Charlotte Harbor

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Background

Charlotte Harbor, located on the west coast of Florida south of Tampa and Sarasota Bays, is the second largest open water estuary in the State. It is also generally considered one of Florida's most pristine and productive estuaries. Most of the harbor is surrounded by an extensive conservation buffer system of well over 21,610 ha (53,398 acres) that the State of Florida began purchasing in the 1970s. Much of the shoreline in this buffer system is unaltered mangrove and salt marsh habitats, thereby providing abundant food and shelter for juveniles of many of the harbor's estuarine species. In addition to the State's ongoing land acquisition program, the U.S. Fish and Wildlife Service operates a series of national wildlife refuges along the Sanibel and Pine barrier islands that continues up into the tidal Caloosahatchee River. The largest of these refuges, J.N. "Ding" Darling, has almost 900,000 visitors every year and is residence to the federally endangered American crocodile (*Crocodylus acutus*). The harbor itself is home to more than 40 endangered or threatened species and boasts a world-class recreational fishing industry, including tarpon (*Megalops atlanticus*), snook (*Centropomus undecimalis*), reddrum (also called redfish; *Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*). Combined with the harbor's commercial fishing industry, fishing has an estimated impact of over one billion dollars annually (Charlotte Harbor Natural Estuary Program, 2000).

Agriculture encompasses the major land use in the greater Charlotte Harbor watershed and is second only to tourism in economic impact. In 1995, a total of 114,520 ha (282,978 acres) within the greater Charlotte Harbor watershed was dedicated to citrus crops—one-third of all Florida citrus acreage (Charlotte Harbor Natural Estuary Program, 2000)—while in 1990 over 404,680 ha or nearly one million acres was devoted to rangeland or pasture for cattle (Charlotte Harbor Natural Estuary Program, 1999). Simultaneously, Florida leads the nation in conversion of farmland to urban lands, and along the coast especially, residential and urban development is rapidly expanding. In 2020, the region is projected to have a population of almost 2 million residents, a 424% increase from the 1960s population of 363,200 (cited in Charlotte Harbor Natural Estuary Program, 2000). Finally, there is an extensive phosphate mining industry within the middle and upper reaches of the northern watershed. The "Bone Valley" phosphate deposit of more than 202,342 ha (499,987 acres) lies primarily within the Peace River subbasin. This phosphate deposit provides almost 75% of the Nation's phosphate supply and 25% of the world's (Charlotte Harbor Natural Estuary Program, 2000). Future mining is expected to move southward towards the harbor and last an additional 30 yr.

In the southwest Florida region, much research has focused on seagrass meadows to ascertain the implications of human impacts on estuarine resources, and to this end Charlotte Harbor is generally considered to be fairly healthy. For much of the greater Charlotte Harbor region, there has been little conclusive evidence of a substantial change in seagrass coverage, and mapping efforts in the harbor since 1982 have not demonstrated significant coverage trends. In addition, pollutant loads have not been documented as a threat to seagrass extent to date in the harbor. The subbasins that make up the greater Charlotte Harbor region face disparate issues, however, and in several subbasins, there may be cause for concern. For instance, in the southern Charlotte Harbor region there was documentation of an approximate 57% loss of seagrasses between the 1940s and 1980s (Harris and others, 1983), believed to be a result of physical alterations in harbor circulation patterns from the dredging of the Gulf Intracoastal Waterway and Sanibel Island Causeway construction. In Lemon Bay, seagrasses may be demonstrating a slight decline in recent years (Kurz and others, 2000), which could in turn be linked to increasing pollutant loads, nitrogen in particular (Tomasko and others, 2001). In Estero Bay, there is evidence of losses but, because of a lack of monitoring efforts and research into possible causes, little inference can be drawn at this time.

Scope of Area

The greater Charlotte Harbor watershed (fig. 1*A* and fig. 1*B*) extends approximately 210 km (130 mi) from the northernmost headwaters of the Peace River to southern Estero Bay and for this effort is divided into six major hydrologic subbasins: Charlotte Harbor; Lemon and Estero Bays; and

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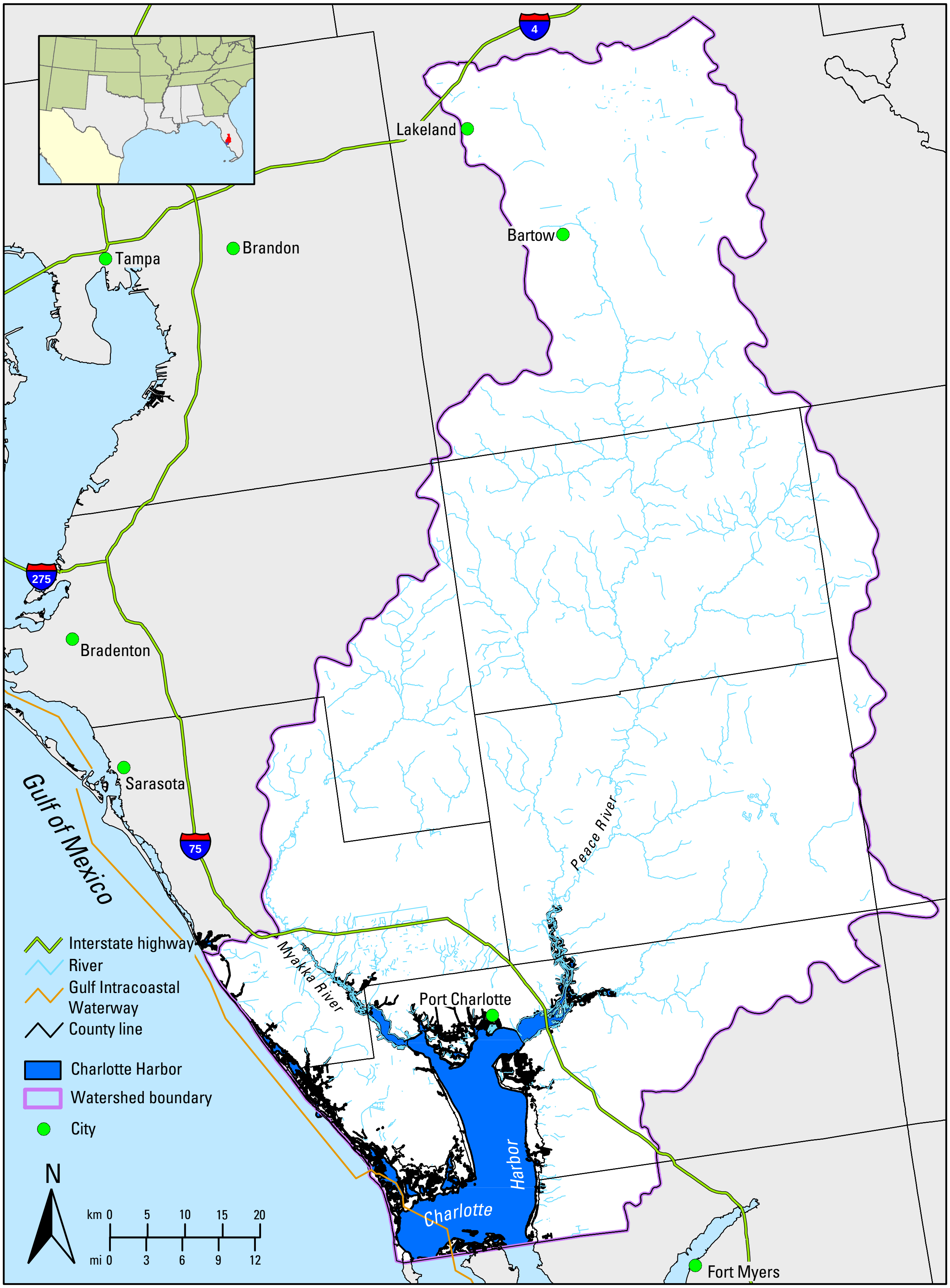

Figure 1*A*. Watershed for northern Charlotte Harbor region.

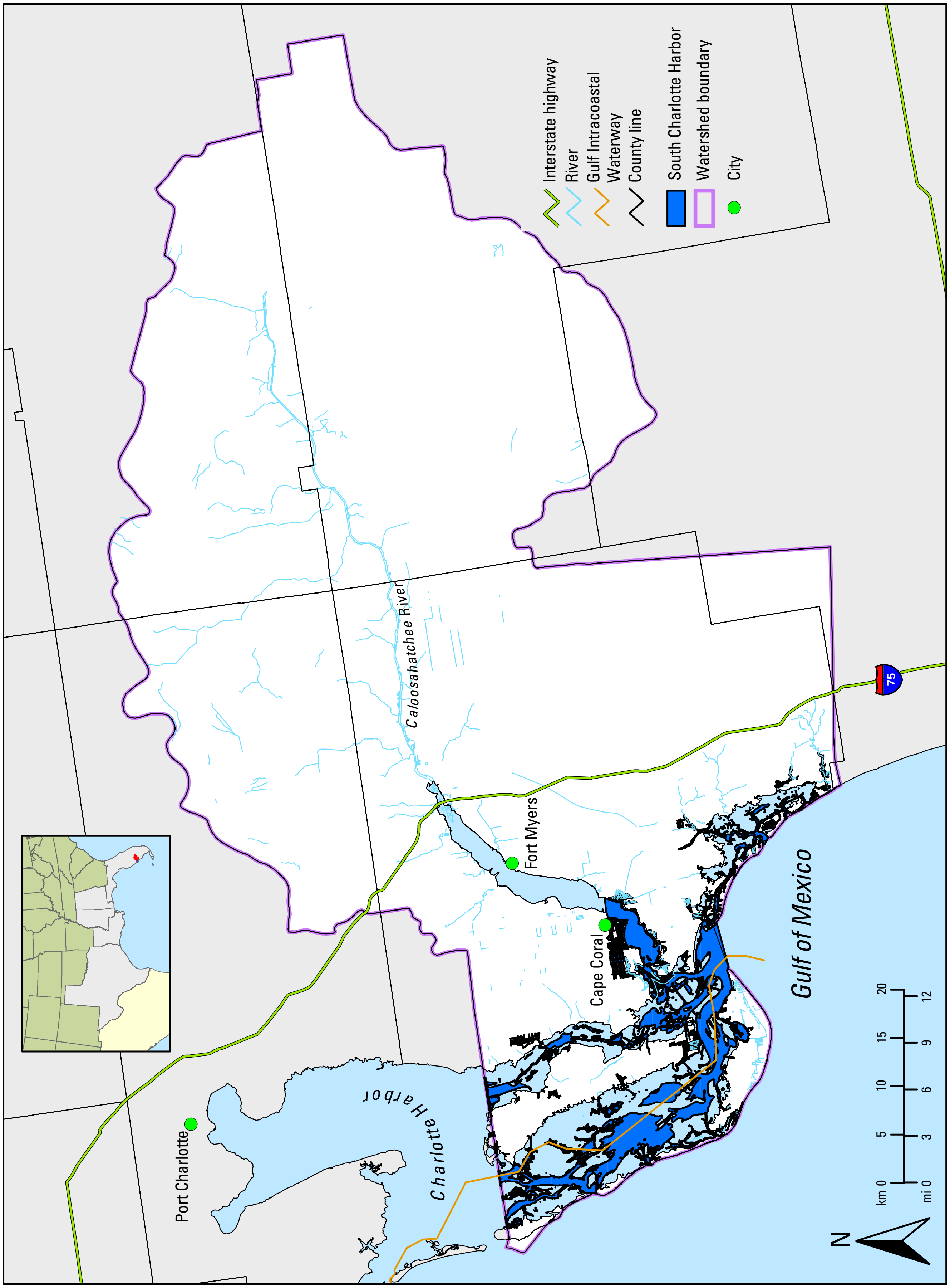

Figure 1*B*. Watershed for southern Charlotte Harbor region.

