Perdido Bay

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Background

Perdido River and Perdido Bay form the western boundary of Escambia County, Fla., as well as the Florida/Alabama State line. Coastal Alabama and northwest Florida are currently experiencing rapid growth and development similar to historical boom years in south Florida. It is likely that unless there are conscious efforts to apply growth management lessons learned from mistakes made in southern Florida, similar costly mistakes may be repeated. Current expansions associated with the Perdido River and Bay watersheds (fig. 1) provide an opportunity to apply "smart growth" principles to restore and protect their water bodies.

Although Perdido Bay covers approximately 130 km^2 (50 mi^2), its watershed encompasses over 3,238 km^2 (1,250 mi^2) of land, tributaries, lagoons, and bayous in Florida and Alabama. Perdido Bay is connected to the Gulf of Mexico through Perdido Pass, and the Gulf Intracoastal Waterway (GIWW) passes through the southern portion of the bay. Perdido Bay includes areas along the coastal and inland sections of Escambia County in Florida, and Baldwin and Escambia Counties in Alabama. Because of its small size, Perdido Bay features rapid changes in water quality in response to rainfall, wind, and tide (Perdido Ecosystem Restoration Group, 1998).

Because Perdido Bay includes oligohaline, mesohaline, and euryhaline systems, this estuary possesses high species diversity. Seagrasses in Perdido Bay provide spawning, nursery, and adult habitat for many commercially and recreationally important catches such as shrimp (*Penaeus* sp.), crabs (*Callinectes* sp.), scallops (*Argopecten* sp.), speckled trout (*Cynoscion* sp.), redfish (*Sciaenops* sp.), and mullet (*Mugil* sp.). Increased shoreline and watershed development, stormwater runoff, septic tanks, wastewater treatment plant effluent, industrial discharges, agriculture, silviculture, and natural occurrences (e.g., hurricanes) have all contributed to the degradation of water quality and the resulting loss of seagrasses in Perdido Bay. Hurricane Frederick, for example, which made landfall at Mobile Bay in 1979, did considerable damage to Perdido Bay seagrasses (Perdido Ecosystem Restoration Group, 1998). Seagrass monitoring efforts in Perdido Bay have shown that from 1940 to 1992, approximately 90% of the historical continuous seagrass coverage has been lost (table 1). Wolf Bay, the largest tributary to southwestern Perdido Bay, has undergone decreasing water quality because of nitrate and phosphate runoff (Livingston, 2001). Eutrophication of Wolf Bay has been attributed to an increase in agricultural land use, which is just one example of a nutrient source within the Perdido Bay watershed (Livingston, 2001).

Two-thirds of Escambia County, Fla., residents live within 16 km (10 mi) of a major waterway. Like most Florida surface waters, Perdido Bay is threatened by human activities. Most residential stormwater sources are located in the southern portions of the watershed, particularly the highly developed Ono Island and Perdido Key areas. Recent statistics reveal that in the years 1997–99, nearly 5,000 new single-family housing units and over 1,400 new multifamily housing units were permitted in Escambia County. Census results indicate that the population of Escambia County increased nearly 13% between 1990 and 2000 (University of Florida, 2000).

Upper Perdido Bay is impacted by runoff from agricultural and silvicultural lands. In 1998, it was determined that 75% of the basin in Baldwin County, Alabama; 70% of the basin in Escambia County, Ala.; and 85% of the basin in Escambia County, Fla., were used for timber production (Perdido Ecosystem Restoration Group, 1998).

Table 1. Perdido Bay seagrass values in hectares (acres) from 1940 to 2002.

Seagrasses	1940	1979	1987	1992	2002
Continuous	365 (880)	38 (94)	124 (307)	40 (99)	
Patchy	114 (282)	171 (423)	103 (255)	74 (183)	
Present					112 (277)

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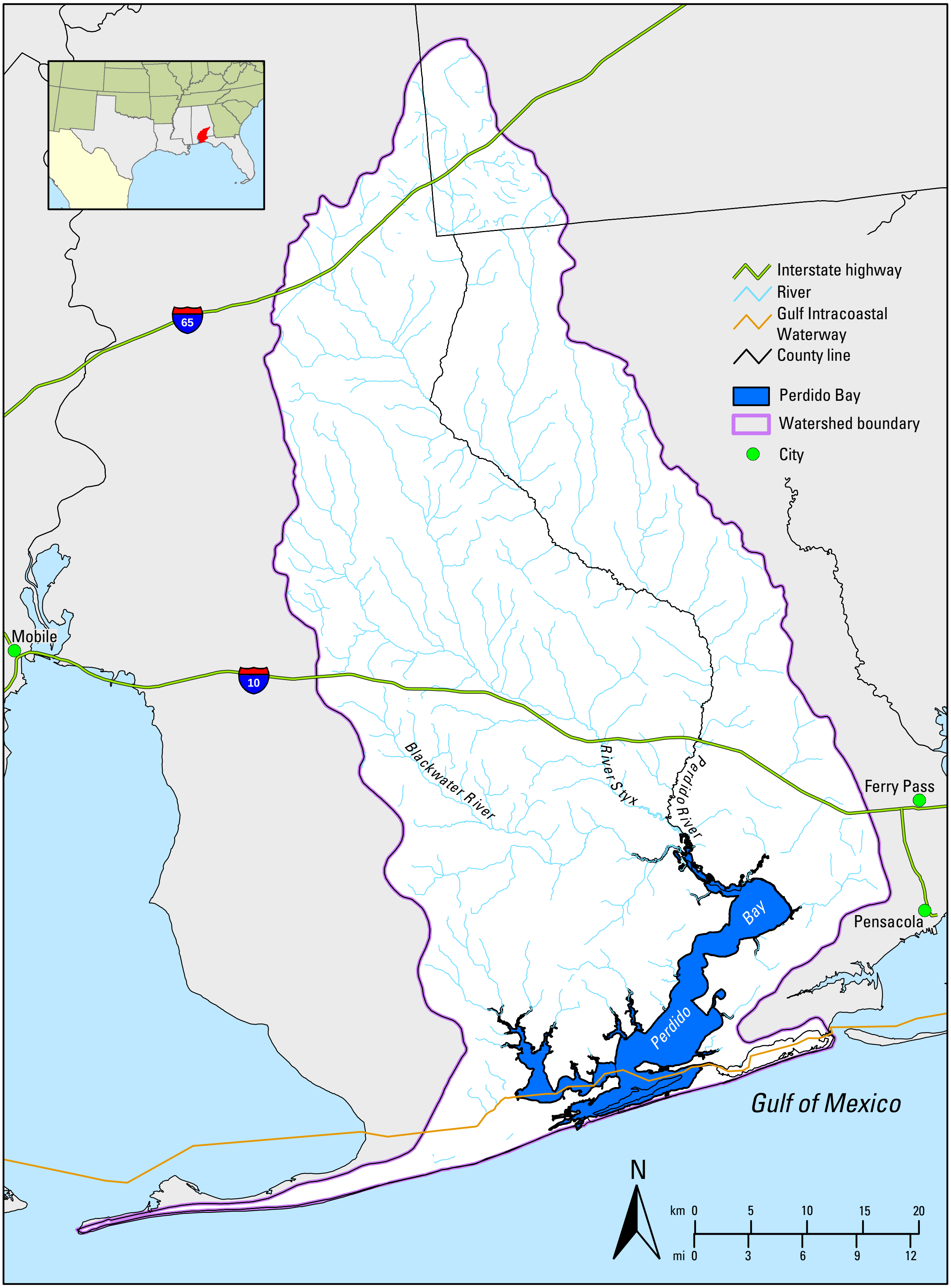

Figure 1. Watershed for Perdido Bay.

