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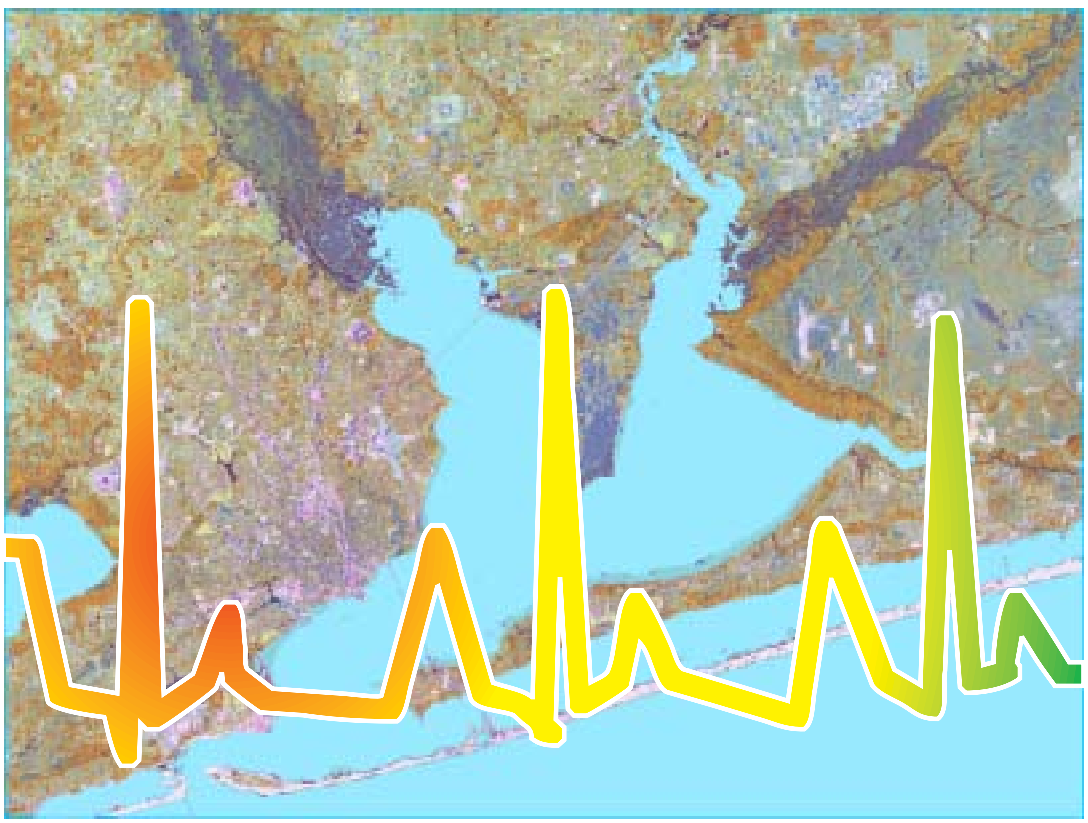
The Ecological Condition of the Pensacola Bay System, Northwest Florida



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Acknowledgments

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Executive Summary

The Pensacola Bay System (PBS) is located in the extreme western panhandle of Florida. The PBS covers 372 km^2 and is comprised of a group of small bays that receive drainage from 18,130 km^2 in northwest Florida and southern Alabama. The PBS encompasses; Escambia, Blackwater, East, and Pensacola Bays. This system is characterized as a drowned river valley with a small outlet into the Gulf of Mexico at the western end of Santa Rosa Island.

Historically, the PBS has had problems with anthropogenic inputs, both point and non-point source, discharging into it's waters (USEPA 1975). Large areas of submerged aquatic vegetation (SAV) and oyster reefs were lost in the late 1960's and early 1970's. After the implementation of regulatory standards in the 1970's, the condition of the system improved. Current priorities for the PBS include; sediments traveling downstream into the bays, and the potential eutrophication of portions of the system due to changes in nutrient loadings.

In estimating the current ecological condition of the PBS three indices were used: a water quality index, a sediment quality index, and benthic condition index. The three indicators were assigned a good, fair, and poor rating. The overall ecological condition for the PBS was assessed using a straightforward combination of the indicator scores.

Water quality was rated "good" for 30% of the PBS, fair for 61%. The quality of the sediment was more diverse, with 8% poor, 60% fair, and 32% good. For benthic organisms, 16% of the area was poor, 13% fair, and 58% good, with 13% having missing values. When the scores for each indice were combined for an overall ecological assessment of the system it indicated that 16% was poor, 68% was fair, and 16% was in good condition.

Results from these indices agree with the popular interpretation of current condition of the system. Overall, the PBS could be described as being in fair to good condition. There are periods, usually in the summer, when portions of the bottom of the system become hypoxic. The PBS can become stratified and contain temporarily elevated populations of pathogens, all associated with rainfall events. Though it is slow to flush, there were no highly elevated concentrations of contaminants in any of the sediments, with the exception of the bayous.
According to our sediment index 92 % of the sediment is in good or fair condition, and the area of wetlands within the system has increased. However, the area of SAV throughout the system is still declining.

Three small tidal estuaries, Bayou Texar, Bayou Chico, and Bayou Grande, are located in the northwest portion of Pensacola Bay. Each of these bayous is shallow and each receives runoff from areas with different land uses. Because of these factors some of the responses reported for the PBS have really been occurring in the bayous. Our study design did not supply enough data points to calculate indices and perform separate assessments, but the bayous have been well characterized.

All three bayous, Texar, Chico, and Grande, had concentrations of the same contaminants present in the water and in the sediment. Each bayou had 8 compounds exceed the ERL guidance values for sediment and 3 exceedances of the State of Florida criteria for Class III waters. Bayou Grande exhibited the lowest concentrations of contaminants in both the water and sediment compared to the other 2 bayous. Bayou Chico ranked next, followed by Bayou Texar with highest concentrations of contaminants. The absence of similar concentrations of contaminants found in the bay system outside each of the bayous indicates that the material may not be easily transported. The bayous appear to be acting as sinks or catchment basins for a large amount of the stormwater runoff. Because each bayou is somewhat isolated from the bay system, the effects of stormwater runoff are contained and in some cases magnified, as indicated by algal blooms and closures due to bacterial levels.

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1.0 General Description

The Pensacola Bay System (PBS) is a river dominated estuarine system located in N.W. Florida. It is comprised of five interconnected water bodies (Figure 1-1): Escambia Bay, Blackwater Bay, East Bay, Pensacola Bay, and Santa Rosa Sound. Santa Rosa Sound will not be addressed in this report. The Escambia River flows into the western portion of the system, Escambia Bay. Both the Blackwater and Yellow Rivers flow into Blackwater Bay which widens into East Bay on the eastern side of the system. Escambia and East Bays converge into Pensacola Bay which connects to the Gulf of Mexico through a narrow pass. The northern portions of the system are an average depth of 2.25 m (Figure 1-2). The southern portion, mainly Pensacola Bay, has an average depth of 6.0 m. The deepest portions of the system (15 - 20 m) are channels dredged for municipal and military navigational purposes. Tidal exchange with the Gulf of Mexico occurs through a narrow pass at the southwestern point of the system. The mean surface salinity at the mouth of the Escambia River ranges from 0 - 5 ppt. However, during periods of low flow, salt water can reach into the lower portions of the Escambia River and into Blackwater Bay.

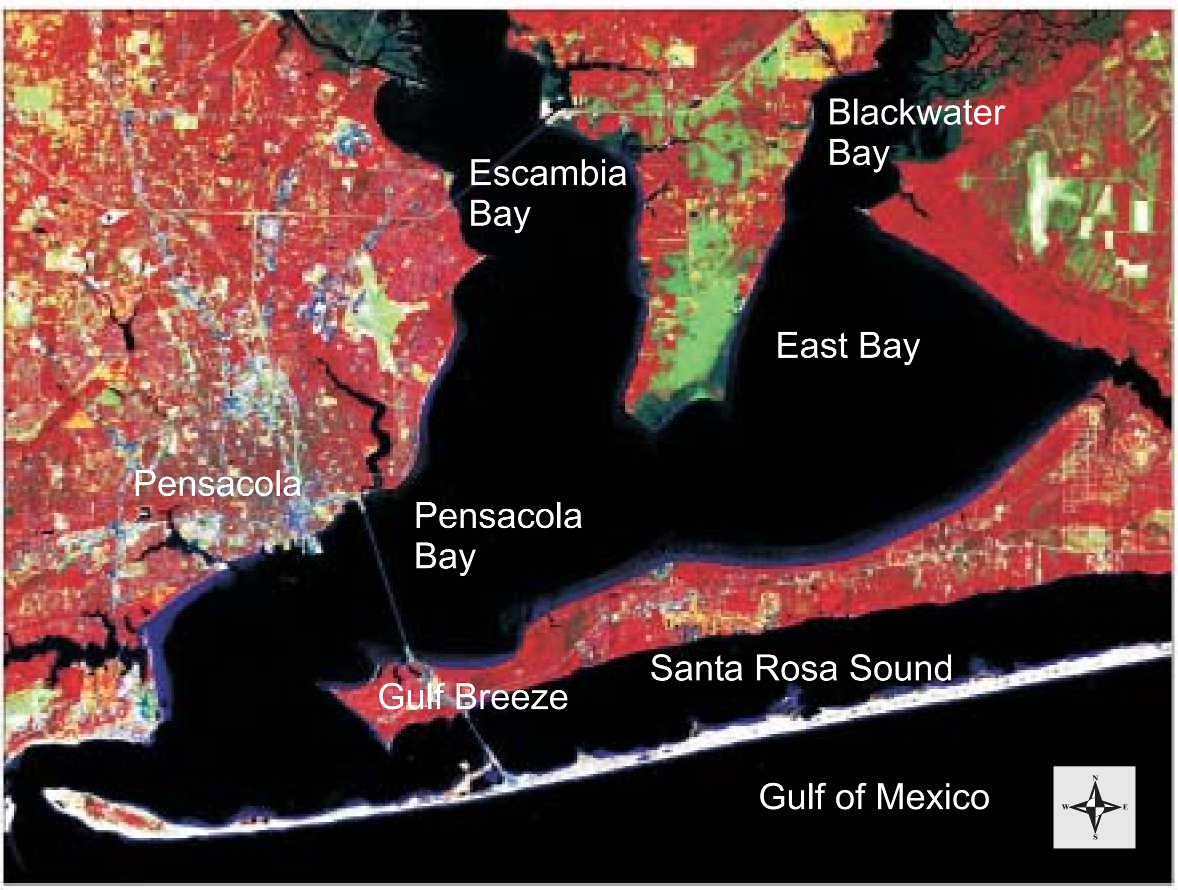

Figure 1-1. Satellite image of the Pensacola Bay System.

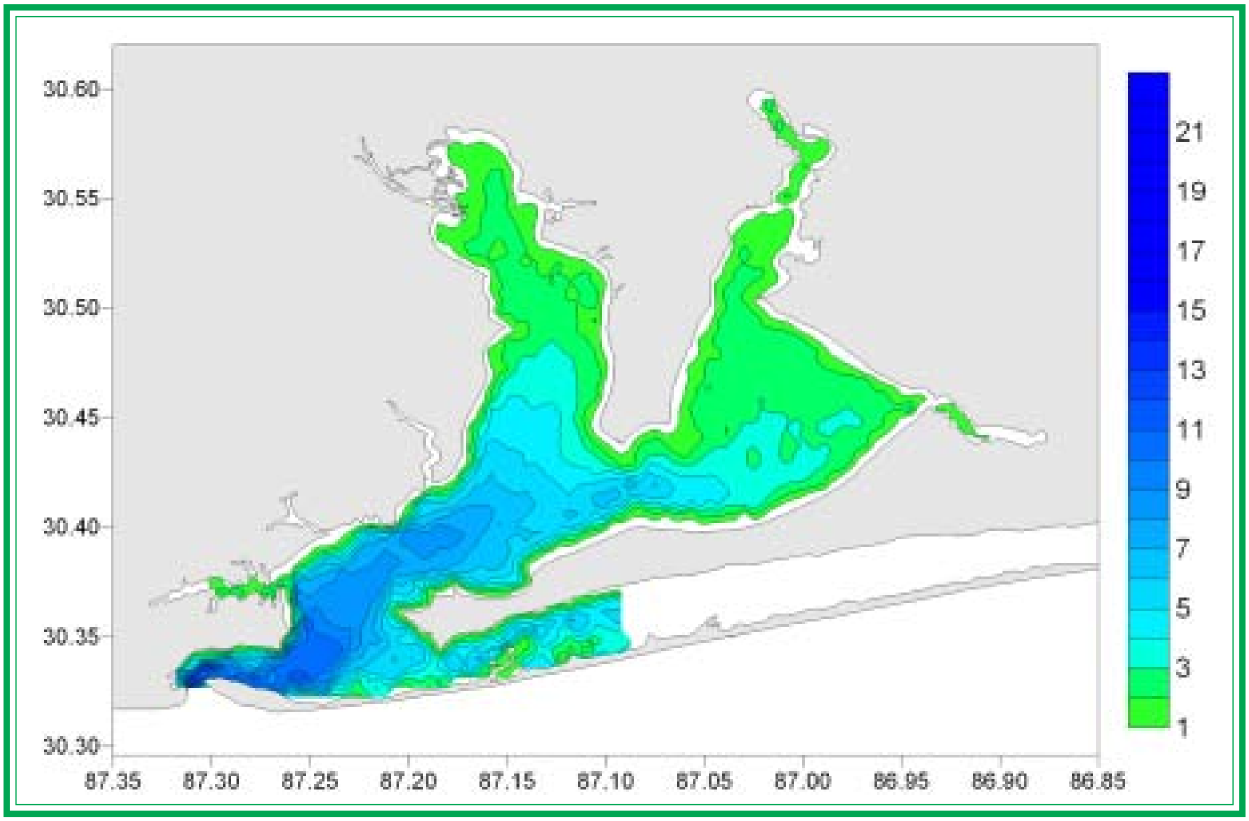

Figure 1-2. Depth contours of the Pensacola Bay System. Depths increase with distance from the shores.

The cities of Pensacola, Gulf Breeze, and Milton are located adjacent to the system. Pensacola is the largest of the three, bordering both northern Pensacola Bay and western Escambia Bay. Milton is located near the mouth of the Blackwater River, and Gulf Breeze is on the southern shore of Pensacola Bay. According to the 2000 US Census, the population of the City of Pensacola was 56,225. The city encompasses approximately 65 km^2 and consists of a mixture of urban and residential areas. Output from the municipal wastewater treatment facility discharges approximately 14 million gallons per day into the northern portion of Pensacola Bay. There are also three bayous within Pensacola that discharge into Pensacola Bay: Bayou Grande (adjacent to NAS Pensacola military reservation), Bayou Chico (used for small ship building and related industries), and Bayou Texar (purely residential, but receives runoff from industry and commerce upstream).

