

Galveston Bay System

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Background

The Galveston Bay system of Texas ranks as the seventh largest estuary in the United States, with about 153,000 ha (378,063 acres) of open water and about 44,000 ha (108,724 acres) of estuarine salt and brackish marshes (White and others, 1993). Figure 1 shows the extent of the Galveston Bay system and its watershed. Its secondary fisheries production is well known, with the system annually accounting for a major portion of the total Texas commercial harvest. In the 1980s, annual production amounted to an average of 35% of the harvest of shrimp, 30% of the blue crab, and 60% of the oyster catch of the Texas coast (Auil-Marshalleck and others, 2002). The Galveston Bay system displays this outstanding resource value despite being in the heart of the Houston metropolitan area. As a result of its location, the estuary has been heavily impacted by industrial and municipal development, discharge of pollutants and wastewater effluents, channelization and dredging projects, subsidence, and alterations in bay-water circulation dynamics. In particular, this region is recognized as a worldwide center for the shipping and petrochemical-refining industries. The Ports of Houston and Galveston, which rank 2d and 12th, respectively, in U.S. shipping tonnage, have greatly altered this bay system because of the extensive supporting network of dredged ship channels and canals, as well as numerous port-related facilities.

The population of the Galveston Bay area is one of the densest in the United States, having grown from 3.2 million in 1980 to 3.9 million in 1990 and to about 4.8 million in 2000 (U.S. Census Bureau, www.census.gov). In 1989, the upland habitats around the bay system consisted of 25% urban lands, 26% croplands, 30% rangelands, 9% forest, and 10% shrublands (White and others, 1993).

For the 1956 period, Fisher and others (1972) mapped approximately 2,024 ha (5,000 acres) of salinity-tolerant, submerged vascular vegetation (i.e., true seagrasses and wigeon grass (*Ruppia maritima*)) in the Galveston Bay system. This mapping did not include the Trinity River delta where considerable oligohaline submerged vegetation (e.g., water celery (*Vallisneria americana*) and wigeon grass) also occurs. The loss of at least 95% of this submerged vegetation by 1975 (White and others, 1985; Pulich and White, 1991) represents

an alarming reduction of valuable estuarine fisheries habitat and environmental degradation.

Scope of Area

The Galveston Bay system is part of the Trinity-San Jacinto estuary, formed by discharge of the San Jacinto and Trinity Rivers into the upper secondary bays (San Jacinto and Trinity Bays). The San Jacinto River contributes median annual freshwater inflows to the bays of about 616.5 m³ (500,000 acre-ft) and the Trinity River 9,247.5 m³ (7.5 million acre-ft). A third major source of inflow to the bay system comes from the Buffalo Bayou/Houston Ship Channel, which carries Houston storm drainage and inflows from smaller tributaries on the west side of Houston.

In general, distinctly different submerged vegetation occurs in three separate estuary segments (fig. 2). The Trinity Bay-upper Galveston Bay segment extends along the western shore of Galveston Bay from Baytown to Texas City and along the eastern shore of Trinity Bay from Anahuac to Smith Point. The West Galveston Bay segment (in the lower Galveston Bay region) is bordered by the mainland to the south of the Houston area and by the Galveston Island shoreline. It extends from the city of Galveston proper down the island to San Luis Pass. Christmas and Drum Bays in the lower Galveston Bay region make up a third segment.

Methodology Employed To Determine and Document Current Status

Pulich and White (1991) determined extant locations of submerged vegetation, covering a minimum of 0.05 ha (0.125 acre), for the Galveston Bay system based on November 1987 color-infrared aerial photographs flown by NASA-Ames (California) and at a scale of 1:65,000. The delineations were corroborated by groundtruthing surveys in summer and fall 1988. White and others (1993) evaluated similar high-altitude, color-infrared photography flown by NASA-Ames in December 1989. Submerged vegetation coverage for these years was photointerpreted from 23 cm x 23 cm (9 inches x 9 inches) positive transparencies and mapped onto U.S.

