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Biogeochemical classification of South Florida's estuarine and coastal waters

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ABSTRACT

South Florida's watersheds have endured a century of urban and agricultural development and disruption of their hydrology. Spatial characterization of South Florida's estuarine and coastal waters is important to Everglades' restoration programs. We applied Factor Analysis and Hierarchical Clustering of water quality data in tandem to characterize and spatially subdivide South Florida's coastal and estuarine waters. Segmentation rendered forty-four biogeochemically distinct water bodies whose spatial distribution is closely linked to geomorphology, circulation, benthic community pattern, and to water management. This segmentation has been adopted with minor changes by federal and state environmental agencies to derive numeric nutrient criteria.

1. Introduction

Most decisions on coastal and marine resource management require habitat classification systems which adequately convey the concept of homogeneity of spatial clusters, in turn adapted to the objectives of such managerial decision. Estuarine and coastal zones have been classified around the world using diverse approaches and criteria including salinity structure, geomorphology, water circulation, etc. (Digby et al., 1998; Spalding et al., 2007). These classification schemes become critical as the need for resource management tools increases to face consequences of development in the coastal zones, especially in regions like South Florida, where estuaries and coasts have experienced the environmental impact of anthropogenic interventions since the 1900s, including major disruptions of its hydrology, sustained urban and agricultural development and climate change (Nuttle et al., 2000; Sklar et al., 2001; Briceño and Boyer, 2010).

The US-Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP) are in the process of deriving numeric nutrient criteria for South Florida's coastal and estuarine waters. Given that spatial–temporal characterization of these water bodies is necessary for such derivation, and important to Everglades' protection and restoration programs, the National Park Service and Florida International University joined resources to obtain a biogeochemical and statistically robust subdivision of these water bodies. We started with *a priori* sub-division of South Florida into basins (e.g., Biscayne Bay, Florida Bay, Florida Keys, Gulf Shelf, Ten-Thousand Islands and Pine Island-Rookery Bay) that reflected reported differences in geomorphology (Davis et al., 1994; Lidz et al., 2003), geographical patterns of water circulation (Lee et al., 2001), residence time (Nuttle et al., 2000; Rudnick et al., 2005), bottom type, urban/agricultural and seagrass and/or mangrove coverage (Fourqurean et al., 2003; Simard et al., 2006).

Classification and grouping of south Florida coastal waters into spatial water quality (WQ) clusters have been performed by Boyer et al. (1997), and Briceño and Boyer (2010) in Florida Bay; by Caccia and Boyer (2005), Hunt and Todt (2006) and Boyer and Briceño (2008a,b) in Biscayne Bay; by Boyer and Briceño (2006) in the Whitewater Bay-Ten Thousand Islands region; and by Boyer and Briceño (2009) in the Florida Keys. These studies used a combination of Principal Component and Cluster Analysis for grouping the sampling sites, except in the work by Hunt and Todt (2006) where a direct cluster analysis of salinity and temperature was performed to group a pool of Miami-Dade County's Department of Environmental Research Management (DERM) and FIU stations. The proposed subdivision, presented here, incorporates additional data and extended period of record (POR). It has been designed to meet three long-range objectives: (1) to describe biogeochemical units that have certain homogeneous natural attributes; (2) to furnish units for inventory and mapping; and (3) to arrange these units in a system that will aid decisions about resource management, namely water quality and nutrient criteria.

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Finally, the health of South Florida's estuaries and coastal waters is critical not only for the preservation of its biodiversity, but also for supporting an important sector of Florida's industry that produces $100 billion a year in revenue and supports over 900,000 direct jobs generated through recreation, fishing, tourism and other water-linked activities state-wide (Visit Florida, 2012; FFWCC, 2012).

