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SEAGRASS DISTRIBUTION IN THE PENSACOLA BAY SYSTEM, NORTHWEST FLORIDA

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ABSTRACT: Aerial surveys of seagrass coverage in the Pensacola Bay system (PBS) have been conducted during 1960, 1980, 1992 and 2003. This report summarizes the results for the 2003 survey and compares the results to those previously reported for other surveys. The estimated coverage of seagrass for the PBS during 2003 was 1,654 ha. Continuous and patchy coverages ranged from 0 to 684 ha and 11 to 543 ha, respectively, for five PBS subsystems. In 2003, the majority of seagrass coverage occurred in Santa Rosa Sound (76%). Declines in total coverage occurred for East Bay (93%) and Escambia Bay (75%) whereas increases were observed for Pensacola Bay (32%) and Santa Rosa Sound (8%). The approximate 9% decline (about 160 ha or 395 a) in total coverage since 1992 represents an estimated 7 to 8 million dollar loss in ecological services. The changes in coverage are likely due to naturally occurring and anthropogenic factors but it is not possible to differentiate the relative contributions of these factors alone and in combination on seagrass distribution. The ability of seagrasses to exist long-term in Florida's fourth largest estuarine system is uncertain due to the adverse effects of rapid urbanization in the watershed. Active resource management which includes more frequent *in-situ* monitoring and aerial assessment and the availability of relevant water and sediment quality criteria protective of submerged aquatic vegetation are needed to prevent future declines.

Introduction

Seagrasses have at least 13 ecological roles (Dawes et al. 2004) and they support a diverse biotic community that may contain as many as 113 species of epiphytes, 148 macroalgal species, 80 macrofaunal species, and 75 fish species (Humm 1964, Virnstein et al.1983, Zieman and Zieman 1989, DeTroch et al. 1996). Seagrass meadows including those dominated by *Thalassia testudinum* Konig (turtle grass), the most abundant species in the Pensacola Bay System (PBS), supported twice the macrofauna than did unvegetated sediments (Santos and Simon 1974, Virnstein et al. 1983). The economic importance of one seagrass acre has been estimated to be between $9,000 and $28,000 (Texas) and $20,500 (Florida) due to commercial, recreational and storm protection functions (Handley et al. 2007) and $19,000 based on nutrient cycling (Costanza et al. 1997). About 1.2 million of 59 million hectares (ha) of seagrasses have been destroyed worldwide during the last decade and, similar to corals, seagrasses are considered to be in a crisis stage. Declines have occurred at 40 locations (Short and Wylie-Echeverria 1996, Hemminga and Duarte 2000) including the Gulf of Mexico (GOM), where seagrass coverage has been reduced 20 to 100% during the past 50 yrs (Dawes et al. 2004, USGS and GOMP 2004). For example, about 85% of the seagrasses along Florida's coasts have been destroyed by 1992 (USEPA 1992).

Florida's Gulf Coast contains about 680,000 ha of seagrasses of which about 2% (17,474 ha) is adjacent to the Florida panhandle region (Madley et al. 2003). The trends in coverage and condition of the seagrasses in northwest Florida are considered to be poorly understood (Dawes et al. 2004). However, seagrass research for the PBS, the focus of this report, has been conducted intermittently during the past 40 yrs (Table 1) and includes four major aerial surveys conducted since the 1960s. The objectives of this report are to summarize the results of the 2003 aerial survey and to compare the results primarily to those for the previous survey conducted during 1992.

Materials and Methods

Study Area

The PBS is located in northwest Florida and its watershed consists of about 18,000 km^2 of forests, agricultural lands, and urban and industrial areas (Figure 1). It is the fourth largest estuary in Florida and extends 32 km inland and comprises about 886 km of coastline and 435 km of inland waterways. Mean water residence time is about 25 d (Solis and Powell 1999). The PBS is comprised of five subsystems: Big Lagoon, East Bay, Escambia Bay, Pensacola Bay, and Santa Rosa Sound (Figure 1, Table 2). Santa Rosa Sound and Big Lagoon are marine lagoons that are parallel to the GOM and retain high salinities due to limited freshwater input. Both areas contain sections that are classified as Outstanding Florida Waters (FDEP 2001).