the Caloosahatchee, Peace and Myakka Rivers. The latter two subbasins, the Peace (a 6,090 km^2 or 2,350 mi^2 basin) and the Myakka (a 1,560 km^2 or 602 mi^2 basin) Rivers, serve as two major sources of fresh water to the Charlotte Harbor estuary (cited in Hammett, 1990). The average discharge from the Peace River is estimated at 60 m^3/s (2,010 ft^3/s) to 75 m^3/s (2,640 ft^3/s), and the Myakka River is estimated at 18 m^3/s (630 ft^3/s), although the discharge is much higher during early July through late September in the summer rainy season (Hammett, 1990).

The third major source of fresh water to the harbor is the Caloosahatchee River (3,570 km^2 or 1,378 mi^2 basin extending to Moore Haven), which contributes an annual average inflow to the lower harbor of approximately 57 m^3/s (2,000 ft^3/s) (Hammett, 1990). The river was channelized and connected to Lake Okeechobee in the late 1800s (although there is some evidence that the Calusa Indians may have created a link between the two waterbodies much earlier (South Florida Water Management District, 1998)) and repeatedly dredged over the next century to provide flood protection and serve as both a source of agricultural and urban water supply and a navigational channel. A series of three locks and dams was constructed along the river, one of which, the W.P. Franklin locks and dam, artificially truncates the river's estuarine system by blocking the natural gradient of fresh to salt water that historically extended upstream during the dry season. It is common to have disparate salinity regimes on the two sides of this lock system during the dry season when the locks are closed. Water exiting the Caloosahatchee River flows both north up lower Matlacha Pass and southern Pine Island Sound and south through San Carlos Bay and Estero Bay to the Gulf of Mexico.

South of the Caloosahatchee River is Estero Bay, a shallow 4,580 ha (11,317 acres) bay with a 780 km^2 (301 mi^2) basin (Charlotte Harbor Natural Estuary Program, 2000). Estero is the receiving water body for the Imperial and Estero Rivers and Hendry, Spring, and Mullock Creeks. This bay's watershed, situated between the cities of Naples and Fort Myers, is an area of very rapid population growth, including a high density of golf courses. The tributaries to Estero Bay all demonstrate a recent increase in phytoplankton blooms, and three are on the State's Impaired Waters List for nutrient impairments.

Finally, Lemon Bay, another shallow bay, is located to the northwest of the Charlotte Harbor subbasin and actually connects the harbor to Sarasota Bay via the Gulf Intracoastal Waterway. This bay is 21 km (13 mi) in length and 0.2 to 1.9 km (0.12–1 mi) wide with a surface area of only 31 km^2 (12 mi^2) (Tomasko and others, 2001). Lemon Bay receives fresh water from several small tributaries: Buck, Coral, Alligator, Forked, Gottfried, Rock, and Oyster Creeks. The waters leaving Lemon Bay in turn drain into the Gulf of Mexico through Stump Pass or by entering Gasparilla Sound and coalescing with the waters exiting Charlotte Harbor to the south.

These 6 hydrologic subbasins are further segmented into 14 segments for analyses of seagrass in this effort (fig. 2). Eight of these segments, from Lemon Bay to the South Harbor area of northern Charlotte Harbor, fall within the Southwest Florida Water Management District's (SWFWMD) jurisdiction (table 1). The other six segments fall under the purview of the South Florida Water Management District (SFWMD).

Table 1. Fourteen subsegments created for analyses of seagrass coverage in the greater Charlotte Harbor region.

Southwest Florida Water Management District Region	
Charlotte Harbor (Northern):	Charlotte Harbor (Southern):
Lemon Bay	Pine Island Sound
Peace River	Matlacha Pass
Myakka River	San Carlos Bay
Middle Harbor	Lower Caloosahatchee River
West Wall	Upper Caloosahatchee River
East Wall	Estero Bay
Placida Region	
South Harbor	

Methodology Employed To Determine and Document Current Status

The SWFWMD and SFWMD conduct seagrass mapping efforts within the Charlotte Harbor region as fulfillment of the districts' obligations under the Charlotte Harbor National Estuary Program's (CHNEP) Comprehensive Conservation and Management Plan (CCMP). The seagrass mapping effort is also included within the SWFWMD's Surface Water Improvement and Management (SWIM) Plan for the northern harbor and Lemon Bay regions. The SWFWMD has conducted the seagrass mapping efforts on a roughly biennial basis since 1988, and the SFWMD initiated the undertaking of biennial seagrass mapping efforts within their area in 1999. In 1999, which was the most recent comprehensive mapping effort for the harbor, the two districts used somewhat dissimilar methodologies in their mapping efforts; however, the SFWMD is using most of the same methodologies as the SWFWMD in future efforts to ensure better data comparability.

Figure 2. Scope of area for the Charlotte Harbor seagrass vignette.

Southwest Florida Water Management District

Seagrass maps are produced through a multistep process on a district-wide basis; therefore, this same methodology is used in Tampa and Sarasota Bays as well as in Charlotte Harbor. First, aerial photographs are obtained during times of good water clarity and moderately high seagrass biomass—usually November or December—after the summer rains have ceased. True color photographs at a scale of 1:24,000 are used, and the film is New Kodak Aerocolor negative film 2445, or a district-approved equivalent. The requisite end and side laps for the photographs are 60% and 30%, respectively. The SWFWMD requires that secchi disk depths be over 2 m, wave height less than 0.61 m (2 ft) and the wind speed less than 16 km/hr (10 mi/hr) on the day the photographs are obtained. The sun angle must be at least 35 degrees and tidal stage must be at no greater than mean tide level. These requirements necessitate that district staff, personnel from supporting agencies, and/or volunteers be out on the estuary checking for the correct conditions on several occasions before an aerial survey is actually flown.

Next, investigators examine bottom cover at various locations in the field to allow identification of distinct photographic signatures and investigate unusual signatures. In the office, the field classifications are matched to signatures on the photographs and used to train the photointerpretation staff. Seagrass signatures are divided into two classes: continuous coverage (<25% unvegetated bottom visible within a polygon) and patchy (>25% unvegetated bottom visible within a polygon. The Florida Land Use, Cover and Forms Classification System (FLUCCS; *http://www.dot.state.fl.us/surveyingandmapping/fluccmanual.pdf*) has been used to divide seagrass into two categories: patchy seagrass as 9113 (>25% unvegetated bottom visible within a polygon) and continuous seagrass as 9116 (<25% unvegetated bottom visible within a polygon). The minimum mapping unit is 0.02 ha (0.5 acres).

For the earlier mapping efforts (1988, fig. 3; 1992, fig. 4; 1994; fig. 5; and 1996, fig. 6) the individual polygons were delineated on Mylar® sheets placed over top of the aerial photographs, and then a zoom transfer scope was used to transfer the delineated polygons to USGS quadrangles. Next, the polygons were digitally transferred to an ArcInfo database. The resulting seagrass maps meet USGS National Map Accuracy Standards for 1:24,000 scale maps. For the 1999 and 2002 seagrass maps, tighter ground control and more sophisticated mapping techniques were used to meet 1:12,000 National Map Accuracy Standards while still using 1:24,000 scale photographs. Analytical stereo plotters were used for photointerpretation in lieu of the stereoscopes. This method allowed for the production of a georeferenced digital file of the photointerpreted images without the need for additional photo to map transfer. Instead of drawing complete polygons each year, effort and errors have been reduced by using the previous effort's digital coverage as the baseline and delineating any changes to seagrass extent for the current effort. This method has provided a change analysis as well as a current seagrass coverage.

Hard copy plots were produced and checked for errors. Finally, between 20 and 40 randomly chosen points were identified for the northern Charlotte Harbor and Lemon Bay regions and plotted for a classification accuracy assessment. The points were randomly selected by using ArcInfo processes and by first defining the coordinates of the study area. The point selection then involved the random generation of numbers based on the minimum and maximum values of the X and Y coordinates of the study area. The numbers that were generated were stored as variables, and a selection was made from the ArcInfo coverage to see if they fit the criteria specified (i.e., seagrass codes = 9113 or 9116). A variable was also set up to be used as a counter, and set to a value of zero (0). If the area did not fit the selection criteria, the "counter" variable was not calculated and the loop ran itself again. If the area fit the selection criteria, a point was placed at the position and the coordinates were stored in the variable; then the "counter" variable was calculated with the next value. This process was repeated until approximately 10–20 points per estuary region were selected. Field staff used the coordinates for the randomly chosen sites, a site map and a Global Positioning System (GPS) unit to visit the locations in the field and classify the bottom cover. These field checks were compared to the map classifications to develop an unbiased determination about classification accuracy of the map. The SWFWMD requires a 90% classification accuracy standard for the seagrass mapping efforts, and accuracies over 95% were achieved in 1999 (figs. 7*A* and 7*B*) and 2002 (fig. 8).

South Florida Water Management District

The 1999 seagrass mapping effort for southern Charlotte Harbor, including Pine Island Sound, Matlacha Pass, San Carlos Bay, the upper Caloosahatchee River, lower Caloosahatchee River and Estero Bay areas, used a different methodology than the SWFWMD's described above. New Kodak Aerocolor negative film 2445 was used for the acquisition of 1:24,000-scale, natural color aerial photographs in December 1999 (AGRA Baymont, 2001). End lap and side lap were required at 60% and 30%, respectively.

A Differential Global Positioning System unit was used to collect 20 ground control points. Also, photoidentifiable "pass points" (between frames following the flight lines) and "tie points" (between flight line strips) were selected and included to the previously surveyed ground control point network. Additionally, ground control points from the SWFWMD aerial photography photointerpretation project in 1999 were included to guarantee an accurate tie between the two areas and resulting maps. This suite of control points was used to accomplish analytical aerotriangulation of the aerial photographs well within the USGS National Map Accuracy Standards for 1:24,000-scale maps.

