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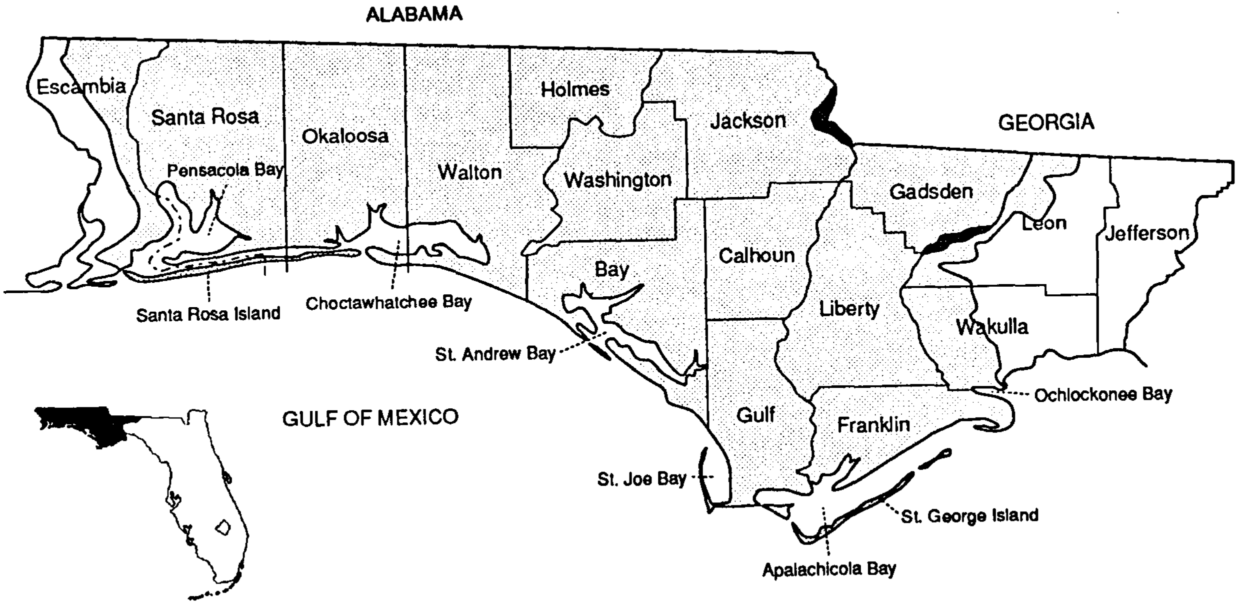
OCS Study
MMS 88-0063

An Ecological Characterization of the Florida Panhandle



U.S. Department of the Interior

Fish and Wildlife Service and
Minerals Management Service

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An Ecological Characterization of the Florida Panhandle

Authors

Steven H. Wolfe
Jeffrey A. Reidenauer

State of Florida
Department of Environmental Regulations
Tallahassee, Florida

and

D. Bruce Means

The Coastal Plains Institute
Tallahassee, Florida

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PREFACE

This report is one in a series that provides an ecological description of Florida's gulf coasts. The watersheds described herein, with their myriad subtropical communities, produce many benefits to people. The maintenance of this productivity through enlightened resource management is a major goal of this series. This report will be useful to the many people who have to make decisions regarding the use of the natural resources of the area.

Any questions or comments about or requests for this publication should be directed to the following:

Information Transfer Specialist
National Wetlands Research Center
U.S. Fish and Wildlife Service
NASA Slidell Computer Complex
1010 Gause Boulevard
Slidell, Louisiana 70458

or

Public Information Unit (OPS-3-4)
Gulf of Mexico OCS Region
Minerals Management Service
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394

CONVERSION FACTORS

Metric to U.S. Customary

Multiply	by	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (mt)	2205.0	pounds
metric tons (mt)	1.102	short tons
kilocalories (kcal)	3.968	BTU
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	by	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
BTU	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F –32)	Celsius degrees

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ACRONYMS

State and Federal agencies and programs

A–C–F	Apalachicola–Chipola–Flint Rivers
ANF	Apalachicola National Forest
FDA	U.S. Food and Drug Administration
FDER	Florida Department of Environmental Regulation
FDNR	Florida Department of Natural Resources
FNAI	Florida Natural Areas Inventory
FREAC	Florida Resources and Environmental Analysis Center
HRS	Florida Department of Health and Rehabilitative Services
IFAS	Institute for Food and Agricultural Service, University of Florida
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NWFWMD	Northwest Florida Water Management District
OCS	Outer Continental Shelf
OFW	Outstanding Florida Water
SR	State Route
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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Chapter 1. INTRODUCTION

1.1 Purpose and Organization

The Florida Panhandle is one of the most rapidly developing regions in the entire State. Coastal cities such as Panama City, Destin, and Pensacola, with their attractive white-sand beaches and clear waters, are the centers of this growth. Concomitant with such growth are rapid alterations in surrounding terrestrial and aquatic habitats caused by increased urbanization, industrialization, sewage and effluent discharge, river flow alteration, stormwater runoff, and dredge and fill activities.

Many Panhandle commercial interests, especially fishing and tourism, are highly dependent upon the maintenance of relatively unaltered habitats. The residents of many small Panhandle coastal communities such as Apalachicola and Carabelle derive practically all their incomes from the seafood industry. If unregulated growth occurs without regard to environmental impacts, the failure of this economy and the end of a unique way of life may follow. In addition, the destruction of the natural coastal setting would seriously curtail tourism.

Critical decisions on the preservation or economic development of particular areas are often made without knowledge of the composition, dynamics, and sensitivity of the local habitats and the associated flora and fauna to perturbations. Additionally, higher level interactions between systems and habitats are often overlooked. This report is an extensive review and synthesis of available literature on the local physical setting and ecology and a discussion of important impacts on the habitats within the Panhandle region. We have attempted to project possible future impacts and to point out areas that need further research before they are permanently altered.

The report is divided into two main sections. Chapters 2, 3, and 4 cover the geology and physiography, the climate, and the many aspects of the surface- and ground-water systems. These chapters provide the physical and chemical background information necessary to understand many of the environmental pressures affecting the biological habitats. These habitats—terrestrial, freshwater, estuarine, and marine—and their inhabitants are described in Chapters 5, 6, and 7. Chapter 8 is a summary of the Panhandle systems and a discussion of their unique aspects as well as of areas that are in need of further investigation.

1.2 The Florida Panhandle: Overview

The Florida Panhandle discussed in this report (Figure 1) extends from the Ochlockonee River basin west to the Florida-Alabama border (not including Perdido River basin and Bay) and north to the Georgia and Alabama borders. Major rivers in the region include the Ochlockonee, Apalachicola, Chipola, Choctawhatchee, Yellow, Blackwater, and Escambia. Major bays and estuarine systems include: Ochlockonee Bay, Apalachicola Bay, St. Joseph Bay, St. Andrew Bay, Choctawhatchee Bay, and Pensacola Bay. Also discussed are the nearshore Gulf of Mexico waters and the adjacent Continental Shelf region.

The Panhandle contains a wide variety of surface waters and physiographic regions. This lends it an ecological diversity found in few other areas in the United States. The Panhandle also boasts several of the largest and most productive estuaries in the State. Local fisheries and the fisheries of much of the coastal area depend on the water quality of these estuaries for spawning and nursery grounds. Their protection must be of high priority. Many inland

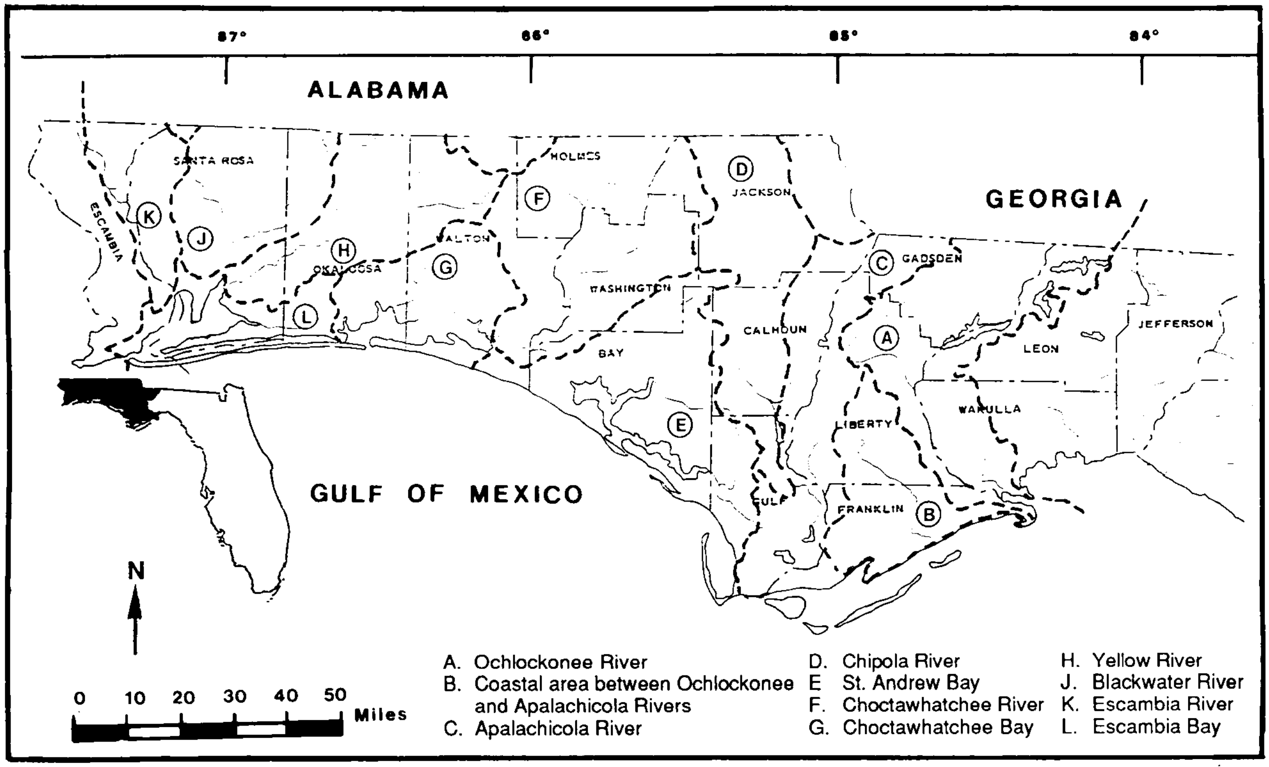


Figure 1. Florida Panhandle drainage basins and features.

areas are undeveloped and probably will remain so in the near future. Other areas, most notably the western coasts, are undergoing explosive growth very similar to that occurring in the southern part of the State. Unfortunately, this growth is often taking place with no more regard given to habitat destruction and environmental impact than is given in the south. We hope this document will help produce wise decisions concerning the direction and methods of Panhandle growth.

Chapter 2. GEOLOGY AND PHYSIOGRAPHY

2.1 Introduction

The animals and plants of any region are greatly affected by its geology. Plants are rooted in soils derived from the inorganic rocks or sediments of the earth's surface and are further affected by the slope, moisture-bearing content, chemistry, and physical nature of the sediments. Animals, in turn, are affected by plants as food and shelter. Animals may also respond directly to the geology of a region because they live on the soil surface or burrow in it. The slope, friability, moisture-bearing capacity, and other properties of soils often have as much influence on animals as on plants.

The surface geology of Panhandle Florida is entirely sedimentary, comprised of three different types of sediment: limestones, organics, and clastics (silt, clay, sand, gravel). The northern half of the Panhandle is dominated by sandy clays or clayey sands deposited by the alluvial action of rivers and streams. The southern half of the Panhandle, especially in the west, is dominated by sands deposited along ancient shorelines. The surface of the ground in the eastern half of the Panhandle and in the vicinity of Marianna, Jackson County, is influenced by the presence of limestones near the surface which have caused the top of the ground to be modified topographically by various types of subterranean solution activity. In low lying areas (stream courses or natural depressions of varying kinds), especially south of Cody Scarp and east of the Choctawhatchee River, peat, muck, and other types of decomposing plant litter are very common.

Panhandle Florida has been slowly emerging from the sea since at least some time in the Miocene. The age of surface sediments, therefore, is older near the Alabama and Georgia borders and becomes progressively younger towards present sea level. The floor of each stand of the sea was a relatively flat, gently seaward-sloping terrace when first exposed by the receding shoreline. Terraces are separated from each other by step-like escarpments or by subtle changes in relief (Figure 2). Since their emergence, terraces have been eroded and dissected by streams and rivers. Entire strata have been removed in some areas, and materials from other strata have been deposited on top of lower terraces, and rearranged by the erosive power of water.

Fifty-two percent of the open gulf beaches from Mexico Beach to a point due south of Tallahassee have been eroding during historical times (Tanner 1975). In the same time period, 35% have been stable, and only 14% have been growing. An astounding 11.2 m per year of beach front has eroded from Cape San Blas between the years 1875 and 1942. Dog Island has been eroding at about 1 m per year, and St. George Island has been lengthening its eastern tip at a rate of about 20 m per year, but the beach face has been eroding at about 1.3 m per year between 1934 and 1970. Given the consensus of scientific researchers that sea level has been rising over the past century and that a greenhouse effect is now measurable due to increased $C0_2$ levels from fossil fuel combustion and other human activities, it seems certain that sea level will continue to rise over the next century. Some geologists have calculated that if all the ice in polar regions and montane glaciers were to melt, the ocean surface would rise at least 100 ft. This is close to the top of the Wicomico terrace, presumably the shoreline at the end of the Pliocene and at the onset of the Pleistocene. The land submerged under the Wicomico sea (Figure 2) indicates that about one-half of the surface of the Panhandle would be inundated in this scenario.

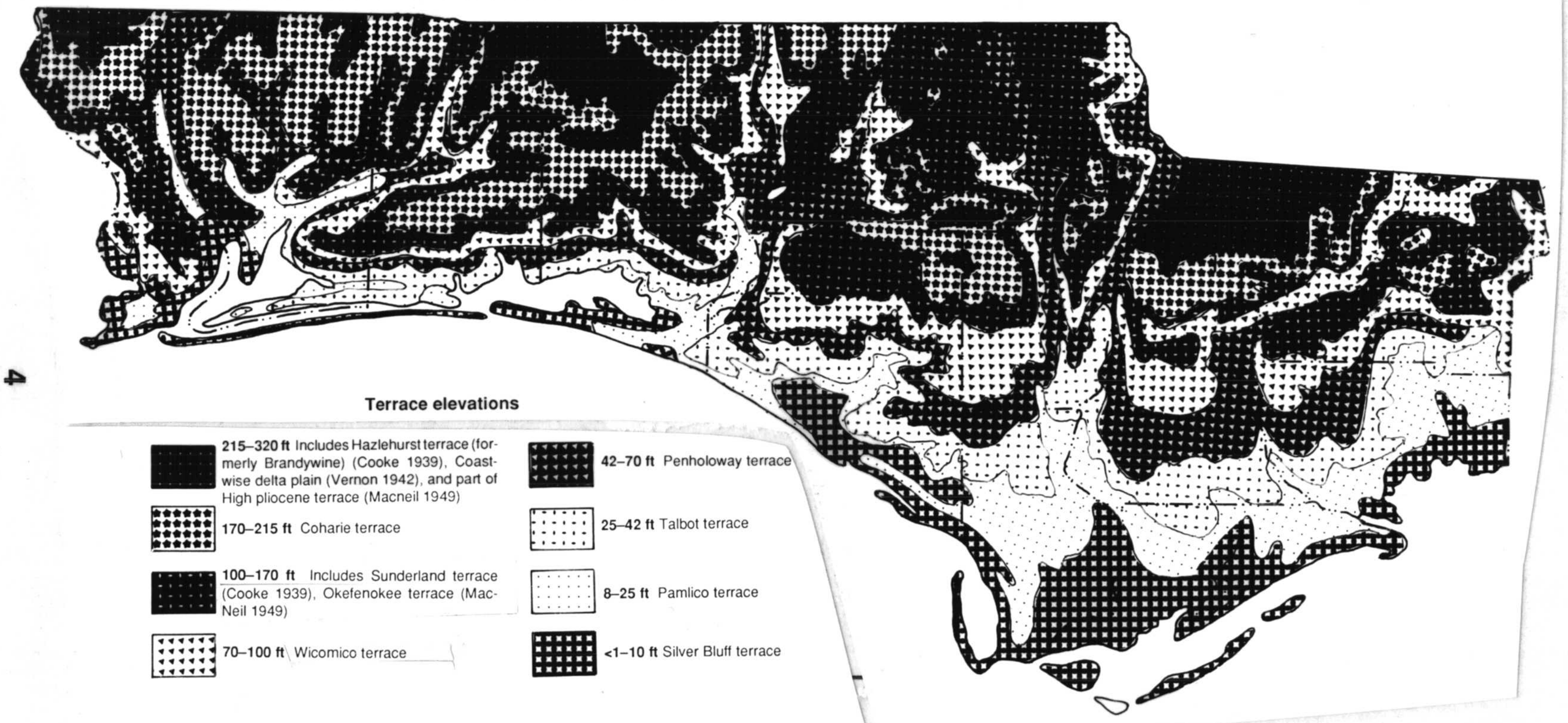


Figure 2. Terraces in the Florida Panhandle formed by previous sea-level stands (after Healy 1975a).

2.2 Structure and Geologic Setting

Three structural features dominate the geology of Panhandle Florida. These are the Gulf of Mexico Sedimentary Basin, Chattahoochee Anticline, and the Apalachicola Embayment. The Panhandle from about Okaloosa County westward is the eastern edge of the Gulf of Mexico sedimentary basin, a negative structural feature (i.e., a depression that receives sediments) whose sediments thicken westward toward the Mississippi River. A positive structural feature (a rise, from which sediments erode) called the Chattahoochee Anticline lies at the eastern end of the negative area, separating it from a smaller negative feature called the Apalachicola Embayment (Figure 3).

The Chattahoochee Anticline is aligned southwest to northeast across the northeastern portion of Panhandle Florida (Figure 3), and is very important to the ecology of the region because it brings Oligocene and Eocene carbonate rocks to the ground surface where the physical and chemical properties of the soil and water are greatly affected by the presence of the carbonates.

The Apalachicola Embayment and its probable northeastward extension, the Gulf Trough, is a negative structural feature that represents a downfallen block of land, called a graben (Schmidt 1984). This negative feature is important to the biology of the Panhandle because it is strongly affected by the predominantly clastic sediments. Clastics differ greatly from carbonates in their chemistry, physical properties, and weathering.

The Apalachicola Embayment (Figure 3) is a relatively shallow basin between the Ocala and Chattahoochee uplifts, narrowest on the northeast and opening up to the south and southwest. The magnitude of the basin increases with depth, indicating that it is a long-developing feature. Near the ground surface the Quaternary and Neogene rocks are gently downwarped, but the deeper Paleogene and Mesozoic rocks are downwarped even more, resulting in older strata that are thicker (Murray 1961). Southward along its axis, the upper sedimentary rocks (Triassic to Recent) of the Apalachicola Embayment plunge to a depth of nearly 15,000 ft before metamorphic Paleozoic rocks are encountered (Applegate et al. 1978). At the eastern limits of

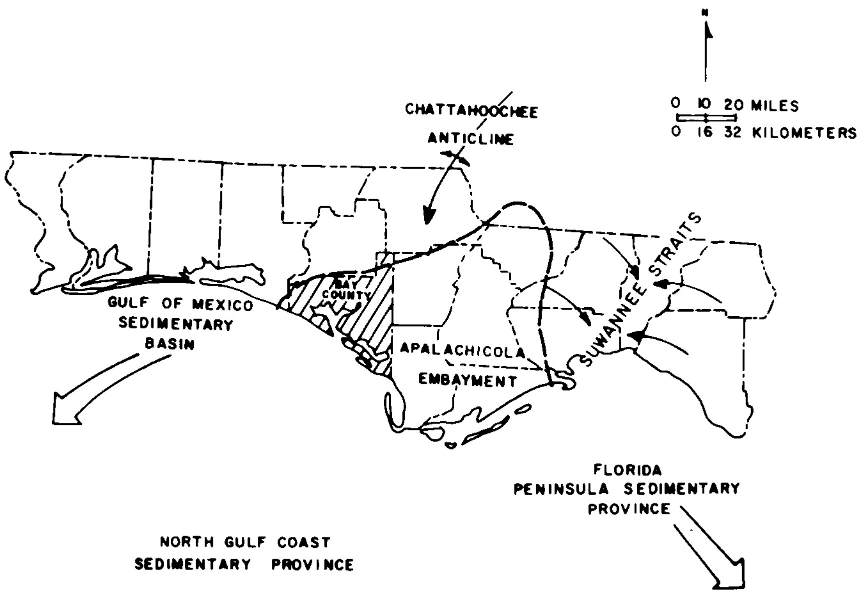


Figure 3. Major structural features of the Florida Panhandle (from Schmidt 1984).

the Apalachicola Embayment, carbonate sediments rise and are exposed at the ground surface beginning at the eastern edge of Panhandle Florida and cresting along the Ocala Arch of the Florida Peninsula Sedimentary Province in the very northwestern part of peninsular Florida (the Big Bend region).

The western Panhandle from about the Choctawhatchee River westward is underlain by westwardly thickening clastic sediments variously bedded as sands, clays, shales, sandstones, and thin limestones. The hard limestones of the central and eastern Panhandle either pinch out or dip deeply west of the Choctawhatchee River and have little or no surface expression on the landform.

The surface sediments of the northern half of the Panhandle west of the Choctawhatchee River are crossbedded sands, gravels, and clays called the Citronelle Formation. These are Pliocene to Recent fluvial deposits that are commonly found at elevations above 200 ft. Tan to light-orange clayey sand is found southward towards the coast in the western Panhandle, and probably represents the reworking of some of the higher Citronelle hills during sea level fluctuations. These clayey sands grade into unconsolidated white to light-gray quartz sands of the Pleistocene to Recent coastal terraces. The terrace deposits generally thicken from zero to nearly 100 ft near the coast.

The eastern Panhandle is an uneven platform of carbonate bedrock over which has been deposited one or more layers of less consolidated clastics. The bedrock consists mainly of limestone (calcium carbonate) and sometimes of dolomite (calcium carbonate with varying percentages of magnesium carbonate). Impurities of sand, silt, and clay increase in the limestones going east. Other limestone has been silicified into layers or veins of chert or flint. The superficial strata of bedrock date to the Eocene, Oligocene, and early Miocene (Figure 4). The bedrock of the eastern Panhandle has been subjected to considerable solution activity, forming numerous caverns, lime sinks, and other karst features.

The clastics consist of sand, silt, clay, shell marl, gravel, rock fragments, phosphate pebbles, and diatomaceous earths. Fossils, including petrified wood, are present in some deposits but absent in others. Sand, silt, and clay are mineral particles defined by their specific diameters.

