HISTORICAL BATHYMETRIC ANALYSIS OF TAMPA BAY

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ABSTRACT

Estuarine depth is the result of coastal sediment budgets that involve terrestrial, marine, and autochthonous sources and sinks. Through the last century Tampa Bay's bathymetry has been altered drastically. Our findings corroborate and add to a previous study which determined that the mean depth of Tampa Bay has increased by more than 5% in the past century. However at finer scale, some areas of the Tampa Bay estuary have become more shallow, such as Boca Ciega Bay and a special study area labeled Feather Sound. Whether the depth of Tampa Bay will change as a result of climate change is an open but important question. Changes in the depth characteristics of Tampa Bay could affect multiple facets of the hydrodynamic system within Tampa Bay including water quality, quantity and circulation. In addition, alteration of depth has the potential to change sediment type and chemistry, the dispersion, abundance, or productivity of seagrasses, and possibly benthic communities including intertidal oysters.

INTRODUCTION

In Florida, approximately 388 to 518 square kilometers of marshland, tideland, and estuarine habitat have been lost to dredging and filling. Both new dredging and maintenance dredging exhibit the potential to damage biological resources (seagrass, benthic fauna, etc.), degrade water quality through sediment and contaminant re-suspension (Johnson 1981), and change sediment type and sediment chemistry (Jones and Candy 1981). Estuaries are altered commonly by dredging to accommodate vessel traffic (Schoellhamer 1996).

Modifications of the Tampa Bay estuary to facilitate coastal development, including port construction, have resulted in the excavation or filling of 44% of the emergent coastal wetlands (i.e. tidal marshes and mangrove forests) (Lewis et al. 1998). The Tampa Bay Estuary has from 1950 to 1980 lost 40% of its seagrass, a consequence of dredging activities, re-suspension of sediment, and nutrient-induced algal blooms. Seagrass serves as a protective nursery to fish and shellfish, as food for manatees, and as a stabilizer of bottom sediment (Poor et al. 2001).

This paper investigates the change of Tampa Bay's bathymetry over the last century via bathymetric sounding data, both historic (1879) and recent (2000). In the past, the dynamics of dredging events for increased access of commercial exports and imports had altered the bottom of the estuary and contributed to changes in vegetation and water quality. In the future, an improved understanding of bay depths and patterns of bathymetry changes will inform assessments of climate change impacts, especially changes in sea level.

MATERIALS AND METHODS

Tampa Bay Management Areas—For this study Tampa Bay was delineated into six management areas including Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Terra Ceia Bay and Boca Ciega Bay (Figure 1). Each management unit possesses unique physical and chemical characteristics influenced by the major and minor tributaries flowing into these management areas. The major tributaries include the Alafia, Hillsborough, Little Manatee and Manatee rivers and several small streams comprising the minor tributaries which contribute approximately 70% of the annual freshwater inflow (Goodwin 1987).

General Study Area—The Tampa Bay ecosystem includes 967 km^2 of primarily unvegetated or sparsely vegetated estuarine waters with an average depth of 3.5 m, 72 km^2 of emergent coastal wetlands, and a 5700 km^2 watershed. Approximately 10% of the 967 km^2 of open water area (101 km^2) has shallow (<2 m) shelves vegetated with seagrasses (Lewis et al. 1998).

Tampa Bay's historical circulation and transport processes, has been considerably modified within the past century, mainly due to dredging of ship channels, construction of major causeways, and usage of the estuarine sediments as shoreline fillings (Santschi et al. 2001).

Areas of Special Interest—Areas of interest were selected to reflect contemporary management concerns for issues related to sedimentation or erosion, and submerged aquatic vegetation (SAV). Areas of interest included an area within Feather Sound, the Southern Interbay Peninsula (labeled MacDill AFB), and a system of offshore bars along the southeast bay shore (labeled Long Bar).

