Exploring the Spatio-temporal Variation of Seagrass Ecosystems in Southern Tampa Bay

Ron Li and Xutong Niu
Department of CEEGS, The Ohio State University
470 Hitchcock Hall, 2070 Neil Avenue
Columbus, OH 43210
614-292-4303
li.282@osu.edu

ABSTRACT

This paper presents the status and outcomes of our efforts in using developed coastal geospatial information technology for studying on seagrass degradation in Tampa Bay, FL, in the last period of our NSF-funded Digital Government project. The research results of the project in the first three years are summarized. In the fourth year, the project is focused on seagrass degradation monitoring and restoration in Tampa Bay, FL. In this paper, the spatio-temporal variation of seagrass coverage in southern Tampa Bay was investigated. The effects of several physical factors on seagrass distribution were also examined. It was found that seagrass distribution is not only influenced by biochemical factors such as nutrient loading, water quality, and light, but also by the underwater landscape and other physical factors.

Categories and Subject Descriptors:
I.6.7 [**Simulation Support Systems**]: Environments

General Terms:
Management, Experimentation

Key Words:
Seagrass degradation and restoration, GIS, Spatio-temporal change analysis, Ecosystem

1. INTRODUCTION

The goal of this project is to investigate and develop technologies to enhance the operational capabilities of federal, state, and local agencies, which are responsible for coastal management and decision-making. We have completed coastal spatio-temporal data collection, set up a spatial data inventory system, and conducted multi-source spatial data integration [5]. In order to facilitate the administrative processes of state and local government agencies, we have developed a web-based system for coastal management and decision making [7]. A shoreline prediction model has also been designed [10]. Based on historic shorelines, future shorelines are predicted and published in a shoreline erosion awareness subsystem [7]. In multi-source spatial data integration, three-year (1999-2001) satellite altimetric data, water-gauge data, and hydrodynamic model hindcast results are compared with the goal of improving operational lake and coastal circulation nowcast and forecasting capabilities[6]. Sub-meter high-resolution QuickBird satellite stereo imagery was also acquired for the southern Tampa Bay area. Applying four different adjustment methods, geo-positioning accuracy of the QuickBird was achieved at a level of 71 cm in the horizontal and 65 cm in the vertical directions. A 3-D shoreline and a high-resolution coastal DEM were also derived [8].

The 2005 Annual National Conference on Digital Government Research, May 15–18, 2005, Atlanta, GA, USA.

In the fourth year of the project, the technologies are evaluated for monitoring and modeling seagrass degradation and restoration in Tampa Bay, Florida. During the late 1800s before human influence, approximately 31,000 ha of seagrass were distributed in Tampa Bay. In 1982, seagrass coverage was reduced to about 8,800 ha. The loss of as much as 70% of the seagrass is due to the impact of human activities on the bay, such as the excessive nutrient loading, increased commercial activities, and dredging operations during the 1950s, ’60s and ’70s [3]. After that, substantial seagrass expansion has occurred throughout the bay because of improved water quality. However, the recovery rate and expansion of seagrasses in several areas have been much slower. In general, the factors controlling seagrass distribution include light, water depth, tide and water movement, salinity, temperature, climate change, and anthropogenic impacts [9]. The natural habitat of seagrass ecosystem also provides a growth bed for seagrass evolution [2]. Through the investigation and study of the spatio-temporal variations of the seagrass in Tampa Bay, the relationships between underwater landscape and the physical factors and seagrass changes are observed.

2. SEAGRASS CHANGE ANALYSIS

The study site, Cockroach Bay, is located in the southern coast of Tampa Bay. A segment of natural shoreline extends 11 km in the northeast–southwest direction. Without experiencing shoreline development, the impact of human activities in this area is relatively less than that in other coastal areas in Tampa Bay. Baywide seagrass coverage maps in 1988, 1990, 1992, 1994, 1996, 1999, and 2001 were generated by the Surface Water Improvement and Management Section of the Southwest Florida Water Management District from 1:24,000 aerial photographs. Two types of seagrass polygons were classified: patchy (>25% of polygon unvegetated) or continuous (<25% of polygon unvegetated) [4]. Other types of non-seagrass polygons, such as tidal flats and water bodies, were also included in the maps. From these maps, four seagrass variation patterns can be observed:

- Degradation zones, where either the density of seagrass polygons has decreased or the seagrasses have completely disappeared.

- Restoration zones, where either the density of seagrass polygons has increased or the seagrasses have emerged from non-seagrass polygons.
- Dynamic zones, where both degradation and restoration of the seagrass happened at least once during the time period from 1988 to 2001.
- Stable zones, where the types of the seagrass polygons have not changed.

In this research, a transition matrix was used to quantify the seagrass variations. By comparing the elements in the matrices, a seagrass variation map was generated. It is found that seagrass variations are dependent on locations of the seagrass habitat:

- Most of the degradation zones were located farther away from the shoreline and exposed to the open ocean water. The farther away the zones are from the shoreline, the deeper the seagrass is under the water.
- The restoration zones appeared at the isolated area north of the bay entrance. They also appeared at the entrance of Cockroach Bay.
- Dynamic zones were exposed to open ocean water, but closer to the land than that of the degradation zones.
- The stable zones are located adjacent to the island boundaries or the shoreline.

