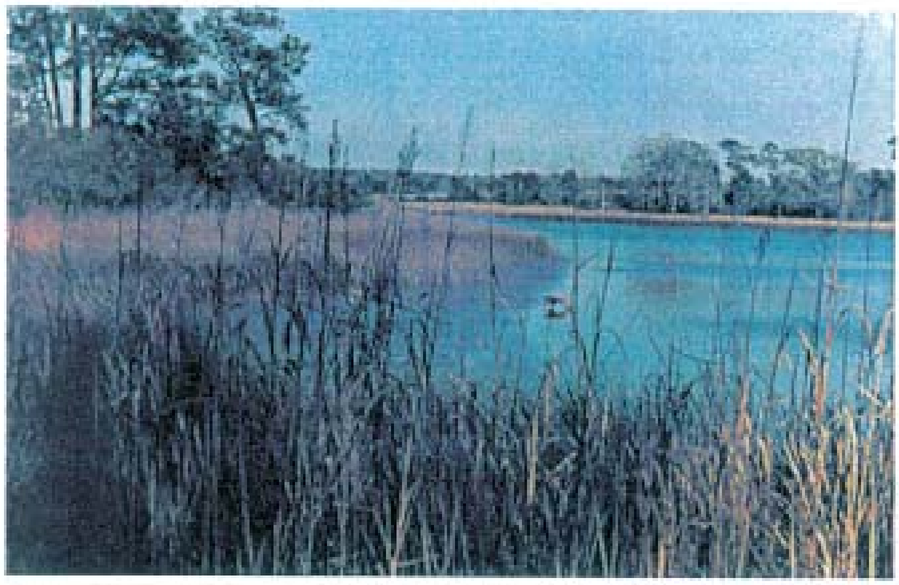
Weeks Bay National Estuarine Research Reserve: An Estuarine Profile and Bibliography



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Editors

Dauphin Island Sea Lab Technical Report 96-01

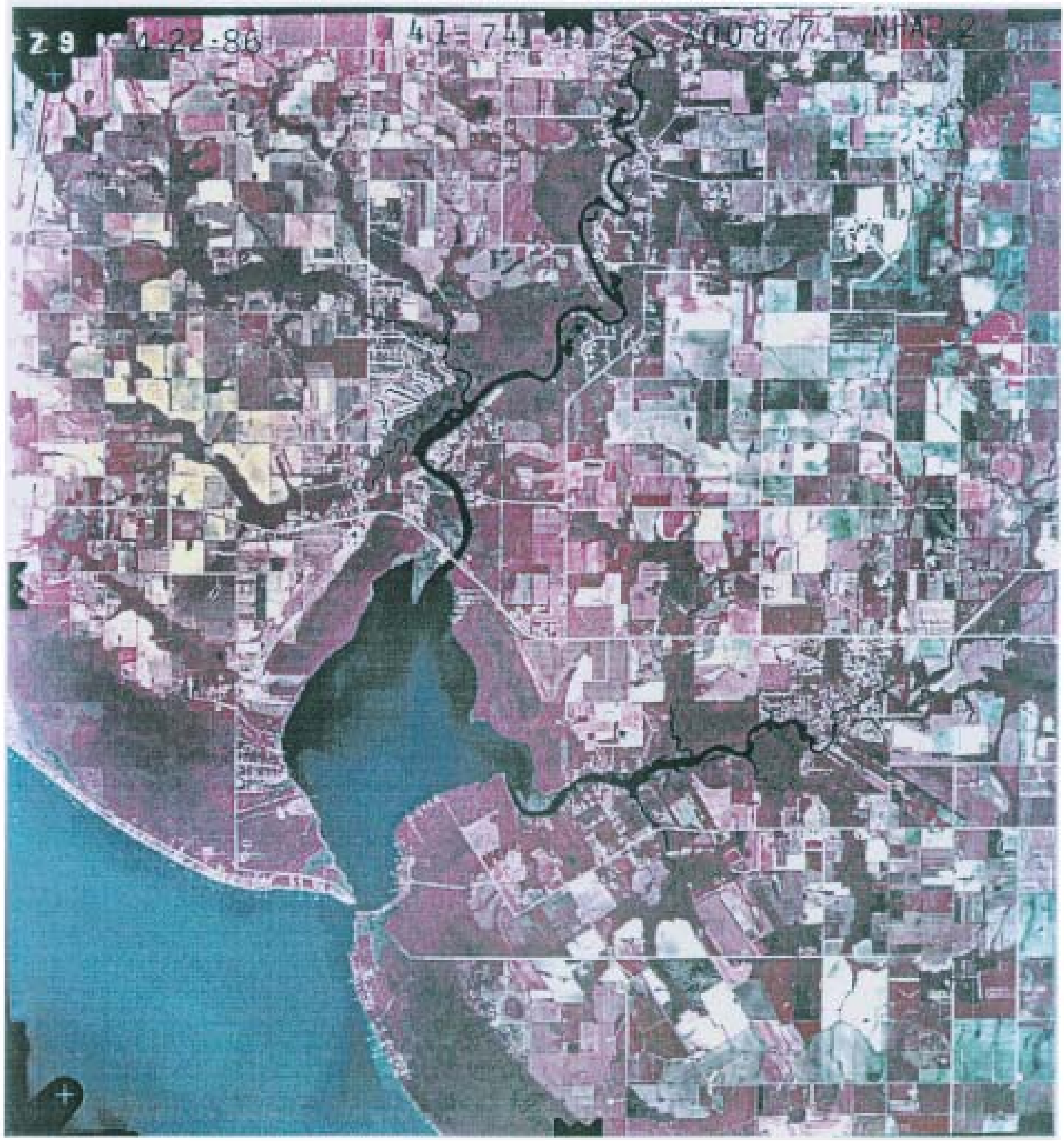
WEEKS BAY
NATIONAL ESTUARINE RESEARCH RESERVE

Dauphin Island Sea Lab
Alabama

NOAA

State Lands Division
Alabama Department of
Conservation
& Natural Resources

Frontpiece



Aerial photograph of the Weeks Bay National Estuarine Research Reserve
April 22, 1986
(1 in = 1 mile)

Acknowledgments

The Weeks Bay National Estuarine Research Reserve is part of the National Estuarine Research Reserve System, established by Section 315 of the Coastal Zone Management Act, as amended. Additional information about this system can be obtained from the Sanctuaries and Reserves Division, Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, US Department of Commerce, 1305 East-West Highway, Silver Springs, Maryland 20910. This profile was prepared under contract NA370R0413.

A great many people have been helpful in the location and retrieval of information concerning the Weeks Bay National Estuarine Research Reserve and the Weeks Bay watershed. These include S.R. Heath, M.S. Van Hoose, and Major J. Waller of the Alabama Dept. of Conservation, Marine Resources Division, P. Harper of the U.S. Fish and Wildlife Service, Dr. G. Regan of Springhill College, Mobile, Alabama, B. Harbour of Bishop State Community College, Mobile, Alabama and S. Brown, Alabama Department of Environmental Management. C. Wood and J. Cowan of the Dauphin Island Sea Lab assisted in preparation of portions of the document. We thank Dr. K. Heck, Dauphin Island Sea Lab, L. Goldman, United States Fish and Wildlife Service and Dr. C. Way, Barry A. Vittor and Associates, Mobile, AL for reviewing this document.

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Preface

The designation of the Weeks Bay National Estuarine Research Reserve recognized the Weeks Bay ecosystem to be of value from both educational / public resource and scientific / research perspectives. Population growth and concomitant development has increased in coastal regions nationwide and is occurring in south Baldwin County, Alabama. In light of the increased pressure on and increased visibility of the Weeks Bay resource, it was deemed necessary to summarize what is known, and perhaps more importantly, what is not known about the Weeks Bay ecosystem. The objective of this document, therefore, is to synthesize the many sources of information, including scientific, historical, social and political information, concerning Weeks Bay.

We have written this profile of the Weeks Bay system to be read and understood by all interested parties, including concerned citizens, monitoring groups, management agencies and scientists interested in Weeks Bay or other estuarine systems. To this end, we have chosen to refer to specific plants and animals by their common names, excluding *Genus species* designations from the text whenever possible. A list of common names and their *Genus species* equivalents is included in Appendix 1.

The last chapter of the document presents a summary of the overall ecology of the Weeks Bay system, a synopsis of information which is lacking and recommendations for research directions and management issues which need to be addressed to preserve the Weeks Bay National Estuarine Research Reserve for future generations.

Section 1: Background and Environmental Setting

Chapter 1: History of the Weeks Bay National Estuarine Research Reserve

by John L. Borom and Tina Miller-Way

During the late 1960's and early 1970's, widespread concern arose over the disturbing trends in coastal waters throughout the country: pollution of coastal waters, closing of shellfish beds, draining of marshes, and other man-induced damage to valuable and productive estuarine systems. The United States Congress passed the Coastal Zone Management Act of 1972, which included the National Estuarine Sanctuary Program (NESP). Congress designated the National Oceanic and Atmospheric Administration (NOAA) responsible for administering the program and working with states in establishing estuarine sanctuaries. Amendments in 1986 changed the name of this program to the National Estuarine Research Reserve System (NERRS).

The goal of the NERRS program is to establish and manage, through federal-state cooperation, a national system of reserves representing different coastal (biogeographic) regions and estuarine types that exist in the United State and its territories. The reserves are to be used primarily for long term scientific and educational purposes and resource protection. Sanctuaries provide relatively undisturbed areas for research and education and as controls against which impacts of man's activities on other areas can be assessed, thus providing information essential to coastal zone management decision making. The NERRS program authorizes funds in the form of 50% matching grants to states for acquiring significant estuarine areas, developing and operating research facilities and conducting educational programs.

The chronology leading to the establishment of the Weeks Bay National Estuarine Research Reserve has been documented by Simms (1989). Her chronology is based upon examination of federal and state documents and personal interviews. The following synopsis is based upon her summary as well as examination of the personal correspondence of some of the parties involved.

The early history of the establishment of the Weeks Bay National Estuarine Research Reserve is linked with that of the Bon Secour National Wildlife Refuge. In the middle and late 1970's, The Nature Conservancy (TNC) purchased several large ecologically sensitive tracts of land in Baldwin County and assisted the United States Department of the Interior in establishing Bon Secour National Wildlife Refuge. One of these tracts, a 615 acre plot known as the Swift tract lying just southeast of the mouth of Weeks Bay, was slated to be incorporated into Bon Secour National Wildlife Refuge. With the proposed extension of the Refuge onto the Fort Morgan Peninsula, US Fish and Wildlife Service requested the deletion of all areas outside of the core of the proposed refuge, namely that on the north shore of Bon Secour Bay / Mobile Bay, including the Swift tract. Discussion regarding the disposition of this land prompted a number of local, TNC and federal agency personnel to propose the formation of an estuarine sanctuary.

In 1980, TNC approached the State of Alabama and agreed to donate the 615 acre Swift tract (Fig. 1) on Bon Secour Bay to the state if the state would apply to have Weeks Bay designated as an estuarine sanctuary. In 1981, the Alabama Coastal Area Board (CAB) applied for a $10,000 grant from NOAA to initiate the evaluation and site selection process. Late in 1981, TNC agreed to include an additional 157 acre plot, known as the Ogburn tract (Fig. 1), in the donation. In the fall of 1982, TNC purchased the Foley tract, a 178 acre plot lying on the northeast shore of Weeks Bay, which would also come to form part of the initial Reserve holdings. Weeks Bay was chosen in Spring, 1982, by the CAB

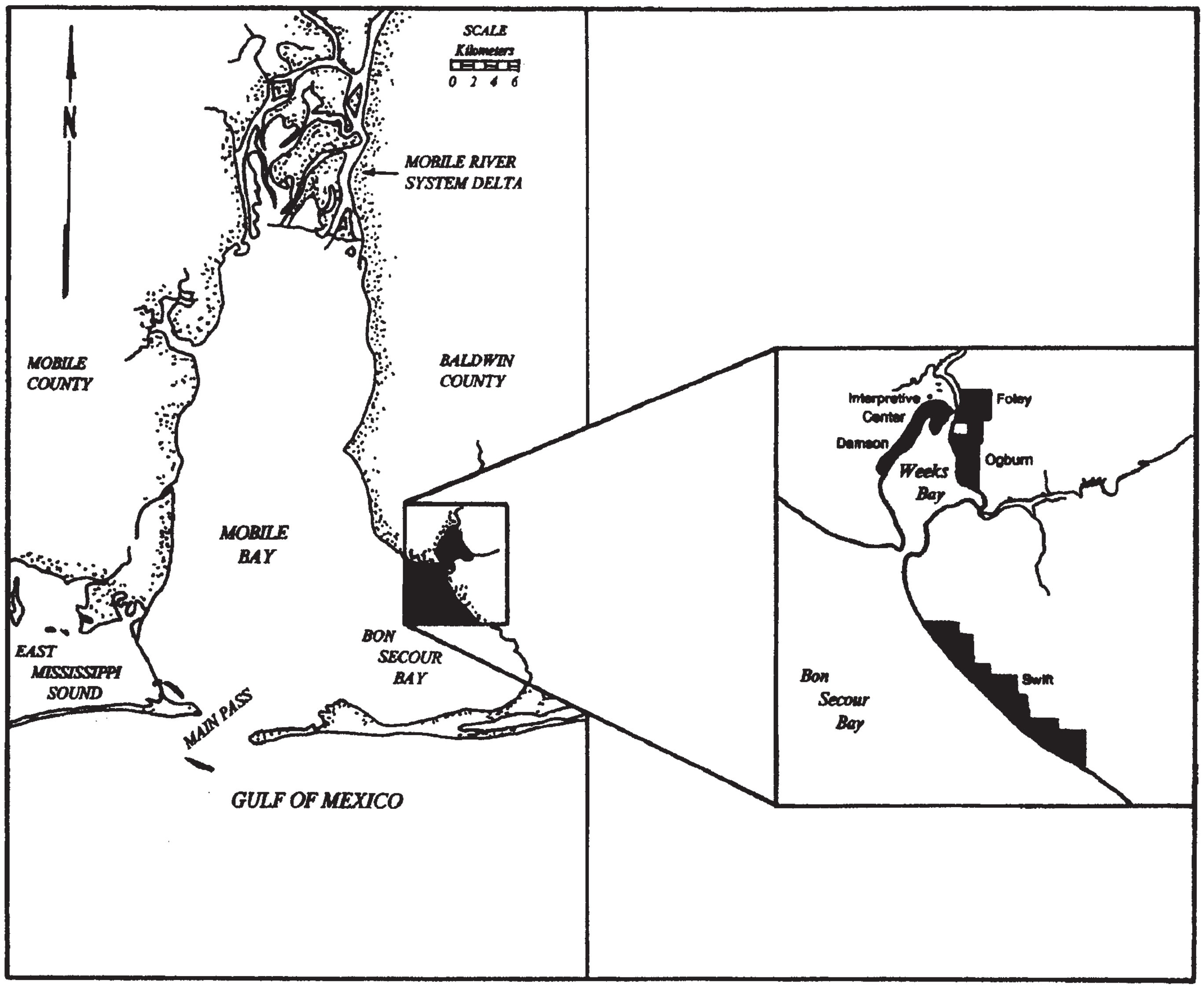


Figure 1: Location of Weeks Bay National Estuarine Research Reserve. Inset shows location of Interpretive Center and land tracts referred to in text.

as the nominee. In June, 1982, the Alabama Department of Conservation and Natural Resources (ACDNR) was awarded a $25,000 pre-acquisition award to develop a Draft Sanctuary Management Plan and an Environmental Assessment analyzing the site. The continuity of the process was affected by the abolition of the Alabama Coastal Area Board by Governor Fob James in the fall of 1982. The functions of the CAB were assumed by the Office of State Planning and Federal Programs.

In 1983, the Draft Management Plan and Environmental Assessment were submitted to the Estuarine Program Division of NOAA for review. At this time, discussion between TNC and the NOAA office over the appraised value of the donated lands delayed the designation process. Final appraisal figures were agreed upon in mid-1984 and the designation process resumed. The draft environmental impact statement and management plans were submitted to the Alabama Department of Economic and Community Affairs (ADECA) by NOAA for review in July, 1984.

In 1985, the state moved from the pre-acquisition phase to the acquisition phase of the project. The state secured a $500,000 grant from NOAA for land acquisition which had to be matched by the state in an equal amount. However, since these funds were not available at the state level, TNC donated the Swift tract and sold the Foley and Ogburn tracts forming the initial upland holdings of the reserve. The state, which claims title to the approximately 1718 acres of subtidal land in Weeks Bay, proposed that this acreage be assigned to the sanctuary. In November, 1985, the Final Environmental Impact Statement and Management Plan for the proposed Weeks Bay National Estuarine Sanctuary was approved by NOAA (US NOAA et al. 1985).

In February, 1986, Weeks Bay was officially designated as the nation's 16th National Estuarine Sanctuary. In April, 1986, concomitant with 1986 amendments, the name of the Reserve was changed to the Weeks Bay National Estuarine Research Reserve (WBNERR). In 1986, TNC purchased a 360 acre tract on the northwest side of Weeks Bay, the Damson tract (Fig. 1) and sold it to the state at cost. The state paid for the property with a land acquisition grant from NOAA. After this addition, Reserve acreage totaled 3028 acres.

Prior to the selection of a permanent Reserve Manager, management of the Reserve was directed by an Advisory Committee composed of agency representatives as defined in the approved management plan. In 1991, this committee proposed the designation of the waters of WBNERR as an "Outstanding National Resource Water" (ONRW). The ONRW status provides for special protection of waters for which ordinary use classifications and water quality criteria do not suffice. These regulations regulate the type and number of potential polluting discharges into Weeks Bay (see Chapter 8 for more detail). After a period of public comment and agency review, ONRW status was conferred by the Environmental Protection Agency (EPA) on the waters of WBNERR in August, 1992.

The Weeks Bay National Estuarine Research Reserve represents the Mississippi delta subcategory of the Louisiana biogeographic province and is a system characteristic of the central Gulf of Mexico coast. It is only one of 3 such Reserves in the Gulf of Mexico region. Habitats included in this reserve are tidal wetlands and swamps, salt marshes, aquatic grass beds, maritime and palustrine upland forests, a pitcher plant bog, bay bottom and mudflat ecosystems. The biological resources of the Reserve are detailed in Chapter 5.

Since its establishment, there have been a number of projects in the Weeks Bay National Estuarine Research Reserve which have enabled the Reserve to better fulfill its mission. In September of 1988, the first nature trail was dedicated. A boardwalk trail was completed late in 1993 while a 4000 square feet visitor center was built in 1994. Public support for the Reserve and its mission has always been strong. Prior to the establishment of the Reserve, no negative comments were received during the public comment period regarding its formation. In 1990, a non-profit entity, the Weeks Bay Foundation, was incorporated to promote public awareness and further fund-raising efforts benefitting the Reserve. A number of private citizens as well as persons from state and local agencies and educational institutions in the area have volunteered their time and effort both in serving on the Advisory Committee and on behalf of the Foundation.

Weeks Bay National Estuarine Research Reserve has been the focus of a variety of studies by the scientific research community in Alabama. In 1995, the Technical Committee of the Weeks Bay Watershed Project compiled a summary of past and present research in WBNERR (Appendix 2). This summary includes NOAA sponsored research as well as research sponsored by other federal and state agencies. The information garnered from these studies is included in this document.

Chapter 2: Environmental Setting

by William W. Schroeder

Weeks Bay (30° 23' N, 87° 50' W) is a small, shallow, microtidal, tributary estuary located on the eastern shore of the Mobile Bay estuary (Fig. 1) in the northern Gulf of Mexico. A tributary estuary is defined herein as an estuary located within a large main estuarine system where the larger estuary serves as the tributary estuary's "coastal ocean" salt source. It is nearly diamond shaped with a surface area of approximately 7.0 x 10^6 m^2 (1718 acres) (Crance 1971). It has a 3.4 km longitudinal axis running north-south from the head of the bay, where the Fish River flows in, to its mouth, where it exchanges water with Mobile Bay, which serves as the adjacent "coastal ocean". Its lateral axis is oriented east-west: the widest section, 3.1 km, occurs in the central region, where the Magnolia River discharge enters along the eastern shore.

Climate

The Weeks Bay estuary lies in the humid subtropical climate region (Trewartha and Horn 1980), a climate that dominates the Gulf Coast states and Florida Peninsula. Summers are characteristically warm while winters are relatively mild with occasional cold waves. In the contiguous United States, this region is second only to the Pacific Northwest in total annual rainfall (Baldwin 1973), receiving precipitation from a combination of winter storms, thunderstorms and tropical systems.

Summer Climate

High pressure over the Atlantic Ocean is a dominant factor in the summer weather pattern. This semi-permanent weather system, called the subtropical anticyclone, provides a persistent southerly flow of humid air from the Gulf of Mexico. This air is normally unstable and thus, is easily lifted and condensed through convective heating or sea breeze convergences. As a result, thunderstorms are frequent and account for the major portion of summer rainfall. The frequency of thunderstorms over coastal Alabama is surpassed in the United States only by the Florida peninsula.

A sea breeze from the Gulf and Mobile Bay produces a prominent area of convergence to the east and west side of Mobile Bay. Largely because of this convergence, the eastern and western shores of Mobile Bay have the highest annual rainfall totals along the Gulf Coast, averaging 165 cm (65 inches). Weeks Bay lies in this eastern convergence area and consequently experiences these high rainfall totals. On the other hand, summer rainfall is considerably less over Mobile Bay and along the immediate shoreline including Weeks Bay due to subsidence within the sea breeze flow. Tropical disturbances also produce high rainfall amounts. However, these systems are typically spatially extensive and thus rainfall amounts vary considerably.

The influx of moisture from the Gulf of Mexico, in combination with numerous thunderstorms, produces a small diurnal temperature range during the summer. Average maximum air temperatures during the summer months vary from the upper 20° C (80° F) to the low 30° C (90° F) range around and over the bay. Although temperatures may rise rapidly during the morning hours, the high frequency of thunderstorms usually limits the daily temperature peak at around 32 to 33° C (90 to 92° F) (Williams 1973). Because of the high absolute humidity during this period, temperatures of 38° C (100° F) or higher are occasionally observed in the bay area.

Winter Climate

During the winter months, the Atlantic subtropical anticyclone retreats southward allowing the polar front to make numerous incursions into the Gulf States region from September to May. On the average, cold waves of polar continental or arctic air last for about three days with the coldest temperatures occurring on the second or third mornings when the winds are weak.

The arrival of polar air is frequently marked by heavy rain and a strong wind shift from southerly to northwesterly. Freezes are not uncommon around the bay. Temperatures of -7°C (20°F) or colder occur every other year on average with readings of -12 °C (10°F) or colder reoccurring approximately every 5 years (Schroeder et al. 1990b). When extremely low temperatures occur for at least two successive nights, freezing of the bay may take place near shore.

The Mobile Bay estuary creates a well defined "temperature shadow " (temperatures moderated by warmer bay waters) along the eastern shore in the vicinity of Weeks Bay. When northwest winds prevail, nighttime temperatures may be 5 to 8 °C (10 to 15 °F) warmer than those experienced on the western shore (Schroeder et al. 1990b). A strong temperature contrast between the bay and the shore or between the bay and an incoming air mass may produce dense fog, a common occurrence in the spring.

Winter Storms

Although summer thunderstorms are numerous and greatly contribute to high annual rainfall totals, winter storms also produce heavy downpours. Those winter storms with the greatest impact upon the estuarine system originate in west Texas or along the Texas coast and are usually formed by upper atmosphere troughs that track across the southwestern U.S. Surface cyclones developing beneath these troughs either move eastward from Texas across the Gulf States or along the coast. Storms of this type gain enormous energy from the contrast between warm Gulf waters and cold polar air positioned over the Gulf states.

Each storm that approaches coastal Alabama is preceded by south and southeast winds. Depending on the central barometric pressure and track of the storm, tides rapidly build ahead of the storm. Winds of 10 to 15 m s^{-1} (20 to 30 k) are not uncommon with higher gusts occurring in squall lines (Schroeder et al. 1990b). The most intense winter storms are those that track across Louisiana, southern Mississippi and southwest Alabama. This track places the bay in the warm sector of a storm very close to the storms' center. Such a position usually results in a strong southerly flow with torrential rain, coastal flooding and a likelihood of severe thunderstorms. When this situation occurs, a squall line forms just ahead of the cold front with individual thunderstorms moving north and northeastward. The high frequency of winter storms originating in Texas and crossing the Gulf states accounts for a secondary rainfall maximum in March for many Gulf coast regions. For areas around the Mobile Bay estuarine system, July slightly exceeds March as the wettest month with an average of more than 17.8 cm (7 in) of rain (Schroeder et al. 1990b).

Tropical Storms

The central Gulf coast has one of the highest frequencies of hurricane landfall in the United States. From 1871 through 1980 an average of 2.2 tropical storms made landfall along every 18.5 km (10 nautical miles) stretch of the coast (Neumann et al. 1981). However, by an oddity of nature the Mobile Bay region had escaped a direct hit from a major hurricane for more than 50 years, a period which ended with Hurricane Frederic in 1979. When a hurricane strikes the Alabama coast, the point of landfall with respect to the entrance to the bay is extremely important. Landfall to the west of the bay results in the full impact of the right-front quadrant on Mobile Bay. The storm surge is forced into the bay and is funnelled northward as occurred in the hurricanes of 1906, 1916 and 1979.

Tropical storms are capable of producing enormous rainfalls over the bay. Rainfall of 13 to 25 cm (5 to 10 in) are not unusual. However, hurricane rainfall totals vary considerably from storm to storm. When totals are high, the combination of flood runoff, erosion and the destruction of trees and buildings in shorelines gullies by wind channeling (Williams 1980), results in the transport of large amounts of sediment and debris into the bay which can have a profound post-storm impact on the ecosystem. When rainfall is low, airborne sea salt does extensive damage to vegetation throughout the surrounding wetlands.

Bathymetry

Weeks Bay has a mean water depth of approximately 1.3 m. A small, 5 to 7 m deep scour feature is located in the narrow mouth of the bay (Fig. 2) and a similar scour feature, 3 to 4 m deep, occurs in the Fish River about 200 m upstream (adjacent to the Hwy 98 bridge) from where it empties into the bay. Water depths in the 2 to 3 m range are found in the lower bay, whereas depths in the upper bay are often 1 m or less (Fig. 2). Although it is expected that Weeks Bay is shoaling, or becoming shallower with time due to local sediment input, the rate at which this is happening is not known due to limited bathymetric data. In a study encompassing the entire Mobile Bay region and thus of low resolution for Weeks Bay, Hardin et al. (1976) estimated deposition on the west side of Weeks Bay to be approximately 1 to 3 ft during the period 1852 to 1973. The eastern portion of Weeks Bay was estimated to have deepened by less than 1 ft during this period.

Hydrology

Tides and Tidal Flows

Tides are principally daily (one high and one low each day) and have a mean range of approximately 0.4 m. Both tidal and subtidal (occurring less frequently than the tides; i.e. over periods greater than one day) currents measured just inside the mouth of the bay flow up to 40 cm s^{-1} (0.75 knots); combined flows have been observed up to 65 cm s^{-1} (1.25 knots). In the narrow opening of the mouth of the bay, currents have been estimated to approach 105 cm s^{-1} (2.0 knots) (Schroeder et al. 1990a).

Freshwater Input

Direct freshwater discharge into the bay comes from the Fish and Magnolia Rivers. Mean combined discharge is estimated at 9 m^3 s^{-1}, with freshets up to 4 times larger occurring throughout the year. The Fish River is the principal source of freshwater, accounting for approximately 73% of the inflow. The maximal flooding event on record for the Fish River is estimated to be 243 m^3 s^{-1} (December 6, 1953; Schroeder et al. 1990a).

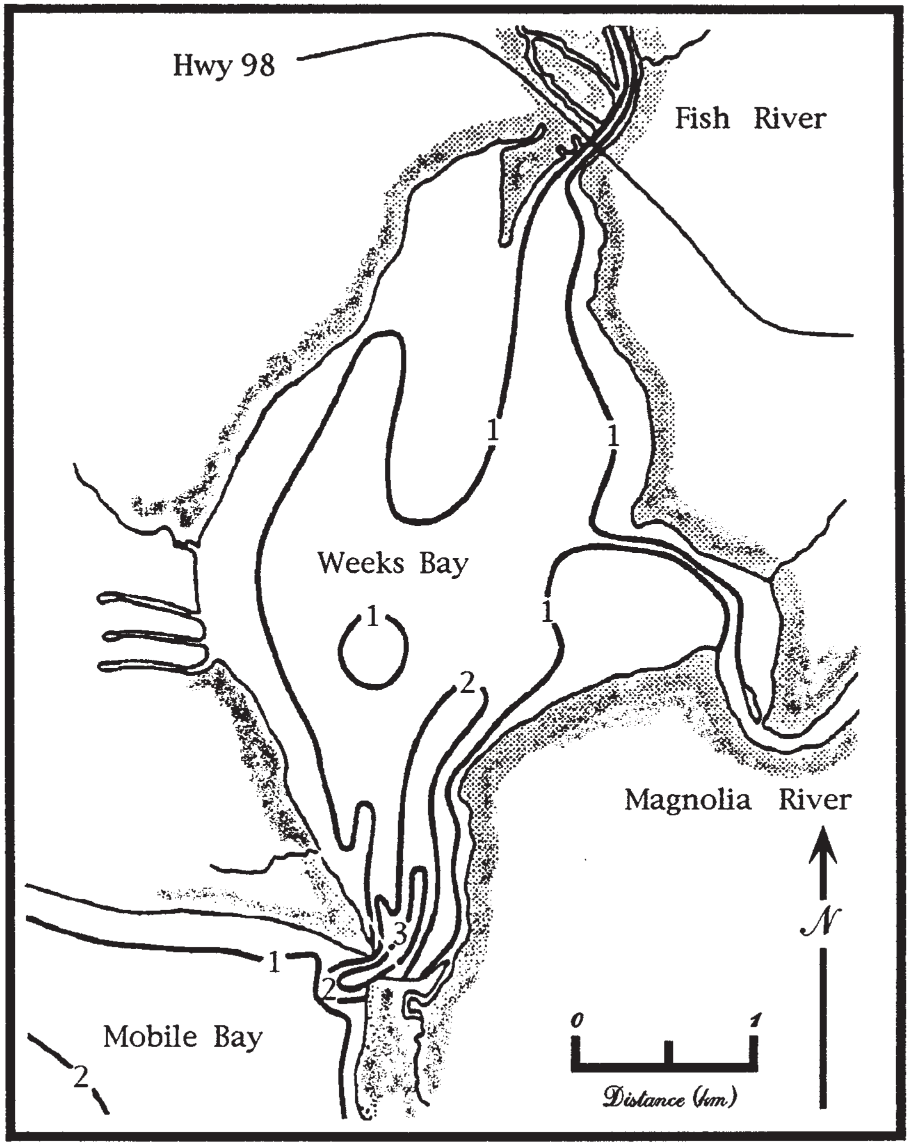


Figure 2: Bathymetric map of Weeks Bay. Depth is in meters.
Adapted from Schroeder et al., 1992.

Salinity Structure

Analysis of salinity data from 14 field surveys, undertaken during equatorial tides (little difference between high and low tide) and fair weather conditions indicate that the salinity regime in Weeks Bay varies significantly both temporally and spatially (Schroeder et al. 1992). Horizontal gradients vary from weak to strong and complex, both in the longitudinal and lateral directions (Figs. 3, 4, 5). Vertical gradients vary from well mixed to strongly stratified (up to 14 ‰ between the surface and 1.5 m depths, in 2.25 m of water). An example of the degree to which the vertical structure within the bay can vary spatially between strongly stratified and well mixed at the same time is illustrated in Fig. 6.

Horizontal and vertical variability observed in the salinity structure of Weeks Bay results principally from flashy local runoff from the Fish and Magnolia Rivers and from subtidal exchanges with the salinity regime in Mobile Bay, both in the barotropic (non-stratified water column) and baroclinic (stratified water column) modes. Under high river discharge and low Mobile Bay salinities (indicating high discharge from the Mobile River), Weeks Bay is nearly fresh except in the deeper channel areas near the mouth and along the eastern shore. Under average freshwater flows in the Fish and Magnolia Rivers, salinity structure is influenced by wind velocity and tidal stage. For example, during equatorial tides, salinities greater than 8 ‰ are generally restricted to the mouth of the bay. At a secondary level, salinity fields can be influenced by bathymetry, particularly deeper areas which either channel near-bottom water within the bay or impound bottom waters in scour holes or depressions, as well as local winds associated with moderate to strong weather events.

Water Exchange between Weeks Bay and Mobile Bay

Two years of wind and water level data and 18 months of river runoff data were utilized by Schroeder et al. (1990a) to investigate subtidal barotropic exchange between Weeks Bay and Mobile Bay. These data were supplemented with occasional current meter records of a few months' duration. Unfortunately, the current meter records were not sufficiently long to relate external driving forces to baroclinic flow between the two water bodies.

It was clear from the long water level and wind records that subtidal barotropic exchange is dominated by a co-oscillation of Mobile Bay and Weeks Bay. The east-west wind stress causes filling or emptying of Mobile Bay (Schroeder and Wiseman 1986) and concurrent filling or emptying of Weeks Bay. The north-south wind stress drives an exchange of water between Mobile Bay and the adjacent continental shelf. This exchange is also reflected in the water level records at Weeks Bay. There was an additional signal in Weeks Bay water level records that appeared to be driven by the local north-south wind stress. This was probably due to the winds blowing over the shallow waters of southeastern Mobile Bay (Bon Secour Bay), immediately adjacent to Weeks Bay.

High river discharge into Weeks Bay is episodic and of short duration. Therefore, the relatively short 18 month time-series data did not permit determination of a statistically significant relationship between river discharge and Weeks Bay water level. Nevertheless, examination of individual flooding events did suggest that large runoff events will both alter the water level in Weeks Bay and drive a strong exchange with Mobile Bay.

