure 1. ASC Indicator Taxonomy

