Water Quality Survey Report for Potential Seagrass Restoration in West Bay of the St. Andrew Bay System in Northwest Florida.

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ABSTRACT

Seagrass losses have been reported for the area of St. Andrew Bay known as West Bay, in Bay County, Florida. Utilizing both field density observations and aerial photography extrapolation for 1953, 1964, 1980 and 1992 images, estimated seagrass losses from West Bay have been reported by the U.S. Geological Survey to be almost 2,000 acres or approximately 50%. Noteworthy anthropogenic events altering the condition of West Bay during this time period have included U.S. Army Corps of Engineers' (USCOE) construction of the Gulf Intracoastal Waterway (GIWW) connection between the oligohaline eastern portion of Choctawhatchee Bay and northwest West Bay in 1938, the 1970 implementation of an aquacultural endeavor involving isolating the southern half of West Bay proper , as well as large sections of the tidal marsh along its shoreline, and the 1970 introduction of a wastewater effluent to southern West Bay from a municipal sewage treatment plant. In an effort to better understand the cause of seagrass losses for the purpose of designing restoration efforts, the U.S. Fish and Wildlife Service conducted a water and sediment quality survey. Suspected sediment contamination (potentially resulting from extensive use of antifouling coatings for nets and equipment during the aquacultural enterprise) was not confirmed with sediment sampling and analysis for metals and organotin compounds. Water column surveys revealed important differences in turbidity (NTU), water clarity (Secchi depth), and salinity (ppt). However, small differences in dissolved oxygen (mg/L), pH (SU), chlorophyll a (ug/L), and temperature (°C) were not thought as important to seagrass loss or restoration efforts. Differences in water quality appeared to be heavily dependent on depth, wind direction, recent precipitation, tidal flow, and proximity to points of allochthonous inputs such as the GIWW, wetland drainage canals created by the Florida Department of Transportation and for silvicultural purposes, urbanization enhanced stormwater runoff, and a wastewater effluent outfall.

KEYWORDS:. Seagrass atrophy, Seagrass restoration, Water quality, Sediment quality

Preface

This report was written primarily for scientific and management purposes. An attempt has been made to present the data in a form that is readily usable by managers who have not had formal training in ecotoxicology. The primary objective of the authors has been to make a positive contribution for the management of the ecological resources of West Bay of the St. Andrew Bay Ecosystem and all coastal systems of the Gulf of Mexico.

Acknowledgments

Many people played important roles in the completion of this project. To all of them, we are most grateful. In particular we thank for their assistance, support and/or peer review of this document: Wendy Gierhart, Patty Kelly,

CONTENTS

TABLES

FIGURES

APPENDICES

Appendix A: Standard operating procedures for field collection of sediment samples.

Appendix B: Water quality data and summary statistics for West Bay water column sampling for incoming tide January 28th 2003.

Appendix C: Water quality data and summary statistics for West Bay water column sampling for March 27th 2003.

Appendix D: Water quality data and summary statistics for West Bay water column sampling for outgoing tide May 14th 2003.

Appendix E: Water quality data and summary statistics for West Bay water column sampling for outgoing tide June 12th 2003.

Appendix F: Water quality data and summary statistics for West Bay water column sampling for outgoing tide June 26th 2003.

Appendix G: Sediment quality data West Bay water sediment sampling in August 2002.

INTRODUCTION

St. Andrew Bay

St. Andrew Bay is located in the Florida panhandle (Figure 1). The St. Andrew Bay system is composed of a number of smaller bays including North Bay, East Bay, West Bay and Lower St. Andrew Bay (Figure 2). The major freshwater inflow source is Econfina Creek, a relatively small tributary (4% of the Apalachicola River's freshwater input). The low volume of freshwater input has been credited with minimal sediment loading (Brim 1998). The minimum sediment loading results in low turbidity and allows the waters in the bay to remain relatively clear, thereby sustaining the growth of some 6,200 acres of submerged vegetation. The dominant seagrass species is turtle grass (*Thalassia testudinum*), but there are also extensive beds of shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*) (McNulty *et al.* 1972). Average salinities are high and often exceed 30 parts per thousand (ppt; Brim, 1998). All of these characteristics create a coastal habitat that supports an unusually high diversity of marine species (Keppner 1996). Information supporting the importance and uniqueness of this system can be found in the more thorough descriptions of the St. Andrew Bay system reported by Brim (1998) and Keppner and Keppner (2001).

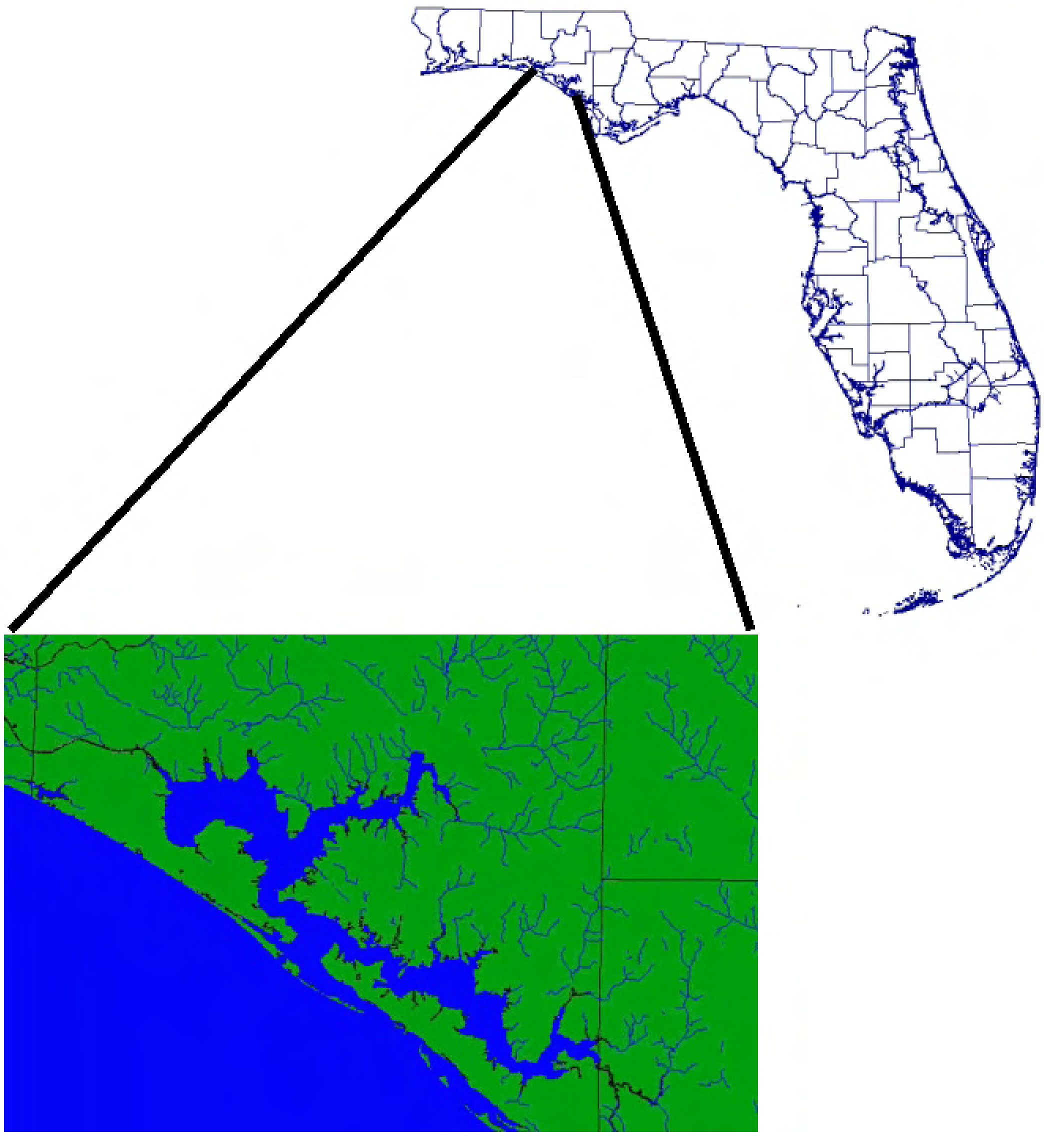

Figure 1: St. Andrew Bay's location in the Florida panhandle.

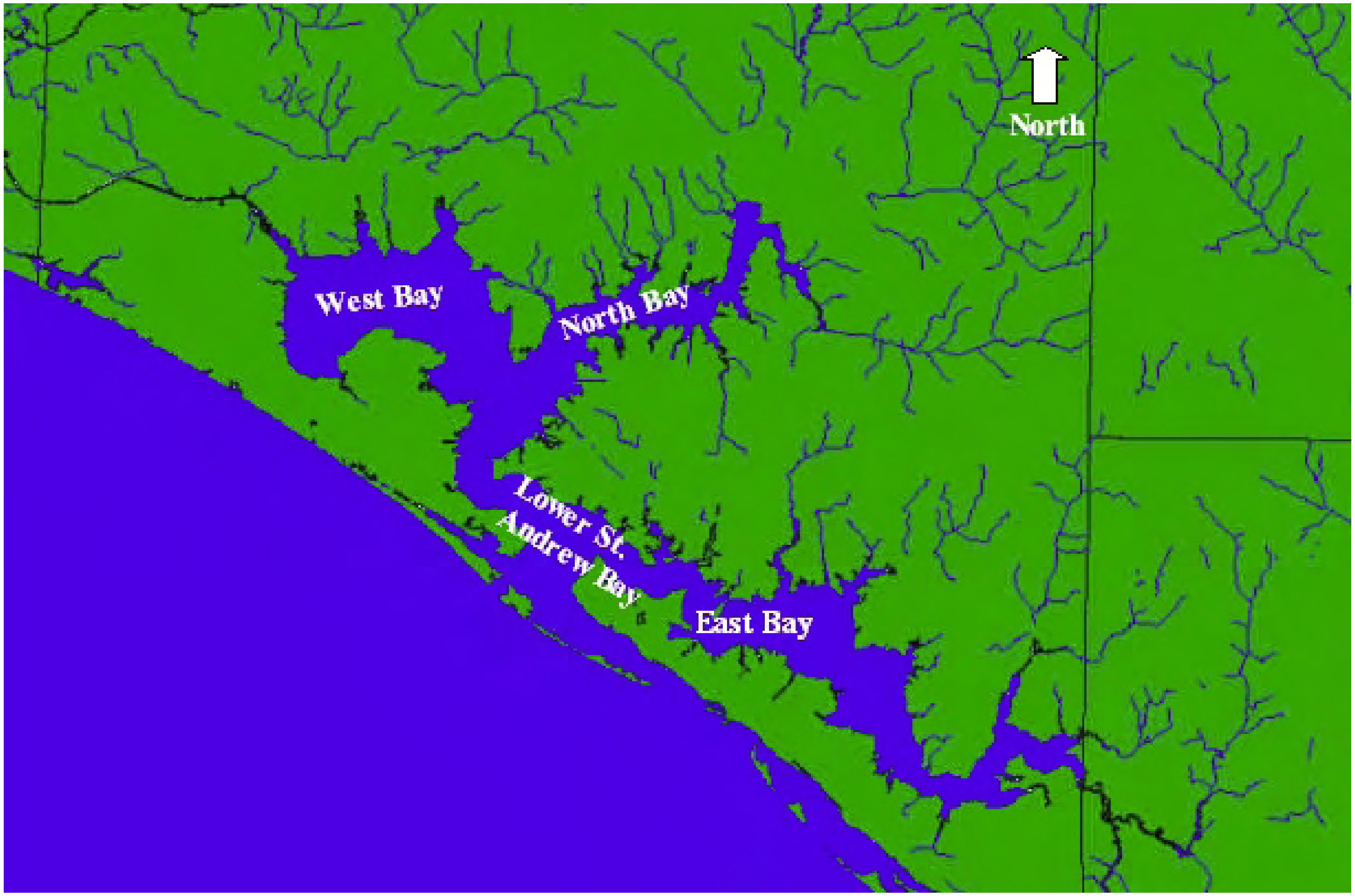

Figure 2: The St. Andrew Bay system is composed of a number of smaller bays including North Bay, East Bay, West Bay and Lower St. Andrew Bay.

West Bay

West Bay, the least developed area in the St. Andrew Bay system, has had little historic freshwater inflow creating an estuarine habitat with moderate to high salinity. Seagrass beds are numerous, and the south shore of West Bay provides the most extensive salt marsh area in this bay (Brim, 1998; Keppner and Keppner, 2001). However, large seagrass losses have been recently reported for West Bay, particularly in the southern portions (USGS, generated images in Figures 3-6). The majority of losses appear to have occurred after 1964, however, data preceding 1953 has not been obtained. In addition, losses continue to occur with seagrass bed expirations verified past the early 1990s. Utilizing both field density observations and aerial photography extrapolation, USGS estimated seagrasses losses from southern West Bay have been proposed to be nearly 2,000 acres.

Natural processes occurring in the West Bay area were accompanied by noteworthy anthropogenic (human-derived) events that may have participated in altering the system's ability to sustain seagrass beds. The first change in the bay system was the U.S. Army Corps of Engineers' (USCOE) construction of the Gulf Intracoastal Waterway (GIWW) connection between the oligohaline (low salt) eastern portion of Choctawhatchee Bay and northwest West Bay in 1938. Another occurrence was the 1970 implementation of an aquacultural endeavor involving isolating the southern half of West Bay proper , as well as large sections of the tidal marsh along its shoreline. A third event was the 1971 introduction of a waste effluent to the southern end of West Bay from a municipal sewage treatment plant for residents of Panama City Beach, Florida. An additional large-scale change to the watershed stemmed from the creation of extensive drainage canals to drain wetland areas on the north and west shores. Locations of various anthropogenic alterations are shown in Figure 7.

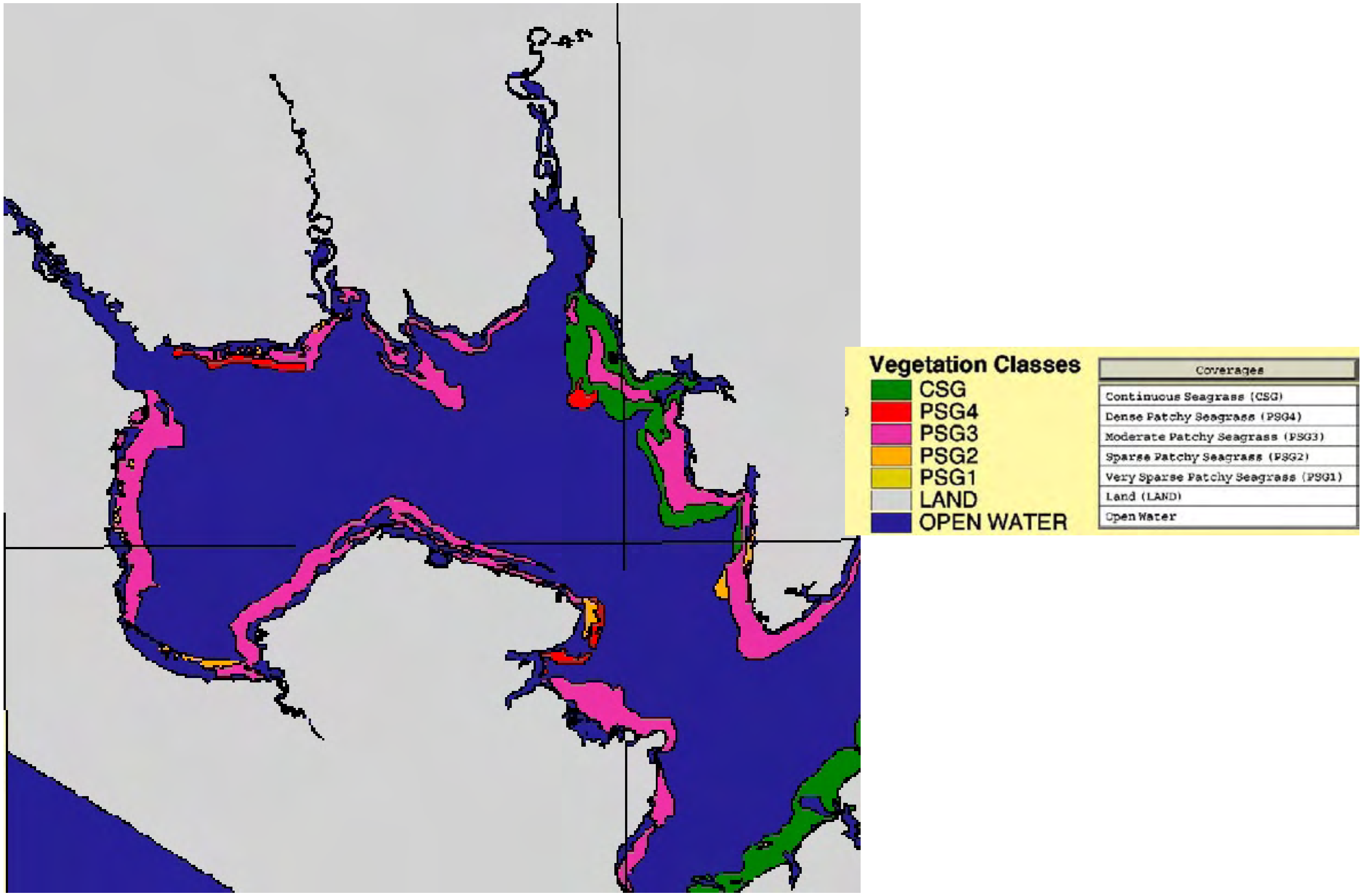

Figure 3: Status of West Bay Seagrasses in 1953.

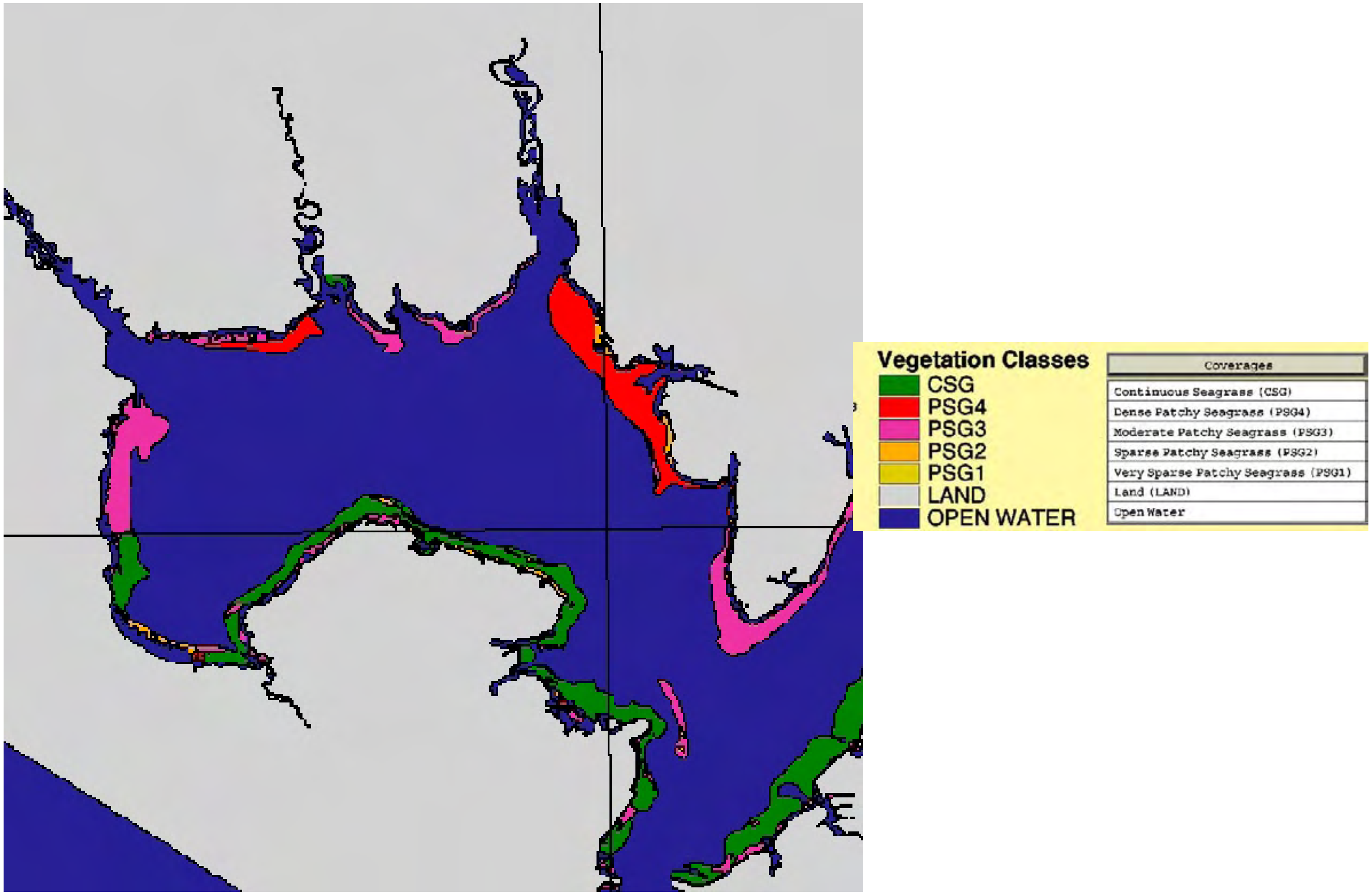

Figure 4: Status of West Bay Seagrasses in 1964.

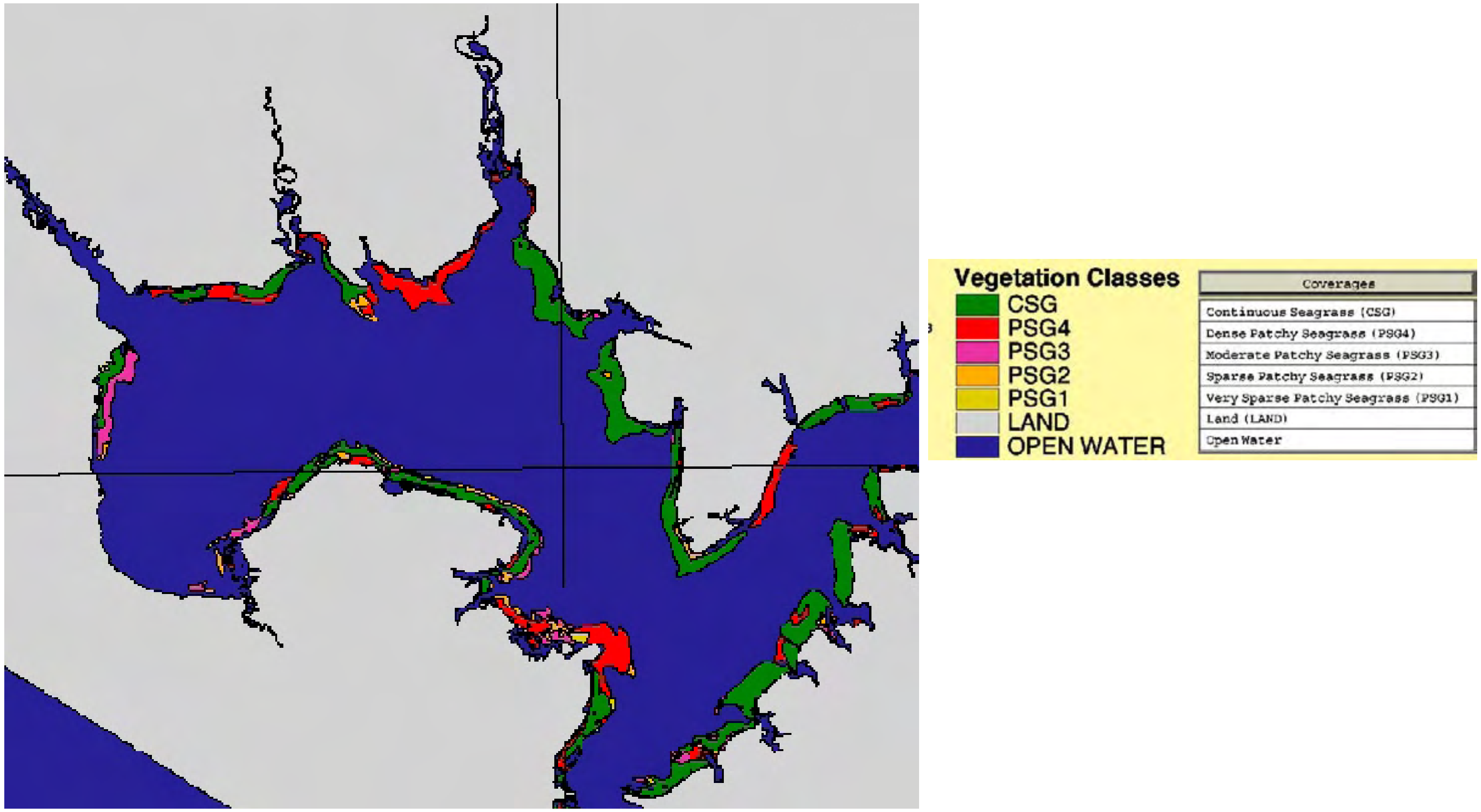

Figure 5: Status of West Bay Seagrasses in 1980.

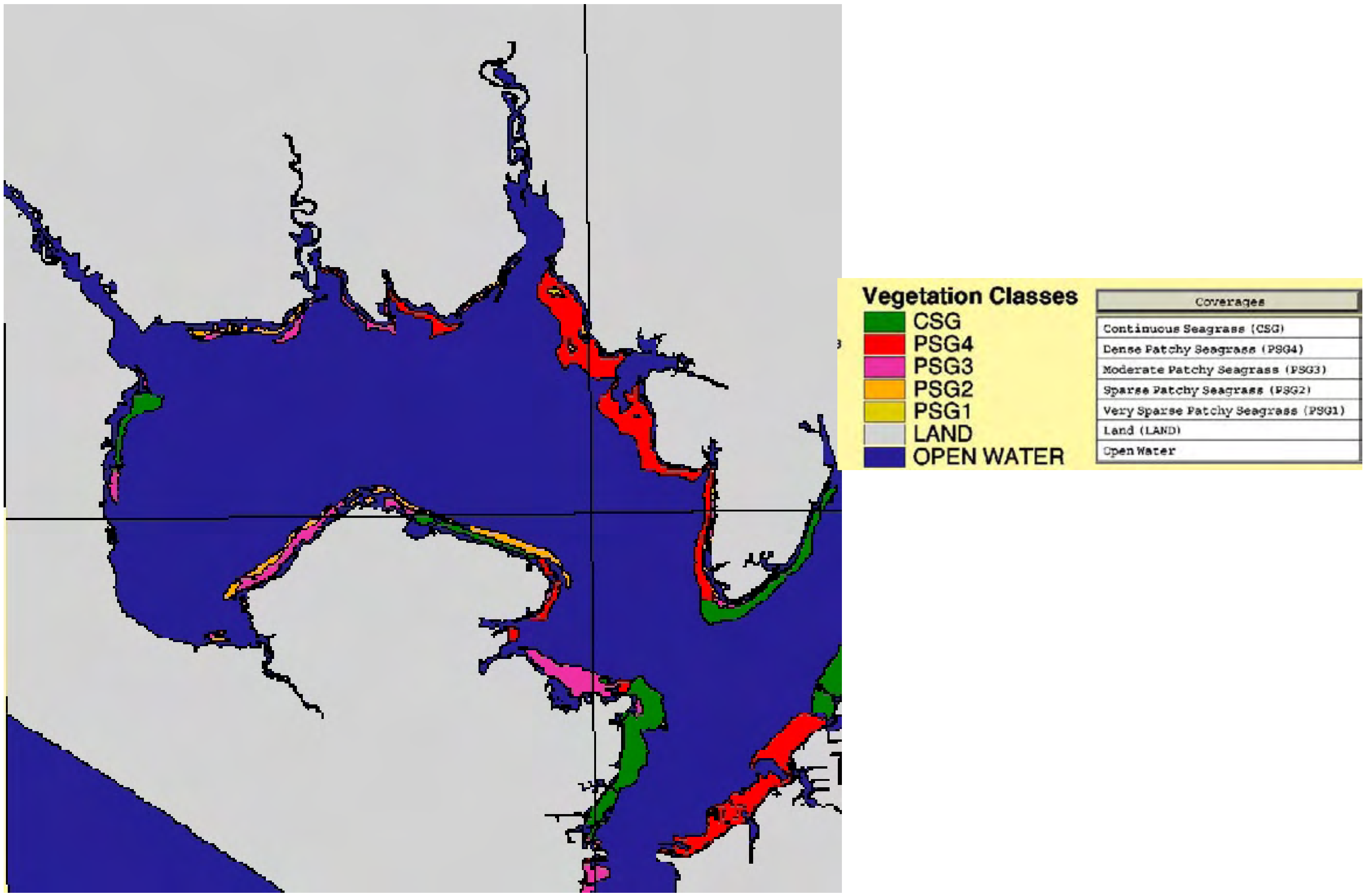

Figure 6: Status of West Bay Seagrasses in 1992.