Aerial Surveys

Although aerial surveys of the PBS are available since the 1940s, only those conducted during 1960, 1980, 1992 and 2003 were specific for determining seagrass coverage. Results of the 1960, 1980, and 1992 surveys have been reported previously (FDEP 2001, Schwenning et al. 2007) and the results for the October 2003 survey form the basis of this report. The experimental techniques for these surveys have differed, and these differences need to be considered in the context of the conclusions for the across-year comparisons reported here. Methodologies for the 1992 and 2003 surveys were similar but not identical. The seagrass data were derived from interpretation of 1:24,000 natural color scale photographs (1992 survey) and 1:12,000 scale color infrared photographs (2003 survey). Personnel from NASA (Stennis, MS) and Aerial Cartographics of America (Orlando, FL) performed the 1992 and 2003 flights, respectively. Black and white photographs (1:24,000 scale) and natural color photographs (1:24,000 scale) were used for the 1960 and 1980 surveys, respectively. Personnel from U.S. Geological Survey's National Wetlands Research Center (NWRC, Lafayette, LA) conducted the mapping procedure which included photo-interpretation of the aerial photographs, cartographic transfer, and digitization for all surveys. The classification scheme for all surveys was derived by USGS/NWRC based on the coastal land cover classification system of the National Oceanic and Atmospheric Administration's Coastwatch Change Analysis Project (NOAA 2003). The amount of groundtruthing or field verification of the aerial surveys has been variable, and for the 2003 survey it consisted of single visits to the five PBS subsystems to confirm seagrass presence. No *in-situ* measurements of plant condition or species identification were performed.

Results and Discussion

Seagrass Coverage

An estimated 1,654 seagrass-vegetated ha (4,085 acres) were present in the PBS based on the October 2003 aerial survey (Table 3). Of this total, most coverage occurred in Santa Rosa Sound (76%). Seagrass coverage as a percent of total surface area was 18% (Santa Rosa Sound), 5% (Big Lagoon), 1% (Pensacola Bay) and < 1% (Escambia Bay, East Bay). Continuous and patchy coverages ranged from 0 to 684 ha and 11 to 543 ha, respectively in the PBS (Table 3). About 52% of the 2003 total coverage was continuous, and almost all continuous coverage (99%) occurred in Santa Rosa Sound and Big Lagoon.

The 2003 total seagrass coverage (1,654 ha) represents an almost 9% reduction relative to the estimated total for the 1992 survey (1,814 ha). Reductions in total coverage relative to 1992 occurred for East Bay (93%), and Escambia Bay (75%) while increases were observed for Pensacola Bay (32%) and Santa Rosa Sound (8%) (Figure 2). Total coverages in Big Lagoon for 1992 and 2003 were almost identical. Continuous coverage decreased in Escambia Bay (69%), Santa Rosa Sound (14%), Pensacola Bay (100%), and East Bay (100%), which contrasted an almost 64% increase in coverage for Big Lagoon. Patchy coverage decreased in Big

TABLE 1. *Listing of seagrass and habitat condition research conducted for the Pensacola Bay System, Florida.*

Subsystem	***References***
Big Lagoon	Hopkins 1973 Heck et al. 1996 Lores et al. 2000 FDEP 2001
East Bay	Van Breedveld 1966 McNulty et al. 1972 Rogers and Blisterfield 1975
Escambia Bay	Moore 1963 USDOI 1970 Livingston et al. 1971 McNulty et al. 1972 Hopkins 1973 Rogers 1974 Rogers and Blisterfield 1975 Woodward and Clyde 1997 Lewis et al. 2000 Lores et al. 2000 Lores and Sprecht 2001 Murrell et al. 2002 Murrell and Lores 2004
Pensacola Bay	Moore 1963 McNulty et al. 1972 Rogers and Blisterfield 1975 Rodriguez and Hunner 1994 Murrell et al. 2002
Santa Rosa Sound	Moore 1963 Van Breedveld 1966 McNulty et al. 1972 Hopkins 1973 Rogers and Blisterfield 1975 Winter 1978 Macauley et al. 1988 Heck et al. 1996 Lores et al. 2000 FDEP 2001 Lewis et al. 2001, 2002
Pensacola Bay System (general)	USEPA 1975 Williams 1981 Lewis 1986 Ridenauer and Shambaugh 1986 Jones et al. 1992 Collard 1991 Thorpe et al. 1997 DeBusk et al. 2002 Dawes et al. 2004 McRae et al. 2004 USEPA 2004 USEPA 2005 Schwenning et al. 2007