The most significant point source discharge into Perdido Bay is a paper mill. The mill discharges approximately 0.92 m^3/s (21 million gal/d) of kraft process effluent into Elevenmile Creek (Perdido Ecosystem Restoration Group, 1998). In addition, effluent from other industrial and domestic wastewater treatment plants increase nutrient levels in the bay. Much of Perdido Bay has been included on the 303(d) list of impaired waters because of low dissolved oxygen and high nutrient levels. As a result of citizen concerns about water quality in Perdido Bay, in July 1998 the Perdido Ecosystem Restoration Group, Florida Department of Environmental Protection (FDEP), National Oceanic and Atmospheric Administration (NOAA), and Florida Department of Community Affairs (DCA) published "Perdido Ecosystem Management Strategies." This publication outlines management policies, action plans, and best management practices for the Perdido Bay watershed.

Scope of Area

Perdido Bay is oriented approximately perpendicular to the Gulf of Mexico, with a length of 53 km (33 mi) and an average width of 4 km (2 mi). Average water depth in the bay is approximately 2 m (7 ft) (Livingston, 2001). Perdido Bay can be divided into three segments: Upper, Middle, and Lower (fig. 2).

The Perdido River, designated by the State of Florida an "Outstanding Florida Water," is a characteristic blackwater stream and the major freshwater tributary of Perdido Bay. The river is also the State boundary between Alabama and Florida. Much of the adjacent lands are used for silviculture. The majority of land along the river is owned by only two corporations. In contrast, the River Styx, which converges with the Perdido River from the west, has experienced substantial residential development.

Upper Perdido Bay

Upper Perdido Bay begins at the mouth of the Perdido River and extends south past the mouths of Elevenmile Creek and Bayou Marcus to Cummings Point. Although a substantial portion of the watershed remains forested, residential development is increasing.

Middle Perdido Bay

Extending southwest from Cummings Point to Innerarity Point, Middle Perdido Bay is the largest segment of the bay. Located on the eastern side of the bay, Tarkiln Bayou is one of the last remaining pristine bayous in northwest Florida. Tarkiln Bayou State Preserve and the Perdido Pitcher Plant Prairie (prioritized for preservation by Escambia County, Fla., and the State of Florida) surround Tarkiln Bayou.

Lower Perdido Bay

Lower Perdido Bay extends from Innerarity Point southward to the Gulf of Mexico and includes Wolf Bay, Cotton Bayou, Old River, and the GIWW eastward to the Theo Baars Bridge. The Lower Perdido Bay watershed includes Innerarity Point and Perdido Key in Florida, and Ono Island and Gulf Shores in Alabama. Although highly developed, with extensive residential and resort areas, this portion of the watershed also includes three State parks, as well as Gulf Islands National Seashore.

Methodology Employed To Document Current Status

The most current mapping study of seagrass coverage for the Perdido Bay area was conducted more than 10 yr ago by the U.S. Geological Survey (USGS) National Wetlands Research Center (NWRC) by using natural-color aerial photography taken in 1992 at a 1:24,000 scale as part of the northeastern Gulf of Mexico seagrass mapping project.

The mapping protocol consisted of stereoscopic photointerpretation, cartographic transfer, and digitization in acccordance with strict mapping standards and conventions. Other important aspects of the protocol included the development of a classification system, groundtruthing, quality control, and peer review.

The information derived from the photography was subsequently transferred using a zoom transfer scope onto a stable medium overlaying USGS quadrangle basemaps. In those cases where the data were inadequate or incomplete, contemporary supplemental data were acquired from other sources and used to complete the photographic coverage.

The seagrass classification system (see appendix for full discussion) used consists of two classes of open water—RIV (riverine, fresh water) and EST (estuarine or marine open water)—and five classes of seagrass habitats. One class is continuous seagrass, CSG, for which no density distinction was made, and the other four classes of patchy seagrass are based on percent ground cover of patches and in increments of 5%—PSG1 (0%–10% very sparse), PSG2 (15%–40% sparse), PSG3 (45%–70% moderate), and PSG4 (75%–95% dense).

The groundtruthing phase included the participation of field staff from Gulf Islands National Seashore, U.S. Fish and Wildlife Service (USFWS), Dauphin Island Sea Lab, Mississippi State University, Alabama Department of Conservation and Natural Resources, and Florida Department of Environmental Protection. Draft maps were sent to the aforementioned agencies and staff for review and comments. All comments received were incorporated into the final maps prepared and delivered.