The US census estimates the populations in the cities of Milton and Gulf Breeze at 7,000 and 5,600 respectively. The City of Milton does not have any permitted discharges into Pensacola Bay, but discharges wastewater into the Blackwater River. The city of Gulf Breeze has no wastewater discharges into the PBS.

The majority of industrial land use within the system is associated with Escambia Bay. Air Products and Cytec both have permits to discharge into upper Escambia Bay. Solutia and Gulf Power have facilities located on the lower Escambia River; both have permitted discharges. The remainder of Escambia Bay is abutted by residential areas. There are also inputs of sediments and nutrients into Escambia Bay from upstream agricultural activities and unpaved surface roads. Blackwater Bay is bordered by the Eglin Air

Force reservation on the east and residential areas on the north and west. Land use is mainly residential in the East Bay watershed.

The Pensacola Bay system is designated for recreational and commercial uses by the State of Florida Department of Environmental Protection. Commercial uses include a shrimp fishery, an active port, and military flight training. Both Escambia and East Bays are utilized for shrimp and oyster fisheries. Fuel and raw materials are delivered to industries along the Escambia River via barges. The bay system also supports an active recreational fishery and a variety of water sports.

Historically, problems in the PBS have been associated with point and non-point source discharges into Escambia Bay and the Lower Escambia River (USEPA1975). Weak circulation and flushing of the system allows particles and dissolved materials in the water to remain in the upper portion of the system for longer periods. Prior to regulatory intervention, massive fish kills and algal blooms were frequently reported in this area. USEPA (1975) required relocating point source discharges to deeper waters, no new permitted discharges, and continued development and implementation of a system wide management plan. After the implementation of these recommendations in the early 1970s, there were noticeable improvements in water quality and a reduction in the number and extent of fish kills (SWIM 1997).

1.1 Bathymetry and Hydrodynamics

The Pensacola Bay System can be subdivided into five subsystems: (1) Upper Escambia Bay; (2) Lower Escambia Bay; (3) Pensacola Bay; (4) Blackwater Bay; and (5) East Bay. The PBS receives freshwater input from; the Escambia River, the Blackwater River, and the Yellow River. Freshwater input from the northwestern portion of the system is greater than 3x that of the northeastern portion. Estimated annual average flows for the Escambia, Blackwater, and Yellow Rivers are 170 m^3/s, 10 m^3/s, and 34 m^3/s respectively. Freshwater input is generally highest from February to April and lowest in October and November (Collard 1991), but has high year to year variability.

The Pensacola Bay System is classified as a drowned river valley. As a coastal plain estuary, this system is partly enclosed by a barrier island, Santa Rosa Island, and an interior peninsula. Salinities within the system range from 0 to 35 ppt. According to Pritchard's (1955) classification based on circulation patterns (salt wedge, partially mixed, vertically homogenous with lateral salinity gradient), the PBS fits into different classifications on both a temporal and spatial scales. A salt wedge is present when river flow is high, but becomes partially mixed during low flow.

As with all estuaries, surface flow tends to be seaward and bottom flow riverward. The upper reaches of the PBS is mesohaline, with salinity ranging between 5-18 ppt, whereas Pensacola Bay is polyhaline (18-30 ppt).

The PBS is a low-energy system dominated by river flow. The average tidal range is 0.5m, classifying the system as microtidal. According to USEPA (1975), based on average river flow and tidal range, PBS should flush on the order of 34 days, but may take as long as 200 days.

The PBS is a positive filled estuary, with sediments primarily derived from the rivers. Sandy sediments occur in the mouths of the rivers and deltas. Silt clays occur in the deeper and central portions of the system. A PBS sediment survey by George (1988), reported an average mean grain size of 0.031 mm. Organic carbon concentrations in the Pensacola Bay sediments rank second highest (avg. = 2.4%) among northeast Gulf of Mexico estuaries, after Mobile Bay.

1.2 Land Use and Habitat

The PBS is influenced by a variety of land use practices. Forested areas in the upper reaches of the tributaries dominate the river watersheds (Fig. 1-3.) Residential and commercial land use increases with increasing proximity to the PBS. Wetlands, which comprise approximately 8% of the land area surrounding the PBS, can serve as natural filters, improving surface water quality by processing or trapping residential, agricultural and industrial wastes, while protecting coastal areas from storm and wave damage. Submerged aquatic vegetation, which can provide food and habitat for many estuarine species, affects nutrient cycling, and sediment stability within the system. Since SAV species are sensitive to changes in water quality, loss of submerged vegetation within an estuary may be indicative of a decline in estuarine health.

As with the abundance of SAV beds, shellfish beds may also be an indicator of the biological health of an estuarine system. The Pensacola Bay system could be a very productive oyster harvest area based on hydrographic data such as salinity and temperature regimes. Oyster landings for Escambia County peaked in 1970 at approximately 140,000 pounds (Collard 1991). Unfortunately, by 1971, over 90% of the commercially harvestable oysters in Escambia Bay fell victim to disease. Degraded water quality, lack of suitable substrate due to dredge disposal, and sediment contaminants have all been suggested as causes for the decline in oyster abundance. Although water quality has improved drastically over the last two decades, oyster populations within the system have been slow to recover. Lack of suitable substrate and oyster disease may be limiting factors at present. Habitat restoration projects such as Project Greenshores are attempting to restore oyster reef habitat (FLDEP 2001). These restoration attempts may provide vital information for re-establishing oyster populations within the system.

The Pensacola Bay System suffered a period of maximum environmental degradation in the late 1960s-early 1970s. This degradation was apparent with massive fish kill, and the loss of submerged aquatic vegetation and oyster beds during that period. With the development and implementation of environmental regulations, the quality of ecosystems throughout the US has improved greatly. Control of discharges into the PBS through the permitting process has resulted in a large improvement of water quality since the problems of the early 1970s. Each state mandates its own requirements or criteria for maintaining water quality, some of which may be more strict than those mandated by the federal government.

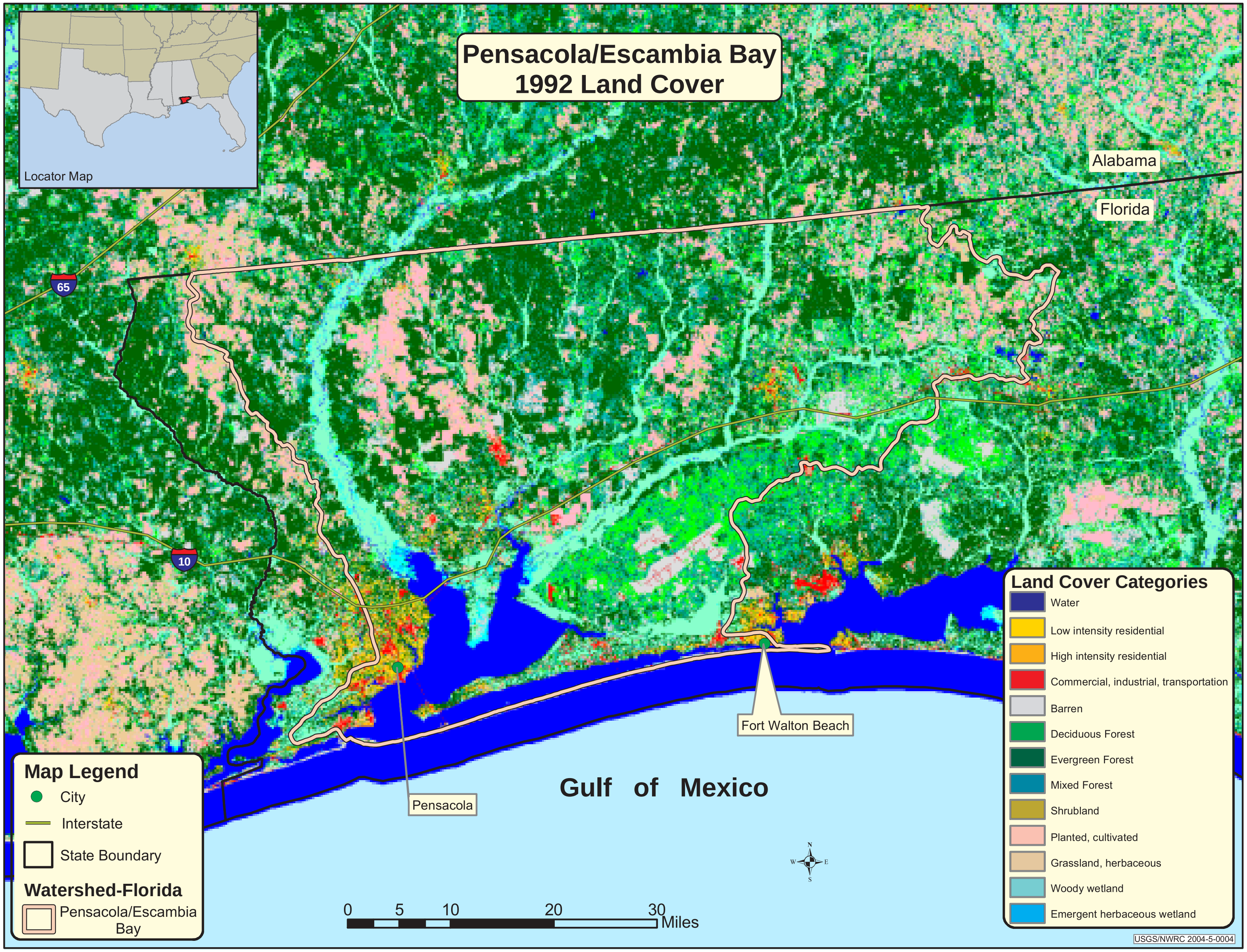

Figure 1-3 Land cover characterization of the watershed draining into the Pensacola Bay system.

2.0 Florida's Watershed Management Approach

The Florida Department of Environmental Protection (FDEP) is responsible for preserving and maintaining the quality of Florida's waters, essential natural resources for aquatic life and recreation, and uses for public consumption, industry, and agriculture. This is a challenging task due to damage caused by past practices, increasing demands placed on the water resources by rapid growth, and the various entities responsible for regulating different activities that may impact water quality. To address this challenge, and to recognize the need for defensible, science-based water quality assessments in support of full implementation of the Clean Water Act, FDEP has designed a statewide, watershed-based approach to water resource management.
Under the watershed management approach, Florida's water resources are managed on the basis of natural boundaries such as river basins and bay systems, rather than political or regulatory boundaries (Figure 2-1). Each of the states six districts are divided into five basin groups to facilitate implementation. The process also focuses on collaboration with local citizens to determine goals and priorities.

The approach is implemented using a five-year cyclical management process with emphasis being placed on public involvement in decision-making. Instead of focusing only on individual sources of pollution, water resources are assessed from a basin-wide perspective that considers the cumulative effects of human activities. The approach is not new, nor does it compete with or replace existing programs. Rather than relying on single solutions to address aquatic resource issues, it is intended to improve the health of surface water and ground water resources by strengthening coordination among activities such as monitoring, stormwater management, wastewater treatment, wetland restoration, land acquisition, and public involvement.

FDEP's Division of Water Resource Management is developing this more comprehensive approach to protecting Florida water quality involving basin-wide assessments and the application of a full range of regulatory and non-regulatory strategies to reduce pollution. The Total Maximum Daily Load (TMDL) is the heart of this approach, and the watershed management approach is the framework for implementing TMDLs.

Section 303(d) of the Clean Water Act (CWA) requires states to submit lists of surface waters that do not meet applicable water quality standards (impaired waters) after implementation of technology-based effluent limitations, and establish TMDLs for these waters on a prioritized schedule. TMDLs establish the maximum amount of a pollutant that a water body can assimilate without causing exceedances of water quality standards. As such, development of TMDLs is an important step toward restoring our waters to their designated uses. Chapter 99-223, Laws of Florida, also known as the "Florida Watershed Restoration Act", sets forth the process by which the 303(d) list is refined through more detailed water quality assessments. It also establishes the means for adopting TMDLs, allocating pollutant loadings among contributing sources, and implementing pollution reduction strategies.

Implementation of TMDLs refers to any combination of regulatory, non-regulatory, or incentive-based actions that attain the necessary reduction in pollutant loading. Non-regulatory or incentive-based actions

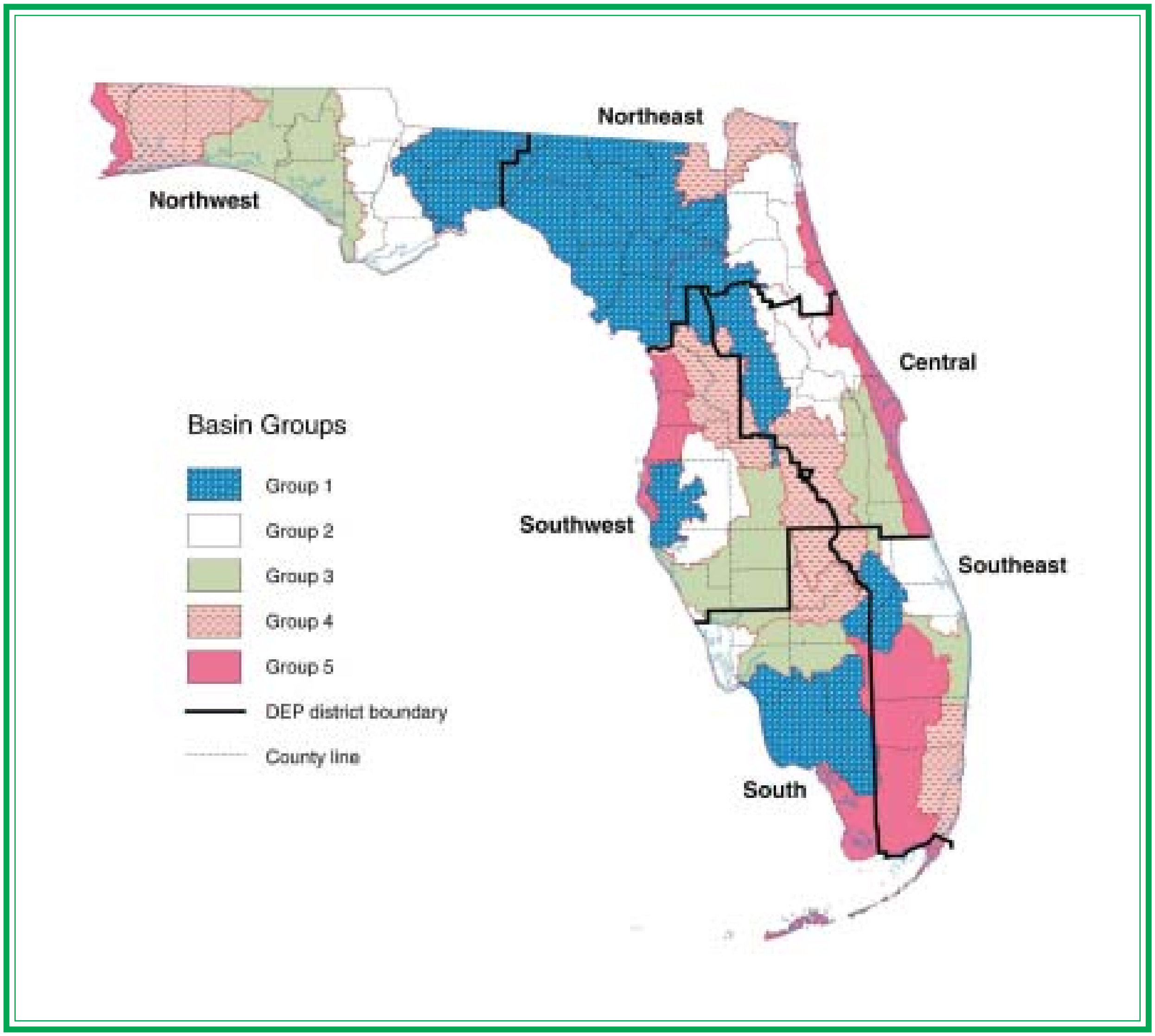

Figure 2-1 Florida DEP's basin delineation for their watershed management approach using natural boundaries.

may include development and implementation of Best Management Practices (BMPs), pollution prevention activities, and habitat preservation or restoration. Regulatory actions may include issuance or revision of wastewater, stormwater, or other permits to include permit conditions consistent with the TMDL. These permit conditions may be numeric effluent limitations or, for technology-based programs, requirements to use a combination of structural and non-structural BMPs needed to achieve the necessary pollutant load reduction.