Prior to photointerpretation, site visits were made for the purposes of advance photosignature identification and investigation of unusual signatures. Photographs and GPS coordinates were taken during these site visits. A photointerpretation key was developed with definitions of each classification category, photographs from site visits, and images of aerial views to be used as a guide throughout the interpretation process.

Covertype boundaries were photogrammetrically digitized by using CADMAP®/dgn software. The data were initially captured digitally into MicroStation NT then later exported to ArcInfo. Classifications of vegetation covertypes were made based on FLUCCS as defined below (The minimum mapping unit was 0.10 ha or 0.25 acres.):

Continuous, dense seagrass beds. The dominant feature of these seagrass beds was continuity (>85% cover), but there may have been variable density within the bed. These beds contained interspersed areas of unvegetated bottom (<10% cover); however, unvegetated bottom or sand patches greater than 0.1 ha (0.25 acres) should have been distinguished within a continuous seagrass bed. The percent cover for continuous seagrass was approximately 85%.

Patchy seagrass beds. Patchy or discontinuous seagrass beds (<10% and >85% cover) greater than 0.1 ha (0.25 acres) that may also have been of variable density.

Algal beds. Beds of attached algae that were distinguishable from seagrass. Where feasible, they were mapped and field verified if >10% cover.

Groundtruthing of completed photointerpretation work involved visiting 40 sites and verifying actual cover type. Sites were selected to include complex areas (i.e., seagrass density variations and algae presence) and the variety of classification categories. These field checks were used as quality assurance checks for verification of accuracy.

Methodology Employed To Analyze Historical Trends

In 1983, the Florida Department of Natural Resources (FDNR) and the Florida Department of Transportation (FDOT) produced a document and associated maps that examined the land use of Charlotte Harbor and Lake Worth Lagoon, Fla. (Harris and others, 1983). Black and white photographs from 1946 and 1951 (referred to in the original document as the 1945 set) were acquired, and 1:24,000-scale, positive, false-color infrared transparencies were produced from flights in April 1982. The 1982 photographs were analyzed with stereoscopic visual equipment; the 1945 photographs did not have the required overlap and endlap to perform stereoscopic analyses. For the 1945 and 1982 photographs, seagrass was delineated onto Mylar® overlays, and then the data were digitized into the FDOT proprietary point-vector database. Maps were produced at 1:24,000 scale.

Classification of the seagrass from the 1945 aerials was performed to the level of only one category (submerged aquatic vegetation) because the quality of the photographs did not allow multiple category classification. The 1982 seagrass was classified to three categories:

- 901 Sparse underwater vegetation: this class was characterized by approximately 70% or more exposed sand in the actual meadow regardless of the patchiness observed within the meadow;
- 903 Moderate-to-dense underwater vegetation: this class encompassed all contiguous meadows with approximately 30% or less uniformly exposed sand; and
- 904 Patchy underwater vegetation: this category was characterized by large unvegetated patches within areas of 1 m^2 or more moderate to dense grass.

For this report, coverages for all datasets, including subsequent mapping efforts, are reported as combinations of all seagrass classification categories employed (i.e., sparse, dense, patchy) and are summarized in table 2.

The Florida Marine Research Institute (FMRI) currently holds the original Mylar® overlays for the 1945 and 1982 photographs. In 1990, FMRI staff registered the original 1982 Mylar® overlays to 7.5 minute quadrangles and redigitized the seagrass polygons to create a digital ArcInfo file. Also, to fill a void in the 1982 mapping effort that did not include southern Estero Bay, FMRI interpreted 1982 Estero Bay extent from 1990 photographs. Because the 1982 data exist in digital format, calculations of seagrass extent based on the 14 seagrass segments were possible for this report and are used as historical data for comparison with the more recent mapping results (fig. 9).

Lack of digital data for the 1945 effort, however, prohibit examination of the 14 seagrass segments for this effort. The total coverage for the 1945 analysis is included briefly in the discussion below, but it is not used for seagrass trend analysis. Seagrass coverage for the 1945 maps were evaluated by USGS quadrangle areas rather than the 14 segments that have been used to define coverage for this report. Also, the geographic boundaries for the 1945 study area do not match the boundaries of the 1982 and subsequent year analyses. (The original 1982 study area boundaries were identical to the boundaries of the 1945 study area boundaries; however, SWFWMD and FMRI recalculated the acreages based on the 14 segments used for recent Charlotte Harbor seagrass investigations as explained above.) Therefore, a comparison of total extent from the 1945 to recent efforts is not possible. Finally, the black and white photographs used in the 1945 effort were of too low a quality for delineating seagrass, and the absence of ground-verification during the year the photographs were produced is reason for caution when examining these data and resulting maps.

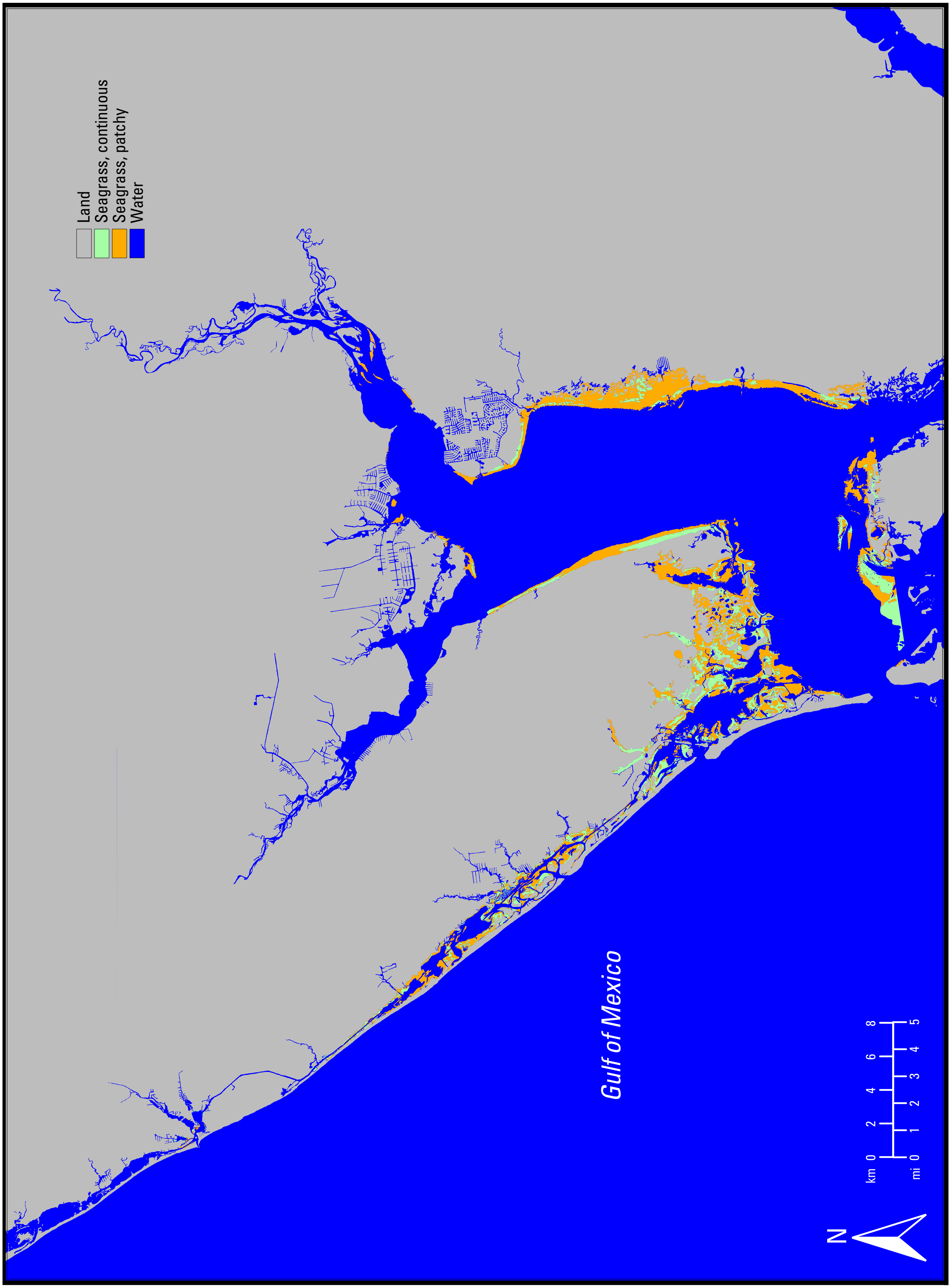

Figure 3. Distribution of seagrass in the northern Charlotte Harbor system, 1988.

