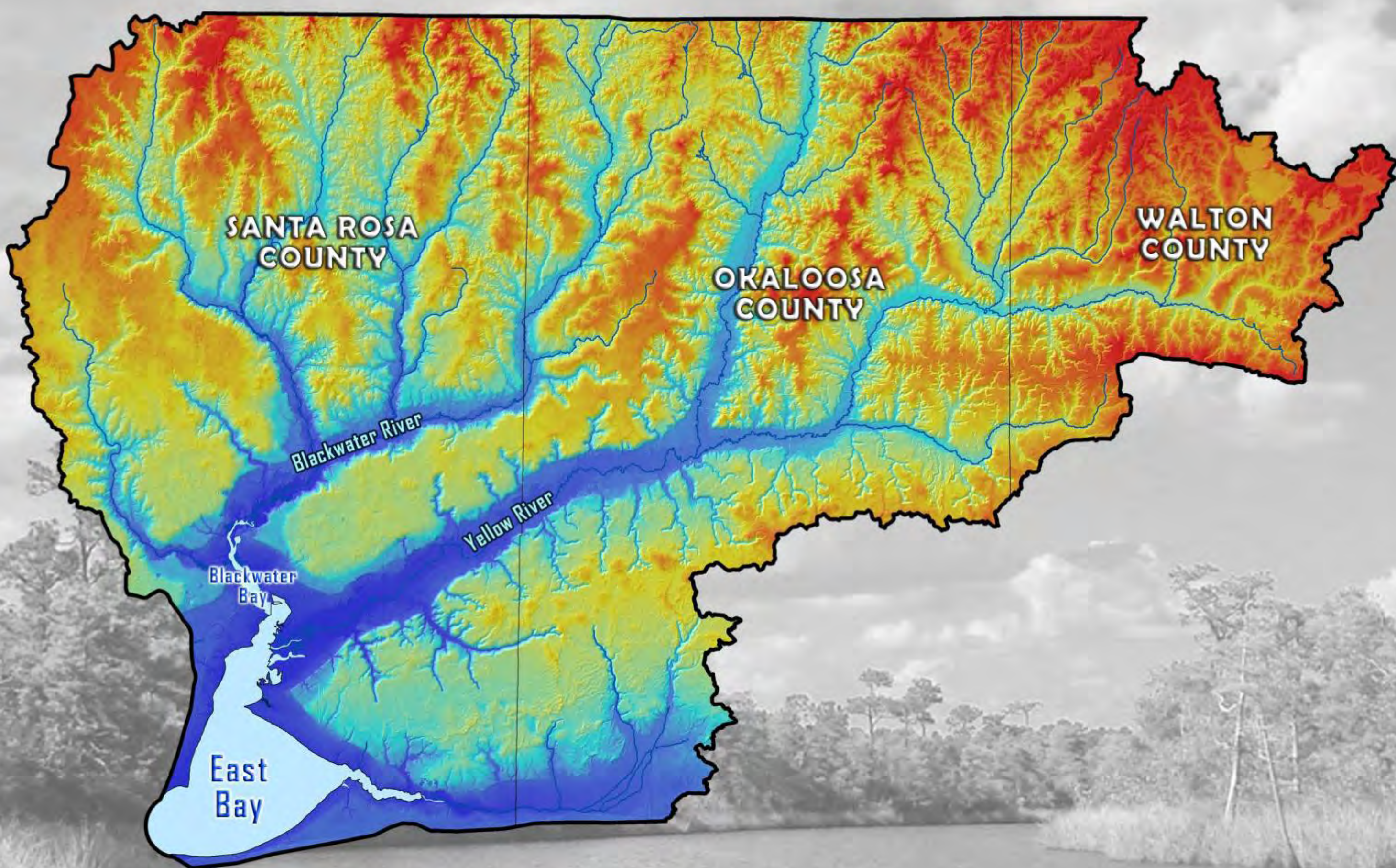
EAST BAY/BLACKWATER BAY/LOWER YELLOW RIVER PRELIMINARY BASELINE RESOURCE CHARACTERIZATION

With a Discussion of Flow-dependent Habitats and Species



By
F. Graham Lewis, Ph.D.

Northwest Florida Water Management District
Water Resources Special Report 2010-02

FINAL REPORT
October 2010

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Cover: *John Crowe, NWFWMD*

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1.0 INTRODUCTION

1.1 Surface Water Improvement and Management Program

The Pensacola Bay system was included by the Northwest Florida Water Management District (NWFWMD) as one of its priority water bodies in the Surface Water Improvement and Management (SWIM) Program. The SWIM Program was initiated by the Florida legislature in 1987 to prioritize surface waters of the state and to develop and implement plans to improve the quality of these waters and their associated resources. The five water management districts were directed to carry out the SWIM Program under the aegis of the Florida Department of Environmental Regulation (now the Florida Department of Environmental Protection (FDEP)). The SWIM Plan for the Pensacola Bay system was originally approved in 1988, with revisions in 1990 and 1997. The 1997 revision expanded the watershed and planning area boundary to include the Escambia, Blackwater, Yellow, Shoal, and East Bay rivers and the majority of Santa Rosa Sound as well as the bays and their associated bayous. The plan includes a variety of projects to assess and improve water, sediment and habitat quality, to enhance public education and awareness, and to assist in the administration, planning and coordination of the various resources management initiatives in the basins (Thorpe et al. 1997).

1.2 Watershed Research and Evaluations

Numerous studies and evaluations related to the Pensacola Bay system provide a broad range of information about activities within the drainage basin. As part of the Pensacola Bay SWIM Program, the NWFWMD identified point sources of pollution within the watersheds (Wiley et al. 1990), completed a review of nonpoint source methodologies (NWFWMD 1993) and developed preliminary nonpoint loading rates for the system (Hunner et al. 1994), assessed existing water and sediment quality data (Jones et al. 1992; Roaza and Pratt 1992; Wood and Bartel 1994), provided stormwater assessments for Bayou Chico (Pratt et al. 1993), Bayou Texar (NWFWMD 1988) and the Palafox/Coyle watersheds (Guo and Pratt 1993; Hunner et al. 1995), reviewed and assessed the current status and trends of biological communities (Collard 1991a) and management options for habitat restoration and monitoring (Collard 1991b), updated the assessment of biological monitoring data collected within the system (Von Appen and Winter 2000) and, most recently, reassessed sediment quality throughout the system (DeBusk et al. 2002).

1.3 Watershed Protection and Preservation

The NWFWMD uses a variety of management strategies and tactics as identified in the Pensacola SWIM Plan (1997) to restore, protect and preserve the water resources in the watershed. Some of the ongoing activities include: hydrologic data collection and monitoring, freshwater needs assessment, local stormwater planning assistance, reuse of reclaimed water, construction of stormwater retrofit facilities and implementation of stormwater Best Management Practices (BMPs), integration of the Flood Hazard Map Modernization Program, preservation of critical lands and habitats, ecological restoration, and public education and outreach. The implementation of these activities is outlined in the SWIM Plan.

In addition to these activities, the NWFWMD initiated a program of water quality protection in the watersheds through land acquisition. Using funds from Preservation 2000, Save Our Rivers, Florida Forever and Florida Department of Transportation, the NWFWMD has purchased property along the Escambia, Blackwater, and Yellow/Shoal Rivers as well as on Garcon Point. As of the end of 2009, the NWFWMD had purchased approximately 34,919 acres along the Escambia, 380 acres along the Blackwater, and 17,742 acres along the Yellow/Shoal Rivers; the District currently owns 3,245 acres on Garcon Point. Additional acreages in these basins have been identified for possible acquisition (NWFWMD 2009).

1.4 Purpose and Scope

Freshwater inflows are a dominant influence on habitat and biological resources within the Pensacola Bay system. The quantity, quality and timing of these discharges is critical to maintaining the estuarine conditions found here. Recent activities in the eastern portion of the drainage basin have the potential to affect biological resources in East Bay/Blackwater Bay prompting this compilation of available data and preliminary baseline resource assessment. The Yellow River, for example, was recently considered for impoundment and use as a surface water source for future public water supplies by the U.S. Army Corps of Engineers (USACOE 2004). An existing Sand and Gravel Aquifer wellfield between the Blackwater and Yellow Rivers that is permitted currently to extract relatively small quantities of groundwater connected to these rivers has been proposed for expansion. Additionally, surface water and/or riverbank wells within the Yellow/Shoal Rivers basin have been proposed to divert small quantities of surface water for public water supply. Potential upstream water diversions within the State of Alabama are also possible, although little is known at present.

The primary focus of this study is to provide a detailed description and characterization of water resources and natural systems within the Blackwater/East Bay system. The following report focuses on those resources potentially affected by altered surface water discharges into East and Blackwater Bays, including the lower portion of the Yellow River.

2.0 THE PENSACOLA BAY SYSTEM

The Pensacola Bay watershed covers nearly 7,000 square miles (Figure 1), about one-third of which is in Florida (Thorpe et al. 1997). This area includes the majority of Escambia, Santa Rosa and Okaloosa Counties, the northwestern quadrant of Walton County, and a substantial portion of southern Alabama. Three major rivers, the Escambia, the Blackwater and the Yellow Rivers, discharge into the Pensacola Bay complex and provide the bulk of the freshwater input to the system. These rivers vary considerably in length, basin size, and type (Thorpe et al. 1997).

The Pensacola Bay estuarine system is a drowned river estuary and lagoon located in the extreme western portion of the panhandle of Florida. The system consists of five interconnecting waterbodies, Pensacola Bay, Escambia Bay, Blackwater Bay, East Bay, and Santa Rosa Sound (Figure 2), with a combined surface area of about 144 square miles (Thorpe et al. 1997), excluding Santa Rosa Sound. The bays stretch approximately 25 miles (roughly west to east, excluding Santa Rosa Sound) along an axis parallel to the Gulf of Mexico and extend about 20 miles inland (Thorpe et al. 1997).

The boundaries of the estuarine system extend from the head of tide on the Escambia River near Quintette, on the Blackwater River approximately 5 km north of US Highway 90, and the Yellow River near its juncture with Blackwater Bay (Orlando et al. 1993). The bays are separated from the Gulf of Mexico by Santa Rosa Island which absorbs the majority of the wave energy to the system. A single 800 m wide inlet (Caucus Channel at Ft. Pickens) provides for the predominant exchange of water between the Gulf and the bays.

The Pensacola Bay system historically supported a rich and diverse ecology, productive fisheries and considerable recreational opportunities (Thorpe et al. 1997). It also provided significant economic and quality-of-life benefits for the residents of northwest Florida. Unfortunately, it has become apparent that the cumulative effects of a variety of human activities over the last several decades have impaired the system's ecology and diminished the benefits it provides. Point and nonpoint pollution, direct habitat destruction, and the impacts of development and other activities throughout the watershed have combined to degrade the health and productivity of the bay.

3.0 GENERAL FEATURES OF EAST BAY/BLACKWATER BAY

The East Bay/Blackwater Bay complex is a relatively small shallow estuarine embayment located in the eastern portion of the Pensacola Bay system (see Figure 2). The bay system consists of a relatively shallow shelf peripheral to a deeper mid-bay region (Figure 3). Blackwater Bay, the northern component, has a surface area of approximately 25 km^2 with a mean depth of 2.0 m; East Bay covers approximately 110 km^2 and has a mean depth of 2.5 m (Collard 1991a).

Circulation in the bays is limited (Jones et al. 1992) and is a function primarily of tidal action, freshwater inflows, basin morphology and winds. Tides are a major component of

Watershed of the Pensacola Bay System

Figure 1. Watershed of the Pensacola Bay system; note over half of the watershed is located outside the State of Florida.

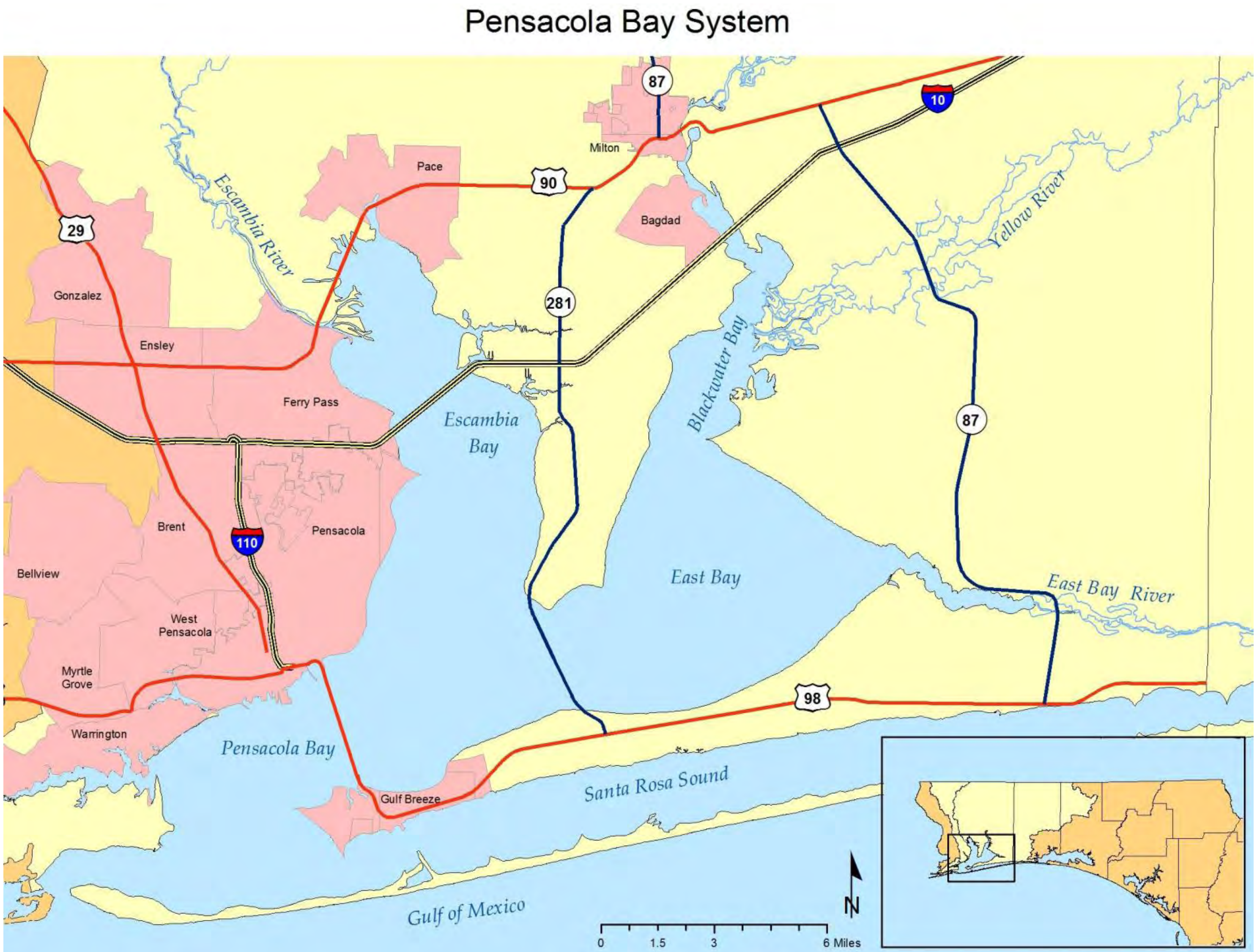


Figure 2. The Pensacola Bay system with Blackwater and East bays making up the eastern portions of the Pensacola estuary.

Pensacola Bay Bathymetry

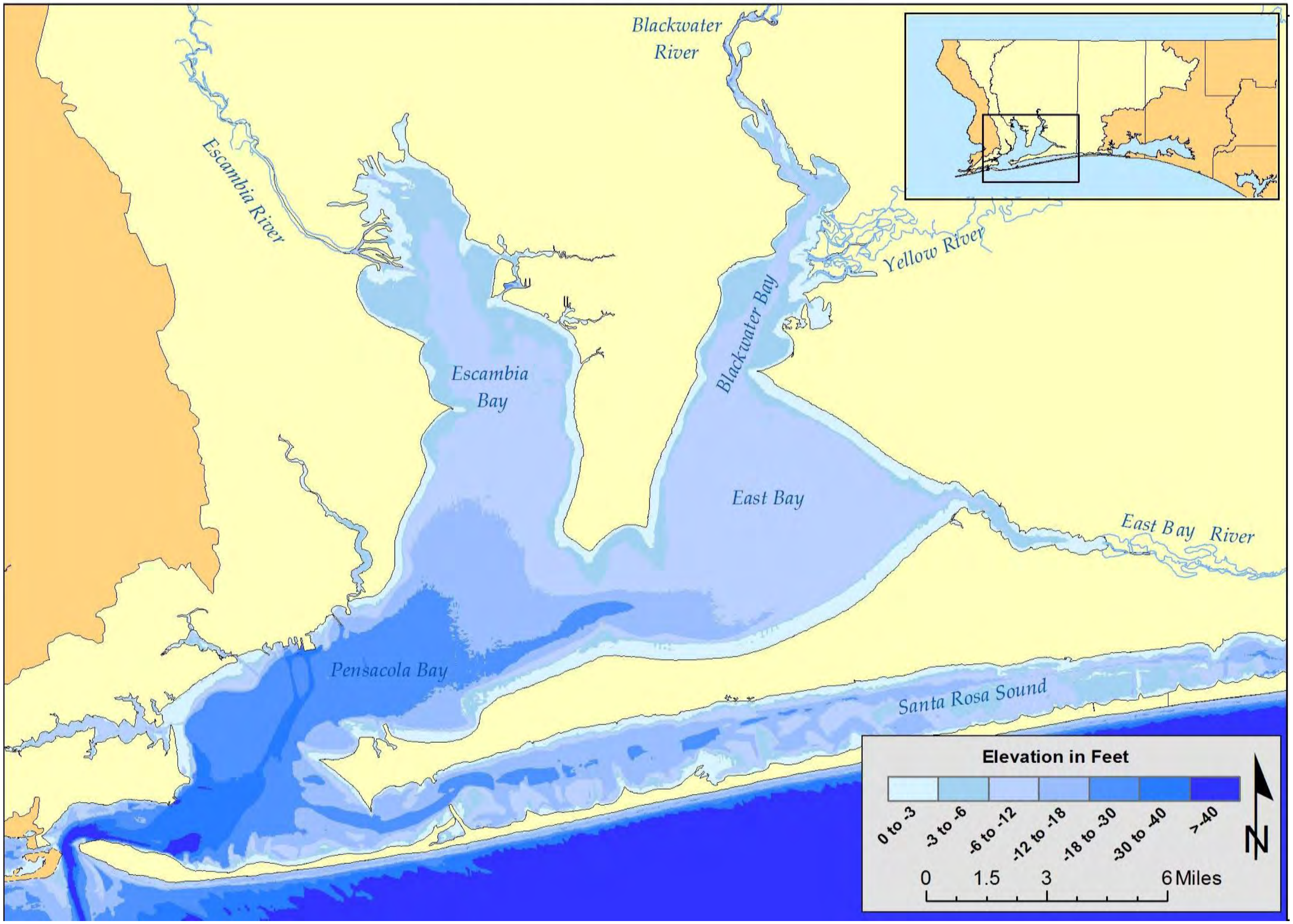


Figure 3. Bathymetric profile of the Pensacola Bay system. Depth contours are shown in feet.

circulation in many estuarine systems; however, because of the location of the Pensacola system along the Gulf coastline, tidal energy is minimal. Tides in this region are predominantly diurnal (one tidal cycle per day) with average amplitude of 0.34 m (1.1 ft) at the entrance on Pensacola Bay.

According to Jones et al. (1992), East Bay is the least affected portion of the Pensacola Bay system to factors influencing circulation; East Bay has very little transport capability due to tidal forcing alone, indicating that circulation is extremely weak. They suggested that East Bay has reduced assimilative capacity because of this limited response to tidal fluctuations. These observations underscored conclusions made by Collard (1991a) that East Bay was one of the more vulnerable areas of the Pensacola Bay system, in part, because of poor circulation and limited flushing.

3.1 Watershed/Drainage Basins

Three watersheds provide the bulk of the surface drainage to the East Bay/Blackwater Bay complex (Figure 4). The majority of freshwater is derived from the Blackwater and Yellow Rivers; a relatively small flow volume is contributed from the East Bay River.

The Blackwater River originates in Bradely, Alabama, and travels south approximately 62 miles before discharging into Blackwater Bay. The river drains approximately 860 squares miles, of which about 700 are within Florida, and has an average annual discharge of about 342 cubic feet per second (cfs), as gaged at Baker, Florida, about 35 miles above its mouth (Mossa 1998). The major source of flow is groundwater discharge from the Sand and Gravel Aquifer, with a smaller contribution from surface runoff. Surface waters drain primarily from acidic flatwoods and other wetlands adjacent to the river, giving it a reddish color due to the presence of tannins and organic acids. The Blackwater River is designated an Outstanding Florida Water and is among the most popular waterbodies in the state for canoeing and other recreactional activities (Thorpe et al. 1997). The upper Blackwater River and its tributaries have been described as swift, relatively shallow and sand-bottomed (Bass and Hitt 1977). The lower Blackwater River system receives discharge from domestic wastewater treatment facilities, and portions of the system are subject to impacts from nonpoint source pollution. A series of lake-like freshwater and brackish basins are found in the lower reach, much of which is tidally influenced. Water quality in general has been characterized as excellent with much of the river basin protected by conservation lands (Thorpe et al. 1997).

The Yellow River originates in Covington County, Alabama, and travels 110 miles to Blackwater Bay. The river has a drainage basin of about 1,365 square miles with an extensive forested floodplain (Thorpe et al. 1997). Average annual discharge is approximately 1,181 cfs as measured at Milligan, Florida, about 40 miles above its mouth (Mossa 1998). The Yellow River is described as a sand-bottom river with shallow, clear-tan waters. The main tributary of the Yellow River is the Shoal River, which originates in northern Walton County. The Shoal River drains approximately 499 square miles (Thorpe et al. 1997) and has an average annual discharge of about 1,104 cfs as gaged at Crestview, Florida, about seven miles above it confluence with the Yellow River (Mossa

Figure 4. Watersheds draining into East Bay/Blackwater Bay.

1998). A recently established gage on the lower Yellow River (SR87 near Milton) downstream of the confluence with the Shoal has measured an average flow of 2,289 cfs. The lower portion of the Yellow River, and parts of Blackwater and East Bays, are managed as the Yellow River Marsh Aquatic Preserve. The Shoal River and waters within the Aquatic Preserve are designated as Outstanding Florida Waters. The Yellow River system is subject to a variety of nonpoint pollution sources, as well as drainage from domestic and industrial wastewater reuse facilities (Thorpe et al. 1997). Urban runoff from the town of Crestview is problematic for both the Yellow and Shoal Rivers (Thorpe et al. 1997). Despite these impacts, water quality throughout the system has been described as some of the most pristine in the state (DEP 1998).

3.2 Land Use

Land use and land cover in the vicinity of East Bay/Blackwater Bay (Figure 5) is predominantly undeveloped wetlands and upland forests to the east (Eglin property),

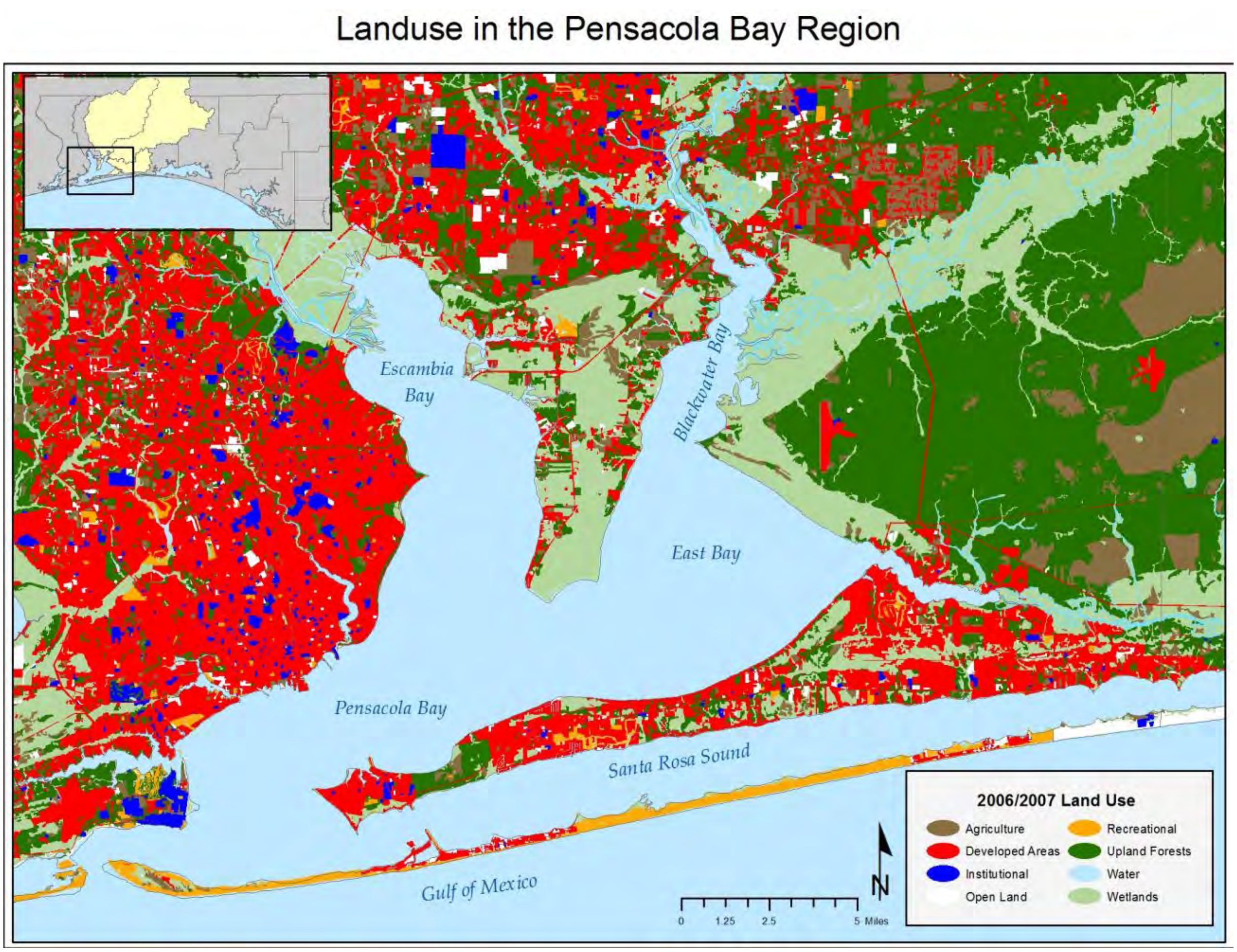


Figure 5. Landuse in the Pensacola Bay region. Landuse/landcover data are based on 2006-2007 information (FDEP 2006-2007).

agriculture and wetlands to the west (Garcon Point), and residential to the north and south associated with the town of Milton and the Gulf Breeze peninsula. Predominant land use within the Florida portion of the East Bay/Blackwater Bay watershed is upland forest, comprising nearly 54% of the acreage; wetlands (19%) and agricultural lands (18%) make up the majority of the remainder. Land use proportions vary somewhat within the three basins with upland forests ranging from 48.1% (East River) to 56.6% (Blackwater) and wetlands spanning from 15.4% (Blackwater) to 26.2% (East River). Developed areas averaged about 7.5% over the watershed, ranging from 7.0% (Yellow) to 11.1% (East River) within the basins.

A significant portion of the watershed is in public ownership (Figure 6) with large tracts owned and managed by the NWFWMD, the State of Florida (e.g. Blackwater State Forest) and federal government (e.g., Gulf Islands National Seashore, Eglin Air Force Base, Hurlbert Field, Naval Air Station Pensacola).

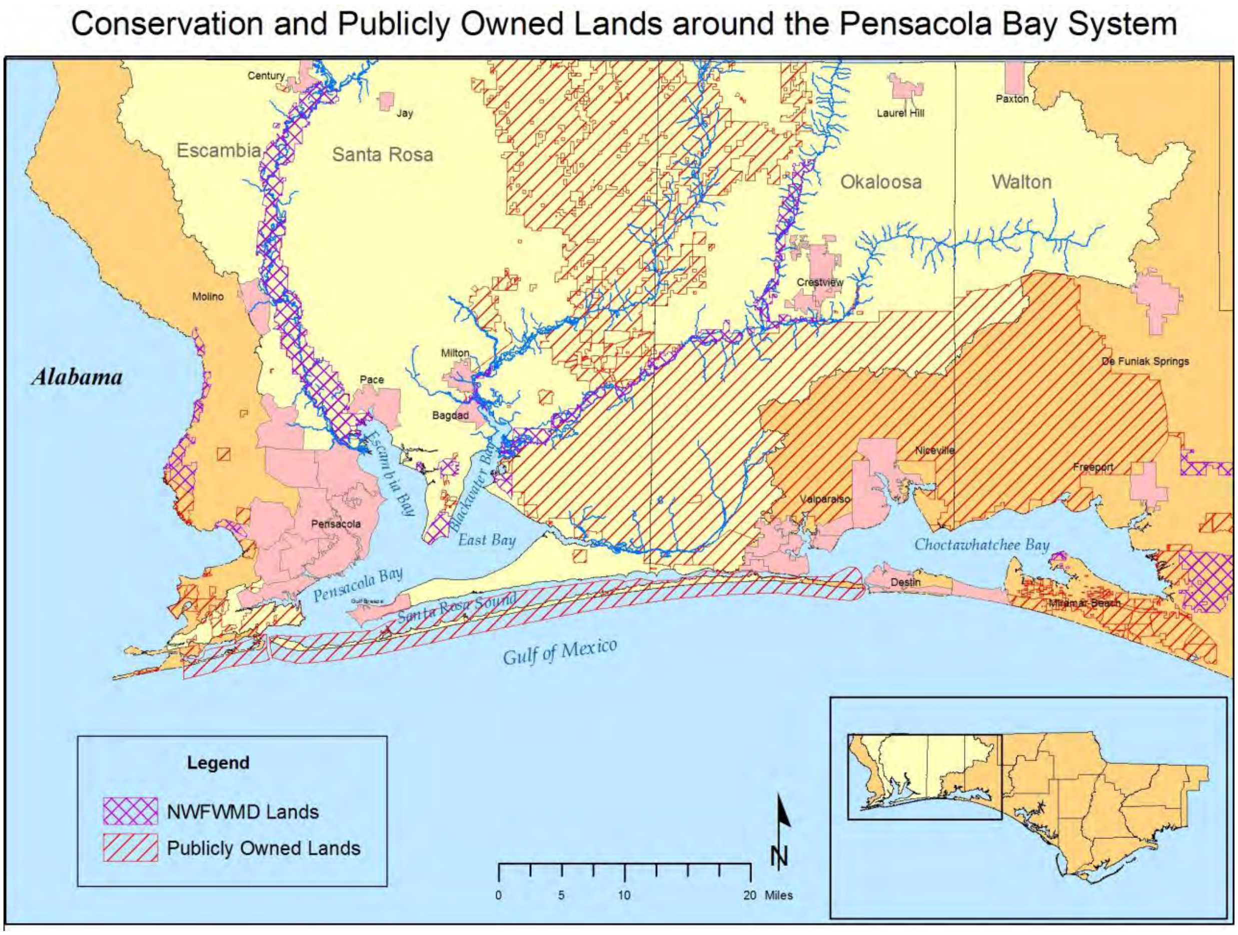


Figure 6. Conservation and publicly owned lands surrounding the Pensacola Bay system.