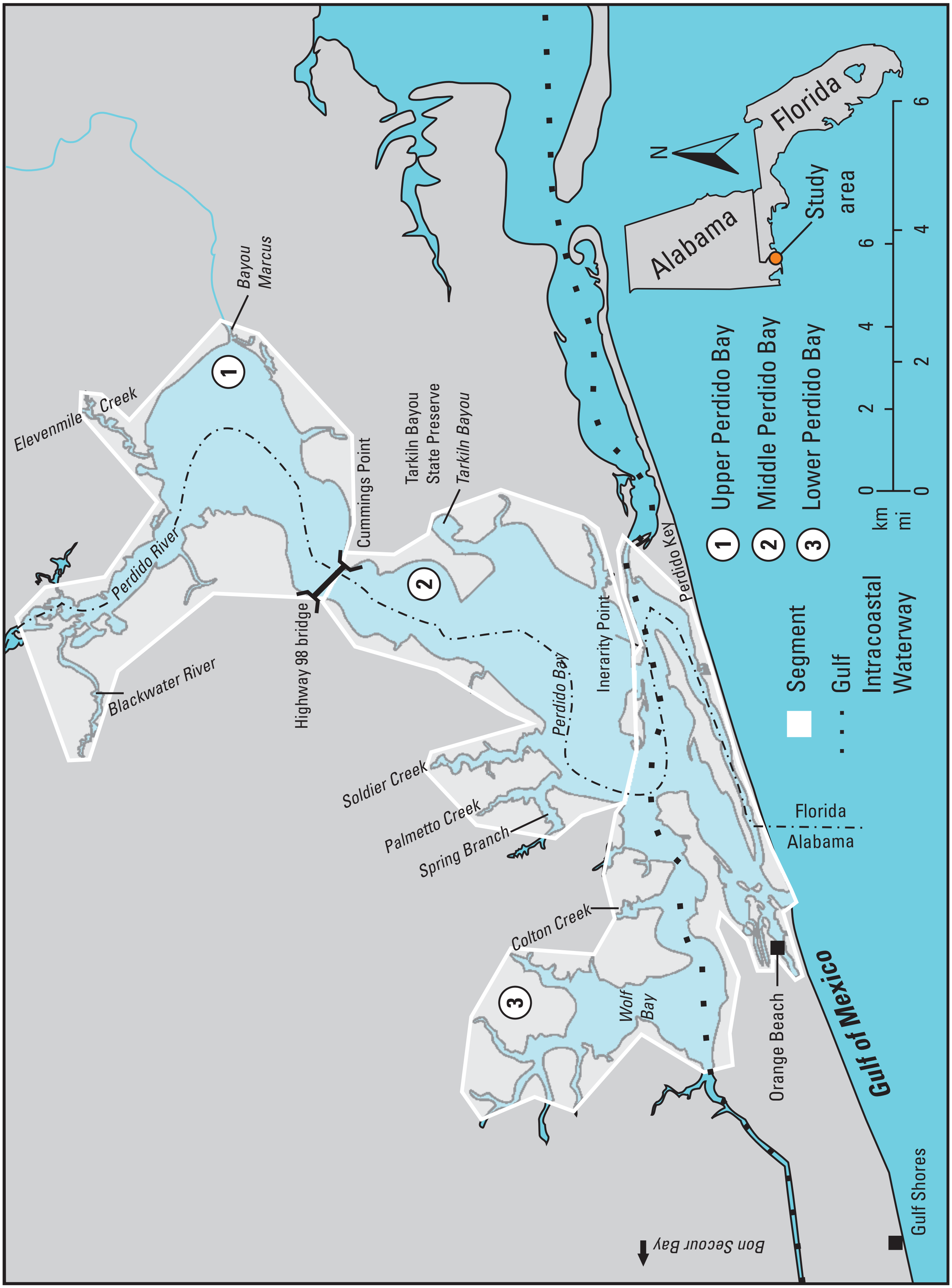

Figure 2. Scope of area for the Perdido Bay seagrass vignette.

Methodology Employed To Analyze Historical Trends

To produce a trend analysis for Perdido Bay, in 1988 and 1989, the NWRC produced a series of historical seagrass maps for the USFWS's Panama City Ecological Services Office and the U.S. Environmental Protection Agency's (EPA) Region IV Near Coastal Waters Program. Black and white photography from 1940–41 (1:20,000 scale), color infrared photography from 1979 (1:65,000 scale), and color infrared photography from 1987 (1:65,000 scale) was used to develop the trend analysis. Each date of aerial photography was analyzed with stereoscopic visual equipment, and seagrasses were delineated onto Mylar® overlays by using a zoom transfer scope with USGS 1:24,000 scale topographic quadrangles as the base maps. The overlays were digitized by using the Wetland Analytical Mapping System (WAMS) and converted into Arc format files. All dates of photography were of good to high quality for delineating seagrasses.

For consistency, classification of the seagrass for the trend analysis followed the same protocol as was used in the development of the Northeastern Gulf of Mexico seagrass mapping using the 1992 aerial photography. The seagrass classification system used consists of the same two classes of open water and five classes of seagrass habitats used to document current seagrass status.

Draft maps were sent out to the USFWS for review and comments. All comments received were incorporated into the final maps prepared and delivered. Although groundtruthing of the 1987 seagrass delineations was performed by NWRC, no groundtruthing took place for the 1940–41 or 1979 historical seagrass delineations.

The NWRC currently holds the aerial photography, the interpreted overlays, and the Mylar® overlays for the 1940–41, 1979, and 1987 maps.

Status and Trends

Seagrass monitoring efforts in 1940 (fig. 3), 1979 (fig. 4), 1987 (fig. 5), 1992 (fig. 6), and 2002 (fig. 7) have documented the decline of seagrass in Perdido Bay (table 1). In the 52-yr period from 1940 to 1992, Perdido Bay lost 355 ha (877 acres), or 74%, of its seagrass coverage. In the 10-yr period from 1992 to 2002, it appears that the rate of seagrass loss may have declined, but Perdido Bay still continued to lose an additional 3 ha (7 acres), or 2.6%, of its seagrass coverage during this 10-yr period. Total loss of seagrass coverage from 1940 to 2002 was 358 ha (885 acres), or 76%.

Upper Perdido Bay

The 1940 data (fig. 3) show only 0.4 ha (0.9 acres) of seagrass in Upper Perdido Bay. By 1979 (fig. 4), the seagrass coverage in this segment of the bay had apparently increased to 4.5 ha (11 acres), and the 1987 (fig. 5) data show 4.3 ha (11 acres) of seagrass. By 1992 (fig. 6), the seagrass coverage in Upper Perdido Bay had decreased to 1.3 ha (3 acres). By 2002, data showed no seagrass present in Upper Perdido Bay.

Middle Perdido Bay

Middle Perdido Bay showed seagrass coverage of 46.1 ha (114 acres) in 1940 (fig. 3). The majority of this coverage was located at the mouths of Soldier Creek and Palmetto Creek on the west side of the bay. By 1979, (fig. 4) seagrass coverage was greatly reduced to only 1.5 ha (4 acres), and by 1987, it had declined to 0.5 ha (1 acre). The 1992 data showed no seagrass present in Middle Perdido Bay, while the 2002 data shows 0.3 ha (0.7 acres).

Lower Perdido Bay

Since 1940, the majority of seagrass in Perdido Bay has been documented in the lower segment. Data show 434 ha (1,072 acres) of seagrass in Lower Perdido Bay in 1940 (fig. 3) and 209.7 ha (518 acres) in 1979 (fig. 4). By 1987 (fig. 5), seagrass coverage was 233.9 ha (578 acres). Photography from 1992 (fig. 6) shows 122.9 ha (304 acres) of seagrass in Lower Perdido Bay, while 2002 data indicate 121.1 ha (299 acres).

Entire Study Area

In 1940 (fig. 3), total Perdido Bay seagrass coverage was 480 ha (1,186 acres). As in subsequent years, most of this acreage (>90%) was located in Lower Perdido Bay. Seagrass maps from 1979 (fig. 4) showed total Perdido Bay seagrass coverage of 215.7 ha (533 acres). By 1987 (fig. 5), the total seagrass coverage in the bay was 239 ha (590 acres); by 1992 (fig. 6), it was 124.2 ha (307 acres); and by 2002, it was 121.3 ha (300 acres).

