

IP33: Predicting Exposure to Sediment Chemical Contaminants in Small, High Salinity Estuaries

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ABSTRACT

Environmental scientists recognize the need to integrate, analyze and communicate ecological information in useful formats for resource management decisions. Environmental modeling allows abstraction and simplification of complex systems and is being increasingly adopted by coastal resource managers to address ecosystem and landscape issues. We used geographic information processing (GIS), principal factor analysis, linear regression, semivariance modeling and kriging to predict risks (sum of chemical contaminant Effects Range Low in sediment, Long et al., 1995) in Murrells Inlet, South Carolina. Ninety candidate variables including measures of landscape features, water quality, sediment quality, disease and biota density were reduced to twenty variables by eliminating redundancy and multicollinearity. Principal factor analyses were used to identify underlying factors that explain most of the system variance. Linear regression analyses identified five variables of the twenty that predicted the sum ERLs ($R^2=0.90$). This regression model was tested in another estuary, North Inlet, South Carolina, with a similarly high regression coefficient. Semivariance modeling and kriging were conducted to model the spatial behavior of the processes that drive the observed pattern of chemical contaminants and incorporate surfaces created from this model into other GIS techniques. Both measured and predicted risks were highly correlated ($p<0.05$) to oyster tissue contaminant burdens but poorly correlated ($p>0.05$) to both sessile and motile species biomass. The results suggest that a small number of relatively easily measured parameters can be used to predict chemical contamination exposure in small, highly productive southeastern estuaries.

METHODS

✓ Criteria were established for measuring risk: cumulative, multiple impacts, common units, long term effects, sensitive, low and/or equally distributed uncertainty and applicable to many sites and circumstances.

✓ Overall model building procedures are shown in Figure 1.

✓ The Effects Range Low (Long et al., 1995) for thirteen chemicals were determined, summed and log transformed (Log Sum ERL) for 30 sites each in Murrells and North Inlets, SC (Table 1).

✓ Twenty normalized variables are listed in Figure 2 along with their principal factor analysis patterns.

✓ Proc Reg (SAS Institute, Inc.) identified compact linear combinations of variables to predict Log Sum ERL (Figures 3 and 4).

✓ Moran's I values were calculated (Geostatistics for the Environmental Sciences, Gamma Design Software) and used to identify separation distances where spatial autocorrelation may be significant (Table 2).

✓ Semivariograms were calculated at a range of lag intervals (Table 2). Semivariogram models and kriging were then used to estimate values across the study area (Figure 5).

✓ Correlations (SAS Institute, Inc.) between five modeled risk measures and both biotic exposure and population estimates are shown in Figure 6.

RESULTS

✓ Principal factor analysis showed three factors explained 56% of the variance with heavy weighting upon:

- cartographic variables on factor one,
- sediment quality on factor two and
- water quality on factor three (Figure 2).

✓ Regression model:

- distance to nearest paved parking lot,
- stream width,
- water ortho-phosphate,
- sediment nitrogen,
- percent sediment silt

predicted Log Sum ERL in two estuaries ($R^2=0.90$, Figures 3 and 4).

✓ A spherical semivariogram model with lag intervals of 800 meters fit the data well (Table 2) with little differences between measured and estimated log Sum ERL (Figure 5).

✓ There were strong correlations between five measures of sediment risk and some oyster tissue concentrations but mostly poor correlations for population effects (Figure 6).

CONCLUSIONS

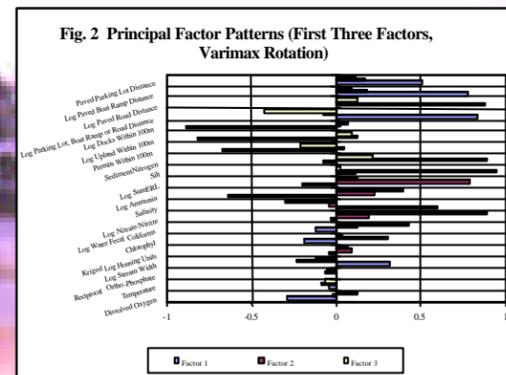
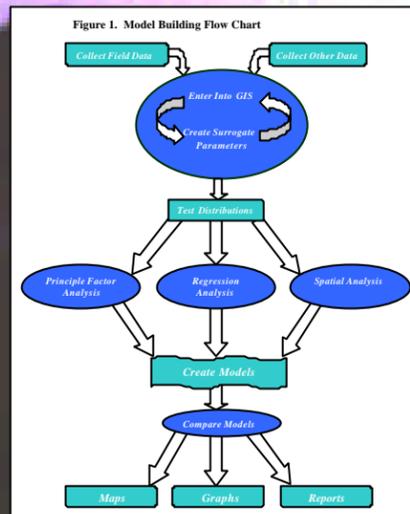
✓ The models demonstrate quantitative links between landscape changes and chemical exposure in resident biota.

✓ Exposure is dependent upon proximity to landscape alterations, water and sediment quality.

✓ Relatively inexpensive measures (e.g., sediment quality) might be used to predict chemical contamination risks.

✓ Risks might be predicted and alternatives tested before expensive development decisions are made.