Each of the state's six districts is divided into five basin groups. Each individual basin cycle will take five years to complete, and the cycle within that basin will be repeated every five years. For the Pensacola Bay watershed, the first phase was initiated in the fall of 2003.

• **Phase 1: Watershed Evaluation**. The Department will conduct preliminary evaluations of the status of the quality of surface water and ground water. This information will be used to generate a planning list of potentially impaired waters for which TMDLs may be needed. At the end of Phase 1, a Basin Status Report will be produced and a strategic monitoring plan will be developed.

• **Phase 2: Strategic Monitoring**. Monitoring will be conducted to help establish whether waters are, in fact, impaired and to collect the data needed to calibrate and verify models for TMDL development. At the end of the second phase, an assessment report will be produced. This report will contain an updated and more thorough assessment of water quality, associated biological resources, and current restoration plans and projects. Waters that are verified as being impaired will be placed on a basin-specific list of impaired waters that will be adopted by the Department through a Secretarial Order. This verified list will be submitted to the U.S. Environmental Protection Agency (EPA) as the state's Section 303(d) list of impaired waters for the basin.

• **Phase 3: Developing and Adopting TMDLs**. TMDLs for priority impaired waters in the watershed will be developed and adopted by rule. Due to fiscal and technical limitations, TMDLs cannot be developed for all listed waters during a single watershed management cycle, therefore waterbodies will be prioritized using the criteria in the Identification of Impaired Surface Waters Rule, Section 62-303, Florida Administrative Code. This rule provides a new scientific approach, with quality assurance and data sufficiency requirements, for identifying and prioritizing impaired surface waters in Florida. The Department evaluates whether waters meet their designated uses, which include aquatic life, primary contact and recreation, fish and shellfish consumption use support, and drinking water. Waters verified as not meeting any one (or more) of their designated uses will be listed on the state's 303(d) list.

• **Phase 4: Developing Watershed Management Plans**. A watershed management plan will be developed, including TMDL implementation plans specifying how pollutant loadings from point and nonpoint sources will be allocated and reduced. The plans will include regulatory and nonregulatory (i.e., voluntary), structural and nonstructural improvements. The involvement of affected stakeholders in this phase will be especially critical.

• **Phase 5: Implementing Watershed Management Plans**. Implementation of the activities specified in the watershed management plan will begin. The watershed management approach is an iterative process. One of its key components is that the effectiveness of management activities (TMDL implementation) will be monitored in successive cycles. Monitoring conducted in Phase 2 of subsequent cycles will be targeted at evaluating whether water quality objectives are being met and whether individual waters remain impaired. The Department also will track the implementation of scheduled restoration activities, to ensure continued progress towards meeting the TMDLs.

This approach is intended to protect and enhance the ecological structure, function, and integrity of Florida's water by promoting the management of entire natural systems and addressing the cumulative effects of human activities on a watershed basis. The approach provides a framework for setting priorities and focusing the Department's resources on protecting and restoring water quality, and aims to increase cooperation among federal, state, regional, and local interests. Emphasizing public involvement, the approach encourages stewardship by all Floridians to preserve water resources for future generations. The watershed approach is intended to speed up projects by focusing funding and other resources on priority water quality problems, strengthening public support, establishing agreements, and funding multi-agency projects. It avoids duplication by building on existing assessments and restoration activities and promotes cooperative monitoring programs. It encourages accountability for achieving water quality improvements through improved monitoring and by establishing TMDLs.

3.0 Study Design

A probabilistic survey design was developed by EPA's Environmental Monitoring and Assessment Program (EMAP) and used in the Pensacola Bay Monitoring Study to estimate ecological status and trends. EMAP was developed in response to the Clean Water Act to advance the science of natural resource monitoring at regional and national scales. Under the Clean Water Act, states and tribes are responsible for reporting on the condition of all their waters. EMAP's surveys use a statistical, scientifically-defensible approach to assess the condition of the nation's waters (Summers et al 1995). The use of a probabilistic survey design to sample the Pensacola Bay System provided a statistically rigorous approach for assessing the ecological condition by insuring unbiased (random), spatially distributed sampling sites. The sampling design generated for this study consisted of 38 sites (Fig. 3-1), sampled quarterly over a five-year period from 1995 - 2000.

The thirty-eight (38) stations were established within the PBS, each equally weighted in their probability of inclusion, using geographical information systems software. The total sampling area assessed for the PBS was about 296 km^2, with each station representing 7.7 km^2. Each station was randomly located within a 7.7 km^2 hexagon (Fig. 3.2). A grid of these hexagons was overlaid upon the PBS at a density to provide the correct sample size.

Figure 3-1 Image of the Pensacola Bay System showing sampling station locations.

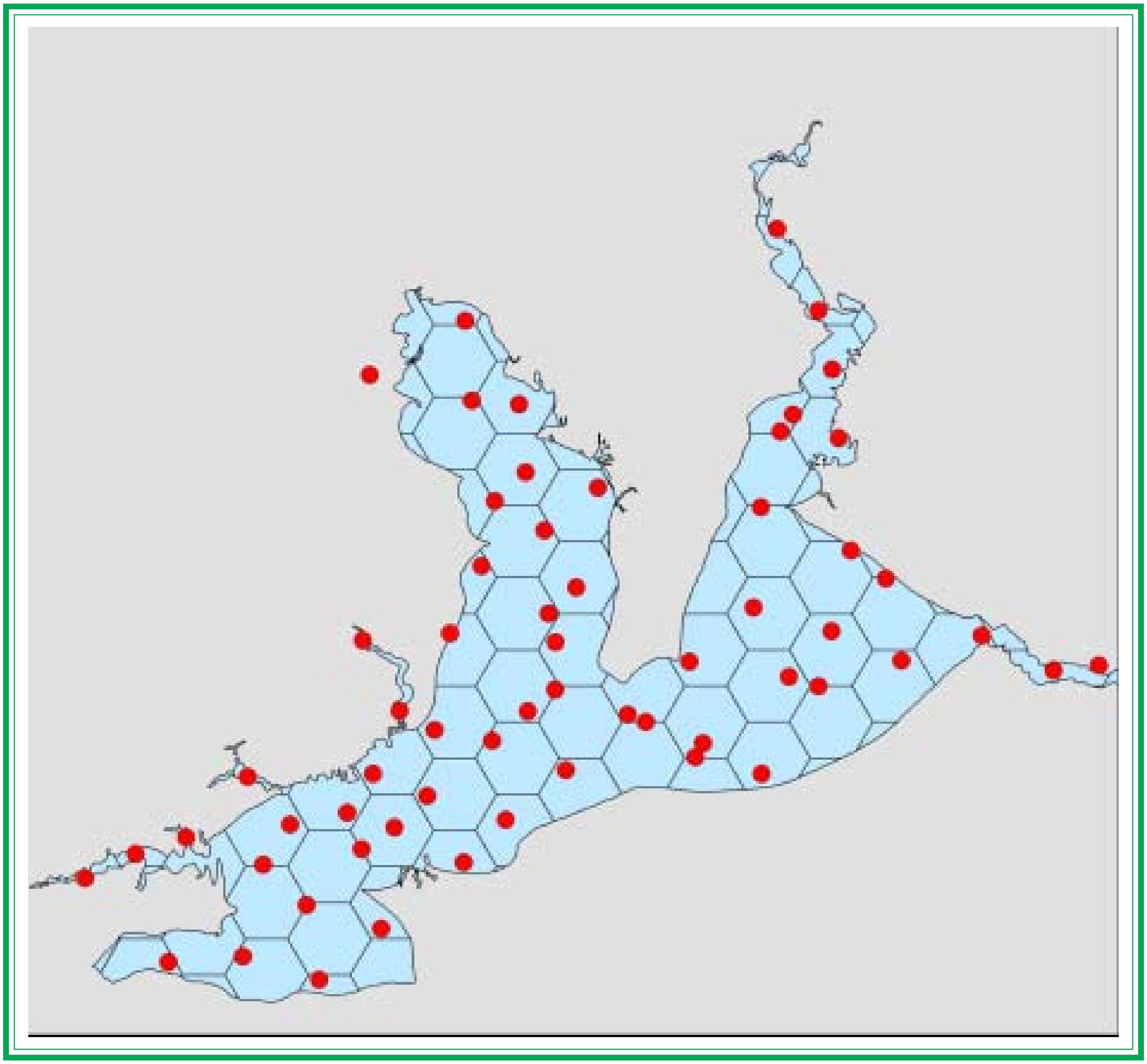

Figure 3-2 Hexagonal grid overlaid onto the Pensacola Bay System with each hexagon representing 7.7 km²^{2}. Circles show the locations of sampling stations.

4.0 Water Quality

Water quality assessments use a set of hydrographic, chemical and biological indicators. Water quality data presented for the Pensacola Bay System include a mixture of hydrographic (salinity, pH, temperature, dissolved oxygen, and light penetration), chemical (nutrients), and biological (benthic community and chlorophyll) measurements.

4.1 Stratification

The distribution of salinity in estuarine systems is modified by freshwater input, tidal forces, and circulation patterns. The water column becomes stratified when lower density freshwater floats atop denser seawater. Stratification can limit the exchange of nutrients and dissolved oxygen across the pycnocline, (the boundary between fresh and salt water). Although estuarine organisms typically are adapted to wide salinity ranges, benthic communities may be altered when altered salinity persists for extended periods. Salinity in the PBS averages 17.5 ppt annually. Surface and bottom salinities are useful for estimating the degree of stratification in an estuary. The Pensacola Bay System is a river dominated system where freshwater flows over saltwater and becomes mixed (Fig. 4-1). When rainfall within the watershed is low, the amount of freshwater entering the system decreases causing decreased stratification throughout the estuary. High freshwater inflows tend to increase stratification. An index of stratification was calculated based upon the difference between the surface and bottom salinities. Differences less than 2 ppt indicates low stratification 2-10 ppt partially mixed, and > 10 ppt highly stratified. Based on this index, 36% of the Pensacola Bay system was highly stratified (Fig. 4-2), with 11% was well mixed, and 53% was partially mixed. Seasonally the PBS shows a higher degree of stratification in winter and summer when compared to the same stations sampled in spring and fall (Fig. 4-3).

4.2 Temperature

Water temperature in the PBS ranged from 8.0 to 33.7 ^{o}C with a mean value of 22.2 ^{o}C. Differences in bottom and surface temperatures exist in the deepest portions of the bay year-round. When seasonal temperatures begin to drop, the surface waters cool and tend to sink causing vertical mixing or “turnovers” of the water column. As the winter months approach, the water cools and water column temperature becomes more uniform. Point source thermal discharges can elevate water temperatures locally and decrease oxygen concentrations. State of Florida permit guidelines for thermal discharge state that the temperature of receiving coastal waters shall not exceed 92^{o} F (33.3^{o} C) in summer months and ambient temperatures shall not be elevated more than 2^{o} F (1.1^{o} C). For the remainder of the year, the temperature must not exceed 90^{o} F (32.2^{o} C) and shall not be elevated more than 4^{o} F (2.2^{o} C) above ambient water temperature.