Layers of shells and their degradation products are often common. Clastics with shell marl are mostly thought to represent the sediments of shallow seas and estuaries. These sediments became terrestrial clastics when sea level dropped. The abundance of oyster shells in many shell marls suggests that oyster bars in bays and lagoons were often covered by sediments that later became terrestrial clastics.

Diatomaceous earth consists largely of the silicified walls of diatoms that accumulated in marine sediments. Such deposits are also known as pipe clay, fuller's earth, and attapulgite. Thick beds are mined commercially in Gadsden County for the production of abrasives and other products. Veins of diatomaceous earth shrink and swell considerably with changes in moisture. This movement requires special foundations for structures built on terrain containing fuller's earth.

Deposition of the various strata of clastics began in the Miocene after the carbonate bedrock had formed. Some of these clastics were once marine sediments of nearshore environments, exposed when the Panhandle was uplifted geologically; others were deposited as alluvium in valleys or as deltaic or estuarine deposits near river mouths. Others were wind-blown deposits such as dunes and still others were sediments in lake bottoms.

The clastic deposits form terraces that slope gently towards the Gulf of Mexico and which are separated from each other either by step-like escarpments or by subtler changes in relief. Since their deposition the terraces have been subjected to considerable erosion and dissection by streams and rivers. Entire strata have been removed from some areas, and the materials of other strata have been reworked by erosional processes.

Peat deposits are common. Peat consists of dead plant matter which may persist for thousands of years or longer without appreciable decomposition. Peats build up in marshes, swamps, and lake bottoms, wherever low oxygen conditions prevail, inhibiting organisms of decay. High acidity and low levels

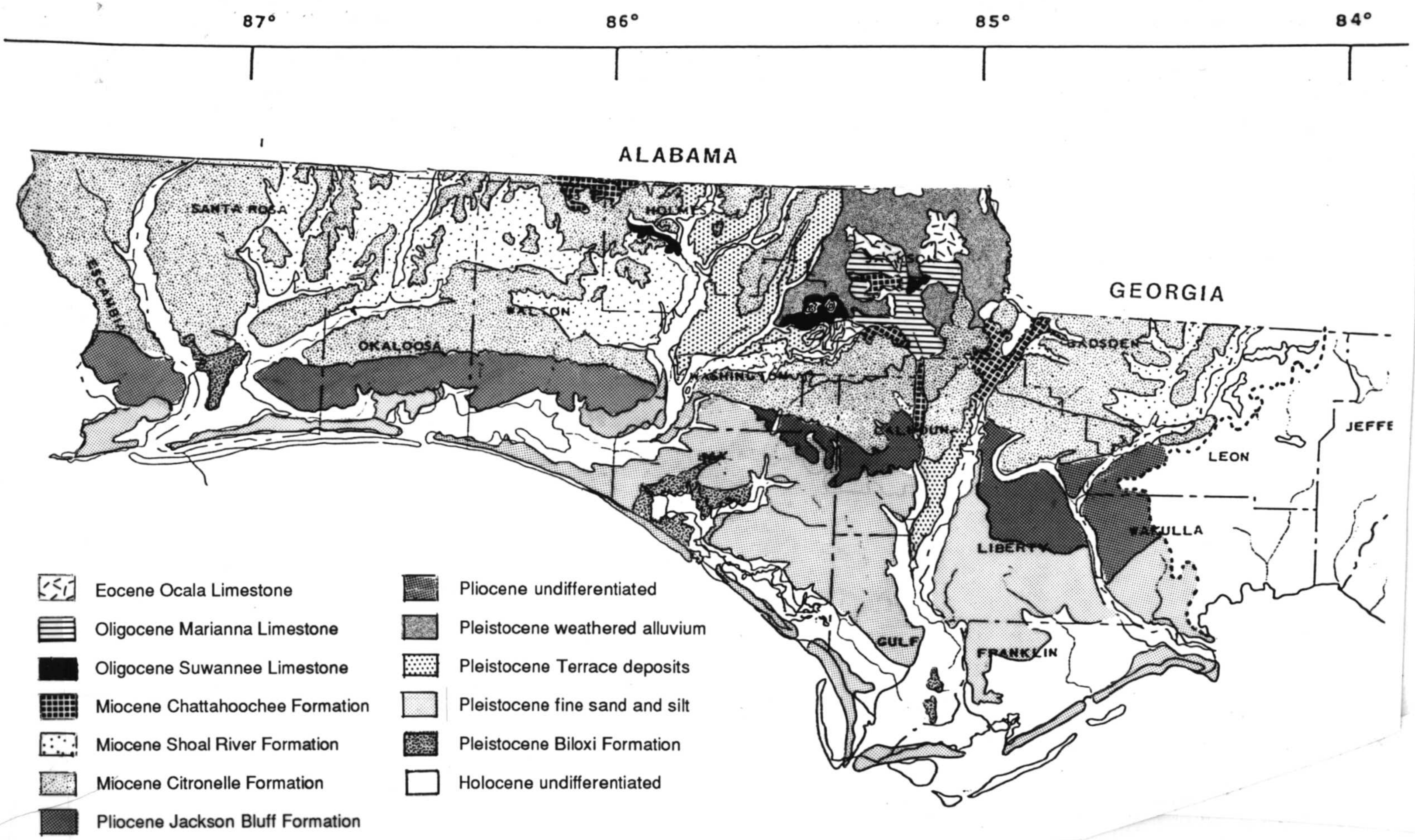


Figure 4. Surface geology of the Florida Panhandle (after Puri and Vernon 1964, Brooks 1981a).

of nitrogen may reinforce this inhibition. The oldest peat occurs at the bottom of a deposit, and new peat forms at the surface as dead plant materials accumulate. Other, nonfibrous peat is generally called muck. Most peats contain some sand, silt, or clay that was transported by water or wind from other areas. Well preserved wood commonly occurs in peat. Florida peat deposits and associated vegetation were surveyed by Harper (1910) and Davis (1946).

2.3 Stratigraphy

The rocks that underlie the Panhandle range in age from late Precambrian to Recent. The oldest rock exposed in the Panhandle is Eocene limestone of the Crystal River Formation. It is found near the surface of the ground in northern Holmes and northern Jackson Counties, and is exposed along the upper Chipola River and upper Holmes and Wrights creeks. The rocks of different age that are outcropped in Panhandle Florida are shown in Figure 4.

2.3.1 Igneous and Paleozoic Rocks

The igneous rocks of Florida include metabasalts in Volusia County, granites in Lake and Orange Counties, granite and diorite in St. Lucie County, and metabasalt in Hillsborough County (Grasty and Wilson 1967, Bass, 1969, Milton and Grasty 1969, Milton 1972, Barnett 1975). Panhandle deep wells have intercepted granite at 12,191 ft in Bay County, dacite porphyry and granodiorite in Gulf County at 13,000 ft, and granite at 14,480 ft below the surface in southern Walton County (Barnett 1975).

The Paleozoic sediments from deep wells in Florida have been described and correlated by Applin (1951), Bridge and Berdan (1952), Cramer (1971), and Barnett (1975). Strata range in age from late Precambrian to Early Devonian based on fossil evidence.

2.3.2 Mesozoic Era

Descriptions of the Mesozoic rocks in the Panhandle have been reported by Arden (1974) and Applegate et al. (1978). Overlying the Paleozoic igneous rocks is the Eagle Mills Formation of the Triassic Age. This formation contains dikes and sills of basic igneous rocks. Its overall lithology has been described by Applegate et al. (1978) as well-indurated, highly micaceous sandstones; argillaceous siltstones; and well-indurated shales.

In the eastern part of Bay County, the Eagle Mills Formation is probably absent, thinning from about 200 ft in western Bay County. The Norphlet, Smackover and Haynesville Formations are found here, overlying the basal granite. These formations are all Upper Jurassic in age. The Norphlet is 267 ft thick and consists of red sandstones, siltstones, and shales. The Smackover Formation is 163 ft thick and is composed of limestone and dolomitic limestones. The Smackover Formation was found to have oil locked in a dense impermeable section of limestone and conglomeritic calcareous sandstone. The next younger formation, the Haynesville, is just over 300 ft thick and is composed of red to gray, very well indurated calcareous shales, a few well sorted fine-grained sandstones, and a few thin-bedded micrites.

All three formations apparently thin westward because only a thin Haynesville section is present in a deep well drilled in western Bay County. West of Bay County these units thicken as they plunge into the Mississippi Embayment. In Bay County, the Eagle Mills Formation is overlain by 2,600 ft of the Cotton Valley Group sediments. This group also overlies the Haynesville section in eastern Bay County (Schmidt and Clark 1980). The Cotton Valley Group is Upper Jurassic in age and is a varicolored mudstone and coarse sandstone.

Above the Cotton Valley sediments are differentiated Lower Cretaceous sands and shales, varying from 5,000 to 6,000 ft in thickness. Above these lie the white sands of the Lower Tuscaloosa Formation, which is Upper Cretaceous in age.

The Tuscaloosa Formation consists of nonmarine, gray to green, fine to coarse, poorly sorted sand and variegated shales underlying a marine member consisting of a gray laminated micaceous glauconitic hard shale with shell fragments and carbonaceous seams and flecks. On top of this, the Tuscaloosa Formation consists of a gray to cream fine calcareous micaceous clayey silty sandstone with beds of calcareous shale. The thickness of the Tuscaloosa Formation varies but has been reported to be over 700 ft thick (Puri and Vernon 1964).

Overlying the Tuscaloosa Formation in Panhandle Florida is the Eutaw Formation: gray to cream calcareous fine sandstone that changed downdip into a soft pasty sandy chalk with limestone seams. It ranges between 150 and 300 ft in thickness.

Above the Eutaw are sediments of the Austin Age. These beds are equivalent to the Mooreville Chalk in Alabama. In northwest Florida, these sediments are gray soft glauconitic micaceous fine-to-coarse quartz sand interbedded with gray-green soft calcareous thinbedded clay, averaging 350 to 450 ft thick. Generally less than 500 ft in thickness, beds of the Taylor Age overlie the Austin Age beds. The uppermost Cretaceous sediments are beds of the Navarro Age. The presence of these sediments is questionable in northwest Florida, but a thin gray pasty marl occurs at the top of the Taylor beds in the western Panhandle.

The Mesozoic sediments total approximately 10,000 ft in combined thickness in the vicinity of Bay County. The first occurrence is generally deeper than 3,000 ft below sea level, and the sequence continues downward to about 13,000 ft below sea level.

2.3.3 Cenozoic Era

In the Florida Panhandle, an unconformity separates the basal Paleocene sediments from the Upper Cretaceous rocks (Applin and Applin 1944, Rainwater 1960). Applin and Applin (1944) have stated that in the Tallahassee area, Paleocene strata lie unconformably on beds of the Taylor Age, with the Navarro equivalent and upper beds of Taylor Age being present.

a. Paleocene Series. The Paleocene Series in Northwest Florida consists of clastic beds of the Midway Age. The Midway Stage has been divided into three units in Alabama: the Clayton, Porters Creek, and Naheola Formations. In the Florida Panhandle, these formations are undifferentiated, which led Chen (1965) to treat the entire stage as the Midway Formation. Lithologically, the formation consists of dark green-gray micaceous and slightly glauconitic laminated calcareous shales, with minor amounts of thinbedded argillaceous and fossiliferous limestones and glauconitic and calcareous sandstones. The thickness of these sediments varies from 250 to 750 ft throughout the central Panhandle.

The Midway Formation underlies the entire Florida Panhandle and extends widely throughout the southeastern Coastal Plain. Regionally, the vertical and lateral changes of lithologic character and the thickness of the unit are rather great, as demonstrated by Chen (1965). His isopach-lithofacies indicate that the clastic sediments, such as glauconitic and arenaceous shale and sandstones, are more dominant around the Chattahoochee Arch than elsewhere in the Panhandle. In addition, calcareous shale is a major lithologic component that occurs over most of the Panhandle region except in the southeastern area (Wakulla and southern Leon Counties), where limestone is predominant.

b. Eocene Series. The Eocene Series in the southeastern Gulf Coastal Plain has been divided into three stages. These stages are the Wilcox Stage, which is Lower Eocene; the Claiborne Stage, which is Middle Eocene; and the Jackson Stage, which is Upper Eocene.

The Wilcox Stage has been divided into three formations in southern Alabama, where it crops out. The stratigraphic equivalent of these three sections (the Nanafalia, Tuscahoma, and Hatchetigbee Formations) has been recognized in the Florida Panhandle as undifferentiated Wilcox. Chen (1965) treats the Wilcox Stage in northwest Florida as a formation.

In the outcrop belt in Alabama to the north of the study area, the Wilcox Stage has been demonstrated to be unconformable with both overlying and underlying rocks. In Florida, however, no distinctive geologic evidence of unconformable relationships is recognized. The Wilcox Formation includes marine and deltaic clastic sediments. These consist of glauconitic and calcareous sandstone and green-gray micaceous calcareous glauconitic and silty shale.

Using regional lithofacies maps, Chen (1965) shows that the amounts of clastic sediments decrease southeastward away from the Panhandle toward peninsular Florida. His maps also show the

Wilcox Formation to vary in thickness from less than 200 ft in the eastern Panhandle to nearly 1,000 ft southeastward.

The exposed strata of the Claiborne Stage in southern Alabama have been divided into three formations which are, in ascending order, the Tallahatta Formation, the Lisbon Formation, and the Gosport Sand. In the subsurface of northwest Florida, the sediments become more calcareous and less readily differentiated into distinct formations (Toulmin 1955). As a result, the Claiborne is divided into only two formations in the western part of Panhandle Florida, the Lisbon Formation at the top and the Tallahatta Formation below. These formations are correlative in time of deposition with the Avon Park Limestone and the Lake City Limestone, respectively, in peninsular Florida.

The Tallahatta Formation in northwest Florida consists of glauconitic and calcareous sandstone, green-gray glauconitic arenaceous and calcareous shale, and glauconitic argillaceous limestone. The Lisbon Formation is commonly a glauconitic arenaceous and fossiliferous limestone with some beds of calcareous shale. The combined thickness of the Claiborne near Bay County approaches 800 ft.

The literature pertaining to the Ocala Group is extensive. Summaries are contained in Vernon (1942, 1951), Cooke (1945), Puri (1957), and Puri and Vernon (1964). The Upper Eocene strata in Florida have been separated by Puri (1957) on the basis of a detailed biostratigraphic study into three formations of the Ocala Group, the Inglis, the Williston, and the Crystal River, in ascending order. In Panhandle Florida, the Ocala crops out in Jackson and Holmes Counties, which are located along the Alabama State line north of Bay County.

In his study on Holmes and Washington Counties, Vernon (1942) was able to divide the Ocala into two lithologic facies. The lower facies is typically developed in southern Alabama; it bears a lower Jackson fauna, and consists of greenish-gray glauconitic sandy limestone. The upper and more typical facies is exposed in Holmes County, and is described by Vernon as a limestone that is light yellow to white, massive, porous, and often silicified.

The Ocala was described in Jackson County by Moore (1955). He describes its lithology as a white to cream colored generally soft granular permeable fossiliferous pure limestone. Overlying the Ocala, Moore identifies the Bumpnose Limestone member of the Crystal River Formation (the youngest and uppermost formation of the Ocala Group). The Bumpnose is characterized by soft, white limestones with *Lepidocyclina chaperi* (a large flat foraminifera).

The top of the Ocala Group dips between 10 and 15 ft/mi as it approaches Bay County from the north (Vernon 1942, Schmidt and Coe 1978). In Bay County, the Ocala is entirely a subsurface unit (Schmidt and Clark 1980). The three formations into which Puri (1957) divided the Ocala are not recognizable in Bay County. As a result, the system devised by Vernon (1942), an upper and lower facies, is applied in Bay County. The lower facies consists of a light orange to white limestone with high porosity, both micrite and sparry calcite cement, crystal and skeletal grain types, small amounts of glauconite and sand, and abundant fossils. Dominant fossils include foraminifera, mollusks, echinoids, bryozoans, and corals. The large foraminifera are dominated by species of *Lepidocyclina, Operculinoides* and *Asterocyclina*. The upper facies is similar, except that glauconite is rare and chert is more common.

In the northern part of Bay County, thicknesses are less than 200 ft, the Ocala being over 300 ft below sea level. In the southern part of Bay County, the top of the Ocala dips to approximately 800 ft below sea level and attains a thickness of over 400 ft. The dip and thickness, therefore, increases in a nearly due-south direction.

c. Oligocene Series. The Oligocene series consists of two formations, the Marianna Limestone and the Suwannee Limestone. Originally named by Matson and Clapp (1909), the Marianna Limestone was described as a soft, porous, light-gray to white limestone at Marianna, Jackson County, Florida. Marianna Limestone is exposed at the surface of the ground along a narrow, nearly east-west band through Marianna, Florida. In Holmes County, the outcrop belt turns to the north and the strike changes to northwest-southeast as it crosses the Alabama state line.

From the outcrop area in Holmes and Jackson Counties, Marianna Limestone dips gently toward the gulf coast (Vernon 1942; Moore 1955; Schmidt and Coe 1978) at approximately 11 to 13 ft/mi. Its dip into southern Bay County is estimated to increase slightly to perhaps 15 or 16 ft/mi. The thickness is generally uniform in Jackson, Holmes and Washington Counties, and probably increases slightly in Bay County.

The name Suwannee Limestone was first used by Cooke and Mansfield (1936) to describe exposures of a hard crystalline yellowish limestone visible on the Suwannee River between Ellaville (Suwannee County) and White Springs (Hamilton County). Later, Vernon (1942), Cooke (1945), Moore (1955), and Reves (1961) established the formation's presence in the Florida Panhandle. The outcrop belt in the north-central Panhandle parallels that of the Marianna Limestone. In general, it can be described as a tan to buff-colored dolomitic and sometimes clayey limestone. In some areas, the Suwannee is predominately dolomitic.

d. Miocene and Pliocene Series. These series have been divided into at least 4 stages and 15 formations, ranging from the Early Miocene Tampa Stage to the Late Pliocene Miccosukee and Citronelle Formations.

Puri and Vernon (1964) defined the Tampa Stage (Lower Miocene) as comprising the Chattahoochee Formation and the St. Marks Formation. They included type-locality descriptions for both formations, but did not attempt to map their areal extent. Since 1964, several publications have reported on the geology of various areas throughout the Florida Panhandle, and all have used Puri and Vernon's nomenclature. Their description describes the St. Marks facies downdip as calcareous, and the Chattahoochee facies updip as silty.

From well cuttings in Bay County, the Tampa Stage limestones can be described as a white to light gray limestone with biogenic, micritic, and crystal grain types, moderately indurated with a micrite cement; minor amounts of quartz sand and a trace of pyrite. It often has a chalky appearance and contains fossil remains of foraminifera, coral, and mollusks (Schmidt and Clark 1980).

The thickness of the Tampa Stage in Bay County is variable. Along the northern part of the county it ranges between 50 and 100 ft thick. The top of the Tampa Stage dips from approximately sea level in the northern part of Bay County to nearly 500 ft below sea level at the extreme southeastern corner of the county. The Tampa stage is entirely subsurface in Bay County. Banks and Hunter (1973) reported on post-Tampa, pre-Chipola sediments in the eastern Florida Panhandle. They called the clays, sands, and shell beds found in Liberty, Gadsden, Leon, and Wakulla Counties the Torreya Formation. The stratigraphic position of the Torreya was determined by the presence of *Miogypsinida* (a foraminiferan genus).

Gardner (1926) named the Alum Bluff Group to include Chipola, Oak Grove, and Shoal River beds. Cooke (1945) then divided the Alum Bluff Group into three formations: the Hawthorn (east of the Apalachicola River), the Chipola, and the Shoal River (both west of the Apalachicola River). Puri (1953), added the Oak Grove of Gardner (1926) to Cooke's three formations and called them all facies of the Alum Bluff Stage (Middle Miocene). Later, Puri and Vernon (1964) included in the Alum Bluff Stage the Shoal River, Oak Grove, Chipola, and Hawthorn Formations and added the Pensacola Clay, Course Clastics, and Fort Preston Formations.

Huddleston (1976) redefined the marine deposits of the central Florida Panhandle. He included in the Alum Bluff Group five formations: the Chipola Formation, the Oak Grove Sand, the Shoal River Formation, the Choctawhatchee Formation, and the Jackson Bluff Formation. The main mass of the Alum Bluff Group was considered by Huddleston to be restricted to the eastern margin of the Gulf Coast Basin and to the vicinity of the Chattahoochee Arch. Planktonic foraminifera were used by Huddleston to establish the time of deposition of the deposits. He reported the Chipola Formation to be Early Miocene, the Oak Grove Sand and part of the Shoal River Formation to be Middle Miocene, the Choctawhatchee Formation of Late Miocene Age, and the Jackson Bluff Formation to be Pliocene in age.

The Chipola Formation was described by Puri and Vernon (1964) in the area of its type-locality as a blue-gray to yellowish-brown highly fossiliferous marl studded with molluscan shells. This marly facies only exists in the vicinity of the Chipola and Apalachicola Rivers. Further west, Cooke (1945) described two other facies: a sandy limestone which he said is mostly subsurface, and a light-colored coarse sandy facies that contains clay.

The lithology of the Chipola varies slightly throughout its extent in Bay County; however, it can be summarized as a very light orange sandy limestone, with crystal, micrite and pellet grain types, fine to coarse grain size, a sparry calcite and micrite cement, with foraminifera, mollusks, coral and bryozoans. Its induration, porosity, sand content, and occasionally the presence of argillaceous material, are the common lithologic variables.

The Chipola is distinguishable from the underlying Tampa sediments in that the Tampa is generally a pure white limestone with relatively few fossils. The Chipola is distinguished from the Bruce Creek again by the latter being a purer limestone. This distinction is a subtle one and often difficult to identify.

The Tampa and Chipola sediments become indistinguishable from the Bruce Creek Limestone downdip. The Chipola Formation along the Washington County line appears to strike almost east-west and maintains a thickness of about 50 ft. The top of the formation dips along the strike from near sea level east of the Econfina Creek to about 150 ft below sea level near East River, a dip of about 5 ft/mile. Gardner (1926) reported on a comprehensive study of the molluscan fauna of the Alum Bluff Group from a number of outcrops in the Florida Panhandle. In 1965 Vokes suggested, as indicated by the Muricinae (Mollusca: Gastropoda), that the formation might be equivalent to the Helvetian of Europe (lower Middle Miocene). The benthic foraminifera of the Chipola Formation were described by Cushman (1920), Cushman and Ponton (1932), and Puri (1953). Puri's report also included a list of identified ostracod species. Planktonic foraminifera were described by Gibson (1967), Akers (1972), and Huddleston (1976). In addition to foraminifera, Akers (1972) discovered the presence of some calcareous nannofossils in the Chipola material. Coral species from the Chipola were reported by Vaughan (1919) and Weisbord (1971). Finally, Bender (1971) dated corals from the Chipola using the He/U radiometric age. He placed a concordant age of 14–18 million years on ten of the samples. This would put the Chipola in the early Middle Miocene or late Lower Miocene.

