Site-Specific Information in Support of Establishing Numeric Nutrient Criteria in Apalachicola Bay

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Executive Summary

This report was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with local scientists, to support the development of numeric nutrient criteria for Apalachicola Bay.[1] The primary purpose of the proposed numeric nutrient criteria is to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment.

Except for water withdrawal issues occurring far upstream of the bay, the Apalachicola system remains relatively free of human impacts. The Apalachicola River and Bay system is located in one of the least populated areas along the Gulf coast. The Apalachicola Estuary, which is dominated by freshwater inputs from the river, is a shallow, lagoon-and-barrier-island complex oriented along an east-west axis. Important habitats include *Spartina/Juncus* marshes, unconsolidated soft-sediment areas, and significant oyster reefs. The Apalachicola Estuary has been described as one of the most productive estuarine systems in the northern hemisphere. This bay is known for its oyster bars and oyster production, producing 90% of Florida's and 10% of the nation's oyster harvest (Livingston 1983a, 1984).

The main source of nutrients in Apalachicola Bay is the Apalachicola River, which dominates water quality in the bay and represents the chief source of freshwater input. Unlike most estuaries around the state, the critical issue in the Apalachicola has been significant, long-term reductions of river flow and associated reductions of loading of nutrients and organic matter. Periods of high nutrient and organic matter loading have been associated with relatively high and beneficial secondary production in this system. Reductions in freshwater flow and nutrients have been associated with adverse effects on the fisheries of the Apalachicola system (Livingston 2010).

Since it is characterized as an alluvial system, maintaining phytoplankton biomass and secondary production of fish and oysters is the main concern in Apalachicola Bay. Phytoplankton is the main source of carbon in the bay (Chanton and Lewis 2002), but Wilson *et al.* (2009) suggest that benthic production is also important. The bay's food webs are driven by *in situ* productivity and, consequently, the bay depends on the input of "new "nutrients to the system. It is for this reason that reductions of river flow (and coincidentally, nutrients) have, on occasion, adversely affected this system in the past (although recovery has been observed when flow and nutrients return). The Apalachicola Estuary is characterized by abundant phytoplankton production, which serves as the basis of a robust food web, yielding a high abundance of oysters, blue crabs, and commercially important fishes.

Maintaining the existing and historical healthy conditions is the recommended approach for developing nutrient criteria for Apalachicola Bay. The greatest concern for the bay is potential reductions in nutrient loads from the river due to reductions in freshwater discharge. Such reductions would result in significant impacts to the bay's food web. For example, the thriving commercial oyster harvest is dependent upon adequate river flow because it provides nutrients for phytoplankton, which are the food supply for the oysters, and it periodically lowers salinity, which serves to reduce oyster predators. The available data demonstrate that the existing nutrient and chlorophyll concentrations provide for a healthy, well balanced system and that maintaining phytoplankton production is critical for protecting the bay's robust food web (Table 1).

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Table 1. Checklist of nutrient enrichment symptoms for Apalachicola Bay

- = Empty cell/no data
N/A =Not Available

Response Variable	Observed Historically or Currently?	Explanation	Source
Low dissolved oxygen (DO) (hypoxia/anoxia)	Yes	Hypoxia in the bay is normally not evident; however, low DO levels (< 4 milligrams per liter [mg/L]) have been noted in some areas. In East Bay, most hypoxic events that occur last less than 4 hours. The low DO episodes are not linked to nutrients and are not associated with adverse biological responses.	Sanger *et al.* 2002; Edmiston 2008
Reduced clarity	No	Color ranges from 0 to over 300 PCUs at individual stations but is generally in the 20 to 160 range, with lower values near the Gulf. High color levels, which are a natural condition associated with swamp runoff, generally occur at the river mouth and in the upper areas of East Bay.	Edmiston 2008; Livingston 2010
Increased chlorophyll *a* concentrations	No	Unlike most estuaries around the state, Apalachicola Bay is an alluvial system and has high primary and secondary productivity, supporting a multimillion-dollar fishery. Research has shown that elevated chlorophyll *a* values near the mouth and in East Bay, St. Vincent Sound, and Apalachicola Bay provide essential and beneficial organic carbon and help the system maintain its healthy condition.	Livingston 2010
Phytoplankton blooms (nuisance or toxic)	Yes	Occasional red tide events, which originate offshore and are transported to the bay by currents, affect the system. These events are not related to nutrients from the Apalachicola Bay system. The bay was last closed for shellfish harvesting due to red tides in 2005 and 2006.	Livingston 2010; Florida Department of Agriculture and Consumer Services (FDACS)
Problematic epiphyte growth	No	Due to natural high color and turbidity, submerged aquatic vegetation (SAV) and epiphytes are naturally rare in the system, and are generally found only in oligohaline areas in East Bay and higher salinity areas in St. George Sound. Variable epiphyte loads are observed in higher salinity seagrass beds located in St. George Sound.	-
Problematic macroalgal growth	No	There is no evidence of adverse macroalgal growth.	-
SAV community changes or loss	Yes	During periods of low river discharge and unusually high salinities in upper East Bay, reductions of fresh/brackish SAV have occurred. A 2005 hurricane also affected the fresh/brackish SAV. Monitoring in St. George Sound shows that SAV bed composition is stable, with some reductions in coverage associated with reduced salinities from extreme winter rain events in 2008 and 2009. Note that none of these changes are associated with nutrients.	Edmiston 2008; Fahrny *et al.* 2006; Yarbro and Carlson 2011
Emergent or shoreline vegetation community changes or loss	No	-	-

Coral/hardbottom community changes or loss	N/A	This habitat type does not typically occur.	-
Impacts to benthic community	No	Variability in benthic communities is associated with freshwater flow.	-
Fish kills	Yes	Episodic fish kills occur due to *Karenia brevis* blooms moving in from offshore, but the blooms are not related to nutrients in Apalachicola Bay. The last reported fish kill due to K. brevis was on November 8, 2005, at East Point. Since the 11/8/05 *K. brevis* event, there have only been three additional fish kills reported to the FWRI database, mostly related to low DO.	Florida Fish and Wildlife Conservation Commission (FWCC) Fish and Wildlife Research Institute (FWRI)

Geographic and Physical Description

Apalachicola Bay is a dynamic and highly productive estuary in the Florida Panhandle. The bay is bar-built, subtropical, and characterized by large quantities of freshwater inflows from the Apalachicola River. The Bay is wide, covering approximately 593 square kilometers (Smith 2003).

Located in Franklin County, FL, Apalachicola Bay is a Class II waterbody (approved for shellfish harvesting). The Bay has been designated as an Outstanding Florida Water (OFW), a National Estuarine Research Reserve (NERR), a U.S. Environmental Protection Agency (EPA) Gulf of Mexico Ecological Management Site (GEM), and a United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve. In 1985, to protect the bay from developmental pressures, the City of Apalachicola and most of Franklin County was designated as an Area of State Concern. Because of significantly improved local laws and urban planning, much of the originally included Areas of State Concern have been de-designated (Edmiston 2008).

The system is divided into four major areas: East Bay, Apalachicola Bay, St. George Sound, and St. Vincent Sound (Figure 1).

East Bay is located east and north of the Apalachicola River delta. It receives direct freshwater inputs from the river, the river's distributaries, and also distributaries draining from Tate's Hell Swamp. Partial causeways along the John Gorrie Bridge, extending both west from Eastpoint and east from the City of Apalachicola, act to separate East Bay from Apalachicola Bay. The bridge is considered to be East Bay's southern limit (Edmiston 2008).

The main, central portion of "Apalachicola Bay" is bordered by St. Vincent Sound and St. Vincent Island to the west, Little St. George Island and St. George Island border to the south, and St. George Sound to the east. There are two passes to the Gulf in Apalachicola Bay. West Pass is a natural pass between St. Vincent Island and Little St. George Sound, and Sike's Cut (also known as Government Cut) is a man-made channel separating Little St. George Island and St. George Island. Apalachicola Bay has a sandy/soft-sediment bottom with numerous oyster bars throughout. Some fringing submerged and emergent vegetation exists along the bay side of St. George Island.

St. George Sound is bordered by St. George Island and Dog Island to the south. Gulf water enters St. George Sound through a large pass between Dog Island and mainland Franklin County. A smaller natural pass to the Gulf, known as East Pass, is located between Dog Island and St. George Island. The Carrabelle River contributes small amounts of freshwater to St. George Sound. Seagrass beds and emergent vegetation are commonly found along its northern shore, with larger beds found around Dog Island. Numerous oyster bars are found throughout, including a nearly continuous series of oyster bars that separate St. George Sound from Apalachicola Bay (Figure 2).

Salinities throughout the bay are dependent upon river flow, local rainfall, basin configuration, wind speed and direction, and water currents (Livingston 1983c). They can range from 0 to 33 ppt (Edmiston 2008). Water within the system generally moves in a westerly direction. Livingston (1983c) found that Bay temperatures are highly correlated with air temperature and wind-mixing of the water column. The bay is relatively shallow (Twichell 2007), with an average depth of 2.3 meters (personal communication, ANERR 2010). Water residence time is approximately 8.5 days (Mortazavi 2000b). Dissolved oxygen values usually range from 4 to 14 mg/L, but most fall between 5 and 12 mg/L (Livingston 1978). See Table 2 for additional physical characteristics of the bay.

Figure 1. Satellite photo of Apalachicola Bay, with labeled sections (picture provided by the ANERR & labels by Cox 2012).

Table 2. Summary of the physical characteristics of Apalachicola Bay.

Data	Values	Source
Estuarine surface area (km^2)	593 km^2	Smith 2003; NOAA
Watershed area (km^2)	51,000km^2	Murrell and Caffrey 2005
Land use	Primarily forested, pine flatwoods, and bottomland hardwoods	Murrell and Caffrey 2005
Mean depth (m)	2.3 m	ANERR
Volume (cubic meters [m^3])	1,074,990,400 m^3	Smith 2003; NOAA
Tidal range (m)	0.58m	Smith 2003; NOAA
Tidal freshwater inflow (1,000 cubic meters per day [1,000 m^{3}d^{-1}])	64,000 m^{3}d^{-1}	Smith 2003; NOAA
Mean water residence time (days)	6 days; 8.5 days (Mortazavi)	Murrell and Caffrey 2005; Mortazavi 2000b
Salinity and salinity zones (practical salinity units)	Average salinity: 19 psu	Smith 2003; NOAA

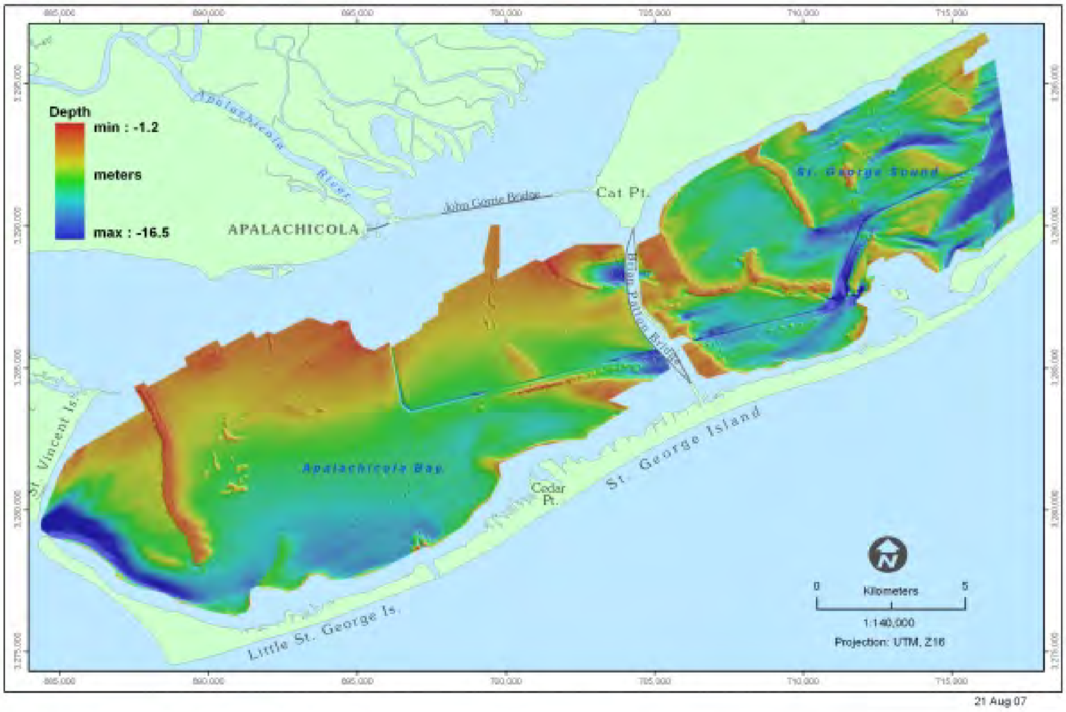

Figure 2 . Bathymetric map of the Apalachicola Bay Estuary (Twichell et al. 2007).

Sources and Fates of Nutrients

The main source of the nutrients in Apalachicola Bay is the Apalachicola River, which is the primary source of fresh water entering the bay and the largest river in the state. The Apalachicola River basin is one part of the Apalachicola–Chattahoochee–Flint (ACF) River system, whose basin is located in mainly three states (Figure 3). The Apalachicola River is formed by the convergence of the Chattahoochee and Flint Rivers. The ACF watershed drains approximately 19,800 square miles. The Apalachicola River provides 83% of the total nitrogen (TN) and 78% of the total phosphorus (TP) found in the bay (Edmiston 2008).

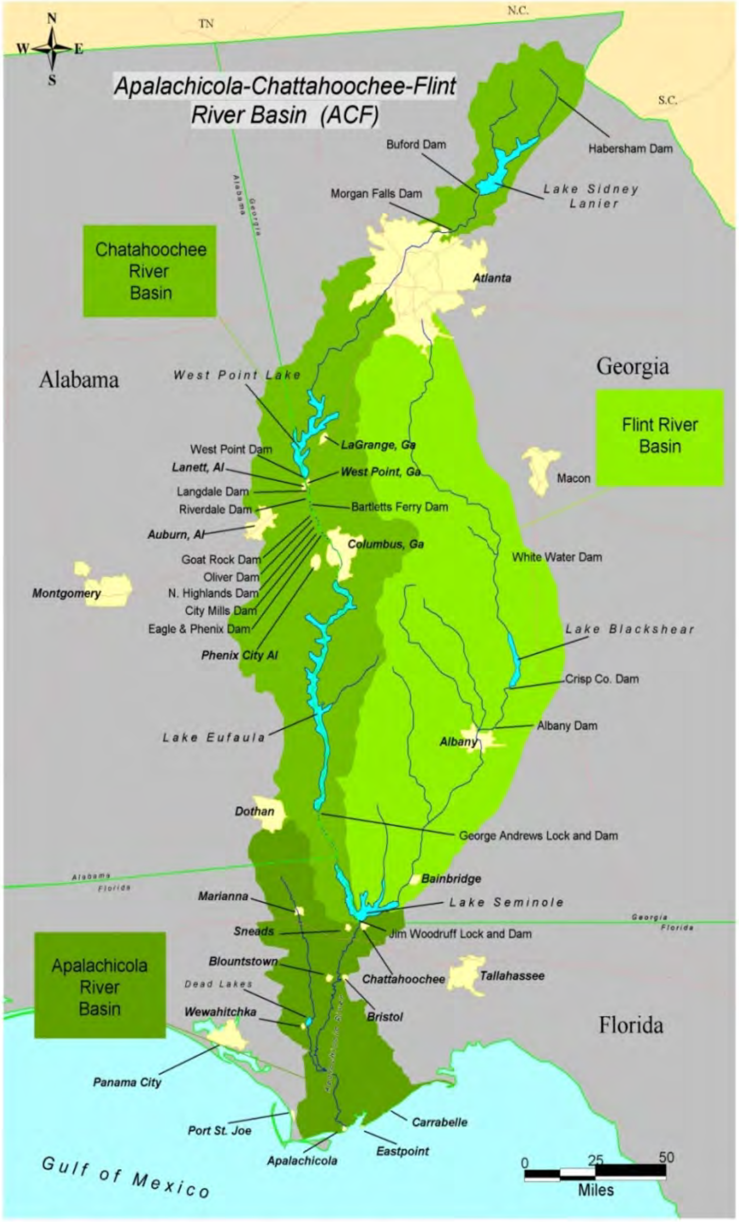

Figure 3. Map of the Apalachicola–Chattahoochee–Flint River Basin. Each separate basin is depicted by a different shade of green (from Wanat 2010).

The river and the nutrients it delivers represent a major source of coastal productivity in the region (Livingston 1983a, 1984; Livingston *et al.* 1997, 1999, 2000, 2002, and 2005). Because of the protective measures taken in the Apalachicola River floodplain, excess nutrient loading from sources in Florida is not of concern. In fact, a significant problem for the Apalachicola is long-term reductions of river flow and associated reductions of the loading of nutrients and organic matter. While high loading of nutrients and organic matter is associated with relatively high secondary production in this system, periods of reduced water delivery are associated with reductions in the fisheries of the Apalachicola system. Nutrients, as the foundation for the estuary's productivity, are transported to the estuary both in the form of detritus and as compounds dissolved in the water column (Livingston 1984b). Nitrogen (N) is limiting in summer and during periods of lower river flow, while phosphorus (P) is limiting in winter, when water levels are typically higher. Phytoplankton productivity is most frequently limited by N availability, less often by P availability (Iverson *et al.* 1997).

Point sources that contribute nutrients to the river and bay include municipal wastewater treatment facilities (WWTFs), industrial wastewater facilities, and combined sewer overflows (Frick *et al.* 1996). There are 15 wastewater facilities in the Apalachicola River Planning Unit: 6 domestic, 8 industrial, and 1 concrete batch plant. The major domestic facilities are the city of Blountstown (1.5 million gallons per day [MGD]), the city of Chattahoochee (0.5 MGD), Florida State Hospital (1.3 MGD), and the town of Sneads (0.495 MGD). The only major industrial facility is the Gulf Power Scholz Steam Plant (Q = 129.6 MGD) (FDEP 2002). The only major surface water discharge facility in the Apalachicola Bay Planning Unit is the city of Apalachicola sewage treatment plant (1.0 MGD), which discharges to a wetland, Huckleberry Creek, the Gulf Intracoastal Waterway (GIWW), and then the Apalachicola River. Figure 4 shows the extent of the Apalachicola River Planning Unit and the Apalachicola Bay Planning Unit.

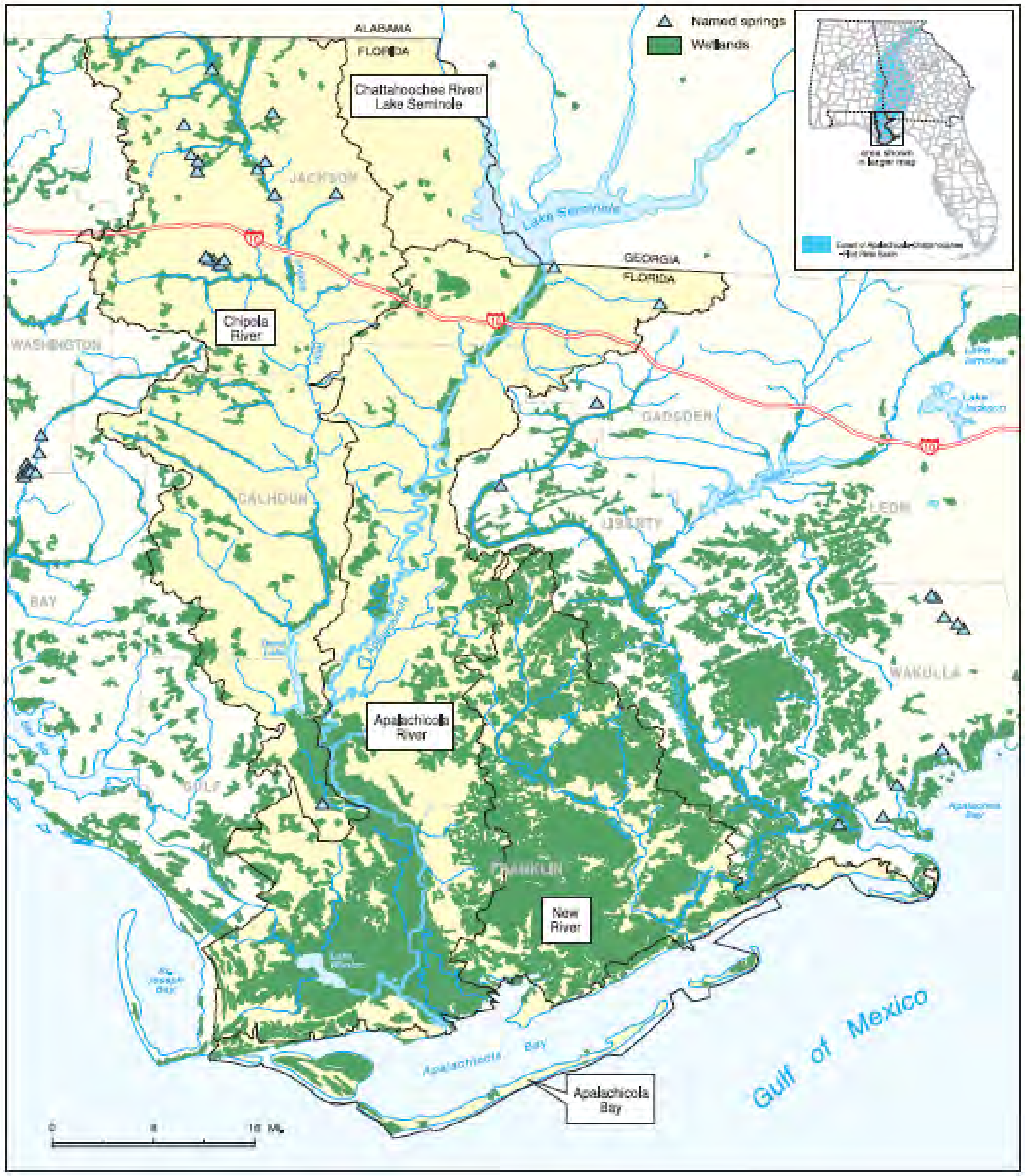

Figure 4. Map of Apalachicola-Chipola Basin including the Apalachicola River Planning Unit and the Apalachicola Bay Planning Unit.

There are 6 small domestic wastewater plants with nonsurface water discharges in the basin, with the largest being the Eastpoint Water and Sewer District (0.1650 MGD). There is only 1 industrial plant: Couch Ready Mix—Eastpoint (FDEP 2002).

Nonpoint sources that contribute nutrients to the bay include runoff from agricultural areas, runoff from urban and suburban areas, septic systems, atmospheric deposition, and the decomposition of natural organic matter (Frick et al. 1996). Apalachicola Bay nutrient concentrations are primarily influenced by river flow, local rainfall, tidal interactions, residence time, flux from benthic sediments, and the resuspension of sediments (Lewis 2003).

Summary of Nutrient Studies

Nutrients adhere to the particulate organic matter (detritus) that eventually falls into the sediments of the shallow Apalachicola system. This nutrient-rich organic matter is colonized by microbial components to form the basis of important detrital food webs (Federle *et al.* 1983a; White 1983a; White *et al.* 1977, 1979a, 1979b). Infaunal (living in or on sediments), detritus-feeding macroinvertebrate assemblages that live in the sediments of the bay are dominated by various species of worms and crustaceans, including *Mediomastus ambiseta, Hobsonia florida*, *Grandidierella bonnieroides,* and *Streblospio benedicti* (Livingston 1984b). The infauna form the food base for sciaenid fishes (Atlantic croaker [*Micropogonias undulates]*, spot [*Leiostomus xanthurus*], and sea trout [*Cynoscion* spp.]) that dominate the estuarine fish populations. Shallow depths and extremely high benthic productivity explain why the Apalachicola Estuary is a primary nursery area along the Gulf coast for blue crabs (*Callinectes sapidus*) and white shrimp (*Litopenaeus setiferus*). These species form the basis of highly lucrative fisheries in the region.

Litter fall in the Apalachicola floodplain (800 grams per square meter [gm^{-2}]) is higher than that noted in many tropical systems and almost all warm temperate systems (Elder and Cairns 1982). These authors found that the annual deposition of litter fall in the bottomland hardwood forests of the Apalachicola River floodplain approximates 360,000 metric tons. Seasonal river flooding transfers detritus from the wetlands to associated aquatic areas (Cairns 1981; Elder and Cairns 1982.

Livingston *et al.* (1974) indicated that in addition to providing particulate organics that fuel the bay system, river input determines nutrient loading to the estuary. Nutrient loading in the Apalachicola River as it enters the bay is relatively high compared with that in other alluvial rivers along the northeast Gulf coast of Florida (Figure 5) (Livingston 2010). Of the 214,000 metric tons (mt) of carbon, 21,400 mt of N, and 1,650 mt of P that are delivered to the estuary over a given year, over half is transferred during the winter-spring flood peaks (Mattraw and Elder 1984). Studies conducted in the bay (Livingston 1976, 1981a, 1983aa, 1984, 2000, 2002) corroborate the timing of these flow events with the delivery of nutrients and dissolved and particulate organic matter as an important factor in the maintenance of the estuarine primary production (autochthonous and allochthonous). There are direct links between the estuarine food webs and freshwater discharges (Livingston 1981a, 1983aa, 1984). Particulate organic carbon delivered to the estuary follows seasonal and interannual fluctuations that are closely associated with river flow ($R^2 = 0.738$) (Livingston 1991). During summer and fall months, there is no direct correlation of river flow and detritus movement into the bay. By winter, there is a significant relationship between microdetrital loading and river flow peaks.

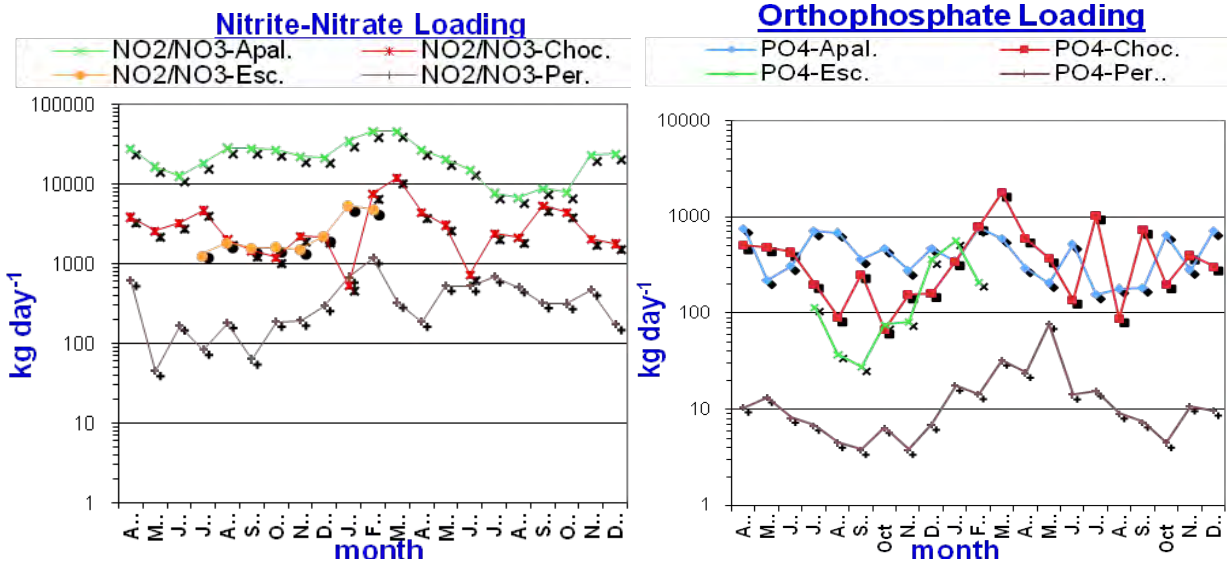

Figure 5. Time-series of nitrite-nitrate and orthophosphate loading in the Apalachicola, Choctawhatchee, Perdido, and Escambia Rivers (Livingston 2010).

Phytoplankton productivity is a major determinant of secondary production in many coastal systems. Boynton *et al.* (1982) reported that the Apalachicola system has high phytoplankton productivity compared with other river-dominated estuaries, embayments, lagoons, and fjords around the world. Nixon (1988) showed that the Apalachicola Bay system ranks high in overall primary production compared with other such systems. Up to 50% of the phytoplankton productivity of the Apalachicola Estuary is explained by Apalachicola River flow (Myers 1977; Myers and Iverson 1977, 1981).

In the Apalachicola system, orthophosphate availability limits phytoplankton during both low- and high-salinity winter periods and during the summer at stations with low salinity (Iverson *et al.* 1997). Conversely, N is limiting during summer periods of moderate to high salinity in the Apalachicola Estuary. Flow rates affect the development of nutrient limitation in the estuary. Nutrient limitation is highest during low-flow summer periods (Figure 5).

The physiography of the Apalachicola Estuary is an important factor in the high primary productivity of the system. The bay is relatively shallow, and wind action frequently resuspends inorganic nutrients (regenerated in the sediments) and mixes them into the euphotic zone, producing periodic peaks of phytoplankton production (Livingston *et al.* 1974; Iverson *et al.* 1997). In deeper estuaries, nutrients can be sequestered in the sediments, and thus can be unavailable for phytoplankton production. Shallow water depth is thus an important factor in the natural productivity of the Apalachicola Estuary.

Recent studies have further documented the influence of the Apalachicola River on nutrient and organic carbon loading to the bay. Chanton and Lewis (1999) found that, despite inputs of large quantities of terrestrial organic matter, net heterotrophy in the Apalachicola Bay system was not dominant relative to net autotrophy, during a 3-year period. Chanton and Lewis (2002), using carbon (δ^{13}C) and sulfur (δ^{34}S) isotope data, noted clear distinctions between benthic and water column feeding types. They found that the estuary depends on river flows to provide floodplain detritus during high-flow periods, and dissolved nutrients for estuarine primary productivity (plants) during lower flows. Floodplain detritus is significant in the important East Bay nursery area, thus showing that peak flows are important in washing such detritus into the estuary. Winter/spring periods of high river flow and macrodetritus delivery to the bay (Livingston 1981a) are coincident with increased infaunal abundance (McLane 1980). Four out of the five dominant infaunal species at river-dominated stations are detritus feeders. The transformation of nutrient-rich particulate organic matter from periodic river-based influxes of dissolved and particulate organic matter coincides with abundance peaks of the detritus-based (infaunal) food webs of the Apalachicola system (Livingston and Loucks 1978; White *et al.* 1979a, 1979b; Livingston 1984b).

A mechanism for the direct connection of increased infaunal abundance was described by Livingston (1983a, 1984b), in which microbial activity at the surface of the detritus (Federle *et al.* 1983a) leads to microbial successions (Morrison *et al.* 1977) that then provide food for a variety of detritivorous organisms (White *et al.* 1979a, 1979b; Livingston 1984b). Mortazavi *et al.* (2000a) found that phytoplankton productivity in river-dominated parts of the Apalachicola Estuary is limited by P in the winter (during periods of low salinity) and N during summer periods of high salinity. The dissolved organic nitrogen (DON) input is balanced by export from the estuary. Mortazavi *et al.* (2000b) determined temporal couplings of nutrient loading with primary production in the estuary. Around 75% of such productivity occurs from May through November, with primary control due to grazing. The research showed that approximately 80% of the daily chlorophyll *a* was consumed by grazers, and mostly occurred in the water column. Mortazavi *et al.* (2000c) provided detailed accounts of the N budgets of the bay. These studies indicated that phytoplankton productivity is an important component of estuarine food webs along the Gulf coast, and that a combination of river-derived organic matter and autochthonous organic carbon provides the resources for consumers in river-dominated estuaries of the Gulf coast. Figure 6 presents a conceptual model of Apalachicola Bay's trophodynamics.

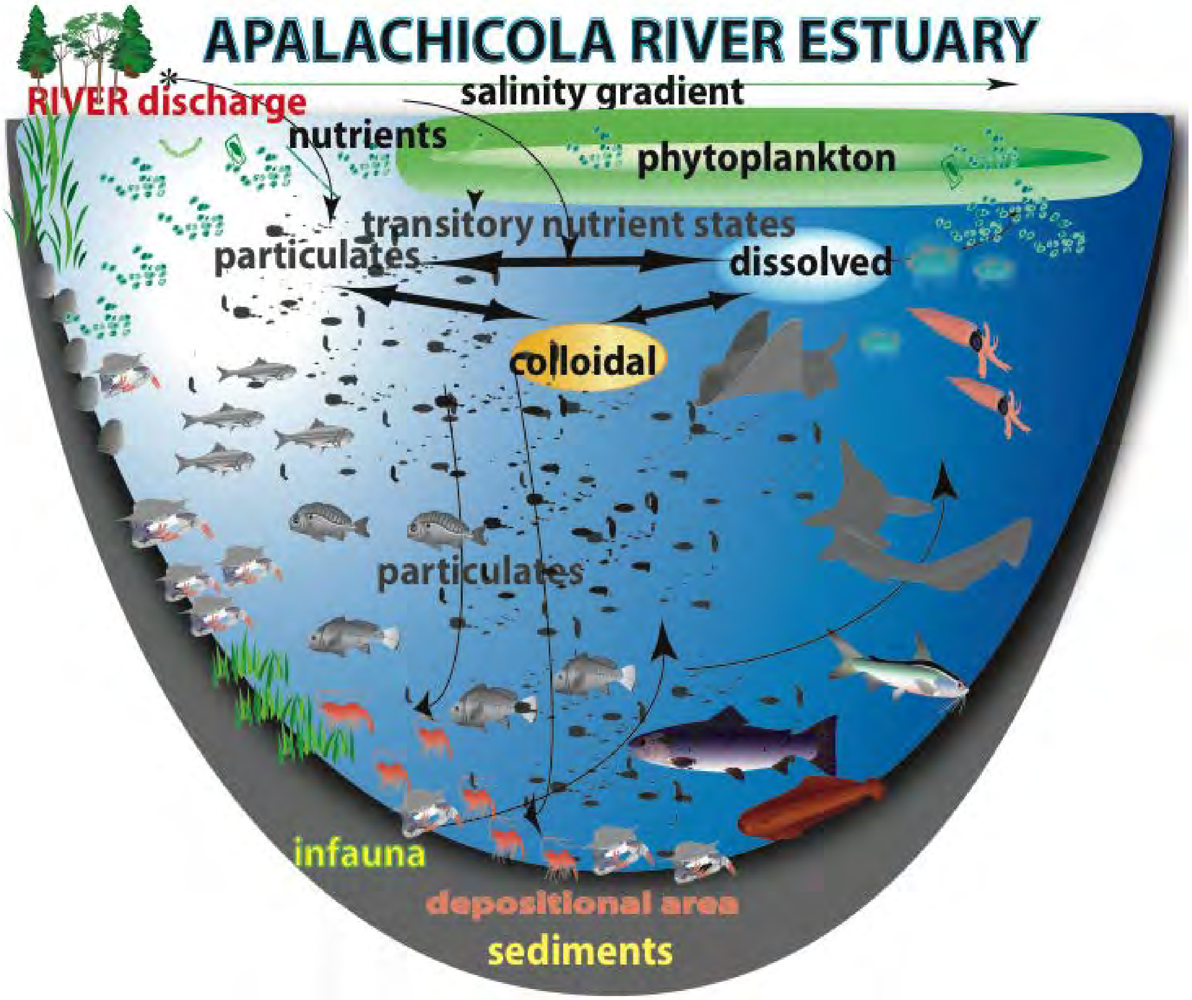

Figure 6. ***Livingston's model of the Apalachicola Bay system, showing key features that result in extremely high primary and secondary productivity.***

Livingston developed a Fish/Infauna/Invertebrate Index (FII) to describe the health of estuaries based on trophic relationships. The index includes determining the biomass (g/m^2) of herbivores, omnivores, and three levels of carnivores (primary= C1, secondary= C2, and tertiary=C3). Figure 7 depicts the pattern and distribution of the various Fish/Infauna/Invertebrate Index trophic levels in a few Gulf estuary systems. For Apalachicola Bay, the index was used to interpret data during a pre- and post-drought period.

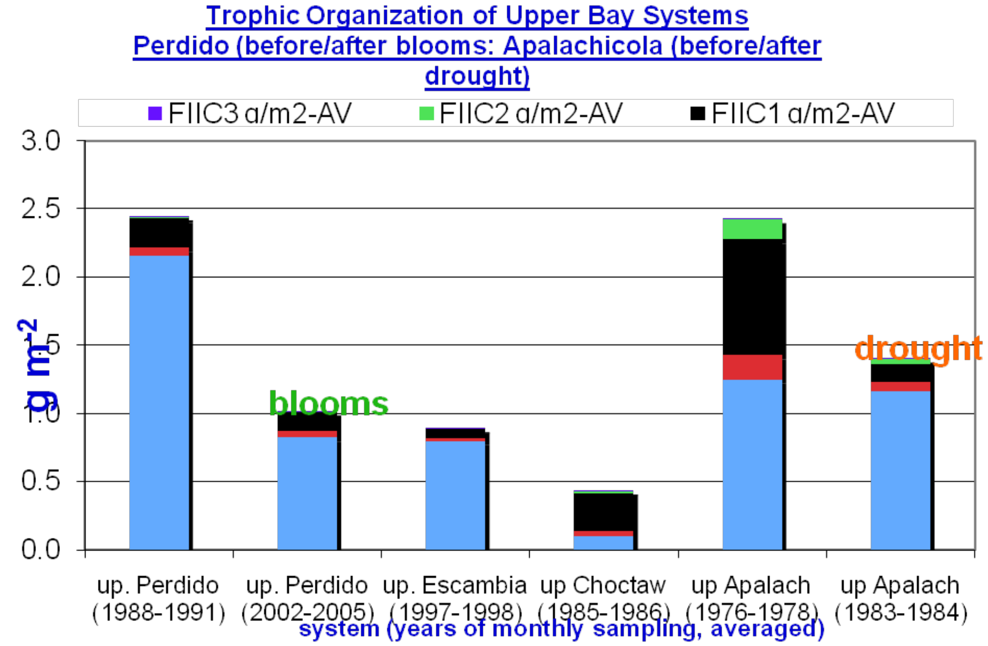

Figure 7. Biomass of three consumer trophic levels at selected north Florida bays, including data for Perdido Bay before and after the occurrence of HABs, and data for Apalachicola Bay, before and after a drought decreased available nutrients.

Daily nutrient loadings to the bay have been determined using data collected over three years, 1993-1996 (Mortazavi *et al.* 2000b). Mortazavi *et al.* (2000b) concluded that nitrate made up 93% of the total DIN input to the estuary at a rate of 22700 ± 2000 kg N d^{-1}; and orthophosphate contributed 465 ± 73 kg P per day. There was a positive relationship between DIN loading and river discharge with loadings shown to increase from November to March and decrease from March to June. In July 1994 there was a tropical storm that greatly increased nitrogen loads entering the bay, and loads remained elevated through the remaining summer. Although there was also a positive relationship between orthophosphate and river flow, no seasonal trends could be found (Mortazavi *et al*. 2000b).

It should be noted that nutrient concentrations in the river fluctuate little over time, but riverine water flow determines the loading of nutrient delivery to the bay (Table 3). The Apalachicola River illustrates the relationship between concentration and river flow (Table 3). Minimum and maximum values are actually 10th and 90th percentile values based on the number of samples for each parameter. An analysis of seasonal data shows a wide range of values in both dissolved nitrate and total phosphorus (TP) concentrations throughout the year, probably related to river flow differences. Further trend analysis shows little change in most nutrients over time in the lower river, except an increase in dissolved nitrate and a decrease in TP.

