Watershed Assessment and Decision Support Tools: e-Estuary – A Decision-Support System for Coastal Managers (WQ MYP)

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AED Peer Review '07

Agency Problem

Watershed and coastal zone management are supported by multiple Clean Water Act (CWA) programs and the Coastal Zone Act Reauthorization Amendments (e.g., NonPoint Source program in Section 6217), and require the integration of regulatory and nonregulatory programs. EPA's Office of Water is evolving to a more pro-active approach to manage environmental problems than is typical of the Section 303(d) process (*Watershed Protection Approach Framework*, 1991). Watershed and ecosystem-based management approaches are more integrative and comprehensive than the stressor-by-stressor approach supported by individual chemical water quality criteria and the traditional Total Maximum Daily Load process. This new approach also typically involves engagement of multiple stakeholder groups in planning and adaptive management at all scales (township, estuary, watershed, state, regional). In response, our research and development approach will provide technical support for managers in their development and implementation of watershed and coastal management plans at multiple scales.

Research Goals

Our framework builds upon existing conceptual models to explain differences in response across systems using classification strategies and site-specific diagnostic tools. Our specific objectives are to:

- Develop a supporting information management framework for estuaries and coastal watersheds that is compatible with ongoing initiatives within the Agency
- Develop and test classification frameworks for coastal watersheds, estuaries, and estuarine segments that facilitate extrapolation of results across systems
- Test segmentation schemes for improved listing, assessment, and management of impaired waters in estuaries
- Provide scientific basis for refining aquatic life designated use(s) and developing the tiered aquatic life use framework for estuaries
- Partition effects of multiple stressors to prioritize management actions for regulatory vs. nonregulatory programs
- Support technical transfer of information and tools to coastal management groups, including collaborative development of tools with local or regional pilot projects.

Conceptualize → Demonstrate → Extrapolate → Visualize/transfer

Stakeholder Groups

Science Inputs

Tools

The basic conceptual model includes three elements: Residence time, Type A modifying factors that determine bioavailability, and Type B modifying factors that alter the relationship between the stressor and the response. Four canonical forms of this model are shown above.

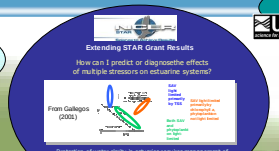
Conceptual Models

US EPA Landscape Predictive Tools Workgroup

A common geospatial framework for organizing, sharing, interpreting, analyzing, and transferring information on coastal systems to clients for environmental decision-making

Monitoring, information mgt., and visualization tools (see related posters)

Site-Specific Diagnostic Tools (see related posters)



Protection of water clarity in estuaries requires management of multiple water quality parameters, i.e., nutrients, turbidity, and water color. Graphical tools have been developed and applied to a small set of estuaries. With appropriate calibration, these approaches could be extended to a much larger suite of systems.

US EPA National Estuarine Experts Workgroup(s)

USGS

(1)

Which estuaries are likely to respond to pollutant loadings or restoration actions similarly to my estuary? How can I identify an appropriate reference estuary or habitat for comparison with my system?

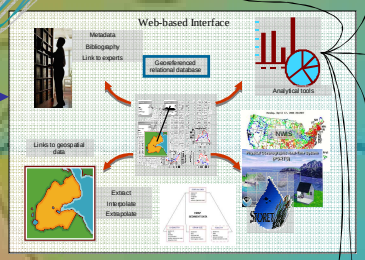
An initial classification of estuaries has been performed to group systems by similarity in geomorphology and tidal regime. Efforts are underway to test the assumption that systems within a class will respond similarly to a given set of nutrient loading and to refine the classification system to support development of nutrient criteria.

Output and tools: Map of estuarine classes and suite of nutrient-response relationships by class

Stressor-response models by system class (see related posters)

Whole- and subsystem-retention time (see related posters)

e-Estuary



How can I segment estuaries into homogeneous units that are appropriate for assigning designated use, reporting condition, listing impairments, and planning management actions, and do so in a consistent fashion?

Estuaries can be segmented by local residence time, and segments coded in hierarchical fashion to efficiently represent upstream-downstream relationships and interactions with adjacent watersheds.

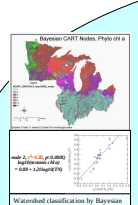
Estuarine segments

Interbasin HUC8 segments

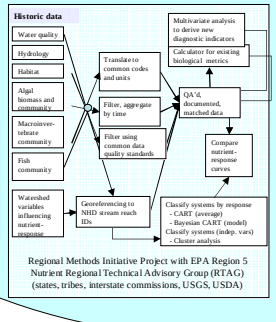
How can I predict potential habitat use for different portions of an estuary and use this information to refine designated use for aquatic life?

Point coverages of habitat features can be interpolated to create continuous coverages which can be combined to predict zones of potential habitat use.

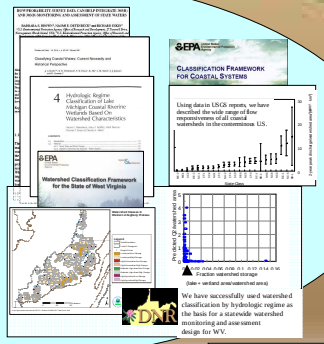
Watershed and Estuarine Classification



Watershed classification by Bayesian CART analysis significantly improved variance explained for seasonal chlorophyll *a*, from 26% for all combined to up to a maximum of 83% for one watershed class.



