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Center Director: Robert Brooks
Title: Integrated Assessment of Estuarine Ecosystems
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Research Category: Environmental Indicators

Objective

This is one of four subprojects under the Atlantic Slope Consortium (ASC) center. The overall objective of the estuarine component of the ASC is to develop indicators for elements of hydrologically linked estuarine ecosystems, including aquatic animals, estuarine and coastal wetlands, and coastal waterbirds. The development and testing of biotic indicators will be conducted in two types of sampling units. *Estuarine wetlands/nearshore shallows,* which are units analogous to small watersheds, are being sampled to develop and test Indices of Biotic Integrity (IBIs) for aquatic fauna and Habitat Suitability Indices (HSIs) for species that use these habitats. *Estuary segments*, which are large units that include deepwater habitats, will be used for developing HSI models for highly mobile species, where direct sampling of organisms is difficult and data are often unreliable.

Progress Summary

This sub-project has been broken down into a number of interactive teams, each focusing on a different component of the estuarine system. Activities of each of these teams will be discussed below.

1. Estuarine faunal team (SERC): Hines, King, Craige, Sparks. 2002 Interns: Sean Sipple, Sarah Grap, William Jackson, Ben Carswell.

1.1. Data collection and analysis
The goal of the estuarine faunal team is to identify attributes of biological assemblages and related abiotic factors that can be used to assess condition of an estuarine segment. The focus during summer 2002 was to characterize fish and benthic invertebrate assemblages and their environments among the subestuaries of 19 SERC estuarine segments.

The upper regions of each subestuary were targeted for sampling to increase the likelihood of detecting watershed–estuary linkages. Sampling stations were stratified by landuse in proportion to shoreline landuse, as computed in GIS. Following a pilot study to determine the appropriate

level of sampling effort for each station, a total of 114 stations were sampled in the 19 segments in July and August. The following data were collected in the field or will be generated following laboratory analyses during winter 2002 and spring 2003: (a) water quality measurements, (b) sediment texture, (c) landuse, bank condition, and habitat, (d) fish and other macrofaunal assemblages, and (e) benthic invertebrate assemblages.

A preliminary analysis of station assessment data, bivalve data from benthic cores, and fyke-net data using Classification and Regression Tree (CART) analysis has indicated that shoreline wetlands and watershed land-use may have important effects on species along the estuarine salinity gradient.

1.2. Synergy and integration with other working groups and institutions

The SERC estuarine team has been working closely with the VIMS estuarine team of the ASC to coordinate estuarine sampling methods and develop and implement a shoreline assessment plan, so that many data will be compatible for integrated analyses and publications. To further integration, a subset of estuarine segments is being studied by both VIMS and SERC. This overlap will allow comparison of indicators developed by each institution and ultimately link results among all estuarine segments. Moreover, these data are compatible with many existing datasets, which will allow both groups to apply existing indexes of estuarine condition as well as link to data spanning much larger spatial scales.

GLEI, which is probably the most similar of the five EaGLe projects to SERC in their field approaches to indicator development, has been very helpful in providing SERC's estuarine faunal team with lists of indicators and protocols for several of their field methods developed during Year 1. As data analyses progress, SERC and GLEI will be in position to contrast similar indicators between two very different estuarine environments.

The SERC estuarine working group has also been active in developing other synergistic relationships. In Maryland, the SERC team has collected white perch tissue that will be analyzed for PCB's by the Maryland Department of the Environment (MDE). These data will be useful to both the MDE and the ASC project. In another example of synergistic activity, a SERC intern studying predation rates on juvenile blue crabs as part of a separately funded project, coordinated his sampling with the SERC estuarine team's fish and invertebrate collections, which provided estimates of predator abundance.

2. Avian Research Team (SERC): Marra, DeLuca, Studds.

2.1. Data collection and analysis

The goal of the avian research team is to develop indicators of estuarine condition using individual, population, and community-level attributes of wetland bird assemblages. To this end, a large amount of effort was put forth into sampling the estuarine segments in Year 2. The types of sampling undertaken included: (a) point count surveys, (b) intensive quantitative sampling, (c) water-foraging bird surveys, and (d) avian habitat sampling. In addition, vegetation measurements were taken at each of the 108 point-counts. Measurements included species composition, horizontal structure, and vertical structure.