Table 3. Nutrient concentrations in the Apalachicola River, Mile 11 (from Frick et al. 1996).

Parameter	Number of Samples	Minimum	Maximum	Median
River flow (cubic feet per second [cfs])	101	11,000	50,000	24,000
TN (mg/L)	63	0.47	0.98	0.71
Total inorganic N (TIN) (mg/L)	83	0.22	0.47	0.32
Total organic N (TON) (mg/L)	55	0.17	0.68	0.35
Dissolved ammonia (mg/L)	84	0.02	0.09	0.03
Dissolved nitrate (mg/L)	98	0.17	0.42	0.27
TP (mg/L)	101	0.02	0.09	0.05

Other nutrient sampling done in the Apalachicola River around the same time includes nutrient concentrations in the lower Apalachicola River (Fulmer 1997; Mortazavi *et al.* 2000a, 2000b,); the results for 1994 to 1997 are as follows:

Nitrate = 0.180 to 0.480 mg/L;
Mean dissolved inorganic nitrogen (DIN) = 0.350 mg/L;
Mean dissolved organic nitrogen (DON) = 0.183 mg/L;
Phosphate (soluble reactive phosphate [SRP]) = 0.001 to 0.016 mg/L; and
Monthly average SRP = 0.0057 +/- 4.1 mg/L.

Understanding low salinity areas in alluvial-river dominated estuaries

In an estuary such as Apalachicola Bay that is dominated by a large, alluvial river, it is important to recognize that the oligohaline zone (the lower salinity portion of the estuary where river water first enters the estuary), has very different ecological characteristics than the higher salinity areas in the lower reaches of the estuary that are more influenced by Gulf of Mexico waters. Because of their distinct ecological characteristics, there should be different expectations for nutrients, turbidity, chlorophyll, and biological productivity in oligohaline areas.

Due to the seasonal variability of river flow in response to rainfall events, low salinity zones of an estuary vary and shift, and can undergo rapid change affecting physical, chemical and biological variables (SFWMD 2009). As illustrated in Figure 8, material carried by freshwater inflow enters the oligohaline zone of the estuary, undergoes geochemical processes associated with a zone of maximum turbidity, and then biological processes associated with a zone of maximum productivity (Church 1986). Suspended sediments derived from terrestrial runoff (and carried by river flow) are trapped in high concentrations near the freshwater/saltwater interface (Jassby 1995, Eyre 1998, Lin and Kuo 2003, North and Houde 2001, 2003, North et al. 2005, Fain et al. 2001). Such zones of high turbidity characterize the upper reaches of partially mixed estuaries around the world (Schubel and Pritchard 1986).

Adjacent to the zone of maximum turbidity, nutrients and other compounds bound to sediments are released, resulting in high aquatic productivity (SFWMD 2009). Because the high turbidity suppresses primary production (due to light extinction), a zone of maximum productivity typically develops further downstream in clearer waters (Fisher *et al.* 1988). The zone of maximum productivity may be composed of several sub-areas, including a zone of maximum primary production (chlorophyll *a*), followed by zones of high abundance of zooplankton, copepods, and fish larvae (Figure 8). These high secondary production zones develop as the algae produced are used as a food source by epibenthic feeders such as polychaetes, mysids, and amphipods (Diaz and Schaffner 1990). In turn, these epibenthic feeders serve as food sources for larval and juvenile fishes. Freshwater inputs containing nutrients help maintain this beneficial production (Fisher *et al.* 1988, Day et al. 1989, Montagna and Kalke 1992), with higher freshwater flows leading to higher yields of desirable species (Loneragan and Bun 1999).

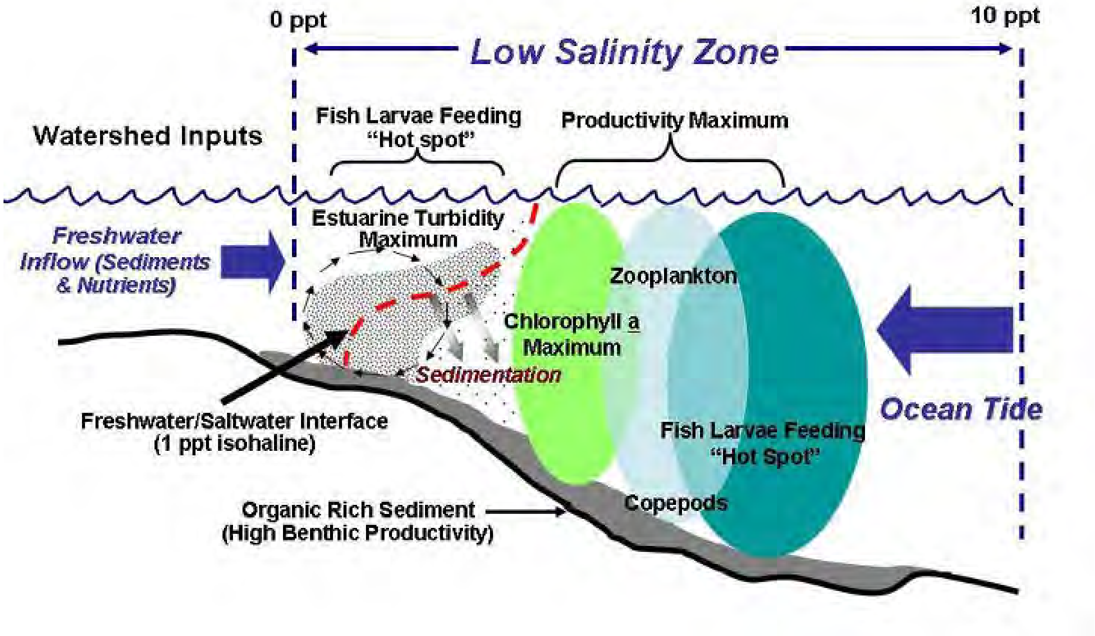

Figure 8. Conceptual representation of a low salinity zone and associated processes, transitioning to an open water estuary (from SFWMD 2009, adapted from Eyre 1998).

One of the most important ecological functions of estuaries consists of their function as nursery areas for the larval and juvenile stages of many species, including commercially important fish and shellfish (Gunter 1961, Rozas and Hackney 1983a, 1984, Odum *et al.* 1984, Jassby *et al.* 1995, Fain *et al*. 2001, North and Houde 2001, 2003, North *et al*. 2005, Yozzo and Diaz 1999). The oligohaline zone is considered critical to the life histories of many of these organisms (Holmes *et al*. 2000, Hughes *et al.* 2000), and provides habitat for a wide variety of juvenile and adult freshwater, estuarine, and marine fishes (Rozas and Hackney 1983a, Odum *et al*. 1984, 1988, Peterson and Ross 1991). Low salinity tidal wetlands provide nursery grounds for many anadromous and catadromous fishes, such as shad, herring (alosids), striped bass (*Morone saxatilis*), and eels (*Anguilla rostrata*) (Massmann 1954). These tidal low salinity areas are characterized by increased concentrations of organic matter, derived from freshwater inputs and *in situ* production (Odum *et al*. 1984). Low salinity tidal creeks provide exceptional habitat for small or larval fishes (Roman et al. 2001, North and Houde 2001, 2003, North *et al.* 2005). Oligohaline zones are known to provide an abundance of food sources and protection from predators, to a broad array of micro- and macroinvertebrates and fish (Diaz and Schaffner 1990, Yozzo and Diaz 1999). Protection from marine predators is associated with both the low salinities and the low visibility associated with suspended solids, color, and abundant phytoplankton (Chesney 1989, Kimmerer 2002).

This protection may help explain why the smallest fish are typically found in low salinity areas (Gunter 1961).

In establishing marine numeric nutrient criteria, it is important to consider that low salinity areas may be expected to exhibit higher nutrient and chlorophyll a levels than higher salinity open water areas. For example, in a study of eight minimally disturbed tidal creeks in South Carolina, Dame *et al.* (2000) showed that summertime chlorophylls typically exceeded 10 ug/L, and were as high as 40 ug/L (Figure 9). In contrast, most Florida open water estuaries are characterized by annual chlorophyll a concentrations of less than 9 ug/L (Figure 10).

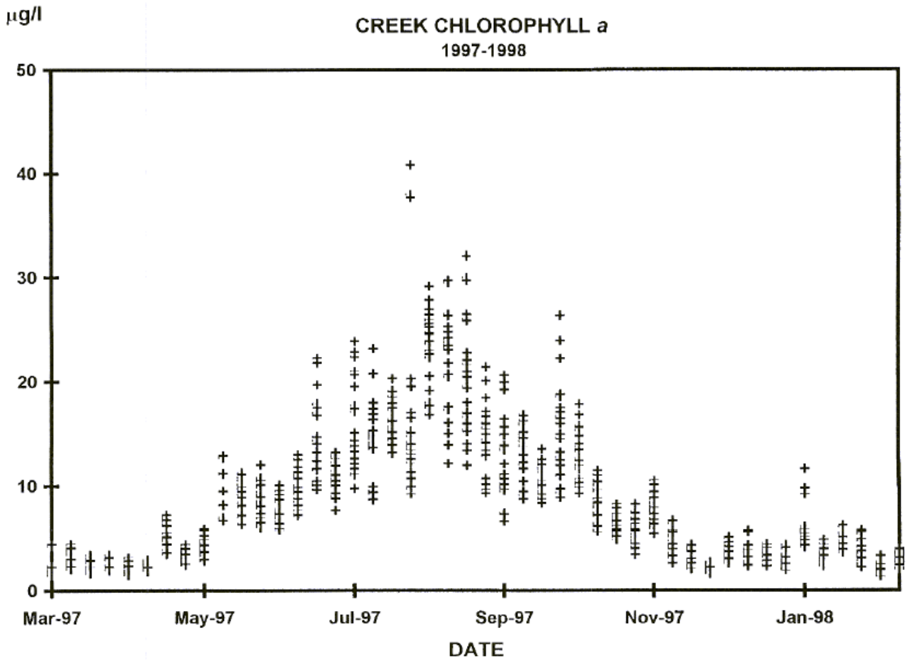

Figure 9. Time-series graph showing background chlorophyll a concentrations (ugIL) from unnamed, minimally disturbed tidal creeks associated with North Inlet, South Carolina, from 1997 to 1998 (triplicates shown) (from Dame et al. 2000).

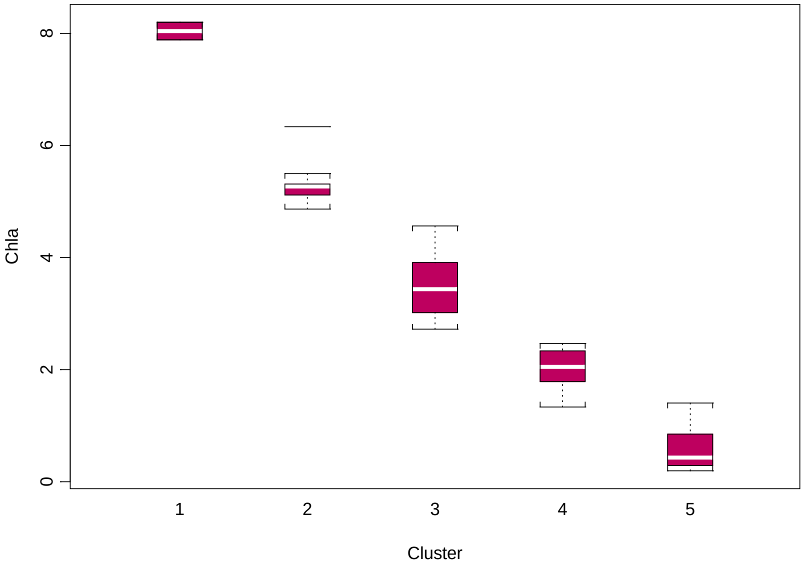

Figure 10. Boxplot of long-term geometric mean chlorophyll a for 75 open water, biologically healthy estuarine segments, which were grouped into 5 clusters generated by an agglomerative cluster analysis (from FDEP 2010).

Biological Summary

SAV

Fresh, brackish, and salt water SAV provides habitat and nursery areas for numerous species. Dominant organisms associated with these vegetation beds include polychaetes, amphipods, chironomid larvae, snails, amphipods, mysids, crabs and shrimp, rainwater killifish, pipefish, silversides, and gobies (Livingston 1984c). Because of its position between upland and unvegetated bay bottom habitats, submerged vegetation links dissimilar ecosystems and is important to the productivity of estuarine systems because it functions as a nursery area, providing food and reducing predation pressure through habitat complexity.

Although SAV abundance is an excellent biological indicator in most high salinity, lagoonal estuaries, the naturally low and fluctuating salinities in much of Apalachicola Bay make SAV presence a less useful metric. In fact, decreased flow from the Apalachicola River, due to upstream diversions in the ACF drainage basin (Fahrny *et al.* 2006), may artificially increase SAV coverage. Furthermore, the mapping of seagrasses has proven especially difficult in the Apalachicola Bay system due to naturally low visibility (Fahrny *et al*. 2006).

Separate surveys of submerged vegetation conducted in the 1980s by Livingston (1980) and CSA (1985) show significant differences in acreages. These differences are probably caused by mapping methods, calculation techniques, change in species (*Myriophyllum*), or the absence of data from eastern St. George Sound (CSA 1985).

At this time, the most complete maps of SAV coverage of the larger Apalachicola Bay were developed using aerials from late 1992-early 1993 (Figure 11). However, FWC's Seagrass Integrated Mapping and Monitoring (SIMM) Program is currently working on interpreting high-resolution aerial photography obtained in October 2010 as part of damage assessment following the Deepwater Horizon Oil Spill. This work is expected to be completed by the end of summer 2012 (Paul Carlson, personal communication, 2012).

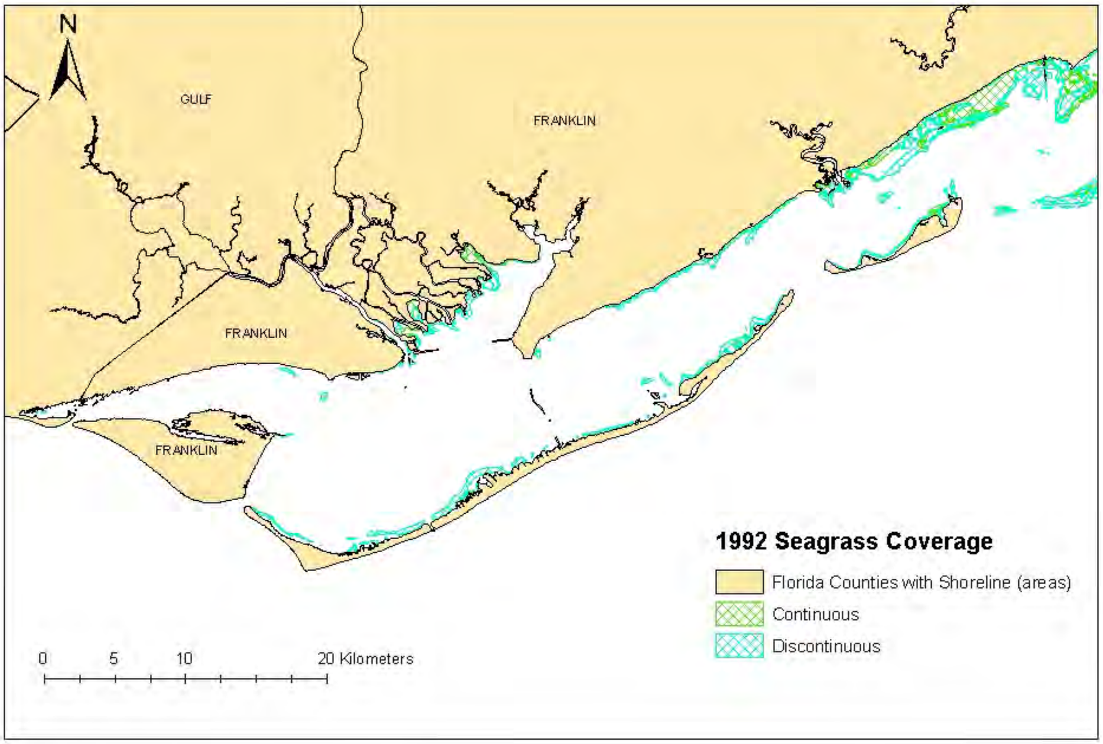

Figure 11. Map of seagrass cover in Franklin County coastal waters, 1992.

The SIMM Program has also been surveying seagrass in St. George Sound (and other Franklin County coastal areas) since 2006. Monitoring as part of this project does not extend further west than St. George Sound. Monitoring points were chosen based on mapping data that restricted points to areas known to have seagrass and to maintain a minimum distance between points (Figure 12) (Maria Merrill, personal communication, 2012). Additionally, areas west of St. George Sound were not chosen as monitoring locations because of the dynamic physical conditions induced by changes in river flow that often act to restrict SAV. As mentioned earlier, monitoring in this area may not provide any useful information about the health of the system.

Figure 12. Map showing Seagrass Integrated Mapping and Monitoring (SIMM) Program monitoring locations in Franklin County, FL (FWC 2012).

SIMM researchers report that the fluctuating salinity of Apalachicola Bay makes SAV coverage there variable and dynamic, while seagrass coverage in St. George Sound, with a more constant salinity regime, is more stable. Note that even in St. George Sound, SAV is not an abundant habitat. In 2009, 80% of the quadrats surveyed were bare of seagrasses (Figure 13) (Yarbro and Carlson 2011).

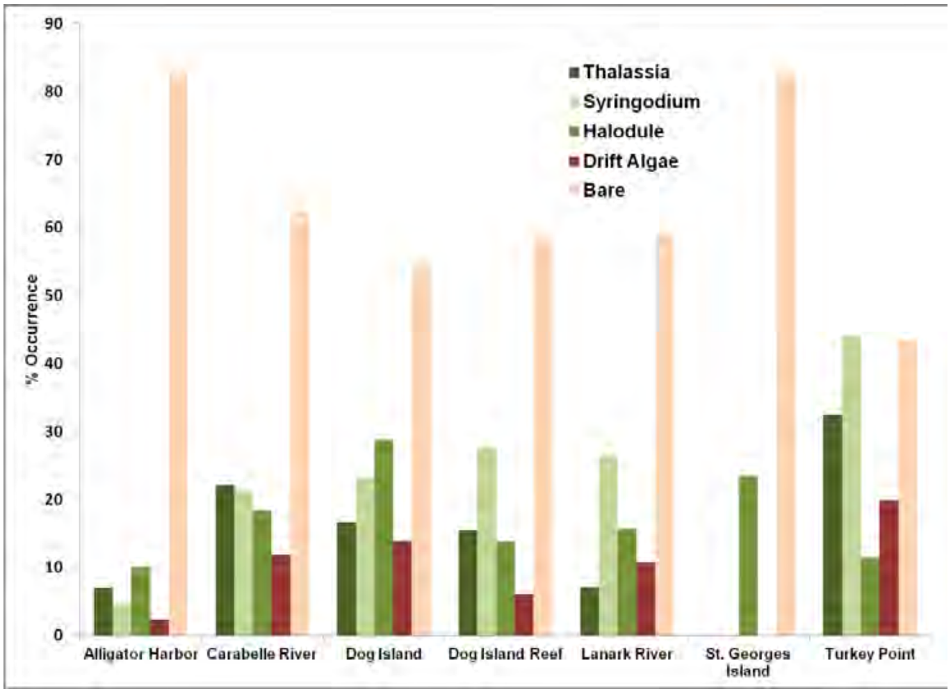

Figure 13. Bar graph showing the occurrence of seagrasses and drift algae in subregions of Franklin County coastal waters as determined by SIMM researchers in 2009 (FWC 2012).

The Apalachicola National Estuarine Research Reserve developed an SAV monitoring program focused in East Bay as part of their System-Wide Monitoring Program (SWMP). The Apalachicola River and Bay Basin went through an extended drought from 1999 to 2002 that resulted in record low flows for much of that period, including the absence of normal winter floods for several years. During this period, unusually high salinities were noted in upper East Bay from ANERR's SWMP data loggers and disappearance of the fresh/brackish SAV in East Bay and the lower river was observed.

Subsequently, beginning in 2002, ANERR mapped submerged vegetation in East Bay at three sites for two years, using transects, quadrats, and a towable underwater video camera to measure distribution and percent cover. The camera allowed for mapping of areas that had never been surveyed (Fahrny *et al.* 2006). In fact, according to a report prepared for NOAA by the ANERR, "the detection of large areas of SAV that had not been mapped previously has significantly expanded the distribution of known SAV in East Bay" (Fahrny *et al.* 2006). In addition, more species were documented than were found in the past (Table 4), either due to a more detailed survey or a change in the SAV community over time. Figure 14 shows SAV distribution and density in 2005 at the conclusion of ANERR's survey.

Table 4. East Bay SAV species list (from Fahrny et al. 2006).

Species Name	Common Name	Native/Invasive
Ceratophyllum demersum	Coontail	Native
Chara spp	Muskgrass	Native
Hydrilla verticillata	Hydrilla	Invasive
Myriophyllum aquaticum	Parrot feather	Invasive
Myriophyllum spicatum	Eurasian watermilfoil	Invasive
Najas guadalupensis	Southern naiad	Native
Najas minor	Spiny naiad	Native
Potamogeton pusillus	Slender pondweed	Native
Ruppia maritima	Widgeon grass	Native
Stuckenia pectinata	Sago pondweed	Native
Vallisneria americana	Tapegrass	Native
Zannichellia palustris	Horned pondweed	Native

On July 10, 2005, Hurricane Dennis pushed an eight foot storm surge into the Apalachicola Bay area. Visual and underwater camera surveys were done post-Dennis, and showed that none of the SAV mapped before the storm survived (Fahrny *et al* 2006). Since then, seagrasses have returned in similar density and composition to what was documented prior to Dennis (Jenna Wanat, personal communication, 2012).

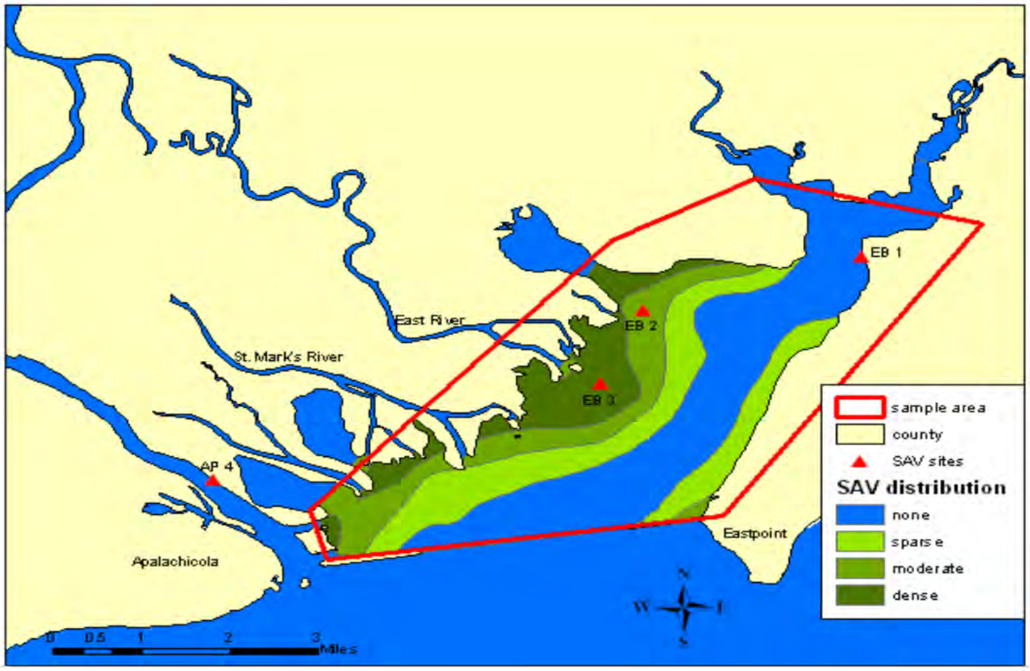

Figure 14. Percent SAV coverage in East Bay and ANERR monitoring sites, June 2005 (Edmiston 2008). Green gradient represents the percent coverage of all species before Hurricane Dennis hit in 2005. Much of the vegetation was lost due to saltwater intrusion and sedimentation. Presently, much of the vegetation had recovered to its previous extent.

Phytoplankton

Phytoplankton is the main source of carbon in the bay, fueling the productive food web (Chanton and Lewis 2002). For many estuarine food webs, benthic and epiphytic algae, along with phytoplankton are the primary carbon sources (Sullivan and Moncreiff 1990; Deegan and Garritt 1997; Moncrieff and Sullivan 2001), but in Apalachicola Bay, phytoplankton provides the primary base for secondary production (Chanton and Lewis 2002), with benthic production being of secondary importance (Wilson *et al.* 2009). Food webs in Apalachicola Bay are driven by *in situ* productivity and therefore depend on the input of "new" nutrients to the system. Compared with other estuaries in the Gulf of Mexico, phytoplankton productivity is high in Apalachicola Bay (Putland 2005).

Researchers have found that phytoplankton productivity varies annually and peaks in warmer summer months (Mortazavi *et* al. 2000) and during lower salinities (Putland 2005). Phytoplankton growth also peaks during warmer temperatures (26° C) and in lower salinities (5 to 20 ppt) (Putland 2005). However, when temperatures are above 26° C, low phytoplankton growth rates are shown to occur. Summer growth peaks are thought to be due to the higher light energy and temperatures available. The drop in growth at temperatures over 26° C can be explained by nutrient limitation (Edmiston 2008). Relationships between chlorophyll and salinity have not been shown to exist nor have any seasonal patterns in chlorophyll concentrations emerged. However, Putland (2005) found that there is a relationship between salinity/temperature and the ratio of chlorophyll to carbon and that phytoplankton carbon peaks in summer and in lower salinity waters. Edmiston (2008) observed that more of the carbon fixed by phytoplankton is allocated to the synthesis of proteins and lipids in lower salinity waters, and therefore, the highest quantity and quality of phytoplankton occurs during summer in lower salinity waters in Apalachicola Bay.

In 2008, a phytoplankton species composition study was performed throughout the bay by Paula Viveros and Dr. Ed Phlips from UF, along with ANERR staff. This study showed that diatoms dominated the community, with some dinoflagellate peaks and moderate cyanobacteria biomass during the summer of 2008. A shift occurred in the fall of 2008, and while diatoms still dominated, cyanobacteria and dinoflagellates became less important. In the winter of 2008, diatoms still dominated, with some dinoflagellate peaks but few cyanobacteria. The most common diatom was *Thalassiosira* sp., the main dinoflagellate found was *Protoperidinium* sp., and the main cyanobacterium observed was *Pseudosolenia calcaravis* (Figures 15 through 26). Salinity, defined by freshwater inflow from the Apalachicola River, is considered to be the single most important determination of the distribution of organisms in the estuary (Livingston 1983a).

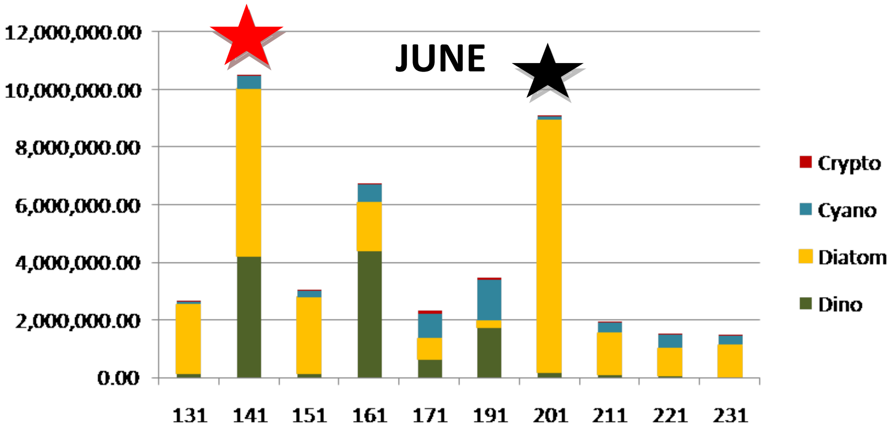

Figure 15. Bar graph depicting phytoplankton composition in Apalachicola Bay (within the bay and offshore), June 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

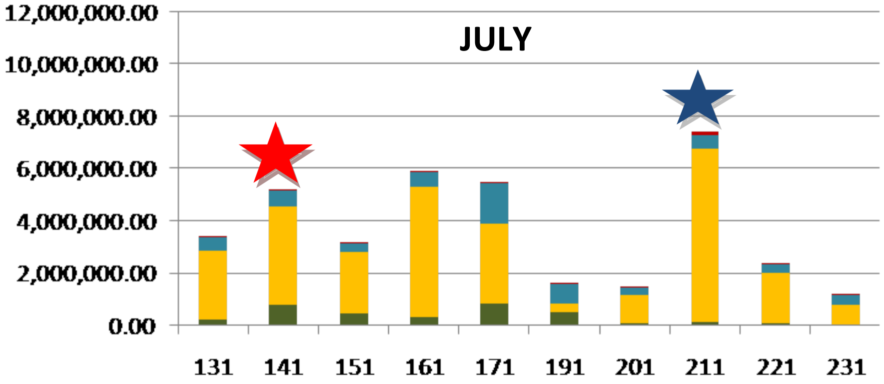

Figure 16. Bar graph depicting phytoplankton composition in Apalachicola Bay (within and offshore), July 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros, 2010).

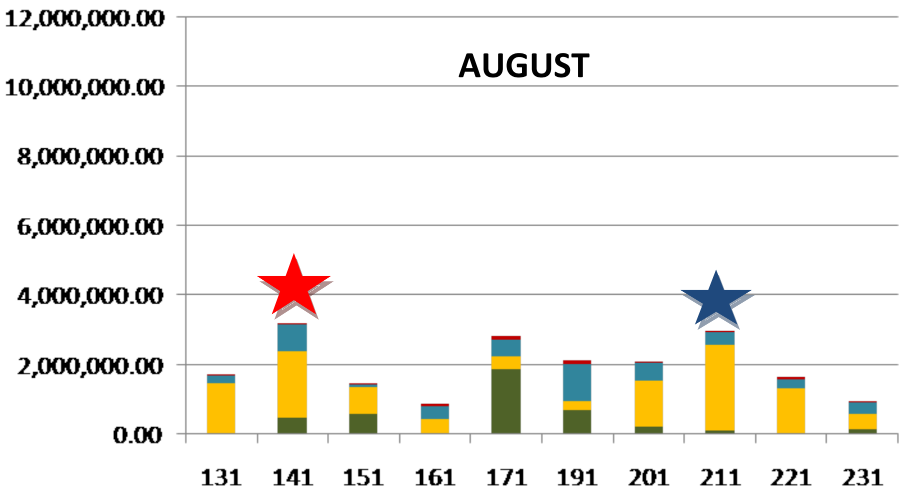

Figure 17. Bar graph depicting phytoplankton composition in Apalachicola Bay (within and offshore), August 2008, by biovolume ($\mu m^3\ mL^{-1}$); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros, 2010).

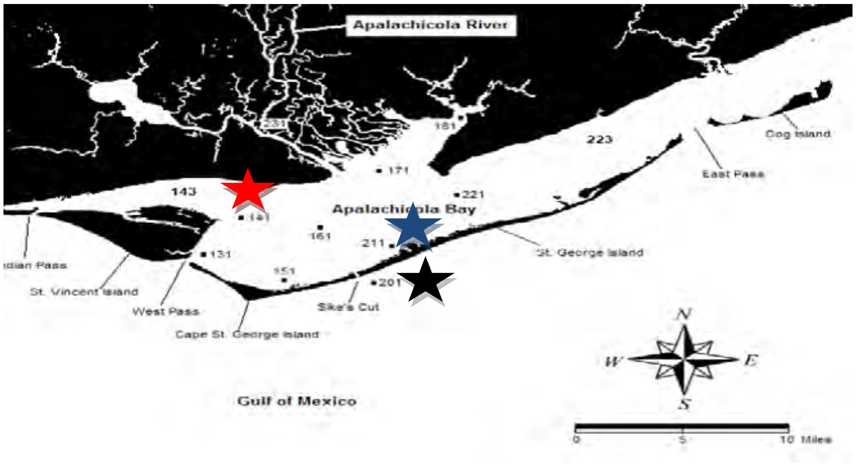

Figure 18. Map of Apalachicola Bay, showing station locations; stars show stations from figures 14-16 above; data from Paula Viveros, UF (figures provided by Viveros 2010).

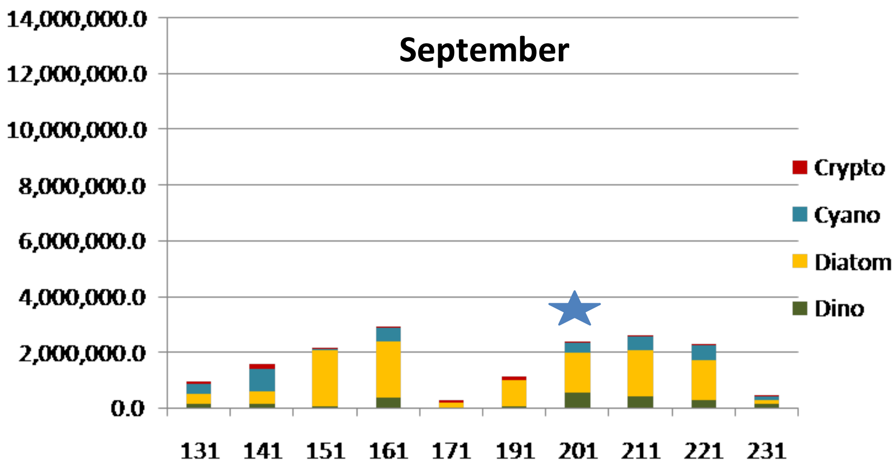

Figure 19. Bar graph showing phytoplankton composition in Apalachicola Bay (within and offshore), September 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

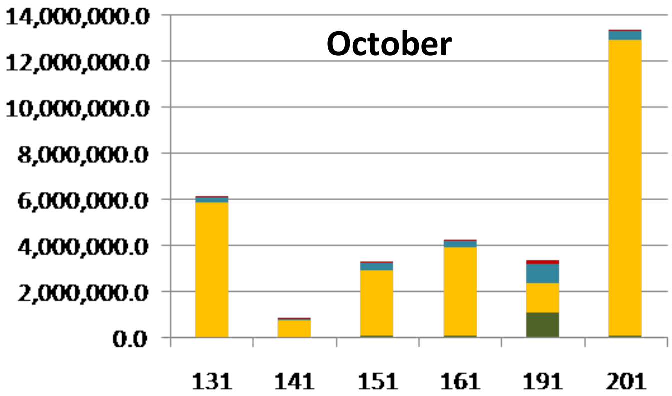

Figure 20. Bar graph showing phytoplankton composition in Apalachicola Bay (within and offshore), October 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

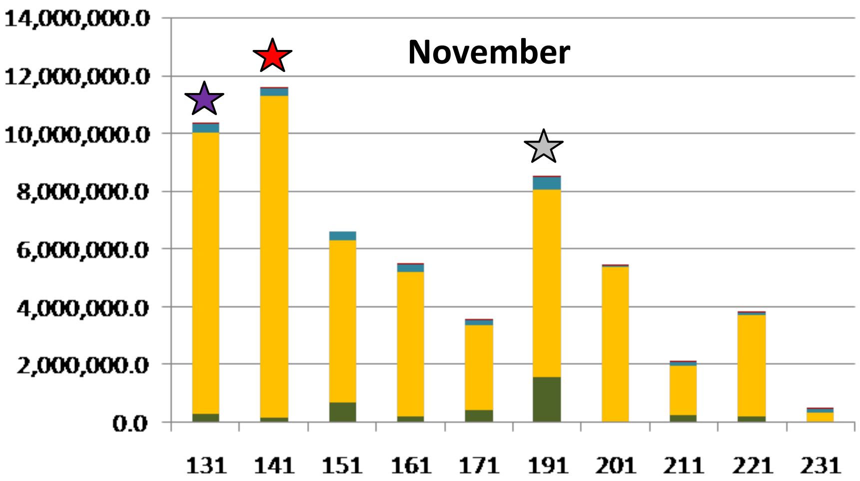

Figure 21. Bar graph showing phytoplankton composition in Apalachicola Bay (within and offshore), November 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

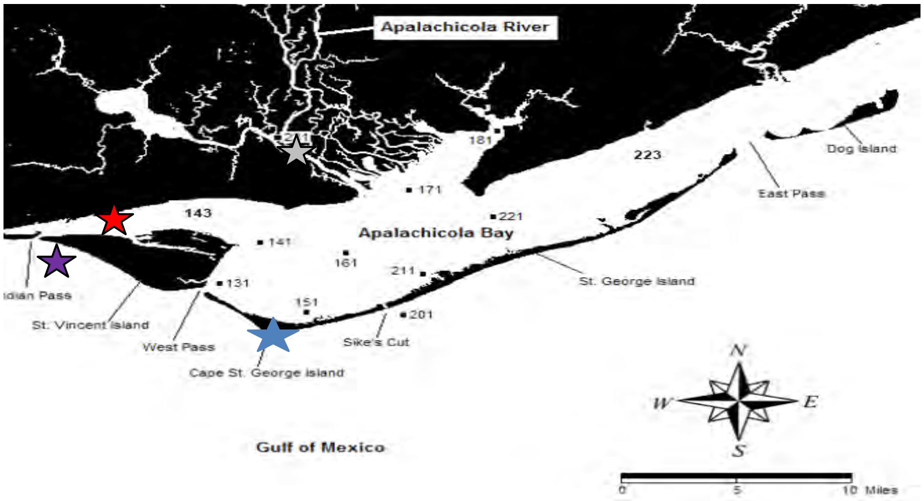

Figure 22. Map of Apalachicola Bay; stars show station locations from figures 18-20 above; data from Paula Viveros, UF (figures provided by Viveros 2010).