U.S. Geological Survey seagrass maps from 1987 (fig. 5) indicate that, in the 47-yr period between 1940 and 1987, approximately 50% of the total seagrass in Perdido Bay had been lost (figs. 3–5). Seagrass acreage decreased from 480 ha (1,186 acres) in 1940 (fig. 3) to 239 ha (590 acres) in 1987 (fig. 5), a loss of 241 ha (596 acres) baywide. Assuming a relatively steady rate of decline, the average rate of seagrass loss over this 47-yr period was approximately 5 ha (12 acres) per year, or just over 1% per year. Middle Perdido Bay lost about 45 ha (111 acres) of seagrass, or 98% of its 1940 total. Lower Perdido Bay lost 199 ha (492 acres) of seagrass, or 46% of its 1940 total. Upper Perdido Bay actually showed an increase of about 4 ha (10 acres) of seagrass during this time period. The decline of seagrass in Lower Perdido Bay was the greatest acreage loss, accounting for 199 ha (492 acres) of the total 241 ha (596 acres) lost baywide.

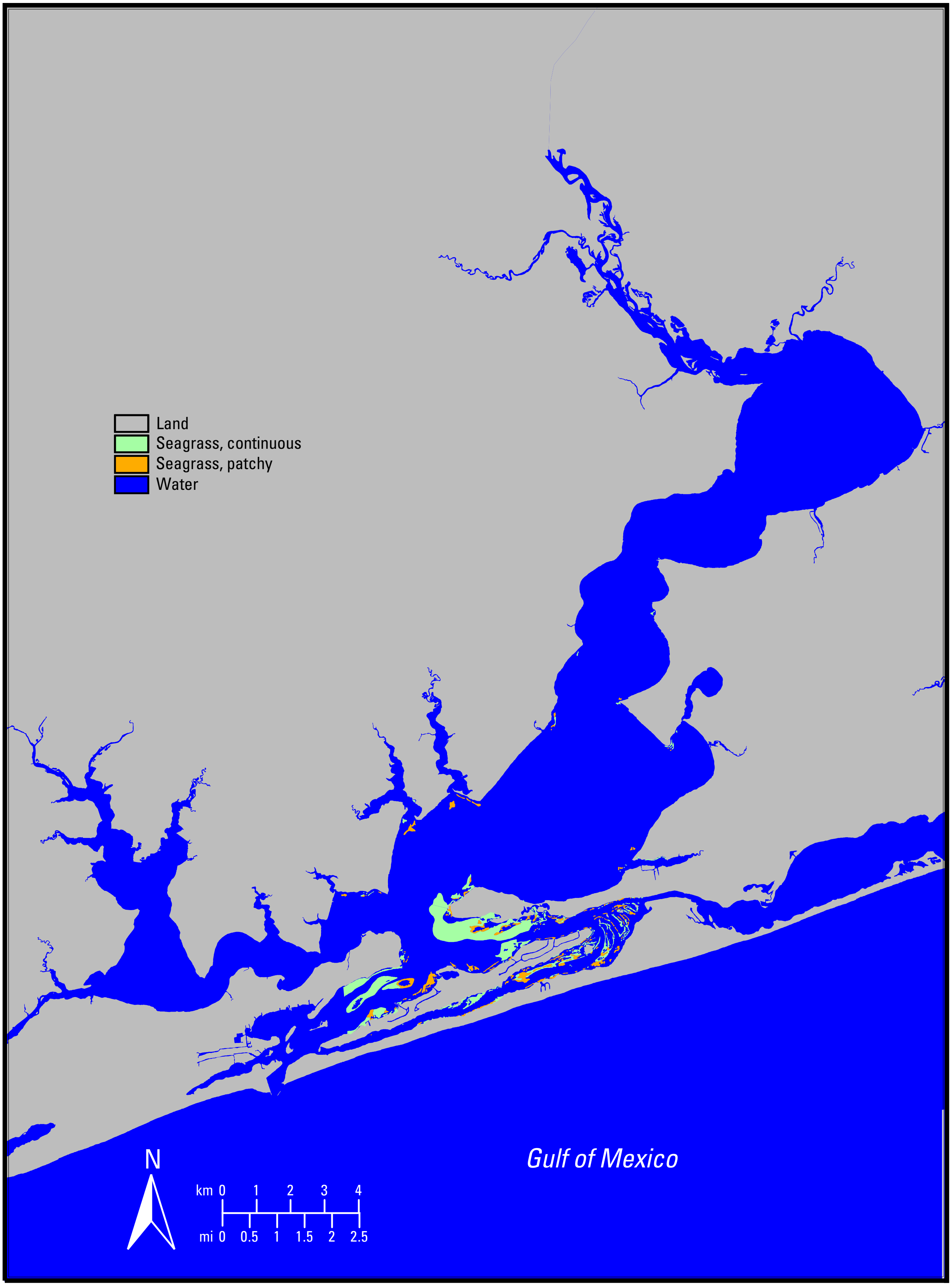

Figure 3. Distribution of seagrass in Perdido Bay, 1940.