The avian team has completed data entry and quality-assurance checks and is presently analyzing data. As part of his Master's thesis, Bill DeLuca has put considerable effort into developing a Wetland Bird Index of Biological Integrity (IBI). Preliminary results suggest that land use in relatively close proximity to the wetlands is most strongly correlated to the IBI, while least correlated at the scale of the complete watershed.

2.2. Synergy and integration with other working groups and institutions
The SERC avian team and the SERC estuarine faunal team have been coordinating all of their efforts. In Year 2, both teams sampled the same estuarine segments to facilitate integration of indicators. One planned integration between these groups is the linking of water-foraging bird data to fish abundance estimates.

The SERC avian team has also been working closely with Tim O'Connell from the PSU watershed group. Tim has provided expertise on avian IBI development and both groups have discussed ways to integrate their IBI results from a variety of different habitats.

3. Wetland and Stream Assessment Team (SERC): Whigham, King, Sparks. Intern: Sipple.

3.1 Data collection and analysis.
The primary objectives of this research team are to: (a) develop indicators of watershed condition and aquatic health using site-level abiotic and biotic attributes of riparian corridors, wetlands, and coastal streams, (b) develop quantitative relationships between site-level measurements and Level 1 landscape assessments, which will largely be conducted by Penn State and the Watershed/Spatial Analysis team, and (c) link watershed indicators to estuarine condition.

To these ends, the SERC wetland/stream team participated in a number of research activities during Year 2.

A. *Stream bioassessments*: As part of a collaborative effort with the Maryland Department of Natural Resources (MD DNR), SERC sampled 60 streams from the 19 estuarine segments in spring of Year 2 using protocols developed for the Maryland Biological Steam Survey (MBSS). SERC is using the MBSS data set to characterize the condition of streams in the estuarine segments, and to calculate the Coastal Plain benthic IBI.

B. *Wetland vegetation sampling.* Data on macrophyte species composition in brackish wetlands collected by the SERC avian team will be used by the SERC wetland/stream team to develop wetland vegetation indicators. *Phragmites* leaf samples will be analyzed for nutrients and metals to help identify potential causes of *Phragmites* expansion.

   Preliminary results indicate that N and P concentrations in *Phragmites* are highly elevated in developed estuarine segments, but are similar among forested, mixed land use, and agricultural segments. A similar trend was observed in the water chemistry data, suggesting that the drought experienced across the region in Years 1 and 2 may have reduced watershed discharges and nutrient loads typically linked to nonpoint sources (e.g., cropland), while increased the relative importance of point sources (e.g., sewage effluent) in developed segments. However, this hypothesis needs further testing.

C. *Riparian assessments*. Two meetings were held at SERC to develop a unified field protocol for conducting riparian, wetland, and stream condition assessments for all ASC personnel. SERC then tested the preliminary field protocol in the Southeast Creek and Back River estuarine segments.

3.2. Synergy and integration with other working groups and institutions

The SERC wetland/stream team is working closely with the SERC watershed/spatial analysis team to develop linkages between spatial data and site-level stream assessment data. One current activity is the application of a variety of distance-weighting schemes to landcover data to identify the most influential scales and patterns of watershed landcover on stream biological condition. A second planned activity is the integration of results from the SERC spatial team's nutrient export models with the SERC wetland team's *Phragmites* nutrient data.

The SERC wetland/stream team also 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.

Within the subestuary portion of the estuarine segments, SERC's wetland team will integrate the site-level *Phragmites* data with VIMS' extensive shoreline assessment data documenting both the linear extent of shoreline wetland habitat as well as the presence and extent of *Phragmites*. Ultimately, these data will allow the concatenation of the SERC spatial team's watershed models, the SERC wetland and avian teams' site-level data on *Phragmites* invasion and nutrient content, the SERC faunal team's site-level water quality data, and the VIMS shoreline assessment of *Phragmites* invasion.