Modelling and Computer Simulations

A three part investigation into the application of calibrated numerical hydrologic models for Weeks Bay was initiated in 1989. The first phase of this research effort

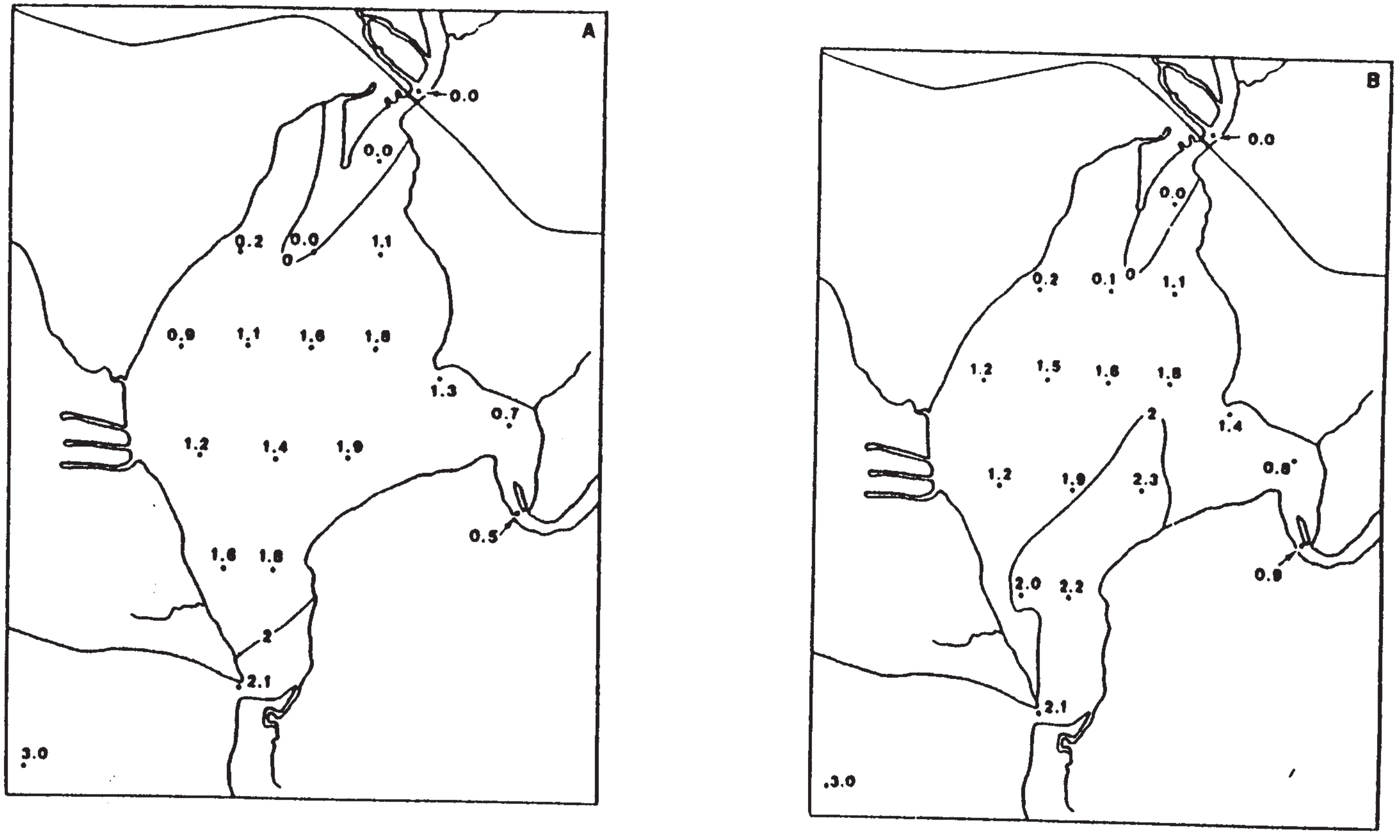


Figure 3: Surface (A) and bottom (B) salinity for Weeks Bay for survey 12, on 10 April 1987.
Adapted from Schroeder et al., 1992.

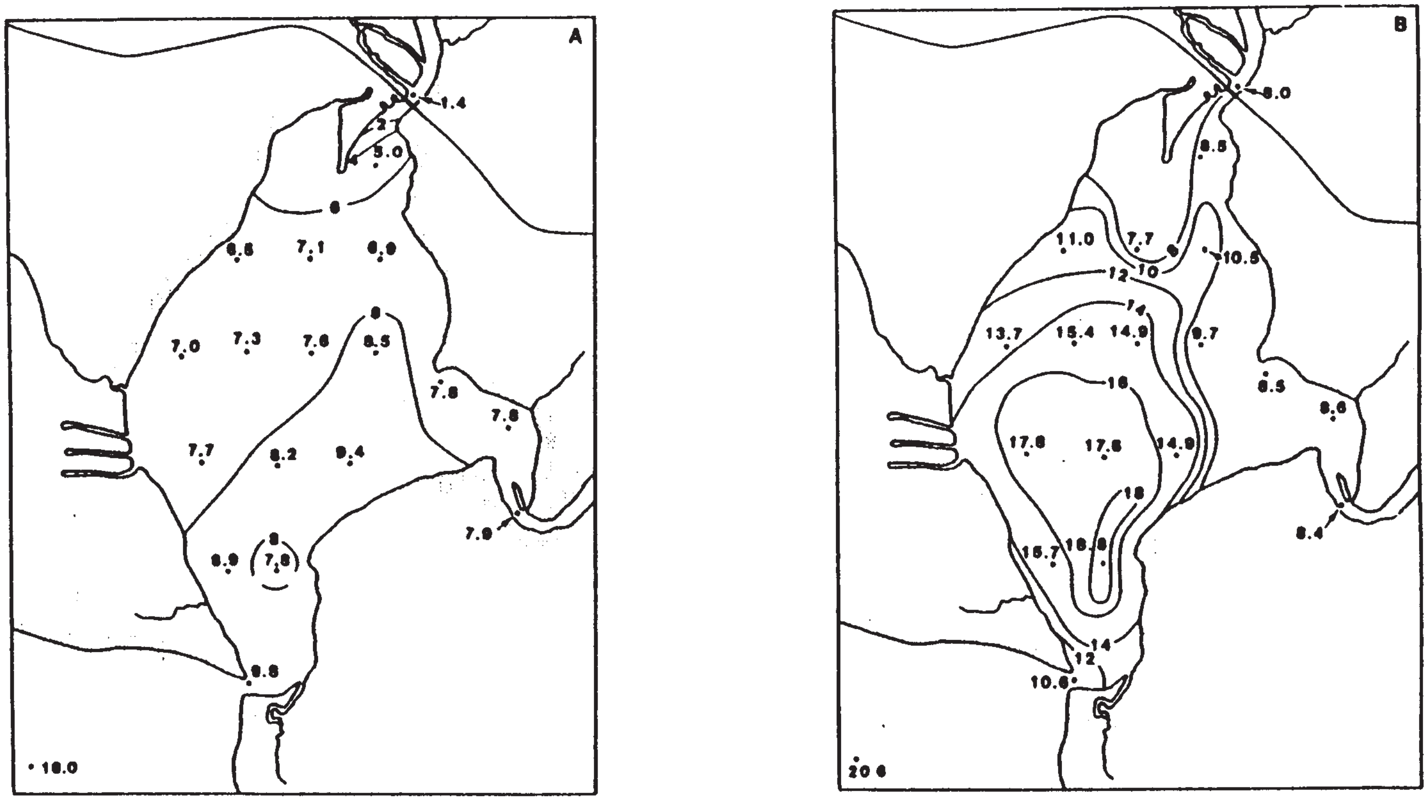


Figure 4: Surface (A) and bottom (B) salinity for Weeks Bay for survey 1, on 20 May 1986.
Adapted from Schroeder et al., 1992.

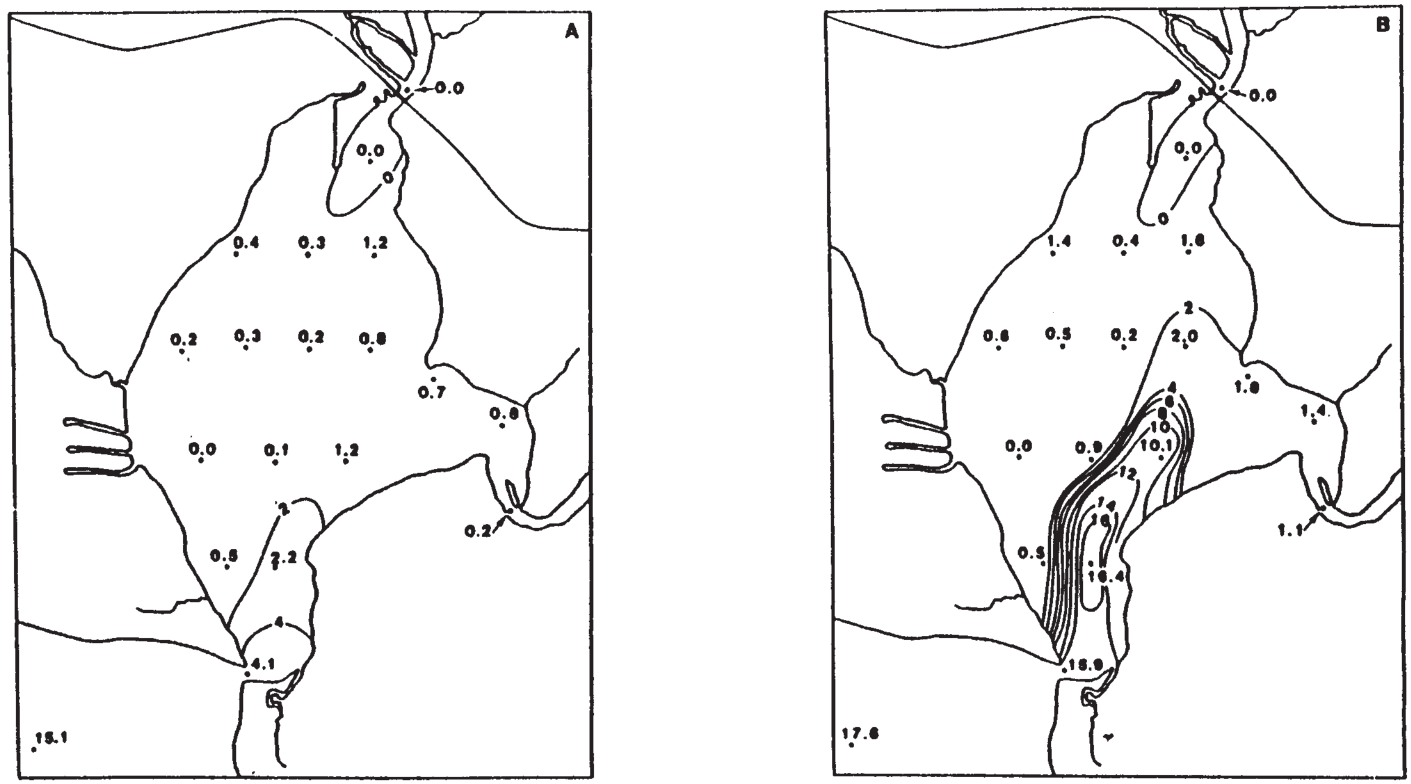


Figure 5: Surface (A) and bottom (B) salinity for Weeks Bay for survey 11, on 2 March 1987.
Adapted from Schroeder et al., 1992.

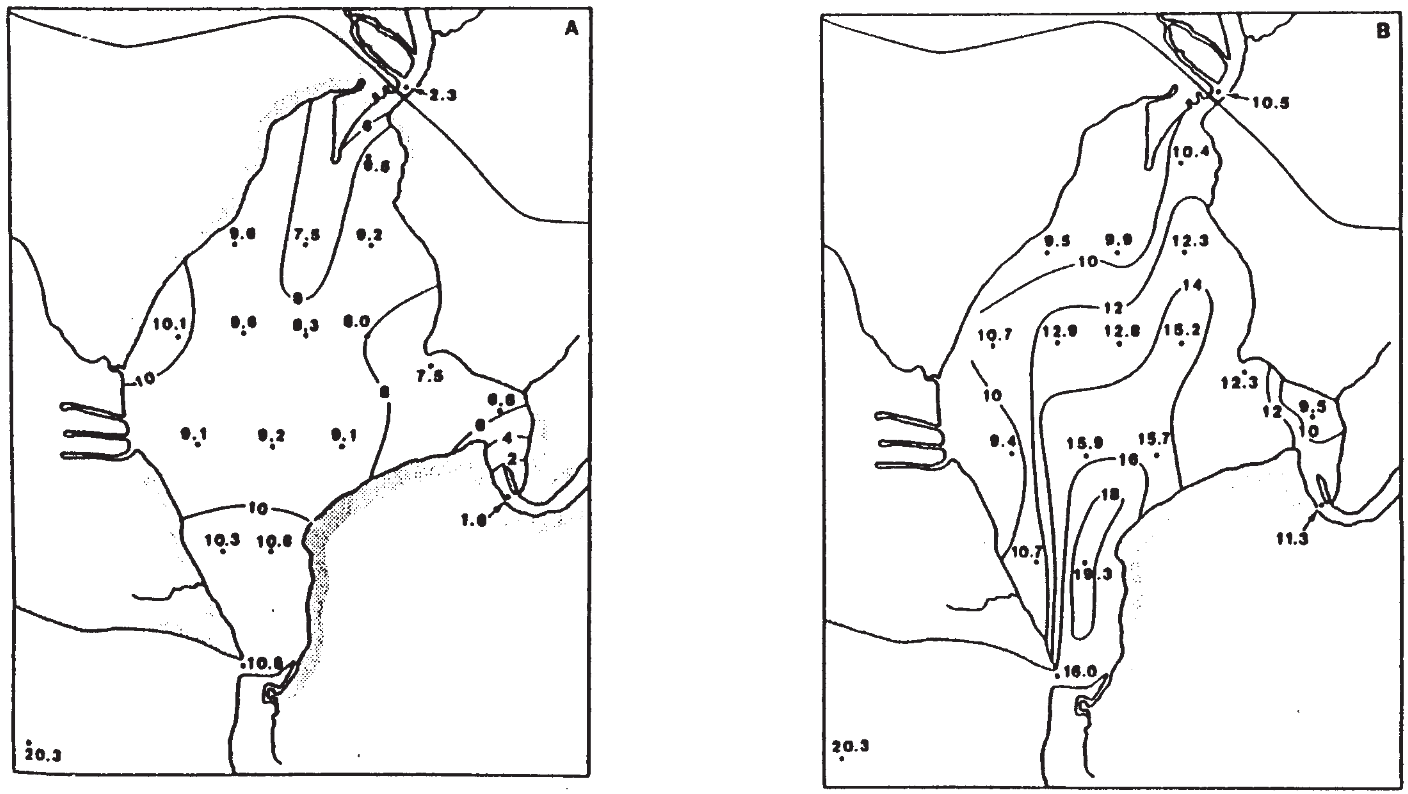


Figure 6: Surface (A) and bottom (B) salinity for Weeks Bay for survey 6, on 15 October 1986. Adapted from Schroeder et al., 1992.

successfully employed existing two-dimensional, depth-averaged hydrodynamic and salinity models (based on the WIFM model) to Weeks Bay under equatorial tides and fair weather conditions (Thollapalli 1990, Thollapalli et al. 1991). Good to very good agreement was obtained between model results and both the magnitude and phase of the tides and field salinity measurements during periods when the bay was well mixed. Results indicated that discharge from the Fish River tends to flow along the bay's western shoreline while Mobile Bay water entering at the mouth flows along the eastern shoreline. The second phase focused on assessing the impact of a hypothetical channel deepening project on water circulation and salinity intrusion patterns within the bay (McCormick 1993). In this study, a two-dimensional, well-mixed model was effectively used to describe potential changes in both the circulation and salinity regimes in Weeks Bay under non-stratified water column conditions. In addition, color graphic interfaces with the numerical simulation output codes were utilized to generate dynamic computer graphic displays of the model results. The third phase of the modeling effort focused on water quality. A combined hydrodynamic and species continuity modeling system (using the WIFM and WASP4 models) was used to simulate the transport and fate of dissolved oxygen, biochemical oxygen demand and organic nitrogen in untreated wastewater flowing into Weeks Bay from the Magnolia River (Lu 1994, Lu et al. 1994). Model output for various case scenarios clearly indicated that tidal state, river discharge and wind velocity all significantly contributed to water quality conditions in both Magnolia River and Weeks Bay.

Geomorphology

The Weeks Bay National Estuarine Research Reserve lies in the Southern Pine Hills subdivision of the Gulf Coastal Plain physiographic province (Chermock et al. 1974). These coastal lands are flat to gently undulating plains indented by many tidal creeks, rivers estuaries and fringed by tidal marshes. Sediments in this region are composed of quartz rich sand interlayered with clays and silts of Miocene through Holocene age. The Weeks Bay embayment was believed to have been formed during the Pleistocene (Smith 1986).

Bottom Sediment Characteristics

The bottom sediments within Weeks Bay are a combination of silts and clays found throughout most of the interior of the bay and relatively clean quartz sands found in three areas of the bay system (Fig. 7) (Haywick et al. 1994). There is a submerged spit-like feature extending southward into the bay from the marshy area on the western side of the terminus of the Fish River, a sandy 'platform' extending from the shoreline around nearly all of the periphery of the bay, and a 'platform' in the very lower reaches of the bay extending westward through the inlet connecting Weeks Bay to Mobile Bay. The source of the silt and clay material, as well as the sand in the submerged spit, is principally from the Fish and Magnolia Rivers. In contrast, the sands around the periphery of the bay are mostly the result of erosional processes along the shoreline. The sands in the vicinity of the inlet at the mouth of the bay are likely derived from bedload input from the rivers, shoreline erosion within the bay and material transported into Weeks Bay from Mobile Bay. Smith (1992) states that there is active erosion along the shoreline of the bay, but that it has not been quantified due to the lack of ground reference points identifiable on aerial photographs.

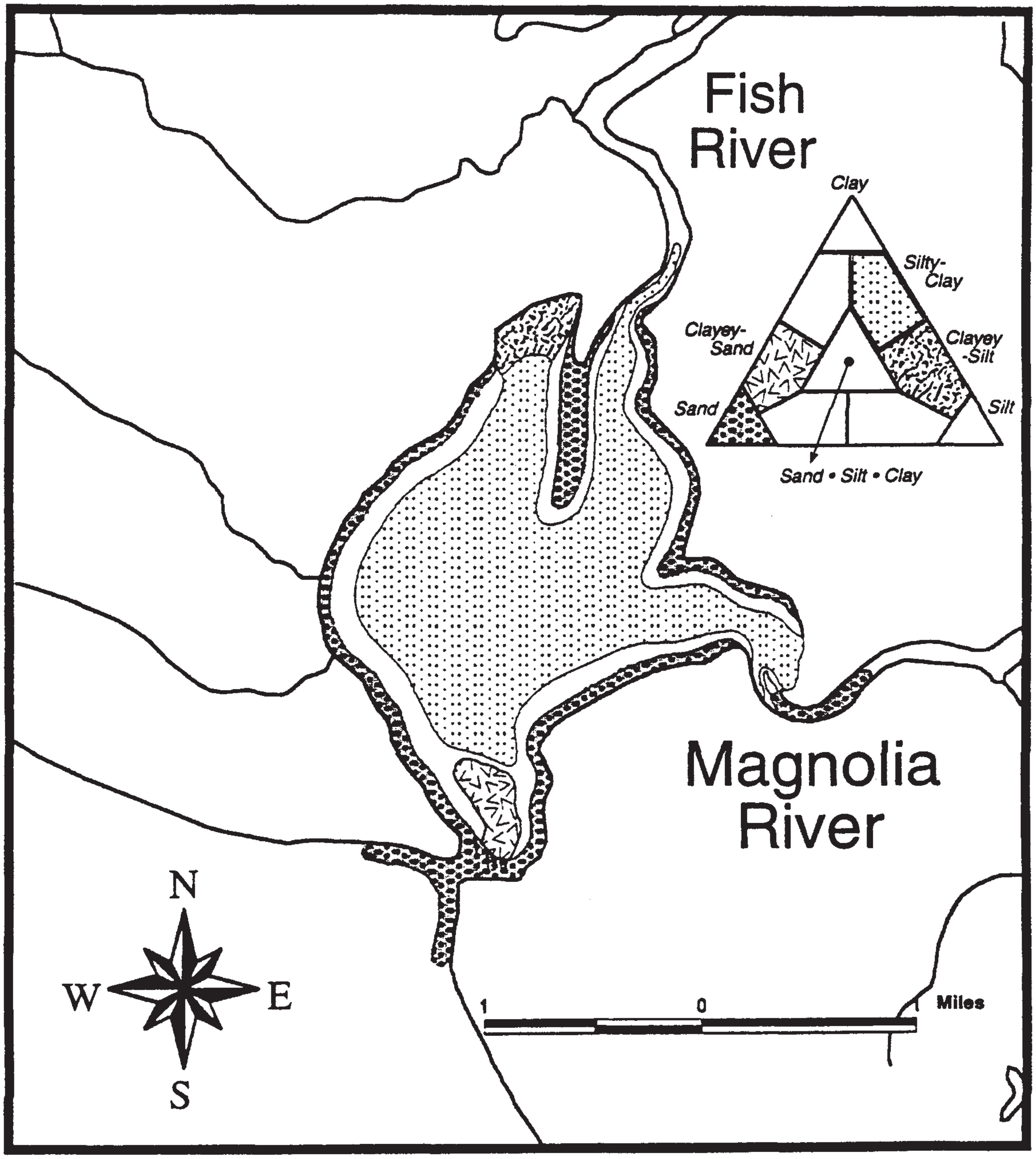


Figure 7: Bottom sediment characteristics of subtidal habitats of Weeks Bay. Adapted from Haywick et al., 1994.

Section 2: Living Resources

Chapter 3: Estuarine Habitats

by Judy P. Stout

Natural areas and areas in various stages of alteration, or recovery from alteration, present a mosaic of habitat types within the boundaries of the Reserve. Natural habitats can generally be divided by location into subaerial portions of the bay and tributaries (within the water column or on the bottom), intertidal emergent marshes, and other emergent habitats that are located at elevations above the bay waters. Utilizing the classifications of the U.S. Fish and Wildlife Service (Cowardin et al. 1979), open water habitats and emergent wetland habitats can be characterized as both palustrine (P) or estuarine (E) based upon the influence of the tides and average salinities of the waters reaching the habitats. Estuarine habitats are influenced by the tides and are flooded by waters with salinities diluted by freshwater but greater than 0.5‰. Palustrine wetlands are tidal or non-tidal in areas where salinities are below 0.5‰. At present, no map which details the distribution of habitat or vegetation types within the entire Reserve exists. Additionally, data are inadequate to assess long term changes in habitat distribution and coverage.

Subaerial Habitats

Characteristics of water column habitats within the bay and its tributaries vary with season, recent meteorological events and hydrodynamics of the system and are thus dynamic in space and time. General descriptions of water quality conditions of these habitats can be found in sections on *Salinity Structure*, *Water Exchange* and *Modelling* in Chapter 2. Biotic utilization of water column habitats and responses to changes within these habitats are detailed in the chapters on *Nutrients and Aquatic Primary Production* and *Estuarine Consumers*.

Benthic habitat in Weeks Bay National Estuarine Research Reserve is dominated by a subtidal, unvegetated soft bottom. Sediment characteristics, which affect utilization of this habitat, are detailed in *Bottom Sediment Characteristics* and summarized in Fig. 7. Other benthic habitats include small patches of submerged aquatic vegetation and hard substrates.

In the Weeks Bay National Estuarine Research Reserve, natural hard substrates are limited to live oysters and clams or their dead shells. Though oyster and clam shells can be seen in midden areas around the bay shore and have been important in the bay's ecology historically, there are no beds or large aggregations of either in the bay at the present time. Currently, hard substrate habitats in the Weeks Bay National Estuarine Research Reserve are primarily man-made structures such as pilings, bulkheads and concrete ramps.

Submerged aquatic vegetation is also limited within the bay. Stout and Lelong (1981) located only two small patches of bottom vegetation, less than an acre each, near the mouth of the bay at Muddy Bayou to the west and a small unnamed creek just inside the bay to the east. Species present were mostly freshwater aquatics (*Vallisneria americana, Myriophyllum spicatum* and *Potamogeton pectinatus),* except for the brackish widgeon grass. A recent survey of these sites failed to relocate these beds (L.G. Adams, personal communication). However, a fringing bed of wild celery now borders both sides of the bay just below the mouth of Fish River and has persisted for the past 5 years (Stearns et al. 1990 and J. Stout, personal observation).

Intertidal Habitats

By the nature of their relationship to tidal patterns within the bay, intertidal marshes provide habitat for aquatic species while flooded, for terrestrial species when fully emergent and for a suite of endemic resident species of marsh fauna at all times. In a 1986-1987 study of the emergent habitats of the Reserve (Stout 1987), intertidal estuarine marshes were the second most abundant habitat type (45 acres of a total of 826 acres mapped from aerial photographs). Bottomland hardwood swamps were the dominant habitat (see below).

Estuarine emergent marshes of the Reserve exist as narrow shoreline fringes and pocket marshes along the shores of the bay and mouths of tributary streams and, to a limited extent, along the intertidal shoreline of Bon Secour Bay within the Swift Tract. Estuarine emergent marshes cover less than 100 acres of Reserve land. The black needlerush dominates marshes within estuarine tidal areas. Associated species reflect differences in average annual salinities and include an outer edge of smooth cordgrass, *Spartina alterniflora*, near the saltier mouth of the bay and giant cordgrass, *S. cynosuroides*, in brackish areas at the head of the bay. The inland border of the marshes may have saltmeadow cordgrass,*S. patens,* and saltgrass, *Distichlis spicata,* equally dominant with needlerush (Sapp et al. 1976, Stout and Lelong 1981).

Higher elevation intertidal areas, only irregularly flooded by the tides, support a woody shrub community usually dominated by the salt shrubs *Baccharus halimifolia* and *Iva frutescens*. Estuarine scrub shrub communities represent approximately 10 acres of Reserve habitat (Stout 1987).

Palustrine (<0.5‰ salinity) tidally influenced wetlands are poorly represented in the Reserve and are most common in the mouths of small streams with low water flow. Although most palustrine plants are perennials, some persist year-round (saw grass, *Cladium jamaicense;* common reed, *Phragmites australis;* and cattail, *Typha angustifolia*) while others die back to the ground in the winter (e.g., arrow arum, *Peltandra virginica;* pickerelweed, *Pontederia cordata,* arrow leafs, *Sagittaria* sp. and alligator weed, *Alternathera philoxeroides*). Therefore, the nature and availability of habitat in these areas may vary seasonally. Together, persistent and non-persistent palustrine marshes comprise less than 5 acres of Reserve habitat (Stout 1987).

Non-tidal Emergent Wetland Habitats

Palustrine forested wetlands (bottomland hardwood swamps) are the most frequently occurring natural habitats in the Reserve. In the most recent survey (1986-1987), 733 acres of a total of 826 acres mapped were of this type (Stout 1987). These habitats are found below the 4 foot contour in seasonally flooded basins surrounding the bay and in intermittent small stream basins. Either needle-leaved evergreen trees (slash pine and long leaf pine) or broadleaved deciduous trees (e.g., tupelos, sweet bay, red maple, tulip poplar and ashes, *Fraxinus pennsylvatica* and *F. profunda*) make-up the majority of a dense canopy. Dominant species vary with the frequency and duration of flooding. Large bald cypress appear from remaining stumps to have been localized dominants in the past but are rare now. Young bald and pond cypress can now be found in the Reserve (Stout 1987).

Under the dominant tree canopy, the swamps are stratified into a short tree/shrub sub canopy of such species as Virginia willow, swamp dogwood and hollies (*Ilex* spp.), and a herbaceous ground cover. Ferns, including cinnamon fern and royal fern, often cover this layer along with the everpresent poison ivy (Stout 1987). As with tree species, plants of both understory layers have distributions relative to their flood tolerance.

Although palustrine forested wetlands (bottomland hardwood swamps) are the most common habitat in the Reserve, there has been little research into the ecology of this habitat from either a structural or functional perspective.

Scrub-shrub palustrine wetlands are of very limited occurrence in the Reserve. Of particular note is an area of the Foley Tract in which the soil is permanently saturated and semi-permanently flooded. A large number of specialized grasses and herbs contribute to high community diversity in this approximately 10 acre habitat. Low nutrient availability favors large populations of unique species of carnivorous plants such as pitcher plants (*Sarracenia psittacina, S. leucophylla)* and sundews (*Drosera* spp.) in the herbaceous layer under shrubs of hollies and wax myrtle and woody vines (*Smilax* spp.) (Stout 1987).

Disturbed habitats

Although the majority of the WBNERR is in a relatively undisturbed condition, historical land uses and resource exploitation enterprises have altered portions of Reserve land. These activities have included agriculture, timber cutting, removal of naval stores and dirt, and residential development. Chapter 6 discusses the human role in the Weeks Bay Estuarine Research Reserve in more detail.

The least obvious, and an activity no longer occurring, is scarring of pines (slash and longleaf) for the collection of pitch for distillation of turpentine. Scarred ("cat faced") individuals eventually died, altering the composition of the tree canopy. Indirect effects of turpentining were the results of controlled burns to remove undergrowth and leaf fall to prevent uncontrolled hot fires that ignited the pitch and destroyed the trees. The actual impact on community composition and the duration of this resource enterprise are not known for the Reserve (Stout 1987).

Large (>5 feet diameter) cypress stumps and abundant pine stumps attest to the prevalence of historic timber removal, especially on the Swift Tract (cypress and hardwoods). A large sawdust pile on the Ogburn Tract is all that remains of a sawmill for local processing of timber harvested in the area. It is difficult to quantify the areal impact of this industry (Stout 1987). Only the upland portions of the Damson and Foley Tracts provide soil types and drainage suitable for agricultural use. Most of the Foley Tract east of County Road 17 has been cleared and farmed. Abandoned agricultural fields are of different ages and thus support successional communities of varying composition. Approximately 30 acres of the Foley Tract are in later stages of a pine-oak succession, while other younger areas are weedy thickets (Stout 1987). A dirt pit in the southeast portion of the Ogburn Tract was once active south of Highway 98 near the Yupon community. This area remains disturbed and represents habitat of very poor quality (Stout 1987).

Tropical storms and hurricanes are probably the primary continuing disturbance to natural communities within the Reserve. Gaps in the tree canopy from fallen trees temporarily stimulate understory woody and herbaceous growth, normally restricted by canopy shading. Windthrows of downed trees create micro-habitats and increase the diversity of plant and animal life. Fallen, decaying tree trunks may provide shelter for nesting and burrowing animals and contain a large insect and larval community which serves as a food source for larger animals. Standing dead snags also may provide nesting habitat, especially for ospreys (Stout 1987).

Chapter 4: Nutrients and Aquatic Primary Production

by Jonathan R. Pennock

Nutrient and micro-algal production dynamics in Weeks Bay are strongly influenced by freshwater discharge from the Fish and Magnolia Rivers, conditions in Mobile Bay and local wind events. As a result, seasonal patterns resulting from changes in freshwater discharge (high discharge: high nutrients and turbidity; low discharge: lower nutrients, low turbidity) are significantly altered by 'event scale' processes. The net effect of these regulating processes is to create an environment that is generally nutrient-rich and productive. In addition, while Weeks Bay is generally viewed as a relatively pristine system, nutrient concentrations are significantly enriched by human activities in the watershed. These nutrients appear to be utilized by forms of phytoplankton and micro-phytobenthos that result in a rich and healthy micro-algal population. This chapter examines the role that nutrients and light have in stimulating, sustaining and regulating micro-algal production in Weeks Bay, and evaluating the temporal and spatial distribution of micro-algal biomass and production in the estuary. Much of the information summarized below originates from a single 2-3 year study in the Weeks Bay estuary (Schreiber 1994, Schreiber and Pennock 1995).

Light

Weeks Bay has a relatively turbid water column as a result of high concentrations of suspended sediment during major runoff events from the Fish River, tidal inputs from Mobile Bay, and resuspension of sediments from the bay bottom during periods of high winds. Overall, light attenuation coefficients range from between -1.0 and -7.5 and display significant 'event scale' variability (Fig. 8). On average, however, the water column is less turbid during low river discharge periods during the summer and fall and more turbid during late winter and spring. As a result of this pattern and the fact that Weeks Bay is extremely shallow, photon flux to the sediments is regularly greater than 100 $\mu E\ m^{-2}\ s^{-1}$ and may reach over 1000 $\mu E\ m^{-2}\ s^{-1}$, sufficient to sustain benthic micro-algal production (Fig. 8).

Nutrients

Nitrate is the dominant form of nitrogen in Weeks Bay (Fig. 9). Concentrations range from 0 to greater than 85 μM over an annual cycle (Figs. 9, 10). There is a clear source of nitrate from both the Fish and Magnolia Rivers during all seasons of the year, although these high concentrations are only sustained in the bay proper during periods of high river discharge. Concentrations do not appear to be increasing significantly over the period of record (Fig. 10). In contrast to nitrate, ammonium concentrations are often at a maximum (1 to 10 μM) within the bay and display less of a seasonal cycle (Fig. 9). With the exception of the two year period, 1990-1992, phosphate concentrations range from 0 to 8 μM over the annual cycle (Figs. 9, 10). Reasons for these periods of elevated concentrations have not been determined. Phosphate concentrations are generally elevated for short periods during high river discharge, again indicating the importance of riverine input to controlling production dynamics in Weeks Bay. Nonvarying values during much of the early part of the long term record (Fig. 10) resulted from analytical limitations. Phosphate concentrations are generally low relative to nitrogen, suggesting that phosphate is potentially the most limiting macro-nutrient for phytoplankton growth. Finally, silicate

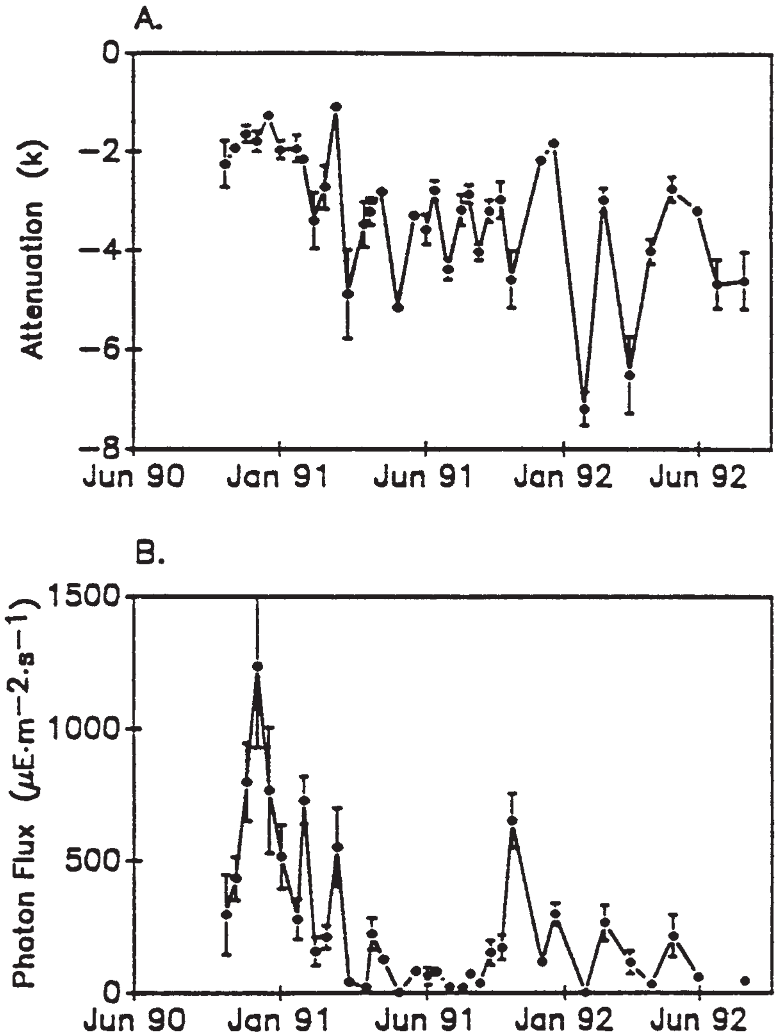


Figure 8: Mean values for the diffuse attenuation coefficient, k, (A) and photon flux to sediments (B) for Weeks Bay, June 1990 to July 1992. Values represent means and standard errors, n=4. From Schreiber and Pennock, 1995.