Regional Methods Initiative Project with EPA Region 5 Nutrient Regional Technical Advisory Group (RTAG) (states, tribes, interstate commissions, USGS, USDA)



We have successfully used watershed classification by hydrologic regime as the basis for a statewide watershed monitoring and assessment design for WV.

(1)

What can I infer from benthic community composition data on the likely nature of stressors influencing my system of interest?

Species	Common Name	Benthic Type	Size	Feeding Type	Reproduction
Rangia cuneata	clam	infaunal	1 cm	suspension	broadcast development
Ampelisca abdita	amphipod	epifaunal	1 cm	suspension	broadcast development
Neanthes succinea	polychaete	infauna-surface	1 cm	suspension	broadcast development
Streblospio benedicti	spionid polychaete	infauna-deeper	moderately big	omnivore	
Mulinia lateralis	clam	infauna	moderately big	suspension	

Information on benthic invertebrate life history and tolerance values can be used to interpret assessment data and to develop meaningful benthic indices

How can I estimate pollutant loadings to estuaries in a consistent fashion? What data are required to parameterize simple loading models?

Look-up tables can be provided with loading coefficients by land use type for different coastal regions.

$$\text{Load} = a^{*}\text{Area}_{\text{Lu1}} + b^{*}\text{Area}_{\text{Lu2}} + c^{*}\text{Area}_{\text{Lu3}} + \ldots$$

Potential Habitat-Use Zones – We are defining and mapping habitat constraints for biotopes to be used as the basis for refining aquatic life use(s) in estuaries, starting with seagrass.

	Temp. Range (°C)	Compensation Point (µmol m⁻²s)	Lt. Sat. (µEinₛ⁻²s)	Half saturation constant (µEinₛ⁻²s)	Min. It. requirement (%)
Z. marina	5 -> 20	0 -> 35	300	140	33
R. maritima	20 -> 30	11 -> 88	700	123	
H. wrightii	20 -> 30	22 -> 235	56.6 h/hr	46.2 h/hr	9.57
T. testudinum	25 -> 32	40	46.7 h/hr	34.2 h/hr	15.06
	S Range (ppt)	**Fine sediment range (%)**	**Current Velocity (m/s)**	**Wave tolerance (m)**	**Sulfide Content (mM)**
Z. marina	5 -> 35	14 -> 29	.3 -> .4	2	400 (max)
R. maritima	0 -> 15	4.7 -> 90	--	0-1	
H. wrightii	20 -> 35	1.8 -> 28.8	--	--	88m mol /m²
T. testudinum	25 -> 35	1.8 -> 47	--	--	350 - 1000

Table 2: Data for the four most commonly monitored North American estuarine seagrass species: *Zostera marina*, *Ruppia maritima*, *Halodule wrightii*, and *Thalassia testudinum*.

Supporting Science Base

Abdelrhman, M.A. 2005. Simplified modeling of flushing and residence times in 42 embayments in New England, USA, with special attention to Greenwich Bay, Rhode Island. Estuarine, Coastal and Shelf Science 62: 339–351

Abdelrhman, M.A. 2007. Embayment characteristic time and biology via tidal prism model. Estuarine Coastal and Shelf Science 74:643-56.

Brown, B, N Detenbeck, and R Eskin (2005) Integrating 305(b) and 303(d): How EMAP Aids in Monitoring and Assessment of State Waters. Environmental Monitoring and Assessment (special issue). Environmental Monitoring and Assessment 103:41-57. (DOI: 10.1007/s10661-005-6854-0)

Campbell DE, Detenbeck NE, Ho KT, Hill BH, Kurtz JC, Burgess RM, Engle VD, Perez KT, Pelletier MC, Szarski V. 2006. Conceptual models and methods for diagnosing the causes of impairments to aquatic systems. U. S. Environmental Protection Agency, Atlantic Ecology Division, Narragansett, RI. 600/R-06/024.

Detenbeck NE, Batterman SL, Brady VJ, Brazner JC, Snarski VM, Taylor DL and Thompson JA (2000) A test of watershed classification systems for ecological risk assessment. Environmental Toxicology and Chemistry 19:1174-1181.

Detenbeck NE, Elonen CM, Taylor, DL, Anderson, LE, Jicha, TM, and Batterman SL. (2003a) Effects of hydrogeomorphic region, watershed storage and mature forest on baseflow and snowmelt stream water quality in second-order Lake Superior Basin tributaries. Freshwater Biology 48(5):911-27.

Detenbeck, NE, LA Jagger, SL Stark, and MA Starry (2003b) WVREMAP Final Report: Watershed Classification Framework for the State of West Virginia. US Environmental Protection Agency, NHEERL, Mid-Continent Ecology Division, Duluth, MN, EPA 600/R-03/141. 55 p.