3.3 Freshwater Discharge

The primary freshwater inflows to the East Bay/Blackwater Bay system include the Blackwater River and the Yellow/Shoal Rivers, both of which discharge into Blackwater Bay proper. Relatively small amounts of freshwater enter East Bay directly through the East Bay River. Gages are located on the Blackwater, Yellow and Shoal Rivers with records extending for over 50 years; the East Bay River is ungaged.

Blackwater River flows, as recorded at the Baker, Florida gage over the period of record (1950 to 2008), are shown in Figure 7. Daily discharge has varied noticeably from 58 cfs to 23,900 cfs over the period of record and exhibited a moderate degree of seasonality. Monthly mean flows ranged from 64 cfs to 2029 cfs. Highest flows are generally found during winter and early spring (January to March) with lowest flows in the fall (September to November). Greatest discharge during the period of record was measured on 29 September 1998 associated with Hurricane Georges. The hurricane made landfall on 28 September 1998 near Biloxi, Mississippi, and turned eastward, dropping large quantities of rainfall over the panhandle during the following two days. Over 24 inches of rainfall were officially recorded at Eglin AFB, to the east, associated with the storm (Guiney 1999), significantly affecting discharge of all rivers in the area.

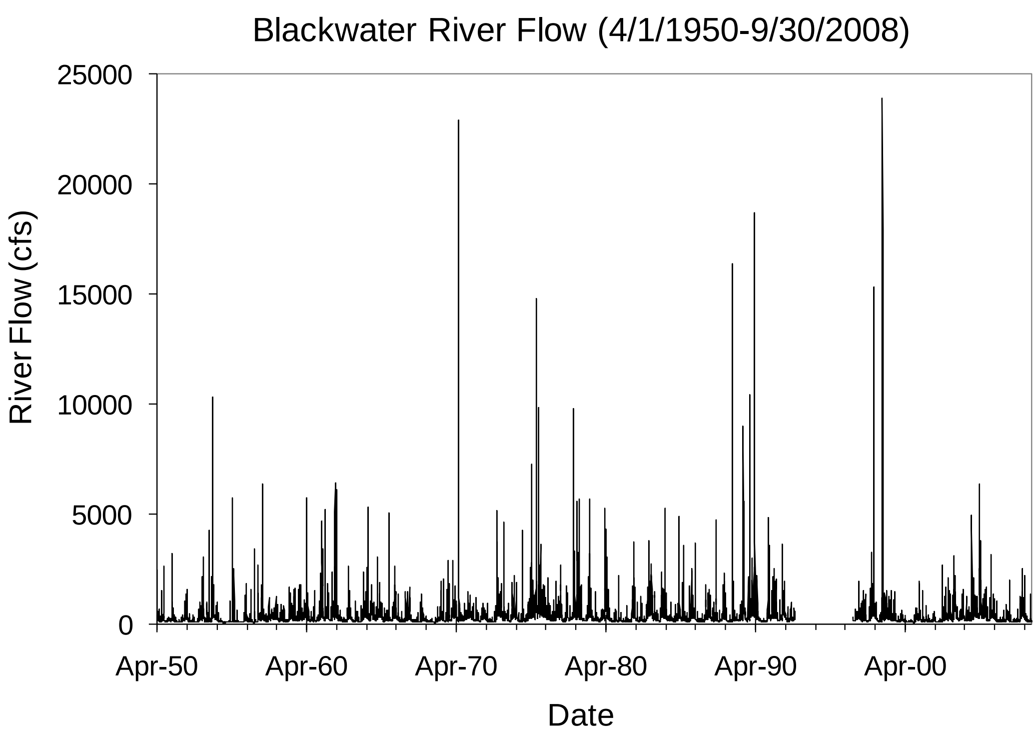


Figure 7. Blackwater River discharge measured at Baker, FL, for the period from April 1950 to September 2008. Missing data: 11/18/92 to 9/30/96. Source: U.S. Geological Survey 2009.

Since the gage at Baker only captures flow from the upper portions of the Blackwater River basin, it is useful to include additional discharge measured at the Big Coldwater Creek gage as a contributor to estuarine inflows. Big Coldwater Creek is a major tributary of the Blackwater River below the Baker gage and as such provides significant inflows into Blackwater Bay. In fact, average flow in the creek is 562 cfs, thus adding more than 1.5 times the flow to the river as that measured at the upstream gage. Discharge varied significantly over the period of record (Figure 8) ranging from 158 cfs to 29,700 cfs. Although discharge was very high associated with Hurricane Georges, greatest flow was measured on 17 March 1990 unassociated with tropical weather conditions.

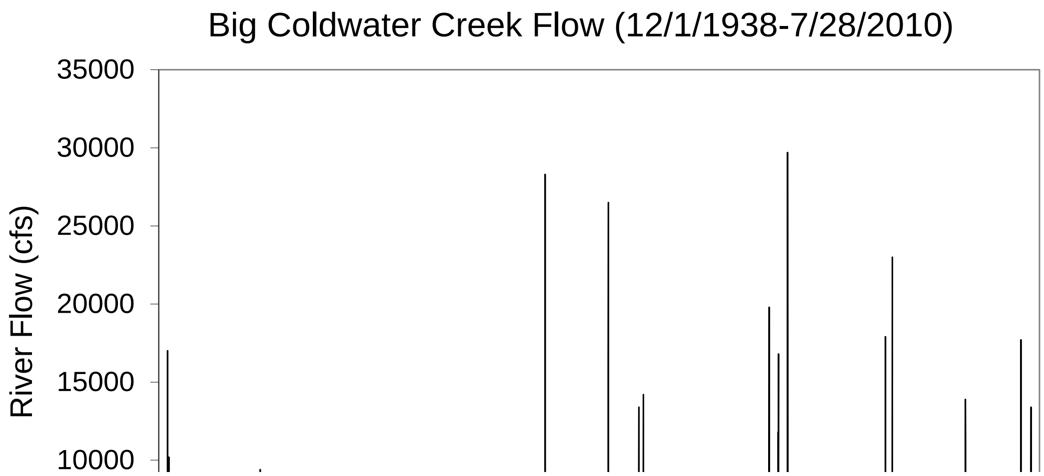


Figure 8. Big Coldwater Creek discharge measured near Milton, FL, for the period from December 1938 to September 2010. Missing data: 6/12/79-2/12/80, 4/23/80-7/14/80, 3/4/92-9/30/97, 9/1/99-4/30/00. Source: U.S. Geological Survey 2010.

Significantly greater amounts of freshwater enter the bay system from the Yellow/Shoal River complex. Both rivers are gaged above their confluence such that freshwater entering Blackwater Bay is a combination of the two. Yellow River discharge, as recorded at the Milligan, Florida gage (1938 to 2008), is shown in Figure 9. Daily flow varied greatly from 123 cfs to 71,700 cfs over the period of record and exhibited moderate seasonality. Monthly mean flows ranged from 127 cfs to 6,587 cfs. Highest flows were generally found during winter and early spring (January to April) with lowest flows in the fall (September to November). Greatest discharge during the period of record was measured on 1 October 1998 associated with Hurricane Georges.

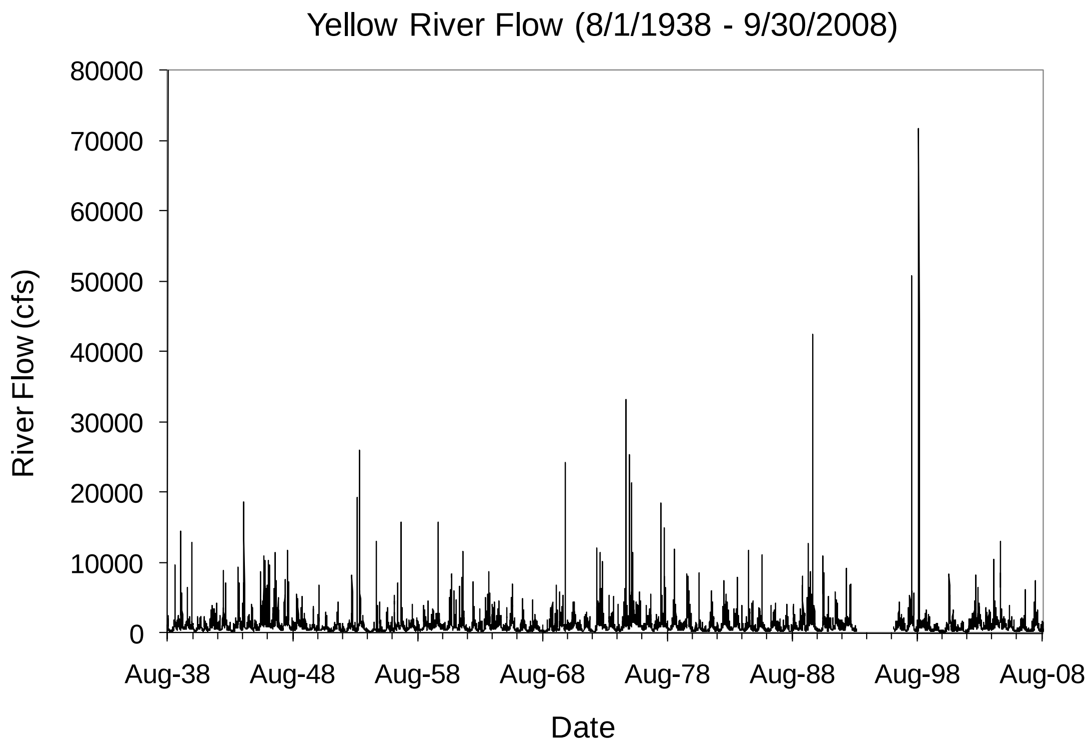


Figure 9. Yellow River discharge measured at Milligan, FL, for the period of record from August 1938 to September 2008. Missing data: 10/18/93 to 9/30/96. Source: U.S. Geological Survey 2009.

Shoal River flows, as recorded at the Crestview, Florida gage over the period (1938 to 2008), are shown in Figure 10. Daily discharge on the Shoal River was similar to that observed for the Yellow River; flows varied greatly from 186 cfs to 55,500 cfs over the period of record and exhibited a moderate degree of seasonality. Monthly mean flows ranged from 261 cfs to 5,436 cfs. As with the Yellow, highest flows are generally found during winter and early spring (January to April) with lowest flows in the fall (October to November). Greatest discharge during the period of record was measured on 30 September 1998, again associated with Hurricane Georges.

The Yellow River is currently gaged at the SR87 bridge near Milton, Florida, below the confluence with the Shoal River. This site provides a measurement of the combined flows from the upper reaches of both rivers although the period of record is considerably shorter (10/1/2001 to present) than for the two upstream gages. Average flow at this site is 2,289 cfs, varying daily from 471 cfs to 9,290 cfs (Figure 11). Seasonality is similar to that noted at other sites.

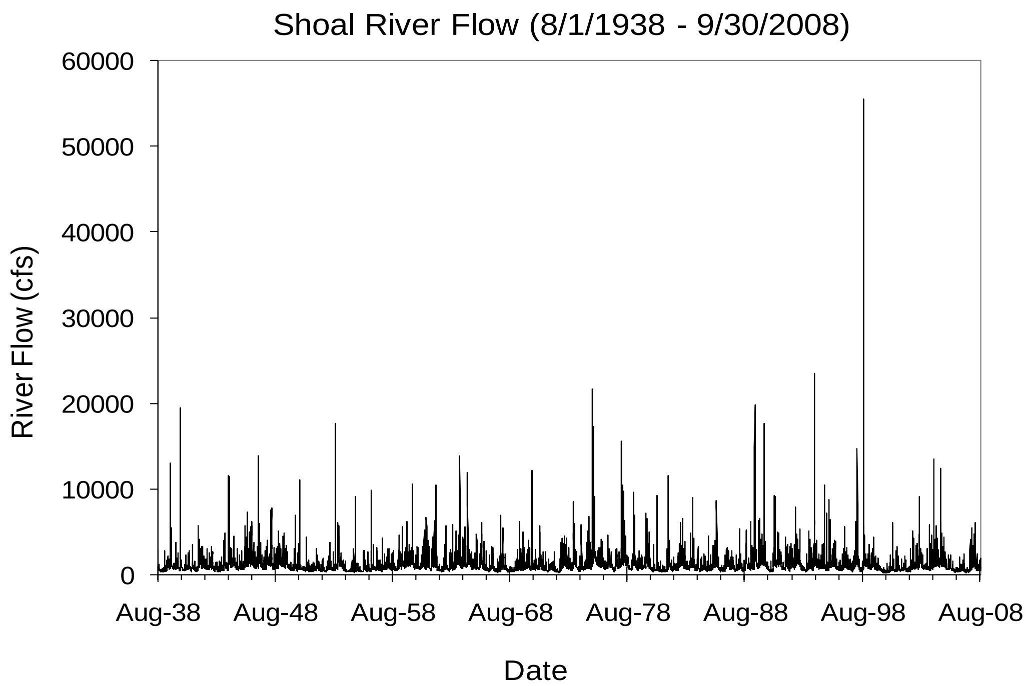


Figure 10. Shoal River discharge measured at Crestview, FL, for the period of record from August 1938 to September 2008. No missing data in the period of record. Source: U.S. Geological Survey 2009.

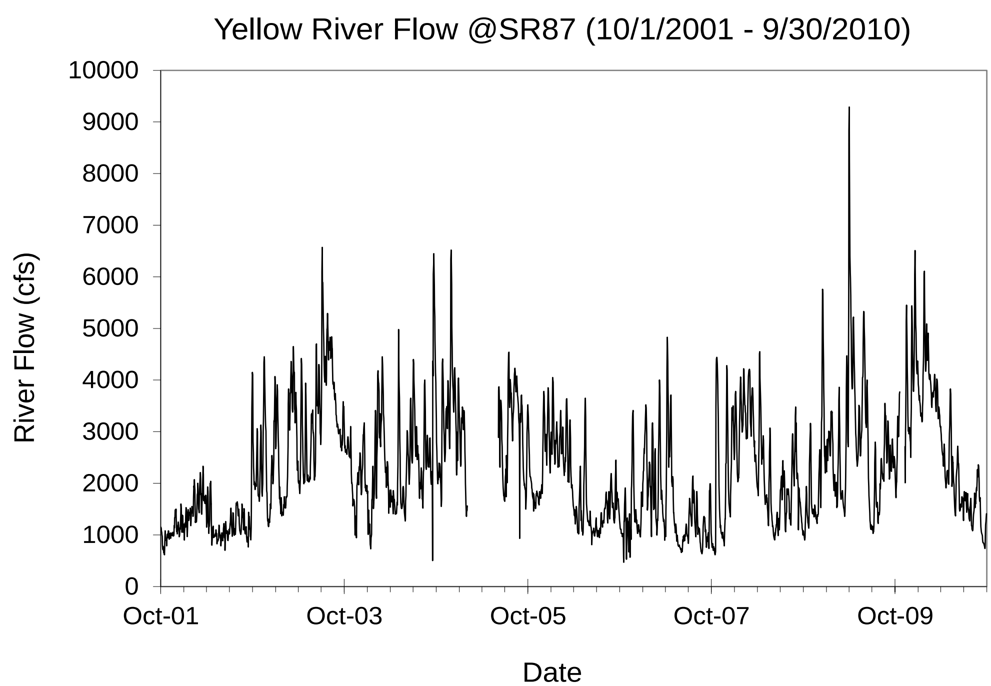


Figure 11. Yellow River discharge measured at the SR87 bridge near Milton, FL for the period October 2001 to September 2010. Missing data: 2/2/05-6/4/05, 10/20/09-11/8/09. Source: U.S. Geological Survey 2010.

3.4 Water Quality Classifications

Surface waters within the East Bay/Blackwater Bay are classified by the State of Florida (Department of Environmental Protection) as either Class II or III. These classifications are based on use, not by the actual quality of the water.

Class II waters are designated as Shellfish Propagation or Harvest areas. These areas have water quality standards focusing on particular components that affect the quality of the shellfish harvested to protect consumers from possible diseases associated with their consumption. Shellfish harvesting areas within East Bay/Blackwater Bay are shown in Figure 12. This recently adopted classification combined the two seasonal scenarios that had previously been in effect.

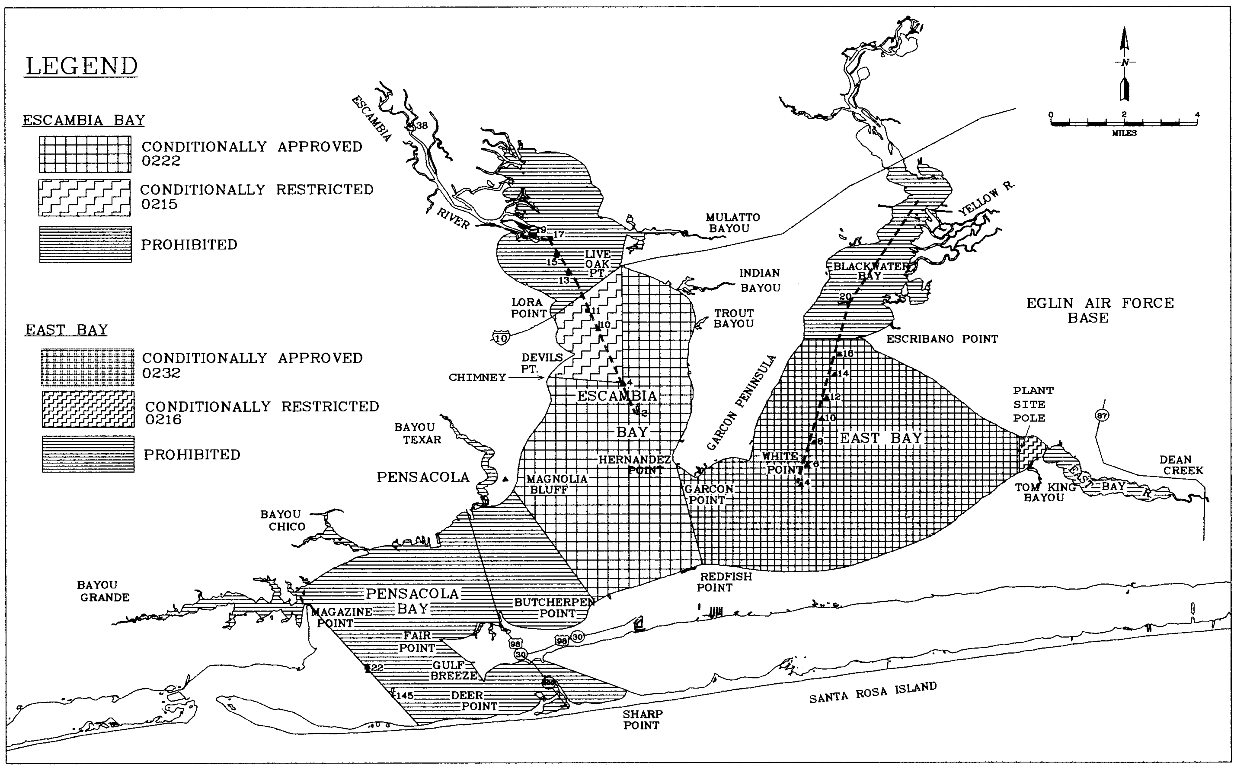


Figure 12. Shellfish harvesting area classifications in the Pensacola Bay system (DACS 2009).

Currently, commercial harvesting is prohibited from all areas of Blackwater Bay and the mouth of the East Bay River. The majority of East Bay is conditionally approved during both seasons with a relatively small portion of the northwestern section of East Bay, between Escribano and White Points conditionally restricted during winter months of November to February. Conditionally approved East Bay waters are open for harvest during the winter months (November to February) unless the Escambia River stage, measured at Century, Florida, exceeds 12.99 feet or the cumulative seven-day rainfall, measured at Philpot Forestry Tower, exceeds 2.43 inches. Conditionally approved East

Bay waters are harvestable during the spring/fall months (March to October) unless the Escambia River stage, measured at Century, exceeds 16.07 feet or the cumulative five-day rainfall, measured at the Molino Forestry Tower exceeds 3.45 inches. A small portion of East Bay waters is conditionally restricted during the winter months when cumulative seven-day rainfall, measured at the Philpot Forestry Tower, exceeds 5.01 inches. In all cases waters are temporary closed when the above conditions occur and are reopened when bacteriological levels meet the standards described in Rule 5L-1.003 and fecal coliform levels in shellfish return to normal background levels.

All surface waters in East Bay/Blackwater Bay not specifically listed as Class II are designated as Class III. Class III waters are designated to provide Recreation and Propagation of Healthy, Well-balanced Populations of Fish and Wildlife. Standards for these waters are not as stringent for most parameters as for the above discussed classes and are directed to maintaining biodiversity and water quality sufficient for human contact such as swimming (hence the name Fishable/Swimable waters). Class III waters are confined to the area of Blackwater Bay north of Interstate 10 and the various rivers and tributaries entering the system.

3.5 Water Quality Characteristics

Considerable water quality data have been collected in the Pensacola Bay System over the last 40 years; yet, most has been restricted to Escambia and Pensacola Bays and their associated bayous. The existing water quality data set for the East Bay/Blackwater Bay is relatively sparse and generally restricted to short-term collections associated with larger sampling efforts focused on other portions of the system. No comprehensive, long-term, water quality monitoring program is being carried out currently in either East or Blackwater Bay. Similarly, water quality information has been collected at numerous riverine sites within the drainage basin yet long-term data are available for only a handful of locations.

As part of the Florida Department of Environmental Protection's (DEP) watershed management approach for protecting water resources and addressing Total Maximum Daily Load (TMDL) requirements, a water quality assessment was developed for the Pensacola Bay system (DEP 2007). Recent water quality data were obtained from the Storage and Retrieval (STORET) databases, new data collected as necessary, and all information was assessed according to methodologies prescribed in the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act. From this assessment a verified list of waterbodies not meeting state water quality standards was generated; TMDLs are to be drafted for these waterbodies.

Several portions of East and Blackwater bays were placed on the verified list as not meeting water quality standards (DEP 2007). Two waterbody segments in Blackwater Bay were listed for excessive mercury in fish tissue while East Bay and one segment off Redfish Point (along the southern shoreline) were included for high historical chlorophyll (indicative of high nutrient concentrations), high total coliform bacteria, and high mercury in fish tissue. Upstream of the estuarine portions of the system, seven segments in the Blackwater River, six segments in the Yellow River and two segments of the Shoal River were included on the verified impaired list. Impaired riverine segments had either high bacterial counts or high concentrations of mercury in fish.

3.5.1 Estuarine Areas

Among the estuarine locations are two sites presently being monitored by the Department of Environmental Protection: one in the upper reach of Blackwater Bay (Site 33030011) and the other in Redfish Cove (Site 33030D71) along the southern shoreline of East Bay (Figure 13). Both sites have been sampled for at least ten years on a weekly basis; but, while they span the spatial extent of the system, they should not be considered as representative of the bay complex overall. Data from these two sites were obtained from Florida STORET and are summarized here for the time period 1998-2009 (Table 1). For comparative purposes and to allow greater spatial coverage, summary water quality data were taken from the comprehensive Escambia Bay Recovery Study (Olinger et al. 1975) done in 1974-1975. Sampling stations covered a broad spatial scale (Figure 13), but were collected over a limited time period; summary data are provided in Table 2. Some conditions are likely to have improved since these mid-1970's collections, yet others have undoubtedly deteriorated (as indicated in Collard 1991a); little information exists to verify potential trends baywide.

Salinity in East Bay/Blackwater Bay varied spatially and temporally during the most recent sampling period (1998-2009) (Florida STORET 2009), ranging from 0 (less than about 40 µS/cm specific conductance) to 34.6 ppt (Table 1). [Note: specific conductance, rather than salinity, was measured at the Blackwater Bay site; values were converted to salinity for comparison according to Tiphane and St.-Pierre (1962)]. Salinity at the upper Blackwater Bay site was very low (mean salinity = 1.1 ppt) with values frequently below 1 ppt; rarely did salinity exceed 10 ppt. This site is located in the transition zone between the lower reach of the Blackwater River and upper reach of the bay, and as such, is usually fresh. Because salinities are usually so low, concentrations of dissolved ions were actually measured as specific conductance rather than salinity. Salinities underwent noticeable seasonal fluctuations with highest values generally in the late summer-fall coincident with low river flows. Salinities at the lower East Bay site were consistently higher (mean salinity = 19.2 ppt) than those measured in Blackwater Bay. Little seasonality was observed; however, dramatic swings in salinity values were noted over relatively short time intervals (i.e., 1-2 weeks) during the ten years of observations (Figure 14). On several occasions, surface salinities varied by as much as 15-20 ppt between weekly measurements. Salinity at the lower East Bay site generally increased during 1999-2001 and 2007-2008 coincident with drought conditions in the southeastern United States (Figure 14); these higher values were not as pronounced in Blackwater Bay.

Location of Water Quality Stations in East Bay

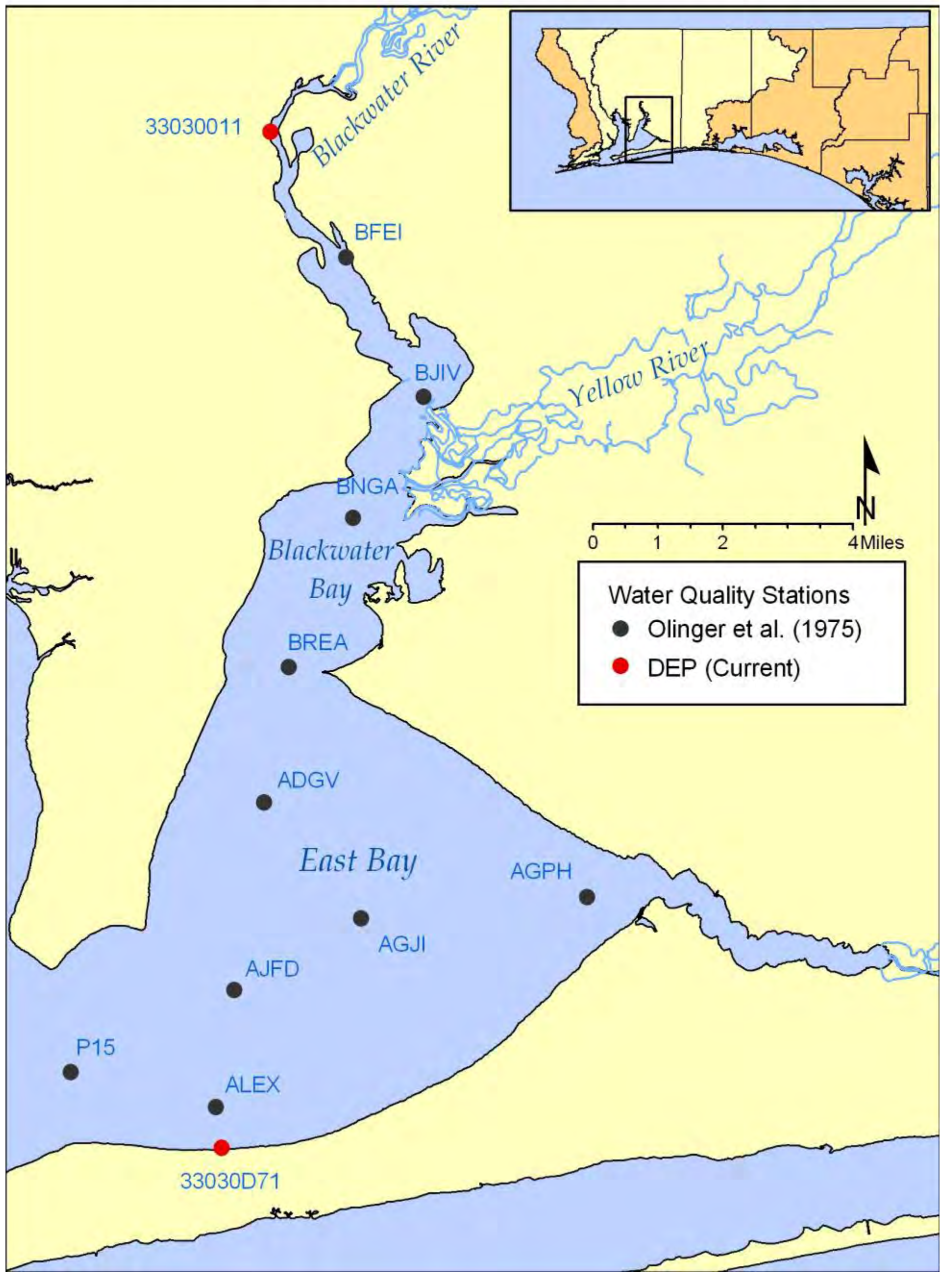


Figure 13. Location of water quality stations in Blackwater and East Bays. Stations shown with black closed circles were sampled during the Olinger et al. (1975) study; those shown in red are currently being sampled by DEP.

Table 1. Summary of water quality characteristics for long-term East Bay/Blackwater Bay collection sites (1998-2009). Samples were taken from surface depths (<0.25m). Data source: Florida STORET (2009).

Site	Salinity (ppt)	Temp (^oC)	DO (mg/l)	TSS (mg/l)	Turbidity (NTU)	Color (PCU)	Nitrate+ Nitrite (mg/l)	Ammonia (mg/l)	TKN (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll (µg/l)
Blackwater Bay (Site 33030011)												
Mean	1.1	20.5	6.8	4.2	3.5	43	0.32	0.03	0.36	0.68	0.014	3.6
Minimum	0.0	7.2	2.4	0.0	1.0	0.0	0.05	0.01	0.09	0.23	0.004	0.6
Maximum	21.4	29.9	11.4	90	25.0	160	0.49	0.30	1.20	1.59	0.036	38.5
East Bay (Site 33030D71)												
Mean	19.2	22.3	7.4	15.4	4.2	24	0.05	0.02	0.38	0.42	0.027	3.6
Minimum	1.5	4.4	1.9	2.5	0.5	0.0	0.00	0.01	0.00	0.02	0.010	0.8
Maximum	34.6	33.6	13.8	177	88.0	200	0.21	0.04	0.63	0.64	0.090	13.7

Characteristics:

Temp = Temperature
DO = Dissolved Oxygen
TSS = Total Suspended Solids
TKN = Total Kjeldahl Nitrogen

Table 2. Summary of water quality characteristics for East Bay/Blackwater Bay sites (1974-1975). Table entries are mean values for surface/bottom samples; only surface chlorophyll was collected. Data source: Olinger et al. (1975).

