Ecology of Pensacola Bay

Chapter 1 - Environmental Setting

Britta Hays

Introduction:

The climate, morphology and hydrodynamics of Pensacola Bay and its watershed greatly influences the presence and abundance of biological communities within the bay. Biological communities such as phytoplankton, seagrasses, marshes, zooplankton, benthos and fish respond to climate and hydrodynamic forcing.

Climate:

Pensacola Bay has a humid subtropical climate with generally warm temperatures (Thorpe et. al 1997). There is an average temperature of 11° C occurring in the coldest month, January, while the warmest months are July and August with an average temperature of 29° C. Winds are normally from the north/northwest in the fall and winter and the south/southwest in spring and summer. Annual rainfall varies from month to month and is heaviest in April, September and October and lightest in January, May and June. Annual precipitation ranges from 73-228 cm. The wettest years were 2005 and 2009 while the driest year was 2006. The warmest year was 2006 and the coolest was 2004 (NOAA). Hurricanes influence the area occasionally; the last major hurricanes were Ivan in 2004 and Dennis in 2005 which caused a great deal of damage to the area. The pattern of hurricane occurrence is about every five to ten years: Eloise(1975), Fredrick (1979), Elena (1985), Opal (1995), Ivan (2004), Dennis (2005) (NOAA).

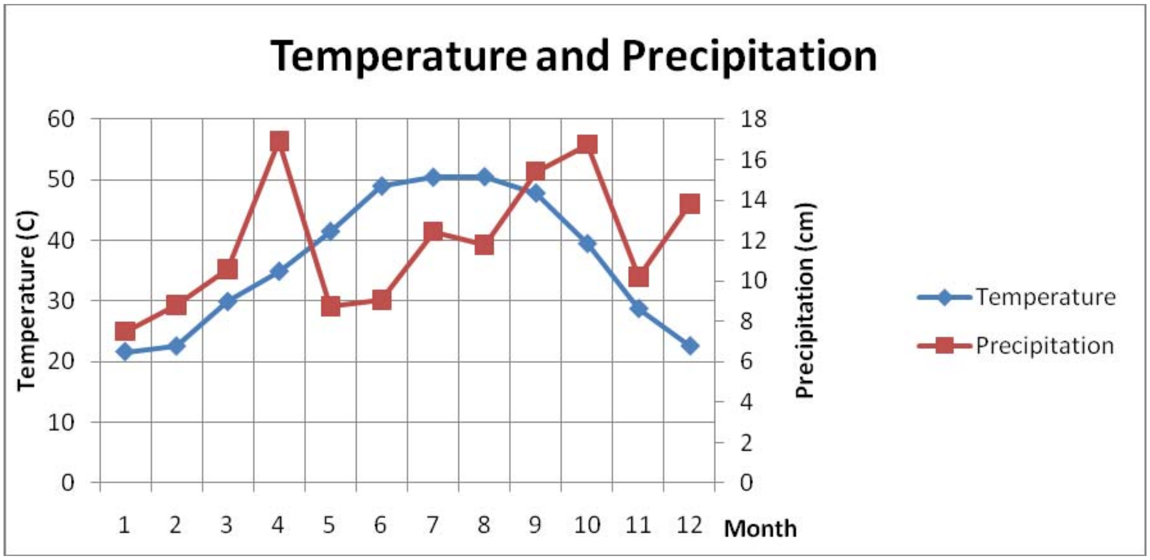

Figure 1-1. Average precipitation (cm) and temperature (° C) (NOAA)

Month	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Jan	10.67	13.05	14.44	11.72	10.33	11.83
Feb	10.95	14.33	12.44	11.67	13.44	12.28
March	17.50	15.33	17.39	17.28	15.22	16.94
April	18.61	18.17	22.28	18.83	19.56	18.89
May	18.44	23.22	24.39	23.72	24.22	24.33
June	24.11	26.72	28.17	27.56	28.44	28.33
July	26.72	28.17	28.72	27.89	29.00	27.67
Aug	27.72	27.89	28.28	29.39	28.39	26.78
Sept	26.78	27.83	25.50	26.89	26.22	26.22
Oct	26.17	21.22	20.61	22.11	20.00	21.50
Nov	17.83	17.33	14.72	15.72	14.83	15.33
Dec	11.11	11.44	13.06	14.72	13.94	10.94

Table 1-1. Temperature Averages (° C) (NOAA)

Month	2004	2005	2006	2007	2008	2009
Jan	3.86	6.60	7.59	10.13	16.87	3.78
Feb	23.50	11.56	9.55	6.40	14.07	11.20
March	2.41	32.84	0.61	5.23	5.99	18.75
April	7.29	62.13	8.41	9.86	8.89	12.29
May	2.34	4.95	8.89	2.95	8.38	27.23
June	29.24	17.96	1.47	5.46	16.26	13.23
July	22.25	19.13	10.85	17.09	14.12	13.51
Aug	16.10	17.55	12.27	6.50	11.89	22.50
Sept	19.05	18.03	24.97	11.20	12.45	25.88
Oct	9.17	0.23	7.16	44.30	20.19	28.65
Nov	23.50	18.97	10.21	12.60	7.01	12.32
Dec	17.96	11.84	12.98	14.94	8.31	34.93

Table 1-2. Precipitation in cm (NOAA)

Morphology:

Pensacola Bay is bounded with Escambia County to the west and Santa Rosa County to the east. The Bay can be divided into 5 major subsections: the bay begins on the west where Escambia River enters the bay and shares its southern boundary with Pensacola Bay. Pensacola Bay empties into the Gulf of Mexico at the Pensacola Pass. On the east side, the Blackwater River empties into Blackwater Bay which becomes East Bay. East Bay merges with Pensacola Bay at Garcon Point. Finally between the Gulf Breeze Peninsula and Santa Rosa Island is Santa Rosa Sound that connects with Pensacola Bay.

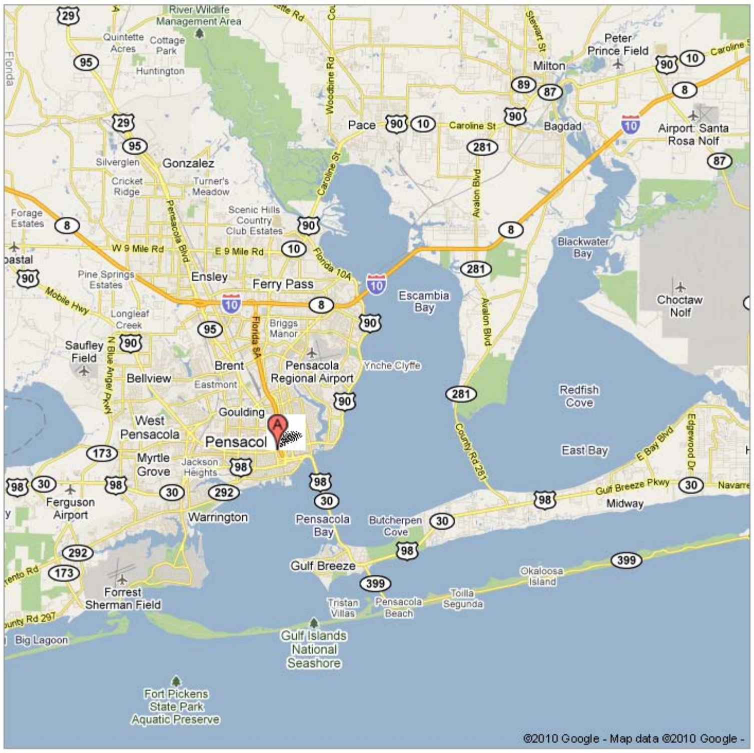

Figure 1-2. Pensacola Bay (Google Maps)

Pensacola Bay is a shallow estuary that can be considered either a coastal estuary or a drowned river estuary (Collard 1991). The mean depth ranges from 1.5 m in parts of Escambia Bay to 6 m in the channel in Pensacola Bay. The Pensacola Bay system has a surface area of 482.23 square kilometers (Mohrherr 2009).

Surface Areas and Mean Depth of Bays (Thorpe et al. 1997)		
Water Body	**Surface Area (sq km)**	**Mean Depth (m)**
Pensacola Bay	140.1	5.94
East Bay	113.7	2.41
Escambia Bay	93.24	2.44
Blackwater Bay	25.38	1.92
Santa Rosa Sound	109.81	2.71

Table 1-3. Surface area and depths of bays.

The soils in the region range from well drained sands that are located generally in the south of the watershed to poorly drained ones that are rich with organic matter and clays located in the north of the watershed (Thorpe et. al 1997). The Pensacola Bay system is underlain by Pleistocene terrace deposits overlying Tertiary beds of sand silt and limestone (Thorpe et. al 1997). The major aquifer is the Sand-and-Gravel Aquifer which feeds into river tributaries which feed into the bay (Thorpe et. al 1997). Sand and mud are deposited in the bay system are a result of erosion in the watershed. It is estimated the annual sediment load is 1.08 million metric tons/year (Thorpe et. al 1997).