A significant synergistic activity outside the ASC has been the collaboration with the MD DNR and the integration with the MBSS, as previously described. MD DNR has provided guidance on using much of the public-domain data and has been quick to provide SERC with in-house data not yet publicly available. This working relationship has been mutually beneficial.

4. Estuarine Shallow Water Fish Team (VIMS)

Our approach is to sample selected HUC units within shallow reaches of mainstem estuary systems, to characterize fish habitat (structural components and water quality), fish communities, and prey communities (benthic and zooplankton). Indicators based on characterizations will be developed and assessed, such as Habitat Quality Indices and Indices of Biotic Integrity (IBI) for estuarine fish communities in the Mid-Atlantic Slope.

During June-August 2002, we surveyed 16 watersheds with varying land use within the Chesapeake Bay estuarine region. Our sampling protocols targeted zooplankton, macroinvertebrate and fish communities, water quality measures, sediment type, and shoreline and physical habitat assessments. Within each watershed we sampled five sites, which corresponded with historic beach seine locations when present.

Fish, macroinvertebrate and zooplankton communities were quantified with count and biomass values. Suspended sediment analyses and sediment typing were completed. Data preparation for calculations of fish and benthic community indices is complete.

Several current and potential indicators that describe fish community and habitat condition were preliminarily examined for applicability over spatial scales (site—watershed level) in three major tributaries of the Chesapeake Bay.

Preliminary indices assessments from recently acquired 2002 field data and historic datasets on fish, benthic and zooplankton communities in shallow estuarine waters were presented at the annual Atlantic Slope Consortium (ASC)-EPA Estuarine and Great Lakes Indicator Development (EAGLE) meeting in Williamsburg, VA, November 2002.

5. Wetland Assessment Team (VIMS)

A three-level protocol for wetlands assessment has been developed at VIMS. The protocol focuses on identification of potential aquatic system stressors and restricts structural observations to only a few parameters. The level I assessment involves comprehensive coverage of all mapped wetlands, achieved with a GIS based analysis of remotely sensed information. It provides a first order evaluation of the condition and functional capacity of wetlands based on their landscape position. The level II assessment uses an analysis of a digital ortho quarter quad (DOQQ) for the site and an on-site evaluation of identified stressors. This approach allows for differential weighting of the various stressors based on their presumed deleterious effect and proximity to the wetland. The on-site (Level III) assessment is conducted to validate the stressor relationships to aquatic health, and includes identifying stressors involving hydrologic modification, toxicity/ acidification/ nutrification, distance from human activity, sedimentation and channel alteration, and vegetation alteration.

During June-October 2002, 16 wetlands with varying land use were surveyed within the Ware River watershed in the Chesapeake Bay estuarine region using the VIMS protocol.

Reference sites will be intensively studied to determine stressor impacts on both the amphibian and avian community. Data will also be collected on plant communities and water quality. Multivariable analysis will be used to compare avian and amphibian population dynamics and concentrations of dissolved nitrogen and phosphate species among wetlands with different stressor levels.

Publications and Presentations

Publication

King, Ryan S. and C. J. Richardson. 2003. Integrating bioassessment and ecological risk assessment: an approach to developing numerical water-quality criteria. *Environmental Management* (in press).

King, Ryan S., M. E. Baker, D. F. Whigham, D. E. Weller, and T. E. Jordan. Spatial considerations for linking watershed landcover to ecological indicators in streams. Invited manuscript to be published in special issue of *Ecological Indicators*.

Presentations

Baker, Matthew E., D. E. Weller, and T. E. Jordan. 2003. Effect of distance-weighted source areas in geographic predictions of nutrient discharge from coastal-plain watersheds. To be presented at the 51st Annual meeting of the North American Benthological Society, Athens, Georgia, May 2003.

Baker, Matthew E., D. E. Weller, and T. E. Jordan. 2003. Effect of distance-weighted source areas in geographic predictions of nutrient discharge. To be presented at the 18th Annual Symposium of the International Association for Landscape Ecology-US Chapter, Banff Centre, Canada, April 2003.

Bilkovic, D.M. and C.H. Hershner. 2002. The applicability of ecological indicators for assessment of fish habitat in the Mid-Atlantic Slope across spatial scales. American Society of Limnology and Oceanography annual meeting, Victoria, British Columbia, June 2002.