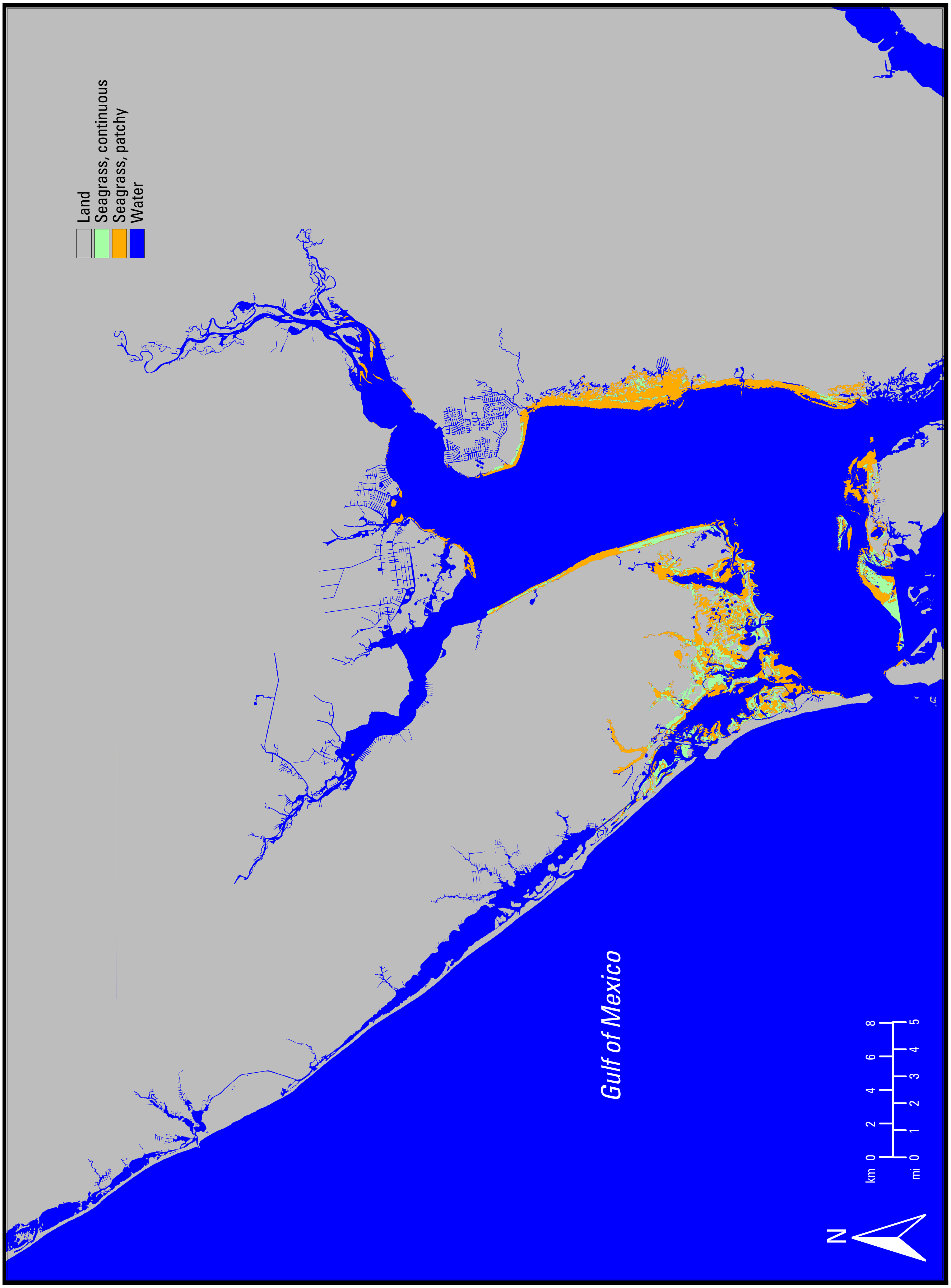

Figure 4. Distribution of seagrass in the northern Charlotte Harbor system, 1992.

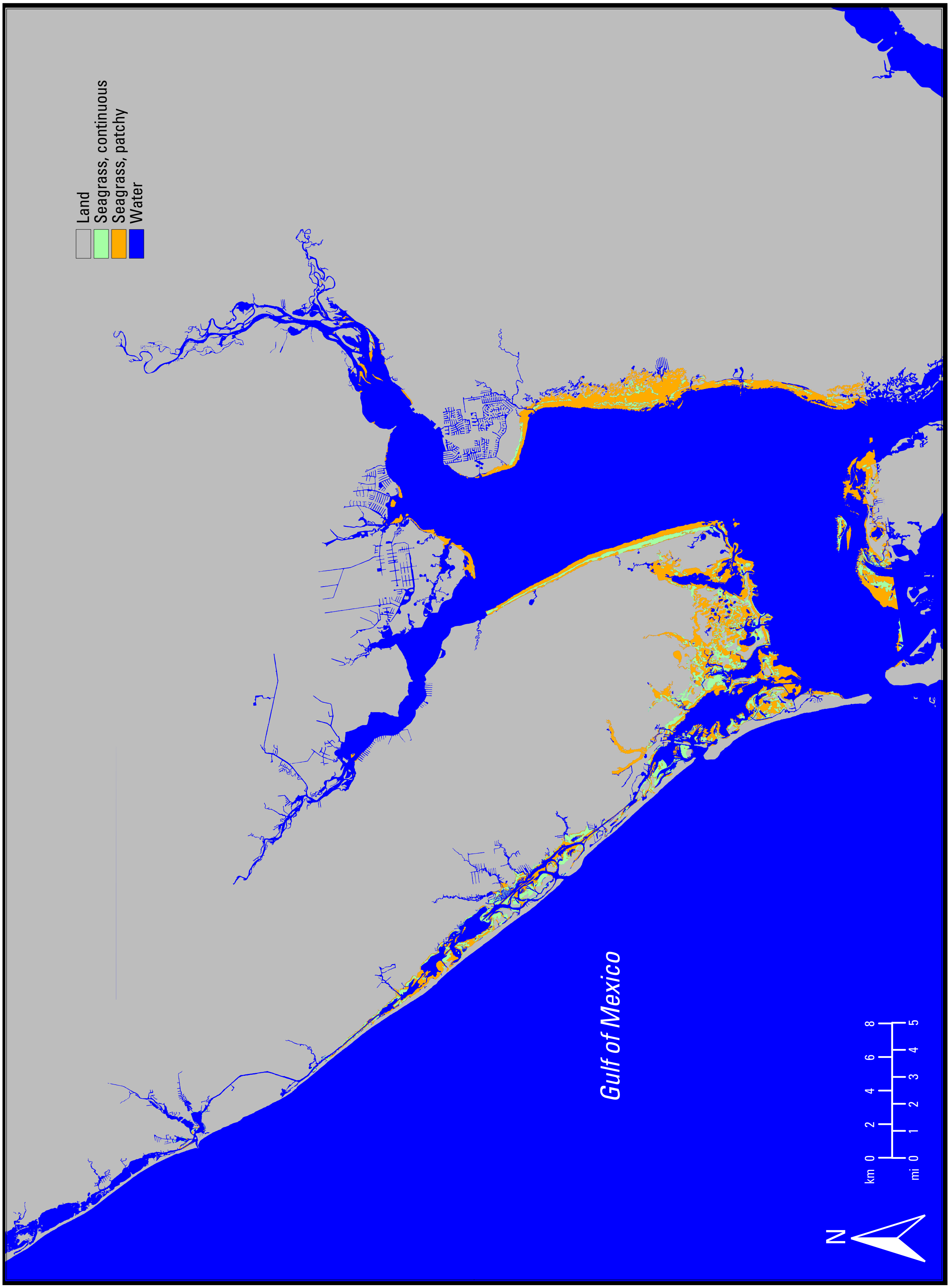

Figure 5. Distribution of seagrass in the northern Charlotte Harbor system, 1994.

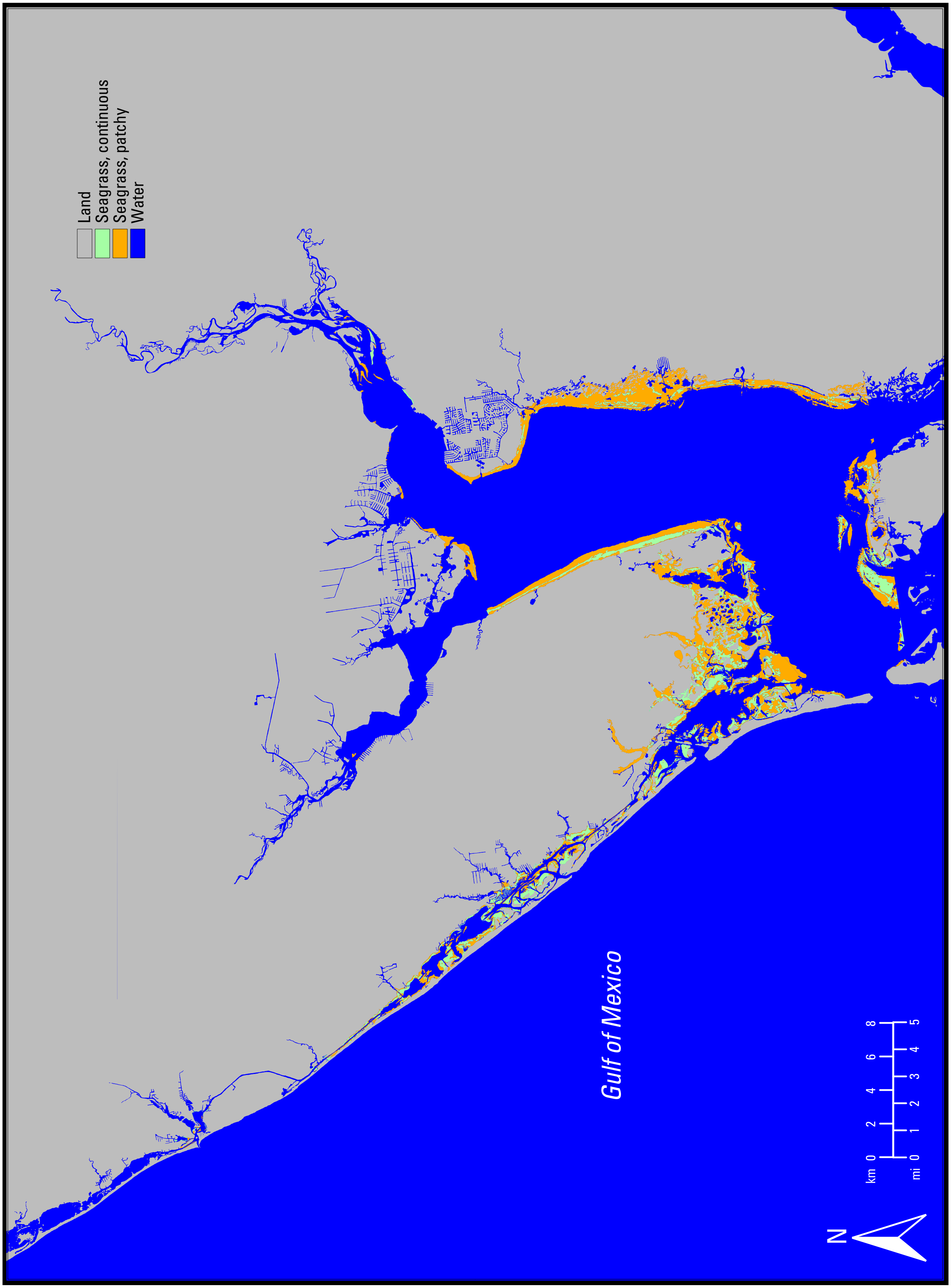

Figure 6. Distribution of seagrass in the northern Charlotte Harbor system, 1996.