Hydrodynamics:

The majority of the freshwater into the system comes from river input. A small fraction comes from rainfall and an even smaller fraction from stormwater runoff. Saltwater enters the system through the Pensacola Pass. Four rivers contribute freshwater to the system: Escambia River, Blackwater River, Yellow River, and Shoal River. The Escambia River is the dominant source of fresh river water to the bay. The Yellow River and the Shoal River combine and discharge into Blackwater Bay. Freshwater input from the four rivers ranges from the Escambia River at 178.3 cubic meters of water/second, making it the greatest source of freshwater, to the Blackwater River with 9.6 cubic meters of water/second, making it the smallest source.

River Discharge into the Pensacola Bay System (Thorpe et. al 1997)	
River	**Annual Discharge (cubic meters/ second)**
Escambia	178.3
Blackwater	9.6
Yellow	33.4
Shoal	31.2

T able 1-4 .River Discharge into Pensacola Bay.

The Escambia River is the major source of freshwater to the Pensacola Bay system. Average monthly discharge of the river changes from month to month. March is the month with the largest average discharge and September and October the least (USGS). This could correspond to precipitation in the watershed. Increased precipitation in the months preceding could cause a peak in river discharge.

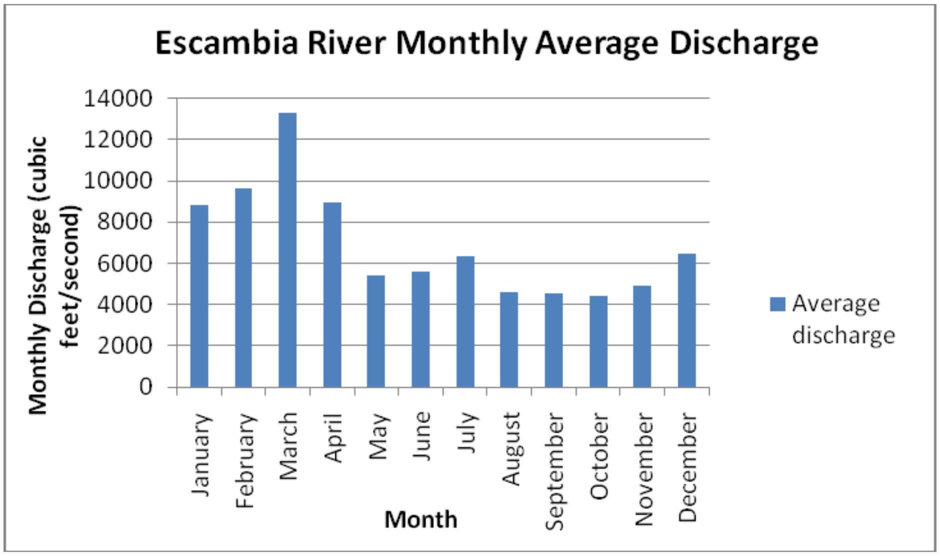

Figure 1-3. Escambia River average discharge at a USGS sampling site at the State Highway 184 bridge. (USGS)

The Pensacola Bay watershed is a microtidal system which means it has a tidal range of less than two meters (Collard 1991). Tides are diurnal and average .45m. The low tidal energy combined with the freshwater input into the system and the shallow depth sets up conditions for the water to be highly stratified. Water is fresher close to the mouth of the river and more saline at Pensacola Pass. In the summer, moderate freshwater river input along with little wind mixing, conditions leads to stratification in Escambia Bay (Hagey and Murrell 2007). In months when there was low freshwater river input, no stratification was present because saline conditions were present further north in the bay. In months with high freshwater input, stratification could be found but only further south in the bay because freshwater dominated the water column further south than during times of lower flow (Hagey and Murrell 2007).

Stratification is salinity dependent not temperature dependent (Hagy and Murrell 2007). In Pensacola and Escambia Bay, the surface water salinity is usually less than 10 and in the bottom layer more than two to three times as saline (Thorpe et al. 1997). When the stratification is present, conditions are ideal for bottom water hypoxia to take place in Escambia and Pensacola Bay because oxygenated waters at the surface do not mix with the hypoxic bottom waters (Hagy and Murrell 2007). Stratification and hypoxia can influence the biological communities in the bay. Extremes in salinity and dissolved oxygen could mean that only more tolerant species thrive. Hypoxia can also be a sign of phytoplankton blooms.

Pensacola Bay has unique features that are important to biological communities in the system. The system is a shallow estuary in a humid subtropical climate. Precipitation, temperature and hurricane occurrence vary from month to month and year to year. Freshwater input and low amplitude tides set up conditions for a highly stratified water column. This stratification can cause bottom water hypoxia. All of these conditions affect the system and the biological communities within them.

Chapter 2 – Plant Communities

Rachel Sharer

Salt marshes

Salt marshes provide a habitat plentiful of sea grasses, where many juvenile fish find protection from predators. Dominant species of flora in Florida salt marshes include *Juncus roemerianus*, black needle rush (Figure 2-1), *Spartina patens*, salt meadow cord grass (Figure 2-2), *Spartina alterniflora*, Smooth cord grass, (Figure 2-3) and *Cladium jamaicense*, sawgrass (Figure 2-4) (EPA). Dominant vegetation is variable dependent on plant ecology in different areas of the salt marsh. Black needle rush occurs along brackish water with higher marsh areas (EPA). Salt meadow cord grass thrives in more saline areas that often flood (EPA). Smooth cord grass is found in areas that are less likely to flood (EPA). Sawgrass is a freshwater plant that grows along the upper edge of a salt marsh. Pensacola Bay saltmarshes also include *Borrichia frutescens*, sea oxeye, *Fimbristylis cymosa*, hurricane grass, *Sporobolus vagrancies*, coastal dropseed, and *Distichlis spicata*, salt grass (EPA).

Figure 2-1. Black needle rush, *Juncus romerianus*
Photograph courtesy of Virginia.gov/

Figure 2-2. Saltmeadow cordgrass, *Spartina patens*

Figure 2-2. Smooth cordgrass, *Spartina alterniflora*
Photograph courtesy of Resource Enviornmental Solutions

Figure 2-4. Sawgrass, *Cladium jamaicense*
Photograph courtesy of Jeffrey Pippin Duke.edu

Seagrass beds

Thalassia testudinum, turtle grass, (Figure 2-5) is an important dominating species in the PBS (Lewis et al., 2008). It is the most abundant plant found within the PBS (Lewis et al., 2008). In October, 2003 sea grass coverage was an estimated 4,085 acres, with 76% of the total coverage occurring in Santa Rosa sound, 5% in Big Lagoon, 1% in Pensacola Bay and less than 1% in Escambia Bay and East Bay (Lewis et al., 2008). Factors that were predicted to have an effect on turtle grass include point and nonpoint source contaminants, prop scarring, dock shading, armored shorelines, and dredging (Lewis et al., 2008).

The PBS has a wide array of seagrass species. However, this information comes from various sources, several which are from unpublished data. Therefore a cumulative study for PBS seagrass beds and saltmarshes, like fisheries data, is also in dire need.

Figure 2-5. Turtle Grass, *Thalassia testudinum*
Photograph courtesy of Phillip Collay

Chapter 3 – Water Column Nutrients and Plankton

Jessie Rosenbaum

Nutrients

Freshwater runoff is the major source of nutrients to the Pensacola Bay System (PBS), particularly the Escambia River, the largest source of freshwater. Therefore, seasonal and spatial patterns should exist in nutrient concentrations. However, nutrient concentrations in the PBS are spatially similar across the system and demonstrate weak seasonal patterns relative to episodic and interannual variation. Nutrients measured during various studies throughout the PBS include dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), and dissolved silicon (DSi), in freshwater sources and the bay. Average DIN is 4.9 uM, average DIP is 0.6 uM, and average DSi is 6.3 uM (Murrell et all, 2002a). Nutrient data can be found in Tables 3-1 and 3-2. Freshwater flow strongly influences nutrient concentrations in the PBS. During a flood, DIN and DIP fluxes can increase 10 to 20 fold over baseline (Murrell et al, 2007). In the summer, DIN concentrations decrease quickly with increasing distance from the Escambia River. Uptake of DIN is also strongest during the summer and weakest during winter and spring, based on conservative mixing (Murrell et al, 2007). Spatial and seasonal patterns of DIP are not as distinct, but appear to follow a similar pattern. Silicon concentrations correlate to temperature and salinity, suggesting that silicon comes from a freshwater source, likely the Escambia River, which may lead to seasonal and spatial variability in diatom communities (Juhl, Murrell, 2008). During the winter and spring when uptake of DIN and DIP is low, nutrient concentrations follow conservative mixing. Departures from conservative mixing in the summer months are controlled more by phytoplankton uptake than freshwater inputs (Murrell et al, 2007).