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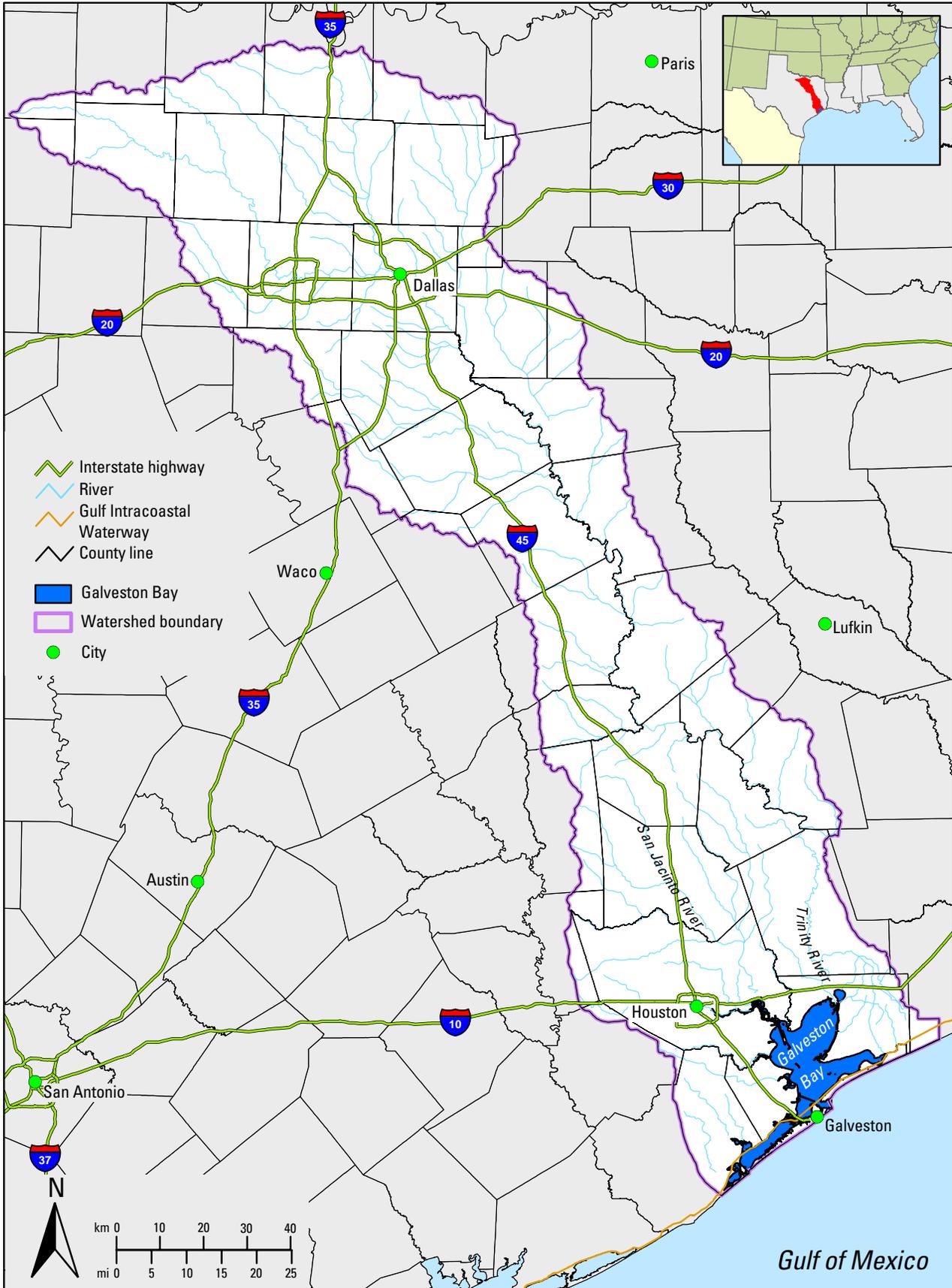


Figure 1. Watershed for Galveston Bay.

Geological Survey (USGS) quadrangle sheets at a scale of 1:24,000 by using zoom transfer scope techniques. Seagrass acreage statistics were determined by digitization with AutoCad™ software. Only generic seagrass distribution was delineated, and no classification of bed types was attempted. Disturbance features, such as residential developments, dredged channels, and boat marinas, were also mapped. The study conducted by Adair and others (1994) basically relied on line-transect field surveys during summer 1987 for qualitative assessment. Quantitative mapping methods (photointerpretation and zoom transfer methods) were not used to construct 1:24,000-scale maps.

Recent aerial photography (true color, Kodak SO358 film, flight scale 1:10,000) for Christmas and Drum Bays was taken on December 15, 1998, by Aerial Viewpoint, Inc., of Houston, Tex., under contract to the Galveston Bay Estuary Program (GBEP). Groundtruthing surveys supported by Global Positioning System (GPS) technology were performed in summer and fall 1999. Texas Parks and Wildlife Department (TPWD) staff in the Coastal Studies Program (Austin) scan-digitized the transparencies by using a flat-bed scanner and registered the raster images to 1:24,000-scale digital orthoquadrangles (DOQs). Seagrass polygons were then delineated with ArcView Image Analyst™ software by using “on-screen” digitization techniques, and datasets were entered into a geographic information system (GIS) (Pulich, 2001).