4.3 pH

The pH in estuarine systems is usually stable due to the buffering capacity of seawater. Measurable changes in pH may occur during in periods of heavy rain, increased river flow, algal blooms, and high

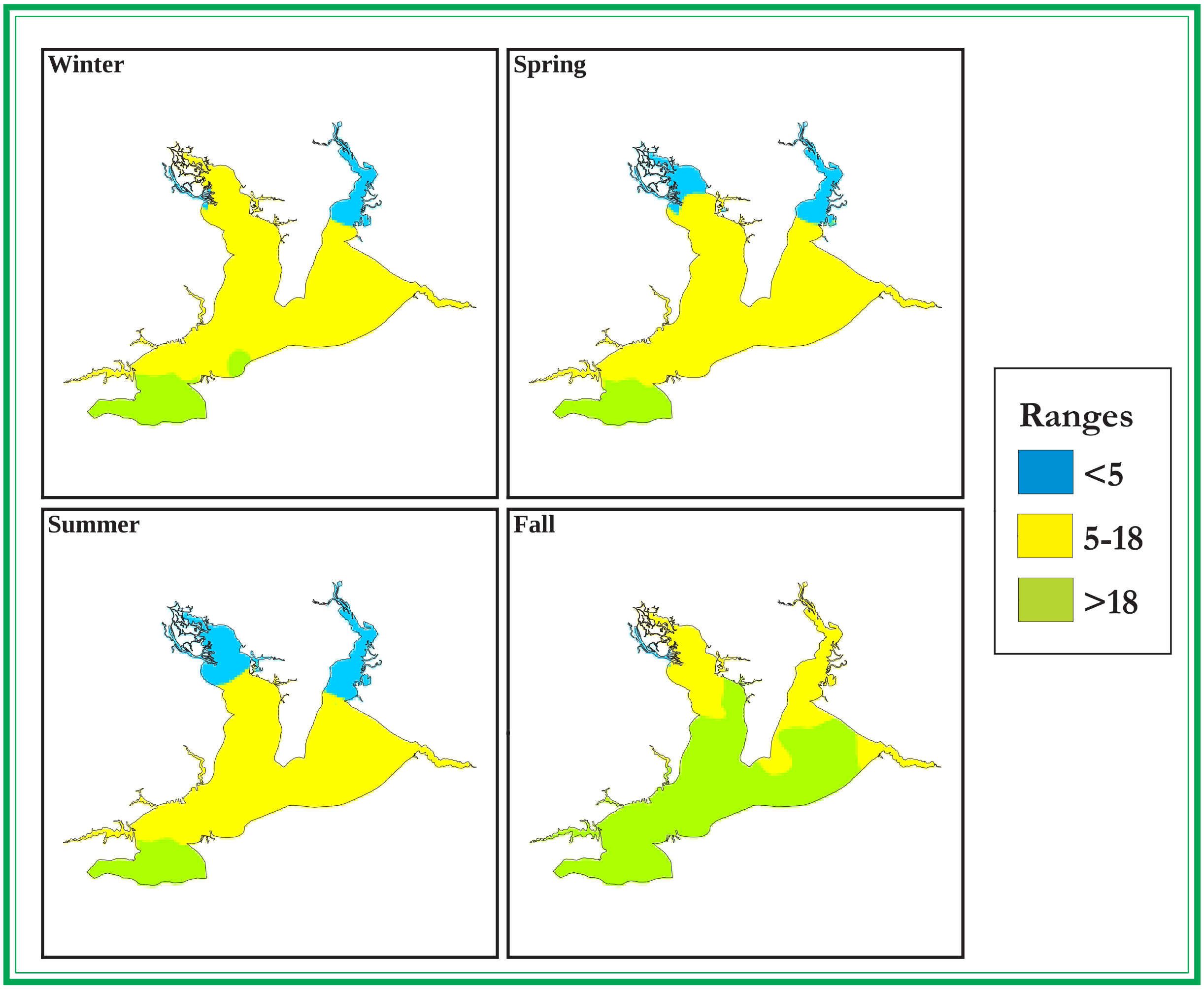

Figure 4-1 Seasonal surface salinity concentrations of the Pensacola Bay system.

oxygen demand. When pH values drop below 6.0 for extended periods ammonium can accumulate in the water column due to a decrease in nitrification process (Schindler 1991). The pH of the Pensacola Bay System ranges between 4.1-9.1 with a mean of 7.8. State of Florida surface water criteria designate a general acceptable pH range of 6.5-8.5. Many organisms are sensitive to pH changes, particularly algal species. Seawater pH may inhibit or enhance the growth rates of phytoplankton species by affecting the availability of nutrients and trace metals. In coastal environments, seawater pH may limit phytoplankton blooms (Hinga 2002). Water column pH also affects the solubility and speciation of contaminants.

4.4 Light

The amount of sunlight that penetrates the water column is important to primary productivity. Algae and submerged aquatic vegetation (SAV) require sufficient light for photosynthesis. The amount of light penetrating the water column is influenced by colored dissolved organic matter (CDOM) concentrations and total suspended solids including self shading algal biomass. Some estuarine systems are naturally turbid, especially shallow, river dominated systems. The upper portions of the Pensacola Bay System, e.g. Blackwater Bay, are characterized by darkened water due to high CDOM content. Water color,

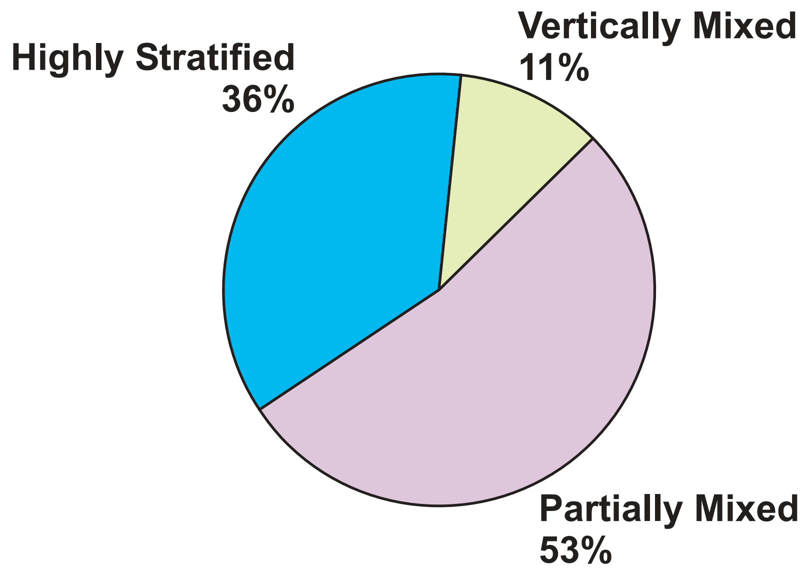

Figure 4-2 Percentages of the Pensacola Bay System exhibiting the different stratification regimes.

however, is not itself an indication of poor water quality. Water quality as a function of water clarity is generally evaluated based on elevated concentrations of chlorophyll and suspended solids.

The PBS historically has supported SAV. The loss of SAV throughout the system has been attributed to poor water quality and may be linked to water clarity. Because the system is shallow, light often reaches the bottom. When the water becomes more turbid, the amount of light reaching the bottom decreases. When less than 10% of the ambient light is observed at a depth of 1 meter, water clarity is considered poor (USEPA 1999). This value is based on the system's ability to support SAV and takes into consideration the natural conditions contributing to light attenuation (CDOM). When light is not limited, and there are excess supplies of nutrients, the conditions are optimal for phytoplankton growth. When phytoplankton become dense, light is absorbed and SAV may suffer due to insufficient light. This situation may cause a shift in the plant community from SAV to phytoplankton. Increases in algal biomass can eventually lead to oxygen problems.

Based on the 10% light guideline at 1 meter, poor water clarity was observed in < 10% of the system in summer. The extent of the poor water clarity varied with season (Fig. 4-4), occurring to a greater extent in the summer months. Areas of poor water clarity generally occurred near the river mouths.

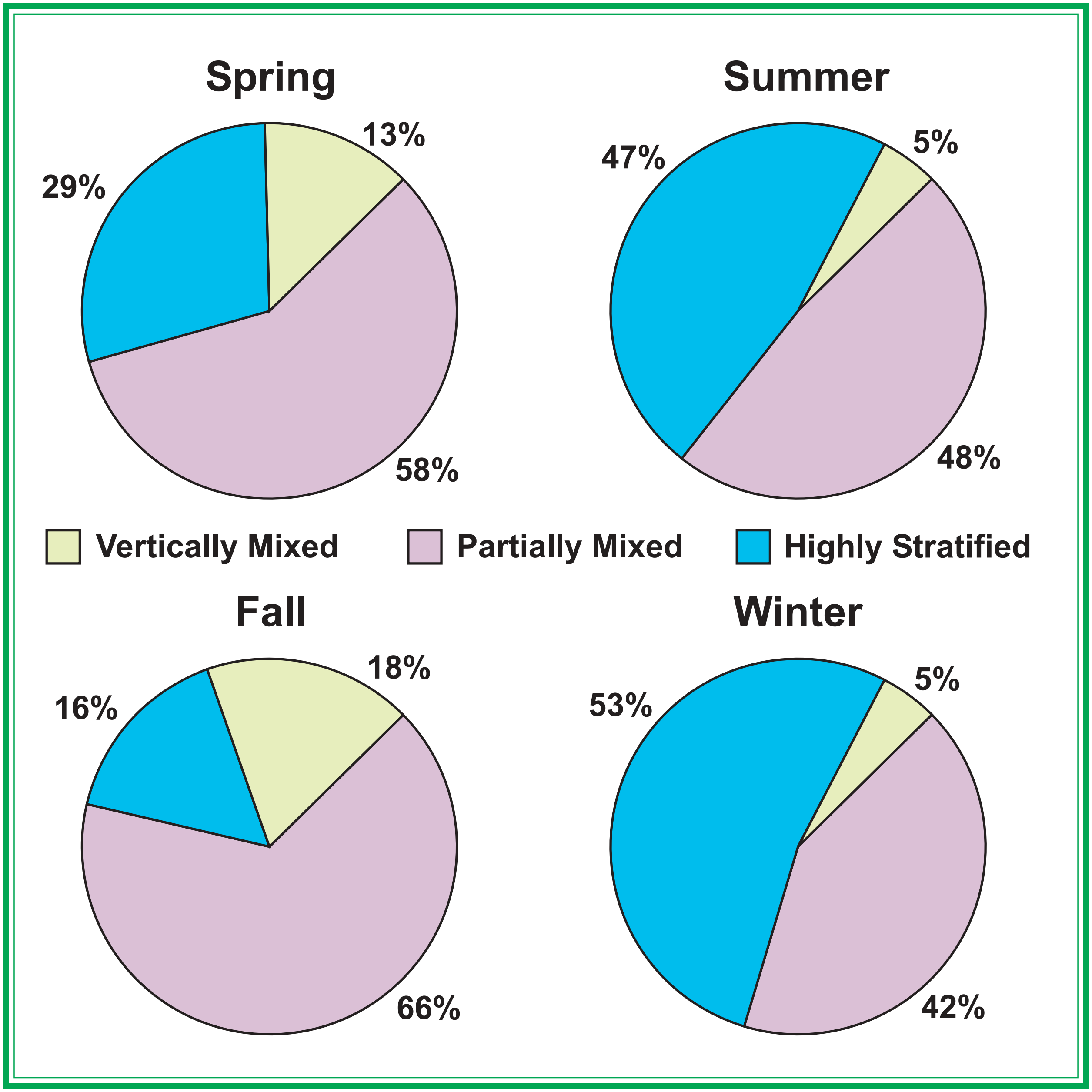

Figure 4-3 Seasonal variation in the different stratification regimes for the Pensacola Bay System.

4.5 Chlorophyll a

The chlorophyll a concentration in the water column of the PBS was used as an estimate of the biomass of phytoplankton present. A large amount of phytoplankton or "bloom" may indicate the presence of excess nutrients, reduce the amount of light penetrating to SAV, and cause hypoxia when the bloom dies and begins to decompose.   If the amount of chlorophyll a exceeds a criterion, the waters are judged to

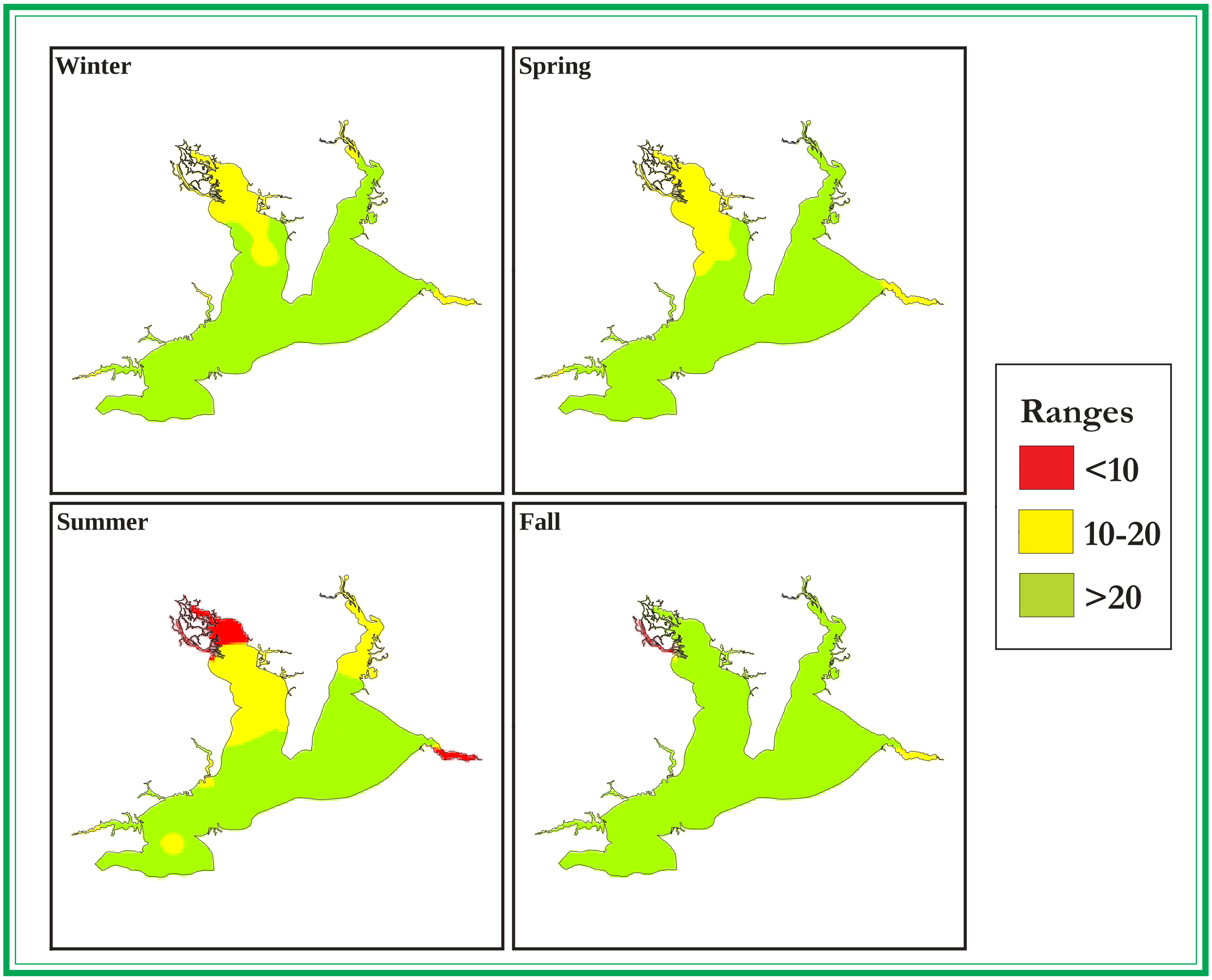

Figure 4-4 Seasonal % light transmission to a depth of 1.0 meter in the Pensacola Bay system.

be degraded or impaired. The State of Florida considers an estuarine water body to be impaired if the mean concentration of chlorophyll a is greater than 11 ug/L for a calendar year. For our data we assigned a poor rating to sites where the chlorophyll a concentration was greater than 20 μg/L; fair was a concentration from 5-20 μg/L; and good was less than 5 μg/L. Approximately 55 % of PBS was rated as having concentrations of chlorophyll a in the good range, while 45% rated as fair, and none of the area was rated poor.