Stations	Salinity (ppt)	Temperature (^oC)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Nitrate+ Nitrite (mg/l)	Ammonia (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll (µg/l)
Blackwater Bay Stations									
BFEI	0.9/10.4	25.8/27.8	5.9/2.2	4.4/5.5	0.093/0.040	0.041/0.099	0.445/0.256	0.018/0.024	3.6
BJIV	1.9/8.3	22.3/23.4	7.5/5.5	5.9/6.1	0.065/0.046	0.025/0.044	0.243/0.284	0.019/0.026	4.5
BNGA	3.0/14.2	22.3/23.6	7.5/5.7	7.0/6.3	0.055/0.032	0.024/0.064	0.226/0.294	0.017/0.020	4.6
BREA	5.9/17.7	22.7/24.0	7.5/4.9	5.2/9.1	0.036/0.028	0.024/0.092	0.236/0.356	0.016/0.022	4.4
East Bay Stations									
ADGV	8.1/18.8	23.0/23.7	7.9/5.2	4.6/6.4	0.030/0.029	0.027/0.072	0.267/0.339	0.014/0.022	3.9
AJFD	12.5/23.5	23.4/23.4	8.0/5.4	3.2/5.3	0.023/0.024	0.027/0.062	0.287/0.334	0.013/0.020	3.8
ALEX	13.8/27.5	23.5/23.7	8.1/4.4	2.1/4.7	0.021/0.028	0.021/0.087	0.325/0.378	0.018/0.020	3.2
AGJI	13.1/22.8	23.3/23.7	8.1/4.7	2.9/5.7	0.021/0.024	0.028/0.077	0.248/0.357	0.013/0.019	3.4
AGPH	13.3/20.2	23.3/23.4	7.8/5.3	3.0/4.8	0.020/0.022	0.032/0.053	0.248/0.306	0.013/0.018	3.5
P15	13.0/28.3	23.7/23.2	7.8/3.8	--	0.022/0.029	0.031/0.096	0.288/0.377	0.020/0.026	3.8

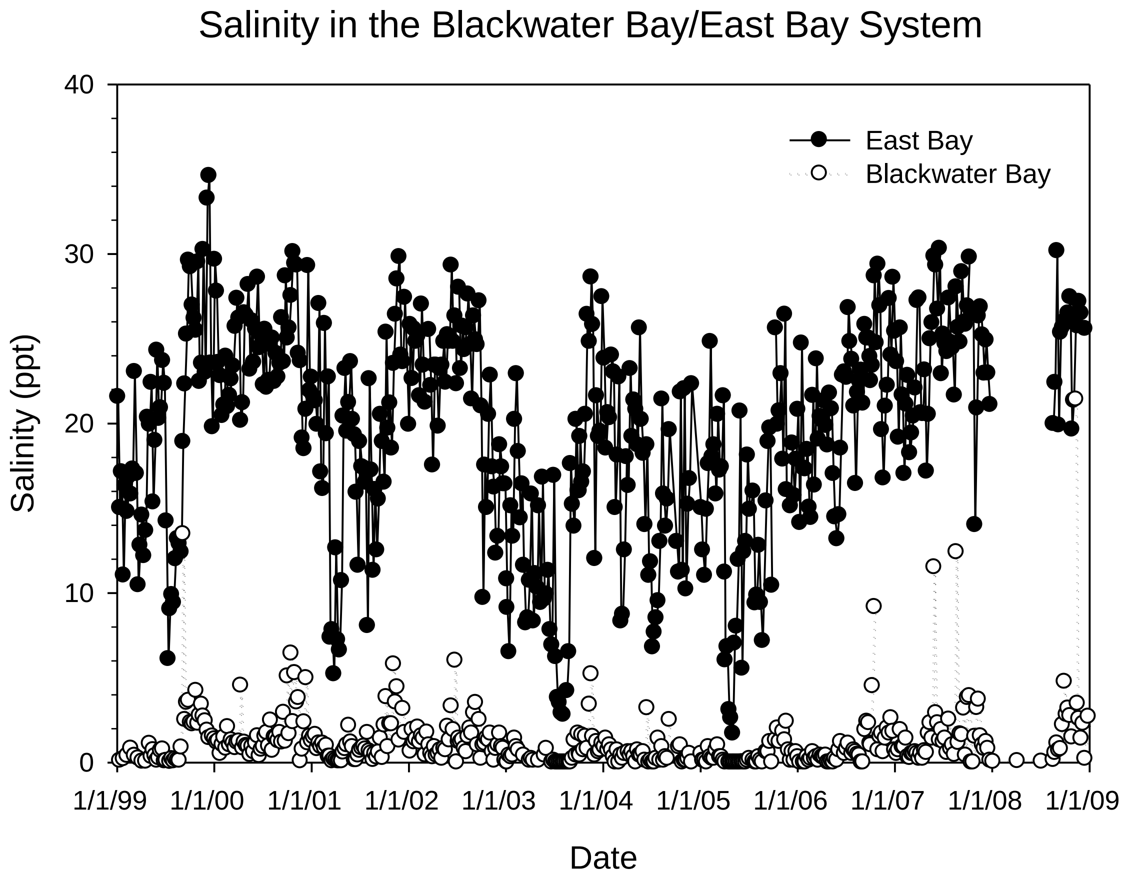
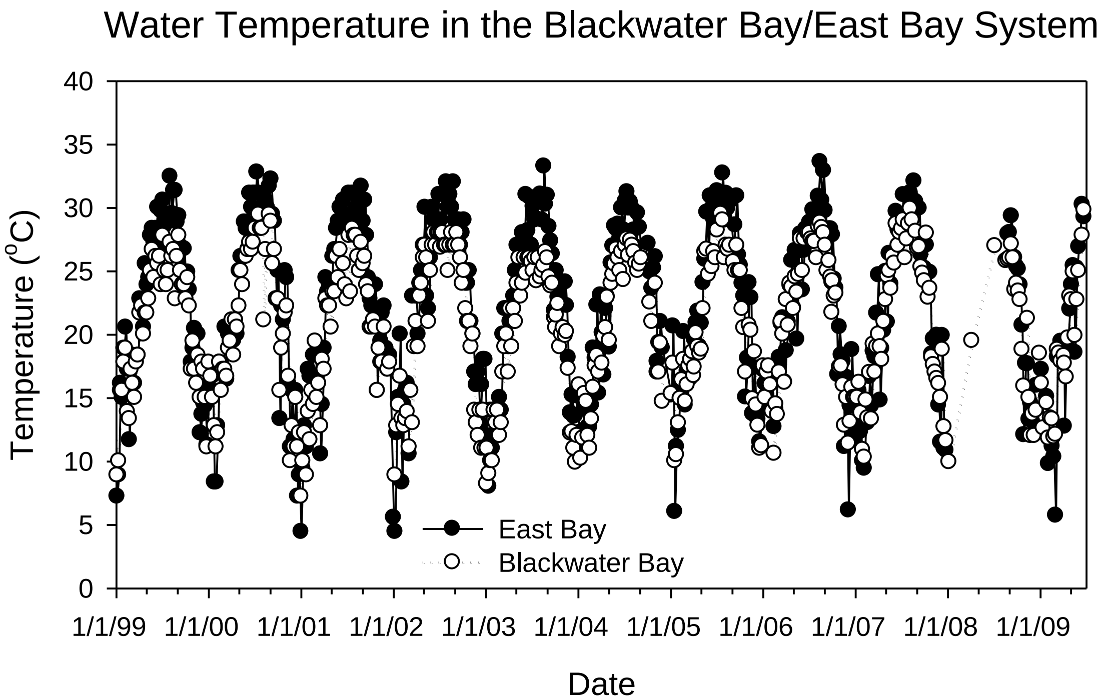


Figure 14. Comparison of salinity between stations in Blackwater Bay (Site 33030011) and East Bay (Site 33030D71). Salinity at the Blackwater Bay site was converted from specific conductance measurements. Data source: Florida STORET (2009).

Mean salinity generally increased with distance from the upper reach of Blackwater Bay to lower East Bay; this was most pronounced during the early sampling program (Olinger et al. 1975; Table 2). Mean surface salinity during the 1975-76 period increased from 0.9 to 13.8 ppt while bottom salinity increased from 8.3 to 28.3 ppt between stations BFEI in Blackwater Bay and P15 in East Bay (Olinger et al. 1975). Significant vertical stratification was noted at all sites (Table 2).

Temperature varied seasonally (Figure 15, upper panel), ranging over the recent 4-year period from 4.4 to 33.6°C (Florida STORET 2009). Winter lows tended to vary more than summer highs. Temperature differed between locations with the Blackwater Bay site moderated seasonally by water from the Blackwater River (i.e., cooler conditions in summer and warmer in winter). This temperature moderation was also observed in the Olinger et al. (1975) data set, with surface and bottom values at the upper Blackwater site (BFEI) averaging at least 3.0°C greater than those at other Blackwater locations (Table 2). Temperature stratification, although small, appeared greater in Blackwater than in East Bay.



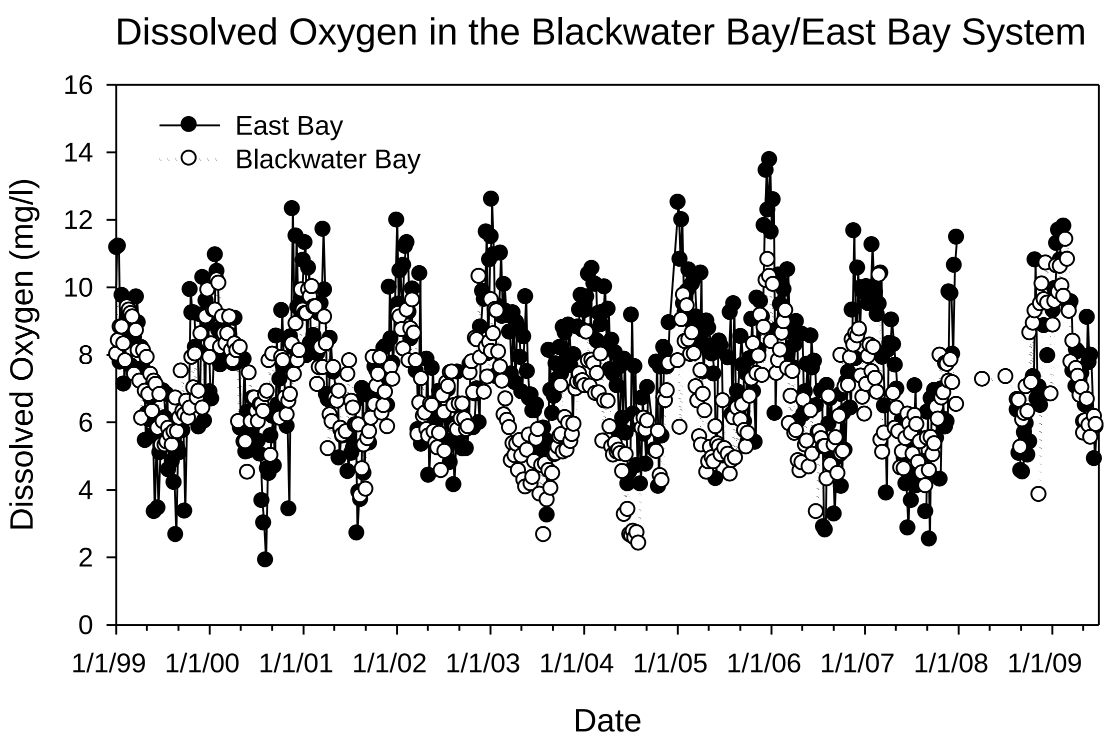


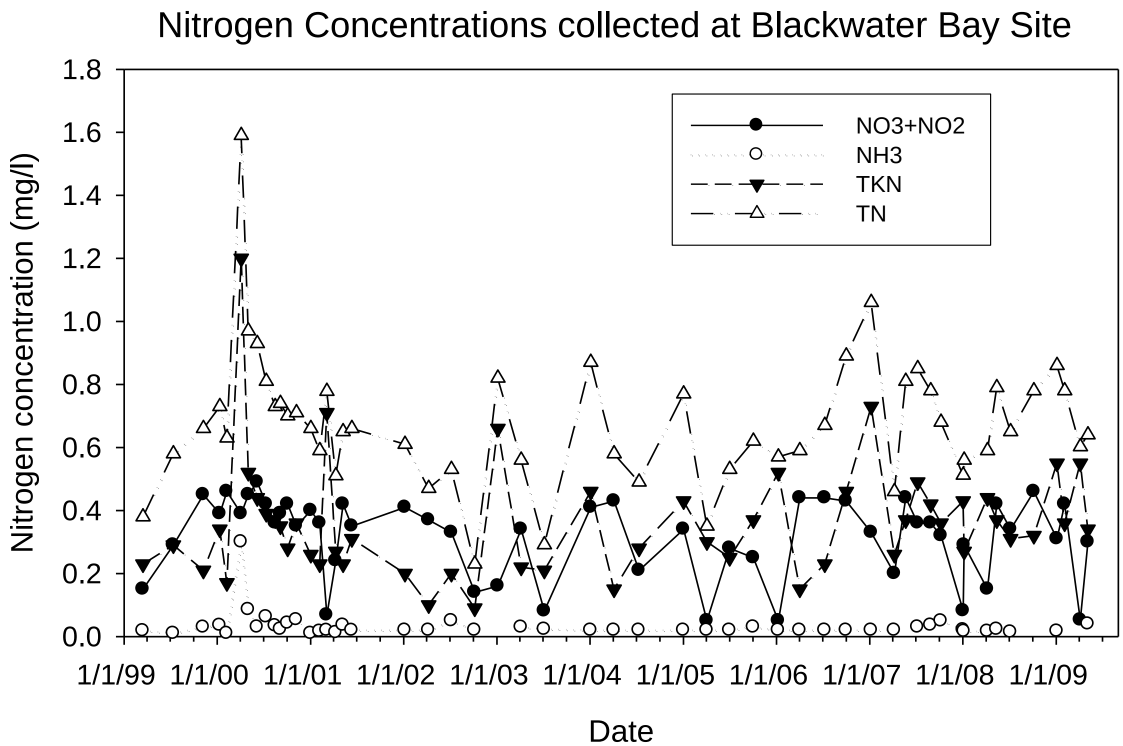
Figure 15. Comparison of water temperature (upper panel) and dissolved oxygen (lower panel) between stations in Blackwater Bay (Station 33030011) and East Bay (Station 33030D71). Data source: Florida STORET (2009).

Water clarity was generally high throughout the bay complex. Surface turbidity values were low with mean values ranging from 3.5 NTUs in upper Blackwater Bay to 4.2 NTUs in lower East Bay (Florida STORET 2009; Table 1). These values were similar or slightly lower than those observed by Olinger et al. (1975) where mean surface turbidity ranged from 7.0 NTUs at BNGA (mid-Blackwater Bay) to 2.1 NTUs at ALEX (lower East Bay) (Table 2). Bottom values were generally higher than surface. Color was higher in Blackwater Bay (Table 1) reflecting the influence of the Blackwater River.

Dissolved oxygen (DO) was relatively high with surface values averaging greater than 6.5 mg/l at both current DEP water quality collection sites (Figure 15, lower panel). DO varied seasonally with high values in winter and lows in summer, inversely related to water temperature (compare upper and lower panels, Figure 15). Greater DO variability was observed in East Bay with values often higher in winter and lower in summer relative to Blackwater Bay. This is likely related to the moderated temperatures in Blackwater relative to East Bay. DO at both locations occasionally dropped below 4 mg/l with more frequent occurrences in lower East Bay than Blackwater (Figure 15, lower panel). Data collected during the Olinger et al. (1975) study indicated similar high surface DO values (Table 2), averaging between 7.5 and 8.1 mg/l at all but one site. Bottom concentrations were lower than surface with two locations averaging below 4 mg/l. Mean DO at the upper Blackwater Bay site (BFEI) was noticeably lower than other locations with 5.9 and 2.2 mg/l observed at the surface and bottom, respectively (Table 2).

Nutrient concentrations were generally low (<1 mg/l TN and <0.03 mg/l TP) throughout the East Bay/Blackwater Bay system, with nitrogen slightly higher in Blackwater Bay and phosphorus higher in East Bay (Tables 1 and 2). Current sampling indicated nitrate+nitrite, ammonia and total nitrogen concentrations were one and one-half to six times greater at the Blackwater Bay site (upper bay) than along the southern East Bay shoreline (Table 1); total Kjeldahl nitrogen was similar at the two sites. A similar spatial trend was observed in the Olinger et al. (1975) data with concentrations declining with distance from the river mouths (Table 2). Some degree of seasonality was noted in the current nitrogen data in Blackwater Bay (Figure 16) with higher values appearing in winter; limited data from East Bay precluded any seasonal assessment. Current nitrate+nitrite levels were noticeably lower than those observed historically. Mean nitrate+nitrite in Blackwater Bay is one-third the mean noted by Olinger et al. (1975) while the East Bay mean is one-sixth that observed historically. Mean total phosphorus in East Bay is currently twice the value in Blackwater (Table 1) and is nearly double that observed historically (Olinger et al. 1975).

Chlorophyll values were low throughout both collection periods (Tables 1 and 2), probably reflecting the relatively low water column nutrient levels. Chlorophyll concentrations appeared relatively uniform among stations, averaging 3.6 μg/l at current monitoring sites (Florida STORET 2009). An occasional high value was noted (up to 38.5 and 13.7 μg/l at Blackwater and East Bay sites, respectively). Numerous samples were at or below detection limits at both current locations. No trends were apparent either spatially or seasonally.



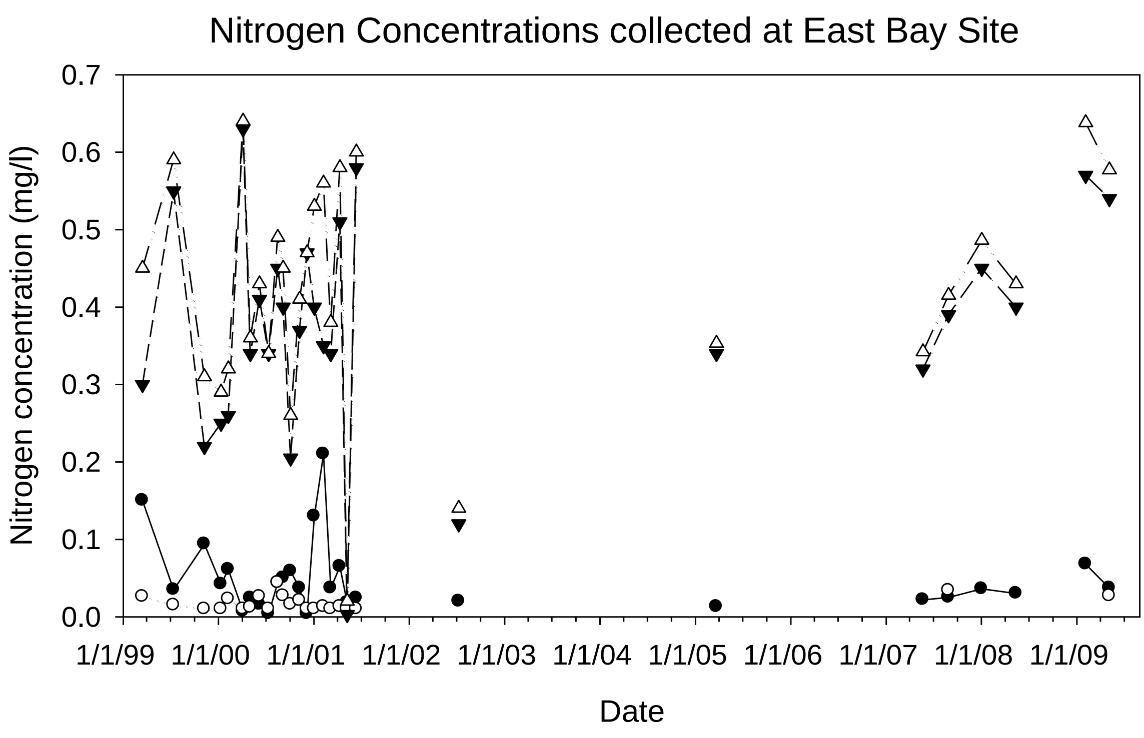


Figure 16. Comparison of nitrate+nitrite (NO_3+NO_2), ammonia (NH_3), total Kjeldahl nitrogen (TKN), and total nitrogen (TN) at sites in Blackwater (upper panel) and East (lower panel) Bays. Limited collections have been made at this site over the last seven years. Data source: Florida STORET (2009).

3.5.2 Riverine Areas

To examine the influence of freshwater inflows to the estuary, water quality characteristics were obtained from the Florida STORET database for a series of 22 sites throughout the Yellow River and lower portion of the Shoal River just upstream of its confluence with the Yellow (Figure 17). Collections were taken by disparate agencies and organizations (e.g., DEP, FFWCC) with varying characteristics examined, sampling procedures and analytical methods. Six of these sites have had multiple collections spanning months to years while the remainder represent single sampling events. Data from all sites are combined and summarized here (Table 3) only to provide an overview of environmental characteristics in various reaches of the system. Long-term data will be plotted separately to examine temporal trends.

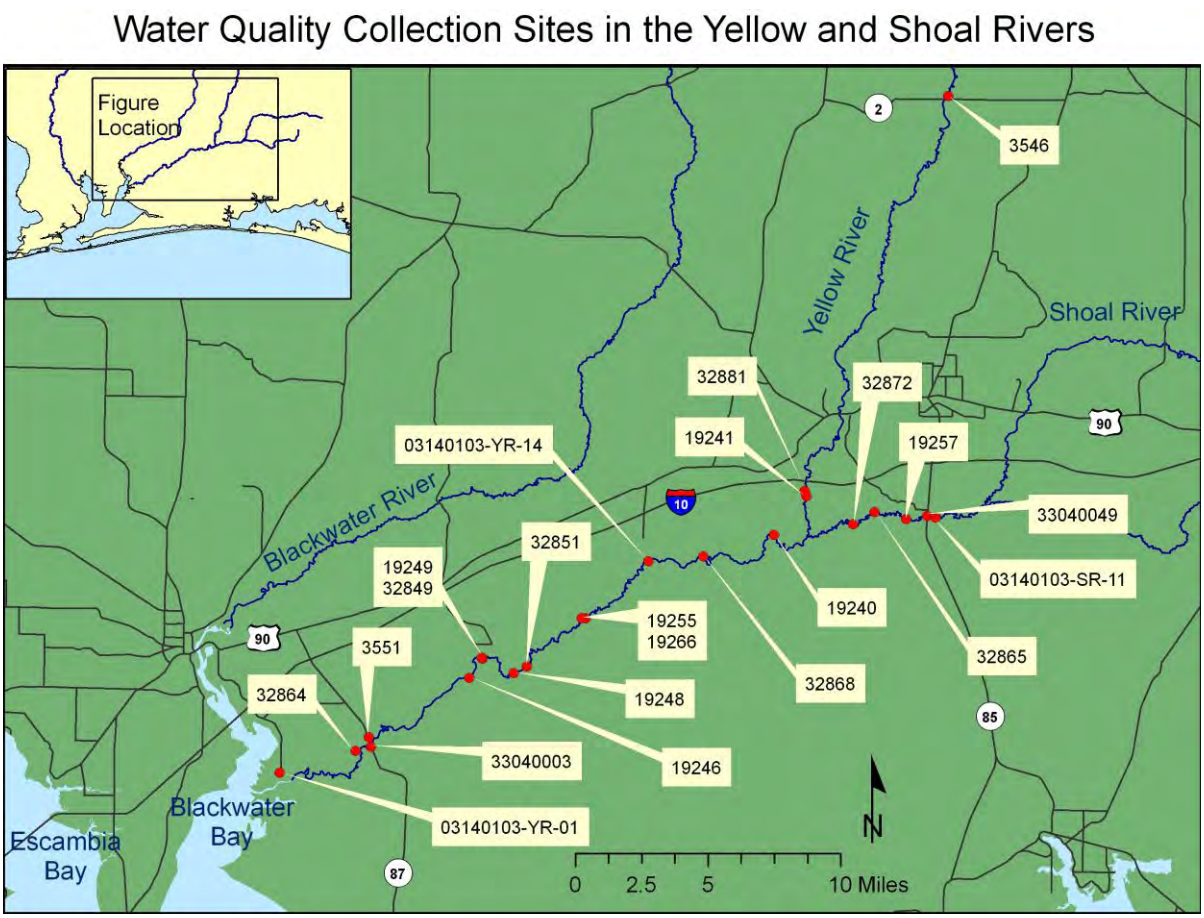


Figure 17. Water quality collection sites on the Yellow and Shoal rivers. These sites are grouped by river reach and the data are summarized in Table 3. Data source: Florida STORET (2009).

Table 3. Summary of selected water quality characteristics collected at sites in the Yellow/Shoal River system. Stations are arranged by location from upstream to downstream (see Figure 17). Table entries are values from surface (<0.5 m) samples over the period of collection. Means are presented where multiple samples were collected (*); otherwise entries represent single sampling events. ** = < detection limits. Data source: Florida STORET (2009).

Station	Specific Conductance (μS/cm)	Temp (^{o}C)	DO (mg/l)	NH_3 (mg/l)	NO_3+NO_2 (mg/l)	TKN (mg/l)	TN (mg/l)	PO_4 (mg/l)	TP (mg/l)	Chl-a (μg/l)
YELLOW RIVER UPPER REACH										
Yellow River @ SR2 (3546)*	74.6	19.6	8.8	0.022	0.10	0.32	0.42	0.033	0.043	<1.4
32881*	74		8.2	0.031	0.11	0.39	0.50		0.024	1.1
19241	50.5		7.7	0.024	0.12	0.42	0.54	0.006	0.049	**
SHOAL RIVER										
03140103-SR-11*	25.6	18.7	8.1	0.127	0.23	0.36	0.59	<0.006	0.039	
Shoal River @ SR85 (33040049)*	25		4.0	0.037	0.17	0.50	0.67		0.021	1.1
19257	26		6.7	0.022	0.16	0.38	0.54	0.024	**	**
32865	29		8.3	0.02	0.16	0.27	0.43		0.009	1.0
32872	29		7.9	0.02	0.16	0.23	0.39		0.009	0.7
YELLOW RIVER MIDDLE REACH										
19240	41.5		6.2	0.039	0.14	0.48	0.62	**	0.034	**
32868	43		7.8	0.03	0.15	0.42	0.57		0.019	1.1
03140103-YR-14*	37.4		7.2	<0.12	0.18	<0.36	<0.48	<0.009	0.041	
19255	36		5.3	0.042	0.11	0.46	0.57	**	0.037	**
19266	38.5		5.7	0.042	0.12	0.47	0.59	**	0.04	**
32851	46.5		7.4	0.025	0.094	0.29	0.38		0.012	0.9
19248	36		4.6	0.065	0.089	0.49	0.58	0.005	0.06	**
19249	35.5		4.6	0.068	0.086	0.54	0.63	0.005	0.067	**
32849	45		7.6	0.027	0.093	0.26	0.35		0.012	1.2
19246	35		4.5	0.064	0.086	0.56		0.005	0.069	**

Table 3. Continued.

Station	Specific Conductance (µS/cm)	Temp (°C)	DO (mg/l)	NH_3 (mg/l)	NO_3+NO_2 (mg/l)	TKN (mg/l)	TN (mg/l)	PO_4 (mg/l)	TP (mg/l)	Chl-a (µg/l)
YELLOW RIVER LOWER REACH										
Yellow River @ SR87 (3551)*	35.3	20.5	7.6	0.016	0.096	0.315	0.41	0.004	0.020	<1.1
33040003*	48.2	20.3	7.0	0.033	0.092	0.38	0.47		0.024	<4.3
32864	36.5		6.8	0.018	0.078	0.32	0.40		0.013	1.2
03140103-YR-01 (marsh)*	32.0	20.8	6.8	<0.06	0.11	<0.32	<0.44	<0.007	0.032	

Characteristics examined:

Temp = temperature
DO = dissolved oxygen
NH_3 = ammonia
NO_3+NO_2 = nitrate + nitrite
TKN = total Kjeldahl nitrogen
TN = total nitrogen
PO_4 = ortho-phosphate
TP = total phosphorus
Chl-a = chlorophyll-a

Overall, freshwater entering the Blackwater/East Bay system from the Yellow River is of relatively high quality (Table 3). Water quality characteristics varied spatially and temporally throughout the collection sites with downstream waters generally showing a mix of those coming from upstream locations. Specific conductance was generally low throughout the system with mean values in the upper reach of the Yellow River (mean = 74.6 μS/cm at Station 3546 at the SR2 bridge) about three times those found in the Shoal River (mean = 25.6 μS/cm at Station 03140103-SR-11). Downstream waters indicated a combination of upstream flows (mean = 35.3 μS/cm at Station 3551 at the SR87 bridge). Long-term data suggested a seasonal trend in values in the upper reach (Station 3546) with higher values during summer/fall months; no seasonal trend is evident in the lower reach (Station 3551) (Figure 18). On only one occasion (October 17, 2006) was specific conductance elevated (1654 μS/cm); this high value was not associated with any of the tropical storms and their related surges. Little difference was observed between surface and bottom values, even in the lower portions of the river; no stratification was noted in the long-term data set collected at the SR87 bridge (Figure 19) except during the single elevated event mentioned above (1654 μS/cm surface, 23555 μS/cm bottom).

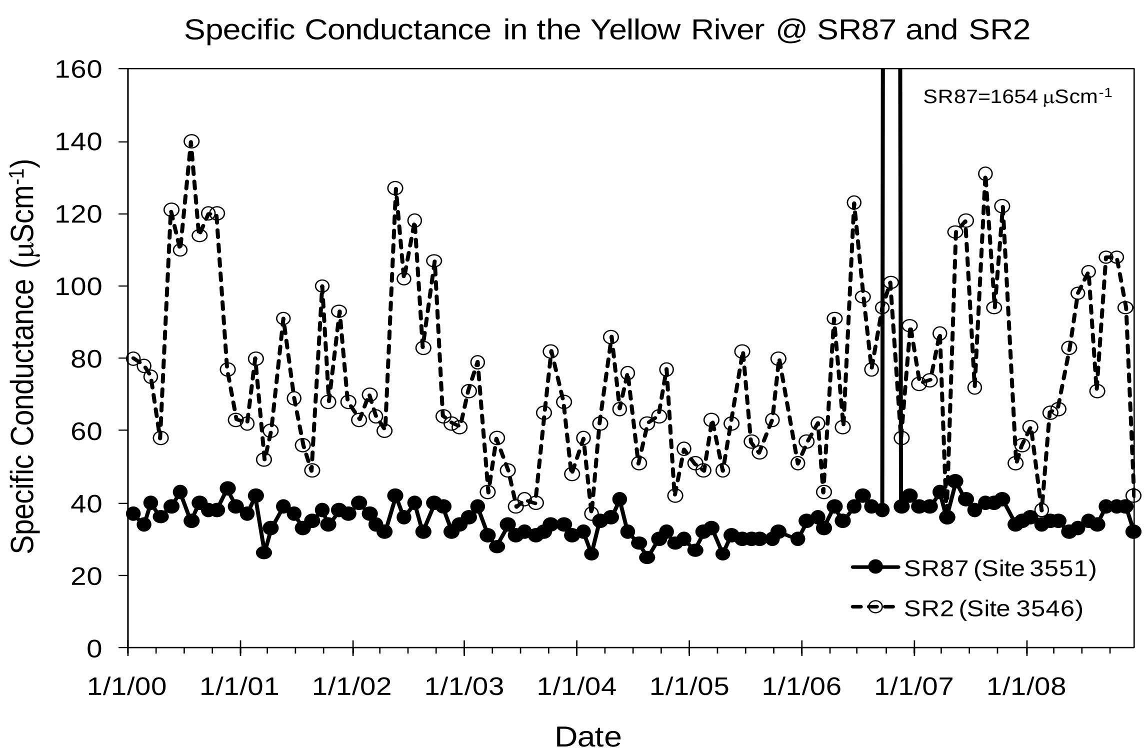


Figure 18. Comparison of long-term surface specific conductance at two sites in the Yellow River. See Figure 17 for site locations. Data source: Florida STORET (2009).