The Feather Sound site is located in Old Tampa Bay on the central eastern shore of the Pinellas peninsula, between the Courtney Campbell causeway and the Gandy causeway with the Interstate 275 causeway intersecting a portion of the study area. The MacDill AFB study site is located at the southernmost tip of the Interbay Peninsula dividing Old Tampa Bay and Hillsborough Bay. The final study location, Long Bar was divided into three units, North Long Bar, Middle Long Bar and South Long Bar respectively, which are located on the eastern shoreline of the Middle Tampa Bay management unit (Figure 1).

Bathymetry Data—The 1879 bathymetry data consists of depth measurements from an 1879 hydrographic chart of Tampa Bay. The chart was created by the U.S. Coast and Geodetic Survey, Chart No. 77. A digital copy of the chart was obtained from the Office of Coast Survey, National Ocean Service, National Oceanic and Atmospheric Administration (NOAA). The digital copy was then georeferenced and depth soundings were digitized and attributed with depth values. Depths were referenced to mean low water (MLW) (USGS web access: http://gulfsci.usgs.gov/library/index.html) The historic 1879 depth data were imported into ArcGIS as point data and interpolated by kriging using ArcGIS Geo-Statistical Analysis (ESRI 2009).

The 2000 bathymetry data were selected with a GIS query procedure that applied spatial and temporal filters to the 47 digital NOAA hydrographic surveys, dating from 1945 to 1996, which cover the Tampa Bay region. Approximately 600,000 soundings were transformed from multiple orthometric and tidal vertical datums to a common vertical reference, the NAD83 ellipsoid (GRS80) (USGS web access: http://chartmaker.ncd.noaa.gov/bathytopo). The data were further processed using NOAAs VDatum Software (Ver 2.2.7, NOAA, Washington D.C., USA) to convert the vertical datum from NAVD 88 to MLW during the current tidal epic.

A difference analysis was performed using ArcGIS Spatial Analyst (Ver 9.3, ESRI, Redlands, CA, USA) to determine how Tampa Bay bathymetry has changed between the time periods. ArcGIS Spatial Analyst zonal statistics (ESRI 2009) were used for management areas and study locations with Tampa Bay (Figure 1).

Statistical Analysis—To determine statistical significance of depths between years and within study areas, non-parametric Wilcoxon 2-Sample Test, Normal Approximation was used. The critical level of significance was set at $\alpha = 0.05$. Results are reported as mean ± standard error where appropriate. All statistical operations were performed with JMP® (Ver 7.0.4, SAS, Cary, NC, USA).

RESULTS

No statistical analysis was performed on Tampa Bay management areas, but qualitatively, Boca Ciega Bay shallowed. Lower and Middle Tampa Bay, Hillsborough Bay, Old Tampa Bay, and Terra Ceia Bay deepened (as mean depth at MLW) (Figure 2 and Table 1).

It was determined using Wilcoxon non-parametric statistics (Tables 2 and 3) that the only area of special interest that was not significantly different between survey periods was the MacDill AFB site. The Long Bar system (Long Bar North, Middle and South) was determined to have deepened significantly and the Feather Sound site had significantly shallowed.

DISCUSSION

Tampa Bay's benthic landscape has been altered drastically through dredging operations aimed at improving the bay for large maritime operations, as evident in the 2000 bathymetry (Figure 1). A major shipping channel has been dredged from the mouth to the upper reaches of Lower Tampa Bay, where it splits into two branches, one entering Old Tampa Bay and the other going into Hillsborough Bay (Galperin et al. 1991). Another factor responsible for overall bay deepening has been the loss of shallow, near-shore environments caused by coastal development (Goodwin 1984). In addition, estuarine depths vary due to inputs of terrestrial and marine sediments, autochthonous biogenic production, natural and anthropogenic changes to inflows, tidal characteristics, bottom profiles, and sea level rise.

