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Center: The Atlantic Slope Consortium - Developing Ecological Indicators for Aquatic Ecosystems of the Atlantic Slope Region
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Title: Integrated Assessment of Watersheds
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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 will be discussed below.

1. Penn State Watershed Team

Compilation of Existing Biological Data Sets: To enhance our ability to make cross comparisons among site-specific biological, chemical, and physical habitat data, and landscape-level GIS data as predictors of ecological condition, we identified and compiled information on existing biological data sets in the Atlantic Slope region. These consisted most commonly of benthic macroinvertebrate and fish data, but algae, mollusks, birds, amphibians, and other taxa were sometimes sampled. The availability of corresponding habitat and water chemistry data was also determined. Data sources included federal and state programs, river basin commissions, and miscellaneous sources (e.g., universities, local studies).

Geographic coordinates were obtained for all sample sites. Information on site selection criteria, sampling methods and parameters measured were also noted. Data sets were then generally grouped according to their quantity and quality of data. This information was used in the watershed selection process (described below) to target watersheds with an abundance of existing high quality data points.

Watershed Selection: A watershed classification completed near the end of Year 1 was used as a starting point for selecting a subset of watersheds in the ASC study region for intensive study. The classification was developed using cluster analysis to group together watersheds with similar influences on their aquatic resources (in this case, landcover and slope characteristics). The clusters were further partitioned by physiographic province to reflect natural variation in aquatic systems due to edaphic, geologic and climatic characteristics. The goal was to select approximately 20 representative watersheds of the 3000+ in the study region for intensive study and additional field data collection. GIS was used as a tool to overlay the geographic locations of existing biological sample points with watershed cluster membership and physiographic province boundaries. Candidate watersheds were then selected visually, with consideration given to factors such as the quantity, quality, and location (e.g., headwaters vs. downstream) of existing data points, the geographic dispersion of watersheds, stream size, and known impacts. Where multiple candidate watersheds existed of roughly equal quality, we selected randomly among them.

The PSU watershed group was asked by the Chesapeake Bay Program (CBP) to apply their watershed classification system at a larger (HUC-8) watershed unit. Analyses were rerun using a watershed delineation supplied by the CPB. The results of this classification are expected to appear on the CPB web site, and be used in future analyses. PSU plans to compare the results of the two analyses to examine the effect of scale on the outcome.

Hotspot Analysis: We continue to pursue unique statistical methodologies to explore relationships between landscape and site-specific data, and how these relationships change across a variety of spatial scales. Collaboration between PSU statisticians and ecologists occurred in a series of documented weekly meetings during the winter, spring, and summer of 2002. One product of this effort was the use of SATScan software (downloaded from the National Institutes of Health) to recognize critical areas, or hot spots, of human disturbance and watershed vulnerability. The scan statistic was originally developed for geographical surveillance of disease, and has performed well during a robust testing effort. The scan statistic was adapted for use in regional environmental and ecological settings by PSU/ASC investigators (Myers et al., 2002; Patil et al., 2003). The result was a map of statistically derived first-level and second-level critical areas (i.e., hotspots within hotspots), which can then be compared to existing biological data. Refinement of this tool is continuing, and it appears to hold great promise in future indicator testing efforts.

Bird Community Index: A recently completed Bird Community Index (BCI) for the mid-Atlantic Highlands is being calibrated for use in the Piedmont and Coastal Plains with data collected for 83 sites during 2001. The BCI will be used as an indicator of condition across broad landscapes for these two ecoregions.

2. 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 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 discharges. Factors considered included different land cover data sets, soil properties, and improved hydrologic characterization.
(2) Incorporating information about the spatial arrangement of landscape features, particularly source areas and riparian forests, to test hypotheses about nutrient and sediment transport. Factors considered include the effect of stream map resolution on riparian buffer summaries, the effects of spatial arrangement of source areas, and the effects of improved mapping/characterization of riparian buffers

Research activities in Year 2 included:

- Exploring effects of different land cover data sets on predictions of nutrient discharge. Preliminary results suggest that different land cover data sets can have a significant impact on the relative proportions of land cover classes and resulting relationships with measured nutrient concentrations.
- Exploring the relationship among soil properties and nutrient discharge. We found that soil properties added predictive power to our nutrient models, though potential covariance with other predictors requires further exploration.
- Exploring the effects of improved hydrologic characterization on predictions of nutrient export. We discovered that watershed morphologies differed significantly across physiographic regions of the Atlantic Slope, that to varying degrees these differences were expressed via water yields and drainage networks, and that such differences have implications our interpretation of nutrient export across the entire study area.
- Evaluating the effect of stream map resolution on riparian buffer summaries. Stream map resolution had a highly significant impact on the areal extent of near-stream lands considered in our riparian metric analysis, though the effect of increasing resolution differed across physiographic regions.
- Exploring the effects of spatial arrangement of source areas on nutrient discharge. Distance weighting analyses revealed both that certain weighted land cover summaries were far better predictors of observed nutrient concentration than others, though these relationships require further exploration.
- Exploring the effects of improved mapping/characterization of riparian buffers. Although riparian metrics are still in development, preliminary analyses suggest that certain metrics were uncorrelated with land cover estimates and accounted for otherwise unexplained variance in nutrient concentrations.

4. ECU Watershed Team

In addition our involvement with identifying appropriate indicators, and developing and field testing data sheets, we contributed to developing a hierarchical classification framework for all wetlands in the Atlantic Slope. Geomorphic position and hydrologic regime provided the foundation of the classification's hierarchy. This was a joint effort among all ASC member institutions and working groups.

A graduate student thesis project, conducted by Chris Bason, has been characterizing beaver ponds as a subclass of headwater riverine wetlands in the Neuse and Tar River watersheds. Because of the extent of beaver alteration of both natural and altered headwater streams and wetlands, this subclass is an important component of our study area. His field work is nearly complete, and data are being analyzed.

5. GIS Team

Over the past year, geographic datasets covering the Atlantic Slope region were acquired from ASC partner organizations, federal agencies, and other sources, updated, edited and re-projected when necessary, and made available to the ASC team members for download. Currently, the data reside on a password protected ftp server at http://www.asc.psu.edu/data.html but all ASC project members and partners are provided with access to the data, both interim and final.

Datasets currently available at the ASC Web site include, but are not limited to, boundary layers of physiographic provinces, geologic formations, watershed ecoregions, and soils; rasters of land use/land cover distributions (NLCD) and DEMs, demographic and socio-economic data information (2000 Census), and hydrology (stream layers). The Pennsylvania Spatial Data Access (PASDA) at Penn State has been working with the Chesapeake Information Management System (CIMS) committee to provide an integrated access point for all data within the Bay region. PASDA provided information to CIMS regarding ASC activities and will be working to acquire relevant data to support the ASC project objectives.

6. Multi-institutional Activities

In a collaborative effort, PSU, SERC, VIMS, and ECU developed and pilot tested a protocol for sampling Stream, Wetland, and Riparian (SWR) areas. The information collected will give an on-the-ground, rapid assessment of watershed condition, which will be used to verify and calibrate assessments performed using remote sensing. The three main components were: 1) classification of the aquatic resources along a specific reach of stream, 2) vegetative and hydrologic characterization of these areas, and 3) identification of site stressors.

Development of the SWR protocol included a series of meetings and field visits involving representatives of each core group of the ASC project. A pilot study was performed in the late summer/fall of 2002, where 2 to 38 sites were sampled in each of 5 watersheds located in different parts of the study region. A stratified random sampling approach was used to select sample sites. Following the pilot study, the protocol was evaluated and revised.

Work continued on developing a hierarchical classification framework for all wetlands in the Atlantic Slope, following the conceptual model used in wetland hydrogeomorphic classifications. A draft classification and accompanying manuscript have been prepared, and are being finalized and reviewed by the co-authors. This paper will be submitted for publication. This was a joint effort among all ASC member institutions and working groups.