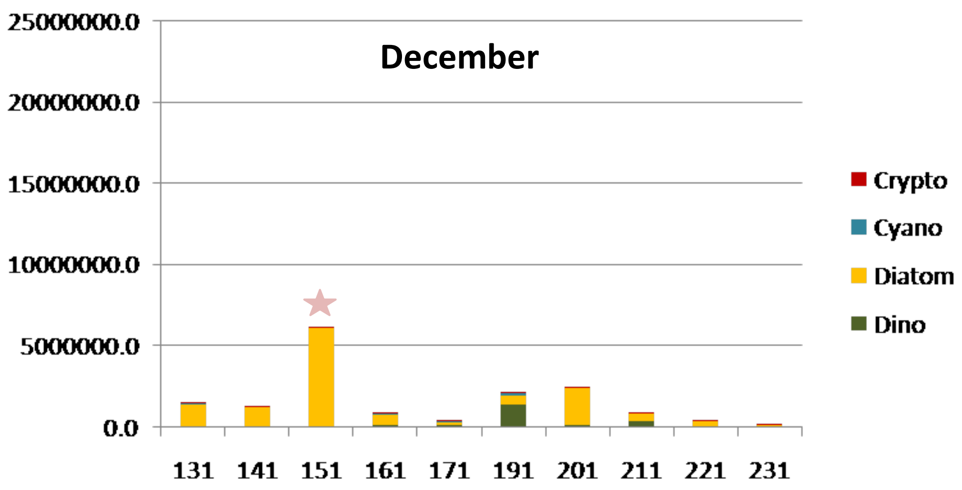

Figure 23. Bar graph showing phytoplankton species composition in Apalachicola Bay (within and offshore), December 2008, by biovolume (µm^3 mL^{-1}); stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

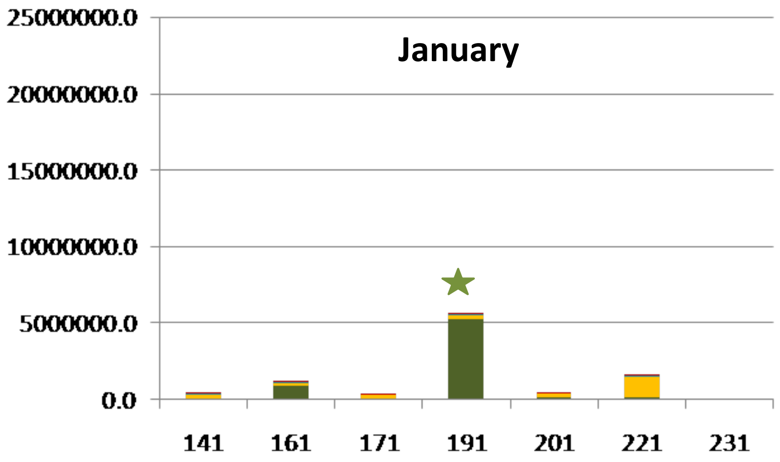

Figure 24. Bar graph showing phytoplankton composition in Apalachicola Bay (within and offshore) by biovolume (µm^3 mL^{-1}), January 2008; stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros 2010).

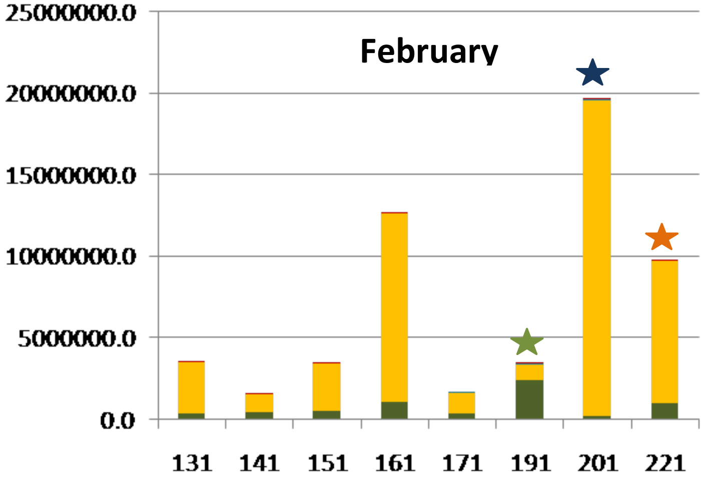

Figure 25. ***Bar graph showing phytoplankton composition in Apalachicola Bay (within and offshore) by biovolume ($\mu m^3\ mL^{-1}$), February 2008; stars show station locations on map below; data from Paula Viveros, UF (figures provided by Viveros, 2010).***

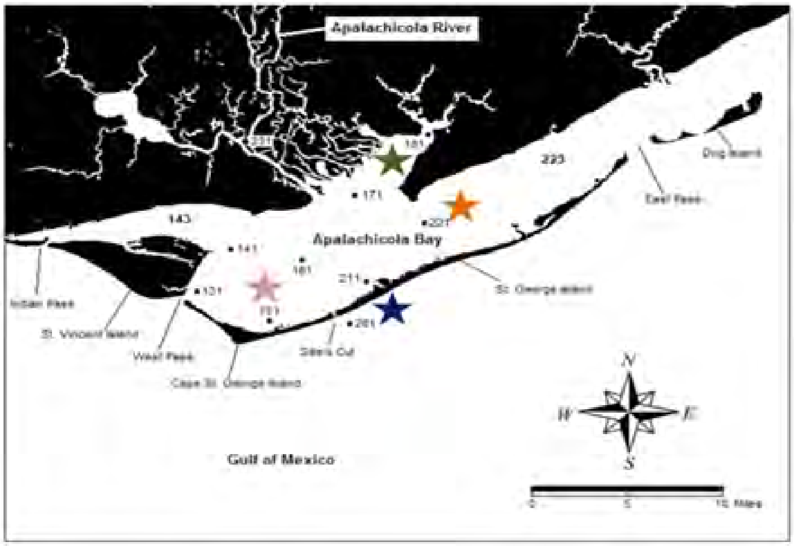

Figure 26. Map of Apalachicola Bay, showing station locations; stars show stations from figures 22-24 above; data from Paula Viveros, UF (figures provided by Viveros, 2010).

Oysters (Crassostrea virginica) (from Livingston 2010)

Oyster bars represent an important and extensive habitat in the Apalachicola Estuary, providing cover and food for diverse assemblages (Livingston 1984b). These include bryozoans, flatworms, annelids, gastropod and pelecypod mollusks, arthropod crustaceans, and fishes. Research on the extensive Apalachicola oyster (*Crassostrea virginica*) reefs goes back to the work of Swift (1896) and Danglade (1917). The Apalachicola Estuary has accounted for about 90% of Florida's commercial oyster fishery (Whitfield and Beaumariage 1977) and about 10% of the oyster production in the United States.

Conditions in the Apalachicola Bay system are highly advantageous for oyster propagation and growth (Menzel 1981; Menzel and Nichy 1958; Menzel *et al.* 1966; Livingston 1984b), with reefs covering about 7% (4,350 hectares [ha]) of bay bottom (Livingston 1984b). The growth rates of oysters in this region are among the most rapid of those recorded (Ingle and Dawson 1952, 1953), with harvestable oysters taken in 18 months. The abundant phytoplankton food source, which is a consequence of riverine freshwater and nutrient inputs, accounts for this high growth rate.

OYSTER RESOURCES LOCATIONS OF APALACHICOLA BAY
Apalachicola Bay System (#16) Shellfish Harvesting Area in Franklin County

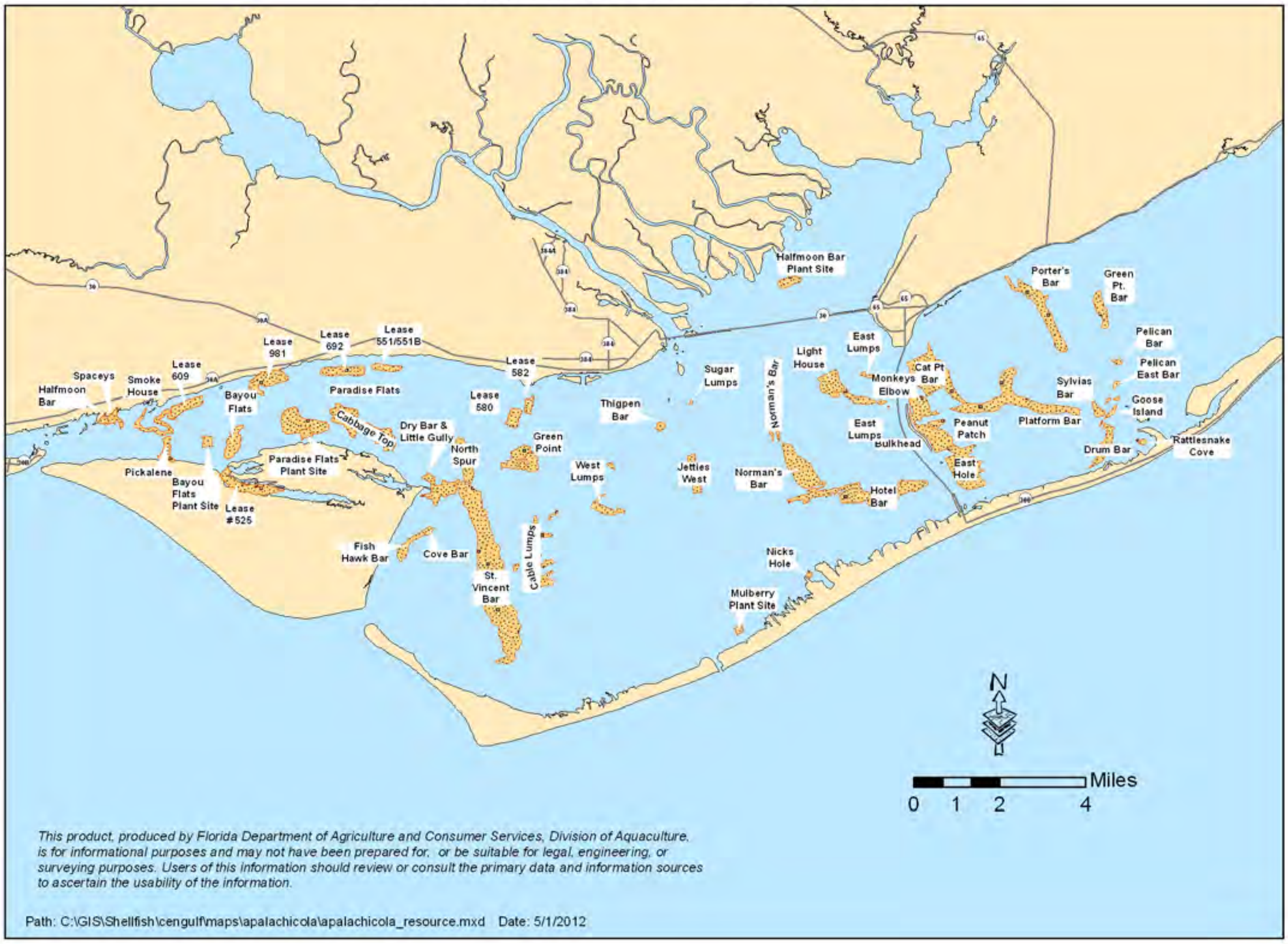

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Figure 27. Oyster bar locations in Apalachicola Bay (FDACS 2012).

The distribution of oyster bars in the estuary (Figure 27) does not differ substantially from that described over 100 years ago.

Livingston *et al.* (1999, 2000) outlined life history descriptions of the Apalachicola oyster population. Long-term changes of the Apalachicola oyster population should be placed within the context of major habitat-controlling features such as Apalachicola River flow. Meeter *et al.* (1979) found that oyster landings from 1959 to 1977 were correlated negatively with river flow. The highest oyster landings coincided with drought conditions. Wilber (1992), using oyster data from 1960 to 1984, found that river flows were correlated negatively with oyster catch per unit effort within the same year and positively with catches 2 and 3 years later. Highest oyster harvests occurred in 1980-1981, coinciding with a major drought. Predation on newly settled spat during periods of high salinity was given as an explanation of the 2-year time lags between low flow events and subsequent poor production.

Overall oyster production is concentrated on three eastern bars (Cat Point [CP], East Hole [EH], Platform [PL]) that are located just off East Point (Figure 28). These areas are subjected to a convergence of highly colored surface water from East Bay (i.e., influenced by the Apalachicola River/Tate's Hell Swamp drainage) and high velocity bottom water currents moving westward from St. George Sound. Maximum growth occurs during periods of low water temperature and high salinity variation (Livingston, 2010). Oyster mortality is highest at St. Vincent's Bar (SV) and areas associated with Sike's Cut (SK). These are the parts of the bay distant to river influence (with high salinity) and are also in close proximity to the entry of oyster predators from the Gulf through the respective passes. The most important oyster predator is the gastropod mollusk, *Thais haemastoma* (Livingston, 2010). Oyster mortality is low at the highly productive reefs in the eastern part of the bay (Cat Point, East Hole). Statistical analyses indicated that oyster mortality was positively associated with maximum bottom salinity and surface residual current velocity (Livingston *et al.* 2000). Mortality was inversely related to oyster density, bottom residual velocity, and bottom salinity.

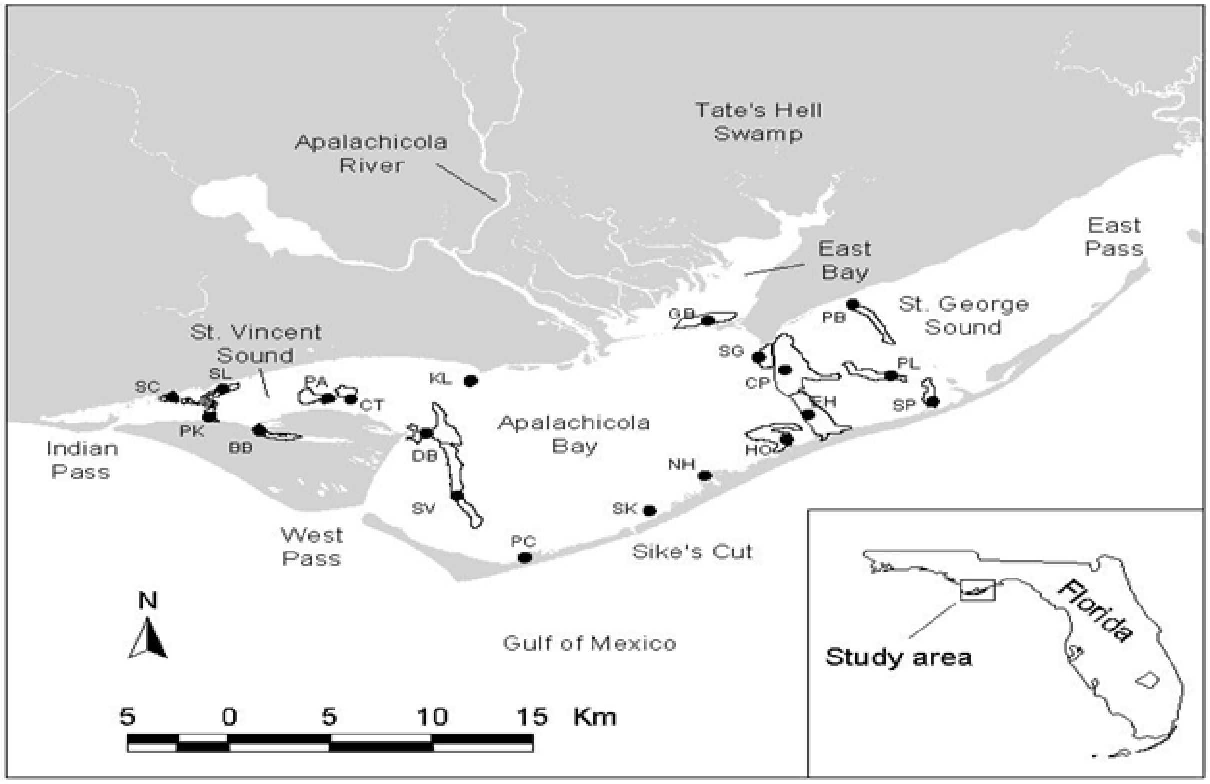


Figure 28 .Oyster bar locations and labels according to research summarized in Livingston 2010.

Oyster bar growth (actual number of oysters in a given bar) and density (numbers of oysters per unit area) were highest at the East Hole, Cat Point, and Platform reefs (*i.e.,* the eastern reefs). Oyster density was lowest in oyster reefs located in St. Vincent Sound. Bar growth, defined as oyster density times bar area, was directly associated with high surface water color and Secchi readings and average bottom current velocities. These results are consistent with the findings that most of the oyster production in the bay occurs in areas subjected to a convergence of highly colored surface water from East Bay (i.e., influenced by the Apalachicola River/Tate's Hell Swamp drainage) and high velocity bottom water currents moving westward from St. George Sound (Livingston 2010). Based on the distribution of oyster density, the primary oyster growing areas were in eastern sections of the bay with maximum growth during periods of low water temperature and high salinity variation.

Livingston calculated a time-averaged model for summer oyster mortality by running a regression analysis with averaged predictors derived from a hydrodynamic model and observed (experimental) mortality rates throughout the estuary. Based on the model, it was determined that high salinity, relatively low-velocity current patterns, and the proximity of a given oyster bar to entry points of saline Gulf water into the bay were important factors that contributed to increased oyster mortality (disease and predation) (Livingston *et al.* 2000). Mortality was a major determinant of oyster production in the Apalachicola estuary with predation as a significant aspect of such mortality. By influencing salinity levels and current patterns throughout the bay, the Apalachicola River was important in controlling such mortality.

Actual mortality data were plotted in Figure 29 so that the behavior of the model relative to real data could be observed. The distribution of mortality during 1985 (moderately low river flow year) was highest in areas directly affected by high salinity; such mortality was also near the entry points of oyster predators (St. Vincent Bar, Scorpion, Pickalene, Porter's Bar). Predation on the primary eastern oyster bars was usually relatively low. The projections of oyster mortality for 1986 (a drought year characterized by much lower river flow than 1985) were considerably higher, especially on the highly productive bars in eastern sections of the bay. Experimental oyster mortality data taken during May 1986 (Figure 29) tended to confirm the model projections. During 1986, the projected predation on high producing bars such as Cat Point, East Hole, Platform and Sweet Goodson would have been extensive. These model projections were verified by losses of oysters on the eastern bars during the most recent drought periods (Livingston 2010).

The effect of river flow, as an indirect determinant of oyster mortality due to predation through primary control of salinity regimes, was a major factor in the development of oysters in Apalachicola Bay. Model results indicated that reductions of river flow would be accompanied by substantial reductions in oyster stocks. Predation is an active factor in the determination of oyster production in the Apalachicola system. An example of its importance is the near total demise of the St. Vincent oyster bar following the opening of Sike's Cut in the mid-1950's. Oyster bar associations include various organisms that prey on oysters (Menzel *et al.* 1958, 1966). Experiments indicated that oyster mortality in the Apalachicola system was related to salinity as a determinant of oyster predation and the geographic position of the reef relative to the natural (East Pass, West Pass, Indian Pass) and man-made (Sike's Cut) entry points of predators from the Gulf (Livingston 2010).

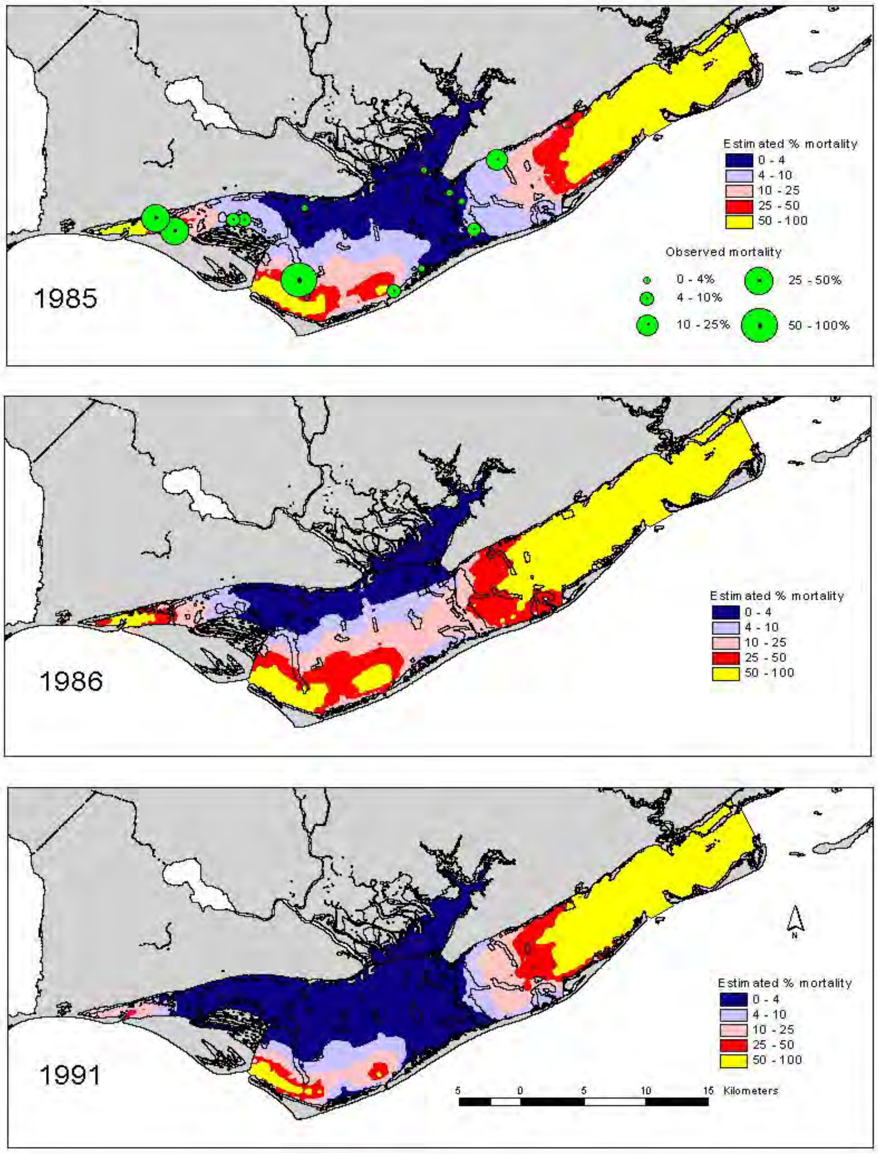


Figure 29. Map of projected oyster mortality in the Apalachicola Bay system based on the statistical model for mortality in 1985 and the hydrodynamic model results for (A) 1985. (B) 1986. (C) 1991. Circles indicate observed mortality values from oyster predation experiments (1985, May-August average).

By coupling hydrodynamic modeling with descriptive and experimental biological data, Livingston *et al.* (2000) were able to determine the effects of potential freshwater diversions on oyster production in Apalachicola Bay. The very high oyster production rates in the Apalachicola system depend on a combination of variables that are directly and indirectly associated with freshwater input as modified by wind, tidal factors, and the physiography of the bay. River flow reduction, whether through naturally occurring droughts, through increased upstream anthropogenic (consumptive) water use, or a combination of the two, could have serious long-term, adverse consequences for oyster populations. Based on the findings of Livingston *et al.* (1997, 2000), anthropogenic reductions of freshwater flow during relatively low-flow periods could extend and exacerbate the effects of natural drought periods on the bay through enhanced oyster mortality by predation and disease. In such a scenario, reductions in oyster production could be extended or, under extreme conditions, made permanent, thereby eliminating the naturally high oyster production of the Apalachicola system.

Infaunal Macroinvertebrates (from Livingston 2010)

In terms of frequency of occurrence, the infaunal macroinvertebrate assemblages in East Bay are dominated by species such as *Mediomastus ambiseta* (below-surface deposit feeder and detritivorous omnivore), *Hobsonia florida* (above-surface deposit feeder and detritivorous omnivore), *Grandidierella bonnieroides* (grazer/scavenger and general omnivore), *Streblospio benedicti* (above-surface deposit feeder and detritivorous omnivore), and *Parandalia americana* (primary carnivore). Larger species of infaunal macroinvertebrates include the plankton-feeding herbivores *Mactra fragilis* and *Rangia cuneata*. Dominant epibenthic (living above sediments) macroinvertebrates in East Bay over the period of study include the palaemonetid shrimp (*Palaemonetes* spp., detritivorous omnivores), xanthid crabs (*Rhithropanopeus harrisi*, a sensitive primary carnivore), blue crabs (*Callinectes sapidus*, primary carnivores at less than 30 millimeters [mm]; secondary carnivores at more than 30 mm), and penaeid shrimp (*L. setiferus, F. duorarum and F. aztecus,* which are primary carnivores at less than 25 mm and secondary carnivores at more than 25 mm). Most of these invertebrate species are browsers, grazers, or seize-and-bite predators.

Penaeid Shrimp (from Livingston 2010)

The numerically dominant invertebrates of the Apalachicola system include white shrimp and blue crabs that, when combined, represented about 70% of the total numbers taken over a 14-year study period. The white shrimp, *Litopenaeus setiferus*, is the numerically dominant penaeid species in the Apalachicola system. White shrimp enter the bay during spring months, and are caught in otter trawls during the summer and fall months. Young-of-the-year white shrimp (less than 25mm) are first noted in East Bay during the early summer months, and they remain in the East Bay area throughout the summer. The second trophic unit of this species is concentrated in East Bay during the summer and fall months. The largest white shrimp trophic unit is located mainly just west of the river mouth and in parts of East Bay. White shrimp are largely absent in the bay by mid- to late November through December.

White shrimp represent the most commercially valuable population in the Apalachicola Estuary, and are distributed in areas most affected by river flows. This distribution is compatible with the importance of freshwater inflows and the resulting productivity that accompanies such flows. The low numbers associated with drought conditions are compatible with the known aspects of white shrimp life history patterns.

Pink shrimp (*Farfantepenaeus duorarum*) and brown shrimp (*Farfantepenaeus aztecus*) occur in lower numbers than the white shrimp. Pink shrimp are usually associated with higher salinities than white shrimp, and young of the year also are most abundant during early fall in East Bay. This appears to be related to food availability in areas receiving freshwater flow. Young brown shrimp are most abundant during late spring, with the primary pattern of distribution just west of the river mouth and in East Bay areas. Once again, both species favor areas receiving direct freshwater runoff from the river.

Callinectes Sapidus (from Livingston 2010)

The blue crab (*Callinectes sapidus*) is another commercially important species in the Apalachicola system. Young-of-the-year blue crabs appear in the bay during the winter months and are largely concentrated in East Bay and along the main river channel of the bay. Secondary increases of this trophic unit occur during late summer to fall months in the upper bay. The next trophic stage appears in the bay during February, with secondary peaks during the summer months. This trophic stage is centered in East Bay. The largest blue crab trophic unit is found in the highest numbers during the summer months in East Bay. In all three blue crab trophic stages, the East Bay nursery area appears to be the favorite habitat. Spatial-temporal blue crab distribution appears to be associated with the relationship of the individual trophic units to freshwater inputs from the river.

The long-term trends of invertebrate distribution indicate that invertebrate numbers are associated with river flow, even though such manifestations of habitat preference vary by species and by trophic unit within each species. High invertebrate numbers during the drought of 1980 to 1981 were due in large part to blue crab predominance. Each species has a very different set of habitat needs throughout its ontological development, with major differences in the spatial/temporal patterns of habitat use.

The one unifying feature that affects such distributions appears to be increased concentrations of invertebrate populations in areas associated with the entry of fresh water into the upper bay. These areas are notable for relatively high organic carbon and nutrient loading and associated productivity. Trophic unit distribution displays a broad spectrum of diverse phase interactions with river input to the bay over seasonal and interannual periods. Feeding habit changes are related to habitat-oriented differences in available food.

Fishes

Livingston 2010

Dominant fishes in East Bay include the plankton-feeding primary carnivore *Anchoa mitchilli* (bay anchovy) and benthic-feeding primary carnivores such as spot (*Leiostomus xanthurus*), hogchokers (*Trinectes maculatus*), young Atlantic croakers (*Micropogonias undulates* less than 70 mm) and silver perch (*Bairdiella chrysoura* 21 to 60 mm). Secondary carnivores among the dominant fishes include larger croakers (more than 70 mm), Gulf flounder (*Paralichthys albigutta*), and sand seatrout (*Cynoscion arenarius*). Tertiary carnivores in East Bay include the larger spotted seatrout (*C. nebulosus*), southern flounder (*P. lethostigma*), largemouth bass (*Micropterus salmoides*) and gar (*Lepisosteus* spp). Except for the bay anchovies, all of the above species live near the sediment-water interface, with most of the trophic organization of the bay dependent on interactions among bottom-living infaunal and epibenthic (living above sediments) macroinvertebrates and fishes. The primary fish dominants, representing about 80% of total fish numbers taken over the sampling period, include bay anchovies, seatrout, spot, and Atlantic croaker. Appendix A provides additional information on a few of the more dominant fish species found in Apalachicola Bay.

Fisheries-Independent Monitoring (FIM) Program

Beginning in 1990 with the Northern Indian River Lagoon, the Florida Fish and Wildlife Conservation Commission's (FWC) Fish & Wildlife Research Institute has released an annual report summarizing the collection of fish and invertebrates in Florida's major estuarine, coastal, and reef systems. Collections from Apalachicola Bay began in 1998 and presently continue. The most recent data are described in the *Fisheries-Independent Monitoring Program 2010 Annual Data Summary Report.* The Apalachicola Bay data described below includes collections from 21.3-m bay seines, 183-m haul seines, and 6.1-m otter trawls (2001 sampling did include collections from a 183-m purse seine and the gear was abandoned in August 2001 indefinitely for Apalachicola Bay). The multiple gear types are used to capture various life history stages of fishes and selected invertebrates from a wide variety of habitats. Single samples are collected from 1-nm^2 grids that are selected randomly. The FIM Program also recognizes “recreational or commercially important species”, referred to as “Selected Taxa”. Figure 30 shows the FIM sampling zones. Table 6 describes data collected in all zones (bay and river zones), while the information in Tables 5, 7, 8 and 9 is limited to Zones A and B (bay zones only).

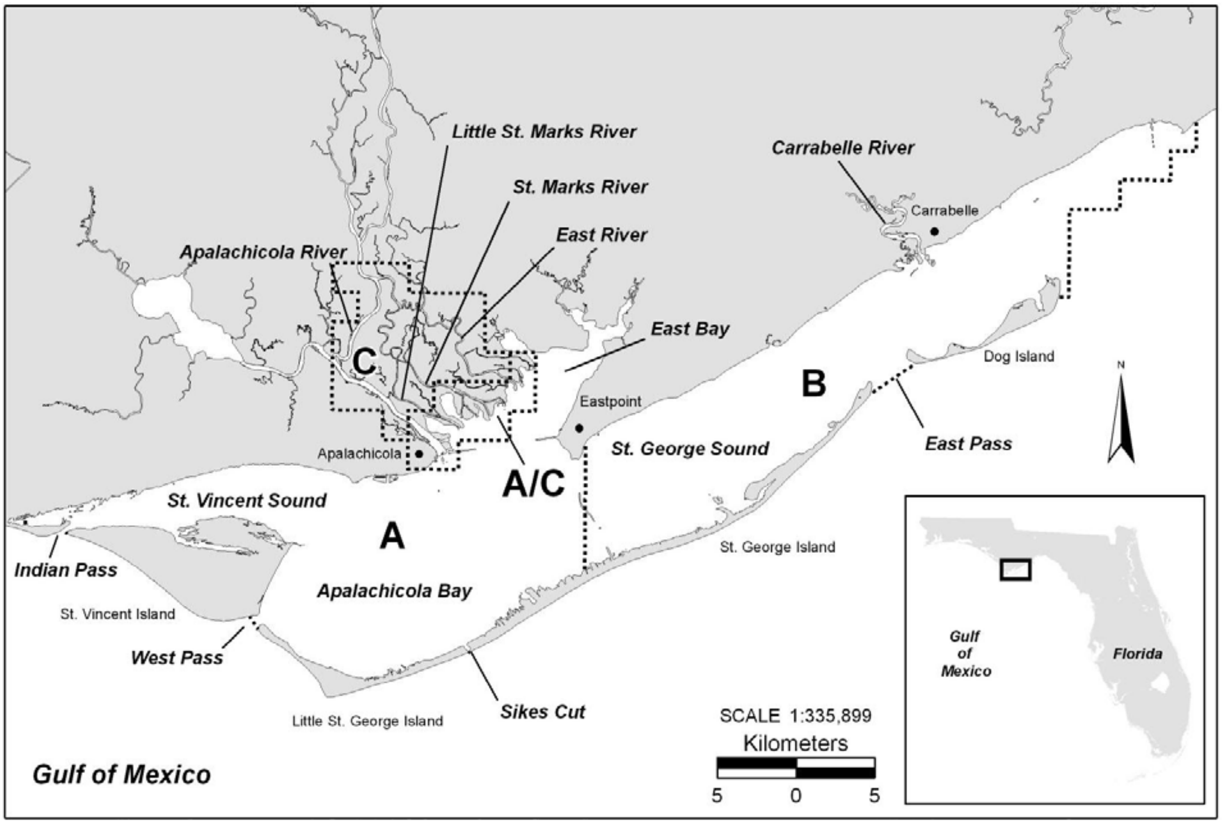


Figure 30. Map of Apalachicola Bay showing FIM zones. Zone C= river zone. Zones A and B= bay zones. (FWC 2011).

Table 5. Abundances of animals in Zones A and B as collected by FWC’s (FWRI’s) Fisheries Independent Monitoring Program 2001-2010.

Year	Animals (Zone A)	Animals (Zone B)	Total Animals	# of Hauls
2001	99,434	40,505	139,939	687
2002	61,912	40,292	102,204	600
2003	106,163	54,842	161,005	600
2004	102,303	43,294	145,597	600
2005	82,679	34,059	116,738	600
2006	93,139	58,938	152,077	600

2007	78,833	38,323	117,156	600
2008	77,724	46,599	124,323	600
2009	71,635	51,191	122,826	600
2010	147,031	72,919	219,950	594

Table 6. Total and Selected Taxa catch statistics (2001-2010) (FIM Program).

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Total Number of Taxa Collected	159	166	170	175	188	184	189	191	195	195
Total Number of Samples	912	852	840	840	840	840	839	840	840	834
Number of Selected Taxa Collected	29	32	29	30	31	31	31	33	31	32
% of Selected Taxa Individuals in Total Catch	31	33.4	32.6	29.2	34	31.3	24	22.5	25.9	28.4

Table 7. Ten Most Dominant Taxa from 21.3-m Bay Seine in Apalachicola Bay through the FIM Program (2003-2010).

2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Leiostomus xanthurus	*Leiostomus xanthurus*	*Leiostomus xanthurus*	*Anchoa mitchilli*	*Lagodon rhomboides*	*Anchoa mitchilli*	*Leiostomus xanthurus*	*Brevoortia* spp.
Anchoa mitchilli	*Brevoortia* spp.	*Brevoortia* spp.	*Brevoortia* spp.	*Anchoa mitchilli*	*Lagodon rhomboides*	*Lagodon rhomboides*	*Leiostomus xanthurus*
Brevoortia spp.	*Lagodon rhomboides*	*Mugil cephalus*	*Leiostomus xanthurus*	*Leiostomus xanthurus*	*Anchoa lyolepis*	*Brevoortia* spp.	*Anchoa mitchilli*
Lagodon rhomboides	*Lucania parva*	*Anchoa mitchilli*	*Anchoa cubana*	*Brevoortia* spp.	*Anchoa cubana*	*Anchoa mitchilli*	*Litopenaeus setiferus*
Lucania parva	*Menidia* spp.	*Lagodon rhomboides*	*Menidia* spp.	*Mugil cephalus*	*Anchoa hepsetus*	*Mugil cephalus*	*Lagodon rhomboides*
Orthopristis chysoptera	*Anchoa mitchilli*	*Menidia* spp.	*Mugil cephalus*	*Menidia* spp.	*Leiostomus xanthurus*	*Harengula jaguana*	*Mugil cephalus*
Menidia spp.	*Mugil cephalus*	*Orthopristis chysoptera*	*Lagodon rhomboides*	*Eucinostomus* spp.	*Mugil cephalus*	*Micropogonias undulatus*	*Orthopristis chysoptera*
Litopenaeus setiferus	*Litopenaeus setiferus*	*Anchoa hepsetus*	*Eucinostomus* spp.	*Anchoa hepsetus*	*Litopenaeus setiferus*	*Eucinostomus* spp.	*Lucania parva*
Eucinostomus spp.	*Eucinostomus* spp.	*Ctenogobius boleosoma*	*Harengula jaguana*	*Orthopristis chysoptera*	*Orthopristis chysoptera*	*Orthopristis chysoptera*	*Membras martinica*
Gobionellus boleosoma	*Farfantepenaeus* spp.	*Bairdiella chrysoura*	*Lucania parva*	*Lucania parva*	*Brevoortia* spp.	*Achoa hepsetus*	*Micropogonias undulatus*

Table 8. Ten Most Dominant Taxa from 183-m Haul Seine in Apalachicola Bay through the FIM Program (2003-2010).

2003	2004	2005	2006	2007	2008	2009	2010
Harengula jaguana	*Brevoortia* spp.	*Brevoortia* spp.	*Lagodon rhomboides*	*Lagodon rhomboides*	*Lagodon rhomboides*	*Lagodon rhomboides*	*Lagodon rhomboides*
Lagodon rhomboides	*Lagodon rhomboides*	*Lagodon rhomboides*	*Micropogonias undulatus*	*Brevoortia* spp.	*Bairdiella chrysoura*	*Harengula jaguana*	*Brevoortia* spp.
Brevoortia spp.	*Harengula jaguana*	*Leiostomus xanthurus*	*Leiostomus xanthurus*	*Leiostomus xanthurus*	*Brevoortia* spp.	*Brevoortia* spp.	*Leiostomus xanthurus*
Leiostomus xanthurus	*Leiostomus xanthurus*	*Harengula jaguana*	*Opisthonema oglinum*	*Micropogonias undulatus*	*Leiostomus xanthurus*	*Bairdiella chrysoura*	*Bairdiella chrysoura*
Mugil cephalus	*Mugil cephalus*	*Micropogonias undulatus*	*Mugil cephalus*	*Bairdiella chrysoura*	*Micropogonias undulatus*	*Micropogonias undulatus*	*Orthopristis chysoptera*
Bairdiella chrysoura	*Bairdiella chrysoura*	*Litopenaeus setiferus*	*Brevoortia* spp.	*Harengula jaguana*	*Orthopristis chysoptera*	*Orthopristis chysoptera*	*Mugil cephalus*
Orthopristis chysoptera	*Dasyatis sabina*	*Mugil cephalus*	*Citharichthys spilopterus*	*Mugil cephalus*	*Mugil cephalus*	*Mugil cephalus*	*Harengula jaguana*
Micropogonias undulatus	*Litopenaeus setiferus*	*Bairdiella chrysoura*	*Bairdiella chrysoura*	*Orthopristis chysoptera*	*Ariopsis felis*	*Leiostomus xanthurus*	*Micropogonias undulatus*
Dasyatis sabina	*Orthopristis chysoptera*	*Dasyatis sabina*	*Dasyatis sabina*	*Dasyatis sabina*	*Harengula jaguana*	*Ariopsis felis*	*Cynoscion nebulosus*
Sciaenops ocellatus	*Mugil curema*	*Mugil curema*	*Elops saurus*	*Mugil curema*	*Dasyatis sabina*	*Dasyatis sabina*	*Dasyatis sabina*

Table 9. Ten Most Dominant Taxa from 6.1-m Otter Trawl in Apalachicola Bay through the FIM Program (2003-2010).