A comparison of historical (1879) and modern (2000) depth data registered to mean low water (MLW) allowed an assessment of depth changes for the entire bay, bay management areas, and areas of special interest (Feather Sound, MacDill AFB, and Long Bar). It was determined that the only area of special interest that was not different between the two surveys was MacDill AFB, which could be caused by the variability of sediment fluxes from Old Tampa Bay, and Hillsborough Bay. The MacDill AFB site may also serve as a point of accumulation due to altered bay circulation. Feather Sound was determined to be significantly shallower, which could have been sheltered from strong circulation forces within Old Tampa Bay due to the three causeways constructed within Old Tampa Bay, and would result in a low degree of sediment transport and deposition. The Long Bar sites were determined to be significantly deeper between the two surveys, which could have been caused by dredging, management activities, and altered bay circulation from earlier dredging activities which could cause altered sediment fluxes. However, Hearn (these proceedings) has also resolved annual to decadal migrations of longshore bar systems in the Terra Ceia Aquatic Preserve, south of the Long Bar system we studied.

The data presented within this study are at two different spatial scales: 2000 bathymetry is extremely fine resolution (more spatially-sensitive) and 1879 bathymetry is more coarse resolution (less spatially-sensitive). Using the best available data at the time the general trend in the data is that, overall, there have been changes to the estuaries' bottom, with more shallowing at Boca Ciega Bay and the Feather Sound special study sites. Boca Ciega Bay is composed mainly of sand and grass flats with a few tidal channels. In addition, Boca Ciega Bay has been dredged and filled extensively, resulting in a large decrease in estuarine habitat. More than 75% of this area is less than 2 m in depth (Brooks and Doyle 1998). Furthermore, Boca Ciega Bay is guarded by barrier islands, which have been documented to be sediment sinks (Penland et al.1998).

CONCLUSIONS

Estuarine depth is the product of coastal sediment budgets that involve terrestrial, marine, and autochthonous sources and sinks. Most previous accounts of estuarine depth changes usually have been related to anthropogenic changes to sediment dynamics via dredging activities or alteration of natural hydrology such as in Safety Harbor and Old Tampa Bay (Peebles et al.

2009). The mean depth of Tampa Bay has increased by more than 5% in the past century (Goodwin 1984), which is consistent with our findings. Whether the depth of Tampa Bay will change as a result of climate change is an open but important question. Changes in the depth characteristics of Tampa Bay could affect water quality, the dispersion, abundance, or productivity of seagrasses, and possible benthic communities including intertidal oysters (see Tomasko, this volume).

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Table 1. Mean depth (meters below MLW) for different water bodies within Tampa Bay (Mean ± Standard Error)

	Hillsborough Bay	Terra Ceia Bay	Lower Tampa Bay	Old Tampa Bay	Boca Ciega Bay	Middle Tampa Bay
1879	2.391±0.003	1.519±0.002	4.327±0.003	2.465±0.002	1.717±0.003	3.983±0.002
2000	3.155±0.007	1.654±0.008	4.914±0.006	2.734±0.004	1.207±0.005	4.49±0.005
Difference	-0.759±0.005	-0.133±0.007	-0.586±0.002	-0.271±0.002	0.513±0.004	-0.504±0.002
Rank	1	5	2	4	6	3

Table 2. Mean Depth at MLW (meters) for Special Interest Areas in Tampa Bay (Mean ± S.E.)

	Feather Sound	MacDill AFB	Long Bar North	Long Bar Middle	Long Bar South
1879	1.33 ± 0.02	2.86 ± 0.05	2.90 ± 0.05	2.63 ± 0.06	4.10 ± 0.08
2000	1.23 ± 0.04	2.65 ± 0.08	3.28 ± 0.07	2.69 ± 0.09	4.50 ± 0.01
Difference	0.09 ± 0.03	0.21 ± 0.05	-0.33 ± 0.03	-0.08 ± 0.04	-0.38 ± 0.05

Table 3. Wilcoxon Statistics, for Special Interest Areas within the Tampa Bay Estuary.