We are also working toward integrating three main areas of our analyses. These are (1) integration of upstream watersheds with downstream estuaries and, related to that, (2) integration

across geographic scales. Several activities are underway in this area. The SERC nutrient discharge model described above will be used to provide expectations for the estuarine study. In addition, the SERC wetland/stream team anticipates integrating with the Penn State GIS team to explore the relationship between their Level 1 spatial assessments and the SERC stream assessments. This integration will be one of the key pieces of information that will link Penn State's data from non-estuarine small watersheds to SERC's estuarine segment data. Additional examples of this type of integration can be found in other sub-reports.

A third important area of integration is in evaluating indicators. We plan to apply EPA's approach described in *Methods for Evaluating Ecological Indicators* (Jackson et al., 2000) for this purpose. Testing of this method is planned for April 2003. Information produced by the Human Dimensions group will also be applied to indicator evaluation.

Publications and Presentations

Publications

Patil G.P., R.P. Brooks, W.L. Myers, D.J. Rapport, and C. Taillie. 2001. Ecosystem health and its measurement at landscape scale: Towards the next generation of quantitative assessments. *Ecosystem Health* 7(4): 307-316.

Patil G.P., R.P. Brooks, W.L. Myers, and C. Taillie. 2002. Multiscale advanced raster map analysis system for measuring ecosystem health at the landscape scale: A novel synergistic consortium initiative. In *Managing for Healthy Ecosystems*, D. Rapport, W. Lasley, D. Rolston, O. Nielsen, C. Qualset, and A. Damania. CRC Press/Lewis Publ. (In press).

Wardrop D.H., J.A. Bishop, M. Easterling, K. Hychka, W. Myers, G.P. Patil, Charles Taillie, and R. P. Brooks. Characterization and classification of watersheds by landscape and land use parameters in five Mid-Atlantic physiographic provinces. *Journal of Environmental and Ecological Statistics*. In press.

Presentations

Patil G.P., J. Bishop, W.L. Myers, C. Taillie, R. Vraney, and D.H. Wardrop. 2002. Detection and delineation of critical areas using echelons and spatial scan statistics with synoptic cellular data. Invited Paper, International Society for Ecosystem Health, Washington, DC. http://www.stat.psu.edu/~gpp/PDFfiles/TR2002-0501.pdf

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Wardrop D.H., J.A. Bishop, M. Easterling, K. Hychka, W.L. Myers, G.P. Patil, and C. Taillie. 2002. Use of landscape and land use parameters for classification and characterization of watersheds in the Mid-Atlantic across five physiographic provinces. Healthy Ecosystems,

Healthy People Conference, International Society for Ecosystem Health, Washington, DC, June 2002. (Invited paper).

Wardrop D.H., J.A. Bishop, M. Easterling, K. Hychka, W.L. Myers, G.P. Patil, and C. Taillie. 2002. Use of landscape and land use parameters for classification and characterization of watersheds in the Mid-Atlantic across five physiographic provinces. Invited Paper, International Environmetrics Society, Genova, Italy.

Future Activities

Additional field sampling using the revised SWR protocol will take place during spring/summer 2003 in approximately 20 watersheds. Integrated analysis will be undertaken of existing biological, chemical, and habitat data, and new data collected as part of the SWR sampling. These analyses will be coordinated with those of SERC's watershed team and with those of the Estuarine Working Group to examine linkages between upstream and downstream conditions. The relationship between site-level and landscape-level indicators will also be explored.

Analyses begun in Year 2 by the SERC Watershed and Spatial Analysis Team will be continued in Year 3. In addition, plans include: (a) Develop topographically based predictions of wetlands, wetland type, hydrologic character, and spatial arrangement; compare with NWI maps in predictions of nutrient discharges, (b) Use wetland predictions and groundwater flux predictions to improve identification of active riparian buffers, (c) Compare summaries of active buffers with existing riparian summaries techniques, and (d) Test the effect of additional watershed descriptors such as impervious surface, septic density, and population density. The resulting improved statistical models will be used to provide expectations for the estuarine component of this study.

Supplemental Keywords: ecological indicator, integrated assessment, aquatic ecosystem, wetland, stream, riparian, watershed, biological integrity, landscape ecology, scaling, GIS, Mid-Atlantic.

Relevant Websites: www.asc.psu.edu