2003	2004	2005	2006	2007	2008	2009	2010
Leiostomus xanthurus	*Leiostomus xanthurus*	*Anchoa mitchilli*	*Micropogonias undulatus*	*Anchoa mitchilli*	*Anchoa mitchilli*	*Anchoa mitchilli*	*Anchoa mitchilli*
Anchoa mitchilli	*Anchoa mitchilli*	*Leiostomus xanthurus*	*Anchoa mitchilli*	*Micropogonias undulatus*	*Micropogonias undulatus*	*Micropogonias undulatus*	*Micropogonias undulatus*
Micropogonias undulatus	*Micropogonias undulatus*	*Micropogonias undulatus*	*Leiostomus xanthurus*	*Lagodon rhomboides*	*Cynoscion arenarius*	*Cynoscion arenarius*	*Leiostomus xanthurus*
Lagodon rhomboides	*Arius felis*	*Cynoscion arenarius*	*Ariopsis felis*	*Leiostomus xanthurus*	*Rimapenaeus constrictus*	*Leiostomus xanthurus*	*Litopenaeus setiferus*
Brevoortia spp.	*Cynoscion arenarius*	*Rimapenaeus constrictus*	*Rimapenaeus constrictus*	*Cynoscion arenarius*	*Etropus crossotus*	*Etropus crossotus*	*Cynoscion arenarius*
Orthopristis chrysoptera	*Litopenaeus setiferus*	*Etropus crossotus*	*Anchoa cubana*	*Orthopristis chrysoptera*	*Anchoa cubana*	*Stellifer lanceolatus*	*Etropus crossotus*

Chloroscombrus chrysurus	*Etropus crossotus*	*Ariopsis felis*	*Callinectes sapidus*	*Microgobius thalassinus*	*Lagodon rhomboides*	*Orthopristis chrysoptera*	*Orthopristis chrysoptera*
Bairdiella chrysoura	*Menticirrhus americanus*	*Menticirrhus americanus*	*Citharichthys spilopterus*	*Etropus crossotus*	*Orthopristis chrysoptera*	*Lagodon rhomboides*	*Ariopsis felis*
Arius felis	*Farfantepenaeus duorarum*	*Lagodon rhomboides*	*Litopenaeus setiferus*	*Rimapenaeus constrictus*	*Leiostomus xanthurus*	*Ariopsis felis*	*Lagodon rhomboides*
Anchoa hepsetus	*Anchoa hepsetus*	*Orthopristis chrysoptera*	*Etropus crossotus*	*Ariopsis felis*	*Farfantepenaeus aztecus*	*Rimapenaeus constrictus*	*Menticirrhus americanus*

Biological Sampling in Florida Panhandle Estuaries to support NNC

General Description of Methods

In April, 2012, DEP started collecting additional biological and water quality data from Panhandle estuaries to support the development of numeric nutrient criteria and to explore and refine the development of biological assessment methods in estuarine environments for eventual statewide use. Apalachicola, Choctawhatchee, St. Andrew, St. Joseph, Pensacola, and Perdido Bays were each sampled twice between April 2012 and July 2012. Sampling stations were located in areas with minimal human impacts to establish baseline expectations. Site selection was based on a combination of aerial photographs, local knowledge, and a site reconnaissance. The biological communities targeted were epibenthic invertebrates and juvenile fish. These groups were selected for study because in addition to providing important information on an estuary's key ecological functioning, the effort level needed to sample and identify these organisms is practical from a human resource perspective.

DEP used multiple gear types (fyke nets, beach seines, and beam trawls) in each estuary to determine which gear, or combination of gears, would yield the best information for the level of sampling effort. All nets were deployed in relatively shallow waters (< 1.5 m deep) with gradually sloping bottoms. Fyke nets are passive sampling devices, especially useful in areas where the substrate (e.g., mangrove roots, oyster beds) may interfere with an active sampling method or where sediments are too soft to allow active wading. Each fyke net was deployed perpendicular to shore for roughly 24 hours. Four nets per site were deployed, with each approximately 25 m from the next net.

Seines are active sampling devices that are commonly used in nearshore, shallow-water habitats. In this study, a 14.5-m beach seine was deployed, parallel to shore, at a depth no more than 1.5-m. Each end of the seine was pulled toward the shore while maintaining contact with the bottom, until the two sides met at the shoreline. Care was taken to avoid loss of organisms when consolidating the catch in a single bucket. The seine was deployed four times per area, approximately 25 m apart.

Beam trawls are an effective gear type for sampling small epibenthic invertebrates and provide useful information on the foundation of the food web in near shore estuarine environments. A 2-m beam trawl was deployed parallel to shore at a depth no greater than 1.5 m. Four trawls were deployed per area, approximately 25 m apart.

In Apalachicola Bay, sampling was completed in Blounts Bay, located in the northern portion of East Bay; and near All Tides Cove, east of Sikes Cut along the western portion of bay-side St. George Island. A total of 95 taxa were collected during both trips. Results of the most commonly captured taxa combining all gear types are shown below in Table 10. Taxa lists by gear type can be found in Appendix E.

Table 10. Most commonly captured taxa across all gear types from two sampling events (April and June 2012) in Apalachicola Bay.

Taxa	Abundance	% of total
***Paleomenetes* spp.**	18348	59.81418
Stephanolepis hispidus	5862	19.11002
Mysidacea	1135	3.700081
Americamysis bahia	992	3.233904
Mnemiopsis mccraydi	915	2.982885
***Menidia* spp.**	661	2.154849
Lagodon rhomboides	505	1.646292
Farfantepenaeus aztecus	280	0.912795
Orthopristis chrysoptera	273	0.889976
Sciaenidae	262	0.854116
Subtotal	29233	95.3%
Total	30675	100%

The following descriptions give more detailed information about the ecology and environmental requirements of the top 10 most abundant species collected in Apalachicola Bay during the two summer sampling events in 2012.

Paleomenetes spp. (ghost shrimp): The genus *Paleomenetes* consists of a number of small transparent shrimp that inhabit both coastal and inland waters throughout the Americas and Europe. Ghost shrimp are among the most widely distributed shallow water benthic macroinvertebrates in Gulf of Mexico and Atlantic estuaries (Anderson 1985). Palaemonetes pugio mature at 1.5 to 2 months of age and 15-18 mm length (Anderson 1985). Although their value as bait or food for humans is minimal, they serve an unquestionable importance to the estuarine trophic system. Their diet as detrivores is varied, and includes organic matter and benthic microinvertebrates. These shrimp are in turn consumed by fish and other macroinvertebrates.

Stephanolepis hispidus: The planehead filefish is found in the Atlantic Ocean at depths of up to 300 meters (980 ft). Its range extends from Nova Scotia to Uruguay in the west and from the Canary Islands to Angola in the east. It is found near the seabed on reefs and over sandy and muddy sea floors. It is often found among *Sargassum* seaweed. This species of filefish feeds on benthic invertebrates including shrimp, and is in turn preyed upon by larger bony fish as well as sharks and rays.

Americamysis spp.: *Americamysis* refers to a new genus of mysid shrimp that is native to the Atlantic and Gulf of Mexico regions of North America. The distribution of the species within *Americamysis* extends along the Atlantic coasts of the Americas from the northeastern United States to Colombia. The known species of this genus are endemic to estuarine and shallow shelf waters, and are considered to be permanent, endemic hyperbenthic fauna of estuarine and other coastal ecosystems. These shrimp are commonly found on sandy or muddy sediments in bays, but may also be associated with *Thalassia* seagrass beds or high salinity estuaries depending on species. *Americamysis* is considered to be omnivorous and has been shown to feed on benthic algae and detritus as well as copepods. These mysid shrimp, which contribute up to 40% of the standing stock of omnivores in some systems, are vital food sources for many commercially and recreationally important fish such as anchovies, catfish, seatrout and drum (Johnson and Allen 2005). They often occur in high numbers and are ecologically important, particularly for role in food chains as a link between the benthic and pelagic systems. These shrimp are known to be sensitive to environmental stressors, and are particularly sensitive to chemical contaminants, as illustrated by their relatively low 96-h LC_{50} values. Due to this sensitivity, EPA promotes the use of *Americamysis (Mysidopsis) bahia* for laboratory testing for acute and chronic toxicity assays.

Mnemiopsis mccraydi: *Mnemiopsis* (comb jelly) is a carnivore that consumes zooplankton including crustaceans, other comb jellies, and eggs and larvae of fish; it is sometimes known to eat smaller individuals of its own kind. It also has several other predators. Many are vertebrates, including species of birds and fish. Some predators include other members of gelatinous zooplankton such as Beroe ctenophores and various Scyphozoa (Kube 2007). *Mnemiopsis mccraydi* is euryoecious, tolerating a wide range of salinity (2 to 38 psu), temperature (2–32 °C or 36–90 °F), and water quality.

Menidia beryllina (Inland silverside): The Inland Silverside is widespread along the Atlantic coast from Maine to Florida, and along the Gulf of Mexico, and is often found well upstream (Hubbs *et al.* 1991). In the Mississippi River they can be found in backwaters and reservoirs as far north as Missouri (hundreds of miles inland). The habitat of the silverside is often shallow, hard bottoms, with frequent migrations to open water in search of food. This species feeds primarily on zooplankton, and is in turn fed on by larger fish and birds. Due to its sensitivity to environmental stressors, the Inland Silverside is approved by the EPA as a standard test organism for acute and chronic toxicity testing.

Lagodon rhomboides (pinfish): *Lagodon rhomboides* is inhabits coastal waters of the Gulf and Atlantic states, stretching from Massachusetts to the Yucatan peninsula. Adult pinfish prefer protected waters between 30 and 50 feet deep, while juveniles are common over seagrass beds or other structure such as rocky bottoms, jetties, pilings, and in mangrove areas where there is cover from predators. They prefer water that has a higher salinity. Pinfish can be found near structure that supports barnacles and mollusks.

While this species spawns in deeper water, it is still considered to be estuarine-dependant and is commonly found around vegetated bottoms or reefs and mangroves. The primary diet of pinfish consists of shrimp, mysids and amphipods; nevertheless, they have been found to exhibit strict herbivory or carnivory depending on conditions or development stage (Muncy 1984). This species is tolerant of temperatures ranging from 10-35 C and salinities ranging from 1-75 ppt, indicating that they are quite tolerant of these environmental variables. Pinfish are known to exhibit schooling behavior, and can consume the epifauna associated with seagrass communities to the point of altering the structure (Stoner 1982). *Lagodon rhomboides is* commonly consumed by larger fish, including game species such as spotted sea trout and flounder. While pinfish may be of little commercial value, they are commonly used as bait fish in recreational fisheries. In bioassays, pinfish were highly sensitive to the pesticide Antimycin A at 7 ppb (Finucane 1969), as well as PCB's (Hansen *et al.* 1971) and mirex (Tagatz 1976). Petrochemical wastes have been shown to depress respiratory rates of the pinfish and cause up to 10% mortality (Wohlschlag and Cameron 1967).

Farfantepanaeus aztecus (brown shrimp): Brown shrimp are natively distributed throughout the Gulf of Mexico and NW Atlantic. Both adult and juvenile specimens tend to populate sandy and muddy substrates, and migrate offshore and nearshore during part of their life cycle. Although brown shrimp are capable of tolerating a wide range in temperature and salinity, wide scale hypoxic regions in the Gulf of Mexico have likely resulted in areas where conditions are not suitable for the brown shrimp (Craig et al 2005). Brown shrimp tend to prefer somewhat turbid waters (e.g., near river mouths) due to the protection afforded from visually-hunting predators and where there is a constant supply of necessary nutrients from re-suspended sediments. These shrimp are omnivorous, and feed primarily on detrital matter and smaller benthic invertebrates, preferentially selecting the latter as they increase in age. The brown shrimp is consumed by carnivorous fish and crustaceans, and serves as a vital link between primary production and consumption in higher trophic levels. Brown shrimp account for about one third of the commercial shrimp harvest in the South Atlantic Region. The commercial harvest of this species is highly managed (primarily to protect undersized shrimp), and peaks during the late summer months in Florida. *Farfantepenaeus* and *Litopenaeus* are within the family of prawns (Penaeidae) that is the most commercially exploited (and farmed) worldwide.

Orthopristis chrysoptera: Pigfish occur in the Gulf of Mexico from Florida to the Yucatan peninsula and on the Atlantic coast from New York to the northern Bahamas and Bermuda, but are less common north of Virginia (Darcy 1983; Sutter and McIlwain 1987; Lindeman and Toxey 2003; Oesterling *et al.* 2004). Juvenile pigfish typically inhabit shallow, near-shore waters, and are often associated with seagrass beds. Adults occur more frequently on deeper flats over soft bottom habitats, such as channel edges and sandy, sparsely vegetated areas; they can also be found on midshelf reefs (Darcy 1983; Sutter and McIlwain 1987; Lindeman and Toxey 2003). Larvae and juveniles are planktivorous, feeding primarily on copepods, shrimp larvae, and mysid shrimp. A gradual shift to a carnivorous diet begins at 1.2 inches, when pigfish will consume various benthic animals such as polychaetes, amphipods, fish larvae, shrimp, and crabs. Pigfish are prey for larger fish such as snappers, groupers, sharks, and spotted seatrout. Pigfish are listed as one of the top candidate species for marine baitfish aquaculture (Oesterling *et al.* 2004).

Sciaenidae: *Sciaenidae* are found worldwide, in both fresh and saltwater, and are typically benthic carnivores, feeding on invertebrates and smaller fish. They are small to medium-sized bottom dwelling fishes that live primarily in estuaries, bays, and muddy river banks. Most of these fishes avoid clear waters such as coral reefs and oceanic islands with a few notable exceptions (i.e., Reef Croaker, High-hat, and Spotted Drum). They live in warm-temperate and tropical waters and are best represented in major rivers in Southeast Asia, Plymouth, UK, northeast South America, the Gulf of Mexico, and the Gulf of California (Johnson and Gill 1998). These fish are commonly top predators in estuarine systems, serving as controls on lower trophic levels. Their diet includes everything from benthic macroinvertebrates to smaller bony fish. Predators are commonly larger fish or sharks, as well as birds in some cases. Many species in this family support commercial and/or recreational fisheries.

2012 Biological Sampling Summary

A variety of trophic levels were represented in the Apalachicola Bay biological samples. Phytoplankton, zooplankton, organic detritus, and carrion are essential sources of nutrition for estuary food webs. Some fish and invertebrates occupy lower levels of the trophic structure by feeding on detritus or carrion while others act as both predator and prey and represent critical energy pathways in the estuarine food web. In Apalachicola Bay, taxa such as mysid shrimp (*Americamysis* spp.) and ghost shrimp (*Paleomenetes* spp.), which feed on detritus and smaller invertebrates were found in high abundance. At the Blounts Bay site alone, over 17,000 *Paleomenetes* sp. were collected. Mysidacea was the most abundant organism collected in the beam trawl during the second sampling event in All Tides Cove. The clam (*Mulinia sp.)* feeds on plankton and other organic matter by filtering it from the water. They were collected during seine pulls in Blounts Bay, and represented a fair amount of the total catch. Primary consumers, such as silversides (*Menidia beryllina*) and anchovies (*Anchoa mitchilli*) were commonly found during sampling and feed on zooplankton at the base of the food web. The carnivorous jellyfish, *Mnemiopsis mccraydi*, also consumes zooplankton, as well as crustaceans, other comb jellies, and the eggs and larvae of fish.

Predatory fish, such as pinfish (*Lagodon rhomboides*) and pigfish (*Orthopristis chrysoptera*) feed on shrimp, mysids, amphipods, and copepods. *L. rhomboides* is commonly consumed by larger fish, including game species such as sea trout (*Cynoscion nebulosus*) which also was collected in Apalachicola Bay. Pigfish are prey for larger fish such as snappers, groupers, sharks, and spotted seatrout. The family Sciaenidae, which made up a dominant portion of the total organisms collected, are frequently top predators in estuarine systems, requiring intact lower trophic levels. Many species in this family support commercial and/or recreational fisheries.

The presence and abundance of *Stephanolepis hispidus,* and the shrimp, *Leander tenuicornis*, *Latreutes fucorum*, and *Latreutes parvulus* at the All Tides Cove site can be attributed to the sargassum present during collections. The shrimp species serve as prey for *Stephanolepis hispidus*.

Near the top of the food web were several piscivorous fish including the spotted sea trout (*Cynoscion nebulosus*) and the silver perch (*Bairdiella chrysoura*). The interconnectedness and complexity of the biological community in Apalachicola Bay suggests that it represents a complex, healthy, and well-balanced ecosystem.

Presence and Frequency of Harmful Algal Blooms (HABs)

Occasional red tide events, which originate offshore and are transported to the bay by currents, affect the system. These events are not related to nutrients from the Apalachicola Bay system. The last closure of parts of the bay due to red tide was in 2005 and 2006. Area 1611 East was closed from September 2, 2005, to January 26, 2006, for a total of 145 days (FDACS) (Table 11). Most recently, *K. brevis* was found at 2 locations, at Pickalene Bar and Green Point in Franklin County on April 27, 2010. Fewer than 1,000 cells were present at each site, and since the cells were found in such small quantities, no adverse effects were observed. These data are routinely collected by FDACS.

Table 11. Apalachicola Bay red tide tracking (FDACS).

Area	Year	Dates	Days Closed	Reason
1611East	2001	10/16/01-11/29/01	43	Red Tide
1611East	2003	11/24/03-11/27/03	2	Red Tide
1611East	2005/2006	9/2/05-1/26/06	145	Red Tide
1611West	2001	10/16/01-12/15/01	59	Red Tide
1611West	2003	11/20/03-12/25/03	35	Red Tide
1611West	2005	8/31/05-11/24/05	84	Red Tide
1612	2001	10/16/01-12/15/01	59	Red Tide
1612	2003	11/20/03-12/18/03	28	Red Tide
1612	2005	8/31/05-12/2/05	92	Red Tide
1622	2001	10/16/01-12/15/01	59	Red Tide
1622	2003	11/20/03-12/18/03	27	Red Tide
1622	2005	8/31/05-12/2/05	92	Red Tide
1632	2001	10/14/01-12/15/01	61	Red Tide
1632	2005	8/31/05-11/24/05	84	Red Tide
1642	2001	10/16/01-11/22/01	36	Red Tide
1642	2001	11/26/01-11/28/01	1	Red Tide
1642	2001	12/5/01-12/13/01	7	Red Tide
1642	2005	9/2/05-12/30/05	118	Red Tide
1621	1999	8/25/99-8/28/99	2	Red Tide
1621	2003	9/22/03-10/1/03	8	Red Tide
1621	2005	8/30/05-9/1/05	1	Red Tide
1652	1999	8/25/99-8/28/99	2	Red Tide
1652	2005	8/30/05-9/1/05	1	Red Tide
1662	1999	8/25/99-8/28/99	2	Red Tide
1662	2003	9/22/03-9/26/03	3	Red Tide
1662	2005	8/30/05-9/1/05	1	Red Tide

Shellfish Production and Frequency/Duration of Bed Closures

During the period of low river flows from 1999 to 2002, there was a collapse of oystering in the Eastern reefs from Cat Point to East Hole. In 2002, a field assessment by FDEP demonstrated that the reduced oyster productivity in eastern bay reefs was accompanied by large numbers of predators that included oyster drills, crown conchs, and sea urchins (G. S. Gunter, pers. comm.). With the return of higher river flows during 2003, there was a marked increase in oyster abundance observed at Cat Point and East Hole, accompanied by a reduction in oyster predators (G. S. Gunter, pers. comm.).

During the 2002 collapse of the eastern oyster reefs, commercial oystering continued in northern sections of western bars, such as Dry Bar and upper St. Vincent Bar (G. S. Gunter, pers. comm.). The above observations during the 1999 to 2002 period of low river flows confirmed the model predictions made by Livingston *et al.* (2000). The model predicted that ongoing reductions of Apalachicola River flow, which are related, in part, to reservoir and other water management practices in Alabama and Georgia, would accentuate the adverse effects of natural droughts. Over prolonged periods, the resilience of the bay to such events would be systematically reduced, which would then lead to more permanent reductions in secondary production biomass (organisms such as oysters, shrimp, blue crabs, and sciaenid fishes) that depends on the interannual cycling of fresh water and nutrients that flow into the bay from the river.

The most recent period of low river flow (2007 to 2009) followed a similar pattern to that observed during the 1999 to 2002 drought. Salinities in East Bay reached unprecedented high levels (greater than 30 ppt), adversely affecting the highly productive eastern oyster bars through a combination of predation and disease (L. Edmiston, J. Wanat, and G. Lewis, pers. comm.). Cat Point, the leading oyster-producing reef in the bay, was particularly affected by excess predators during the recent drought. During the period of increased salinity, oyster catches were largely restricted to less productive bars in the western parts of the bay. These observations further verified the Livingston *et al.* (2000) oyster model.

Fish Kills

Appendix D lists reported fish kills in relation to the *K. brevis* bloom in Franklin County, from 2001 to April 2, 2012, from the FWRI fish kill database. Appendix D also includes two fish kills reportedly due to low dissolved oxygen and an algae bloom, in January 12, 2002 and June 8, 2011, respectively. Most of the sampling is done by members of the public, who call the FWRI hotline to report seeing dead fish.

Water Quality Studies

ANERR Monitoring

ANERR has a System-Wide Monitoring Program to monitor nutrients and has been collecting data since 2002. The program includes sampling at 11 sites around the bay, including a river site and an offshore site outside Sike's Cut, and temporal sampling at East Bay over a diel cycle (approximately 25 hours) (Figure 31). ANERR measures dissolved nitrate, nitrite, ammonium, SRP, and chlorophyll *a*. Results indicate that nutrient concentrations in the river do not fluctuate greatly, and nutrient loading to the bay is controlled by the river flow. Other factors influencing nutrient concentrations are rainfall, tidal interactions, flux from sediments, and sediment resuspension. Nitrate concentrations in the system range from 0.003 to 0.400 mg/L and average 0.193 mg/L. Phosphate concentrations range from 0.001 to 0.016 mg/L and average 0.007 mg/L**.** Chlorophyll a values in the system range from 0.2 to 32.2 mg/L and average 5.9 mg/L.

Sampling also includes physical parameter measurements. ANERR has data-loggers at three locations in the bay: Cat Point, Dry Bar, and East Bay. The loggers are placed 0.5 m from the bottom. The Cat Point data logger is 2 m below the surface, while the Dry Bar and East Bay loggers are 1.5 m below the surface. Figure 32 shows daily average salinities at Cat Point and Dry Bar from June 1992 through 2011. Cat Point is located at the western extent of St. George Sound. Dry Bar is located in the western portion of Apalachicola Bay, offshore of St. Vincent Island. Both of these locations have very productive oyster bars and are affected by freshwater inputs from the Apalachicola River. Since 1992, salinities at both locations have increased approximately 5 ppt. Daily average dissolved oxygen (DO), turbidity, and pH measures for 2011 are shown in Figures 34-36. Note that DO and turbidity are variable at all locations and that pH is noticeably lower at the East Bay site compared to Cat Point and Dry Bar due to runoff from Tate's Hell Swamp.

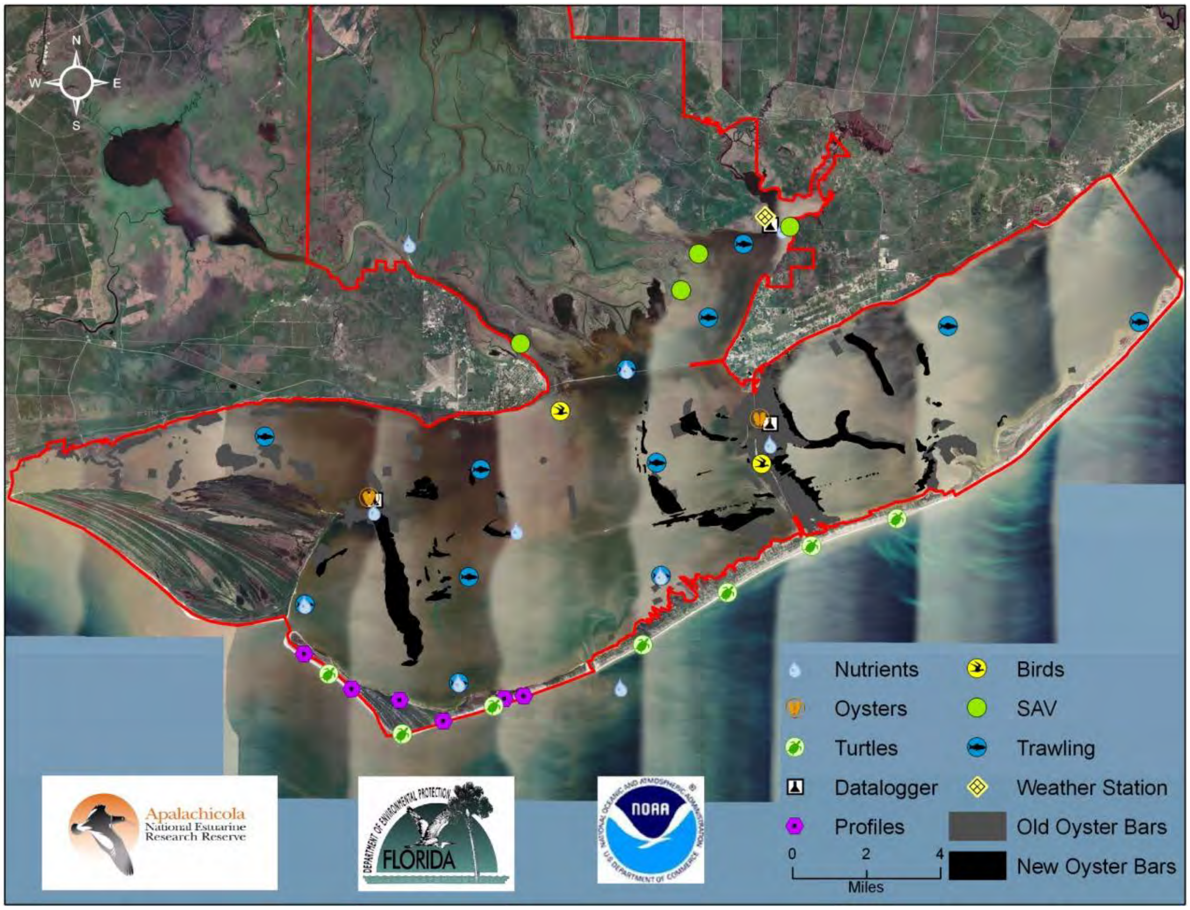


Figure 31. Map of ANERR long-term monitoring locations throughout Apalachicola Bay (Wanat 2010).

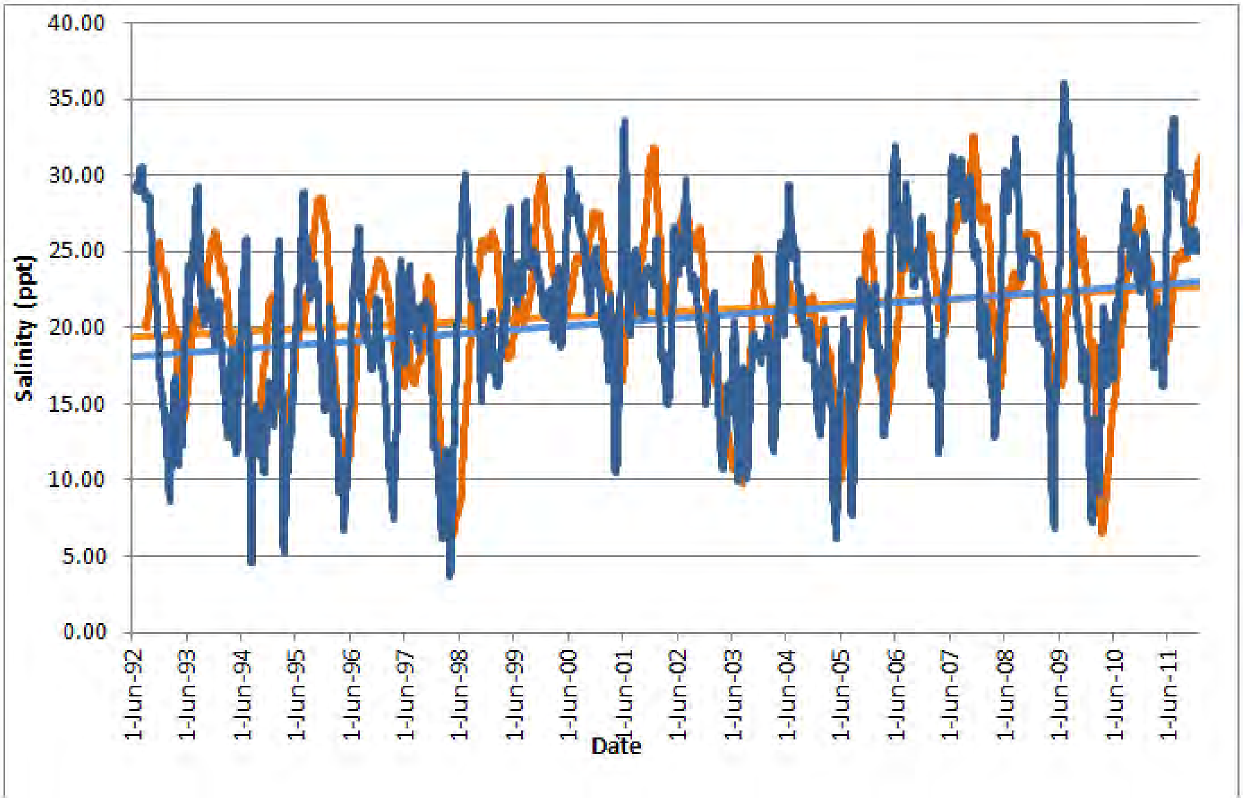


Figure 32. Time-series of daily average salinity at Cat Point (Orange) and Dry Bar (Blue), 1992–2011 (provided by the ANERR, 2012).

Figure 33. Areal extent of salinity zones in Apalachicola Bay under various flow regimes. Map at left shows salinity contours in the bay when river flow is between 15,000 and 35,000 cfs. Map at right shows salinity contours in the bay when river flow is below 15,000 cfs (provided by the ANERR).

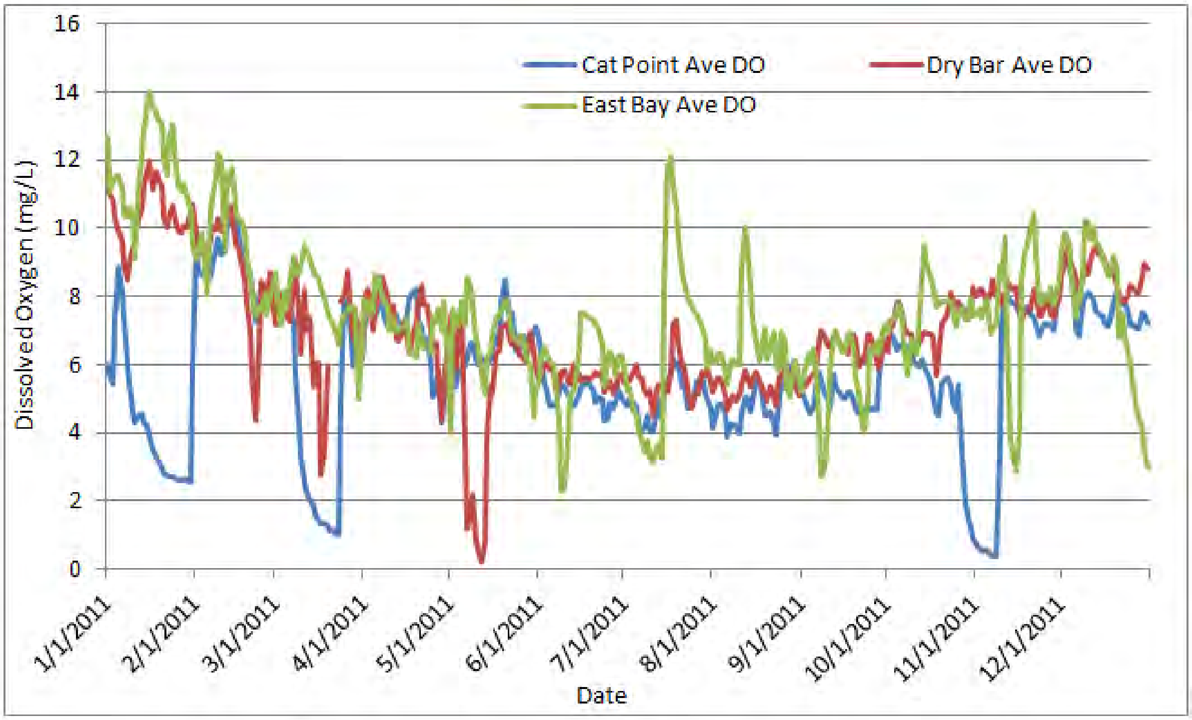


Figure 34. DO (mg/L) at the three data logger locations, from 2011 ANERR data (provided by the ANERR).

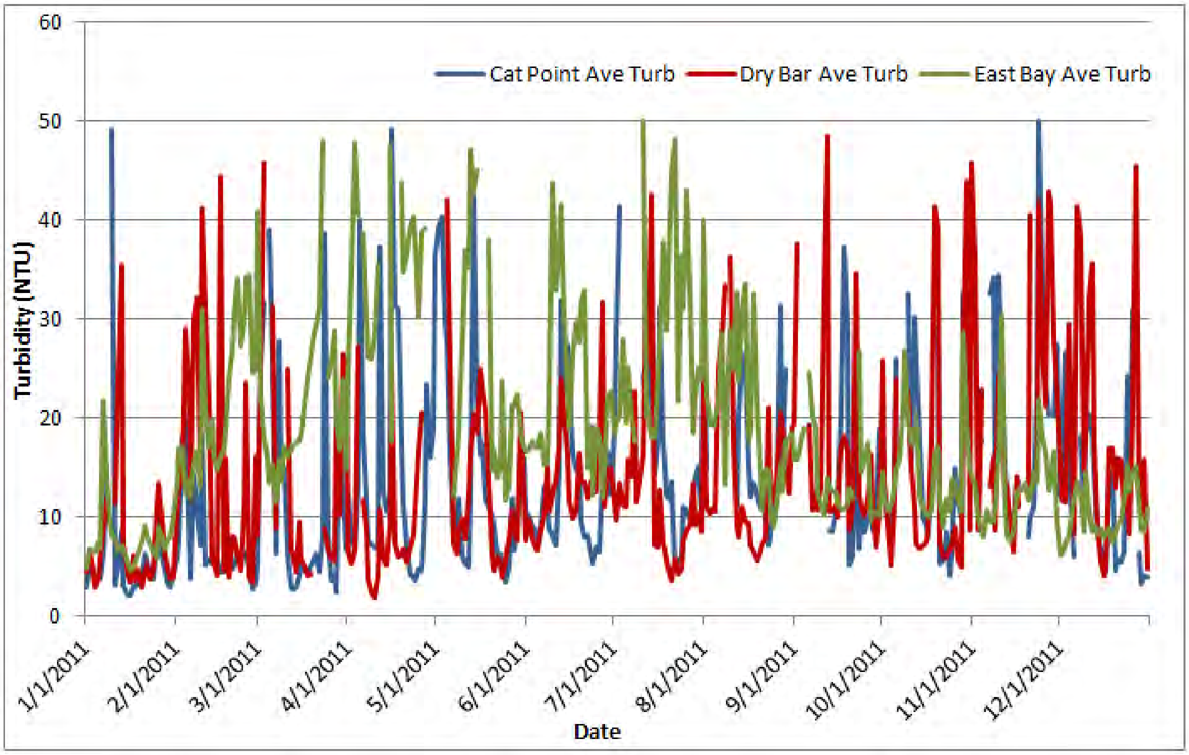


Figure 35. Turbidity at the three data logger locations, from 2011 ANERR data (provided by the ANERR).

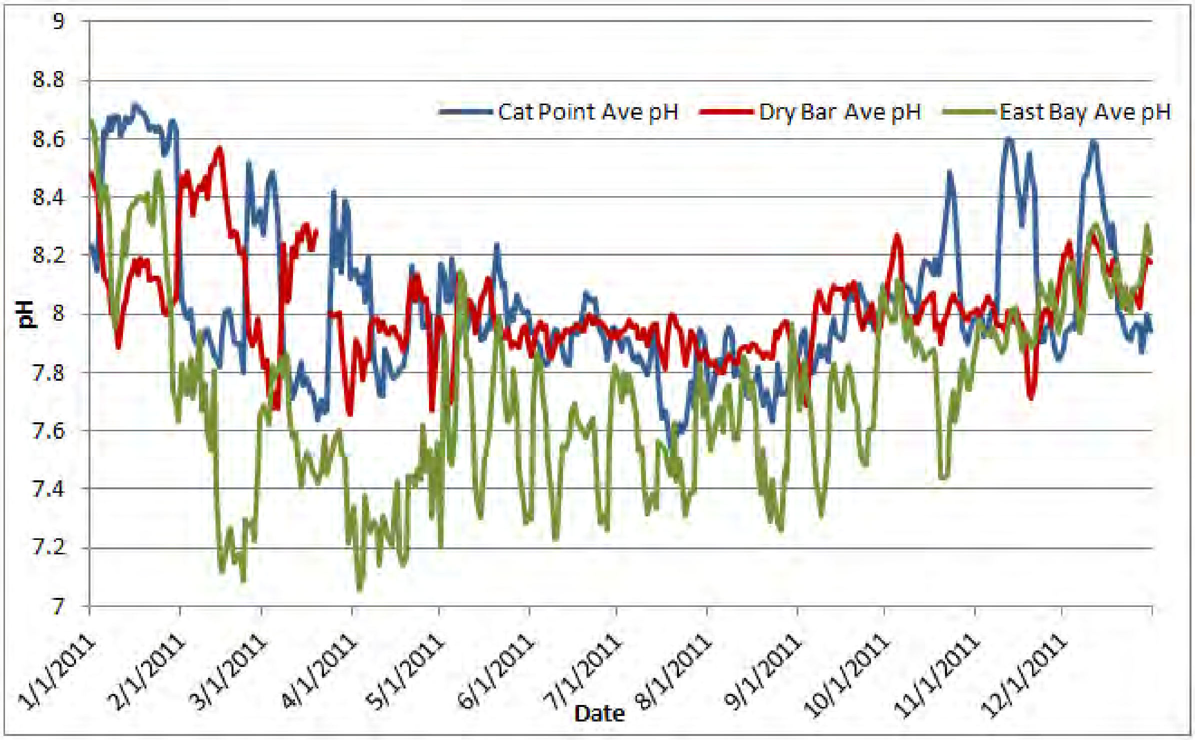


Figure 36. pH at the three data logger locations, from 2011 ANERR data (Wanat 2010).

Water Quality Studies by Paula Viveros (UF) and ANERR

UF and ANERR are studying the relationship between Apalachicola River discharge and a number of variables in the bay (correlative sampling), including salinity, chlorophyll, and nutrient concentrations (Tables 12 through 17). They found an inverse relationship between salinity and discharge, and an inverse relationship between river discharge and chlorophyll *a* (*i.e.,* as discharge increases, chlorophyll *a* decreases) (Figure 37). Chlorophyll *a* values were higher in summer. They found that as river discharge increases, N increases, but P remains approximately the same.

The phytoplankton community in the bay is dominated by diatoms, with higher biovolume in summer. In winter, there are much lower diatom volumes and some increases in dinoflagellates. Preliminary information on nutrient limitation analyses indicates that P is the limiting nutrient for algae in the river, while the bay and coastal area are co-limited by N and P.

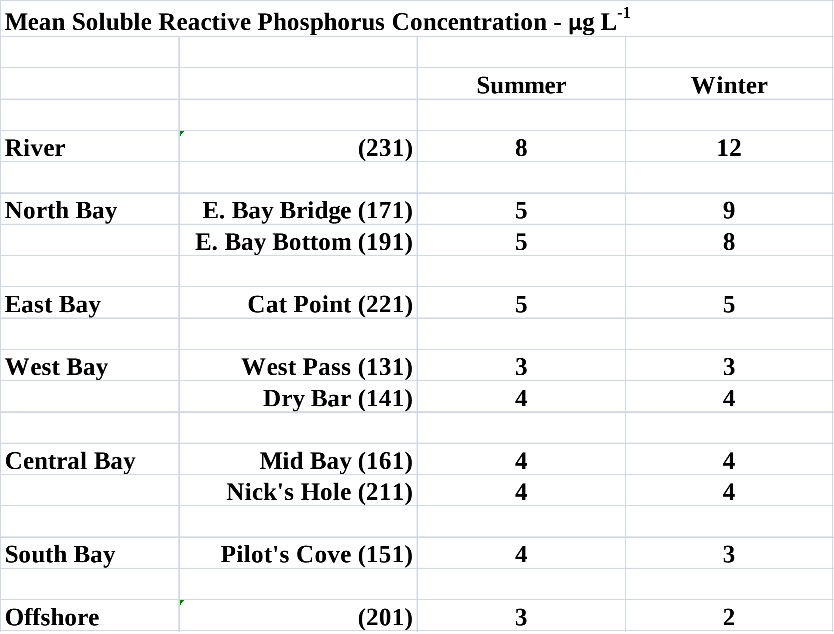
Table 12. Mean DIN concentration for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).