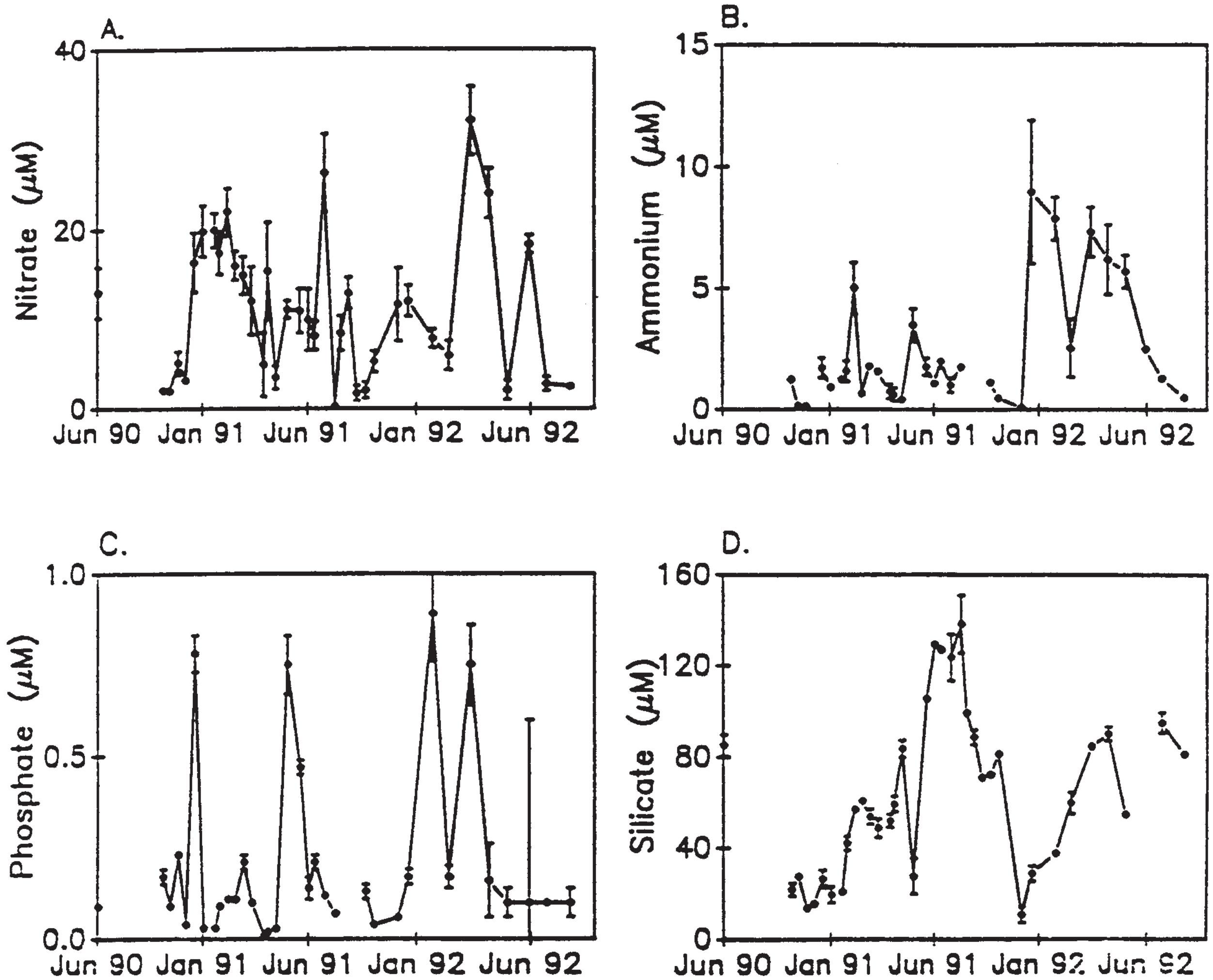


Figure 9: Mean nutrient concentrations, June 1990 to July 1992, for Weeks Bay. Nitrate (A), ammonium (B), phosphate (C) and silicate (D). Values represent means and standard errors, n=4. From Schreiber and Pennock, 1995.

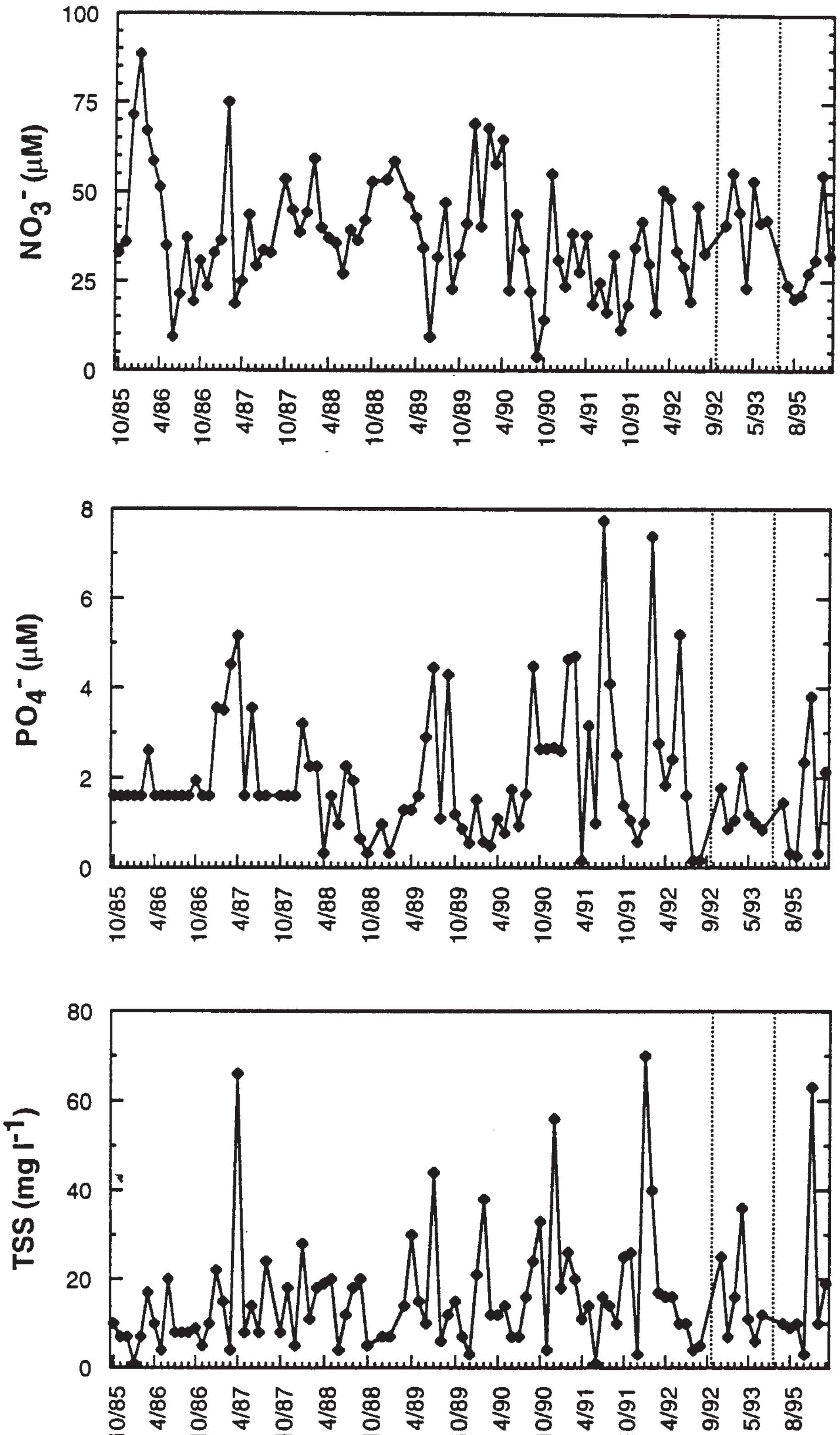


Figure 10: Nitrate (top panel), phosphate (middle panel) and total suspended solids (bottom panel) concentrations at the mouth of Fish River over a 10 year period, 1985 to 1996. Dashed lines indicate discontinuities in the dataset. From S. Brown, ADEM, personal communication.

concentrations are generally high (20 to 140 µM) and most likely not limiting to diatom production within the estuary (Fig. 9).

Primary Production

Micro-Algal Biomass

Phytoplankton biomass in the water-column (measured as chlorophyll *a*) is enriched in Weeks Bay relative to that in the Fish and Magnolia Rivers and that in Mobile Bay. Algal blooms generally occur in January through March of the year and may attain concentrations as high as 80 µg chl l^{-1}. When converted to estimates of biomass per unit area, phytoplankton concentrations in the water-column are found to range between 10 and 90 mg chl m^{-2} over the annual cycle (Fig. 11). These values are generally 2-3 fold greater than the biomass of benthic micro-algae which range between 5 and 30 mg chl m^{-2} over the seasonal cycle. Overall, benthic micro-algae contribute approximately 25% of the micro-algal biomass in Weeks Bay, although during some periods more than 60% of total micro-algal biomass may be found in the benthic micro-algae (Fig. 11).

Micro-Algal Production

Phytoplankton production in Weeks Bay averages 348 gm m^{-2} y^{-1}, with the highest rates being found during the summer. On average, rates of benthic micro-algal production were found to be approximately 21% of that of phytoplankton, with contributions as high as 43% observed during the late fall (Fig. 12). This rate of production is generally higher than that found in neighboring Mobile Bay, and is in the same range as rates reported for other estuaries world-wide. Benthic microalgal production (determined using ^{14}C techniques) represented approximately 21% of this total. Regression analysis indicated that light, nitrate, seston and benthic chl-*a* biomass were important in explaining variation in benthic microalgal production rates, but that approximately 65% of that variation could not be explained by these factors. These results suggest that benthic production in Weeks Bay is highly variable and regulated by 'event-scale' processes such as physical mixing and resuspension.

Submerged Aquatic Vegetation Productivity

While small beds of submerged aquatic grasses exist in Weeks Bay (see Chapter 3), there is no information on the contribution of these areas to the overall productivity of the Weeks Bay system.

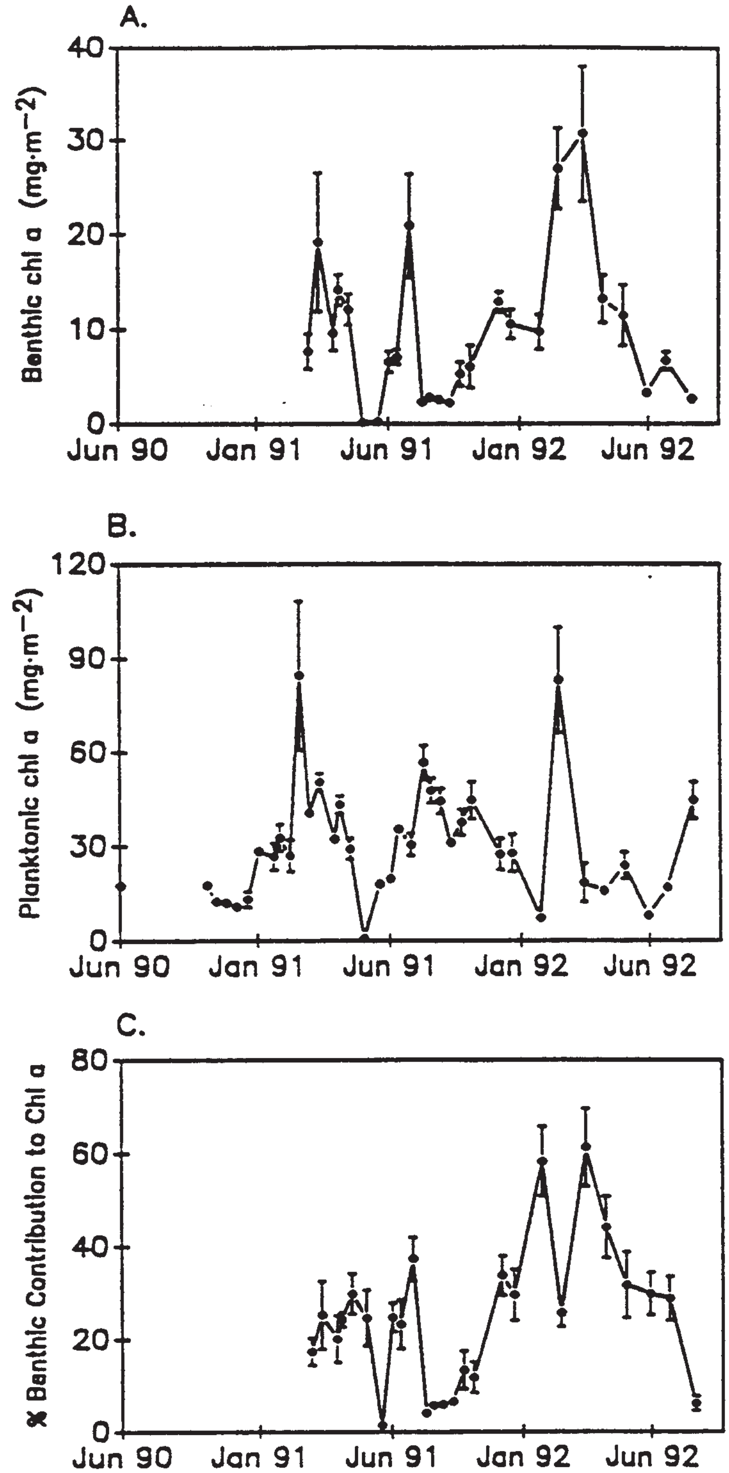


Figure 11: Benthic chlorophyll *a* (A), planktonic chlorophyll *a* (B), and percentage benthic contribution to microalgal chlorophyll *a* (C) for Weeks Bay, June 1990 to July 1992. Values represent means and standard errors, n=4. From Schreiber and Pennock, 1995.

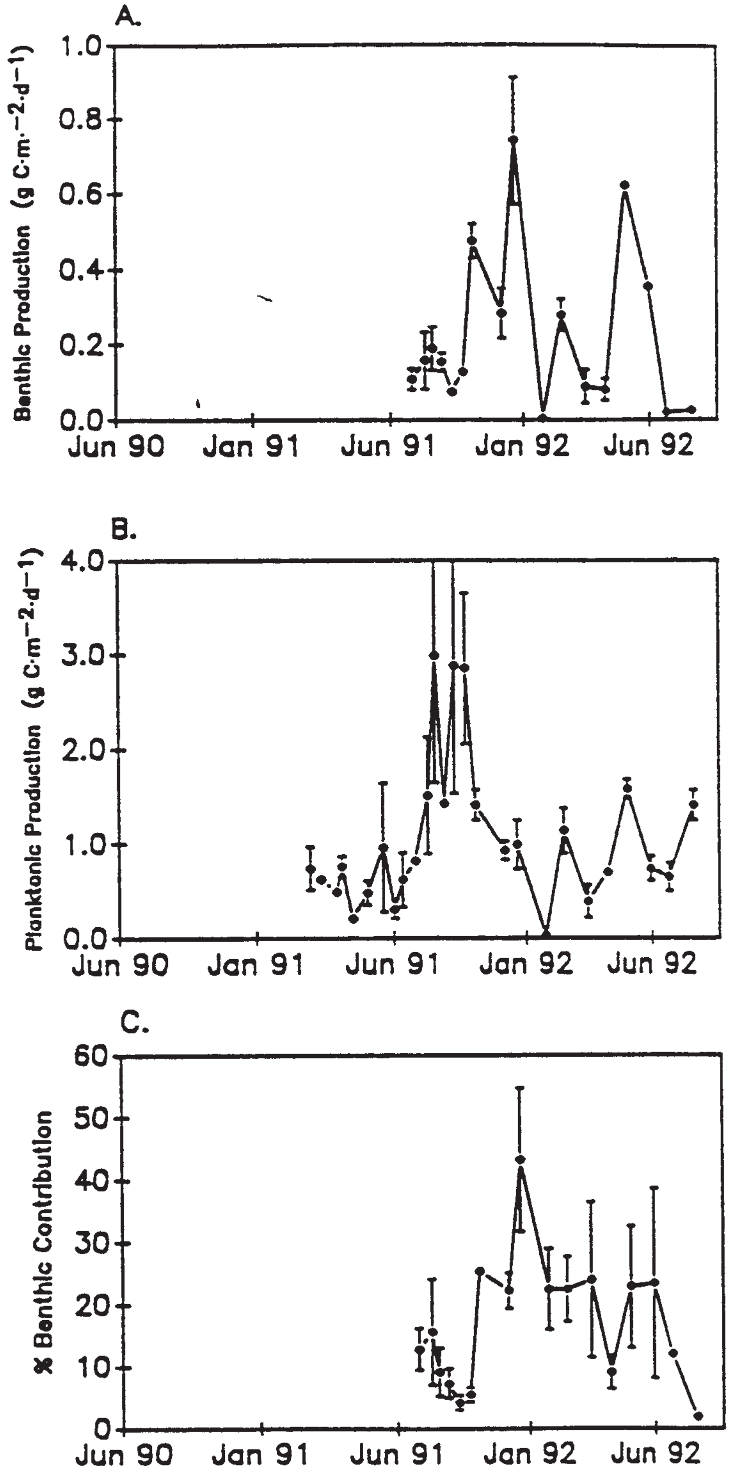


Figure 12: Benthic primary production (A), planktonic primary production (B) and percentage contribution to microalgal primary production (C) for Weeks Bay, June 1990 to July 1992. Values represent means and standard errors, n=4. From Schreiber and Pennock, 1995.

Chapter 5: Estuarine Consumers

by Michael R. Dardeau

Estuarine living resources range from the unseen yet crucial microbes and plankton to the more conspicuous and sought after commercial and sport species. Much of the economic and aesthetic value of Weeks Bay is manifested in its living resources. Birds and fish afford recreational opportunities. Mullet and blue crabs provide for commercial harvests and young fish and shrimp feed and grow in the marshes and submerged grasses before migrating to Mobile Bay and the Gulf of Mexico. Because diversity and abundance of inhabitants in this unique and productive environment are linked to complex physical and biological interactions, changes in animal populations often signal declining habitat quality or quantity. The importance of animal communities, as a valuable resource and as indicators of a healthy ecosystem, makes them a priority in monitoring and research efforts.

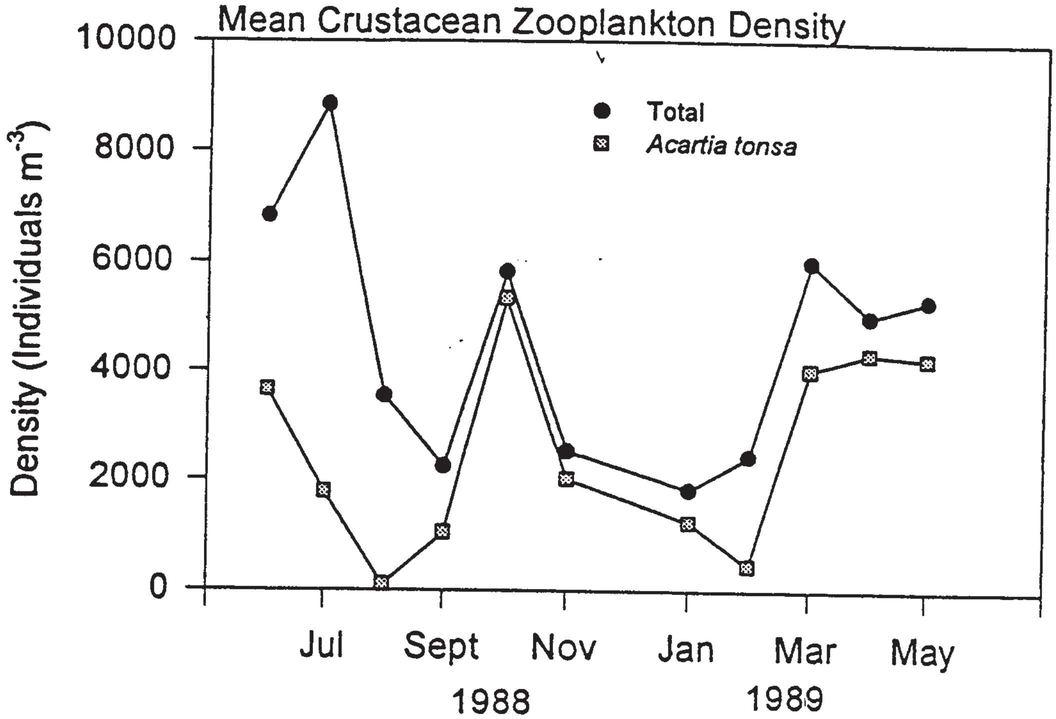
Aquatic Fauna

Zooplankton

Data on the holoplankton, or permanent plankton, in Weeks Bay have been reported by Bain and Robinson (1990) and Stearns et al. (1990). The zooplankton assemblage was numerically dominated by rotifers; crustaceans were second in abundance. Calanoid, cyclopoid and harpacticoid copepods were present throughout the year, while cladocerans appeared only during low salinity conditions. As in most southeastern estuaries, *Acartia tonsa* was the most abundant species, comprising at least half of all crustacean zooplankton taken within the bay during fall, winter and spring (Fig. 13). Only during summer months, when both density and richness were highest, did other species, notably *Halicyclops fosteri* and *Oithona* spp., approach the density of *A. tonsa*. Overall, zooplankton abundance was lowest during winter months (Fig. 13), when many species such as *Pseudodiaptomus coronatus*, and *Eurytemora* sp. were absent. Two harpacticoids, however, *Onychocamptus chathamensis* and *Pseudostenhelia wellsi*, were most abundant during winter. Diurnal zooplankton density averaged 1,336 m^{-3} in the study of Robinson and Bain (1989). Densities of nocturnal samples taken during the same period averaged 6,883 m^{-3} (Stearns et al. 1990), indicating that diel vertical migration is an important process in this shallow system. Bain and Robinson (1990) noted that mean densities varied dramatically from 1988 to 1989. Highest zooplankton abundances were associated with saline, turbid water masses that moved into the bay in summer and fall.

Generally, zooplankton species were distributed throughout Weeks Bay (Sterns et al. 1990). Exceptions were those species associated with a particular salinity regime or those associated with vegetated substrates. The cyclopoid copepods, *Saphirella* sp. and *Oithona colcarva*, were most abundant in salinities ranging from 10 - 20 ‰ while the cladocerans *Alona*, *Bosmina*, *Bosminopsis*, *Ceriodaphnia*, *Daphnia* and *Diaphanosoma* were only present in areas dominated by fresh water. At least two copepods, *Eurytemora* sp. and *Leptocaris kunzi*, were most abundant in vegetated areas (black needlerush, saltmarsh cordgrass, and wild celery) in Weeks Bay.

Preliminary experiments designed to estimate seasonal impacts of grazing by zooplankton within different habitats indicated that grazing pressure differed seasonally, as well as between habitats (Fig. 14) (Sterns et al. 1990). In any given sampling period, grazing of primary production by zooplankton was greater in unvegetated, shallow, open



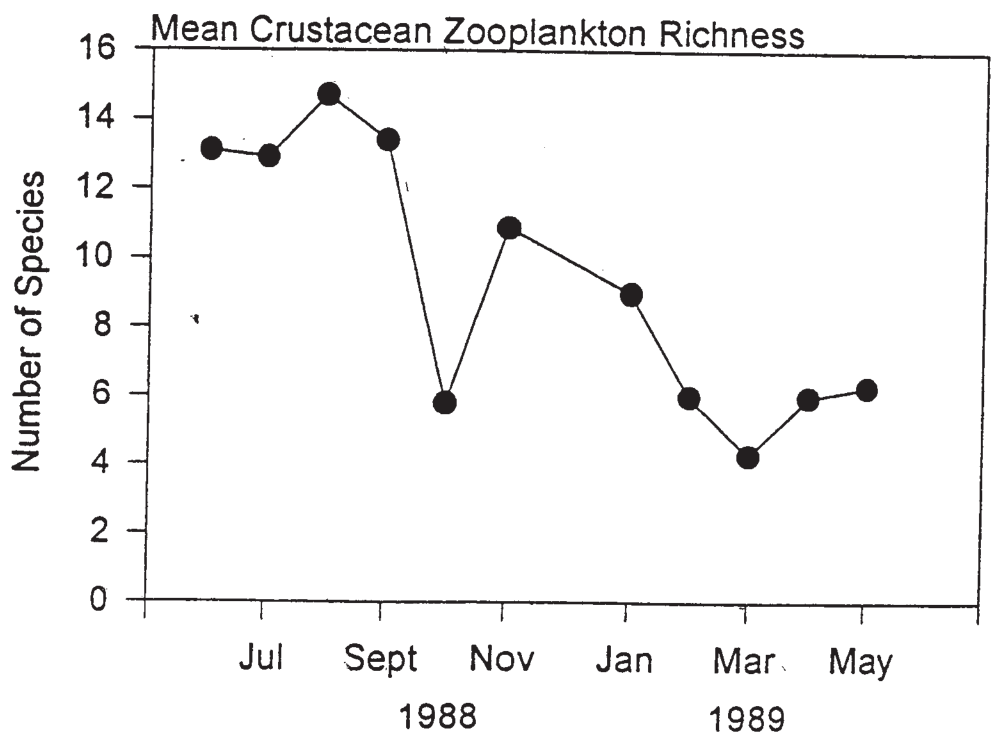


Figure 13: Mean crustacean zooplankton density (top panel) and species richness (bottom panel) at eight baywide stations sampled (70 µm net) monthly from 1988-1989. Adapted from Stearns et al., 1990.

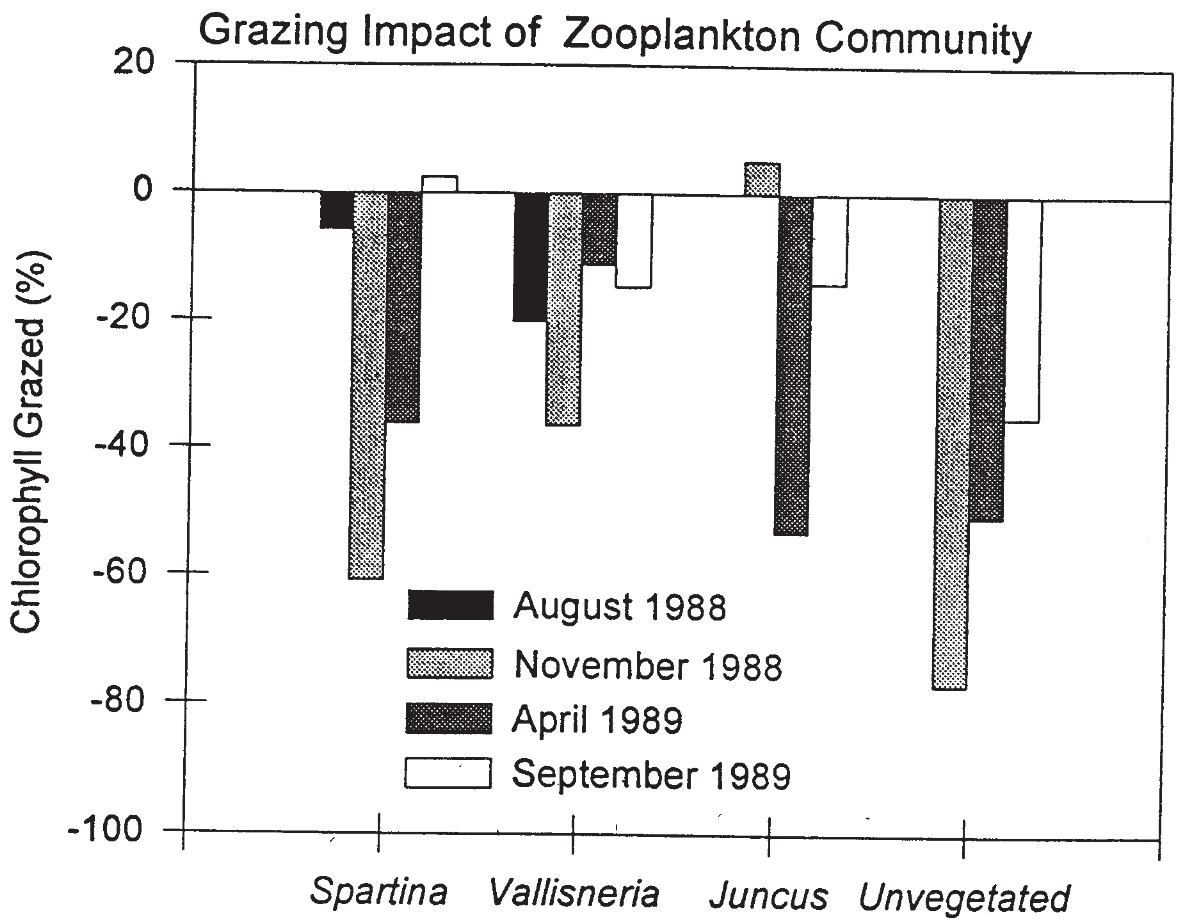


Figure 14: Seasonal and habitat variation in grazing of chlorophyll *a* in Weeks Bay. Percentages are expressed relative to water filtered through a 70 μm net and incubated *in situ*. Adapted from Stearns et al., 1990.

bay bottom than in any vegetated habitat. Grazing pressure was least in wild celery (*Vallisneria*) habitat. The greatest impact of grazing occurred in the fall in all habitats except black needlerush. In this habitat, fall grazing was minimal and grazing rates were greatest in spring. These results, however, are preliminary and serve to indicate only general trends.

Gelatinous zooplankton, such as jellyfish and ctenophores, are considered important predators of crustacean zooplankton in nearby Mississippi Sound (Philips et al. 1969), and in estuarine systems in general (Valiela 1995). However, no information on these taxa in Weeks Bay has been reported.

Meroplankton are larval stages of invertebrates and fishes which spend from hours to months as plankton before assuming their adult form. The important meroplanktonic species in Weeks Bay include the commercially important penaeid shrimps, blue crabs, oysters and most fishes.

Both brown and white shrimp spawn offshore, undergo several molts as planktonic larvae, metamorphose into postlarvae and begin to move into an estuary after about a month offshore (Loesch 1965, Heath 1979). Entrance to Weeks Bay by brown shrimp has been shown to be accomplished by nocturnal vertical migration from the benthos into the water column either in anticipation of, or in direct response to, flood tide signals such as a salinity increase (Matthews 1988, Matthews et al. 1991). Postlarvae move into marshes and rivers of Weeks Bay and begin to grow very rapidly. After maturing into juveniles and assuming a benthic existence, they reverse their inshore migration, and move back into Mobile Bay as they approach legal size. Brown shrimp postlarvae begin this seasonal migration in December and January while white shrimp postlarvae begin to enter the estuary in July and August. During three years of sampling at a mid-bay station, Alabama Department of Conservation's Marine Resources Division found postlarval brown shrimp from December to July with peak abundances in March, April and May. Postlarval white shrimp were not captured in the bay itself but were abundant in Fish and Magnolia River (ADCMRD 1988).

Like shrimp, blue crabs spawn in high salinity water, usually at the mouth of bays. Early zoeal stages develop offshore but the final larval stage, the megalopae, return to the estuary to settle and develop into juveniles (Tatum 1979). Settlement, however, occurs in high salinity water close to the Gulf of Mexico (Rabalais et al. 1995). Blue crab megalopae are rare (McClintock and Marion 1990) or absent (ADCMRD 1988) in Weeks Bay.

Ichthyoplankton, a term which refers to the planktonic larval stage of fishes, can be a numerically significant component of the plankton in many estuarine systems (Valiela 1995). Although no published information on ichthyoplankton exists for Weeks Bay, raw data are available in the files of ADCMRD (see Section 4, Recommendations).

Infauna

Infauna are organisms living within the sediment and are conveniently divided into three groups, in order of increasing size, microfauna, meiofauna and macrofauna. These size classes correspond to major taxonomic and functional groupings. There have been no studies which have focused on the populations of microfauna and meiofauna in Weeks Bay.

Macrofauna, those organisms larger than 0.5 mm, are also not well studied in Weeks Bay. Studies are limited to those of Bault (1970) and Bain and Robinson (1990). Bault (1970) collected 18 individuals from a mid-bay station with sediment he characterized as oxidized, sandy clay. These included three common estuarine polychaete species (*Hobsonia florida*, *Laeonereis culveri*, and *Eteone* sp.), rhynchocoels and insect larvae. Due to inadequate sampling methodology, he was unable to determine densities or seasonality. Bain and Robinson (1990) found that polychaetes comprised 83% of all infauna at stations along the margins of Weeks Bay. Other taxa, each representing less than five but more than one percent of the total abundance, were rhynchocoels, amphipods, insects, mysids, oligochaetes, gastropods and bivalves. Mean density in this study was 4,861 m^{-2}, a value comparable to infaunal density at a shallow, oligohaline station in upper Mobile Bay (Dardeau et al. 1990). Highest densities of infauna were found in different habitats in different seasons: silty sediments (spring), nearshore environments (summer), and turbid, freshwater (fall).

Although they did not focus exclusively on the Weeks Bay estuary, Swingle and Bland (1974a) reported that the common rangia, *Rangia cuneata*, was found at densities of 1-5 m^{-2} at stations in the vicinity of Weeks Bay (Weeks Bay, Fish, Magnolia Rivers, and Bon Secour Bay).