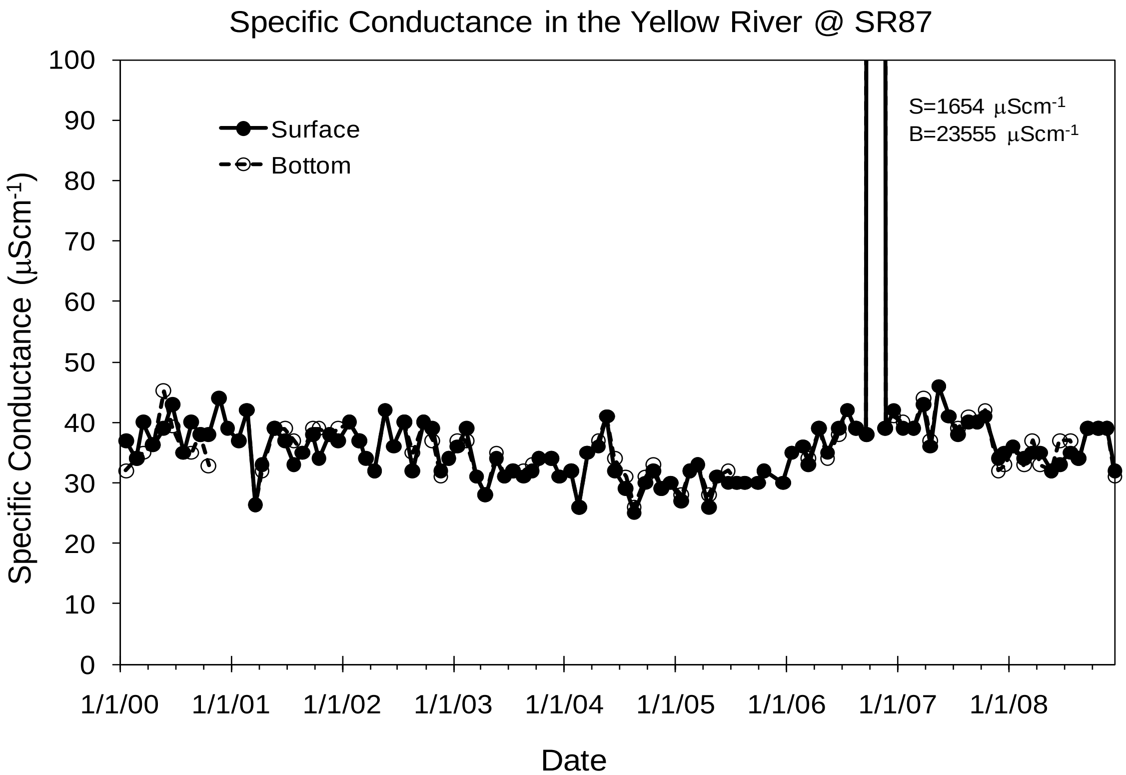


Figure 19. Comparison of long-term specific conductance from surface and bottom samples taken in the lower Yellow River (Site 3551 at the SR87 bridge). See Figure 17 for site location. Data source: Florida STORET (2009).

Dissolved oxygen was fairly high (> 6 mg/l) throughout the river (Table 3); however, several sites had values between 4-5 mg/l (from single sampling events usually). Long-term means from the upper (Station 3546) and lower (Station 3551) reaches indicated high DO concentrations, 8.8 mg/l and 7.6 mg/l, respectively (Table 3). Long-term river concentrations displayed similar seasonal patterns (Figure 17) to those noted in the bay with higher values observed during colder winter months. DO was consistently higher at upper reach Station 3546 than at lower Station 3551. Concentrations were observed below 4 mg/l on only one occasion (Station 3551 in September 2004) over the ten-year collection period (Figure 20).

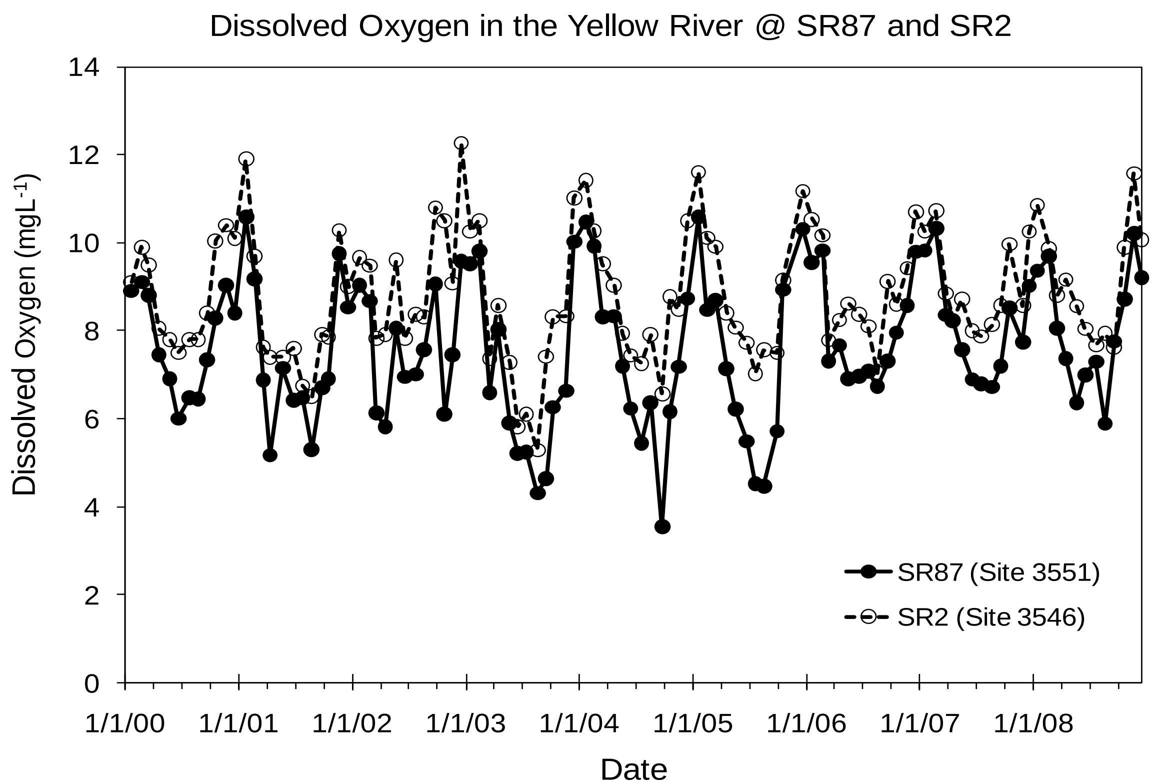


Figure 20. Comparison of long-term dissolved oxygen at two sites in the Yellow River. See Figure 17 for site locations. Data source: Florida STORET (2009).

Nitrogen concentrations throughout the river system were relatively low with values generally less than 0.04 mg/l ammonia, 0.15 mg/l nitrate+nitrite, 0.40 mg/l TKN, and 0.60 mg/l TN (Table 3). Phosphorus was somewhat elevated in the upper reach of the Yellow River (0.033 mg/l at Station 3546) yet values were less than 0.007 in the lower reach; TP was usually below 0.04 mg/l throughout the system. Seasonality was not apparent in the long-term data from either the upper and lower reach (Figures 21 and 22). With relatively low nutrient concentrations it was not surprising to find low chlorophyll at all sites (Table 3); numerous samples had concentrations below detection limits.

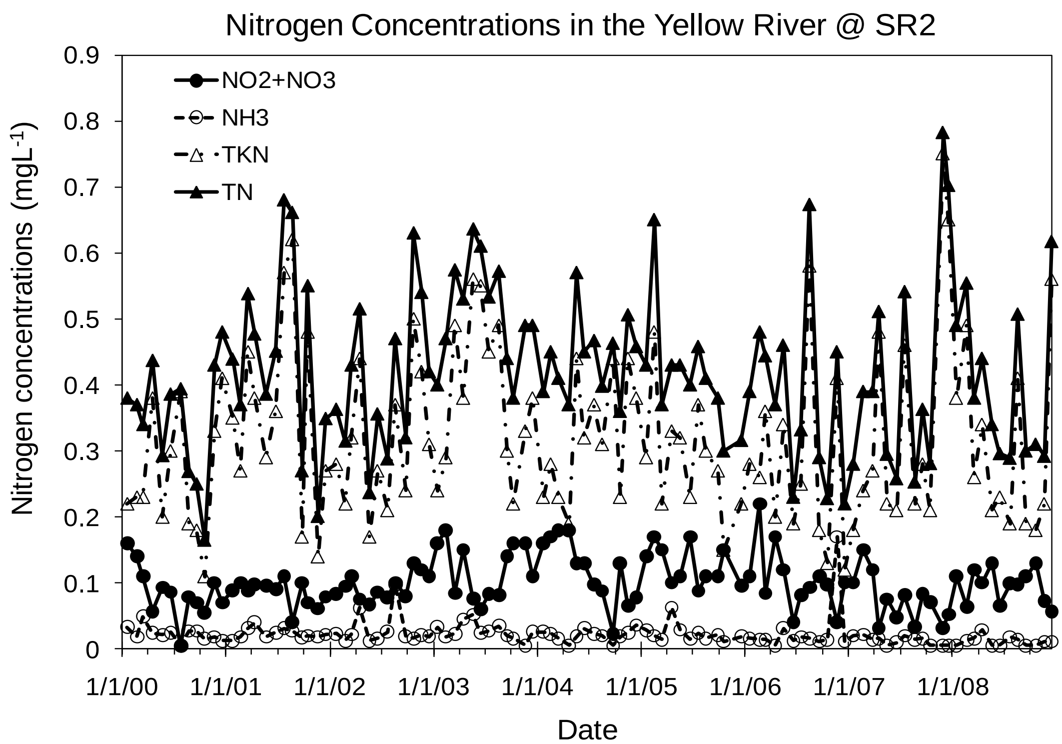


Figure 21. Long-term nutrient concentrations at Station 3546 (at the SR2 bridge) in the upper reach of the Yellow River. See Figure 17 for site locations. Data source: Florida STORET (2009).

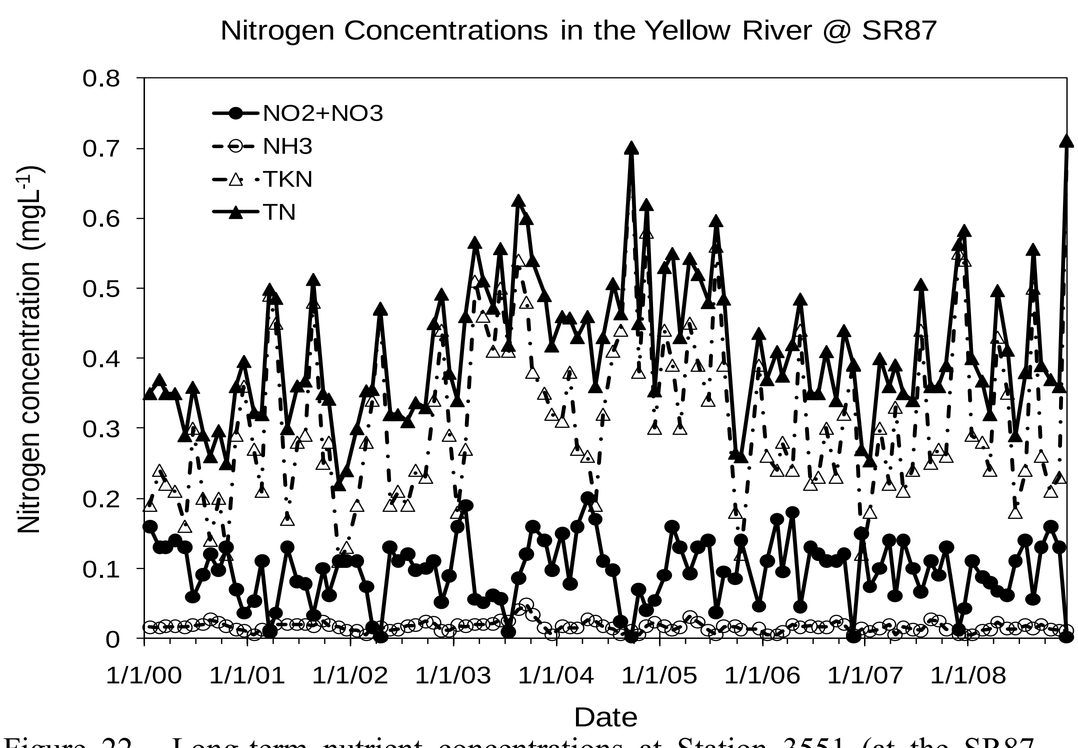


Figure 22. Long-term nutrient concentrations at Station 3551 (at the SR87 bridge) in the lower reach of the Yellow River. See Figure 17 for site locations. Data source: Florida STORET (2009).

3.6 Sediment Characteristics

Three extensive studies have been carried out examining the nature of the sediments in the Pensacola Bay system (Horvath 1968; Olinger et al. 1975; George 1988). Of these, Horvath (1968) and George (1988) investigated the physical makeup of the sediments, while Olinger et al. (1975) took a comprehensive view of sediment contamination. These studies, along with others, have been summarized by Collard (1991a), Jones et al. (1992), and DeBusk et al. (2002).

3.6.1 Physical Properties

Bay wide, the range of grain sizes and the average grain size has been reported to have decreased over the twenty years between the two major sedimentological studies (Collard 1991a; Jones et al. 1992); average grain size appears to have decreased from 4.13ϕ (Horvath 1968) to 6.39ϕ (George 1988) [Note: Phi units increase as particle sizes decrease]. Additionally, Horvath (1968) observed the average sand-silt-clay percentages for East Bay sediments were 59-17-22, respectively; George (1988) noted percentages of 22-25-53, respectively.

In comparing results from these two studies, both Collard (1991a) and Jones et al. (1992) appear to have overlooked the confounding nature of different station locations (see Figure 8 in Jones et al. 1992). Horvath's samples contained numerous inshore locations (samples collected in depths less than 6 feet) representative of the nearshore sandy shelf; these shallow stations appear to be underrepresented in George's collections. In addition, Horvath sampled throughout Santa Rosa Sound, a large sandy lagoon not sampled by George. Thus, it is not surprising that George reported smaller particle size and differences in composition relative to the earlier study.

Lack of inshore samples, however, only partially explains differences noted between the two studies (Horvath 1968; George 1988). Examining sediment distribution maps (as depicted in Figures 14 and 15 in Jones et al. 1992), it is clear that some areas of the Pensacola Bay system have indeed undergone changes. Blackwater Bay appears to have shifted from a sandy to a relatively silty-clay environment. At the same time, the silty-clay area of central East Bay has noticeably expanded. Thus, while the observation of decreasing particle size may be correct, it may not be as extreme as noted by Collard (1991a) and Jones et al. (1992). In general for East Bay/Blackwater Bay, grain size is related to depth with fine to medium grain quartz sands noted along the shallow shelf grading to fine silty clays and clayey silts in the deeper areas (see sediment maps; Figures 9-15 in Jones et al. 1992). These changes are likely due to increased erosion resulting from land use practices in the basin coupled with the poor circulation pattern inherent to East Bay (as discussed by Collard 1991a).

3.6.2 Sediment Contamination

Numerous studies examined sediment contamination throughout the Pensacola Bay system, yet most have focused on Escambia and Pensacola Bays, and their associated bayous. Limited data collection occurred from sites in East and Blackwater Bays (Olinger et al. 1975; EPA unpublished data surveys 1992, 1996 [presented in DeBusk et al. 2002]; Seal et al. 1994; Long et al. 1997). Olinger et al. (1975) is the largest and most comprehensive data set available for Pensacola Bay sediments, in general, and East Bay/Blackwater Bay specifically; unfortunately, the data set is fairly outdated. Early sediment contamination studies have been summarized in Collard (1991a) while more recent works were discussed by DeBusk et al. (2002). Two EPA studies (1992, 1996) are discussed by DeBusk et al. (2002) which contain numerous sampling sites in both Blackwater and East Bays. However, as with water quality, no current large-scale sediment survey is underway.

Selected sediment data from Olinger et al. (1975) are summarized in Table 4. Where available, mean concentrations are given as reported for Total Organic Carbon (TOC), Total Phosphorus (TP), Total Organic Nitrogen (TON), and a variety of metals; mean concentrations are given for Escambia and Pensacola Bays for comparison with East and Blackwater Bays. Overall, moderate levels of organic carbon were found in East Bay sediments (no data were given for Blackwater Bay) with TOC ranging between 3-4 percent. TOC generally increased from nearshore to midbay, where the highest levels were found (Olinger et al. 1975). Long et al. (1997) noted TOC concentrations ranging from 3.1-3.9% in East Bay and 2.6-7.1% in Blackwater Bay. Moderate to high TOC concentrations coupled with limited hydrodynamic circulation in Blackwater and East

Table 4. Sediment quality in the Blackwater Bay/East Bay system. Selected characteristics are presented for Blackwater, East, Escambia and Pensacola Bays for comparison. Table entries are mean values. Data source: Olinger et al. (1975).

Bay Area	TOC	TP	TON	Al	Cd	Cr	Cu	Ni	Pb	Zn
Blackwater	*	*	*	4684	< 1.0	13.1	2.5	2.8	13	19.7
East	38.7	0.19	0.59	10554	< 1.0	38.4	4.4	8.7	16.2	28.8
Escambia	31.4	0.25	0.57	10078	< 1.0	39.7	8.7	8.8	18.5	43.2
Pensacola	35.4	0.47	0.71	14565	1	55.7	19.3	15.7	39.8	140.3

Units = Total Organic Carbon (mg/g), Total Phosphorus (mg/g), Total Organic Nitrogen (mg/g), Aluminum (ppm), Cadmium (ppm), Chromium (ppm), Copper (ppm), Nickel (ppm), Lead (ppm), Zinc (ppm)

* no data

Bays have prompted some authors (Collard 1991a; Jones et al. 1992) to caution that these two areas are more vulnerable than other parts of the system to increasing development and concurrent pollution.

East Bay and Escambia Bay had comparable values of TP and TON, with concentrations in both areas less than that in Pensacola Bay (Table 4). Depth distributions of TP and TON were reported to be similar to that of TOC, with greatest values found at midbay locations (Olinger et al. 1975).

Sediment metal concentrations generally increased from Blackwater Bay to Pensacola Bay (Table 4). Concentrations were similar for cadmium, chromium, nickel and lead between East and Escambia Bays; highest values for all metals examined were observed in Pensacola Bay with lowest in Blackwater Bay. It should be noted, however, that aluminum concentrations followed, or likely contributed to, the above distribution pattern. Lowest mean aluminum value was noted in Blackwater Bay (4,684 ppm) and highest in Pensacola Bay (14,565 ppm); East and Escambia Bays had comparable and intermediate levels. Aluminum has been used to standardize metal concentrations for a variety of estuarine sediment types and is generally related to grain size, with high aluminum concentrations found in fine-grain silts and clays. Significant positive relationships have been observed between aluminum and various metals (Windom et al. 1989; Schropp et al. 1990; Summers et al. 1996) with higher metals concentrations naturally occurring in sediments with higher aluminum.

Based on these metal:aluminum standardizations, sediments in Blackwater and East Bays do not appear to be enriched in metals to any degree. With aluminum ranging only from 4,684 to 14,565 mg/kg (ppm), the sites reported in Olinger et al. (1975) were probably relatively sandy with low to moderate amounts of silts and/or clays. Concentrations of metals would be expected to be relatively low, and in fact, they were. Plotting metal:aluminum ratios, lead and zinc were the only metals that appeared enriched, and only slightly so. Examining metal:aluminum data from Long et al. (1997) for Blackwater and East Bays (Table 5), only zinc showed slight enrichment. While nearly all metal concentrations were higher at sites reported by Long et al. (1997) compared with Olinger et al. (1975), aluminum concentrations were likewise significantly higher as well. Sites sampled by Long et al. (1997) were primarily from fine-grained, silt-clay sediments with grain size between 6.2 and 9.4ϕ; only the upper Blackwater Bay station had coarser sediments (3.4ϕ). All recently collected sediment metals concentrations reported for Blackwater and East Bays by DeBusk et al. (2002) were considered in the low to moderate contamination range based on the Sediment Quality Assessment Guidelines (SQAGs) developed by MacDonald (1994).

Synthetic organic compounds have been observed throughout the Pensacola Bay system with considerable interest focused on polychlorinated biphenyls (PCBs) since an industrial leak of Arochlor 1254 in the Escambia River in 1969. Sampling six years after the spill, Olinger et al. (1975) observed PCB concentrations remained widespread throughout the system; yet levels appeared to be significantly reduced. They estimated that PCBs were decreasing in sediments at a rate of about 90 percent per year. Olinger et

Table 5. Sediment quality in the Blackwater Bay/East Bay system. Selected characteristics are presented for three sites in Blackwater Bay and three sites in East Bay. Stations are oriented from north to south. Data source: Long et al. (1997).

Bay Area	C%	N%	Grain Size	Al	Cd	Cr	Cu	Ni	Pb	Zn
Blackwater Bay										
31	2.6	0.17	3.44	19700	0.22	30.5	10	7.9	18.1	45.3
30	7.1	0.48	8.89	35200	0.25	70.4	19.1	20.5	37	93
29	5.2	0.37	8.95	40900	0.26	72	19.1	20	35.7	101
East Bay										
26	3.1	0.29	6.23	40800	0.21	73.5	16.2	20.2	33.8	105
27	3.9	0.37	9.37	56100	0.15	101	20.1	27.2	42.9	131
28	3.9	0.39	9.3	51700	0.16	101	18.8	27	42.7	128

Units =		
	Total Organic Carbon (%)	Chromium (ppm)
	Total Organic Nitrogen (%)	Copper (ppm)
	Grain size (ϕ)	Nickel (ppm)
	Aluminum (ppm)	Lead (ppm)
	Cadmium (ppm)	Zinc (ppm)

al. (1975) also reported that of 21 pesticides analyzed only DDE (a DDT derivative) was widespread in distribution. DDE was noted in both Blackwater and East Bays, but did not exceed concentrations of 1.9 ppb. All recently collected sediment PCB data and nearly all DDE (as well as DDD and DDT) concentrations reported for Blackwater and East Bays by DeBusk et al. (2002) were considered in the low contamination range based on the SQAGs developed by MacDonald (1994). No pesticide or PCB information was presented by either Seal et al. (1994) or Long et al. (1997) for Blackwater and East Bays.

Low and high molecular weight polycyclic aromatic hydrocarbons (PAHs), as well as total PAHs, were observed throughout Blackwater and East Bays, but were considered in the low contamination range (DeBusk et al. 2002) using the above cited SQAGs (MacDonald 1994). Only slight PAH enrichment was noted by Seal et al. (1994) and Long et al. (1997) at some sites.

Based on their review of recent metals and synthetic organics data throughout the Pensacola Bay system, DeBusk et al. (2002) highlighted the bayous, upper- and mid-Escambia Bay, and portions of Pensacola Bay near the downtown waterfront as the areas of greatest contamination concern. While observing detectible quantities of most contaminants reviewed, concentrations in Blackwater and East Bays were low and generally considered to be of only low toxicity.

4.0 HABITATS ASSOCIATED WITH THE EAST BAY COMPLEX

The East Bay/Blackwater Bay watershed supports a variety of biotic communities and maintains a high level of biodiversity. Those habitats directly associated with surface waters of East Bay include: palustrine forests, fresh/brackish wetlands, tidal salt marshes, submerged aquatic vegetation (SAV), soft and hard bottom. Approximately 175,120 acres of wetland habitats are found in the watersheds draining into the East Bay/Blackwater Bay system (Figure 23; NWI 2008) with nearly half found in the Yellow River basin. This acreage estimate combines only the wetland forests, marshes (all kinds) and SAV beds; soft and hard bottom are not included.

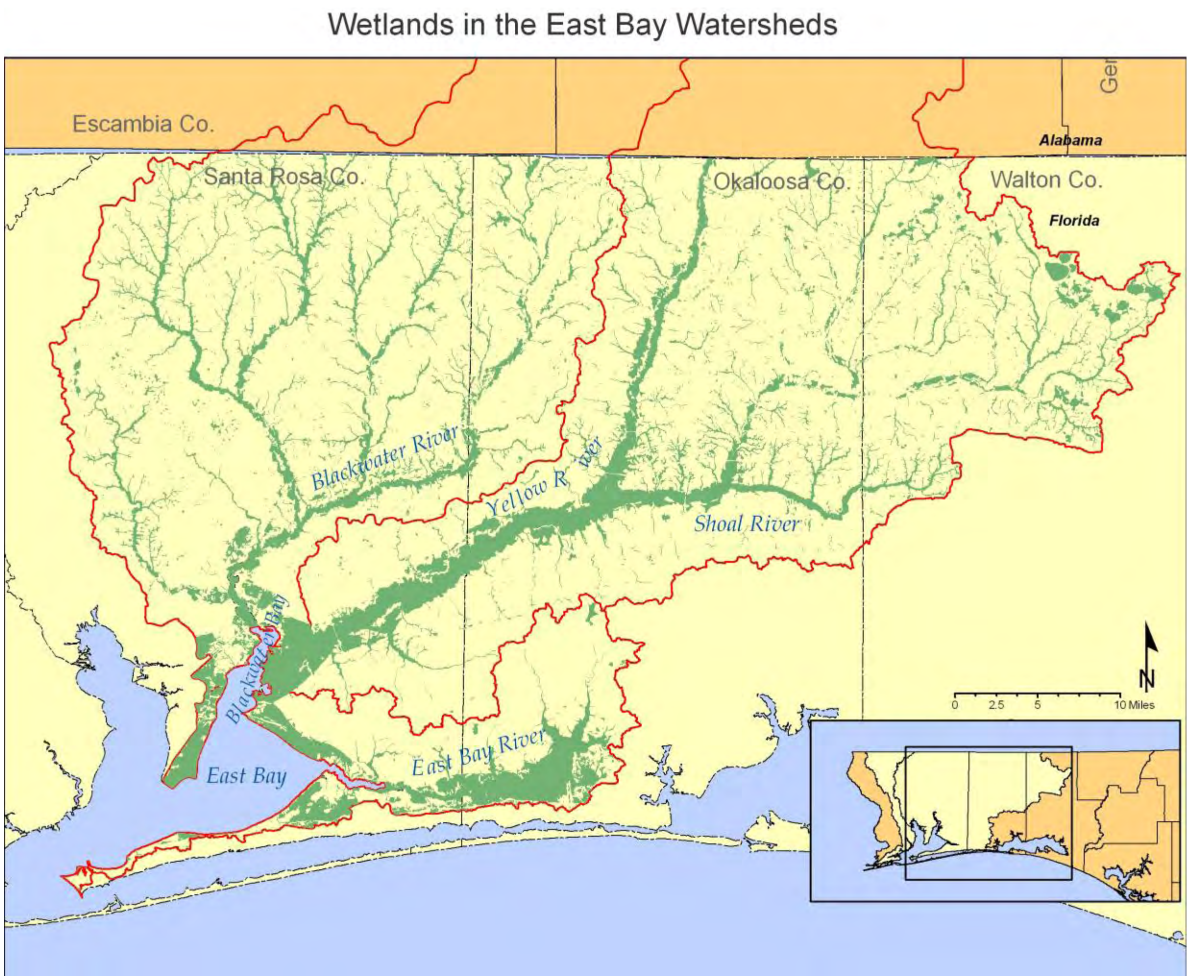


Figure 23. Wetlands in the East Bay watersheds. Mapped wetlands include all National Wetland Inventory (NWI) palustrine and estuarine categories combined for the Florida portions of the three East Bay/Blackwater Bay drainage basins. Data source: NWI 2008.

4.1 Palustrine Forests

Few investigations have focused on the wetland forests of the lower portion of the Yellow River and Blackwater River basins, although studies are planned for parts of the Yellow River Aquatic Preserve (S. Alexander, DEP, personal comm.). Based on forest community studies in the Apalachicola, Ochlockonee, Wakulla/St. Marks and other panhandle systems (Clewell 1986; Leitman et al. 1984, 1991, 1993; Darst and Light 2008), riverine forests in this area are likely composed of at least three major vegetation types: bottomland hardwoods, cypress swamps and coastal tidal swamps. The distribution of these forests types are heavily influenced by elevation, the degree and type of inundation, and proximity to the coast (i.e., salt water).

Bottomland hardwood forests occupy wet-mesic to nearly hydric habitats that are usually associated with stream and river floodplains (Clewell 1986). Habitats in these forests are generally inundated, sometimes briefly but sometimes for prolonged periods annually. During the dry season, the root zone is usually well aerated. In areas where flooding is more pronounced, cypress-tupelo swamps dominate. These swamps are characterized by prolonged hydroperiods in which the soils are inundated at least several weeks every year and often for as long as six months (Clewell 1986). Coastal swamps occur along river floodplains within the zone of tidal influence and along the inland margins of tidal marshes (Clewell 1986). While freshwater conditions generally prevail, coastal swamps are subject to tidal fluctuations and can tolerate some salt water inundation. Proximity to the coast results in rapid dissipation of flood waters precluding lengthy or prolonged inundation during seasonal flooding. Generally uniform hydrological conditions and occasional salinity shock likely limit the species present.

Much of the lower Yellow River floodplain appears composed of mixed bottomland hardwood forests; these forests are quite variable yet diverse in floral composition. Leitman et al. (1984) and Darst and Light (2008) described several variants of this mixed bottomland hardwood forest from the Apalachicola River basin that are likely to be found in the Yellow River. These include both high and low bottomland hardwood habitats and tupelo-cypress swamps; these forest types are influenced primarily by surface elevation and degree of inundation.