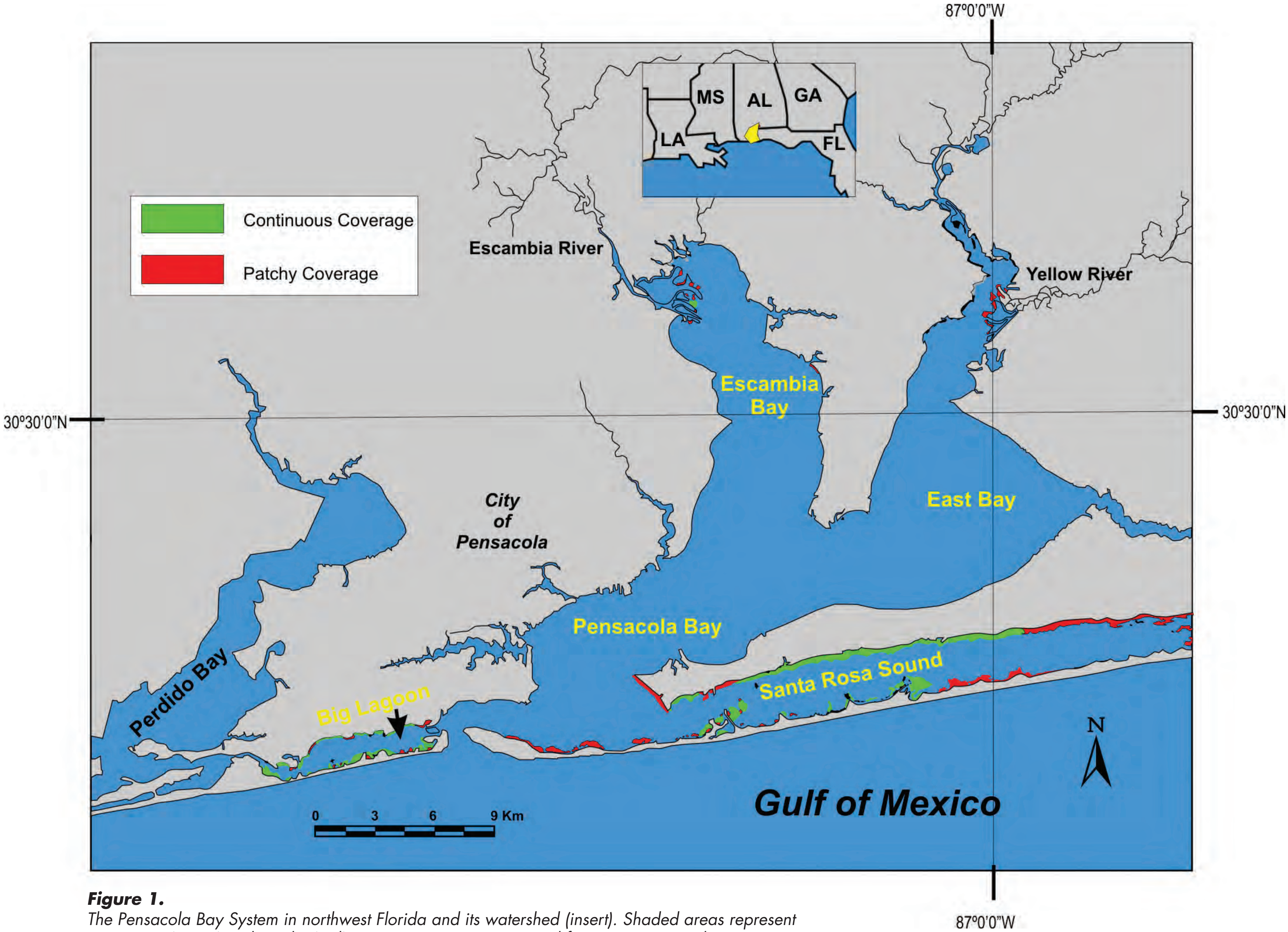

Figure 1.
The Pensacola Bay System in northwest Florida and its watershed (insert). Shaded areas represent continuous (green) and patchy (red) seagrass coverage estimated from a 2003 aerial survey.

TABLE 2. *Geomorphological characteristics and water body classifications for Pensacola Bay subsystems. Some data adapted from USEPA (1975). N/A – not available.*

Subsystem	Surface Area (km^2)	Volume (10^6 m^3)	Mean Depth (m)	Water Body Classification[1]	Florida Impaired Water[2]	Assessed Parameters
Big Lagoon	46.8	N/A	N/A	2 (OFW)	N	-
East Bay	25.9	259.3	2.4	2	Y	Fecal coliforms, Nutrients
Escambia Bay	57	225.7	2.4	3M	Y	Nutrients
Pensacola Bay	133.6	793.8	5.9	3M	Y	Bacteria
Santa Rosa Sound	68.2	N/A	N/A	2 (OFW)	Y	Fecal coliforms

[1] *2 = shellfish propagation or harvesting, 3M = Recreation, propagation and maintenance of well-balanced populations of fish and wildlife (FDEP 1996). OFW = Portion designated as Outstanding Florida Water (OFW) (FDEP 2004).*

[2] *Contains segments for TMDL development (FDEP 2006).*

Lagoon (51%), East Bay (93%), and Escambia Bay (76%) and increased in Pensacola Bay (50%) and Santa Rosa Sound (58%).