Methodology Employed To Analyze Historical Trends

The study by Pulich and White (1991) documented the chronology of submerged vegetation decline from the mid-1950s. Seagrass distribution at different time periods was quantitatively mapped, and the causes of trends were evaluated. The sources and scale of historical photography analyzed for the entire system were as follows: 1956, 1:24,000-scale black and white photomosaics from Edgar Tobin Aerial Surveys, San Antonio, Tex.; 1961, 1962, and 1965, 1:20,000-scale black and white photographs from the U.S. Coast and Geodetic Survey; 1975, 1:24,000-scale color-infrared photographs from National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC), Houston, Tex.; and 1982, 1:24,000-scale color-infrared photographs flown by Texas General Land Office. Copies of all archived photography originally flown by the Federal or State agencies were obtained through Texas Natural Resources Information System, Austin, Tex. Except for 1982 photography, seagrass coverages from all other photomissions were photointerpreted and transferred by zoom transfer scope to USGS 1:24,000-scale quadrangle maps, and then acreage statistics were determined by digitization with AutoCad™ software. Former occurrences of seagrass in the bay area were corroborated from project reports of TPWD

biologists at the laboratory in Seabrook (Pullen, 1961; West, 1973); from interviews with knowledgeable field biologists from agencies (pers. commun. with Robert Hofstetter and Charles Wilkes, TPWD; Roger Zimmerman, National Marine Fisheries Service) and universities (Sammy Ray, Texas A&M University-Galveston); from interviews with many local fishermen; and from review of other archived aerial photographs. Photography from 1982 was used only for visual observations.

Physical and hydrographic factors affecting distribution and growth of submerged rooted plants were analyzed in an attempt to identify processes contributing to seagrass impacts. Seagrass distribution was correlated chronologically with historical data on the following physical/hydrographic processes: shoreline erosion, relative sea-level rise associated with subsidence, hurricane and other climatic events, physical alterations related to channel dredging and onshore developments, and degradation in selected water quality parameters.

Status and Trends

The study conducted by Pulich and White (1991) examined all regions of Trinity Bay, upper and West Galveston Bays, and Christmas Bay. Environmental conditions at stressed sites where vegetation had disappeared were also compared with sites where plants persisted (i.e., east Trinity and Christmas Bays). Seagrass declines could be attributed to different processes in two different parts of Galveston Bay; upper Galveston and Trinity Bays showed significant contrast with lower Galveston Bay. In their parallel study on the status of seagrass in the Galveston Bay system, Adair and others (1994) reviewed and corroborated many of the Pulich and White (1991) observations. This later study by Adair and others (1994), however, proposed that environmental factors and the mechanism(s) causing submerged vegetation decline in West Bay were still unidentified although point-source pollution was probably involved. The acreage results presented below are from Pulich and White (1991).

Upper Galveston Bay and Trinity Bay

Figure 3A shows at least 86 ha (212 acres) in 1956 of submerged vegetation (wigeon grass, based on archived field reports), offshore of Clear Lake in the Seabrook area. Severe subsidence, erosion, and shoreline disturbance are likely to have placed wigeon grass along this western shoreline of upper Galveston Bay under considerable stress, which made these beds vulnerable to complete destruction by Hurricane Carla in fall 1961. Figure 3B shows this Seabrook shoreline in 1979, with dense development and devoid of submerged vegetation. Currently, fringe beds of wigeon grass still occur on the eastern shoreline of Trinity Bay in the proper season (60 ha, or 148 acres, were mapped here in 1987).



Figure 2. Scope of study area for the Galveston Bay system vignette.

West Galveston Bay

A different scenario for West Galveston Bay, consisting of typically polyhaline waters, emerges from the compilation of available data. True seagrasses, consisting of predominately shoal grass (*Halodule wrightii*), formerly occurred in this western part of the Galveston Bay system, both along the back side of Galveston Island and on the northern shoreline along the mainland. Based on historical photoanalysis, about 458 ha (1,132 acres) of shoal grass were estimated along the back side of Galveston Island during 1956 and 125 ha (308 acres) estimated during 1965 (Pulich and White, 1991). In 1975 photographs, only 37 ha (91 acres) of shoal grass beds were visible in the 3.6-km (2-mi) shoreline section just north of San Luis Pass. Wigeon grass had always been found mixed in with these shoal grass beds and continued to be found sporadically in some shoreline areas of Galveston Island after 1979, which is when shoal grass was last observed by fishermen in West Galveston Bay. All of these seagrass beds had disappeared completely by the early 1980s, as no trace was evident in July 1982 photographs (1:24,000 scale). Several small patches of turtle grass (*Thalassia testudinum*) were also located along the Galveston Island shoreline just north of San Luis Pass until the late 1970s, according to anecdotal reports.

Christmas Bay

Although true seagrasses disappeared from West Galveston Bay during the late 1970s, a remnant population survived in the secondary bay system of Christmas and Drum Bays, in the extreme southwest region adjacent to Galveston Island. Figure 4 shows seagrass distribution for Christmas and Drum Bays based on December 1998 color aerial photography and year 2000 ground surveys. Total coverage in Christmas and Drum Bays was mapped at 172 ha (424 acres) and consisted predominately of mixed shoal grass and star grass (*Halophila engelmannii*) (with wigeon grass often abundant, especially during spring). Shoal grass beds in Christmas Bay

are also interspersed with about 20 patches of turtle grass along the south shore (totaling 0.65 ha, or 1.6 acres).