River swamps are found on the wettest sites with the greatest duration and frequency of inundation. Sites are typically continuously flooded from 4 to 9 months each year (Darst and Light 2008). These swamps are dominated by water tupelo (*Nyssa aquatica*), swamp tupelo (*N. biflora*), Ogeechee tupelo (*N. ogeche*), bald cypress (*Taxodium distichum*), pop
ash (*Fraxinus caroliniana*) and planer tree (*Planera aquatica*). Variation within swamp types was observed with varying relative abundance of the above dominant trees. Chief associates in these swamps include red maple (*Acer rubrum*), overcup oak (*Quercus lyrata*), pumpkin ash (*F. profunda*), and sweetbay (*Magnolia virginiana*). Low bottomland hardwood forests occupy somewhat drier portions of the floodplain with less inundation; continuous flooding usually lasts 2 to 4 months per year (Darst and Light 2008). These forests are dominated by water hickory (*Carya aquatica*), green ash (*F. pennsylvanica*), overcup and swamp laurel (*Q. lauriflora*) oaks, sweetgum (*Liquidambar styraciflua*) and American elm (*Ulmus americana*). Hackberry (*Celtis laevigata*) and red maples are often found as associates. High bottomland hardwoods are located at higher elevation, drier sites than either the river swamps or the low bottomland hardwoods. These areas are commonly inundated for 2 to 6 weeks each year (Darst and Light 2008).

Sweetgum, hackberry, ironwood (*Carpinus caroliniana*), water oak (*Q. nigra*) and possum haw (*Ilex decidua*) predominate with swamp laurel oak and green ash found as chief associates.

Similar forest composition was observed in the floodplain of the Ochlockonee River (Leitman et al. 1991, 1993); forest type in the various topographic zones was strongly influenced by hydrologic conditions. Lowest areas of the floodplain were dominated by Ogeechee tupelo and bald cypress with lesser amounts of planer tree and pop ash. Low terraces were dominated by swamp laurel oak and red maple; sweetgum and Ogeechee tupelo were also found in relatively high abundance. Higher elevation sites (termed high terraces) were occupied by sweetgum, spruce pine (*Pinus glabra*), live (*Q. virginiana*) and water oaks; swamp laurel oak, American holly (*Ilex opaca*) and swamp tupelo were relatively common as well.

Coastal swamps have been described by Light et al. (2002) for the lower Suwannee River. Canopy composition in these lower tidal swamps was dominated by pumpkin ash, bald cypress, swamp tupelo, with pumpkin ash, swamp tupelo, sweet bay, cabbage palm (*Sabal palmetto*) and loblolly pine (*Pinus taeda*) dominating in the lower tidal mixed bottomland and hammocks. Cabbage palms were found in all tidal communities as both canopy and subcanopy trees. Lower tidal hammocks, as described by Light et al. (2002), vary in elevation and in distance from the Gulf, thus in exposure to river flooding, tidal surge, and salinity. Hammocks closest to the Gulf tended to have the largest proportion of cabbage palms.

Clewell (1986) described most of the forest along the Blackwater River as a cedar swamp dominated by Atlantic white cedar (*Chamaecyparis thyoides*) in the overstory on the levees with American holly in the understory. Other common trees noted included water and live oaks, southern magnolia (*Magnolia grandiflora*), swamp bay (*Persea palustris*), loblolly pine and titi (*Cyrilla racemiflora*). Clewell's description is brief and is not accompanied by additional site information; the spatial extent is unknown and it is unclear if this account pertains to the lower reach of the river.

Based on the limited information available to date, detailed forest composition and distribution in the lower reaches of these systems are uncertain and will await further survey and monitoring to determine specific community types and abundances. Preliminary investigations have confirmed the dominance of bald cypress, Atlantic white cedar, swamp laurel and overcup oaks, swamp and silver bays, red maple, black gum and slash pine (*Pinus elliottii*) in the lower Yellow River floodplain, and as such are similar to other panhandle river floodplain forests.

The bulk of the wetlands found within the watershed are palustrine forests (including palustrine forested and scrub-shrub categories); these are found primarily in the river floodplain corridors. Of the 154,757 acres of wetland forests in the three basins, most is located in the Yellow River basin (49.4%) followed by the Blackwater (32.6%) and East Bay (18.0%) rivers. The majority of the palustrine forest in the Yellow River lies downstream of its confluence with the Shoal River and is associated with the widening expanse of river floodplain.

4.2 Fresh/Brackish Wetlands

The fresh and brackish wetlands include both emergent and submergent plant forms and result in a floral continuum from the headwaters to the estuary. A riparian marsh habitat is found in the freshwater portion of the system with the brackish marsh extending downstream through the oligohaline region of the estuary where salinities range from 0 to 15 ppt. Marsh species composition is likely influenced by a combination of salinity tolerance and differences in soil type, elevations and competitive interactions.

This habitat is primarily limited to the oligohaline region of the estuary where salinities range from 0 to 15 ppt and is generally located along river mouths subject to tidal influence. Often the emergent portions of these fresh/brackish marshes are dominated by sawgrass (*Cladium jamaicense*), maidencane (*Panicum hemitomon*), giant cutgrass (*Zizaniopsis miliacea*) and cattails (*Typha* spp.), but may contain large interspersed patches of black needlerush (*Juncus roemerianus*). In the underwater areas, various species of submerged aquatic vegetation (see below) often proliferate.

The presence of true fresh/brackish wetlands in the East Bay/Blackwater Bay area appears limited to the sizeable delta region at the mouth of the Yellow River, the mouths of the Blackwater and East Bay Rivers and the tributary bayous which have freshwater inflows. Additionally, large emergent wetlands are found at the southern end of Garcon Point. The most recent NWI data (2008) indicate 2,527 acres of estuarine emergent vegetation in the East Bay/Blackwater Bay area (Figure 24), with the largest tracts located in the delta of the Yellow River and the lower portion of Garcon Point. However, this NWI coverage does not appear to accurately differentiate the acreages of fresh/brackish wetlands from tidal salt marsh. The majority of the delta marsh is classified as estuarine emergent (generally interpreted as salt marsh); yet personal observations indicate the presence of numerous fresh/brackish species. Palustrine emergent vegetation is not mapped in the delta (except in the most upstream portion) but is widely scattered throughout the basins (6,794 acres). Nearly 45% of the mapped palustrine emergent habitat is found in three large wetland areas (Figure 24), two of which are on Garcon Point and not associated with the river mouths. Based on a composite of these NWI data, the Yellow River delta marsh is estimated at about 1,500 acres and is composed of a mix of fresh, brackish and salt marsh species. One older source (DNR 1989) estimated that the Yellow River delta marsh covered about 2,400 acres but did not indicate how much of this included portions of the forested wetlands.

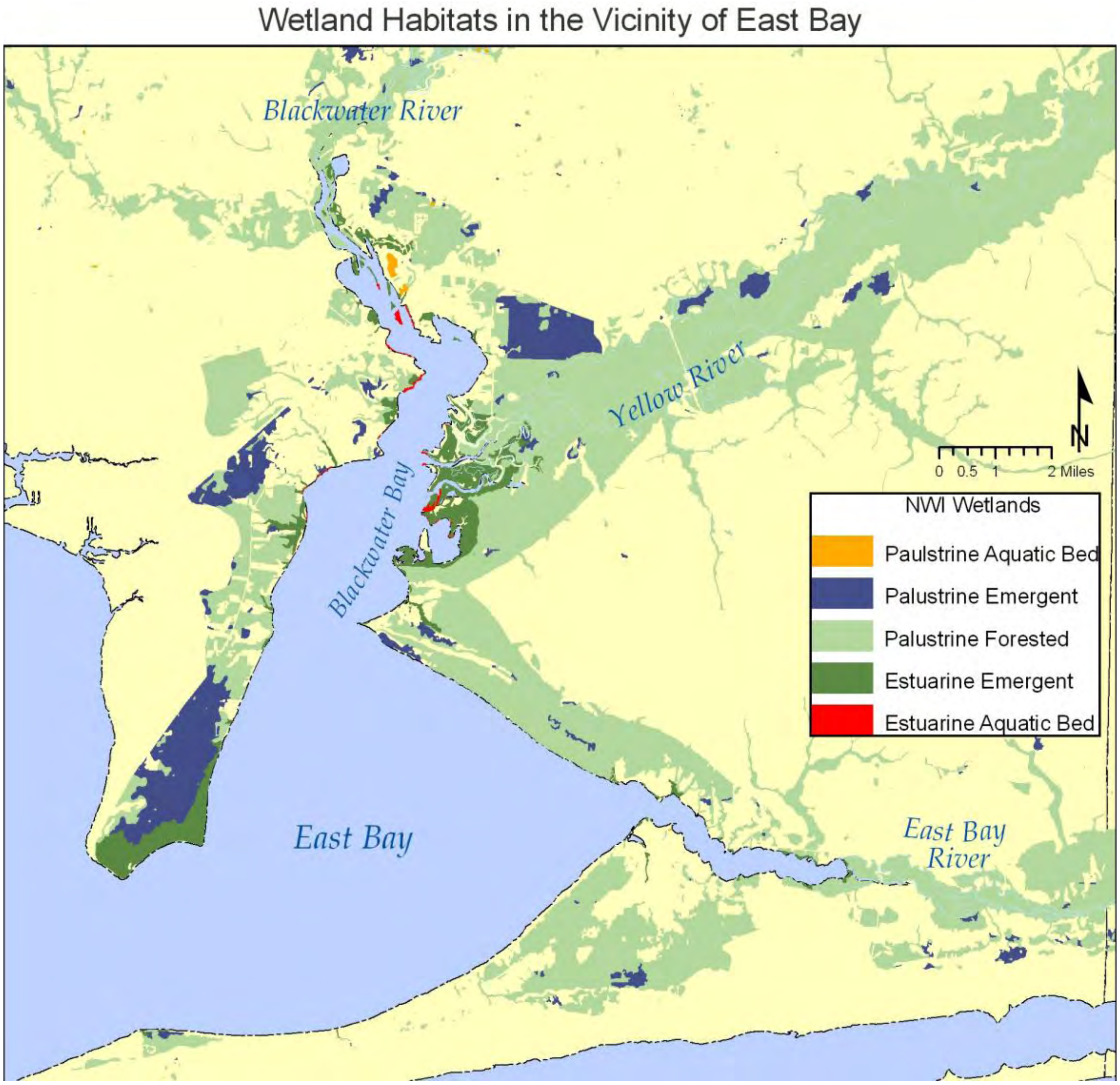


Figure 24. Wetland habitats in the vicinity of East Bay. Mapped wetlands include the National Wetland Inventory (NWI) palustrine and estuarine categories found in the vicinity of East and Blackwater bays. Data source: NWI 2008.

4.3 Tidal Salt Marshes

Salt marshes are similar to brackish marshes in that they serve as a transition between terrestrial and marine systems. Generally, salt marshes are intertidal and develop along relatively low energy shorelines. Unlike brackish marshes, they may be found under significantly more saline conditions. Salt marshes in the panhandle are usually characterized by large, fairly homogeneous expanses of dense black needlerush (*Juncus roemerianus*). Often they are accompanied on the waterward side by smooth cordgrass (*Spartina alterniflora*). The *Juncus* and *Spartina* zones are very distinctive and can be separated easily by elevation, with *Spartina* inhabiting the lower, regularly flooded zone, and *Juncus* found in higher, less flooded area. Frequently, additional species of cordgrass (*Spartina* spp.), salt grass (*Distichlis spicata*), glasswort (*Salicornia virginica*), various sedges (*Scirpus* spp.) and the common cane (*Phragmites australis*) occur.

Generally, tidal marshes can be divided into four ecological zones governing by elevation and extent of inundation: *Spartina alterniflora* zone, *Juncus* marsh, salt flats, and barrens (Wolfe et al. 1988). The *Spartina alterniflora* zone typically fringes tidal creeks and channels. A small landward increase in elevation permits development of lush *Juncus* stands that are by far the most extensive and conspicuous feature of the tidal marsh. *Juncus* plants may grow to 6-7 feet in height throughout the majority of the marsh declining to about one-half this height at the landward edge of the marsh near the flatwoods where they merge with the salt flats. Stunted plants of several genera typify the flats, especially *Salicornia*, *Batis*, *Borrichia* and *Aster*. The barrens are landward of the flats and consist of bare ground flooded by high tides for only brief periods. This infrequent tidal inundation coupled with long exposure to sunlight results in such high salt content of the soil that most plants are excluded. True salt marshes appear limited to the higher salinity regions of the East Bay/Blackwater Bay complex with an expansive area noted on Garcon Point.

Early estimates of tidal marsh habitat in the East Bay area (McNulty et al. 1972) indicated about 3,307 acres occurred; these were shown in Figures 23 and 24 of the above cited report. More recent information, available from the National Wetlands Inventory (NWI), indicated about 2,500 acres of emergent estuarine marsh habitat adjacent to the two bays (Figure 24). No distinctions were made in either study between fresh/brackish and tidal salt marsh; NWI coverage combines the habitats and classifies them as either palustrine or estuarine (generally interpreted as salt marsh) emergent. It is unclear if the difference in these two estimates depicts real habitat loss or differences in mapping methodologies between the two sources. The largest contiguous tidal salt marsh area (1,544 acres) is located along the southern shore of Garcon Point, north and southwest of White Point (Figure 24). Smaller areas are scattered throughout many of the higher salinity, tributary bayous as well as mixed with fresh and brackish species in the river deltas.

4.4 Seagrass/Submerged Aquatic Vegetation

Seagrasses represent one of the most important and productive habitats in estuarine and nearshore environments. Seagrass beds support highly diverse and abundant floral and faunal communities and provide spawning, feeding, nursery and protective refugia for a wide array of aquatic organisms including many of recreational and commercial value. Seagrass beds in the Pensacola Bay system are dominated by turtle grass (*Thalassia testudinum*) and shoal grass (*Halodule wrightii*). Other species include manatee grass (*Syringodium filiforme,* referred to as *Cymodocea* in Collard 1991a), star grass (*Halophila engelmannii*) and widgeon grass (*Ruppia maritima*, not referred to as a true seagrass by Collard 1991a). The majority of seagrass found in the Pensacola system is located in Santa Rosa Sound with only small beds scattered in parts of Pensacola, Escambia, East and Blackwater bays.

Vertical zonation of seagrasses generally correlates with tidal level in most shallow estuarine waters (Zieman 1987). *Halodule wrightii* and *Ruppia maritima* are abundant intertidally, with *Ruppia* preferring a somewhat lower level than *Halodule*; *Thalassia*, *Syringodium* and *Halophila* are found only below low water levels. Low or unusually high salinity may restrict or eliminate *Thalassia* and *Syringodium*. *Thalassia* and *Syringodium* are usually associated with stable, near-marine salinities (20-36 ppt), open coastal water, and subtropical to tropical temperatures. *Halodule* is generally found in more estuarine conditions (10-25 ppt), but also forms dense stands in open coastal, high-salinity regions, in areas of high water movement or in tidal flats where it is subject to exposure. *Ruppia* is most common in very brackish water (1-5 ppt), with meadows extending into the mouths of rivers (Dawes 1987).

Submerged aquatic vegetation (SAV) is the fresh/brackish water equivalent to seagrasses and includes such species as tapegrass (*Vallisneria americana*), pondweed (*Potamogeton* spp.) and widgeon grass (*Ruppia maritima*). SAV beds provide many of the same functions as seagrass beds, only in the fresh to oligohaline portions of the estuary. Generally these species can tolerate only minor intrusion of salt for short periods of time and as such are limited to relatively narrow regions at the head of estuaries.

The shallow nearshore zone of the lower Yellow River and estuary is inhabited by moderate amounts of SAV which appear relatively well established along sluggish river bends and estuarine shoreline to depths of about three feet (DNR 1989). Tapegrass and lemon bacopa (*Bacopa caroliniana*) were most prevalent with an understory including widgeon grass, southern naiad (*Najas guadalupensis*), green fanwort (*Cabomba caroliniana*) and bladderwort (*Utricularia* sp.). The exotic Eurasian watermilfoil (*Myriophyllum spicatum*) was identified from the bay, but was reported as sparse (DNR 1989). Distribution of vegetation was depicted in Figure 3 of the above cited report.

Submerged vegetation in the East Bay/Blackwater Bay area was estimated to occupy only about 310 acres in the early 1970s (McNulty et al. 1972); these acreages were shown in Figures 23 and 24 of the above cited report. Small patches of seagrass were depicted along the southern shoreline of East Bay and a large elongated, relatively contiguous bed was noted along the northeastern shore, southeast of Escribano Point. No areas of submerged vegetation were mapped for Blackwater Bay, although they were likely present (see Figure 3 in DNR 1989). While discussed as "seagrass" acreage, no data were given to differentiate seagrass from SAV. Since no SAV beds were actually mapped in the vicinity of either the Blackwater or Yellow Rivers, it is unclear (but doubtful) whether they were included in the total acreage estimates.

Mapping of NWI data from the mid-1990s indicated approximately 220 acres of submerged vegetation observed primarily along the shoreline in Blackwater Bay, with widest expanse along the eastern shore associated with the Yellow River delta marsh. Using the more current 2008 NWI data (Figure 24), SAV was estimated to cover about 83 acres; much of the mid-Blackwater Bay SAV previously mapped (1995) does not appear in this later data set. Because of potential differences in mapping methodologies between these studies, it is unclear how much of the estimated acreage differences depict actual habitat loss. Seagrass losses throughout the Pensacola Bay system, however, are well documented (Olinger et al. 1975; Collard 1991a; Schwenning 2001) with significant declines observed throughout the East Bay area. Noticeably absent in the 1990's survey were the beds southeast of Escribano Point and along the southern shore of East Bay.

Two additional surveys shed more light on historical trends in seagrass decline and provide the most recent assessment of seagrass/SAV coverage in the system. Using historical photographic data, the U.S. Geological Survey's National Wetland Research Center (USGS/NWRC) estimated a significant decline in seagrass coverage in East Bay/Blackwater Bay from the 1960s to present (Handley et al. 2007). The authors estimated overall coverage declined from about 1,175 acres in the 1960s to 245 acres in the 1980s rising to 408 acres in the early 1990s. Continuous beds consistently declined from 110 to 30 acres between 1960 and 1980 with only 13 acres estimated by 1992. These acreages (both continuous and patchy) were confined to areas north of Escribano Point (i.e., Blackwater Bay proper) with highest density observed around the mouth of the Yellow River.

In 2003 a series of aerial photos were taken throughout the panhandle by the U.S. Fish and Wildlife Service to estimate the current status of seagrass coverage. These photos were digitized and mapped by USGS/NWRC but were not included in the above cited publication. Results of this effort estimated seagrass/SAV coverage at 284 acres with most cover found within Blackwater Bay (as noted previously). This value might indicate an additional decline over the last 20 years.

Combining results from these various surveys, the amount of seagrass/SAV in the East Bay/Blackwater Bay complex has been and is currently low (likely less than 100 acres) representing less than 0.3% of bay bottom (approximately 33,360 total acres). Despite its low frequency of occurrence, however, this habitat is one of the more important in the system and appears concentrated in areas proximal to freshwater inflow points.

4.5 Soft-bottom Habitat

Unvegetated sand and mud make up the bulk of the bay bottom in the Pensacola Bay system and its subareas, including Blackwater and East Bays. These bottoms, although devoid of most structure, can be none-the-less quite productive in terms of infaunal organisms and the communities they support. These areas can serve as significant feeding habitat for a variety of fin and shellfish of recreational and commercial value. Much of the bottom in the Pensacola Bay system, however, is covered with unconsolidated, ooze-like sediments, particularly in the deeper areas; benthic macroinvertebrate surveys have provided presumptive evidence that primarily stress-tolerant near-surface infaunal species are favored throughout these regions (Collard 1991b).

In his summary of biological trends and current status of the Pensacola Bay system, Collard (1991a) listed a variety of pejorative terms that had been used to describe these soft sediments including, "sludge", "organic muck", "gelatinous ooze", "reducing", "contaminated", "stressed", "degraded", and "heavily polluted". These terms were most often used subjectively and presented, in his opinion, without adequate backup technical information (Collard 1991a). None-the-less, the consensus remains that soft-bottom habitats comprise the majority of the bottom in the system, are relatively unproductive and may be increasing in size in some portions of the system, particularly Blackwater and East Bays.

4.6 Hard-bottom Habitat

Most of the hard substrate habitat in panhandle estuaries is artificial, comprised of structures such as jetties, bridges, and pier pilings. Of the naturally occurring hard substrate habitats in this area, oyster reefs are the most abundant as well as ecologically and economically important.

The biology of the oyster has been extensively studied because of its economic interests (Galtsoff 1964; Kennedy et al. 1996). Oysters are typically reef building organisms, growing on the shell substrate accumulated from generations of oysters. They may occur in both intertidal and subtidal environments. The primary reef-building commercial oyster in the panhandle is the Eastern or American oyster (*Crassostrea virginica*). This species grows in a wide salinity range (10-30 ppt) with optimal growth occurring at water temperature of about 25°C. Frequently reefs also contain large numbers of other bivalve mollusks such as horse oysters (*Ostrea equestris*) and hooked mussels (*Ischadium recurvum*).

The location and distribution of oyster reefs depend on many interacting factors which include complex combinations of geological, physical, chemical and biological processes. Reef oysters, although tolerant of broad ranges on important habitat variables such as temperature and salinity, are susceptible to various forms of physical disturbance and adversely affect or destroy reef structures. Success of the eastern oyster depends of factors that influence spawning, planktonic larval development, metamorphosis of the spat stage, and longevity of the sexually mature adult. Commercial harvesting, predation, disease and physical processes such as sedimentation (burial) are major causes of mortality in the developing oyster reefs. Water circulation is important for larval transport, settlement, delivery of food (phytoplankton), and removal of waste. Salinity is a key factor in the incidence of predation and disease, with both increasing with increasing salinity.

Oyster habitat in the Pensacola Bay system is limited in distribution with bars suffering massive mortalities during the last 40 years (Collard 1991b). Significant dieoffs (with up to 100% mortality) have been recorded at least once per decade since the 1960s (e.g., 1963, 1971, 1987); smaller-scale dieoffs occurred more frequently, but were not adequately recorded. The 1971 dieoff caused by the protozoan pathogen *Perkinsus marinus*, was attributed, at least in part, to environmental stress. Continued poor water and sediment quality are suggested as primary factors restricting oyster growth and reproduction in the area (Collard 1991b).

Estimates of the coverage of oyster habitat in the East Bay/Blackwater Bay area appear to differ significantly over time. Early estimates indicated very limited available oyster habitat with only about 218 acres of reefs in the system (McNulty et al. 1972). Of these, 80 acres were in public bars with 138 acres in private leases. Seven locations were mapped (see Figure 23 of the cited report). At the time this report was drafted, no reef enhancements projects were underway. Reports compiled recently by the Florida Department of Agriculture and Consumer Service (Knight 2003) indicate 12 charted natural bars and eight enhancement sites within the two bays (Figure 25); no lease sites are shown on the current maps. Commercial harvesting is currently allowed only on those reefs in East Bay (see Figure 12 for approved shellfish harvesting areas); bars located in Blackwater Bay are not approved. Enhancement (relocation of clutch, i.e., old oyster shell) of reef areas was begun in 1972 and has been carried out sporadically since, with major efforts in 1987, 1988, 1990 and 2000 (see Figure 25).

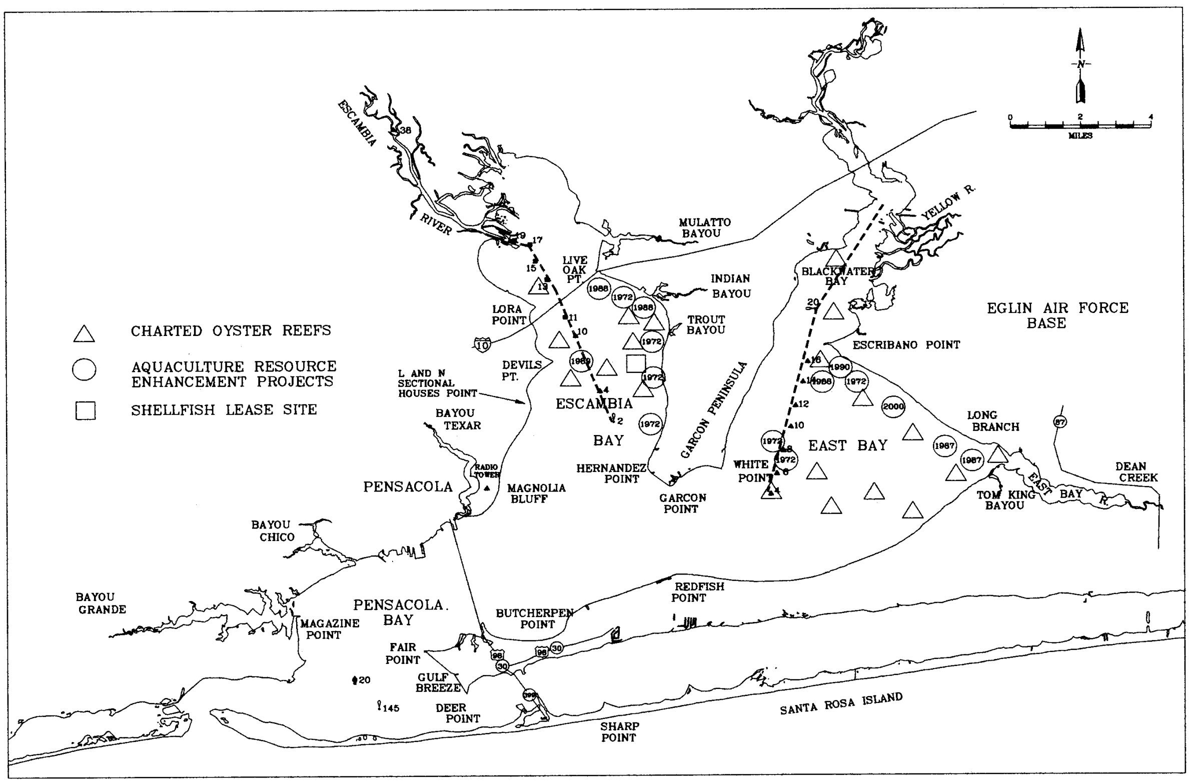


Figure 25. Charted oyster resources, including natural reefs, aquaculture enhancement areas and shellfish lease sites, located in the Pensacola Bay system (DACS 2003). Numbers inside the open circles (i.e., aquaculture enhancement projects) indicate the year in which the enhancement was accomplished.

5.0 FAUNAL COMMUNITIES IN THE EAST BAY/BLACKWATER BAY SYSTEM

Ecological information on invertebrate and fish communities in the East Bay/Blackwater Bay estuary appears limited to a handful of studies, with the two most comprehensive occurring nearly 25 years apart (Olinger et al. 1975; Livingston 1999). The former study (Olinger et al. 1975), known as the Escambia Bay Recovery Study, was designed to document environmental conditions in the Pensacola Bay system, determine significant mechanisms degrading Escambia Bay, and assess feasibility of restoration. While other small studies were carried out since in various portions of the bay, Collard (1991a) described the Olinger work as "the only comprehensive study accomplished on the PBS [i.e., Pensacola Bay system] to date". Although designed primarily to examine Escambia Bay, collections were taken in parts of Blackwater and East Bays. Collections were made using benthic grabs for infauna/epifauna (collectively termed benthic macrofauna), and bag seines and balloon trawls for fishes and large, motile invertebrates (primarily shrimp). Sampling was done either bimonthly or quarterly during 1973-74. Selected portions of the data were taken from tables and appendices in Olinger et al. (1975) and are summarized here.

No large-scale study of the system was done until Livingston (1999) [and others; see summary in Gallagher et al. (1999)] investigated the possible effects of an additional waste load from Champion International Corporation, now International Paper Corporation (pulp and paper mill located in Cantonment currently discharging waste water to Perdido Bay via Eleven Mile Creek) redirected into the Escambia River. As with the Olinger et al. (1975) work, Livingston's collections were concentrated in Escambia Bay, with some sampling accomplished in Blackwater and East Bays.

Sampling stations of interest included: 1 site in the Blackwater River, 1 in the Yellow River, 3 in Blackwater Bay and 4 in East Bay. Collections were taken for benthic infauna and epifauna, and fishes during 1997-98. Data were unavailable directly from Livingston (1999), but summary information was taken from Von Appen and Winter (2000) for comparison. These comprehensive investigations, as well as the numerous small-scale studies examining portions of the system, have been summarized by Collard (1991a) for those occurring prior to 1990 and by Von Appen and Winter (2000) for those occurring between 1990-2000.

Riverine portions of the East Bay/Blackwater Bay system have been sampled for benthos and fishes by the Florida Fish and Wildlife Conservation Commission (FFWCC) sporadically over the last 50 years. Early collections were reported by Byrd et al. (1962) and Bass et al. (1979). Recent collections have been made at a variety of sites throughout the lower Yellow, Shoal and Blackwater rivers (J. Knight, FFWCC, personal comm.).

5.1 Benthic Macrofauna (Infauna/Epifaunal)

Benthic invertebrate communities were examined at seven sites in the Yellow and Shoal rivers (Figure 26) during 1978-1979; abundance and biomass of benthic organisms were recorded from shoreline and mid-river locations (Bass et al. 1979). Clearly, higher densities and biomass were observed at Yellow River sites relative to Shoal stations with shoreline locations having greater amounts of both compared to mid-river. Yellow River densities ranged from 211-506 individuals per m^2 along the shoreline and 25-137 in mid- river; biomass ranged from 2.5-63 grams per m^2 along the shore compared with 0.1-1.8 in mid-river. Shoal River sites had densities from 201-310 individuals per m^2 along the shore and 49-74 in mid-river; biomass ranged from 0.1-0.8 grams per m^2. Sites on both rivers were dominated by midge (Tendipedidae) and mayfly (Ephemeroptera) larvae, oligochaetes and bivalves (particularly the Asiatic clam *Corbicula leana* [probably *C. fluminea*]) with some variation noted between rivers. Overall, Yellow River habitats were considered relatively productive when compared with other river systems (i.e., Blackwater, Escambia and Suwannee rivers) while Shoal sites were deemed relatively unproductive. Differences between the Yellow and Shoal river productivity were suggested to be related to the greater proportions of organic debris/detritus in the Yellow River.