The Bruce Creek Limestone was named by Huddleston in 1976. He included it in a group of three formations he mapped in coastal Walton County. The three formations, in ascending order, are the Bruce Creek Limestone, the St. Joe Limestone, and the Intracoastal Limestone. Huddleston placed these three formations in the Coastal Group, which he explained was a new name for Alum Buff equivalent carbonate units that underlie the coastal area of Walton County and vicinity.

The Coastal Group is recognized by Huddleston as far west as Niceville in Okaloosa County, and as far east as Carrabelle in Franklin County. He further states that it is not present in southern Washington County, or at Alum Bluff in Liberty County.

This formation has been identified previously as a limestone facies of the Chipola Formation (Gardner 1926, Cooke and Mossom 1929). Limestones of similar description were reported by Cooke and Mossom (1929) in southwestern Washington County in the vicinity of the Choctawhatchee River. Samples from the type outcrop on Bruce Creek in Walton County can be correlated lithologically with cuttings and cores from areas in Bay County. Only two lithologic types within the group can be recognized. The two types consist of well-consolidated white to light gray limestone, overlain by a poorly consolidated argillaceous abundantly microfossiliferous limestone.

In Bay County, the Bruce Creek Limestone is a white to light yellow-gray moderately indurated granular to calcarenitic limestone. It may contain up to 20% quartz sand, with common minor accessories being phosphorite, glauconite, and pyrite. In some locations, sparry calcite or dolomite is present. It is commonly cemented by micrite and becomes less indurated toward the east. The Bruce Creek Limestone is dominated by macrofossils, but microfossils including planktonic and benthic foraminifera, ostracods, bryozoans, and calcareous nannofossils are also present.

The Bruce Creek Limestone is overlain in Bay County by the Intracoastal Formation or the Jackson Bluff Formation. It is distinguished from the Intracoastal unit by containing less sand, clay, and phosphate. It is also much more indurated and crystalline. The Bruce Creek Limestone also contrasts in color with a white to light yellow-gray being easily distinguished from the olive to gray green color of the Intracoastal Formation. Lastly, the Bruce Creek Limestone is less fossiliferous than the Intracoastal Formation with its abundant fossils. In northern Bay County, the Bruce Creek Limestone is sometimes overlain by the Jackson Bluff Formation, which is much less indurated and contains larger quantities of sand and clay. The Jackson Bluff Formation essentially is an olive-green shell marl, which is easily distinguished from the white, crystalline to micritic Bruce Creek Limestone.

The Bruce Creek Limestone extends westward across southern Walton County and is thought to lose its identity somewhere in Okaloosa County. To the east, it has been identified in a core on St. Joe Spit in Gulf County and in a core near Dead Lake in Calhoun County. The Bruce Creek Limestone is a very low-angle, wedge-shaped deposit reaching a maximum thickness along the gulf coast of about 300 ft. Planktonic foraminifera place the Bruce Creek Formation in the Middle Miocene (Huddleston 1976).

Sediments of the Choctawhatchee Stage in the Florida Panhandle are exposed in a narrow band extending from 20 mi west of Tallahassee, Leon County, northwest to DeFuniak Springs, Walton County, a distance of about 80 mi. The exposed sediments are tan, orange-brown, or gray-green sandy clays, clayey sands, and shell marls. The outcrops generally are poorly exposed and small. True stratigraphic relationships are poorly understood (Puri and Vernon 1964, Rainwater 1964, Waller 1969, Akers 1972, Huddleston 1976).

The Intracoastal Formation describes the body of sediments which was called the Intracoastal Limestone and St. Joe Limestone in Walton, Bay, Okaloosa, Calhoun, Gulf, and Franklin Counties (Huddleston 1976). The Intracoastal Formation in Bay County is a low-angle, wedge-shaped deposit up to 240 ft thick and occurring principally along the coast. It thins and rises to the north, and extends westward into southern Okaloosa County. The upper part of the Intracoastal Formation, although predominantly a quartz sand, can easily be distinguished from the Pliocene to Recent sand because it contains phosphorite, poorly consolidated limestone, and foraminifera.

The Hawthorne Formation exhibits a wide range of lithotypes in the Panhandle, including shallow marine carbonates, restricted lagoonal clays, and possible prodelta clastics. Thought to be middle Miocene in age, it underlies most of the surface outcropping sediments of the Tallahassee Red Hills in the Panhandle. Its influence on plants and animals is confined, therefore, to the lower slopes of ravines where it has been exposed by gully erosion. It is most common in central Florida where it was described.

The Jackson Bluff Formation is found through most of the central and southern parts of the Panhandle. Its outcrop pattern is a narrow belt extending from southern Washington County eastward to the Jackson Bluff area of Leon County. From there the outcrop belt apparently turns southwest where exposures occur in the vicinity of Crawfordville in Wakulla County (Banks and Hunter 1973, Huddleston 1976).

The Jackson Bluff Formation along the lower Ochlockonee River consists of three clayey, sandy shell beds, differentiated on the basis of lithology and mollusks. In Bay County the Jackson Bluff Formation is a calcareous sandy clay to clayey sand containing large quantities of mollusk shells. Along the coast in the vicinity of Bay County the Jackson Bluff Formation is underlain by the Intracoastal Formation. The limestone portions of the Jackson Bluff Formation has more mollusks and is better indurated than the Intracoastal Formation. In color, the Jackson Bluff limestones are light grays in contrast to the olive-green to buff color of the Intracoastal Formation (Schmidt and Clark 1980). Overlying the Jackson Bluff Formation is the Pliocene to Recent Sand Unit, which is readily distinguished from the Jackson Bluff Formation by having no limestones, very little clay, and almost no fossils. Studies of the planktonic foraminifera of the Jackson Bluff Formation place its age as Late Pliocene (Akers 1972, Huddleston 1976).

The Miccosukee Formation is a series of silts, sands, clays, and gravels that were deposited as deltaic and fluvial sediments. It outcrops in the Tallahassee Red Hills beginning about the Ochlockonee River (eastern margin of the Panhandle as we have defined it), and is common eastward through the Northern Highlands and Central Highlands of peninsular Florida at the highest elevations. Thought to be Late Pliocene in age, it may be contemporaneous with the Citronelle Formation of the Panhandle. Most of its physical and chemical properties that affect plants and animals are the same as those of the Citronelle Formation.

The Citronelle Formation is composed of prodeltaic, deltaic, and fluvial deposits of sands, clays, and gravels. These clastics appear to have been deposited contemporaneously with the Miccosukee Formation, but are geographically separated from it. The Citronelle deposits outcrop across the Northern Highlands from Gadsden County and Liberty County on the east to Escambia County on the west. They range in thickness from a few tens of ft in the western Tallahassee Red Hills to hundreds of ft in the Western Highlands. In the Gulf Coastal Lowlands, the Citronelle Formation thins toward the coast, and is overlain by terrace sands and other Pleistocene and Recent deposits.

Clays and silts in the Citronelle Formation give soils derived from it their loamy character. The water retaining capacity of these soils make them better suited for a wide range of plants, such as the rich groundcover flora of grasses and forbs in the longleaf clayhill community. These soils are more nutrient rich from inorganic mineral leachates than the pure quartz sands of sandhills.

The high clay and silt content of the Citronelle Formation facilitates surface erosion by allowing excessive rainwater to runoff over the surface of the ground. Because of this and the generally higher elevations reached in the Panhandle by the Northern Highlands, landforms underlain by the Citronelle at the surface are highly gullied. The topographic relief of the Northern Highlands is due, primarily, to this erosion. The ravine valleys provide many of the lower valley slopes that are naturally protected from fire, allowing mesic hardwoods communities to develop on them. Many animals and plants are maintained in the fire-protected ravines, and accommodated by the higher humidity of ravines.

e. Pleistocene to Recent. The relatively short period of the Pleistocene (2.0 million years) witnessed several drastic fluctuations in sea level. These were brought on by climate changes that caused water in the oceans of the world to accumulate in continental ice sheets and extensive montane glaciers. As the glaciers grew, ocean levels dropped to as much as 300–400 ft lower than the present sea level. During warm interglacial periods ocean waters rose, but probably did not exceed present sea level until the past 10,000 years (end of the Pleistocene). Evidence from the two lower terraces, the Silver Bluff (1–10 ft) and the Pamlico (8–25 ft), indicate that two stands of the sea slightly higher than present may have lasted for short periods of time before the present sea level was established only about 6,000 years ago.

As a result of these post-Pleistocene fluctuations, coastal regions of the Panhandle less than about 25–35 ft above sea level have experienced a complicated history of erosion, deposition, and reworking of sediments from the action of rainfall, wind, and waves. Dunes, bars, spits, beach ridges, and other coastal features were stranded inland as sea level receded. Some of these are delineated on the physiographic map of the Panhandle (Figure 5).

The consequences of sea level fluctuations during the Pleistocene had little effect upon the present exposed land surfaces of the Panhandle above the two terraces just mentioned. This is because once the ocean withdrew from the higher terraces it never returned. The surface of the Panhandle above the Pamlico terrace was exposed to erosion and colonization by plants and animals just as this area is today. Pleistocene sea level fluctuations had their greatest effects, however, on the lands that today are submerged under the ocean. During lowered levels of the ocean surface much of the present sea floor was exposed to the air and to colonization by terrestrial plants and animals. During the Pleistocene the acreage of the Panhandle increased by a factor of 1 1/2 to 2 times by newly emerged Continental Shelf that was annexed to the present coastline.

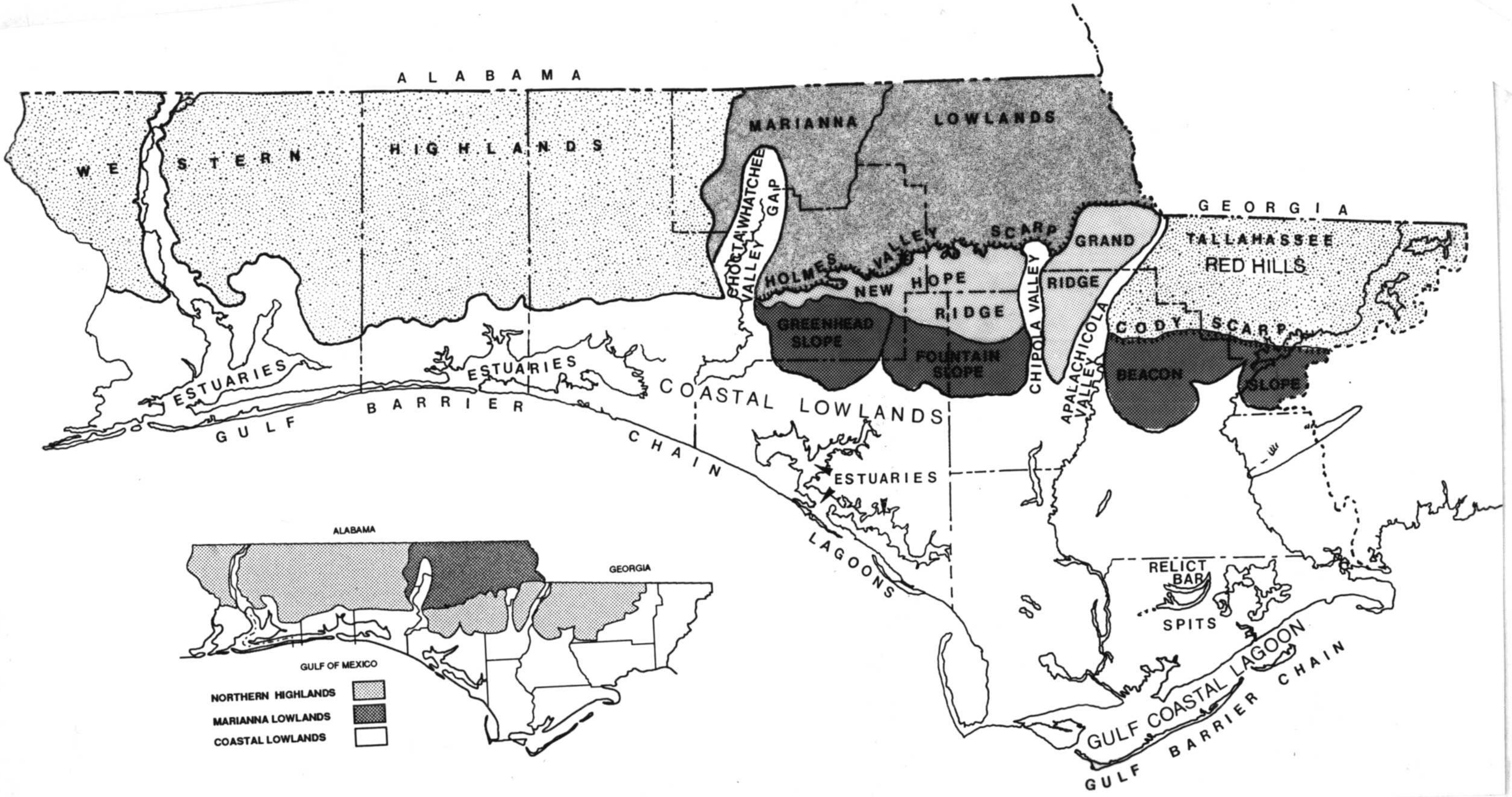


Figure 5. Physiography of the Florida Panhandle (after Puri and Vernon 1964, Brooks 1981b).

The present-day coastline is marked by beach ridges, barrier islands, spits, lagoons, estuaries, wave-cut cliffs, dunes, swales, sloughs, flats, and other topographic features created by Recent coastal processes. Beach ridges are marine in origin, formed by wave swash, which pushes sand up high as a berm adjacent to an existing beach, effectively moving the beach to the seaward side of the new sand berm, or beach ridge. This often happens during certain types of storms. Beach ridges usually occur side by side, as on St. Vincent Island.

Dunes are of wind-blown origin and may assume any shape or orientation. Drifting sand grains become rounded and their surfaces are scratched or frosted from abrasion by other sand grains. Dunes can build up 30 ft or more on top of the beach ridges they usually are perched on. Sand left on the beach by wave swash dries out during high tide and is subject to being moved up the dune face by the proper winds. Two adjacent barrier islands of the present coastline exemplify the complicated interactions of wind, wave, sand supply, and offshore currents. St. George Island has increasingly large wind-created dunes going east to west. Immediately west, however, St. Vincent Island is entirely composed of relatively low elevation, wave-created berms aligned in parallel sets. Shell fragments are less common on dunes than on beach ridges because they are less amenable to transport by wind than by water. The size of the grains, the lack of a carbonate adhesive leached from shells, and the rounded surface of grains allows dunes to be eroded or reworked more easily than beach ridges. Furthermore, the water holding capacity of dunes is much less than that of beach ridges, and dunes provide severely xeric soils for plants. This is true of the actively forming dunes along the present coastline as well as the ancient dunes and dunefields stranded far inland at the edge of ancient stands of the sea.

Barrier islands that have formed in the past 6,000 years or so are common along the coast of the Panhandle. These generally are parallel to the coast and consist of series of beach ridges, dunes, swales, interdune flats, and sloughs. East to west, these are Dog, St. George, St. Vincent, and Santa Rosa Islands. Barrier spits form in similar fashion to barrier islands, but are connected to the mainland at one of their ends. East to west, they are Alligator Spit, Indian Peninsula, St. Joseph Spit, Crooked Island, Shell Island (once a spit, broken by dredging), and Perdido Key. A lagoon is the brackish water bay (also called an estuary) between barrier islands or spits, and the mainland. Panhandle Florida is abundantly endowed with brackish water lagoons, providing important habitat for sea birds and ocean fisheries. Big Lagoon, Santa Rosa Sound, St. Andrew Sound, and St. George Sound are among the largest of these.

The plants and animals of Panhandle Florida have contact with and are influenced by the soils they are rooted in, or live on, or burrow into. Most of the soils of the Panhandle are of Pleistocene to Recent age, and are presently actively being formed, reworked, and reformed by the action of rainwater. Only on hardrock limestone outcrops such as those along the Chipola, Apalachicola, Ochlockonee, Sopchoppy Rivers or at various other places such as Falling Waters State Park do older sediments directly influence animals and plants as a physical substrate. Sediments older than the Pleistocene also are exposed on ridge slopes and hogbacks of the Northern Highlands that are under active gullying (so that the parent Miccosukee or Citronelle Formations are exposed). On the surface of lower slopes, and especially in the bottoms of streams, rivers, flats, and depressions, the sediments are of Recent origin.

Pleistocene and Recent sands and organic deposits are the main surface sediments of the Panhandle south of Cody Scarp. These occur in thicknesses of a few inches to dozens of feet. They are residual, leached, and reworked sediments from older deposits.

2.4 Physiography

2.4.1 The Northern Highlands

The Northern Highlands (Figure 5) extend across the Panhandle from the big bend region on the east to Alabama on the west. To the north, they extend into Georgia and Alabama along the entire length of the northern boundary of Florida. The almost continuous highland is parted by the larger stream valleys, several of which form a large low area called the Marianna Lowlands (see below). The marginal slopes of the Northern Highlands are well drained by dendritic streams but the tops are gently sloping plateaus.

The Northern Highlands are limited on the south by the Cody Scarp which extends regionally through the East Gulf and Atlantic Coastal Plains (Doering 1960). This outfacing scarp is the most persistent topographic break in the State. Its continuity is unbroken except by the valleys of major streams, but its definition is variable. In many places, it can be delineated with unequivocal sharpness; in others it is shown only by a gradual reduction of average elevation, and a general flattening of terrain as the lower elevations are reached (Puri and Vernon 1964).

The significant subdivisions of the Northern Highlands include the Western Highlands, Grand Ridge, New Hope Ridge, Washington County outliers (Knox Hill), and the Tallahassee Red Hills (Figure 5).

The Western Highlands is a belt of high, rolling hills that stretch between Escambia County on the west and Holmes and Walton Counties on the east. The soils are derived from the undifferentiated sands and clayey sands of the Citronelle Formation, providing dry conditions on the upland slopes and ridge crests. Downslope it is common to find seepage water emerging from gentle slopes, resulting in wetland communities called hillside seepage bogs (Clewell 1971, Wharton et al. 1976, Means and Moler 1979). At the eastern end of the Western Highlands in Holmes and Walton Counties, low, wet karst depressions resulting from solution subsidence of the underlying Tertiary limestones are common. From Okaloosa County westward, however, subsurface solution activity is not recognizable. The highest elevations in Florida occur in the Western Highlands southeast of the border town of Florala, Alabama, north of Walton County.

Grand Ridge and New Hope Ridge (Figure 5) are two fragments of the Northern Highlands that have been isolated between the Western Highlands and the Tallahassee Red Hills by the Choctawhatchee, Chipola, and Apalachicola river valleys. Grand Ridge has little that is distinctive biologically, but it does contain Ocheesee Pond, one of the larger lakes of the Panhandle and a remnant wetland formed in an ancient, abandoned bed of the Apalachicola River. The Holmes Valley Escarpment borders the northern edge of New Hope Ridge, and holds promise for interesting biological exploration in the future. North facing slopes in the Panhandle often harbor northern relicts.

The high remnant hills of Washington County — Orange, Rock, High, Oak, and Falling Water — indicate that the Northern Highlands were once continuous and that the Western Highlands, New Hope Ridge, Grand Ridge, and Tallahassee Red Hills were connected.

The Tallahassee Red Hills are a heterogeneous mix of rolling topography that sweeps south from the Georgia State line to Cody Scarp, and runs from the Apalachicola River on the west to the Suwannee River basin on the east. We have defined the eastern margin of the Panhandle as lying along the bed of the Ochlockonee River because a strong change occurs here in the underlying geology and surface physiography. East of the Ochlockonee River, the Tallahassee Red Hills lie in the Florida Big Bend, and the surface of the landform there is dominated by subsurface limestone solution. Large, solution subsidence basins dot the landscape and contain large lakes such as Lakes Jackson, Iamonia, Miccosukee, and Lafayette, and a host of smaller lakes and swamps. West of the Ochlockonee River, in the Panhandle, the rolling relief of the Tallahassee Red Hills is caused primarily by surface runoff. The terrain in this area is more relieved than any other area in Florida because of short tributaries incising the hills. In addition to the the deep stream valleys, or ravines, there are high (>200 ft) bluffs overlooking the Apalachicola River on the east.

2.4.2 The Marianna Lowlands

The Marianna Lowlands in Holmes, Washington, and Jackson Counties cover a rectangular area of approximately 30 x 64 mi and extend into Alabama and Georgia along the principal streams. They are bounded on the west by the Western Highlands, on the southeast by Grand Ridge, and on the south by New Hope Ridge. Because of the abandoned valleys and stranded alluvial deposits, it is believed that Marianna Lowlands were generally developed along the valleys of the Apalachicola, Chattahoochee, Chipola and Choctawhatchee Rivers.

The land surface is well drained and has a well developed dendritic stream pattern. It is pocked by sinks interspersed with rolling hills and abrupt ridges. The ridges are bounded by stream channels or by sink rims. Broad, shallow basins are generally present, some filled by water. The Marianna Lowlands possess Florida's most extensive system of air-filled cavern passageways, and the only ones in the Panhandle. The calcium-rich soils that develop on top of the limestone are often moist and rich in nutrients.

2.4.3 The Gulf Coastal Lowlands

The Gulf Coastal Lowlands physiographic region extends inland to its contact with the Northern Highlands along Cody Scarp (Figure 5). It is continuous from southern Escambia County on the west to Wakulla and southern Leon Counties on the east. The Gulf Coastal Lowlands are generally low in elevation and poorly drained on the east, but rise to form a high, sandy, well-drained plateau whose southern margin is a wave-cut escarpment west of Walton County. Coastal terraces characterize many of the landforms of the Gulf Coastal Lowlands and their low scarps form the boundaries between them.

The Gulf Coastal Lowlands are at least as diverse physiographically and biologically from west to east as are the Northern Highlands. Puri and Vernon (1964) listed nine subdivisions and there may be more. Immediately adjacent to the coast, the Gulf Coastal Lowlands are composed of barrier islands, lagoons, estuaries, coastal ridges, sand dune ridges, and relict spits and bars, with intervening coast-parallel valleys. Inland, northern Bay, southern Washington, and western Calhoun Counties have well developed karst ponds and lakes.

Greenhead Slope is a massive sand deposit that is pocked by circular depressions and round lakes. Aside from the limestone-dominated Marianna Lowlands, Greenhead Slope is the only other land area of the Panhandle exhibiting extensive karst features. It possesses a few steepheads, some draining into Econfina Creek and others into karst depressions.

Beacon Slope east of the Apalachicola River has more steepheads developed in it than any other part of the Panhandle, although by sheer volume of flow some on Eglin Air Force Base are larger. Because Beacon Slope is immediately adjacent to and below the well developed Apalachicola ravines in the Tallahassee Red Hills, the steephead ravines of Beacon Slope support most of the same endemic and relict species that are found just north.

