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A comparison of blue crab and bivalve $\delta^{15}N$ tissue enrichment in two North Carolina estuaries

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An inverse relationship was observed between tissue enrichment and water quality.

Abstract

Stable isotope analyses ($\delta^{15}N$) were used to examine invertebrate tissue enrichment in two North Carolina estuaries with differing amounts of nutrient loading. Bivalves collected from a nutrient sensitive estuary yielded a significant difference in mean nitrogen isotopic composition of tissue (10.4‰ ± 0.82; $N = 66$) compared to bivalves collected from a less nutrient sensitive estuary (6.4‰ ± 0.63; $N = 45$). Similarly, blue crabs from nutrient sensitive sites had a nitrogen isotopic composition of 11.4‰ (±1.3, $N = 77$), which was significantly different ($P < 0.001$) than the tissue of less nutrient sensitive blue crabs (9.6‰ ± 0.6; $N = 77$). The results showed that an inverse relationship exists between invertebrate tissue enrichment and indicators of water quality across estuarine sites. This study suggests that a relationship may exist between nutrient sources and subsequent energy transfer to estuarine consumers in two North Carolina estuaries.

Keywords: Bivalve; Blue crab; Tissue enrichment; Stable isotope analyses

1. Introduction

Nutrient pollution of estuarine and marine ecosystems is regarded as one of the highest priority problems facing the health of species that occupy these habitats (Vitousek et al., 1997; Boyer and Howarth, 2002). Human activities enhance quantities of nitrogenous compounds to watersheds, restructure vital habitat, and change resource availability through alteration of biogeochemical cycles (Valiela et al., 1992; Duarte, 1995; Heip, 1995). Rates of nitrogen, predominantly nitrate (N) loading of anthropogenic nitrogen to estuaries have been increasing across most coastal areas worldwide (Caraco and Cole, 1999; Galloway et al., 2004). Alterations of food and resource availability, especially in highly productive systems, represent bottom-up perturbations of food web dynamics (McClelland and Valiela, 1998a; Micheli et al., 2001). These shifts in trophic levels modify consumer interactions, impact community structure, and may decrease biodiversity in aquatic habitats (Polis and Strong, 1996; Micheli et al., 2001). Associated with these trophic level shifts is the prevalence of eutrophic conditions (e.g., excess nutrients, harmful algal blooms, low dissolved oxygen), which have increased substantially in estuaries since the 1980s (Heip, 1995; Burkholder and Glasgow, 1997; Lalli, 1997; Paerl, 1999).

This study utilized the stable isotopic ($\delta^{15}N$) composition of tissue to examine the trophic level relationships of blue crabs (*Callinectes sapidus*), bivalves (*Rangia cuneata* and *Corbicula fluminea*), and particulate organic matter (POM) in two North Carolina river estuaries with different levels of nutrient loading. Stable isotope analysis represents an effective approach for following the transfer of organic matter sources within an estuarine food web as a result of trophic interactions (Fry and Sherr, 1984; Minagawa and Wada, 1984; Rau et al., 1992). This technique provides a powerful tool for assessing

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the potential anthropogenic sources that influence trophic level relationships (Michener and Schell, 1994; Micheli et al., 2001). Although long-term storage of N is thought to be an important sink in estuaries with relatively short residence time (Nixon et al., 1996), the prevalence of benthic biota may increase the overall N regeneration process (Newell, 2004).

The Neuse River Estuary (NRE), which contains half of the research sites in this study, has been exposed to considerable non-point source runoff and animal waste from farm operations, as well as effluent from human wastewater point sources (NCDENR, 2001; Pinckney et al., 2001). The NRE begins east of New Bern, North Carolina and extends eastward (54 km) into the Albemarle Pamlico Ecosystem (Fig. 1). The average total N concentrations at the river estuarine interface of the NRE have been considered excessive (NCDENR, 2002). The relative contributions of nutrient sources, of wastewater to the NRE include 60% agricultural, 18% urban runoff and point sources and 15% forested and wetlands. Atmospheric deposition has been shown to account for a substantial part of the nitrogen supplied to North Carolina estuarine waters, although contributions of this source are not conclusive (Whithall et al., 2003; Paerl et al., 2004). Coinciding with these conditions, land use has changed in the basin over the past 20 years with an overall increase in urban and agriculture (NCDENR, 2002).