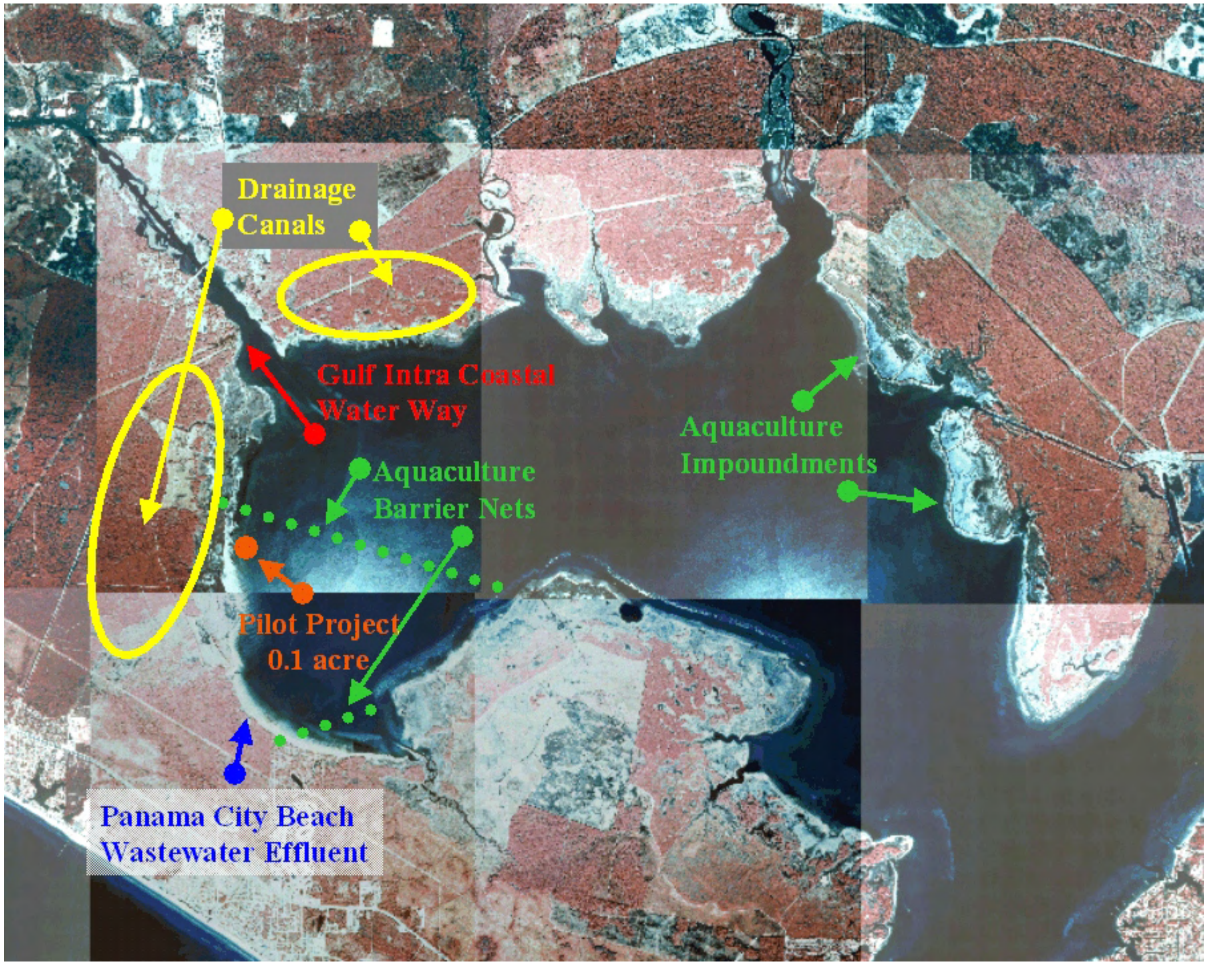

Figure7: Locations of various anthropogenic alterations relative to West Bay.

As it was described by Marlene Womack (1998), the connection between Choctawhatchee Bay and West Bay was the final segment constructed to complete the GIWW, preempting the need for vessels to leave the GIWW and travel through the Gulf of Mexico between Choctawhatchee Bay and St. Andrew Bay (Figure 8). Construction was approved in 1932, however, work began in late 1936. The final connection was completed in June 1938 and measured 100 feet wide and 9 feet deep. (Marlene Womack, The News Herald 1998). Today the GIWW channel measures 12 feet deep and 125 feet in width. The increase in size marks more than the increase in barge size and traffic through the GIWW. This final portion of the GIWW was constructed across several natural drainage areas that discharge water into the canal, causing the channel to fill with washed in sediments with each precipitation event. To this day, the USCOE continually maintains this channel to prevent its filling in permanently (Marlene Womack, The News Herald 1998).

In 1970 a shrimp farming aquacultural facility was permitted and began operation. West Bay modifications from the operation included the construction of two long-standing diked areas that isolated 600 acres (two 300 acre impoundments) of tidal salt marsh on the north shore of West Bay. Additional alteration of West Bay possibly affecting seagrass success may have resulted from the isolation of southern West Bay with small mesh (8mm square) barrier nets. Nets for such uses were treated with antifouling paints or coatings (Figure 9), often containing metals such as arsenic, chromium and copper or organic tin compounds (Voulvoulis *et al.* 2002, Thouvenin *et al.*, 2002, Thomason *et al.* 2002, Valkirs *et al.* 2003). The paint chips depicted on the ground in Figure 8 were collected by the U.S. Fish and Wildlife Service in 1998, analyzed, and found to contain a large amount (26,510 mg/kg dry weight, 26,510 ppm, 2.7%) of the heavy metal copper. The antifouling compound also contained 0.2% organotin. The nature and purpose of these coatings was to be a biocide as was the rotenone treatment employed to remove all fish that would potentially eat the shrimp in the culture area. Stress to seagrasses also plausibly occurred with the use of boat-towed trawls to harvest the cultured shrimp behind the barrier nets in the area of greatest seagrass loss. The physical and mechanical strain on the benthic environment as a result of this activity may have been significant and related to losses.

The addition of a treated municipal wastewater effluent outfall in West Bay appeared in 1971. The outfall was (and is) the permitted discharge point for the City of Panama City Beach wastewater treatment plant (Figure 10). Nutrients, metals, pharmaceutical, and other contaminants have been associated with municipal wastewater effluents even when compliance with permit restrictions is maintained (Garric *et al*, 1996; Baerenklau 1996, Harries *et al*. 1997, Doherty *et al*. 1999, Hemming *et. al*, 2001a, Hemming *et. al*, 2001b). Improved treatment processes has, in all probability, reduced the total loading from this system as technology has become more economically achievable However, failure to comply with some limitations, such as copper, has been involved with the scheduled removal of this discharge from West Bay by 2007 (NPDES FL0021512-002).

More subtle and less defined large changes to the watershed of West Bay were introduced with the excavation of extensive land draining canals on to the west and north of West Bay (Figure 11). The canals allowed water that would naturally reside in wetland areas adjacent the bay to easily drain from those lands and flow directly to West Bay. Exactly when these canals were excavated is not clear. However, it has been suggested that they were created in the 1960s in an effort to provide adequate drainage for the building of roads by the Florida Department of Transportation and for silviculture activities (Pers. Comm. Mark Thompson, NOAA Fisheries). The drainage of these wetland areas via rapid transport to West Bay provided an introduction of freshwater and characteristic wetland runoff constituents (nutrients, detritus, oxygen demand etc.). The cumulative importance of these numerous inputs has not been determined.

A large pending threat to the stability of the West Bay system and the restoration of depleted seagrasses may be urban development planned for the watershed and its tributaries. Ever more significant, nonpoint source pollution and stormwater events have the potential to dramatically impact water quality in our bays and estuaries. The increased urbanization that threatens many panhandle ecosystems will bring an associated increase in impermeable surface area, increase toxicant loadings to those surfaces, decrease infiltration through natural treatment pathways, and decrease vegetative treatment of nonpoint sources of pollution. Current stormwater management measures are inadequate to protect Florida's natural resources.

The influence of water quality on seagrass success is well documented and often highlights the importance of water clarity (Buzzelli *et al.*, 1998; Fonseca et al. 1998; Livingston *et al.*, 1998) and high salinity (Fonseca et al. 1998; Livingston *et al.*, 1998; Hanisak, 2002), however, numerous indirect factors and conditions have also been implicated as stressors (Fonseca et al. 1998; Pergent *et al.*, 1999; Prange and Dennison, 2000; Jones *et al.* 2001; Macinnis and Ralph, 2002; Barwick and Maher, 2003). In an effort to better understand the current state of West Bay and toevaluate the potential for successful seagrass restoration efforts, the Service conducted a water quality survey under various environmental settings. Sediment samples were also taken to determine if metals contamination was present.

Figure 8: The Gulf Intra Coastal Water Way connection between Choctawhatchee Bay and West Bay.

Figure 9: Photographs taken at the shrimp aquaculture offloading site demonstrating the occurrence of net treatment with antifouling coatings (red to orange coating on nets and ground).

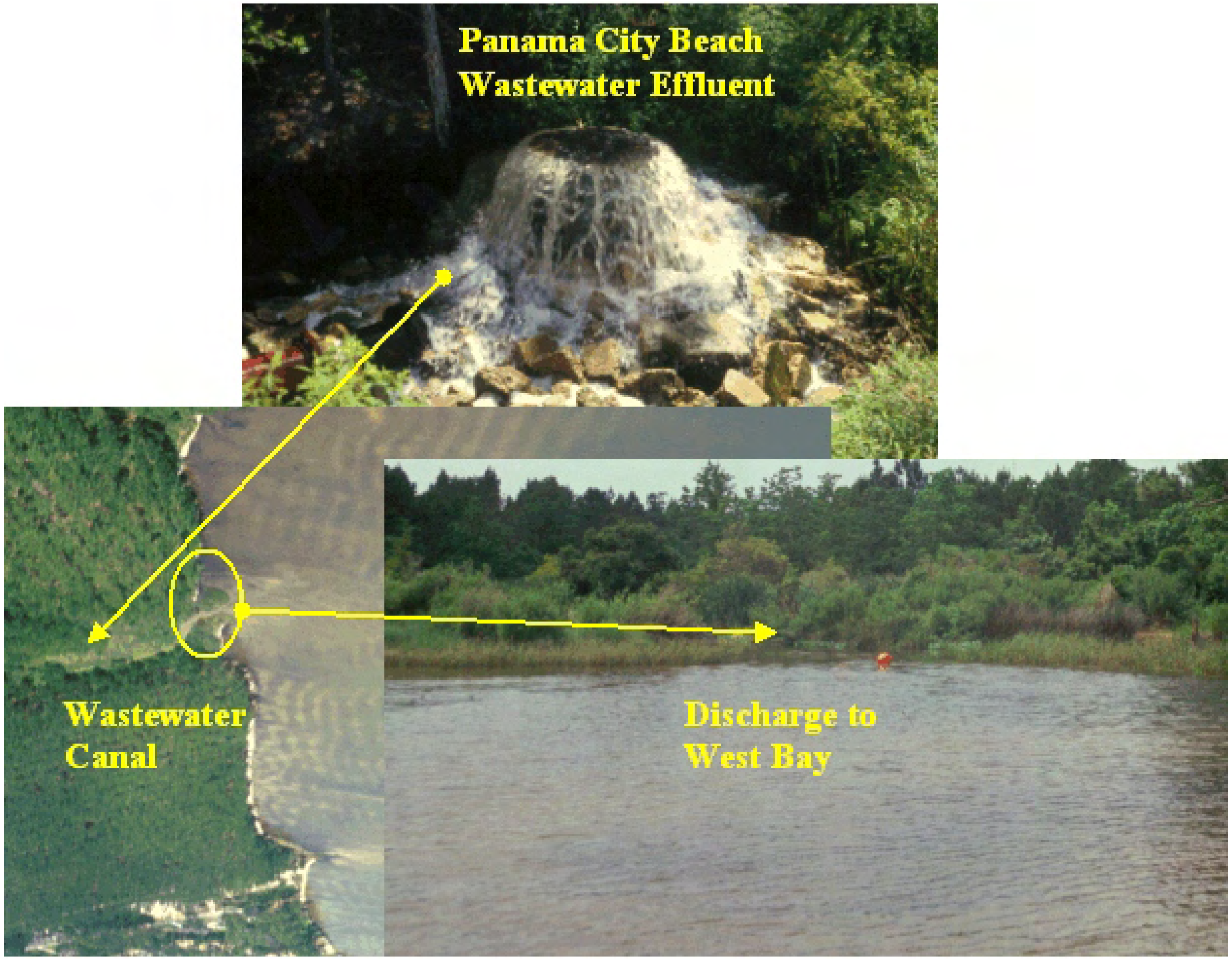

Figure 10: Panama City Beach municipal wastewater effluent outfall and discharge.

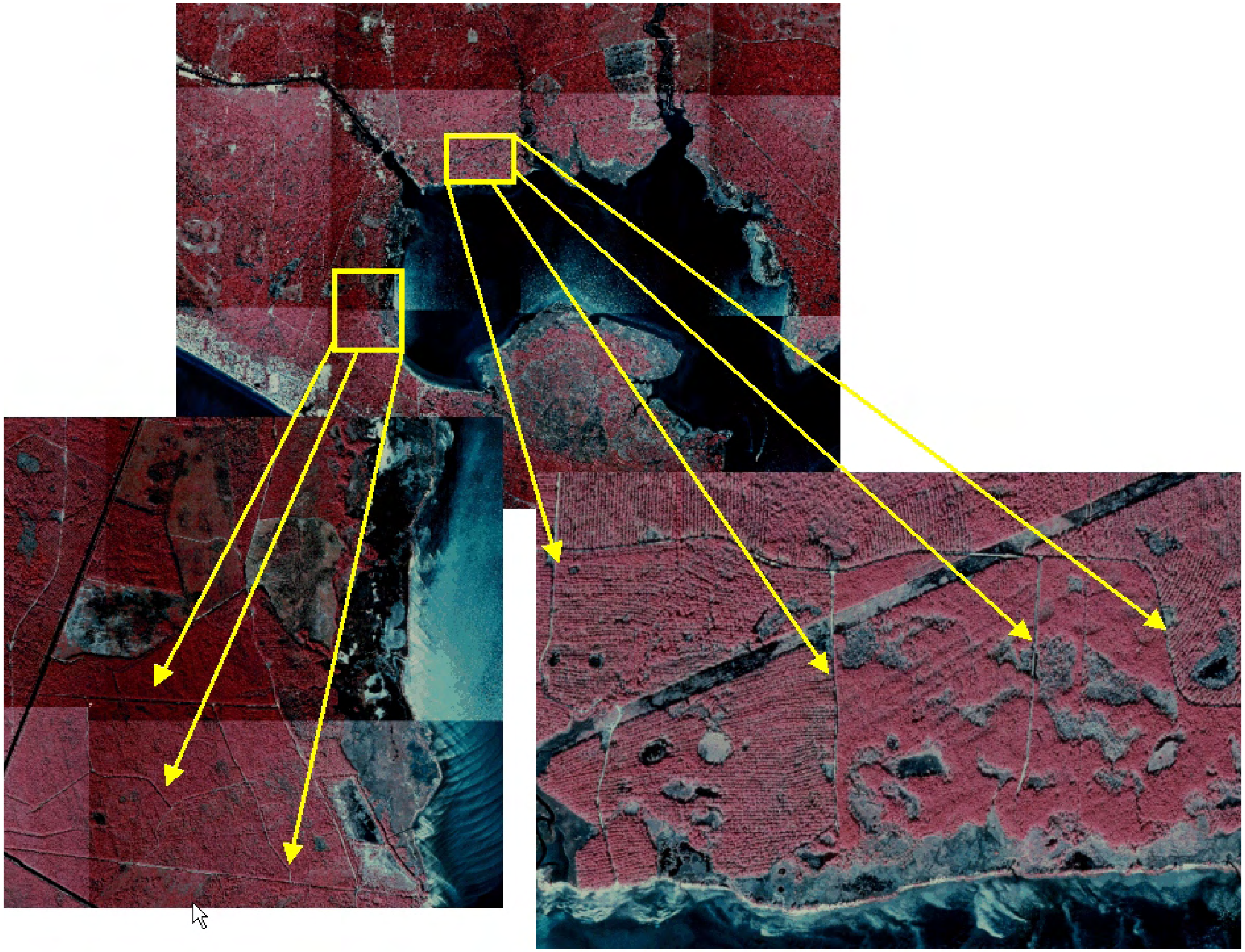

Figure 11: Canals draining wetland areas to the west and north of West Bay.

MATERIALS AND METHODS

Water Column Sampling

Water quality in West Bay and the adjacent GIWW was monitored using a YSI Model 6600 multiparameter data logger. The instrument included a rapid pulse dissolved oxygen probe, conductivity/temperature probe, fluorescence derived chlorophyll probe, nephlometric turbidity probe, pH probe and calculated salinity and total dissolved solids. Readings were taken at a depth of 1 meter. The data was recorded to a YSI 650 Multiparameter Display System. Secchi disk measures were also taken at each site as a measure of water clarity. Secchi depth calculations were based on averaging readings taken while lowering and raising the disk. Water quality monitoring was performed at sites depicted in Figures 12-16 (exact locations in appendices). Sampling conditions varied by season, recent precipitation, and winds and were conducted during 3 incoming tides and 3 outgoing tides.

Statistical analyses on water quality data were performed using JMP version 5.01 (SAS Institute Inc, 2002). Statistically significant differences were accepted at $\alpha=0.05$. Analyses were conducted on replicate sampling at a 4 to 10 second interval performed from 5 to 10 minutes at each site. Data were analyzed with parametric Analysis of Variance when assumptions of normality and homogeneity were met. The Tukey-Kramer Honest Significant Difference (HSD) multiple comparison tests (MCT) was used when differences were found. When parametric assumptions were not met, the non-parametric Kruskal-Wallis analysis was used with ranked Tukey-Kramer HSD MCT when differences were found.

Data were also evaluated for ecological significance to the recovery of seagrasses in West Bay. Semi-quantitative risk estimations were applied to the data to elucidate areas less suited to restoration efforts during each various sampling condition.

Sediment Sampling

Sediment samples were collected from 10 sites in West Bay as depicted in Figure 17 (exact location in appendices). Standard operating procedures for field collection of sediment samples (PCFO-EC SOP 004) are provided in Appendix A. Sediment samples were composite samples consisting of three ~200 ml subsamples. Samples were collected using a standard ponar 316 stainless steel grab. Depth of sediment samples collected depended on the type of sediment at each station (maximum depth in silt ~10 cm). Samples collected in the field were immediately put into laboratory-certified, chemically-cleaned, 1-liter amber glass jars with Teflon-lined lids and placed on ice in coolers. Samples were temporarily stored at the Panama City Field Office (PCFO) in freezers at 5º C until shipment to analytical laboratories. Sediment samples were analyzed for metals and organic tin compounds to examine the extent to which the aquacultural net treatment may have impacted the bay sediments. Analyses for organotins were carried out by Geochemical and Environmental Research Group, Texas A&M Research Foundation, 833 Graham Road, College Station, TX 77845. Analyses for inorganic metals were performed by Trace Element Research Laboratory, VAPH/CVM Highway 60, VMA Bldg, Room 107, College Station, TX 77843-4458. Analytes are listed in Table 1. Sediment analytical results were compared to the Effects Range Low (ERL) and Effects Range Median (ERM) criteria of Long *et al.* (1995) to estimate risk to living resources from exposure to contaminated sediments.

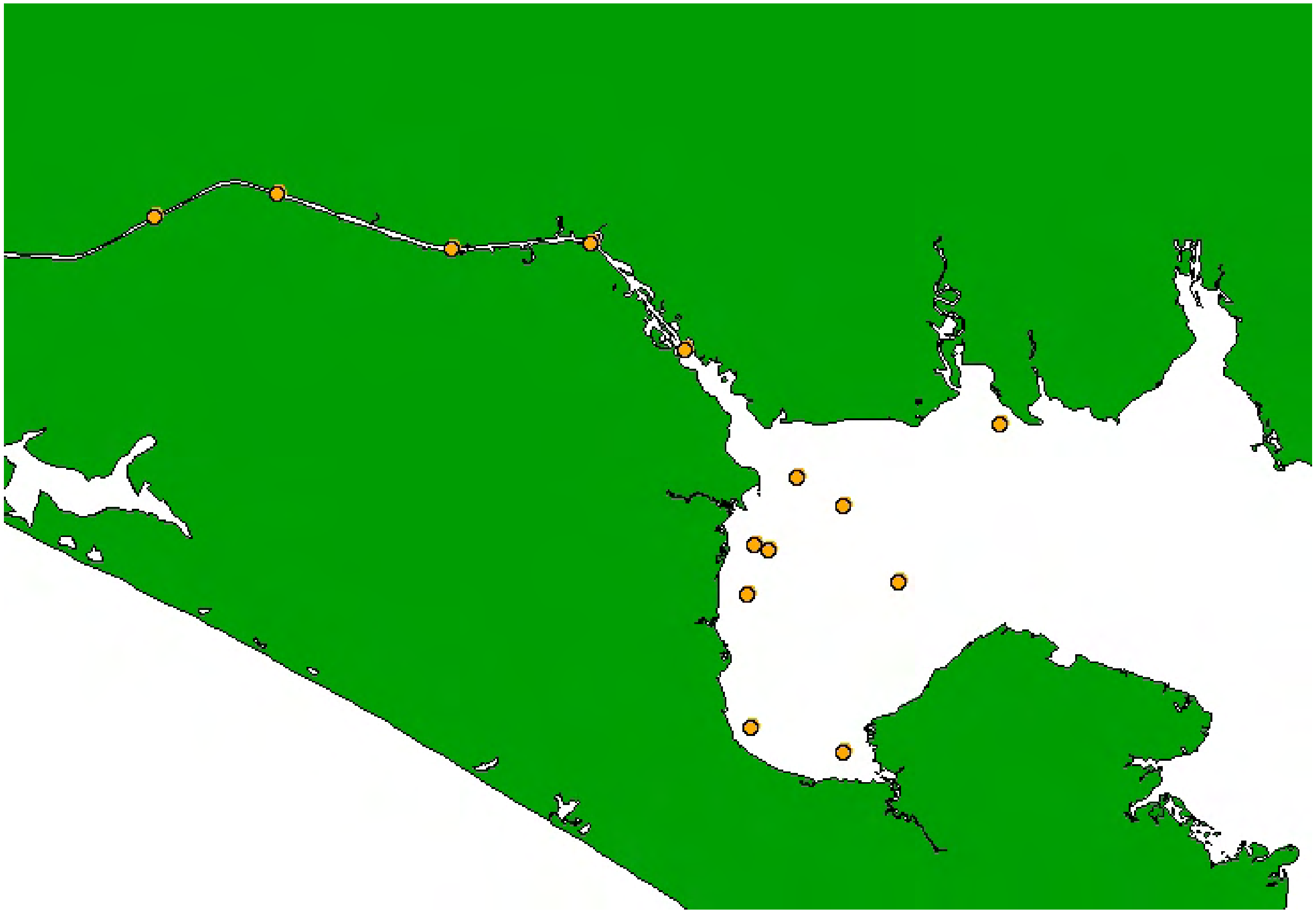

Figure 12: Sampling locations for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

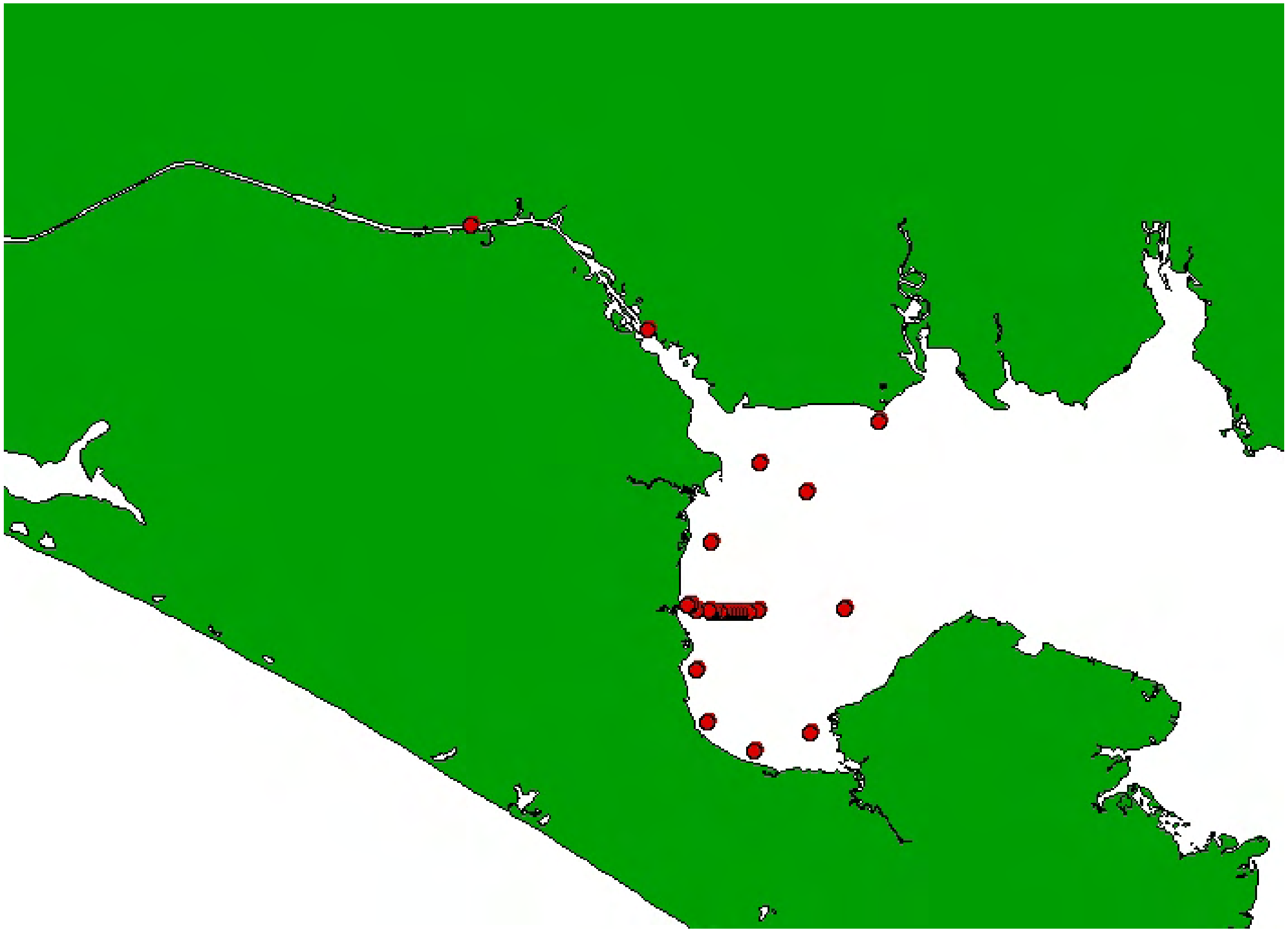

Figure 13: Sampling locations for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