Researchers have demonstrated both potential nitrogen and phosphorus limitation of primary production in Pensacola Bay with temporal variability. The Redfield ratio is an ideal of ratio of nitrogen and phosphorus for phytoplankton production. DIN:DIP ratios above the Redfield ratio indicate the system is potentially phosphorus limited and DIN:DIP ratios below the Redfield ratio indicate the system is potentially nitrogen limited. Average DIN:DIP in the bay varies above and below the Redfield ratio, possibly because of seasonal variation in river inputs (Table 3-2, Murrell et al, 2002a). Murrell's study in 1998 and 1999 found potential phosphorus limitation in the PBS, even though DIN:DIP ratios were usually below the Redfield ratio (Murrell et al, 2002a). The potential for phosphorus limitation does not imply that phytoplankton are experiencing nutrient stress. Other studies have found nitrogen limitation with high DIN:DIP ratios. In both studies there was potential for nutrient limitation, with no evidence of true nutrient stress.

Table 3-1. DIP, NO3, and chl measurements from fall 2009

Distance from Escambia River (km)	DIP (uM)	Chl (ug/L)	NO3 (uM)
0	0.37		14.4
18.35	0.17	3.56	11.1
20.01	0.11	7.82	6
21.83	0.08	10.61	2.5
25.32	0.06	7.03	0
26.13	0.07	5.21	0
30.35	0.08		1
33.36	0.08	4.5	
39.73	0.08	3.68	
45.26	0.06	2.78	

Table 3-2. Annual and seasonal DIP, DIN, and DIN:DIP ratios for 1999, 2000, and 2001 (Adapted from Murrell et al 2007).

	DIN (mmol/m3)			DIP (mmol/m3)			DIN:DIP		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
Winter		9.1	7.2		0.47	0.06		19.4	110.8
Spring		4.4	4.1		0.38	0.15		11.6	36.3
Summer	6.4	2.7	3.3	0.34	0.38	0.07	19.9	7.1	58.3
Fall		3.5	3.3		0.17	0.05		21.4	67.4
Annual		4.9	4.5		0.35	0.08			68.2

Phytoplankton

In the upper estuary, cyanobacteria abundance peaked in the summer, exceeding $3E^{10}$cells/L. Net phytoplankton abundance was $6.0E^{5}$ cells/L. Diatoms dominate the larger size fraction; the most common genera being Thalassiosira, Pennales, and Cyclotella. Chlorophytes, cryptophytes, and dinoflagellates were also present (Murrell, Lores 2004) (Table 3-3).

Livingston found that the diatom *Cyclotella choctawhatcheeana* was the most abundant species, followed by the dinoflagellate *Prorocentrum cordatum*. Overall, phytoplankton densities were lowest in the winter and highest in late summer. By contrast, species richness peaks during fall and spring and is lowest in summer and winter (Livingston, 1998). This could be due to competition between phytoplankton species or zooplankton feeding patterns and preferences.

Table 3-3. Dominant phytoplankton taxa and relative abundances from Murrell and Lores (2004).

Taxa	**Abundance (x 10^3/L)**
Thalassiosira	150
Pennales	119
Cyclotella	43
Chlorella	35
Chroomonas	31
Procentrum	24
Thalassionema	23
Fragilariaceae	21
Chlorophyceae	19
Chlorococcaceae	16
Nitzschia	19
Gymnodinium	12
Chaetoceros	12
Coscinodiscus	9.3
Plagioselmis	5.1
Chlamydomonas	4.3
Navicula	3.2
Cryptophyceae	3.0
Skeletonema	2.9
Selenastrum	2.8
Lyngbya	2.8

Chlorophyll concentrations follow patterns in primary productivity. Chlorophyll is higher is the summer and lower in the winter and spring. The average chlorophyll in the upper bay is 8.2 ug/L (Murrell et al, 2002a).

Cyanobacterial abundances were strongly correlated with temperature. Near the mouth of the Escambia River, cyanobacterial concentrations were much lower, suggesting that cyanobacteria enter the estuary from the Gulf of Mexico. In size fractionation studies during warmer summer months, about 90% of the chlorophyll is associated with cells of <5 um, primarily cyanobacteria (Murrell et al, 2007). Chlorophyll concentration is lowest closest to the Escambia River because cyanobacterial abundances are lowest near the river. In the 2004 Murrell and Lores study, chlorophyll concentrations averaged 6.8 ug/L. Temperature has a large influence on community composition, with cyanobacteria abundance increasing with temperature. Nutrient concentrations also affect composition and chlorophyll concentrations because phytoplankton under nutrient stress can decrease the amount of chlorophyll contained in the cell body.

Zooplankton

The zooplankton community in Pensacola Bay is dominated by *Acartia tonsa*, which is commonly found in similar estuaries. During the winter, zooplankton biomass reaches a minimum of 1.4 ug C/L and in May a maximum of 34.1 ug C/L. Zooplankton production ranges from 0.3-27.5 ug C/L/day, with the lowest production when water temperatures were lowest (Murrell, Lores, 2004). During the summer months, the zooplankton community shifts toward *Oithona* sp. It also includes *Balanus* sp., *Oikopleura* sp., *Clausicalanus furcatus,* and *Podon* sp.

Since this shift corresponds with increases in cyanobacteria, it may be caused by changes in food sources for the zooplankton. Nanoplankton, like the cyanobacteria, are too small to provide an efficient food source for macrozooplankton. *Acartia tonsa* may become food limited after exerting heavy grazing pressure on the larger phytoplankton, allowing the community composition to shift. However, microzooplankton grazing is a significant sink for phytoplankton production (Murrell et al, 2002b). The seasonal and spatial variation in grazing impact is small.

Chapter 4 – Benthos

Kendra Straub

Benthic microalgae production and biomass can be high in shallow, euphotic estuaries like Pensacola Bay. The benthic microalgae of estuarine habitats have often been reported to have patchy distribution or micro-heterogeneity of biomass and production attributed largely to variations in light and temperature (Allison, 2000). Benthic microalgae, microphytobenthos, periphyton, and biofilms communities in Pensacola Bay are dominated by Bacillariophyceae

(Allison, 2000). Microphytobenthos may also include chlorophytes, cyanophytes, and other photoautotrophic taxa that can be locally dominant in algal mats (Allison, 2000). In many estuaries, light limits production, but this is not the case in Pensacola Bay. Pensacola Bay has low turbidity and high light penetration indicating that primary production occurs through much of the water column and benthos (Murrell, 2009). In fact, Allison (2000) found that the average photic depth of Pensacola Bay is approximately 5 m, meaning that 78% of the bay could potentially support microphytobenthos production (Figure 4-1). Cloud cover and the associated decrease in light reduces benthic primary productivity by an order of magnitude (Allison 2000) compared to benthic primary productivity during times of little cloud cover. Benthic algae are photosynthetically efficient and have not been shown to saturate at high light levels (Figure 4-2).

Figure 4-1. Percentage of incident light reaching the bottom of Pensacola Bay. From Murrell (unpublished data) (Allison 2000).

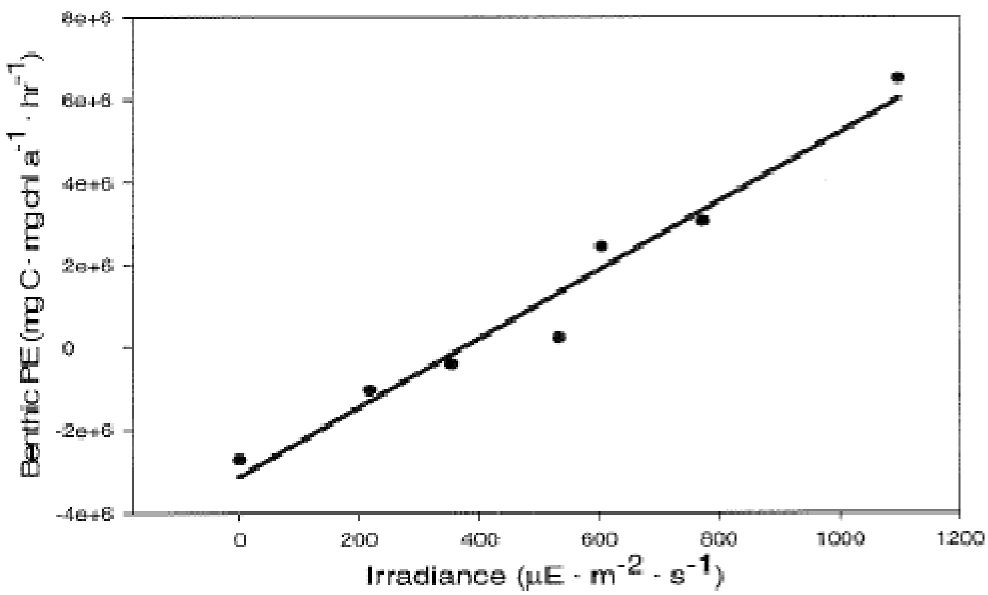

Figure 4-2. Benthic photosynthetic efficiency response to irradiance intensity (Allison 2000).