Mapping from 1975 and 1987 aerial photography (Pulich and White, 1991) revealed seagrass coverage of 93 ha (230 acres) and 77 ha (190 acres), respectively. White and others (1993) also examined the 1950s photography and estimated about 130 ha (321 acres) in Christmas Bay in 1956. These data seem to suggest that Christmas Bay grassbeds may have also declined during the 1960s through the 1980s period although not as precipitously as in West Galveston Bay. Based on the recent 1998 mapping results (172 ha, or 425 acres, of seagrass), this trend would appear to be reversing.

The size of the increase in seagrass acreage between 1988 and 1999 (as well as the decrease between 1975 and 1987) is probably misleading, however, because reexamination of the 1987 photography reveals that some seagrass was probably missed during this previous mapping because of turbid, high-tidal water and lack of resolution in the high-altitude 1987 photos. White and others (1993) were able to corroborate this idea by examination of 1989 color-infrared aerial photography. They remapped Christmas Bay seagrass from the 1989 photography and determined that about 156 ha (385 acres) of seagrass were present then. The 1989 photographs were taken at a lower tide (in December) than were the 1987 photographs (in November) 2 yr earlier, and seagrasses would have been more clearly visible.

Causes of Change

Upper Galveston-Trinity Bays

In mid-September 1961, Hurricane Carla physically destroyed the wigeon grass beds along the Seabrook shoreline late in the annual growth cycle (Pullen, 1961). As a result, increased erosion occurred during the ensuing winter and spring when the area is normally subjected to the full force of north and northeasterly winds associated with frontal

passages. Increased nearshore water depth caused by the ongoing subsidence would have further reduced the amount of light reaching bay bottom and submerged vegetation, thus eliminating suitable wigeon grass habitat along the Seabrook shoreline as shown in a 1979 aerial photo (fig. 3B). This loss of habitat would account for the



Figure 3. Aerial photographs of upper Galveston Bay along the Seabrook shoreline in 1956 (A) and 1979 (B). Arrows indicate where seagrass was present in 1956.