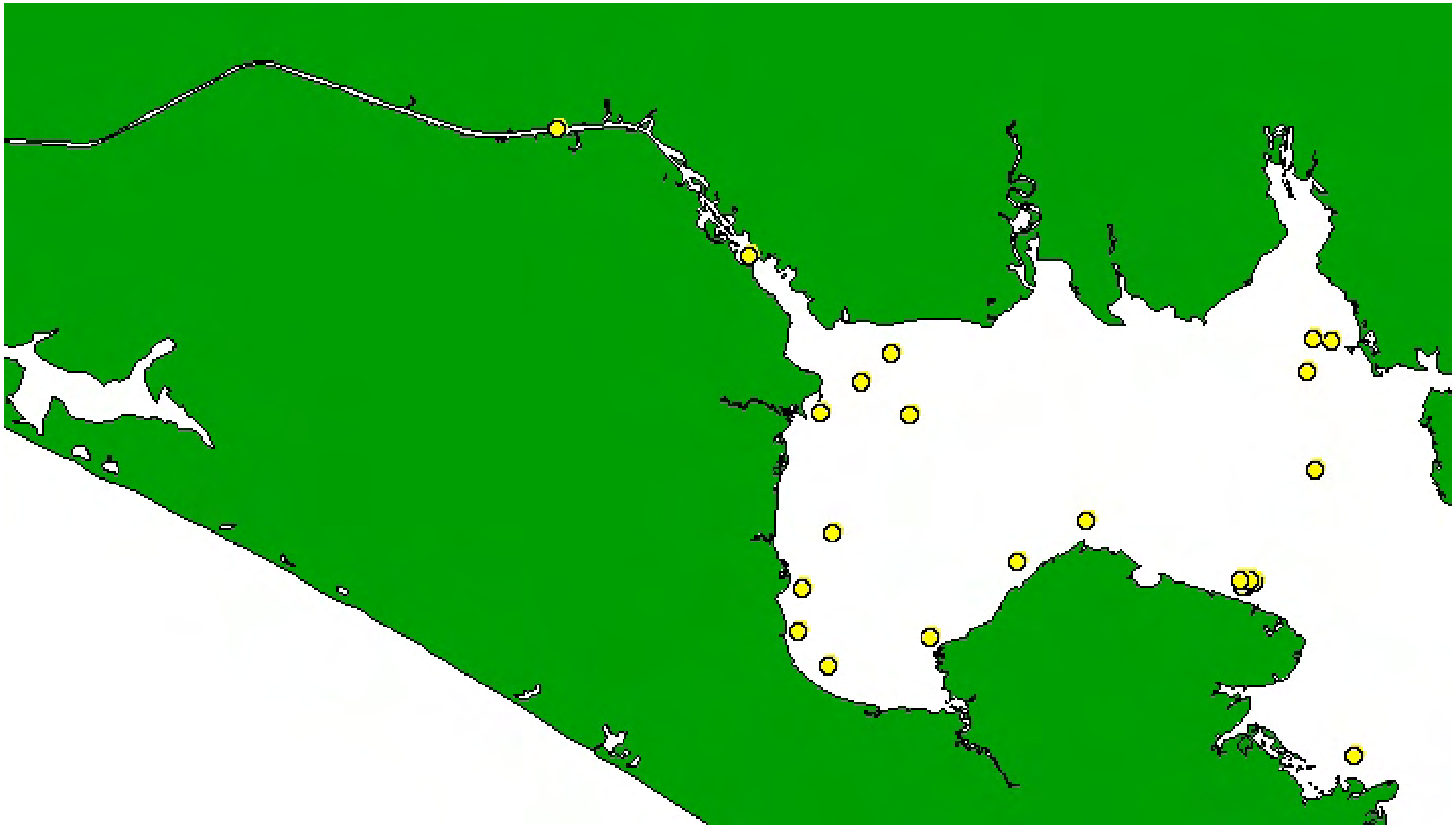

Figure 14: Sampling locations for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 15: Sampling locations for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

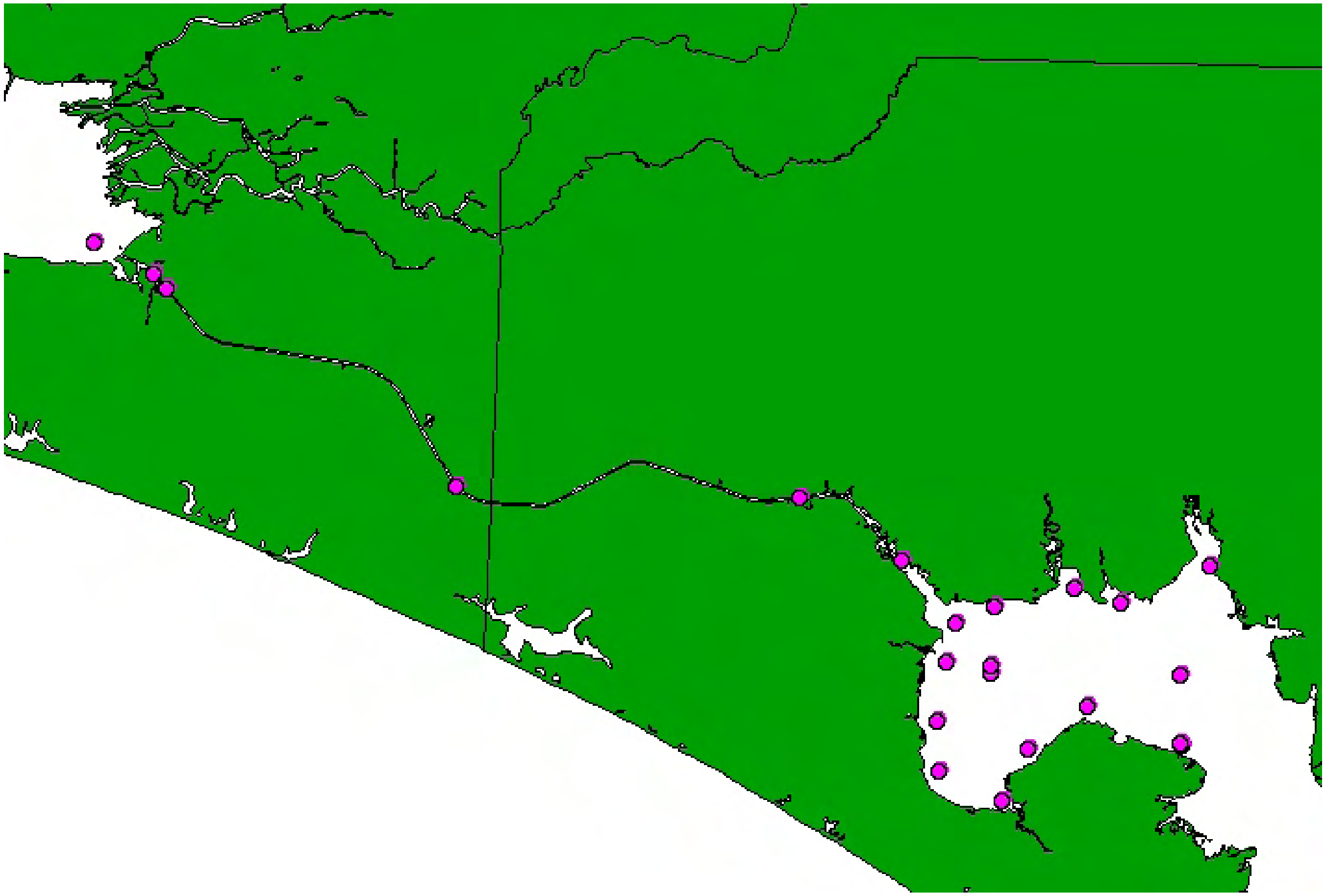

Figure 16: Sampling locations for outgoing tide June 26th water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

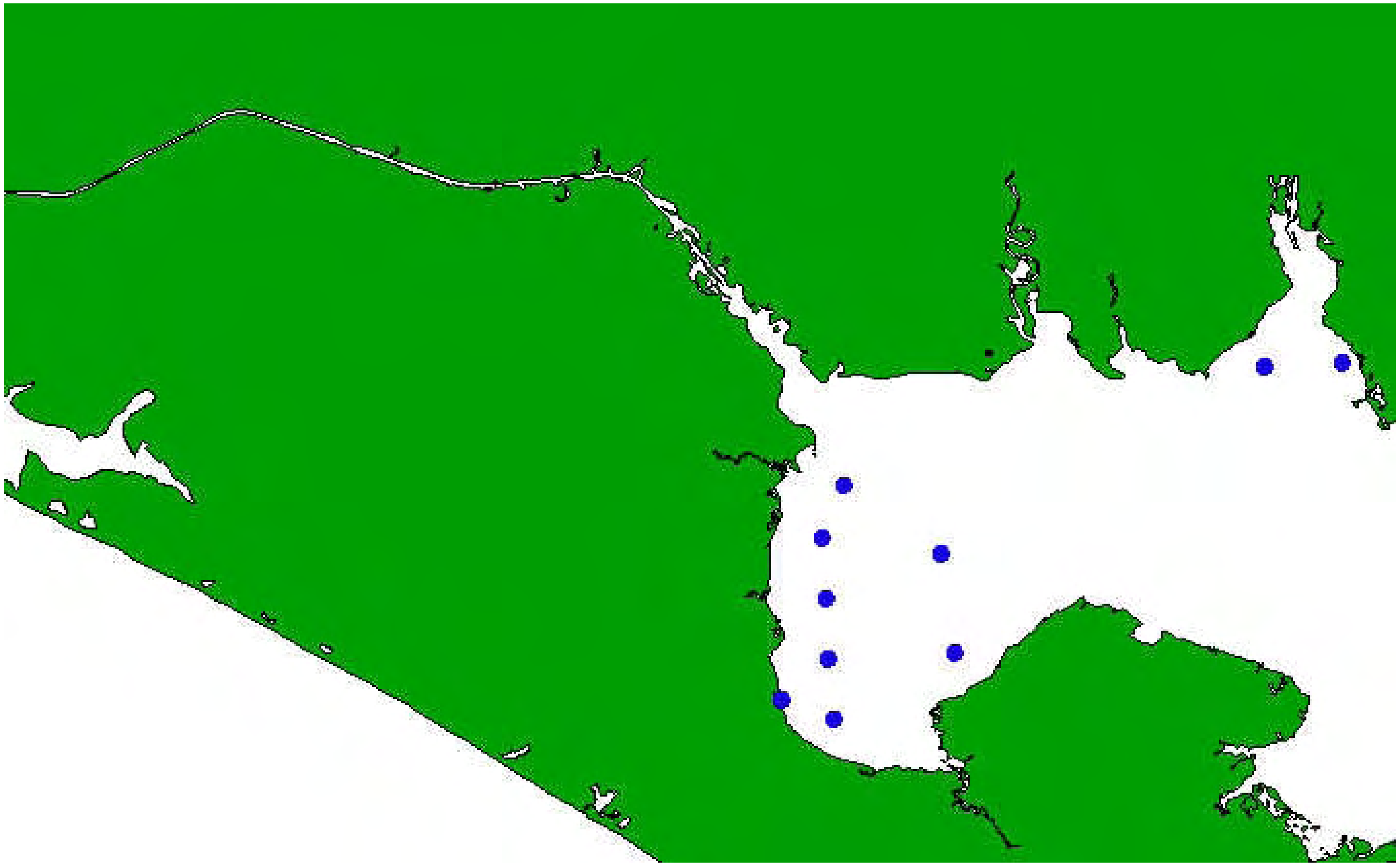

Figure 17: Sediment sampling locations during August 2002 in West Bay in the St. Andrew Bay system, Bay County, Florida.

Table 1: Chemical analytes measured in sediment samples taken in August 2002 from West Bay of the St. Andrew Bay system in Bay County

Metals	
*Silver	Magnesium
Aluminum	Manganese
*Arsenic	Molybdenum
Boron	*Nickel
Barium	*Lead
Beryllium	Selenium
*Cadmium	Strontium
*Chromium	Thallium
*Copper	Vanadium
Iron	*Zinc
*Mercury	

Organotins	
Monobutyltin	Tributyltin
Dibutyltin	Tetrabutyltin

* Sediment Quality Guidelines available from Long et al. 1995.

RESULTS

Water Column Sampling

Incoming Tide, January 28th 2003:

Temperatures were seasonally cool around 10°C (50°F) and skies were clear. Winds were from the south to southeast at 5 mph creating a very light chop toward the northern shore of West Bay. Measures were taken during an incoming tide resulting from a -1.0 foot low tide at 7:03 a.m. moving toward a 1.6 foot high tide at 7:28 p.m. A strong current was qualitatively observed flowing toward Choctawhatchee Bay from West Bay through the GIWW. Rainfall totals for the month of January were less than 1 inch and no rain was recorded 72 hours prior to sampling (NWFWMD).

Sites in West Bay possessed significantly higher dissolved oxygen (DO), salinity (ppt) and pH ($p<0.0001$) in comparison to sites in the GIWW. Conversely, sites within the GIWW exhibited significantly higher turbidity (NTUs), chlorophyl (Chl a) and temperature (°C) ($p<0.0001$) than sites in West Bay. Secchi disk depths were not always valuable because visibility exceeded depth at many sites (Figure 18). The differences observed among sites during this sampling period does not necessarily show diminished water quality, but merely statistically significant differences. Figures 19-24 show a qualitative rating system and the spatial relationships of the various data.

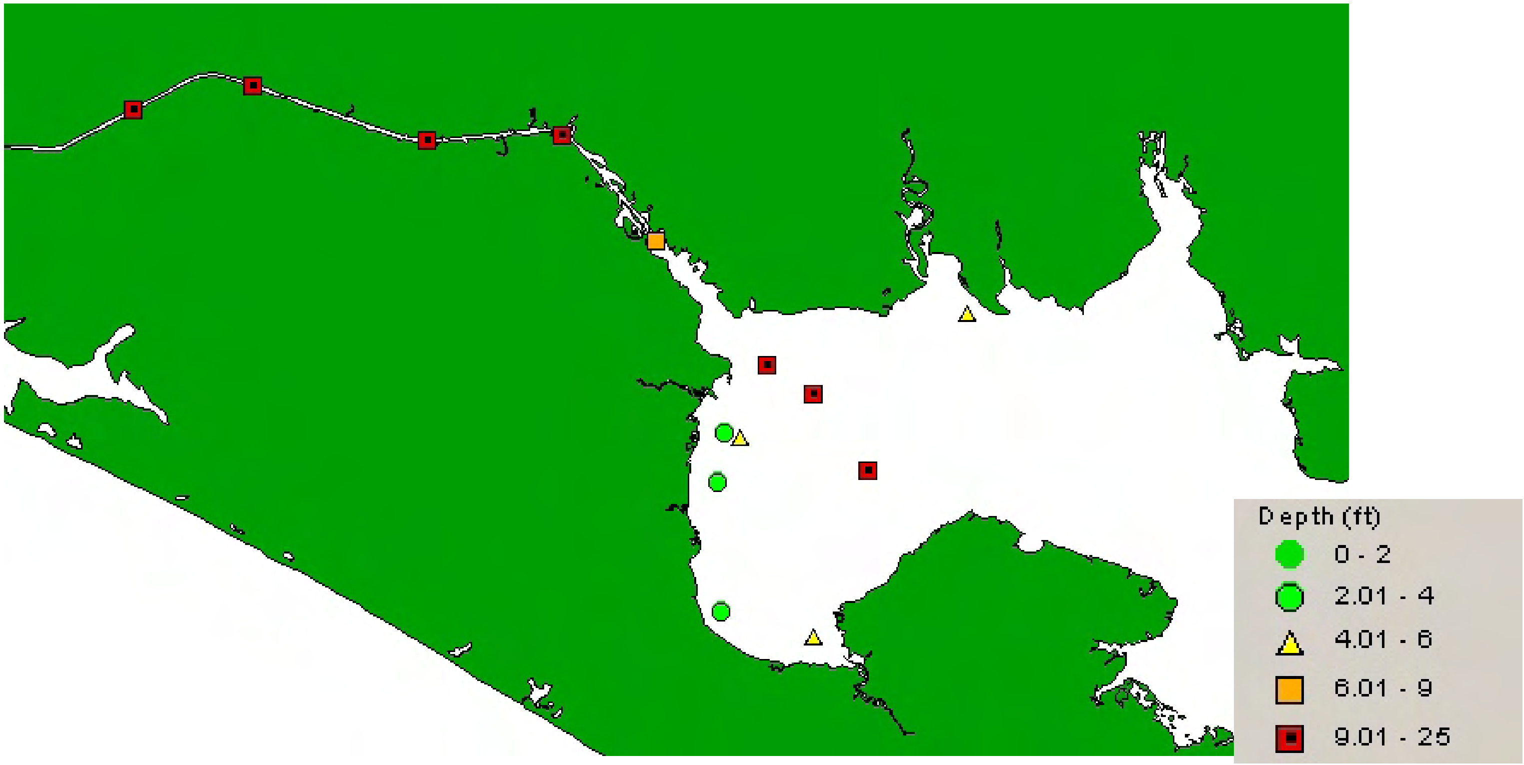

Figure 18: Depth data by sample location for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

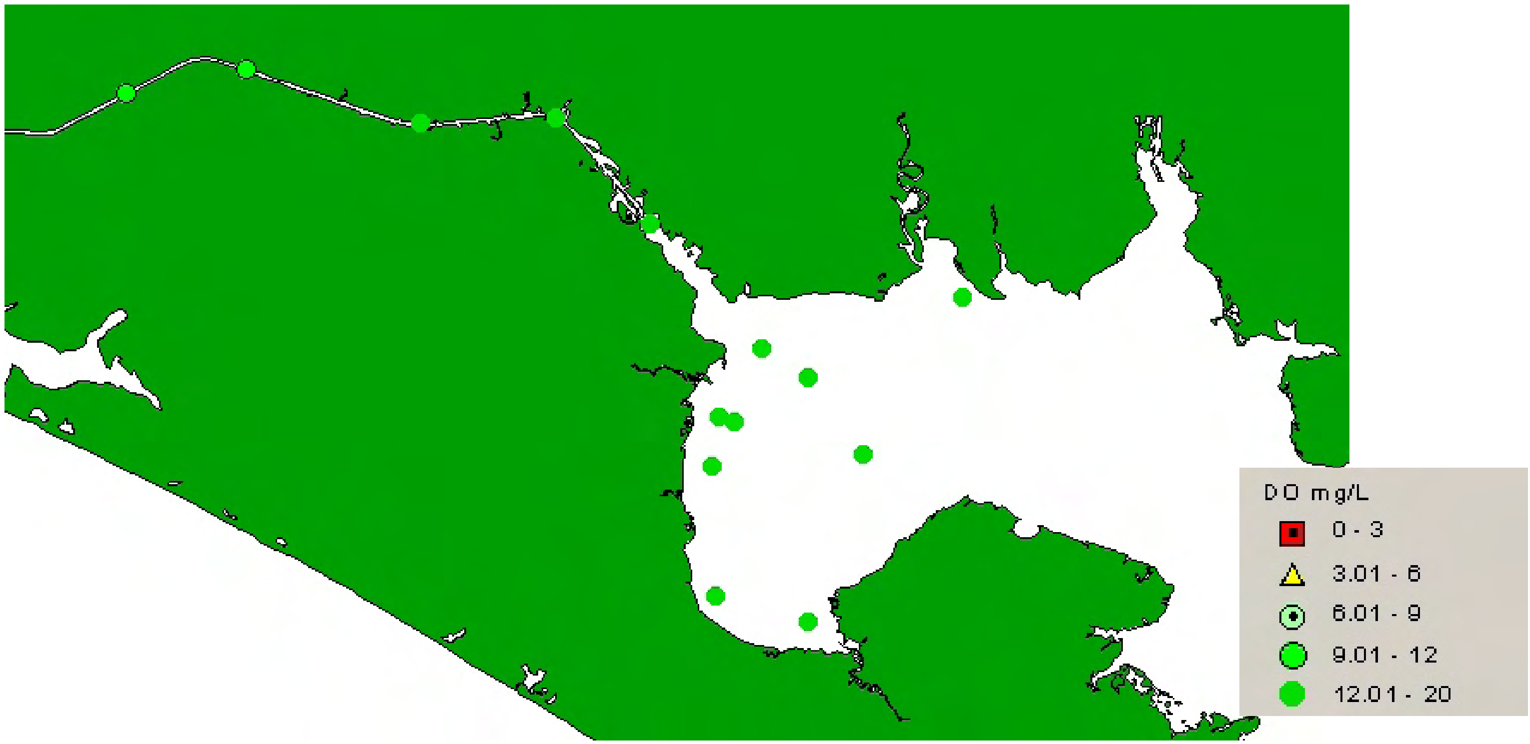

Figure 19: Dissolved oxygen data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

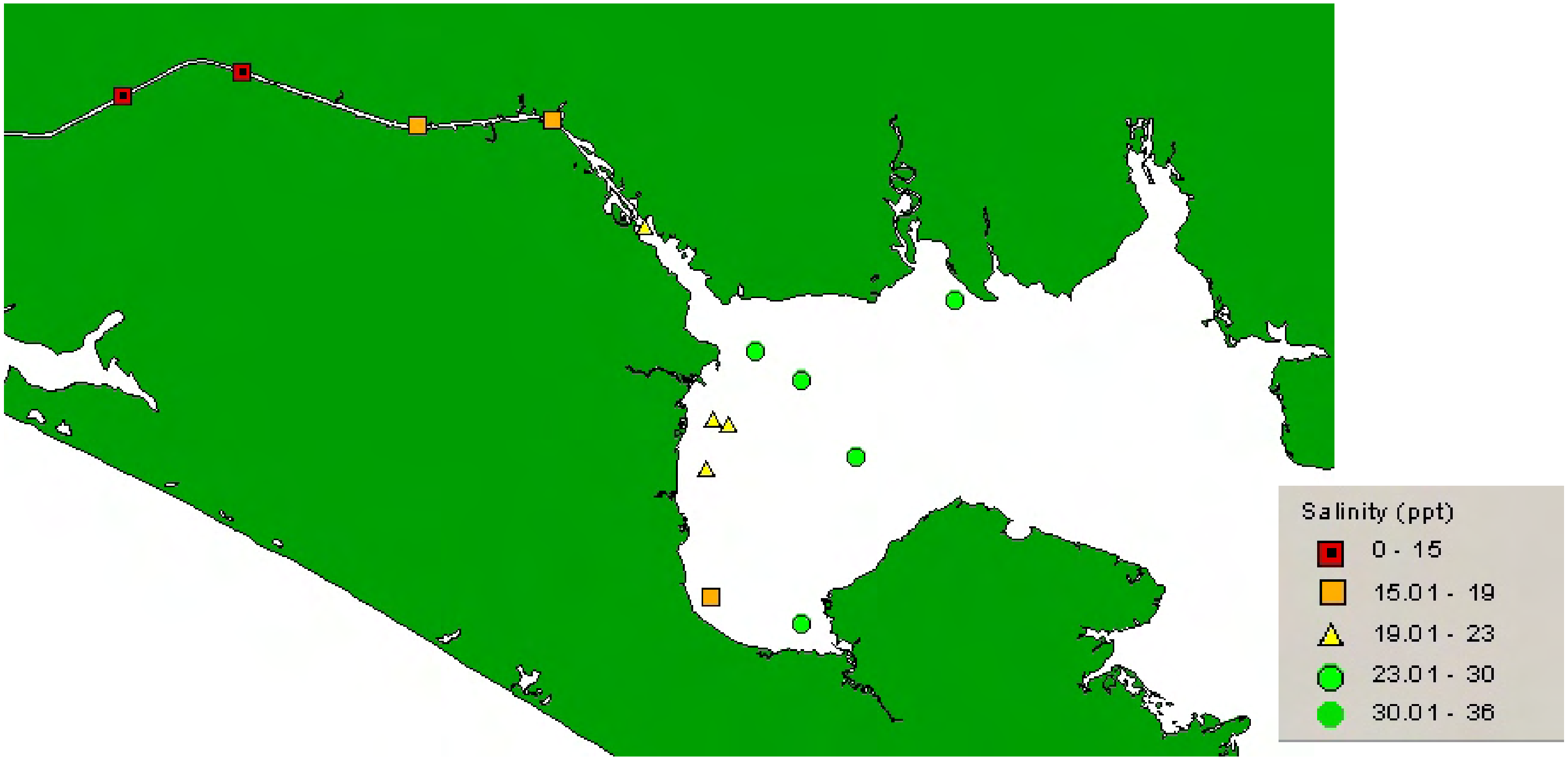

Figure 20: Salinity data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

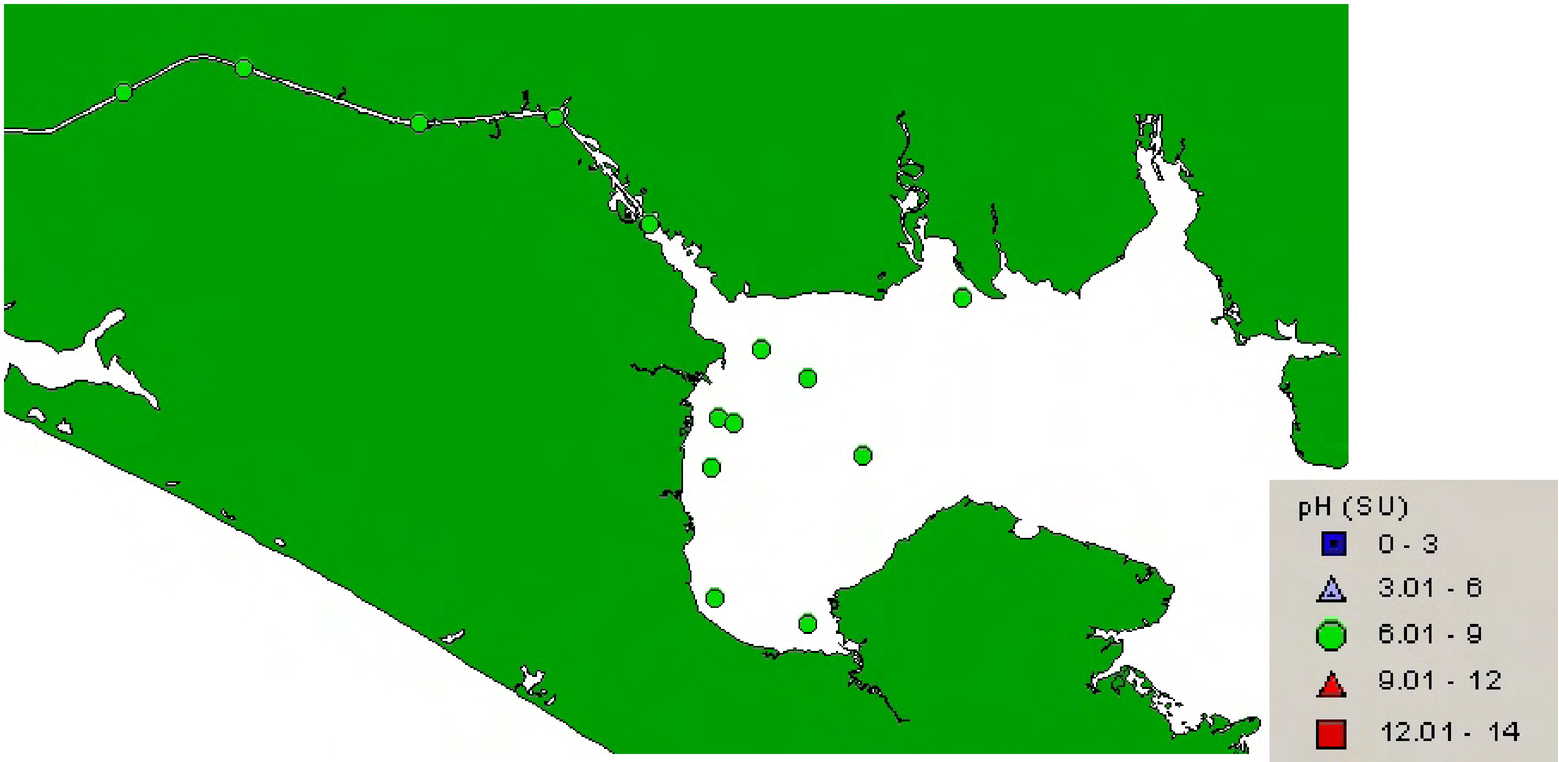

Figure 21: pH data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 22: Turbidity data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 23: Chlorophyll data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida