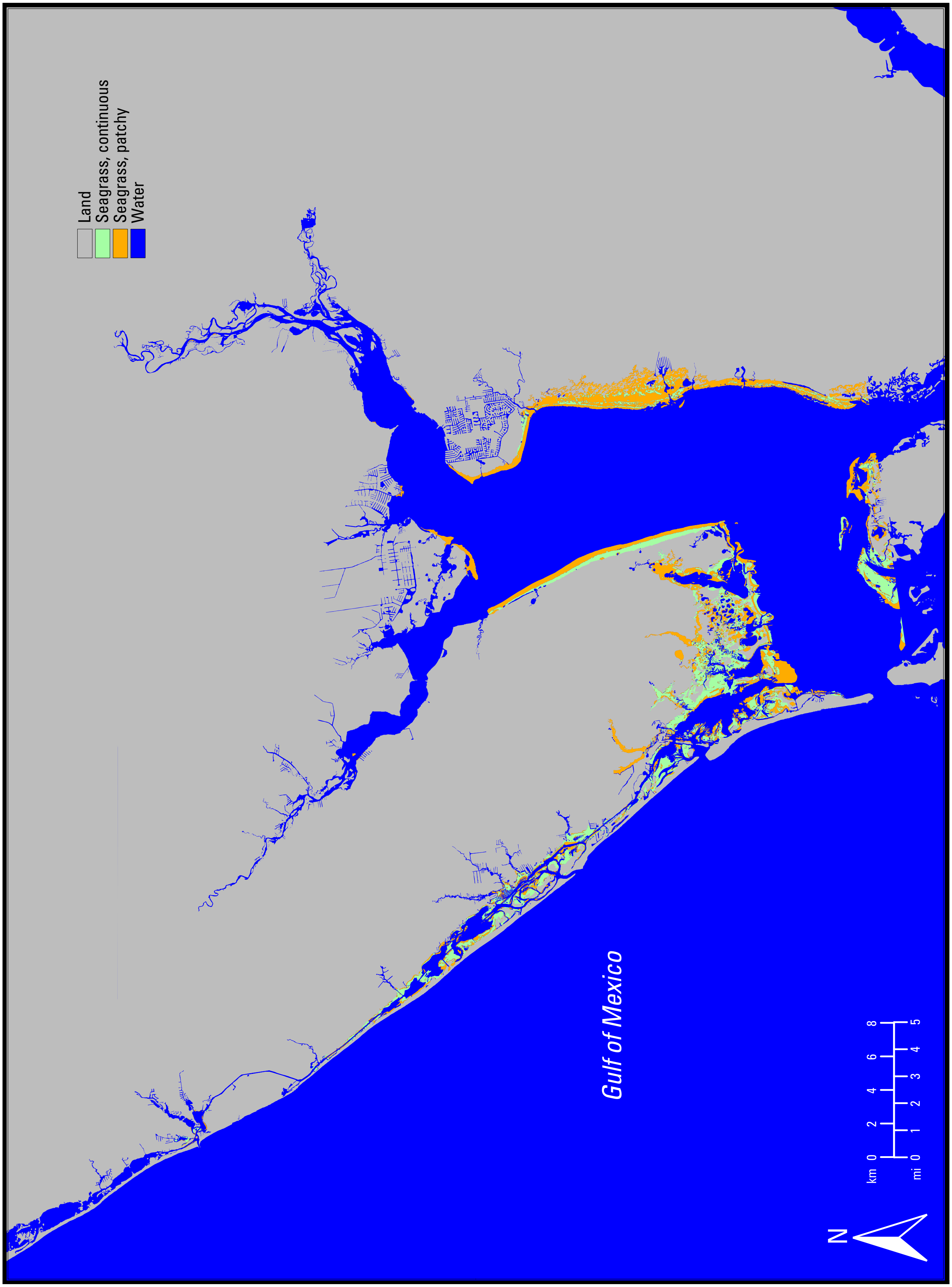

Figure 7A. Distribution of seagrass in the northern Charlotte Harbor system, 1999.

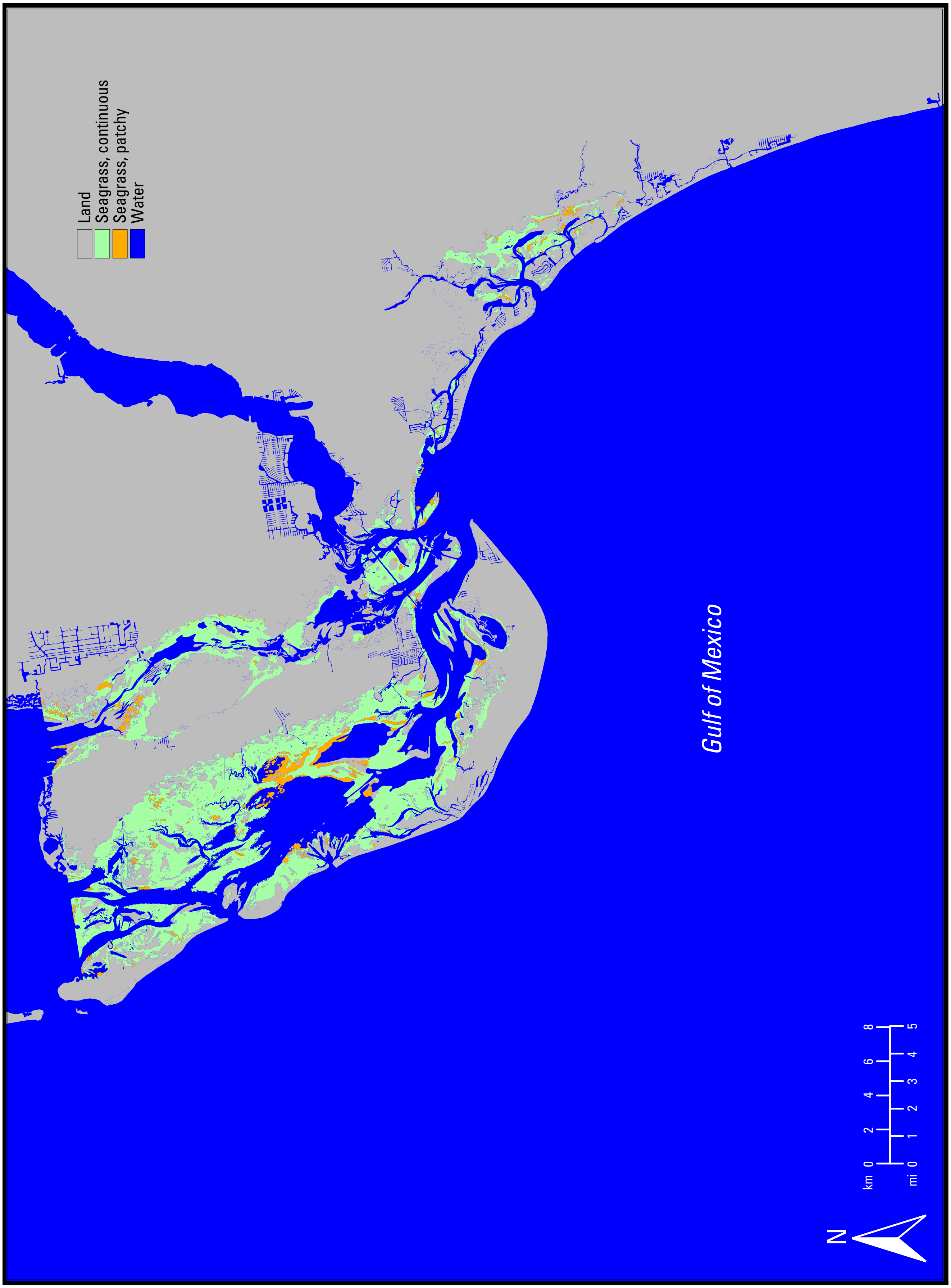

Figure 7*B*. Distribution of seagrass in the southern Charlotte Harbor system, 1999.

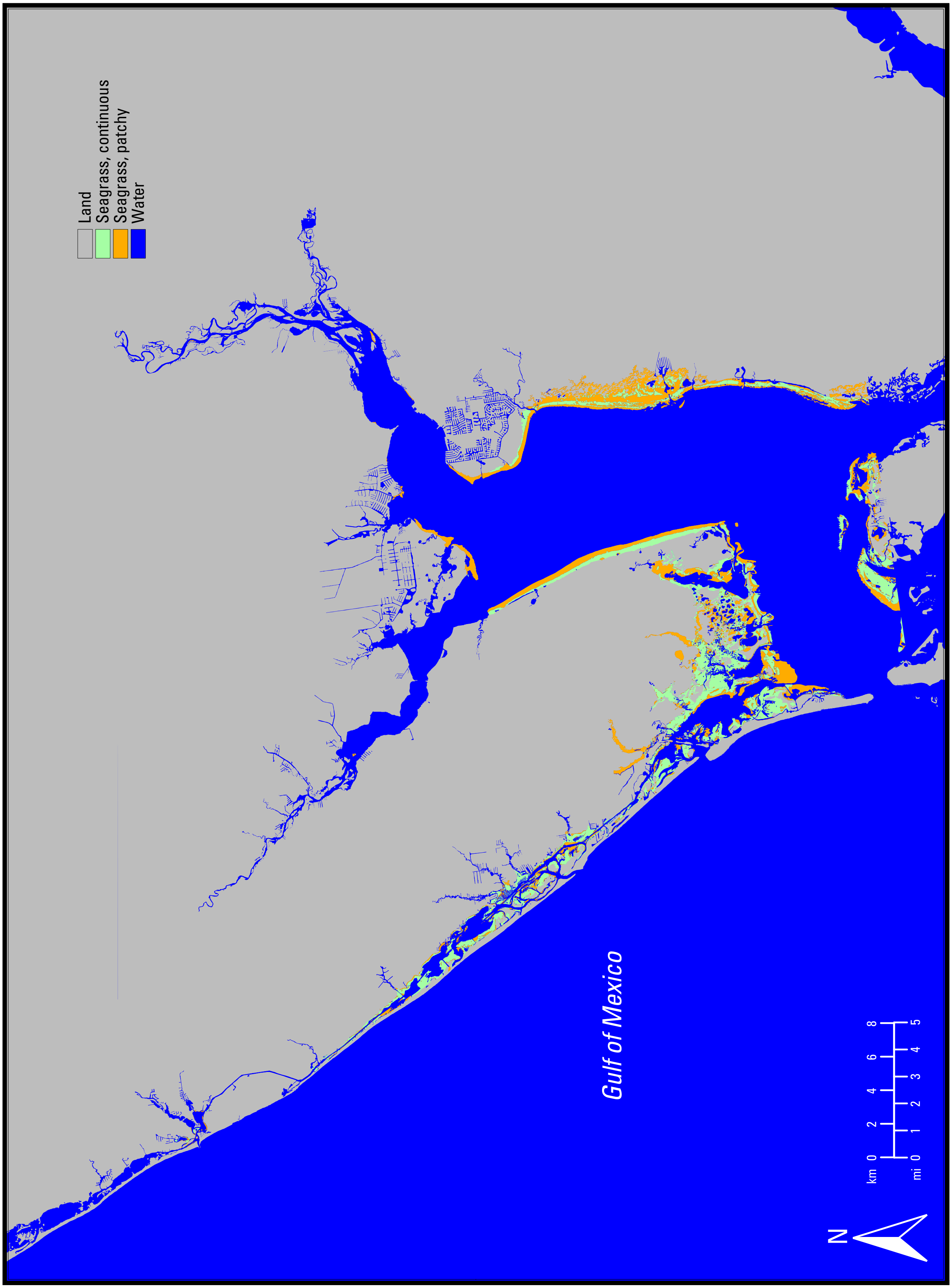

Figure 8. Distribution of seagrass in the northern Charlotte Harbor system, 2002.

Table 2. Seagrass coverage in hectares (acres) by year in the 14 subsegments of the greater Charlotte Harbor region.