4.6 Dissolved Oxygen

Oxygen dissolved in the water is required by most aquatic species. Dissolved oxygen is an excellent indicator of overall water quality. Dissolved oxygen may be depleted due to the decay of organic matter by bacteria or animal respiration. This depletion is mostly observed in near-bottom waters during warm summer months, where respiration consumes more oxygen than is replenished. When oxygen is depleted to a level that begins to stress aquatic organisms, it is referred to as hypoxia. Hypoxia, or the more severe condition, anoxia (no oxygen), may contribute to the death of aquatic organisms that cannot escape, or cause behavioral changes which make species more vulnerable to predation.

Organic matter is delivered via sewage discharges, stormwater runoff, and rivers draining into the PBS. In addition, excess nutrients can stimulate algal growth. The algae die and are subsequently decomposed, contributing to oxygen depletion. Estuarine fish and invertebrates can become chronically stressed if dissolved oxygen concentrations remain below 5.0 mg/L. In addition to the threat to aquatic life, nutrient concentrations are also affected. Under hypoxic conditions, ammonia and phosphorus contained in bottom sediments are released. These nutrients are then available for algal uptake and may fuel more primary production, continuing the cycle. For the protection of aquatic life, the State of Florida has established dissolved oxygen criteria for marine waters to average no less than 5.0 mg/L in a 24-hour period and to never be less than 4.0 mg/l in a single reading. Some estuarine waters are naturally more susceptible to dissolved oxygen problems due to poor mixing; however, anthropogenic inputs of nutrients and organic matter usually exacerbate the condition.

The PBS experiences low dissolved oxygen during the summer months (Fig. 4-5). The extent of poor oxygen conditions using a conservative criterion of, < 2.0 mg/L, increases as temperatures and stratification increase. Seasonal averages of dissolved oxygen indicate no occurrences of poor dissolved oxygen in winter, but poor conditions in approximately 24% of the PBS area are present in summer. Approximately 1% of area sampled exhibited low dissolved oxygen in spring and fall. Evaluating the causes of hypoxia in the system requires careful consideration in terms of ecosystem management due to multiple factors. Naturally occurring conditions such as stratification and temperature increases can be significant in modifying oxygen concentrations. Factors related to primary productivity can be evaluated by examining the dissolved nutrient, chlorophyll a, and organic carbon concentrations.

4.7 Dissolved Inorganic Nutrients

Nutrients delivered to estuarine and coastal systems support biological productivity. Sources of anthropogenic nitrogen and phosphorus include applied fertilizers (urban runoff and agricultural runoff), livestock waste, and atmospheric deposition from fossil fuel combustion (Table 1). Nutrients are regenerated internally during decomposition and other microbial processes.

Excessive levels of nutrients can cause intense biological productivity that leads to hypoxia. The process of nitrification is significantly reduced under anoxic conditions, preventing an important process that can return fixed nitrogen to atmospheric nitrogen (N_2). Biologically available nitrogen (NO_3, NO_2, NH_4, DON) promotes phytoplankton, blooms. Certain nitrogen species, such as ammonia, can be toxic to aquatic life. Phosphorus limitation for the growth of phytoplankton has been observed in portions of the PBS (Murrell et al, 2002). In this situation nitrogen is in excess and it is the amount of phosphorus entering the system that limits the productivity.

Because of the impact of nutrients on primary productivity they are major factors of concern in the development of limits allowed to be discharged into the PBS. Development of these regulatory limits is crucial for the protection of biological integrity of estuarine systems. Concentrations of dissolved nutrients in the surface water are indicators of the amount available for primary productivity. Although no

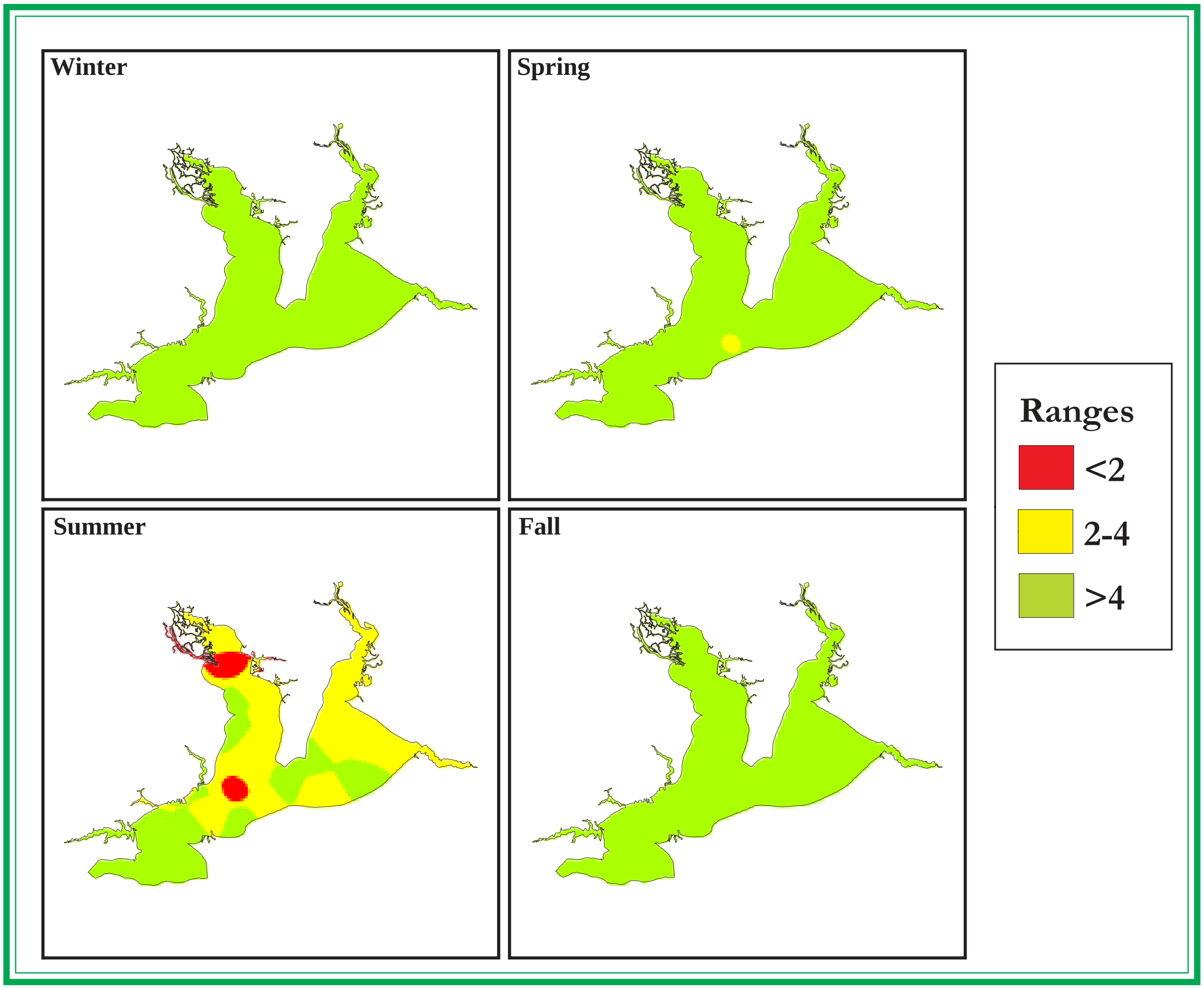

Figure 4-5 Seasonal bottom dissolved oxygen concentrations (ppm) of the Pensacola Bay system.

criteria are established for nutrient concentrations in estuarine surface waters for the State of Florida, an EPA recommended guideline for estuarine waters is a 10:1 ratio of nitrogen to phosphorus. Nitrogen and phosphorus concentrations are highest in the bayous of the PBS. These areas are typically poorly flushed and are the receiving waters for a large amount of urban runoff. The upper portions of Escambia Bay, closest to the river, tend to be higher in nitrogen and phosphorus, and are diluted by seawater (nutrient poor) or removed by algal uptake, as the water moves through the system. Nutrient concentrations observed in the surface waters of the PBS are rarely in excess of 0.1 mg/L N and 0.05 mg/L P. The hydrodynamics of the system, which provide a flushing time for the entire system of 21-34 days, may be very important in controlling the nutrients in the system, thereby limiting the development and frequency of algal blooms.

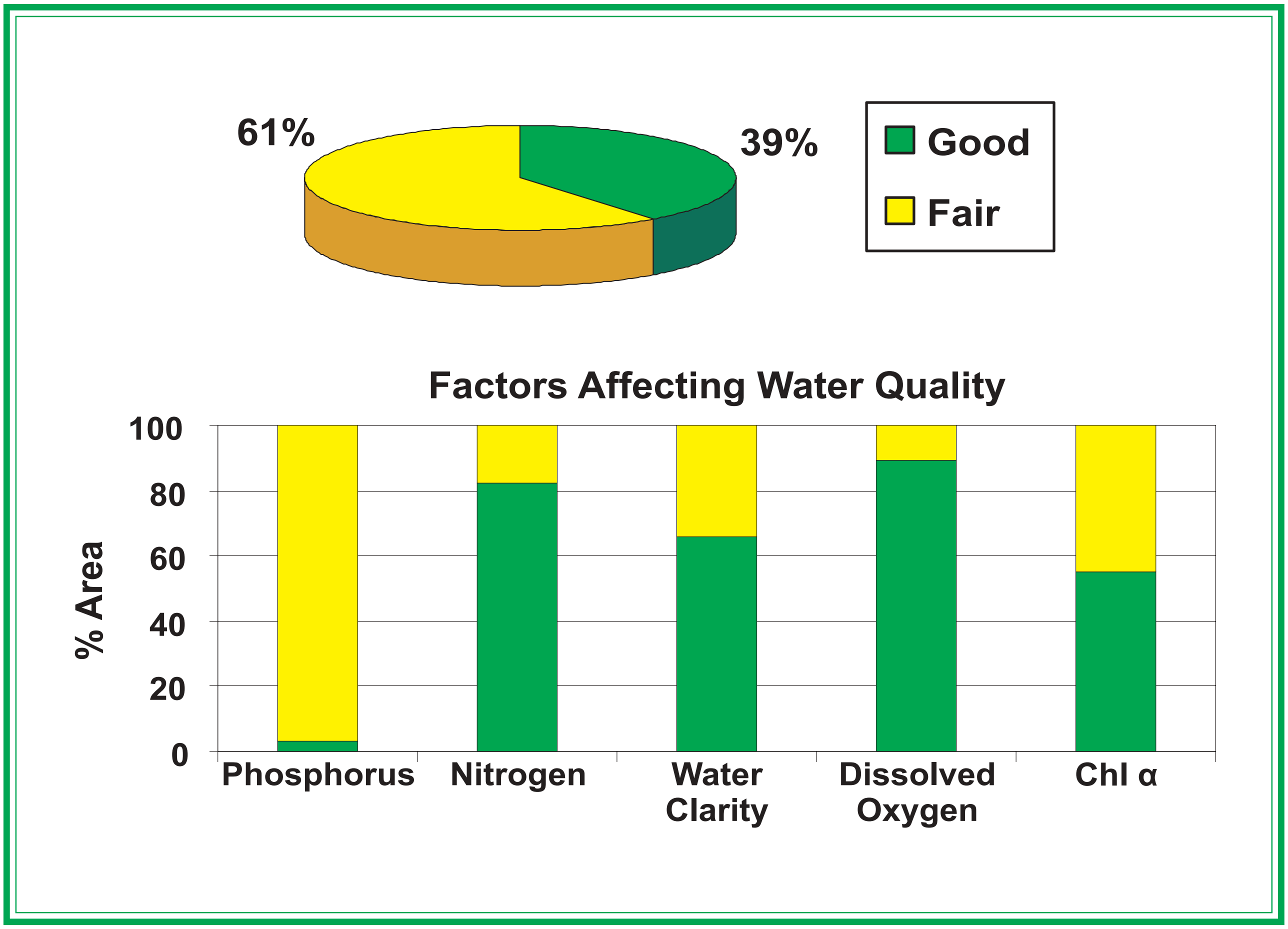

Figure 4-6 Percentages of the Pensacola Bay System exhibiting good, fair, or poor water quality based on a calculated index.

4.8 Water Quality Index

The water quality index that was developed for this report was based on five variables each averaged across seasons: water clarity, dissolved oxygen, chlorophyll *a*, nitrogen, and phosphorus. Each of the variables was assigned a rating of good, fair, or poor. The ratings were then combined to rank each of the sites. With this ranking, the areal extent of the ratings could be assessed. Based on this approach, 39% of the area of the PBS had good water quality, with 61% having fair water quality, and 0% having poor (Fig. 4-6). Phosphorus, chlorophyll *a* concentrations, and reduced water clarity were the major contributors to the fair ranking.

5.0 Sediment Quality

Pensacola Bay System sediments are composed mainly of materials which originate up the rivers that have been washed downstream. Sediment transport throughout the system is dependent upon sediment grain size and the river flow. Finer sediments, such as silt and clay can be transported throughout, while the coarser sands tend to settle closer to the river mouths. Pensacola and Escambia Bay sediments are composed mostly of sand, whereas those from East and Blackwater Bays are mainly clay. Pensacola Bay sediments were assessed in many ways, based on total organic carbon content, chemical contaminant concentrations, and benthic condition.

5.1 Silt / Clay

The silt/clay fraction of sediment is defined as that portion which is less than 63 μm in diameter. If 80% of a sample of sediment is classified as being silt/clay, it is described as mud, and if < 20% of a sample of sediment is classified as silt/clay, it is described as sand. There are also a number of descriptions for the mixtures of the two types. The majority of the sediments in the Pensacola Bay System fall between the two types and are >20%, but <80% silt/clay (Fig. 5-1). The majority of the mud is located along the delta of the Escambia River or in the bayous of Pensacola Bay.

5.2 Total Organic Carbon

Total organic carbon (TOC) is a measure of how much organic matter occurs in sediments. Runoff and sewage outfalls may contribute to higher organic content. Carbon content in sediments may be elevated following algal blooms, rain events, and sewage spills. Decomposition of organic material contributes to oxygen consumption. In combination with benthic invertebrate community analyses, organic carbon content can be useful in sediment quality assessment. Total organic carbon content usually correlates positively with the percentage of silt/clay in the sediments.

Hyland et al. (2000) found that extreme concentrations of TOC can have adverse effects on benthic communities. TOC levels below 0.05% and above 3.0% were related to decreased benthic abundance and biomass. No total organic carbon concentrations measured in the PBS fell into the lower end, but approximately 40% of the area had sediment TOC concentrations in excess of 3.0%. For sediment quality >5% TOC is considered poor and <2% TOC is considered good. Approximately 5% of the area within the PBS had TOC concentrations greater than 5.0%. According to the Surface Waters Improvement and Management Program Report (NWFWMD, 1991), the Pensacola Bay had the second highest organic carbon content (after Mobile Bay) among Gulf of Mexico estuaries.