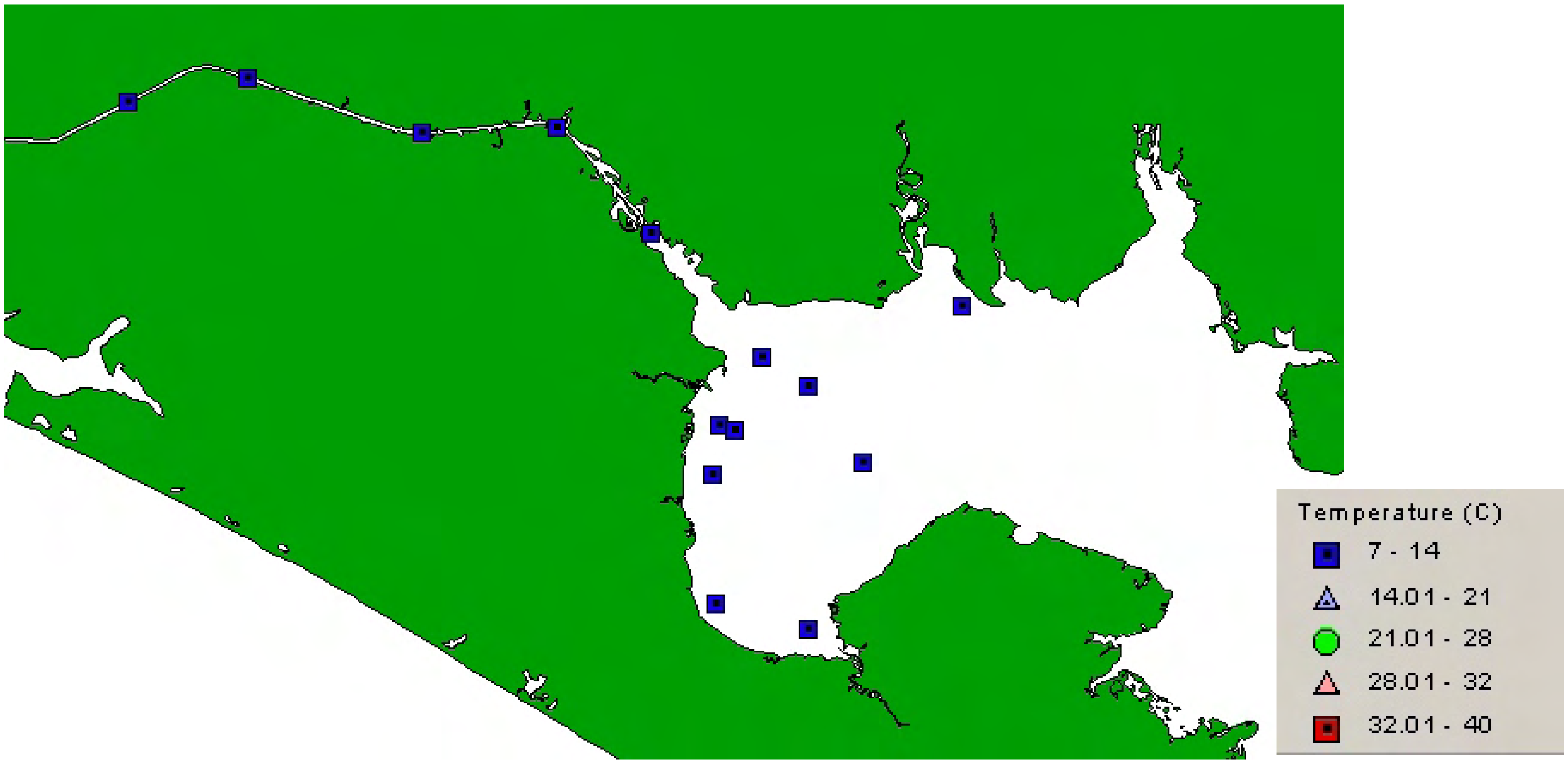

Figure 24: Temperature data for incoming tide January 28th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Incoming Tide, March 27th 2003:

Moderate temperatures of approximately 21°C (70°F) and clear skies were present with a 10-15 mph east wind and moderate chop toward the western shore of West Bay. Measures were taken during an incoming tide resulting from a -0.5 foot low tide at 6:40 a.m. moving toward a 1.6 foot high tide at 7:17 p.m. A strong current was qualitatively observed flowing toward Choctawhatchee Bay from West Bay through the GIWW. Rainfall totals for the month of March were in excess of 9 inches with 1.3 inches of rainfall recorded in the study area within 12 hours of sampling (NWFWMD).

Significantly lower salinity and lessor Secchi depth measures were found in shallow areas on the western shore of West Bay and in the GIWW ($p<0.0001$). Turbidity and temperature were significantly higher in shallow areas on the western shore of West Bay and in the GIWW ($p<0.00001$). Additionally, turbidity was high in a shallow-water site on the northern shore. Dissolved oxygen was found to be significantly lower in the GIWW. Statistically significant differences between sites for the parameters of chlorophyll concentration and pH were observed but not thought to be ecologically meaningful ($p<0.0001$). Qualitative interpretations of the data are spatially presented in Figures 25-31 in an attempt to emphasize ecological significance rather than statistical significance.

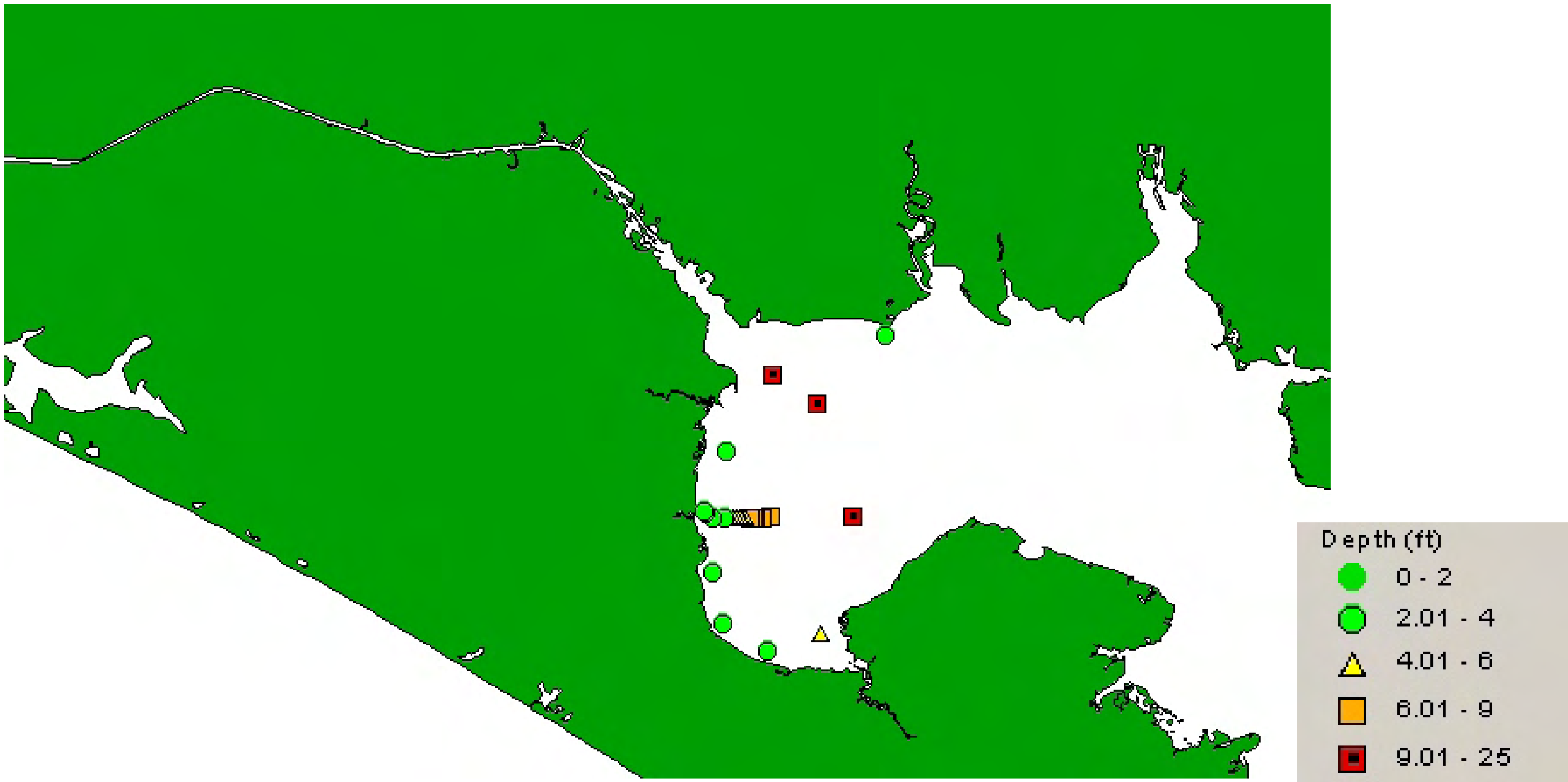

Figure 25: Depth data by sample location for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

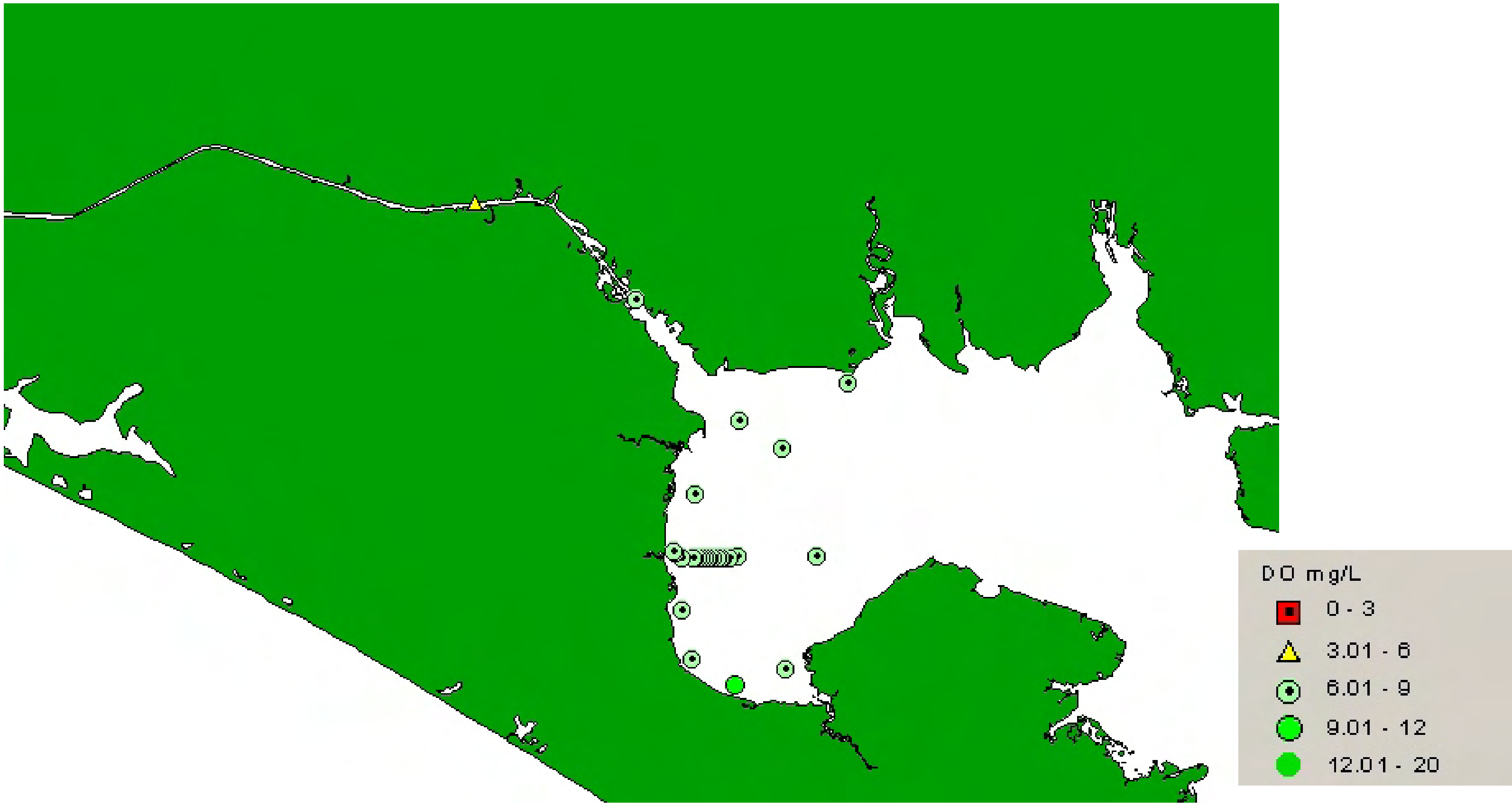

Figure 26: Dissolved oxygen data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

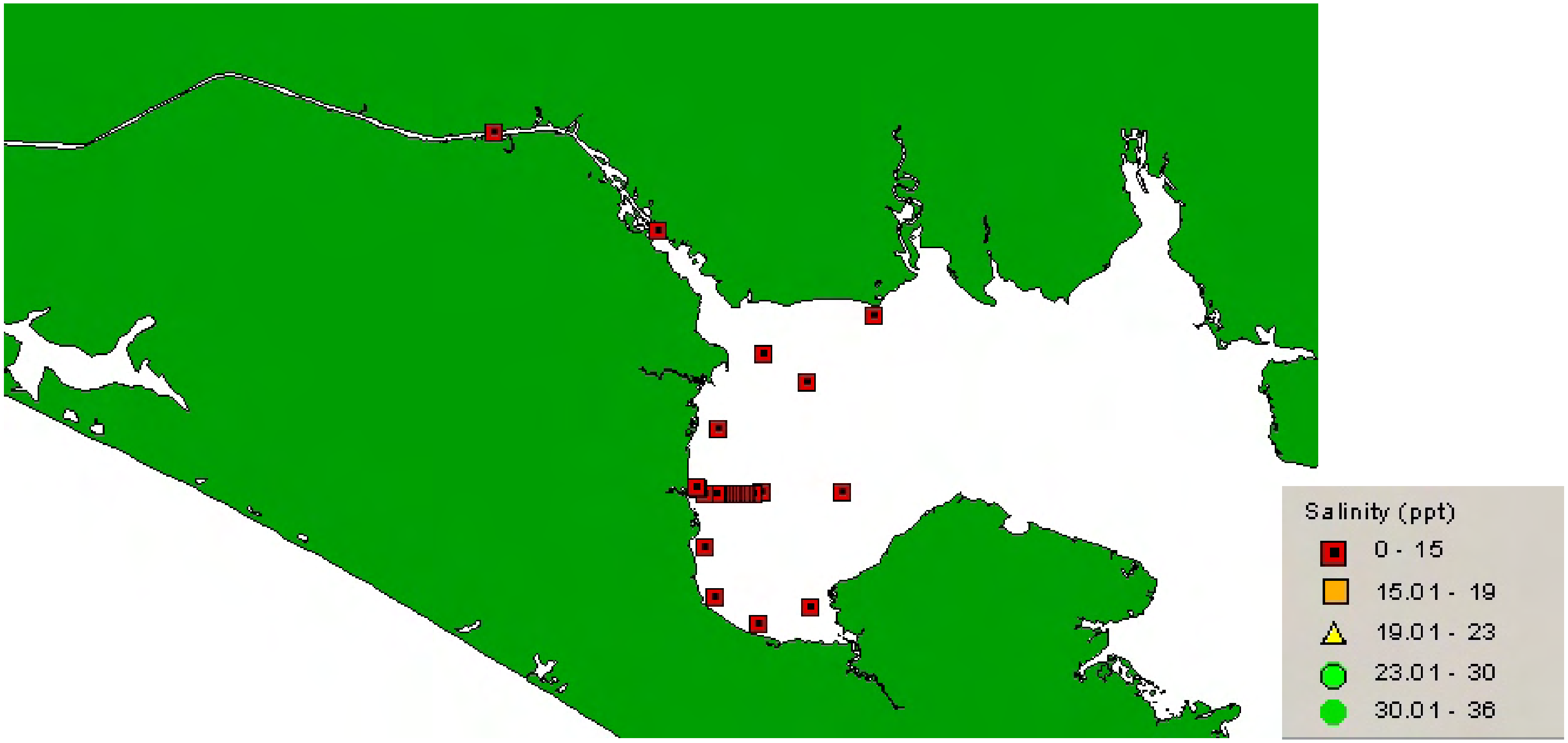

Figure 27: Salinity data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 28: pH data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 29: Turbidity data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

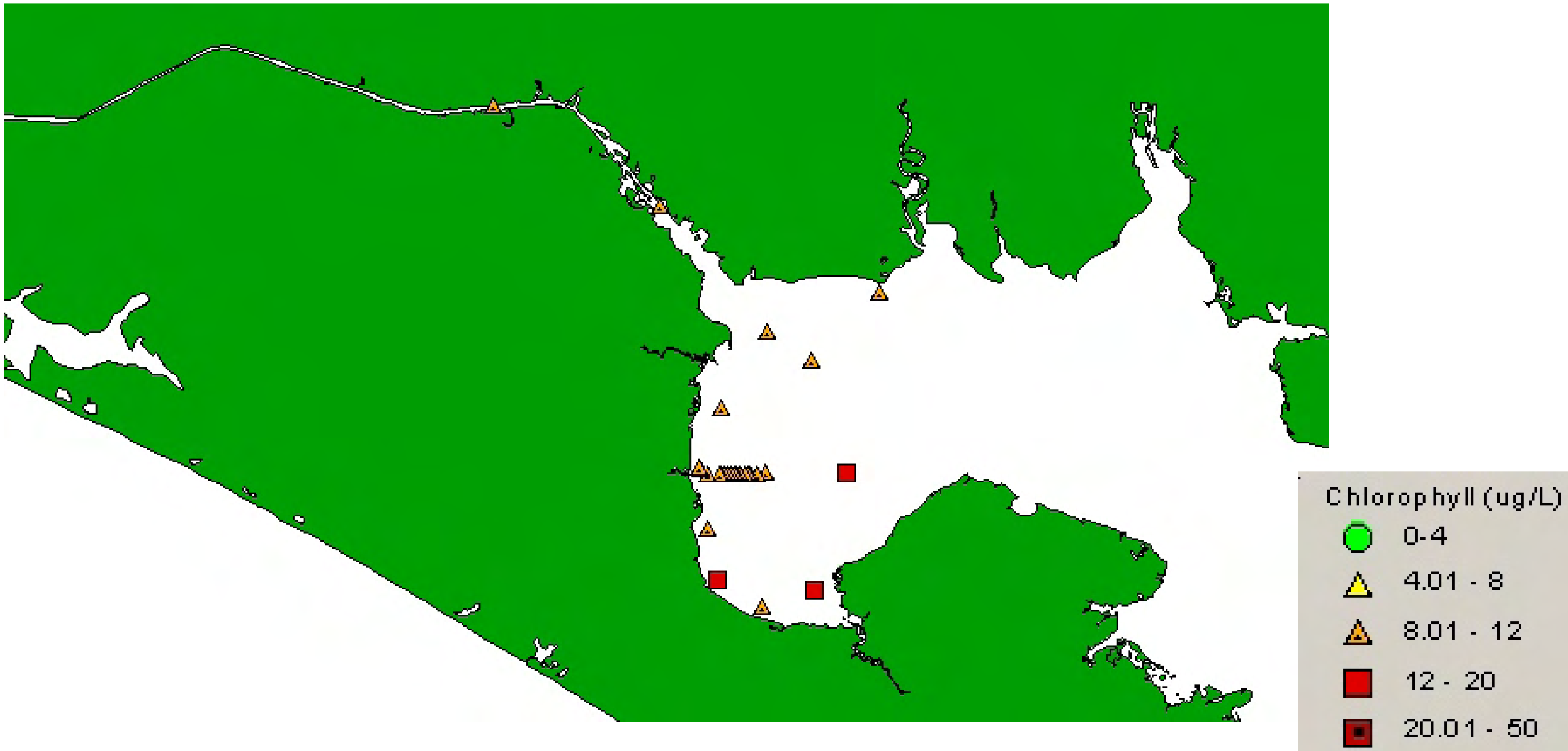

Figure 30: Chlorophyll a data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

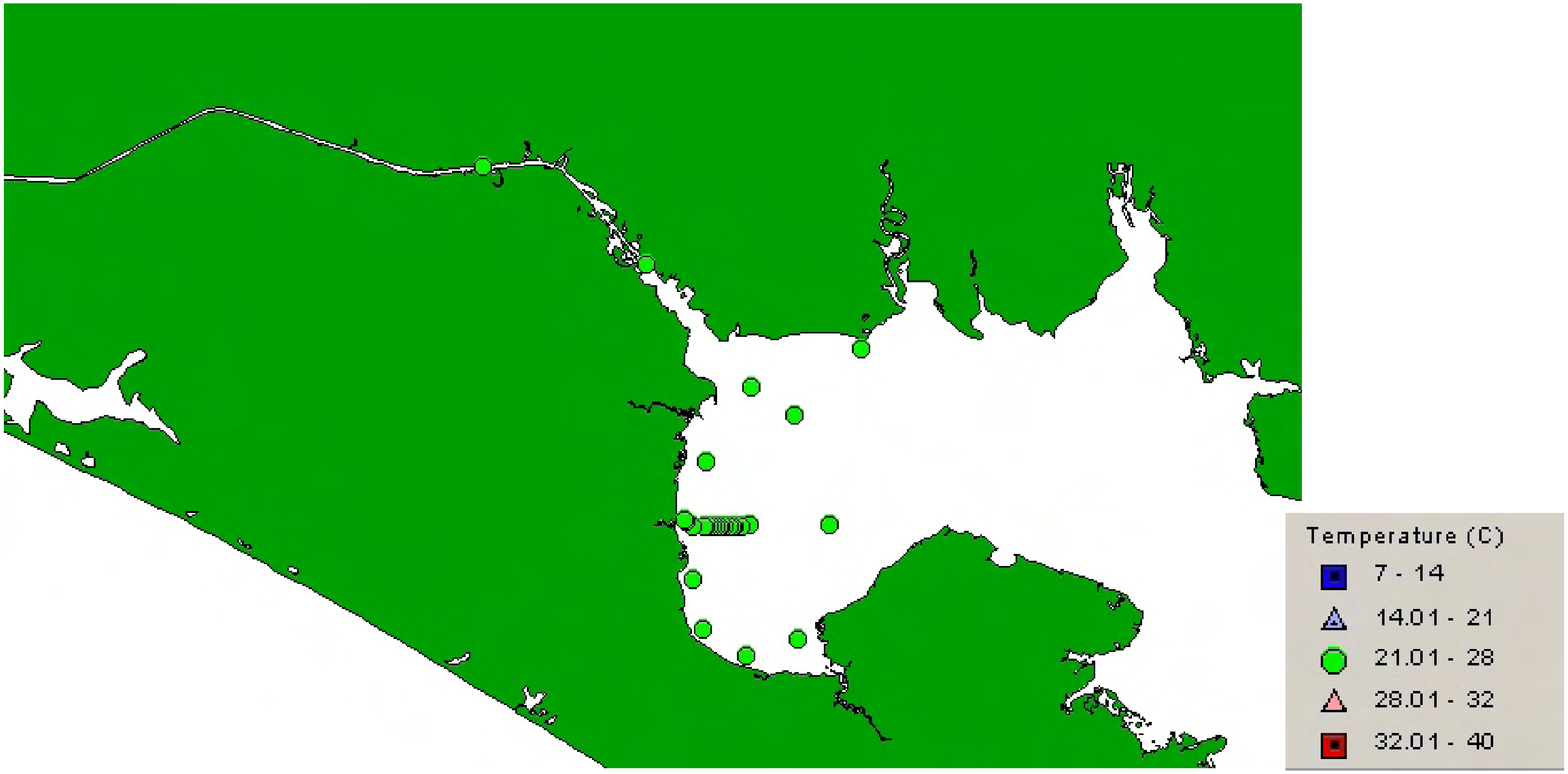

Figure 31: Temperature data for incoming tide March 27th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Outgoing Tide, May 14th 2003:

Warm temperatures of approximately 29°C (85°F) and clear skies were present with a 5 mph east wind shifting to 5 mph south to southwest early (~9:30 a.m.). Light to no chop present on West Bay. Measures were taken during an outgoing tide resulting from a 1.9 foot high tide at 10:06 a.m. flowing to a -0.1 foot low tide at 8:46 p.m. Current in the GIWW proceeded toward West Bay from Choctawhatchee Bay. Rainfall totals for the first 2 weeks of May were less than one inch and no rainfall was recorded in the area within 72 hours of sampling (NOAA).

Dissolved oxygen, temperature, and pH were significantly different among sites ($p<0.00001$). pH measures did present a possible decreasing trend with distance toward Choctawhatchee Bay for sites approaching, and in, the GIWW, although differences were small. Differences were also observed among sites near and in the GIWW and the rest of West Bay for the parameters salinity ($p<0.00001$), turbidity ($p<0.00001$) and chlorophyll concentration ($p<0.0001$). A possible trend was revealed of increasing salinity with distance from Choctawhatchee Bay and into West Bay from the GIWW. This trend also progressed down the western shore of West Bay. A similar trend for turbidity and chlorophyll (to a lesser extent) was possible. Secchi depth measures were not taken in triplicate, but did appear similar to the turbidity measures in NTUs. To demonstrate these possible correlations, data are presented spatially with an anticipated ecologically relevant qualitative rating system in Figures 32-38.