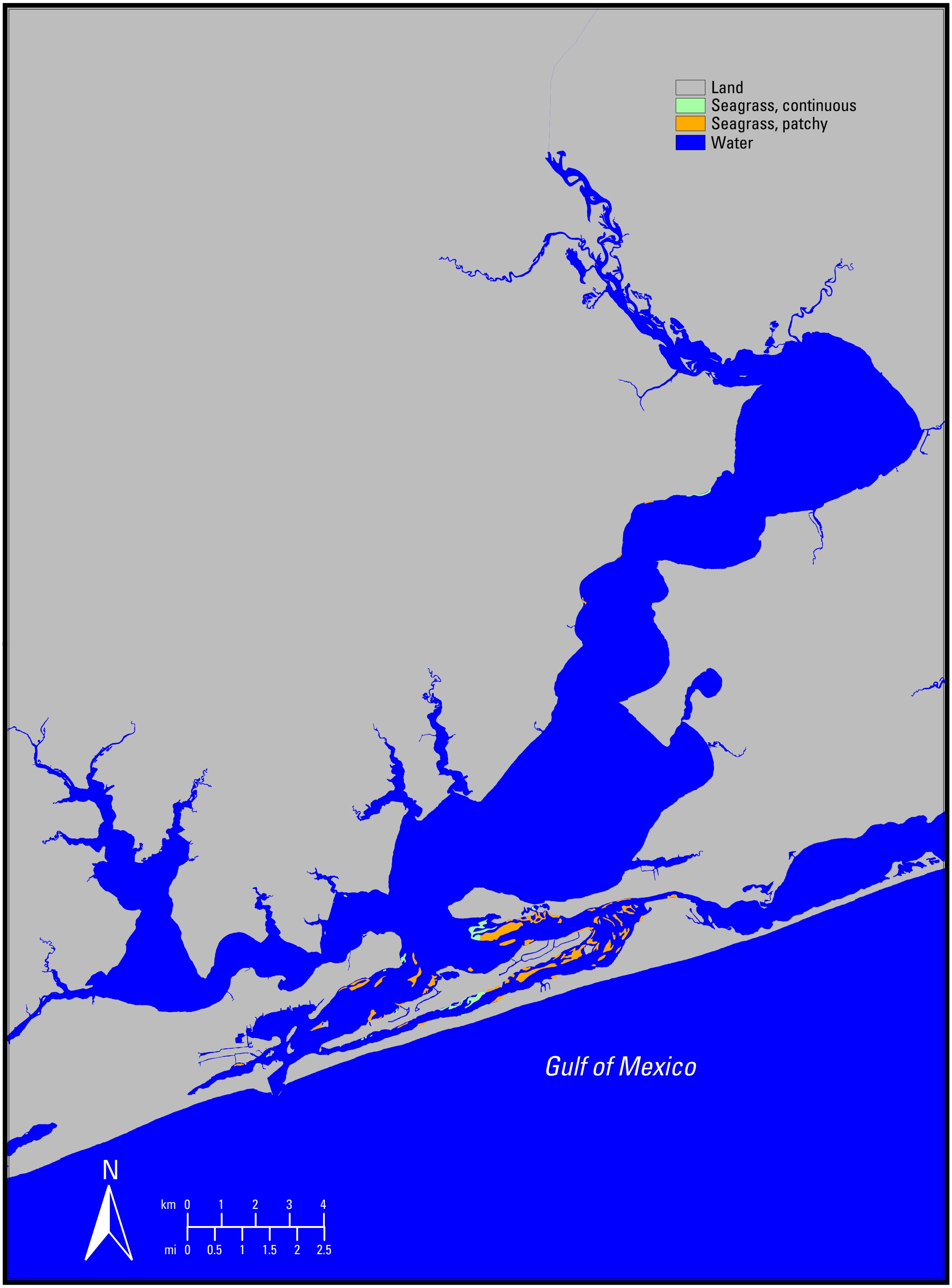

Figure 4. Distribution of seagrass in Perdido Bay, 1979.

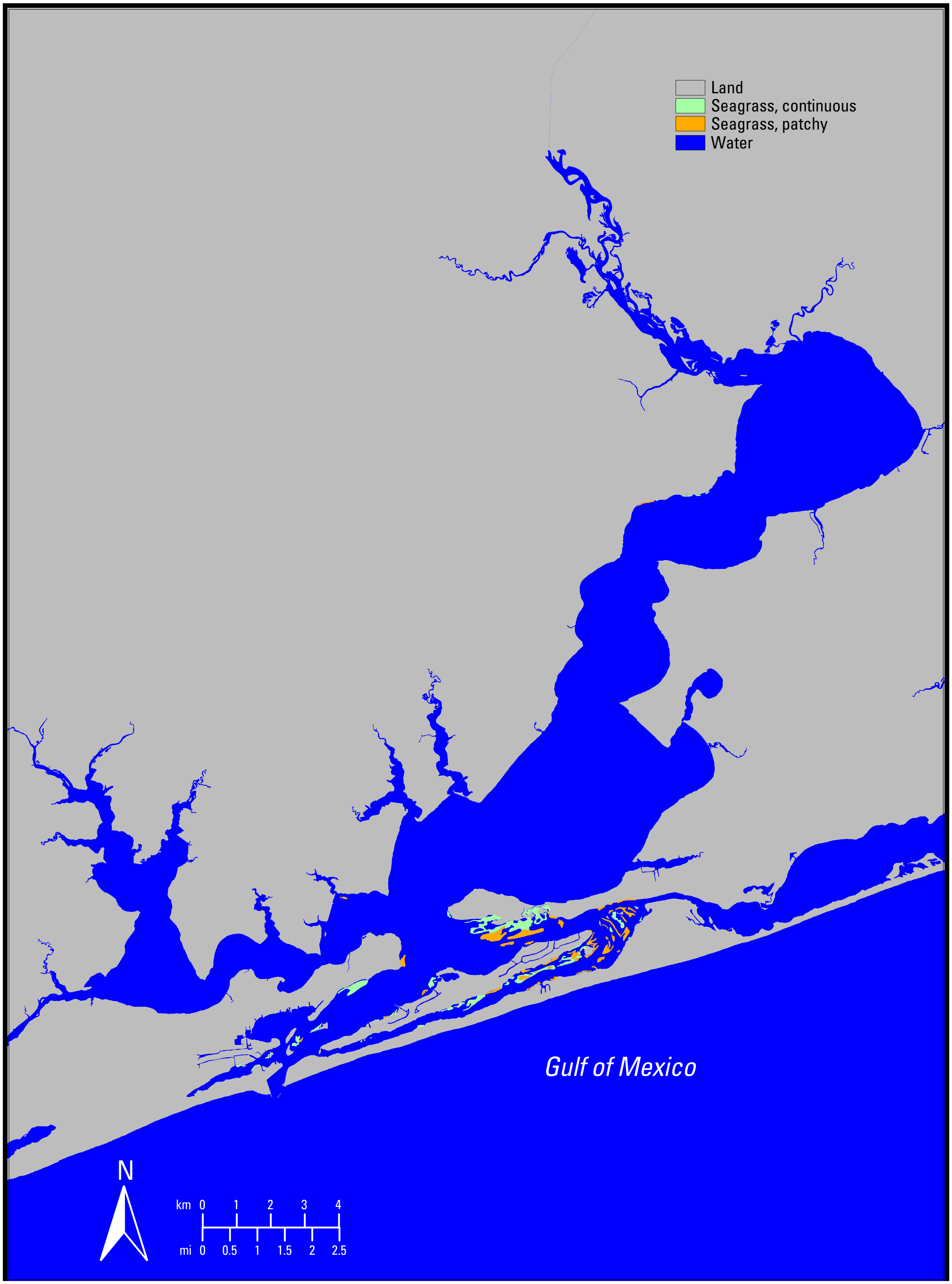

Figure 5. Distribution of seagrass in Perdido Bay, 1987.