Study Site	Z Score	Prob>|Z|
Feather Sound	-3.91	<0.05
MacDill AFB	0.49	0.62
Long Bar North	3.90	<0.05
Long Bar Middle	-3.59	<0.05
Long Bar South	2.91	<0.05

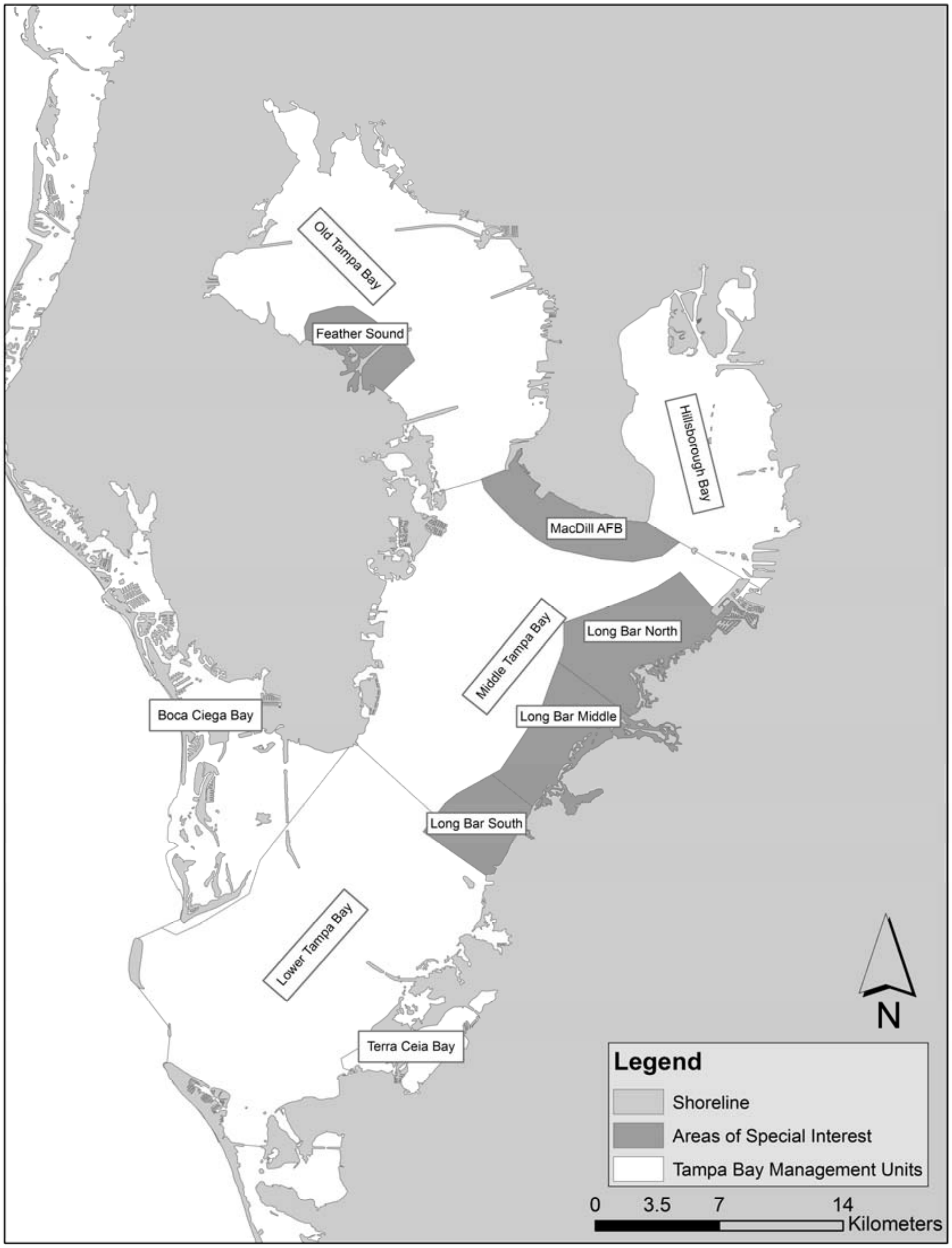

Figure 1. Tampa Bay and component management units and areas of special interest.