Pensacola Bay benthic productivity was estimated to account for between 16 and 32% of total system gross production (Murrell et al. 2009). Benthic production can vary across location in an estuary. Murrell et al., (2009) found that benthic production accounted for a higher percentage of integrated production in shoal sites than in channel sites (28% and 0.7% respectively). Not surprisingly, based on the high chlorophyll a concentrations (ranging from 1.12 to 19.65 µg g^{-1}) in wet sediment (Table 4-1), Smith and Caffrey (2009) found that benthic microalgae were abundant in the shallow sediments of Escambia Bay, while the lowest concentrations of chlorophyll a were seen at the deepest sites (Smith, Caffrey 2009).

High benthic productivity is typical of shallow areas of estuarine systems, particularly in temperate and tropical latitudes (Murrell et al 2009). On the whole, Allison (2000) found that Pensacola Bay has relatively low overall productivity coupled with a relatively low benthic respiration rate (Figure 4-3), which they attribute to the proportionally large area of sandy sediments with low organic levels. The high net ecosystem metabolism in Pensacola Bay is maintained by high light levels and low nutrient inputs (Murrell et al. 2009). In addition to light, other physical factors such as storms and resulting freshwater intrusion can also affect microalgae. Storm events in the estuarine systems can result in decreased benthic respiration and dramatic loss in production (Allison 2000). For example, Allison (2000) found that microphytobenthos production and biomass decreased following major storm events because of resuspension of sediments reducing light levels.

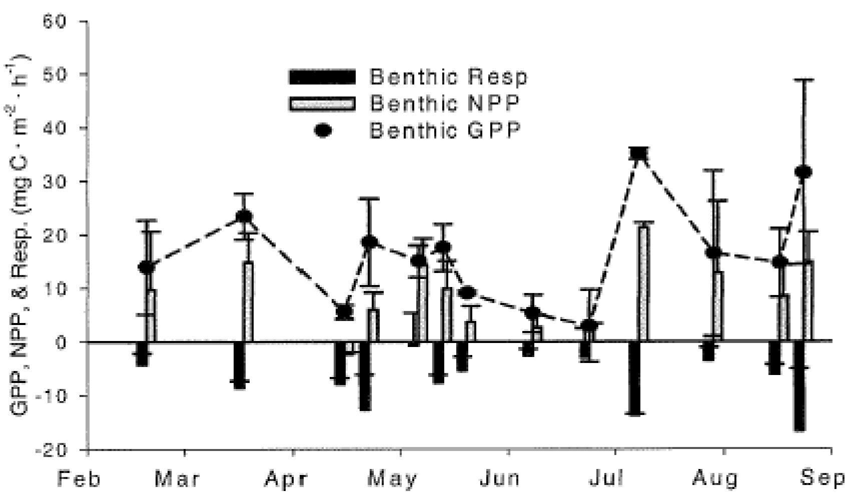

Figure 4-3. Benthic microalgal net and gross production and respiration during 2005 (February through April) (Allison 2000).

Table 4-1. Chlorophyll a and physical parameters of channel and shoal sites (Smith and Caffrey, 2009).

Site	Depth (m)	Secchi (m)	Chla (μg/l)
Channel 1	2.62	0.75	12.9
Channel 2	2.74	1	16.6
Channel 3	4.27	2.25	4.4
Channel 4	5.7	1.52	4.4
Shoal 1	1.34	1	26.8
Shoal 2	1.37	0.95	5.1
Shoal 3	1.25	0.8	13.5
Shoal 4	0.91	0.91	0.6
Shoal 5	1.52	1.41	0.6
Shoal 6	2.9	1.22	1.3

In addition to physical factors, nutrients can control primary productivity. Nutrients can come from a variety of sources including the Escambia River which is the main freshwater source to the Pensacola Bay system (Murrell et al. 2007). Freshwater flow strongly influences the flux of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) into Escambia Bay (Murrell et al. 2007). Time series of DIN and DIP distributions have shown higher concentrations in the upper Pensacola Bay which decrease along the estuarine gradient (Murrell et al. 2007). Benthic fluxes are driven by concentration gradients between the overlying water and porewater (Smith, Caffrey 2009). They are an important factor in sustaining high productivity (Smith, Caffrey 2009) and represent recycling of nutrients within the system. Phosphate is also a key nutrient to algal production. The Pensacola Bay system is a net sink for phosphorus because of algal uptake and phosphorus adsorption onto minerals (Murrell et al. 2009). The cycling of phosphorus in this system is complex and may need further study before the pathways of DIP are understood (Murrell et al. 2009). Allison (2000) found that nitrogen and phosphorus were co-limiting benthic microalgal production in the portion of the bay he studied (Butcherpen Cove).

The organisms living in the benthos are an important component of the estuarine ecosystem. Macroinvertebrates alter geochemical conditions at the sediment-water interface, promote decomposition and nutrient cycling, and transfer energy to other food components (Brown et al. 2000). Different systems are characterized by different communities of benthic dwellers. Dominance by different macrobenthic trophic groups suggests differences in food-resource and food web interactions, and may be indicative of differences in ecosystem-level processes (Brown et al. 2000). Benthic communities of northern Gulf of Mexico estuaries are usually characterized by burrowers that live near the sediment-water interface and few deep-burrowing species (Brown et al. 2000). The main concentrations of infauna and epibenthic macroinvertebrates have been observed in the relatively shallow areas including upper Escambia Bay and Blackwater Bay that receive direct runoff from regional river system (Livingston 1999). Infaunal species richness peaks in the high salinity sections of Pensacola Bay (Livingston 1999). In general, researchers have found relatively low overall biomass of infauna, epibenthic invertebrates, and fishes in the Pensacola Bay system (Livingston 1999). Livingston, in a 1999 study, found the three dominant species of infaunal macroinvertebrates in the Pensacola Bay system to be *Mediomastus ambiseta*, *Streblospio benedicti*, and *Lepidactylus sp.* (Livingston 1999). Murrell et al. (2009) found the most abundant species to be *Mediomastus ambiesta, Tubificidae sp., and Paraprinonspio pinnata* (Table 4-2). The spatial distribution of the infaunal macroinvertebrate biomass (Figure 4-4) follows that of the nutrient loading and chlorophyll a concentrations of the system, which indicates a direct response of biomass to increased nutrient loading (Livingston 1999). The dominant epibenthic macroinvertebrates include brown shrimp (*Penaeus aztecus*) and blue crabs (*Callinnectus sapidus*) (Livingston 1999). The species richness of this group is low in areas identified to have point sources of pollution (Livingston 1999). Species distribution (Figure 4-5) can be affected by predation and other interspecies interactions. For example, penaeid distribution is inversely related to infaunal biomass which could indicate feeding on the infauna since penaeid shrimp are predators on infaunal groups (Livingston 1999).

Table 4-2. Phylum, class, order, family, genus, species and average abundance of the dominant species collected from sites in Pensacola Bay (2003-2004) (Murrell et al. 2009).

Phylum	Class	Order	Family	Genus	Species	Average Abundance
Annelida	Polychaeta		Capitellidae	Mediomastus	ambiseta	887
Annelida	Clitellata	Haplotaxida	Tubificidae	Tubificidae		507
Annelida	Polychaeta	Canalipalpata	Spionidae	Paraprionospio	pinnata	502
Annelida	Polychaeta		Capitellidae	Mediomastus		401
Annelida	Polychaeta	Canalipalpata	Spionidae	Streblospio	benedicti	380
Mollusca	Bivalvia			Bivalvia		126
Nemertea				Nemertea		123
Mollusca	Bivalvia	Nuculoida	Nuculanidae	Nuculana	acuta	100
Annelida	Polychaeta	Aciculata	Pilargidae	Sigambra	tentaculata	87
Annelida	Polychaeta	Aciculata	Goniadidae	Goniadides	carolinae	78
Annelida	Polychaeta		Capitellidae	Mediomastus	californiensis	78
Annelida	Polychaeta		Opheliidae	Travisia	Hobsonae	75
Annelida	Polychaeta		Orbiniidae	Leitoscoloplos	fragilis	73
Annelida	Polychaeta	Aciculata	Pilargidae	Sigambra	bassi	70
Arthropoda	Malacostraca	Cumacea	Bodotriidae	Cyclaspis	varians	65
Chordata	Cephalochordata		Branchiostomidae	Branchiostoma		65
Mollusca	Bivalvia	Veneroida	Veneridae	Veneridae		62
Annelida	Polychaeta		Cossuridae	Cossura	delta	57
Arthropoda	Malacostraca	Amphipoda	Haustoriidae	Acanthohaustorius	uncinus	49
Annelida	Polychaeta	Aciculata	Pilargidae	Parandalia	americana	46