Grap, Sarah, R. S. King, F. D. Craige, and A. H. Hines. Factors influencing the distributions of blue crabs and bivalves in subestuaries of Chesapeake Bay, USA. To be presented at the Benthic Ecology Meeting 2003, Groton, CT, March 2003.

King, Ryan S. and C. J. Richardson. Detecting changepoints in biological attributes: an approach to developing numerical water-quality criteria. Presented at the 50th Annual Meeting of the North American Benthological Society, Pittsburgh, PA. May 2002.

King, Ryan S., M. E. Baker, D. F. Whigham, D. E. Weller, and T. E. Jordan. 2003. Spatial considerations for linking watershed landcover to ecological indicators in streams. Invited paper to be presented at the 6th International Association for Landscape Ecology World Congress, Darwin, Australia, July 2003.

King, Ryan S., M. E. Baker, M. Hurd, P. F. Kazyak, D. F. Whigham, D. E. Weller. 2003. Spatial factors influence linkages among watershed landcover, environmental conditions, and macroinvertebrate assemblages in coastal-plain streams. To be presented at the 51st Annual meeting of the North American Benthological Society, Athens, Georgia, May 2003.

Weller, Donald E., S. Walters, T. E. Jordan, and S. D. Prince. 2003. Effects of land cover uncertainty on models predicting watershed nutrient discharges. Presentation at the 18th Annual Symposium of the International Association for Landscape Ecology-US Chapter, Banff Centre, Canada, April 2003.

Whigham, D.F., M. Leck, and R. King. 2003. Plant species diversity in tidal freshwater and tidal brackish wetlands of the mid-Atlantic coast. To be presented in the symposium on

'Coastal Wetland Vegetation as a Harbinger of Environmental Change'. Conservation Biology annual meeting. Duluth, MN, June 2003.

Future Activities:

Estuarine Faunal Team:
Spring of Year 3 will be used to finish processing benthic samples, data entry and QA/QC, completion of a SERC estuarine-segment database, data analyses, and preparation for the Year 3 field season. Year 3 will be used to re-sample the nine "intensive" estuarine segments to allow assessment of year-to-year variation in indicators and implications for indicator development. Bottom trawl sampling will also be undertaken in these nine segments. In addition, 13 estuarine segments that were not sampled in Year 2 will be added.

Avian Team: Year 3 will be used to re-sample the nine intensive estuarine segments, which will allow an assessment of year-to-year variation in indicators and implications for indicator development. In addition, 13 estuarine segments that were not sampled in Year 2 will be added. Spring of Year 3 will largely be dedicated to preparing a manuscript on the Wetland Bird IBI.

Wetland and Stream Assessment Team:
Stream bioassessment sampling in Year 3 will follow the plan developed in Year 2. Using the MBSS protocol, approximately 60 additional streams will be sampled in Year 3 in 13 new estuarine segments; re-sampling will occur in a few streams in the nine intensive segments to assess year-to-year variation. *Phragmites* sampling in Year 3 will also follow the field plan used in Year 2. SERC is planning to hire a temporary biologist to conduct riparian assessments in a few selected estuarine segments. This work will be coordinated with Penn State's GIS team to identify sampling locations and ultimately develop a linkage to their Level 1 assessment. During spring and summer of Year 3, the SERC wetland/stream team will prepare two manuscripts using the MBSS dataset.

Estuarine Shallow Water Fish Team: Twelve watersheds have been selected for survey in the summer of 2003 following similar protocols as 2002. Of these watersheds, two that were sampled in 2002 and will be reassessed in 2003 due to the lack of historic data in these regions. Watershed sampling locations will be in estuarine segments of Maryland, Virginia and North Carolina. Many of the watersheds selected will coincide with efforts at SERC and Penn State in assessing the health of estuarine wetland systems.

Supplemental Keywords: ecological indicator, estuary, wetland, fish, invertebrates, zooplankton, birds, vegetation, *Phragmites*, IBI, HSI, water quality

Relevant Websites: www.asc.psu.edu