Mean DIN Concentration - $\mu g\ L^{-1}$			
		Summer	**Winter**
River	**(231)**	**388**	**472**
North Bay	**E. Bay Bridge (171)**	**223**	**342**
	E. Bay Bottom (191)	**88**	**123**
East Bay	**Cat Point (221)**	**125**	**160**
West Bay	**West Pass (131)**	**64**	**146**
	Dry Bar (141)	**82**	**171**
Central Bay	**Mid Bay (161)**	**121**	**238**
	Nick's Hole (211)	**73**	**149**
South Bay	**Pilot's Cove (151)**	**55**	**120**
Offshore	**(201)**	**46**	**41**

Table 13. Mean TDN concentration for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).

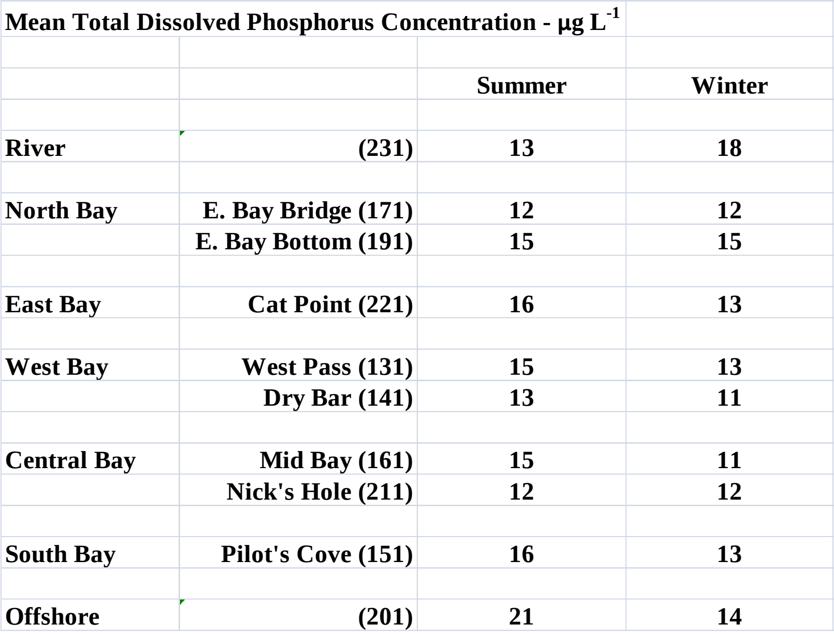
Mean Total Dissolved Nitrogen Concentration - $\mu g\ L^{-1}$			
		Summer	**Winter**
River	**(231)**	**460**	**625**
North Bay	**E. Bay Bridge (171)**	**316**	**471**
	E. Bay Bottom (191)	**314**	**357**
East Bay	**Cat Point (221)**	**300**	**283**
West Bay	**West Pass (131)**	**196**	**260**
	Dry Bar (141)	**217**	**292**
Central Bay	**Mid Bay (161)**	**233**	**401**
	Nick's Hole (211)	**206**	**265**
South Bay	**Pilot's Cove (151)**	**174**	**220**
Offshore	**(201)**	**146**	**144**

Table 14. Mean SRP concentration for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).



Mean Soluble Reactive Phosphorus Concentration - µg L^{-1}			
		Summer	Winter
River	(231)	8	12
North Bay	E. Bay Bridge (171)	5	9
	E. Bay Bottom (191)	5	8
East Bay	Cat Point (221)	5	5
West Bay	West Pass (131)	3	3
	Dry Bar (141)	4	4
Central Bay	Mid Bay (161)	4	4
	Nick's Hole (211)	4	4
South Bay	Pilot's Cove (151)	4	3
Offshore	(201)	3	2

Table 15. Mean total dissolved phosphorus (TDP) concentration for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).



Mean Total Dissolved Phosphorus Concentration - µg L^{-1}			
		Summer	Winter
River	(231)	13	18
North Bay	E. Bay Bridge (171)	12	12
	E. Bay Bottom (191)	15	15
East Bay	Cat Point (221)	16	13
West Bay	West Pass (131)	15	13
	Dry Bar (141)	13	11
Central Bay	Mid Bay (161)	15	11
	Nick's Hole (211)	12	12
South Bay	Pilot's Cove (151)	16	13
Offshore	(201)	21	14

Table 16. Mean salinity for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).

Mean Salinity - psu			
		Summer	**Winter**
River	**(231)**	**0**	**0**
North Bay	**E. Bay Bridge (171)**	**14**	**8**
	E. Bay Bottom (191)	**13**	**10**
East Bay	**Cat Point (221)**	**27**	**19**
West Bay	**West Pass (131)**	**30**	**20**
	Dry Bar (141)	**25**	**17**
Central Bay	**Mid Bay (161)**	**24**	**15**
	Nick's Hole (211)	**27**	**18**
South Bay	**Pilot's Cove (151)**	**30**	**22**
Offshore	**(201)**	**34**	**33**

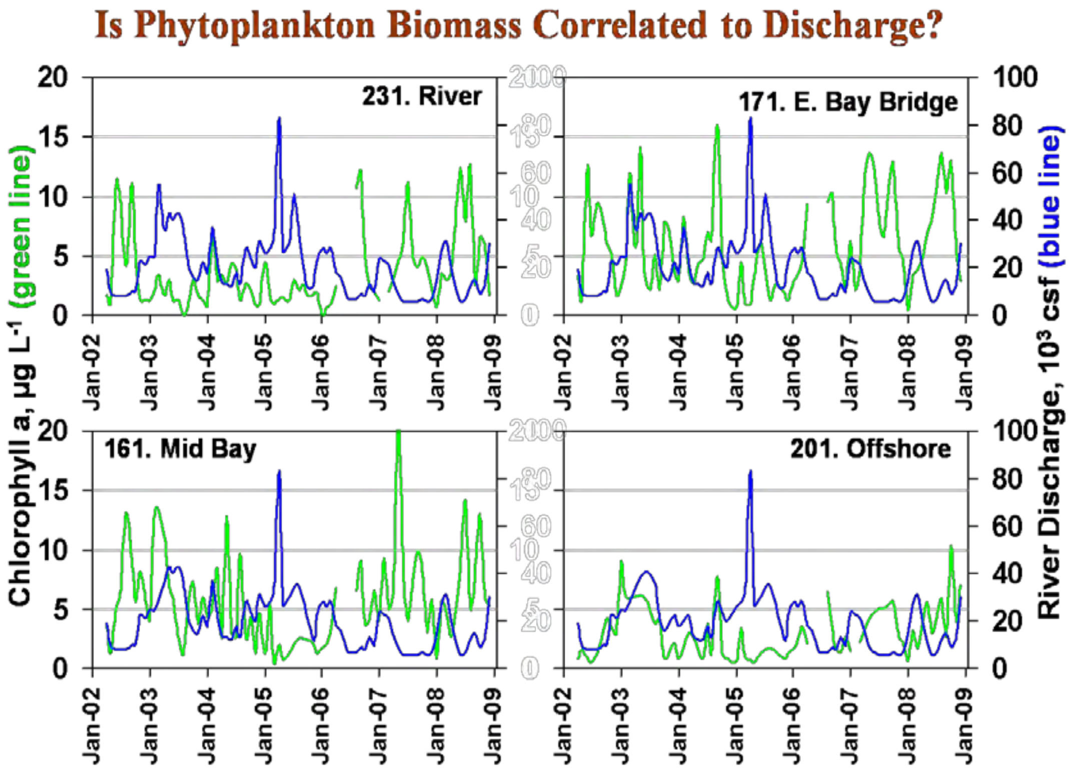


Figure 37. Chlorophyll a compared with river flow for four stations in the bay, 2002–09, from Paula Viveros, UF (provided by Viveros 2010).

Table 17. Mean chlorophyll a concentration for different areas of Apalachicola Bay, in summer and winter, from Paula Viveros, UF (provided by Viveros 2010).

Mean Chlorophyll a Concentration - µg L^{-1}			
		Summer	**Winter**
River	**(231)**	**5**	**2**
North Bay	**E. Bay Bridge (171)**	**8**	**4**
	E. Bay Bottom (191)	**13**	**11**
East Bay	**Cat Point (221)**	**7**	**4**
West Bay	**West Pass (131)**	**6**	**4**
	Dry Bar (141)	**9**	**4**
Central Bay	**Mid Bay (161)**	**7**	**5**
	Nick's Hole (211)	**6**	**4**
South Bay	**Pilot's Cove (151)**	**5**	**4**
Offshore	**(201)**	**4**	**3**

FDEP Data Analysis

FDEP assessed the data available from the IWR Run 45 database as well as data provided by Dr. Skip Livingston, the Apalachicola National Estuarine Research Reserve, and Dr. Ed Phlips at the University of Florida. The QA/QC procedures described in the next section were followed. For the assessment, Apalachicola Bay was divided into four segments: Apalachicola Bay, East Bay, St. Vincent Sound, and St. George Sound.

Annual geometric means for corrected-chlorophyll α, total nitrogen, and total phosphorus for each of the four segments in Apalachicola Bay are found in Figures 38 through 49. Annual geometric means for chlorophyll, TP, and TN in St. George Sound, while variable over time, were characterized by values below 8 ug /L, 0.04mg/L, and 0.41mg/L, respectively. In Apalachicola Bay, variability in chlorophyll, TP, and TN was relatively high, likely related to variations in river flow. Average annual geometric means for chlorophyll, TP, and TN were 4.4 ug/L, 0.68 mg/L, and .05 mg/L, respectively. East Bay, which is most directly affected by river flow, had higher chlorophyll annual geometric means, but lower TN and TP means, during the recent years with very low river flow (longer residence time).

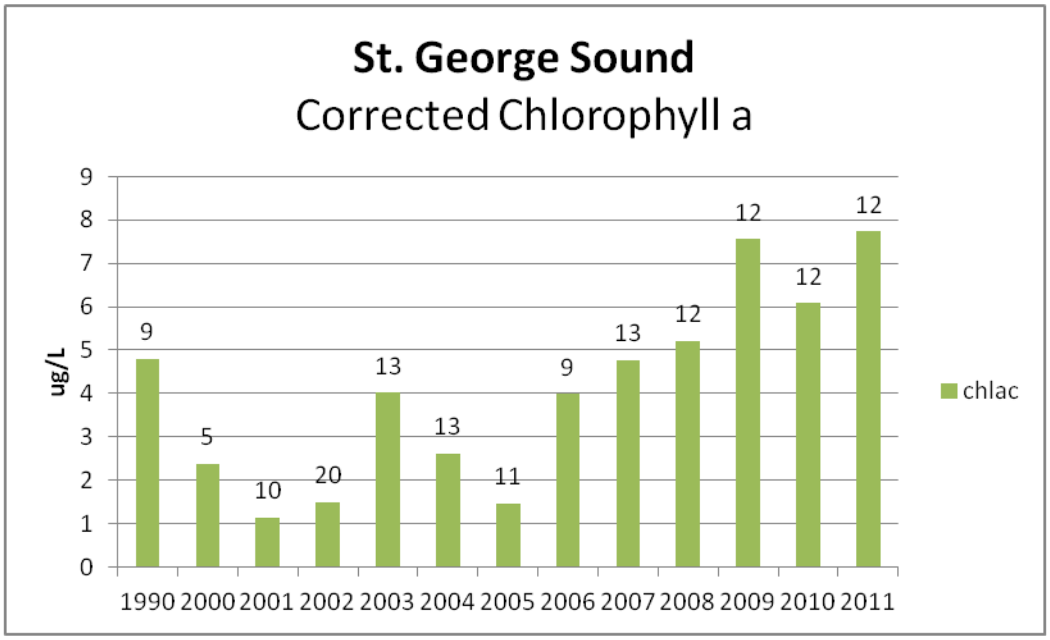


Figure 38. Graph of corrected chlorophyll a annual geometric means for St. George Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

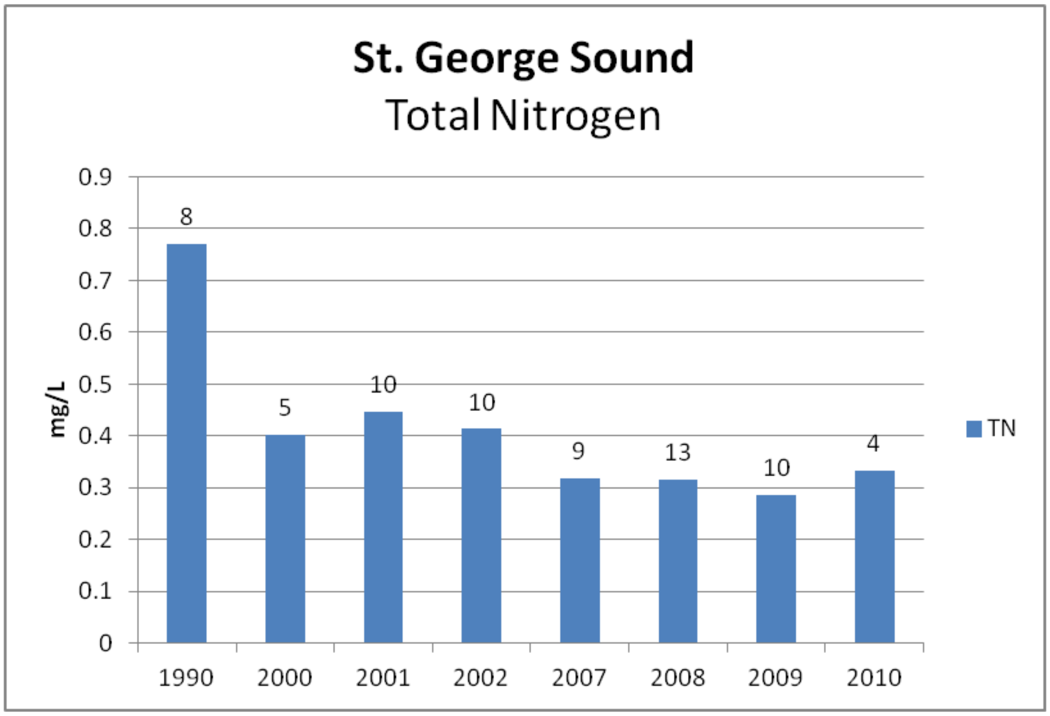


Figure 39. Graph of total nitrogen annual geometric means for St. George Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

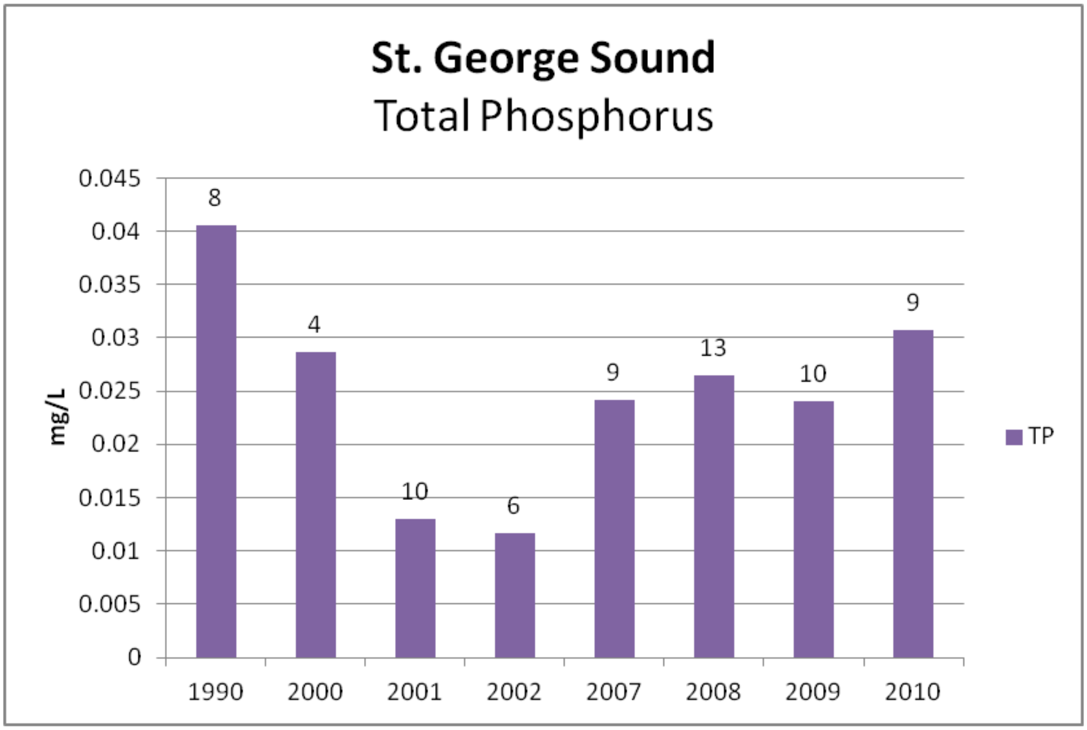


Figure 40. Graph of total phosphorus annual geometric means for St. George Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

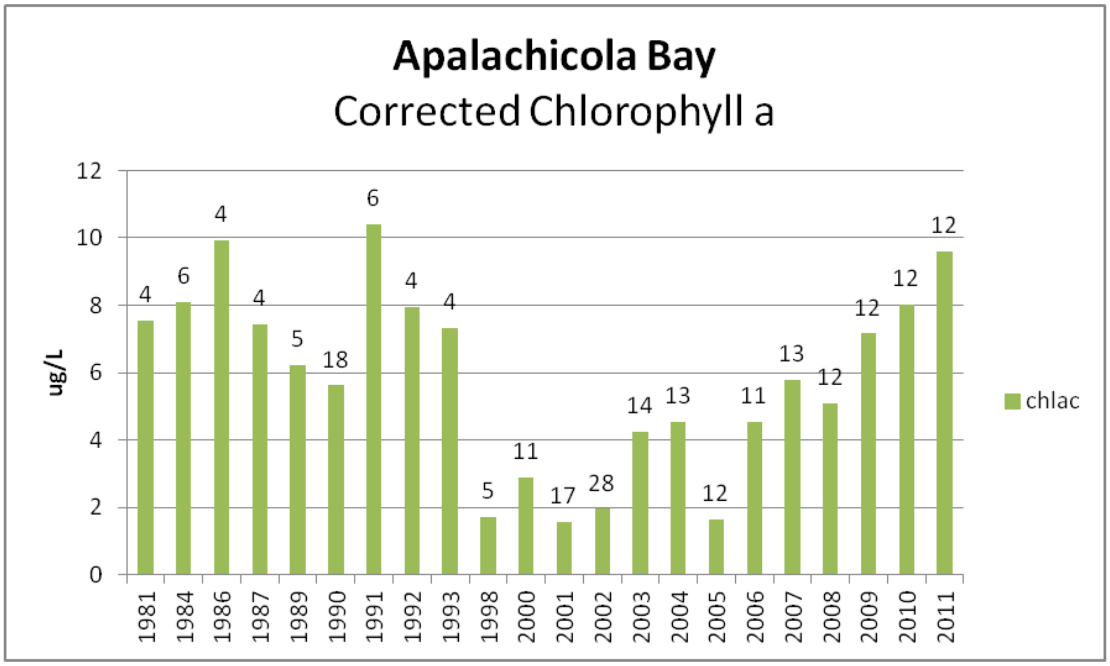


Figure 41. Graph of corrected chlorophyll a annual geometric means for Apalachicola Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

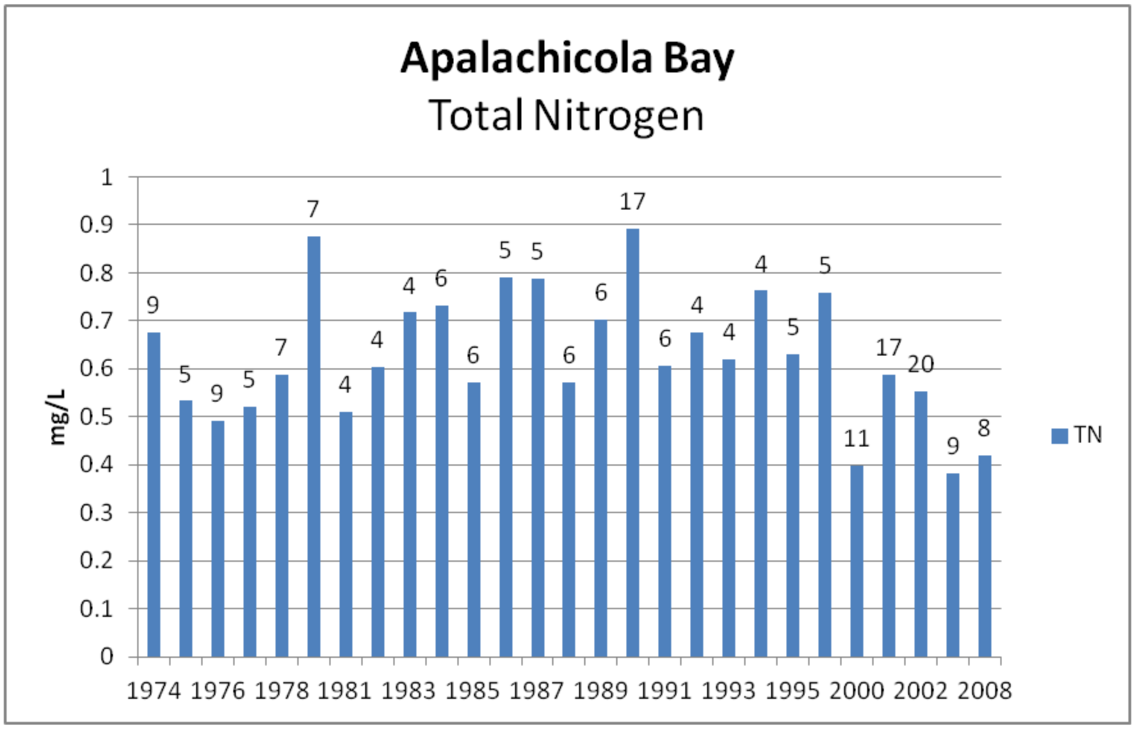


Figure 42. Graph of total nitrogen annual geometric means for Apalachicola Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

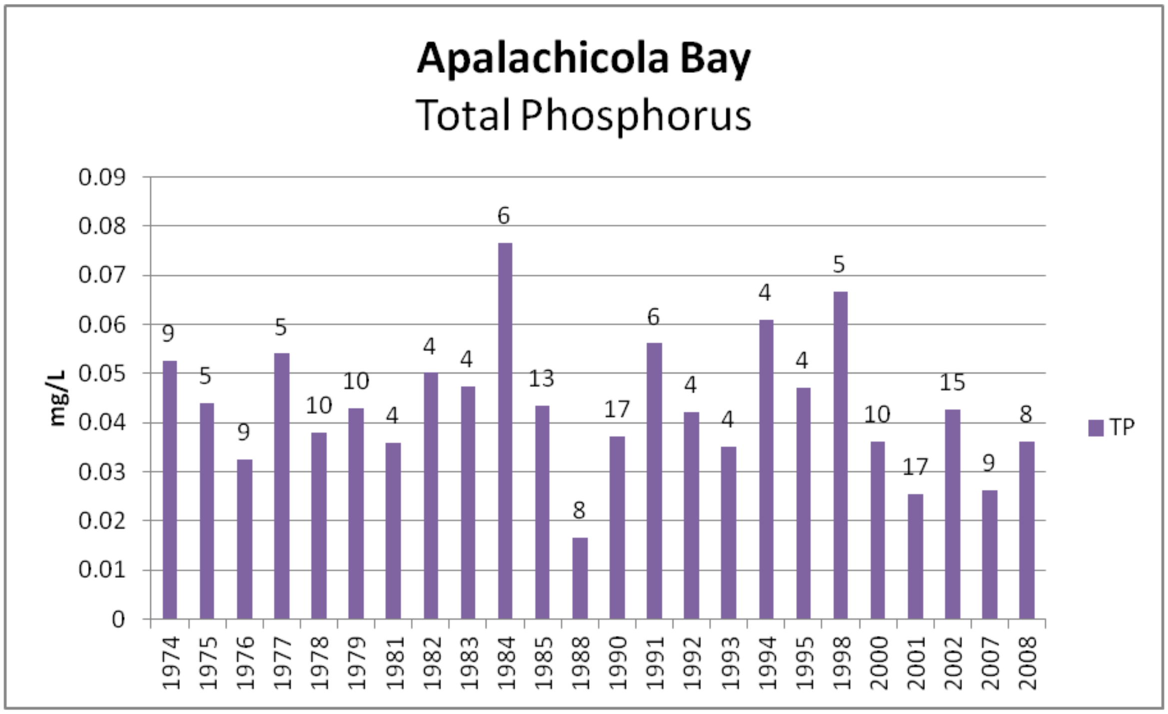


Figure 43. Graph of total phosphorus annual geometric means for Apalachicola Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

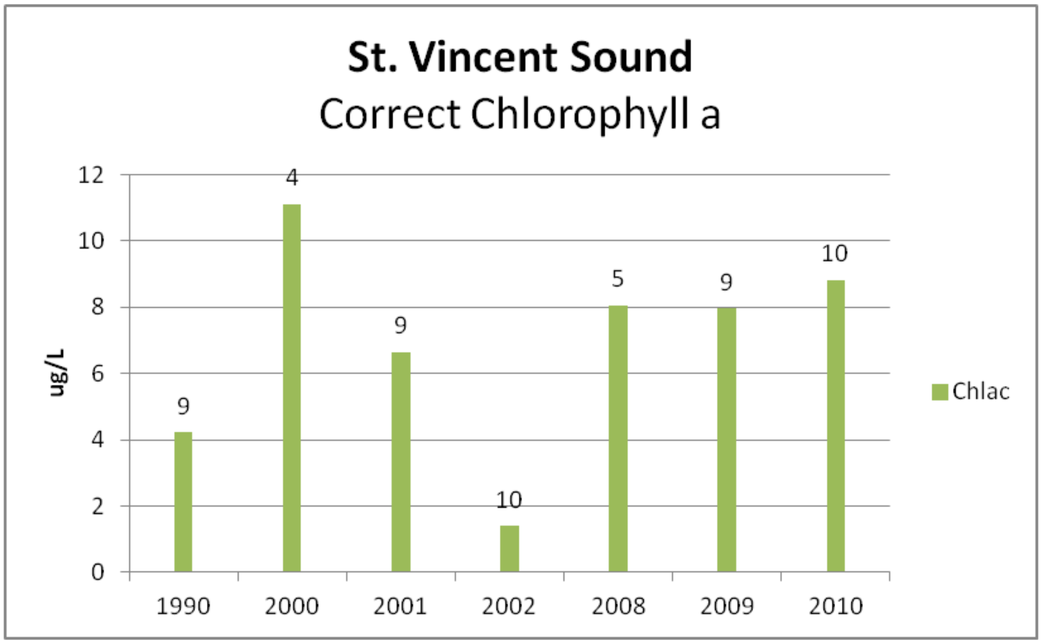


Figure 44. Graph of corrected chlorophyll a annual geometric means for St. Vincent Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

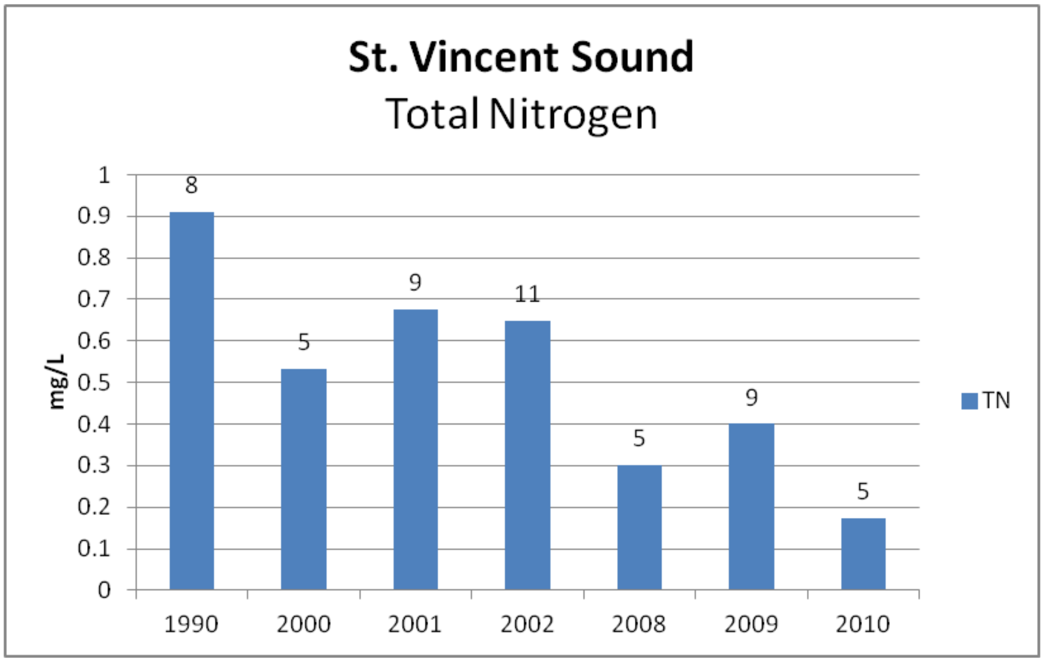


Figure 45. Graph of total nitrogen annual geometric means for St. Vincent Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

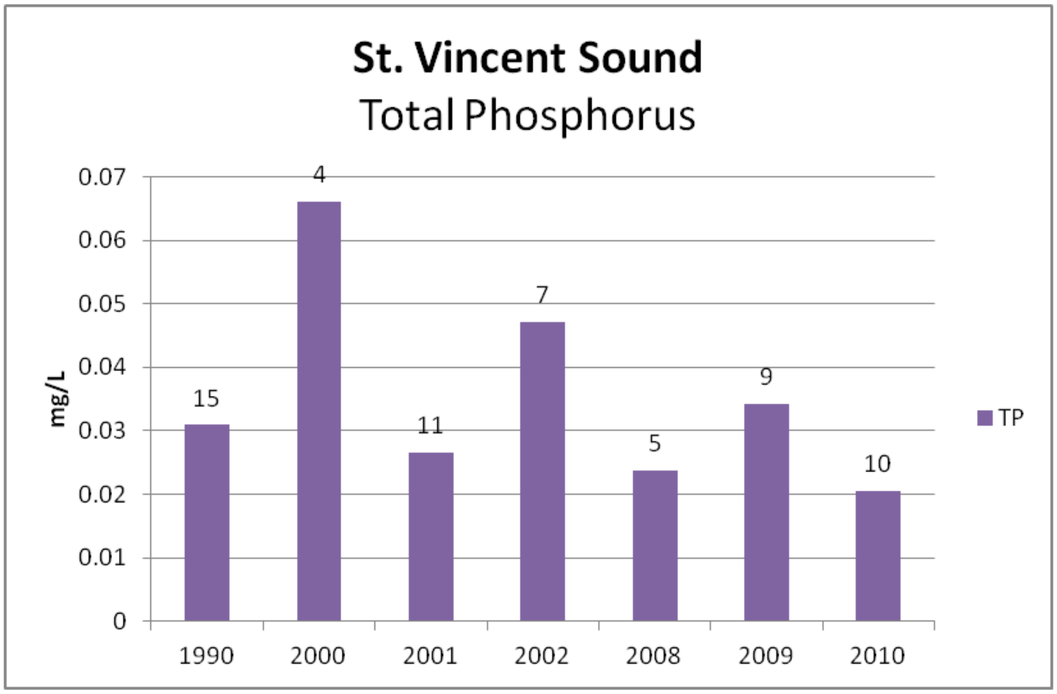


Figure 46. Graph of total phosphorus annual geometric means for St. Vincent Sound. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

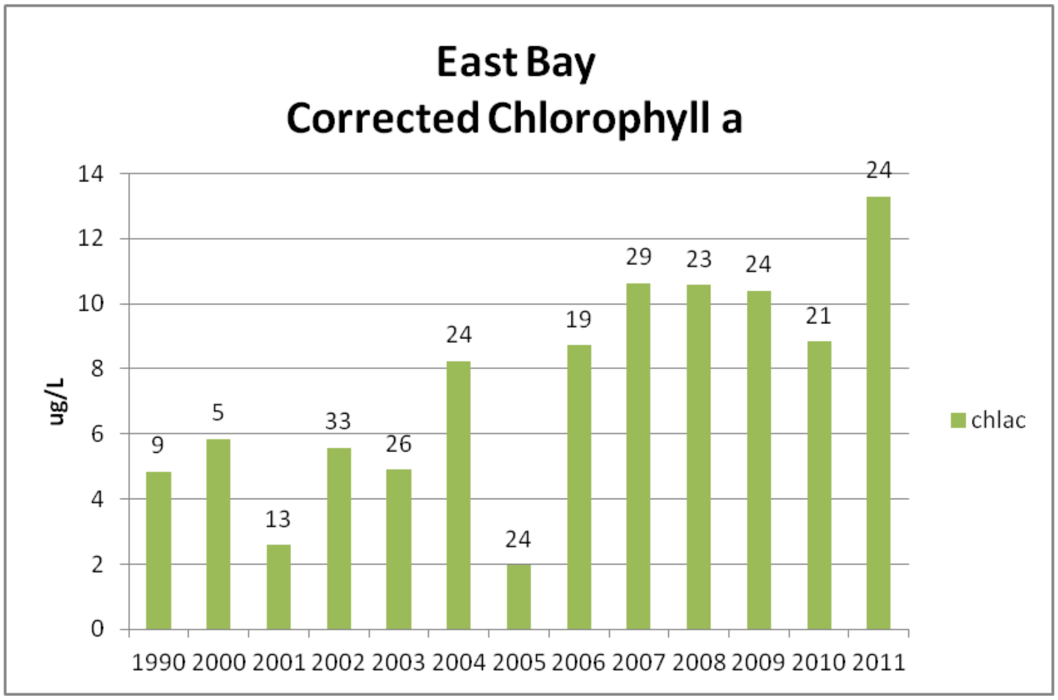


Figure 47. Graph of corrected chlorophyll a annual geometric means for East Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

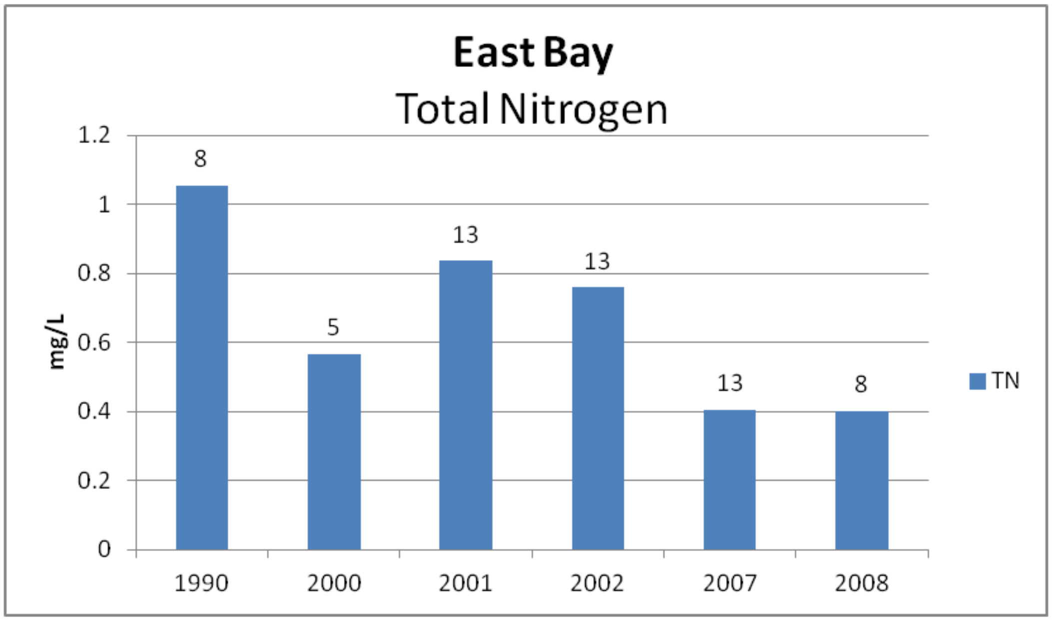


Figure 48. Graph of total nitrogen annual geometric means for East Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

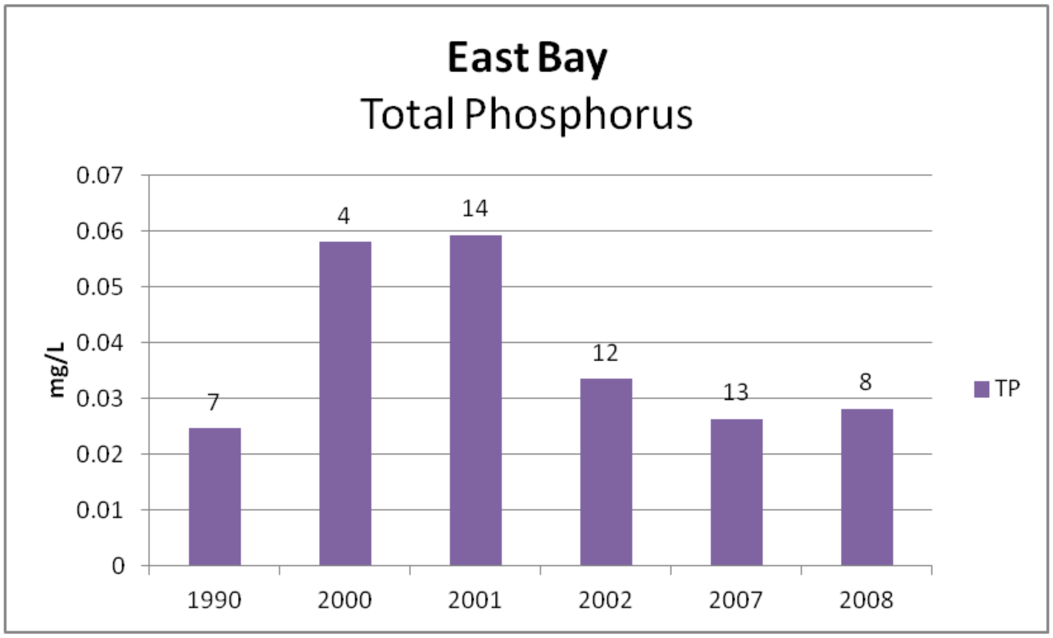


Figure 49. Graph of total phosphorus annual geometric means for East Bay. Number above each bar represents the number of daily averaged samples for that year that went into the geometric mean calculation.

Other Data Source Information and Data Interpretation

The datasets used for NNC development consisted of data from the IWR (Impaired Water Rule) Run 45 database. If additional data existed for a specific estuary, it was appended to the Run 45 data. After the complete dataset was assembled, data were screened for qualifier codes. Data with the following codes were excluded from the dataset: H, J, K, N, O, Q, Y, and ?. If a qualifier code of U or T was given, half of the reported MDL value was used. Table 18 gives qualifier code descriptions as seen in Rule 62-160.700.) Total nitrogen values were calculated by adding nitrate/nitrate and TKN values (using samples collected on the same day and at the same location).