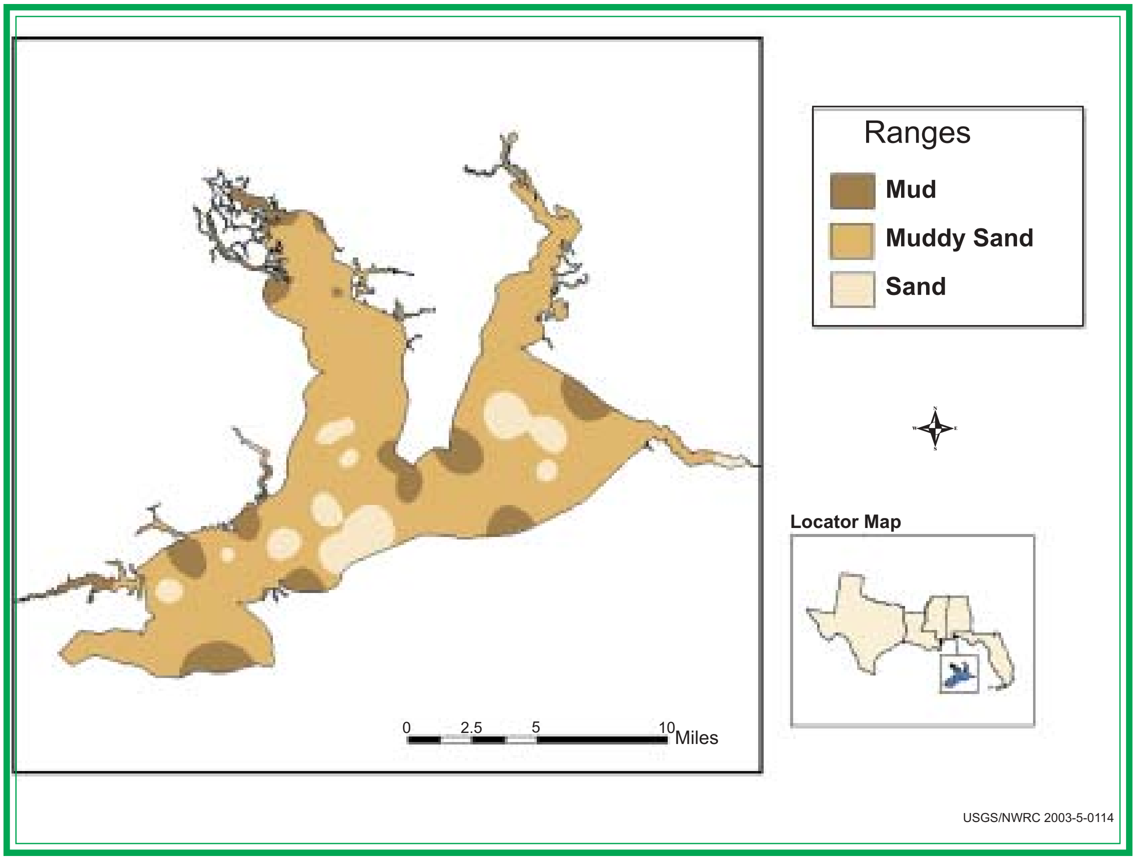

Figure 5-1 The extent and locations of different sediment types in the PBS.

5.3 Contaminants

Sediment contaminants (metals, pesticides, PCBs and PAHs) can adversely affect estuarine organisms. The biological effects of contaminants vary, ranging from acute toxicity to sublethal effects such as reduced reproductive capability. Industrial and municipal discharges all contribute to urban and agricultural runoff, accidental spills, and atmospheric deposition. Few regulatory criteria are established for sediment contaminants, making it difficult to evaluate the levels present in the PBS. Guidelines developed by NOAA (Long and Morgan 1990, Long et al. 1995) provide benchmarks for determining contaminant levels that may have negative affects on estuarine organisms. The effects range low (ERL) is defined as the concentration of a contaminant that may result in biological effects 10% of the time. The effects range medium (ERM) is the concentration at which a contaminant may have an biological effect 50% of the time. These guidelines are based on literature surveyed and are considered experimental.

The Ecological Condition of Gulf of Mexico Estuaries (USEPA 1999), reported that areas of Pensacola Bay had severely contaminated sediments, with as many as 40 chemicals at concentrations greater than the ERL guideline. These areas were located primarily in the bayous and in the mainstem of Pensacola Bay. A station in Bayou Texar had sediment with concentrations of mercury, total DDT, and zinc that were greater than the ERM guidance. Sediment from stations in both Bayou Texar and Bayou Grande exceeded the ERL guidance values for all 7 metals listed, with the station in Bayou Grande also exceeding the ERM value for zinc.

The bayous are small, poorly flushed, partially enclosed bodies of water. Particle retention times are longer, therefore sediment contaminants may accumulate resulting in higher concentrations than sediments in the open bay. Additionally, the bayous are more susceptible to human use activities. The higher sediment contaminant concentrations may reflect all of these factors.

Contaminants accumulated in the sediment may be available for uptake by benthic organisms. Contaminants may be acutely toxic (kill relatively quickly) to the organism or bio-accumulate (concentrate in the body tissue). This accumulation can be magnified upwards through the food chain as other organisms feed on these contaminated ones. This magnified concentration may eventually become toxic to the upper level consumers. The toxicity of several of the sediments in Pensacola Bay was tested using standard testing protocols with representative marine organisms. Only sediments collected from Bayou Texar and Bayou Grande exhibited toxicity towards estuarine amphipods and crustaceans (Lewis et al.

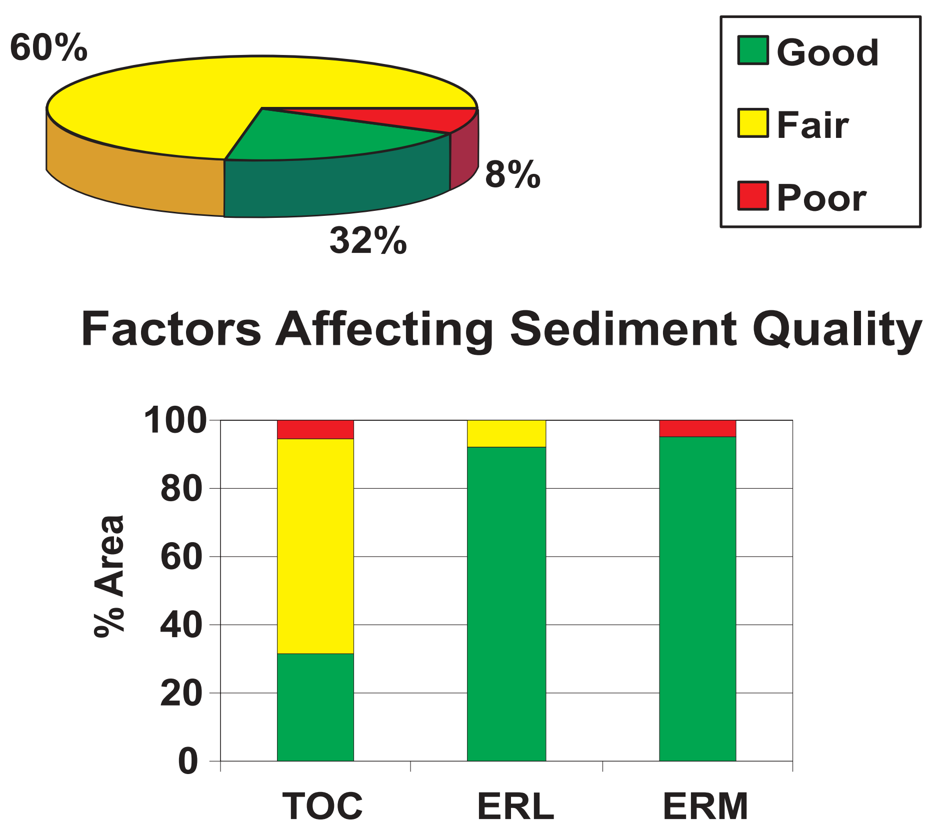

Figure 5-2 Percentages of the Pensacola Bay System exhibiting good, fair, poor sediment quality based on a calculated index.

2001). The results of these acute toxicity tests correlate well with the results of the chemical analyses of bayou sediments exceeding the ERM and ERL guidance values.

5.4 Sediment Index

Based on a cumulative score from three indicators, TOC, concentrations above ERL, and concentrations above ERM, approximately 8% of the Pensacola Bay System has poor sediment quality (Fig. 5-2).

5.5 Benthic Index

Engle and Summers (1998) used Pensacola Bay to examine the causes of benthic condition. Correlating the quantity and diversity of organisms living in the sediments with levels of contaminants and the physical characteristics of the sediment Engle (1998) estimated the overall health of the benthic population. The benthic index that was created identified 12 of the 40 sites sampled as degraded (Fig. 5-3). These data were collected from 18 sites in 1996 and were primarily located in the main stem of Pensacola Bay and in the bayous. In development of the benthic index, Engle and Summers (1998) determined that concentrations of lead, silver, and the number of contaminants with concentrations greater than the ERL guidance were the most important parameters distinguishing degraded and undegraded sites.

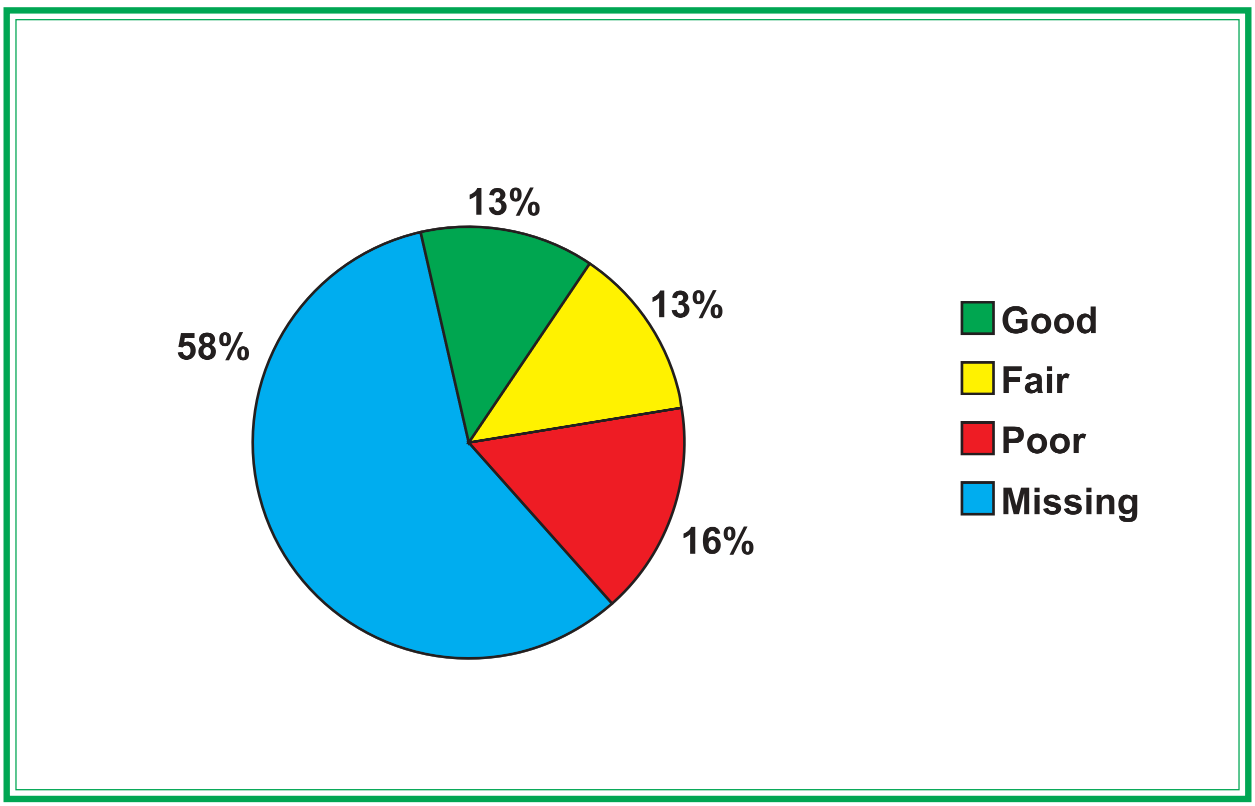

Figure 5-3 Percentages of the Pensacola Bay System exhibiting good, fair, poor quality of benthos based on a calculated index.

6.0 Land Use and Habitat

The PBS, contained within the Escambia River watershed, is influenced by a variety of land use practices. Forested areas in the upper reaches of the tributaries are the dominant land cover in the Escambia River watershed (Fig. 6-1) Residential and commercial land use increase with increasing proximity to the PBS. Emergent woody wetlands comprise approximately 8% of the land area surrounding the Pensacola Bay System. Wetlands serve as natural filters, improving surface water quality by processing residential, agricultural and industrial wastes, trapping sediments and removing nutrients, while protecting coastal areas from storm and wave damage.

In addition to the buffering capacity, wetland and estuarine areas provide essential habitat for fish, shellfish, migratory birds and other wildlife. Tidal marshes are critical habitats for juvenile shrimp, blue crabs and some species of gamefish, for example, spotted seatrout. The quality and coverage of wetland habitat has been linked to the harvest of commercially important species such as shrimp (Boesch and Turner 1984). Wetland loss in Gulf of Mexico estuaries was high historically, but the rate of wetland loss has slowed significantly. Drainage and development of wetlands for commercial and residential use are the major cause of wetland loss in the state of Florida (Duke and Kruczynski 1992).

During the period from 1979-1996, the PBS showed a net loss of wetland habitat of approximately 809 hectares, about 7% (Fig. 6-2). Not all of the wetland losses in the Gulf of Mexico are due to coastal development. Sea-level rise, coastal subsidence, and interference with normal erosion and deposition processes also contribute. The greatest contribution to wetland loss was attributed to the conversion of wetlands to uplands; only about 10% of the loss was conversion of wetlands to open water. Recognition of the ecological and economical importance of wetlands during the last decade has spurred the restoration and protection of these critical habitat areas.

Seagrass, or SAV, play a vital role in sustaining the ecological functions of estuaries. Water quality and light availability are key factors determining the health and distribution of SAV. Seagrasses provide food and other habitat values, such as protection from predators, for many estuarine species. Blue crabs and estuarine fishes, especially very young juveniles, are often found at much higher densities in SAV beds than in unvegetated habitats. Seagrasses act as filters and processors of nutrients and sediments, thereby helping to stabilize estuarine ecosystems. Since SAV species are sensitive to changes in water quality, loss of submerged vegetation within an estuary may be indicative of a decline in estuarine health.