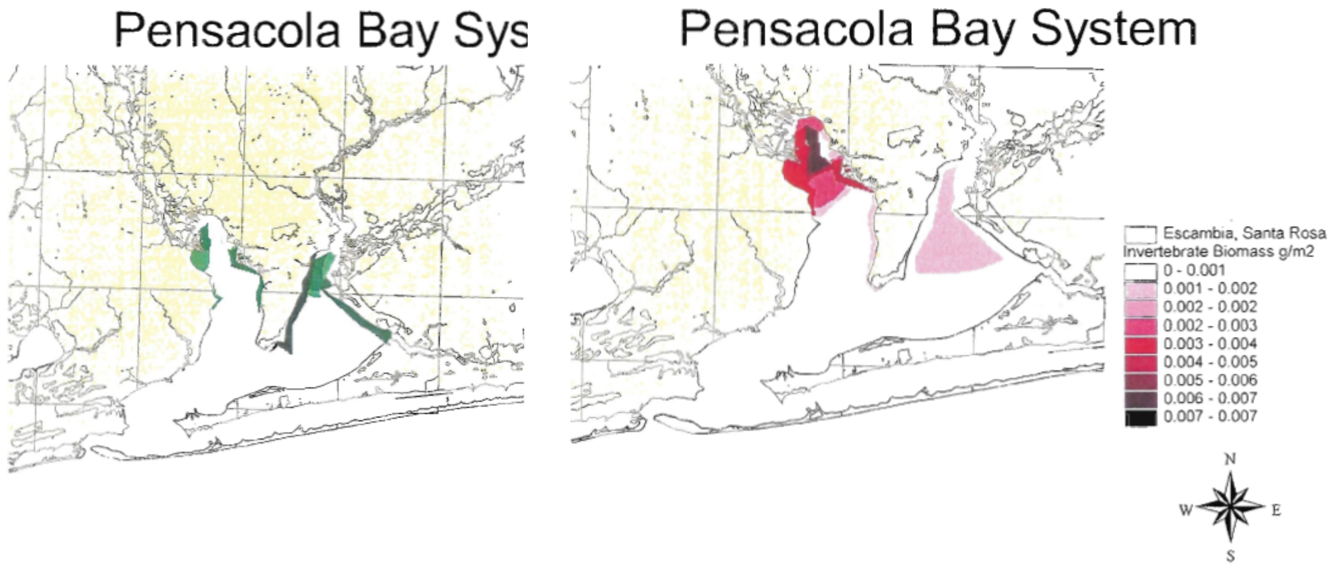

Figure 4-4. Maps of the distribution of infaunal biomass and invertebrate biomass (g/m2) in the Pensacola Bay system. Data was taken at quarterly intervals (June 1997, September 1997, December 1997, March 1998) (Livingston 1999).

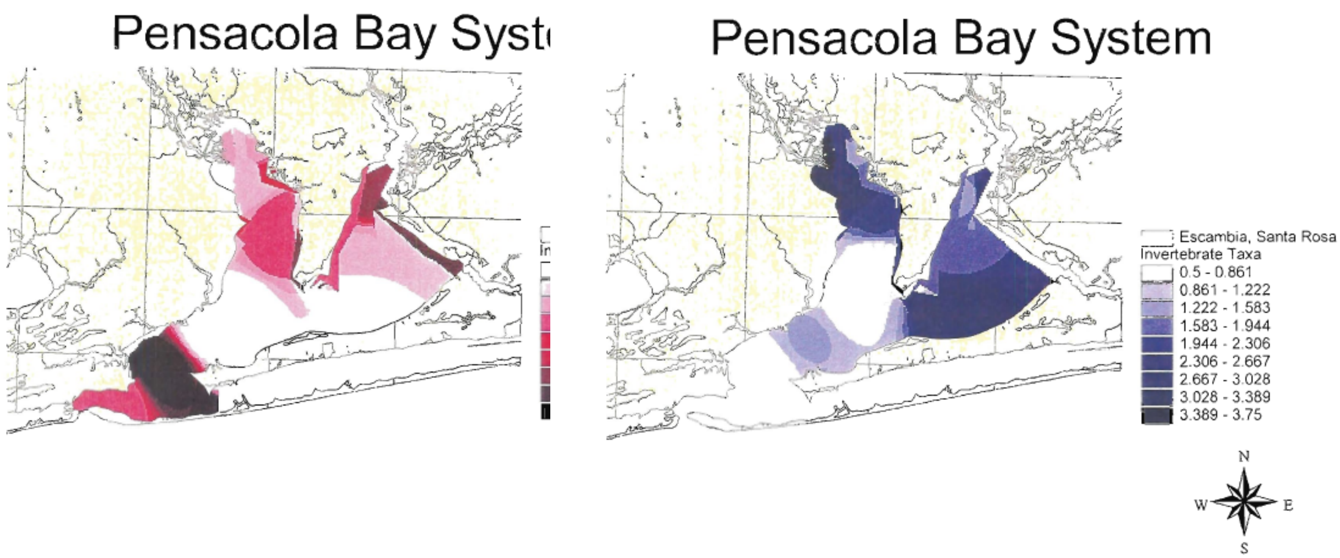

Figure 4-5. Maps of distribution of the number m^{-2} of infaunal macroinvertebrates, and epibenthic invertebrates (Livingston 1999).

The Pensacola Bay system includes various sediment types that affect the benthos living in the area (Figure 4-6). In general, the sediments from the deeper parts of the estuary are finer grained and have larger detrital carbon components than the sands from more shallow areas (Murrell et al. 2009; Smith and Caffrey, 2009). Macrobenthic community trophic structure varies along selected environmental gradients, most notably sediment type, in which greater proportions of deposit feeders and fewer suspension feeders are expected with increasing silt-clay content (Brown et al., 2000).

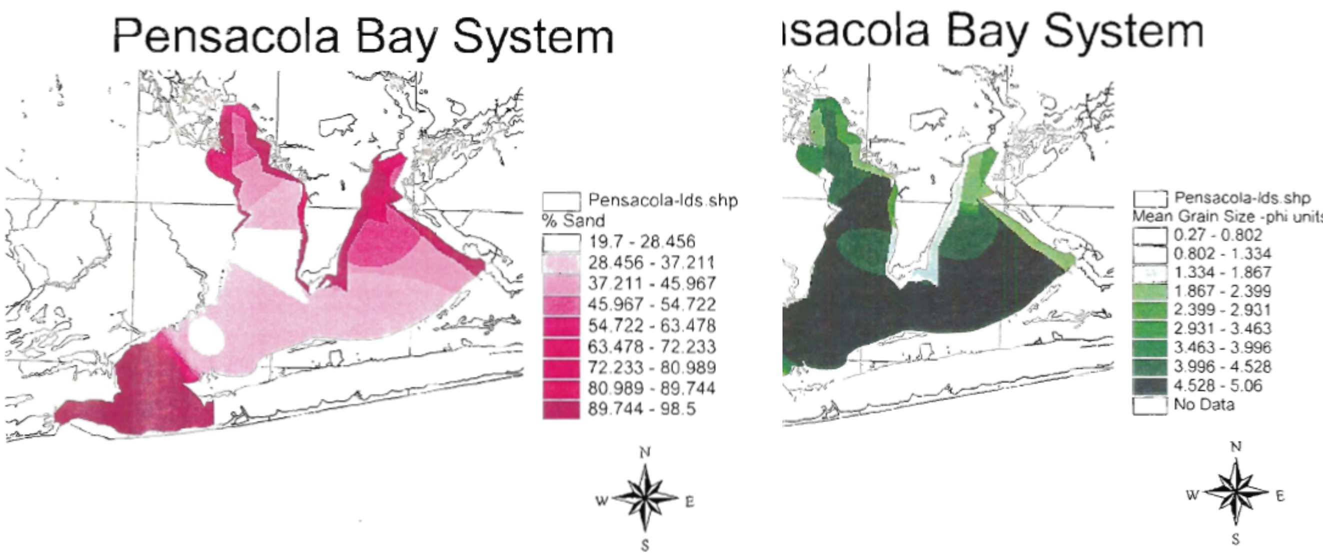

Figure 6. Sediment analysis of Pensacola Bay. Data includes % sand and mean grain size (phi units) (Livingston 1999).

Many contaminants such as polychlorinated biphenals (PCBs), metals, and polyaromatic hydrocarbons (PAHs) can be associated with the sediment. When these contaminants partition into sediments, it creates a potential source for organism exposure (Brown et al., 2000). Benthic organisms are relatively sedentary and therefore cannot escape the contaminants present within the sediments that they reside on or within (Rakocinski et al. 1997). Brown et al. (2000) found a significant negative correlation between sediment contaminant (PAH and metals) concentration and benthic trophic diversity. In general, increasing levels of contamination favor larger populations of short-lived opportunistic taxa, smaller body sizes, and fewer large deep-dwelling species (Rakocinski et al. 1997). The richness and biomass of macrobenthic species are highest in stable, undisturbed communities and grade to depauperate in unstable, disturbed areas (Gaston et al., 1998). Reduction in taxonomic richness and trophic diversity can indicate a shift in the benthic community function that may be important for material cycling and decomposition (Brown et al. et al. 2000). Different taxa respond to sediment contamination to varying degrees. For example, Gaston et al. (1998) found that subsurface deposit feeders such as the polychaetes species *Mediomastus californiensis,* dominate contaminated sites in Gulf of Mexico estuaries. This dominance suggests that certain trophic groups have a tolerance for contaminants (Gaston et al. 1998). Subsurface deposit feeders may acquire this tolerance as a result of their relationship with the sediments, including bioturbation and subsequent flux of contaminants (such as metals) (Gaston et al. 1998). Pensacola Bay has a large percentage of contaminated sites according to a study conducted by Engle and Summers (1999). This level of contamination indicates that a similar pattern would exist in Pensacola Bay.