Beacon Slope, Fountain Slope, Greenhead Slope, and the massive sand deposit in southern Santa Rosa, Okaloosa, and Walton Counties may all be ancient coastal sand deposits formed contemporaneously during the Pliocene when the sea stood near Cody Scarp. Today they are stranded inland by lower sea level, but it is significant that each feature contains numerous steepheads and endemic plants and animals that may have evolved on each feature during the long period when each was part of a developing barrier island-lagoon set.

Relict bars and spits are common in Gulf, Liberty, and Franklin Counties. In fact, ancient bird's-foot deltas can be traced on the land surface on both sides of the lower Apalachicola River. Moreover, this part of the Gulf Coastal Lowlands is biologically so distinctive that it probably deserves its own physiographic rank. At least 15 races and species, and one genus of plants and animals have their distributions centered on the lower Apalachicola valley (Means 1977). Many unique, silt-bottomed savannas and cypress wetlands occur here, and the region beckons for further exploration.

2.5 Regional Marine Geology

Two regional geologic features control the coastal configuration of the Florida Panhandle: the Apalachicola or Southwest Georgia embayment and the Chattahoochee arch (Figure 3) (Schnable 1966). The Apalachicola embayment is a shallow basin (syncline) situated between the Ocala and Chattahoochee uplifts. It is located where the east-west strike of the coastal element changes to approximately north-south in southwestern Georgia and northern Florida (Murray 1961). The Apalachicola delta lies near the center of the embayment. The thickness of the Pleistocene and Miocene sediments in the eastern portion of the area reflect the influence of the Ocala uplift as a structural high (Schnable and Goodell 1968).

The thickness of the tertiary sediments in the northeastern Gulf of Mexico is substantially less than those of the northwestern and north central gulf (Vause 1959). This is probably a result of the Apalachicola delta region lying further from the main axis of the Gulf Coast Geosyncline than most coastal areas to the west and as a result being more stable and structurally less complex (Schnable 1966). Pleistocene to Recent sediment thicknesses along the present coast vary from less than 3 m in the easternmost portion of the Panhandle to 36 m in the westernmost part (Figure 6) (Schnable 1966).

Several investigators have examined the offshore sediments in the region (Lapinski 1957, Milton 1958, Chen 1978). West of Ochlockonee Bay, the Apalachicola and Ochlockonee Rivers supply alluvium downdrift for a system of barrier islands (Dog Island, St. George Island, and St. Vincent Island), beaches, spits, and bars. The Ochlockonee and Apalachicola are the eastern most rivers carrying appreciable amounts of detrital and mineral matter to the gulf. The region from the western end of St. George Island to the Ochlockonee Bay is classified as a low-energy area (Figure 7) (Tanner 1960b). The sediment from alluvial and shelf sources is mostly lost to coastal deposition west of St. Joseph Bay where the 25-m depth contour approaches the nearshore region and funnels material from the westward drift out into deeper water (Stout 1984). Further west, Santa Rosa Island receives sediment downdrift from Choctawhatchee Bay and sands from the Continental Shelf (Kwan 1969).

Most of the fine-grained sediment carried by the Apalachicola and Ochlockonee Rivers is contained within the estuaries (Kofoed and Gorsline 1963). Kofoed (1961) and Schnable and Goodell (1968) concluded that no significant quartz sand was being supplied to the littoral drift system outside the barrier-island chain. They contended that the "large volume of sand composing the barrier islands and offshore shoals can have been supplied only during lower sea-level stands." There has been extensive beach erosion on the spits and barrier islands in recent time in this area of supposed excess sediment (Warnke 1967). Clear evidence for erosion are tree stumps in the water on the beaches near East Point in the Apalachicola system and on St. George Island.

The littoral drift, or longshore sand transport, along the Panhandle coast has been described by Tanner (1964), Bruno (1971), and Walton (1976). Figure 8 gives a view of littoral drift along a portion of the Panhandle from Cape San Blas in Gulf County to the western border of Okaloosa County. From the western end of the Panhandle toward Bay County, the shoreline becomes concave. This natural concavity is broken by St. Joseph Bay. The area from Panama City west to East Pass is presently undergoing erosion. In recent geologic times this area may have been a source of sand for areas to the west (Walton 1976). In contrast, the shoreline from East Pass (St. Andrew Bay system, Bay County) to Perdido Pass may have been an area of accretion (Santa Rosa Island is evidence) in recent geologic times, though Santa Rosa Island is now in a state of equilibrium.

There are no true barrier islands present in the region west of St. Joseph Bay to Destin (Tanner 1960b). Moderate-energy waves form the gulf front beaches. From Panama City Beach to Destin the shoreline is a mainland beach (Gorsline 1966). For approximately 85 km the beach is unbroken, with only small streams interrupting the continuity. Associated with the larger streams are small brackish-water bays. A wide recent beach abuts a prominent bluff 6–10 m high. The present coast is relatively stable.

From Choctawhatchee Bay Pass westward to the Alabama border, a series of narrow barrier islands border the mainland. Santa Rosa Island is nearly 81 km long and is not more than 0.7 km wide. It represents the largest unbroken stretch of beach in the eastern Gulf (Brooks 1973). The beach is composed of pure white quartz sand (median diameter approximately 0.25 mm). During heavy storms there is local washover across the island. There is extensive dune development on the eastern fifth of the island.

Near the western end of the island salt marsh peat is exposed on the foreshore. The foreshore slope is relatively steep (approximately 9°–10°) so that the 15-m depth contour comes within 0.6–0.8 km of the shoreline. Because of this steep ramp, the area has recorded some of the highest waves in the northeast Gulf of Mexico (Gorsline 1966, Brooks 1973).

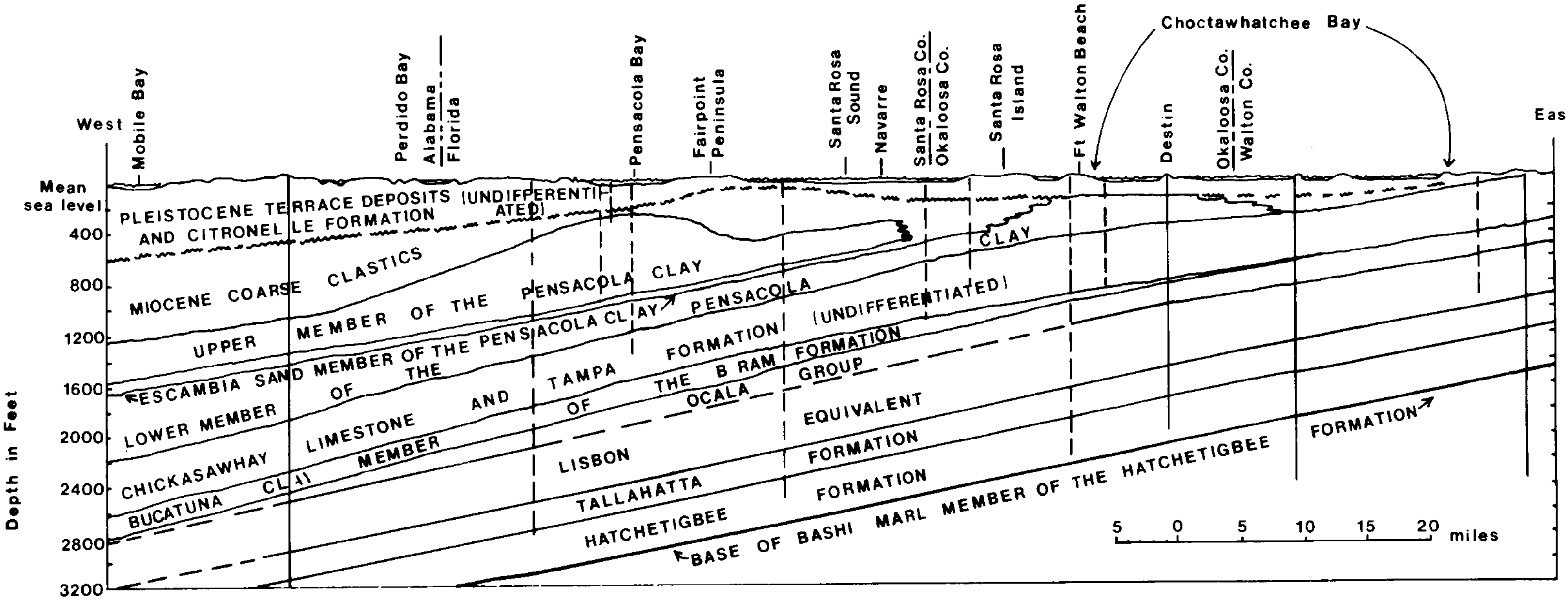


Figure 6. The thickness of Eocene to Recent sediments along the Panhandle coast from Choctawhatchee Bay to the Alabama-Florida border (after Marsh 1966).

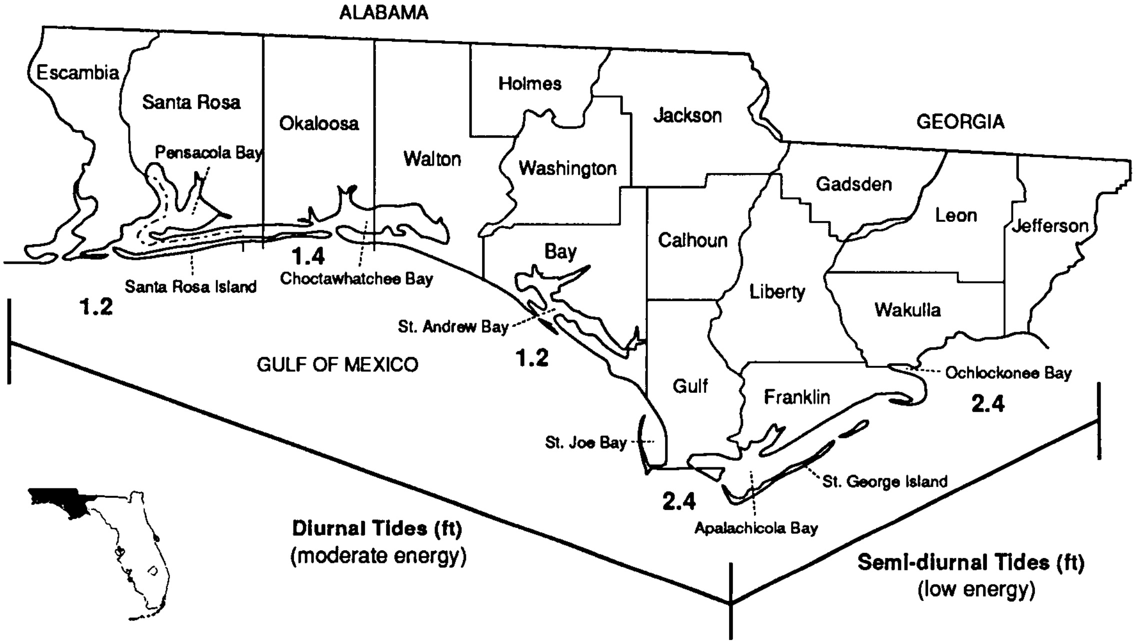


Figure 7. Coastal energy levels and tidal ranges for the northeastern Gulf of Mexico (after Stout 1984).

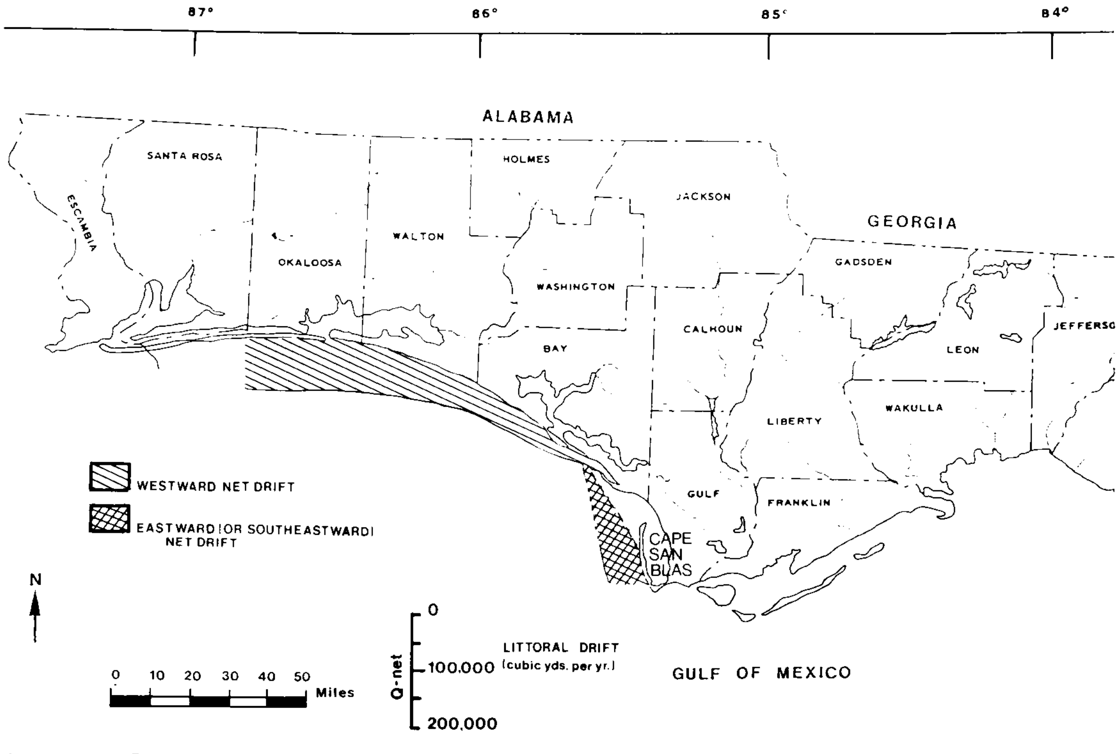


Figure 8. Schematic of net littoral drift along "idealized" Panhandle coast (after Walton 1976). Q_{net} shows magnitude of littoral drift in cubic yds/yr.

The northeastern Gulf of Mexico is not as tectonically active as areas to the west. The Apalachicola delta region has been a relatively stable area since at least Pamlico (Sangamon — the last glacial recession) time (Schnable 1966).

There are two prominent offshore morphological features present in the eastern portion of the Panhandle region: the two large shoal areas off Cape San Blas/Cape St. George (Stauble 1971) and the submarine sand bodies in the nearshore gulf off Choctawhatchee Bay (Figure 9; Hyne and Goodell 1967). The two broad shoals extend nearly 16 km into the gulf and are characterized by a series of broad ridges and troughs. Mean grain size of the quartz sand increases seaward from the beach and therefore the sand in these shoals is coarser than the sand now being transported by the longshore drift system (Schnable 1966). The present energy levels along this coast are not sufficient to redistribute or remove sand from the shoal areas or sand bodies (Tanner 1961, 1964; Tanner et al. 1961). The outer shoals have remained relatively unchanged for over a century (Schnable 1966). The sands in these offshore areas are relict and were probably originally deposited at some early low stand of sea level.

Several mechanisms have been proposed to explain the origin of the shoals. One is a storm-surge

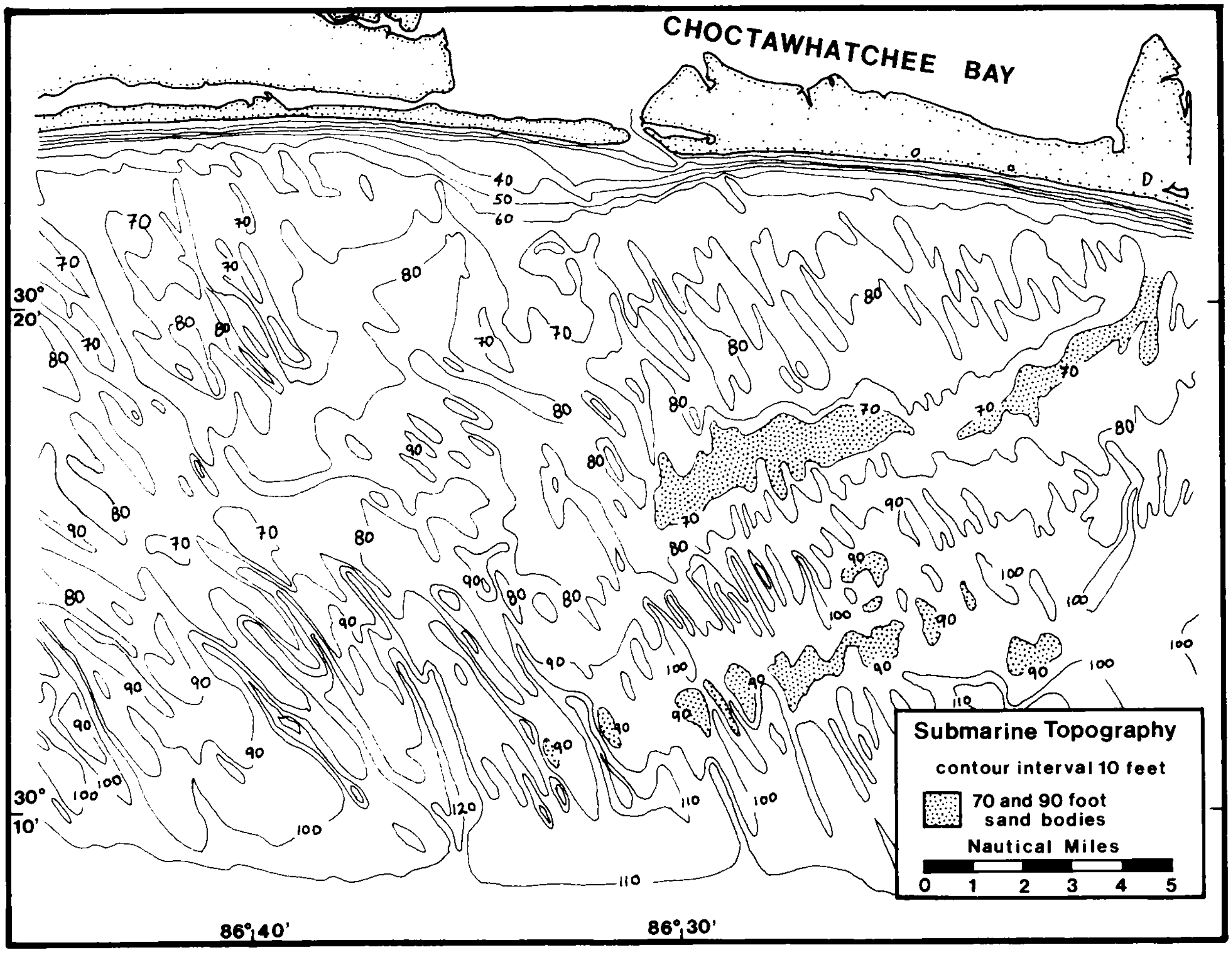


Figure 9. Nearshore bottom topography off Choctawhatchee Bay showing sand body features (after Hyne and Goodell 1967).

phenomenon that formed the ridge and trough configuration (Tanner 1960a). Others have proposed that the shoals are drowned barriers, although the sand has been extensively reworked. In addition, the ridges of the shoals contain concentrations of heavy minerals that may indicate a dune origin (Schnable 1966).

An interesting discovery has been made in the offshore waters south of Panama City Beach. Remnants of an ancient forest are present at a depth of approximately 18 m directly south of the beach and in 6 to 15 m of water nearer the St. Andrew Bay entrance (Lawrence 1974, Burgess 1977, Salsman and Ciesluk 1978). The latter site is located beneath sediments comprising the present-day barrier island complex. The wood dates from 27,00 to 36,500 years old and is believed to be part of a large forest that covered the area during a lower sea level stand. The forest extends many kilometers south of the present shoreline. The wood is mostly pine but contains small amounts of hardwoods such as oak, beech, hickory, and elm. This suggests the vegetation was very similar to present-day stands 32–48 km north of Panama City. The submerged forest further supports the contention that the present-day beaches and islands are recent geologic features.

2.6 Local Marine Geology

The following section is a discussion of the origin and geological aspects of the major bay systems included in the Panhandle region.

2.6.1 Ochlockonee Bay

The Ochlockonee Bay represents a drowned river valley that was cut during lower stands of sea level in the Pleistocene. Bottom topography at the mouth of the bay resembles a drowned delta with two linear shoals on each side of the channel that may represent an old river channel with natural levees on each side. The "old" Ochlockonee River probably had several routes to the gulf during the late Pleistocene (Schnable 1966).

The stratigraphy of the nearby region is unique in the Panhandle. The Miocene is very close to the surface at the present coastline in the vicinity of Turkey Point-St. Teresa (Figure 10). From there the

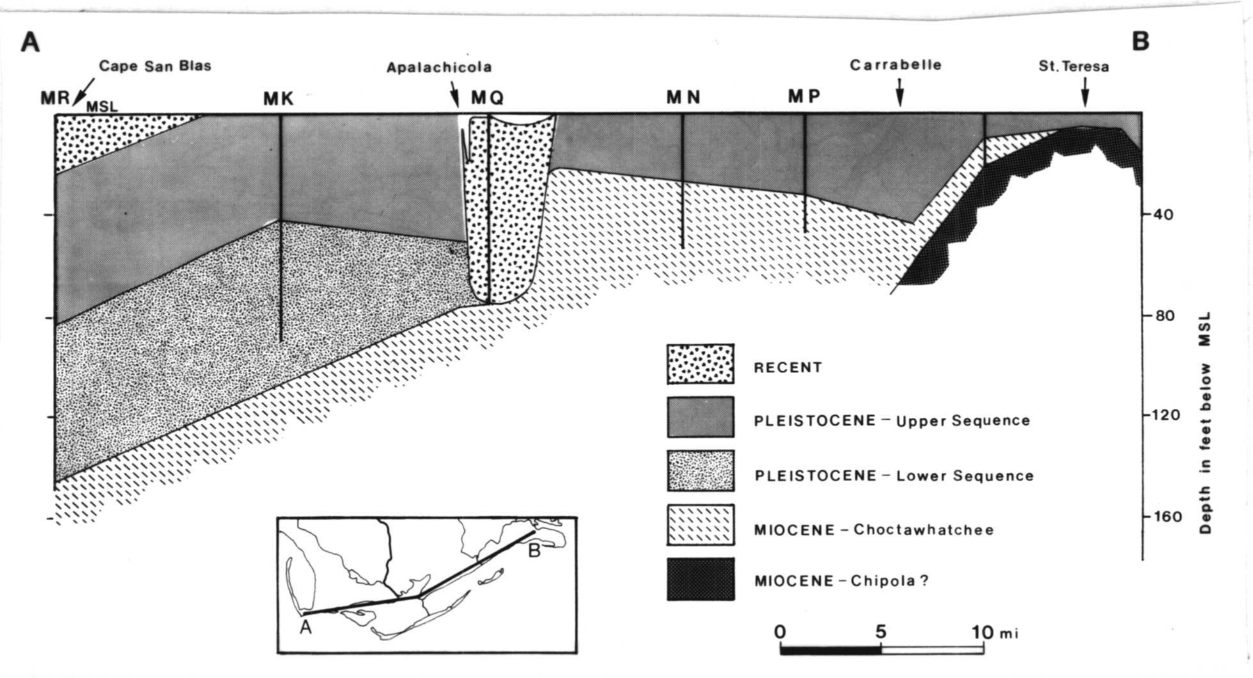


Figure 10. Stratigraphy of coastal region from Cape San Blas to Ochlockonee Bay in the eastern Panhandle (after Schnable 1966).

surface dips to the southwest and the Pleistocene-Miocene contact is approximately 45 m below the ocean floor off Cape San Blas.