Detenbeck, Naomi E., Colleen M. Elonen, Debra L. Taylor, Leroy E. Anderson, Terri M. Jicha, and Sharon L. Batterman. (2004). Region, Landscape, and Scale Effects on Lake Superior Tributary Water Quality. Journal of the American Water Resources Association (JAWRA) 40(3):705-720.

Detenbeck, N.E., V.J. Brady1, D.L. Taylor, V.M. Snarski and S.L. Batterman. 2005a. Relationship of stream flow regime in the western Lake Superior basin to watershed type characteristics. Journal of Hydrology. 309(1-4): 258-276 (doi:10.1016/j.jhydrol.2004.11.024).

Detenbeck NE, D Cincotta, JM Denver, SK Greenlee, AR Olsen, and A Pitchford. (2005b) Watershed- based survey designs. Environmental Monitoring and Assessment (special issue). 103:59-81. (DOI: 10.1007/s10661-005-4774-7)

Detenbeck, NE, MM Moffett, M Pearson, TP Simon, and D Albert. 2007. Flow and nutrient-based classification for Lake Michigan coastal riverine wetlands. Chapter 4 in Coastal Wetlands of the Laurentian Great Lakes, TP Simon and PM Stewart (eds.), AuthorHouse. Bloomington, IN. pp. 115-136.

Gallegos C.L. 2001. Calculating optical water quality targets to restore and protect submerged aquatic vegetation: Overcoming problems in partitioning the diffuse attenuation coefficient for photosynthetically active radiation. Estuaries 24(3):381-397.

Hagy, J. D., L. P. Sanford, and W. R. Boynton. 2000. Estimation of net physical transport and hydraulic residence times for a coastal plain estuary using box models. *Estuaries* 23(3): 328-340.

Kurtz, J.C., N.D. Detenbeck, V.D. Engle, K. Ho, L.M. Smith, S.J. Jordan and D.Campbell. 2006. Classifying Coastal Waters: Current Necessity and Historical Perspective. Estuaries and Coasts 29: 107-123.

U. S. Environmental Protection Agency, 2004, Classification Framework for Coastal Systems, U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, EPA Report EPA-600/R-04/061.

US EPA Tiered Aquatic Life Use workgroup(s): National, Estuarine

Region 1: New England
Serving Connecticut, Maine, Massachusetts, Newhampshire, Rhode Island, Vermont & 10 Tribal Nations

Impact and Outcomes:

Past

Risk Assessment: Impact to Outcome – Watershed classification provided the principles behind watershed-based survey designs, the subject of a special session in the EMAP 2003 symposium. Principles were applied through technical support to Office of Pesticide Programs in their development of a national atrazine monitoring program as part of the 2003 re-registration process for atrazine.

Ongoing

Nutrient criteria guidance – Classification concepts have been incorporated into draft nutrient criteria guidance for wetlands and are being included in draft guidance on approaches to nutrient criteria for estuaries. In collaboration with an interagency workgroup, we will be comparing three approaches to classification of estuaries: a conceptual hydrogeomorphic model, EPA/NOAA cluster analysis, and a new Bayesian Classification and Regression Tree approach.

The research and development activities described above are providing support for multiple programs in the Office of Water and related activities by EPA Regions, the states, tribes, and local coastal or watershed management groups. Activities will provide the basis for:

1) the definition of estuarine listing segments for combined 305(b)/303(d) reports the states are required to submit
2) a framework for refining aquatic life use designations in estuaries and exploring tiered aquatic life use concepts at an ecosystem scale
3) classification frameworks to support monitoring and assessment
4) prioritization of subwatersheds for management activities, and water quality criteria development (particularly for nutrients)
5) diagnosis of causes of impairment in estuaries
6) partitioning effects of local point source or contaminated sediments from upstream nonpoint sources
7) establishing restoration targets
8) ultimately supporting cost-benefit analyses of alternative management strategies for estuaries

Future Directions

- Geodatabase
  - Development of a geodatabase structure suitable for 4-D estuarine and associated watershed data
  - Incorporation of historic estuarine data (NCA, NWIS, STORET, NERRS, NEPs, etc) and real-time data streams (COOS, NOAA)
- Classification
  - Comparison of three classification approaches to support derivation of nutrient criteria for estuaries
  - Addition of temporal component with atmospheric-ocean teleconnection indices + hydroclimatic zones
  - Merger of watershed and estuarine classification approaches
- Site-specific diagnostic tools
  - Completion of database of benthic community attributes for diagnostic analysis
  - TOC-grain size relationships
  - Quantile regression to partition effects of multiple stressors
- Outreach
  - ERF 2007 special session and panel discussion on decision-support tools for coastal management (NGOs, NEPs, NOAA, states, regions, academia)
  - Coordination with other EPA initiatives
    - Watershed Central (watershed management support tools)
    - Landscape Predictive Tools workgroup products
  - Coordination with sister agency initiatives
    - NOAA NowCOAST
    - NOAA NE Integrated Ecosystem Assessments
    - NatureServe Ecosystem-based management tools

EPA Atlantic Ecology Division Narragansett, Rhode Island

Detenbeck, Watershed AssessPeerRV07.ppt 9/17/07