Some of the data available for the bay was obtained by Florida COASTWATCH. The lab that analyzes the COASTWATCH samples does not have the accreditation required by the DEP Quality Assurance (QA) Rule (Chapter 62-160, F.A.C.), and does not comply with several other components of the QA Rule. However, the data were used to derive the NNC based on the following considerations for using COASTWATCH results to inform water quality standards development:

1. Chlorophyll a is reported without correction for phaeophytin. FDEP has determined that phaeophyton-corrected chlorophyll *a* are more appropriate for water quality criteria, and therefore the uncorrected (less accurate) chlorophyll a data may be considered as estimated values. Additionally, samples for chlorophyll are prepared using a procedure different than those provided in the chlorophyll methods approved by DEP. See http://www.dep.state.fl.us/water/sas/qa/docs/application-chlorophyll-a-methods.pdf
2. The method for the determination of TN in water samples is not listed as an EPA-approved method at 40 CFR, Part 136.3. The preservation method for the TN and TP samples (freezing) is not an approved preservation method in the DEP SOPs. However, Bachmann and Canfield (1996) and Canfield et al. (2002) demonstrated that results from these methods are comparable to results from other labs using approved methods. Two recent comparison studies between the FDEP lab in Tallahassee and the COASTWATCH lab showed very comparable results between labs for TN and TP. These studies suggest that it is appropriate to use the long-term CBA dataset, in conjunction with other data sources where available, to inform numeric nutrient criteria proposals.
3. COASTWATCH lab results do not include appropriate data qualifiers, as required by the FDEP QA Rule, for cases in which lab quality control measures did not pass or unusual circumstances surround the sampling events. Therefore, the data were evaluated for possible outliers or unusual data points.

Table 18. Qualifier codes used for data screening (Rule 62-160.700).

H	Value based on field kit determination; results may not be accurate. This code shall be used if a field screening test (i.e., field gas chromatograph data, immunoassay, vendor-supplied field kit, etc.) was used to generate the value and the field kit or method has not been recognized by the Department as equivalent to laboratory methods.
J	Estimated value. A "J" value shall be accompanied by a detailed explanation to justify the reason(s) for designating the value as estimated. Where possible, the organization shall report whether the actual value is estimated to be less than or greater than the reported value. A "J" value shall not be used as a substitute for K, L, M, T, V, or Y, however, if additional reasons exist for identifying the value as an estimate (e.g., matrix spiked failed to meet acceptance criteria), the "J" code may be added to a K, L, M, T, V, or Y. Examples of situations in which a "J" code must be reported include: instances where a quality control item associated with the reported value failed to meet the established quality control criteria (the specific failure must be identified); instances when the sample matrix interfered with the ability to make any accurate determination; instances when data are questionable because of improper laboratory or field protocols

	(e.g., composite sample was collected instead of a grab sample); instances when the analyte was detected at or above the method detection limit in a blank other than the method blank (such as calibration blank or field-generated blanks and the value of 10 times the blank value was equal to or greater than the associated sample value); or instances when the field or laboratory calibrations or calibration verifications did not meet calibration acceptance criteria.
K	Off-scale low. Actual value is known to be less than the value given. This code shall be used if:
	1. The value is less than the lowest calibration standard and the calibration curve is known to be non-linear; or
	2. The value is known to be less than the reported value based on sample size, dilution.
	This code shall not be used to report values that are less than the laboratory practical quantitation limit or laboratory method detection limit.
N	Presumptive evidence of presence of material. This qualifier shall be used if:
	1. The component has been tentatively identified based on mass spectral library search; or
	2. There is an indication that the analyte is present, but quality control requirements for confirmation were not met (i.e., presence of analyte was not confirmed by alternative procedures).
O	Sampled, but analysis lost or not performed.
Q	Sample held beyond the accepted holding time. This code shall be used if the value is derived from a sample that was prepared or analyzed after the approved holding time restrictions for sample preparation or analysis.
Y	The laboratory analysis was from an improperly preserved sample. The data may not be accurate.
?	Data are rejected and should not be used. Some or all of the quality control data for the analyte were outside criteria, and the presence or absence of the analyte cannot be determined from the data.
T	Value reported is less than the laboratory method detection limit. The value is reported for informational purposes only and shall not be used in statistical analysis.
U	Indicates that the compound was analyzed for but not detected. This symbol shall be used to indicate that the specified component was not detected. The value associated with the qualifier shall be the laboratory method detection limit. Unless requested by the client, less than the method detection limit values shall not be reported (see “T” above).

Application of Water Quality Models to Support NNC Development

As outlined in the EPA’s document “Methods and Approaches for Deriving Numeric Criteria for Nitrogen/Phosphorus Pollution in Florida’s Estuaries, Coastal Waters, and Southern Inland Flowing Waters”, the application of water quality simulation models was one of the approaches used by EPA to develop NNC. Tetra Tech Inc. was contracted to setup and calibrate a series of linked watershed and estuarine models for Florida estuaries. These models link causal variables such as TN and TP to ecological indicators such as chlorophyll *a* and water clarity, and establish protective nutrient levels based on specific biological assessment endpoints.

The FDEP is evaluating the use of these models in panhandle estuaries as another line of evidence in the development of NNC that would be protective of designated uses as described in the state’s water quality regulations. FDEP included information about the models in this document to inform stakeholders about the models and their possible application, but it should be noted that the models were not used to develop the draft nutrient criteria proposed for the Apalachicola Bay estuarine system.

Tetra Tech Inc.

Watershed Model

A dynamic watershed model, Loading Simulation Program in C++ (LSPC), was used to estimate the quantity of water and pollutants associated with runoff from rain events associated with the contributing watershed of the estuary. The LSPC model includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms that simulate surface and subsurface flow from pervious land areas and surface flow from impervious land areas, and determines nutrient loading by using buildup-washoff algorithms. The model also has the ability to simulate direct point sources to the stream reaches. Water quality and hydrology over the 1997 -2009 period was simulated based on the most current land cover information available. LSPC provides tributary flows and temperature to the hydrodynamic model used and tributary water quality concentrations to the water quality model used. In addition to a simulation under existing conditions, “background” scenarios could be simulated in which point sources were removed and land uses were converted to natural (combination of forest and wetland).

Estuary Hydrodynamic and Water Quality Models

The Environmental Fluids Dynamic Code (EFDC) is a multifunctional, surface-water modeling system, which includes hydrodynamic, sediment contaminant, and eutrophication components. The model uses a curvilinear-orthogonal horizontal grid and a sigma or terrain-following vertical grid. The EFDC hydrodynamic model was run independently and a hydrodynamic linkage file was linked with the Water Quality Analysis Simulation Program (WASP7) to simulate the hydrodynamics and water quality conditions in each estuary. The hydrodynamic file generated by EFDC transfers segment volumes, velocities, temperature and salinity, as well as flows between segments.

WASP7 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program. Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. Figure 50 illustrates linkages between the models and the associated outputs.

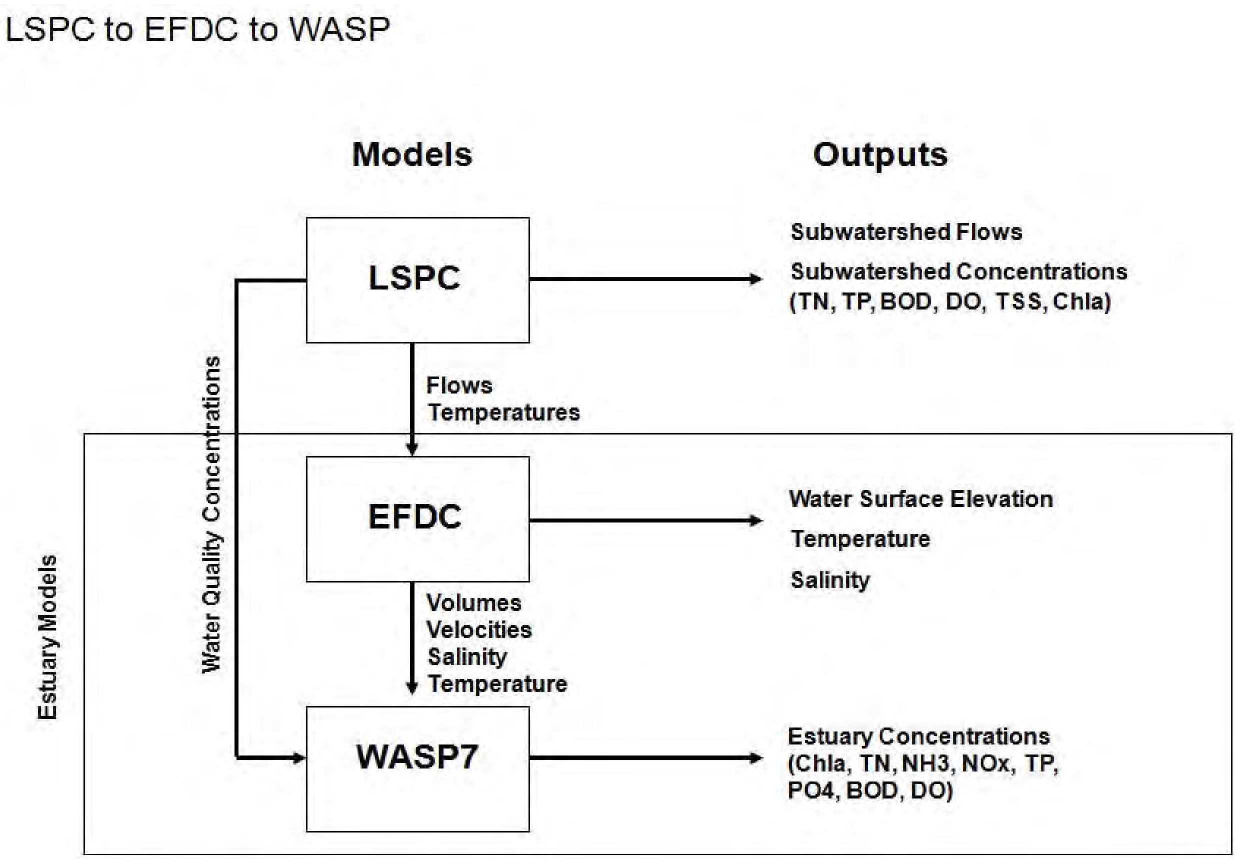


Figure 50. Linkages between Watershed and Estuary Models

APALACHICOLA MODELING

Watershed Model Components:

The watershed and subwatersheds for the Apalachicola basin were based on the United States Geological Survey (USGS) Hydrologic Unit Code (HUC) level 12 delineations and the National Hydrography Dataset (NHD) 100,000:1 catchments and flowlines (Figure 51). Information on land uses (Figure 52), soil characteristics (Figure 53), weather stations (Figure 54), and point sources (Figure 55) are all essential input elements to the watershed model. Sites with long-term flow and water quality records are used in the model calibration and validation process.

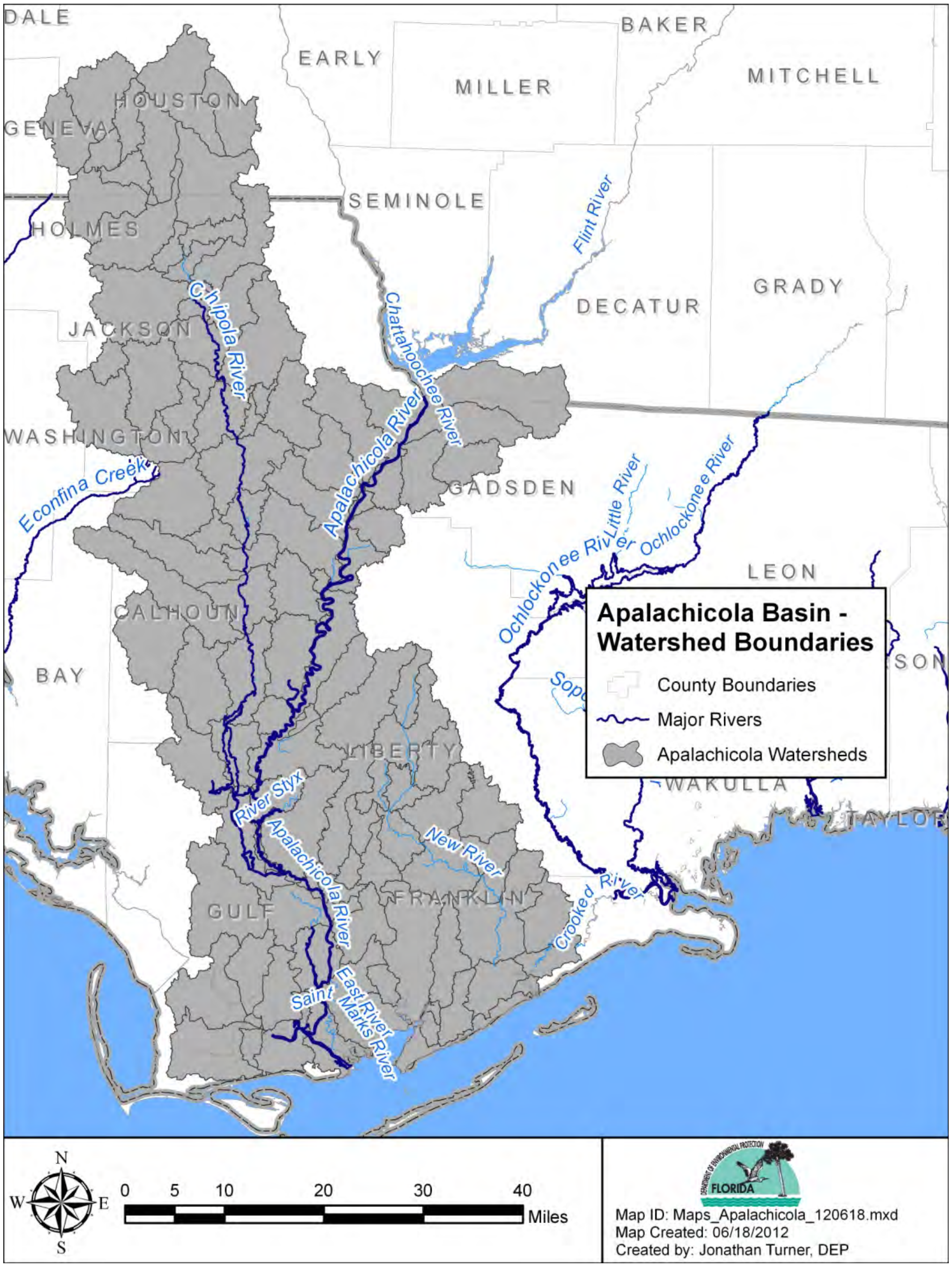
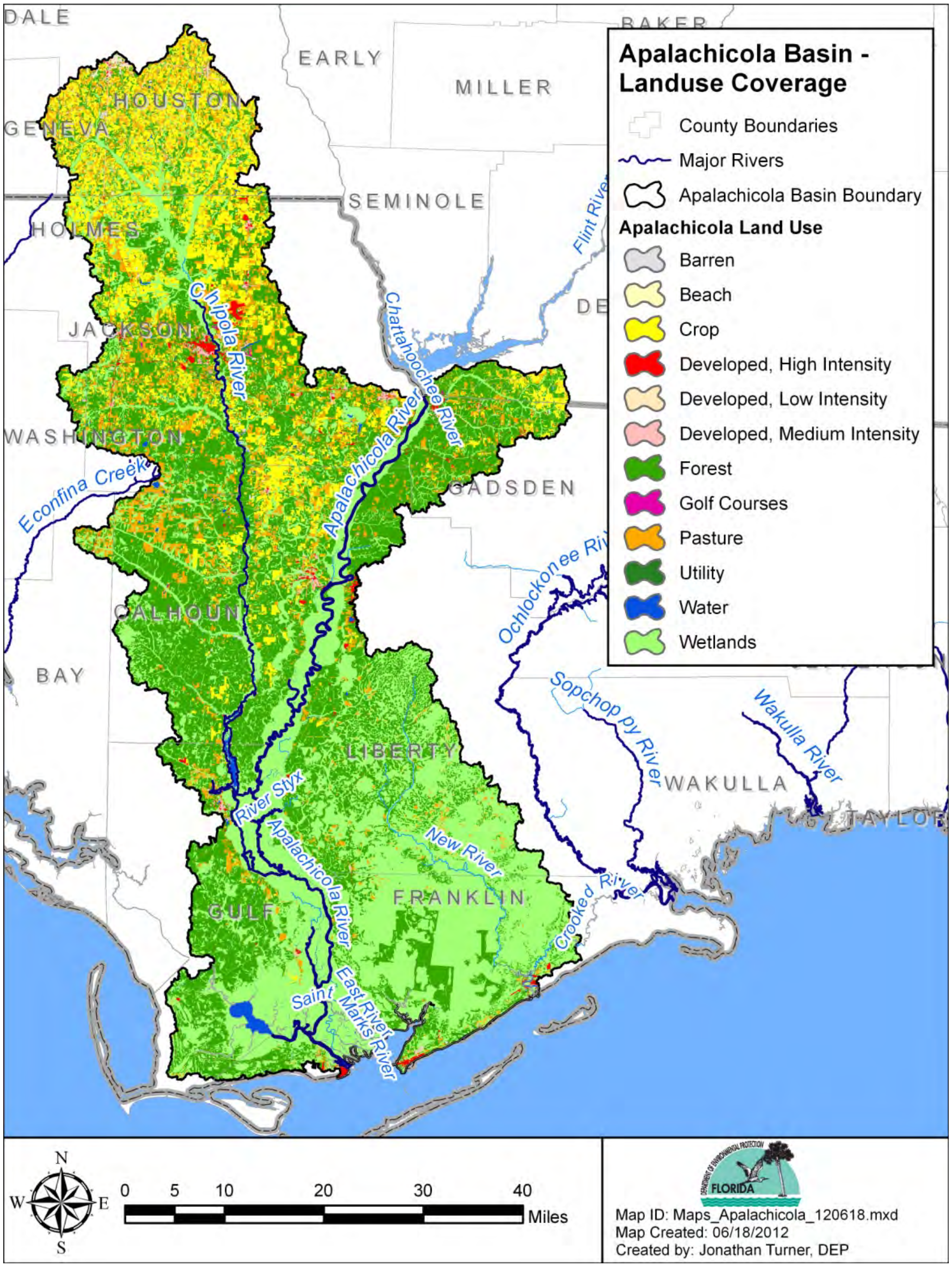


Figure 51. Map of Apalachicola Basin Delineation.



Map ID: Maps_Apalachicola_120618.mxd
Map Created: 06/18/2012
Created by: Jonathan Turner, DEP

Figure 52. Map of Apalachicola Basin Landuse Delineations.

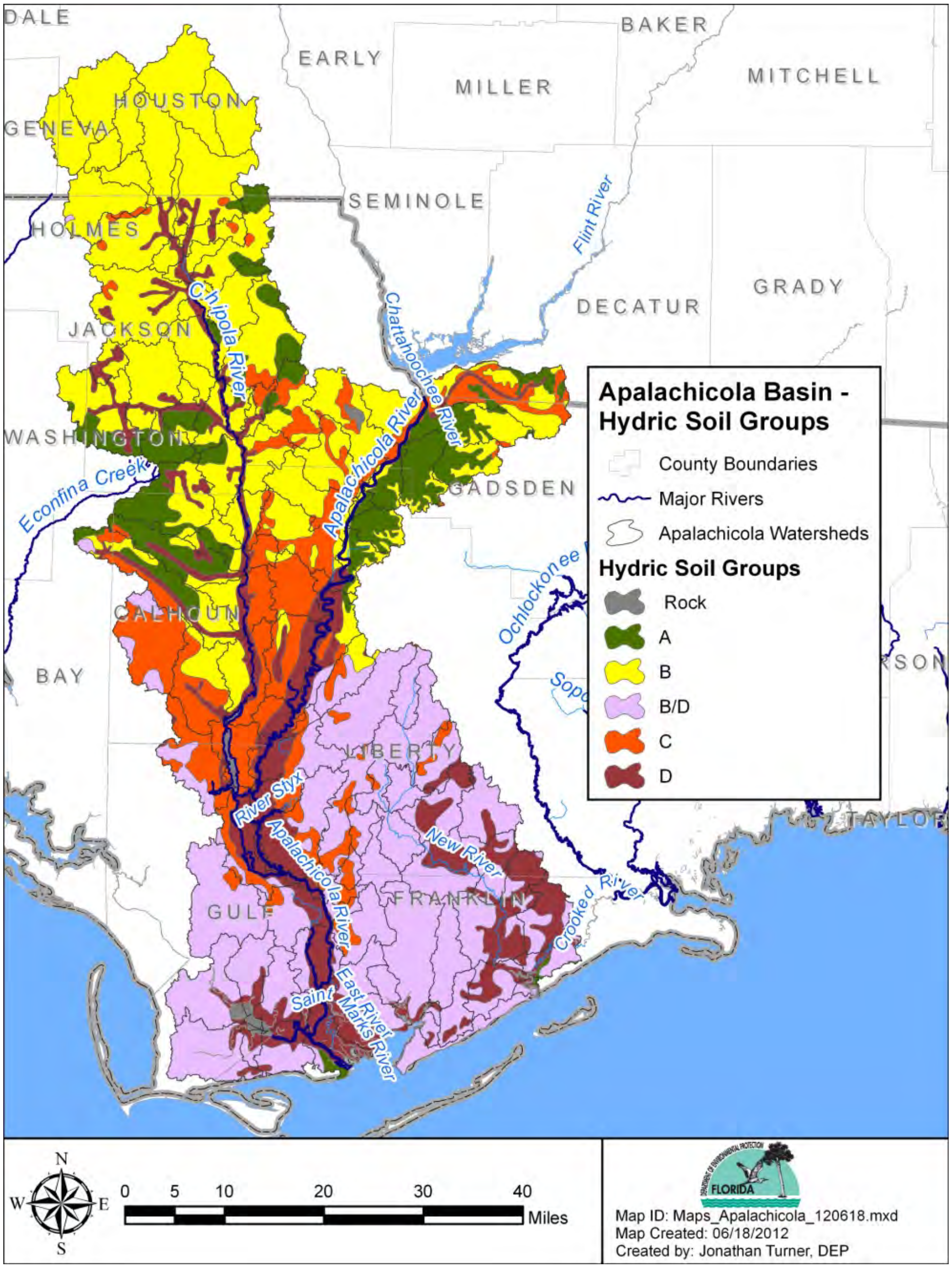


Figure 53. Map of Apalachicola Basin Hydric Soil Groups.

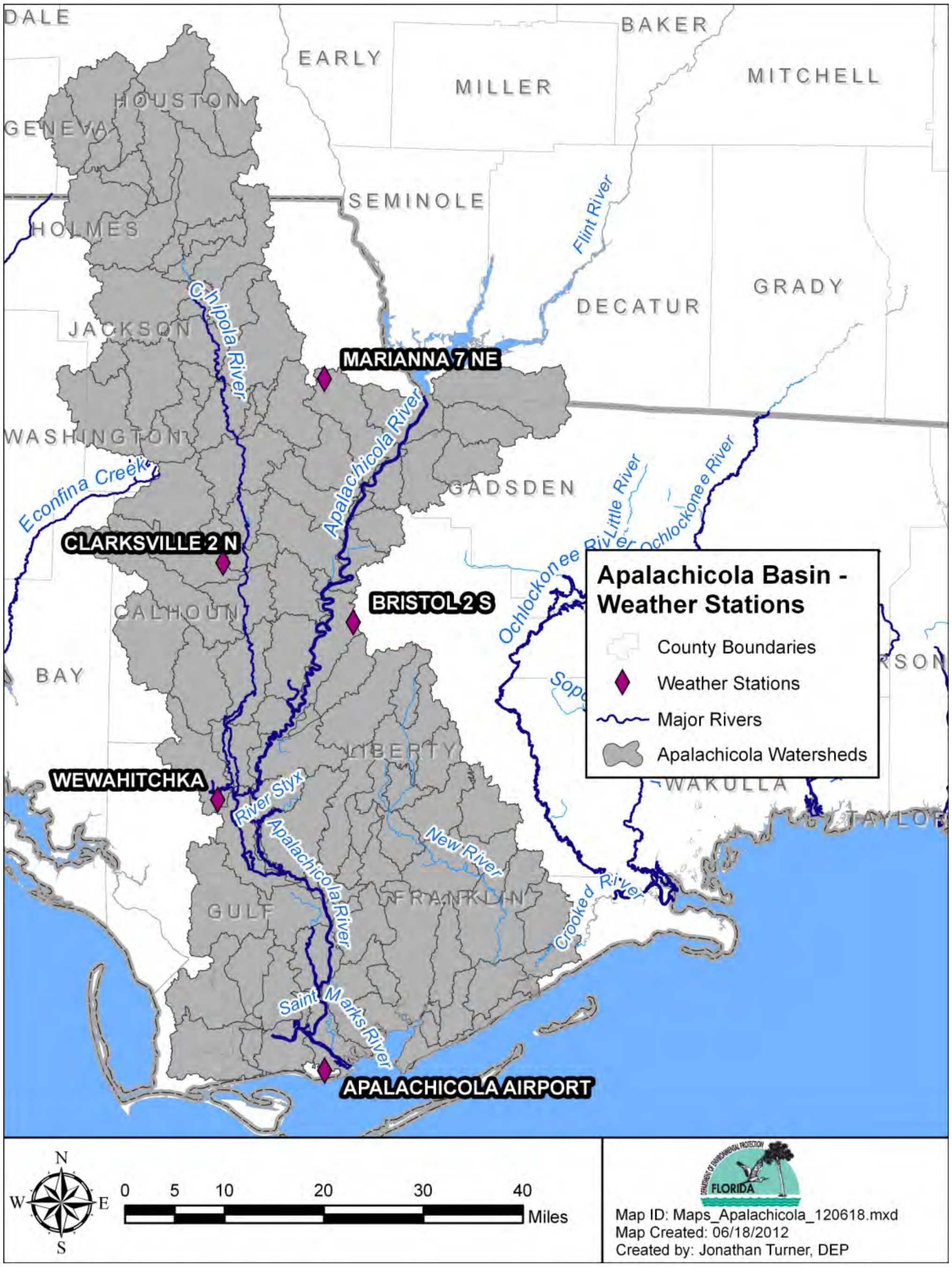


Figure 54. Map of Apalachicola Basin Weather Stations.

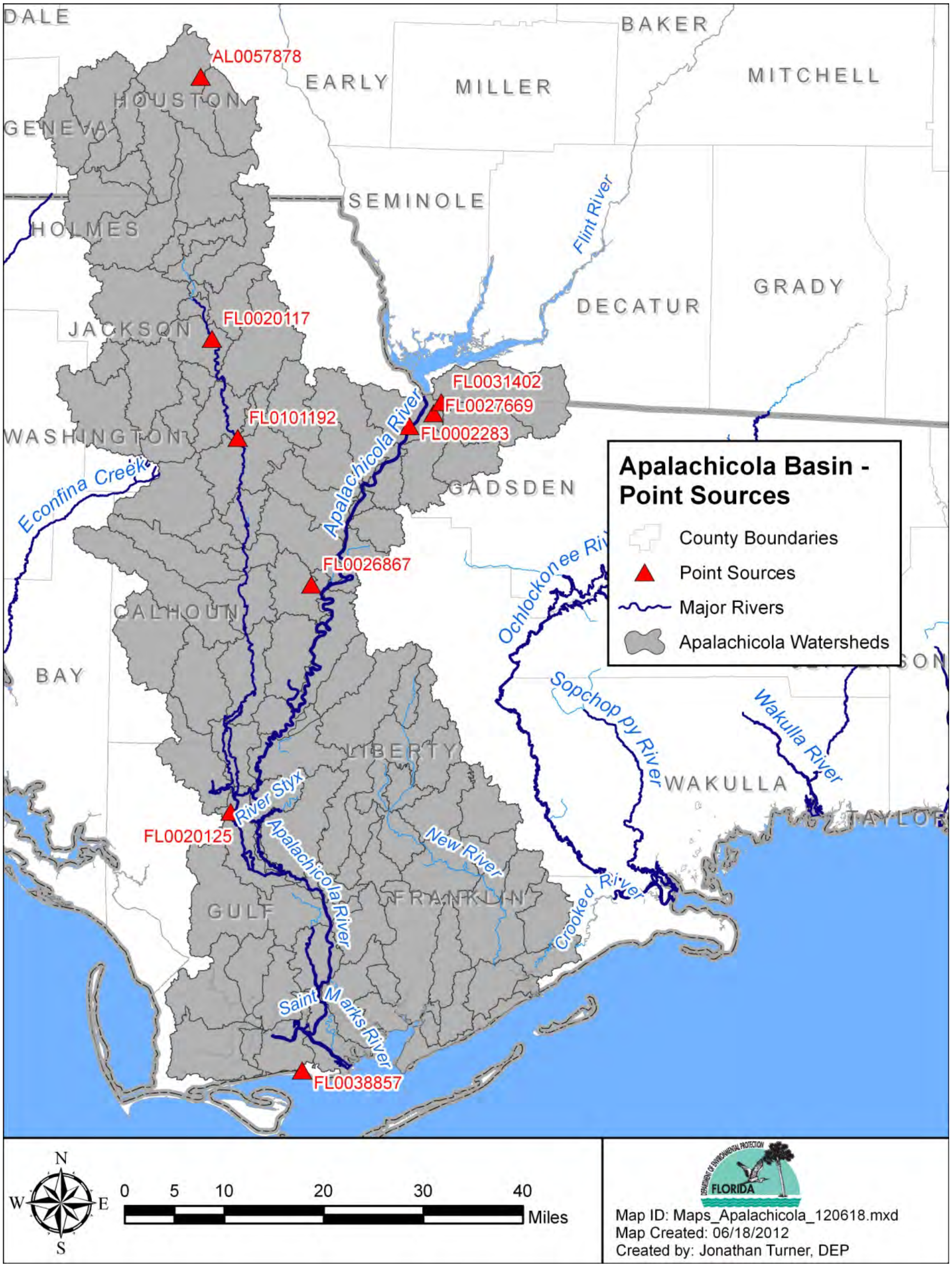


Figure 55. Map of Apalachicola Basin Point Sources.

Estuary Hydrodynamic and Water Quality Models:

The estuary hydrodynamic and water quality modeling approach used by Tetra Tech Inc. for the Apalachicola was different from the other panhandle estuaries. Tetra Tech Inc. used the EFDC hydrodynamics and water quality model to simulate Apalachicola Bay to Clearwater Harbor as a single model (Florida Big Bend Model) that included eight 8 digit HUC watersheds (Apalachicola, Apalachee, Ochlockonee, Econfina, Suwannee, Waccasassa, Withlachoochee, and Crystal) (Figure 56 and 57). The model included 3995 horizontal grids and 4 layers. The Department is currently working with EPA and Tetra Tech Inc. to set up the Apalachicola Estuary with the EFDC hydrodynamics and WASP7 water quality models. The following figures illustrate the Apalachicola portion of the Big Bend Model.

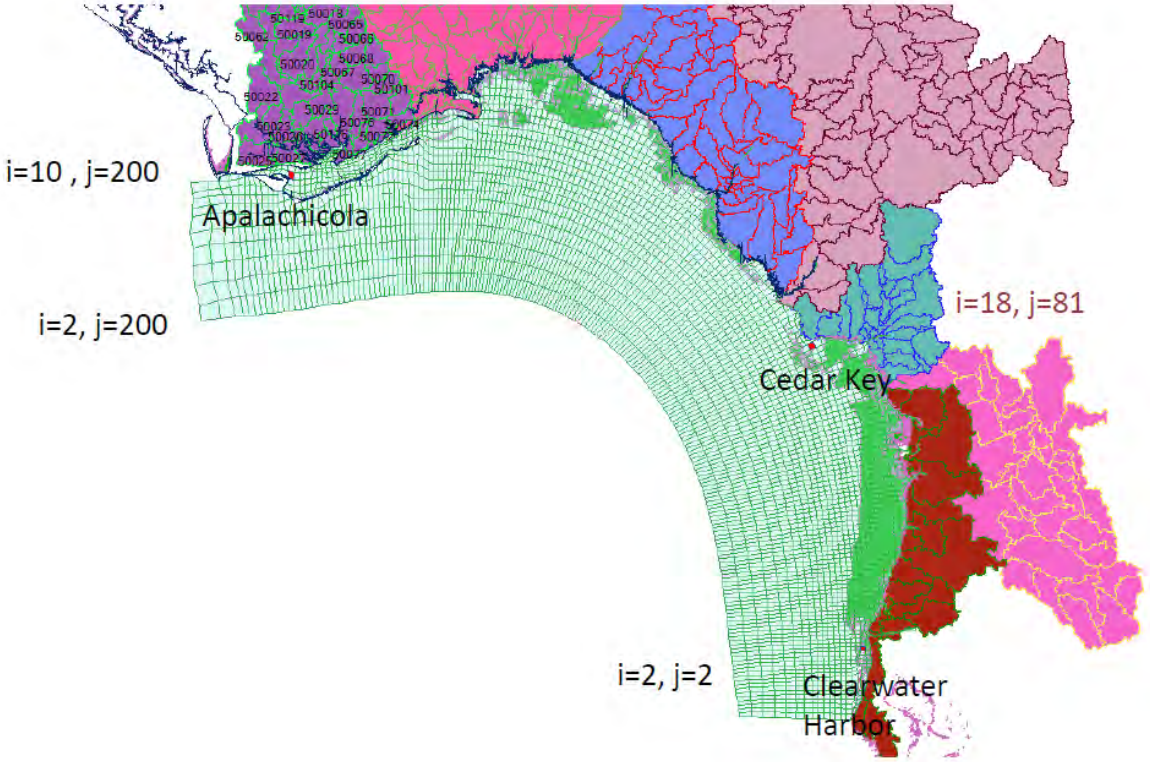


Figure 56. Map showing Florida Big Bend Model grids.

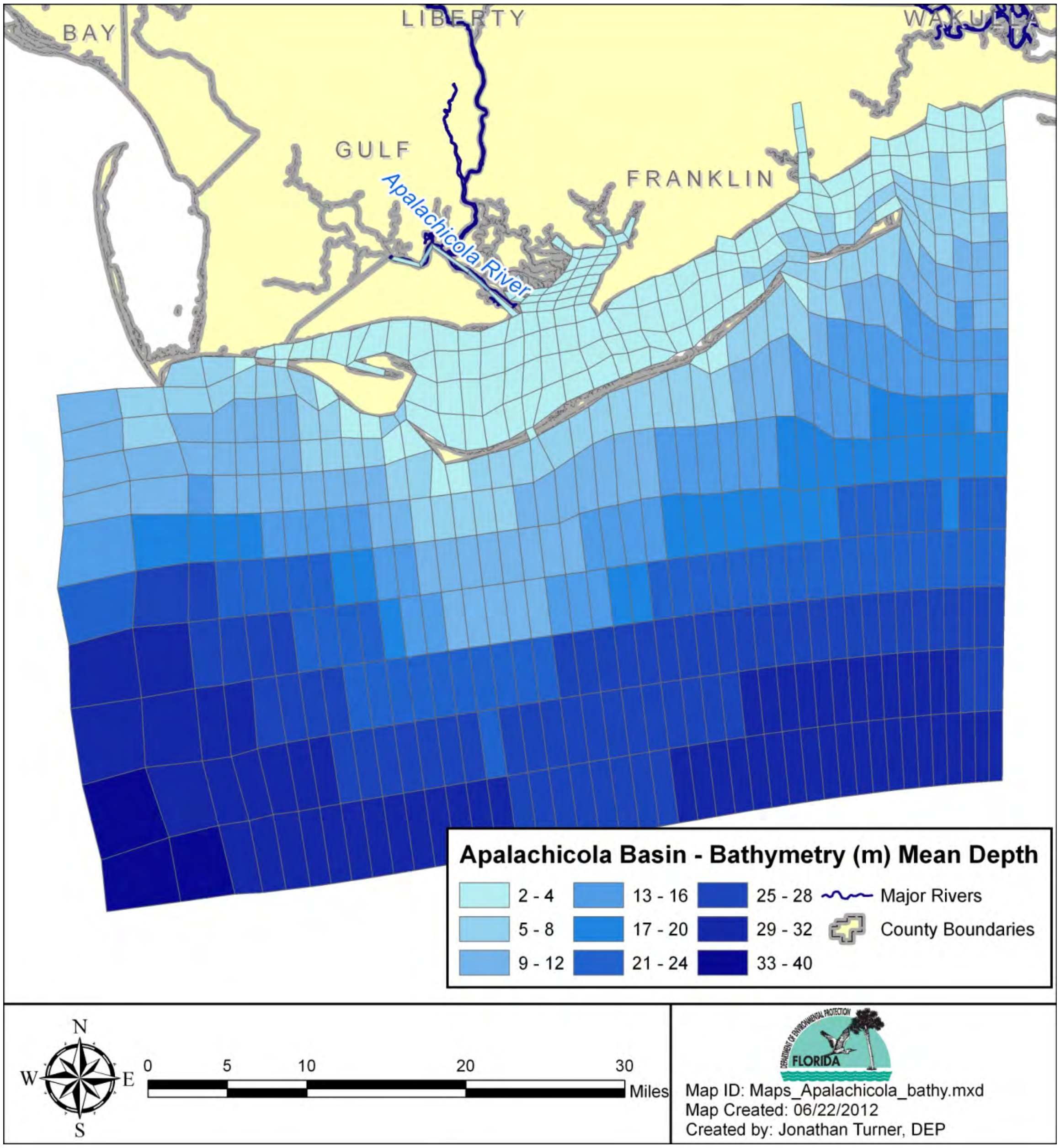


Figure 57. Map of EFDC and WASP Model Domain.

The estuary was divided into five zones including an offshore zone based on salinity contours (Figure 58). Model outputs from simulations over the 2002 - 2009 period can be aggregated over time within each zone to evaluate nutrient concentrations based on specific ecological endpoints.