2.6.2 Apalachicola Bay

During the Cretaceous period, the present Apalachicola River system was submerged under ancient seas (Tanner 1983). The origin of the present Apalachicola River probably occurred some time during the Miocene epoch (Livingston 1984). The present structure of the bay is nearly 10,000 years old (Tanner 1983). The present barrier island chain formation began approximately 5,000 years ago when sea level reached its modern position. It was at this time that the general configuration of the bay was determined, except for the southward migration of the delta flat (Tanner 1983).

2.6.3 St. Joseph Bay

Stewart and Gorsline (1962) described the following sequence of events leading to the formation of modern St. Joseph Bay:

(1) Following the last rise of sea level (approximately 5,000 years ago), a series of north-south trending beach ridges was formed and an open coast profile was established offshore. An even older set of ridges was submerged and subjected to marine degradation, resulting in the formation of a shoal trending south-southwest from the mainland through the Cape San Blas area.

(2) A large distributary of the Apalachicola River, its course controlled by beach ridge development, emerged about 8 km north of the present bay and deposited a wedge of fine-grained material over the terrace sediment. At approximately the same time, gyral currents established by the presence of the southern shoal initiated spit growth from the east.

(3) Rapid spit development segregated a large portion of the older surface and prevented substantial filling of the bypassed area. At this time, the detrital supply from the distributary had ceased and sand supplied by longshore drift and biologic carbonate formed the major contribution.

(4) Development of stronger tidal currents in recent times controlled spit growth and furnished a mechanism for the transport of sand into the basins. Sand has completely covered the fine-grained material to the north. Under the lower energy conditions of the past lagoon, sand encroachment has been slow and limited, and a large portion of the older surface remains relatively unobscured.

Present-day sedimentation in the bay comes from 2 dominant sources: the coastal transport of clean quartz sand from the east and biological activity within the area itself. In the absence of a substantial amount of silt-size quartz particles, carbonate tests and shell fragments increase in importance as the applied energy of the environment decreases southward in the lagoon. Residual gravels and sands dominate a sizeable portion of the southern slope of the bay that is removed from active deposition of detrital material (Figure 11).

Since the formation of the enclosing spit, a reduced rate of deposition has preserved the bottom contour in the central portion of the lagoon. The depth and gradient closely approximate that of the offshore slope (Stewart and Gorsline 1962). There is a far larger accumulation of clay in the central bay basin than can be accounted for by present minor sources. This has led to the conclusion that these fine sediments represent a relict surface produced by the discharge of an old distributary of the Apalachicola River.

The sediments of the area are typical of those from a Coastal Plain source. Small differences can be attributed to attrition and loss in transport. Less than 1% of the typical east gulf "kyanite-staurolite" suite of heavy minerals is present. Kaolinite, montmorillonite, and illinite are the clay minerals present, with kaolinite dominating.

2.6.4 St. Andrew Bay System

The St. Andrew Bay system is a typical tidal embayment. It appears that it was formed during the last major rise in sea level (the Holocene transgression) that took place approximately 5,000 years ago. As sea level rose and flooded the valley of a local river system, ocean waves and longshore currents built up a barrier bar across the mouth of the resulting bay.

Uniform sediment ridges on the bottom of St. Andrew Bay were documented by Salsman et al. (1966). The ridges, composed of a fine sand, were asymmetric, with steep slopes, 30 to 60 cm high,

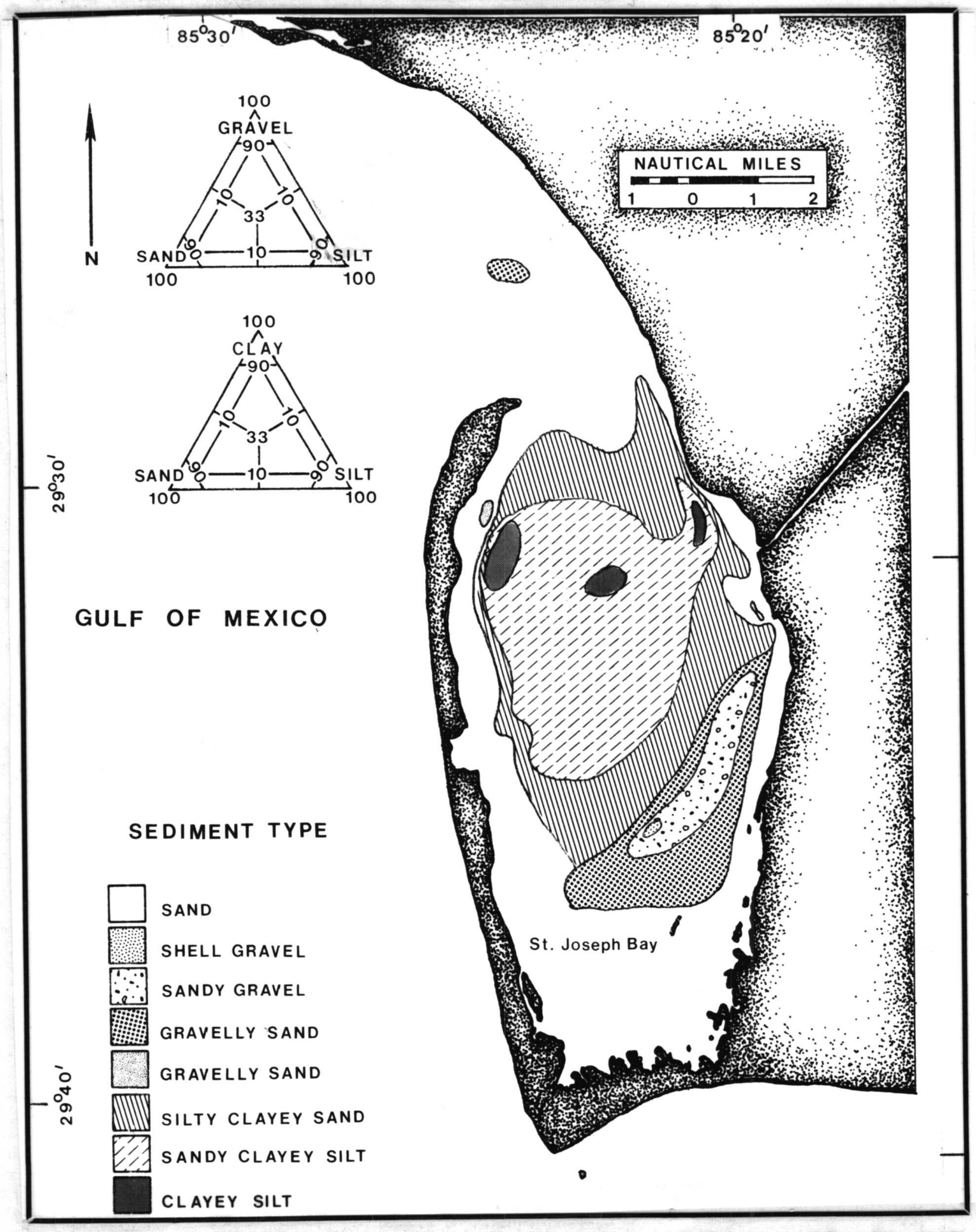


Figure 11. Surface sediment composition in St. Joseph Bay (after Stewart and Gorsline 1962).

facing down current, and had 13 to 20 m wavelengths. The predominant flood tide caused them to migrate northeastward at an average rate of 1.35 cm per day. The migration rate was very sensitive to changes in current speed. Near the leading edge of the ridge zone, where sand transport was primarily of bed-load mode, each ridge passing a point left behind an average 12 cm-thick sand layer.

Holmes and Goodell (1964) have reported on the sediments in St. Andrew Bay.

2.6.5 Choctawhatchee Bay System

The region presently covered by the Choctawhatchee Bay was as much as 92 m above sea level during the Pleistocene epoch (Puri and Vernon 1964) and became gradually inundated by oceanic waters in more recent times. As the Gulf of Mexico approached its present level, a persistent westerly drift of littoral sand created Moreno Point. This barrier eventually isolated the bay from the gulf, except for a narrow passage through the embayment now known as Old Lagoon Pass. At times before the formation and stabilization of East Pass, Choctawhatchee Bay became a freshwater lake when periodic shoaling closed the natural pass.

The land immediately adjacent to the bay is composed of unfossiliferous sand and clay deposits of Pleistocene and Tertiary age (Puri and Vernon 1964). Moreno Point is part of a massive sand ridge described by Tanner (1964). Sand cliffs from 2 to 4 m high make up the north shoreline of the bay. The narrow Garnier and Rocky bayous in the northwest corner of the bay have very steep shores, with sharp slopes extending down to depths of more than 10 m. This contrasts with the eastern end, which is marshy due to poor drainage, and the western end, which is composed of residual sand. Both of these ends are relatively shallow, with low gradient slopes. The bedrock limestone underlying Choctawhatchee Bay is found at a depth of approximately 45 m (Tanner 1964). The recent sediments of the bay are described by various authors (e.g., Postula 1967, Palacas et al. 1968, 1972).

Goldsmith (1966) reported a large contrast in condition between the present sedimentary environment and the one previously occupying the area. He reported the following sequence of events leading to the formation of Choctawhatchee Bay.

(1) A sharp rise in sea level (7,000 to 20,000 years ago) inundated the Pleistocene River valleys, from the coastal embayments that are presently the bayous on the north side of the bay. Between 3,000 and 7,000 years ago, when the rate of sea-level rise slowed, the westward longshore drift system began to form Moreno Point, the eventual barrier spit. It was not until sometime after 3,000 years ago that Moreno Point effectively closed off the bay.

(2) Isolation from the Gulf of Mexico had a profound effect upon the sedimentary environment within the bay, producing modifications in three factors that caused the sediments to undergo radical alteration. Biologically, the present environment lacks the prolific shell-producing organisms of the past. Physically, the entrapment of fine material brought by the Choctawhatchee River may have brought on the decline of the formerly abundant and diverse molluscan life of the bay. Finally, the changes in both biological and physical conditions caused modifications in the physiochemical environment, as reflected in the low alkalinity and highly reducing character of the surface sediments of the bay.

Minor fluctuations in sea level within historical times in Choctawhatchee Bay have been documented by the presence of submerged trees (approximately 0.5 m under water) next to emergent marsh remnants (1 m above water) (Goldsmith 1966). These features are located at about the middle of the south shoreline of the bay. This change in water level of the bay may be related in part to general coastal subsidence determined by Marmer (1952) from tidal observation.

Of historical note, farmers originally dug a ditch across Santa Rosa Island that eventually became the main Destin channel and resulted in major changes in the depositional and erosional patterns within the bay. The channel has since been maintained by the U.S. Army Corps of Engineers.

2.6.6 Pensacola Bay System

The recent sedimentology of the Pensacola Bay system is a result of watershed erosion since the Pleistocene epoch (Olinger et al. 1975). During the Pleistocene, Citronelle deposits were reworked and intermixed with marine terrace sediments (Marsh 1966). These deposits are presently eroding. Present-day sediments consist primarily of unconsolidated sand, silts, and clays of the Coast Plain Province that were deposited before the last sea-level rise. This layer is underlain by a veneer of Pleistocene terrace deposits that overlie tertiary beds of sand, silt, and limestone (Figure 12). The Citronelle Formation, the only formation with marine outcrops in the region is composed of layers of sand, gravel, iron-cemented sandstone, fossil woods, and kaolinite (Marsh 1966).

Horvath (1968) described the recent sedimentology of the Pensacola Bay system:

(1) Sediments enter into the system from two sources: stream discharge from the surrounding land, and wave and current action that bring them into the bay from the Gulf.

(2) The Escambia River discharges more coarse material into the bay than do the other rivers.

(3) Sediment distribution reflects the bay's circulation pattern, consisting of strong north-flowing currents along the eastern shores and south-flowing currents near the western coasts.

(4) Sand-size sediment predominates with silt-clay being the second most abundant.

(5) Grain size increases in every direction away from the bay center.

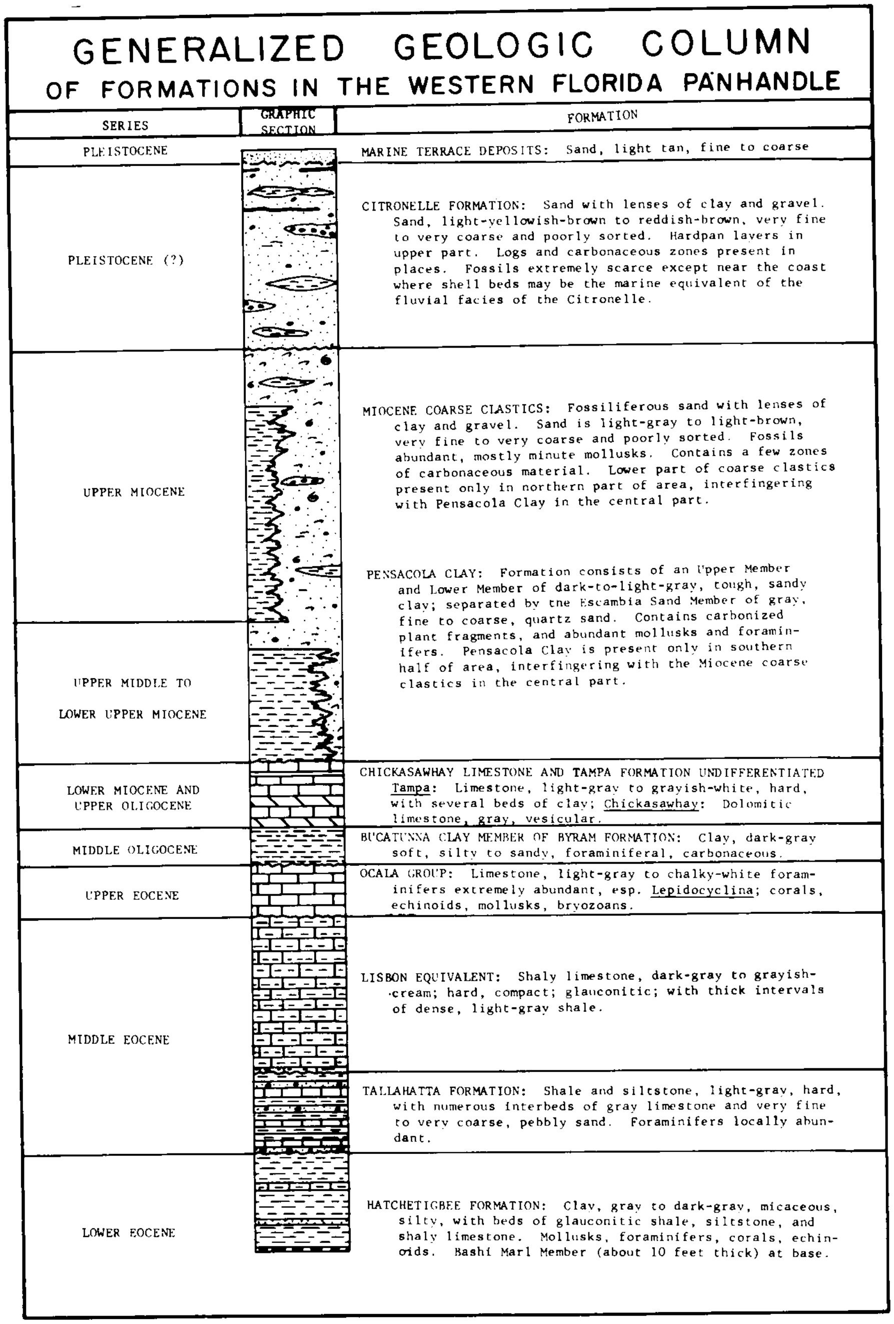
(6) The main mineral constituents are quartz, kaolinite, montmorillonite, and calcite.

(7) The Santa Rosa Sound is different from the three bays in the Pensacola Bay system, with a coarser mean grain size and lower average silt-clay content. Most of its sediments were probably derived from offshore sources and are not of fluvial origin.

2.7 Offshore (Outer Continental Shelf) Oil and Gas Reserves

Recently, the development of the Outer Continental Shelf (OCS) oil and gas resources has been a major concern of coastal Panhandle residents. At present, three offshore lease areas lie off the immediate Panhandle coast (Figure 13): (1) the Pensacola area; (2) the Destin Dome area, and; (3) the Desoto Canyon area.

Since the early 1970's, various oil companies have maintained exploratory interest in these lease areas. The Destin Anticline and the southwest corner of the Pensacola area are believed the most promising as hydrocarbon-producing areas (Figure 13). Eighteen exploratory wells have been drilled within the Destin Dome area in the Smackover geological formation, as of the summer of 1985. The depths to which the wells were drilled, 5185–5795 m, indicate natural gas may be a more likely yield than oil. Thus far, the natural gas discovered in the Smackover Formation in other regions has contained hydrogen sulfide (said to be "sour") that is corrosive and must be subjected to more costly processing than higher quality gas. Offshore oil activities have the potential for many harmful impacts to the nearshore coastal habitats. Some of these are discussed in the chapters dealing with the individual estuarine and marine habitats.



GENERALIZED GEOLOGIC COLUMN
OF FORMATIONS IN THE WESTERN FLORIDA PANHANDLE

SERIES	GRAPHIC SECTION	FORMATION
PLEISTOCENE		MARINE TERRACE DEPOSITS: Sand, light tan, fine to coarse
PLEISTOCENE (?)		CITRONELLE FORMATION: Sand with lenses of clay and gravel. Sand, light-yellowish-brown to reddish-brown, very fine to very coarse and poorly sorted. Hardpan layers in upper part. Logs and carbonaceous zones present in places. Fossils extremely scarce except near the coast where shell beds may be the marine equivalent of the fluvial facies of the Citronelle.
UPPER MIOCENE		MIOCENE COARSE CLASTICS: Fossiliferous sand with lenses of clay and gravel. Sand is light-gray to light-brown, very fine to very coarse and poorly sorted. Fossils abundant, mostly minute mollusks. Contains a few zones of carbonaceous material. Lower part of coarse clastics present only in northern part of area, interfingering with Pensacola Clay in the central part.
UPPER MIDDLE TO LOWER UPPER MIOCENE		PENSACOLA CLAY: Formation consists of an Upper Member and Lower Member of dark-to-light-gray, tough, sandy clay; separated by tne Escambia Sand Member of gray, fine to coarse, quartz sand. Contains carbonized plant fragments, and abundant mollusks and foraminifers. Pensacola Clay is present only in southern half of area, interfingering with the Miocene coarse clastics in the central part.
LOWER MIOCENE AND UPPER OLIGOCENE		CHICKASAWHAY LIMESTONE AND TAMPA FORMATION UNDIFFERENTIATED Tampa: Limestone, light-gray to grayish-white, hard, with several beds of clay; Chickasawhay: Dolomitic limestone, gray, vesicular.
MIDDLE OLIGOCENE		BUCATUNNA CLAY MEMBER OF BYRAM FORMATION: Clay, dark-gray soft, silty to sandy, foraminiferal, carbonaceous.
UPPER EOCENE		OCALA GROUP: Limestone, light-gray to chalky-white foraminifers extremely abundant, esp. Lepidocyclina; corals, echinoids, mollusks, bryozoans.
MIDDLE EOCENE		LISBON EQUIVALENT: Shaly limestone, dark-gray to grayish-cream; hard, compact; glauconitic; with thick intervals of dense, light-gray shale.
		TALLAHATTA FORMATION: Shale and siltstone, light-gray, hard, with numerous interbeds of gray limestone and very fine to very coarse, pebbly sand. Foraminifers locally abundant.
LOWER EOCENE		HATCHETIGBEE FORMATION: Clay, gray to dark-gray, micaceous, silty, with beds of glauconitic shale, siltstone, and shaly limestone. Mollusks, foraminifers, corals, echinoids. Bashi Marl Member (about 10 feet thick) at base.

Figure 12. Generalized geologic column of formations in the western portions of the Florida Panhandle (after Marsh 1966).

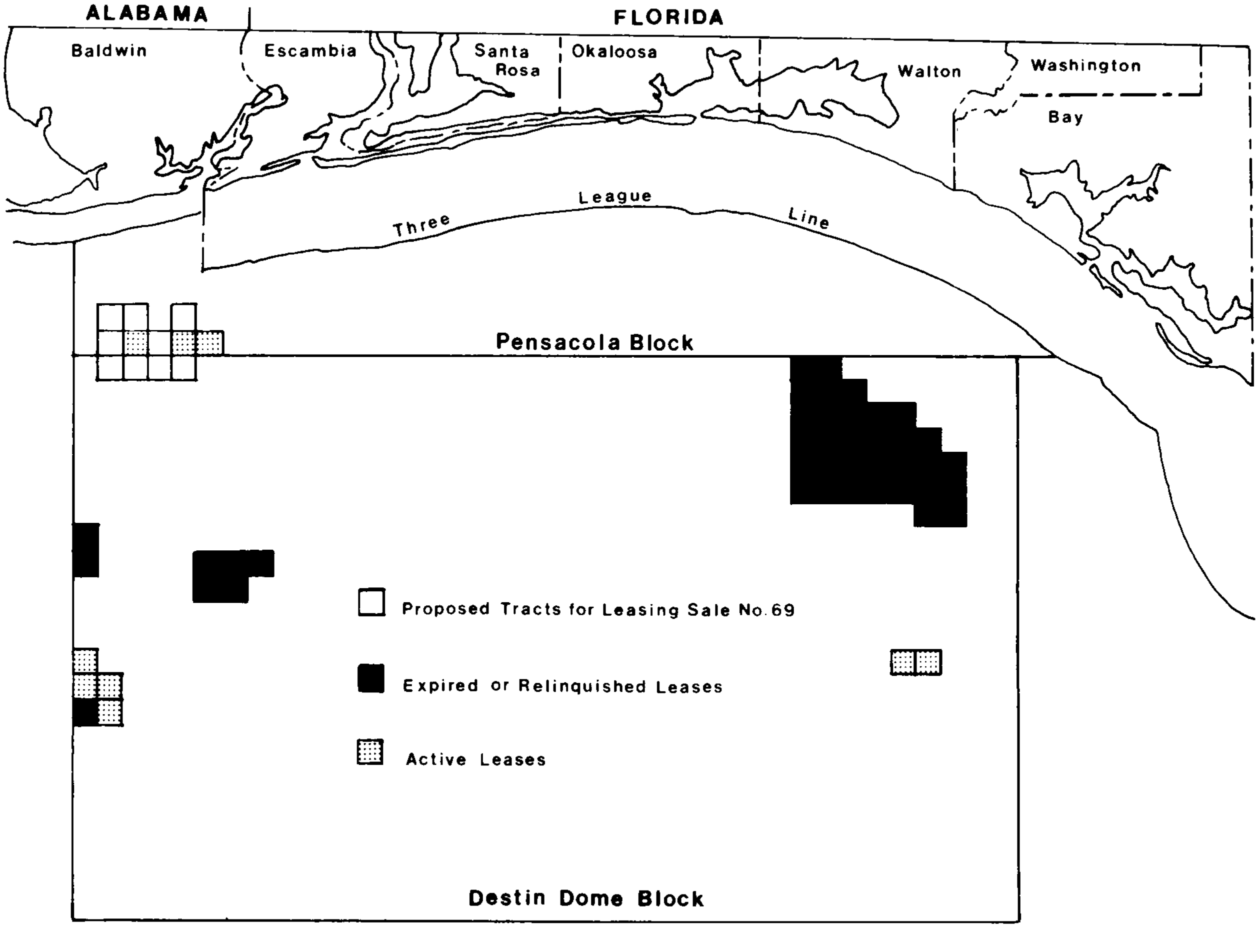


Figure 13. OCS leases in the Pensacola and Destin Dome Blocks offshore from west Florida (Lynch and Risotto 1985).