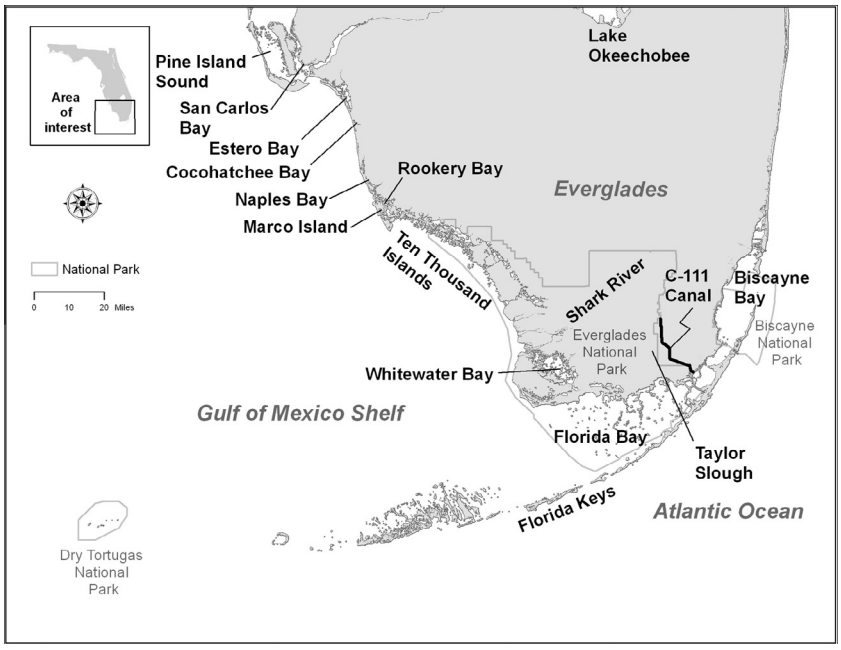

Fig. 1. South Florida's coasts and estuaries.

Table 1
Summary of inputs and results from segmentation analysis.

	Biscayne Bay	Florida Bay	Florida Keys	Whitewater Bay-10,000 Islands	Shelf	Southwest Florida
POR	Jun/96 to Sep/08	Mar/91 to Dec/07	Mar/95-Oct/09	Sep/92-Sep/08	May/95-Sep/07	Jan/99-Sep/09
Input variables for factor analysis	TN TP CHLA TOC SAL_S DO_S TURB NOX NO2 NH4 SRP	TN TP CHLA TOC SAL DO TURB TON NO3 NO2 NH4 SRP TEMP	TN TP CHLA TOC SAL DO TURB TEMP	TN TP CHLA TOC SAL DO TURB NH4	TN TP CHLA TOC SAL DO TURB NH4 NOX	TN TP CHLA TOC SAL_S DO_S TURB NO3 NO2 NH4 SRP
Stations	30	28	155	47	49	29
Factors	5	6	4	4	4	5
Acct Variance	73%	79%	66%	75%	63%	81%
Clusters	$n = 9$ Card Sound (CS) North Central Inshore (NCI) North Central Outter (NCO) Northern North Bay (NNB) South Central Inshore (SCI) South Central Mid Bay (SCM) South Central Outter (SCO) Southern North Bay (SNB) Manatee-Barnes Sound (MBS)	$n = 6$ Central Florida B. (CFB) Eastern-Central (ECFB) North Florida B. (NFB) Coastal Lakes (CL) South Florida B. (SFB) West Florida B. (WFB)	$n = 7$ Back Bay (BKB) Back Shelf (BKS) Lower Keys (LK) Middle Keys (MK) Upper Keys (UK) Marquesas (MAR) Offshore (OFF)	$n = 8$ Black River (BR) Coastal Transition Z. (CTZ) Gulf Islands (GI) Internal Waterways (IWW) Mangrove Rivers (MR) Ponce de Leon (PD) Shark River Mouth (SRM) Whitewater Bay (WWB)	$n = 3$ Inner (IGS) Mid (MGS) Outter (OGS)	$n = 11$ Collier Inshore (CI) Estero Bay (EB) Marco Island (MARC) Naples Bay (NB) Pine Island S. (PINE) San Carlos B. (SCB) Cocohatchee (COCO) Rookery Bay (ROOK) Rookery B. South (RBS) Gullivan Bay (GB) Barfield Bay (BAR)