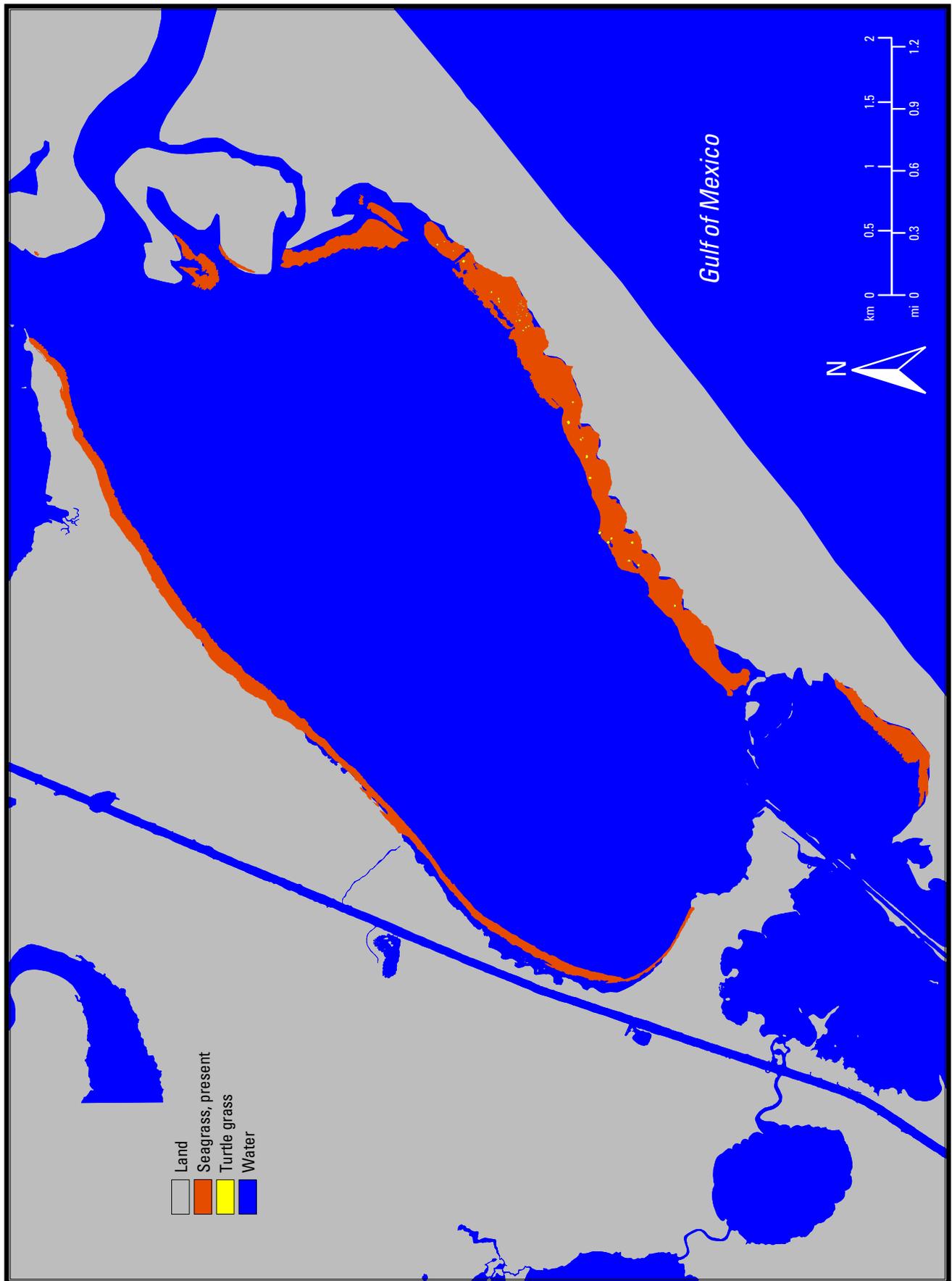


Figure 4. Distribution of seagrass in Christmas and Drumm Bays, 1998.

complete disappearance of submerged vegetation in this bay area after 1961. A few areas along this shoreline that do have shallow depths are in exposed, high wave energy zones where wigeon grass was not found in the 1950s. This hypothesis is further supported in a comparison of the Seabrook shoreline area to the eastern shoreline of Trinity Bay. Areas on this opposite shoreline with suitable depths (i.e., unaffected by subsidence) that were protected during Hurricane Carla still support substantial wigeon grass beds (61 ha, or 150 acres, in 1987) during the proper season.

The upper bay near Seabrook, east of Houston, had also experienced major geomorphic modifications from land subsidence in the 1960s and 1970s (Swanson and Thurlow, 1973). Gabrysch (1984) calculated that groundwater withdrawal caused the Seabrook area to subside over 0.66 m (2.2 ft) between 1964 and 1973, or equivalent to a rate of about 6 cm (2.4 inches) per year. As a result, water depths near the Seabrook shore would have increased 30–60 cm (1–2 ft) between 1968 and 1977. Turbid freshwater inflows, after the drought of the late 1950s ended, added to the ongoing processes of subsidence, erosion, and shoreline disturbance and likely placed wigeon grass along this western shoreline of upper Galveston Bay under considerable stress, ultimately making it vulnerable to destruction by Hurricane Carla in 1961. This timeline agrees with observations of Eleuterius (1987), who reported a 33% reduction in seagrass beds in the Mississippi Sound as a result of erosion and sedimentation during Hurricane Camille and subsequent reductions in salinities in the aftermath of flooding.

The shoreline in the upper Galveston Bay area is predominantly an erosional one, and as a result, this shoreline has been artificially stabilized in many areas by bulkheads, riprap, and other erosion-control measures (Paine and Morton, 1986). In areas of rapid subsidence such as the Seabrook area, however, these stabilizing features also contribute to deeper water conditions near shore by inhibiting the natural development of a broad, shallow, and gently sloping, subaqueous, bay-margin profile that would likely develop along an unmodified, retreating shoreline. Figure 3B reveals the results of extensive bulkheading and associated urban development along the Seabrook shoreline in 1979, as well as the complete lack of seagrass (i.e., wigeon grass) along this western upper bay shore. Water depths of approximately 1 m (3.3 ft) were measured at shoreline bulkheads during surveys in the Seabrook area in 1988.

West Galveston Bay

Although Hurricane Carla slightly damaged West Galveston Bay shoal grass beds in 1961, the major decline of seagrass in this segment between 1956 and 1965 suggests a stronger correlation with increased residential and commercial waterfront development. During this same time period, many such shoreline projects occurred adjacent to West Galveston Bay, and these projects represented classic examples of

“dredging and filling” of bay wetlands. Figure 5 shows the extent of such typical channel-front marina construction in 1989 along lower Galveston Island. Subsequent stress to seagrasses would have been caused by shoreline erosion, redistribution of dredged sediments, excessive nutrient loading from wastewater discharges, nonpoint-source runoff, and impact from recreational boats. Although there was only minor impact from subsidence to this area (Gabrysch, 1984), this process would also have contributed to slightly deeper water depth. In many respects, this explanation is consistent with the mechanism proposed for the decline of seagrass in Chesapeake Bay (Kemp and others, 1983); Cockburn Sound, Australia (Cambridge and McComb, 1984); and Tampa Bay, Fla. (Lewis and others, 1985). These cases document the serious damage to seagrasses from physical habitat disturbance and various agents that reduce water-column light penetration.