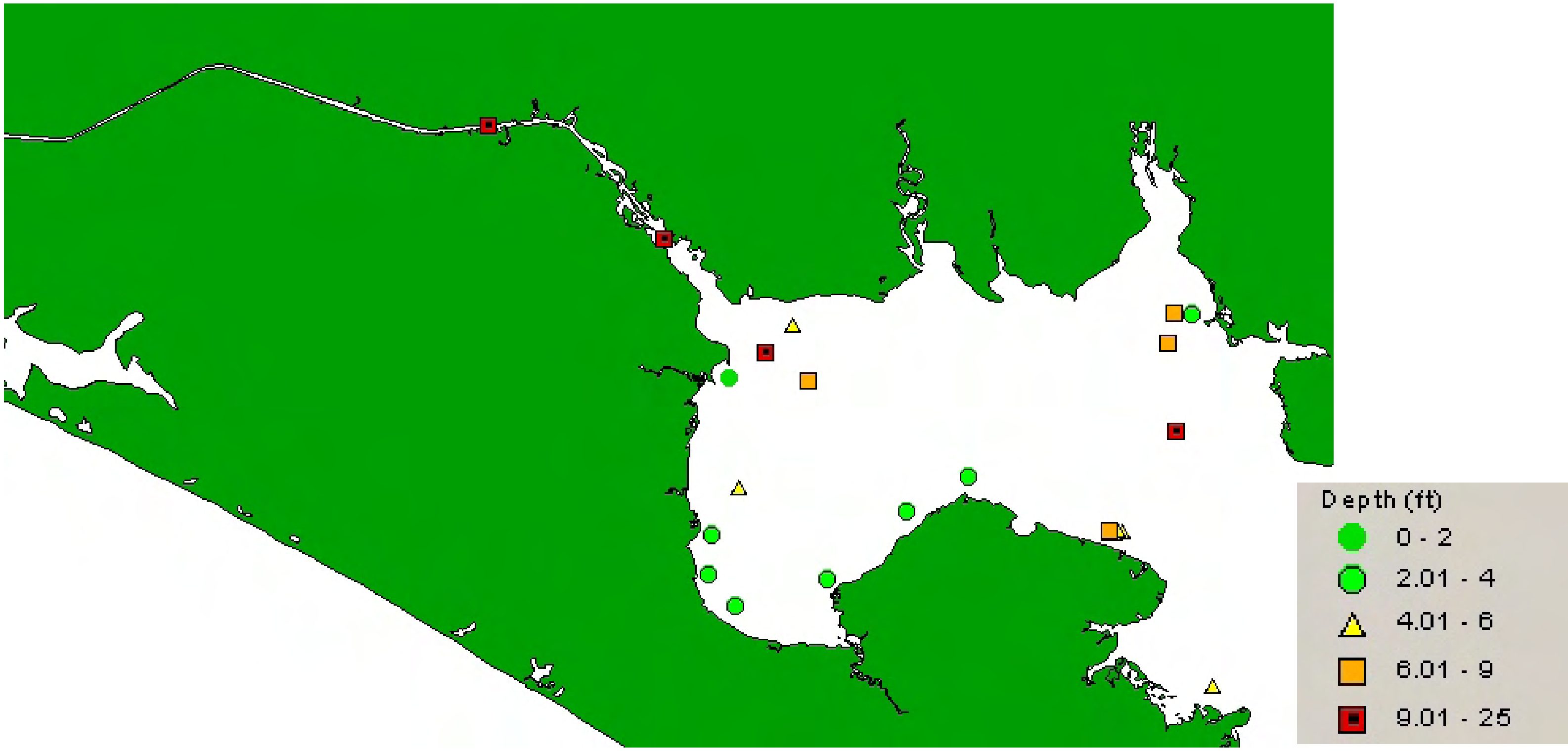

Figure 32: Depth data by sample location for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

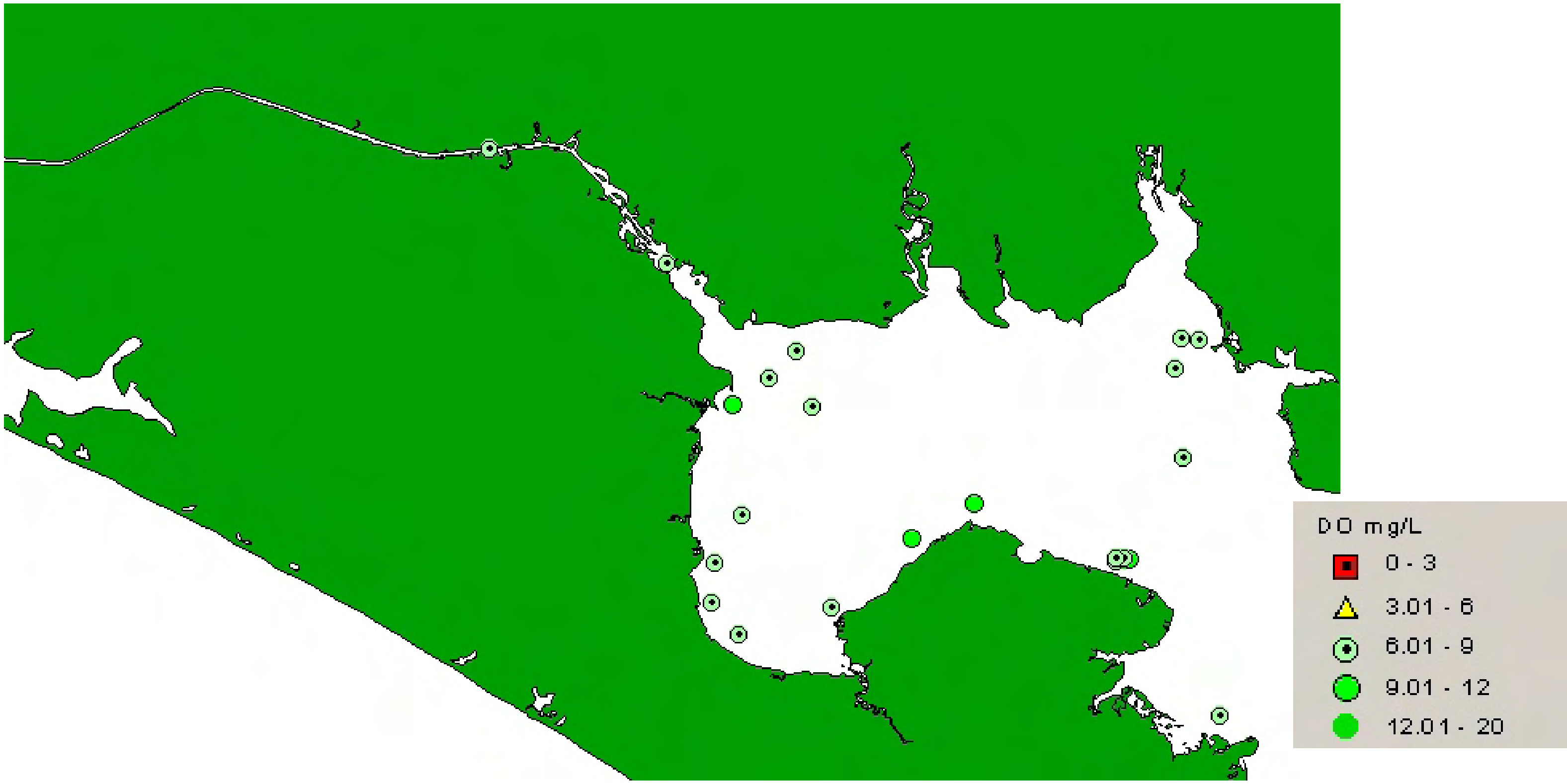

Figure 33: Dissolved oxygen data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

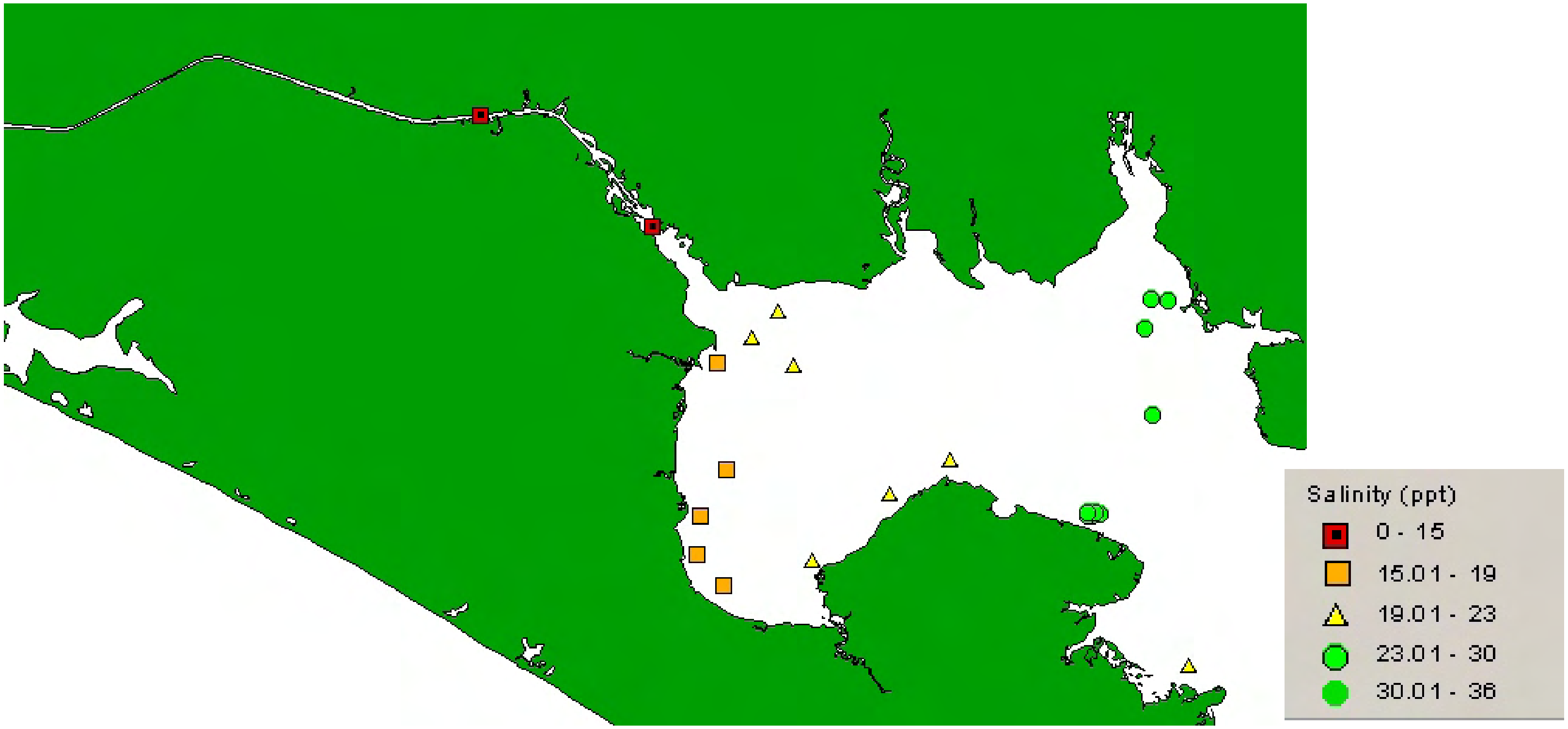

Figure 34: Salinity data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

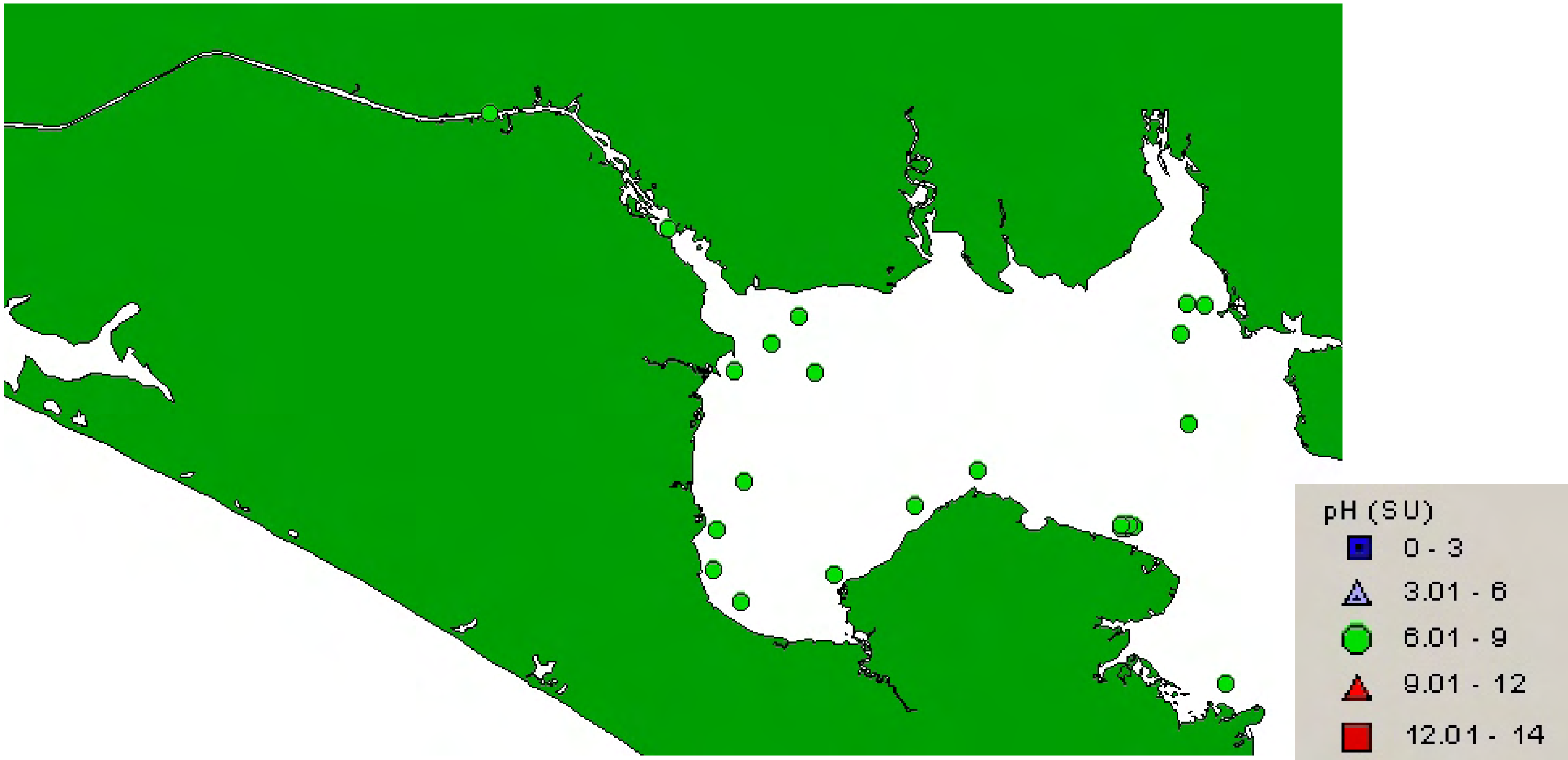

Figure 35: pH data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

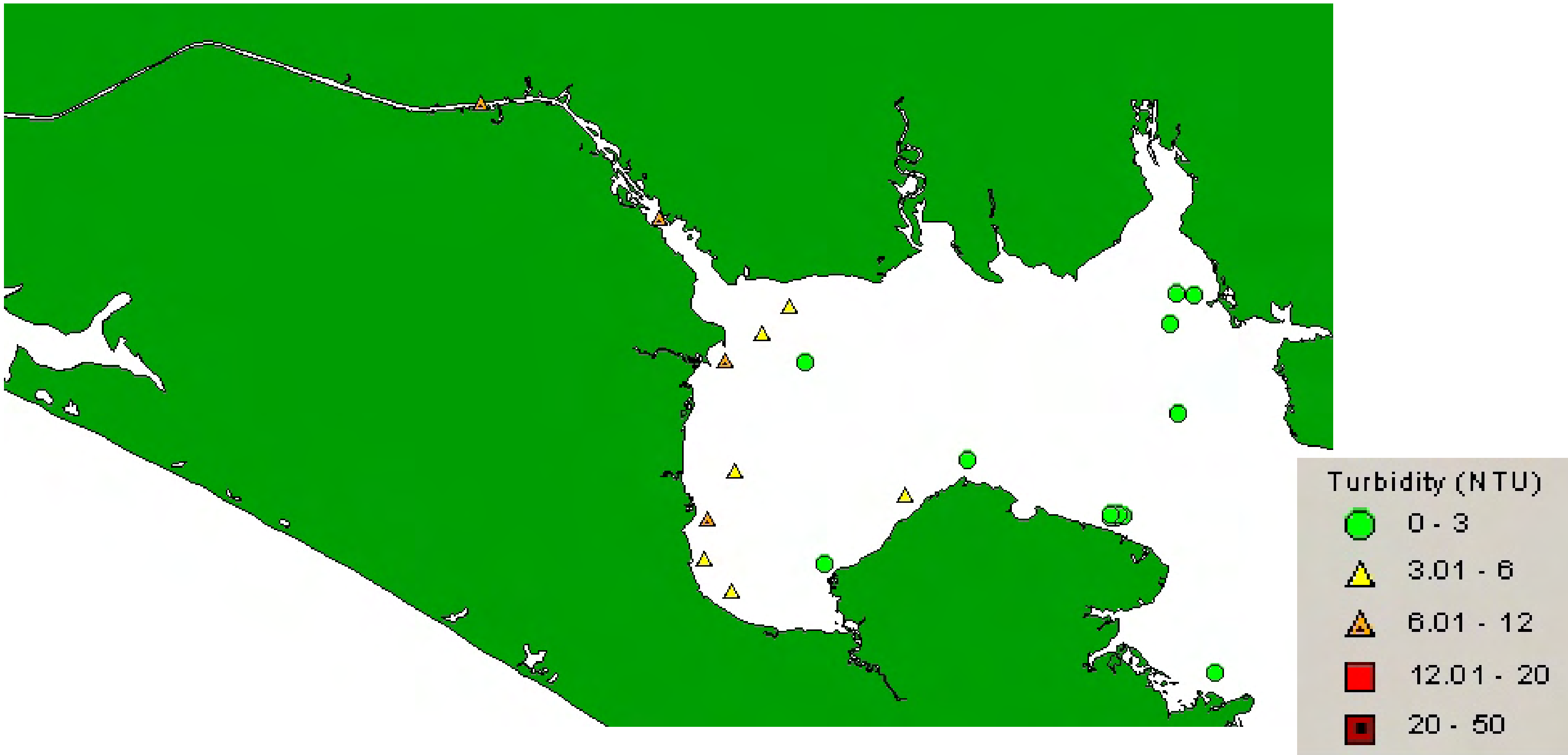

Figure 36: Turbidity data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 37: Chlorophyll data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida

Figure 38: Temperature data for outgoing tide May 14th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Outgoing Tide, June 12th 2003:

Air temperature was 27°C (80°F) rising to 33°C (92°F) by mid day. Skies were partly cloudy with occasional passing showers. Winds were predominantly from the southeast at 10-15 mph, increasing to 15-20 mph later in the day (1:30 p.m. CST). Moderate chop was present. Measures were taken during an outgoing tide resulting from a 2.0 foot high tide at 9:21 a.m. flowing to a –0.5 foot low tide at 8:46 p.m. Current in the GIWW proceeded toward West Bay from Choctawhatchee Bay. Recent heavy rains produced localized totals exceeding 5 inches for the week immediately prior to sampling and at least 0.5 inches the evening prior to sampling (NOAA). A dredging operation was performing maintenance dredging at the West Bay mouth of the GIWW.

Dissolved oxygen, temperature, and pH were significantly different among sites ($p<0.00001$). pH measures were again similar among all sites, but the lowest readings were taken in the GIWW. Small differences in temperature may have been the result of sampling time and dissolved oxygen differences were small. Differences were also observed among sites near and in the GIWW and the rest of West Bay for the parameters salinity ($p<0.00001$), turbidity ($p<0.00001$) and chlorophyll concentration ($p<0.0001$). Salinity was also relatively low near North Bay on this sampling date. Secchi depth measures were not taken in triplicate, but again showed good agreement with turbidity measures in NTUs. To illustrate the distribution of water quality parameters, data are presented spatially with an anticipated ecologically relevant qualitative rating system in Figures 39-45.

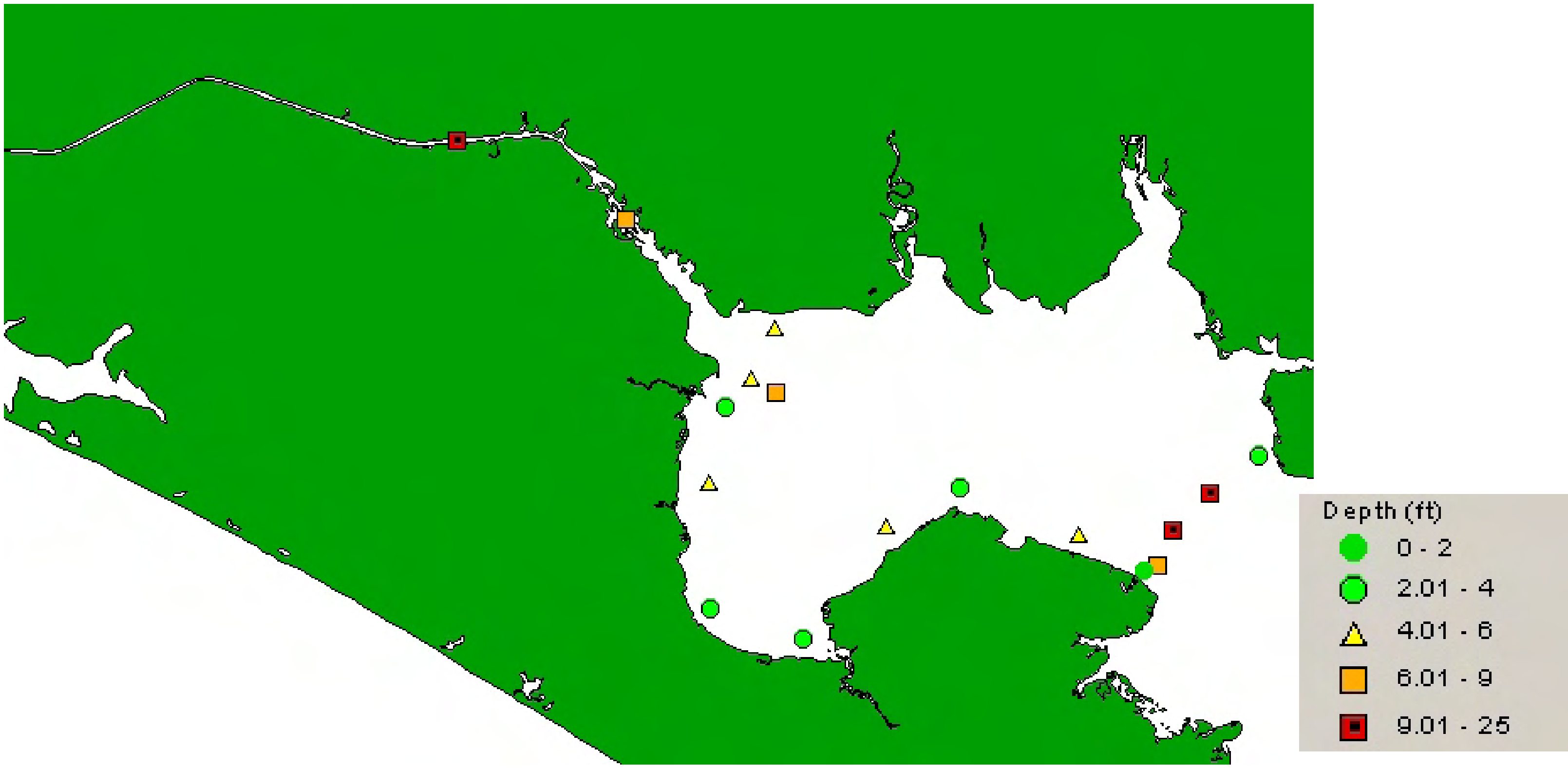

Figure 39: Depth data by sample location for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

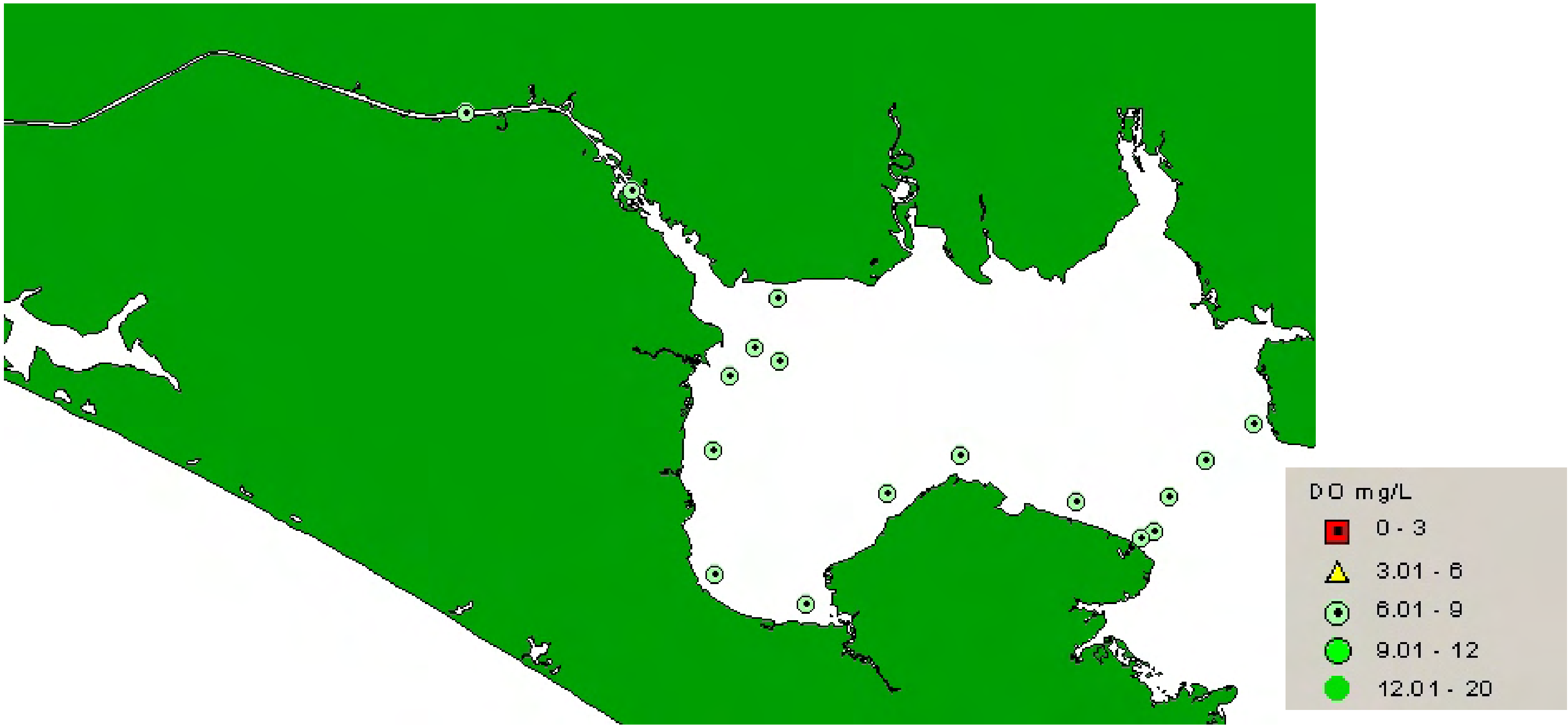

Figure 40: Dissolved oxygen data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