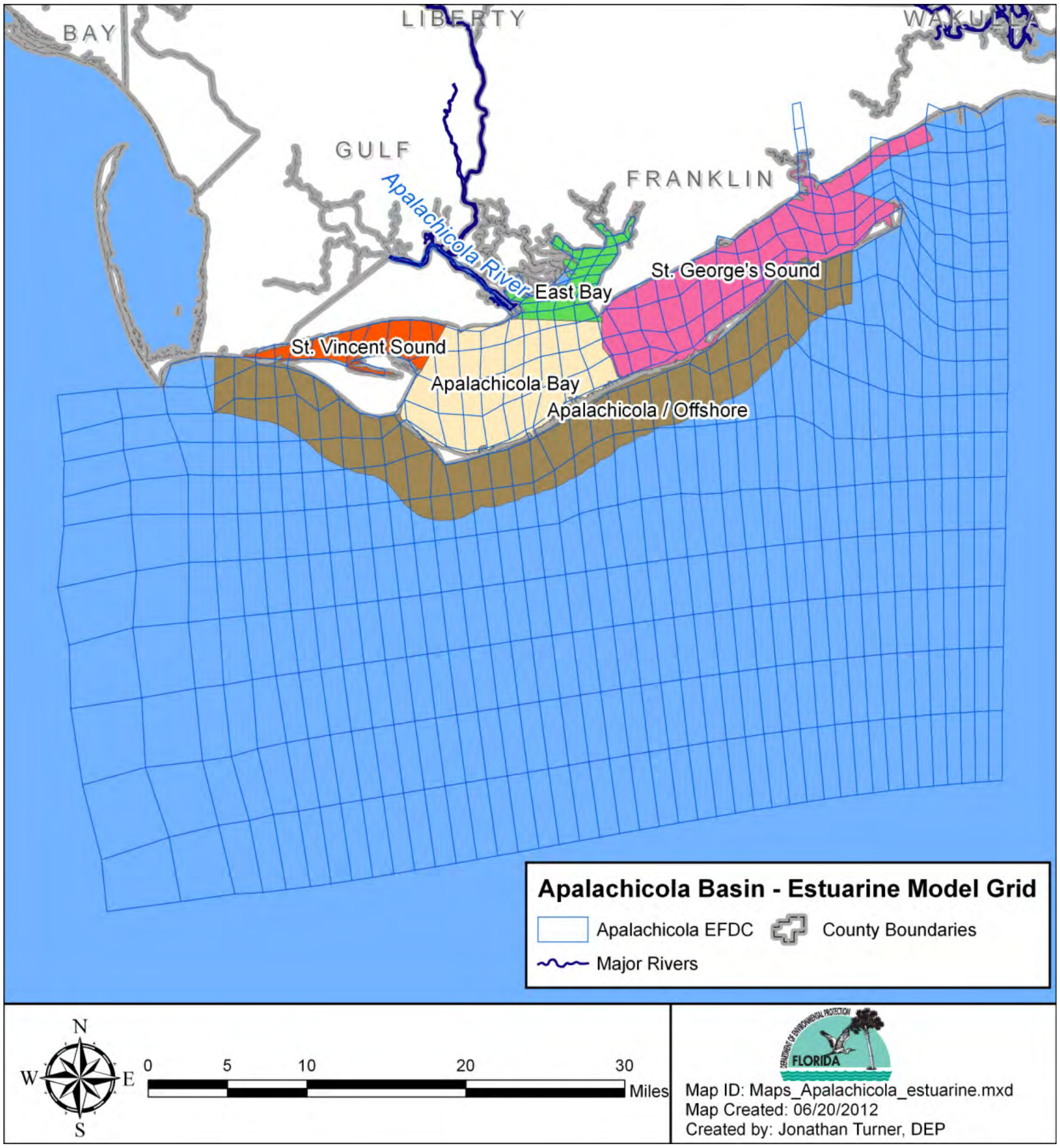


Figure 58. Map showing the five Apalachicola Estuary Zones.

Model Targets

The Environmental Protection Agency (EPA) is in the process of developing nutrient criteria for Florida's estuaries. While EPA's draft criteria will not be available until Nov. 30, 2012, Department staff met with a representative of EPA Region 4 and EPA Headquarters' modeling consultants (Tetra Tech) in Atlanta, Georgia to review their modeling results and evaluation criteria, and to obtain copies of the LSPC, EFDC, and WASP models EPA used to asses both the current condition (EPA calibrated model) and a background condition (natural condition) as described above. Based on the information provided during these meetings and teleconferences, it is the Department's understanding that EPA used a multiple line of evidence approach to determine if Apalachicola Bay meets Florida's narrative criteria for nutrients. Central to the methodology was the establishment of a series of 5 zones (segments) based on salinity gradients within the Apalachicola Bay system. These zones are depicted in **Figure 58**.

Both the FDEP and EPA approaches to the development of numeric nutrient criteria ensure water quality standards are met and designated uses are protected. While FDEP primarily used a weight of evidence approach involving empirical data, both FDEP and EPA considered the following endpoints:

- Balanced Faunal Communities;
- Healthy Seagrass Communities; and
- Balanced Phytoplankton Biomass and Production.

The multiple lines of evidence that EPA considered are described below.

A. Balanced Faunal Communities: Dissolved Oxygen (DO) Requirements

To ensure that faunal communities were protected, each Zone was required to achieve:

1. A daily average DO of 5.0 mg/L (as a water column average) 90% of the time over the 2002 to 2009 simulation period (note that DEP proposed marine DO criteria requires a DO saturation of 42%);
2. A minimum DO of 4.0 mg/L (as a water column average) 90% of the time over the 2002 to 2009 simulation period; and
3. A three-hour average DO no lower than 1.5 mg/L (as an average of the bottom two layers in WASP and the bottom 4 layers of RCA) over the 2002 to 2009 simulation period.

B. Healthy Seagrass Communities

To ensure that nutrients do not interfere with the establishment, maintenance or restoration of healthy seagrass communities, EPA established depth targets for seagrass colonization for each Zone and then evaluated the depth to which seagrass could successfully colonize and propagate by:

1. Determining the locations where the growing season average bottom light equals or exceeds 20% of the surface light, for both the current and natural conditions;
2. Comparing the areas where historic seagrass coverage achieved the 20% (or greater) bottom light target (for both current and natural conditions); and
3. Comparing areas where the growing season average 20% bottom light target was achieved against the Zone depth targets developed by EPA.

C. Balanced Phytoplankton Biomass and Production

To ensure that Harmful Algal Blooms did not occur, chlorophyll *a* levels were required to not exceed 20 µg/L more than 10% of the time in any Zone during the 2002-2009 simulation period.

Downstream Protection

Empirical data demonstrates that existing nutrient and chlorophyll a levels in Apalachicola Bay are fully protective of Balanced Faunal Communities, Healthy Seagrass Communities, and Balanced

Phytoplankton Biomass and Production. Furthermore, because the downstream segments are also healthy at the current nutrient loads, the proposed criteria are inherently protective of downstream waters.

Hydroqual Model

In addition to the Tetra Tech Inc. model, Hydroqual analyzed existing TN, TP, and flow data and, considering flow to be an explanatory variable, estimated long-term nutrient loads (Hydroqual, 2010).

Available water quality and flow data were obtained from the following sources: U.S. Geological Survey (USGS) for flow and water quality; and Florida STORET for water quality. Figure 59 shows the locations where river data were available, with the stations at the Lake Seminole outlet (Florida STORET at U.S. Highway 90 and USGS Gauge #02358000) and Sumatra (USGS Gauge #02359170) containing the most data. These two stations (Lake Seminole and Sumatra) were used to complete the river loading analyses. The data were used to develop concentration relationships to flow, so that the daily flow record could be used to develop long-term estimates of river concentrations and loads for TN and TP. Ultimately, annual geometric mean loads were developed to be used in developing protective loads to Apalachicola Bay.

Figures 60 and 61 present the data obtained for flow, TN, and TP at Lake Seminole and Sumatra from 1975 to 2009, along with the recently adopted stream nutrient thresholds for TN (0.67 mg/L) and TP (0.06 mg/L) as horizontal dashed lines. The flow values range from about 5,000 to 200,000 cfs, the TN values range from about 0.3 to 1.5 mg/L, and the TP values range from about 0.01 to 0.1 mg/L. These data were used to develop concentration relationships to flow using the data from 1990 to 2009 (Figure 62). This period was chosen since pre-1990 TN data at Lake Seminole appeared less reliable and more variable than the post-1990 data. Although strong correlations between concentration and flow were not observed, generally increasing trends in concentration were observed with increasing flow. Log-log regressions were completed on the data, and Table 19 and Figure 62 present the resulting equations.

Table 19. Concentration flow regression equations for the Lake Seminole and Sumatra stations (Hydroqual).

Location/Source	TN Equation	TP Equation
Lake Seminole	$0.244Q^{0.116}$	$0.0038Q^{0.223}$
Sumatra	$0.675Q^{0.005}$	$0.0008Q^{0.379}$

Figures 63 and 64 present the calculated daily loads based on the concentration-flow regression equations and the daily flows at Lake Seminole and Sumatra from 1975 to 2009. The solid blue horizontal lines in each panel represent annual geometric means of flow, TN load, and TP load. In general, the calculated TN and TP loads compare well with the observed loads.

Since the concentration-flow relationships are not very strong (little variation with flow), much of the load variation to Apalachicola Bay is due to the hydrology of the river. In order to incorporate the hydrology (flow) variation into developing nutrient criteria or protective nutrient loads, probability distributions of TN and TP loads were developed by Hydroqual. Figures 65 and 66 present log probability distributions of calculated annual geometric means for TN and TP loads for the period from 1975 to 2009 at Lake Seminole, and from 1978 to 2009 at Sumatra. Table 20 shows the upper distribution of the nutrient loads at two stations in the Apalachicola River. Nutrient criteria structured to maintain this distribution of loads over time would assure that the necessary water flow and beneficial nutrient inputs needed to sustain the system would be delivered. For more information on the modeling, see Appendix C.

Table 20. Upper distribution of Apalachicola River statistical nutrient loads (after Hydroqual 2010).

- = Empty cell/no data

-	Lake Seminole	Sumatra
TN load (lbs/day)	67%-81,633 95%-116,509 99%-130,085 Maximum-130,112	67%-93,582 95%-116,971 99%-118,274 Maximum-118,301
TP load (lbs/day)	67%-3,639 95%-5,375 99%-6,064 Maximum-6,065	67%-4,755 95%-6,459 99%-6,558 Maximum-6,560

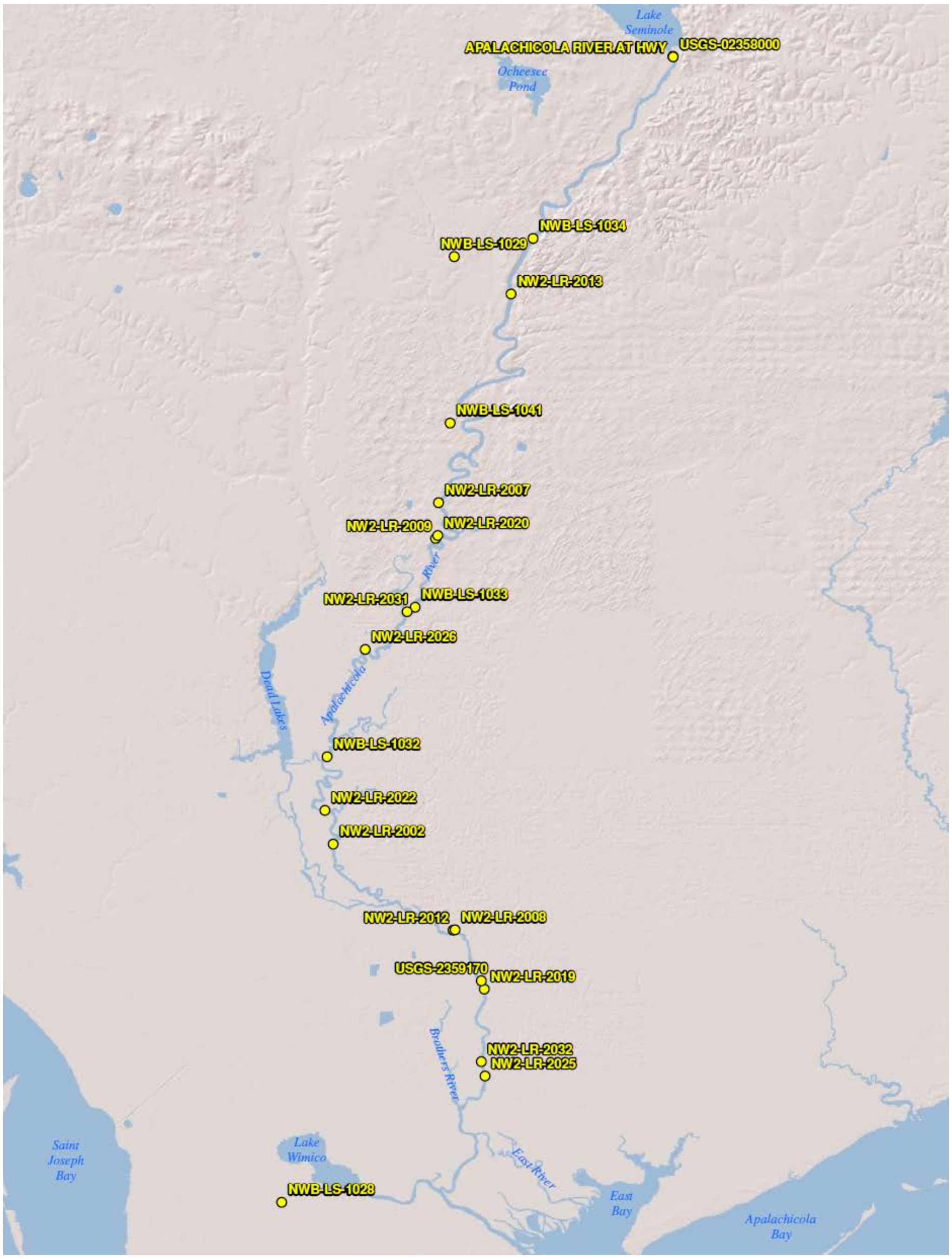


Figure 59. Station map of the Apalachicola River, from Lake Seminole to the Gulf coast (HydroQual).

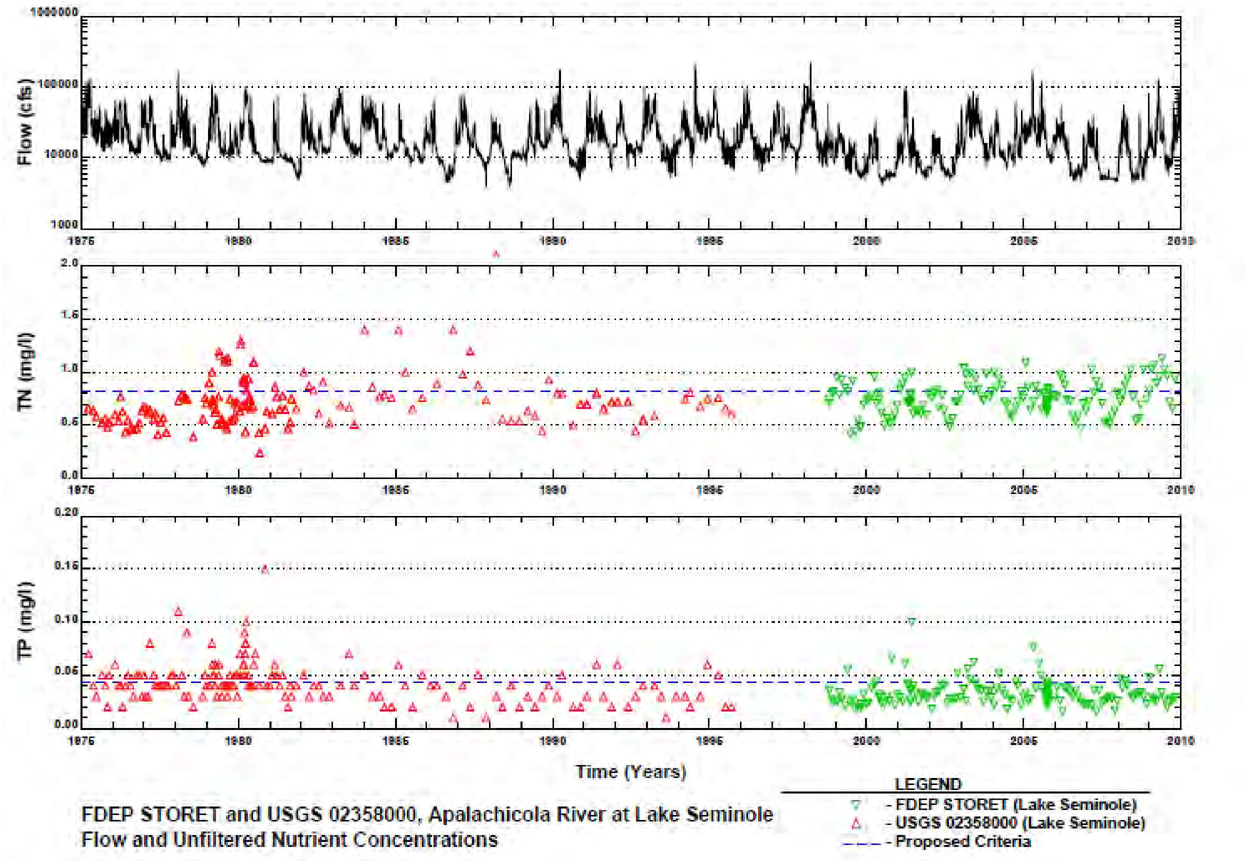


Figure 60. Flow compared with TN and TP concentrations for the Apalachicola River at Lake Seminole; data from Florida STORET and USGS 0235800 (HydroQual).

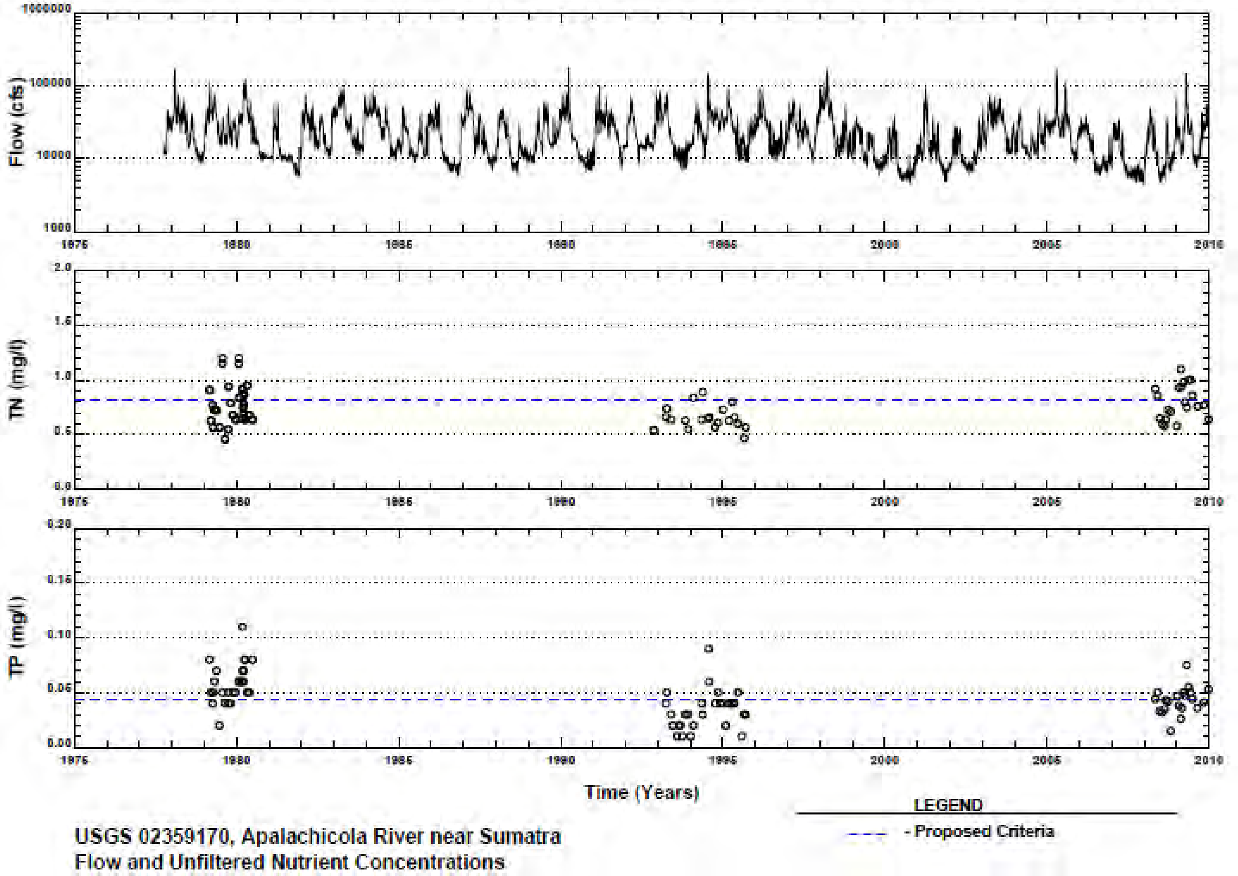


Figure 61. Flow compared with TN and TP concentrations for the Apalachicola River near Sumatra, data from USGS-2359170 (HydroQual).

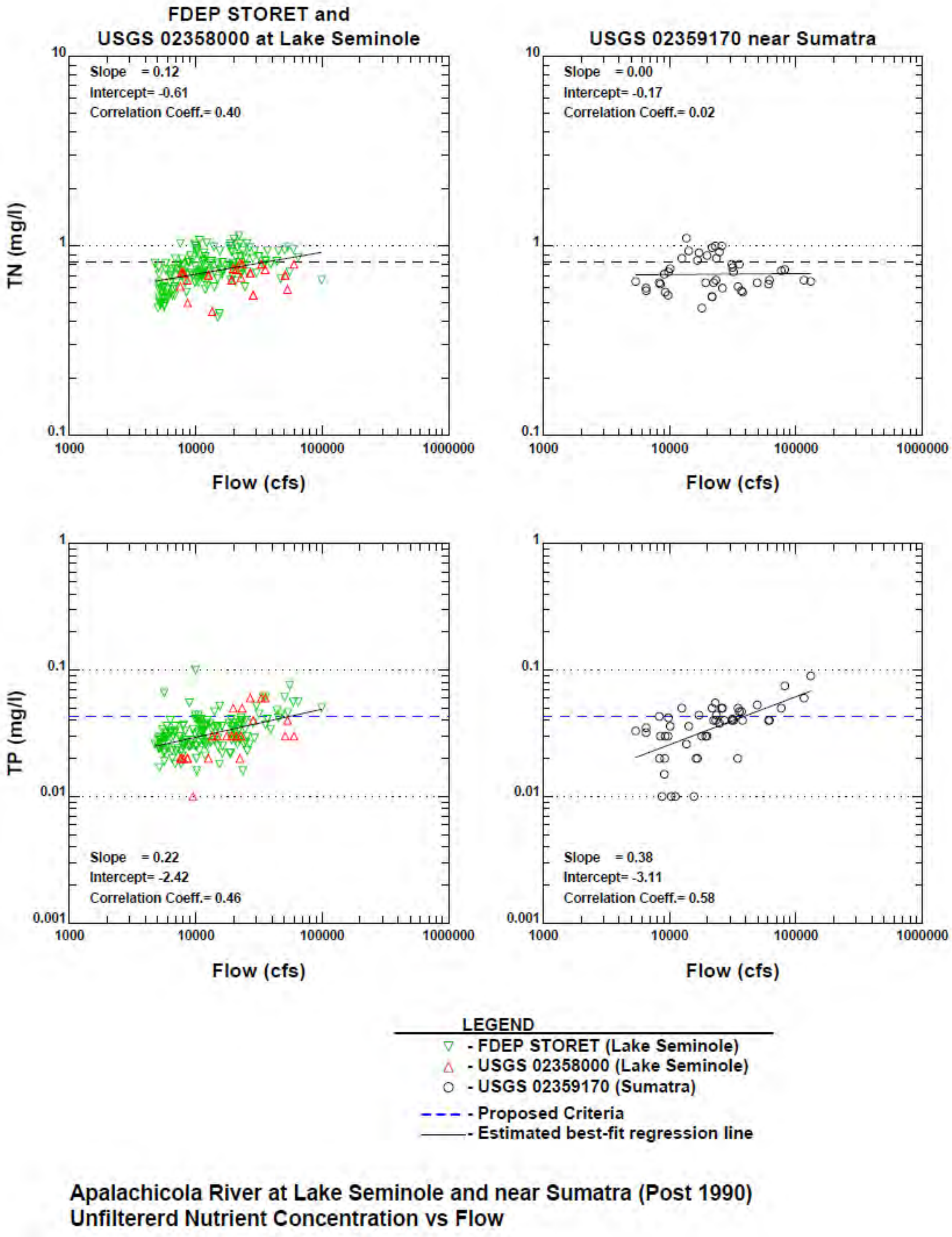


Figure 62. TN and TP concentrations versus flow for the Apalachicola River at Lake Seminole and near Sumatra (post-1990) (HydroQual).

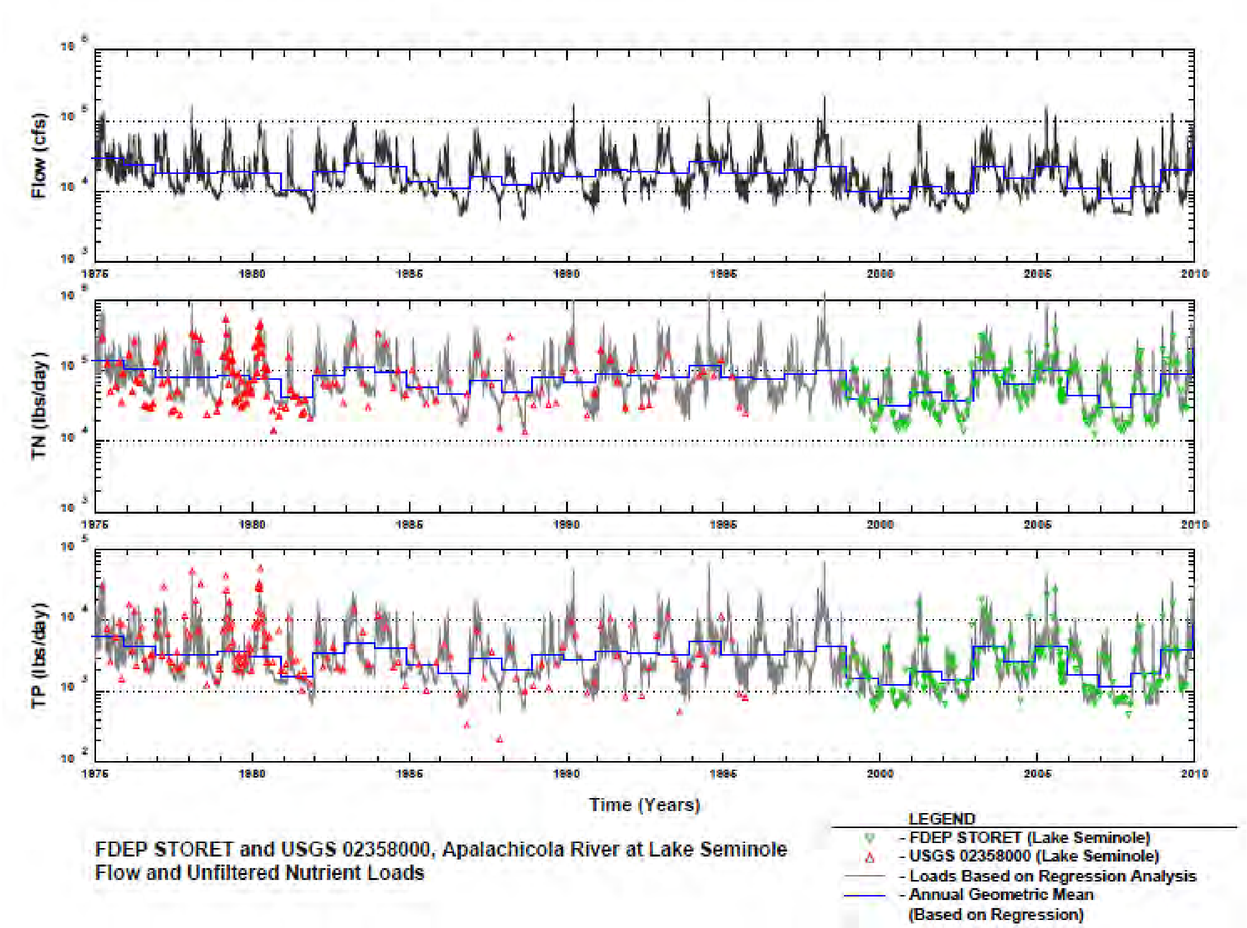


Figure 63. TN and TP compared with flow for the Apalachicola River at Lake Seminole; data from Florida STORET and USGS 02358000. Graphs show data points, load based on regression analysis, annual geometric mean (HydroQual).

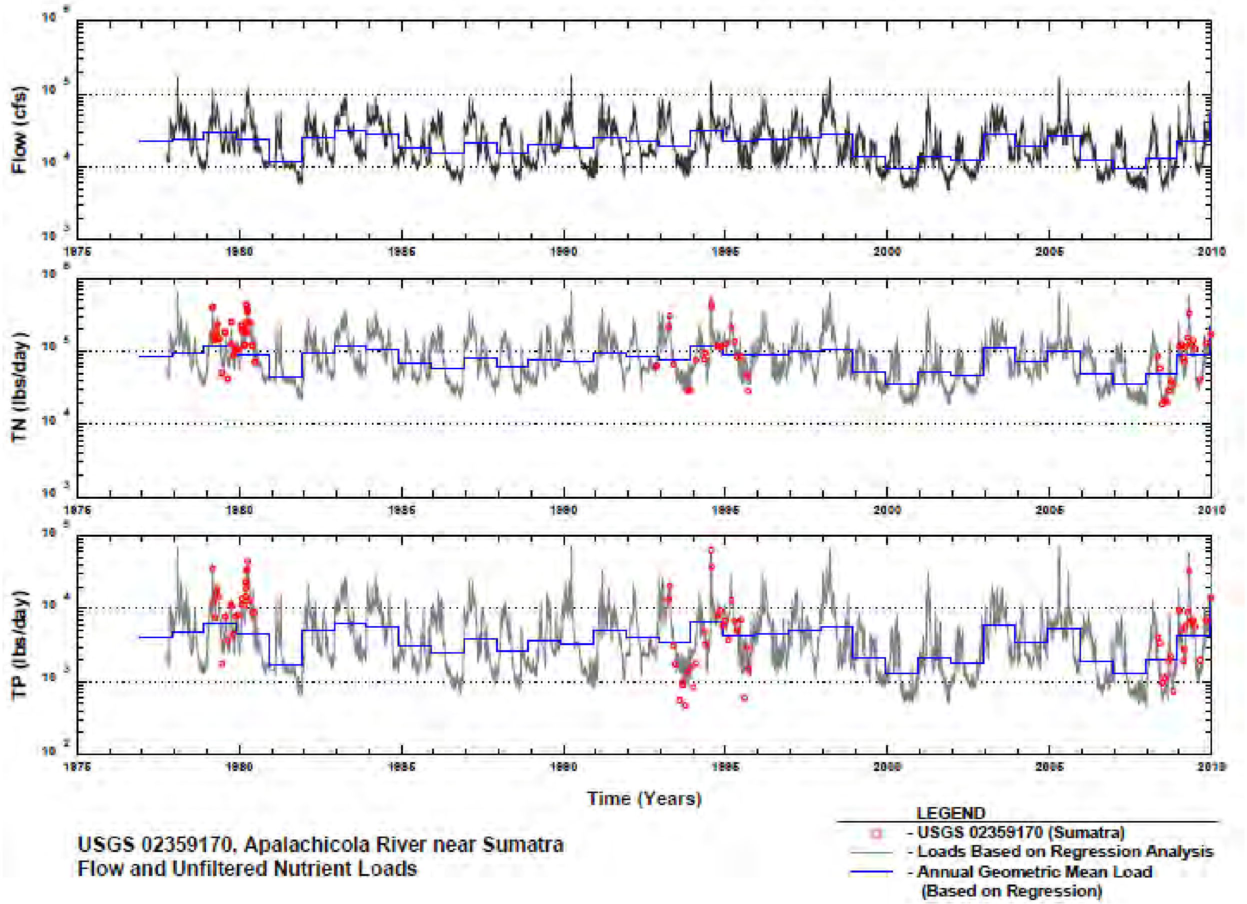


Figure 64. TN and TP compared with flow for the Apalachicola River near Sumatra; data from USGS-2359170. Graphs show data points, load based on regression analysis, annual geometric mean (HydroQual).

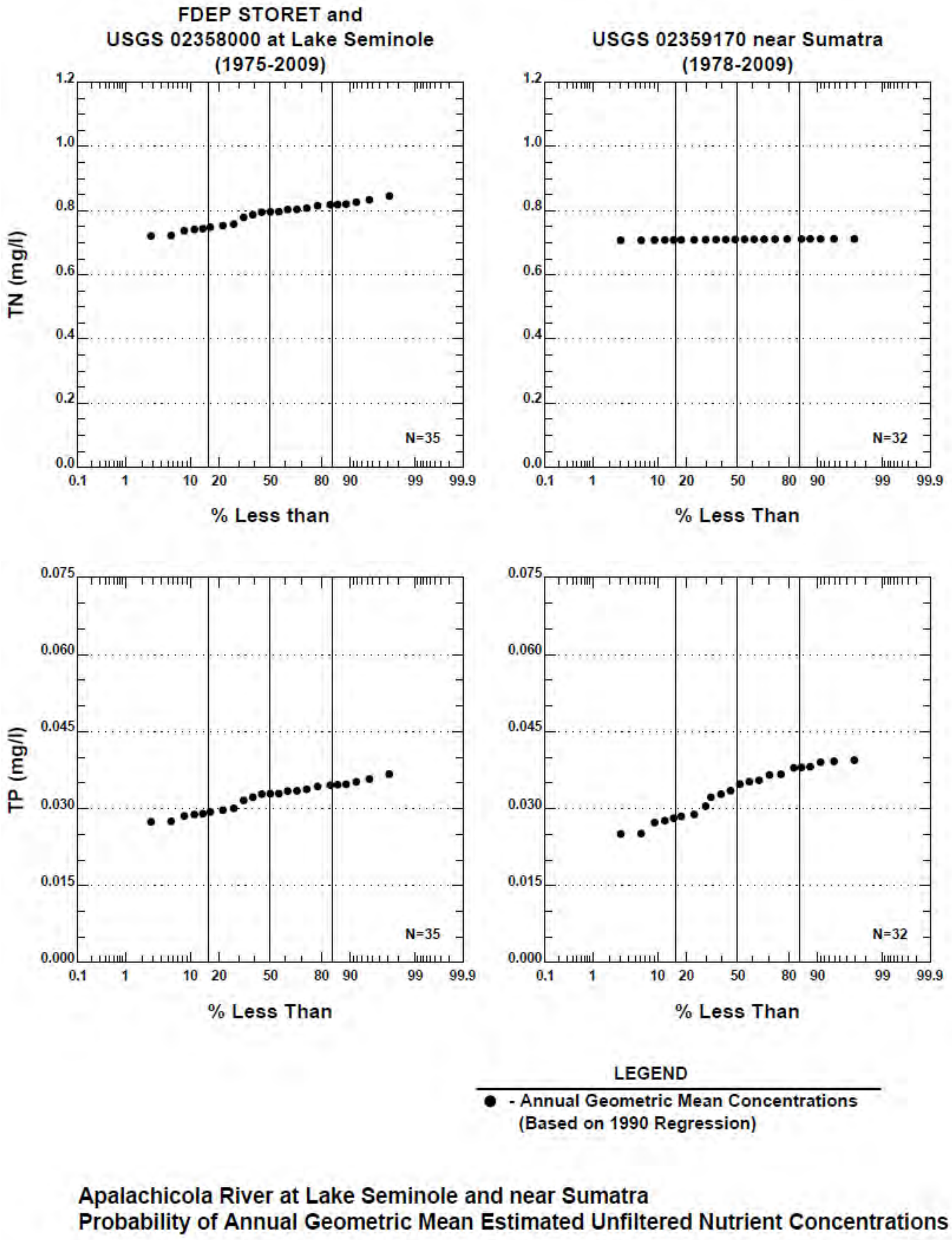


Figure 65. Annual geometric mean for TN and TP concentrations for the Apalachicola River at Lake Seminole and near Sumatra (HydroQual).

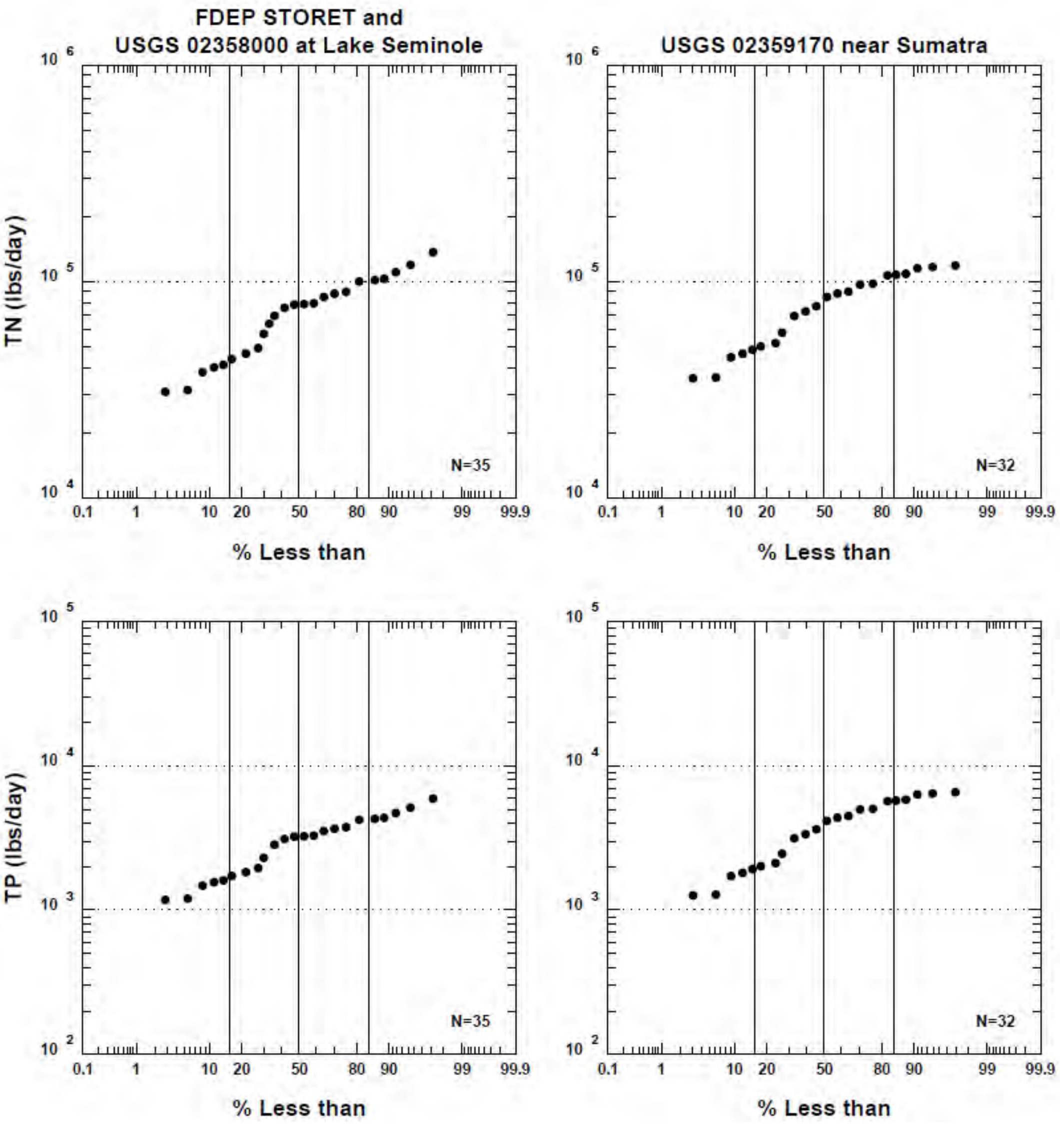


Figure 66. Probability of annual geometric mean estimated unfiltered nutrient loads for the Apalachicola River at Lake Seminole and near Sumatra (HydroQual).