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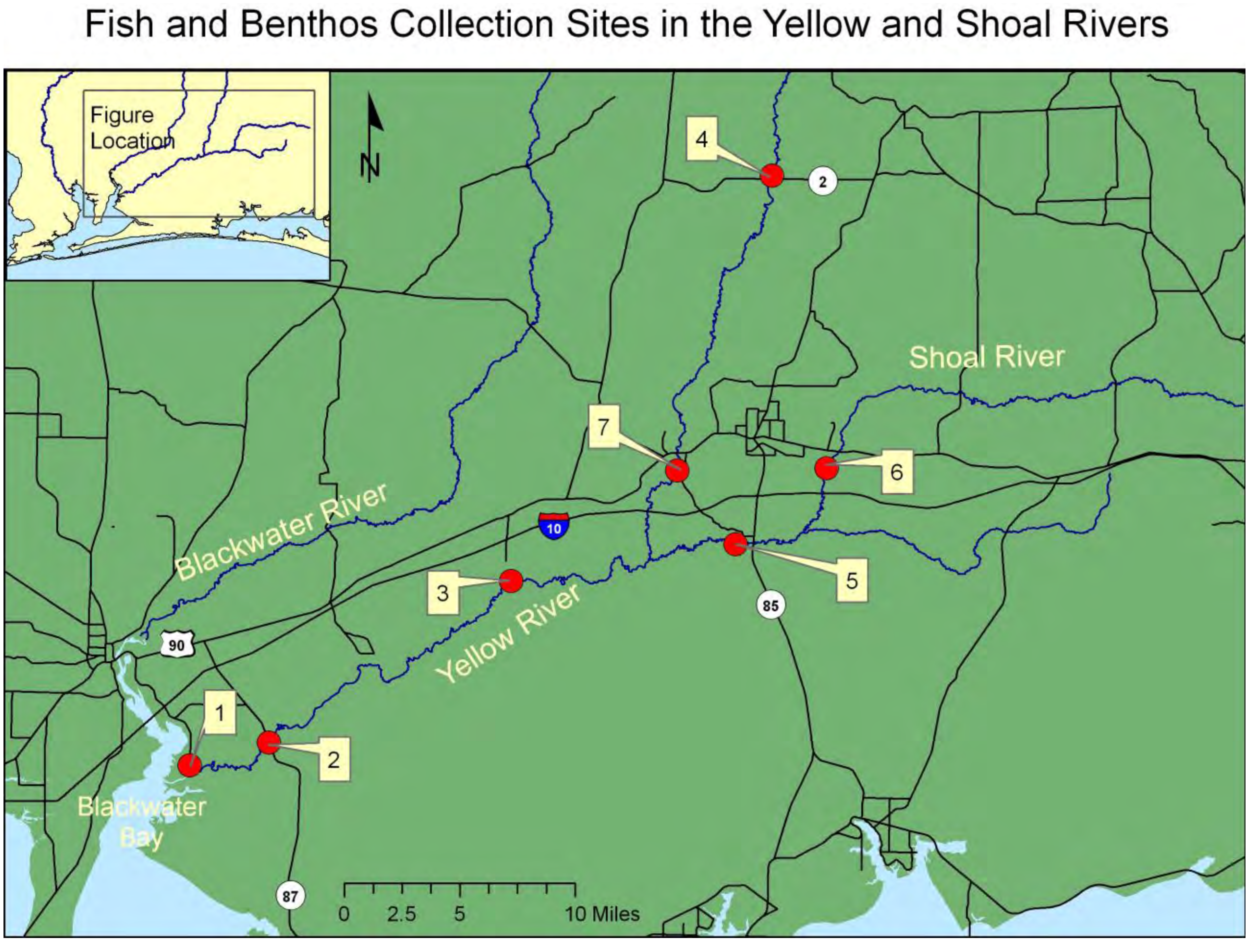

Figure 26. Fish and benthos collection sites in the Yellow and Shoal rivers taken during 1978-1979 by the FFWCC. Benthic collections were taken at all sites while fishes were sampled only at sites 1-6. Data source: Bass et al. (1979).

Sixty-nine benthic macrofaunal taxa were collected from three transects in the East Bay/Blackwater Bay system (Table 6) (Olinger et al. 1975). Fauna were dominated by amphipod and decapod crustaceans, gastropod and pelecypod molluscs, and polychaete worms. Densities were generally low to moderate at most sites, ranging from 56 to 4,272 individuals per square meter (Table 7). Lowest densities tended to be found at the muddy, fine-grained sites at the waterward end of each transect; higher densities were generally found at inshore sandy locations. Overall, highest density was noted at a transition site (EBEC), located between the sandy shelf and deeper mud stations on the northeast side of East Bay. Species richness (number of species per site) was low with number of taxa per site ranging from 8 to 26 (Table 7). Highest species richness was noted at another transition site (EBEE), but not concurrent with the highest density (EBEC). Interestingly, both highest density (EBEC) and highest species richness (EBEE) were noted from the same transect in northeastern East Bay and were found at stations adjacent to the site with the lowest species richness (EBED). Species diversity, like species richness, was low ranging from 0.50 to 2.52 (Table 7). The station (EBEC) with the highest density (4,272 inds/m^2) and next to the highest species richness (25 taxa) had one of the lowest

Table 6. Summary of benthic macrofaunal taxa collected in Blackwater and East Bays during 1973-74 by Olinger et al. (1975). Collections were taken from 11 stations over 3 transects in the two bays.

- Arthropoda
  - Crustacea
    - Amphipoda
      - *Ampelisca vadorum*
      - *Corophium* sp. (near *C. acutum*)
      - *Grandidierella bonneroides*
      - *Haustorius* sp.
      - *Listriella* sp. (near *L. barnardi*)
      - *Melita nitida*
      - *Monoculodes edwardsi*
      - *Monoculodes* sp.
    - Isopoda
      - *Cyathura* sp.
      - *Edotea* sp.
      - *Erichsonella filiformis*
    - Tanaidacea
      - *Leptochelia* sp.
    - Cumacea
      - *Oxyurostylis smithi*
    - Mysidacea
      - *Mysidopsis bigelowi*
      - *Praunus* sp.
    - Decapoda
      - *Callianassa jamaicense*
      - *Callinectes ornatus*
      - *Callinectes sapidus*
      - *Eurypanopeus depressus*
      - *Farfantepenaeus aztecus*
      - *Litopenaeus setiferus*
      - *Micropanope* sp.
      - *Neopanope texana*
      - *Palaemonetes pugio*
      - *Palaemonetes* sp.
      - *Pinnixa sayana*

- Mollusca
    - Gastropoda
      - *Crepidula plana*
      - *Neritina reclivata*
      - Nudibranchs
      - *Odostomia* spp.

Table 6. Benthic macrofaunal taxa list (continued).

	Gastropoda (continued)	
		Polinices duplicata
		Retusa canaliculata
	Pelecypoda	
		Amygdalum papyria
		Brachiodontes exustus
		Brachiodontes recurvus
		Crassostrea virginica
		Cyclinella tenuis
		Ensis minor
		Macoma mitchelli
		Martesia cuneiformis
		Martesia smithi
		Mercenaria campechiensis
		Mulinia lateralis
		Mysella planulata
		Polymesoda caroliniana
		Tagelus plebeius
Polychaeta		
	Ampharetidae	
		Amphicteis gunneri
	Arabellidae	
		Drilonereis cylindrica
	Capitellidae	
		Heteromastus filiformis
	Glyceridae	
		Glycera oxycephala
	Goniadidae	
		Glycinde solitaria
	Hesionidae	
		Gyptis capensis
	Maldanidae	
		Grayierella sp.
		Isocirrus longiceps
	Nereidae	
		Laeonereis culveri
		Neanthes succinea
	Onuphidae	
		Diopatra c. *cuprea*
	Orbiniidae	
		Haploscoloplos fragilis
	Pectinariidae	
		Pectenaria gouldii

Table 6. Benthic macrofaunal taxa list (continued).

		Pilargidae	
			Ancistrosyllis hamata
			Parandalia fauveli
			Sigambra bassi
		Sigalionidae	
			Sthenelais boa
		Spionidae	
			Paraprionospio pinnata
			Polydora caeca
			Polydora websteri
			Scolelepis squamata
Nemertea			
			Cerebratulus lacteus
Echinodermata			
	Holothuroidea		
			Synaptula hydriformis

Table 7. Summary of benthic macrofauna collected in Blackwater and East Bays during 1973-74 by Olinger et al. (1975). Collections were taken from 11 stations over 3 transects in the two bays.

Stations	Density (No. of inds/m^2)	Species Richness (No. of spp/site)	Diversity (H')
Blackwater Bay			
BWA	286.2	18	2.44
BWB	348.7	21	2.48
BWC	412.9	21	2.11
Mean	349.3	20.0	2.34
East Bay East			
EBEA	55.9	10	1.75
EBEB	150.6	13	1.72
EBEC	4271.7	25	0.96
EBED	1595.7	8	0.22
EBEE	1527	26	1.32
Mean	1520.2	16.4	1.19
East Bay West			
EBWA	239.4	19	2.45
EBWB	244.3	23	2.52
EBWC	788.7	12	0.50
Mean	424.1	18.0	1.82
East Bay Deep			
EBD	82.0	10	1.79

diversities (0.96), resulting probably from a high level of dominance by one or a few taxa. These collections generally support the notion of a relatively depauperate benthic fauna in East Bay.

Collard (1991a) developed a master species list as part of his review of the biological trends and current status of the Pensacola Bay system. His review, based on pre-1990 studies, included a total of 408 primarily sessile infaunal macroinvertebrate taxa, 82 of which were recorded from Blackwater and East Bays. Of these, 17 taxa from East Bay/Blackwater Bay were widely considered to be indicators of stressed environments. In his examination of biological trends, Collard (1991a) concluded that short-term benthic faunal increases and decreases reported in the documents that he reviewed suggested that the Pensacola Bay system had not significantly changed in the last 30-35 years. In fact, taking seasonal and annual fluctuations into account, benthic invertebrates in 1990 appeared in much the same overall condition, with low biomass and diversity, as noted in the 1950s. He further stated that Blackwater and East Bays, and their associated bayous, may be the exceptions to this relatively stable view. These areas seemed to have been adversely impacted at a greater rate than other portions of the system; however, inadequate sampling precludes definitive conclusions.

Livingston (1999) [as summarized by Von Appen and Winter 2000] examined 40 sites throughout the Pensacola Bay system, 10 of which were located in East and Blackwater Bays and associated rivers. No community quantification was provided in Von Appen and Winter, only subjective summaries. Overall, Livingston found degraded benthic infaunal communities in most areas, likely due to toxic sediment contaminants. Infaunal biomass was greatest in upper Escambia Bay, associated with high primary production probably resulting from the high nutrient loading from the Escambia River. Highest infaunal biomass was noted in the shallow shelf areas of upper Escambia and Blackwater Bays in the vicinity of river inflows. Infaunal species diversity was highest in the high salinity portions of mid-Escambia and Pensacola Bays. Low infaunal biomass and species diversity was observed in deeper areas of East Bay, lower and eastern portions of Escambia Bay, and portions of Pensacola Bay. Indicator species for pollution were found in these areas.

5.2 Shrimp and Crab Abundance

Shrimp were poorly represented in PBS collections overall (Table 8) and specifically in East Bay (Olinger et al. 1975). Only about 16% of the shrimp collected baywide were found in East Bay samples, with the majority of these being brown shrimp (*Farfantepenaeus aztecus*); very few pink (*F. duorarum*) or white shrimp (*Litopenaeus setiferus*) were observed.

Livingston (1999) [as summarized by Von Appen and Winter 2000] noted low overall secondary productivity throughout the Pensacola Bay system. As with infauna, highest benthic epifaunal abundance was noted in upper Escambia Bay and was dominated by brown shrimp (*F. aztecus*) and blue crabs (*Callinectes sapidus*). Blackwater and East Bays were largely devoid of epibenthic macroinvertebrates, while low numbers were found in Pensacola and lower Escambia Bays.

Table 8. Summary of shrimp collected in East and Escambia Bays during 1973-74 by Olinger et al. (1975). Collections were taken from 11 stations throughout the two bays and are summarized by region.

Species	East Bay	Upper Escambia	Middle Escambia	Lower Escambia	Bayous	Total Catch	Percent of Total Catch in East Bay
Number of Trawls	22	24	24	24	29	123	17.9%
Penaeidae							
Farfantepenaeus aztecus (brown shrimp)	57	59	51	42	153	362	15.7%
Farfantepenaeus duorarum (pink shrimp)	4		7	26		37	10.8%
Litopenaeus setiferus (white shrimp)	14	4	11	4	50	83	16.9%
Totals	75	63	69	72	203	482	15.6%

5.3 Fish Abundance

Fishes were sampled at a variety of sites throughout the Yellow and Shoal rivers by the FFWCC over the last 50 years; early reports include those of Byrd et al. (1962), Bass et al. (1979) and Bass (1993). Byrd et al. (1962), using rotenone and gill and trammel nets, recorded 79 species for the Yellow and Shoal river collections. Samples from the Yellow River were dominated by channel catfish (*Ictalurus punctatus*), black madtom (*Noturus funebris*), weed (*Notropis texanus*) and blacktail shiner (*N. venustus*), bay anchovy (*Anchoa mitchelli*) and menhaden (*Brevoortia patronus*). Bluegill (*Lepomis macrochirus*) and warmouth (*L. gulosus*), speckled madtom (*Noturus leptocanthus*), pirate perch (*Aphredoderus sayanus*), blackspotted topminnow (*Fundulus olivaceus*) and an unidentified minnow (*Notropis* sp.) were most abundant in Shoal River collections. No comparisons of relative abundance could be made between the rivers because of differences in sampling effort.

Bass et al. (1979) sampled fish populations at six locations (Stations 1-6; Figure 26) in the Yellow and Shoal rivers during 1978-1979; collections were made using electrofishing gear and were standardized for catch per hour of sampling. Forty-six species were observed over all sites (Table 9) with only 10 taxa common to all locations. Fourteen species were found only in one sub-basin with 11 of these restricted to the Yellow River and only 3 confined to the Shoal. Of these, only the redear sunfish (Yellow) and the unidentified cyprinids (Shoal) were found to be common. Overall, the fish community was dominated by blacktail and weed shiner, blacktail redhorse, spotted sucker, bluegill, longear sunfish and blackbanded darter. Distinct faunal communities were noted in different reaches of the river system. Longnose gar, golden shiner, spotted sucker, bluegill and redear sunfish dominated the lower Yellow River marsh (Site 1) while clear chub, blacktail and weed shiner, blacktail redhorse and blackbanded darter were most abundant at the upper reach site (Site 4). Similar to the upper Yellow reach, Shoal River locations were dominated by blacktail and weed shiner, blacktail redhorse and blackbanded darter. Fewest species and lowest catch rates (catch per hour) were noted in the lower reach of the Yellow River (Sites 1 and 2); catch rates were three to four times greater at middle and upper river locations.

Bass (1993) compared fish communities in four river systems draining into either Pensacola or Perdido bays; of the 75 small stream sampled, 24 were located in the Yellow River. Fifty-nine species were observed over all sites (Table 10) of which 47 taxa were found in the Yellow River. Greatest number of species and number of individuals per site were noted in the Yellow River with least abundance and diversity at Perdido River sites; however, comparisons are hampered by unequal sampling efforts in the various river systems. Relative abundances of common fishes (Table 10) differed somewhat among the systems. Yellow River sites were dominated by weed, sailfin and blacktail shiners and blackbanded darter while sailfin and flagfin shiners and blackbanded darters were common on the Blackwater and Perdido. Weed, sailfin and rough shiners along with Dixie chub were most abundant in the Escambia.

Fishes have been sampled in recent years throughout the Yellow and Shoal rivers by the FFWCC (Figure 27); collections are summarized here by river reach (Table 11). Sixty species were observed throughout the river system with noticeable differentiation by reach; only 11 species were common to all reaches. Least number of species (29) was noted in the lower reach of the river and was possibly influenced by salinity intrusion in the river delta. Little salinity intrusion, however, was noted at the upper end of this reach (i.e., SR87 bridge; see water quality section). Several species collected in the lower reach are typically found in low salinity waters including longnose gar (*Lepisosteus osseus*), striped mullet (*Mugil cephalus*) and Atlantic needlefish (*Strongylura marina*); several freshwater species found in this reach are known to tolerate low salinities including largemouth bass (*Micropterus salmoides*), lake chubsucker (*Erimyzon sucetta*) and coastal shiner (*Notropis petersoni*).

Fish communities have been examined at relatively few sites in the estuarine portions of the Blackwater/East Bay system; collections were taken by Bass and Hitt (1977) in Blackwater Bay and by Olinger et al. (1975) in East Bay. More recently, Livingston (1999) sampled 10 locations in Blackwater and East Bays including the mouths of the Blackwater and Yellow rivers.

Bass and Hitt (1977) sampled two sites in Blackwater Bay: a lower site along the northern shore of Escribano Point (Station 1) and an upper site approximately halfway down the western shore at Bay Point (Station 2). Collections were taken with a variety of methods including seines, gill nets and trawls in the brackish areas, and electrofishing and rotenone in the freshwater areas. Unfortunately, comparisons between the upper and lower sites are hindered by the different types of sampling gear used; only very subjective, qualitative assessments can be made.

Table 9. Abundance of fishes collected by electrofishing at six sites in the Yellow and Shoal rivers (1978-79). Abundance is shown as catch per hour of electrofishing. Stations are shown in Figure 26. Data source: Bass et al. (1979).

Species	Yellow River Sites				Shoal River Sites	
	1	2	3	4	5	6
Spotted gar	1.3	1.3	0.3			0.3
Longnose gar	13.0	0.7	0.7		1.0	
American eel			0.3			
Bowfin					0.3	
Redfin pickerel	0.3					0.3
Chain pickerel	1.7	1.7	1.0		0.3	
Silverjaw minnow				1.2	0.3	2.0
Clear chub			5.0	20.2	3.3	4.0
Sailfin shiner				0.4		
Longnose shiner			0.7	3.1	6.0	4.3
Flagfin shiner			0.7	0.4		
Blacktail shiner		1.7	40.3	26.7	78.3	40.3
Golden shiner	4.0					
Pugnose minnow	0.7		0.3		0.3	0.3
Coastal shiner	1.3	0.3				
Weed shiner	0.3	4.0	67.0	60.5	77.7	68.7
Cyprinidae spp. (unidentified)					38.3	
Lake chubsucker	1.0					
Sharpfin chubsucker	0.3		0.3		0.3	
Spotted sucker	3.7	4.7	6.0	7.0	1.3	2.7
Blacktail redhorse	0.3	2.0	13.3	27.1	8.0	7.3
Channel catfish			0.7	1.6		
Yellow bullhead		0.3				0.3
Speckled madtom		0.3	1.0	0.4	0.3	0.3
Pirate perch	0.3	1.7	2.3	1.2	0.3	0.7
Starhead topminnow	0.3					
Blackspotted topminnow	0.7	1.0	0.7	0.8	1.7	3.7
Brook silverside	0.7			1.6	1.3	1.7
Rock bass		3.7	0.7	2.7	2.7	4.0
Warmouth	2.0	2.3	3.3	1.9	1.3	2.3
Bluegill	21.0	13.7	3.0	5.4	1.7	6.7
Dollar sunfish		0.3		0.4	0.3	
Longear sunfish	0.3	7.3	15.0	5.0	4.7	6.7
Redear sunfish	8.3	3.7	1.0	2.3		

Table 9. Continued.

Species	Yellow River Sites 1	2	3	4	Shoal River Sites 5	6
Spotted sunfish	2.3	4.0	1.7	1.9	2.0	2.0
Lepomis sp. (fry)					0.3	
Spotted bass				0.4		
Largemouth bass	2.0	3.0	2.7	1.9	2.0	4.0
Black crappie	1.0					
Florida sand darter			1.7		0.3	
Speckled darter		1.0	1.7	1.9	0.3	1.0
Gulf darter		0.7	0.3	0.9	0.3	0.7
Etheostoma sp.			0.3			2.0
Blackbanded darter		1.0	5.3	6.6	8.7	10.0
Southern flounder		0.7				
Hogchoker			0.7			
Total Catch per Hour	67.0	61.0	179.7	183.3	244.0	176.7
Total Number of species	23	24	30	26	29	25

Table 10. Comparison of relative abundances of common fishes (those constituting 1% or more of total collected) collected in small streams within the Pensacola and Perdido Bay watersheds (1988-1993). Four sites were excluded because they were located on streams draining directly into bay waters. Data source: Bass (1993).

Species	All Sites	Yellow River	Blackwater River	Escambia River	Perdido River
Number of Sites	75	24	28	13	6
Weed shiner	22.6	38.5	2.0	29.3	1.6
Sailfin shiner	21.3	17.3	36.9	10.6	27.6
Flagfin shiner	9.7	3.3	23.7	2.5	9.6
Blackbanded darter	9.2	7.9	11.9	2.7	19.5
Blacktail shiner	3.7	7.2		1.0	1.8
Longnose shiner	2.9	5.2	1.2	1.2	
Mosquitofish	2.9				
Speckled madtom	2.9	2.8	4.1	1.7	5.3
Rough shiner	2.6			17.2	
Blackspotted topminnow	2.4	2.2	2.0	1.0	3.6
Spotted sunfish	2.2	1.9	1.4	3.5	1.6
Dixie chub	2.0		1.5	7.5	4.8
Orangeside darter	1.9	1.6	4.0	1.6	3.3
Silverjaw minnow	1.4	2.5			5.0
Southern brook lamprey	1.3		2.8	1.9	2.9
Redfin pickerel	1.2		2.0		1.4
Bluegill	1.1	1.0			
American eel				1.4	5.3
Black madtom		1.1		1.1	2.0
Clear chub				3.8	
Bluehead chub				3.7	
Longear sunfish				1.0	
Total Number of Species	59	47	39	45	29
Number of Individuals	17686	8834	5733	3216	987
Mean Number per Site	236	368	205	247	165

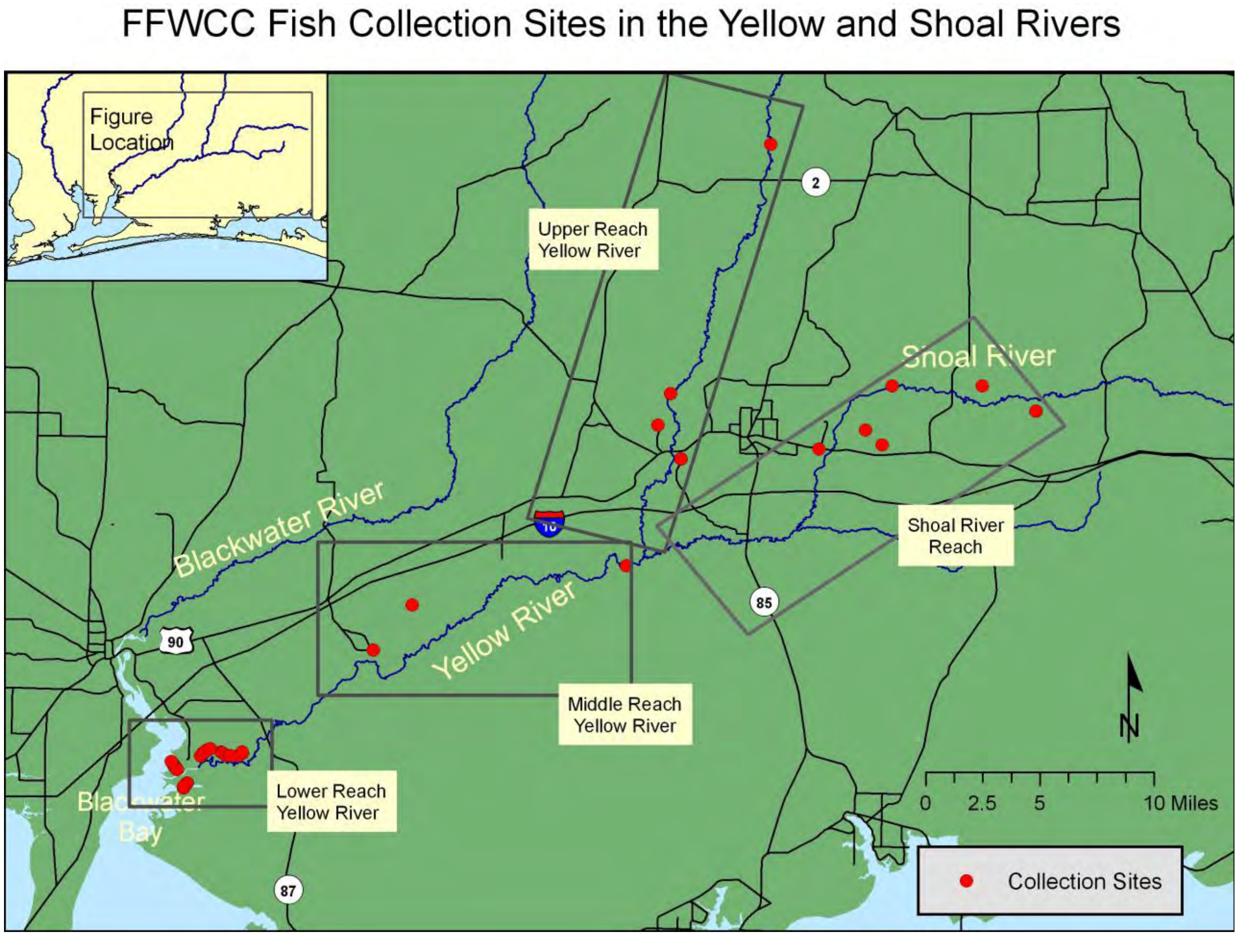

Figure 27. Recent fish collection sites on the Yellow and Shoal rivers, including small tributary streams and creeks. Stations are combined by reach with data summarized in Table 11. Data source: Florida Fish and Wildlife Conservation Commission (2009).

Table 11. List of common fishes collected by reach in the Yellow and Shoal rivers by the Florida Fish and Wildlife Conservation Commission (2005-2008; unpublished data). Reach locations are shown in Figure 27.

Species	Common Name	Yellow River			Shoal River
		Lower	Middle	Upper	
Ambloplites ariommus	Shadow bass		X	X	X
Ameiurus natalis	Yellow bullhead		X	X	X
Amia calva	Bowfin	X	X	X	
Ammocrypta bifascia	Florida sand darter		X	X	X
Anguilla rostrata	American eel			X	X
Aphredoderus sayanus	Pirate perch		X	X	X
Centrarchus macropterus	Flier			X	X
Ctenopharyngodon idella	Grass carp		X		
Cyprinella venusta	Blacktail shiner	X	X	X	
Erimyzon sucetta	Lake chubsucker	X	X	X	
Erimyzon tenuis	Sharpfin chubsucker	X			
Esox americanus	Redfin pickeral	X	X	X	X
Esox niger	Chain pickeral	X	X		
Etheostoma colorosum	Coastal darter		X	X	X
Etheostoma davisoni	Choctawhatchee darter			X	X
Etheostoma edwini	Brown darter		X	X	X
Etheostoma stigmaeum	Speckled darter	X	X		X
Etheostoma swaini	Gulf darter			X	X
Fundulus escambiae	Russetfin topminnow*	X			
Fundulus olivaceous	Blackspotted topminnow		X	X	X
Gambusia affinis	Western mosquitofish				X
Gambusia holbrooki	Eastern mosquitofish		X	X	X
Hybopsis sp. cf winchelli	Coastal chub		X	X	X
Ichthyomyzon gagei	Southern brook lamprey		X	X	X
Ictalurus furcatus	Blue catfish	X	X		
Ictalurus punctatus	Channel catfish	X	X	X	X
Labidesthes sicculus	Brook silverside	X	X	X	X
Lepisosteus oculatus	Spotted gar	X	X	X	X
Lepisosteus osseus	Longnose gar	X	X	X	
Lepomis auritus	Redbreast sunfish		X	X	X
Lepomis gulosus	Warmouth	X	X	X	X
Lepomis macrochirus	Bluegill	X	X	X	X
Lepomis marginatus	Dollar sunfish		X	X	X
Lepomis megalotis	Longear sunfish	X	X	X	X
Lepomis microlophus	Redear sunfish	X	X	X	X

Table 11. Continued.

Species	Common Name	Yellow River Lower	Yellow River Middle	Yellow River Upper	Shoal River
Lepomis punctatus x miniatus	Spotted x redspotted sunfish**	X	X	X	X
Macrhybopsis sp. cf aestivalis	Florida chub			X	X
Micropterus punctulatus	Spotted bass	X		X	X
Micropterus salmoides	Largemouth bass	X	X	X	
Minytrema melanops	Spotted sucker	X	X	X	X
Morone saxatilis	Striped bass	X		X	
Moxostoma poecilurum	Blacktail redhorse	X	X	X	X
Mugil cephalus	Striped mullet	X			
Notropis amplamala	Longjaw minnow		X	X	X
Notropis chalybaeus	Ironcolor shiner		X	X	X
Notropis harperi	Redeye chub		X	X	
Notropis longirostris	Longnose shiner		X	X	X
Notropis petersoni	Coastal shiner	X	X	X	X
Notropis texanus	Weed shiner	X	X	X	X
Noturus funebris	Black madtom		X		X
Noturus leptacanthus	Speckled madtom		X	X	X
Opsopoeodus emiliae	Pugnose minnow		X		X
Percina nigrofasciata	Blackbanded darter		X	X	X
Pomoxis nigromaculatus	Black crappie	X	X		
Pteronotropis hypselopterus	Sailfin shiner		X	X	X
Pteronotropis signipinnis	Flagfin shiner		X	X	X
Pylodictis olivaris	Flathead catfish	X	X	X	
Semotilus thoreauianus	Dixie chub				X
Strongylura marina	Atlantic needlefish	X			
Trinectes maculates	Hogchoker		X	X	X
Species number by reach		29	47	47	44

* also called eastern starhead topminnow
** possibly redspotted sunfish

A summary of fishes caught is given in Table 12. Forty-three taxa were collected at both sites combined with 19 species found off Escribano Point and 34 taxa noted at Bay Point. Despite having greater number of species at the upper site, total number of fishes collected was about one-quarter that of the lower site. As expected, the lower site was characterized by typical estuarine species including menhaden (*Brevoortia patronus*), tidewater silverside (*Menidia beryllina*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), and striped mullet (*Mugil cephalus*). Spot and croaker comprised nearly 70 percent of the fishes collected here. With the exception of a single species (longnose gar, *Lepisosteus osseus*), all fish collected at the lower site were marine. The upper site was dominated by oligohaline/fresh water species such as naked goby (*Gobiosoma bosc*) and sunfish (*Lepomis gulosus*, *L. microlophus* and *Micropterus salmoides*). In addition to sunfish, a variety of other freshwater species such as bowfin (*Amia calva*), American eels (*Anguilla rostrata*), chain pickerel (*Esox niger*) and coastal shiner (*Notropis petersoni*) were found only at the upper site. Of the taxa collected at the uppersite, about half were marine and half freshwater. Interestingly, Gulf pipefish (*Syngnathus scovelli*) were collected only at the upper site indicating the presence of grass beds.