Pensacola Bay has a natural sensitivity to hypoxia, or the reduction in dissolved oxygen (Murrell et al. 2009). Increased nitrogen inputs can contribute to algal blooms which, may lead to bottom water hypoxia and anoxia, benthic species mortality, and elimination of nitrification (Smith and Caffrey 2009). When evaluating seasonal patterns in benthic macrofaunal abundance in a Gulf of Mexico estuary, Flemer et al. (1998) found that the depauperate status of the upper bay were largely explained by low dissolved oxygen. Yet, high light conditions in Pensacola Bay are sometimes capable of supporting primary production which can offset respiratory oxygen demand and reduces the occurrence of such low oxygen conditions (Murrell et al. 2009). This disparity could be explained by the fact that the upper bay was just one of the many sites sampled by Murrell et al. (2009), while many of the sites were sandy, which have relatively low benthic respiration rates.

Small scale dredging which can also have an effect on water and sediment quality has occurred in Pensacola Bay (Lewis et al. 2000). Areas in the Pensacola Bay system, such as Bayou Texar and the Escambia River channel, have undergone dredging in the past (Lewis et al. 2000). Surprisingly, dredging events in shallow bayous have not been found to be major factors in environmental condition (Lewis et al. 2000). This may be due to the fact that urbanized bayous are continuously impacted by development in their watersheds (Lewis et al. 2000).

Information gained from monitoring benthic macroinvertebrate communities has been widely used to measure the status and trends in the ecological condition of estuaries (Engle and Summers 1999). Short-term disturbances such as hypoxia and long-term disturbances such as sediment contamination affect the population and dynamics of benthic communities (Engle and Summers 1999). By summarizing the composition and diversity of benthic invertebrates, benthic indices have been developed to characterize environmental quality of estuaries (Engle and Summers 1999). Assessing the ecological status of Pensacola Bay is problematic due to its overall signs of degraded sediment quality (Engle and Summers 1999). For example, Engle and Summers (1999) categorized 90% of the Pensacola Bay sites as degraded with severely contaminated sediments occurring throughout the bay. Overall, Pensacola Bay is characterized by high light levels reaching the sediments which support high benthic production (Murrell et al. 2009) and a depauperate invertebrate community (Engle and Summers 1999).

Chapter 5 – Fish Communities

Rachel Sharer

The Pensacola Bay System (PBS) has been significantly underrepresented in fisheries research. Most research in the Pensacola, Florida, area is focused on fish in the Gulf of Mexico, but not specifically for the PBS. Thus, the fish species that reside in PBS are estimates based on the surrounding areas. Knowing what species reside in the Bay, where their habitat is, and their ecology, is important for protection. Further research is imperative to assess distribution of fish species in the PBS.

Two major studies have reported fish abundance and composition in the PBS (Livingston, 1999; Stevenson, 2007). The most comprehensive study of fish communities on the PBS is in Livingston (1999). The study had sample sites located around the entire PBS (Figure 5-1). However, a second study (Stevenson, 2007) on the PBS sampled only two study sites and was dominated by a completely different group of species. The study sites included an open water site (OW) and a non-vegetated marsh edge (NVME) (Figure 5-2). An open water site has a sand bottom and no vegetation (Stevenson, 2007). A non-vegetated marsh edge has an open sand bottom within 10m of marsh vegetation (Stevenson, 2007). Livingston (1999) only reported on the dominant species found, while Stevenson (2007) reported on all species found throughout the study.

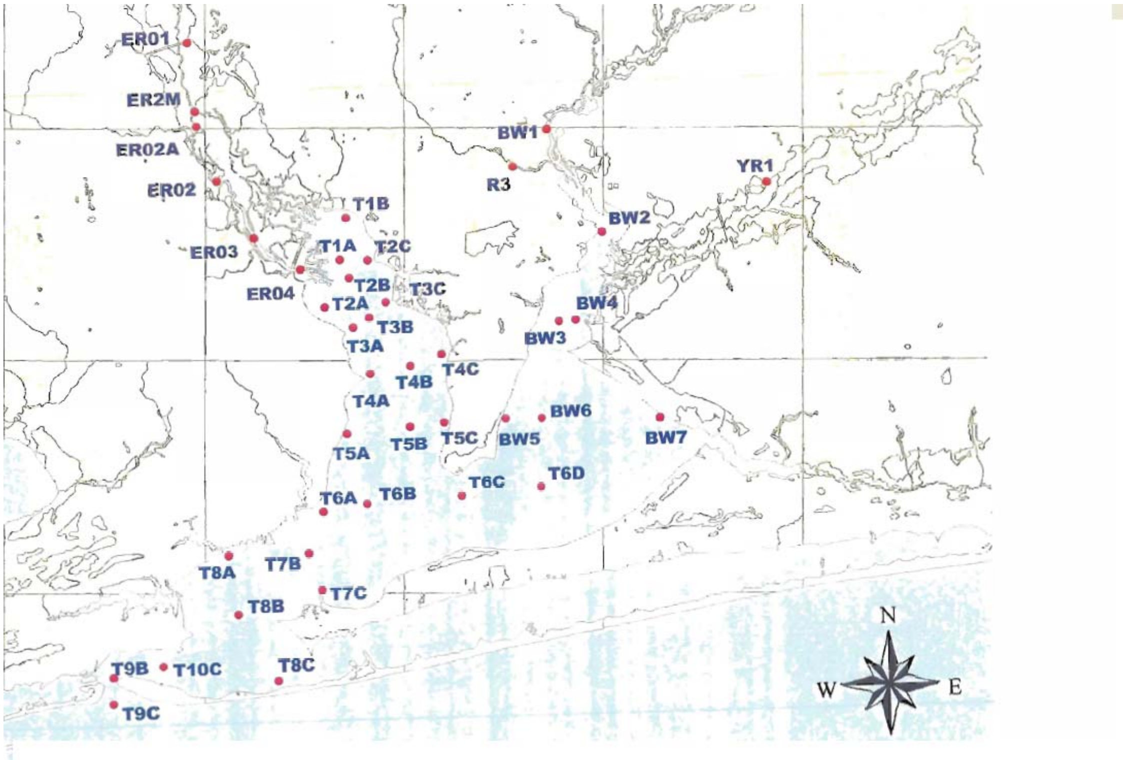

Figure 5-1. The study sites used around the Pensacola Bay System by Livingston(1999).

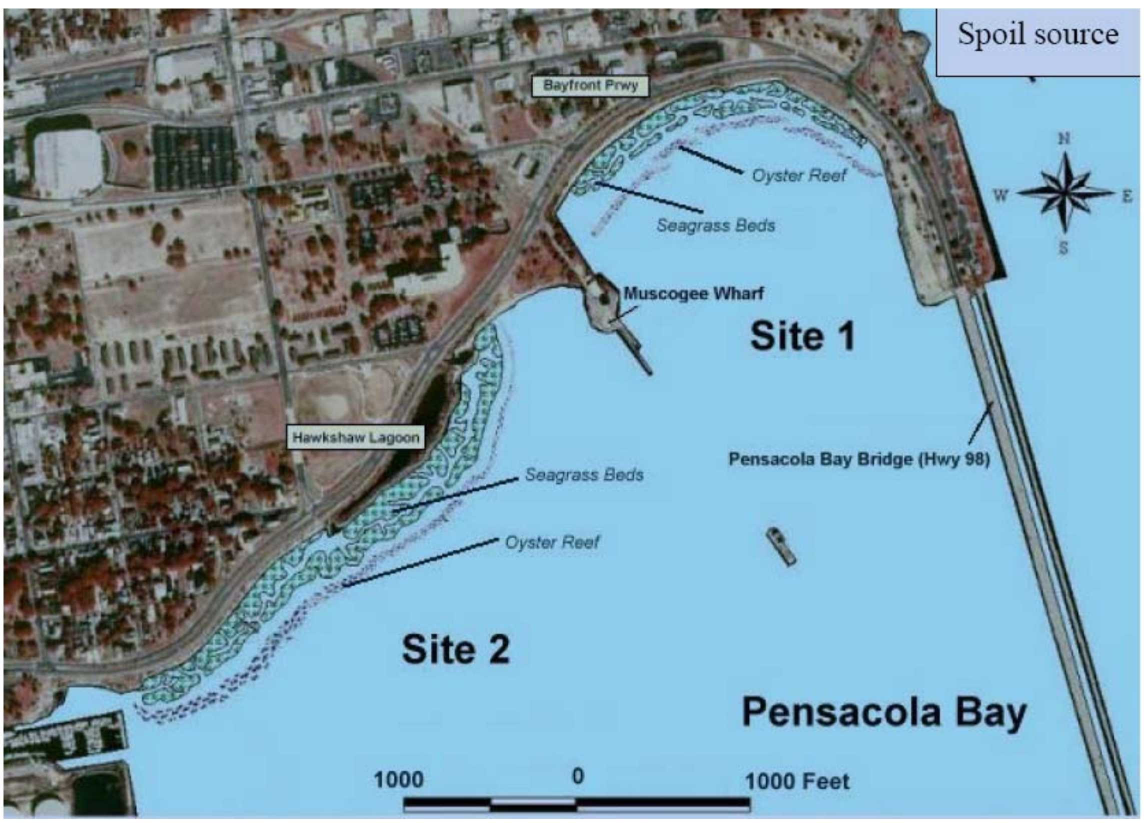

Figure 5-2. The study sites used in the Pensacola Bay System by Stevenson(2007).