Only one study to date has addressed functional relationships among trophic levels in Weeks Bay. Bain and Robinson (1990) used principal components analysis and multiple regression analysis to ascertain that benthic invertebrate density was frequently an important predictor of habitat use by fish and shrimp in Weeks Bay.

Nekton

True estuarine nektonic species are outnumbered in Weeks Bay by transient fishes entering the estuary for varying periods of time, either from the rivers or the marine environment (Fig. 15). Many are euryhaline, marine spawned, juveniles, like Atlantic croaker, Gulf menhaden or striped mullet, which use Weeks Bay as a nursery area. Other species, such as spotted sea trout, winter in the Fish and Magnolia Rivers, passing through Weeks Bay during fall and spring (Byrd 1955). Migratory patterns overlap, resulting in a fish community in which species composition is dependent not only on season but on prevailing environmental conditions, particularly salinity (Bain and Robinson 1990).

Numerically dominant species are frequently postlarvae that enter Mobile Bay and its subestuaries, such as Weeks Bay, in winter and spring. Winter postlarvae are predominately spot, Atlantic croaker and Gulf menhaden. Spring postlarvae consist of sand seatrout and several species of the families Bothidae and Gobiidae (Shipp 1987). These small fishes become large enough to be captured by conventional gear in fall and spring. Seine samples taken monthly at the mouth of Weeks Bay (Fig. 16) showed peaks of abundance in October and March. The former was due primarily to bay anchovies, while the latter resulted from high numbers of mullet and menhaden. Lowest abundances of all species generally occurred during winter and summer. Bain and Robinson (1990) found that anchovies and menhaden largely determined total fish densities. Abundance of these species regulated the rate of decline in total fish abundance between spring and fall.

Species richness appears to be greatest during fall and spring and least during summer and winter (Fig. 16). Multivariate techniques were used by Bain and Robinson (1990) to identify attributes associated with presence or abundance of common fish species (Table 1). They found that distribution of nekton in Weeks Bay was generally oriented along a nearshore-offshore (shallow-deep) gradient during periods of low river flow. Nearshore habitats were characterized as clear, fresh, calm and shallow. Offshore habitats were turbid, saline, turbulent and deep. During periods of high river flow, habitats were arranged along a more typical riverine - estuarine salinity gradient from river mouth to estuary mouth. In many cases, the preferred habitat of nektonic species changed seasonally

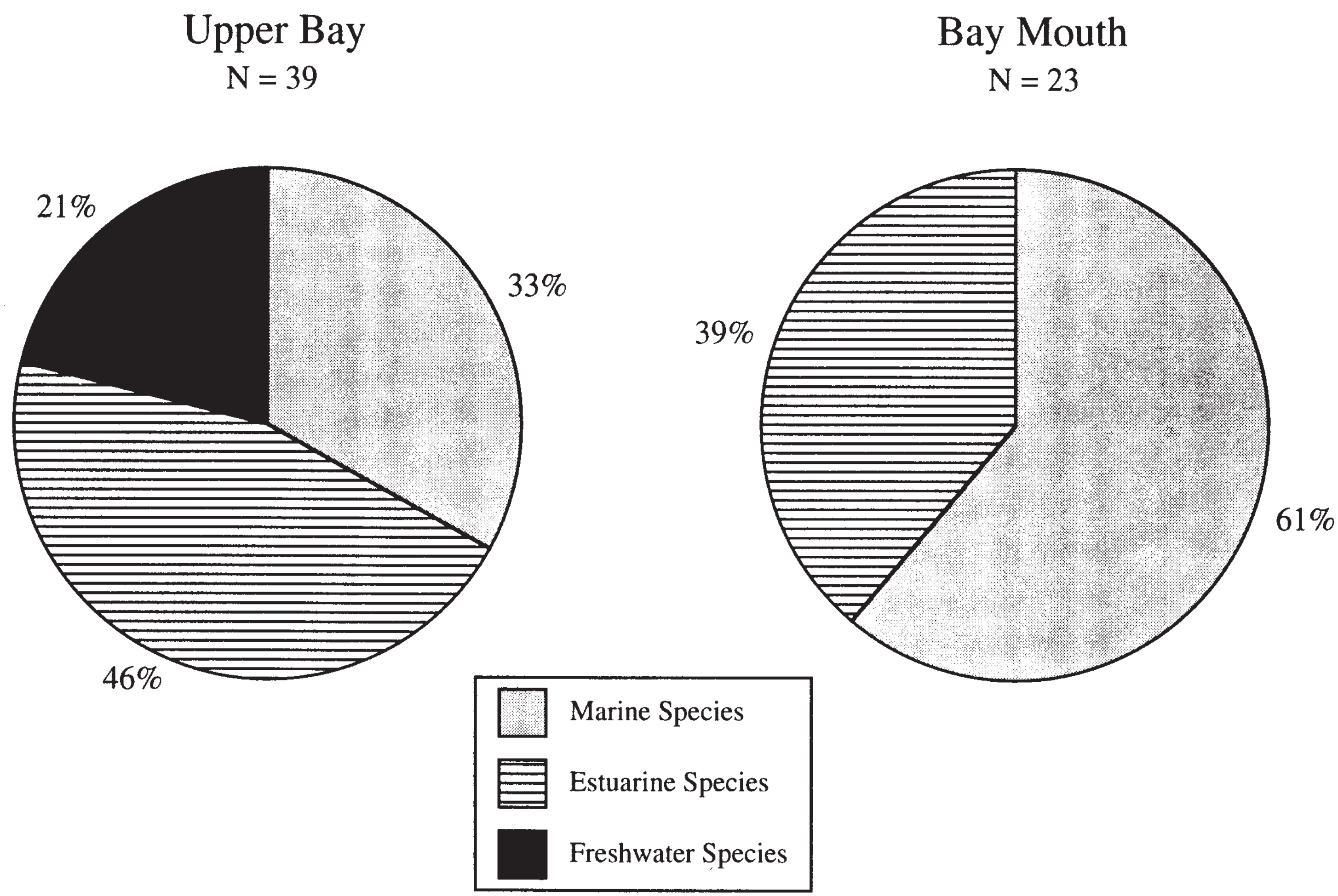


Figure 15: Species composition at stations sampled (by seine) monthly at the upper and lower ends of Weeks Bay from 1970-1972. From Swingle and Bland, 1974b.

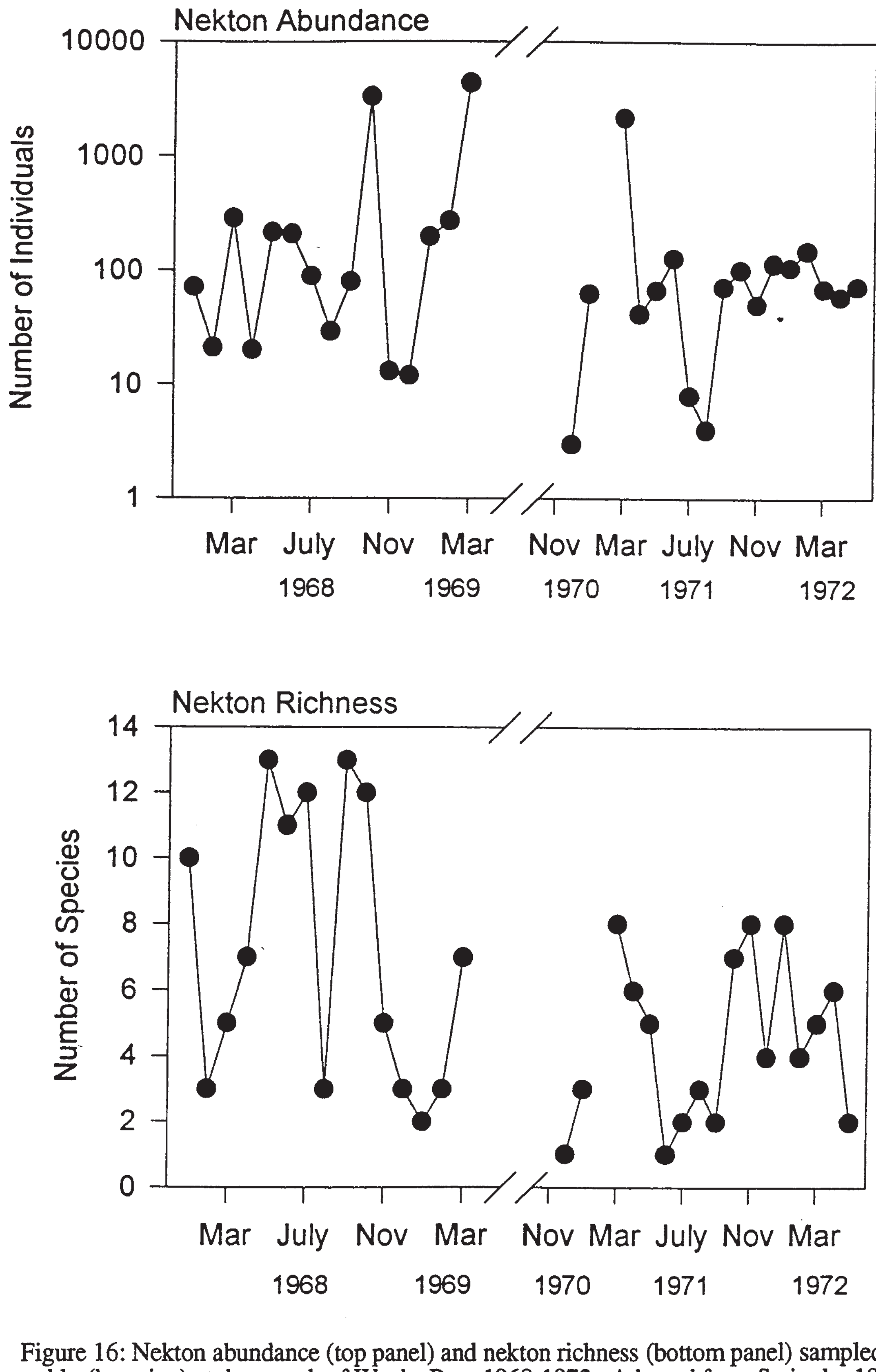


Figure 16: Nekton abundance (top panel) and nekton richness (bottom panel) sampled monthly (by seine) at the mouth of Weeks Bay, 1968-1972. Adapted from Swingle, 1971; Swingle and Bland, 1974b.

Table 1: Habitat attributes associated with presence or abundance of fishes listed in rank order of importance. Maximum densities (no. m^{-2}) captured in block nets, sampled seasonally in 1989, are shown in parentheses.

	Descriptors of Utilized or Heavily Populated Habitats					
Taxa	Spring		Summer		Fall	
Gulf menhaden	Warm, turbid, saline, shallow	(263.3)	†		†	
Bay anchovy	Turbid	(4.0)	Turbid, saline	(86.6)	Turbid, saline, deep, warm	(22.2)
Rainwater killifish	Clear, freshwater, still	(0.7)	†		†	
Tidewater silverside	Shallow	(8.8)	†		Turbid	(0.7)
Gulf pipefish	Shallow, fresh, still, clear	(2.8)	†		†	
Pinfish	Nearshore	(3.3)	*	(1.1)	†	
Sand seatrout	Saline	(0.4)	†		†	
Spot	Nearshore, shallow, saline	(0.6)	†		†	
Atlantic croaker	Still, offshore, silt	(1.7)	†		*	(1.7)
Black drum	*	(0.1)	†		†	
Darter goby	*	(2.8)	Silt	(0.3)	Silt, shallow, still	(2.8)
Bay whiff	*	(0.1)	Silt, turbid, deep	(0.1)	Offshore, cool	(0.6)
Hogchoker	Clear, fresh	(0.1)	*	(0.1)	†	
Threadfin shad	†		Turbid, deep, fresh	(1.4)	†	
Hardhead catfish	†		Offshore, saline	(0.3)	†	
Naked goby	†		Still	(0.2)	Nearshore, fresh, clear	(2.4)
Lined sole	†		†		Clear, fresh	(0.4)
Blackcheek Tonguefish	†		†		Warm, saline	(0.5)

* Species did not utilize habitat with particular attributes (model ineffective for all variables).
† Species captured in fewer than 5 samples.

Source: Bain and Robinson, 1990

but, in general, salinity and water transparency were important abiotic factors. However, there may be other controls on distribution. Swift (1983) found that a seine station at the mouth of Weeks Bay had a similar species composition to a station in Bon Secour Bay due south of Weeks Bay on the north shore of the Fort Morgan peninsula, probably because of the presence of wild celery beds (*Vallisneria americana*) at both sites. His multivariate analyses also implicated season and salinity as important predictors of community structure. It appears that in Weeks Bay, groups of species adopt smooth sequences of species distributions across different habitat types rather than specializing on a particular estuarine habitat.

Seasonal migrations by nekton are a significant feature of trophic relationships and energy flow in Weeks Bay. Many nektonic species are present in huge numbers and feed heavily on prey populations. Fishes common in Weeks Bay may be classified as planktivores (e.g., shad, anchovies and menhaden), benthic omnivores (e.g., gobies, flatfish, black drum, croaker and spot), pelagic omnivores (tidewater silverside), detritivores (e.g., mullet), or epibenthic carnivores (e.g., seatrout and silver perch) (Odum 1970, Sheridan and Livingston 1979). Others, like the pinfish, show ontogenetic shifts in feeding strategies, functioning as predators in early life history stages, but shifting to a more omnivorous diet by adding plants to their diet as they age (Stoner 1980). The more abundant fishes feed at low trophic levels or are generalists able to utilize a variety of prey. Most nekton species in Weeks Bay are temporary residents that maximize their opportunities within the range of prevailing conditions.

Terrestrial Fauna

Amphibians and Reptiles

Although Marion and Dindo (1987, 1988) characterized the reptile and amphibian fauna of the Weeks Bay Reserve as "reasonably rich", most of the species they encountered were found in the Fish and Magnolia Rivers and their adjacent banks. The only reptiles adapted to estuarine salinities are the alligator, the diamondback terrapin and the Gulf saltmarsh water snake (Neill 1958). Marion and Dindo (1987, 1988) occasionally sighted alligators but, despite considerable effort, found no Gulf saltmarsh water snakes and only a single Mississippi diamondback terrapin in the Weeks Bay Reserve. The latter species may be rare because it prefers high salinity saltmarshes, an uncommon habitat in Weeks Bay (Marion and Dindo 1987).

With the exception of alligators, there have been no sightings of Federally or State Threatened or Endangered reptiles in Weeks Bay. An occasional Alabama red-bellied turtle (Federally Endangered) or alligator snapping turtle (State Threatened), however, may enter Weeks Bay from the Fish or Magnolia Rivers (Mount 1975, Marion and Dindo 1987, 1988). With the possible exception of the Atlantic Ridley, it is unlikely that any of the five species of sea turtle would be found in Weeks Bay, due to low average salinities in the Weeks Bay system. No sightings have been confirmed. Nearly every reptile potentially encountered in Weeks Bay is afforded protection by the state or federal government (Table 2).

Mammals

Mammalian population diversity in Weeks Bay is considered "average or below average" (Marion and Dindo 1988). Raccoons and marsh rabbits are the dominant mammals in the marsh and along shorelines. Marine mammals, federally protected under the Marine Mammal Protection Act of 1972, are occasional visitors to Weeks Bay.

Table 2: Species in need of special attention reported or expected to occur in Weeks Bay, Alabama. *

	State	Federal
Reptiles		
American Alligator	SC †	T ¥
Gulf Salt Marsh Water Snake	SC	
Atlantic Ridley	E	E
Mississippi Diamondback Terrapin	SC	
Alabama Red-Bellied Turtle	T	E
Birds		
Brown Pelican	-	E
Reddish Egret	SC	
Wood Stork	E	E
Mottled Duck	SC	
Osprey	SC	
Bald Eagle	E	T
Black Rail	SP	
Snowy Plover	E	
Wilson's Plover	SC	
Piping Plover	SC	E
American Oystercatcher	SC	
Gull-Billed Tern	SC	
Mammals		
Marsh Rabbit	SP	
West Indian Manatee	XP	E

* Categories are from Mount, 1984 and
U.S. Department of Interior, Fish and Wildlife Service, 1991.

† SC = Special Concern
T = Threatened
E = Endangered Species
SP = Poorly Known
XP = Extirpated

¥ The American alligator is listed as Threatened because of similarity of appearance to other protected species and is not protected by the Endangered Species Act of 1973.

Holliman (1979) reported Atlantic bottlenose dolphin moving into Weeks Bay and the Fish and Magnolia Rivers. Newspaper accounts of a manatee in Fish River in 1991 were followed by the discovery of a dead manatee in Mobile Bay between Weeks Bay and Point Clear (Dr. G. Regan, personal communication).

Birds

Marion and Dindo (1987, 1988) monitored bird populations seasonally in Weeks Bay over a two year period. Grebes, cormorants, ducks and coots were present most often in the winter and spring while gulls, terns and long-legged waders were present year round (Table 3). Several groups of birds were conspicuously absent in their study. Tricolored herons and black skimmers, species associated with high salinity or saltmarsh environments, were rare or absent. Marsh ducks, which feed on submerged aquatic vegetation were not present, presumably reflecting the limited extent of this resource within Weeks Bay. Small wading birds are apparently precluded by the absence of exposed mudflats.

Long term records of breeding birds or winter residents, in the form of breeding bird counts or Christmas bird counts, are not available for the Weeks Bay Reserve. Both are conducted annually in Baldwin County but neither includes area within reserve boundaries. A historical record of nesting in the Weeks Bay area by snowy egrets, tricolored herons and little blue herons was reported by Johnson (1979) but has not been verified.

Weeks Bay Estuarine Research Reserve contains relatively pristine habitat located in a migratory corridor for many threatened neotropical species. Thus, new species will undoubtedly continue to be added to the current species list (Table 3). Only two species, the osprey and brown pelican, are considered in need of special attention, but several others may eventually be found.

Commercially Important Species

Shrimp

Weeks Bay is used as a nursery and staging area by juveniles of all three southeastern species of commercial penaeid shrimps. Occupation of the estuary is seasonal with different species present in the estuary at different times. Brown shrimp metamorphose from postlarvae in early spring and are present in Weeks Bay until June or July before emigrating to Mobile Bay (Fig. 17). White shrimp juveniles are most abundant during late summer and fall (Fig. 17). Pink shrimp are much rarer in Weeks Bay than brown or white shrimp. Catch per unit effort (CPUE) data indicate that this species generally follows the same seasonal pattern as brown shrimp (ADCMRD 1988).

As they grow larger, all three species emigrate from Weeks Bay. Tagging studies by the Alabama Department of Conservation Marine Resources Division (ADCMRD 1987, 1988) indicated that most brown shrimp tagged in Weeks Bay moved west into Mobile Bay while most white shrimp released in Weeks Bay were recaptured either in upper Mobile Bay or around Dauphin Island. Between 70 and 90% of shrimp of both species recaptured were within ten miles of the release point, indicating a high level of utilization by local shrimpers. The furthest returns were from south of the Louisiana coast, approximately 225 miles from Weeks Bay. No shrimp released in Bon Secour or Mobile Bay were recaptured within the Weeks Bay estuary.

Table 3: Birds recorded during 20-minute observations at each of four 300 m shoreline transects in the Weeks Bay National Estuarine Research Reserve from 1986-1988.

	Winter	Spring	Summer	Fall
Common Loon	C *	R	ns	ns
Horned Grebe	C	U	ns	R
Pied-billed Grebe	C	U	ns	C
Red-necked Grebe	R	ns	ns	ns
Double-crested Cormorant	C	C	ns	C
Mallard	R	Domestic Only	Domestic Only	Domestic Only
Blue-winged Teal	C	U	ns	ns
Wood Duck	R	C	U	R
Common Goldeneye	R	ns	ns	ns
Hooded Merganser	C	R	ns	ns
Common Merganser	C	ns	ns	ns
Red-breasted Merganser	C	R	ns	ns
American Coot	C	R	ns	C
Brown Pelican	C	C	ns	C
White Pelican	ns	ns	ns	R
Herring Gull	C	C	R	U
Ring-billed Gull	C	R	R	R
Laughing Gull	C	C	C	C
Forster's Tern	U	C	C	C
Common Tern	C	C	C	C
Little Tern	C	C	C	C
Royal Tern	C	C	C	C
Sandwich Tern	ns	ns	U	ns
Great Blue Heron	C	C	C	C
Green Heron	ns	C	C	U
Little Blue Heron	ns	ns	C	C
Great Egret	C	C	U	C
Snowy Egret	C	ns	R	R
Yellow-crowned Night Heron	ns	ns	U	U
White Ibis	ns	ns	ns	U
Glossy Ibis	ns	ns	ns	R
King Rail	U	U	U	U
Clapper Rail	U	U	U	U
Semipalmated Plover	ns	R	ns	ns
Wilson's Plover	R	ns	ns	ns
Osprey	C	U	C	R
Belted Kingfisher	C	C	C	C

Source: Marion and Dindo, 1988

* C - Common, U - Uncommon, R - Rare, ns - not sighted

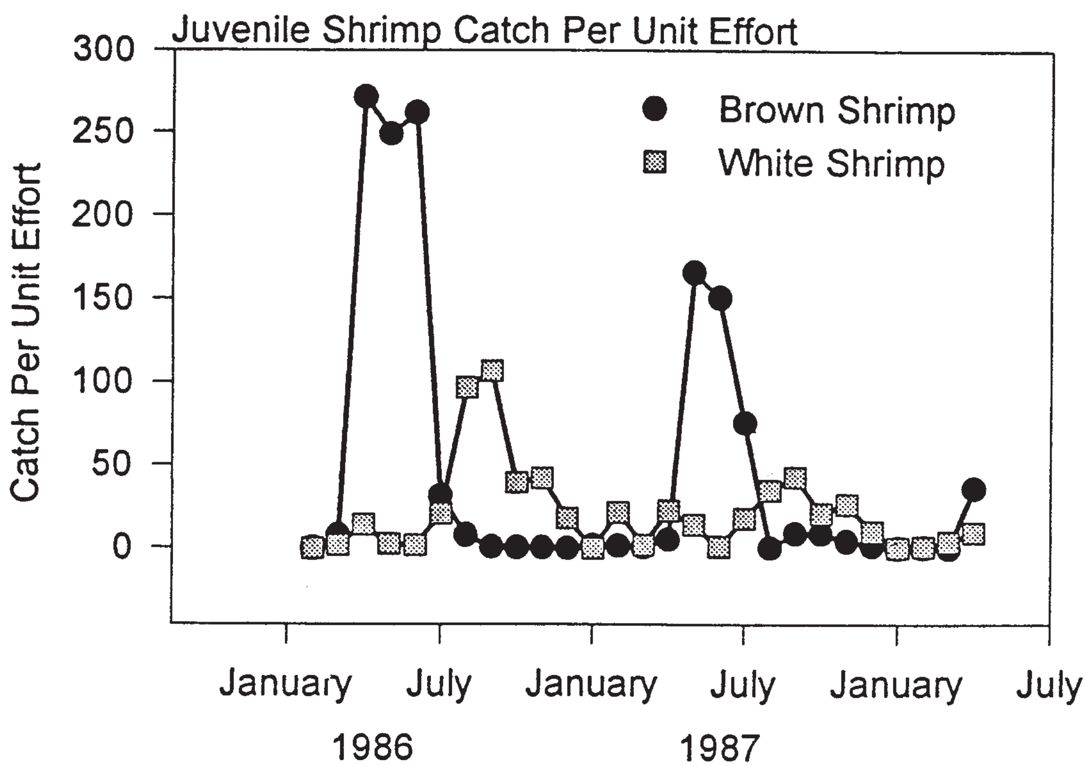


Figure 17: Juvenile brown and white shrimp captured at a mid-bay station (otter trawl) from 1986-1988. From ADCMRD Technical Reports, 1987, 1988.

Because shrimp present in Weeks Bay are nearly always smaller than the legal average count of 68 per pound, Weeks Bay was permanently closed to shrimping by the Alabama Department of Conservation in 1980. Recognizing the high degree of utilization by local shrimpers, a half mile buffer zone was created near the mouth of Weeks Bay in 1988 to allow emigrating shrimp to spread over a wider area and increase the number of shrimp surviving to spawning age.

Blue Crabs

McClintock et al . (1993) examined population dynamics of the blue crab, *Callinectes sapidus*, in Weeks Bay. Populations sampled from three sites in Weeks Bay varied in density from month to month but not in a predictable annual pattern (Fig. 18). Furthermore, interannual variation was significant, with crab numbers much higher in 1989-1990 than in 1990-1991 (Fig. 18). More than half of the blue crabs collected were juveniles (20-80 mm carapace width). Adult crabs, although always present, were not abundant. Reproduction was annual (one generation per year), with gonadal maturation occurring during summer and fall. Ovigerous females were never present in Weeks Bay, probably emigrating to the mouth of Mobile Bay to spawn. Recruitment of juvenile crabs (<20 mm carapace width) was noted in August of one year and but in March of another. Modal cohort analysis indicated that adult size was reached in 12-18 months. Distributions within the bay indicated that the upper bay site, near the mouth of Fish River, was dominated by very young juveniles while the site nearest the bay mouth had the highest proportion of adult crabs, corroborating the apparent function of Weeks Bay as a nursery area for the blue crab.

Oysters

The earliest mention of oyster reefs in Weeks Bay was by Ritter (1896). He noted that the live reefs with which he was familiar 25 years previously were no longer present. Interestingly, he noted that experiments with planted beds in Weeks Bay were in progress. May (1971), in a survey of oyster resources in Alabama waters did not record oyster reefs from the Weeks Bay area but did collect oysters from the mouth for tissue analysis. Populations of oysters in nearby Bon Secour Bay have a history of overexploitation (Eckmayer 1979).

Weeks Bay is presently classified as conditionally closed to shellfish harvest by the Alabama State Health Department. Ongoing sampling indicates that fecal coliform levels exceed criteria for safe harvest (see Chapter 7).

Finfish

Over 90% of the fishery landings on the Gulf coast involve species that spend some portion of their lives in estuarine habitats (Gunter et al. 1974, Nixon 1980). The most abundant commercial finfish species in Weeks Bay is the gulf menhaden. They exist in Weeks Bay as juveniles, feeding and growing in the bay until emigrating and supporting a major commercial fishery in the Gulf of Mexico.

Several species, including sheepshead, white trout, mullet and flounder, are commercially harvested within Weeks Bay by gill netting. Speckled trout and redfish were also fished commercially until their designation as gamefish in 1985. One of the traditional sources of commercial fisheries information are the landings data collected by the National Marine Fisheries Service. Because they are collected from a larger geographic region, these data are of little use for discerning dynamics for the Weeks Bay system.

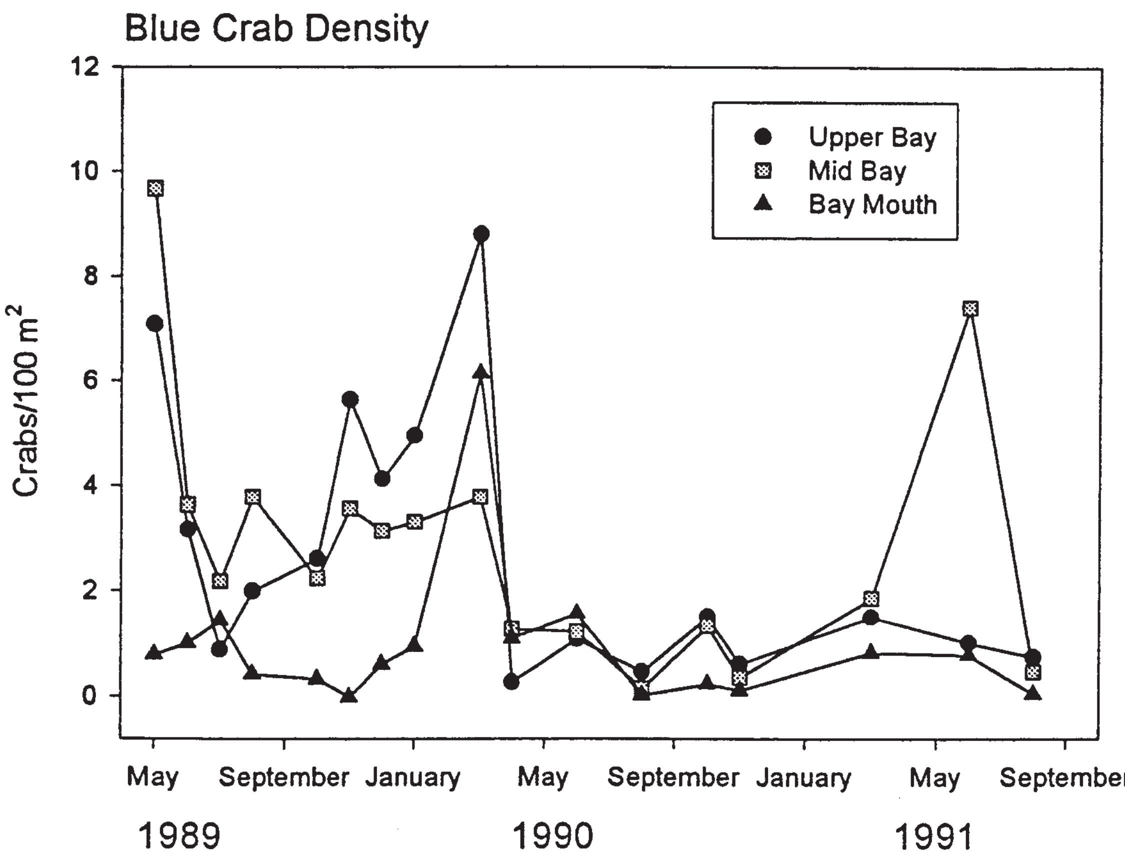


Figure 18: Mean densities of blue crab collected (trawl) from 1988-1991 at 3 sites in Weeks Bay. Adapted from McClintock et al., 1993.

Section 3: The Human Role in the Weeks Bay Watershed: Past and Present

Chapter 6: Land Use

by Cherie Arcenaux

Pre-History Land Uses

The land areas encompassing Weeks Bay and the Fish River and Magnolia River subwatersheds, appear to have always served human inhabitants as areas for hunting, fishing and crop production. The Weeks Bay area is rich in prehistoric archeological remains. It is reasonable to assume that prehistoric nomadic Indian tribes traversed this area because of its natural abundance of fish and wildlife.

Archaeologists have divided the prehistory of the southeastern United States into four basic time periods: the Paleo, Archaic, Woodland and the Mississippian Periods. The Paleo Indian period (12,000-8000 B.C.) is often thought of as a time when mammoths and mastodons were hunted by humans. The Archaic Period (8000-1200 B.C.) found man untilizing the forests and water around him. Hunting and fishing were still important, but the gathering of wild foods, such as nuts and berries, and the collecting of clams and oysters from the bays were increasing in importance. The Woodland (1200 B.C. - A.D. 1000) period is marked by Indians creating and using primitive clay pottery for utensils and storage containers. Archeological evidence suggests that Woodland Indians relied more heavily on estuarine fishing and shellfish collecting than previous Indian groups. This implies that they existed in larger groups and employed more efficient techniques than in earlier periods. Additionally, during the Woodland period, plants began to be grown in small gardens. This established the basis for the more complex and advanced Mississippian (A.D. 1000-1600) Indian Cultures.

The Mississippian Indian groups which were known to have previously existed in the Mississippi River Valley appear to have migrated to the Mobile Bay area about A.D. 1000. Earthen mounds, which were the foundation of large religious and political buildings, date from this period. Pottery shapes and designs changed significantly at this time. Indian villages that were inhabited year round were present when early Spanish explorers entered this area in the 16th Century (U.S. Army Corps of Engineers, 1989).

Settlement And Early Land Uses

Early European exploration concentrated upon major waterways in initial search of riches and safe harbors. Successful early settlements occurred only in sites that were near protected waters and afforded trade with other areas. The sustained success of the Ports of Pensacola and Mobile and the maritime activity associated with Mobile Bay encouraged the settlement of Baldwin County. The first land grant in the Weeks Bay area was issued in 1715 to Joseph Simon de la Pointe by the French governor of Louisiana, De La Mothe Cadillac. Many of these early land grants were upheld when the American period of governance began in 1813.

Situated between the two seaports and near large navigable rivers, and because of its abundance of pine trees, Baldwin County became a major source for naval stores. Naval stores are the raw materials such as pitch and tar used in the construction and maintenance of wooden ships. The base material for production of tar and pitch is turpentine which is extracted from pine trees.

It is known that between 1900 and 1933 approximately 13 corporations were formed in Baldwin County to distill pine resin. Besides large corporations, smaller companies also practiced this trade. As of 1926, approximately 40 such operations were listed for Baldwin County. Several of these operated within the Weeks Bay watershed: Turkey Creek Turpentine Company, Malbis Plantation and Baldwin Timber and Naval Stores. Several residents of the town of Magnolia Springs were also users of the pine resources near Weeks Bay. Lumber and turpentine production were an important industry in the Weeks Bay area even as recently as the first quarter of this century. Remnants of old turpentine stills abandoned in the woods and pine tree stumps with diagonal cuts in the bark for draining pine sap still exist throughout the area.

The earliest white settlers in Baldwin County planted the same crops commonly grown by the Indians, including Indian corn, beans, pumpkins and melons. Eventually, they added peas, potatoes, rice, and cotton. Agriculture began to develop rapidly about 1918, particularly in the southern part of the county. Much of the acreage in old growth or in areas that had been cut over was settled by groups of Greeks, Italians Germans, French and Swedes, mainly from the Midwestern States. These people tried new crops including tobacco and citrus fruits as well as vegetables and general crops. Yet, timber and timber products maintained a position of importance as steady income producers (USDA SCS 1964).

In modern history, the area now known as Weeks Bay was reported as Berwick's Bay (Lupton 1878) in the earliest documented report of marine fishes from Alabama. The author noted the area as a favorable fishing ground containing croaker, trout, redfish and immense schools of mullet.

Current Land Use

South Alabama Regional Planning Commission (SARPC 1993) has developed a Baldwin County Existing Land Use Map based upon a survey and analysis conducted in 1992 (Fig. 19). This information is comprehensive relative to documented uses and activities at that time and it encompasses the entire Weeks Bay watershed area. Land use patterns indicated by this survey are summarized in Table 4.

Development of shopping areas has followed population movement. These areas have been located with respect to existing centers, residential density and transportation facilities. A substantial increase in commercial shopping areas has occurred recently, especially along the Eastern Shore and in the City of Foley, areas which are within the Weeks Bay watershed.

Woodlands currently represent one of Baldwin County's largest land use categories (resource production and extraction, Table 4). There are extensive areas located through the county that are in timber production and are owned by paper companies.