[Note: 1982 coverage calculations differ from Harris and others (1983) report because of subsegment boundary delineations. The 1983 report calculated coverage within USGS quadrangles; 1988–96 extent taken from Kurz and others (2000)]

Subsegment	Year						
	1982*	**1988**	**1992**	**1994**	**1996**	**1999**	**2002**
Lemon Bay		1,055 (2,607)		1,073 (2,651)	1,054 (2,604)	1,044 (2,580)	1,043 (2,577)
Myakka River	238 (588)	202 (499)	130 (321)	189 (467)	209 (516)	191 (472)	185 (457)
Peace River	378 (934)	158 (390)	166 (410)	196 (484)	225 (556)	109 (269)	137 (339)
Charlotte Harbor (northern)							
East Wall	1,548 (3,825)	1,372 (3,390)	1,361 (3,363)	1,416 (3,499)	1,371 (3,388)	1,452 (3,588)	1,454 (3,593)
West Wall	672 (1,660)	585 (1,445)	495 (1,223)	675 (1,668)	794 (1,962)	699 (1,727)	699 (1,727)
Middle Harbor	70 (173)	50 (124)	50 (124)	60 (148)	76 (188)	63 (156)	64 (158)
Placida Region	948 (2,343)	1,408 (3,479)	1,376 (3,400)	1,337 (3,304)	1,450 (3,583)	1,503 (3,714)	1,531 (3,783)
South Harbor	3,513 (8,681)	3,684 (9,103)	3,636 (8,985)	3,633 (8,977)	3,626 (8,960)	3,340 (8,253)	3,313 (8,186)
Subtotal (excluding Lemon Bay)	7,367 (18,204)	7,458 (18,429)	7,214 (17,826)	7,505 (18,545)	7,751 (19,153)	7,357 (18,179)	7,383 (18,243)
Charlotte Harbor (southern)							
Pine Island Sound	9,853 (24,347)					10,484 (25,906)	
Matlacha Pass	3,245 (8,018)					2,456 (6,069)	
San Carlos Bay	2,420 (5,980)					1,504 (3,716)	
Upper Caloosahatchee River	0					0	
Lower Caloosahatchee River	242 (598)					1 (2)	
Estero Bay	2,504 (6,187)*					1,008 (2,491)	
Subtotal (excluding Estero Bay)	15,760 (38,943)					14,445 (35,694)	
Grand total	25,631 (63,334)	8,513 (21,036)	7,214 (17,826)	8,578 (21,196)	8,805 (21,757)	23,854 (58,943)	8,426 (20,821)

*The Florida Marine Research Institute interpreted Estero Bay from 1990 photographs to fill a void in the 1982 photographs.

Status and Trends

Since the first mapping of seagrass in Lemon Bay in 1988, coverage calculations have remained relatively consistent through the 2002 time period. However, seagrass coverage in Estero Bay may have dramatically changed because a 60% (1,496 ha or 3,697 acres) decrease was recorded from 1982 to 1999 (note: coverage estimates for the southern portion of Estero Bay reported in these 1982 data were actually obtained from 1990 photographs). It should be noted that mapping methodologies between these two time periods were not identical, and groundtruthing was scarce in Estero Bay for the 1982 study (Frank Sargent, oral communication). Field verification work for the 1999 study (as well as a preliminary study done in 2003) found large areas of accumulated drift algae over sand and seagrass areas; therefore, it is possible that the Estero Bay coverage in the 1982 study incorporates drift algae wracks. The decrease in coverage in Estero Bay from 1982 to 1999 must be viewed with these caveats in mind.

For the following comparisons of seagrass area in the greater Charlotte Harbor estuarine complex, area calculations for Lemon Bay and Estero Bay are not included. The first reliable seagrass interpretation work for Charlotte Harbor was created with the 1982 photographs. Interpretation of the photographs resulted in 23,127 ha (57,147 acres) total seagrass. In 1999 the most recent comprehensive mapping project for the greater Charlotte Harbor estuarine complex produced seagrass estimates of 21,802 ha (53,873 acres). Thus, from 1982 to 1999 the mapping results indicate an overall 6% (1,325 ha or 3,274 acres) decrease of seagrass (see table 3).

Combined estimates for the seven segments in Charlotte Harbor under the SWFWMD jurisdiction (Myakka River, Peace River, East Wall, West Wall, Middle Harbor, Placida Region, and South Harbor) have fluctuated up and down within a variance of less than 1,236 ha (3,054 acres) since the 1982 study. The 1999 extent is only 10 ha (25 acres) less than the 1982 value, while the 2002 coverage is 16 ha (39 acres) greater (fig. 10).

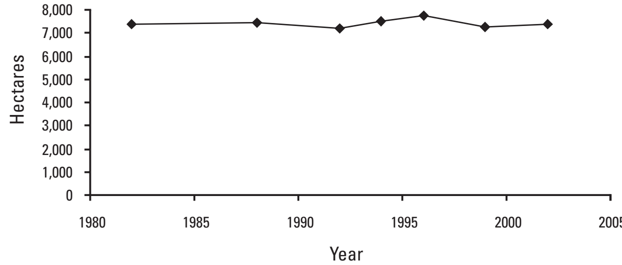

Figure 9. Seagrass extent in the northern Charlotte Harbor region (except Lemon Bay) since 1982.

Table 3. Comparison of 1982 to 1999 seagrass coverage by subbasin (in hectares; conversions to acres are provided in table 2).

Segment	Year		Change	% Change
	1982	1999		
Myakka River	238	191	-47	-20
Peace River	378	109	-269	-71
Charlotte Harbor (northern)				
East Wall	1,548	1,452	-96	-6
West Wall	672	699	27	4
Middle Harbor	70	63	-7	-10
Placida Region	948	1,503	555	59
South Harbor	3,513	3,340	-173	-5
Subtotal	7,367	7,357	-10	0
Charlotte Harbor (southern)				
Pine Island Sound	9,853	10,484	631	6
Matlacha Pass	3,245	2,456	-789	-24
San Carlos Bay	2,420	1,504	-916	-38
Upper Caloosahatchee River	0	0	0	0
Lower Caloosahatchee River	242	1	-241	-100
Subtotal	15,760	14,445	-1315	-8
Total	23,127	21,802	-1325	-6

The five Charlotte Harbor segments within SFWMD jurisdiction (Pine Island Sound, Matlacha Pass, San Carlos Bay, lower Caloosahatchee River, and upper Caloosahatchee River) constitute the majority of the seagrass coverage in the Charlotte Harbor region—almost double that of the northern region in 1999, for example. These five segments have experienced an 8% (1,315 ha or 3,249 acres) decrease in seagrass from 1982 to 1999. This southern area accounts for approximately 77% of the total 6% seagrass coverage decline in the greater Charlotte Harbor region from 1982 to 1999.

Causes of Change

The subbasins included in the Charlotte Harbor Estuarine Complex face disparate issues that can result in changes of seagrass extent from historical conditions. Northern Charlotte Harbor appears to lack a significant trend in seagrass extent since the 1982 mapping effort, and it appears that seagrass extent in this subbasin is largely a factor of inflows from the Peace and Myakka Rivers. Nonetheless, in other subbasins within the Charlotte Harbor region, there is growing concern

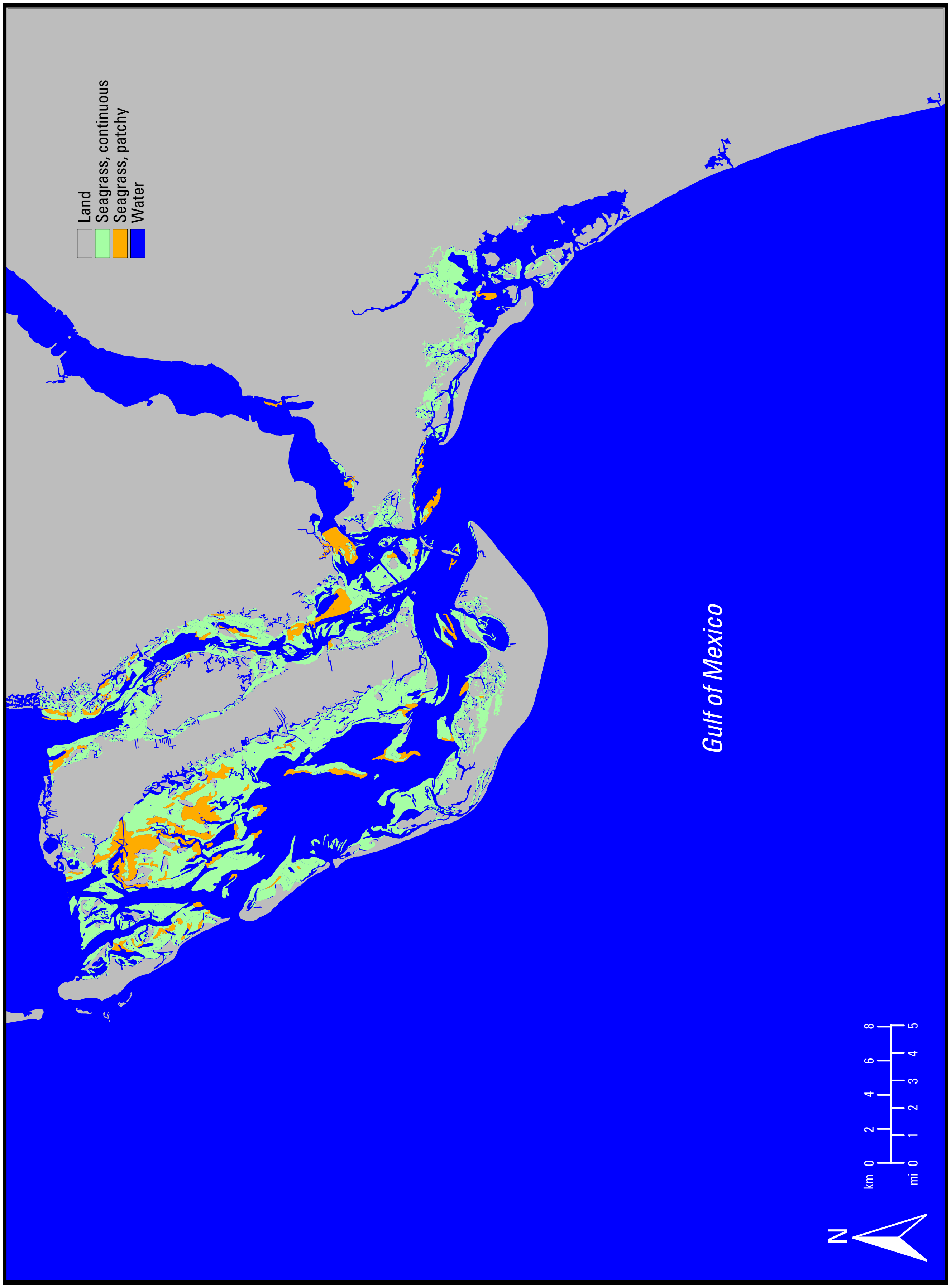

Figure 10. Distribution of seagrass in the southern Charlotte Harbor system, 1982.

that seagrasses are being harmed by human impacts. For instance, seagrass coverage in Lemon Bay showed a 1.8% decrease from 1994 to 1996 (Kurz and others, 2000); this coverage then remained constant in 1999 and 2002. The potential small decrease may be linked to decreases in water clarity associated with increases in nutrient loads (Tomasko and others, 2001) and resuspension of estuary bed sediments (Judy Ott, oral communication). There is also documentation of a large loss of seagrass coverage in southern Charlotte Harbor from the 1940s because of physical alterations and resulting changes in flow patterns within this region. The seagrass beds in all three of the rivers demonstrate marked changes in extent with each mapping effort, perhaps in part because of photointerpretation issues but also because of concomitant changes of river flows in the Peace and Myakka Rivers and water management in the Caloosahatchee River. Finally, the Charlotte Harbor region is considered one of the most severely impacted regions of Florida by boat propeller scarring (Sargent and others, 1995).