The dominant species found in Livingston (1999) were *Leiostomus xanthurus* (Spot, Figure 5-3), *Micropogonias undulates,* atlantic croaker (Figure 5-4), *Brevoortia patronus,* gulf menhaden (Figure 5-5), *Chloroscombrus chrysurus*, atlantic bumper, Figure 5-6), and *Anchoa mitchilli,* bay anchovy (Figure 5-7) (Livingston, 1999). Highest fish biomass was found in central parts of upper Escambia Bay (Figure 5-8 and 5-9; Livingston, 1999). Two dominant species, spot and Atlantic croaker, were located in central and upper Escambia bay, in deeper water during the summer and fall, and in the lower part of the bay during spring (Figure 11; Livingston, 1999). The third most abundant fish, gulf menhaden, was also found throughout Escambia bay and in East bay during spring (Livingston, 1999). Bay anchovies were prevalent throughout the year in upper Escambia Bay (Livingston, 1999). Atlantic bumper appears only in the fall, but dominates western Escambia Bay (Livingston, 1999). This part of the bay is historically affected by more anthropogenic activity than other areas of the bay (Livingston, 1999). The activity in the western Escambia Bay could signify that Atlantic bumper is an indicator of anthropogenic stress (Livingston, 1999).

Figure 5-3. Spot, *Leiostomus xanthurus*
Photograph courtesy of Smithsonian Environmental Research Center

Figure 5-4. Croaker, *Micropogonias undulates* Photograph courtesy of Smithsonian Environmental Research Center

Figure 5-5. Gulf menhaden, *Brevoortia patron* Photograph courtesy of Garold W. Sneegas

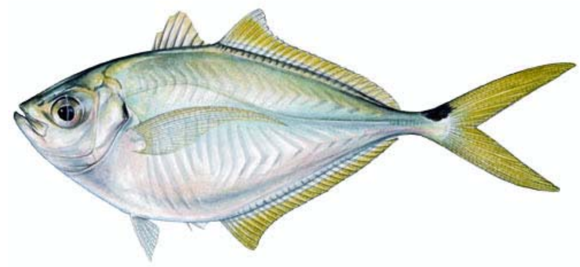

Figure 5-6Atlantic bumper, *Chloroscombrus chrysuru* Florida sportsfishing.com

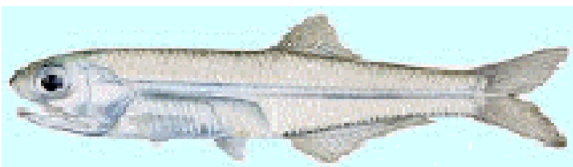

Figure 5-7. Bay Anchovy, *Anchoa Mitchili* photograph courtesy of Diana Peebles FWC

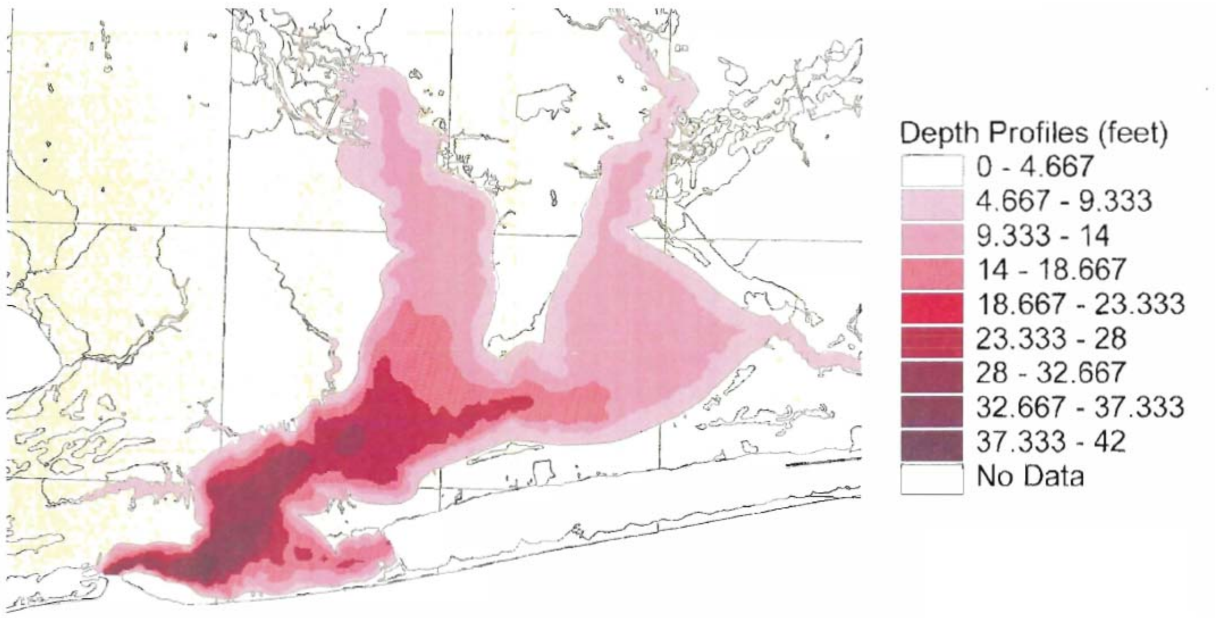

Figure 5-8. Depth distribution around the Pensacola Bay System (Livingston, 1999).

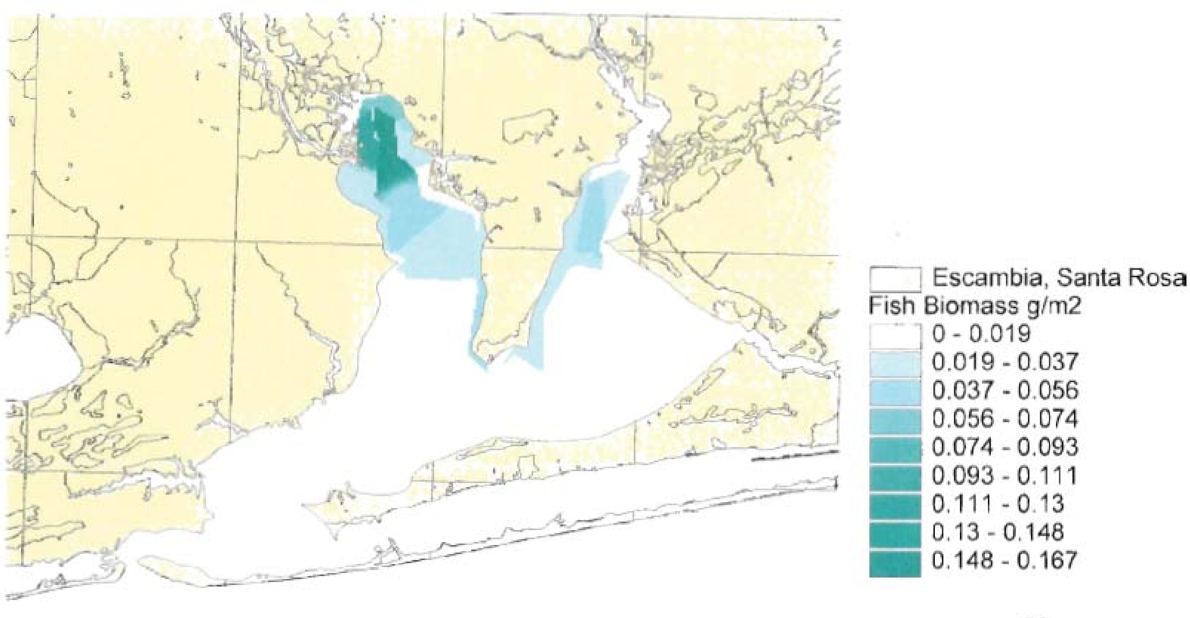

Figure 5-9. Fish biomass distribution in the Pensacola Bay system (Livingston,1999).