Chapter 3. CLIMATE

3.1 Introduction

The Florida Panhandle experiences a mild, subtropical climate as a result of its latitude (30°–31° N) and the stabilizing effect of the adjacent Gulf of Mexico (Bradley 1972). The waters of the gulf moderate winter cold fronts by acting as a heat source and minimize summer temperatures by producing cooling sea breezes. This gulf influence is strongest near the coast, weakening inland. Fairly detailed long-term climatological summaries are available for Apalachicola and Tallahassee. Though Tallahassee lies a few miles outside the eastern boundary of what we call the Panhandle, it is the location of much data collection and will be used to provide a more comprehensive report. More limited data are also available for Pensacola and certain other Panhandle locations (Jordan 1973). The locations of NOAA climatological stations are shown in Figure 14.

3.2 Climatological Features

3.2.1 Temperature

The annual average of the mean daily temperature is in the upper 60's Fahrenheit with mean summer temperatures in the low 80's and mean winter temperatures in the low 50's. Annual and seasonal temperatures vary greatly (Figures 15 and 16) with summer highs generally in the low to mid 90's with occurrences of 100 °F or higher infrequent. The summer heat is tempered by sea breezes along the coast and up to 50 km inland, as well as by the

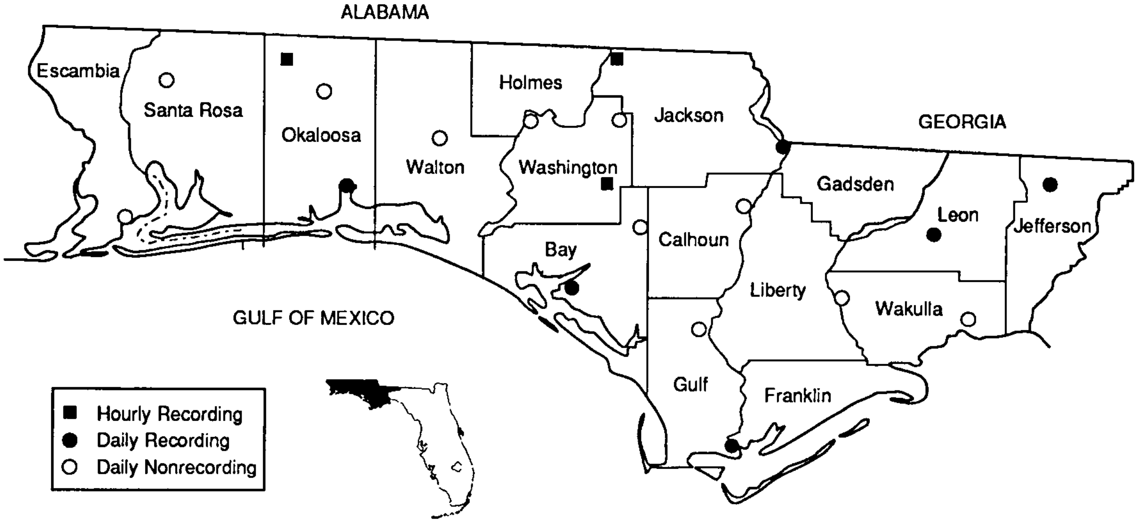
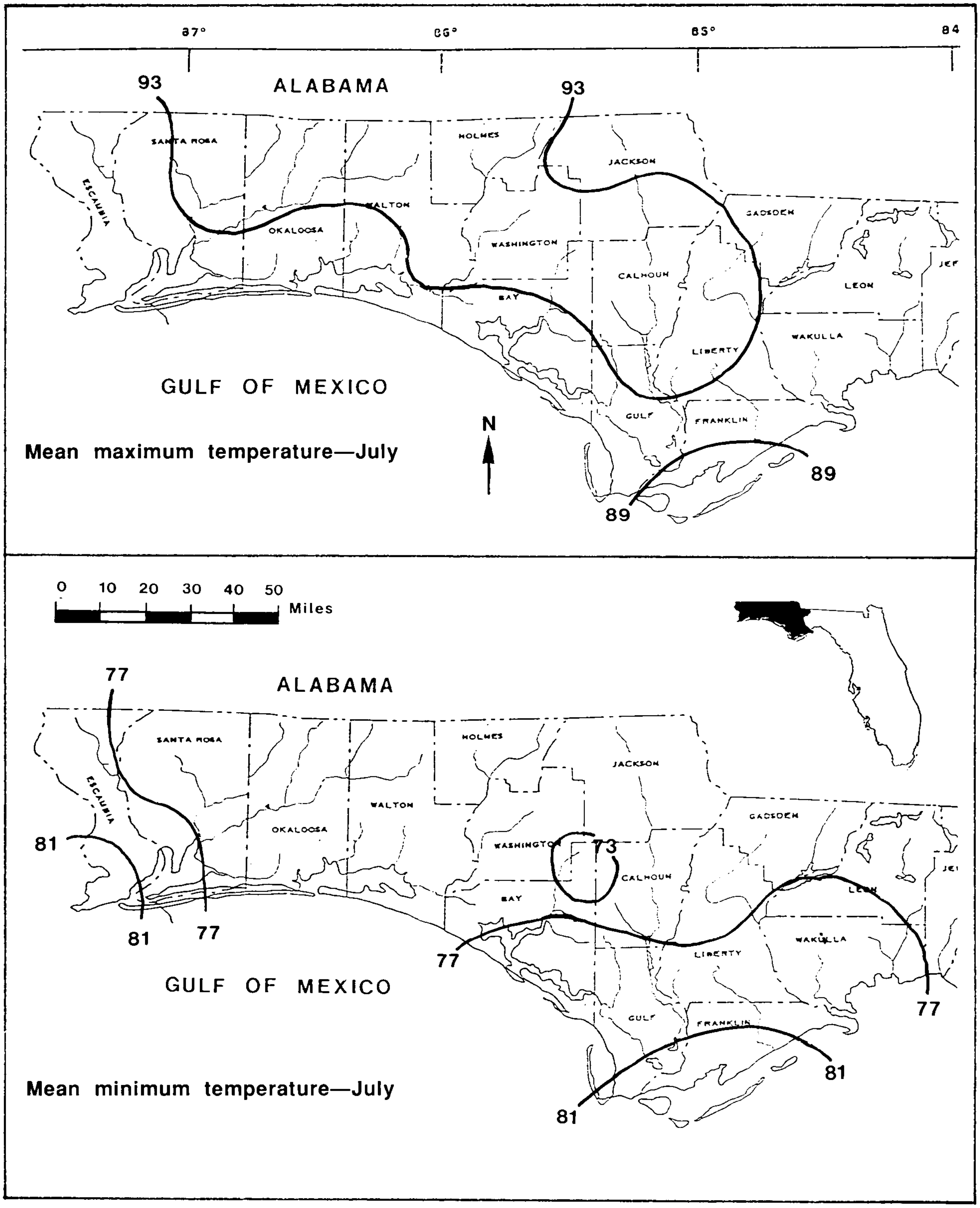
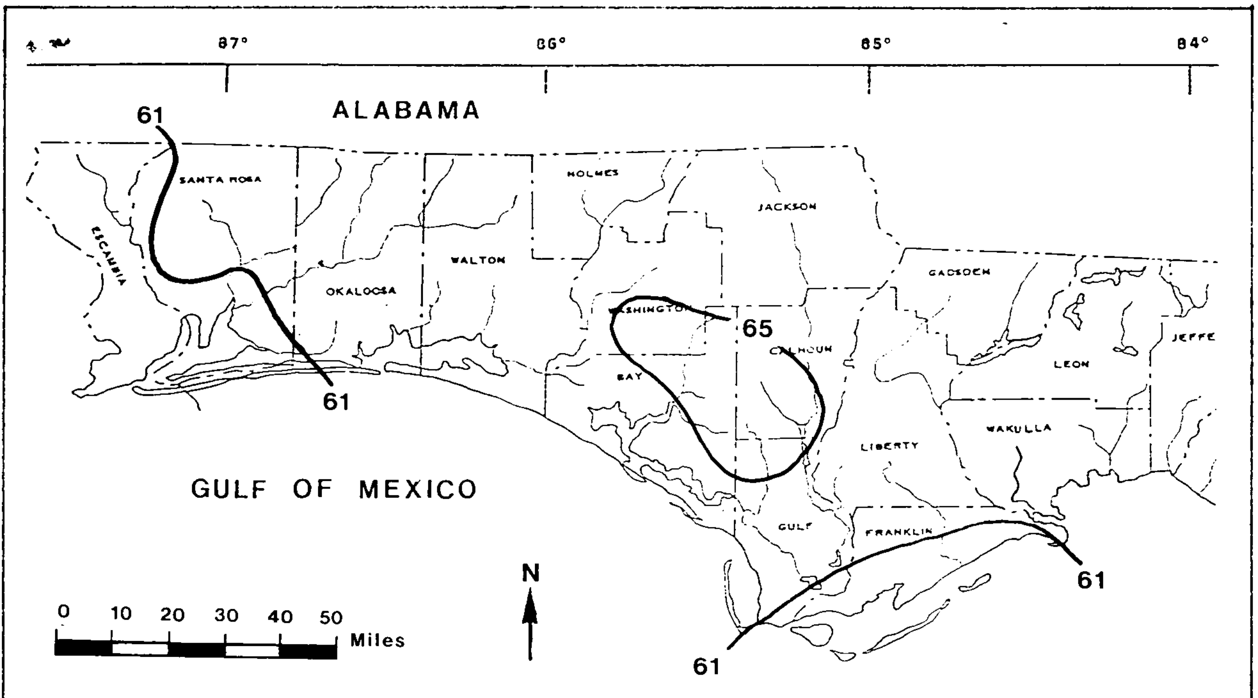


Figure 14. NOAA climatological station sites in the Florida Panhandle (after Wagner et al. 1984).

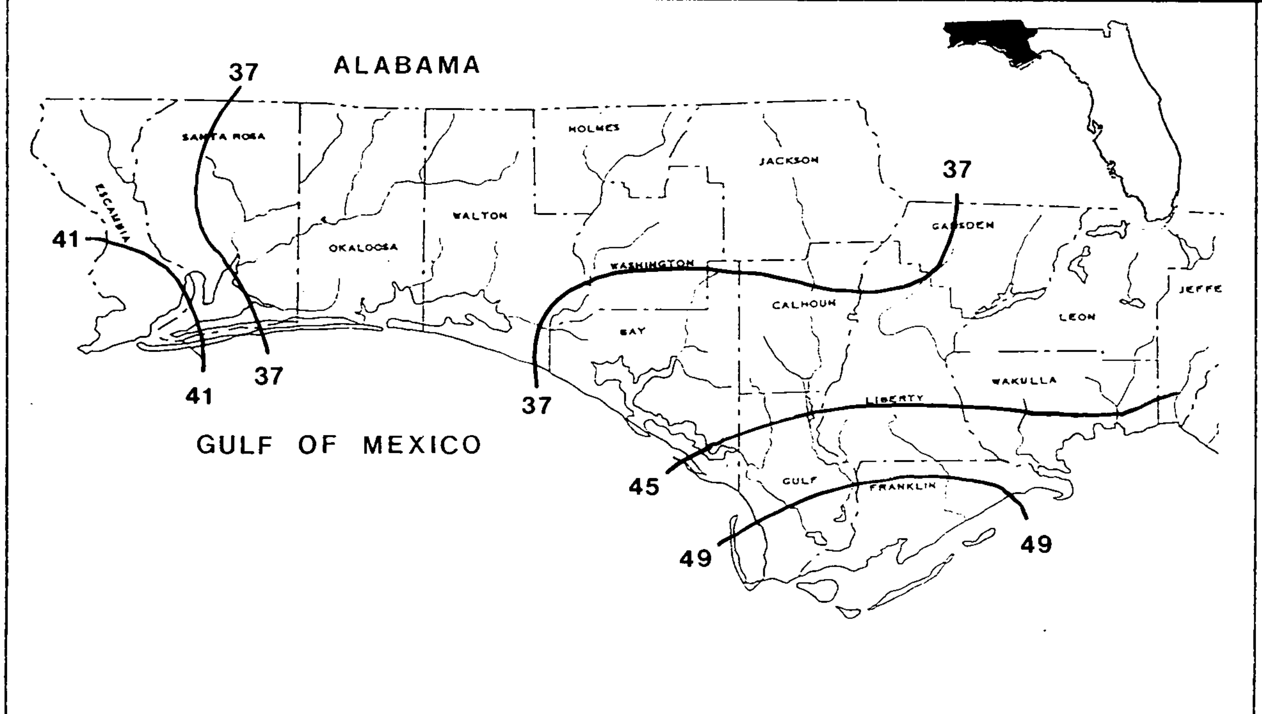

Mean maximum temperature—July

Mean minimum temperature—July

Figure 15. Isotherms for mean maximum and mean minimum July temperatures in the Florida Panhandle (after Fernald 1981).



Mean maximum temperature—January



Mean minimum temperature—January

Figure 16. Isotherms for mean maximum and mean minimum January temperatures in the Florida Panhandle (after Fernald 1981).

cooling effect of frequent afternoon thundershowers. Thundershowers occur on approximately half of the days during summer and frequently cause 10 to 20 degree drops in temperature (Bradley 1972).

Winter temperatures are quite variable due to the frequent passage of cold fronts. The colder of these fronts are of Arctic origin and may bring minimum temperatures ranging from 15 to 20 °F with single-digit lows some years. Temperatures rarely remain below freezing during the day and the cold fronts generally last only 2–3 days. Temperatures in the 60's °F and sometimes 70's °F often separate the cold fronts. This weather pattern results in average low temperatures in the mid 40's °F during the coldest months (mid-January through mid-March).

3.2.2 Rainfall

The Florida Panhandle has two peak rainfall periods: a primary one during summer (June– August) and a secondary one during late winter through early spring (February–April). Additionally, there are two periods of low rainfall: a pronounced one during October–November and a lesser one in April–May (Figure 17). Average annual rainfall across the Panhandle is near 152 cm, varying from approximately 163 cm at the west end to about 142 cm at the east end (Figure 18). The dearth of gauging stations in some Panhandle regions may affect the accuracy of the isopleth placements in these figures. The annual rainfall varies widely (Figure 19), and the maximum recorded amount has ranged from 73 cm at Pensacola in 1954 to 284 cm at Wewahitchka in 1966 (Wagner et al. 1984).

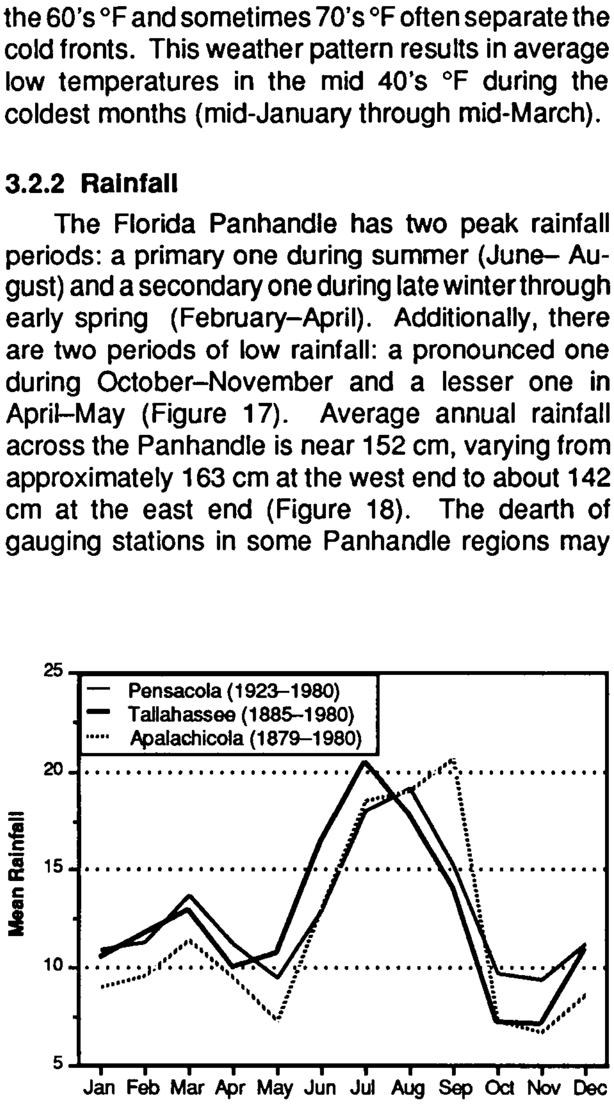


Figure 17. Seasonal rainfall variation at selected sites in Florida Panhandle (data from U.S. Dept. Commerce 1980a,b,c).

During rainy years the maximum rainfall tends to occur near the coast; however, during dry years the rainfall maximum occurs farther inland. Rainfall patterns tend to be more consistent approximately 25–95 km inland (Jordan 1984). Rainfall gradients are quite strong along some portions of the gulf coast; annual totals are as much as 12–25 cm less at stations very near the coastline than at those a few kilometers inland (Jordan 1973).

Studies of the distribution of summer rainfall, based on weather radar observations at Apalachicola and with the results supported by corresponding studies at Tampa, showed that showers within 160 km of the radar installation were nearly as frequent over the sea as over the land when averaged over a 24-hour period (Smith 1970). This and similar studies in south Florida (Frank et al. 1967) found high numbers of showers over land in the afternoon and low numbers in the early morning. They found a minimum number over the sea in the afternoon and a maximum during late night and early morning, especially within 50 km of the coast.

When interpreting the rainfall data, it is important to note that the start and end of the rainy seasons may vary by 6 or 7 weeks from year to year. As seen in Table 1, the majority of thunderstorm activity occurs during the summer.

Most of this summer rainfall occurs in the afternoon in the form of often heavy local showers and thunderstorms of short duration (1–2 hours) that are on rare occasions during the spring accompanied by hail. Summer rain which lasts for longer periods is often associated with occasional tropical disturbances. Winter rains are associated with frontal systems and are generally of longer duration than the summer rains, but are fewer in number and have a slower rate of rainfall accumulation. Hourly data taken at Tallahassee beginning in the 1940's through the 1970's demonstrate the different diurnal patterns of the summer and winter rains (Figure 20). Snowfall

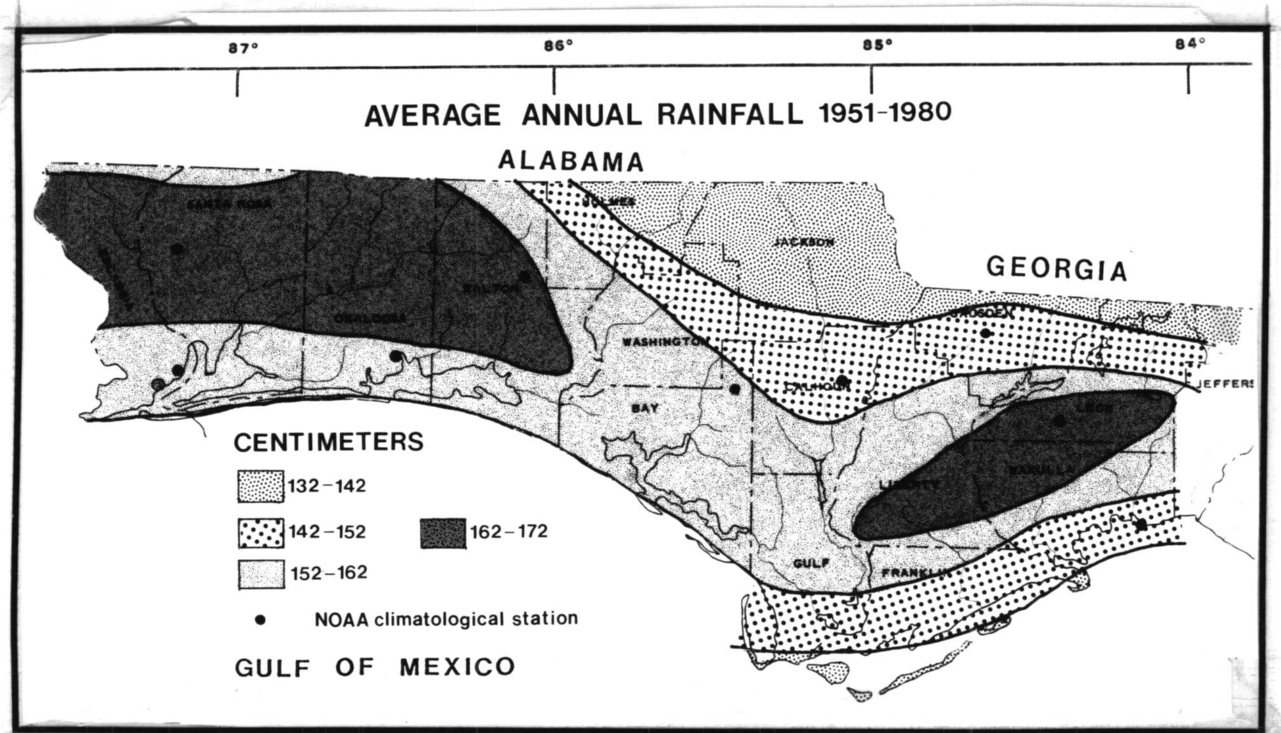


Figure 18. Panhandle average annual rainfall and NOAA climatological station locations (after Jordan 1984).

occurs at rare intervals across the Panhandle, approximately 1 year in 10 for measurable falls, and approximately 1 year in 3 for trace amounts (U.S. Dept. of Commerce 1980a, 1980b, 1980c).