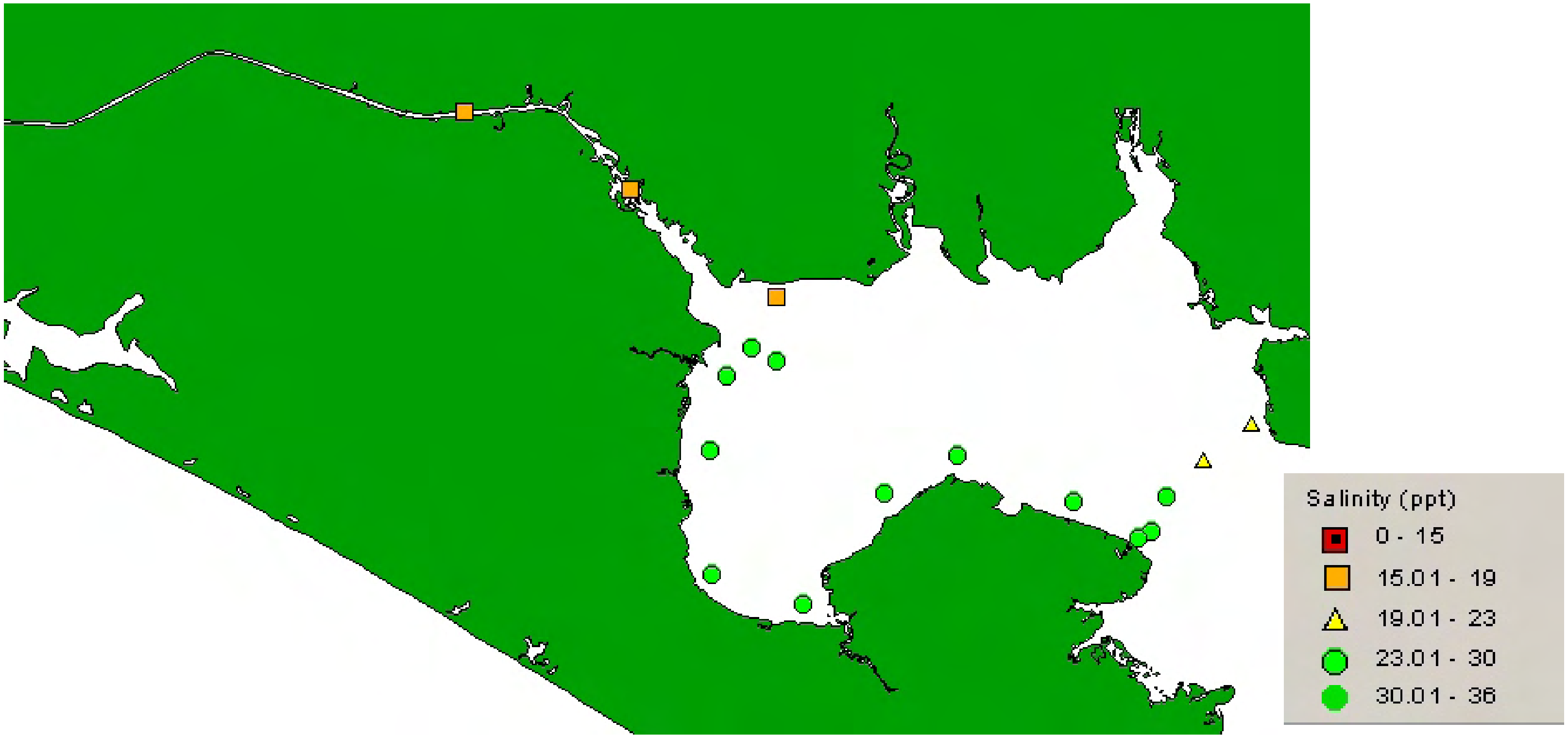

Figure 41: Salinity data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Figure 4: pH data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

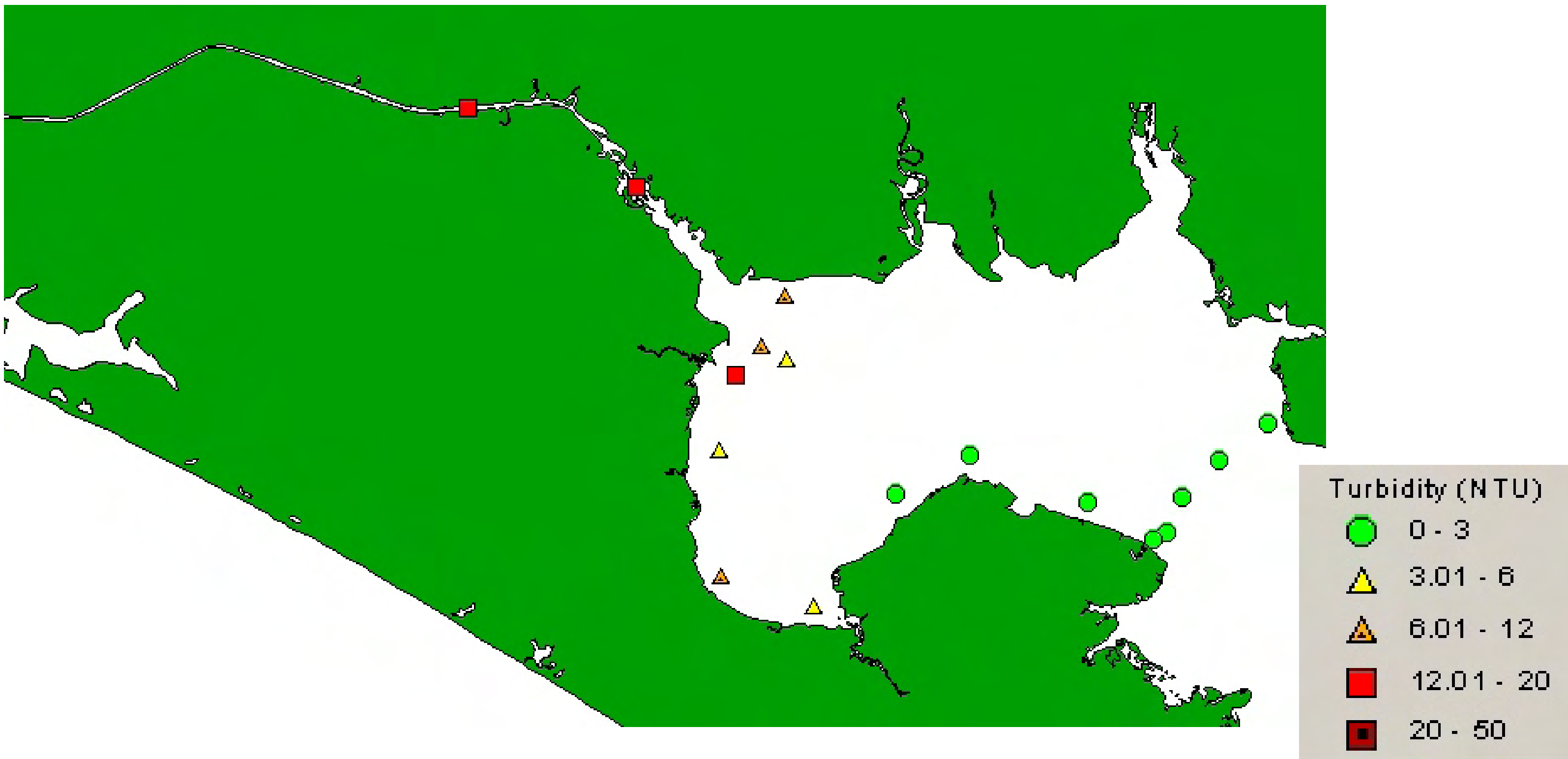

Figure 43: Turbidity data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

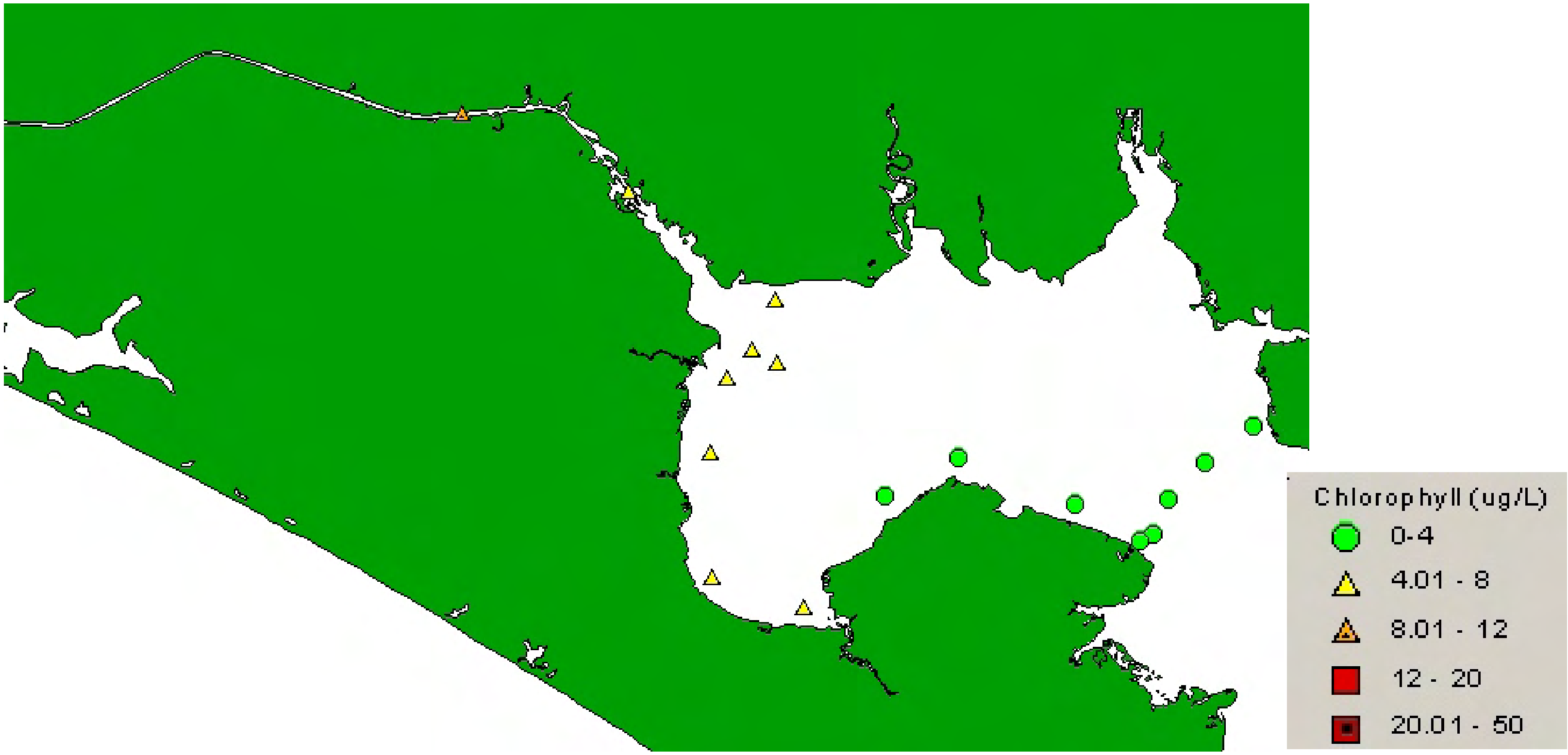

Figure 44: Chlorophyll data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida

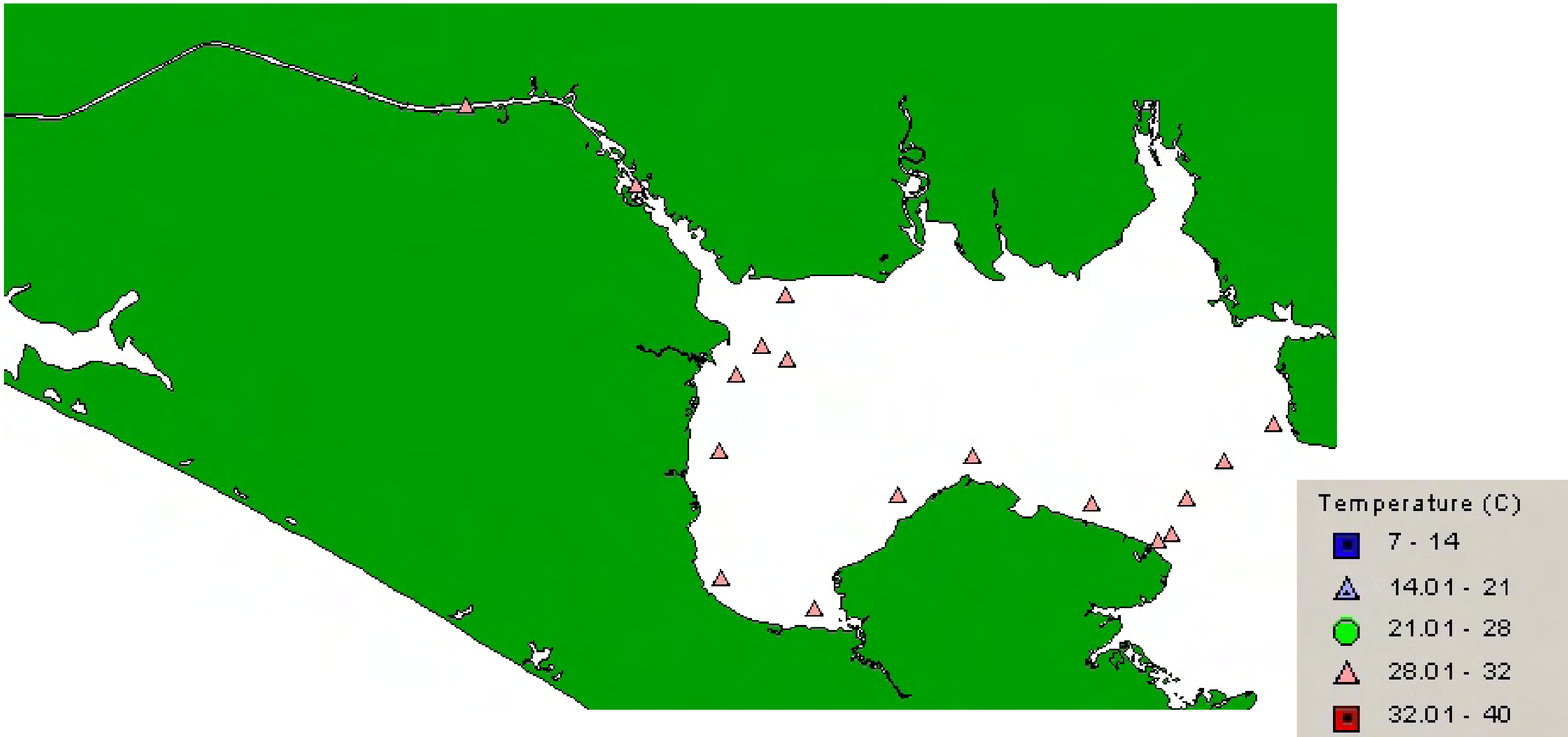

Figure 45: Temperature data for outgoing tide June 12th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Outgoing Tide, June 26th 2003:

Air temperature was 26°C (79°F) rising to 31°C (88°F) by mid day. Skies were clear. Winds were from the east to southeast early (5-7 mph) switching to the west in the afternoon (5-7 mph, 2:40 p.m. CST). Light chop was present. Measures were taken during an outgoing tide resulting from a 1.9 foot high tide at 9:11 a.m. flowing to a –0.2 foot low tide at 9:11 p.m. Current in the GIWW proceeded toward West Bay from Choctawhatchee Bay, but closer inspection showed a divergent split in direction half way between the two bays. This split sent waters in the GIWW toward both Choctawhatchee and West Bays simultaneously. This had not previously been observed due to the range limits of the earlier surveys. Intensive rains preceded this survey with totals exceeding 6-8 inches within 7 days. However, the 3 days following those rains and immediately preceding this sampling were without precipitation (NOAA). A dredging operation continued to perform maintenance dredging at the West Bay mouth of the GIWW as they had been during the June 12th 2003 sampling.

Significant differences ($p<0.00001$) in temperature and pH were not thought to be ecologically relevant, however, the same possible trend of lower pH within the GIWW was again present. Dissolved oxygen was lower (3-5 mg/L) in much of the sampling area than previously recorded, particularly for samples taken in the GIWW and the one sample taken at a 9 foot depth in central West Bay ($p<0.0001$). Turbidity ($p>0.00001$) and chlorophyl ($p>0.0001$) were higher in the GIWW and Choctawhatchee Bay, particularly in the area at the eastern end of the Choctawhatchee Bay to West Bay GIWW connection where maintenance dredging was being performed. Turbidity increased greatly between West Bay and the GIWW (and Choctawhatchee Bay), but was greatest immediately down-tide (downstream) from the dredge site and somewhat further down-tide at the mouth of the GIWW. Secchi depth measures were not taken in triplicate, but were again similar to turbidity data. Chlorophyl was equally high in Choctawhatchee Bay and was high down-tide of the dredging area. The GIWW also had higher chlorophyl levels as a whole than in West Bay. Salinity was lower overall with substantially lower ($p>0.0001$) measures taken in Choctawhatchee Bay and the GIWW. Interestingly, the salinity did not decrease entirely with distance from West Bay to Choctawhatchee Bay. There existed an area in the mid-ICWW where the salinity was lowest. It was on either end of this area that currents took divergent paths to both Choctawhatchee Bay and West Bay. It was observed that freshwater leached from the banks and cliffs of the GIWW, as well as, drainage culverts that discharged into this same area. Data are presented spatially with an anticipated ecologically relevant qualitative rating system in Figures 46-53. An additional salinity figure was added with a lower range legend to show the very low salinities observed in Choctawhatchee Bay and GIWW.

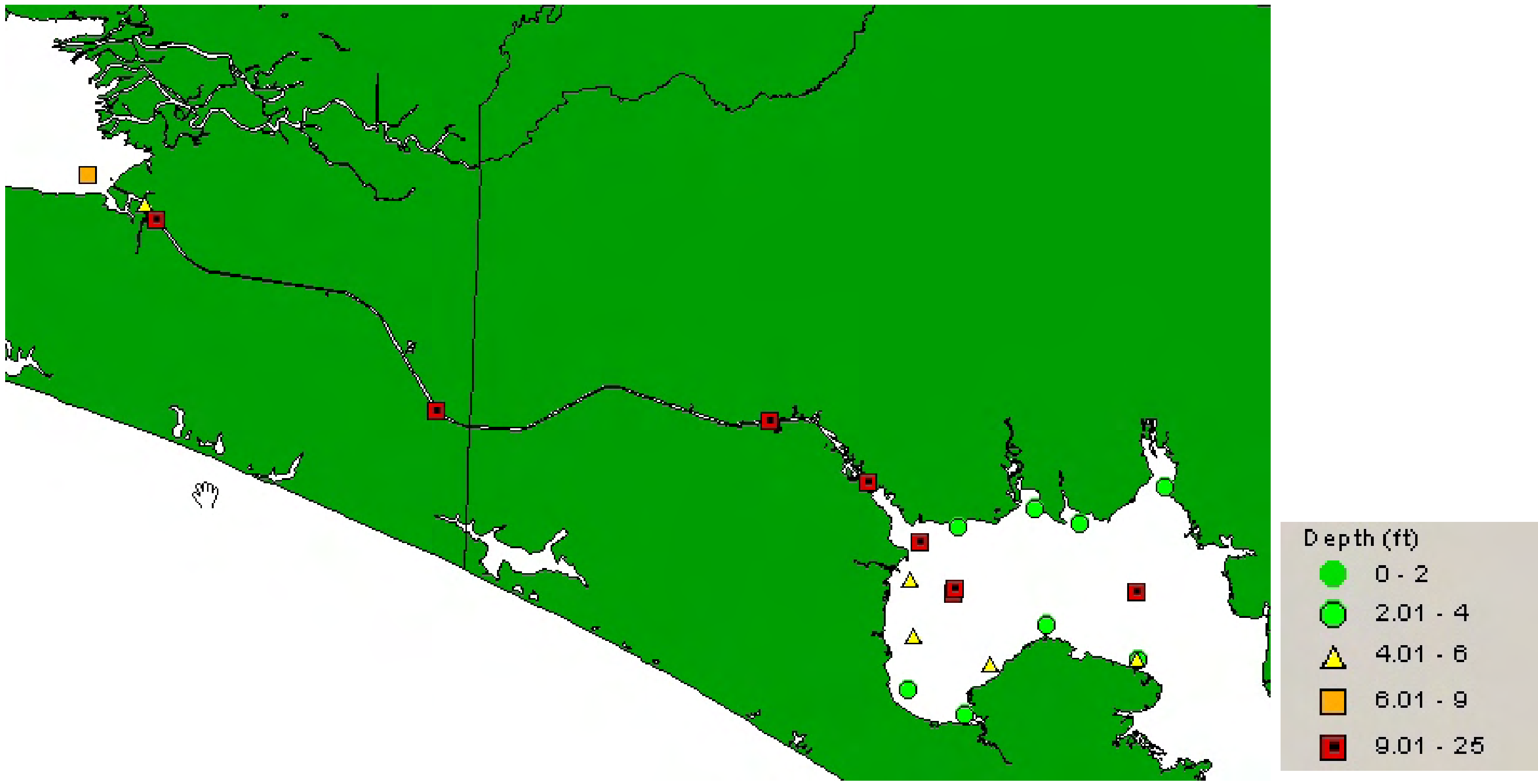

Figure 46: Depth data by sample location for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

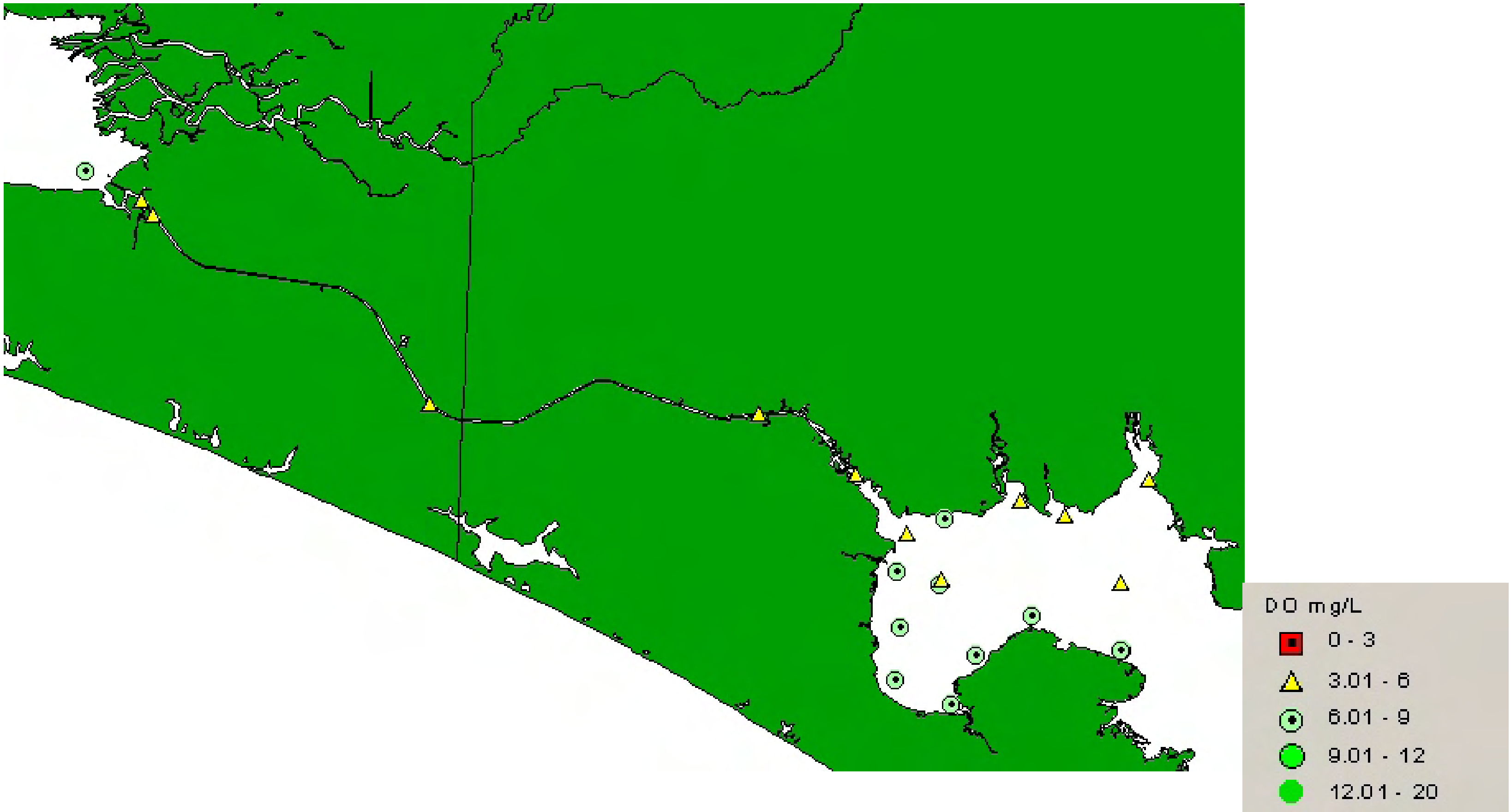

Figure 47: Dissolved oxygen data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