✓ After appropriate validation (ongoing), the models might be applicable to 300 similar high salinity estuaries in the Southeastern US.



Model	Lag Distance (m)	Lag Interval (m)	Range (m)	Semi-Variance R2	Number of Neighbors	Search Radius (m)	Kriged Cross Validation R2
Spherical	7020	800	4910	0.797	10	2000	0.29
		1600	2000	0.286	16	2000	0.286
		4000	8775	0.286	4000	0.236	
Exponential	7020	1000	2180	0.754	10	2000	0.249
		1600	2000	0.246	16	2000	0.246
		4000	8775	0.225	4000	0.215	
Spherical	7020	1200	2340	0.925	10	2000	0.244
		1600	2000	0.244	16	2000	0.215
		4000	8775	0.205	4000		

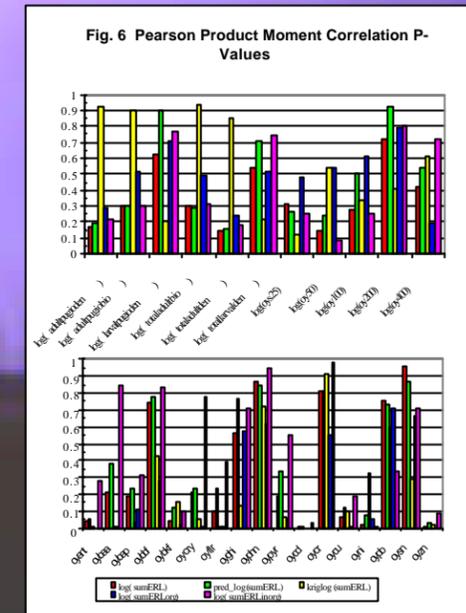
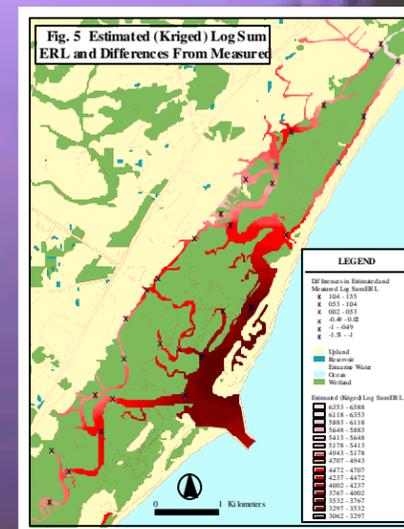
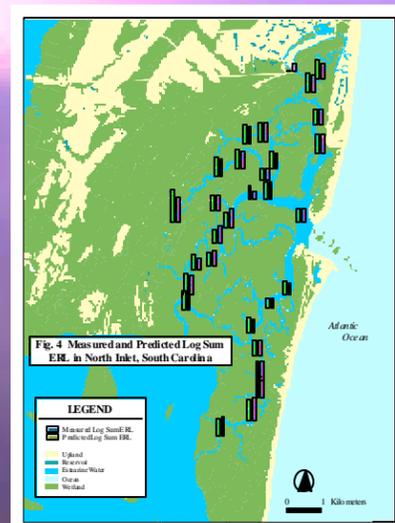
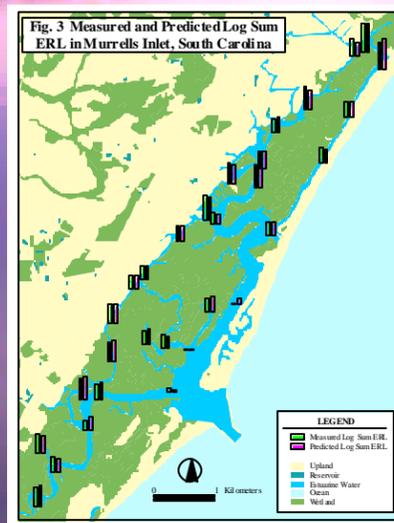


Table 1. The Effects Range Low, mean value and range of 13 chemicals measured at 30 sites in Murrells and North Inlets, South Carolina

Chemical	ERL	Murrells Inlet		North Inlet	
		Mean	Range	Mean	Range
Phenanthrene (ng/g)	240	23.7	0.8-69.6	6.8	0-21.0
Anthracene	85.3	11.8	0-148	1.6	0-13.0
Fluoranthene	600	52.7	0-54.8	10.1	0-36.0
Pyrene	665	63.7	0.2-62.0	12.5	1.0-42.0
Benzo (a)anthracene	261	56.2	0.4-126	10.1	1.0-47.0
Chrysene	384	51.0	0.5-63.0	12.9	1.0-33.0
Benzo (a)pyrene	430	58.6	0-71.2	11.0	1.0-34.0
Cadmium (=ng/g)	1.2	0.2	0-41.7	0.4	0-0.6
Copper	34	6.1	1.2-61.5	10.7	1.9-23.4
Lead	46.7	10.3	0.2-152	13.0	1.2-23.6
Nickel	20.9	5.9	2.4-78.5	11.1	0.9-19.6
Chromium	81	25.0	6.7-76.8	36.7	3.5-57.4
Zinc	150	30.0	0-59.1	47.9	14.1-79.4



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