Waters on the 303(d) List

Table 21 shows the Group 2 Verified 303(d) List for the Apalachicola Bay Basin, including several coastal waterbodies within the Apalachicola Bay region. With the exception of one chlorophyll listing for one segment of Apalachicola Bay (WBID 1274B), all of the listings are related to mercury or bacteria. Mercury impairment is clearly not related to nutrients, and as described below, it is FDEP's position that the bacteria related listings are also not related to nutrients. Also, DEP has determined that the historic, generally applicable IWR chlorophyll target is not appropriate for the site-specific conditions associated with Apalachicola Bay, and has therefore proposed more accurate criteria in this document.

Table 21. Impaired waters in the Apalachicola Bay Basin.

- = Empty cell/no data
N/A = Not Available
[1] II = Class II; IIIM = Class III Marine

Planning Unit	WBID	Waterbody Segment	Water-body Type	Water-body Class[1]	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Concentration of Criteria or Threshold Not Met	Priority for TMDL Development	Projected Year for TMDL Development
Apalachicola Bay	1266	St. George Sound	Estuary	2	Mercury (based on fish consumption advisory)	Exceeds Florida Department of Health (FDOH) threshold (>0.3 milligrams per kilogram [mg/kg])	High	N/A
Apalachicola Bay	1274	Apalachicola Bay	Estuary	2	Fecal Coliforms	≤14 Most probable number per 100 milliliters (MPN/100mL)	Low	2003
Apalachicola Bay	1274	Apalachicola Bay	Estuary	2	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	1288	Money Bayou	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	1289	Direct Runoff to Bay	Estuary	3M	Bacteria (in shellfish)	Exceeds SEAS threshold	Low	N/A
Apalachicola Bay	1289	Direct Runoff to Bay	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	1291	Indian Lagoon	Estuary	3M	Bacteria (in shellfish)	Exceeds SEAS threshold	Low	N/A
Apalachicola Bay	1291	Indian Lagoon	Estuary	3M	Mercury (based on fish	Exceeds FDOH threshold	High	N/A

Planning Unit	WBID	Waterbody Segment	Water-body Type	Water-body Class[1]	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Concentration of Criteria or Threshold Not Met	Priority for TMDL Development	Projected Year for TMDL Development
					consumption advisory)	(>0.3 mg/kg)		
Apalachicola Bay	1292	Direct Runoff to Bay	Estuary	2	Bacteria (in shellfish)	Exceeds SEAS threshold	Low	N/A
Apalachicola Bay	1292	Direct Runoff to Bay	Estuary	2	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8018	Gulf of Mexico (Franklin County, Gulf County)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8020	Gulf of Mexico (Franklin County, St. George Island)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8021	Gulf of Mexico (Franklin County, St. George Island)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8022	Gulf of Mexico (Franklin County, Dog Island)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8023	Gulf of Mexico (Franklin County, Dog Island)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	1266A	Carrabelle Beach	Beach	3M	Bacteria (Beach Advisories)	≥21 days of beach advisories	High	N/A
Apalachicola Bay	1274A	East Bay	Estuary	2	Fecal Coliforms	≤14MPN/100 mL	Low	2008
Apalachicola Bay	1274A	East Bay	Estuary	2	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A

Planning Unit	WBID	Waterbody Segment	Water-body Type	Water-body Class[1]	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Concentration of Criteria or Threshold Not Met	Priority for TMDL Development	Projected Year for TMDL Development
Apalachicola Bay	1274B	Apalachicola Bay	Estuary	2	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	1274B	Apalachicola Bay	Estuary	2	Nutrients (Chlorophyll-a)	≤ 11 μg/L	Medium	N/A
Apalachicola Bay	1274C	Direct Runoff to Bay	Coastal	2	Bacteria (in shellfish)	Exceeds SEAS threshold	Low	N/A
Apalachicola Bay	1274C	Direct Runoff to Bay	Coastal	2	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
Apalachicola Bay	8020A	St. George Island 11th St. W	Beach	3M	Bacteria (beach advisories)	≥21 days of beach advisories	High	N/A
Apalachicola Bay	8021A	St. George Island Franklin Blvd.	Beach	3M	Bacteria (beach advisories)	≥21 days of beach advisories	High	N/A
Apalachicola Bay	8021B	St. George Island 11th St. E	Beach	3M	Bacteria (beach advisories)	≥21 days of beach advisories	High	N/A
Apalachicola Bay	8022A	St. George Island State Park	Beach	3M	Bacteria (beach advisories)	≥21 days of beach advisories	High	N/A
Apalachicola Bay	8019	Gulf of Mexico (Franklin County)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
New River	1256	Alligator Harbor	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
New River	1278	East Bayou	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	Low	N/A
New River	1278	East Bayou	Estuary	3M	Bacteria (in shellfish)	Exceeds Shellfish Evaluation & Assessment Section (SEAS)		

Planning Unit	WBID	Waterbody Segment	Water-body Type	Water-body Class[1]	Parameters Assessed Using the Impaired Surface Waters Rule (IWR)	Concentration of Criteria or Threshold Not Met	Priority for TMDL Development	Projected Year for TMDL Development
						thresholds		
New River	1279	West Bayou	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	-	N/A
New River	1279	West Bayou	Estuary	3M	Bacteria (in shellfish)	Exceeds SEAS threshold	-	N/A
New River	1283	Blounts Bay	Estuary	3M	Bacteria (in shellfish)	Exceeds SEAS threshold	-	N/A
New River	1283	Blounts Bay	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	-	N/A
New River	8024	Gulf of Mexico (Franklin County; Alligator Harbor)	Coastal	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
New River	1034A	New River	Estuary	3M	Mercury (based on fish consumption advisory)	Exceeds FDOH threshold (>0.3 mg/kg)	High	N/A
New River	8024A	Alligator Point	Beach	3M	Bacteria (Beach Advisories)	≥ 21 days of beach advisories	High	N/A

Impairment for Bacteria Not Necessarily Indicative of Anthropogenic Impact

The use of fecal coliforms as an indicator of the presence of human pathogens has been under scrutiny in Florida for the past decade. One of the priorities of the Gulf of Mexico Alliance (GOMA) is the need to improve microbial source tracking (MST) and pathogen detection methods for use under Gulf of Mexico conditions (GOMA 2009). The GOMA Pathogens Workgroup recently submitted comments regarding the status of EPA recreational water quality criteria (GOMA 2009). It expressed concern that the EPA recreational criteria were derived in places that do not represent Gulf of Mexico conditions, and that the use of fecal indicators was not appropriate for waters primarily influenced by natural animal sources. Areas in the Gulf of Mexico for which the workgroup thought the EPA criteria might not be appropriate included low-population-density coastal areas, areas of heavy rainfall, subtropical latitudes, and areas where waters contain a large amount of organic detritus material and/or colored dissolved organic matter (CDOM) (GOMA 2009).

Boehm *et al.* (2009) express similar concern about the current and proposed recreational criteria, and specifically call attention to the need for further research and revision in tropical waters and waters adversely impacted by urban runoff and animal feces. This is not to say that fecal coliform and enterococci bacteria cannot indicate human sources or cannot co-occur with nutrient inputs, but that there is ample evidence to caution against assuming that the presence of these bacteria automatically indicates the presence of anthropogenic nutrients.

The following text is from a review conducted by Dr. V. Jody Harwood of the University of South Florida as part of a microbial source tracking project she is conducting for FDEP:

> *The main groups of indicator bacteria for recreational water quality assessment in use today include fecal coliforms, or a specific member of that group, Escherichia coli, in fresh water and the genus Enterococcus in both fresh and estuarine/marine waters. However, in order for the indicator concept to work optimally there are many assumptions that must hold true. One of the most important assumptions is that indicator bacteria must co-occur with human pathogens when pathogens are present and pose a human health risk. Unfortunately, recent research has indicated that this assumption is often false by showing that the presence of indicator bacteria do not always correlate well with the presence of pathogens such as Salmonella, Campylobacter, Cryptosporidium, Giardia, or enteric viruses (Anderson et al. 2005; Bonadonna et al. 2002; Harwood et al. 2005; Lemarchand and Lebaron 2003; Lund 1996; Rees et al. 1998).*
>
> *One important reason for the lack of correlation between traditional fecal indicator bacteria and pathogens is that the indicator bacteria are not specific to humans, or to other hosts known to shed human pathogens in their feces, but are present in the intestines of all warm-blooded animals and some cold-blooded animals (Souza et al. 1999). Because not all animals are equally likely to carry human pathogens, contamination from all sources does not represent an equal health risk. Thus, some sources of fecal contamination in water are of greater concern than others. Furthermore, there is increasing evidence of naturalized or environmentally adapted strains indicator bacteria (both coliforms and enterococci) that are capable of persisting in a culturable form for extended periods, or even growing, in a wide variety of environmental matrices, including terrestrial soils, aquatic sediments, and attached to aquatic vegetation (Byappanahalli and Fujioka 1998; Byappanahalli et al. 2003; Ishii et al. 2006; Jeng et al. 2005; Ksoll et al. 2007; Solo-Gabriele et al. 2000; Topp et al. 2003; Whitman et al. 2003). If indicator bacteria are persisting in environmental matrices their reintroduction into the water column, such as might occur during storms or high recreational activity, may lead to false positive indications regarding contamination and public health risk. As a result of these two confounding factors, it is now clear that simply measuring concentrations of waterborne indicator bacteria do not offer detailed enough information to properly determine health risks associated with recreational water use. Furthermore, this practice does not allow specific sources of contamination to be identified or targeted for remediation of water quality.*

Numeric Nutrient Criteria Recommendations

The well-developed scientific database for the Apalachicola River and Bay system indicates that nutrients delivered to the bay from the Apalachicola River are integral to the welfare of this highly productive system. Reductions of nutrient inputs and increases in salinity due to decreased river flow are accompanied by adverse changes in the overall secondary production of the estuary. The data demonstrate that there no need to reduce nutrient loading to the bay from the river. In fact, any attempt to restrict nutrients would be counterproductive to the key fisheries of the bay and would exacerbate the stress caused by recent increases in drought frequency.

For Apalachicola Bay, maintaining the upper distribution of the nutrient loads associated with healthy conditions is the numeric nutrient goal. Maintaining historic nutrient loads from the Apalachicola River will protect the trophic functioning of the bay, and ensure that the necessary water flow and beneficial nutrient inputs needed to sustain the system would be delivered.

Proposed Numeric Nutrient Criteria

To be applied consistently and to provide an appropriate level of protection, water quality criteria need to include magnitude, frequency, and duration components. The magnitude is a measure of how much of a pollutant may be present in the water without an unacceptable adverse effect. Duration is a measure of the time period over which the magnitude will be applied. It is preferable to derive the magnitude component of a criterion through a cause-effect relationship (such as that measured through toxicity testing). The magnitude would then be set at a level that would protect a majority of the sensitive aquatic organisms inhabiting the system. Absent sufficient data to demonstrate a cause-effect relationship, the magnitude may be set at a level designed to maintain the current data distribution, accounting for natural temporal variability, assuming the current conditions are protective of the designated uses of the waterbody. Since a criterion derived based on the existing data distribution has no direct link to any observed cause-and effect relationship, it is assumed that maintaining the current data distribution will preserve the uses associated with that distribution.

The frequency and duration components of the criteria are best established as additional descriptors of the reference condition data distribution. Specifically, these components should be part of a statistical test designed to determine whether the long-term distribution of data has shifted upward from the reference distribution. This test would then be used to determine whether future monitoring data are consistent with the magnitude (long-term average) defined by the reference dataset. It is critical to account for the natural variability surrounding the magnitude expression and to control for statistical errors. The magnitude component can be set at the long-term central tendency (geometric mean) of the distribution, while the frequency and duration components describe how often and by how much nutrient concentrations can be above the central tendency while still being consistent with the reference distribution. The proposed methods for derivation of the magnitude, frequency and duration components of numeric nutrient criteria for estuaries with healthy existing conditions is described briefly below. More details concerning the statistical approaches used can be found in the document, *Overview of FDEP Approaches for Nutrient Criteria Development in Marine Waters*.

Magnitude

The magnitude component represents a level of nutrients demonstrated to be protective of the designated use. For the “healthy existing conditions” approach, the magnitude can be interpreted as the central tendency of the baseline distribution and may be set at a level that represents a long-term average condition of that distribution. For the “healthy existing conditions” approach, the Department proposes establishing the magnitude as an annual geometric mean, not to be exceeded more than once over a three year period.

The objective of this magnitude component is to maintain the long-term average concentration at the level observed in the baseline data set. Exceedance of the one magnitude component more than once in a three-year period would provide strong evidence that the waterbody nutrient levels had increased above the baseline distribution.

Frequency and Duration

To provide a consistent and appropriate level of protection, the duration and frequency components of the criteria must be consistent with the derivation of the magnitude component. While the magnitude component of the criteria was derived based on a long-term geometric mean concentration, it is not practical to assess compliance with the criteria on the same long-term basis. Instead, a statistical test can be developed to allow the application of the criteria on a shorter-term basis. For the criteria to be protective, the duration component of the criteria (*e.g.*, single sample maximum, annual geometric mean) must be linked to the response time frame of the sensitive endpoint. Short-term averaging periods (*e.g.,* 1 to 30 days) would be appropriate for nutrient criteria where a sufficiently robust cause-effect relationship has demonstrated that a eutrophic response occurs over such time frames. If, however, such a short-term response cannot be demonstrated, or there is no indication of use impairment, then longer averaging periods should be considered.

For example, since the relationship between nutrient and chlorophyll *a* response in Florida lakes was extremely weak, with a much more robust relationship found when data were evaluated based on annually averaged log-transformed data, FDEP and EPA used an averaging period of a year to assess the enrichment in Florida lakes with the criteria being expressed as an annual geometric mean. Likewise, the nutrient criteria for estuaries will be assessed annually. Since the duration and frequency components of the criteria must be consistent with the derivation of the magnitude component to provide a consistent and appropriate level of protection, the long-term geometric mean target cannot simply be applied as an annual mean. Doing so would result in unacceptably high Type I failure rate (identifying a healthy system as being impaired), since approximately 50% of the individual years can be expected to be above the long-term mean. Therefore, the long-term target must be adjusted to allow for the application to a shorter duration with an acceptable Type I error rate of no more than 10%. This assessment of the Type I error rate is related only to addressing the null hypothesis that future monitoring data are equivalent to the baseline distribution. This Type I error does not take into account the possibility that a higher nutrient threshold would be fully protective of the use. The Type I error rate, for the current application, may be defined as the rate of incorrectly concluding that the mean of (future) monitoring data is greater than the baseline or reference long-term mean condition identifying. Type I statistical errors result in the management decision error to incorrectly list a healthy waterbody as impaired.

An annual target concentration with an approximate 10% Type I error rate for a given frequency can be derived by appropriately accounting for the annual variability above the mean. This annual target concentration can be derived as an upper percentile of the distribution of the annual geometric mean concentrations. Previous proposals by EPA have used 3-year assessment periods to express the magnitude and duration nutrient criteria components. Assuming a 3-year assessment period, it can be statistically determined that using the 80th percentile of the annual geometric means from the long-term dataset with a frequency and duration of no more than once during the 3-year period will achieve the targeted 10% error rate**.** Therefore the proposed criteria will be applied such that the 80th percentile of the annual geometric mean concentrations cannot be exceeded in more than 1 out of 3 years.

Summary of the Proposed Criteria

For a “healthy existing conditions” dataset, the Department considered several potential ways to express the NNC. The Department’s proposed approach is to set the magnitude as an annual geometric mean limit established at the upper 80 percent prediction limit of the spatially averaged annual geometric means, with a frequency and duration of no more than 1 annual geometric mean exceeding the limit in a 3-year period.

DEP’s preferred expression of healthy existing conditions nutrient criteria is an annual geometric mean not to be exceeded more than once in a three-year. Calculation of this limit ideally requires a minimum dataset of nine to ten years (*i.e.*, at least three independent three-year periods) to confidently estimate the upper end of the long-term distribution of annual geometric means. However, for some segments of Apalachicola Bay, the period of record is insufficient to derive such an annual limit. For these segments, the Department is proposing an alternative approach expressed as a segment-wide daily average value not to be exceeded in more than ten percent of the daily averages. The daily average value was calculated as the upper 90% prediction limit of segment-wide daily average values, assuming a lognormal distribution (Helsel and Hiersh 2002), for segments with a minimum of 30 daily values. For segments with less than 30 values, the nonparametric 90th percentile was set as the daily average value. The Department is seeking any additional data sources.

A summary of the available data and proposed criteria for the protection of a healthy, well-balanced aquatic community for four segments in Apalachicola Bay are provided in Table 22.

Table 22. Proposed numeric nutrient criteria for all segments of Apalachicola Bay, including TP, TN, and Chlorophyll a. Notes are provided at the bottom of the table to detail which approach is most appropriate based on data limitations.

TP (mg/L)								
Annual Geometric Mean Limit Approach					**Daily Average Limit**			
Segment	**Existing Long-Term Geometric Mean**	**Number of Calculated Annual Geometric Means**	**Standard Deviation (Ln TP)**	**Maximum Annual Geometric Mean (1 of 3-year exceedance rate)**	**Geometric Mean**	**Standard Deviation (Ln TP)**	**Number of total samples**	**Daily Average not to be exceeded in >10% of the values**
St. George Sound	0.023	8	0.319	0.032	**0.026**	**0.898**	**88**	**0.083**

East Bay	0.035	6	0.338	0.049	**0.034**	**0.846**	**61**	**0.101**
St. Vincent Sound	0.030	6	0.264	0.040	**0.031**	**0.997**	**52**	**0.116**
Apalachicola Bay	**0.042**	**26**	**0.469**	**0.063**	0.037	0.941	203	0.125
TN (mg/L)								
Annual Geometric Mean Limit Approach					**Daily Average Limit**			
Segment	**Existing Long-Term Geometric Mean**	**Number of Calculated Annual Geometric Means**	**Standard Deviation (Ln TN)**	**Maximum Annual Geometric Mean (1 of 3-year exceedance rate)**	**Geometric Mean**	**Standard Deviation (Ln TN)**	**Number of total samples**	**Daily Average not to be exceeded in >10% of the values**
St. George Sound	0.384	7	0.372	0.550	**0.430**	**0.584**	**91**	**0.92**
East Bay	0.641	6	0.356	0.913	**0.644**	**0.422**	**67**	**1.12**
St. Vincent Sound	0.456	7	0.536	0.766	**0.510**	**0.587**	**55**	**1.10**
Apalachicola Bay	**0.644**	**27**	**0.311**	**0.844**	0.625	0.586	214	1.33
Chlorophyll a (ug/L)								
Annual Geometric Mean Limit Approach					**Daily Average Limit**			
Segment	**Existing Long-Term Geometric Mean**	**Number of Calculated Annual Geometric Means**	**Standard Deviation (Ln TN)**	**Maximum Annual Geometric Mean (1 of 3-year exceedance**	**Geometric Mean**	**Standard Deviation (Ln TN)**	**Number of total samples**	**Daily Average not to be exceeded in >10% of the**

				rate)					values
St. George Sound	**3.29**	**13**	**0.673**	**6.1**		3.31	0.995	156	12.0
East Bay	**5.77**	**13**	**0.570**	**9.7**		6.04	0.959	303	20.7
St. Vincent Sound	4.48	4	0.882	11.8		**3.54**	**1.415**	**33**	**17.4**
Apalachicola Bay	**4.84**	**22**	**0.621**	**8.4**		4.04	0.952	264	13.8

Notes:

1- **All TN and TP standard deviations are based off of natural log transformations.**
2- **Criteria will be expressed as two significant figures.**
3- **The Apalachicola Bay segment has sufficient data to develop nutrient criteria by means of the annual geometric mean limit approach for TN, TP, and chlorophyll a. The criteria are expressed as a maximum annual geometric mean not to be exceeded in more than one out of three years.**
4- **St. George Sound TN and TP criteria were developed using the single sample value approach. The criteria is set as a single sample limit not to be exceeded in >10% of samples. For chlorophyll, St. George Sound had sufficient data to use the annual geometric mean limit approach.**
5- **East Bay TN and TP criteria were developed using the single sample value approach. For chlorophyll, East Bay had sufficient data to use the annual geometric mean limit approach.**
6- **St. Vincent Sound TN, TP, and chlorophyll a criteria were developed using the single sample value approach.**

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Appendix A: Nutrients in Apalachicola River-Bay System

Report written by Dr. Robert J. Livingston, retired FSU professor, for FDEP. The report is found under the name Appendix A for Apalachicola Bay Report.doc. This report outlines the various research done by Dr. Livingston from 1970 to 2008; it includes a physical description of the Apalachicola Bay and River system, nutrients in the Apalachicola system, dominant species found in the Apalachicola system, the trophic organization of the bay, recent drought trends and bay productivity, and conclusions.

Livingston, R.J. 2010. *Nutrients in Apalachicola River-Bay system.* Unpublished report for the Florida Department of Environmental Protection.

Anchoa mitchilli

The youngest bay anchovies enter the bay during early summer, and are located mainly in East Bay. They eventually move to the river in the late fall. The second anchovy trophic unit moves to the river area during fall months. Overall, this species is closely tied to freshwater flows from the Apalachicola River, and populations move from summer distributions in East Bay to fall distributions in the Apalachicola River channel. Long-term changes of the anchovy trophic units indicated peak numbers of the first trophic unit between peak river flows (1973-75) and drought conditions (1980-81). Peak numbers were noted during the first year of the drought, with major decreases during succeeding years. This distribution was consistent with the postulated increases of plankton during the first year of the drought. The second trophic unit showed relatively low numbers during and after the 1980-81 drought.

Cynoscion arenarius

The sand seatrout, a piscivorous fish that feeds primarily on anchovies (Sheridan and Livingston 1979), reaches peak numbers during late spring and early summer. The distribution of the first 2 trophic units is located largely in East Bay and around the Apalachicola River mouth from late spring to early fall. The larger sand seatrout are located mainly near the river channel of the bay. This distribution generally follows that of the bay anchovies. The long-term trends of this species indicate relatively low numbers during the second year of the drought followed by subsequent increases during succeeding years. The patterns of anchovy distribution in time could reflect predation pressure by the sand seatrout.

Leiostomus xanthurus

Young-of-the-year spot enter the bay during winter-early spring periods, and are concentrated in East Bay and areas near the river mouth. Older spot move to the lower parts of Apalachicola Bay. This distribution in consistent with known distributions of infaunal macroinvertebrate distribution in space and time, and is a trophic response to herbivorous and omnivorous species that respond directly to river inflows to the bay. Temporal changes of spot indicated a major increase of young spot during the second year of the drought followed.

Micropogonias undulates

Young-of-the-year Atlantic croaker enter the bay during winter-spring months and are located mainly in East Bay and west of the river mouth. The larger forms move throughout the bay during summer months. There were no overt temporal trends of this species.

Appendix B: Fish Landings by County and Year for all Florida Counties except Walton

An Excel spreadsheet that shows pounds caught and trips made per Florida county for each year from 1998 to 2008, except for Walton County. The only county that was used in preparing this report was Franklin County because it encompasses all of Apalachicola Bay. This spreadsheet covers finfish, invertebrates, and shrimp, and also provides a grand total for landings. The Excel file is found under the name Appendix B for Apalachicola Bay Report.xlsx.

Appendix C: Apalachicola River Nutrient Loadings

This memorandum summarizes the analyses performed by HydroQual Inc. to assist in the development of TN and TP loads for the Apalachicola River, in order to support nutrient criteria development in Apalachicola Bay. While these analyses may not result in specific nutrient criteria values, the objective is to present an approach and corresponding results that can be used for the development of final values. Existing TN, TP, and flow data were analyzed and, considering flow to be an explanatory variable, long-term nutrient loads were estimated. In addition, Apalachicola Bay water quality data from ANERR's System Wide Monitoring Program were analyzed.

HydroQual Inc. June 23, 2010. *Apalachicola River nutrient loadings.* Technical memorandum prepared for the Florida Department of Environmental Protection, Tallahassee, FL.

Appendix D: Fish Kills Associated with *K. brevis* in Franklin County, 2001–June 21, 2010

Source: FWRI fish kill database
Note: Specimen count is the number of specimens found dead. Most of the sampling is carried out by members of the public, who call the FWRI fish kill hotline to report the dead fish.

Report Number	*Date Reported	City	*County	Call Category	*Probable Cause	Waterbody Name	Specimen Count	Comment
100901	10/9/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	40	Pompano, Trout
112401	11/24/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	99	Species Unknown–Also reporting respiratory irritation.
112501	11/25/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	200	Mullet–Beach at 10th St. West on St. George Island
112501	11/25/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	100	Mullet
112601	11/26/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	200	Mullet
112601	11/26/2001	Panama City	Franklin	Fish Kill	Red Tide	St. Andrews State Park	200	Mullet
112601	11/26/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	50	Whiting–Also reporting respiratory irritation.
112701	11/27/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	50	Mullet, Catfish–Also reporting respiratory irritation.
112801	11/28/2001	St George Island	Franklin	Fish Kill	Red Tide	St George Island	80	Catfish, Mullet
011202	1/12/2002	Alligator Point	Franklin	Fish Kill	Low dissolved oxygen	Alligator Point	200	Singerlands
091602	9/16/2002	Apalachicola	Franklin	Fish Kill	Red Tide	Gulf City Canal	100	Mullet–Near chemical plant, all along canal. Gulf City Canal
091902	9/19/2002	Apalachicola	Franklin	Fish Kill	Red Tide	St. Joseph Bay	200	Lizardfish, Pigfish,

								Pinfish, Gafftopsail, Catfish–Most decomposed, mouth gaping, no lesions, gasping.
091903	9/19/2003	Apalachicola	Franklin	Fish Kill	Red Tide	St George Island	100s	Bonnethead Shark, Needlefish, Hardhead Catfish– ½ mile west of Lighthouse.
092003	9/20/2003	Apalachicola	Franklin	Fish Kill	Red Tide	St George Island	100s	Flounder, Croaker, Whiting, Baitfish–Odor of red tide, respiratory irritation.
092003	9/20/2003	Apalachicola	Franklin	Fish Kill	Red Tide	St George Island	20	Flounder, Ladyfish–Was on St. George Island State Park 09/20/03. Saw several dozen small flounder and ladyfish washed ashore. Were dead but intact (not decomposed). Family and I started coughing.
092103	9/21/2003	Apalachicola	Franklin	Fish Kill	Red Tide	St George Island	5	Remora–I previously submitted a report and gave "pilot fish" as one of the dead fish species seen. That

								was incorrect, it was Remoras. There were 5 of them and they were all approximately 12 inches long.
092103	9/21/2003	Apalachicola	Franklin	Fish Kill	Red Tide	St Josephs Island	100	Flounder, Species Unknown–I was at St. George Island today and stunned at the dead fish and eels on the beach. I have gone there for years and never seen anything like this. They were continuing to wash in. There were even Pilot Fish.
092303	9/23/2003	St George Island	Franklin	Fish Kill	Red Tide	St George Island Beach	Unknown Count	Croaker, Pinfish, Unidentified Species–Has someone reported the fish kill yet?–Yes
041204	4/12/2004	East Point	Franklin	Fish Kill	Red Tide	St Joe Bay	12	Spot, Catfish, Spider Crab–FDEP is heading over there to do some counts and collect a few specimens.
041604	4/16/2004	East Point	Franklin	Fish Kill	Red Tide	St Joseph Bay	9	Red Drum, Shad–This kill already

								reported by FDEP.
006885	9/22/2004	East Point	Franklin	Fish Kill	Low dissolved oxygen	Chipley Creek	100s	Mullet
082505	8/25/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Dog Island	100s	Snapper, Red Drum, Black Grouper, Pinfish, Grunt–Due south of Dog Island 4 miles to 11 miles out.
082905	8/29/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Carrabelle to B Tower	200	Hog Snapper, Grunt, Grouper–Also east of Dog Island.
083005	8/30/2005	Alligator Point	Franklin	Fish Kill	Red Tide	Bald Point State Park	100s	Grouper, Horned Fish, Baitfish–Has 72 dead fish–sending water sample. Ocklocknee River–at mouth.
083005	8/30/2005	East Point	Franklin	Fish Kill	Red Tide	St Joseph Bay	Unknown Count	Shark, Grouper, Species Unknown–Reporting respiratory irritation.
083005	8/30/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	Unknown Count	Trout, Whiting, Puffer, Catfish, Eel, Redfish–Casa Del Mar to St George Island Plantation.
083005	8/30/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	1000s	Grouper, Redfish, Trout, Snapper, Grunt, Eel, Catfish–East

								Side Gorrie Drive.
09090105	9/1/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	20-100	Puffer, Grouper, Catfish, Species Unknown–Bad smell.
090405	9/4/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	1000s	Eel, Flounder, Catfish–Do not call–tourist–gone. Reporting eye and respiratory irritation.
090405	9/4/2005	St George Island	Franklin	Fish Kill	Red Tide	1 ½ Mi. State Park Entrance	1000s	Shark, Eel, Dolphin
090505	9/5/2005	East Point	Franklin	Fish Kill	Red Tide	St George Island Plantation	100	Species Unknown–The dead fish were seen on the bay side of St. George Island Plantation (west end).
090505	9/5/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	Unknown Count	Species Unknown–There are many large fish.
090605	9/6/2005	East Point	Franklin	Fish Kill	Red Tide	Little St George Island	3	Tiger Shark–We found the sharks washed up on the beach of Little St. George Island. The 3 were approximately 6 to 8 feet in length and partially decomposed. There has been an ongoing red

								tide event on the island, but the sharks were more decomposed than anything else.
090705	9/7/2005	East Point	Franklin	Fish Kill	Red Tide	St George Island Bay	20-100	Eel, Snapper, Grouper– Reporting respiratory irritation also.
091705	9/17/2005	Apalachicola	Franklin	Fish Kill	Red Tide	Crooked Island Sound	5547	Mullet, Red Drum, Sheepshead, Stingray, Trout, Jack Crevalle– Unbelievable number of dead and dying fish, many, many thousands. Other species included menhaden, scaled sardine, southern stargazer, sharksucker, flounder, spanish mackerel, king mackerel.
091805	9/18/2005	St George Island	Franklin	Fish Kill	Red Tide	Nick's Hole	1000s	Species Unknown– Fish are from small to medium size.
092605	9/26/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Carrabelle Beach	1000s	Redfish, Hammerhead Shark, Croaker, Puffer–3 miles south

								of Carrabelle. Ho Hum Travel Park.
092605	9/26/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Carrabelle Beach	1000s	Redfish, Sheepshead, Toadfish, Hammerhead Shark, Baitfish, Stingray, Baitfish
092605	9/26/2005	St George Island	Franklin	Fish Kill	Red Tide	St George Island	86	Mullet, Catfish, Batfish–Many dead fish there were on the beach. The smell was awful. Rough surf from Hurricane Rita helped wash much off the beach and the red tide was so strong.
092605	9/26/2005	St Teresa Beach	Franklin	Fish Kill	Red Tide	Alligator Point & FSU Marine Lab	Unknown Count	Bonnethead Shark, Stingray, Flounder, Pigfish
092805	9/28/2005	St George Island	Franklin	Fish Kill	Red Tide	Park Entrance	1000s	Flounder, Catfish, Red Grouper–Flounder are small.
092805	9/28/2005	Carrabelle	Franklin	Fish Kill	Red Tide	St George Sound	2002	Stingray, Grunt–The fish were washed up along the bank. Probably between 4 to 6 per foot of the shoreline. This Saturday,

								this was along the shore at my home.
092905	9/29/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Carrabelle Beach	100s	Red Drum, Mullet, Shark, Stingray, Species Unknown–Reporting respiratory irritation.
092905	9/29/2005	Carrabelle	Franklin	Fish Kill	Red Tide	Carrabelle Beach	306	Mullet, Red Drum, Shark–Went to beach myself and observed the dead fish. Can see dead fish all the way down the beach as far as you can see.
100105	10/1/2005	Carrabelle	Franklin	Fish Kill	Red Tide	St George Sound	20-100	Pinfish, Hammerhead Shark–Willing to take water samples.
100205	10/2/2005	Carrabelle	Franklin	Fish Kill	Red Tide	St George Sound	100s	Shark, Stingray, Pinfish, Red Drum, Mullet–A lot of sharks, but few rays.
100505	10/5/2005	Lanark	Franklin	Fish Kill	Red Tide	Dog Island	1000s	Stingray, Shark, Species Unknown–Would like us to collect samples.
100505	10/5/2005	Carrabelle	Franklin	Fish Kill	Red Tide	St George Sound	Unknown Count	Pinfish, Anchovy, Shark, Toadfish, Croaker, Gulf Flounder

100705	10/7/2005	St George Island	Franklin	Fish Kill	Red Tide	Plantation Airstrip	1015	Mullet, Trout–Small inlet from the bay near our house full of dead mullet and a few other species.
100705	10/7/2005	St George Island	Franklin	Fish Kill	Red Tide	Resort Vacation Properties	Unknown Count	Species unknown–I am not sure of how many or what kind.
101005	10/10/2005	St George Island	Franklin	Fish Kill	Red Tide	Randolf Tray Canal	100s	Mullet, Pinfish–Dead fish are mostly Pinfish. West of bridge.
101005	10/10/2005	Apalachicola	Franklin	Fish Kill	Red Tide	Alligator Bay	1000	Alewives–Noticed a red tide smell to the air.
110805	11/8/2005	East Point	Franklin	Fish Kill	Red Tide	West Pass–Apalachicola	25	Gar
082510	8/25/2010	Apalachicola	Franklin	Fish Kill	Low dissolved oxygen	Bayou Creek	40	Species Unidentified
082510	8/25/2010	Carrabelle	Franklin	Fish Kill	Low dissolved oxygen	Bayou Creek	40	Red Drum
082510	8/25/2010	Carrabelle	Franklin	Fish Kill	Low dissolved oxygen	Yents Bayou-Bayou Creek	20-100	Red Drum
060811	6/8/2011	Carrabelle	Franklin	Fish Kill	Algae Bloom	St. George Sound-Hidden Beaches Road	Unknown	Mullet
060811	6/8/2011	Carrabelle	Franklin	Fish Kill	Algae Bloom	Hidden Beaches	20-100	Unidentified Species
092811	9/28/2011	Apalachicola	Franklin	Fish Kill	Low dissolved oxygen	Scipio Creek	Unknown count	Spot

Appendix E: List of taxa collected during biological sampling in Summer 2012

Total number of taxa and total abundance are given at the bottom of each gear type.
Sampling trips April 24-25, 2012 and June 13-14, 2012.

Gear: Fyke Net		**Gear: Beach Seine**		**Gear: Beam Trawl**	
Taxa	**Abundance**	**Taxa**	**Abundance**	**Taxa**	**Abundance**
Paleomenetes spp.	17340	*Paleomenetes spp.*	670	Mysidacea	1135
Stephanolepis hispidus	5668	*Mnemiopsis mccraydi*	643	*Americamysis bahia*	992
Menidia spp.	658	*Lagodon rhomboides*	305	*Paleomenetes spp.*	338
Lagodon rhomboides	200	*Stephanolepis hispidus*	194	*Mnemiopsis mccraydi*	177
Leiostomus xanthurus	144	*Orthopristis chrysoptera*	159	Sciaenidae	162
Farfantepenaeus aztecus	128	*Farfantepenaeus aztecus*	116	Gastropoda	49
Orthopristis chrysoptera	114	Sciaenidae	100	*Farfantepenaeus aztecus*	36
Menidia beryllina	101	*Anchoa mitchilli*	95	Isopoda	18
Bairdiella chrysoura	96	*Bairdiella chrysoura*	93	*Nassarius vibex*	16
Mnemiopsis mccraydi	95	*Mulina* sp.	80	*Syngnathus scovelli*	10
Farfantepenaeus duorarum	51	*Leiostomus xanthurus*	72	*Menidia* spp.	9
Paguroidea	47	*Mugil* spp.	57	*Callinectes sapidus*	8
Gambusia holbrooki	45	*Menidia beryllina*	41	*Stephanolepis hispidus*	6
Mugil cephalus	23	*Cynoscion nebulosus*	29	Syngnathidae	6
Brevoortia spp.	22	*Anchoa hepsetus*	21	*Farfantepenaeus duorarum*	5
Callinectes spp.	21	*Syngnathus scovelli*	17	*Neritina reclivata*	5
Mugil spp.	20	*Anchoa* spp.	13	*Lagodon rhomboides*	4
Micropogonias undulatus	18	*Callinectes sapidus*	11	*Symphurus plagiusa*	4
Callinectes sapidus	15	*Oligoplites saurus*	11	*Bairdiella chrysoura*	3

Cynoscion nebulosus	10	*Callinectes* sp.	10	*Gammarus* spp.	3
Aluterus scriptus	8	*Synodus foetens*	8	Xanthidae	3
Myzobdella lugubris	8	Amphipoda	7	*Brevoortia* spp.	2
Trinectes maculatus	8	Isopoda	7	*Melongena corona*	2
Melongena corona	6	*Microgobius gulosus*	7	Mysidae	2
Neritina reclivata	6	*Hemiramphus brasiliensis*	6	Panaeidae	2
Xanthoidea	5	*Sciaenops ocellatus*	6	*Sphoeroides parvus*	2
Farfantepenaeus spp.	4	*Neritina reclivata*	5	*Syngnathus* spp.	2
Fundulus similis	3	*Paguroidea*	5	Xanthoidea	2
Myrophis punctatus	3	*Eucinostomus harengulus*	3	Amphipoda	1
Sciaenops ocellatus	3	*Eurypanopeus depressus*	3	*Anguilla rostrata*	1
Ariopsis felis	2	*Leander tenuicornis*	3	Bivalvia	1
Ctenogobius beleosoma	2	*Menidia* spp.	3	*Corophium* spp.	1
Gobiosoma bosc	2	*Brevoortia* spp.	2	*Cynoscion nebulosus*	1
Hypsoblennius hentz	2	*Hyppolyte zostericola*	2	*Eurypanopeus* spp.	1
Latreutes tucorum	2	*Latreutes fucorum*	2	*Leiostomus xanthurus*	1
Leander tenuicornis	2	*Lucania parva*	2	*Orthopristis chrysoptera*	1
Nassarius vibex	2	*Lutjanus synagris*	2	*Petrolisthes armatus*	1
Opsanus beta	2	*Micropogonias undulatus*	2	Polychaeta	1
Symphurus plagiusa	2	*Platybelone argalus*	2	*Sciaenops ocellatus*	1
Xanthidae	2	*Sphoeroides nephelus*	2	**Total Taxa= 39**	**Total Abundance= 3014**
Anchoa mitchilli	1	*Sphoeroides parvus*	2		
Chilomycterus spp.	1	*Caranx latus*	1		

Conus spp.	1	*Cirolina* sp.	1		
Cynoscion arinarius	1	*Eurypanopeus*	1		
Harengula jaguana	1	*Farfantepenaeus duorarum*	1		
Histrio histrio	1	*Hippocampus zosterae*	1		
Isopoda	1	*Latreutes parvulus*	1		
Lucania parva	1	*Libinia dubia*	1		
Menippe mercenaria	1	*Littoraria irrorata*	1		
Paleomonetes pugio	1	*Littorina* spp	1		
Poecilia latipinna	1	*Micropogonias* spp.	1		
Prinotus tribulus	1	*Opsanus beta*	1		
Rachycentron canadum	1	*Paralichthys albigutta*	1		
Sphoeroides parvus	1	*Petrolisthes armatus*	1		
Total Taxa= 54	**Total Abundance= 24904**	*Symphurus plagiusa*	1		
		Tozeuma carolinese	1		
		Xanthidae	1		
		Xanthoidea	1		
		Total Taxa= 58	**Total Abundance= 2835**		