Agriculture follows woodlands as a major land use (resource production and extraction, Table 4). The southern portion of Baldwin County is also heavily farmed with soybeans, corn and potatoes as some of the dominant crops.

A recent inventory of land uses in the Fish River watershed was conducted and incorporated into a GIS format (Beck 1995). The categories and acreage of each land use are indicated in Table 5. From a resource management perspective, GIS applications such as this one would be invaluable as a means to track and predict growth scenarios and attendant impacts. At this time, however, there is no database with which to evaluate

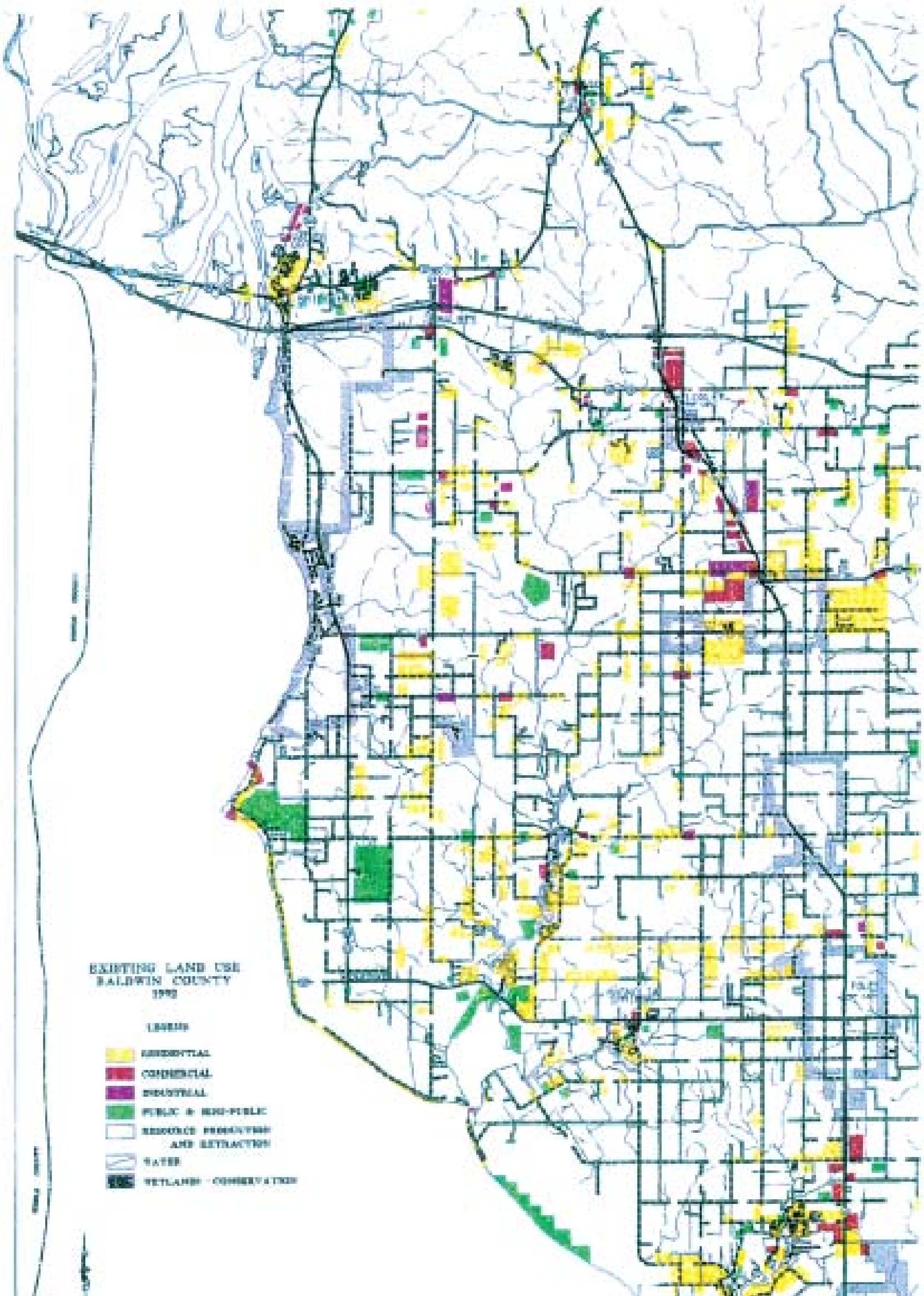


Figure 19: Existing land use in Baldwin County in 1992. From SARPC, 1993.

Table 4: Existing land use, Baldwin County, 1990.

Classification	Acres	Total Acres	% Developed	% Total
Residential	12,285		27	1
Commercial	1,802		4	0
Industrial	907		2	0
Public / Semi-public	31,036		67	3
Subtotal Developed		46,030	100	4
Resource production and extraction	721,463			68
Vacant	68,345			7
Wetlands	174,082			17
Water	46,462			4
Subtotal Undeveloped		1,010,352		96
Total Area		1,056,382		100

Source: South Alabama Regional Planning Commission, 1993

Table 5: Acreage of land use practices in the Fish River watershed.

Classification	Land Area (ha) *
Cropland	
summer pastures	3,599 †
bare-plowed	10,469
Orchards, mixed trees	4,179
Mixed grasses, cover crops	4,667
Woodland	17,324
Water	658
Total	40,896

* Hectares can be converted to acres by multiplying by 2.47.
† Values are rounded to the nearest integer.

Source: Beck, 1995

decade-length changes in land uses in areas immediately adjacent to WBNERR and consequently, estimate land loss to development.

Predicting Future Land Use

A Generalized Land Use Plan of Baldwin County was developed in 1992 by the South Alabama Regional Planning Commission (Fig. 20, SARPC 1993). The plan was based upon recent population changes (Table 6) and development projections. Baldwin County was identified as the fastest growing county in the state from the period 1980 to 1990. The purpose of the land use plan is to provide adequate amounts of land for delineated land uses based on the projected growth of the County and to ensure that these comprise a harmonious arrangement for uses for the County and its residents.

The Baldwin County Land Use Plan was designed as a general guide for long-range development in the County (Fig. 20). Changes in projected (2010) and current (1990) land use in Baldwin County are described in Table 7. The Baldwin County Land Use Plan clearly indicates a likelihood of increased residential growth, especially along water bodies, for the area of Baldwin County which includes the Weeks Bay estuarine system and the watersheds of the Fish and Magnolia Rivers. Commercial growth is also predicted to occur in this area, especially along transportation arteries. The implications of this growth, both short and long-term, indicate that management of growth is the challenge for resource management county-wide, and specifically in the Weeks Bay watershed.

South Alabama Regional Planning Commission's 1993 Situation Analysis (SARPC 1993) offers the following conclusions and recommendations:

> "From a planning perspective, the most important aspects of assuring quality development resulting from population growth in any area are implementing growth management policies that provide a suitable arrangement of compatible land uses with adequate infrastructure (roads, drainage, water, sewer) that protects and blends with the natural environment. Thus, controlling the physical development of the County is of prime importance, and it is an issue that must be dealt with "up front" as people come into the area. Properly constructed new subdivisions in compatible zone areas are a key to the future quality of physical development in the County. By requiring properly improved streets, drainage and utilities as developments occur, the County will eliminate many new problems that would have to be corrected at some future date, at higher than present prices, and most likely at taxpayers' expense".

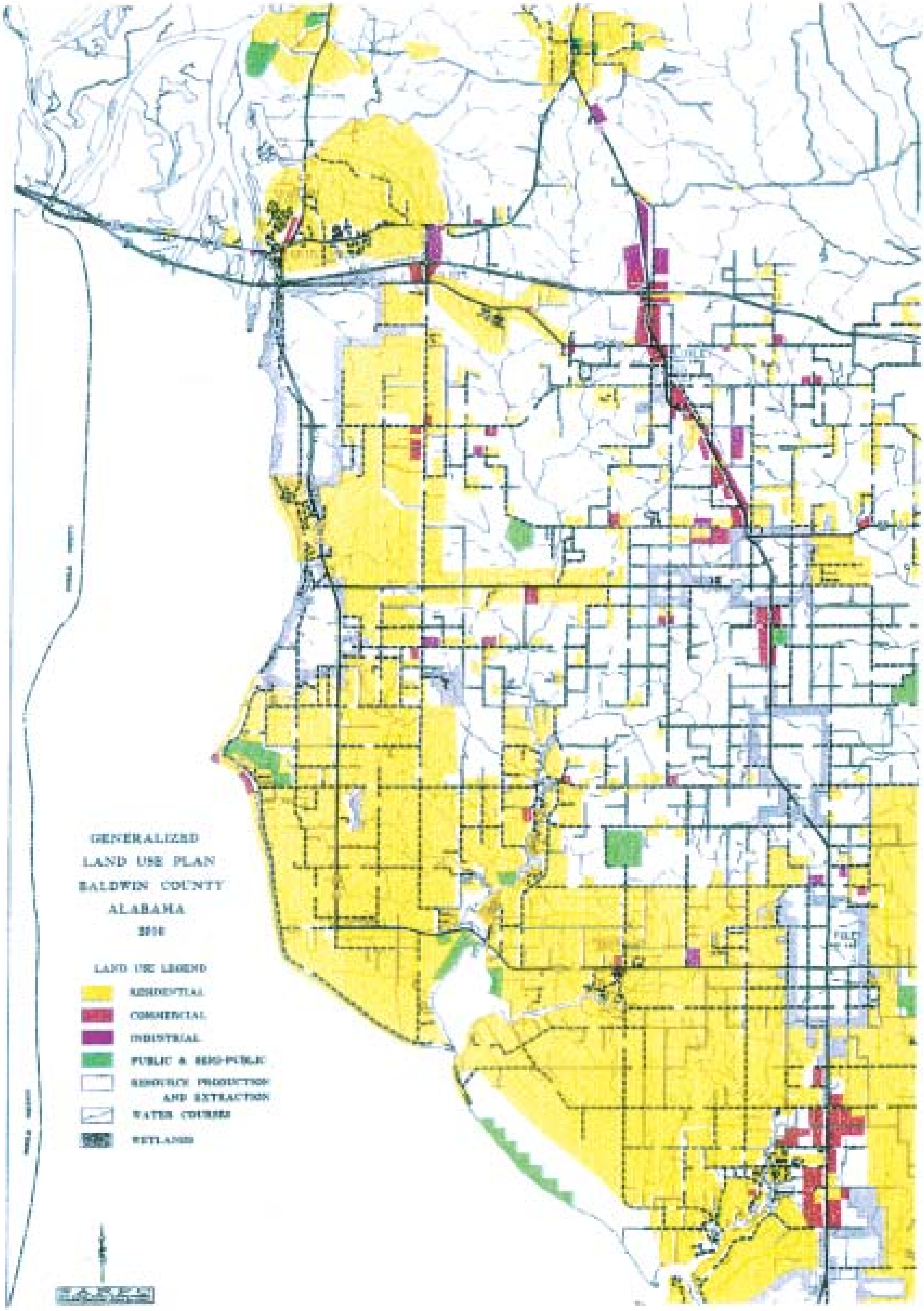


Figure 20: Generalized land use plan for Baldwin County. Note anticipated large increase in acreage for residential development. From SARPC, 1993.

Table 6: Components of population change: Natural increase and migration in Baldwin County, 1980-1990.

	Number	Percent
1980 Population	78,556	
Births: 1980-1990	13,132	
Deaths: 1980-1990	7,899	
Natural Increase	5,233	+6.66
Expected 1990 Population	83,789	
US Census 1990 Population	98,280	
Migration *	14,491	+8.45
Net Increase	19,724	+25.1

* Positive values represent migration into Baldwin County.

Source: South Alabama Regional Planning Commission, 1993

Table 7: A comparison of existing and future land use requirements for Baldwin County illustrated in the County Land Use Plan.

Classification	Acres 1990	Acres 2010	Change Number	Change Percent
Residential	12,285	16,250	3,965	+32.28
Commercial	1,802	2,708	906	+50.28
Industrial	907	1,586	679	+74.86
Public / Semi-public	31,036	42,742	11,706	+37.72
Subtotal Developed	46,030	63,286	17,256	+37.49
Resource production	721,463	718,546	-2917	-0.40
and extraction				-20.98
Vacant	68,345	54,006	-14339	-20.98
Wetlands	174,082	174,082	0	0
Water	46,462	46,462	0	0
Subtotal Undeveloped	1,010,352	993,096	-17256	-1.71
Total Area	1,056,382	1,056,382		

Source: South Alabama Regional Planning Commission, 1993

Chapter 7: Pollution

by John F.Valentine and Tina Lynn

Estuaries by their definition are areas in which rivers and coastal waters mix. Therefore, the potential for anthropogenic water pollution in any estuarine reserve is high. Historically low population density and resource use levels have minimized pollution problems in the Weeks Bay watershed. However, increasing development pressure and population growth in the area will result in an increasing number of pollution problems. These problems will arise from both point and non-point sources.

Point source pollution

Activities which result in a concentrated discharge into surface waters may be referred to as point source discharges and include sites such as municipal wastewater treatment facilities and industrial sites. No point sources discharge directly into Weeks Bay, however, several point sources discharge directly into the Fish and Magnolia Rivers, the upstream tributaries to Weeks Bay. These include the town of Loxley's municipal wastewater treatment system (secondary treatment, 3 celled lagoon system, < 25 million gallons per day), Plantation Hills subdivision wastewater treatment system (secondary treatment , 1 tank package system, < 25 million gallons per day) and numerous small industrial facilities.

The third phase of a modeling and computer simulation effort for Weeks Bay dicussed in Chapter 2 dealt with aspects of water quality (Lu et al. 1994). Under a simulated discharge of untreated wastewater in the Magnolia River and a non-stratified bay, results suggested that modest population increases in the Magnolia River area and the associated increases in wastewater discharges would not cause the deterioration of water quality, as determined by biochemical oxygen demand and organic nitrogen concentrations, in Weeks Bay. This result was primarily due to the dominance of freshwater input to Weeeks Bay by the Fish River. This study also concluded that water quality (i.e. dissolved oxygen, biochemical demand and organic nitrogen concentrations) was significantly influenced by wind velocity and direction and river discharge levels. However, the degree to which sediment-water column interactions affect water quality has not been investigated for Weeks Bay.

Nonpoint source pollution

As in estuaries worldwide, nonpoint sources of pollution are the greatest threat to water quality in the Weeks Bay watershed (Weber et al. 1992, Forbes and Forbes 1994). Consequences of nonpoint source pollution can include reduction in fish catches, closure of areas to swimming, and perhaps most dangerous, the pollution of commercial shellfish with toxic substances which can cause serious health consequences for humans (Weber et al. 1992).

Nonpoint source pollution is generally associated with stormwater runoff which carries sediment, nutrients, toxins and organic material into receiving waters. In addition, groundwater, which eventually enters the surface waters of Weeks Bay, can become contaminated by water percolating through the soil. Thus, nonpoint sources of pollution include rainfall runoff from parking lots, industrial sites, landfills, air pollutants, leaching of toxic chemicals from ships hulls, leaking septic tanks, overflows from municipal storm sewers. Agricultural runoff also contributes nutrients, pesticides and fecal coliform bacteria (found in animal and human waste).

Nonpoint source pollution problems originate from both the urban and rural areas of the Weeks Bay watershed. It has been estimated that more than 80% of all land within Baldwin County is under agricultural development. The majority of this acreage is found along the Fish and Magnolia Rivers, tributaries of Weeks Bay (Loyacano and Smith 1979, Crozier and Dindo 1990). Cotton is becoming a major crop in Baldwin County. The type of intensive row crop farming used to grow cotton, involves the widespread use of aerially applied pesticides, and consequently poses immediate threats to water quality.

During weekends and holidays, the Fish and Magnolia Rivers receive heavy recreational use. Fishing, water skiing, swimming, boating and jet skiing are some of the activities enjoyed by the public in these areas. Three marinas are located in the Weeks Bay watershed. Baywatch Marina is located in Weeks Bay at the mouth of Fish River. The Marlow Boat Basin is located on Fish River in Marlow. River Park Marina is located upstream in Fish River, just south of the County Road 32 bridge. Baywatch and River Park Marinas have small boat storage areas, a wharf, a provisions store and fueling facilities. Discharge of oils, fuel and human sewage to surface waters from these activities are a source of nonpoint source pollution to the Weeks Bay estuary. There are currently neither public restrooms nor pump out facilities on or near Weeks Bay. Trash and litter are often associated with recreational activities and are a persistent problem at two popular public access areas on Weeks Bay (View Point Landing, located at the mouth of Weeks Bay and Manatee Park, at the mouth of Fish River).

Nontoxic pollution problems

Dissolved Oxygen

Oxygen in estuarine waters is one of the most widely measured water quality indicators because it regulates metabolic processes at individual and ecosystem levels. As in all estuarine ecosystems, dissolved oxygen in Weeks Bay is affected by the biological processes of photosynthesis and respiration and the physical process of wind driven mixing. Over a six year period (1987-1993), monthly oxygen values at middepth at a station at the mouth of Fish River ranged from 4.5 to 12.6 mg l^{-1} (Fig. 21) (S. Brown, ADEM, personal communication). Most of the lower values occurred during summer months, while the higher values were characteristic of winter months. These values generally reflect good water quality and are regarded as more than adequate to support healthy populations of a diverse suite of estuarine species. However, the single value below 5.0 mg l^{-1} does represent a violation of the Alabama's Fish and Wildlife Water Quality Criteria. Dissolved oxygen in Weeks Bay evidences no negative impacts of nutrient enrichment (hypoxia, anoxia). There have been no reported occurrences of 'jubilees', periods of naturally occurring low dissolved oxygen levels, in Weeks Bay.

Nutrient Enrichment

A proper balance of nutrients is critical to the ecological health of estuarine systems such as Weeks Bay. The two most important nutrients, in terms of water quality, are nitrogen and phosphorus. Typically these nutrients control levels of biological production in aquatic ecosystems. Excessive nutrient loading to marine and brackish ecosystems can reduce water clarity, result in algal blooms, and negatively impact aquatic grassbeds. Input of these nutrients occurs most commonly via stormwater runoff containing fertilizers,

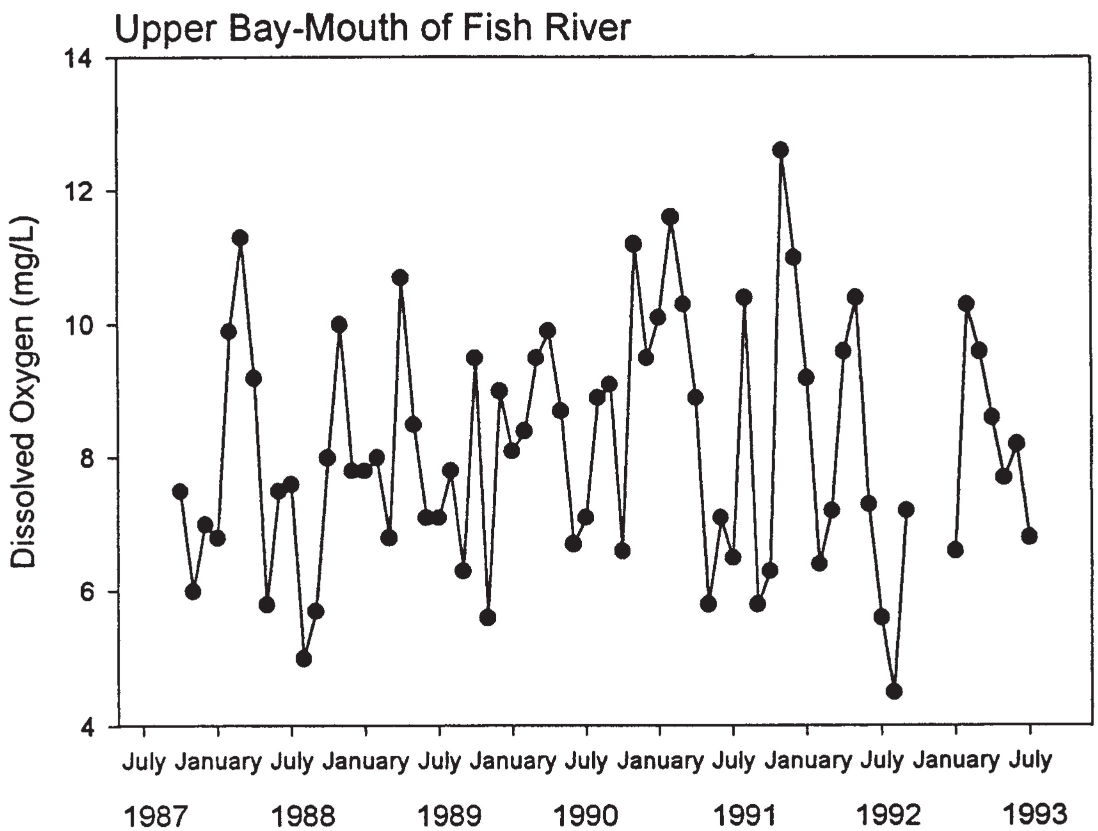


Figure 21: Dissolved oxygen concentrations at the confluence of Fish River and Weeks Bay, 1987-1993. From S. Brown, ADEM, personal communication.

septic effluent, and plant and animal wastes. Fertilizers, applied to lawns, row crops, orchards and forest areas can be a significant source of nutrient loading. The severity of the loading is affected by leaching rates which are dependent upon fertilizer type, application method, ground cover, climate, and soil conditions. Residential sites in the watershed can contribute to the nutrient loading through inadequate or failing septic systems. It has been estimated that 90% of the residents in the Weeks Bay watershed rely on septic tanks for their wastewater treatment. Conventional septic systems only provide for a partial treatment of wastewater. Effluent typically contains 40-60 mg/l nitrogen and as much as 15-20 mg l^{-1} phosphorus (Horsley 1991). The cumulative effects of these systems could result in high nutrient concentrations in groundwater and downstream receiving surface waters (see Ch. 4 for nutrient concentrations at the mouth of Fish River and in Weeks Bay). The severity of septic tank leakage and nutrient loading from septic tank use in the Weeks Bay watershed is not known. A program designed to monitor fecal coliforms (a potential indicator of leakage from septic tanks) has been recently implemented (see Appendix 3).

Sedimentation

On geological time scales, sedimentation is an important and natural process in estuarine systems. However, anthropogenic activities within estuarine watersheds can significantly accelerate rates of sedimentation and affect quality of the sedimenting material. Increased sedimentation can alter benthic communities, reduce light penetration, alter nutrient cycling, contribute to increased oxygen consumption and reduce navigability within the estuary. The resulting reduction in water clarity will affect productivity and impact habitat quality. Sediment accumulation may also alter circulation patterns and flushing rates within a basin. Lastly, while not toxic directly, the silt and clay sediments characteristic of Weeks Bay and its tributaries are highly reactive and can adsorb, sequester and transport nutrients, toxic contaminants, metals and pathogens throughout the waters of Weeks Bay.

The National Resource Conservation Service has estimated that 22,500 tons of sediment are transported to Weeks Bay each year. There are approximately 450 miles of dirt roads and 12 dirt pits in the Weeks Bay watershed which contribute large amounts of sediment to the Weeks Bay system. Efforts to control erosion from the 10 acre Silverhill dirt pit, which has been an open pit since 1960, has recently been initiated through an EPA funded program. There is no active dredging program in Weeks Bay. Residential development and subdivision construction can lead to soil erosion if drainage, grading and revegetation are not well planned and controlled. Riparian areas function as natural filters, preventing sediment and excessive amounts of nutrients from reaching surface waters, however, much of the natural riparian and marsh areas adjacent to Fish and Magnolia Rivers has been converted to fill and bulkhead along the shoreline of waterfront homes. There is no current estimate of the percent of shoreline to Weeks Bay which is bulkheaded.

Toxic contaminants

Metals

The potential sources of metal enrichment within the Weeks Bay NERR include but are not limited to emissions from engines which burn leaded gasoline and surface coatings such as marine paints used by boaters and commercial fishermen. Metals (e.g., arsenic, cadmium, lead and copper to name a few) can also be found in fungicides, fertilizers and pesticides which are all used extensively in agricultural practices (Weber et al. 1992). Of the metals, mercury, cadmium, and lead are considered to be among the most dangerous to human and ecosystem health. However, copper, zinc, silver, and chromium also pose significant threats to the environment (Forbes and Forbes 1994).

Interpretation of data based solely on sediment metal concentrations is often difficult as natural variation and anthropogenic effects cannot be easily separated. Schropp and Windom (1988) and Windom et al. (1989) developed a management tool which allows managers to assess the likelihood of metals contamination within estuaries. This method relies on the relationship between naturally occurring concentrations of metals and aluminum in estuarine sediments. Initially managers must establish the natural relationship between potential metal contaminants and aluminum in sediments from "clean locations." Once this relationship is established, statistical confidence intervals are generated and comparisons for each of the metals at a location of concern are plotted on graphs. If metal concentrations at locations of concern fall outside the statistical confidence intervals, there is initial evidence for metal enrichment.

In 1991, the Alabama Department of Environmental Management reported findings on metal concentrations from sediments at 53 stations located around coastal Alabama. Of these stations one was located in Weeks Bay and one in the Fish River. Overall metal concentrations in these sediment samples were low (Table 8). Comparisons of these concentration data with aluminum to metal ratios (Figs. 22, 23) suggest that sediment metal concentrations in Weeks Bay and the Fish River are within the range of natural variability observed in coastal Alabama. Of the eight metals examined, only barium in samples collected from Fish River was found to exceed the range of natural variability observed in coastal Alabama.

In addition to the ADEM study, there are two other unpublished studies which measured sediment chemical contaminant concentrations in Weeks Bay (W. Ishphording, personal communication; W Schroeder, personal communication). Neither of these studies showed evidence of metals concentrations higher than those in the ADEM study. In the data set collected by Dr. W. Schroeder, there is evidence that metal concentrations were highly variable within the reserve. Concentrations were highest in sediments near the mouths of the Fish and Magnolia Rivers and one creek that receives runoff from an unregulated (unpermitted) landfill along the northeastern shore of the reserve (W.W. Schroeder, personal communication). There are no reported measurements of metal concentrations within the Weeks Bay water column.

There has been a recent report of a mercury contaminated largemouth bass in Fish River (Fish Tissue Monitoring Program, ADEM Letter Report, 1996). The fish were collected at the confluence of Fish River and Polecat Creek in the October 1995 sampling. Reported mercury levels were 1.29 ppm in a composite sample and led to the issuance of a public health advisory for the Fish River by the Alabama Department of Public Health.

Chlorinated Compounds

Agricultural and industrial chlorinated compounds are widely dispersed throughout the estuaries of the United States. This form of contamination occurs almost exclusively as a result of human activities. The diversity of the compounds is extraordinary and each has different levels of toxicity for different species. Some of these compounds have been associated with declines in bird and mammal populations along the coasts of the United States. Since the end of the 1960's, the use of chlorinated compounds has been banned in the United States. However, chlorinated compounds are persistent in the environment and have been shown to have significant negative effects on marine organisms (see Valiela 1995 for a short overview). Two such groups of chlorinated compounds that are present within the Weeks Bay NERRS include the polychlorinated biphenyls (PCB's) and

Table 8: Sediment metal concentrations in Weeks Bay and Fish River.

Location	Metal concentrations in sediments (ppm)									
	Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Mercury	Lead	Zinc
Fish River *	71500	6.8	453.0	0.40	87.5	24.0	36850	0.95	37.5	119.0
Weeks Bay *	61000	6.4	320.5	0.45	76.0	20.5	34900	0.90	32.0	90.5
Fish River †	68222	7.1	411.0	<0.05	91.2	22.4	39312	<0.05	33.4	127.8
Weeks Bay †	57500	5.9	301.0	<0.05	81.3	17.2	25114	<0.05	29.4	84.2
Fish River ‡	nd ¥	nd	20.9	nd	38.1	6.5	6875	nd	nd	46.4
Magnolia River ‡	nd	nd	42.3	nd	85.9	17.7	12963	nd	nd	104.9
Weeks Bay ‡	nd	nd	24.8	nd	52.4	8.9	10238	nd	nd	105.3

* Alabama Department of Environmental Management, 1991
† W. Schroeder, personal communication, based on data provided by W. Ishphording
‡ W. Schroeder, personal communication, unpublished data
Values are based on averages from 16 stations in Weeks Bay and 1 station each in the Fish and Magnolia Rivers.
¥ not determined

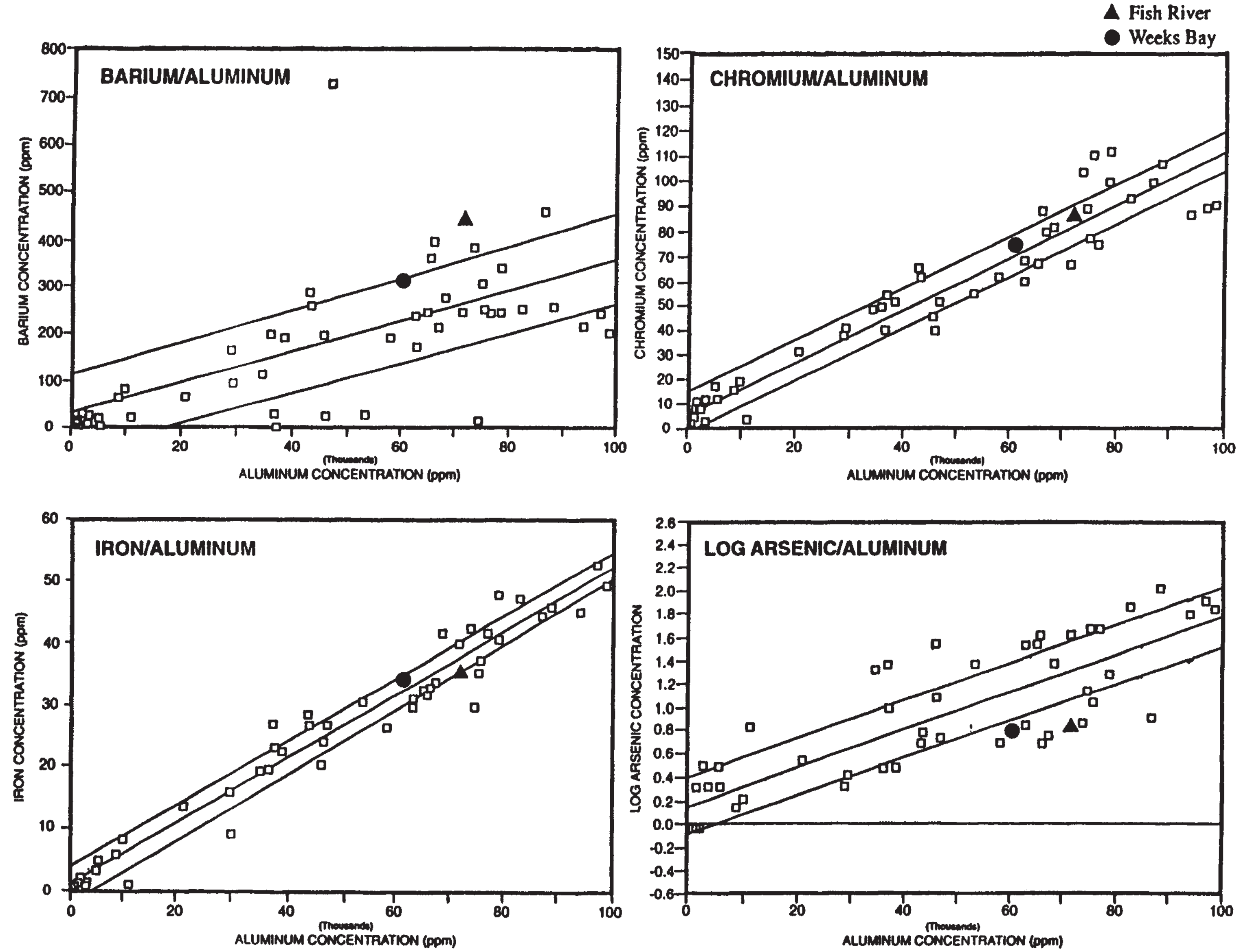


Figure 22: Aluminum to metal ratios for sediments in coastal Alabama. Stations which fall outside of the confidence intervals are potentially enriched in metals relative to other coastal Alabama sites (see text). Closed points indicate Weeks Bay and Fish River sediments. Note potential enrichment of barium in the Fish River. From ADEM Technical Report, 1991.