The most comprehensive review of historical seagrass extent for the Charlotte Harbor region is the 1983 FDNR report described above (Harris and others, 1983). This report documented a 29% decrease in seagrass, from 33,572 ha (82,959 acres) to 23,672 ha (58,495 acres) between 1945 and 1982 for the harbor, excluding Lemon and southern Estero Bays. As explained above, neither the study area boundary nor the segment delineations for the 1945 data within the 1983 report correlate with this current effort and are therefore problematic for use in direct coverage comparisons with subsequent year efforts; however, the report did theorize about the causes of change in the region that is very useful for this discussion. The authors noted a decrease in seagrasses in the deep edges of seagrass beds and the deeper portions of the harbor, and they theorized that the loss was a result of decreasing water clarity with increasing pollutants and changing drainage patterns. The study also determined that 40% of the total region-wide loss was located solely within the lower Pine Island Sound area. When combined with the loss of southern Matlacha Pass and San Carlos Bay areas, this loss equaled 57% of the total Charlotte Harbor region-wide loss of 29%. The authors contributed this substantial loss to the dredging of the Intracoastal Waterway and construction of a bridge and multiple causeway islands to Sanibel Island in the 1940s and 1960s. Using nautical maps, the authors noted that a shallow bar less than 1.5 m (5 ft) in depth with deeper channels (2.4–4.6 m or 8–15 ft) on either side, had served as a tidal node that extended entirely across Pine Island Sound. During an ebb tide, flow occurred to the north and south of this bar. This shallow bar was apparently the location of the one of the first channel dredging operations in the 1940s. In the 1960s, the Intracoastal Waterway was dredged through Pine Island Sound and up the Caloosahatchee River, and the Sanibel Causeway, including its spoil islands, was constructed across San Carlos Bay. The authors reasoned that the diversion of water from the Caloosahatchee River into Pine Island Sound and the changes of circulation patterns as a result of these two projects have lowered the salinities in the lower Caloosahatchee River estuary, San Carlos Bay, Matlacha Pass, and Pine Island Sound areas. Also, during the dredging of the Intracaostal Waterway and construction of the Sanibel Causeway, direct loss of seagrasses was due to the excavation and sidecast fill over the nearby seagrass beds (cited in Harris and others, 1983; James Beever, written communication). Following both projects, loss of seagrasses ensued because of turbidity and spoil spread (James Beever, written communication).

Indirect impacts to seagrass extent in Charlotte Harbor from pollutant loads have not been documented. Relative to Tampa, Sarasota, and Lemon Bays to the northwest, Charlotte Harbor is highly influenced by the freshwater inflows of its large watershed. The surface area of the harbor is approximately 700 km^2 (270 mi^2), whereas the watershed is almost 11,300 km^2 (4,362 mi^2), a ratio of watershed to open water of over 12:1 (Southwest Florida Water Management District, 2000). The result of this large watershed is that the waters of the harbor are often a dark, brownish, tea color caused by the influx of tannins and suspended mater from the watershed. For instance, a 1987 study found that nonchlorophyll suspended matter (including detritus, cellular material, and minerals) accounts for an average of 72% of light attenuation in the water column, color (dissolved matter) accounts for 21%, phytoplankton chlorophyll for 4% and water itself the remaining 3% (McPherson and Miller, 1987), and another evaluation of light attenuation in 1999 found that color, turbidity and chlorophyll accounted for 66%, 31% and 4% of light attenuation (Dixon and Kirkpatrick, 1999). Water clarity in the harbor increases with increasing salinity (McPherson and Miller, 1987; McPherson and Miller, 1994; Dixon and Kirkpatrick, 1999; Tomasko and Hall, 1999). Thus, the light reaching the tops of seagrass beds is largely a factor of basin runoff and flows from the three major tributaries—the Peace, Myakka, and Caloosahatchee Rivers (McPherson and Miller, 1987; Tomasko and Hall, 1999; Doering and Chamberlain, 1999). In turn, seagrass coverage changes in the harbor and the tidal reaches of the rivers are thought to be a function of changes in these freshwater inflows. For example, the East Wall segment of Charlotte Harbor has in general consistently more seagrass coverage and more stable meadows than the West Wall segment (the latter demonstrated by the greater average species abundance of turtle grass; Staugler and Ott, 2001), probably because of the freshwater inflows from the Peace and Myakka Rivers that concentrate more towards the Western Wall. Also, in general the maximum depths of seagrass beds increase with increasing distance from the mouths of the Peace and Myakka Rivers and increasing salinities (Dixon and Kirkpatrick, 1999).

In comparison, relative to Charlotte Harbor, the Lemon Bay subbasin has a much smaller watershed, with a ratio of watershed to open water of 5:1, and water clarity is much more strongly tied to phytoplankton levels (Tomasko and others, 2001). Phytoplankton biomass was calculated to contribute 12% to 39% of light attenuation within the water column with a mean percent of 29%, and depth distribution of seagrasses in Lemon Bay is largely a factor of chlorophyll a concentrations (Tomasko and others, 2001). Kurz and others (2000) noted a small decrease in seagrass coverage in Lemon Bay from 1994 to 1996, and this coverage then remained stable from 1996 to 2002 (table 2). The decrease represents less than a 2% loss and falls well within the margin of sampling error and so should be viewed accordingly. Nevertheless, with increasing urbanization pressure and accompanying increases in nonpoint source nutrient loads, there is increasing concern over the preservation of the seagrass beds in this subbasin. Annual nitrogen loads to the bay were estimated to have increased 59% since predevelopment (1850) to 1995 conditions, and they are predicted to increase 45% by 2010 from 1995 levels (Tomasko and others, 2001). Septic tank systems are thought to play a significant role in this increase, especially during the 9-mo dry season. Septic tanks are estimated to contribute 28% of the nitrogen load October through June and 14% July though September (Tomasko and others, 2001). Finally, Lemon Bay is also relatively shallow, and boating activities help stir up bottom sediments, further aggravating water-clarity problems.

In the southern Charlotte Harbor region, there has been less documentation of seagrass extent than in the northern areas, and less is understood about possible coverage changes and causes of such over time. In the northern Pine Island Sound and Matlacha Pass segments, suspended matter and dissolved matter are still the dominant factors in light attenuation, and turbidity increases in impact as one moves south in either region (McPherson and Miller, 1987; Dixon and Kirkpatrick, 1999). McPherson and Miller (1987) found that Pine Island Sound was dominated by noncolored waters from the Gulf of Mexico, while parts of Matlacha Pass and San Carlos Bay were affected by local runoff and discharges from the Caloosahatchee River. Suspended matter, however, the source of which appeared to be the bed of the estuary (McPherson and Miller, 1987), was the major contributor of light attenuation in the southern regions of these segments (McPherson and Miller, 1987; Dixon and Kirkpatrick, 1999). In the tidal head of the Caloosahatchee River and San Carlos Bay, light is attenuated mostly by dissolved materials or color, while in the more upper reaches of the river, chlorophyll a may be the major contributor (Doering and Chamberlain, 1999). As discussed earlier, however, a significant loss of seagrasses from historical conditions in the southern Charlotte Harbor region stemmed from the physical alterations caused by the Gulf Intracoastal Waterway dredging and Sanibel Causeway construction. Changes in seagrass extent in these areas largely result from inflows from the Caloosahatchee River that now flow into lower Pine Island Sound and Matlacha Pass and the resulting reduced salinities (Harris and others, 1983) and possible resuspension of sediments (McPherson and Miller, 1987).

Little is known about possible causes of coverage changes where coverage existed in Estero Bay, but anecdotal evidence points to resuspended sediments as the major problem with light reaching seagrass beds. At the same time, there is also strong evidence of increasing nutrient enrichment of the tributaries into this subbasin. A new water quality-monitoring program by the local county government that collects light attenuation and supplemental data and the expansion of both seagrass mapping and transect monitoring by the SFWMD and FDEP into the bay will help fill the knowledge gaps in this area.

Finally, the scarring and subsequent loss of seagrass beds by boat propellers has been a significant issue in the entire Charlotte Harbor region. Most of Charlotte Harbor is relatively shallow, averaging only 2.1 m (7 ft) in depth, with a deep depression in Boca Grande Pass (22 m or 72 ft) (Stoker, 1986), leaving it vulnerable to the propeller dredging of inexperienced or imprudent boaters. A 1995 effort by the State determined that the Charlotte Harbor region is one of the most heavily scarred areas in Florida (Sargent and others, 1995). Simultaneously, the area faces the pressures of a hearty tourism industry and a rapidly growing population, which includes an increase in boating activities and in the size of those boats. Area resource managers face a growing number of requests to allow dredging for greater access to the more shallow areas and the development of private docks for riparian landowners or marinas. A study of 27 docks averaging 113.94 m^2 (1,226 ft^2) in total area constructed over grass beds in Pine Island Sound and San Carlos Bay found boat propeller dredging associated with roughly one- third of the docks and an average area of 6.89 m^2 (74 ft^2)of dredged area per dock (Loflin, 1995). Additionally, the study found an average 128.84 m^2 (1,386 ft^2) seagrass “shadow” or area of seagrass loss associated with the total size of each dock. The study did not address the effects of changes in dock dimensions (height and width) or the possible cumulative impacts of docks to seagrasses on a region-wide basis, but it is apparent that boating activities are having a deleterious impact on the seagrasses of Charlotte Harbor.