In the second study, in which fish were sampled from the OW and NVME sites, four fish were continually the most abundant (Figure 5-2). They were *Mugil cephalus*, striped mullet,(Figure 5-10), *Menidia peninsulae*, tidewater silverside, (Figure 5-11), spot, and *Lagodon* *rhomboids*, pinfish, (Figure 5-12) (Stevenson, 2007). Out of 34 species caught, the remaining species made up 5% of the overall catch (Stevenson, 2007). Fish abundances were low between May to December, but increased in January, when young of the year (YOY) started to appear (Stevenson, 2007). Spot varied in abundance related to spawning (Stevenson, 2007). The spot YOY appeared throughout the spring, until the population decreased in April and June (Stevenson, 2007). Striped mullet were found in large numbers at both sampling sites (Stevenson, 2007). Abundance of this species peaked in March and declined in late spring and summer (Stevenson, 2007). One of the few species which preferred the open water site was tidewater silverside (Stevenson, 2007). Silversides were captured irregularly, but numbers peaked in the month of January (Stevenson, 2007). Catch rates were consistent throughout the year for pinfish, except in the winter when catch rates were zero (Stevenson, 2007). Pinfish were much less abundant than the other three most commonly found fish (Stevenson, 2007).

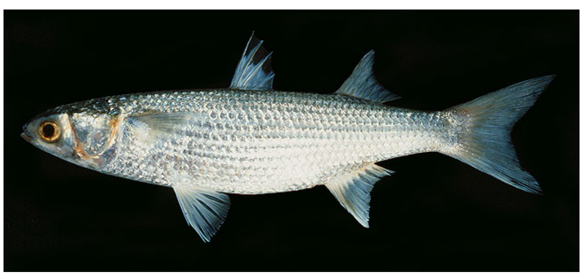

Figure 5-10. Striped Mullet, *Mugil cephalus* photograph courtesy Randall, J.E. 1997 Fishbase.org

Figure 5-11. Tidewater silverside, *Menidia peninsulae* Photo fishbase.org Howell, W.M. and Jenkins, R.L.

Figure 5-12. Pinfish, *Lagodon rhomboides*
Photograph courtesy of Sanford Biology Department

The United States Environmental Protection Agency has sampled the PBS for selected years. The data is unpublished, but begins in 1992, 1996, and continues with 2000-2004. In 1992 and 1996 the most abundant species caught was atlantic croaker (EPA Storet). Atlantic bumper was the most abundant fish in 2000 for Escambia Bay and Pensacola Bay (EPA Storet). Bay anchovy was one of the most abundant fish found in all years, except 2002 (EPA Storet). Spot were in highest abundance for Escambia Bay 2003 data (EPA Storet). The 2004 data shows mojarras, *Eucinostomus spp.,* to be plentiful in Pensacola Bay (EPA Storet). These data were taken yearly, however; they were never taken consistently from the same part of the PBS. Therefore, the data are still highly variable and it is difficult to see fish distribution and abundance.

Mullet are a prominent species of the PBS and food to the southern US (Anderson, 1958). They have a cosmopolitan distribution and can tolerate salinities from 113 ppt to freshwater (Odum, 1970). Mullet are an important part of the food chain and are unique due to their herbivorous diet. Adults will ingest sediment to help with the digestion of plant and detritus material. However, juveniles will feed on small larval fish and plankton (Odum, 1970). They move offshore to spawn between the months of October to February, with a peak in December

(Odum, 1970;Anderson, 1958). Juvenile mullet live offshore until they reach 18 to 28mm, and by the end of their first year they will reach a standard length near 160mm (Anderson, 1958).

Bairdiella chrysoura, silver perch (Figure 5-13), while not as abundant as other species previously discussed, are in the family Sciaenidae. The members of this family are important to commercial and recreational fisheries. Silver perch spawn in estuarine areas, spawning occurs several times in one season (Grammer et al., 2009). Spawning season occurs between March and May (Grammer et al, 2009). The maximum size and age of silver perch is 171 mm standard length and 4 years old (Grammer et al., 2009). However, the majority of the population is year class 1 or 0 (Grammer et al., 2009). Most of the population matures by the end of year zero (Grammer et al., 2009). Silver perch feed in a diel pattern, occurring from 12am-12pm (Waggy et al., 2007.) Their diet consists of invertebrates, such as copepods and mysid shrimp (Waggy et al., 2007).

Figure 5-13. Silver Perch, *Bairdiella chrysoura* Photograph courtesy of NSW Primary Industries

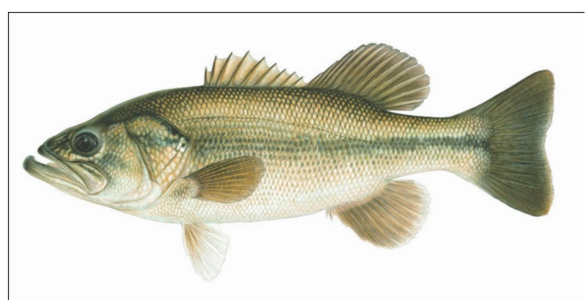

Figure 5-14. Largemouth bass, *Mirtopercus salmoides* Photograph courtesy of US Army Corps of
Engineers Nashville district

Trophic level was shown to be influenced by the distribution of species abundance throughout the PBS. Herbivores were found mostly in upper Escambia Bay and the shallow eastern portion of East Bay (Figure 5-8; Livingston, 1999). They were positively associated with clay in the Blackwater-East Bay system, as well as sediment and organics in Escambia Bay

(Livingston, 1999). Omnivores were present in deep upper Escambia Bay, as well as Blackwater Bay (Livingston, 1999). Primary carnivores, feeding on herbivores and detritvores, were prevalent in shallow areas of Escambia Bay, as well as in the Blackwater-East Bay system (Figure 5-8; Livingston, 1999). In Escambia Bay, primary carnivores were positively associated with clay and silt in Escambia Bay (Livingston, 1999). Secondary carnivores, who feed on herbivores and primary carnivores, and tertiary carnivores, which feed on primary and secondary carnivores and omnivores, thrived in deeper areas of upper Escambia Bay (Livingston, 1999). In Blackwater-East Bay system, secondary carnivores were positively associated with dissolved oxygen (DO), sediments, organics and clay (Livingston, 1999). This relationship shows that primary carnivores were associated with herbivores; secondary carnivores were associated with primary carnivores, and tertiary carnivores were associated with secondary carnivores (Livingston, 1999). It also demonstrates that fish were positively associated with certain areas of the bay based on trophic level (Livingston, 1999).

Pensacola Bay has been affected by anthropogenic effects that have exposed fish communities to a variety of contaminants from multiple sources. Fish collected during the demolition of the I-10 bridge include *Archosargus probatocephalus* (Sheepshead), *Cynoscion nebulosus* (white trout), *Micropogonias undulates* (croaker), and mullet (Mohrherr et al., 2009). Fish were collected and samples tested for trace metals, dioxins/ furans and poly-carbonated biphenyls (PCB's) (Mohrherr et al., 2009). Eight of the samples exceeded Environmental Protection Agency (EPA) standards, with the highest being in mullet (Mohrherr et al., 2009).

Bioaccumulation of contaminants, primarily PCBs and mercury, were measured in mullet and *Mictopercus salmoides,* largemouth bass, (Figure 5-14) by the University of West Florida's Center for Environmental Diagnostics and Bioremediation (CEDB). They began sampling with mullet and largemouth bass from various areas around the Bay. These fish were likely chosen because of either their consumption rate or abundance. The results from the largemouth bass showed levels of mercury and PCBs that exceeded US EPA recreational fisher screening values safe for human consumption with mercury levels exceeding US EPA standards in 17 out of 21 locations sampled (Snyder and Karouna-Renier, 2009). PCB content was low for largemouth bass in all areas except the Escambia river delta (Snyder and Karouna-Renier, 2009). While sampling in lower Escambia, near a historical point source, CEDB found PCB levels to exceed 65 times the amount measured in upper Escambia River (Snyder and Karouna-Renier, 2009). Older largemouth bass had higher levels within their tissues, indicating bioaccumulation (Snyder and Karouna-Renier, 2009). However, PCBs were only found at sites to have known historic PCB contamination (Snyder and Karouna-Renier, 2009). All mercury concentrations for mullet were low (Snyder and Karouna-Renier, 2009). PCBs were above EPA standards in both Escambia Bay and Escambia River for mullet (Snyder and Karouna-Renier, 2009).

Species of fish within the PBS can be estimated with a compilation of all the studies mentioned. Several of the studies overlap in several of the species reported, but overall each of the reports is highly variable. Fish abundance reporting was also inconsistent. To get a proper estimate of species within the PBS, a study is needed that combines location, habitat and time of year.

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