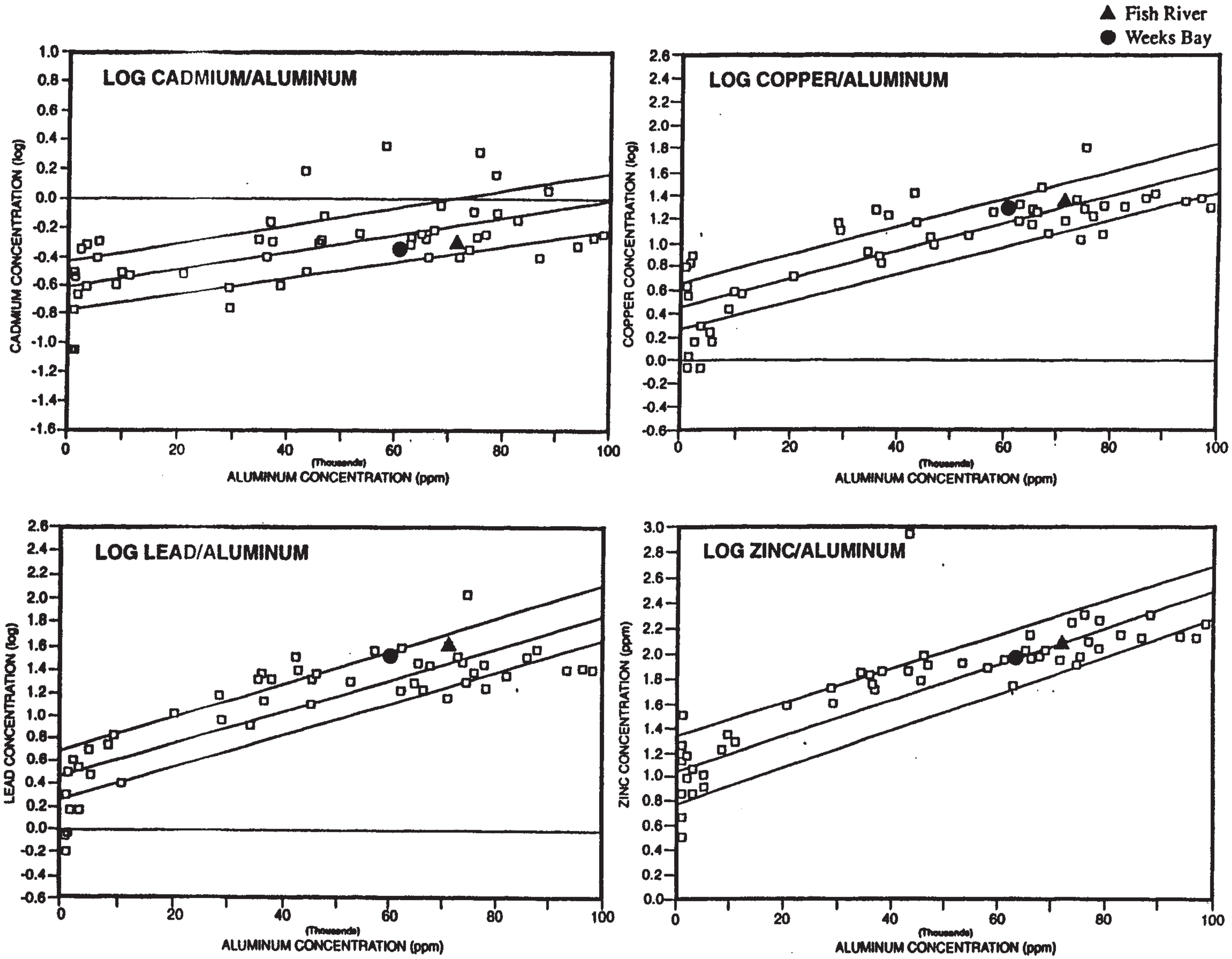


Figure 23: Aluminum to metal ratios for sediments in coastal Alabama. Closed points indicate Weeks Bay and Fish River sediments. Note the lack of enrichment in Weeks Bay and Fish River. (See Figure 22 for complete legend.) From ADEM Technical Report, 1991.

pesticides. PCB is a generic term for 209 chlorine-based compounds that have been used in a variety of commercial applications. The major input of PCB's to the environment come from leachates from landfills, municipal wastewater and industrial effluents, the treatment of waste water sludge and atmospheric deposition (due to the incomplete incineration of PCB contaminated wastes). Pesticides include those compounds that kill or control undesirable insects, weeds, rodents, fungi, bacteria and other organisms. May (1971) reported low levels of the metabolites of DDT, DDE and DDD in oyster tissue from individuals collected at the mouth of Weeks Bay in 1969.

Two separate studies, one conducted by Dr. W. Schroeder (Dauphin Island Sea Lab) and an ongoing study by Dr. Judith Lytle (Gulf Coast Research Laboratory), have described PCB and pesticide concentrations in the sediments of Weeks Bay. Concentrations reported by Schroeder were low for most contaminants (Table 9). Dr. Lytle has measured the concentrations of these compounds in the water column as well (Table 10). Comparisons of Dr. Lytle's water column data with established EPA Water Quality Criteria found no evidence that PCB or pesticide levels should cause concern for Weeks Bay managers. Examinations of the two sediment data sets also suggest that there is little evidence of high levels of contamination within the sediments of the reserve based on the large number of reported non detects (Tables 9, 10).

Polycyclic Aromatic Hydrocarbons (PAH's)

Potential sources of PAH's in the marine estuarine environment include but are not limited to: atmospheric deposition, sewage treatment facilities, storm water runoff, vessel discharges (e.g., bilge pumping), and leaching of creosote from pilings. PAH's may also enter estuarine environments through the incomplete combustion of wood from forest fires, and fuel. The impacts of PAH's on marine organisms are relatively unknown but there is evidence that they can have mutagenic, teratogenic, and carcinogenic effects on marine organisms. Because PAH's are tightly bound to fine grained sediments it is possible for them to remain in estuarine environments for long periods of time. To date, no measurements of PAH's in Weeks Bay NERRS have been reported.

Fecal Coliform Bacteria

Water has always been a medium for the transmission of human microbial diseases such as typhoid, dysentery and infectious hepatitis. Intestinal microorganisms from warm-blooded animals (including man) enter rivers, streams and estuaries contributing pollution to these environments following significant rainfall events. Sources of these microbes include sewage treatment facilities, septic tanks and industrial sites as well as farms. At present, livestock have access to streams in the Weeks Bay watershed.

Fecal coliform bacteria are one such group of microorganisms that represent concern for human health officials. As a result, public health officials routinely test water samples and shellfish tissue for fecal coliform density. Fortunately, most fecal coliform bacteria die in relatively short periods of time in sewage systems and coastal waters. When densities are high enough, however, fecal coliform bacteria can threaten public health through direct contact (e.g., swimming in infected waters) or through the direct ingestion of contaminated shellfish.

Of the contaminant data sets collected from within the Weeks Bay NERR, only fecal coliform bacteria have been collected over a sufficiently long enough period of time to show temporal trends (Fig. 24). With a few exceptions, fecal coliform densities at a station near the mouth of the bay have been uniformly low (<50 per 100 ml). In contrast, densities in the upper bay are generally higher and more dynamic (Fig. 24), a result which

Table 9: Pesticide and PCB concentrations in sediments from 10 locations around Weeks Bay, Alabama.

	Concentration $\mu g\ kg^{-1}$ (=ppb)									
Parameter	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10
Alpha-BHC	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Gamma-BHC (Lindane)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Beta-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Delta-BHC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4, 4'-DDE	1.4	2.4	2.9	5.3	3.5	5.2	1.0	1.5	1.5	<1
Dieldrin	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4, 4'-DDD	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endosulfan II	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4, 4'-DDT	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endrin Aldehyde	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Endosulfan Sulfate	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Methooxychlor	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chlordane	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Toxaphene	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1016	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1221	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Aroclor-1232	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1242	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1248	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1254	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Aroclor-1260	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20

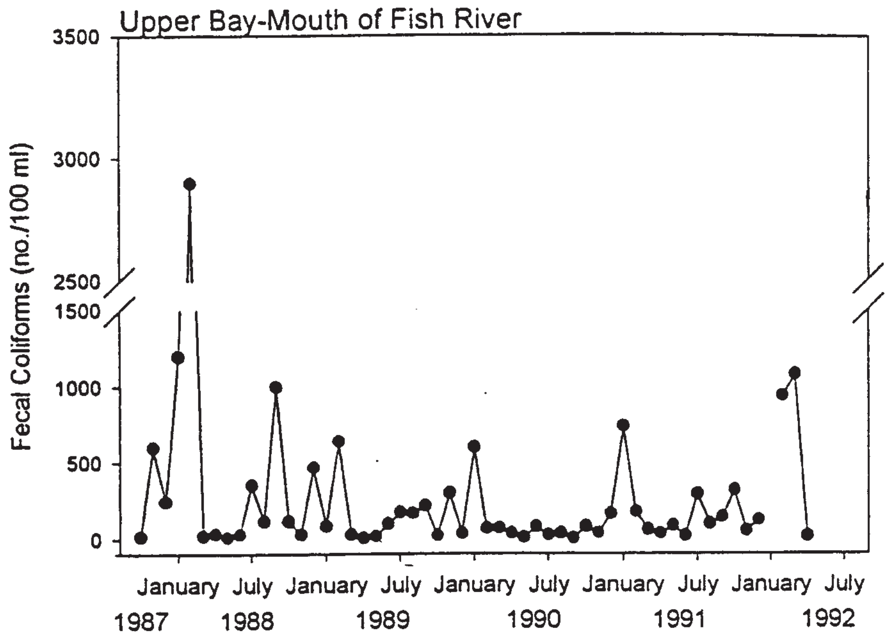
Source: W. Schroeder, personal communication, unpublished data

Table 10: Pesticide and PCB concentrations in Weeks Bay, Alabama.

	Water Column Concentrations (µg L^{-1})				Sediment Concentrations (µg g^{-1})			
Parameter	Bay Rd. Crossing	Miserable Creek	Nolte Creek	Weeks Creek	Magnolia River	Pilings Gut	Turkey Branch	West Little Magnolia Bay
Alpha-BHC	nd *	nd	nd	nd	nd	nd	nd	nd
Atrazine	2.5500	nd	nd	nd	nd	nd	0.1014	0.0672
Gamma-BHC (Lindane)	nd	nd	nd	nd	nd	nd	nd	nd
Beta-BHC	0.7530	0.1340	0.0301	0.0182	0.0017	0.0015	0.0011	0.0015
Heptachlor	nd	0.0088	nd	nd	0.0003	0.0003	0.0004	0.0002
Delta-BHC	nd	nd	nd	nd	0.0007	0.0006	0.0005	nd
Aldrin	0.0217	nd	nd	nd	0.0006	0.0003	0.0003	0.0003
Heptachlor Epoxide	0.0068	nd	nd	0.0049	nd	0.0003	nd	0.0002
Endosulfan I	nd	nd	nd	nd	nd	nd	nd	nd
4,4'-DDE	0.0183	0.0143	nd	nd	0.0039	0.0016	0.0071	0.0015
Dieldrin	0.0398	0.0252	0.0321	0.0249	0.0033	0.0015	0.0016	0.0015
Endrin	nd	nd	nd	nd	0.0021	0.0014	nd	nd
4,4'-DDD	<2	<2	<2	<2	<2	<2	<2	<2
Endosulfan II	nd	0.0336	nd	nd	nd	nd	nd	nd
4,4'-DDT	nd	nd	nd	nd	0.0047	0.0012	nd	nd
Endrin Aldehyde	0.0976	0.0808	0.0800	0.0656	0.0039	0.0026	0.0054	0.0026
Endosulfan Sulfate	nd	nd	nd	nd	0.0061	0.0033	0.0040	nd
Methoxychlor	nd	nd	nd	nd	0.0047	nd	nd	nd
Permethrin	nd	nd	nd	nd	nd	nd	nd	nd
Triflurin	0.0209	0.0144	0.0197	0.0089	0.0003	0.0002	0.0006	nd
2, 4 D	nd	nd	nd	nd	0.5111	0.2895	0.5003	0.4677
Simazine	nd	nd	nd	nd	nd	0.0832	nd	nd
Cyanazine	nd	nd	nd	nd	nd	nd	nd	nd
Aroclor	0.0641	nd	nd	nd	nd	nd	0.0035	nd
Propanil	nd	nd	nd	nd	0.0040	0.0043	nd	0.0045
Metolachlor	1.9620	0.1629	0.1705	0.3083	0.0171	0.0089	0.0127	0.0088
Chlorpyrifos	0.0227	0.0501	0.0319	0.0200	0.0044	0.0018	0.0020	0.0017
Fenvalerate	nd	nd	nd	nd	nd	nd	nd	nd

* not determined

Source: J. Lytle, personal communication



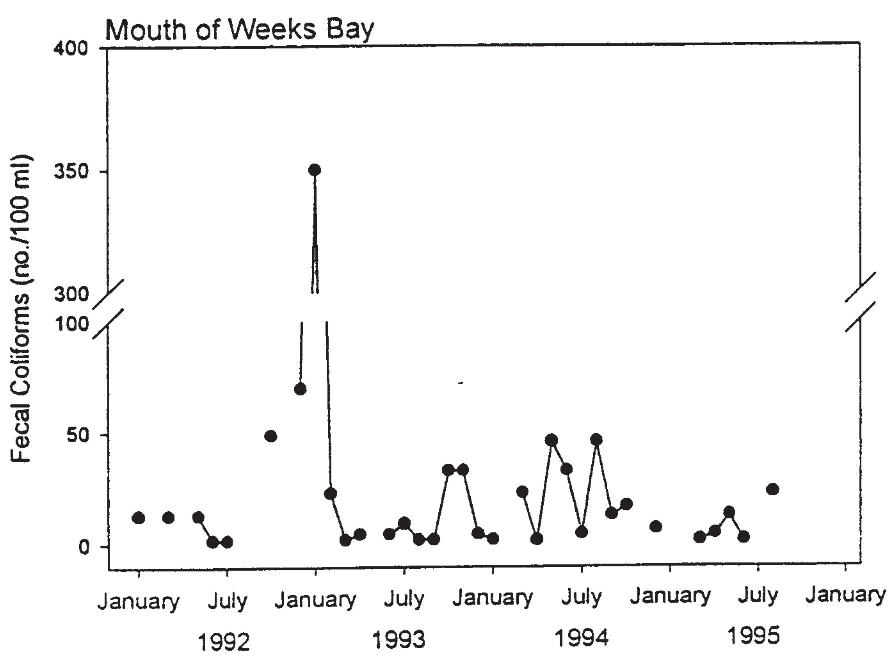


Figure 24: Fecal coliform densities at the confluence of Fish River and Weeks Bay (top panel; from S. Brown, ADEM, personal communication) and the mouth of Weeks Bay (lower panel; from L. Bryd, Alabama Department of Public Health, Seafood Branch, personal communication). Note the difference in the periods of record for the 2 stations.

probably reflects the role of river discharge. Although these densities are low relative to water quality criteria for swimming, public water supply and fish and wildlife designations, they exceed those for shellfish harvesting. Requirements to open shellfish harvesting are: 1) replicate water samples must have a mean concentration of fecal coliforms less than 14 per 100 ml water and 2) less than 10% of the samples can exceed 43 per 100 ml. As a result, the waters of Weeks Bay are considered conditionally closed to shellfish harvesting (Dr. Lewis Byrd, Alabama Department of Public Health, Seafood Branch, personal communication).

Consequences for Estuarine Resources

The consequences of toxic chemical contaminants to estuarine organisms are dependent on several factors. These include its bioavailability, its persistence and the degree to which it affects an organism's metabolism (Capuzzo and Moore 1986). Determinations of these factors are important because they provide the basis for sound risk assessment (Forbes and Forbes 1994).

To date, there have been few evaluations of the fate and effects of chemical contaminants entering the Weeks Bay NERR. In two separate published abstracts, scientists at GCRL reported preliminary evaluations of toxicity by pesticides on macrophytes within the Weeks Bay watershed (Lytle and Lytle 1995; Lytle et al. 1995). From these evaluations, they found that current levels of pesticides entering the watershed are having modest or little effect on various parameters of plant growth within the watershed. They hypothesize that most pesticides settle out in creek and river sediments prior to entering Weeks Bay.

Chapter 8: Management Issues

by L.G. Adams, Tina Lynn and Bob McCormack

Management issues concerning estuarine resources at Weeks Bay are similar to those all along the Gulf region. Rapid development in Baldwin County is impacting the estuary, the reserve and its watershed in many ways. The primary concerns include loss of habitat, including marsh and other wetland areas, buffer and upland areas through coastal development, deterioration of water quality by point and nonpoint source pollution including agricultural impacts, pesticide use / runoff and septic tank / drain field pollution, exotic species introductions, species extinctions, and hydrologic changes due to loss or diversion of freshwater input.

Weeks Bay estuary has a value that is inherent to the people of Alabama. It is a part of the public ownership at the state and federal level. Public lands and state waters of the Weeks Bay area are under a trust that sets aside these areas for public benefit. The Public Trust doctrine states that "public trust lands, waters, and living resources in a State are held by the State in trust for the benefit of all of the people", and establishes the right of the public to fully enjoy public trust lands, waters and living resources for a wide variety of recognized uses. Due to their public nature, the title to public trust lands is not a singular title in the manner of most real estate titles. Rather, public trust land is vested with two titles, one dominant, *jus publicum*, and one subservient, *jus privatum* (Slade et al. 1990). The former includes the rights of the public to fully use and enjoy trust lands and waters for commerce, navigation, fishing, bathing and other related public purposes. The subservient title establishes the private rights of the individual in the use and possession of trust lands. When one doctrine is in conflict with the other, litigation may arise.

Thus, legal conflicts do occur and present problems in the management of the Weeks Bay National Estuarine Research Reserve. For example, development activities in the watershed may clear acreage up to the river banks. Red clay is trucked in to provide an impervious and level land base. For many months following this activity, however, rains wash eroded material into rivers discharging into Weeks Bay, elevate turbidity and exacerbate problems. While activities such as this are the expression of private ownership, they impact public trust. Even when laws are in place which should discourage undesirable behavior, these situations of misuse of private rights often go unnoticed or occur without legal consequences. With the designation of Weeks Bay as a National Estuarine Research Reserve and an Outstanding National Resource Water, management plans must ensure that the watershed is monitored closely and that local government upholds the Public Trust Doctrine for the people of Alabama.

Water Quality

Water quality has received a high priority in the Weeks Bay NERR research program. This research program has incorporated a watershed approach. The geographical limits of the Weeks Bay watershed are illustrated in Figure 25. In 1993, the Weeks Bay Watershed Project was initiated by the U.S.D.A. Natural Resource Conservation Service (NRCS), Environmental Protection Agency (EPA) Gulf of Mexico program and the Alabama Department of Environmental Management (ADEM) in cooperation with numerous other federal and state agencies. This project was created as a framework to coordinate an intensive watershed monitoring program, identify primary causes of point and nonpoint source pollution and provide educational and technical

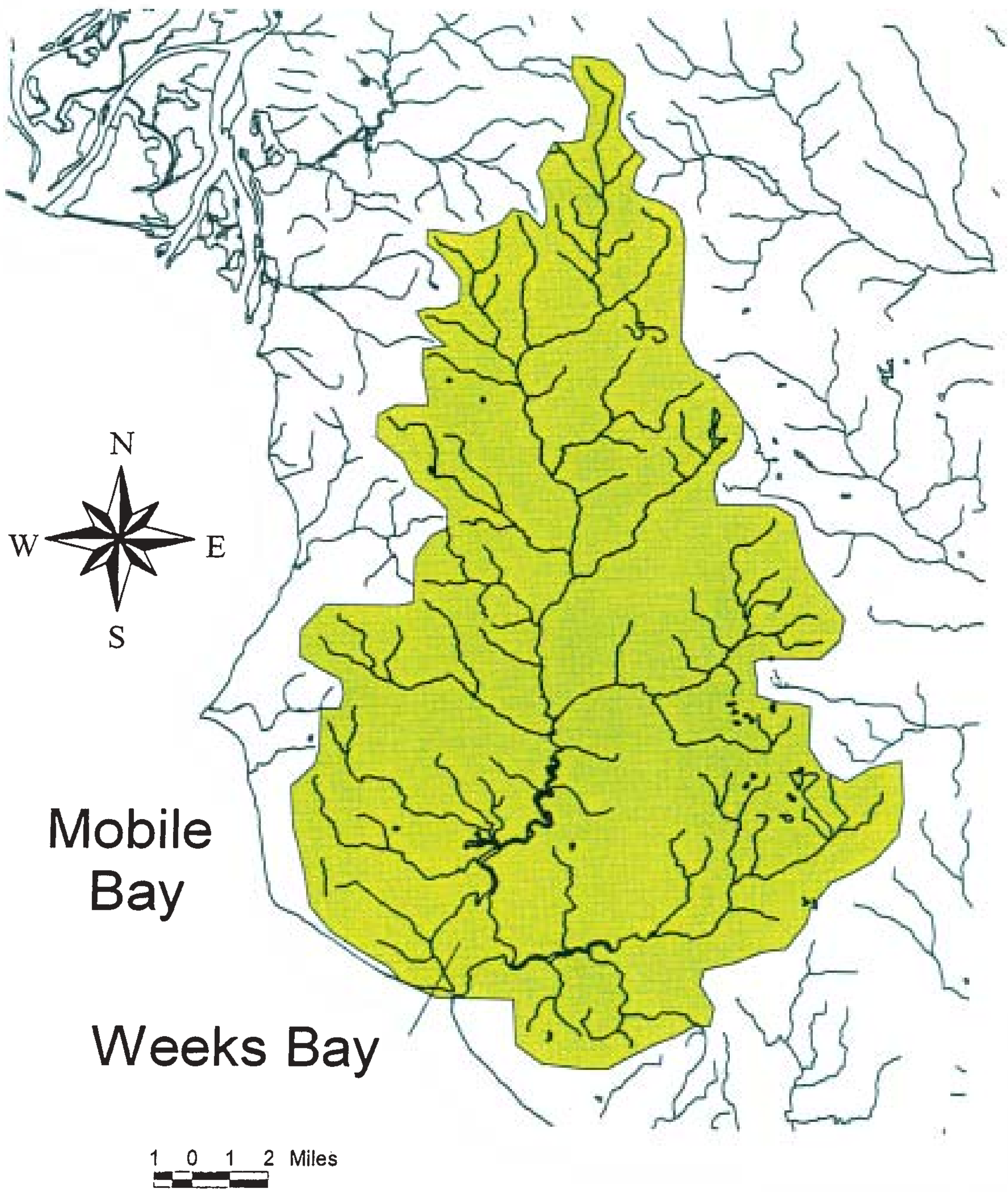


Figure 25: Geographic boundaries of the Weeks Bay watershed.
Source: B. Harbour, BSCC, personal communication.

assistance in pollution prevention activities. Accomplishments of the Weeks Bay Watershed Project for the period September 1993 to June 1996 are presented in Appendix 3.

The Weeks Bay Watershed Project is a multi-agency project directed by a Steering Committee, Planning and Objectives Committee, Technical Committee, Education Committee and a Citizens Advisory Committee. Approximately 20 federal, state and local organizations are involved in the project. Watershed Project funding sources include the EPA Section 319 program and the EPA Gulf of Mexico Program.

Regulatory Controls

In February of 1992, Weeks Bay was designated as an Outstanding National Resource Water (ONRW). ONRW's provide special protection of waters for which ordinary use classifications and water quality criteria do not suffice. The ONRW designation offers special protection for waters of ecological significance. Most people view ONRW's as the highest quality waters of the United States.

Weeks Bay does not have any point sources which discharge directly to its waters and future point sources of pollution are prohibited in ONRW's (ADEM Division 6 Regulations Chapter 335-6-10.10 (b)(i)).

The level of authority in regulating new or expanded point sources in waters upstream to Weeks Bay is uncertain. This is an immediate concern in the management and protection of Weeks Bay water quality. New public wastewater treatment facilities and the expansion of existing facilities are currently being pursued by municipalities in the watershed. ADEM Division 6 Regulations, Chapter 335-6-10-.10 (b)(iii) states:

> "no new point source discharges or expansion of an existing point source discharge to waters of, or tributary to, Outstanding National Resource Waters shall be allowed if such discharge would not maintain and protect water quality within the Outstanding National Resource Water."

ADEM addresses the issue of water quality protection and maintenance of ONRW's for new or expanded point source discharges during the permitting process. Mathematical water quality models, one of the tools typically used in the development of permit limitations, provide a mechanism for evaluation of the impacts of the proposed action. Although these models have the capability to assess the cumulative impacts of multiple point source discharges, they cannot assess cumulative impacts of multiple point and nonpoint source discharges.

Nonpoint source discharges are managed in accordance with ADEM's nonpoint source control programs. Educational and technical assistance to landowners on the implementation of Best Management Practices (BMP's) is provided through ADEM, WBNERR and Natural Resource Conservation Service. The state and county health departments manage other activities such as the siting and installation of septic systems.

Managing Water Quality - Monitoring and Education

A number of programs have been initiated to improve water quality in Weeks Bay and involve local citizens in watershed management. Several agencies are contracted through the Weeks Bay Watershed Project to conduct water quality monitoring activities. Since January of 1994, the Geological Survey of Alabama (GSA) in conjunction with ADEM has had an ongoing surface water monitoring program. This program consists of physical, chemical and biological components designed to provide sufficient background information to allow analysis of BMP implementation effectiveness. GSA is currently monitoring a total of 16 stations in the watershed.

The US Geological Survey began a surface water quality monitoring program in October of 1995. This project involves maintaining an instream gaging station located on Fish River near the town of Silverhill and two tidal gaging stations, located at the mouth of Fish River and on the western shore of Weeks Bay.

A volunteer monitoring program was established in the Weeks Bay watershed in April, 1994. With guidance from Alabama Water Watch, 24 sites are currently being monitored by 20 volunteers. Fifteen sites are located on Fish River and its tributaries while the remaining encompass the Magnolia River and its tributaries. Volunteers are trained to test 6 water quality parameters including dissolved oxygen, pH, turbidity, alkalinity, hardness and salinity.

In May of 1995 Weeks Bay Reserve Foundation and Weeks Bay National Estuarine Research Reserve staff initiated a fecal coliform sampling program in Fish River. Reserve staff and volunteers collect weekly samples at 5 stations. The purpose of this sampling program is to provide a comparison of fecal coliform concentrations among the five stations in Fish River during a range of weather conditions.

A number of public awareness activities have been pursued by WBNERR and the Watershed Project. Targeted audiences have included decision makers, watershed residents and farmers and citizens of Alabama's coastal counties. Public awareness activities include newsletters, brochures, press releases, workshops and speaking engagements. In addition, a number of demonstration projects have been established in the watershed. These projects demonstrate alternative on-site wastewater treatment methods and agricultural best management practices.

Habitat Loss

Southern Baldwin County is experiencing rapid development. The direct effect of this development in the Weeks Bay watershed is the loss of prime habitat; wetland areas are being filled and developed and upland buffer areas are being converted for residential and commercial uses (Roach et al. 1987). Loss of habitat in the WBNERR is also occurring through indirect effects of these development activities. A recent qualitative survey by reserve staff has noted that submerged aquatic vegetation (SAV) habitat was greatly reduced in 1995 compared to 1981 (Stout and Lelong 1981). The areas which appeared to be most impacted were in the northern part of the bay where previously reported beds of *Vallisneria americana* were absent and in the southwestern portion of the bay where *Ruppia maritima* was no longer present. Increased sedimentation resulting from soil disturbances in upland buffer areas reduces light penetration in aquatic habitats, modifies substrate composition and may eliminate available hard bottom habitat such as oyster reefs. Increased nutrient loading resulting from changes in the quality of runoff and discharge waters has adverse effects on the structure and function of communities within the reserve. The management plan for WBNERR will address these concerns through land acquisition activities.

Land Acquisition

The Weeks Bay NERR is concerned about current and future problems resulting from the rapid development within its watershed. A large number of acres have changed ownership over the last few years. Four tracts adjacent to Reserve lands are currently being developed for residential housing. Two of these tracts are in close proximity to salt marsh habitat and will undoubtedly impact the Weeks Bay estuarine system.

Lands in the Weeks Bay watershed should be managed in a way which minimizes detrimental impact. Outright purchase and ownership by the State, Weeks Bay Foundation, or non-governmental organizations such as The Nature Conservancy or Forever Wild are the most obvious management techniques to reach this goal. To buffer negative impacts in Weeks Bay, Fish River and Magnolia River, and to protect prime nursery grounds and productive habitats, the Reserve plans to purchase lands that become available for sale. Land of interest for acquisition include marshes, upland buffer areas, waterfront access (to facilitate research and educational activities), and wetland or upland areas slated for potential condominiums and commercial operations. Shoreline salt marsh and wetland habitat is perhaps the most critical area of concern in the WBNERR. Buffer and upland areas include tracts of land that are inland of shoreline habitat but which impact the estuary indirectly regulating non-point source pollution to the system. Short of ownership, techniques which assist property owners in adopting practices which minimize adverse effects should be developed and implemented. Best management practices (BMP's) during farming, construction and other land intensive activities can reduce the severity of nonpoint source pollution in the Weeks Bay watershed.

As stewards of Weeks Bay and its watershed, the Reserve has implemented guidelines for waterfront construction in Weeks Bay (Appendix 4). A committee was selected to create guidelines which would protect the resources of Weeks Bay and uphold the riparian rights of the private landowner. The committee was composed of members from various divisions in the state government including State Lands, Coastal Programs, Weeks Bay Reserve, and Conservation and Natural Resources. Other committee members included representatives from the U.S. Army Corps of Engineers and the Dauphin Island Sea Lab. This group held their first working session in November 1994 and met again in August 1995. At the November 1994 meeting, the committee established 12 criteria for ecologically sound shoreline development. These criteria aimed to prevent irreparable damage to the productivity of the Weeks Bay estuary by extensive and unnecessary construction. The August 1995 meeting reevaluated these criteria such that some were rewritten or removed while other criteria were added. The updated criteria are presently implemented by the US Army Corps of Engineers - Mobile District when evaluating permit applications in Weeks Bay. Violators of the permit criteria will be investigated by the Alabama Department of Environmental Management, the Weeks Bay National Estuarine Research Reserve and the US Army Corps of Engineers. If there is evidence of habitat destruction, legal action may be initiated.

Section 4: Summary and Recommendations

The Weeks Bay National Estuarine Research Reserve was established a decade ago to preserve a microcosm of the greater Mobile Bay system. The primary purposes of reserves in the NERRS program are scientific and educational: preservation provides relatively undisturbed areas for research on natural ecological relationships in coastal systems, non-impacted areas for assessing effects of man's activities in other estuarine areas and a vehicle for increasing public knowledge and appreciation of the function, values, benefits and problems of estuarine ecosystems. In the last ten years, the Weeks Bay National Estuarine Research Reserve has fulfilled these purposes. The goal of this document was to present the state of knowledge of the Weeks Bay estuarine system.

Summary

The Weeks Bay National Estuarine Research Reserve typifies warm, shallow, river-dominated estuaries in the Gulf of Mexico region. River discharge and meteorological events determine much of the physical nature of the Reserve waters. Thus, the system shows annual, seasonal and short-term (days) variation in physical characteristics. The limited data on the biotic resources of Weeks Bay indicate a typical oligohaline to mesohaline estuarine system. Habitat heterogeneity is relatively low, with open bay bottom the predominant habitat. Much of the surrounding land in the Reserve is wetland and bottomland hardwood forest, habitats decreasing in areal extent over the southeastern region of the country. Annual microalgal primary productivity in Weeks Bay is relatively high, as in most estuaries in the Gulf of Mexico region. Limited data suggest that the dynamics of production reflect the dynamic nature of the bay's physical controls. Thus, short-term changes in physical characteristics caused by meteorological events may regulate primary production in the bay. Nutrient signatures indicate the importance of river discharge but do not appear to reflect extreme anthropogenic impacts in the watershed. The salinity regime coupled with low habitat diversity result in characteristically low species diversity in the Reserve's waters. Within Weeks Bay, seasonal migrations and changing salinity regimes have profound effects on the abundance and spatial distribution of organisms. Yet, the limited data suggest that Weeks Bay fulfills the traditional nursery function associated with estuarine systems.

Much of the area surrounding the Weeks Bay National Estuarine Research Reserve has been used for purposes which have relatively low impact on the watershed. Thus, data available to date indicate that low population density, silviculture and agriculture in the watershed have not caused large anthropogenic impacts in Weeks Bay. The limited data on dissolved oxygen, nutrient and chemical concentrations in the waters of Weeks Bay do not reflect a highly disturbed ecosystem. However, data on contaminant concentrations in the water and sediments of Weeks Bay and its tributaries are limited. Thus, it is premature to make definitive statements about the state of environmental contamination within Weeks Bay. Land use patterns in the Weeks Bay watershed are predicted to shift dramatically towards residential usage. With the designation of Weeks Bay as an Outstanding National Resource Water, point source discharges to the area will not be a problem. However, with this predicted shift in land use patterns comes the potential for increasing problems with nonpoint source pollution and eutrophication of the bay's waters. The current management plan recognizes these potential problems and is focusing on water quality issues. Additionally, current management efforts have begun to incorporate a watershed approach to water quality issues.

Gaps in the knowledge base

Bathymetry and surface sediments

Accurate knowledge of the bathymetry and the composition and distribution of the surficial sediments are fundamental requirements for describing and understanding many of the structural and functional characteristics of other components of the Weeks Bay ecosystem. The available bathymetry and sediment data are outdated: both the most recent water depth surveys and the single baywide assessment of surficial sediments were conducted over a decade ago.

Estuarine Habitats

The summary of what is known regarding habitat type and distribution results from a single study which dates from just after the establishment of the Reserve. There have been many changes since this time and there is a need for updated information on the areal coverage of the habitats in the WBNERR. Some of the acreage recently added to WBNERR was not included in the initial survey. Controlled burns which have been conducted in some portions of the Reserve, specifically the bog area, may have altered habitat distribution. Preliminary data indicate that the coverage of aquatic grass beds has changed since the establishment of the Reserve. The available data do not allow an assessment of wetland loss or gain.

Nutrients and Aquatic Primary Production

Data on nutrient dynamics in the Weeks Bay ecosystem are limited in temporal or spatial coverage. While monitoring data exist back to the mid-1980's, they are limited to a single station at the mouth of the Fish River. In contrast, the single baywide study on nutrient dynamics and primary production was limited to 2-3 years, an inadequate period for assessing potential long-term changes in the Reserve. Comparisons of these datasets indicate differences between the bay proper and the monitoring station which need to be resolved. With the monitoring studies recently initiated by ADEM, GSA and WBNERR, a more complete dataset will be available for assessing long term changes in the Weeks Bay system. Available data on the dynamics of aquatic primary production documents the magnitude and patterns or production, there are no data on the factors regulating primary production. Additionally, there are no data at present on the species composition of the phytoplankton assemblage in Weeks Bay. Predictions of alterations in the Weeks Bay system due to anthropogenic impacts are not possible without this understanding.

Estuarine Consumers

Most of the data cited on the estuarine fauna in Weeks Bay are fragments of larger studies which included stations in Weeks Bay. As a result, spatial coverage was often limited to a single station and temporal coverage was, at best, monthly for a year or two. Analysis was frequently little more than tables of species abundances. Even this basic information was not available for several groups, notably microfauna, meiofauna, nannoplankton, gelatinous zooplankton, ichthyoplankton and large nekton. Distribution and abundance of early life stages are known only for a few commercially harvested species. Little is known about interannual variation in animal populations in Weeks Bay and thus, nothing can be deduced regarding long term changes. Perhaps more importantly, data regarding trophic dynamics, that is food webs, secondary production and energy transfer, of the Weeks Bay system are completely lacking.

Pollution

Data which could reflect on non-toxic water quality parameters such as dissolved oxygen and nutrient levels are temporally or spatially limited. As with data on nutrient concentrations, recently initiated or ongoing studies will alleviate this limitation. There are a limited number of published and unpublished data sets or ongoing surveys of contaminant concentrations in the water and sediments of Weeks Bay and its tributaries, the Fish and Magnolia Rivers. In many cases existing data was collected by different investigators with different objectives. Because much of the data is now somewhat dated, it was not possible to determine the comparability of the analytical methods and sampling protocols which were used by the various investigators. The lack of bioeffects testing makes it impossible to determine if ambient contaminant levels are sufficient to have deleterious effects on indigenous fauna within the bay. While EPA Water Quality Criteria exist to evaluate chemical contaminant concentrations in the water column, there are few established sediment quality criteria to assess levels of sediment contamination. In addition, there have been few attempts to measure chemical contaminants across seasonal and spatial scales which are an important source of variation in contaminant levels in many estuaries.