Olinger et al. (1975) sampled considerably more areas and with greater gear consistency (trawls only) than did Bass and Hitt (1977), allowing for greater comparison among sites. A summary of the fishes caught in East Bay is shown in Table 13 along with those collected from other sections of the PBS for comparison. Of the 48 taxa collected baywide, 32 were noted from East Bay. Overall, abundance was slightly greater at East Bay locations than in any section of Escambia Bay but was lower than that caught at bayou sites. East Bay fishes were dominated by menhaden, anchovies (*Anchoa hepsetus* and *A. mitchelli*), spot and croaker; these five species comprised nearly 92 percent of the fishes collected. Three species (Gulf pipefish; Gulf kingfish, *Menticirrhus littoralis*; black-cheeked tonguefish, *Symphurus plagiusa*) were collected only in East Bay, but were represented by less than five individuals each.

Livingston (1999) [as summarized by Von Appen and Winter 2000] observed highest fish biomass and species diversity in upper Escambia and upper Blackwater Bays associated with high primary production. The highest fish biomass was found in areas where infaunal abundance was also highest, possibly due to dependence on infauna as a food source. Two of the most abundant fish species, spot (*Leiostomus xanthurus*) and Atlantic croaker (*Micropogonias undulatus*), are benthic feeders. Two plankton feeders (*Anchoa hepsetus* and *A. mitchelli*) were also observed in high abundance in East Bay. High numbers of fish indicator species for pollution were found in areas stressed by anthropogenic activities, including eastern areas of upper Escambia Bay, western areas of lower Escambia Bay, and Pensacola Bay.

Table 12. Summary of fishes collected in Blackwater Bay during 1976-77 by Bass and Hitt (1977). Collections were made at numerous sites using a variety of methods; only estuarine locations are reported here. Samples were taken seasonally but are summarized below over the entire collection period.

	Escribano Point (St. 1)				Bay Point (St. 2)		
Species	Seines	Gill Nets	Trawls	Total	Electrofishing	Rotenone	Total
No. of Samples	16	3	4	23	2	2	4
Lepisosteidae (gars)							
Lepisosteus oculatus					2		2
L. osseus		2		2	4	1	5
Lepisosteus sp. (fry)					2		2
Amiidae (bowfins)							
Amia calva					1		1
Anguillidae (freshwater eels)							
Anguilla rostrata					2	1	3
Ophichthidae (snake eels)							
Myrophis punctatus						10	10
Clupeidae (herrings)							
Alosa chrysochloris		1		1			
Brevoortia patronus	8	64	4	76		3	3
Engraulidae (anchovies)							
Anchoa mitchelli			14	14	11	13	24
Esocidae (pikes)							
Esox niger					2		2
Cyprinidae (minnows and carps)							
Notropis petersoni					11	4	15
Catostomidae (suckers)							
Minytrema melanops					2	3	5
Ictaluridae (freshwater catfishes)							
Noturus gyrinus						1	1
Ariidae (sea catfishes)							
Arius felis		7	7	14			
Belonidae (needlefishes)							
Strongylura marina					8		8
Cyprinodontidae (killifishes)							
Fundulus confluentes	1			1			
Fundulus sp.	2			2			
Lucania parva						4	4
Atherinidae (silversides)							
Labidesthes sicculus					2		2
Menidia beryllina	404		10	414	2		2

Table 12. Summary of fishes collected in Blackwater Bay (continued).

Species	Escribano Point (St. 1)				Bay Point (St. 2)		
	Seines	Gill Nets	Trawls	Total	Electrofishing	Rotenone	Total
No. of Samples	16	3	4	23	2	2	4
Syngnathidae (pipefishes)							
Syngnathus scovelli						16	16
Centrachidae (sunfishes)							
Enneacanthus gloriosus					1		1
Lepomis gulosus					3	3	6
L. macrochirus					35	12	47
L. megalotis						1	1
L. microlophus					42	26	68
L. punctatus					1	3	4
Micropterus salmoides					20	14	34
Gerreidae (mojarras)							
Eucinostomus argenteus			1	1		1	1
Sparidae (porgies)							
Lagodon rhomboides			5	5	5		5
Sciaenidae (drums)							
Bairdiella chrysoura		5	12	17			
Cynoscion arenarius		5	13	18			
Cynoscion nebulosus		3		3			
Leiostomus xanthurus	15	32	888	935	16	4	20
Micropogonias undulatus	46	30	443	519	1	6	7
Mugilidae (mullet)							
Mugil cephalus	41	20	4	65	1		1
Gobiidae (gobies)							
Gobionellus boleosoma						4	4
Gobiosoma bosc						266	266
Microgobius gulosus						9	9
Stromateidae (butterfishes)							
Peprilus alepidotus			1	1			
Triglidae (searobins)							
Prionotus tribulus						3	3
Soleidae (soles)							
Trinectes maculatus	2			2	1	7	8
Unidentified	1			1	1		1
Total	520	169	1402	2091	176	415	591

Table 13. Summary of fishes collected in East and Escambia Bays during 1973-74 by Olinger et al. (1975). Collections were taken from 11 stations throughout the two bays and are summarized by region.

Species	East Bay	Upper Escambia	Middle Escambia	Lower Escambia	Bayous	Total Catch	Percent of Total Catch in East Bay
Number of Trawls	22	24	24	24	29	123	17.9%
Dasyatidae (stingrays)							
Dasyatis sabina	1				1	2	50.0%
Dasyatis sayi	1			1		2	50.0%
Lepisosteidae (gars)							
Lepisosteus osseus	4	24	1			29	13.8%
Elopidae (tarpons)							
Elops saurus		2	1		5	8	0.0%
Clupeidae (herrings)							
Brevoortia patronus	486	1570	270	255	6724	9305	5.2%
Dorosoma petenense		10			5	15	0.0%
Harengula jaguana	241		1	13		255	94.5%
						0	
Engraulidae (anchovies)						0	
Anchoa hepsetus	1975	173	1273	1670	101	5192	38.0%
Anchoa mitchelli	5563	5522	5690	3601	10190	30566	18.2%
Synodontidae (lizardfishes)							
Synodus foetens	2		5	2	1	10	20.0%
Ictaluridae (freshwater catfishes)							
Ictalurus punctatus					5	5	0.0%
Ariidae (sea catfishes)							
Arius felis	42	3	30	27	21	123	34.1%
Bagre marinus			1			1	0.0%
Batrachoididae (toadfishes)							
Opsanus beta			1			1	0.0%
Atherinidae (silversides)							
Menidia beryllina		1			5	6	0.0%
Syngnathidae (pipefishes)							
Syngnathus louisianae				1		1	0.0%
Syngnathus scovelli	1					1	100.0%
Carangidae (jacks)							
Caranx hippos	2	10	1		10	23	8.7%
Chloroscombrus chrysurus	383	9	181	45		618	62.0%
Oligoplites saurus		2			1	3	0.0%
Selene vomer	2			1	1	4	50.0%

Table 13. Summary of fishes collected in East and Escambia Bays (continued).

Species	East Bay	Upper Escambia	Middle Escambia	Lower Escambia	Bayous	Total Catch	Percent of Total Catch in East Bay
Number of Trawls	22	24	24	24	29	123	17.9%
Gerreidae (mojarras)							
Eucinostomus argenteus		1			112	113	0.0%
Sparidae (porgies)							
Archosargus probatocephalus	2		7	2		11	18.2%
Lagodon rhomboides					25	25	0.0%
Sciaenidae (drums)							
Bairdiella chrysoura	7	2	16	7	52	84	8.3%
Cynoscion arenarius	211	172	157	162	885	1587	13.3%
Cynoscion nebulosus	2				7	9	22.2%
Leiostomus xanthurus	1329	2828	2387	767	6515	13826	9.6%
Menticirrhus americanus	5		2	5		12	41.7%
Menticirrhus littoralis	5					5	100.0%
Micropogonias undulatus	1907	1493	1363	1166	1986	7915	24.1%
Ephippidae (spadefishes)							
Chaetodipterus faber		1				1	0.0%
Mugilidae (mullet)							
Mugil cephalus	1				23	24	4.2%
Polynemidae (threadfins)							
Polydactylus octonemus	37	131	145	70	84	467	7.9%
Gobiidae (gobies)							
Goboides broussonneti					1	1	0.0%
Gobionellus hastatus					17	17	0.0%
Gobionellus shufeldti		1				1	0.0%
Trichiuridae (cutlassfishes)							
Trichiurus lepturus	9	3	3	10		25	36.0%
Scombridae (mackerals and tunas)							
Scomberomorus maculatus			3			3	0.0%
Stromateidae (butterfishes)							
Peprilus alepidotus	10	4	5	1		20	50.0%
Triglidae (searobins)							
Prionotus tribulus	1			1		2	50.0%

Table 13. Summary of fishes collected in East and Escambia Bays (continued).

Species	East Bay	Upper Escambia	Middle Escambia	Lower Escambia	Bayous	Total Catch	Percent of Total Catch in East Bay
Number of Trawls	22	24	24	24	29	123	17.9%
Bothidae (lefteye flounders)							
Citharichthys spilopterus	2	1	2	4	3	12	16.7%
Etropus crossotus	3		3	4		10	30.0%
Paralichthys lethostigma	4				4	8	50.0%
Soleidae (soles)							
Trinectes maculatus	1	1		1	5	8	12.5%
Cynoglossidae (tonguefishes)							
Symphurus plagiusa	1					1	100.0%
Tetraodontidae (puffers)							
Spheroides parvus	3			4	2	9	33.3%
Diodontidae (porcupinefishes)							
Chilomycterus schoepfi				1		1	0.0%
Totals	12243	11964	11548	7821	26791	70367	17.4%

5.4 Commercial Landings

Dramatic declines in commercial harvests of shellfish and finfish have been observed by numerous authors for the Pensacola Bay System (see summary in Collard 1991a). These declines have been attributed to a variety of causes including declining water and sediment quality and loss of habitat (Collard 1991a). However, as discussed by Collard (1991a), much of the evidence for declines is anecdotal with little quantitative data to define the trends.

Commercial harvests of several estuarine species have been reported for the Pensacola Bay system, with a portion of the landings presumably derived from East Bay/Blackwater Bay (Florida Fish and Wildlife Research Institute 2010). Landings are reported by the county in which they are sold to a wholesale seafood establishment and do not necessarily reflect the actual location of capture. Landings discussed here are those reported for Santa Rosa County as it was thought that these would better assess commercial harvest specific to the East Bay/Blackwater Bay area. While overall county landings include such offshore finfish as grouper and snapper, some commercial species are caught entirely or in part in the estuary. Blue crabs and oysters fall into the former group, having been harvested entirely within the bay; shrimp, mullet and several other species are harvested from both the nearshore Gulf and portions of the estuary.

Of these species, blue crabs and mullet dominated the Santa Rosa County harvest over the last six years (Table 14); relatively small catches have been reported for shrimp and oysters. Blue crabs clearly outweighed all other invertebrate species landed during 2004 and 2005 with catches diminishing during recent years; oyster and blue crab landings were similar during 2007 and 2008. Catches of both species have declined significantly from that recorded in 2000 and 2001 (data not included in table) when blue crab catches exceeded 400,000 pounds and oyster landings averaged 46,000 pounds. Although low for several years, oyster landings have steadily rebounded to near historical levels (44,926 pounds in 2009). Finfish landings have been highly variable with total catches ranging from 63,000 to 266,000 pounds; mullet comprised a majority of all commercial finfish accounting for between 71 and 84% of the total harvest.

5.5 Threatened and Endangered Species

The Pensacola Bay ecosystem supports about 40 species of plants and 45 species of animals designated by the federal government or the State of Florida as either threatened, endangered or species of special concern (see Table 7 in Thorpe et al. 1997 for listed species occurring in the Pensacola Bay system watershed). Of these, only a limited number of species have been sighted or have the potential for inhabiting the submerged portions of East Bay/Blackwater Bay; these include Gulf sturgeon (*Acipenser oxyrhynchus desotoi*) and West Indian manatee (*Trichechus manatus*).

Table 14. Recent commercial harvests of selected estuarine species landed in Santa Rosa County compared with all finfish (estuarine and marine) landed in the county. Landings are given in pounds with the number of trips in parentheses. Landings reported here are those sold to a wholesale seafood establishment within the county and do not reflect the actual location of capture. Data source: FFWRI (2010).

	2004	2005	2006	2007	2008	2009
INVERTEBRATES						
Blue crab	64,931 (294)	38,440 (152)	23,026 (93)	11,068 (94)	22,216 (126)	8,162 (84)
Shrimp (Total)	5,250 (26)	--	3,250 (4)	3,350 (18)	580 (6)	2,559 (26)
Brown	1,034 (11)	--	3,250 (4)	2,250 (15)	580 (6)	1,697 (11)
White	--	--	--	1,100 (3)	--	862 (15)
Oysters	5,385 (54)	1,647 (22)	6,014 (99)	13,630 (178)	18,935 (167)	44,926 (330)
FISH						
Mullet (Total)	53,470 (220)	194,303 (382)	208,734 (522)	160,306 (394)	123,673 (397)	103,499 (352)
Black	51,353 (213)	193,927 (377)	191,850 (490)	157,530 (376)	120,450 (372)	95,196 (320)
Silver	2,117 (7)	376 (5)	16,884 (32)	2,776 (18)	3,223 (25)	8,303 (32)
Flounder	1,489 (31)	7,907 (114)	2,212 (105)	841 (38)	1,963 (52)	4,781 (39)
Seatrout						
Silver	--	111 (3)	152 (20)	549 (16)	660 (22)	2,644 (27)
Spotted	193 (7)	2,435 (25)	1,744 (18)	555 (28)	1,087 (35)	837 (31)
Sheepshead	599 (11)	21,367 (48)	8,992 (96)	1,074 (40)	1,064 (27)	858 (19)
All Finfish	63,291 (312)	265,668 (551)	265,905 (663)	192,082 (493)	162,562 (521)	124,312 (500)

Hoehn (1998) cited 19 rare and imperiled freshwater fish observed in the Pensacola Bay watersheds. Of these, six were noted from the Yellow/Shoal rivers and two from the Blackwater River; 18 species were found in various portions of the Escambia River. Only two of the 19 species, Gulf sturgeon and Alabama shad (*Alosa alabamae*), are likely to occur in estuarine portions of the system. [Note: The Alabama shad is not a federal or state-listed species, but was included by Hoehn based on Millsap et al. (1990).] Both species are anadromous and migrate up coastal rivers in the spring to spawn. An additional four species have been noted in freshwater portions of the Yellow and Shoal rivers, including the goldstripe darter (*Etheostoma parvipinne*), Florida chub (*Macrhybopsis* [=*Extrarius*] n. sp. cf *aestivalis*), blacktip shiner (*Lythrurus atrapiculus*), and bluenose shiner (*Pteronotropis welaka*). The blackmouth shiner (*Notropis melanostomus*) was noted from the Blackwater River but has not been recorded in the Yellow/Shoal. The Florida chub was recently found at sampling sites in the Shoal and upper reach of the Yellow River in FFWCC collections reported earlier (see section on Faunal Communities – Fish abundance Table 11).

The entire Pensacola Bay estuarine system (Unit 9), as well as the Escambia River system (Unit 3) and the Yellow River system (Unit 4), has been designated as critical habitat for the Gulf sturgeon (USFWS 2003). The Pensacola Bay system provides winter feeding and migration habitat for both the Escambia River and Yellow River subpopulations. Recent tracking studies have observed winter migrations of fishes in the region and have identified specific areas in the bay where members of these subpopulations collect, or migrate through, during the fall and winter season (USFWS 2003). Gulf sturgeon showed a preference for several locations in the bay, including Redfish Point and Escribano Point, near Catfish Basin. Sandy shoal areas along the south and east side of Garcon Point, and the south shore of East Bay (Redfish Point) appeared to be commonly used, especially in the fall and early spring. During midwinter, deep holes north of the barrier island near Pensacola Pass were congregation common areas.

The Yellow River system (Unit 4 in USFWS 2003) includes most of the main stem of the Yellow River and distributaries, the main stem of the Shoal River below Highway 85, and the lower portion of the Blackwater River from its confluence with Big Coldwater Creek. The Yellow River subpopulation of Gulf sturgeon found in these areas was recently estimated to consist of about 580 fish of 1 meter (3.3 feet) or greater in size.

Five potential spawning sites of the Gulf sturgeon were identified recently (Parauka and Giorgianni 2002) in the Yellow River between Alabama Hwy 55 and Florida Hwy 90; three of these sites are in Florida. The sites ranged from 150 to 1200 feet in length, and consisted of hard clay, rock and limestone banks and walls with rock and hard substrate. Maintaining adequate water depths and velocities appear to be necessary to insure successful spawning and egg development (Wakeford 2001). Summer resting areas have been identified in both the lower Shoal and Blackwater Rivers with staging noted in deeper areas of the Blackwater.

Beck et al. (2000) listed occurrence records of four imperiled species in the Pensacola Bay System. They included 3 records of Gulf sturgeon, 7 occurrences of Kemp's ridley sea turtles and one occurrence each of the dwarf seahorse (*Hippocampus zosterae*) and the fringed pipefish (*Anarchopterus criniger*); these latter two species were considered imperiled by The Nature Conservancy but are neither state nor federally listed. Interestingly, the dwarf seahorse was the only species denoted as being sighted in East Bay. This observation is unlikely in that high salinity seagrass flats, designated as primary habitat, are absent from East Bay. Observations of sea turtles, either Kemp's ridley (*Lepidochelys kempii*) or the more common loggerhead (*Caretta caretta*), have been made along the outer barrier beaches, in the inlet and extreme lower portions of the Pensacola system, but are highly unlikely in the East Bay/Blackwater Bay complex. With the exception of the Gulf sturgeon, sightings of these species are thought to be incidental and do not represent resident populations.

6.0 IMPORTANCE OF FRESHWATER TO THE LOWER YELLOW RIVER AND THE BLACKWATER/EAST BAY SYSTEM

Freshwater inflow is thought to be one of the most important variables influencing riverine ecosystem components (e.g., fish populations, floodplain forest composition, nutrient cycling) both directly and indirectly (Poff et al. 1997; Richter et al. 1997; Richter et al. 2003). A river's flow regime has been described as the "master variable" governing many other parts of the riverine system (Richter et al. 2003) and includes characteristics of magnitude, frequency, duration, timing and rate of change (Poff et al. 1997). Increased natural variability of these characteristics generally results in greater diversity and complexity of riverine habitats and is essential to successful life-cycle completion for many aquatic, riparian and wetland species (Richter et al. 1996). Variation in hydrologic conditions frequently influences population dynamics of these species by affecting reproductive success, natural disturbance, biotic competition and predator-prey relationships (Poff and Ward 1989). Modifications to the hydrologic regime can result in alterations to the species composition, structure and function of these systems primarily through changes in the physical habitat (Richter et al. 1996).

The role of freshwater input in determining the productivity of river-dominated estuaries has been extensively discussed (Snedaker et al. 1977; Schroeder 1978; Cross and Williams 1981; Longley 1994; Livingston et al. 1997; Estuarine Research Federation 2002). Under natural river inflow conditions, the combination of generally high levels of primary production together with reduced predator activities by marine organisms have established conditions favoring rapid growth and enhanced productivity of estuarine populations that are adapted to rapidly changing environmental conditions (Livingston 1984, 1991). This is particularly noticeable in systems with moderate to large riverine input and near the head of estuaries with relatively small freshwater inflow.

A key component of the estuarine environment is its dynamic nature, which in part is a function of an ever-changing, non-uniform freshwater input. This freshwater input is modified by basin morphology, winds and tides to produce highly variable conditions both spatially and temporally. The seasonal timing and magnitude of inflows are highly important, particularly during the critical periods of reproduction and growth. Relatively few organisms have evolved the physiological and behavioral adaptations to tolerate these widely fluctuating conditions; yet, those that have may be found in high numbers. These organisms have evolved life history strategies to maximize the benefits provided by the estuary. Despite the seasonal and interannual variation, inflows to panhandle estuaries display a recurrent pattern of winter peaks and summer-fall lows. This pattern is reflected in the seasonality of individual estuarine organisms that display species-specific phase-lagged relationships to flow (Livingston 1991).

6.1 Species and Habitats with Freshwater Dependence

Several species and habitats identified in this resource characterization appear dependent on freshwater flow to varying extents. While little long-term quantitative data exist on the abundance of species and habitats in the East Bay/Blackwater Bay watershed relative to river discharge, inferences can be made based on studies in nearby water bodies and the comparative amounts of freshwater entering the system. Based on the similarity of species composition between the East Bay/Blackwater Bay fauna and that collected in these neighboring areas, it seems reasonable to assume similar general relationships exist here with environmental characteristics.

Studies carried out recently in Apalachicola Bay (summarized in Lewis et al. 1997) indicated that the abundance and distribution of dominant estuarine organisms were associated with various environmental factors such as river flow, rainfall, salinity and temperature. These associations, however, were highly variable and differed for each species (or taxonomic group) and for each bay region. While some consistency across bay regions was noted for some species (or taxonomic groups), no single large-scale pattern was observed across the range of organisms examined. Flow and salinity were significant contributors to the infaunal variance explained while salinity (and occasionally flow) was influential for some shrimp catch. Temperature was the most frequently noted characteristic influencing the dominant fishes. Similar findings were noted for the dominant fishes and invertebrates in the Suwannee River estuary (Tsou and Matheson 2002). Salinity was an important covariate, along with bottom vegetation, affecting recruitment in nine of 13 species; water temperature was associated with abundances of six species. East and Blackwater bays share many of the same dominant species with Apalachicola Bay and the Suwannee River estuary; presumably similar relationships with environmental variables exist.

In addition, significant correlations were found between annual fisheries catch and Apalachicola River flow (Wilber 1992, 1994). As with fisheries-independent data, commercial harvests of blue crabs and oysters were related to flow in different ways. Annual blue crab landings from both Franklin and Wakulla counties (Wilber 1994) were positively related to river flows during the previous year's growout period (September to May). Annual commercial oyster landings were related positively to flows two years before (Wilber 1992). Both relationships suggest mechanisms related to the physical conditions in the bay during the early life history stages of the organisms which may be coupled to either increased food or decreased predation (both of which are provided by increased river flows). Increased oyster mortality (from both predation and disease) was associated with increased salinity in Apalachicola Bay (Livingston et al. 1999, 2000). Blue crabs, and to a lesser degree oysters, make up a significant fraction of commercial landings in the Santa Rosa area and may be affected by changes in freshwater discharges from the Yellow and Blackwater rivers.

Overall ecological system function in estuaries may also depend on freshwater inflows. Primary productivity is intimately linked to riverine input of dissolved inorganic nutrients. This relationship, however, is mediated by the residence time of freshwater in the estuary, which is clearly a function of freshwater inflow (primarily) and winds and tides (secondarily). In Apalachicola Bay about 75% of the estuarine phytoplankton production occurs during the warm, low-flow months of May to November (Mortazavi et al. 2000). Phytoplankton standing stock during this time, as estimated by chlorophyll concentrations, is relatively low and a function of phytoplankton growth rate, zooplankton grazing, nutrient limitation (primarily nitrogen), sedimentation, and export from the bay. The latter three factors are significantly affected by freshwater discharge.

Recent studies (Chanton and Lewis 1999, 2002) provide evidence that the bulk of the secondary production in large alluvial river estuaries (i.e., Apalachicola Bay) is fueled from *in situ* phytoplankton productivity. Zooplankton grazing can clearly result in substantial reductions in plankton biomass and provide a primary trophic transfer for phytoplankton primary production to upper level consumers in the estuary (Putland and Iverson 2007a, b). In addition, phytoplankton production can enter the food web through deposition to bottom sediments and subsequent incorporation into higher trophic levels through deposit-feeding infauna and epifauna. Organisms inhabiting areas closest to the mouth of the river and its distributaries appear more reliant on river-borne detritus than those living in areas more distant. However, even for these organisms, phytoplankton productivity plays a major role in faunal diets, making up at least half of the carbon transferred on average (Chanton and Lewis 2002).

The East Bay/Blackwater Bay estuary differs from Apalachicola Bay in several important ways that influence primary production: lower freshwater inflows, increased residence time, and moderately eutrophic conditions resulting in historically higher chlorophyll concentrations. Without more information on nutrient loading and primary productivity in this system, it is difficult to predict production dynamics; however, the importance of primary producers to food web dynamics is clear.

The emerging picture of the structure and function of faunal assemblages in estuaries is one of overall stability amid and dependent upon a high level of variability and productivity in the system. Relatively few species inhabit estuaries, but those that do are physiologically and behaviorally adapted to the highly fluctuating conditions. These species are found in high numbers and biomass in response to high levels of primary production (both autochthonous and allochthonous). While individual species respond in different ways to changes in flow and its associated characteristics, the overall function (e.g., trophic organization) of the system is relatively constant within normal flow ranges. Deviations in river discharge, at both low- and high-flow ends of the flow spectrum, may be reflected in faunal changes that last several years. Permanent flow modifications could be accompanied by important changes in estuarine productivity, related changes in faunal representation within the food web, and the potential reduction and loss of specific estuarine populations.

This discussion points to the complexity of estuarine systems and supports an adherence to the natural flow paradigm (Richter et al. 1997) which states: *the full range of natural intra- and interannual variation of hydrological regimes, and associated characteristics of timing, duration, frequency and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems*. Modifications in flow characteristics may be accompanied by subtle changes in estuarine faunal assemblages. Some populations will benefit while others will be negatively affected. Maintenance of overall system integrity requires minimizing departures from historical flows.

6.2 Flow Dependence and Salinity Tolerance

Habitats potentially vulnerable to changes in fresh water inflow include palustrine forests, freshwater and brackish marshes, tidal salt marshes and submerged aquatic vegetation beds, most of which are located in the upper reaches of the bay system in relatively close proximity to the mouths of the Yellow and Blackwater rivers. Species living in these habitats have varying abilities to tolerate salt and could be impacted adversely by long-term declines in freshwater inputs with subsequent intrusion upstream of saline water. To assess this potential vulnerability, salinity tolerance ranges were compiled from the literature for the dominant organisms observed in both riverine and estuarine portions of the system (Appendix Tables A-1 for flora and A-2 for fauna). Ranges are provided for different life history stages, where available. In general, estuarine species have wide salinity tolerances to cope with the dynamic, highly variable environment; food is often the limiting factor. Freshwater species, on the other hand, are less tolerant (often intolerant) of saline conditions and the amount of inundation is often more influential in determining habitat and species distributions; salinity may determine the downstream limit of their distribution.

6.2.1 Palustrine Forests

Floodplain and coastal hammock forests of the Yellow and Blackwater rivers are composed of a variety of species with varying tolerances to salinity (Appendix Table A-1). The two dominant species in the lower reaches of both rivers, bald cypress and Atlantic white cedar, display moderate salinity tolerance. Bald cypress exhibited significant reductions in photosynthesis and gas conductance at salinities between 2 and 8 ppt (Pezeshki et al. 1990; McLeod et al. 1996; Allen et al. 1997) with reduction in growth at salinities as low as 2 ppt (Conner et al. (1997). Mortality of 100% was noted at 10 ppt (Conner and Askew 1992). Little information exists on the tolerance range of Atlantic white cedar; however, other co-dominant species appear less tolerant and may be impacted more severely with reduction in freshwater inflow (see tolerances in Appendix Table A-1).

Light et al. (2002) examined the structure of the floodplain vegetation community in the lower Suwannee River basin and projected changes with varying amounts of freshwater depletions. Fourteen specific forest types were described within the riverine, upper tidal and lower tidal reaches of the river. They suggested that floodplain forest composition was primarily determined by duration of inundation and saturation, depth and frequency of floods, and salinity. Each forest type is associated with a specific range of durations of inundation and saturation and characteristic flood depths. Permanent long-term reductions in flow would result in decreases in duration of flooding and soil saturation which in turn lead to changes toward drier forest types and a movement upstream of forest species restricted by flood depths. Additionally, the boundary between forest and marsh (i.e., tree line) will shift upstream as salinity intrudes further upriver. Salt-intolerant species will retreat upstream as tidal movement extends further from the Gulf and forest species composition will be altered to include a greater percentage of salt-tolerant forms. Flow reductions will also result in decreases in the amount of inundated floodplain area affecting not only forest composition but also reducing habitat for a variety of floodplain animals, including fishes, reptiles and amphibians, birds and mammals. Similar findings were noted for the floodplain ground-cover vegetation (Darst et al. 2002). They suggested lower flows will result in changes in the understory species composition as some plants retreat upstream, decline in abundance or disappear altogether due to inundation requirements (i.e., flood depth and duration) and/or salt intolerance.

A variety of ecological consequences may result from these floodplain vegetation changes (Light et al. 2002). As changes occur in forest composition (i.e., movement toward drier forest types) there is an increased possibility of exotic invasion, an increased risk of human disturbance, a decrease in concomitant biological diversity because of vertical structure and microhabitat loss as forests are converted to marsh, a decrease in area of the wettest swamps and important swamp species such as cypress, and a decrease in canopy basal area, species richness and associated wildlife. A loss of saturated soils may result in a decrease in soil water retention and subsequent soil oxidation, decrease in soil denitrification, and an increased vulnerability to fire. Finally, a loss of inundated areas will be accompanied by decreases in aquatic habitat used by a variety of both floodplain dependent and main channel species that use the floodplain for feeding, shelter and reproduction.

Examining sea-level rise and the retreat of coastal forests, Williams et al. (1999) observed that zonation among tree species along the Florida Gulf coast was related to tidal-flooding frequency. Tree species number correlated negatively with frequency of flooding. Only cabbage palm (*Sabal palmetto*) and southern red cedar (*Juniperus virginiana*) were present on the most frequently flooded plots with cabbage palms the only living tree on the wettest sites. Live oaks (*Quercus virginiana*) occurred in areas with intermittent tidal flooding. Loss of tree species with inundation appeared the result of cessation of regeneration caused by exposure to salt. Forest understory replacement by salt marsh species appeared to follow, rather than cause, failure of regeneration. Field zonation patterns appeared consistent with greenhouse studies examining the relative salt tolerance of seedlings (Williams et al. 1998). Of the species examined, cabbage palm and southern red cedar were best able to maintain green leaves under experimental salt exposure; live oak survived high salt concentrations by dying back and resprouting. While their study focused on the effects of sea-level rise, the authors noted that coastal forest retreat as described could be accelerated by drought or upstream consumptive water use by humans (Williams et al. 1999).

Other authors have similarly addressed this retreat, discussing transitions in forested wetlands along gradients of salinity (Brinson et al. 1985; Brinson et al. 1995). With upstream movement of saline waters, forest changes are more pronounced at the transitions between wetland types. Freshwater forested wetlands tend to give way to brackish herbaceous wetlands. Two phases of transition are described in which the first appears to be the death of trees dominating the upper canopy and their replacement by mixed shrubs and herbaceous plants which are in turn replaced by herbaceous brackish marsh during the second phase (Brinson et al. 1985). The intrusion of salt water not only results in osmotic stress (and reduced water availability) to the trees but also is accompanied by abundant sulfate and the increased potential for anaerobic respiration. Toxicity to a variety of tree species often results under these conditions with sulfide accumulation in the surrounding sediments (Brinson et al. 1995). If high salinities are wide spread and persistent, swamp forests may be replaced by brackish marsh as was observed at the mouth of the Santee River, South Carolina (Kjerfve 1979). Some movement of the tree line with subsequent encroachment by marsh may occur in the lower Yellow and Blackwater river floodplains depending on the magnitude of upstream flow reductions.