Historical Perspective

The numerous seagrass investigations conducted in the PBS have been temporally and spatially inconsistent and research methodologies have varied. Seagrass mapping has been the focus of most studies, and only limited information is available describing physiological and morphological parameters of plant condition such as above- and below-ground biomass, shoot density, blade height and epiphyte/biomass ratio, which have been reported for grasses in Big Lagoon, Santa Rosa Sound and Escambia River delta region (Heck et al. 1996, Lores et al. 2000, FDEP 2001).

Historically, the largest seagrass declines within the PBS occurred between 1960 and 1980 and subsequent declines have been less severe (Table 3, Figure 2). Seagrass meadows in Santa Rosa Sound and Big Lagoon, with few exceptions, have dominated the PBS since 1960 (coverage range as a percent of total = 75 to 90%). Their combined dominance increased 12% since 1992 to 87% of total coverage in 2003. The consistent coverages in these areas are due, at least in part, to relatively less urbanization of the shorelines (sections are included in a state park and a national seashore) and to limited freshwater input which stabilizes salinity and reduces the entry of watershed contaminants. In a detailed study conducted in these areas (Heck et al. 1996), seagrasses declined during 1993 – 1995 in both areas due to a combination of propeller scarring, reduced water clarity, changes in salinity and burial due to hurricanes. Lores et al. (2000) reported seagrass coverage was also decreasing in Big Lagoon during 1997 and 1998.

Seagrass research has been conducted less frequently in East, Escambia and Pensacola Bays, where seagrasses have been relatively uncommon since the 1960s (range of combined total coverages = 9 to 25%; Table 3). Seagrass coverage in East Bay was almost non-detectable and the least of any subsystem in 2003. Submerged aquatic vegetation in Escambia Bay is primarily limited to tidal freshwater grasses, *Vallisneria americana* Michx (tape grass) in the upper reaches and the more salinity tolerant *Ruppia maritima* L. (wigeon grass) in more seaward areas. *Vallisneria americana* is not a true seagrass, although its ecological value is similar to that of seagrasses. This species is included in this analysis, since prior assessments did not differentiate between species. Total coverage in Escambia Bay fluctuates greatly, with a

TABLE 3. *Continuous (C) and patchy (P) seagrass coverage (hectares) in Pensacola Bay subsystems. Data for 1960, 1980 and 1992 aerial surveys from Schwenning et al. (2007).*

		AERIAL SURVEY			
Subsystem		**1960**	**1980**	**1992**	**2003**
Big Lagoon	C	107	193	99	162
	P	164	43	118	58
East Bay	C	45	12	5	0
	P	431	87	160	11
Escambia Bay	C	4	4	36	11
	P	101	20	143	34
Pensacola Bay	C	44	10	13	0
	P	328	46	101	151
Santa Rosa Sound	C	1,247	850	796	684
	P	1,387	629	343	543
TOTAL		**3,858**	**1,894**	**1,814**	**1,654**

historical maximum occuring in 1992 followed by a 75% decline in 2003. Lores et al. (2000) reported increased coverage of *V. americana* near the Escambia River delta for 1997 and 1998 relative to 1992, but coverage decreased during 2000 due to drought and high salinity (Lores and Sprecht 2001). Although continuous seagrass coverage in Pensacola Bay was not detectable in 2003, patchy coverage increased from 101 ha to 151 ha since 1992.

Causes of Seagrass Declines

The factors responsible for declines in seagrass coverage for the PBS, other than direct effects due to mechanical and physical factors, have been more often speculative than confirmed. Supportive documentation is limited, and current understanding of the causative factors responsible for the seagrass changes alone and in combination remains elusive, which has limited effective restoration efforts and resource management. Declines have been attributed to controllable factors such as point and nonpoint source contaminants, prop scarring, dock shading, armoured shorelines, and dredging, as well as to the non-controllable effects of episodic weather events which have been increasing in recent years. A few investigators have reported the effects of nutrients (Heck et al. 1996, Lores et al. 2001) and low salinity (Lores and Specht 2001) and the potential for chemical phytotoxicity (Lewis et al. 2007) on seagrasses within the PBS.