Recommendations

The following section presents several recommendations for future efforts in the Weeks Bay National Estuarine Research Reserve. These were offered by contributing authors as well as agency personnel and are presented in no specific order. It is suggested that a workshop including all interested agencies be held to amend these recommendations as well as prioritize them.

1. It is recommended that efforts be focused to increase the level of knowledge of the ecology of the Weeks Bay National Estuarine Research Reserve. The data on which knowledge of the ecology of the bay and its watershed is based is extremely limited. While most of these suggestions necessitate the expenditure of funds, many could be implemented with limited financial resources.

    a. Given the addition of significant acreage to the Reserve since its inception and the associated baseline studies, a comprehensive update of the distribution and coverage of habitat types would increase understanding of the resources of the Reserve. The resulting map of habitat distribution would enable assessments of the loss or gain in acreage of critical habitats such as wetlands.

    b. Given the documented importance of submerged aquatic vegetated habitats (SAV) in supporting diversity and its historical occurrence in regions of the Reserve, a comprehensive update of the distribution and abundance of SAV should be undertaken.

    c. Given the increased development in land in the Weeks Bay watershed and the paucity of water and sediment quality data, funds allocated to collecting and assimilating these data would increase knowledge of the stresses imposed on the Weeks Bay system.

d. Despite the dominance of the bottomland hardwood swamp / forest habitat in the Reserve, little is known about the ecology of this habitat and its importance to the functioning of the entire Weeks Bay system.

e. Several data sets available at Alabama Department of Conservation Marine Resources Division (ADCMRD) could be analyzed to fill data gaps in this report. ADCMRD has occupied a mid-bay trawl station monthly for over 10 years. These unreported data could be used to evaluate long term trends in nekton populations. They also sampled ichthyoplankton for several years at a station near the mouth of the bay. It seems likely that nearly all commercial landings of mullet, flounder and crabs are sold locally. It may be possible to persuade local dealers to estimate how much of their total volume comes from within Weeks Bay. Finally, ADCMRD has conducted creel surveys of recreational fishermen throughout Alabama for many years. Their reports do not distinguish Weeks Bay data, but it may be possible to analyze the data differently. If so, interannual variation in sport fishing effort and catch in Weeks Bay could be evaluated.

f. Several datasets concerning Weeks Bay exist among members of the research community yet have not been analyzed. Funds allocated to support graduate students, for example, would permit the entry of this information into the public domain.

g. In order to assess anthropogenic changes in the bay's morphology, hydrology and sedimentary characteristics from development pressures in the watershed, there is a need for updated and more complete data on water depth and sediment composition. This would permit the construction of fine scale maps of bathymetry and sediment characteristics.

h. No data exists on the species composition of the phytoplankton community. Without baseline data on this community, it is not possible to document novel or toxic species which are appearing in many anthropogenically impacted waters.

i. Research conducted on the Weeks Bay ecosystem has been primarily focused on the species level. As such, there is only a very general understanding of how these components interact. Yet this understanding is paramount to the prediction of changes in the system due to changes in surrounding environments. There are no estimates of secondary production of the Weeks Bay system. There is no information on food web connections in the bay. There are no data on interactions between the water column and benthic environment of the bay, especially with regard to the faunal community. Lastly, there is no understanding of the degree or type of interactions among the various habitats in the Weeks Bay system. There are other oligohaline to mesohaline estuarine systems systems in the southeast for which similar information exists. These studies could serve as a starting framework for efforts to better understand the functioning of the WBNERR ecosystem.

j. The constrained morphology and relative size of Weeks Bay and its watershed offer an ideal system for basic research examining the role of an estuary as a transformer of materials. With discrete and narrow inputs and outflow locations, as well as a relatively geographically small bay (and thus easily sampled), system-wide studies are simplified. Design and logistical constraints of research on the effects of anthropogenic changes in the watershed are also minimized by the fortuitous morphology of this system. System-wide studies have generally been most illuminating in estuarine systems in which inflows and outputs are easily quantified. It is recommended that effort be put forth to secure funding for system-wide studies of the Weeks Bay estuary.

k. The Reserve could install a clipboard at the scenic overlook for visitors to record unusual bird sightings. This would help to validate the existing checklist of birds and perhaps add new species. Long term trends in avian abundance could be tracked via volunteer events modeled on the Breeding Bird Counts and Christmas Bird Counts. Although not restricted to Reserve boundaries, some information could be gained from an examination of past bird counts.

2. It is recommended that efforts be made to apply a watershed approach to the understanding and management of the Weeks Bay ecosystem.

a. The information in this document is primarily constrained to the boundaries of the Weeks Bay National Estuarine Research Reserve. The publication of an additional site characterization which includes available information on the Weeks Bay watershed (i.e. the Fish and Magnolia River drainages) would permit a greater understanding of the relationship between the Reserve proper and its watershed.

b. The Magnolia River subwatershed of the Weeks Bay estuarine system should be inventoried, the information digitized and added to the current geographic information system (GIS) of the system. This information already exists for the Fish River watershed.

c. The problems of nonpoint source pollution necessitate a watershed approach. With the documented increase in the population of Baldwin County, the problem of nonpoint source pollution should become a focus of effort by managing and coordinating agencies. The extent and magnitude of the problem as well as real and potential sources need to be clearly identified. These should be a high priority for research efforts. Once more is learned about the potential problem in the Weeks Bay National Estuarine Research Reserve, management plans need to address its alleviation.

3. It is recommended that there be efforts to enhance the public's awareness of the Weeks Bay National Estuarine Research Reserve.

a. While the Reserve has become a well-known resource to the citizens of Mobile and Baldwin Counties, statewide awareness could be enhanced. One vehicle to achieve this goal would be the publication of an article in a journal with statewide circulation aimed at the citizenry such as *Alabama Conservationist.*

4. It is recommended that land acquisition and habitat restoration become a part of the management plan.

a. Weeks Bay has lost much of its submerged aquatic vegetation. Restoration techniques have become sufficiently successful to merit the expenditure of funds to restore this habitat to Weeks Bay. Coincident with this, however, must be efforts to control water clarity through management of sediment inputs to the bay. Increasing residential development in the Fish and Magnolia River drainages will undoubtedly place this issue forefront for a number of years.

b. At this time, there is no synthesis of the extent of human impacts to the shoreline of Weeks Bay. There is a need to quantify these impacts which include such items as the extent of shoreline bulkheading. Perhaps the most useful form of this synthesis would be a map, either in graphic or computer (GIS) form.

c. Shellfishing has been restricted for some time in Weeks Bay due to high fecal coliform counts. In an optimistic view, it is suggested that this form of pollution will become less important with the predicted increase in residential development in the area as more residents move from septic systems to city sewage systems. Efforts to control this form of microbial pollution are necessary prior to any large efforts to restore oyster beds within the Reserve's waters.

d. Discussions should occur on the efficacy of pursuing changes in zoning regulations for critical lands in the watershed. Zoning may be a useful tool to protect critical areas subject to human impacts, such as groundwater recharge areas.

e. Land acquisition is the most efficient manner by which watershed-based management can be implemented. It is suggested that whenever possible, funds be allocated for the purchase of additional land for WBNERR. Lands being considered for inclusion should not be limited to those immediately adjacent to the Reserve, but should include critical lands (wetlands, groundwater recharge areas, etc.) in the entire watershed. This policy would necessitate the identification and prioritizing of critical areas.

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Appendix 1

List of common names and species equivalents for plant and animal species with collection records or possible occurrence in the Weeks Bay National Estuarine Research Reserve

PLANTS

Alligator Weed	*Alternanthera philoxeroides*
American Beech	*Fagus grandifolia*
American Bulrush	*Scirpus americanus*
American Elder	*Sambucus canadensis*
American Holly	*Ilex opaca*
Arrow Arum	*Peltandra virginica*
Arrow Leaf	*Sagittaria lancifolia*
Arrowhead	*Sagittaria falcata*
Atlantic White Cedar	*Chamaecyparis thyoides*
Bald Cypress	*Taxodium distichum*
Bamboo Vine	*Smilax laurifolia*
Barbara's Buttons	*Mashallia tenuifolia*
Beak Rush	*Rhynchospora chapmanii; R. ciliaris; R. glomerata; R. plumosa; R. miliacea; R. pusilla; R. rariflora*
Beggar–ticks	*Bidens mitis*
Big Cordgrass	*Scirpus cynosuroides*
Black Gum	*Nyssa sylvatica*
Black Needlerush	*Juncus roemerianus*
Black Titi	*Cliftonia monophylla*
Black Willow	*Salix nigra*
Bladderwort	*Utricularia cornuta; U. juncea; U. biflora*
Blazing Star	*Liatris spicata*
Blue–eyed Grass	*Sisyrinchium atlanticum*
Blueheart	*Buchnera floridana*
Bog Bachelor Button	*Polygala lutea*
Bog Button	*Lachnocaulon digynum*
Bog Moss	*Mayaca aubletii*
Bracken Fern	*Pteridium aquilinum*
Broom Sedge	*Andropogon virginicus*
Buckwheat Tree	*Cliftonia monophylla*
Bushy Aster	*Aster dumosus*
Butterwort	*Pinguicula lutea; P. planifolia*
Candy Root	*Polygala nana*
Cane	*Arundinaria gigantea*
Catbrier	*Smilax auriculata*
Cattail	*Typha domingensis; T. latifolia*
Cinnamon Fern	*Osmunda cinnamomea*
Climbing Hydrangea	*Decumaria barbara*
Coastal Water–Hyssop	*Bacopa monnieri*
Colic Root	*Aletris aurea; A. farinosa*
Common Sweetleaf	*Sympiocos tinctoria*
Cow Pea	*Vigna luteola*
Cross Vine	*Bignonia capreolata*
Dahoon Holly	*Ilex cassine*
Dangleberry (Huckleberry)	*Gaylussacia frondosa; G. mosieri*
Devilwood	*Osmanthus americana*
Dodder	*Cuscuta campestris*
Dog Fennel	*Eupatorium capillifolium*
Dogwood	*Cornus florida*
Downy Serviceberry	*Amelanchier arborea*
Eastern Red Cedar	*Junperus virginiana*
Ebony Spleenwort	*Asplenium platyneuron*

Elliotts Blueberry (Mayberry)	*Vaccinium elliottii*
Eryngo	*Eryngium integrifolium*
Eurasian Watermilfoil	*Myriophyllum spicatum*
Evergreen Bayberry	*Myrica heterophylla*
False Asphodel	*Tofieldia racemosa*
False Hoarhound	*Eupatorium rotundifolium*
False Pimpernel	*Lindernia dubia*
Fetterbush	*Leucothoe axillaris*
	Lyonia lucida
Fireweed	*Erechtites hieracifolia*
Flat Sedge	*Cyperus virens*
Flat–topped Goldenrod	*Euthamia tenuifolia*
Flax	*Linum medium*
Fleabane	*Erigeron vernus*
Foxtail Clubmoss	*Lycopodium alopecuroides; L. carolinianum*
Foxtail Grass	*Setaria geniculata*
Gallberry	*Ilex glabra*
Giant Bulrush	*Scirpus californicus*
Glasswort	*Salicornia bigelovii; S. virginica*
Goldenrod	*Solidago patula*
Golden Club	*Orontium aquaticum*
Golden Crest	*Lophiola americana*
Grass Pink Orchid	*Calopogon pulchellus*
Greenbriar	*Smilax laurifolia*
Greenbrier (Sawbrier)	*Smilax glauca*
Gulf Cordgrass	*Scirpus spartinae*
Hazel Alder	*Alnus serrulata*
Hedge Hyssop	*Gratiola virginiana*
Henbit	*Lamium amplexicaule*
Highbush Blueberry	*Vaccinium corymbosum*
Honeycomb Head	*Balduina uniflora*
Indian Plantain	*Arnoglossum ovatum*
Inkberry	*Ilex glabra*
Intermediate Sundew	*Drosera intromedia*
Japanese Climbing Fern	*Lygodium japonicum*
Japanese Honeysuckle	*Lonicera japonica*
Knot Grass	*Paspalum distichum*
Ladies Tresses Orchid	*Spiranthes praecox; S. vernalis*
Large Gallberry	*Ilex coriacea*
Large–flower Polygala	*Polygala grandiflora*
Laurel Oak	*Quercus laurifolia; Q. hemisphaerica*
Leafless Sedge	*Cyperus haspan*
Live Oak	*Quercus virginiana*
Lobelia	*Lobelia flaccidifolia; L. glandulosa; L. puberula*
Loblolly Bay	*Gordonia lasianthus*
Loblolly Pine	*Pinus taeda*
Longleaf Pine	*Pinus palustris*
Marsh–pink	*Sabatia macrophylla*
Marsh Bulrush	*Scirpus cyperinus*
Marsh Elder	*Iva frutescens*
Marsh Fleabane	*Pluchea camphorata; P. purpurascens*
Marsh Gerardia	*Agalinis maritima*
Marsh Hay Cordgrass	*Scirpus patens*
Marsh Mallow	*Hibiscus moscheutos*

Marsh Morning Glory	*Ipomoea sagittata*
Marsh Pennywort	*Hydrocotyl umbellata*
Marsh Purslane	*Seauvium maritimum*
Meadow Beauty	*Rhexia petiolata; R. alifanus; R. lutea*
Milkweed	*Asclepias lanceolata; A. longifolia*
Milkwort	*Polygala brevifolia; P. cruciata*
Mist Flower	*Conoclinium coelestinum*
Muhly Grass	*Muhlenbergia expansa*
Muscadine Vine	*Vitis rotundifolia*
Musky Mint	*Hyptis alata*
Narrow Leaf Cattail	*Typha angustifolia*
Narrow–leaf Ludwigia	*Ludwigia linearis*
Netted Chain Fern	*Woodwardia areolata*
Nut Rush	*Scleria ciliata; S. reticularis*
Olney Bulrush	*Scirpus olneyi*
Pale Pitcher Plant	*Sarracenia alata*
Panic Grass	*Panicum consanguineum; P. ensifolium; P. spretum; P. scabriusculm*
Parrot Pitcher Plant	*Sarracenia psittacina*
Pepper Vine	*Ampeiopsis arborea*
Piedmont Azalea	*Rhododendron canescens*
Pink Sundew	*Drosera capillaris*
Pipewort	*Eriocaulon compressum; E. decangulare; E. lineare; E. ravenelii*
Plume Grass	*Erianthus giganteus*
Poison Ivy	*Toxicodendrom radicans*
Poison Sumac	*Rhus vernix*
Pond Cypress	*Taxodium ascendens*
Popcorn Tree	*Sapium sebiferum*
Possum Haw	*Viburnum nudum*
Purple Pitcher Plant	*Sarracenia purpurea*
Purple Silkyscale	*Anthaenantia rufa*
Rayless Goldenrod	*Bigelowia nudata*
	Chondrophora nudata
Red Bay	*Persea borbonia*
Red Chokeberry	*Aronia arbutifolia*
Red Maple	*Acer rubrum*
Red (Sweet–red)Pitcher Plant	*Sarracenia rubra*
Red–Root	*Lachnanthes caroliniana*
Reed	*Phragmites australis; P. communis*
Resurrection Fern	*Polypodium polypodioides*
Rice Cutgrass	*Leersia virginica*
Rosebud Orchid	*Cleistes divaricata*
Rose–crested Orchid	*Pogonia ophioglossoides*
Rose Gentian	*Sabatia brevifolia; S. macrophylla; S. stellaris*
Rough Skullcap	*Scutellaria integrifolia*
Royal Fern	*Osmunda regalis*
Rush	*Juncus debilis; J. diffusissimus; J. marginatus; J. scirpoides; J. trigonocarpus*
Salt Grass	*Distichlis spicata*
Salt Marsh Aster	*Aster tenuifolius*
Saltmarsh Bulrush	*Scirpus robustus*
Saltmarsh Fibristylis	*Fibristylis castanea*
Salt Marsh Loosetrife	*Lythrum lineare*

Salt Marsh Mallow	*Kostelwtzkya virginica*
Saltmeadow Grass	*Spartina patens*
Sand Vine	*Cynanchum palustre*
Saw Grass	*Cladium jamaicense*
Saw Palmetto	*Serenoa repens*
Sea Bite	*Suaeda linearis*
Sea Lavender	*Liminium nashii*
Sea Myrtle	*Baccharis halimifolia*
Seaside Goldenrod	*Solidago sempervirens*
Sedge	*Fimbristylis autumnalis* *Carex glaucescens*
Shortleaf Sundew	*Drosera brevifolia*
Slash Pine	*Pinus elliottii*
Slender Goldenrod	*Solidago stricta*
Slender Pondweed	*Potamogeton pusillus*
Slender Seed–box	*Ludwigia virgata; L. hirtella*
Smartweed	*Polygonum punctatum*
Smooth Cordgrass	*Spartina alterniflora*
Snakeroot	*Zigadenus glaberrimus*
Sneezeweed	*Helenium brevifolium*
Soft Stem Bulrush	*Scirpus validus*
Sourwood	*Oxydendrum arboreum*
Southern Bayberry	*Myrica cerifera*
Southern Magnolia	*Magnolia grandiflora*
Sparkleberry	*Vaccinium arboreum*
Sphagnum Moss	*Sphagnum sp.*
Spike Rush	*Eleocharis cellulosa; E. parvula; E. microcarpa; E. tuberculosa; E. flavescens*
Spoonflower	*Peltandra sagittifolia*
St. John's Wort	*Hypericum mutilum; H. virginicum; H. cistifolium; H. brachyphyllum; H. fasciculatum; H. crux–andreae*
Star Anise	*Illicium floridanum*
Sundew	*Drosera capillaris*
Sunflower	*Helianthus heterophyllus*
Swamp Azalea	*Rhododendron visocsum*
Swamp Bay	*Persea palustris*
Swamp Chestnut Oak	*Quercus michauxii*
Swamp Cyrilla	*Cyrilla racemiflora*
Swamp Red Bay	*Persea palustris*
Swamp Tupelo	*Nyssa sylvatica* var. *biflora*
Sweet Bay Magnolia	*Magnolia virginiana*
Sweet Gum	*Liquidambar styraciflua*
Sweet Pepperbush	*Clethra alnifolia*
Sweet (Red) Pitcher Plant	*Sarracenia rubra*
Switch Cane	*Arundinaria tecta; A. gigantea*
Switch Grass	*Panicum virgatum*
Tapegrass	*Vallisneria americana*
Thoroughwort	*Eupatorium mohrii; E. recurvans; E. perfoliatum*
Threadleaf Sundew	*Drosera filiformis*
Three–Awn Grass	*Aristida affinis; A. virgata*
Tickseed	*Coreopsis linifolia*
Toothache Grass	*Ctenium aromaticum*
Torpedo Grass	*Panicum repens*
Trumpet Creeper	*Campsis radicans*

Tulip Tree	*Liriodendrom tulipifera*
Umbrella Grass	*Fuirena squarrosa; F. scirpoidea*
Umbrella Sedge	*Cyperus odoratus; C. virens*
Virginia Chain Fern	*Woodwardia virginica*
Virginia Creeper	*Parthenocissus quinquefolia*
Virginia Willow	*Itea virginica*
Water Dropwort	*Oxypolis filiformis*
Watergrass	*Echinochloa walteri*
Water Hemp	*Acnida cuspidata*
Water Horehound	*Lycopus rubellus*
Water Oak	*Quercus nigra*
Wax Myrtle	*Myrica cerifera*
White Fringe Orchid	*Habenaria blephariglottis*
White Oak	*Quercus alba*
White–topped Pitcher Plant	*Sarracenia leucophylla*
White–Top Sedge	*Dichromena latifolia*
White Trumpet Pitcher Plant	*Sarracenia leucophylla*
Widespread Maiden Fern	*Thelypteris normalis*
Widgeongrass	*Ruppia maritima*
Willow Oak	*Quercus phellos*
Witch Hazel	*Hamamelis virginiana*
Yaupon Holly	*Ilex vomitoria*
Yellow– Eyed Grass	*Xyris caroliniana; X. difformis; X. iridifolia; X. baldwiniana; X. ambigua*
Yellow Jessamine	*Geisemium simpervirens*
Yellow Milkwort	*Polygala cymosa; P. ramosa*
Yellow Pitcher Plant	*Sarracenia alata; S. flava*
Yellow Poplar	*Liriodendron tulipifera*
Yellow Rhexia	*Rhexia lutea*

REPTILES_

Alligators

American Alligator	*Alligator mississippiensis*

Turtles

Alabama Red–bellied Turtle	*Pseudemys alabamensis*
Alligator Snapping Turtle	*Macroclemys temminckii*
Atlantic Ridley Turtle	*Lepidochelys kempi*
Common Snapping Turtle	*Chelydra serpentina*
Florida Cooter	*Pseudemys floridana*
Florida Softshell Turtle	*Trionyx ferox*
Gopher Tortoise	*Gopherus polyphemus*
Gulf Coast Box Turtle	*Terrapene carolina major*
Loggerhead Musk Turtle	*Sternotherus minor*
Miss. Diamondback Terrapin	*Malaclemys terrapin pileata*
Yellow–bellied Pond Slider	*Pseudomys scripta*
River Cooter	*Pseudemys concinna*
Stinkpot Musk Turtle	*Sternotherus odoratus*

Lizards

Broadheaded Skink	*Eumeces laticeps*

Eastern Glass Lizard	*Ophisaurus ventralis*
Five–lined Skink	*Eumeces fasciatus*
Green Anole	*Anolis carolinensis*
Ground Skink	*Scincella lateralis*
Six–lined Racerunner	*Cnemidophorus sexlineatus*

Snakes

Banded Water Snake	*Nerodia fasciata*
Black Pine Snake	*Pituophis melanoleucus lodingi*
Black Racer	*Coluber constrictor*
Coral Snake	*Micrurus fulvius*
Corn Snake Rattlesnake	*Elaphe guttata*
Eastern Diamondback	*Crotalus adamanteus*
Eastern Garter Snake	*Thamnophis sirtalis*
Eastern Indigo Snake	*Drymarchon corais couperi*
Eastern Kingsnake	*Lampropeltis getulus getulus*
Eastern Mud Snake	*Farancia abacura*
Eastern Ribbon Snake	*Thamnophis sauritus sauritus*
Florida Green Water Snake	*Natrix cyclopion floridana*
Florida Pine Snake	*Pituophis melanoleucus mugitus*
Gray Rat Snake	*Elaphe obsoleta spiloides*
Green Water Snake	*Nerodia cyclopion*
Gulf Saltmarsh Water Snake	*Natrix fasciata clarki*
Pine Woods Snake	*Rhadinaea flavilata*
Rainbow Snake	*Farancia erytrogramma*
Ringneck Snake	*Diadophis punctatus*
Rough Green Snake	*Opheodrys aestivus*
Scarlet Kingsnake	*Lampropeltis triangulum elapsoides*
Speckled Kingsnake	*Lampropeltis getulus holbrooki*
Water Moccasin (Cottonmouth)	*Agkistrodon piscivorus*
Yellow–bellied Water Snake	*Nerodia erythrogaster flavigaster*

AMPHIBIANS

Barking Tree Frog	*Hyla gratiosa*
Bronze Frog	*Rana clamitans clamitans*
Bullfrog	*Rana catesbeiana*
Dusky Gopher Frog	*Rana areolata sevosa*
Dwarf Salamander	*Manculus quadridigitatus*
Eastern Lesser Siren	*Siren intermedia intermedia*
Flatwoods Salamander	*Ambystoma cingulatum*
Fowler's Toad	*Bufo woodhousei fowleri*
Gray Treefrog	*Hyla chrysoscelis*
Greater Siren	*Siren lacertina*
Green Treefrog	*Hyla cinerea*
Gulf Coast Mud Salamander	*Pseudotriton montanus*
Mole Salamander	*Ambystoma talpoideum*
Narrowmouth Toad	*Gastrophryne carolinensis*
Oak Toad	*Bufo quercicus*
One–toed Amphiuma	*Amphiuma pholeter*
Pig Frog	*Rana grylio*
Pine Woods Treefrog	*Hyla femoralis*

Red Spotted Newt	*Notopthalmus viridescens*
River Frog	*Rana heckscheri*
Slimy Salamander	*Plethodon glutinosus*
Southern Chorus Frog	*Pseudacris nigrita*
Southern Cricket Frog	*Acris gryllus gryllus*
Southern Dusky Salamander	*Desmognathus fuscus auriculatus*
Southern Leopard Frog	*Rana pipiens sphenocephala*
Southern Red Salamander	*Pseudotriton ruber vioscai*
Southern Toad	*Bufo terrestris*
Spring Peeper	*Hyla crucifer*
Squirrel Treefrog	*Hyla squirella*
Three–lined Salamander	*Eurycea longicauda*
Three–toed Amphiuma	*Amphiuma tridactylum*
Two–lined Salamander	*Eurycea bislineata*
Two–toed Amphiuma	*Amphiuma means*

FISHES

Alligator Gar	*Atractosteus spatula*
American Eel	*Anguilla rostrata*
Atlantic Gulf Sturgeon	*Acipenser oxyrinchus*
Atlantic Bumper	*Chloroscombrus chrysurus*
Atlantic Croaker	*Micropogonias undulatus*
Atlantic Cutlassfish	*Trichiurus lepturus*
Atlantic Midshipman	*Porichthys plectrodon*
Atlantic Needlefish	*Strongylura marina*
Atlantic Spadefish	*Chaetodipterus faber*
Atlantic Stingray	*Dasyatis sabina*
Atlantic Threadfin	*Polydactylus octonemus*
Banded Drum	*Larimus fasciatus*
Banded Pygmy Sunfish	*Elassoma zonatum*
Banded Topminnow	*Fundulus auroguttatus (Fundulus cingulatus)*
Bay Anchovy	*Anchoa mitchilli*
Bay Wiff	*Citharichthys spilopterus*
Bayou Killifish	*Fundulus pulvereus*
Bearded Brotula	*Brotula barbata*
Bighead Sea Robin	*Prionotus tribulus*
Black Banded Darter	*Percina nigrofasciata*
Black Crappie	*Pomoxis nigromaculatus*
Black Drum	*Pogonias cromis*
Black Madtom	*Noturus funebris*
Blacktail Redhorse	*Moxostoma poecilurum*
Blacktail Shiner	*Cyprinella venusta*
Blackcheek Tonguefish	*Symphurus plagiusa*
Blackspotted Topminnow	*Fundulus olivacrus*
Blackwing Sea Robin	*Prionotus rubio*
Blue Catfish	*Icalurus furcatus*
Blue Runner	*Caranx crysos*
Bluefish	*Pomatomus saltatrix*
Bluegill	*Lepomis macrochiris*
Bluespotted Sunfish	*Enneacanthus gloriosus*

Bluntnose Jack	*Hemicaranx amblyrhynchus*
Brook Silverside	*Labidesthes sicculus*
Bull Shark	*Carcharhinus leucas*
Bullhead Minnow	*Pimephales vigilax*
Chain Pickerel	*Esox niger*
Chain Pipefish	*Syngathus louisianae*
Channel Catfish	*Ictalurus punctatus*
Cherryfin Shiner	*Lythrurus roseipinnis*
Clown Goby	*Microgobius gulosus*
Coastal Shiner	*Notropis petersoni*
Cobia	*Rachycenton canadum*
Code Goby	*Gobiosoma robustum*
Common Carp	*Cyprinus carpio*
Cownose Ray	*Rhinoptera bonasus*
Creek Chub	*Semotilus atromaculatus*
Crested Cusk Eel	*Ophidion welshi*
Crevalle Jack	*Caranx hippos*
Cuban Anchovy	*Anchoa cubana*
Darter Goby	*Gobionellus boleosoma*
Diamond Killifish	*Adinia xenica*
Dixie Chub	*Semotilus thoreauianus*
Dollar Sunfish	*Lepomis marginatus*
Emerald Sleeper	*Erotelis smaragdus*
Everglades Pygmy Sunfish	*Elassoma evergladei*
Fat Sleeper	*Dormitator maculatus*
Feather Blenny	*Hypsoblennius hentz*
Flagfin Shiner	*Pteronotropis signipinnis*
Flathead Catfish	*Pylodictis olivaris*
Flier	*Centrarchus macropterus*
Freckled Blenny	*Hypsoblennius ionthas*
Fresh Water Drum	*Aplodinotus grunniens*
Freshwater Goby	*Gobionellus shufeldti*
Frillfin Goby	*Bathygobius soporator*
Fringed Flounder	*Etropus crossotus*
Gafftopsail Catfish	*Bagre marinus*
Gizzard Shad	*Dorosoma cepedianum*
Golden Shiner	*Notemigonus crysoleucas*
Golden Topminnow	*Fundulus chrysotus*
Grass Pickerel	*Esox Americanus*
Gray Snapper	*Lutjanus griseus*
Green Goby	*Microgobius thalassinus*
Gulf Butterfish	*Peprilus burti*
Gulf Darter	*Etheostoma swaini*
Gulf Flounder	*Paralichthys albigutta*
Gulf Herring	*Brevoortia patronus*
Gulf Killlifish	*Fundulus grandis*
Gulf Menhaden	*Brevoortia patronus*
Gulf Pipefish	*Syngathus scovelli*
Gulf Toadfish	*Opsanus beta*
Hardhead Catfish	*Arius felis*
Harvestfish	*Peprilus alepidotus*
Highfin Carpsucker	*Capiodes velifer*
Hogchoker	*Trinectes maculatus*
Inland Silverside	*Menidia beryllins*

Inshore Lizard Fish	*Synodos foetens*
Ironcolor Shiner	*Notropis chalybaeus*
Lady Fish	*Elops saurus*
Lake Chubsucker	*Erimyzon sucetta*
Lane Snapper	*Lutjanus synagris*
Largemouth Bass	*Micropterus salmoides*
Least Killifish	*Heterandia formosa*
Least Puffer	*Sphoeroides parvus*
Leatherjack	*Oligoplites saurus*
Lined Seahorse	*Hippocampus erectus*
Lined Sole	*Achirus lineatus*
Longear Sunfish	*Lepomis megalotis*
Longnose Gar	*Lepisosteus osseus*
Lyre Goby	*Evorthodus lyricus*
Marsh Killifish	*Fundulus confluentus*
Mosquito Fish	*Gambusia affinis*
Naked Goby	*Gobiosoma bosci*
Paddlefish	*Polyodon spathula*
Pigfish	*Orthopristis chrysoptera*
Pinfish	*Lagodon rhomboides*
Pink Wormfish	*Microdesmum longipinnis*
Pirate Perch	*Aphredoderus sayanus*
Planehead Filefish	*Monacanthus hispidus*
Pugnose Shiner	*Opsopoeodus emiliae*
Pygmy Killifish	*Leptolucania ommata*
Rainwater Killifish	*Lucania parva*
Red Drum	*Sciaenops ocellatus*
Redear Sunfish	*Lepomis microlophus*
Rock Sea Bass	*Centropristis philadelphica*
Rough Silverside	*Membras martinica*
Russetfin Topminnow	*Fundulus escambiae*
Sailfin Shiner	*Pteronotropis hypselopterus*
Sailfish Molly	*Poecilia latipinna*
Saltmarsh Topminnow	*Fundulus jenkinsi*
Sand Seatrout	*Cynoscion arenarius*
Scaled Sardine	*Harengula jaguana*
Scrawled Cowfish	*Lactophrys quadricornis*
Shadow Bass	*Ambloplites ariommus*
Sharksucker	*Echeneis naucrates*
Sharpfin Chubsucker	*Erimyzon tenuis*
Sharptail Goby	*Gobionellus oceanicus*
Sheepshead	*Archosargus probatocephalus*
Sheepshead Minnow	*Cyprinodon variegatus*
Shrimp Eel	*Ophichthus gomesi*
Silver Chub	*Macrhybopsis storeriana*
Silver Perch	*Bairdiella chrysoura*
Silver Seatrout	*Cynoscion nothus*
Silverside Shiner	*Notropis candidus*
Silverband Shiner	*Notropis shumardi*
Silverstripe Halfbeak	*Hyporhamphus sp.* cf. *unifasciatus*
Singlespot Frogfish	*Antennarius radiosus*
Skilletfish	*Gobiesox strumosus*
Skipjack Herring	*Alosa chrysochloris*
Smallmouth Buffalo	*Ictiobus bubalus*

Smooth Puffer	*Lagocephalus laevigatus*
Southern Flounder	*Paralichthys lethostigma*
Southern Hake	*Urophycis floridana*
Southern Kingfish	*Menticirrhus americanus*
Southern Puffer	*Sphoeroides nephelus*
Southern Stargazer	*Astroscopus y–graecum*
Speckled Worm Eel	*Myrophis punctatus*
Speckled Madtom	*Noturus leptacanthus*
Spinycheek Sleeper	*Elotelis sp.* cf. *amblyopsis*
Spot	*Leiostomas xanthurus*
Spotfin Mojarra	*Eucinostomus argenteus*
Spotted Bass	*Micropterus punctulatus*
Spotted Gar	*Lepisosteus oculatus*
Spotted Hake	*Urophycis regia*
Spotted Seatrout	*Cynoscion nebulosis*
Spotted Sucker	*Minytrema melanops*
Spotted Sunfish	*Lepomis punctatis*
Star Drum	*Stellifer lanceolatus*
Starhead Topminnow	*Fundulus notti*
Striped Anchovy	*Anchoa hepsetus*
Striped Bass	*Morone saxatilis*
Striped Blenny	*Chasmodes bosquianus*
Striped Burrfish	*Chilomycterus schoepfi*
Striped Killifish	*Fundulus majalis (Fundulus semilis)*
Striped Mullet	*Mugil cephalus*
Swamp Darter	*Etheostoma fusiforme*
Threadfin Shad	*Dorosoma petenense*
Tidewater Mojarra	*Eucinostomus harengulus*
Tidewater Silverside	*Menidia peninsulae*
Trunkfish	*Lactophrys trigonus*
Twoscale Goby	*Gobiosoma longipala*
Violet Goby	*Gobioides broussoneti*
Warmouth	*Chaenobryttus gulosus*
Weed Shiner	*Notropis texanus*
Whip Eel	*Bascanichthys scuticaris*
White Crappie	*Pomoxis annularis*
White Mullet	*Mugil curema*
Yellow Bullhead	*Ameiurus natalis*
Yellow Bass	*Morone mississippiensis*

INVERTEBRATES

Blue Crab	*Callinectes sapidus*
Brown Shrimp	*Penaeus aztecus*
Fiddler Crab	*Uca pugilator; U. pugnax*
Gammarid amphipods	
Grass Shrimp	*Palaemonetes pugio; P. vulgaris*
Green Nerite	*Neritina reclivata*
Hardback Shrimp	*Trachypenaeus sp.*
Isopod	*Cyathura polita*
Mantis Shrimp	*Squilla empusa*
Marsh Clam	*Rangia cuneata*
Oyster	*Crassostrea virginica*