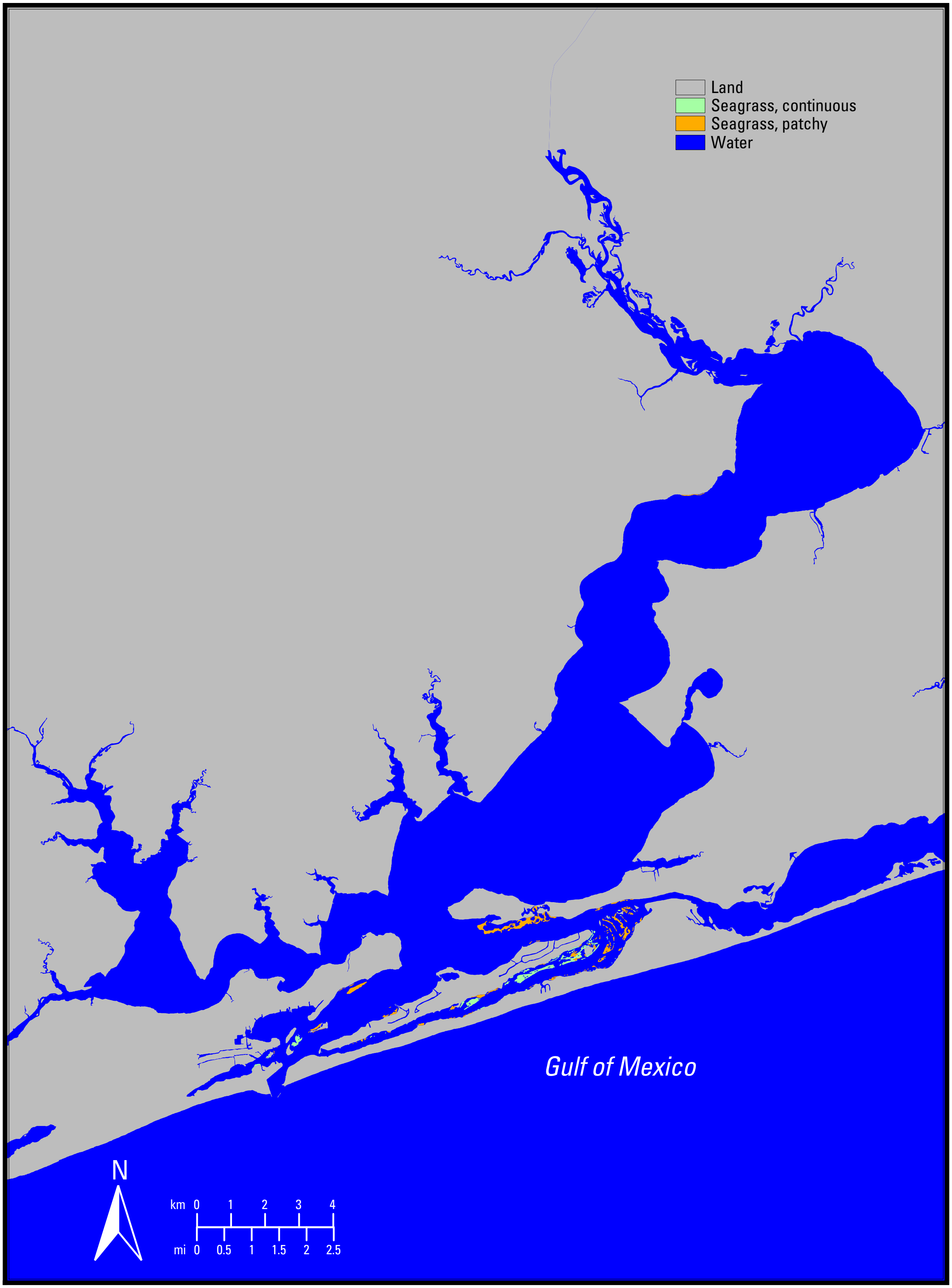

Figure 6. Distribution of seagrass in Perdido Bay, 1992.

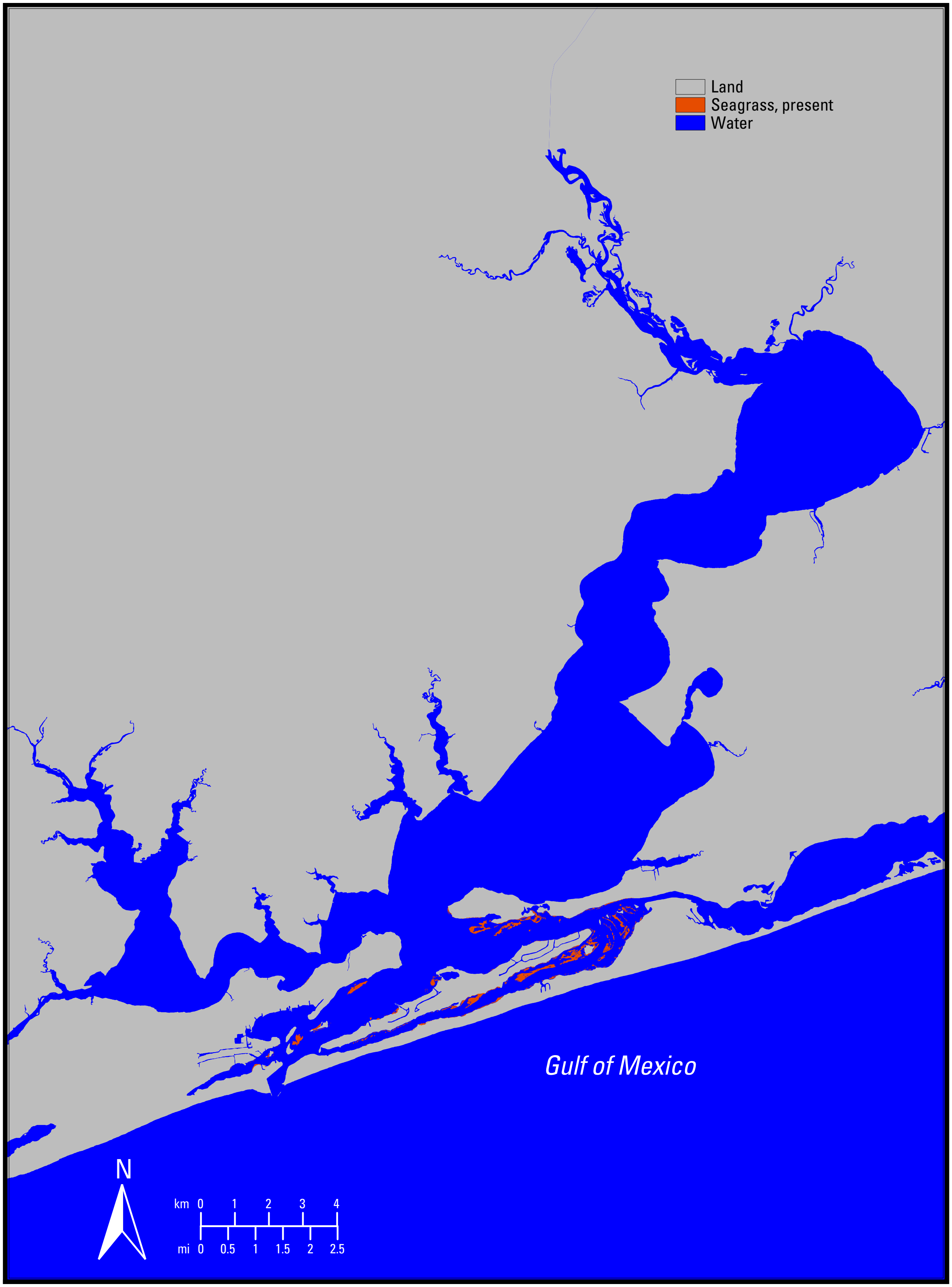

Figure 7. Distribution of seagrass in Perdido Bay, 2002.