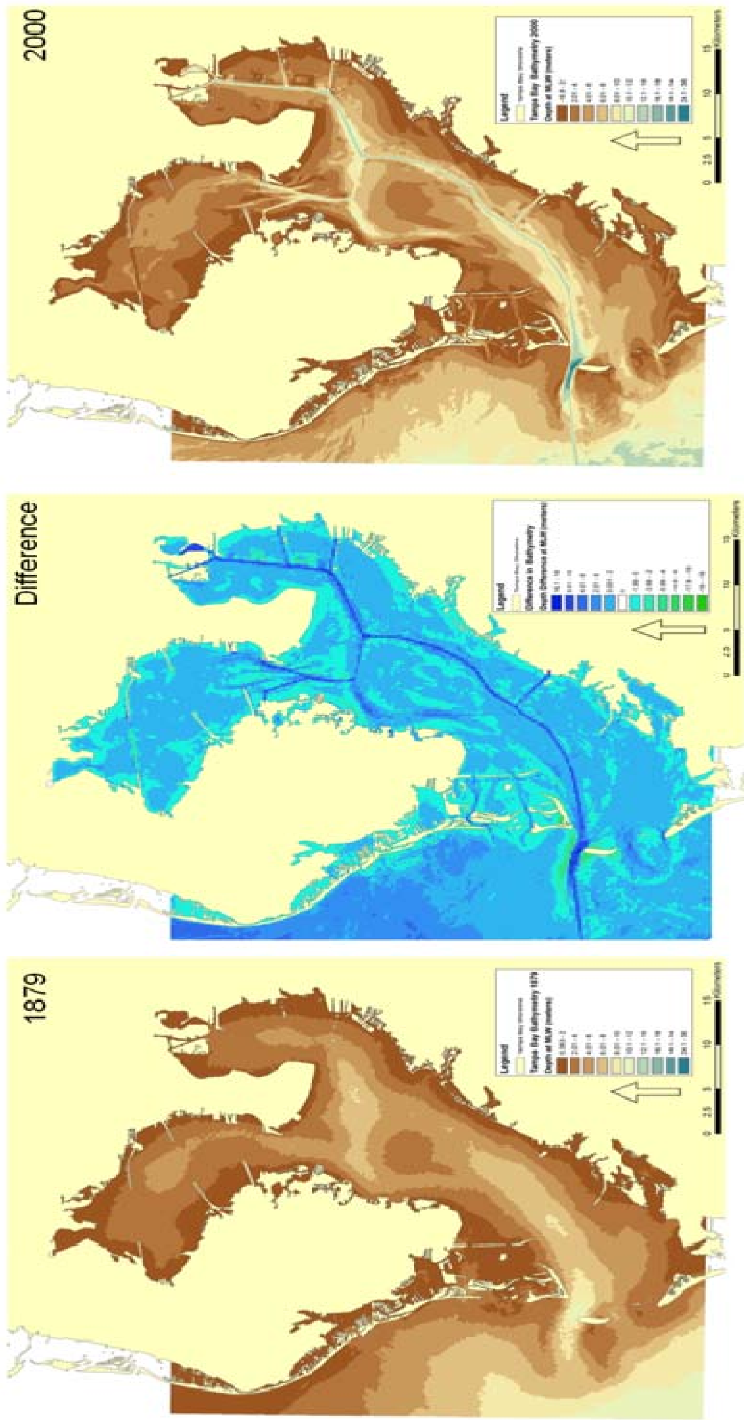

Figure 2. Comparison of Mean Low Water bathymetry of Tampa Bay between 1879 and 2000.