Pink Shrimp	*Penaeus duorarun*
Polychaeta	*Laeonereis culveri*
	Neanthes succinea
	Amphicteis gunneri
Portunid Crab	*Ovalipes guadalupensis*
	Portunus gibbesii
	Callinectes sapidus
Sergistid Shrimp	*Acetes americanus*
Spider Crab	*Libinia emarginata*
Square–Backed Fiddler Crab	*Sesarma cinereum*
Squid	*Lolliguncula brevis*
Stone Crab	*Menippe mercenaria*
Striped Hermit Crab	*Clibanarius vittatus*
White Shrimp	*Penaeus setiferus*

MAMMALS

Armadillo	*Dasypus novemcinctus*
Atlantic Bottlenose Dolphin	*Tursiops truncatus*
Big Brown Bat	*Eptesicus fuscus*
Bobcat	*Felis rufus*
Cotton Mouse	*Peromyscus gossypinus*
Eastern Cottontail	*Sylvilgus floridanus*
Eastern Gray Squirrel	*Sciurus carolinensis*
Eastern Mole	*Scalopus aquaticus*
Eastern Pipistrelle	*Pipistrellus subflavus*
Eastern Woodrat	*Neotoma floridana*
Evening Bat	*Nycticeius humeralis*
Florida Black Bear	*Ursus americanus floridanus*
Gray Fox	*Urocyon cinereoargenteus*
Hispid Cotton Rat	*Sigmodon hispidus*
House Mouse	*Mus musculus*
Marsh Rabbit	*Sylvilagus palustris*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethica*
Norway Rat	*Rattus norvegicus*
Nutria	*Myocastor coypus*
Opossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
Red Bat	*Lasiurus borealis*
Red Fox	*Vulpes vulpes*
Rice Rat	*Oryzomys palustris*
River Otter	*Lutra canadensis*
Seminole Bat	*Lasiurus seminolus*
Southern Flying Squirrel	*Glaucomys volans*
Southern Short–tailed Shrew	*Blarina carolinensis*
Striped Skunk	*Mephitis mephitis*
White–tailed Deer	*Odocoileus virginianus*
West Indian Manatee	*Trichechus manatus*

BIRDS

Acadian Flycatcher	*Empidonax virescens*
Alder Flycatcher	*Empidonax alnorum*
American Avocet	*Recurvirostra americana*
American Bittern	*Botaurus lentiginosus*
American Black Duck	*Anas rubripes*
American Coot	*Fulica americana*
American Crow	*Corvus brachyrhynchos*
American Egret	*Casmerodius albus*
American Goldfinch	*Carduelis tristis*
American Kestral	*Falco sparverius*
American Oystercatcher	*Itaematopus palliatus*
American Redstart	*Setophaga ruticilla*
American Robin	*Turdus migratorius*
American Swallowtailed Kite	*Elanoides forficatus*
American White Pelican	*Pelecanus erythrorhynchos*
American Wigeon	*Anas americana*
American Woodcock	*Philohela minor*
Anhinga	*Anhinga anhinga*
Ash–throated Flycatcher	*Myiarchus cinerascens*
Bachman's Sparrow	*Aimophila aestivalis*
Bachman's Warbler	*Vermivora bachmanii*
Baird's Sandpiper	*Calidris bairdii*
Bald Eagle	*Haliaetus leucocephalus*
Band–tailed Pigeon	*Columba fasciata*
Bank Swallow	*Riparia riparia*
Barn Swallow	*Hirundo rustica*
Barred Owl	*Strix Varia*
Bay–breasted Warbler	*Dendroica castanea*
Bell's Vireo	*Vireo bellii*
Belted Kingfisher	*Ceryle alcyon*
Bewick's Wren	*Thryomanes bewickii*
Blackburnian Warbler	*Dendroica fusca*
Blackpoll Warbler	*Dendroica striata*
Black–throated Blue Warbler	*Dendroica caerulescens*
Black–billed Cuckoo	*Coccyzus erythropthalmus*
Black–throated Gray Warbler	*Dendroica virens*
Black–headed Grosbeak	*Pheucticus melanocephalus*
Black–chinned Hummingbird	*Archilocus alexandri*
Black–shouldered Kite	*Elanus caeruleus*
Black–legged Kittiwake	*Rissa tridactyla*
Black–crowned Night–Heron	*Nycticorax nycticorax*
Black–bellied Plover	*Pluvialis squatarola*
Black Rail	*Laterallus jamaicensis*
Black Scooter	*Melanitta nigra*
Black Skimmer	*Rynchops niger*
Black–necked Stilt	*Himantopus mexicanus*
Black Tern	*Chlidonias niger*
Black Vulture	*Coragyps atratus*
Black &White Warbler	*Mniotilla varia*
Blue Grosbeak	*Guiraca caerulea*
Blue Jay	*Cyanocitta cristata*
Blue–Gray Gnatcatcher	*Polioptila caerulea*

Blue–winged Teal	*Anas discors*
Blue–winged Warbler	*Vermivora pinus*
Boat–tailed Grackle	*Quiscalus major*
Bobolink	*Dilochonyx oryzivorus*
Bonaparte's Gull	*Larus philadelphia*
Brewer's Blackbird	*Euphagus cyanocephalus*
Broad–winged Hawk	*Buteo platypterus*
Brown Booby	*Sula leucogaster*
Brown Creeper	*Certhia familiaris*
Brown Pelican	*Pelecanus occidentalis*
Brown Thrasher	*Toxostoma rufum*
Brown–headed Cowbird	*Molothrus ater*
Brown–headed Nuthatch	*Sitta pusilla*
Buff–Breasted Sandpiper	*Tryngites subruficollis*
Bufflehead	*Bucephala albeola*
Burrowing Owl	*Athene cunicularia*
Canada Goose	*Branta canadensis*
Canada Warbler	*Wilsonia canadensis*
Canvasback	*Aythya valisineria*
Cape May Warbler	*Dendroica tigrina*
Carolina Chikadee	*Parus carolinensis*
Carolina Wren	*Thryothorus ludovicianus*
Caspian Tern	*Sterna caspia*
Cattle Egret	*Bubulcus ibis*
Cedar Waxwing	*Bombycilla cedrorum*
Cerulean Warbler	*Dendroica cerulea*
Chestnut–sided Warbler	*Dendroica pensylvanica*
Chimney Swift	*Chaetura pelagica*
Chipping Sparrow	*Spizella passerina*
Chuck Will's Widow	*Caprimulgus carolinensis*
Clapper Rail	*Rallus longirostris*
Clay–colored Sparrow	*Spizella pallida*
Cliff Swallow	*Petrochelidon pyrrhonota*
Common Barn Owl	*Tyto alba*
Common Goldeneye	*Bucephala clangula*
Common Grackle	*Quiscalus quiscalus*
Common Ground Dove	*Columbina passerina*
Common Loon	*Gavia immer*
Common Merganser	*Mergus merganser*
Common Moorhen	*Gallinula chloropus*
Common Nighthawk	*Chordeiles minor*
Common Snipe	*Capella gallonago*
Common Tern	*Sterna hirundo*
Common Yellowthroat	*Geothlypis trichas*
Connecticut Warbler	*Oporonis agilis*
Cooper's Hawk	*Accipiter cooperii*
Dark–eyed Junco	*Junco hyemalis*
Dickcissel	*Spiza americana*
Double–crested Cormorant	*Phalacrocorax auritus*
Downy Woodpecker	*Picoides pubescens*
Dunlin	*Calidris alpina*
Eared Grebe	*Podiceps nigricollis*
Eastern Bluebird	*Sialia sialis*
Eastern Kingbird	*Tyrannus tyrannus*

Eastern Meadowlark	*Sturnella magna*
Eastern Phoebe	*Sayornis phoebe*
Eastern Screech Owl	*Otus asio*
Eastern Wood Pewee	*Contopus virens*
European Starling	*Sturnus vulgaris*
Evening Grosbeak	*Coccothraustes vespertinas*
Field Sparrow	*Spizella pusilla*
Fish Crow	*Corvus ossifragus*
Forster's Tern	*Sterna forsteri*
Fox Sparrow	*Passerella iliaca*
Franklin's Gull	*Larus pipixcan*
Fulvous Whistling Duck	*Dendrocygna bicolor*
Gadwall	*Anas strepera*
Glaucous Gull	*Larus hyperboreus*
Glossy Ibis	*Plegadis falcinellus*
Golden Crowned Kinglet	*Regulus satrapa*
Golden Eagle	*Aquila chrysaetos*
Golden–winged Warbler	*Vermivora chrysoptera*
Grasshopper Sparrow	*Ammadramus savannarum*
Gray Kingbird	*Tyrannus dominicensis*
Gray Cheeked Thrush	*Catharus minimus*
Great Black–backed Gull	*Larus marinus*
Great Blue Heron	*Ardea herodias*
Great Crested Flycatcher	*Myiarchus crinitus*
Great Egret	*Casmerodius albus*
Great Horned Owl	*Bubo virginianus*
Greater Scaup	*Aythya marila*
Greater Shearwater	*Puffinus gravis*
Greater White–fronted Goose	*Anser albifrons*
Greater Yellowlegs	*Tringa melanoleuca*
Green–backed Heron	*Butorides striatus*
Green–winged Teal	*Anas crecca*
Grey Catbird	*Dumetella carolinensis*
Groove–billed Cuckoo	*Crotophaga sulcirostris*
Gull–billed Tern	*Gelochelidon nilotica*
Hairy Woodpecker	*Picoides villosus*
Harris's Sparrow	*Zonotrichia querula*
Henslow's Sparrow	*Ammodramus henslowii*
Hermit Thrush	*Catherus guttatus*
Herring Gull	*Larus argentatus*
Hooded Merganser	*Lophodytes cucullatus*
Hooded Warbler	*Wilsonia citrina*
Horned Grebe	*Podiceps auritus*
Horned Lark	*Eremophila alpestris*
House Sparrow	*Passer domesticus*
House Wren	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Kentucky Warbler	*Opornis formosus*
Killdeer	*Charadrius vociferus*
King Rail	*Rallus elegans*
Lapland Longspur	*Calcarius lapponicus*
Lark Sparrow	*Chondestes grammacus*
Laughing Gull	*Larus atricilla*
Least Bittern	*Ixobrychus exilis*

Least Flycatcher	*Empidonax minimus*
Least Sandpiper	*Calidris minutilla*
Least Tern	*Sterna antillarum*
LeConte's Sparrow	*Ammospiza leconteii*
Lesser Golden Plover	*Pluvialis dominica*
Lesser Scaup	*Aythya affinis*
Lesser Yellowlegs	*Tringa flavipes*
Lincoln's Sparrow	*Melospiza lincolnii*
Little Blue Heron	*Egretta caerulea*
Loggerhead Shrike	*Lanius ludovicianus*
Long–billed Curlew	*Numenius americanus*
Long–billed Dowitcher	*Limnodromus scolopaceus*
Long–eared Owl	*Asio otus*
Louisiana Heron	*Egretta tricolor*
Louisiana Waterthrush	*Seiurus motacilla*
Magnificent Frigatebird	*Fregata magnificens*
Magnolia Warbler	*Dendroica magnolia*
Mallard	*Anas platyrhynchos*
Marbled Godwit	*Limosa fedoa*
Marsh Wren	*Cistothorus palustris*
Masked Booby	*Sula dactylatra*
Merlin	*Falco columbarius*
Mississippi Kite	*Ictinia Mississippiensis*
Mottled Duck	*Anas fulvigula*
Mourning Dove	*Zenaida macroura*
Mourning Warbler	*Oporornis philadelphia*
Nashville Warbler	*Vermivora ruficapilla*
Northern Bobwhite	*Colinus virginianus*
Northern Cardinal	*Cardinalis cardinalis*
Northern Flicker	*Colaptes auratus*
Northern Gannet	*Sula bassanus*
Northern Harrier	*Circus cyaneus*
Northern Mockingbird	*Mimus polyglottos*
Northern Oriole	*Icterus galbula*
Northern Parula	*Parula americana*
Northern Pintail	*Anas acuta*
Northern rough–winged Swallow	*Stelgedopteryx serripennis*
Northern Shoveler	*Anas clypeata*
Northern Waterthrush	*Seiurus noveboracensis*
Oldsquaw	*Clangula hyemalis*
Olive–sided Flycatcher	*Nuttallorus borealis*
Orange–crowned Warbler	*Vermivora celata*
Orchard Oriole	*Icterus spurius*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Painted Bunting	*Passerina ciris*
Palm Warbler	*Dendroica palmarum*
Parasitic Jaeger	*Stercorarius parasiticus*
Pectoral Sandpiper	*Calidris melanotos*
Peregrine Falcon	*Falco peregrinus*
Philadelphia Vireo	*Vireo philadelphicus*
Pied–billed Grebe	*Podilymbus podiceps*
Pileated Woodpecker	*Dryocopus pileatus*

Pine Siskin	*Carduelis pinus*
Pine Warbler	*Dendroica pinus*
Piping Plover	*Charadrius melodus*
Pomarine Jaeger	*Stercorarius pomarinus*
Prairie Warbler	*Dendroica discolor*
Prothonotary Warbler	*Protonotaria citrea*
Purple Martin	*Progne subris*
Purple Finch	*Carpodacus purpureus*
Purple Gallinule	*Porphyrula martinica*
Redhead	*Aythya americana*
Red Knot	*Calidris canutus*
Red–breasted Merganser	*Mergus serrator*
Red–breasted Nuthatch	*Sitta canadensis*
Red–necked Grebe	*Podiceps grisegena*
Red–necked Phalarope	*Phalaropus lobatus*
Red–shouldered Hawk	*Buteo lineatus*
Red–tailed Hawk	*Buteo jamaicensis*
Red–throated Loon	*Gavia stellata*
Red–winged Blackbird	*Agelaius phoeniceus*
Reddish Egret	*Egretta rufescens*
Red Phalarope	*Phalaropus fulicarius*
Red–eyed Vireo	*Vireo olivaceus*
Red Cockaded Woodpecker	*Picoides borealis*
Red–headed Woodpecker	*Melanerpes erythrocephalus*
Red–bellied Woodpecker	*Melanerpes carolinas*
Ring–billed Gull	*Larus delawarensis*
Ring–necked Duck	*Aythya collaris*
Ringed Turtle Dove	*Streptopelia risoria*
Rock Dove	*Columba livia*
Rose–breasted Grosbeak	*Pheucticus ludovicianus*
Roseate Spoonbill	*Ajaia ajaja*
Rough–legged Hawk	*Buteo lagopus*
Royal Tern	*Sterna maxima*
Ruby–Crowned Kinglet	*Regulus calendula*
Ruby–throated Hummingbird	*Archilochus colubris*
Ruddy Duck	*Oxyura jamaicensis*
Ruddy Turnstone	*Arenaria interpres*
Rufous Hummingbird	*Selasphorus rufus*
Rufous–sided Towhee	*Pipilo erythrophthalmus*
Rusty Blackbird	*Euphagus carolinus*
Sage Thrasher	*Oreoscoptes monyanus*
Sanderling	*Calidris alba*
Sandhill Crane	*Grus canadensis*
Sandwich Tern	*Sterna sandvicensis*
Savannah Sparrow	*Passerculus sandwichensis*
Say's Phoebe	*Sayornis saya*
Scarlet Tanager	*Piranga olivacea*
Scissor–tailed Flycatcher	*Muscivora foficata*
Seaside Sparrow	*Ammospiza maritima*
Sedge Wren	*Cistothorus platensis*
Semipalmated Plover	*Charadrius semipalmatus*
Semipalmated Sandpiper	*Calidris pusilla*
Sharp–shinned Hawk	*Accipiter striatus*
Sharp–tailed Sparrow	*Ammospiza caudacuta*

Short–billed Dowitcher	*Limnodromus griseus*
Short–eared Owl	*Asio flameus*
Short–tailed Hawk	*Buteo brachyurus*
Smith's Longspur	*Calcarius pictus*
Snow Goose	*Chen caerulescens*
Snowy Egret	*Egretta thula*
Snowy Owl	*Nyctea scandiaca*
Snowy Plover	*Charadrius alexandrinus*
Solitary Sandpiper	*Tringa solitaria*
Solitary Vireo	*Vireo solitarius*
Song Sparrow	*Melospiza melodia*
Sooty Shearwater	*Puffinus griseus*
Sooty Tern	*Sterna fuscata*
Sora	*Porzana carolina*
Spotted Sandpiper	*Actitus macularia*
Sprague's Pipit	*Anthus spragueii*
Stilt Sandpiper (Buff–breasted Sandpiper)	*Tryngites subruficollis*
Summer Tanager	*Piranga rubra*
Surf Scoter	*Melanitta perspicillata*
Swainson's Hawk	*Buteo swainsoni*
Swainson's Thrush	*Catherus ustulatus*
Swainson's Warbler	*Limnothlypis swainsonii*
Swamp Sparrow	*Melospiza georgiana*
Tennessee Warbler	*Vermivora peregrina*
Tree Swallow	*Iridoprocne bicolor*
Tricolored Heron	*Egretta tricolor*
Tropical Kingbird	*Tyrannus melancholicus*
Tufted Titmouse	*Parus bicolor*
Tundra Swan	*Cygnus columbianus*
Turkey Vulture	*Cathartes aura*
Upland Sandpiper	*Bartramia longicauda*
Veery	*Catharus fuscescens*
Vermilion Flycatcher	*Pyrocephalus rubinis*
Vesper Sparrow	*Pooecetes gramineus*
Virginia Rail	*Rallus limicola*
Warbling Vireo	*Vireo gilvus*
Water Pipit	*Anthus spinoletta*
Western Kingbird	*Tyrannus verticalis*
Western Meadowlark	*Sternella neglecta*
Western Sandpiper	*Calidris mauri*
Western Tanager	*Piranga ludoviciana*
Whimbrel	*Numenius phaeopus*
Whip–poor–will	*Caprimulgus vociferus*
White–winged Dove	*Zenaida asiatica*
White Ibis	*Eudocimus albus*
White–faced Ibis	*Plegadis chihi*
White–breasted Nuthatch	*Sitta carolinensis*
White–rumped Sandpiper	*Calidris fuscicollis*
White–winged Scoter	*Melanitta fusca*
White–throated Sparrow	*Zonotrichia albicollis*
White–crowned Sparrow	*Zonotrichia leucophrys*
White–eyed Vireo	*Vireo griseus*
Willet	*Catoptrophorus semipalmatus*

Willow Flycatcher	*Empidonax traillii*
Wilson's Phalarope	*Steganopus tricolor*
Wilson's Plover	*Charadrius wilsonia*
Wilson's Storm Petrel	*Oceanites oceanicus*
Wilson's Warbler	*Wilsonia pusilla*
Winter Wren	*Troglodytes troglodytes*
Wood Duck	*Aix sponsa*
Wood Stork	*Mycteria americana*
Wood Thrush	*Hylocichla mustelina*
Worm–eating Warbler	*Helmitheros vermivorus*
Yellow–headed Blackbird	*Xanthocephalus xanthocephalus*
Yellow–breasted Chat	*Icteria virens*
Yellow–billed Cuckoo	*Coccyzus americanus*
Yellow–bellied Flycatcher	*Empidonax flaviventris*
Yellow–bellied Sapsucker	*Sphyrapicus varius*
Yellow–crowned Night Heron	*Nycticorax violaceus*
Yellow Rail	*Coturnicops noveboracensis*
Yellow–throated Vireo	*Vireo flavifrons*
Yellow–throated Warbler	*Dendroica dominica*
Yellow–rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*

ZOOPLANKTON

Calanoid Copepods

Acartia tonsa
Eurytemora sp.
Pseudodiaptomus coronatus

Cyclopoid Copepods

Halicyclops fosteri
Oithona colcarva
Oithona nana
Oithona sp.
Saphirella sp.

Harpacticoid Copepods

Ectinosomidae
Leptocaris kunzi
Nitocra spinipes
Onychocamptus chathamensis
Paronychocamptus wilsoni
Pseudostephelia wellsi
Scottolana canadensis

Cladocerans

Alona sp.
Bosmina sp.
Bosminopsis deitersi
Ceriodaphnia sp.
Chydorus sp.
Daphnia sp.
Diaphanosoma sp.

Appendix 2

Summary of Past and Present Research at Weeks Bay National Estuarine Research Reserve

NOAA Funded Research

April, G.C. 1993. Estuarine Modeling
Computer simulation of hydrodynamic and salinity behavior of Weeks Bay, Alabama at equatorial tide conditions.
Status: *Complete*

Numerical simulation of the Weeks Bay estuary: The impact of a hypothetical channel construction project on water movement and salinity patterns
Status: *Complete*

Bain, M. 1990. Abiotic and biotic factors influencing microhabitat use by fish and shrimp in Weeks Bay National Estuarine Research Reserve.
Status: *Complete*

Hopkins, T.S. 1988. The hydrology of baseline nutrient levels (C, N and P) and primary production in the Weeks Bay NERR.
Status: *Unknown*

Lockaby, G., K. Flynn, L. Teeter and R. Lowrance. Relationships between landscape characteristics and non-point source pollution to coastal estuaries.
Status: *In progress*

Marion, K.R. and J.J. Dindo. 1987. Use of indicator species as a means of assessing the environmental conditions of the Weeks Bay National Estuarine Research Reserve. NOAA Technical Report Series OCRM/SPD. Washington, D.C.
Status: *Complete*

Marion, K.R. and J.J. Dindo. 1988. Enhancing public awareness of estuaries: A natural history survey of the Weeks Bay NERR.
Status: *Complete*

McClintock, J.B. and K.R. Marion. 1990. Habitat utilization, population dynamics, reproductive biology and trophic ecology of the blue crab in Weeks Bay, Alabama.
Status: *Complete*

Pennock, J.R. and T.S. Hopkins. 1991. Biogeochemical and hydrodynamic regulation of nutrient / production dynamics in shallow, terrestrially impacted estuaries.
Status: *Complete*

Schroeder, W.W., W.J. Wiseman, Jr. and S.P. Dinnel. 1989. Wind and river induced fluctuations in a small, shallow tributary estuary.
Status: *Complete*

Stout, J.P. 1987. Delineation of emergent habitats of the Weeks Bay NERR.
Status: *Complete*

Stearns, D.E. 1990. Zooplankton community composition, species abundance, and grazing impact: Tidal, monthly, and seasonal and habitat differences
Status: *Complete*

Other Funding

Marine Environmental Sciences Consortium

Schreiber, R.A. and J.R. Pennock. 1995. The relative contribution of benthic microalgae to total microalgal production in a shallow sub-tidal estuarine environment.
Status: *Complete*

Mississippi-Alabama Sea Grant

Pennock, J.R. and J.J. Cowan, Jr. 1996 Nutrient-enhanced production and trophic dynamics in Weeks Bay, Alabama.
Status: *In progress*

Field Validation Research Program, US EPA

Lytle, J.S and T.F. Lytle. Field validation of pesticide impact in Weeks Bay, Alabama.
Status: *In progress*

Weeks Bay National Estuarine Research Reserve Fellowship

Wimberly, P. Investigating the benefits of best management practices in controlling nonpoint source pollution in the Weeks Bay watershed.
Status: *In progress*

Wolfe, D.L. and D. W. Haywick. 1994. Rock lithification at Magnolia Springs.
Status: *Complete*

Auburn University Cooperative Extension Service

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Status: *Complete*

EPA Watershed Project Grants (*all in progress*)

Alabama Department of Public Health. Construction and monitoring of alternative on-site treatment systems in Weeks Bay Watershed.

Alabama Water Watch, Auburn University. Establishing a citizen monitoring group in the Weeks Bay Watershed.

Baldwin County Soil and Water Conservation District. Weeks Bay pollution prevention project: Cost-share for agricultural BMP's.

Geological Survey of Alabama. Monitoring agricultural BMP's (chemical, physical and biological parameters) on Fish and Magnolia Rivers.

Geological Survey of Alabama. Pesticides and groundwater data - thematic map.

United States Geological Survey. Two USGS stage and one instream gaging stations in the Weeks Bay watershed.

Appendix 3

Weeks Bay Watershed Project Accomplishments: September 1993 - June 1996

I. General

A. Twenty-four volunteer monitoring sites established in watershed and monitored on a bi-weekly basis, beginning May 1995.

B. GIS equipment and database in place.

C. Ten (10) Adopt-A-Stream sites established. Volunteers clean up litter at sites on a monthly basis.

D. Over four thousand (4,000) acres of cropland put in conservation tillage in watershed with Soil and Water Conservation District (SWCD) Weeks Bay Pollution Prevention Project cost-share.

E. Seventeen (17) acres of prior-converted wetlands restored with SWCD Weeks Bay Pollution Prevention Project cost-share.

F. Watershed Project newsletter (semi-annual) and brochure developed.

G. Nonpoint source critical land (294 acres) in watershed identified and conditionally approved by for purchase by EPA.

H. Five (5) constructed wetland demonstration projects in place along Fish River through cooperative project with Alabama Department of Public Health.

I. Citizens Advisory Committee formed in October 1995. Ten (10) watershed residents serve on CAC and meet monthly. Committee members were nominated by Planning and Objectives Committee and were appointed by SWCD supervisors. CAC meetings are advertised and open to the public.

J. BMP recognition program, "Partners for Clean Water" initiated for forestry, agricultural and construction sites.

II. Presentations and Exhibits

A number of outreach activities have been pursued to raise awareness for the Weeks Bay Watershed Project. Targeted audiences have included government agencies at all levels (especially those active in coastal/water quality management activities), watershed residents and farmers, local media, and citizens who live in Baldwin and Mobile Counties. To date, twenty-six (26) presentations have been made to civic and community groups in Mobile and Baldwin Counties.

III. Tours

Watershed tours highlight EPA-funded demonstration projects in the watershed including 5 constructed wetland sites, wetland restoration sites, agricultural conservation tillage practices, citizen monitoring sites, and other sites where pollution controls have been implemented.

A. Alternative On-Site Wastewater Treatment Workshop (September 20, 1995)
Participants of the Alternative On-Site Wastewater Treatment Workshop were taken on a tour to view constructed wetland and peat biofilter demonstration sites in watershed.

B. ADEM Watershed Tour (October 20, 1995)
A group of approximately 40 representatives of ADEM and other resource agencies toured the watershed to view demonstration projects by boat and bus.

C. Dirt Road Tour (February 1, 1996)
Representatives of ADEM, NRCS, Baldwin County Engineering Dept. and local citizens toured the watershed to view dirt roads with severe erosion problems that threaten water quality.

D. Citizen Advisory Committee Tour (March 12, 1996)
Approximately twenty (20) citizens, agency representatives, media representatives, and SWCD supervisors toured Weeks Bay Watershed to view demonstration projects and existing problem areas.

III. Workshops

The Weeks Bay Watershed Project has conducted workshops for teachers, school children, professional groups, and citizens on a variety of water quality and nonpoint source topics.

A. Annual Nonpoint Source Teachers Workshop (August 1, 2, 10, 11, 1995)
Sixteen teachers, Alabama Cooperative Extension Service (ACES) personnel, and volunteers attended this workshop. This workshop was an advanced workshop, which built on the principles taught the previous year. A watershed investigation component was included this year to provide participants with a hands-on nonpoint source problem-solving activity.

B. Alabama Water Watch Certification Workshops (April, August)
On April 19, 1995 twelve volunteer monitors were certified to monitor water quality in the Weeks Bay Watershed. A second certification workshop was held August 1, 1995 during the NPS Teacher Workshop. Three volunteer monitors were certified in addition to the teachers and ACES personnel.

C. Alternative On-Site Wastewater Treatment Workshop (September 20, 1995)
Thirty-seven engineers, installers, pumpers and other individuals interested in alternative on-site wastewater treatment systems attended a one-day technical workshop sponsored by the Weeks Bay Watershed Project. This workshop, held at Faulkner State Community College, consisted of one-half day of classroom instruction and one-half day field trip to view demonstration projects in the watershed.

D. Bayside Academy Science Club (October 17, 1995)
Twelve members of the Bayside Academy Environmental Club attended a mini-water quality monitoring workshop.

E. Citizens Septic Workshop (November 2, 1995)

Approximately forty-five citizens attended an evening workshop on septic tank maintenance and alternatives to conventional septic systems.

F. Alabama Water Watch Certification Workshop (March 9, 1996)
Twenty-nine volunteer monitors were certified to monitor water quality in the Weeks Bay Watershed.

G. Advanced Water Quality Workshop (May 18, 1996)
Fifteen certified monitors attended this six-hour workshop to learn monitoring techniques for additional parameters including *E. coli*, nitrates, and phosphates.

H. Educators Workshop - Non-point source pollution in the watershed. (June 25-28, 1996) Thirty-five state-wide participants including teachers, engineers and consultants interested in water quality attended this workshop.

Appendix 4

Criteria for Pier Construction in Weeks Bay Baldwin County, Alabama

1. **Pier and / or Walkway:**

a. **Length of structure**: The entire structure may extend to 3 feet MLW (mean low water) plus 20 feet waterward, or 300 feet waterward of MHW (mean high water), whichever distance is shorter.

b. **Width and Height**: The maximum width of the pier shall be limited to 5 feet and the height of the pier must be at least 5 feet above MHW.

c. **Marsh Front**: If the property is fronted by a marsh or a marsh fringe, the maximum width of the walkway shall be limited to 5 feet and the height of the walkway must be at least 5 feet above marsh ground elevation. Please refer to Number 3 for conditions on installing pilings crossing a marsh.

d. **Decking Boards**: The spacing between the wooden decking of the walkway over the marsh fringe and of the pier must be no less than 0.75 inch when finished to allow light penetration. Light penetration may also be achieved by the use of metal grating. Decking boards shall be no wider than 12 inches.

2. **Pier Deck Area**:

a. **Number of Decks**: There shall be no more than one pier deck area (deck) per single owner pier.

b. **Size**: The deck shall be no larger than 10 feet by 10 feet (100 square feet including the pier width). The deck may be covered (roofed) and have screened walls (no enclosed or solid walls).

c. **Plumbing**: No plumbing or toilet facilities shall be located on or service the pier or deck.

3. **Walkway Conditions for Crossing Wetlands**:

a. **Impacts to Habitat**: Adverse impacts to the marsh must be avoided during construction and future use.

b. **Machinery**: Support pilings for the walkway crossing the marsh shall be installed by hand with no heavy machinery operating in the marsh.

c. **Spoil**: Excess material excavated for installation of the pilings shall be removed from the wetland areas so that existing elevation remains unaltered.

4. **Boat Berthing Area(s)**:

a. **Single owner pier**: There will be no more than two boat berths (uncovered, no enclosure).

b. **Mooring pilings**: A total of six mooring pilings may be installed. The boat berthing area(s) may be up to 20 feet by 26 feet. The mooring pilings will be installed parallel to and a maximum of 20 feet waterward of the pier / deck / access dock.

c. **Boat Access Dock**: One 2 feet wide by 10 feet long boat access dock may be constructed per berthing area. Access dock may be lower than decking.

d. **Lateral Line**: Boats berthed at permitted structures must be a minimum of 10 feet inside the lateral riparian line. Berthed vessels should not either physically preclude or have the effect of precluding public access to public waters adjacent to the upland.

5. **Construction Requirements**:

a. **Setback**: All structures shall be set back a minimum of 25 feet from the applicant's lateral riparian rights line. However, a 10 feet setback from the applicant's lateral riparian rights line may be approved should the applicant's riparian area be inadequate to maintain a 25 feet setback from the riparian rights line.

b. **State and Local Requirements**: It is the permitee's responsibility to comply with all state and local requirements applicable to your activity. This permit DOES NOT supersede any other mandated requirements.

c. **Lease Requirement**: Facilities and activities which constitute exclusive use of state-owned submerged land, or have the effect of precluding public access to those lands, require an appropriate lease from the Lands Division of the Alabama Department of Conservation and Natural Resources (ADCNR). *Note*: Activities covered by this General Permit normally do not require a lease from ACDNR.

d. **Corps of Engineers Permit Required**: These pier critieria in no manner eliminate the requirement to obtain a U.S. Army Corps of Engineers permit of all construction activities within the jurisdiction of that agency.

6. **Riparian Rights (Water Access Rights)**:

a. **Ownership**: Permit applicants must show evidence of riparian ownership with an affirmation of accuracy as part of the application process.

b. **Lateral Riparian Lines**: The burden of locating lateral riparian lines is the responsibility of the riparian owner.

c. **Riparian Rights Area**: All structures and other activities must be within the riparian rights area of the applicant and must be designated in a manner that will not restrict or otherwise infringe upon the riparian rights of adjacent upland riparian owners. Configuration, location or design of the structure may not either physically preclude or have the effect of precluding public access to public waters adjacent to the upland. It is recommended that the structure be centered on the applicant's property.

7. **Dredging**:

No dredging to create channels, or any other bottom disturbance, shall be permitted.

8. **Grassbed Survey**:

Prior to issuance of a permit, a grassbed survey may be required. Pier construction shall be done in such a way as to prevent damage to aquatic vegetation.

9. **Shoreline Protection**:

Shoreline protection shall only be considered in those areas where the riparian vegetation proves inadequate in preventing erosion. The shoreline protection is LIMITED TO the placement of riprap. Filter cloth shall be required. The activity shall not exceed one cubic yard per running foot placed along the bank below the high tide line.

10. **Community Piers**:

Communal areas which share riparian ownership may construct a "community pier" to provide riparian access. Permits will take into consideration the number of riparian owners involved in the project.

FOR CONSIDERATION BY THE WEEKS BAY TASK FORCE

***Note**: These are the conditions of the Ono Island Task Force.*

Conditions for Construction of Piers Crossing Grassbeds (submersed vegetation):

a. **Span**: A minimum span of 20 feet will be maintained for pilings being installed within the grassbeds. Staggered spacing may be appropriate to install pilings in areas void of grassbeds.

b. **Machinery**: Installation of pilings within the grassbeds must be either driven with a shallow barge mounted pile driver or they may be jetted in place. If they are jetted, a small, hand-held pump will be used. Care must be taken that neither jet action of the water nor the pump itself is allowed to uproot the vegetation. The amount of time the jet is on will be limited to that necessary to install each individual piling. To minimize sediment deposition over grassbeds, a hole will first be dug through the root system with post hole diggers and then the jet will be used to set the piling.

c. **Residual Sediment**: Any sediment deposition around the piling after installation will be removed, either by the use of a small suction pump or by physically removing the sand to areas outside the grassbeds.

d. **Width**: All structures wider than 6 feet shall be constructed outside the limits of the grassbed.

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