U.S. Geological Survey seagrass maps from 1992 (fig. 6) show that total seagrass coverage in Perdido Bay was approximately 124 ha (306 acres). The percentage of seagrass lost in the 5-yr period from 1987 to 1992 was 48% (figs. 5 and 6). Total Perdido Bay seagrass acreage decreased from 239 ha (591 acres) to 124 ha (306 acres) during this time period. The average rate of seagrass loss during this 5-yr period was 141 ha (348 acres) per year, or almost 10% per year. Only about 1.2 ha (3 acres) of seagrass remained in Upper Perdido Bay, and only about 122 ha (301 acres) remained in Lower Perdido Bay. Unlike the 1940 (fig. 3) and 1987 (fig. 5) data, the 1992 (fig. 6) data indicated that no seagrass remained in Middle Perdido Bay. Seagrasses that were present at Palmetto and Soldiers Creeks had been lost by 1992.

In the 52-yr period from 1940 to 1992 (figs. 3–6), Perdido Bay lost 355 ha (877 acres), or 74%, of its seagrass coverage. The greatest loss of seagrasses occurred in Lower Perdido Bay where 310 ha (766 acres) of these 355 ha (877 acres) were lost. The lower section of Perdido Bay is the area that experienced the greatest developmental pressure during this 52-yr time period. Most of this development was related to vacation home construction and tourism.

It appears that during the 1992 to 2002 period, the rate of seagrass loss has declined. Data show a loss of 3 ha (7 acres), or 2.6%, during this recent 10-yr period, which equates to an estimated rate of decline of less than 0.3% per year.

Causes of Change

Upper/Middle Perdido Bay

Waters in Upper/Middle Perdido Bay are greatly influenced by the Perdido River, Elevenmile Creek, Bayou Marcus, Soldier Creek, Palmetto Creek, and numerous smaller tributaries. Wastewater and paper mill effluent are major point sources of pollution that can contain high levels of nutrients. Nonpoint pollution sources within the watershed include agricultural and silvicultural runoff that also can contribute high levels of nutrients to Perdido Bay. Other tributaries of Middle Perdido Bay (e.g., Palmetto Creek, Soldier Creek, and Bayou Garcon) have been residentially developed. Residential runoff (e.g., fertilizers, pesticides, and herbicides) also may affect water quality. Although primarily used for silviculture, lands surrounding Middle and Upper Perdido Bay and Perdido River are vulnerable to future residential development.

Lower Perdido Bay

Lower Perdido Bay has been greatly affected by accelerated residential, resort, and marine development. Numerous homes, condominiums, hotels, and marinas have crowded the coastline resulting in increased impervious surfaces and increased stormwater runoff, which usually cause increased nutrient enrichment, increased turbidity, decreased water clarity, decreased light penetration, and loss of seagrass. Ono Island and Perdido Key are approaching the maximum limits of development. Increased impervious surfaces generally contribute to greater amounts of urban stormwater running off into surrounding surface waters and transporting various pollutants such as fertilizers, pesticides, hydrocarbons, metals, and other toxins. Numerous marinas and residential docks, with associated vessels and activities, can provide additional stress to water quality and seagrasses.

Throughout Florida, the primary cause of water quality degradation is eutrophication Florida Department of Environmental Protection, 2000. Eutrophication has been blamed for seagrass losses in Florida and elsewhere (Cambridge and others, 1986; Tomasko and others, 1996). Loss of Perdido Bay seagrasses may be due to the result of decreased light, which is likely caused by increased turbidity and eutrophication. The degradation of water quality in the bay has occurred over time in proportion to population growth, increased land use, and development within the watershed. Over the past 10 yr, there has been a steady increase in population and development in the watershed and a concomitant loss of seagrasses.

Nutrient input is reported to be a major factor in Perdido Bay's water quality problems (Livingston, 2001). Residential and agricultural runoff are likely nutrient sources, as are domestic wastewater treatment facilities and paper mill discharges. Excess nutrients cause the reduction of light available to seagrass for photosynthesis in two general ways: (1) epiphytic growth, stimulated by nutrients, directly shade seagrass photosynthetic pigments; (2) nutrients cause phytoplankton blooms that absorb photosynthetically active radiation (PAR) in the water column.

Long-term trends are often viewed as gradual change over time; however, natural events such as hurricanes may cause large magnitude changes in a short time period. For example, the 1979 (fig. 4) seagrass maps were developed from data collected several months after a major hurricane (i.e., Frederick) heavily impacted Perdido Bay. Thus, when analyzing long-term trends, caution should be used when viewing short-term fluctuations in seagrass coverage that are to the result of isolated events.

Species Information

Three species of seagrasses have been found in Perdido Bay: wigeon grass (*Ruppia maritima*), shoal grass (*Halodule wrightii*), and turtle grass (*Thalassia testudinum*). Although not a true seagrass, the freshwater species water celery (*Vallisneria americana*) has been reported as the dominant submerged aquatic vegetation in the shallow, oligohaline waters of Upper Perdido Bay (Davis and others, 1999). Less frequently, wigeon grass occurs in shallow waters of Upper

Perdido Bay (Kirschenfeld and Turpin, personal observation). In contrast, euhaline species, shoal grass and turtle grass, are predominantly found in Lower Perdido Bay (Kirschenfeld and Turpin, personal observation).

Monitoring for Seagrass Health

Perhaps because of greater attention given to the larger Pensacola Bay System in Florida, or Weeks Bay and Mobile Bay in Alabama, management of Perdido Bay water quality and marine resources (e.g., seagrasses) has not been given adequate attention.

In 1991, the USFWS prepared a report on the changes in submerged vegetation coverage in Perdido Bay from 1940 to 1987 by analyzing and interpreting historical maps developed from aerial photography (U.S. Fish and Wildlife Service, 1991). In this report, a distinction was made between the true seagrasses and submerged vegetation, the latter of which additionally includes water celery. While no new field monitoring or water quality data were collected, the map analysis concluded that there was a loss of 235.5 ha (582 acres) of submerged vegetation, or a 48% net loss, from 1940 to 1987 (figs. 3–5).

Several transplanting efforts involving wigeon grass and water celery in upper Perdido Bay have indicated that water quality may be suitable for seagrass restoration efforts (Davis and others, 1999; Davis and Kirschenfeld, personal observation).