6.2.2 Freshwater/Brackish Marshes

Freshwater and brackish marshes are found through much of the lower Yellow River and may be subjected to some impacts from salt intrusion in the lower reach of the basin. Marshes in the Yellow are dominated by needlerush, sawgrass, pickerelweed, bull rush and a variety of other emergent and submergent species with varying degrees of salt tolerance (Appendix Table A-1). Some species like duckpotato and pickerelweed have been observed in salinities up to nearly 9 ppt, while bull rush was recorded up to nearly 17 ppt (Penfound and Hathaway 1939). On the other hand, needlerush has a wide range of tolerance (see salt marsh section). Most other species found in the area displayed either significant declines in germination, growth, and photosynthesis or increases in mortality at salinities in the range of 2-6 ppt (Appendix Table A-1). These species may be affected by reductions in freshwater inflows and salinity increases. Slash pine and southern red cedar are among the overstory trees observed throughout the Yellow River marsh; these species were noted along the levee and at higher elevations in the marsh interior. While red cedar is noted for its salt tolerance, the presence of numerous dead slash pines scattered throughout the marsh is likely evidence of the detriment effects of salinity intrusion during recent tropical storm events.

Tidal marshes and their response to external variables were examined in the Suwannee River delta (Clewell et al. 1999). They found no relationships between individual marsh species abundance from shoreline transect sites and any of the environmental variables measured, particularly salinity or salinity maximum. There was a strong negative relationship, however, between the *Cladium-Juncus* (i.e., sawgrass-needlerush) abundance ratio and several variables, particularly mean salinity (R^2=0.85) and salinity maximum (R^2=0.91). *Cladium* is more prominent in freshwater areas while *Juncus* is more salt tolerant. For vegetation in the marsh interior, electrical conductivity/salinity was the single most important variable influencing plant abundance and species composition. Marsh vegetation was very heterogeneous with species composition and dominance highly variable spatially. Patchiness was likely caused in part by storm-related disturbances like erosion, knocked over plants, salt-kill and storm wrack deposition. These disturbances kill or destroy sizeable areas of live vegetation (particularly the dominant sawgrass and needlerush) and open up bare space for colonizing species. Over time sawgrass and needlerush grow into these areas and regain dominance.

Clewell et al. (1999) suggested that long-term low flows may be accompanied by several changes in the tidal marshes. It is likely that no change will occur in the hydroperiod because of the proximity to the Gulf and the influence of tides; however, marsh inundation is likely to be more saline. Higher salinity may cause no harm to salt tolerant species such as *Juncus* (needlerush), *Phragmites* (giant cane), *Spartina* (cordgrass), *Scirpus* (bull rush) and *Typha* (cattail) but less tolerant species will likely not persist. Less tolerant species will retreat upstream ahead of the migration of more salt tolerant species. Significant ecological harm may be visible upstream in riverbank marshes where mesohaline marsh may replace oligohaline marsh which in turn may expand into the freshwater zone. Some tidal river swamps may become salt stressed and be replaced by tidal salt marsh; yet, currently no extensive salt marsh is found in or adjacent to the river deltas. Some upstream retreat and conversion of these fresh/brackish marshes may be expected in the Yellow River depending upon the magnitude of flow and salinity change experienced.

6.2.3 Tidal Salt Marshes

Salt marsh contributes only a small fraction of the overall wetlands acreage in the upper portions of East and Blackwater bays. Its expanse is significantly greater in lower East Bay and on Garcon Point. These marshes are dominated by black needlerush (*Juncus roemerianus*) and smooth cordgrass (*Spartina alterniflora*), both displaying wide tolerance to salt (Appendix Table A-1). Needlerush has been observed growing in salinities up to 60 ppt (Eleuterius 1984). Growth was noted to be inversely related to salinity with greatest production in freshwater. Similarly cordgrass is found in environments with salinities ranging from near fresh to almost full sea water (Mendelssohn and Marcellus 1976; Pulich 1990); greatest production was noted at salinities less than 19 ppt (Mendelssohn and Marcellus 1976). Needlerush and cordgrass, because of their salt tolerance, are able to compete favorably and dominate in areas where less salt tolerant vegetation cannot survive. Some limited expansion of these marshes into the lower Yellow River may occur depending upon the magnitude of flow and salinity change. No effects are anticipated in the more broadly distributed salt marshes throughout lower East Bay with their high tolerance for moderate to high salinities.

6.2.4 Submerged Aquatic Vegetation (*SAV*)

Salinity intrusion may affect SAV negatively in the lower reaches of the Yellow River delta and adjacent portions of Blackwater Bay. Tapegrass (*Vallisneria americana*), for example, is a salt-tolerant freshwater angiosperm that occurs in fresh, oligohaline, and mesohaline reaches of estuaries in the eastern United States and Gulf of Mexico; it is one of several species found in the SAV beds throughout the Wakulla River. Published salt tolerances (Appendix Table A-1) vary with growth cessation reported to occur from 6.6 (Haller et al. 1974) to 15 ppt (Doering et al. 1999); other work suggested mortality at salinities greater than 15 ppt (Kraemer et al. 1999). Doering et al. (2001) noted that while significant mortality occurred at 18 ppt, the degree of mortality was proportional to the duration of exposure. Recovery could be achieved with return to low salinity. They suggested that a 70-day intrusion of 18 ppt is near the upper limit of what might be tolerated without a net population reduction. This degree of intrusion would result in an approximate 80% reduction in shoot density, but with return to low salinity, recovery to pre-intrusion density was estimated in about 115 days. Multiple, repeated salinity intrusions, however, were not examined and could be expected to have more serious and perhaps unrecoverable consequences.

Tapegrass has been observed in the lower Yellow River marsh and adjacent areas in Blackwater Bay; some impacts may be sustained depending on the magnitude of flow reduction. On the other hand, widgeon grass (*Ruppia maritima*) has also been found in the area and has relatively high salt tolerance. Other species likely to occur, such as southern naiad (*Najas guadalupensis*), green fanwort (*Cabomba caroliniana*), dwarf arrowhead (*Sagittaria subulata*) and coontail (*Ceratophyllum demersum*), are primarily freshwater species with limited salt tolerances (Appendix Table A-1). Some impacts to these species may occur even with moderate freshwater reductions. Exotic species such as Eurasian watermilfoil and hydrilla (if present) have relatively low salinity tolerances (exception: Twilley and Barko (1990) observed highest biomass of watermilfoil at 12 ppt) and may be affected in the lower reaches of the system if they occur.

Examining SAV beds in the lower tidal portion of the Suwannee River, Estevez and Sprinkel (1999) suggested that reduced flows will increase salinity in the lower river and cause an up-stream retreat and overall reduction of SAV beds. These consequences likely result from specific river-bed morphology (i.e., narrow to nonexistent shorelines upstream in the Suwannee) and lack of potential colonizing estuarine or marine grasses at the river mouth and in Suwannee Sound. They further suggested that as the SAV beds retreat upstream the overall community assemblage will be simplified by loss of sensitive species. Total bed area, cover or biomass might not be reduced, but habitat diversity could be negatively affected by species loss. Further down the Gulf coast in the Chassahowitzka, Homosassa and Crystal rivers, SAV biomass approached zero at sites where annual average salinity was greater than 3.5 ppt (Hoyer et al. 2004). While similar upstream movement of SAV beds might occur in the Yellow River, it is unclear what will happen in the lower delta and bay. Widgeon grass is present in the lower reach of the system, has wide salinity tolerances (Appendix Table A-1) and may expand coverage with moderate salt water intrusion. The replacement of the diverse and abundant SAV with fewer estuarine-tolerant species may result in a decrease in habitat structure with subsequent declines in associated epifauna.

6.2.5 Oyster Reefs

Oyster reefs are limited to a few scattered locations throughout East and Blackwater bays. While these reefs do not support a commercial fishery they provide important habitat for organisms seeking food and shelter. Changing freshwater inflows may modify the salinity structure somewhat over these beds with subsequent effects on oysters.

The eastern oyster (*Crassostrea virginica*) is an estuarine resident and as such tolerates the dynamic conditions found there; salinity tolerances for various life history stages are shown in Appendix Table A-2. Adult oysters can survive in salinities from freshwater to 45 ppt with optimal conditions for growth between 10 and 30 ppt (Longley 1994; Pattillo et al. 1997). While capable of surviving at low salinities for short periods of time, oysters generally shut down and do not feed below about 3 ppt (Loosanoff 1953). Eggs and larvae prefer moderate salinities (10-29 ppt) with optimal growth of spat occurring from 13 to 30 ppt (Pattillo et al. 1997). Predation and disease, as contributors to mortality, affect oyster population dynamics and are directly related to salinity; both are higher in high salinity waters. A variety of predators feed on oysters including gastropod mollusks (*Thais haemastoma* and *Melongena corona*), crabs (*Callinectes sapidus* and *Mennippe mercenaria*) and fishes (*Pogonias cromis* and *Archosargus probatocephalus*). The southern oyster drill (*T. haemastoma*) is thought to be one of the major predators along the Gulf coast and is limited by average salinity below 15 ppt (Butler 1953). Crown conch (*M. corona*), while preferring salinities between 20 and 29 ppt, have been found in waters as low as 8.5 ppt (Hathaway and Woodburn 1961). High levels of mortality on some reefs have been attributed to the sporozoan parasite *Perkinsus marinus*, also called "Dermo". Incidence of *Perkinsus* infection is correlated with temperature and salinity (Soniat 1996) with mortality suppressed at low salinity. Infection intensity increases as salinity increases with 9 to 12 ppt as a minimum threshold (Ragone and Burreson 1993). Little is known concerning the occurrence of predators and disease on East and Blackwater bay reefs. Declining freshwater inflows may increase the incidence of both on the reefs with subsequent influence on oyster population dynamics dependent on the amount of change. Livingston et al. (2000) noted increased oyster mortality in Apalachicola Bay was related to increased salinity. Bergquist et al. (2006) found oyster percent cover and density in the Suwannee River estuary to be significantly and negatively related to salinity.

6.2.6 Faunal Abundance and Distribution

Information on the benthic invertebrate and fish assemblages in the East Bay/Blackwater Bay/Yellow River system was gleaned from the studies of Byrd et al. (1962), Olinger et al. (1975), Bass and Hitt (1977), Bass et al. (1979), Bass (1993), Livingston (1999) and continuing fish collections by FFWCC. While these investigations are not inclusive of all sampling, they have provided representative characterizations of the faunal communities in the area.

6.2.6.1 River Benthos

Although based on limited information, riverine benthic invertebrate communities appear dominated by mayfly and chironomid midge larvae, oligochaete worms and bivalve mollusks (Bass et al. 1979). These species are typical of freshwater systems and generally exhibit intolerance to salt. Densities were higher along the shoreline relative to mid-river and higher in the Yellow relative to the Shoal River. Abundance was suggested as being related to the presence of organic debris/detritus in the system. Aquatic vegetation, usually significantly correlated with invertebrate abundance, was conspicuously lacking in the river primarily due to high turbidity and lack of light penetration in the water column.

6.2.6.2 Riverine Fishes

Many of the fishes documented from riverine collections of Byrd et al. (1962), Bass et al. (1979), Bass (1993) and FFWCC (ongoing) are freshwater species with limited range of salinity. Recent FFWCC sampling, however, indicates numerous freshwater species inhabiting the lower Yellow River marsh. Many of these species have the ability to invade the oligohaline and mesohaline zones and have been collected at salinities as high as 15 to 20 ppt. Swingle and Bland (1974) recorded numerous examples of these latter species in Alabama waters which are cited here along with the maximum salinity recorded: longnose gar (*Lepisosteus osseus*) 21.7, channel catfish (*Ictalurus punctatus*) 12.6, chain pickerel (*Esox niger*) 7.5, golden shiner (*Notemigonus crysoleucas*) 10.7, weed shiner (*Notropis texanus*) 2.2, coastal shiner (*N. petersoni*) 7.4, lake chubsucker (*Erimyzon sucetta*) 14.4, spotted sunfish (*Lepomis punctatus*) 17.5, redear sunfish (*L. microlophus*) 14.4, bluegill (*L. macrochirus*) 13.8, black crappie (*Pomoxis nigromaculatus*) 2.4, and largemouth bass (*Micropterus salmoides*) 17.5. While many of these freshwater species will be relatively unaffected by minor salinity encroachment, others will likely retreat upstream leaving the most salinity-tolerant taxa at downstream locations.

6.2.6.3 Estuarine Benthos and Fishes

Estuarine benthic communities in East Bay/Blackwater Bay are characterized by low abundance and diversity (Olinger et al. 1975; Collard 1991a; Livingston 1999). Fauna are dominated by amphipod and decapods crustaceans, gastropod and bivalve mollusks, and polychaete worms.

Species present are typical of northern Gulf estuarine areas with numerous stress-indicator taxa noted (Collard 1991a; Livingston 1999). These communities will likely be relatively unaffected over most of their distribution by minor shifts in environmental conditions due to changing freshwater inflows. Relative high infaunal biomass was noted in upper Blackwater Bay in shallow areas adjacent to river inputs (Livingston 1999). These areas may see declines if river inflows are significantly reduced.

Faunal communities inhabiting the scattered downstream salt marshes will be little affected by salinity intrusion; these species, in fact, may expand their habitat if the fresh-salt marsh line retreats upstream. Most of the larger salt marshes in the system are located in areas removed from direct river input and will be unaffected. Common marsh invertebrates include marsh periwinkle (*Littorina irrorata*) and fiddler crabs (*Uca* spp.); blue crabs are frequent migrants into the tidal creeks. The marsh fish community is dominated by a number of resident (longnose killifish *Fundulus similis*, Gulf killifish *F. grandis*, sheepshead minnow *Cyprinodon variegatus*, sailfin molly *Poecilia latipinna* and tidewater silverside *Menidia beryllina*) and migrant species (bay anchovy *Anchoa mitchelli*, Gulf menhaden *Brevoortia patronus*, pinfish *Lagodon rhomboides*, spot *Leiostomus xanthurus*). These species dominate many Gulf coastal marshes and estuaries and display wide tolerances for environmental conditions, including salinity. Salinity ranges for dominant salt marsh organisms, where available, are shown in Appendix Table A-2. No adverse affects are anticipated for these species with small freshwater flow reductions.

In general, invertebrate and fish species found in Blackwater/East Bay are typical estuarine inhabitants with broad environmental tolerances (Appendix Table A-2). East Bay fishes were dominated by menhaden, anchovies, spot and croaker (Olinger et al. 1975; Livingston 1999). These are some of the most abundant inhabitants of Gulf estuaries and are adapted for highly fluctuating and variable conditions. Many of these species spawn in nearshore Gulf waters such that their eggs and larvae are found predominantly in high salinity. Larvae move into estuaries where they reside as juveniles and grow before emigration again to the Gulf. As adults most have been recorded in salinities from near freshwater to 35 ppt; some are frequent inhabitants of hypersaline lagoons with salinities >45 ppt. Despite their high tolerance, greatest abundance is often found in mesohaline conditions (5-18 ppt). Because of these wide salinity tolerances, little change in distribution and population dynamics of these species is likely with small declines in freshwater inflows.

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8.0 APPENDICES - Salinity Tolerances for Selected Organisms

Appendix A-1. Representative salinity tolerance ranges for the dominant plants (palustrine forest, emergent marsh - fresh and salt, submerged aquatic vegetation and seagrasses) found in portions of Blackwater and East Bays and the lower Yellow River, Florida. Tolerances are given along with the source of information. Table entries are salinity values given in parts per thousand.

Species	Salinity Range	References
Palustrine Forest		
Bald cypress (*Taxodium distichum)*	0-8.9 2-7 (58-84% reduction in photosynthesis) 100% mortality of seedlings at 30 for ≥2 days (flooded) 73% mortality at 8; leaf area reduction at >4 100% mortality of seedlings at 10 (flooded); decreased photosynthesis at 2 (flooded), unaffected at 2 (watered) 2-8 (significant reductions in photosynthesis and stomatal conductance in seedlings) Seedling growth (height) reduced at 2, no reduction in diameter or biomass	Penfound and Hathaway (1938) Pezeshki et al. (1990) Conner and Askew (1992) Allen et al. (1994) McLeod et al. (1996) Allen et al. (1997) Conner et al. (1997
Cabbage palm (*Sabal palmetto*)	8-15 photosynthesis declined nearly 65%; none observed at 15; seed and seedlings survival greater at low (avg 3) vs. high (avg 23) salinity sites in field <5% survival of seedlings at 22, 25% at 15, 35% at 8, 65% at 4, >80% at 2; 25% green leaves at 15, 65% at 4	Perry and Williams (1996) Williams et al. (1998)
Green ash (*Fraxinus pennsylvanica*)	0.8-8 (48-88% reduction in photosynthesis) 100% mortality of seedlings at 10 (flooded); severly decreased photosynthesis at 2 (flooded), unaffected at 2 (watered) Seedling growth (height, diameter, biomass) reduced at 2	Pezeshki et al. (1990) McLeod et al. (1996) Conner et al. (1997)
Loblolly pine (*Pinus taeda*)	100% mortality of seedlings at 30 for ≥2 days (flooded)	Conner and Askew (1992)
Live oak (*Quercus virginiana*)	<10% survival of seedlings at 22, 50% at 15, 75% at 8, >75% at 4; <25% green leaves at 8, 25% at 4	Williams et al. (1998)
Sweet gum (*Liquidambar styraciflua*)	No survival of seedlings at >8, <5% at 4, 50% at 2; no green leaves at >8, <5% at 4, 50% at 2	Williams et al. (1998)
Red maple (*Acer rubrum*)	80% mortality of seedlings after 1-day exposure to 27, 100% >2 days; greatly reduced growth after 1-day exposure	Conner and Askew (1993)

Species	Salinity Range	References
Emergent Marsh (Fresh)		
Duck potato (*Sagittaria lancifolia*)	0.0-8.9 2.9 (37-45% decrease in photosynthesis; 34-67% decrease in stomatal conductance) 4.8 (tissue damage); 15 100% mortality ≥2 significantly reduced germination 4.6 (increased biomass relative to control at 2.3, in field) ≥6 (tissue damage); 12 (low mortality) >6 (reduced growth)	Penfound and Hathaway (1938) Pezeshki et al. (1987) McKee and Mendelssohn (1989) Baldwin et al. (1996) Webb and Mendelssohn (1996) Howard and Mendelssohn (1999) Spalding and Hester (2007)
Common arrowhead (*Sagittaria latifolia*)	2 (decreased survival, growth and time to emergence); 4 (reduced germination)	Delesalle and Blum (1994)
Pickerelweed (*Pontederia cordata*)	0-8.9 2.5 (highest recorded)	Penfound and Hathaway (1938) Clewell et al. (1999)
Maidencane (*Panicum hemitomon*)	0.0 9.4 (growth reduction); 15 100% mortality 7.6-10 lethal limits in lab experiments ≥6 (growth reduction); 12 (significant mortality) ≥4 (reduced growth, increased mortality)	Penfound and Hathaway (1938) McKee and Mendelssohn (1989) Hester et al. (1998) Howard and Mendelssohn (1999) Spalding and Hester (2007)
Bullrush (*Scirpus americanus*)	5.5-16.8 6 (highest recorded) ≥6 (some growth reduction); 12 (no mortality)	Penfound and Hathaway (1938) Clewell et al. (1999) Howard and Mendelssohn (1999)
Sawgrass (*Cladium jamaicense*)	0-2 4±3 (LA statewide) 8 (highest recorded)	Penfound and Hathaway (1938) Chabreck (1972) cited in Clewell et al. (1999) Clewell et al. (1999)
Emergent Marsh (Salt)		
Smooth cordgrass (*Spartina alterniflora*)	5.5-49.7 15.2±7.8 mean (LA statewide) 0.6-33.0 (<19 higher production) 6-34 (20±8 mean) 2-28 (12±7 mean) 83-115 lethal limits in lab experiments	Penfound and Hathaway (1938) Chabreck (1972) cited in Longley (1994) Mendelssohn and Marcellus (1976) Pulich (1990) cited in Longley (1994) Hester et al. (1998)
Black needlerush (*Juncus roemerianus*)	1.2-44.3 13.9±8.3 mean (LA statewide) 0-60 growth decreasing with salinity (max in freshwater) 0-20 0.5-38 (mean 17.3±9.3) 0->40	Penfound and Hathaway (1938) Chabreck (1972) cited in Longley (1994) Eleuterius (1984) Clewell (1986) Woerner and Hackney (1997) Touchette (2006)

Species	Salinity Range	References
Submerged Aquatic Vegetation (SAV)		
Tapegrass (*Vallisneria americana*)	<10 survived (0.2-3.3 growth; 6.7 no growth) 0-12.8 present (5.3 mean); 2.2-13.9 absent (7.6 mean) <12 growth unaffected <15 survival (higher growth <3 in dry, <9 in wet season) >ca. 15 upper limit to survival 18 upper limit with mortality proportional to exposure time up to 70 days >15 increased mortality	Haller et al. (1974) Davis and Brinson (1976) Twilley and Barko (1990) Doering et al. (1999) Kraemer et al. (1999) Doering et al. (2001) Frazer et al. (2006)
Dwarf arrowhead (*Sagittaria subulata*)	6 (highest recorded)	Clewell et al. (1999)
Southern naiad (*Najas guadalupensis*)	>10 no survival (0.2-6.7 highest growth; 6.7-10 growth very low) 1.73 (mean) observed in field	Haller et al. (1974) Hoyer et al. (2004)
Coontail (*Ceratophyllum demersum*)	1.92 (mean) observed in field	Hoyer et al. (2004)
Claspingleaf pondweed (*Potamogeton perfoliatus*)	>4 biomass and flower production decline	Twilley and Barko (1990)
False loosestrife (*Ludwigia repens*)	3 (highest recorded)	Clewell et al. (1999)
Eurasian watermilfoil (*Myriophyllum spicatum*)	4 highest net photosynthesis, declines at >16; >16 P:R ratio declines >13.3 no survival (0.2-6.7 highest growth; 6.7-13.3 growth decline) 12 highest biomass 2.04 (mean) observed in field >15 increased mortality, decreased growth	McGahee and Davis (1971) Haller et al. (1974) Twilley and Barko (1990) Hoyer et al. (2004) Frazer et al. (2006)

Species	Salinity Range	References
Seagrasses		
Widgeon grass (*Ruppia maritima*)	<28 to set seed 0-33.2 (<25 ma) <74 lab survival (>46 no growth) 16-24 in field 0->60 (up to 390) in field 0-40 (10-20 optimal) 0-30 (growth lower in pulsed salinity) 36-70 (>55 stress threshold)	Bourn (1935) cited in Longley (1994) Phillips (1960) McMillan and Moseley (1967) Zimmerman and Livingston (1976) Kantrud (1991) summary table Murphy et al. (2003) La Peyre and Rowe (2003) Koch et al. (2007)
Shoal grass (*Halodule wrightii*)	1-60 (dwarfing at high salinity); 25-34 abundant <74 lab growth 3.5-52.5 lab survival 23-37 lab survival 17(6 min)-36 in field May-55 5-45 blade growth (10-35 max) 35-62 in field 36-70 (>65 stress threshold)	Phillips (1960) McMillan and Moseley (1967) McMahan (1968) McMillan (1974) Zimmerman and Livingston (1976) Dunton (1996) Lirman and Cropper (2003) Cotner et al. (2004) Koch et al. (2007)

Appendix A-2. Representative salinity ranges for the dominant animals (invertebrates and fishes) found in portions of Blackwater and East Bay and the lower Yellow River, Florida. Salinity ranges are given for different life history stages, where available, along with the source of information. Table entries are salinity values given in parts per thousand; ma = most abundant in stated range.

Species	Eggs and Larvae	Juveniles	Adults	References
Invertebrates				
Eastern oyster			<3 no feeding	Loosanoff (1953)
(*Crassostrea virginica*)			5-30	Galtsoff (1964)
		3-44		Copeland and Hoese (1966)
	16-22 setting abundant			Chatry et al. (1983)
	17-24 optimal-spat		0-45 (10-30 best survival; 10-24 ma)	after Longley (1994)
	7.5-34 (10-22 optimal)-eggs 5-39 (25-29 optimal)-larvae	5.6-35 (13-30 optimal)-spat	2-43.5 (14-30 optimal for growth)	after Pattillo et al. (1997)
			2-35	Livingston et al. (2000)
			11-29 (means per site; 4-24 mean lows)	Bergquist et al. (2006)
Blue crab			0-30+ (2.0-4.9 ma)	Swingle (1971)
(Callinectes sapidus)			0-28.5	Swingle and Bland (1974)
		0-40 (<13 optimal)	0.1-60.0 (lit review)	Copeland & Bechtel (1974)
	23-30 for hatching	6-25 ma	0-60	after Longley (1994)
	10-33 (23-28 optimal)-eggs >5 (16-36 highest survival)-larvae	2-21 ma	<10 ma (males) 23-33 ma (egg-bearing females)	after Pattillo et al. (1997)
Grass shrimp			0-21.3 (10-15 ma)	Swingle (1971)
(*Palaemonetes pugio*)			0-25.4 (15-20 ma)	Swingle and Bland (1974)
	20-25 optimal-larvae		0-55 (2-36 ma)	after Pattillo et al. (1997)

Species	Eggs and Larvae	Juveniles	Adults	References
White shrimp		<10 ma		Gunter et al. (1964)
(*Litopenaeus setiferus*)		8-34		Perez Farfante (1969)
			1.3-30+ (5-10 & 25-30 ma)	Swingle (1971)
			2.7-35.0 ma	Stokes (1974)
		0-38 (no optimal)	0.2-45.3 (lit review)	Copeland & Bechtel (1974)
			1.1-28.5	Swingle and Bland (1974)
	5-15 (optimal)-postlarvae	1-20 ma	0-48	after Longley (1994)
	0.4-37 postlarvae	0.3-41 (<10 ma)	>27 offshore-usually	after Pattillo et al. (1997)
Fishes				
Bay anchovy			2.3-36.9 (<15 ma)	Gunter (1945)
(*Anchoa mitchelli*)			5-35	Springer and Woodburn (1960)
			0-30	Tabb and Manning (1961)
			0-34 (20-30 ma)	Swingle (1971)
			0-34 (25-30 ma)	Swingle and Bland (1974)
	0.5-1, 20-25	0-40	1-32	after Pattillo et al. (1997)
	0-30 (10-20 ma): means	0-30 (<15 ma): means	0-30 (<15 ma): means	Peebles et al. (2007)
Gulf menhaden			2-33.7	Gunter (1945)
(*Brevoortia patronus*)			6.6-34.2	Springer and Woodburn (1960)
	6.6-33.2 larvae	0.1-31.6 (10-15 & >30 ma)		Swingle (1971)
		0-26 (<12 optimal)	0.0-54.3 (lit review)	Copeland & Bechtel (1974)
		0-40+ (<12 ma)		Longley (1994)
	>29 eggs & early larvae		0-67 (20-25 ma)	after Pattillo et al. (1997)
	5-30 postlarvae			
Gulf killifish			2-37.1 (5-15 ma)	Gunter (1945)
(*Fundulus grandis*)			0.8-35.6 (15-30 ma)	Kilby (1955)
			0.8-16.2 (<15 ma)	
			3.7-29.8 (13-20 ma)	Springer and Woodburn (1960)
			0-5 & 20-25	Swingle (1971)
			0-25	Swingle and Bland (1974)
	5-40 (5-18.3 optimal)-larvae		0-76.1	after Pattillo et al. (1997)

Species	Eggs and Larvae	Juveniles	Adults	References
Longnose killifish (*Fundulus similis*)			2-37.1 (20-30 ma)	Gunter (1945)
			0.8-37.6 (15-30 ma)	Kilby (1955)
			3.2-32.3	Springer and Woodburn (1960)
			5-30 (10-25 ma)	Swingle (1971)
			4.7-30 (>10 ma)	Swingle and Bland (1974)
Sheepshead minnow (*Cyprinodon variegatus*)			2-35.7 (10-25 ma), one collection at 71.5	Gunter (1945)
			0.8-35.6 (15-30 ma)	Kilby (1955)
			0-26.1 (<15 ma)	
			0-35	Tabb and Manning (1961)
			10-25 (20-25 ma)	Swingle (1971)
			0.9-25	Swingle and Bland (1974)
			0-142 (10-30 ma)	after Pattillo et al. (1997)
Tidewater silverside (*Menidia beryllina*)			0-34.9 (15-20 ma), one collection at 71.3	Gunter (1945)
			3.5-37.6 (15-30 ma)	Kilby (1955)
			0-26.1 (<15 ma)	
			17-26	Tabb and Manning (1961)
			0-5 & 15-20 ma	Swingle (1971)
			0-23.8	Swingle and Bland (1974)
	0-30 (2-8 optimal)-larvae	0-34.5 (2-28 optimal)	0-120 (<45 ma)	after Pattillo et al. (1997)
Pinfish (*Lagodon rhomboides*)			2.1-37.2	Gunter (1945)
			3.7-35.1	Springer and Woodburn (1960)
			8-37	Tabb and Manning (1961)
		2-30+ (>20 ma)		Swingle (1971)
			0-43.8	Pattillo et al. (1997)
Atlantic croaker (*Micropogonias undulatus*)			2-36.7 (<15 ma)	Gunter (1945)
			5-29.8	Springer and Woodburn (1960)
			19-32	Tabb and Manning (1961)
		0-30+ (5-15 ma)		Swingle (1971)
			0-29.1	Swingle and Bland (1974)
	25-35 (optimal)-eggs 15-35 (optimal)-larvae	0-37 (6-15 optimal)	0->60	after Longley (1994)
	15-36 larvae	0-36.7 (10-20 ma)	0-70 (15-20 ma)	after Pattillo et al. (1997)

Species	Eggs and Larvae	Juveniles	Adults	References
Spot (*Leiostomus xanthurus*)			2-36.7 (>15 ma)	Gunter (1945)
			5-34.2	Springer and Woodburn (1960)
			9-48	Tabb and Manning (1961)
		0.1-30+ (5-20 & >30 ma)		Swingle (1971)
			0-28.5	Swingle and Bland (1974)
	30-35 eggs 6-36 larvae	0-36.2 (>10 ma)	0-60 (15-30 ma)	after Pattillo et al. (1997)
Silver perch (*Bairdiella chrysoura*)			2.1-33.7 (<25 ma)	Gunter (1945)
			3.7-35 (>20 ma)	Springer and Woodburn (1960)
			9-48	Tabb and Manning (1961)
			0.2-30 (>10 ma)	Swingle (1971)
			3.5-28.5 (>15 ma)	Swingle and Bland (1974)
	14.3-26 eggs <1-37.4 (>10 ma) larvae	0-35.5 (>20 ma)	0-48	after Pattillo et al. (1997)