SAV decline in the PBS, as documented by Olinger (1975), was significant in Escambia Bay from the 1940s through the early 1970s. By 1974, SAV beds in Escambia Bay were almost nonexistent (Rogers and Bisterfield 1995). A gap in survey data for SAV beds for the PBS existed until the early 1990s. A 1992 USGS survey showed a significant improvement in the distribution of SAV in Escambia Bay (Fig 6-3). The increase in SAV coverage has been attributed to reduced nutrient loadings, achieved through improved wastewater treatment methods. Mapping and monitoring of SAV in the Pensacola Bay System in 1998 showed continuing improvement in upper Escambia Bay. According to Lores and Specht (2001), grassbeds in areas of the system characterized by lower salinities are recovering faster than those associated with higher salinity. Coastal development is considered to be the major cause for the lack of SAV recovery in higher salinity areas.

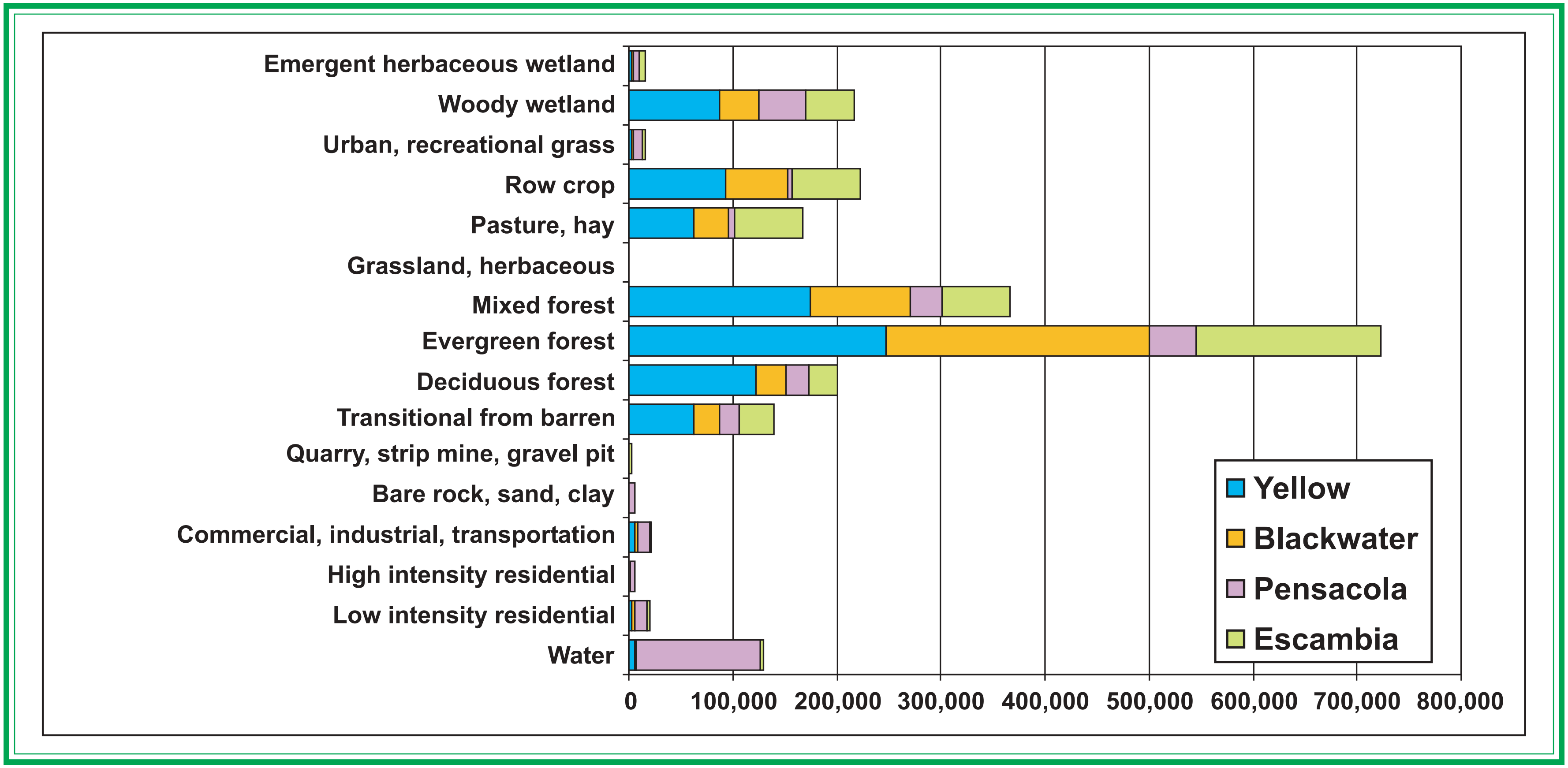

Figure 6-1 Land use characterization of the watershed draining into the Pensacola Bay system.

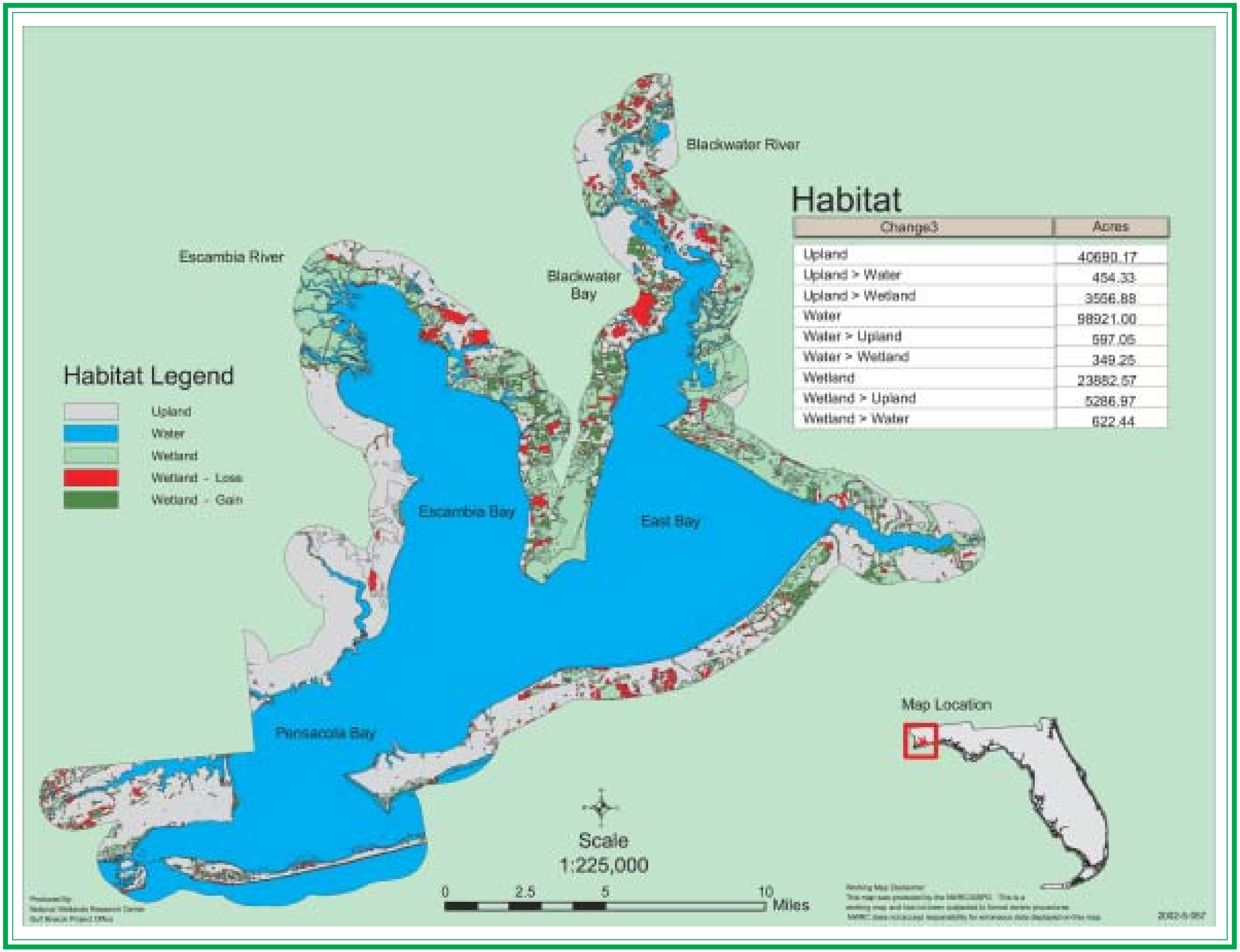

Figure 6-2 Net loss of wetland habitat in the PBS from 1979-1996.

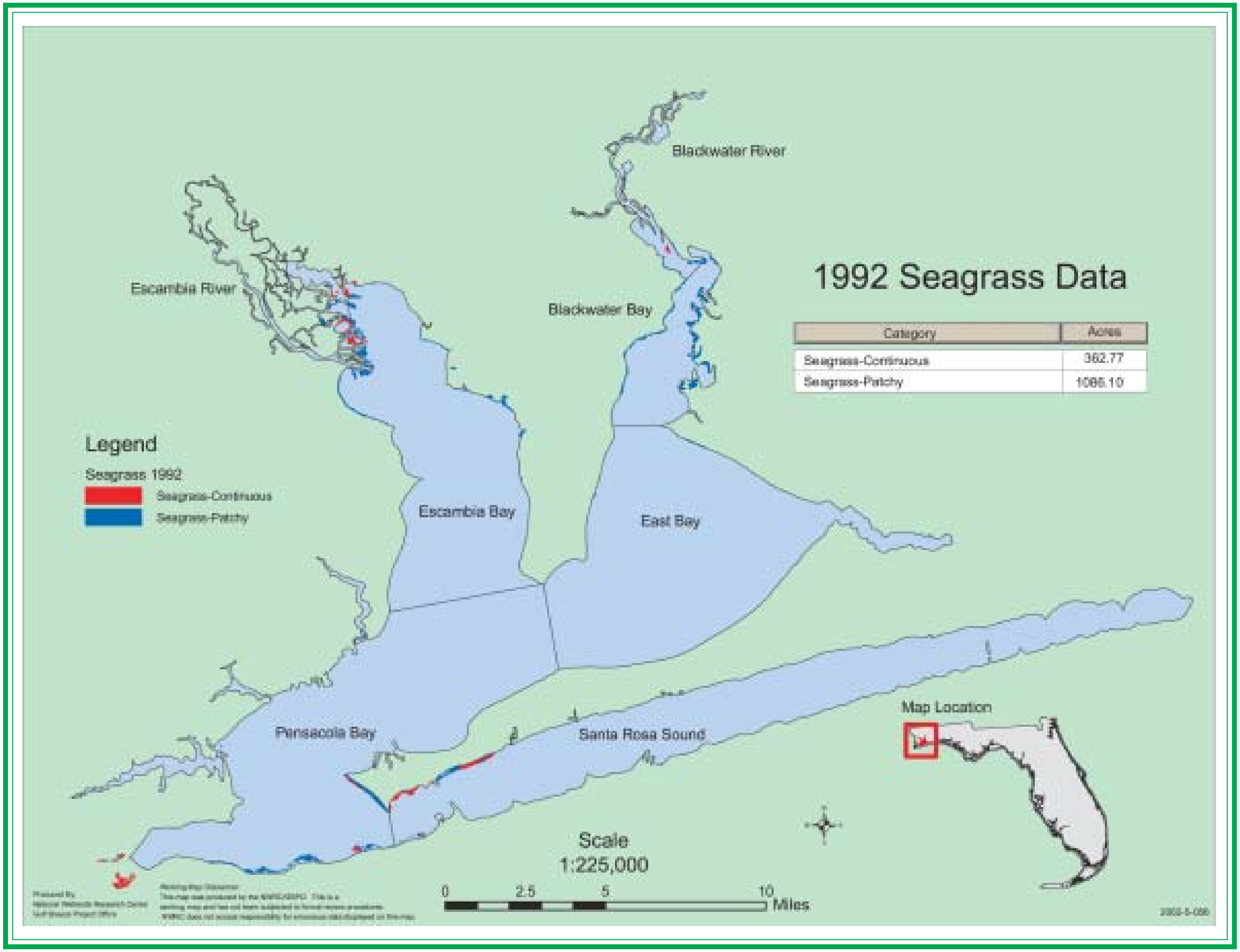

Figure 6-3 A 1992 survey of the extent of submerged aquatic vegetation throughout the Pensacola Bay System.

As with the abundance of SAV beds, shellfish beds may be an indicator of the biological health of an estuarine system. The Pensacola Bay system could be a very productive oyster harvest area based on hydrographic data such as salinity and temperature regimes. Oyster landings for Escambia County peaked in 1970 at approximately 63,502 kg (Collard 1991). Unfortunately, by 1971, over 90% of the commercially harvestable oysters in Escambia Bay fell victim to the parasitic disease caused by Perkinsus marinus, also known as Dermo. Lack of the hard substrate that larval oysters require for settlement, due to removal of dredged material and the loss of living oyster reefs to disease, has contributed to the decline. Although water quality has improved dramatically over the last two decades, oyster populations within the system have been slow to recover. Suitable substrate may be a limiting factor at present. Habitat restoration projects such as Project Greenshores are attempting to restore oyster reef habitat (FLDEP 2001). These restoration attempts may provide vital information in re-establishing oyster populations within the system.

In summary, the Pensacola Bay System suffered a period of maximum environmental degradation in the late 1960s-early 1970s, apparent in the loss of SAV and oyster beds during that period. The improvement of water quality and implementation of best land use practices, in conjunction with protection of wetland areas, are vital steps in the restoring and protecting the ecological health of the PBS.

7.0 Ecological Condition

In determining the current ecological condition of the PBS three indices were used: a water quality index, a sediment quality index, and benthic condition index. The supplemental information for developing the indices was presented in the appropriate sections. The three indicators were assigned a good, fair, and poor rating. These ratings were each assigned numerical values which were then averaged in order to create an overall score for the PBS. The use of indicators to describe coastal condition is still experimental. In this report, condition rating is based on reference conditions to address change in expectations for the indicators. The overall ecological condition for the PBS was assessed using a straightforward combination of the indicator scores.