A major difference between Galveston Bay and these referenced bay systems may be the degree to which increased turbidity, subsidence, or eutrophic/polluted conditions have contributed to seagrass loss. Excessive nutrient or organic loading is believed to stress seagrass populations by stimulating growth of planktonic and epiphytic algae, as well as by causing premature senescence (Phillips and others, 1978; Kemp and others, 1983). Evidence of this stress was suggested by the observations that particulate chlorophyll made up a higher percentage of the suspended material in West Bay compared to Christmas Bay during years when seagrass was actually declining (Pulich and White, 1991). Heavy growths of epiphytes or phytoplankton inhibit seagrass photosynthesis by reducing the light available for absorption by plant leaves (Sand-Jensen, 1977; Dennison and others, 1993). In addition, phytoplankton blooms associated with storm or sewage runoff often cause anoxic events, which pose a lethal stress to seagrass because of the sulfide production during decomposition processes, especially in warm weather and calm water conditions (Nienhuis, 1983). Senescence, and then plant death, would quickly result if these highly toxic conditions occurred during historical low-dissolved oxygen



Figure 5. Lower Galveston Island north of San Luis Pass in 1989 showing marina and shorefront development (NASA-Ames color-infrared photograph, 1:63,000 scale).

events that often occurred in West Galveston Bay during the 1960s and 1970s.

While impacts from individual factors are difficult to separate and quantify from this analysis, the evidence is compelling that cumulative impacts from dredging, subsidence, shoreline activities, effluent discharges, and Hurricane Carla have been deleterious to seagrasses in the Galveston Bay system. Before reliable restoration of seagrass habitat in this bay system could occur, concerted efforts had to be made to control or eliminate the environmental stresses caused by humans.

Christmas Bay System

Although a higher salinity regime was suggested as a contributing factor favoring survival of Christmas Bay seagrass beds (Adair and others, 1994), actual data indicate that salinity in Christmas Bay is not significantly different from the lower third of West Galveston Bay, that is, from Snake Island to San Luis Pass (Pulich and White, 1991; Sheridan and others, 1998). This latter area is where turtle grass and shoal grass disappeared in the late 1970s. Actually, the seagrass dynamics appear consistent with the relative protection of Christmas Bay from human-caused factors (e.g., absence of major dredging and waterfront development in the bay, lack of point-source discharges, and generally low nonpoint-source runoff), as observed by Tomasko and others (1996). Recent seagrass increases in the lower Galveston and Christmas Bays region may reflect the renewed efforts to protect estuarine resources and water quality under State and Federal coastal zone programs.

Species Information

The Trinity Bay-upper Galveston Bay segment, a generally low-salinity area, has been historically characterized by the occurrence of mostly wigeon grass, with occasional other freshwater submerged vegetation. The West Galveston Bay segment, a moderate-salinity (mesohaline) area, historically has contained true seagrasses, predominately shoal grass, mixed with wigeon grass at times. Christmas and Drum Bays contain well-developed, polyhaline seagrass communities, including predominately shoal grass and star grass, and some turtle grass. This area represents the northernmost location for turtle grass on the Texas coast and is somewhat of a distribution anomaly because the closest known population is far to the south in Aransas Bay near Rockport.

Since the late 1950s, seagrass vegetation in upper Galveston and Trinity Bays (excluding the Trinity River delta) has consisted entirely of wigeon grass beds. There are anecdotal reports that shoal grass occurred there in the first half of the 1900s, but these reports are unconfirmed. In West Galveston Bay, shoal grass has historically been the predominant seagrass. In certain seasons, however, particularly

in spring, localized grassbeds will contain some wigeon grass. As mentioned previously, a few small patches of turtle grass also occurred at the lower end of Galveston Island near San Luis Pass up until the late 1970s. These patches were interspersed in the large beds dominated by shoal grass.

Monitoring for Seagrass Health

Seagrass monitoring was not conducted while seagrasses were actually disappearing in the Galveston Bay system. As indicated above, studies since 1988 have been conducted after seagrass declines. These results have demonstrated the need for a proactive, regular monitoring program to assess seagrass health and to detect impacts before complete loss of seagrass habitat. Monitoring would also be important for documenting the success of restoration efforts. This documentation is a primary objective of the proposed coastwide Texas Seagrass Monitoring Program, which is currently under development (see Statewide Summary for Texas section) by State resource agencies (Pulich and others, 2003). As recommended by Neckles (1994), it is critical for such a program to develop good indicators of seagrass community health and then establish a statistically robust sampling scheme to measure these indicators.

Because of its sensitive, remnant seagrasses, the Christmas Bay system has been a priority conservation site for State resource management programs. In 1988, this area was designated an official State Coastal Preserve and State Scientific Area by the Texas General Land Office and TPWD, the two State agencies with primary coastal management authority for coastal wetlands. This designation allows for special monitoring programs and management regulations to provide extra protection to the seagrass community and other fisheries resources there. Water-quality protection and avoidance of wetland impacts are major legal safeguards provided by the Clean Water Act regulations (both section 404 and section 401). Monitoring of discharges of pollutants and wastewater, shoreline erosion control, and stringent mitigation measures for oil and gas exploration are being implemented for seagrass protection through various State and Federal programs (Galveston Bay National Estuary Program, 1995; Texas Parks and Wildlife Department, 1996).