Despite large average annual rainfalls, droughts occur (Figure 21). Even short periods of drought, when combined with the reduced area of lakes and wetlands and the low water table found during generally dry years, can cause extensive crop losses in the agricultural areas, as well as increase damage from forest fires. Fires during extended droughts can cause severe damage even in the longleaf pine areas adapted to seasonal fires and result in the burning of parched wetlands and other habitats normally protected from fire. These areas, not adapted to the normal periodic fires of the pine forest, may recover very slowly (Means and Moler 1979).

3.2.3 Winds

a. Normal wind patterns. From March through September, the Panhandle is under the western portion of the Bermuda high-pressure cell, which has a general clockwise (anticyclonic) circulation of the low-level winds (i.e., those measured at an altitude of 600–900 m) (Atkinson and Sadler 1970) (Figure 22). The latitude at which the wind shifts from out of the southeast to out of the southwest (the "ridgeline"—shown by the dashed lines in Figure 22) changes substantially during spring and summer. During October through February, a western anticyclonic cell separates from the Bermuda anticyclone and establishes itself in the Gulf of Mexico (Figure 22). The center of the cell migrates somewhat as indicated by the **X**'s, but generally results in low-level winds from a westerly direction over the Panhandle.

These circulatory patterns indicate that the Panhandle is primarily influenced by tropical air masses in the spring and summer and by continental (cold) air masses during the fall and winter. The prevailing winds in the Florida Panhandle are from a southerly direction during the spring and summer (Figure 23). Locally, wind directions may be determined by

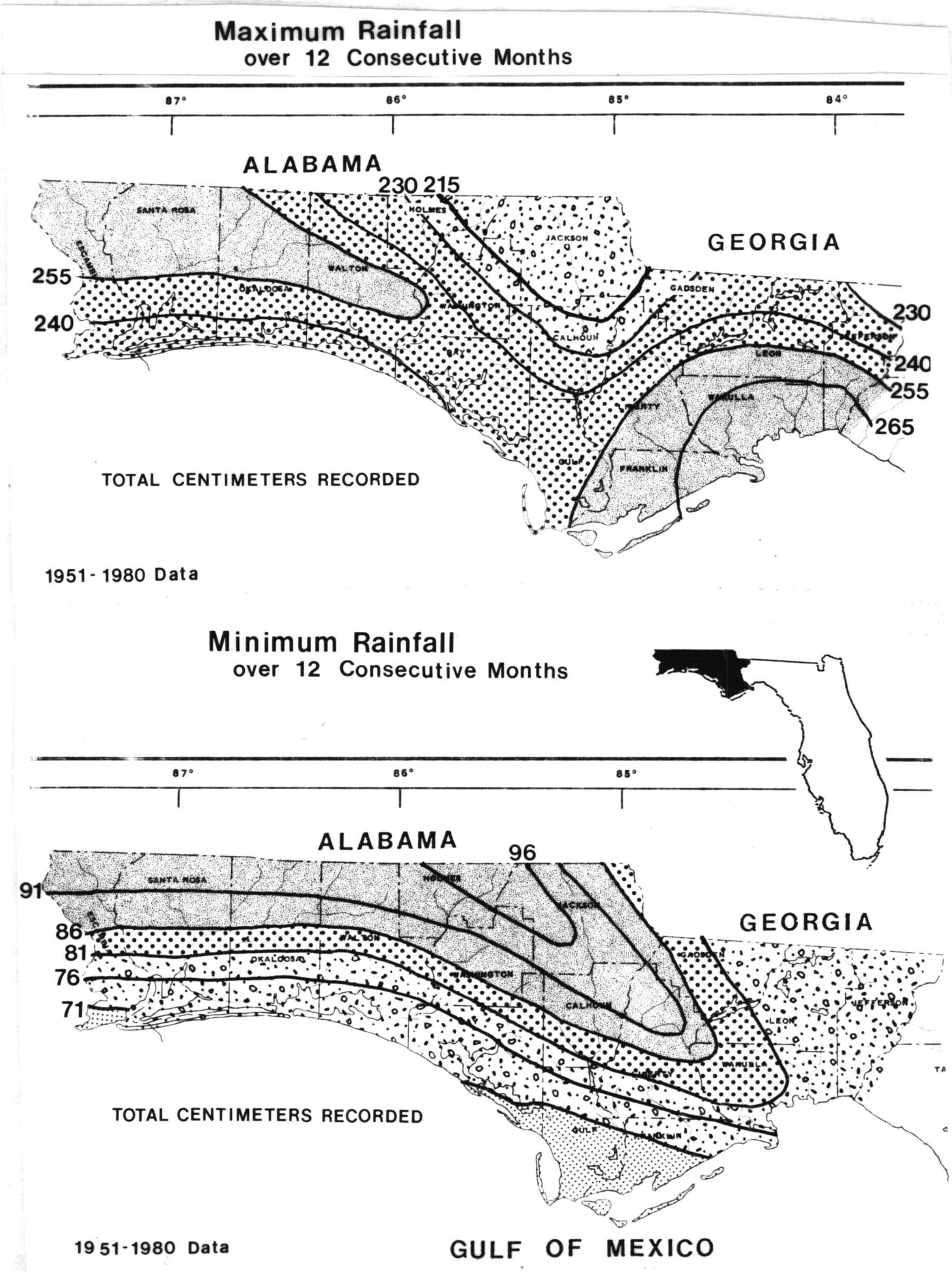


Figure 19. Panhandle maximum and minimum 12-month rainfall (after Jordan 1984).

Table 1. Panhandle thunderstorm frequency statistics (Jordan 1973).

	Mean annual days with thunderstorms	Percent of thunderstorms during June–Sept	Percent of thunderstorms during Nov–Feb
Pensacola	65	65	12
Apalachicola	73	73	7
Tallahassee	79	70	6

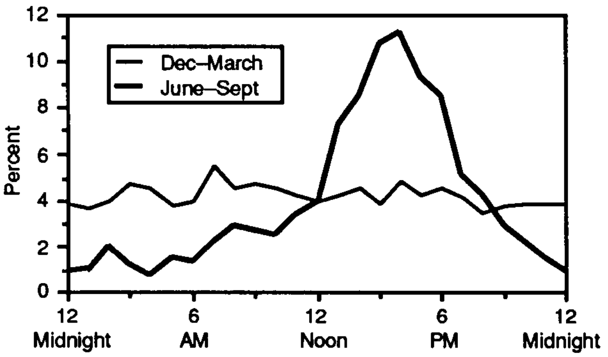


Figure 20. Percent of total daily rainfall during individual hours of the day at Tallahassee (after Jordan 1984).

thunderhead formation and thunderstorms. Wind direction changes with the passing of each cold front; most commonly these occur during the fall and winter (September through March). As the front passes through, the wind, which normally blows out of a southerly direction, rapidly changes direction with a clockwise progression ("clocks") through the west, then pauses out of the northwest quadrant for approximately 1–3 days, blowing toward the front receding to the south or southeast. After the front has passed a sufficient distance to allow the "normal" wind patterns to reassert themselves, the wind finishes clocking through the east and back to the south. The directional orientation of the front and the direction from which the wind blows immediately following its passage depends upon the origin of the front; the winds are from the north for fronts of Arctic and Canadian origin, from the west to northwest for those of Pacific origin.

This cycle is sometimes interrupted by the approach of a new cold front closely following the first.

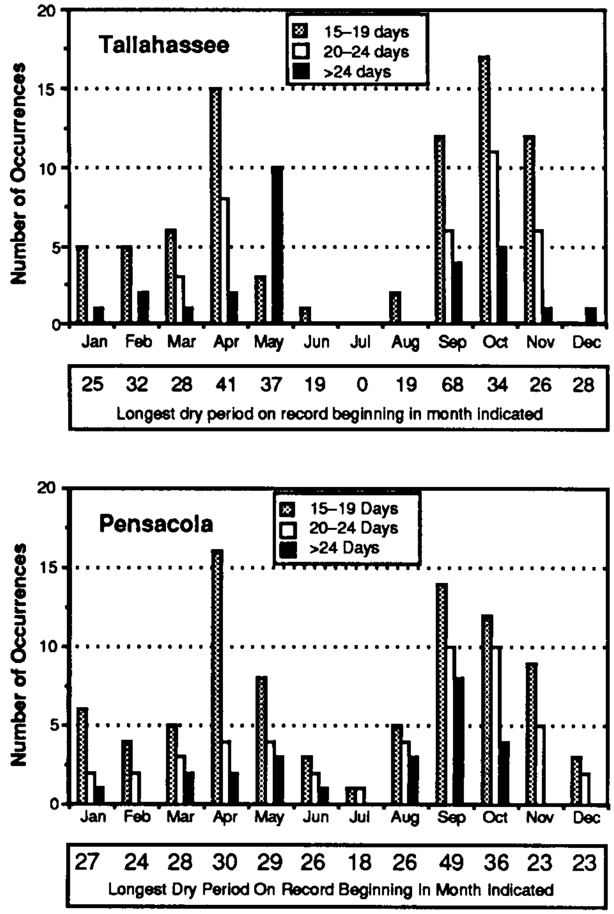
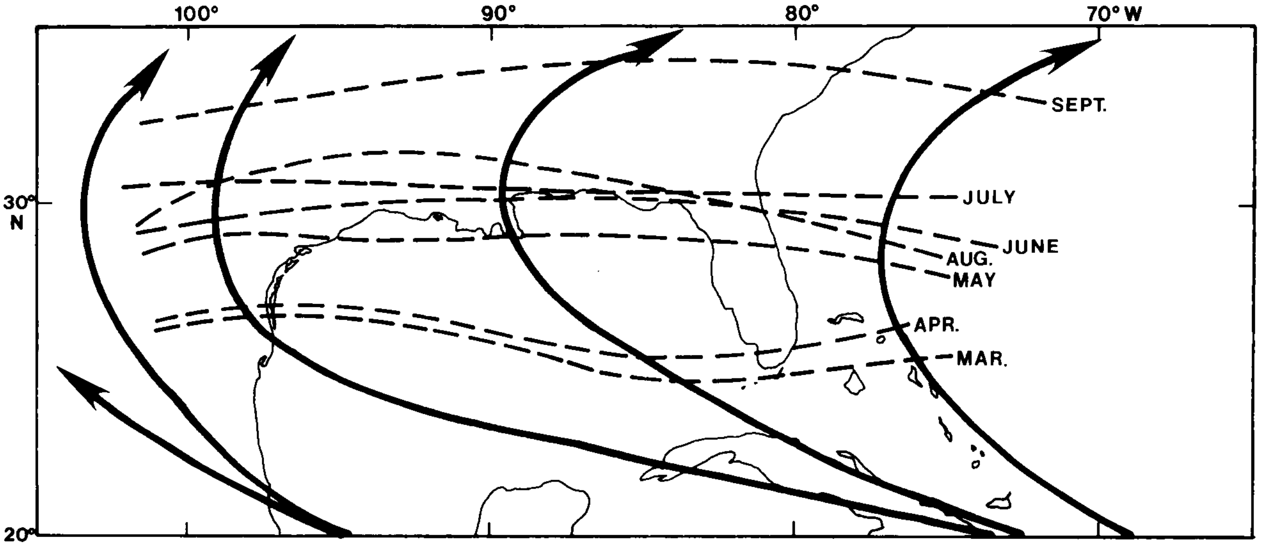
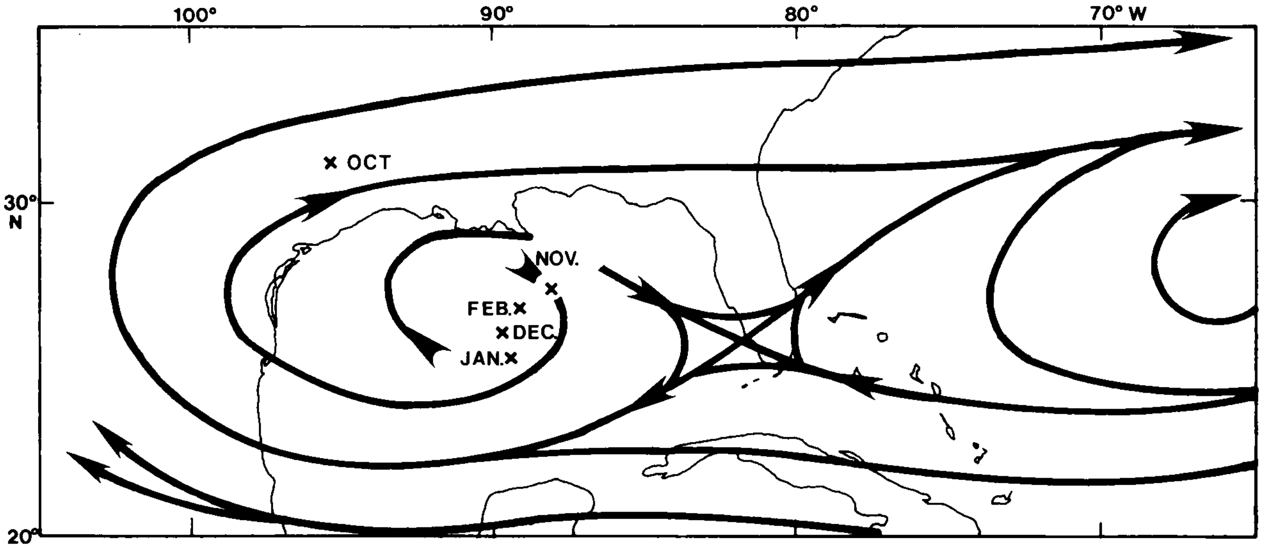


Figure 21. Occurrence of extended dry periods at Tallahassee and Pensacola, 1950–80 [no day over 0.25 cm] (after Jordan 1984).

As a result, the most prevalent winds during September through February (the season of frontal passages) are out of the northern half of the compass



March–September

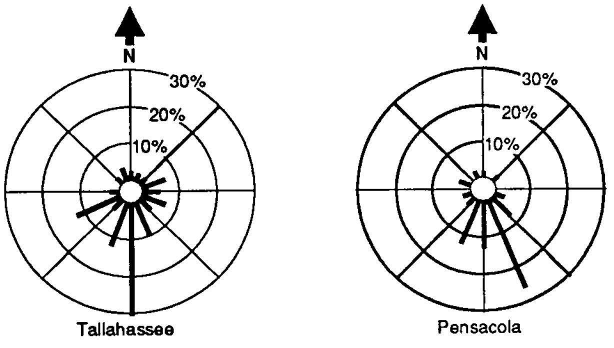


October–February

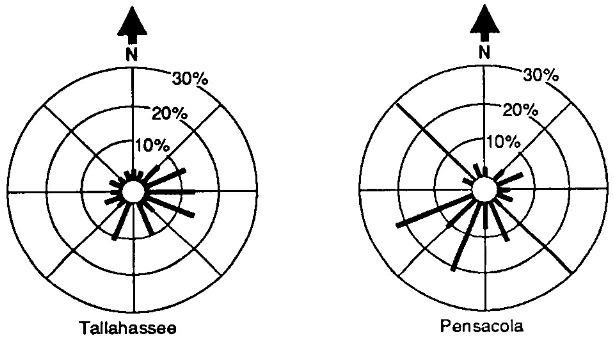
Figure 22. Low-level (600–900 m) winds (from Atkinson and Sadler 1970).

(following the fronts) with less frequent and weaker winds from the southern half of the compass (before the fronts) (Figure 24). The annual average resultant wind (i.e., the vector sum of the monthly wind speed and direction) in the Panhandle is from the north. This is due to the greater wind speeds that follow the winter fronts than blow during the rest of the year. All of these wind patterns are somewhat erratic due to convective forces inland and because of the resulting land- and sea-breeze mechanism near the coast.

The mean monthly wind strength is less in summer months than during the fall, winter, and spring (Figure 25). Since data for Pensacola were unavailable, those for Mobile are included in the figure. Inland stations exhibit somewhat lower

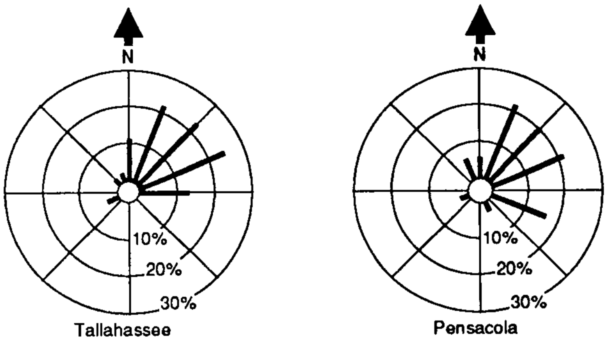


Spring (March–May)

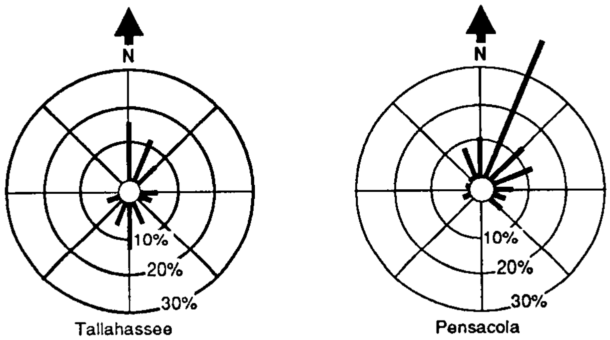


Summer (June–August)

Figure 23. Percentage of time wind blew from different directions in Panhandle during spring and summer, 1959–79 average (after Fernald 1981).



Fall (September–November)



Winter (December–February)

Figure 24. Percentage of time wind blew from different directions in Panhandle during fall and winter, 1959–79 average (after Fernald 1981).

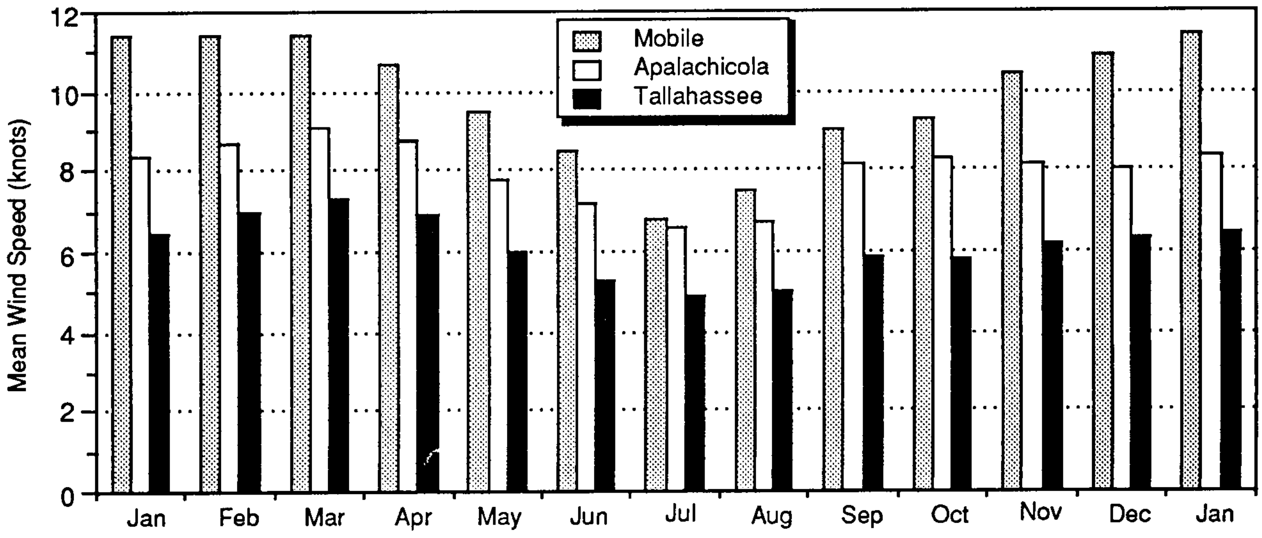


Figure 25. Seasonal windspeed at sites in and near the Florida Panhandle (after Jordan 1973).

average speeds than those along the coast (Jordan 1973). The highest 1-minute sustained wind speed is seldom over 50 km/h, though sustained non-hurricane-associated winds in the 85–95 km/h range have been recorded (Bradley 1972). These peak sustained wind speeds are generally higher at the eastern end of the Panhandle than at the western end (U.S. Dept. of Commerce 1980a, 1980b, 1980c; Fernald 1981).

b. Hurricanes, tornadoes, and waterspouts. Hurricanes pose a major threat to the Florida Panhandle. A hurricane is a cyclonic storm (i.e., the winds rotate counterclockwise in the northern hemisphere) with sustained wind speeds in excess of 120 km/h. Forty-eight hurricanes have come ashore in this region from 1885 to 1985. Figure 26 shows the tracks for hurricanes hitting the Florida Panhandle during this period while Table 2 gives their monthly distribution.

