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Spatial and temporal variation in seagrass coverage in Southwest Florida: assessing the relative effects of anthropogenic nutrient load reductions and rainfall in four contiguous estuaries

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Abstract

The estuaries of Tampa Bay, Sarasota Bay, Lemon Bay, and Upper Charlotte Harbor are contiguous waterbodies located within the subtropical environment of Southwest Florida. Based on an examination of rainfall data over the period of record (1916–2001) within the watersheds of these estuaries, there is no evidence for spatial differences (at the watershed level) or monotonic trends in annual rainfall. During the 1980s, nitrogen loads into Tampa Bay and Sarasota Bay (generated primarily by domestic wastewater treatment facilities) were reduced by 57% and 46%, respectively. In response, both Tampa Bay and Sarasota Bay have lower phytoplankton concentrations, greater water clarity and more extensive seagrass coverage in 2002 than in the early 1980s. As there is no evidence of a concurrent trend in rainfall during the period of 1982–2001, it is unlikely that variation in rainfall can account for the observed increase in seagrass coverage in these two bays. In contrast, seagrass coverage has remained relatively constant since the mid 1980s in Lemon Bay and Charlotte Harbor. Domestic wastewater treatment facilities are minor sources of nitrogen to Lemon Bay, and water clarity in Charlotte Harbor varies mostly as a function of dissolved organic matter and non-chlorophyll associated turbidity, not phytoplankton levels. Even in estuaries that share boundaries and are within 100 km of each other, varied responses to anthropogenic changes and natural phenomena were observed in water quality and associated seagrass extent. Resource management strategies must take into account system-specific factors—not all strategies will result in similar results in different systems.

Keywords: Seagrass; Water quality; Eutrophication; Florida; Estuaries

1. Introduction

Between 1950 and 2000, Florida's population increased from approximately 2.7 million to nearly 16 million residents, with 3 million new residents moving to the state during the 1990s alone (Letson, 2002). More than 70% of Floridians live in coastal counties, which is where most of the state's building permits are issued, as well (Florida Department of Community Affairs [FDCA] 1996). Waterborne trade, beach-related tourism, and land development are much larger contributors to the economy of Florida's coastal counties than commercial fishing, with annualized net worths of $47 billion, $15 billion, $11 billion, and $202 million, respectively (FDCA, 1996). With an estimated economic impact of just under $3 billion a year (Letson, 2002),

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even the value of recreational fishing activities (both residents and visitors) pales beside that of more intensive uses of Florida's natural resources. As the intrinsic value of a clean environment is difficult to quantify (Pearce, 1993), successful management and protection of Florida's natural resources is often done despite, rather than because of, the economic pressures of continued development. Tools that can be used to track the effectiveness of efforts to restore and/or protect water quality have tremendous value, given this scenario.

In Southwest Florida, a substantial amount of research has focused on the relationships between human population, land use patterns, pollutant loads, estuarine water quality, and seagrass health. In Tampa Bay, historical losses of seagrass coverage have been linked to both direct and indirect impacts (i.e., Lewis et al., 1985; Lewis, 1989; Haddad, 1989). In contrast, recent (1982–1996) increases in seagrass coverage in Tampa Bay have been linked to improved water quality in the bay (i.e., Johansson, 1991; Johansson and Ries, 1997; Lewis et al., 1998; Johansson and Greening, 1999). Improvements in the early 1980s in the treatment and disposal of wastewater discharges by the Cities of Tampa, St. Petersburg and Clearwater have been identified as major causes of improved water quality in Tampa Bay (Johansson and Greening, 1999). A similar situation exists in Sarasota Bay, where recent (1988–1996) increases in seagrass coverage are most likely related to reductions in anthropogenic nitrogen loads to the bay by the City of Sarasota and Manatee and Sarasota Counties (Kurz et al., 1999). However, significant nonpoint sources of nitrogen loads still exist, especially urban stormwater runoff and septic tank systems.

In contrast to Tampa and Sarasota Bays, neither Lemon Bay nor Upper Charlotte Harbor (i.e., waters north of 26°40′ N latitude) seem to have experienced any substantial changes in seagrass coverage during the period of 1982–1996 (Kurz et al., 1999; Tomasko et al., 2001). The relatively stable seagrass coverage in Upper Charlotte Harbor in recent years could be related to the comparatively minor importance of phytoplankton populations to overall light attenuation in the Harbor (McPherson and Miller, 1987). That is, the relationship between pollutant loads and seagrass meadows may not be as recognizable in Upper Charlotte Harbor as in Tampa Bay (Tomasko and Hall, 1999).

This paper will review some of the information available relating to pollutant loads and water quality for contiguous Southwest Florida estuaries, to determine the relationships (if any) between anthropogenic versus natural phenomena and temporal variation in seagrass coverage. Also, this paper updates a previous summary of the status and trends in seagrass coverage in Southwest Florida (Kurz et al., 1999) by including data from two additional mapping events, in 1999 and 2002.

2. Materials and methods

2.1. General description of locations

For purposes of this paper, the following estuaries will be considered: 1) Tampa Bay, 2) Sarasota Bay, 3) Lemon Bay, and 4) Upper Charlotte Harbor (Fig. 1). The region "Upper Charlotte Harbor" will include only those areas north of 26°40′ N latitude. The climate in this portion of Southwest Florida is subtropical, with warm, wet summers and mild, dry winters. Annual average temperatures range between 21 and 24 °C, depending upon distance from the coast and latitude (Southwest Florida Water Management District [SWFWMD] 1999). Mean annual rainfall usually ranges between 136 and 144 cm year^{-1}, with more than half that amount occurring during the typical wet season of June to September (SWFWMD, 1999).

The different estuaries vary in terms of both the size of the open waters of each system, as well as the size of each system's watershed (Table 1). With a watershed:open water ratio of 24.3:1, Upper Charlotte Harbor experiences a much greater influence of freshwater inflow than Sarasota Bay (ratio of 2.9:1). Tampa Bay and Lemon Bay have similar watershed:open water ratios (6.2:1 and 4.9:1, respectively); values that are intermediate between those for Sarasota Bay and Upper Charlotte Harbor.

2.2. Pollutant loading models

Manipulative studies in Upper Charlotte Harbor have shown nitrogen to be the principal nutrient limiting primary production (Montgomery et al., 1991). In addition, strong empirical evidence points to the importance of nitrogen in controlling phytoplankton biomass in Tampa Bay (e.g., Johansson, 1991; Wang et al., 1999). In Lemon Bay, nitrogen loads appear to be related to water column chlorophyll *a* values (Tomasko et al., 2001). Consequently, pollutant loading models for these four estuaries focus on nitrogen as the primary nutrient of concern.

Nitrogen loading estimates for Tampa Bay, Sarasota Bay, Lemon Bay, and Upper Charlotte Harbor combine both measured nitrogen loads and estimated loads from difficult to quantify sources. For Tampa Bay, approximately 57% of the watershed is gaged for both flow and water quality, allowing for direct estimates of loads. However, much of the developed portions of these same watersheds drain directly to the bay, downstream of any gages. In situations such as this, loads from stormwater runoff are estimated using predictions based on rainfall, land use, soils, and seasonal land-use-specific water quality concentrations (Greening and Janicki, unpublished data; Pribble et al., 2001). In Upper Charlotte Harbor, 87% of the Peace River's watershed is gaged,