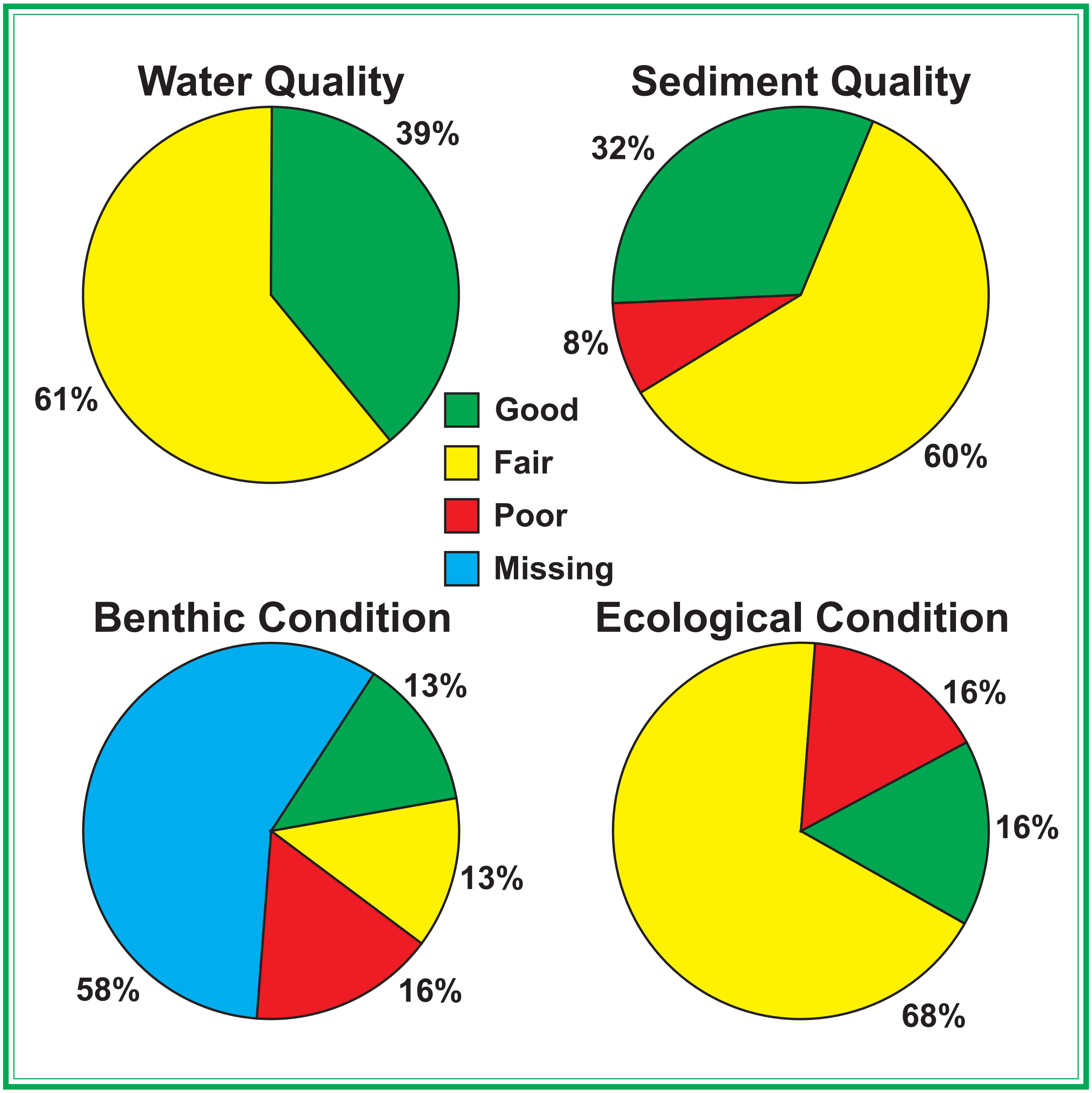

Figure 7-1 Percentages of the Pensacola Bay system exhibiting the different levels based on different indicator scores.

For water quality, 30% of the PBS was in good condition, with 61% fair (Fig. 7-1). The quality of the sediment was more diverse, with 8% poor, 60% fair, and 32% good. For benthic organisms, 16% of the area was poor, 13% fair, and 58% good, with 13% having missing values. When the results of these analyses were combined to determine the ecological condition of the system it indicated that 16% was poor, 68% was fair, and 16% was in good condition.

Results from these indices agree with the popular interpretation of current condition of the system. Overall, the PBS could be described as being in fair to good condition. There are periods, usually in the summer, when portions of the bottom of the system become hypoxic. The PBS can become stratified and contain temporarily elevated populations of pathogens, all associated with rainfall events. Though it is slow to flush, there were no highly elevated concentrations of contaminants in any of the sediments, with the exception of the bayous which will be addressed in a following section. According to our sediment index 92 % of the sediment is in good or fair condition, and the area of wetlands within the system has increased. However, the area of SAV throughout the system is still declining.

8.0 Bayous

8.1 Description

Three small tidal estuaries, Bayou Texar, Bayou Chico, and Bayou Grande, are located in the northwest portion of Pensacola Bay (Fig. 8-1). Each of these bayous is shallow and each receives runoff from areas with different land uses. Because of these factors some of the responses reported for the PBS have really been occurring in the bayous. Our study design did not supply enough data points to calculate indices and perform separate assessments, but the bayous have been well characterized. The most recent data have been summarized for this report.

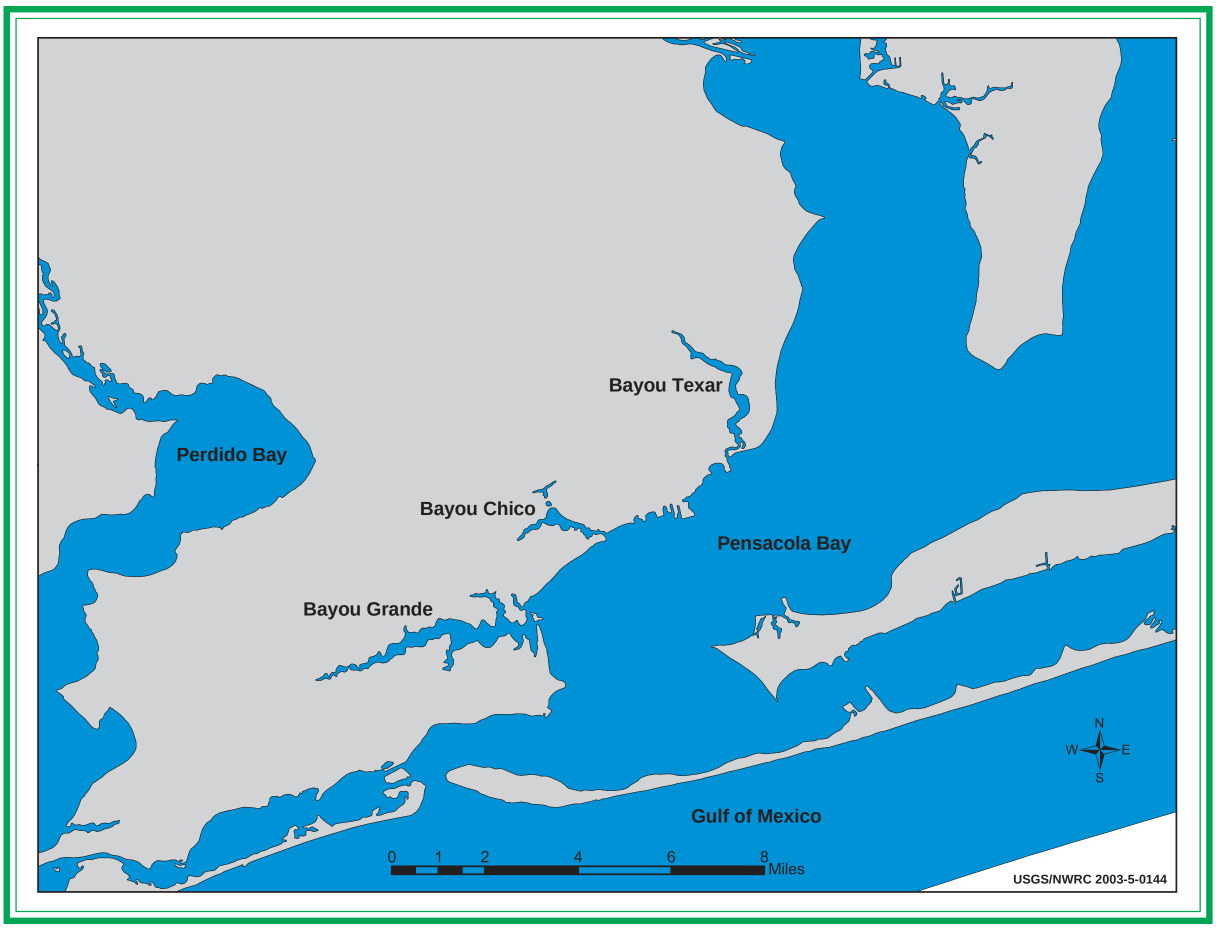

Figure 8-1 Locations of Bayou Texar, Bayou Chico, and Bayou Grande.

8.2 Bayou Texar

Lewis (2001) characterized Bayou Texar as having a surface area of 1.4 km^2 with a volume of 3 million cubic meters ($3 \times 10^6 m^3$) and an average depth of 2 meters. It is described as a residential bayou with recreational uses. It flushes at a higher rate than the other bayous, approximately 24% of its volume daily. There are several factors acting upon Bayou Texar that can potentially impact it. There are maintained lawns extending to the water's edge, it receives stormwater runoff from Carpenters Creek, and it also receives groundwater from a superfund site. Bayou Texar designated use is for recreational fishing and water sports.

Bayou Texar exhibits annual concentrations of nitrogen and phosphorus that are greater than the other bayous and the PBS (Smith et. al. 2001). The elevated nutrients correlate with a high concentration of chlorophyll a in the bayou. Concentrations of nitrogen have been observed to be four times greater than those measured in the open bay system during the summer. Spring fertilizer application and increased stormwater runoff may be driving the nitrogen concentrations. There have also been elevated levels of fecal bacteria associated with the runoff events, causing closure of the bayou to recreational activities. Surface waters in Bayou Texar exceed the State of Florida criteria for Class III waters for cadmium, copper, and nickel (Table 8-1). Sediment concentrations of polycyclic aromatic hydrocarbons (PAHs), DDTs, copper, lead, cadmium, and zinc exceed both the probable effects level (PEL) for the State of Florida and ERL guidance value. Sediment concentrations of mercury in the upper bayou exceed the ERM guidance values (Table 8-2).

Table 8-1. Analyte Maximum measured concentration in water (ug/L). Values in bold exceed the FL criteria for Class III marine waters.

	Criteria	Bayou Texar	Bayou Chico	Bayou Grande
Cadmium	9.3	**15.0**	**13.7**	**13.5**
Chromium	50	43.0	36.5	13.7
Copper	2.9	**22.4**	**18.7**	**18.2**
Lead	5.6	ND	ND	ND
Nickel	8.3	**33.0**	**29.5**	**16.7**
Zinc	86	22.3	21.7	22.6

ND = Below detection limit.

8.3 Bayou Chico

Bayou Chico is the smallest of the three bayous with a surface area of 1.0 km^2, volume of 2 million cubic meters (2×10^6 m^3), and an average depth of 2 meters. The land use surrounding Bayou Chico is split, with the southern portion industrial and the northern portion residential. The industrial area consists of marinas, dry docks, ship construction, barge operations, metals salvage, and a large chemical manufacturing facility. Stormwater runoff has impacted the bayou to such an extent that the local government and citizen groups have focused on efforts to control runoff through increased treatment and regulation. In addition to the stormwater, Bayou Chico also receives the discharges from a large number of septic tank drain fields.

Seasonally, Bayou Chico had the highest concentrations of chlorophyll a (30 μg/L) in the summer, higher than any of the other bayous, although the nitrogen and phosphorus levels never exceeded 0.15 mg/L. A chlorophyll concentration of this level would classify Bayou Chico as impaired under the State of Florida criteria, and rank poor using our index. Surface waters from the bayou exceeded the State of Florida criteria for Class III waters for cadmium, copper, and nickel (Table 8-1). Sediment concentrations of polychlorinated biphenyls (PCBs), DDTs, copper, lead , and zinc exceeded the PEL and ERL values. Concentrations of arsenic, cadmium, and mercury in the sediments also exceeded the ERL value (Table 8-2).

Table 8-2.

Analyte — **Maximum measured concentration in sediment. Metals (ug/g dry wt.), Organics (ng/g dry wt.). Values in bold exceed the ERL guidance (Long et al. 1995).**

Analyte	ERL	Bayou Texar	Bayou Chico	Bayou Grande
Arsenic	8.2	1.1	**11.7**	7.9
Cadmium	1.2	**2.9**	**1.9**	**4.8**
Chromium	81	51.7	56.8	**178.1**
Copper	34	**237.8**	**206.9**	**38.1**
Lead	46.7	**155.5**	**147.5**	**128.9**
Mercury	0.15	**1165.2***	**428.1**	**172.9**
Nickel	20.9	17.4	20.4	14.2
Zinc	150	**1069.6**	**979.9**	**199.2**
Total DDT	1.6	**29.3**	**80.5**	**17.2**
Total PAHs	4020	**4475.2**	-	179.1
Total PCBs	22.7	**22.9**	**99.7**	**70.2**

**** Value exceeds the ERM guidance (Long et. al.)***

8.4 Bayou Grande

Bayou Grande is approximately four times larger than the other two bayous, with a surface area of 4.3 km^2, a volume of 10 million cubic meters($1 \times 10^7 m^3$), and an average depth of 3 meters. Land use around the bayou is mixed; residential on the northern side, with a military installation (Naval Air Station Pensacola) to the south. Both areas contribute to the stormwater runoff into Bayou Grande, and the residential side has a large number of septic tank drain fields. Naval Air Station Pensacola has a marina, a golf course, aircraft runway, and areas of dense woods adjacent to the bayou. In addition, NAS Pensacola also has restoration sites or areas that have been identified as requiring contamination assessment and soil remediation. The bayou is utilized for both recreational fisheries and watersports.

The chlorophyll and nutrient concentrations in Bayou Grande are similar to those measured in the open bay system. The only exception was that chlorophyll a was elevated (12 μg/L) in the summer compared to the open bay (6 μg/L). The surface waters in Bayou Grande contained concentrations of cadmium, copper, and nickel that exceeded the State of Florida criteria for Class III waters (Table 8-1). Sediments from the bayou exceeded the PEL and ERL for cadmium, chromium, lead, and DDTs. The ERL was also exceeded for PCBs, copper, mercury, and zinc (Table 8-2).

8.5 Summary

All three bayous, Texar, Chico, and Grande, had concentrations of the same contaminants present in the water and in the sediment. Each bayou had 8 compounds exceed of the ERL guidance values for sediment and 3 exceedances of the State of Florida criteria for Class III waters. Bayou Grande exhibited the lowest concentrations of contaminants in both the water and sediment compared to the other 2 bayous. Bayou Chico ranked next, followed by Bayou Texar with highest concentrations of contaminants. The absence of similar concentrations of contaminants found in the bay system outside each of the bayous indicates that the material may not be easily transported. These contaminants may be binding to the sediments and remaining in the bayous due to the low flushing and transport rates. The bayous appear to be acting as sinks or catchment basins for a large amount of the stormwater runoff. Because each bayou is somewhat isolated from the bay system, the effects of stormwater runoff are contained and in some cases magnified, as indicated by algal blooms and closures due to bacterial levels.

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