The PBS is a contaminant-impacted estuary based on the results of many reports included in Table 1. Turbidity due to erosion and accelerated eutrophication have reduced light penetration in all subsystems. In addition, regulatory effects-based guidelines and criteria to protect marine life in water and sediment have been commonly exceeded in several subsystems for several non-nutrient contaminants (for example, DeBusk et al. 2002, USEPA 2005), suggesting a potential for toxicity. This is the case for Escambia Bay, which is the most contaminated subsystem and a priority site for conservation (Beck et al. 2000). In contrast, Santa Rosa Sound is the least chemically contaminated area within the PBS (FDEP 2001, Lewis et al. 2007).

Despite differences in environmental conditions among subsystems, it remains to be determined if the sensitivities of seagrasses and other submerged aquatic vegetation to non-nutrient contaminants is equivalent to those for zoobenthos and fish for which most regulatory numerical guidelines and criteria have been developed. In addition to this uncertainty is the continued absence of national and state numerical nutrient criteria which further hinders effective management of these marine angiosperms.

Summary and Recommendations

Despite the limitations and sources of error associated with aerial seagrass photography (see Carlson and Madley 2007), it was clear that there has been no net gain in seagrass coverage within the PBS since 1992. The few site-specific gains in coverage were overshadowed by declines in other subsystems which resulted in an estimated net loss of about 9% or 160 ha (~ 395 acres) system-wide. The relevance of the 2003 coverage to current coverage (2007) is unknown. Two major hurricanes, Ivan (2004) and Dennis (2005) made almost direct landfall near the PBS. Their impacts have not been reported in the scientific literature, nor have impacts associated with the ongoing urbanization of the PBS shoreline that has occurred since 2003.

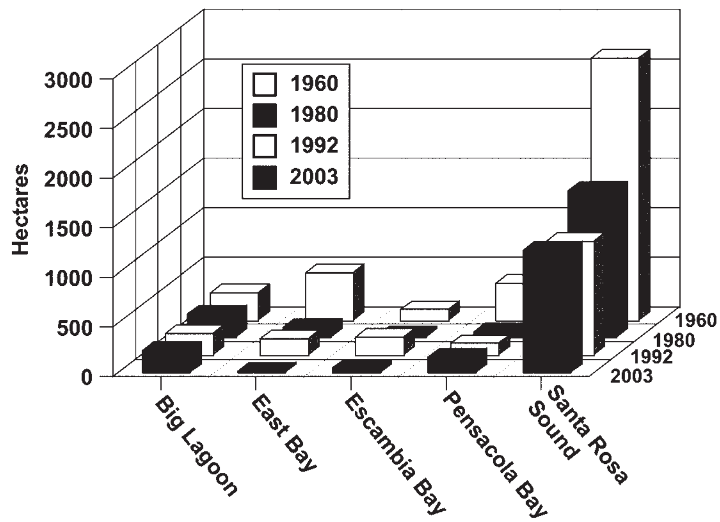

Figure 2.
Total seagrass coverage (hectares) for five subsystems in the Pensacola Bay System based on four aerial surveys. Data for 1960, 1980 and 1992 surveys from Schwenning et al. (2007).

The rapid urbanization of the PBS watershed is expected to continue. The populations in Escambia and Santa Rosa Counties is predicted to increase 20% and 64%, respectively, by 2020 (Zwick and Carr 2006). The magnitude of this urban transformation on near-shore seagrasses is unknown. This uncertainty will remain until an effective and long-term resource management plan is implemented, particularly for near-shore areas containing extensive seagrass coverage such as Santa Rosa Sound. Several management plans have been proposed (Rogers and Blisterfield 1975, Collard 1991, FDEP 2001), and these should include frequent aerial assessments (every 3 to 5 yrs) to determine coverage and more frequent *in-situ* evaluation to determine plant condition. These assessments are important so that in the long-term biocriteria predictive of habitat quality can be developed. Other management considerations should include promotion of shoreline configurations supportive of seagrass meadows and increased efforts to control coastal entry of non-point source contaminants. Of additional importance is the need to establish a separate designated use category to protect coastal submerged vegetation as well as the development of supportive regulatory numerical criteria for common near-shore contaminants and those of emerging concern (Daughton 2005).

Finally, assessment of the economical value of ecosystem services has become increasingly important to the environmental policy and management process (Costanza et al. 1997, Carpenter and Turner 2000, USEPA 2006). The loss of ecological services associated with the estimated 395 acre decline in seagrass coverage for the PBS since 1992 represents an approximate $8.1 million impact ($20,500/acre; Handley et al. 2007) or, if based on nutrient cycling, a $7.5 million loss ($19,000/acre; Costanza et al. 1997).

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