The findings indicated that there is a relationship between seagrass habitat and seagrass geospatial variations.

3. PHYSICAL FACTORS

To evaluate the effects of seagrass geospatial variations, three physical factors were examined, including bathymetry, slope, and annual water level changes.

A 30-m resolution topo-bathy dataset generated by USGS/NOAA was used as the bathymetry map of seagrass habitat. Based on the bathymetry, a slope map was calculated using ESRI ArcGIS Desktop 9.0. Due to water level changes, bathymetry data should not be invariant. Annual water level changes from 1988 to 2001 were calculated from observations obtained from the water gauge station (station No. 8726520) in St. Petersburg, Florida. Each annual water level was deducted as a constant from every point in the bathymetry data to generate a sequence of simulated dynamic bathymetry data. The water depths and slopes were then extracted for each seagrass variation zone and it is observed that:

- The mean depth of the degradation zones is the greatest, which is well matched with its horizontal locations, which are farther away from the shoreline. The mean depth of the restoration zones is the smallest. The mean depths of both stable and dynamic zones are the same. However dynamic zones have a larger standard deviation for depth, which is corresponding to dynamic seagrass changes.
- The degradation zone has the biggest mean slope and the biggest standard deviation as well. The other three zones have the similar mean values.

4. FUTURE RESEARCH

In this paper, spatio-temporal seagrass variation in southern Tampa Bay was investigated. Four kinds of seagrass variation zones were defined according to the seagrass distribution changes: stable, degradation, restoration, and dynamic zones. From the seagrass variation map, it was found that the underwater landscape and location of the seagrass habitat play an important role in seagrass evolution.

For future research, the micro impacts of shoreline changes, sea level changes, bathymetric changes, sandbar movement, waves and currents, and biochemical influences on coastal ecosystem will be investigated in a small coastal region with the support of high-resolution geospatial data. A self-adaptive modeling system will be developed to investigate coastal environmental changes, predict ecological variation, and provide critical information for coastal ecosystem monitoring, management, and decision making.

ACKNOWLEDGMENTS

This project is supported by the National Science Foundation—Digital Government Program.

REFERENCES

[1] COUCLELIS, H., 1985. Cellular worlds: a framework for modelling micro-macro dynamics. *Environment and Planning A*. 17: 585-96.

[2] GREENING, H.S., 2004. Factors Influencing seagrass recovery in Feather Sound, Tampa Bay, Florida. Report submitted to Pinellas County Environmental Foundation by the Feather Sound Seagrass Recovery Workgroup.

[3] JOHANSSAN, J.O.R. 2000. Historical overview of Tampa Bay water quality and seagrass: issues and trends. In *Seagrass Management: It's Not Just Nutrients!*, St. Petersburg, Florida, Aug 22–24, 2000, H.S. GREENING, Eds. Tampa Bay Estuary Program, 1-10.

[4] KURZ, R.C., 2000. Seagrass mapping: accuracy issues. In Seagrass Management: It's Not Just Nutrients!, St. Petersburg, Florida, Aug 22–24, 2000, H.S. GREENING, Eds. Tampa Bay, Florida, 109 - 213

[5] LI, R., BEDFORD, K.W., SHUM, C.K., RAMIREZ, J.R., ZHANG, A., AND DI, K. 2002. Digitalization of Coastal Management and Decision Making Supported by Multi-dimensional Geospatial Information and Analysis. In: *Proceedings of the NSF National Conference for Digital Government Research "dg.o 2002"*, Los Angeles, CA, May 20-22, 2002,.53-59.

[6] NIU, X., KUO, C.-Y., VELISSARIOU, V., LI, R., BEDFORD, K.W., AND SHUM, C. K. 2003. Multi-source Coastal Data Analysis. In: *Proceedings of the NSF National Conference on Digital Government Research*, Boston , MA., May 18-21, 2003, 227-230.

[7] NIU, X. MA, R. ALI, T., AND LI, R. 2005. Mobile GIS and Coastal Management. Photogrammetric Engineering and Remote Sensing, 71(4). (In Press)

[8] NIU, X., WANG, J., DI, K., AND LI, R. 2004. Geometric Modeling and Processing of QuickBird Stereo Imagery. Proceedings of ASPRS Annual Conference, Denver, Colorado , May 23-28, 2004 . (CDROM)

[9] SHORT, F.T., COLES, R.G., AND PERGENT-MARTINI, C. 2001. Global seagrass distribution. In: Global Seagrass Research Methods, F.T. SHORT AND R.G. COLES, Eds. Elsevier Science B.V., Amsterdam, The Netherlands, 5-30.

[10] SRIVASTAVA, A., NIU, X., DI, K., AND LI, R. 2005. Shoreline Modeling and Erosion Prediction. In: *Proceedings of the ASPRS Annual Conference*, Baltimore, MD, March 7-11, 2005.