Water quality declines, caused by excessive N loading have prompted the state to support a 30% reduction of N inputs into the NRE (Fear et al., 2004). Point and non-point source waste can enter ground and surface water (Mikkelsen and Gilliam, 1996), which have created a condition of nutrient stress in the NRE especially during high discharge events (Spruill et al., 1996; Karr et al., 2001). From the upper to mid areas, the NRE has experienced excess total N concentrations, frequent algal blooms, low dissolved oxygen, and fish kills (Paerl et al., 1998; Pinckney et al., 2001; Whithall et al., 2003). This ecosystem is classified as a ‘‘nutrient sensitive’’ watershed by the state (NCDENR, 2001). The Alligator River Estuary (ARE) is part of the Pasquotank River Basin and is the second major estuary examined in this study. In contrast to the NRE, the ARE does not drain major urban areas or animal farm operations and does not include a major wastewater point source. The ARE sub-basin has been classified as having ‘outstanding resource waters’ (NCDENR, 2002). The highest proportion (>50%) of land use for this river basin was a combination of forested and wetlands. Results have shown that average total N concentrations in the ARE were less than 0.05 mg N l^{-1} from 1995 to 2000 (McMahon and Woodside, 2000; NCDENR, 2002).

Previous research has utilized stable isotope analyses to identify estuarine food web alterations by delineating consumer and producer pathways (Peterson and Fry, 1987; Riera et al., 2000; Carmichael et al., 2004). Estuaries sensitive to anthropogenic nutrient loading, which degrade water quality, have been linked to heavier isotopic signatures of nitrogen sources and primary producers (Valiela, 1992; Deegan and Garritt, 1997; McClelland and Valiela, 1998b; Costanzo et al., 2001). Threats to the availability of food sources for consumers have ramifications for the development of benthic populations (Kennish, 1992). Fry (1999) measured heavy $\delta^{15}N$ values of bivalves as a result of watershed nitrogen loading in a San Francisco estuary. Despite the well-documented importance of blue crab and bivalve fisheries to estuaries (McLusky, 1989; Levinton, 1995; NCDMF, 2002; Gosling, 2003), few comprehensive studies have examined the trophic

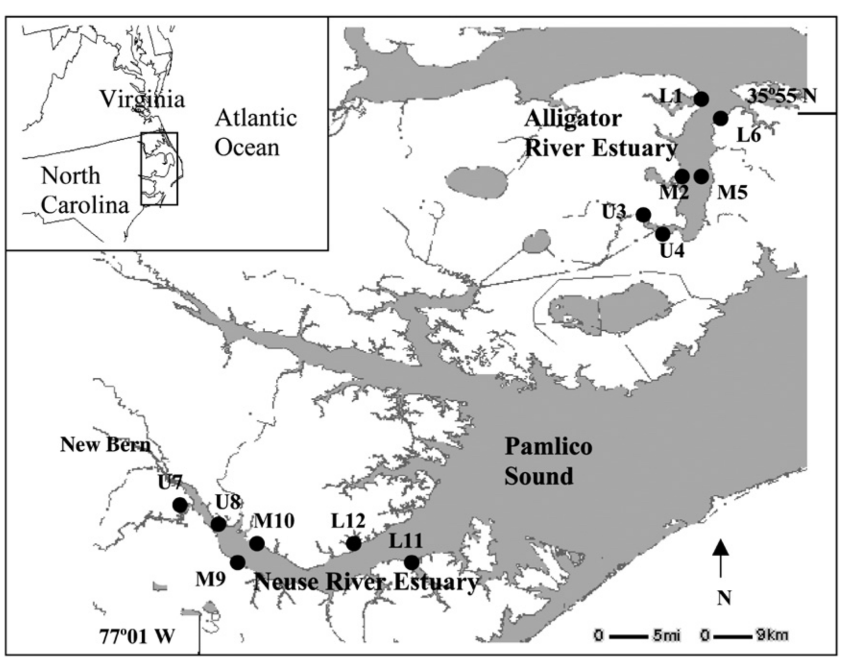

Fig. 1. Map of study sites in eastern North Carolina. Station codes describe the location of each collection site. Upper estuarine sites include U3, U4, U7 and U8. Mid estuarine sites include M2, M5, M9, and M10. Lower estuarine sites include L1, L6, L11, and L12. Scale bar is in nautical miles.