Since its inception in 1988, the Galveston Bay National Estuary Program (GBEP) has worked to develop management plans and strategies focused on wetlands such as the pristine Christmas Bay system. The Christmas Bay Coastal Preserve was one of GBEP's first action-plan demonstration projects. Currently a "BayWatch" conservation plan is being developed to protect Christmas Bay from physical impacts (e.g., dredging or shoreline development) and to detect water-quality degradation, which will help to enhance seagrass beds.

Mapping and Monitoring Needs

The proposed Texas Seagrass Monitoring Program (Pulich and others, 2003) will combine a two-part approach of intensive probabilistic field sampling and landscape sampling from aerial photography. Aerial photography will be flown at 1:24,000 scale every 5–10 yr for status and trends assessment of the entire bay system, while annual photography at 1:9,600 or larger scale will be flown at sites where field sampling is occurring. The high-resolution photography will be especially important for monitoring seagrass habitat quality at target sites or documenting recovery of former seagrass areas.

Restoration and Enhancement Opportunities

State, Federal, and nonprofit agencies have been focusing on seagrass restoration in lower Galveston Bay. The GBEP identified submerged vegetation restoration as a major element of its Comprehensive Conservation and Management Plan (Galveston Bay National Estuary Program, 1995). A management goal was set to restore a total of 567 ha (about 1,400 acres) of seagrasses by the year 2004. Since 1994, U.S. Environmental Protection Agency (EPA), GBEP, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and TPWD have provided substantial funding to reestablish true seagrasses in the lower part of West Galveston Bay where salinities and other water conditions are considered favorable.

The Near Coastal Waters Program of EPA Region 6 funded work in 1994 by Peter Sheridan (formerly at Galveston National Marine Fisheries Lab) to restore two sites on the back side of Galveston Island: one mid-island site at Snake Island Cove and a southern island site at Redfish Cove north of San Luis Pass (see Hammerstrom and others, 1998). In total, 1 ha (2.5 acres) was transplanted in late April and early May 1995 by using donor shoal grass plants from eastern and western Matagorda Bay. The Redfish Cove site became permanently established, and a 0.4-ha (1-acre) initial bed has expanded and now covers about 2 ha (5 acres). The Snake Island site survived about 1 yr and then failed rather abruptly over the summer period of the second year. Analysis of various factors and the dynamics of die-off suggest that primarily sediment factors may be involved and that water column light conditions, salinity, and eutrophic conditions seem to be ruled out (Sheridan and others, 1998).

Seagrass transplanting efforts have continued along this Galveston Island shoreline. In 1999, with funding from GBEP, Sheridan's group performed another restoration project as a follow-up to their 1994 work. This project examined the source of donor plant material as a factor in seagrass transplant success. Shoal grass donor plants were obtained from populations in Christmas Bay, East Matagorda Bay, Matagorda

Bay, and the previous Redfish Cove site. Donor material was transplanted to areas in West Galveston Bay around the Redfish Cove-San Luis Pass area and has been monitored to determine effects of donor-plant source on transplanting survival. Although final results are not complete, there is some indication that local plants (i.e., from Christmas Bay) have surprisingly fared poorly. In October 2000, a third project was initiated by Sheridan at the Galveston Island State Park areas of Dana Cove and Carancahua Cove. This work, funded by the Natural Resource Damage Assessment (NRDA) Program, was in conjunction with a major wetland restoration project involving geotube engineering and marsh terracing techniques.

As part of the overall plan to stabilize eroding shoreline along the edge of Galveston Island, seagrass transplanting was conducted within the submerged cells created by marsh levee terracing. A newer transplanting technique was also compared and involved testing the planting boat/injection wheel method from Aquatic Subsurface Injection Systems, Inc. (ASIS), Tampa, Fla. This work, described in the Texas Coastal Bend vignette (this report), is detailed in a TPWD report by McEachron and others (2001). Seagrass donor material was obtained from the cooling pond of the Central Power and Light powerplant at Corpus Christi, Tex., and transplanted as either floating wrack or plugs in peat pots. Results to date indicate rather poor success for all planting techniques in the marsh terrace cells (P. Sheridan, 2003, oral commun.).

