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Estuarine habitat quality reflects urbanization at large spatial scales in South Carolina's coastal zone

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ABSTRACT

Land cover patterns were evaluated in 29 estuarine watersheds of South Carolina to determine relationships between urban/suburban development and estuarine habitat quality. Principal components analysis and Pearson product moment correlation analyses were used to examine the relationships between ten land cover categories and selected measures of nutrient or bacterial enrichment in the water column and contaminant enrichment in sediments. These analyses indicated strong relationships between land cover categories representing upland development and a composite measure of 24 inorganic and organic contaminants using the Effect Range Median-Quotient (ERM-Q). Similar relationships also were observed for the summed concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals. Data obtained from tidal creeks generally showed stronger correlations between urban/suburban land use and pesticides and metals compared to data obtained from larger open water habitats. Correlations between PAH concentrations and the urban/suburban land cover categories were similar between creek and open water habitats. PCB concentrations generally showed very little relationship to any of the land cover categories. Measures of nutrient enrichment, which included total Kjeldahl nitrogen (TKN), nitrate–nitrite, phosphorus, chlorophyll-a, and total organic carbon, were generally not significantly correlated with any land cover categories, whereas fecal coliform bacteria were significantly and positively correlated with the urban/suburban land cover categories and negatively correlated with the non-urban land cover categories. Fecal coliform correlations were stronger using data from the open water sites than from the tidal creek sites. Both ERM-Q and fecal coliform concentrations were much greater and more pervasive in watersheds with relatively high (>50%) urban/suburban cover compared to watersheds with low (<30%) urban/suburban cover. These analyses support the hypotheses that estuarine habitat quality reflects upland development patterns at large spatial scales, and that upland urbanization can result in increased risk of biological degradation and reduced safe human use of South Carolina's coastal resources.

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1. Introduction

Development along most of the coastal zone of the United States is projected to increase from 80 million to 127 million people over the next 20 years (Zinn, 1997). In South Carolina alone, population growth in the coastal counties has been increasing rapidly, with more than 1.04 million people estimated to be living in the eight coastal counties in 2004 (SC Budget and Control Board, 2005). This number is expected to increase another 30% by 2025. The construction of infrastructure (e.g., roads, commercial development, residential housing, industry) that accompanies human development will alter the rate and volume of freshwater inflow as well as the type and amount of pollutants introduced into estuaries (Fulton et al., 1993; Mallin et al., 2000), with considerable potential for estuarine habitat degradation. Many other developed coastal states are already observing serious degradation of their coastal estuarine habitat, due largely to high contaminant and nutrient concentrations (Bricker et al., 1999; USEPA, 2004) and increased fecal coliform bacterial levels which impact the suitability of these estuaries for shellfish harvesting and primary contact recreation (Vernberg et al., 1996; Mallin et al., 2000; Kelsey et al., 2004; Nelson et al., 2005).

While changes in the quality of receiving water bodies in response to changes in land use associated with urbanization have been well documented for freshwater drainage systems (Schueler, 1994; Arnold and Gibbons, 1996; Schueler and Holland, 2000), similar studies are generally lacking in estuarine environments. Sanger et al. (1999a,b) and Holland et al. (2004) documented the effects of land use change on the quality of intertidal creek habitats that represent the headwaters of many estuarine drainage systems in South Carolina. Their studies indicated that when impervious cover exceeded 10–20% of the upland watershed, there were measurable alterations in the hydrography, salinity variance, sediment characteristics, contaminant levels, and fecal coliform loadings in these small creeks. When the amount of impervious surface exceeded 20–30%, living resources were affected as well. Because those studies were generally limited to the intertidal headwater portions of tidal creeks, it is unclear whether similar effects would be observed in larger subtidal creeks or more open estuarine water bodies such as South Carolina's tidal rivers, bays and sounds.

Other studies in South Carolina have examined alterations in estuarine habitat quality related to differences in land use patterns (e.g., Vernberg et al., 1992; Fulton et al., 1993), but these studies were limited to two relatively small watersheds in the state. Studies conducted in other states have documented degradation of estuarine habitats with elevated levels of urbanization and population density at larger spatial scales (Comeleo et al., 1996; Dauer et al., 2000; Paul et al., 2002; Nelson et al., 2005). However, many of these studies may not be applicable to South Carolina as they were conducted in estuaries that have much greater urban/suburban, industrial, and agricultural inputs, or they involved regions other than the southeast coast of the United States.

Within the southeast US, South Carolina and Georgia have unique coastal watershed characteristics compared to North Carolina and Florida due to relatively high tidal amplitudes (4.6–7.9 m; International Marine, 1995) and low coastal topography. Together, these characteristics result in extensive marshgrass-dominated wetlands and complex tidal creek systems that drain the upland areas. These tidal creeks support a diverse assemblage of estuarine fauna and serve as critical nursery habitat for many of those species. As a result, several monitoring programs have recently focused on evaluating the condition of both tidal creek and larger open water habitats (Van Dolah et al., 2000, 2002, 2003, 2004a,b, 2006). The combination of these studies provides a rich database to evaluate relationships between estuarine habitat quality and upland land use patterns in coastal watersheds. In this study, we seek to determine (1) whether significant relationships can be observed between upland land cover and estuarine habitat quality in watersheds of moderate size, and (2) if so, whether differences in these relationships can be observed between tidal creeks and larger water bodies.

2. Methods

We selected 29 US Geological Survey (USGS) 14-digit Hydrologic Unit Code (HUC) watershed boundaries for analysis of land use patterns (Fig. 1). The HUCs were selected to include the full range of watersheds that were characterized by different proportions of upland development and were limited to those that contained at least three sites that had been sampled for one or more of the estuarine water or sediment quality measures considered here.

Land cover characteristics were analyzed using Landsat Thematic Mapping Imagery obtained primarily in 1997/1998 by the USGS Earth Resources Observation Systems (EROS) Data Center. This imagery has a spatial resolution of 30×30 m and has been analyzed by the Land, Water and Conservation Division of the South Carolina Department of Natural Resources for land cover patterns (SCDNR, unpublished). Since a high percentage of the estuarine water and sediment quality data available for assessing the condition of South Carolina's estuaries were obtained from studies that had been conducted between 1993 and 2002, this Landsat imagery provided a useful assessment of existing land use patterns that corresponded to the same approximate time period when the environmental data were collected.

The imagery classifications compiled by the SCDNR include: open water; emergent wetlands; scrub/shrub wetlands; forested wetlands; scrub/shrub uplands; forested uplands (deciduous, evergreen and mixed); cultivated land; grassland/pasture; bare land; high intensity urban; and low intensity urban. Scrub/shrub wetland, scrub/shrub upland, and deciduous forest never comprised more than 4%, 8% and 4% of total upland cover, respectively, within any HUC and were therefore merged with the most ecologically similar land cover type to reduce the number of categories. These included merging scrub/shrub wetlands with forested wetlands, grassland/pasture with scrub/shrub upland, and deciduous forest with mixed forest upland. The low and high urban land use categories were analyzed both separately and combined. Low and high urban cover were defined by the SCDNR as having 30–75% and greater than 75% urban–suburban cover, respectively. The 29 HUCs were intersected with the land cover data within a GIS to obtain an estimate of the total area and