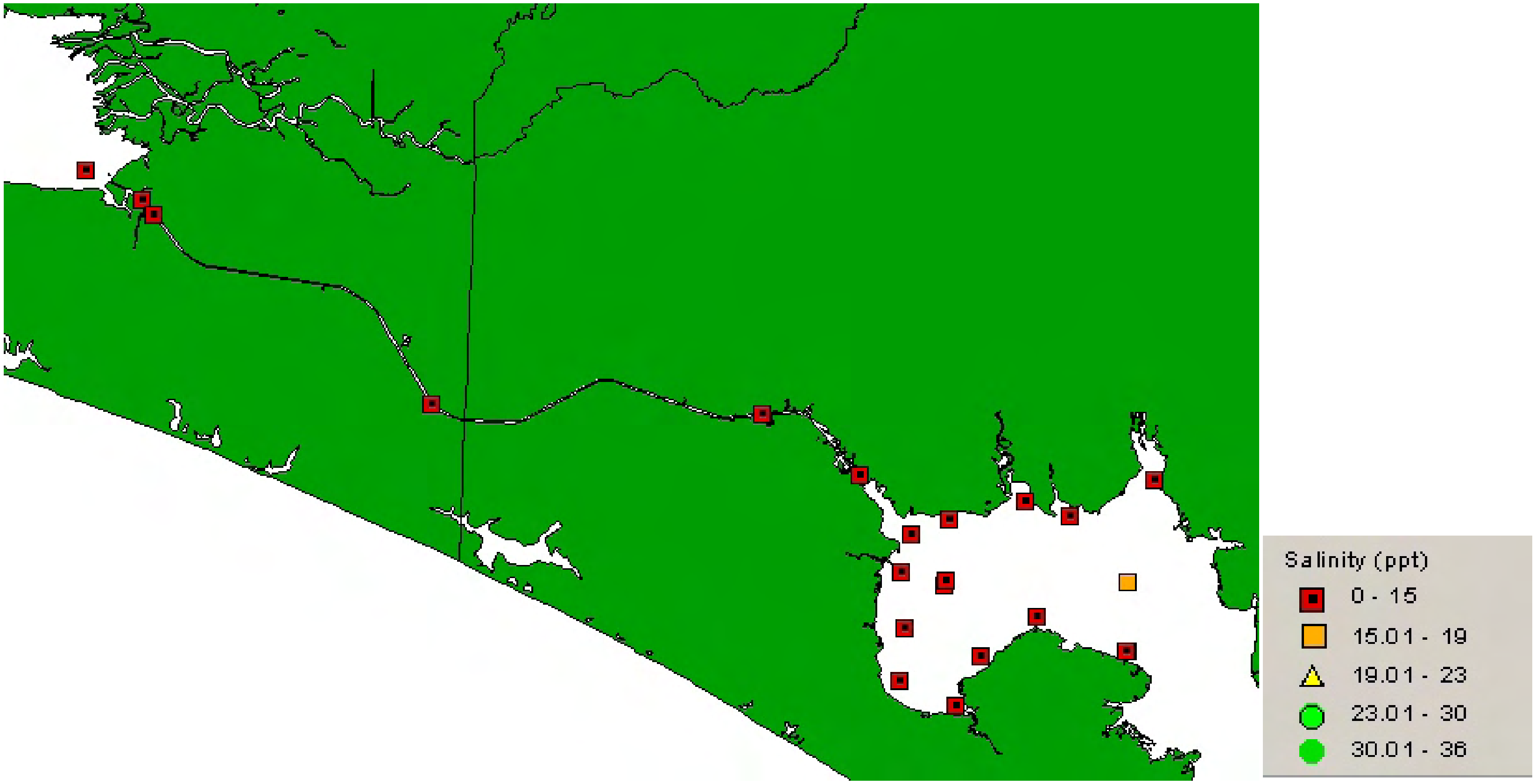

Figure 48: Salinity data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

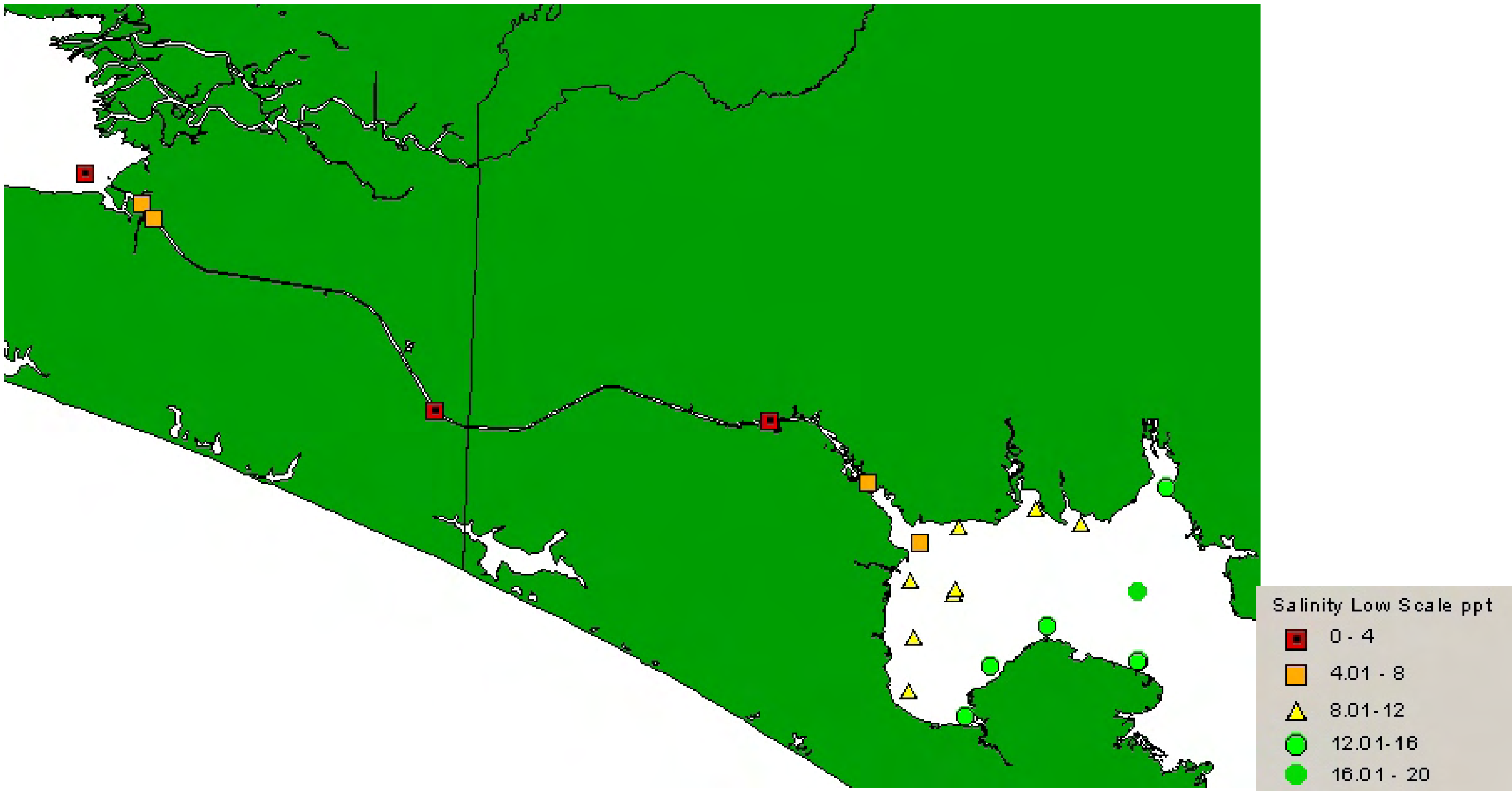

Figure 49: Lower scale salinity data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

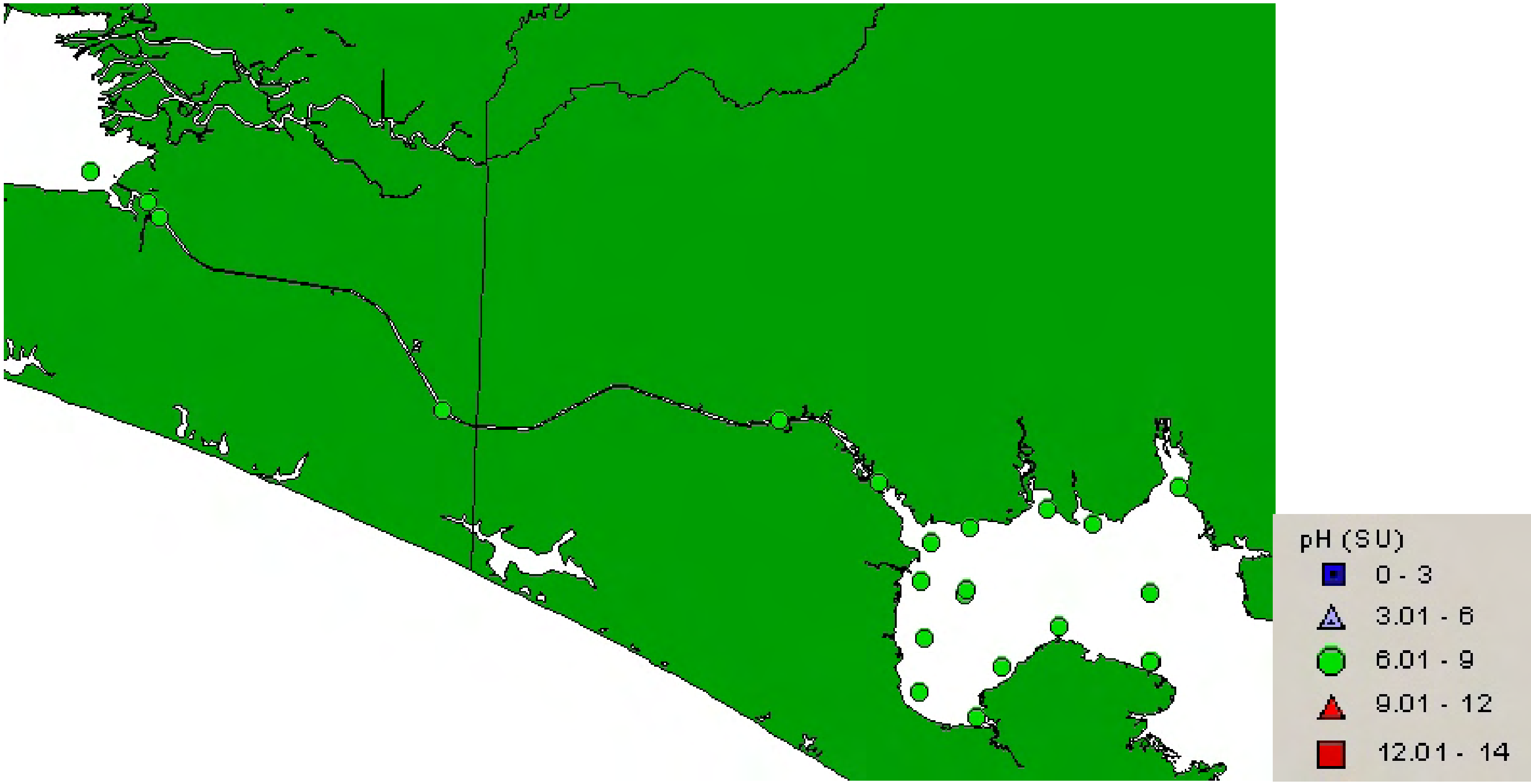

Figure 50: pH data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

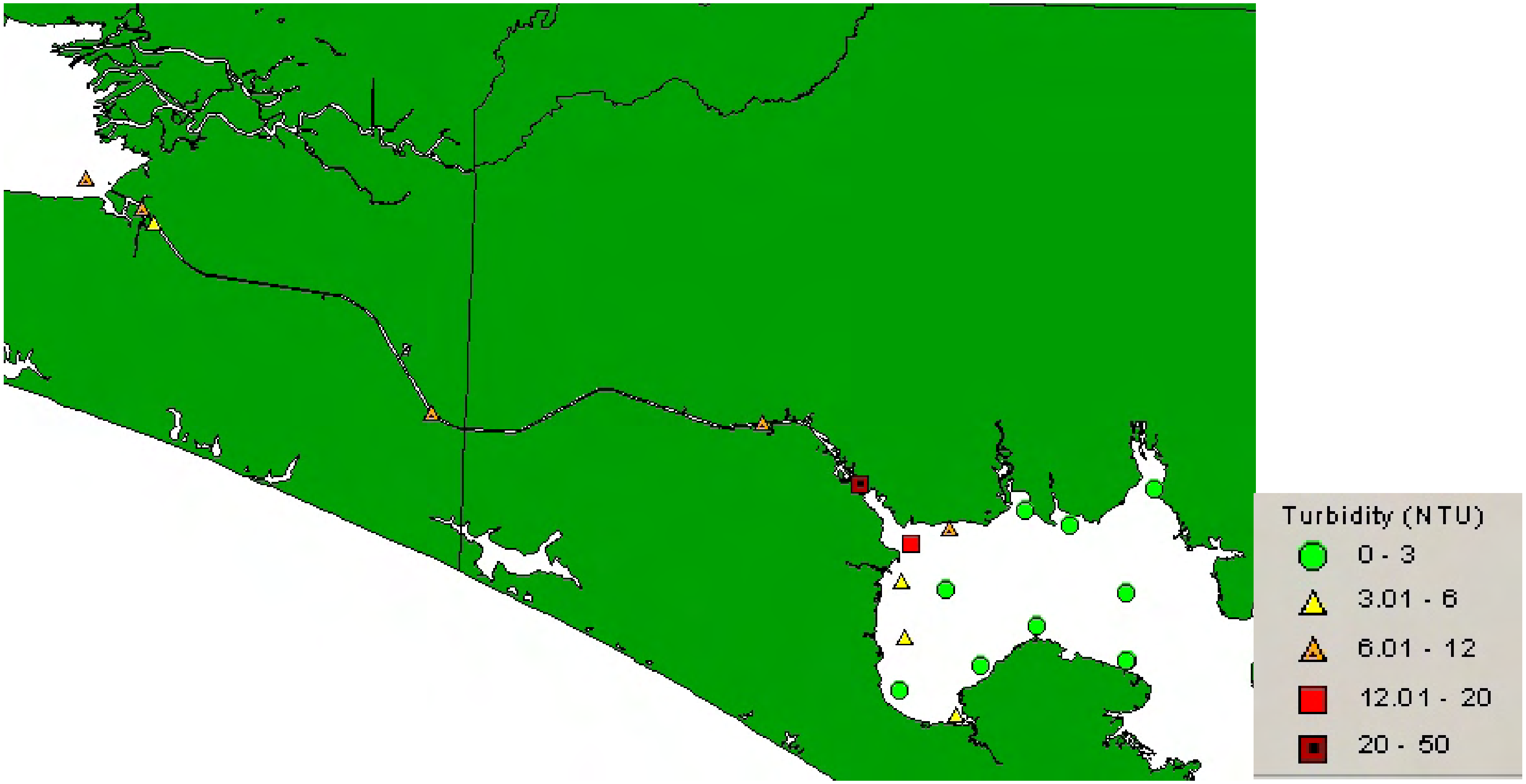

Figure 51: Turbidity data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

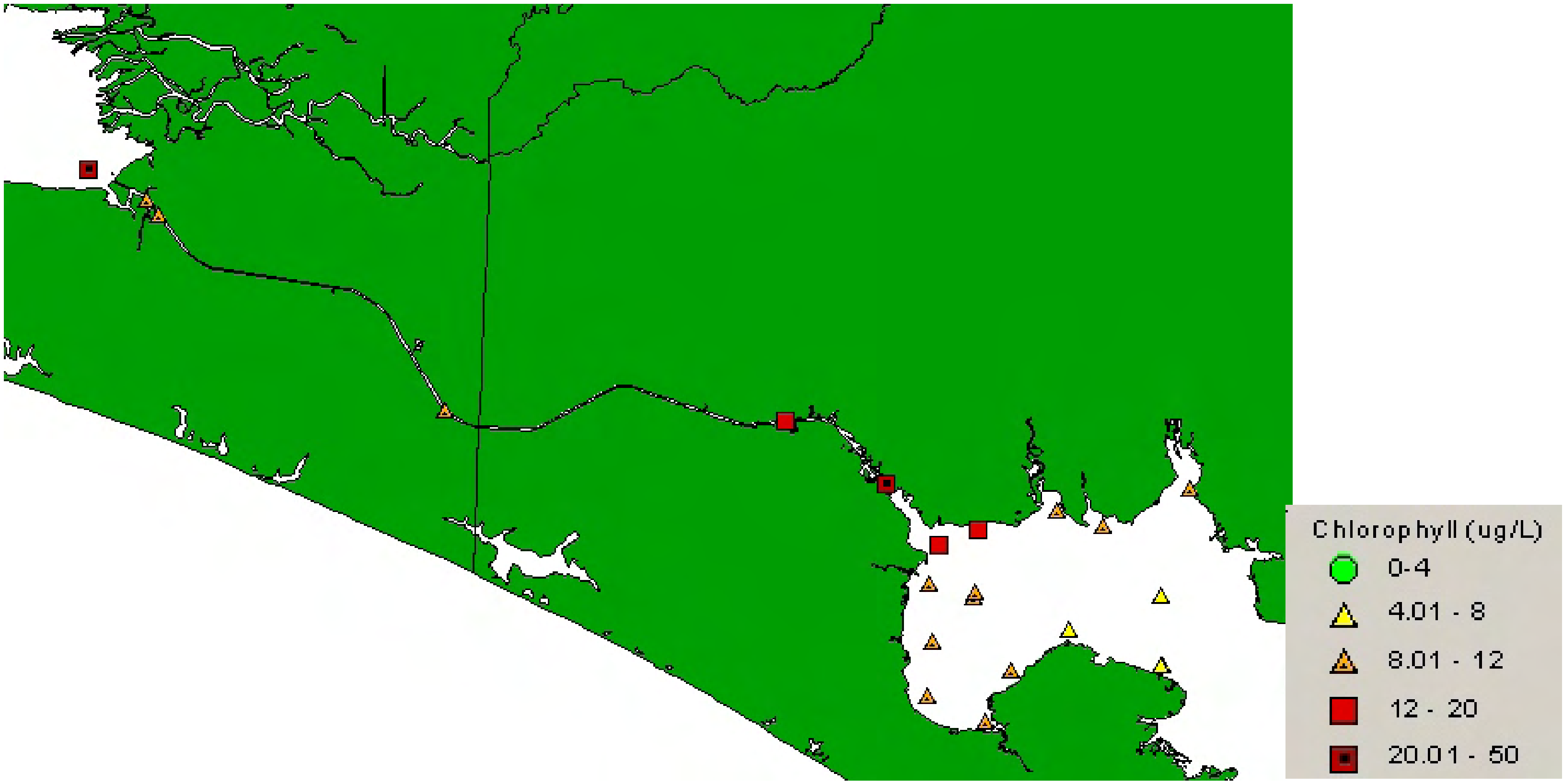

Figure 52: Chlorophyll data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida

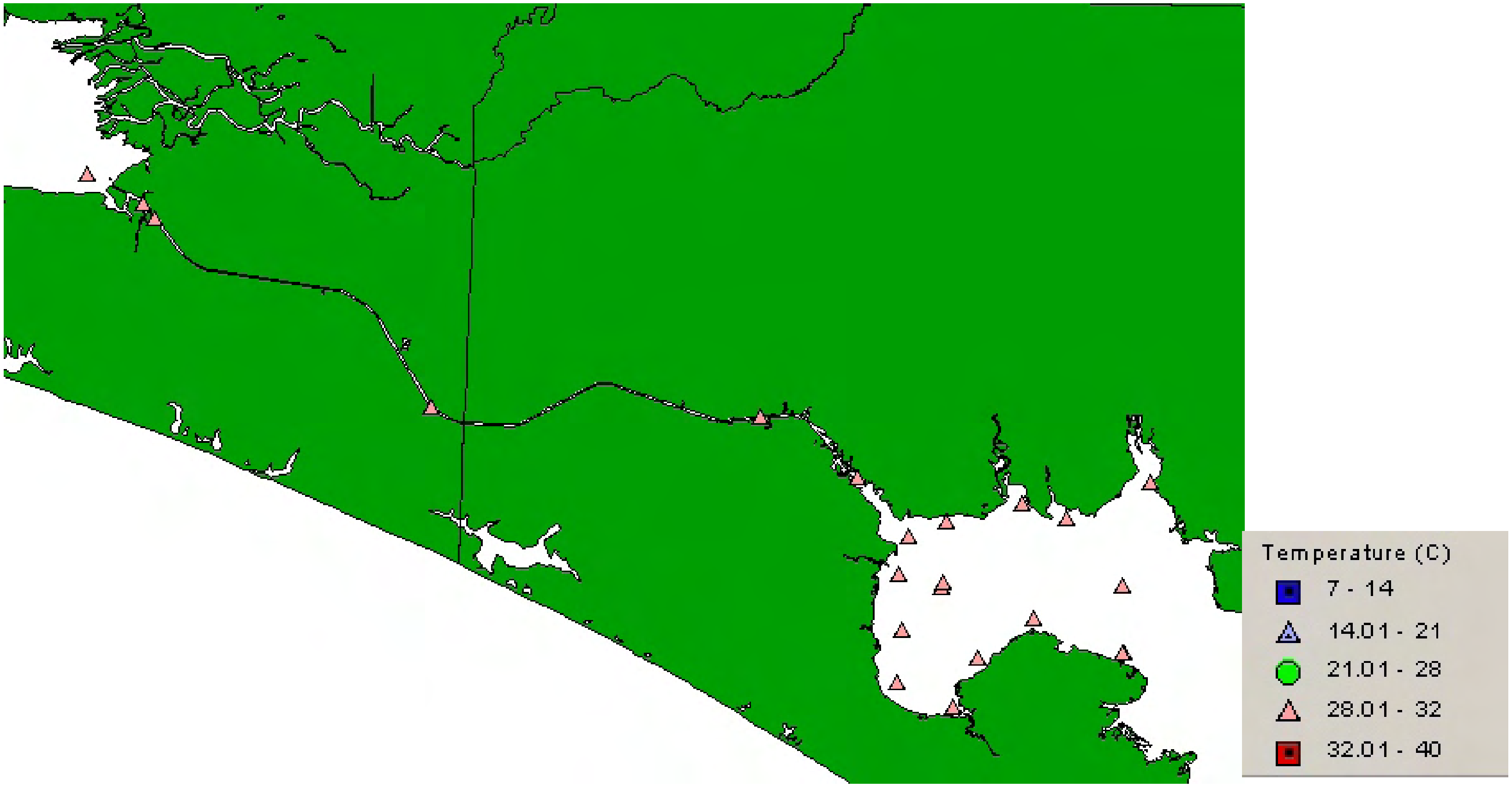

Figure 53: Temperature data for outgoing tide June 26th 2003 water quality survey of West Bay in the St. Andrew Bay system, Bay County, Florida.

Final incoming tide survey:

The third incoming tide survey to be conducted was not completed due to consistent heavy precipitation in the area. Results were not expected to have been dissimilar from the earlier sampling immediately following heavy rains. Results were expected, but not confirmed, to be like those presented for the March water quality survey.

Sediment Sampling

Organotin analytes were not found above the detection limits in sediment samples taken in West Bay. Detection limits are provided with full analytical results in the appendices. Inorganic metal analyses performed on the same samples yielded similar results. No sediment analytes proved noteworthy or exceeded the sediment quality guidelines provided by Long *et al.* (1995, Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments).

DISCUSSION

This report summarizes the U.S. Fish and Wildlife Service's water quality survey of West Bay of the St. Andrew Bay system in Bay County, Florida. The survey was designed to achieve a better understanding of the current state of water quality in West Bay. Water quality is a well known determining factor in seagrass losses versus success (Gallegos and Kenworthy, 1996; Fonseca et al. 1998; Livingston et al., 1998; Wang et al., 1999; Jone et al., 2001; Hannisak, 2002). Further, some have speculated that knowledge of water quality could allow for developing optimal seagrass restoration plans or even forecasting seagrass distributions (Johansson, 1995; Fourqurean et al., 2003).

For the above reasons, the Service performed this investigation to provide guidance for further investigations needed to assess the potential for success of restoration efforts in West Bay. Results are discussed below by tidal condition and sampling date. The results represent discrete sampling times and therefore should not be interpreted to represent all conditions that the West Bay system experiences.

Water Column Sampling

Incoming Tide, January 28th 2003:

As would be expected during January, the water temperatures were seasonally cool (below 14°C). These cool water temperatures allowed high dissolved oxygen concentrations (12-15 mg/L) at all sites as a consequence of supersaturation (113-146 %). Hydrogen ion concentrations (pH) were neutral (7.39-8.25), but did differ between sites in the open bay (8.03-8.25) and GIWW sites (7.39-7.78). These differences in pH likely reflected the differences in salinity between the open bay (20.26-26.65 ppt) and GIWW(11.05-18.26 ppt) due to the distinct water chemistries of each. However, there was one outlier in West Bay with lower salinity. The possible trend in salinity and pH contrasting the open bay from the GIWW on incoming tide was reinforced by differences in turbidity levels (0.57-3.73 NTU open bay, 5.70-11.0 NTU GIWW) and chlorophyll concentrations (1.50-6.10 ug/L open bay, 4.37-6.43 ug/L GIWW). Variable turbidity was also observed within the GIWW during a chance event that allowed measures immediately before (5.8 NTU) and after (11.0 NTU) the passage of a tug boat pushing two fully loaded fuel barges, thereby demonstrating resuspension of bottom sediments with GIWW use. However, the turbidity returned to the original level within 15 to 20 minutes after tug boat passage.

A site in southern West Bay also had a salinity (18.41 ppt) that was also somewhat lower than other bay sites (20.26-26.65 ppt). The more subtle salinity difference at this site suggested another source of freshwater input, potentially the Panama City Beach municipal wastewater effluent outfall, a forestry drainage ditch, or the tidal creek sub-watershed to the southeast of the site that drains a subdivision and golf course area. The low tide, at a time of year when tides are especially low, may have emphasized the contribution of the input. However, no concomitant difference in pH, turbidity, or chlorophyll concentration was noted as was for the GIWW.

The influence of the incoming tide in all likelihood affected the distribution of these water quality parameters. Currents flowing from West Bay into the GIWW westward were qualitatively observed during sampling. The resulting water chemistry of samples showed differences between waters of the open bay and those in, and at the mouth of, the GIWW. The degree of mixing between waters in the open bay and the GIWW was unclear, however, it seems probable that waters from the more saline West Bay had mixed with the more brackish GIWW to some undefined extent. The true differences in water chemistry between these waters is likely to be more clear with sampling further west in the GIWW and in West Bay on outgoing tides that would bring waters from the GIWW eastward.

Incoming Tide, March 27th 2003:

Weather conditions around the time of this sampling were dissimilar from the January sampling in many ways. Water temperatures were warmer (21.3-23.1°C), heavy rains had preceded sampling, and southeast winds drove moderate waves that broke on the western shore of West Bay. As a result of the heavy precipitation over the past few weeks, salinity was lower overall ranging from 10.8 to 13.2 ppt, with the exception of the uppermost site in the GIWW that had an mean salinity of 9.6 ppt. pH was similar at all sites (7.34-8.1). The highest pH measure coincided with the highest dissolved oxygen measure (10.1 mg/L). Dissolved oxygen at this site was higher than other bay sites (7.9-8.5 mg/L) and considerably higher than GIWW sites (5.8-6.9 mg/L), indicating two possible areas of allochthonous (external from the bay) water introduction. The higher dissolved oxygen and pH site was located in southern West Bay between the Panama City Beach municipal wastewater effluent outfall and the unnamed tidal creek (described above) reemphasizing the probability of input in this area of the bay. Albeit, inputs from northern West Bay again resulted in far lower salinity measures even on incoming tide.

Chlorophyll concentrations (8.6-13.0 ug/L) were higher in March as would be expected by the warming temperatures, longer days and nutrients being introduced via the consistent precipitation. The influence of chlorophyll on turbidity was negligible at these concentrations as was evident by the highest chlorophyll concentrations being (13.0 ug/L) measured at the same site the lowest turbidity measures (1.4 NTU) were observed. Turbidity in the open bay was largely related to depth, wind speed and direction, and wave energy, as was most clearly demonstrated by the westward transect performed from the open bay to the western shore. Turbidity was inversely proportional to depth (Non parametric Spearman Rho, $p<0.0001$, $r=-0.6798$). Turbidity in the GIWW was consistently higher (10.6-13.8 NTU) than depth (>10 feet) would have indicated when compared to the open bay sites.