The USFWS has been very active in restoration efforts. The Clear Lake USFWS office funded applied research by Beldaire Environmental Inc. from 1997 to 1999 to establish shoal grass in Snake Island Cove and Mentzell Bayou-Dana Cove areas at Galveston Island State Park. After 3 yr of effort during which some 6,735 m² (72,500 ft²) of shoal grass was transplanted, the Snake Island site was reported to contain only 70 m² (750 ft²) of shoal grass in 2000. Donor plants for all attempts were taken from Redfish Bay grassbeds near Aransas Pass, Tex., and planted as bare-root sprigs over various months from May through December. The USFWS, in collaboration with TPWD, has recently been instrumental in determining effectiveness of the ASIS planting/injection boat method from Tampa, Fla. Several extensive plots in Dana Cove and Snake Island Cove (over 0.8 ha, or 2 acres, total) were planted by ASIS with shoal grass sprigs from Corpus Christi in October 2000. These results showed very poor (2%–8%) success in 2002 from the injector boat method of transplanting.

Since 1998, when nontransplanted seagrasses first reappeared in the Dana Cove area, major seagrass recolonization has been underway near the Galveston Island State Park shoreline (Ikenson, 2001; John Huffman, USFWS, pers. commun., 2001). Star grass was the predominant species when patches were first noticed during reconnaissance for the Galveston Island State Park wetland restoration project there, with some shoal grass also present. Seagrass patches covered an estimated 4 ha (10 acres) the first year noted (fall 1998) and had spread to approximately 16 ha (40 acres) in December 2000. Annual color aerial photography has been taken for

several years documenting the establishment and expansion dynamics of the grassbed. By December 2001, these patches had spread to more than 40.5 ha (100 acres) (estimated) and now contain considerable shoal grass.

The history of this recolonization event is under study, but there is circumstantial evidence that the source of the donor material is the upper Laguna Madre near Corpus Christi. This donor material can be traced to biologist Bryan Pridgeon with USFWS (formerly at the Clear Lake office), who brought several truckloads of shoal grass-star grass wrack from the Laguna Madre near the Corpus Christi Central Power and Light powerplant. This seagrass wrack material was transported to West Galveston Bay by truck and released into two cages in the State park waters near Dana Cove in December 1996. Only cursory follow-up monitoring was conducted to determine survival or establishment success over the next 2 yr, and it was not until fall 1998 that sufficient seagrass became established to be detected by field surveys. Since 1999, progressive seagrass expansion has been well documented from the annual aerial photographic surveys.

Based on the early progress of these “volunteer” beds in the Galveston Island State Park project, prospects are very good for successfully establishing new seagrass beds in additional projects in West Galveston Bay that are currently underway. The TPWD, USFWS, GBEP, the National Oceanic and Atmospheric Administration, the Texas General Land Office, and local industry and nonprofit partners are engaged in other restoration activities involving the creation of erosion barriers to protect existing marsh areas and restore marsh areas previously lost to subsidence and erosion. A recently completed project in Jumbile Cove and additional projects underway in Jumbile Cove and Delehide Cove in West Bay are anticipated to create hundreds of acres of shallow water habitat suitable for reestablishing seagrasses. The shallow, protected areas within the restoration sites are ideal for reestablishing seagrass beds, as the calm waters and established vegetation allow for precipitation of suspended solids and prevent resuspension of settled sediments, improving the clarity of water within the project sites.

The natural, unsupervised recolonization by seagrasses in Dana Cove is certainly evidence that conditions in this part of West Galveston Bay are now favorable to support major seagrass beds. The failure of some manipulated restoration projects in other parts of West Galveston Bay area (e.g., Sheridan, ASIS Inc.), however, sounds a note of caution to such efforts. These project results suggest that our scientific knowledge of seagrass restoration techniques may still be lacking and that we need a better theoretical basis of the controlling factors which determine success or failure of restoration projects.

Another element of the Galveston Bay restoration program involves establishment of a seagrass plant nursery. For a number of years, Jim Webb at Texas A&M University at Galveston has been developing and operating a seagrass and marsh plant nursery facility for applied research purposes. Through research and student projects, significant progress is

being made in culturing shoal grass, wigeon grass, and turtle grass strains adapted to the Galveston Bay environment. These nursery-grown plants could eventually serve as the source (donor) material for large-scale applied restoration projects around the bay. Most of the donor material has been collected from Galveston and Christmas Bays and is being maintained in outdoor pond facilities on Pelican Island in Galveston.

In April 2002, the Galveston Bay Foundation (GBF) and GBEP organized and led citizen volunteers in collecting shoal grass plants from Cold Pass near Christmas Bay and then transplanting the sprigs to a 0.2-ha (0.5-acre) site in Redfish Cove (West Galveston Bay) as part of the annual GBEP “Marsh Mania” event. The main purpose of this outreach activity was to begin organizing and training citizen volunteers to work on seagrass and other wetland restoration projects. Through such educational events, an organized group of trained, interested citizens will become available for additional seagrass plantings which are being planned in the future. The GBEP and GBF will be able to call upon these experienced volunteers when needed. Though overall restored areas may be relatively small, the event promotes public awareness and stewardship of important and fragile seagrass habitats.

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