Weekly and monthly water quality monitoring data have been collected in Perdido Bay by biologists at the FDEP office in Pensacola. Measured parameters include nutrient levels, chlorophyll a, turbidity, Secchi depth, fecal bacteria, dissolved oxygen, temperature, and conductivity/salinity. In addition, Livingston (2001) published an extensive collection of many years of phytoplankton and nutrient data that was the result of studying the effects of pulp mill effluent on the Perdido Bay ecology.

Mapping and Monitoring Needs

As existing data show, the rate of seagrass loss in Perdido Bay appears to have increased from a loss rate of about 1% per year, from 1940 to 1987 (figs. 3–5), to a loss rate of about 10% per year, from 1987 to 1992 (figs. 5 and 6). More recently, however, from 1992 to 2002, it appears that the loss rate of seagrass in Perdido Bay has declined to less than 0.3% per year. Efforts should be undertaken to determine what activities and what best management practices have been implemented in Perdido Bay from 1992 to 2002 because data show an apparent successful effort to reduce the rate of decline of seagrass in the bay. Other estuarine systems could benefit from this information. If seagrass loss is still continuing, as historical trends indicate, additional seagrass preservation efforts and water quality improvements will be required in order to reverse this downward trend in seagrass coverage. The continued loss of seagrass, and the continued loss of its important intrinsic functions and values, will result in the further degradation of the ecology of Perdido Bay.

Restoration and Enhancement Opportunities

A seagrass monitoring effort and development of a seagrass management plan have recently been completed for nearby Big Lagoon and Santa Rosa Sound (Florida Department of Environmental Protection, 2001). Efforts such as this one should be expanded to include Perdido Bay.

In 1991, EPA biologists transplanted water celery in several different planting configurations in Upper Perdido Bay (Davis and others, 1999). In 1997, EPA and FDEP biologists successfully transplanted water celery and wigeon grass in Upper Perdido Bay (Davis and Kirschenfeld, personal observation). These results suggested that seagrass transplant efforts may be successful.

In recent years, there has been an elevated public awareness of environmental concerns in Escambia County, Florida, including water quality deterioration and loss of seagrasses. In 1998, the Pensacola FDEP office, in association with the Perdido Ecosystem Restoration Group (1998), led an effort to organize stakeholder meetings, develop action plans and management strategies, and publish *Perdido Ecosystem Management Strategies*. This document highlighted the public's concerns with poor water quality in Perdido Bay and the need for coordinated restoration efforts. In 1999, a special State of Florida Grand Jury issued a report on air and water quality concerns in Escambia County, which included 27 recommendations. These recommendations called for increased water quality monitoring efforts, more stringent water quality rules and regulations, reduced point and nonpoint sources of pollution, and the protection and preservation of environmentally sensitive lands. Perdido Bay has been classified as an Outstanding Florida Water, which means that there are more restrictive permit conditions required for developmental activities in this area.

Local efforts have been made to improve the water quality of Perdido Bay. Routine water quality monitoring by volunteers and publication of the data in the local newspaper (*Pensacola News Journal*) have heightened the public's environmental awareness. Citizens' efforts to reduce fertilization of lawns and reduce the use of pesticides and herbicides will help improve water quality. Local government efforts to reduce stormwater runoff and retrofit old storm drains will also help to improve water quality. The major industrial source of pollution to Perdido Bay is currently improving its process to improve the quality of its 0.92 m^3/s (21 million gal/d) of kraft mill effluent that is discharged into Elevenmile Creek and Perdido Bay. The cumulative positive effects of these efforts should be documented for positive reinforcement that these improvements and efforts are worthwhile.

Additional development will surely occur along the coast, but more stringent State and local regulations could be implemented to minimize negative environmental impacts. Improving the water quality of Perdido Bay, implementing coastal growth management plans, and continuing seagrass restoration efforts could reverse the trend of declining seagrass abundance.

References

Bortone, S.A., and Turpin, R., 2000, Tape grass life history metrics associated with environmental variables in a controlled estuary, *in* Bortone, S.A., ed., Seagrasses. Monitoring, ecology, physiology, and management: Boca Raton, Fla., CRC Press, p. 65–79.

Cambridge, M.L., Chiffings, A.W., Britton, C., Moore, L., and McComb, A., 1986, The loss of seagrass in Cockburn Sound, Western Australia: possible causes of seagrass decline: Aquatic Botany, v. 24, p. 269–285.

Davis, W.P., Davis, M.R., and Flemer, D.A., 1999, Observations of the regrowth of subaquatic vegetation following transplantation: a potential method to assess environmental health of coastal habitats, *in* Bortone, S.A., ed., Seagrasses. Monitoring, ecology, physiology, and management: Boca Raton, Fla., CRC Press, p. 295–307.

Florida Department of Environmental Protection, 2001, Seagrass management plan for Big Lagoon and Santa Rosa Sound: Pensacola, Fla., Florida Department of Environmental Protection.

Hotchkiss, N., 1972, Common marsh, underwater, and floating-leaved plants of the United States and Canada: New York, Dover Publications, Inc.

Livingston, E., 1988, A Florida development manual: a guide to sound land and water management: Tallahassee, Fla., Florida Department of Environmental Regulation.

Livingston, E., McCarron, E., Scheinkman, M., and Sullivan, S., 1989, Florida nonpoint source management plan, volume 2: Tallahassee, Fla., Florida Department of Environmental Regulation, Bureau of Surface Water Management, Nonpoint Source Management Section.

Livingston, R.J., 2001, Eutrophication processes in coastal systems: origin and succession of plankton blooms and effects on secondary production in Gulf Coast estuaries: Boca Raton, Fla., CRC Press.

Perdido Ecosystem Restoration Group, 1998, Perdido ecosystem management strategies: Pensacola, Fla., Florida Department of Environmental Protection.

Tomasko, D.A., Dawes, C.J., and Hall, M.O., 1996, The effects of anthropogenic nutrient enrichment on turtle grass (*Thalassia testudinum*) in Sarasota Bay, Florida: Estuaries, v. 19, p. 448–456.

U.S. Fish and Wildlife Service, 1991, Changes in submerged vegetation in Perdido Bay, 1940–1987: Panama City, Fla.

U.S. Geological Survey, 2002, Aerial photography and photointerpretation of seagrass coverage in Perdido Bay: 1940, 1987, 1992: Lafayette, La., U.S. Geological Survey, National Wetlands Research Center, *http://sabdata.cr.usgs.gov/sabnet_pub/pub_sab_app.aspx?prodid=789.*

University of Florida, 2000, Florida Statistical Abstract 2000: Gainesville, Fla., Bureau of Economic and Business Research, Warrington College of Business Administration, University of Florida.

Oral and Written Communication

Davis, W.P., and Kirschenfeld, T., 2002, Personal observation: Gulf Breeze, Fla., U.S. Environmental Protection Agency.

Kirschenfeld, T., and Turpin, R., 2002, Personal observation: Pensacola, Fla., Escambia County Neighborhood and Environmental Services Department.