Lower salinity and dissolved oxygen concentrations combined with higher turbidity (when normalized by depth) again indicated a different water quality (somewhat lower based on dissolved oxygen) in the GIWW. This is particularly noteworthy when considering the short distance up the GIWW that was sampled and the potential for more extreme differences further away from West Bay. Conversely, higher dissolved oxygen and slightly higher pH may have again illustrated another aqueous introduction from the wastewater outfall and/or tidal creek in southern West Bay. However, the magnitude of the indicated inputs in southern West Bay were apparently smaller when compared to those from the northern shore of West Bay and the GIWW. Additionally, the contribution of the numerous drainage canals on the western and northern shores demonstrates that draining of these extensive areas cannot be discounted as insignificant inputs.

Outgoing Tide, May 14th 2003:

The first sampling on an outgoing tide was performed during a month with very little precipitation and warm temperatures. The calm winds produced only light chop on the warmer waters (26.2-29.0°). Water temperatures progressively warmed with daylight hours to the highest measured. The lack of wind and rain allowed for the isolated observation of the influence that a third major factor, the outgoing tide, had on West Bay water quality.

Despite the warmer water temperatures, dissolved oxygen concentrations were 6.9-13.1 mg/L. Two of the three readings below 7.5 mg/L were taken in the GIWW (6.9 and 7.5 mg/L) and the third was taken at the mouth of Burnt Mill Creek (7.0 mg/L). Nevertheless, all dissolved oxygen concentrations measured were adequate to support both flora and fauna. pH ranged from 7.4 to 8.6 for all sites. Again the lower pH readings were found progressively more as salinity decreased. Salinity differences were large between sites in the open bay (16-23.4 ppt) and sites in the GIWW (10.3 and 6.9 ppt). To elaborate, the salinity decreased with distance into the GIWW; and open bay salinities were 16.2-18.7 on the western shore, 20.5-22.8 ppt in the central bay, and above 23.0 ppt in the eastern bay (except for one site in the southeast near North Bay, 22.7 ppt). The salinity trend was similar to possible trends in turbidity and chlorophyll concentration. Turbidity was highest (6-10 NTU) in the GIWW and in shallow areas (<3 feet) near the western shore. Turbidity was also somewhat higher (3-6 NTUs) in the central bay where salinities were intermediate, but were lower (0-3 NTU) in the more saline eastern bay. To a lessor extent, chlorophyll concentrations were higher (4-8 ug/L) in the GIWW and along the western shore than in the eastern bay (0-4 ug/L).

This survey, conducted during an outgoing tide, provided useful information about the movement of water from different possible inputs into West Bay. The water quality differences observed during the previous incoming tides changed in distribution with outgoing tides. This assumption was reached because the influences of precipitation and wind driven waves were not present during this sampling. Water quality distribution revealed that less saline, more turbid waters had higher chlorophyll concentrations, presumably originating in the GIWW, and extending westward into West Bay. A possible intermediate mixing zone separated this area from the more saline and less turbid waters of eastern West Bay. These observations support the hypothesis that large allochthonous contributions are coming into West Bay via the northern shore and progressing south and west into the bay. However, the western and northern shores may also be the source of significant stormwater input via drainage canals that would have similar effects on water quality in that area of the bay.

No indication of significant allochthonous contributions was observed connected to the wastewater outfall or tidal creek on this sampling date. The earlier observations were of subtle differences in water quality and these may have been masked by the larger differences introduced from other sources on this outgoing tide.

<u>Outgoing Tide, June 12th 2003:</u>

Temperatures were slightly warmer and very consistent (29.3-30.9°C) among sites on the second outgoing tide sampling of West Bay. The weather was quite different compared to the first outgoing tide sampling. Two varied factors thought to be of large importance to the water quality of West Bay included the strong southeast winds and the heavy rains preceding the sampling. All three driving factors (tidal movement, wind/waves, and precipitation) contributed to some undefined degree to the water quality conditions of West Bay on this sampling date.

Salinity measurements showed a similar pattern to the May outgoing tide sampling in that open bay sites salinities (23.2-25.4 ppt) were higher than those associated with the GIWW (17.3-18.86 ppt) or near the mouth of Burnt Mill Creek (19.3 and 20.3 ppt). Western bay sites did not have lower salinity measures than open bay sites during this sampling as they did in the prior outgoing tide sampling. However, turbidity NTUs and chlorophyll concentrations were higher in both the GIWW and on the western shore of West Bay. Turbidity was highest in (and at the mouth of) the GIWW (9.0-14.3 NTU), intermediate around the western shore (4.3, 5.0 and 8.3 NTU), and lowest in the central and eastern bay (0.9-2.3 NTU). Chlorophyll concentration were similar between the sites associated with the GIWW (4.4-6.7 NTU) and those along the western shore (4.5-5.9 NTU), but were all somewhat higher than central bay (2.5-3.2 NTU) and eastern bay (2.5-3.1 NTU) sites. Dissolved oxygen concentrations (6.3-8.2 mg/L) were not thought to have been limiting at any site and the overall pH range was small (7.8-8.2 SU) during this sampling.

It is noteworthy that the site that showed the highest turbidity and chlorophyll concentration, but the lowest dissolved oxygen and pH, among western shore sites was located just north of the wastewater outfall, transportation drainage ditch, and tidal creek on the southwestern West Bay shore. Turbidity was measured to be almost twice as high as locations to either side of this site despite salinity being of the highest recorded this date. It is difficult to speculate on a possible allochthonous source that would very locally increase turbidity, but not decrease salinity. The observation could have been dismissed as inherent variability if this area had not differed slightly in water quality during both the January and March incoming tide surveys.

Taken as a whole, the causes of the various water quality conditions may have been numerous, but it is likely the tidal circulation, recent precipitation, and wind-driven wave energy played key roles. The pattern of turbidity, chlorophyll and (to a lesser extent) salinity resembled that exhibited by the outgoing tide in May. The water movement appeared to be from the GIWW down the west shore of West Bay. However, the pattern was also similar to the incoming tide in March with the strong southeast wind and waves breaking on the northern and western shores. In both cases, heavy precipitation preceded the sampling and may have thereby increased the turbidity via large episodic inputs to the system as was evident from the ubiquitous presence of tannin stained water during all surveys that followed heavy rains. The pattern of decreasing turbidity eastward in the bay was consistent for both this and the March incoming tide sampling. However, in March the precipitation inputs were reflected in very low salinities (<15 ppt) bay-wide, despite the more saline waters coming into West Bay as a result of the incoming tide. This was not the case for this outgoing tide sample because salinities of the western shore sites (24.9-25.4 ppt) were similar to central (23.6-24.4 ppt) and eastern bay (23.2-23.6 ppt) sites, despite lower salinities in the GIWW (17.9 and 18.9 ppt) and near the mouth of Burnt Mill Creek (19.3 and 20.3 ppt).

Notwithstanding, the drainage canals on the western and northern shores could again have contributed significantly to the water quality conditions observed. In particular, the decreased salinity near the northern West Bay area may be a strong indication of this possibility. The influence of each driving factor cannot be separated in field evaluations, despite optimistic efforts to catch various combinations. Data must be interpreted with consideration of all environmental contributions and conditions.

Outgoing Tide, June 26th 2003:

This final water quality survey was the most geographically extensive and was performed two days after heavy rains. The wind was moderate to light, variable and from the south, and at times, west. The tide was outgoing and moved the waters of the GIWW into both West Bay and Choctawhatchee Bay simultaneously. The assumption that Choctawhatchee Bay waters travel down the GIWW on outgoing tides toward, and into, West Bay was observed not to be accurate in all situations. Water temperatures remained warm (28.1-31.3°C) as seen in the previous survey and did not differ considerably from site to site.

The heavy rains again stained the entire bay with tannic acids via stormwater runoff. This nonpoint source storm runoff also had a large influence on salinity, as it had in earlier surveys, reducing it below 15 ppt at all but one eastern bay site (18.22 ppt). However, this was the first occasion when salinity variation within the GIWW and Choctawhatchee Bay was observed. Salinities below 4 ppt were recorded in Choctawhatchee Bay and central GIWW, although, sites between Choctawhatchee Bay and the central GIWW had salinities between 4 and 8 ppt, as did sites nearing West Bay. There was an apparent higher salinity portion of the GIWW caught between the oligohaline Choctawhatchee Bay and the similar salinity of the central GIWW. The condition was most clearly displayed by lowering the salinity scale used for Figure 49. This figure more clearly illustrates the unexpected salinity distribution. Sites in the central GIWW (0-4 ppt) and Choctawhatchee Bay (0-4 ppt) had lower salinities than sites in the western GIWW between them (4-8 ppt). The eastern GIWW (0-4 ppt) was again much less saline than West Bay with its trend of increasing salinity southward and eastward (16-20 ppt).

This observation may suggest large freshwater inputs entering the GIWW between the two bays. Observations were made of consistently flowing stormwater drains and groundwater seepage from the cliff banks of the central portion of the GIWW likely contributed to some undefined extent. Although the low saline conditions frequently found in Choctawhatchee Bay would provide a convenient explanation for the trend observed from the GIWW to West Bay, this scenario would not account for the observations made during this survey. Taken together, the salinity variation and the observed tidal flow divergence supports a partial rejection of the hypothesis stating that freshwater flows almost exclusively from Choctawhatchee Bay to West Bay via the GIWW on outgoing tides thereby altering the water chemistry of West Bay.

The salinity distribution pattern was again similar to both turbidity and chlorophyll concentrations. Turbidity was highest in the GIWW (6-22 NTU), but an area of lower turbidity (5.8 NTU) was found to coincide with the unexpected increased salinity in the western GIWW. Turbidity was again found to decrease with distance southeastward and turbidity readings at southern and eastern sites were low (0-3 NTU). Although overall chlorophyll concentrations were markedly higher on this date, chlorophyll concentrations were highest on either end of the GIWW (12-22 ug/L) when compared to the central GIWW (9-11 ug/L) or the majority of West Bay (8-12 ug/L). The most southeasterly sites again had the lowest chlorophyll readings (5-7 ug/L).

Dissolved oxygen concentrations were lower overall during this sampling. The decline likely resulted from a combination of warm water temperatures and the chemical and biological oxygen demand resulting from the material carried by the recent rains.

Dissolved oxygen ranged from 5.6 to 7.2 mg/L in most areas, with the exception of the GIWW (3.8-4.8 ug/L) and one anomalous site in the eastern open areas of West Bay (4.8 ug/L). Measured pH varied little among sites, but did appear to differ slightly when comparing the Choctawhatchee Bay and GIWW sites (6.5-6.9) to open West Bay sites (7.0-7.8). The pH differences again reflected the noted differences in salinity distribution as proposed for earlier survey data.

Sediment Sampling

Sediment contamination from the historic shrimp aquaculture operation (extensive chemical treatment of 36,000 feet of confinement nets) was proposed as a possible contributing cause for the seagrass losses. Organic tins and inorganic metals were analyzed for because of their reported extensive use to minimize the growth of organisms that foul marine structures (Voulvoulis *et al*., 2002; Thouvenin *et al*., 2002; Thomason *et al*., 2002; Vlakirs *et al*., 2003). Additionally, high concentrations of copper (26,510 ppm or 2.7%) and organotin (0.2%), common components with arsenic and other metals in antifouling paints, had been previously found at the net-treatment site adjacent to a dipping vat (Pers. Comm. Michael Brim, U.S. Fish and Wildlife Service). Seagrass susceptibility to metal toxicity is well known (Ralph and Burchett, 1998; Prange and Dennison, 2000, Macinnis and Ralph, 2002; Barwick and Maher, 2003), as are the implications for wildlife resulting from organic metals (organotins) used in antifouling treatments (Nicolaidou and Nott, 1998; Kajiwara *et al*., 2000; Tanabe, 2002; Gagne *et al*., 2003; Siah *et al*., 2003). This survey revealed no sediment contamination with metals or organic metals originating from antifouling paints or coatings. It should be noted, however, that net treatment took place between 1970 and 1975, some 28 years ago.

Sediment analyses showed no organotin compounds (monobutyltin, dibutyltin, tributyltin, and tetrabutyltin) above the detection limits of each analysis (<0.005 mg/L or <5 parts per billion). Similarly, inorganic metal concentration were not dissimilar to background levels in St. Andrew Bay or other area bays (Brim, 1998; Brim et al. 1998). No metals exceeded sediment quality guidelines provided for estuarine sediments (Long et al. 1995). Additionally, no metal concentrations were suspect upon normalization by sediment iron or aluminum concentration (a method used to look for sites that are unusual in their metal ratios, Morel and Gschwend, 1987).

Sediment analytical results suggested that metal concentrations (organic or inorganic) were not limiting to the growth of seagrasses at the time of sampling. Although the data represent composite samples taken throughout the bay on only one occasion, the persistent nature of metals in sediments and the agreement with previous bay-wide sample data support the analytical results.

The analytical data does not exclude the possibility that the extensive loss of seagrasses from southern West Bay resulted from metals contamination that no longer is present. The data also does not account for the physical and mechanical or hydrologic alterations resulting from the aquacultural endeavor. Significant insult may have been imposed on the seagrasses by the physical and mechanical action of repetitive net trawling across the seagrass beads for shrimp harvest. The data also do not account for the stresses that may have been imposed via flow restrictions and other hydrologic alterations caused by activities such as the net barricades that isolated the entire southern bay.

CONCLUSIONS

The hydrologic condition of this coastal aquatic system is complex and involves numerous factors. Natural phenomena such as the tides, winds and waves, and precipitation had easily recognized effects. However, it was apparent that the water quality of the West Bay system is under substantial influence by factors that have been anthropogenically introduced. Notwithstanding, this survey represents only five days and existing conditions conditions and cannot be taken to explain or illustrate in full the complex and dynamic nature this system, but rather, may demonstrate noteworthy differences in water quality, contributions of natural factors, possible influences of human derived changes, and identification of nonpoint source inputs at unexpected locations.

If conditions observed during this survey reflect typical water quality conditions in West Bay, then water quality could be limiting seagrass recovery and growth. Salinity and water clarity stresses may be sufficient to prevent successful seagrass establishment. Water quality trends appear to be driven predominantly by tides, precipitation and wind driven waves. These driving factors controlled the distribution of considerable inputs to West Bay that resulted in areas of distinct water quality. Large contributions entering northern West Bay apparently originated in the Gulf Intracoastal Water Way (GIWW) and were characterized by lower salinity, water clarity, pH, and dissolved oxygen than in the south and eastern areas of West Bay. The source of freshwater entering the GIWW likely came from multiple places, and at least included contributions from Choctawhatchee River via Choctawhatchee Bay, groundwater seepage into the GIWW, direct rainfall, and stormwater drains discharging into the GIWW. Another more subtle input to West Bay seemingly existed in southern West Bay in the area of the Panama City Beach municipal wastewater effluent outfall and a tidal creek sub-watershed that drains a subdivision and golf course area. Wetland drainage canals on the western and northern shores of West Bay are also the source of probable input, but these were not easily distinguished from the larger contributions to these areas.

It was not possible to clearly define the timing of events that surrounded the extensive loss of seagrasses from West Bay, particularly in the southwestern bay. It is also unclear if water quality led to the decline, or if seagrasses declined for other reasons, and subsequently their absence led to increased turbidity and other water quality differences in West Bay. It is quite possible that mechanical stresses imposed on the southwest bay as a result of the aquacultural endeavor in the 1970s, physically removed the seagrasses from the southwestern bay. Increases in turbidity may have followed due to the loss of the ecological function of the seagrasses that naturally enhance water clarity via nutrient utilization and particulate filtration. Therefore, it is plausible that water quality limitations to seagrass regrowth may have resulted from the initial loss of seagrasses. Compounding these challenges to seagrass re-establishment were numerous anthropogenic alterations that may have significantly increased external inputs to the bay.

Taken together, water quality conditions in West Bay, particularly in areas where seagrasses have been lost, were different than in areas with healthy seagrass beds. Lower salinity and high turbidity and chlorophyll concentrations were different most often between areas. Considerable evidence suggests that the source of these changes to water quality resulted directly from anthropogenic changes to the West Bay watershed.

Further investigation into the extent of water quality differences in West Bay and their distribution pattern will be required to appropriately design a restoration plan. However, the data indicate that current sediment contamination with metals from antifouling paint from a historic shrimp aquaculture operation can be ruled out as a limiting factor. A more concentrated focus is recommended for water quality distribution in West Bay with particular emphasis on salinity, water clarity (turbidity, chlorophyll concentration, and color), pH and dissolved oxygen. Additional parameters should include those that will help to identify sources of allochthonous (external) inputs to the bay such as nutrients, oxygen demand, traceable isotopes and bacteria. A followup investigation that would begin to address these needs is described in the recommendations section.

RECOMMENDATIONS

The following recommendations are offered for consideration. The following are based on the results of this preliminary survey and are intended for use in developing a comprehensive plan for evaluating West Bay.

West Bay Water Quality Survey

Background:

In an effort to better understand the environmental condition of, and management challenges to, West Bay, several days were spent performing site visits with stakeholders. Site reviews were followed by stakeholder meetings hosted by the U.S. Fish and Wildlife Service (Service). Stakeholder meetings were used to identify, discuss and prioritize factors in need of preliminary evaluation. Comments were consolidated and disseminated to participants for review and feedback. The environmental condition of West Bay is of special interest to the Service because of the bay's value to trust resources. The Service is also involved in the coordination of local and federal interests in a seagrass pilot project, and in restoration of salt marsh along the southern shore. Investigation into the environmental integrity of West Bay was performed by the Environmental Quality Division of the Service.

Recommended Study Plan Brief:

USFWS proposes the following water quality and quantity study plan to further facilitate the COE's efforts to more sharply define the actual ecological conditions in West Bay. We believe that investigation into these parameters in the manner described will assist in the determination of the most ecologically profitable efforts needed for the restoration of the West Bay ecosystem.

Recommended sampling locations are depicted in Figure 1. The 12 open water sampling locations were selected based on the results of the preliminary survey (described above) in the development of the research plan. Data collected by the USFWS indicated a likelihood that water quality in West Bay was being altered by allochthonous factors. To evaluate the source and extent of these external contributions the sampling should include the following parameters:

Standard Parameters	**Stormwater Parameters**	**Novel Parameters**
Dissolved oxygen	Phosphorus (Total, Soluble)	Stable isotopes
Salinity/conductivity	Nitrogen (Total, Organic,	(Nitrogen and Carbon)
pH	Ammonia, Inorganic)	Hydrologic Flow profiling
Air and Water Temperature	Total Suspended Solids	Physical wave energy
Turbidity	Bacteria / pathogens	(wave force over seagrass)
Chlorophyll	(Total & Fecal colilforms)	Input volumes (inflow source)
Clarity /Secchi depth	Total Organic Carbon	Nutirent/Solids Loading
Depth	Metals (Cu, Pb, Zn, Cd)	Nutrient mass balance
Wind Pattern and Velocity	COD and BOD	Photosynthetic Radiation

Standard Parameters - measured USFWS

Stormwater Parameters - typical of allochthonous (external) inputs

Novel Parameters - to elucidate source, distribution and loadings from allochthonous inputs

Measurement of the standard and stormwater parameters in open water samples listed above will greatly improve understanding of the ecological significance of the dynamic water quality in West Bay. Measurement of the more novel parameters will provide a determination of hydrologic and allochthonous input sources, distribution and loadings, as well as, physical stresses on the seagrass areas. Data show large differences in the water quality of West Bay and adjacent tributaries with tide, season, winds, antecedent (preceding) precipitation and sediment disturbing activities. For this reason it is recommended that sampling be conducted twice each month and include both an incoming and outgoing tide of maximum magnitude. These sampling periods should include as many variable wind, precipitation, etc. events as possible per season.

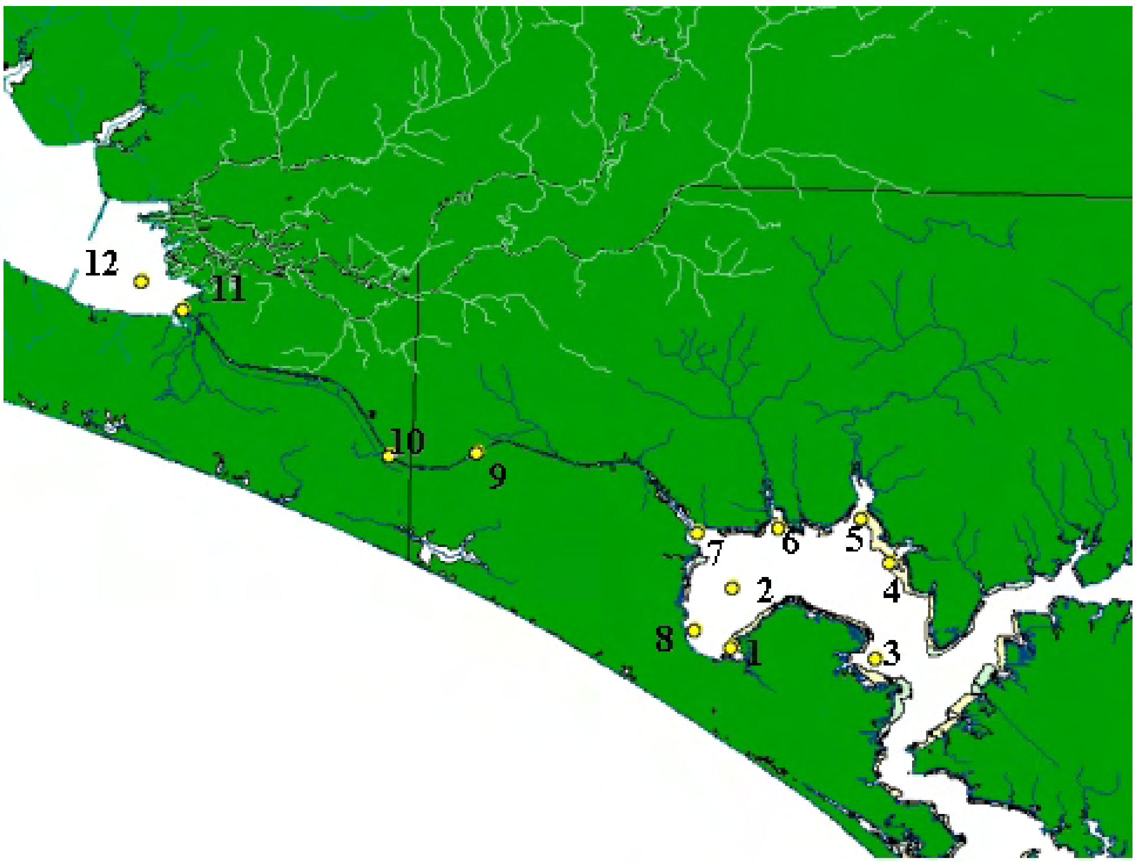

Figure 54. Recommended sampling locations for the U.S. Army Corps of Engineers 206 Program information gathering process for West Bay of the St. Andrew Bay System, Bay County, Florida.

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APPENDICES

Appendix A

Standard operating procedures for field collection of sediment samples (PCFO-EC SOP 004).

PCFO-EC SOP 004

STANDARD OPERATING PROCEDURES
SEDIMENT SAMPLING FOR CHEMICAL ANALYSES

To maintain and assure quality control, sediment samples collected for shipment to USFWS- approved analytical laboratories will be obtained and handled as follows:

COLLECTON OF SAMPLES FROM COASTAL WATERS OR LARGE RIVERS

1. **Sampling Devices** - The following devices are approved for obtaining sediment samples:

   A) Ponar grab, Standard. Manufactured from 316 stainless steel Including jaws, side plates, underlip plate, screen. frame, screens and hinge pin. 583 micron mesh top screens, weight empty - 21 kg (45 lbs), sampling area 22.85 cm. x 22.85 cm (9" x 9").

   B) Ponar grab, Petite. Manufactured with 316 stainless steel including jaws, side plates, underlip plate, screen frame, screens and hinge pin. 583 micron mesh top screens, weight empty - 6.8 kg (15 lbs), sampling area 15.24 x 15.24 cm (6" x 6").

2. **Sediment Sampling Boat**-

   A) fiberglass boat with outboard motor equipped as follows:

      1) navigation and positioning capabilities including: a) loran navigation system, b) chart-printing depth recorder, c) compass, d) appropriate navigation charts.

      2) 12 volt electric winch; steel ginpole with heavy duty pulley; 100' of 1/2" braided nylon lift rope.

3. **Other Equipment and Supplies** -

   A) Stainless steel sample pan 28 x 48 x 10 cm.

   B) Pre-cleaned, chemical-free, glass 1.0 liter sample jars with screw-top lids having Teflon liners.

   C) Pre-cleaned, chemical-free stainless steel utensils.

   D) Clean insulated ice chests with ice.

   E) Permanent, glass-adhesive markers.

   F) Bound collection logbook or individual record sheets.

   G) Disposable laboratory gloves.

   H) Meters: dissolved oxygen, salinity, temperature, pH and others, as appropriate.

4. **Operational Procedures** -

A) Prior to each *collection day* the ponar sampler will be scrubbed and washed with a detergent solution, rinsed thoroughly with tap water, and then rinsed with distilled water. After each collection *field*trip the ponar will be cleaned, as above, and stored properly.

B) The daily collection plan shall provide, to the greatest extent possible, for sampling to begin at the least contaminated station, with work advancing toward the most contaminated station.

C) Sediment samples obtained at *sampling stations* will be composite samples. Each composite will consist of five individual ponar sub-samples collected 3 meters apart along a straight-line transect, with the collection boat anchored. Move from one *sub-sample position* to the next by slipping the anchor line to provide approximately 3 meters of horizontal drift.

D) Place each ponar sub-sample in the sample pan. Take approximately 150 grams - of sediment from the center of the sub-sample using appropriate utensils and place it in the collection jar designated for that station. After obtaining each sub-sample, rinse utensils, wash deck, sample pan, and the ponar sampler with seawater or river water.

Note: 150 grams *of* sub-sample collected from each *of* the 5 sub-sample positions (about 750 grams *of* sample total) should result in the sample jar being about 3/4 full. This leaves adequate space in the jar for any expansion of the sample during freezing.

E) During collection of the third ponar sub-sample, record the *station location* by loran positions and by latitude and longitude. At this time, also record all other station information (such as depth, salinity. water temperature, etc).

F) Place each sub-sample (total. n=5) in the appropriate pre-labeled, sample jar. Secure the lid and place sample on ice in a cooler.

G) After work at each *sampling station* is complete, clean the ponar. Sample pan, wash deck and utensils thoroughly and rinse with seawater or river water.

H) For field trips involving more than one day, samples will be frozen and stored in a portable field freezer.

I) After each collection day double-wrap each full sample jar with clean. heavy-duty aluminum foil, place a second identification label over the foil and store in a freezer.

J) Upon returning to the Panama City Field Office samples will be transferred to a *laboratory freezer* and held at -230 degrees centigrade (-10 Fahrenheit) until shipment for chemical analyses. Sediment samples for particle size analysis will be held at 40 °C.

Appendix B:
Water quality data and summary statistics for West Bay water column sampling for incoming tide January 28th 2003.

Appendix C:

Water quality data and summary statistics for West Bay water column sampling for March 27th 2003.

Appendix D:

Water quality data and summary statistics for West Bay water column sampling for outgoing tide May 14th 2003.

Appendix E:

Water quality data and summary statistics for West Bay water column sampling for outgoing tide June 12th 2003.

Appendix F:
Water quality data and summary statistics for West Bay water column sampling for outgoing tide June 26th 2003.

Appendix G:
Sediment quality data West Bay sediment sampling in August 2002.