Monitoring for Seagrass Health

As a supplement to the mapping efforts through aerial photography to estimate seagrass extent, the FDEP—Charlotte Harbor Aquatic Preserves Office has established a series of 50 transects distributed over most of the six subbasins (excluding only Estero Bay and tidal Caloosahatchee River). Beginning in 1999 these 50 fixed transects are visited annually during September through early November to determine declines or improvements in seagrass conditions by detecting changes in seagrass depth distributions, epiphyte coverage, short shoot densities, and species composition. Program researchers use the Braun-Blanquet Cover Abundance Scale (for more information, see *http://chla.library.cornell.edu/cgi/t/text/text-idx?c=chla;idno=2917578*) to estimate seagrass species abundance for individual species and collect blade length, sediment type, and epiphyte coverage and type at 50-m (164-

ft) intervals along each transect (or 10-m or 33-ft intervals for transects shorter than 50 m). Also, water quality data, such as photosynthetically active radiation and salinity, and short shoot density are gathered at mid bed. In 2000 the quarterly collection of seagrasses for disease analysis of turtle grass was added to the program. In 2002 this monitoring program was expanded to include the Caloosahatchee River and five transects within Estero Bay.

Species Information

The FDEP transect monitoring program allows for the determination of species composition within the various major seagrass beds in the Charlotte Harbor Estuarine Complex. Five seagrass species have been identified in these subbasins: turtle grass, shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), wigeon grass (*Ruppia maritima*), and star grass (*Halophila engelmannii*) (table 4). In 1999 and 2000, shoal grass was determined to occur most frequently throughout the region, with 55.6% and 62.9% occurrence and within each harbor segment, with the exceptions of Pine Island Sound and San Carlos Bay (Staugler and Ott, 2001). In Pine Island Sound, turtle grass occurred most frequently with 59.5% in 1999 and 65.9% in 2000. In San Carlos Bay, manatee grass, with 60% (1999) and 66.7% (2000) abundance, and turtle grass, with 46.7% (1999) and 77.8% (2000) coverage, were almost equally ubiquitous.

Table 4. Seagrass species present at the Florida Department of Environmental Protection transect monitoring sites (from Staugler and Ott, 2001).

[No transects were located within the Middle Charlotte Harbor, Caloosahatchee River, and Estero Bay segments in 2001]

Region	Number of Sites	Species Present
Lemon Bay	6	Shoal grass (*Halodule wrightii*), turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*)
Gasparilla Sound/ Placida Region	7	Shoal grass, turtle grass, manatee grass
Myakka River	6	Shoal grass, turtle grass (1999), wigeon grass (*Ruppia maritima*)
Peace River	6	Shoal grass
Western Charlotte Harbor	3	Shoal grass, turtle grass, wigeon grass (1999 in northernmost site)
Eastern Charlotte Harbor	4	Shoal grass, turtle grass
Pine Island Sound	9	Shoal grass, turtle grass, manatee grass
Matlacha Pass	6	Shoal grass, turtle grass, manatee grass (found at 1 transect in northern M.P.), star grass (*Halophila engelmannii*)
San Carlos Bay	3	Shoal grass, turtle grass, manatee grass

Anecdotal evidence suggests that wigeon grass can be found in the Peace and Myakka Rivers and may alternate in prevalence with water celery (*Vallisneria americana*), depending on river flows and salinity. The FDEP monitoring program located wigeon grass in the tidal Myakka River in both 1999 and 2000 and within the West Harbor Wall segment at its northernmost site in 1999. Star grass is found only in Estero Bay and Matlacha Pass. The recent expansion of the transect monitoring into Estero Bay in 2002 found the presence of shoal grass, turtle grass, and star grass in the bay. Finally, paddle grass (*Halophila decipiens*) has been documented in Estero Bay (Mackenzie, written communication) and the East Wall of Charlotte Harbor (Tomasko, written communication).

Mapping and Monitoring Needs

Southwest Florida is rapidly urbanizing, and there is a need to continually evaluate the impacts of this urbanization on invaluable estuarine resources. Currently, biennial seagrass mapping efforts exist in the entire Charlotte Harbor region that are important in allowing resources managers to ascertain the spatial and temporal changes of seagrass coverage in coastal waters. In the Charlotte Harbor region, the SFWMD and SWFMD effectively share the responsibility of accomplishing these biennial seagrass maps. And while there has been much closer coordination and communication in the past several years between the districts for these efforts, there are several issues with the consistency of timing, accuracy of photointerpretation, data collection methodologies, and reporting that could be enhanced. For instance, intradistrict aerial surveys for the maps may be flown as late as April during one year's mapping effort and in November or December in another. Also, the interdistrict aerial surveys may be off by several months or more. In the most recent mapping effort, the SWFMD flew to their boundary—the "South Harbor" segment of northern Charlotte Harbor—in January 2002. The SFWMD, however, flew to their boundary in January 2003. These timing inconsistencies, caused in large part by uncontrollable water clarity and flight conditions, cause data comparability issues between these individual efforts. It is problematic to compare seagrass coverage data collected in April, during the winter dry season, to data collected in November, nearer the end of the summer wet season, because seagrass extent may vary substantially between the two seasons. Also, SFWMD may not include a postmap classification accuracy assessment requirement in their mapping efforts, while the SWFWMD requires a minimum of 90% accuracy. Although these relatively minor issues may continue to plague the mapping work in the future, the CHNEP and its many integral partners are fostering closer coordination between the two districts and spurring the use of similar mapping and postmap production methodologies. The mapping efforts by both districts are vital to the understanding and protection of coastal resources and need to continue.

In addition, there is now a transect monitoring program that encompasses the entire Charlotte Harbor Estuarine Complex. The fixed transects monitoring for seagrass health, species abundance, and bed length was expanded in 2002 into the Caloosahatchee River and Estero Bay and is expected to greatly broaden the region's knowledge of the seagrass beds in those subbasins. The FDEP Charlotte Harbor and Estero Bay Aquatic Preserves and South District offices conduct these monitoring programs, which can use up a great deal of their resources. For instance, because of the large size of their study area, the Charlotte Harbor Aquatic Preserves office alone monitors 50 transects with two dedicated staff members and a group of volunteers. This annual monitoring event usually occupies 2–4 d per week for approximately a 2-mo period. This program builds upon similar programs in the region, such as one in Tampa Bay, and is considered essential to the understanding of the health and quality of the essential fish habitat in the southwest Florida region.

Restoration and Enhancement Opportunities

Charlotte Harbor has not demonstrated a significant trend in overall seagrass extent since 1982, and therefore there has not been a strong impetus for seagrass restoration projects in the area, with the possible exception of the restoration of boat propeller scars. As explained above, the Charlotte Harbor region was determined to be one of the most severely impacted regions in Florida for boat propeller scarring in the 1995 statewide evaluation of the issue (see Sargent and others, 1995). Indeed, the local entities that make up the CHNEP incorporated the reduction of such scars as a major component of the CHNEP's management plan. In order to better understand this issue and determine future steps to alleviate the problem in Charlotte Harbor, the CHNEP and FMRI are currently undertaking a change analysis of the severity and location of propeller scars within the region since the 1995 effort. Also, there are several proposed efforts to attempt the restoration of heavily scarred areas by planting seagrass plugs or injecting nutrients in the scarred areas. FMRI is proposing a multiyear project to evaluate the various methods that seek to speed the recovery of boat propeller scars in seagrass beds and may use the Charlotte Harbor region in their efforts.

With support of the CHNEP, the SWFWMD Surface Water Improvement and Management (SWIM) Program has developed a pollutant load reduction goal for the northern Charlotte Harbor region that should reduce or maintain current nitrogen inputs into Charlotte Harbor. The goal was developed to alleviate human impacts on hypoxic events in the northern Charlotte Harbor region (Southwest Florida Water Management District, 1993). Hypoxia, or episodes of dissolved oxygen below 2 mg/L, occurs almost annually when the waters of northern Charlotte Harbor become stratified (Camp, Dresser, and McKee, Inc., 1998). When inflows from the Peace and Myakka Rivers reach over 3,785,400 m^3/day (1 billion gallons per day) during the summer wet season, the water column in the harbor stratifies, with the less dense fresh water flowing on top of the heavier, more saline waters. This flow creates a cap that reduces the movement of oxygen into the deeper waters. Nutrients and bacteria in the water column and sediments can combine to create a demand for oxygen that lowers the available oxygen in the water column. Increases in nutrient loading may be increasing the frequency, duration, and severity of the harbor's hypoxia events, and the district has proposed projects to reduce the nitrogen loads from the headwaters of the Peace River with a series of wetlands, media filtration, or settling ponds. The SWFWMD and the CHNEP hope these projects will at a minimum offset expected increases in nitrogen caused by development over the next decade. The reduction in nutrients may also have coincident benefits for the seagrass beds within northern Charlotte Harbor, because while nutrient inputs and resulting chlorophyll a concentrations may not contribute largely to light attenuation within the water column of Charlotte Harbor, they may cause heavier epiphyte loads on seagrass blades.

In Lemon Bay, there is an ongoing project by the SWIM Program with support from local governments and the CHNEP to determine the annual nitrogen loads from each of the six major tributaries into the bay. The district hopes that with this information, they, the CHNEP, and the local governments can then prioritize those basins that most contribute nitrogen to the bay and in turn develop projects to at minimum mitigate future nitrogen inputs. It is hoped that such projects will protect the seagrass beds in Lemon Bay from declines with future development, and likewise, similar research efforts are being proposed for Estero Bay to the south of Charlotte Harbor and the Caloosahatchee River as well.

Within the southern Charlotte Harbor region, including the Caloosahatchee River, Pine Island Sound, Matlacha Pass, and San Carlos Bay, the SFWMD is evaluating various methods to better protect estuary resources from harmful hydrologic conditions stemming from the artificial connection of the Caloosahatchee River to Lake Okeechobee. They have successfully promulgated minimum flows and levels rules that establish a minimum flow the SFWMD must meet to protect estuary resources from low flow conditions. The SFWMD is, in turn, currently designing projects, with support from State, Federal and local agencies, to increase storage within the Caloosahatchee River watershed to allow this rule to be met more frequently in the future through the Comprehensive Everglades Restoration Plan (*http://www.evergladesplan.org/index.cfm*). It is hoped also that these projects will allow the district to manage the timing and quantity of releases from the

Franklin Locks system to the estuary to better mimic a natural flow regime.

The SFWMD in 2003 also designated the southern Charlotte Harbor region and Estero Bay as SWIM plan waterbodies, and now development of pollutant load reduction goals is required for these areas. In close coordination with this effort, a local nonprofit entity, the Estero Bay Nutrient Management Partnership, which includes representatives from the SFWMD, local governments, the CHNEP, citizens and industry, is developing voluntary nutrient reduction goals for the Estero Bay subbasin.

Finally, the SFWMD is developing circulation models of the southern Charlotte Harbor region, including Pine Island Sound, Matlacha Pass, San Carlos Bay, and Caloosahatchee River to help better understand flow patterns in that area. The local government agencies are contemplating new designs for the Sanibel Causeway and are using this model to evaluate the causeway's implications on estuarine resources.

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