Much of hurricane damage is caused by the local rise in sea level known as storm surge. For hurricanes striking the Panhandle from the gulf, this rise occurs east of the "eye" (the storm's center) as the counterclockwise wind circulation about the eye pushes water ahead and traps it against the coastline. An embayment helps contain this water and can increase storm-surge magnitudes substantially when a hurricane strikes its western side. Tidal stage and phase, bottom topography, coastline configuration, and especially wind strength combine to

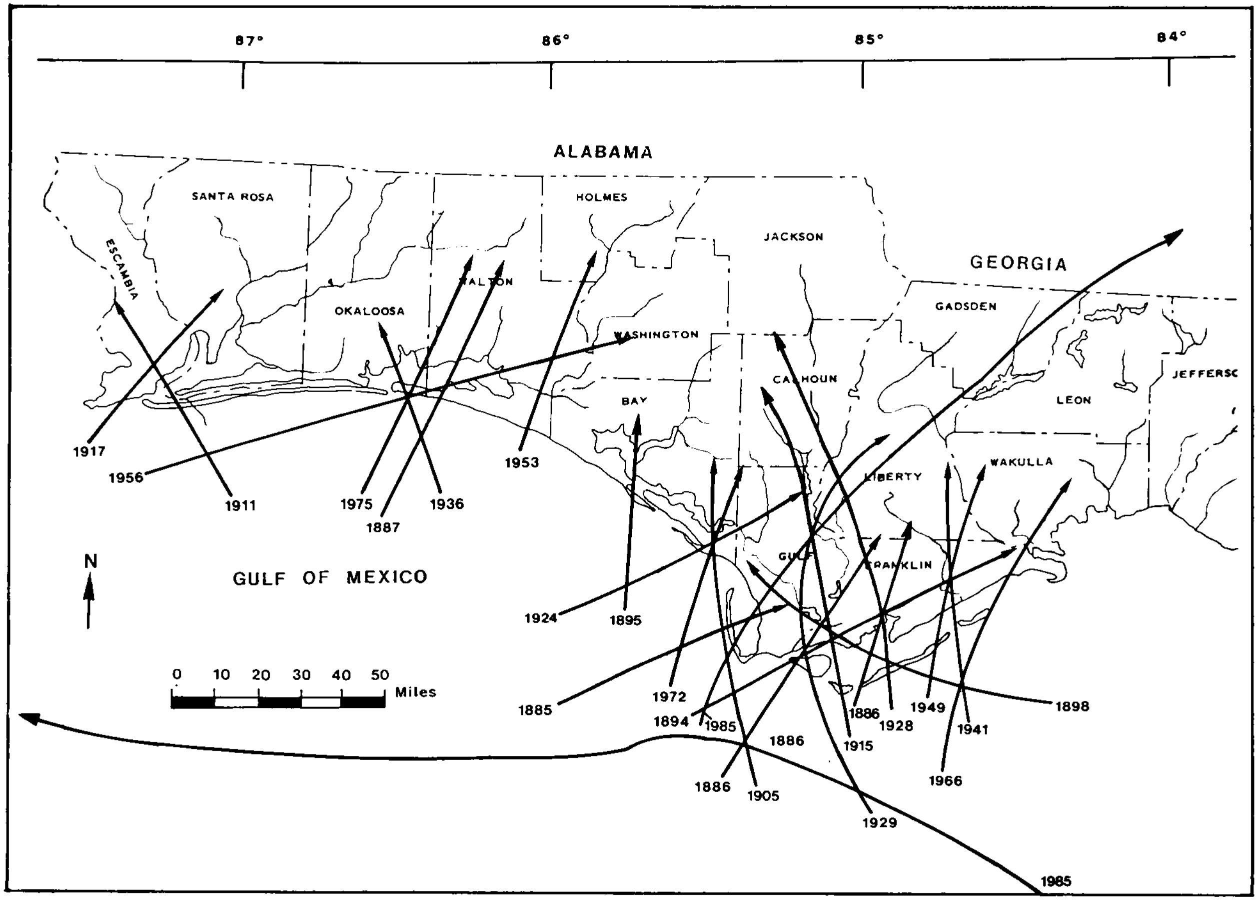


Figure 26. Paths of hurricanes striking the Panhandle coast, 1885–1985 (after Jordan 1984, Case 1985).

Table 2. Total number of hurricanes and tropical storms striking or passing within 150 miles of the Florida Panhandle during 1885-1985 (Jordan 1984, Case 1986).

Jun	Jul	Aug	Sep	Oct	Nov–May	Total
7	5	8	20	6	2	48

determine the storm-surge magnitude. The State of Florida addressed coastal safety, property protection, and beach erosion during hurricanes in Henningsen and Salmon (1981).

Tornadoes and waterspouts form infrequently. They occur most commonly in the spring, associated with frontal weather systems, and in connection with tropical storms and hurricanes. Tornado paths in Florida are usually short, and historically damage has not been extensive. Waterspouts occasionally come ashore but dissipate quickly after reaching land and, therefore, affect very small areas (Bradley 1972).

3.2.4 Insolation

The amount of sunlight, or insolation, reaching the Florida Panhandle directly affects temperature as well as photosynthesis. It indirectly affects processes in which these factors play a role, including weather patterns, rates of chemical reactions (e.g., metabolism), productivity, and evapotranspiration (evaporation and water transpired into the atmosphere by plant foliage). The amount of insolation is controlled by two factors: season and atmospheric screening.

a. Seasonal changes. Seasonal insolation is controlled by five factors: (1) the changing distance between the Sun and Earth as Earth follows its elliptical orbit; (2) the increasing thickness of the atmosphere through which the solar rays must travel to reach the Earth's surface at points north or south of the orbital plane (Figure 27); (3) the reduced density of rays striking an area on Earth's surface north or south of the orbital plane (Figure 28); (4) the changes in cloud cover associated with the progression of the seasons; and (5) seasonally induced changes in atmospheric clarity due to particulates. Factors 2 and 3 are caused by Earth's axial tilt relative to the orbital plane and the resultant change

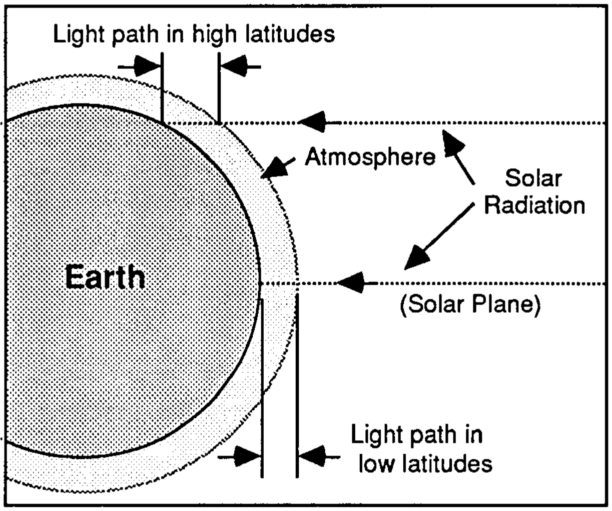


Figure 27. Change in length of atmospheric light path with change in distance above or below orbital plane.

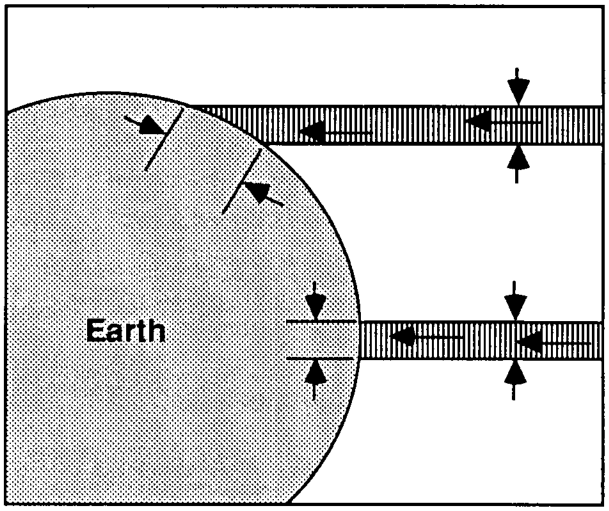


Figure 28. Change in light intensity at Earth's surface with change in distance above or below orbital plane.

in the angle at which solar rays strike a point on the globe during Earth's year-long trip around the sun. This change alters the distance through the atmosphere that the rays must travel and, therefore, changes the percentage of the rays reflected or absorbed by the atmosphere. Factors 4 and 5 are products of seasonal variations in insolation upon circulation of air masses, hence the effects from insolation affect the amount of it reaching the Earth's surface. The concentration of screening particulates in the atmosphere is further affected by seasonal variations in emissions resulting from human activities (e.g., smoke from heating during winter) and by the variations in the speed with which both natural and anthropogenic particulates are removed by rainfall or diluted by atmospheric circulation.

b. Atmospheric screening. Absorption or reflection by water vapor, clouds and atmospheric particulates such as dust and smoke effectively reduce the solar radiation penetrating to the Earth's surface. On a clear day approximately 80% of the solar radiation entering the atmosphere reaches the Earth's surface. About 6% is lost because of scattering and reflection and another 14% from absorption by atmospheric molecules and dust. During cloudy weather another 30%–60% may reflect off the upper surface of the clouds and 5%–20% may be removed by absorption within the clouds. This means that from 0% to 45% may reach Earth's surface (Strahler 1975). Thus it is clear that the single largest factor controlling short term insolation is cloud cover.

The percentage of cloud cover varies seasonally (Figure 29), as do the patterns of cloud cover. The seasonal patterns of cloudiness are controlled primarily by extratropical cyclones and fronts in the winter, and by localized convective weather patterns in the summer. Though the types of clouds and rainfall patterns are different under each of these systems, they result in similar amounts of cloudiness and rainfall in winter and summer in the Panhandle. Daily cloud cover variations are considerably greater in winter than in summer. That is, in summer many days have partial cloud cover while in winter the days tend to be entirely overcast or entirely clear. In south Florida, where winter cyclones and fronts are less frequent, the winter and summer amounts differ greatly.

The maximum insolation striking Earth's atmosphere at the latitude of Panhandle Florida is approximately 925 langleys/day (Strahler 1975). Figure 30 shows the seasonal variation of the daily insolation

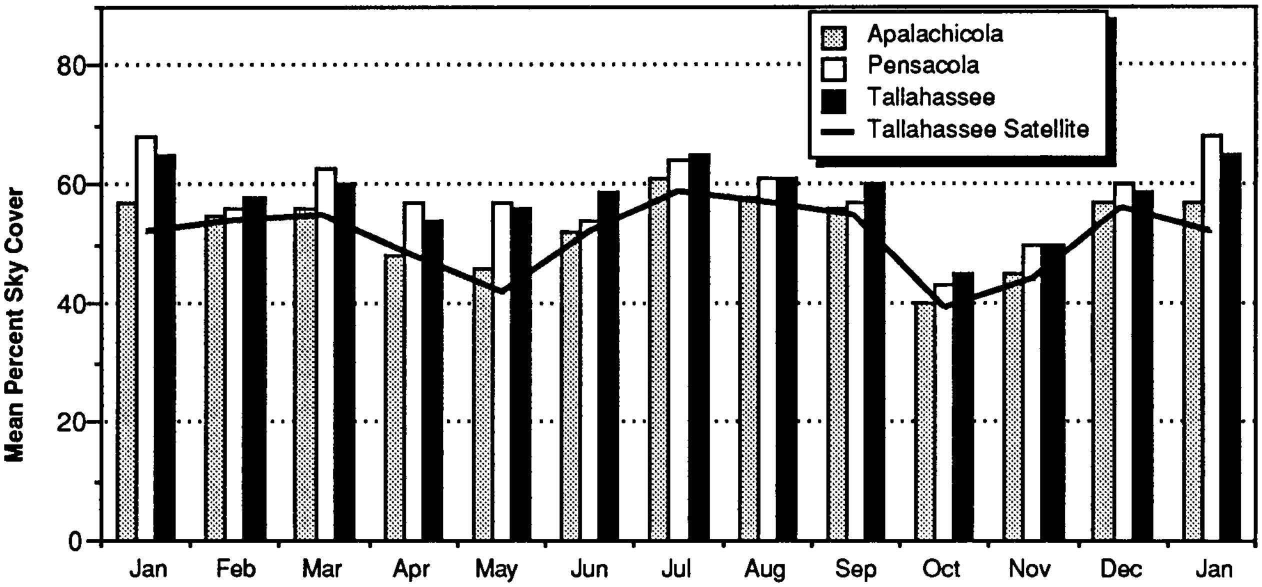


Figure 29. Mean daytime sky cover (data from U.S. Dept. of Commerce 1980a,b,c) and Tallahassee cloud cover from 3 years of satellite data (after Atkinson and Sadler 1970).

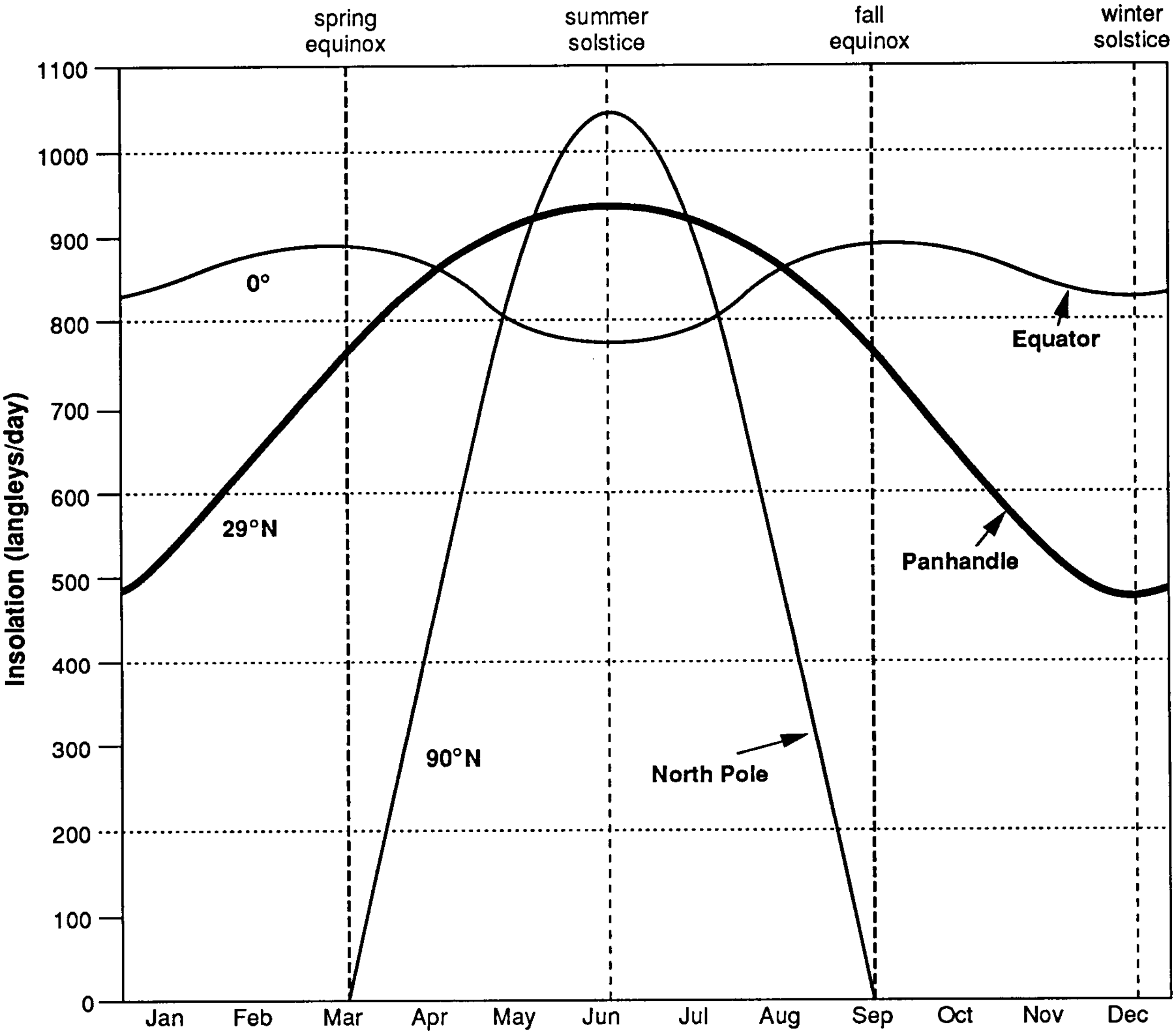


Figure 30. Variations in insolation striking the atmosphere depending on latitude and season (after Strahler 1975).

striking the atmosphere over the Panhandle region. The monthly average of the daily insolation amounts actually received at Tallahassee and Apalachicola are presented in Figure 31. In addition, the percent of possible sunshine measured at Tallahassee and Pensacola is presented in Figure 32.

Atmospheric clarity over the Panhandle is, with the exception of clouds, generally very good. Occasional atmospheric inversions during summer months may result in "haze" as natural and anthropogenic aerosols are trapped near the surface and concentrated, thereby reducing insolation.

3.2.5 Relative Humidity

The Florida Panhandle is an area of high relative humidity. Relative humidity is the amount of water vapor in the air, expressed as a percent of saturation at any given temperature. Air incapable of holding further water vapor (saturated) has a relative humidity of 100%. The amount of water necessary to saturate a volume of air depends upon temperature.

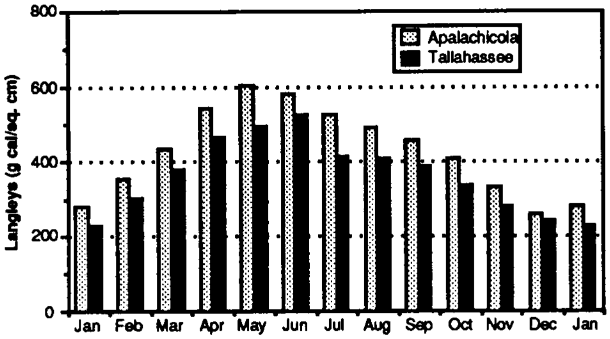


Figure 31. Monthly insolation at selected sites in Florida Panhandle (after Bradley 1972).

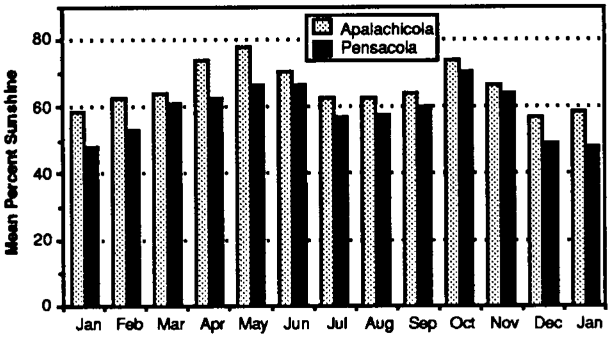


Figure 32. Percent of possible sunshine at selected sites in Panhandle (data from U.S. Dept. of Commerce 1980a,b,c).

Air at a higher temperature is capable of holding more water than that at a lower temperature; therefore, air near saturation will become oversaturated if cooled. This oversaturation can produce dew, precipitation, or, when very near saturation, clouds or fog. In the seasons when prevailing winds bring moist air from the Gulf of Mexico (i.e., spring, summer, fall), humidity is often 85%–95% during the night and early morning, and 50%–65% during the day (Bradley 1972).

High relative humidity can greatly accentuate the discomfort of high summer temperatures. There are several formulas commonly in use (e.g., Temperature Humidity Index, Humidity Stress Index, Humiture) that generate a "comfort" value based upon a combination of temperature and humidity. The afternoon Panhandle climate during June through September is usually well into the uncomfortable zone. These indices are based on the effect of humidity upon evaporation rates. The humid air flowing from the Gulf of Mexico has minimal capacity to hold further moisture. As a result, evaporative drying of wetlands and other water bodies in the Panhandle is minimized, thereby helping to maintain them between rains. Summer rains and slow evaporation also provide ideal conditions for many fungal and bacterial diseases, prominent problems in area farming (Shokes et al. 1982).

Fog is common at night and in the early morning hours as the ability of the cooling air to hold water decreases and the relative humidity rises over 100%. Heavy fogs (visibility ≤ 0.4 km) generally form in the late fall, winter, and early spring. On the average, they occur 35–40 days per year (Bradley 1972). Apalachicola experiences fog on an average of 14% of the days in November through March, and 2% of the days from April through October (Jordan 1973). Fogs usually dissipate soon after sunrise.

3.3 Effects of Climate on Ecosystems

Climate exerts control on the regional ecology through two major mechanisms. The normal climate of the Panhandle establishes the basic conditions under which all species must be able to live and compete if they are to find a niche in the ecosystem. The occasional abnormal or extreme climatic condition may prevent establishment of a species that would otherwise thrive by producing periodic local extinctions or near-extinctions. The rare severe or prolonged freeze, heat wave, drought, or flood may decimate a population so that years or decades are required for its reestablishment.

No clear separation exists between conditions constituting normal and extreme climatic conditions. Regular events which are beyond a species' ability to adapt may reduce what would otherwise be a dominant organism to a minor position in the ecosystem or prevent its establishment altogether. A Panhandle example is the mangrove. A dominant species on Florida's southwest coast, mangroves are represented in the Panhandle by one small colony of black mangrove on the bay side of the eastern end of Dog Island. In conditions otherwise conducive to mangrove growth, the occasional cold winters limit them to this marginal colony. In contrast, an otherwise minor organism may be dominant through its ability to survive the climatic extreme and thereby outcompete ecological rivals. Relatively small changes in the "normal" extremes of climate may produce effects on ecosystem composition as large as those produced by changes in the average climate. An example might be a situation where a slow-growing and reproducing shrub species and a fast-growing and reproducing shrub species compete for space in a forest clearing commonly visited by foraging wild pigs. All other factors being equal, the slow-growing species might dominate, even though it would be very slow to recolonize areas where it was dug up by the pigs, because it could better tolerate the annual dry summers. An increase in the normal summer rainfall (a change in the "average climate") might lead to dominance of the fast-growing species. The same effect might result, however, if the area began to experience previously unknown hard freezes during occasional winters (a change in the climatic extremes), and the slow-growing species was killed by freezes while the fast-growing species was freeze tolerant. Either change will have the greatest effect upon those organisms living near their limits of tolerance.

3.4 Major Influences on Climate

3.4.1 Natural Influences on Climate

a. Long-term influences on climate. Long-term changes (over thousands to millions of years) in worldwide climate are primarily a function of changes in the concentration of atmospheric carbon dioxide (CO_2) (Revelle 1982). Carbon dioxide traps incoming solar radiation (Hansen et al. 1981). This effect is commonly known as the "greenhouse effect." The resulting temperature increase allows the atmosphere to hold more water vapor, itself an effective greenhouse gas, which accentuates the warming. Other gases (e.g., methane, nitrous oxide, chlorofluorocarbons) act similarly, but their effects are generally subordinate to those of CO_2 because of their relatively low concentrations. The Sun "drives" Earth's climate since the wind and rain systems, as well as the temperature regime, are products of varying insolation.

b. Short-term influences on climate. Short-term (up to hundreds of years) natural fluctuations in climate are generally caused by changes in insolation screening. The concentration of natural atmospheric particles results from the balance between input from wind scouring (particularly of desert and other arid regions), volcanic dust output, smoke from forest fires and volcanoes, and removal by gravitational settling and atmospheric scrubbing during rainfall.

The Panhandle, along with the rest of the northern temperate lands, has experienced an approximately 0.1 °C reduction in average temperature over the last decade despite an increasing greenhouse effect worldwide. It is probable that this is the result of: (1) the screening of insolation at these latitudes by increased atmospheric smoke and dust from recent increased volcanic activity and/or dust from the expanding Sahara desert and drought areas in North Africa, and /or (2) variation in the Sun's output (Hoffman et al. 1983). These variations are historically common and Titus and Barth (1984) concluded that they were incapable of overwhelming the overall greenhouse effect.

Periodic changes in climate and weather affecting the Panhandle have recently been tied to the phenomenon known as El Niño. Though all the parameters of cause and effect are not yet understood, a major current off the coast of Peru, which drives the upwelling responsible for one of the world's largest fisheries, apparently moves well offshore and weakens because of changes in the wind patterns driving it. Changes in equatorial wind patterns which either cause the shift in water currents or are caused by the shift (which factors are cause and which are effect are not yet understood) affect worldwide climate by altering patterns of rain, temperature, and wind. The Panhandle may have just recovered from a period of weather in the early 1980's influenced by an exceptionally strong El Niño. The hotter and drier summers and warmer winters followed by a rebound period of spring flooding, heavy summer rainfall, and colder winters that have been experienced in the Panhandle and other unusual weather patterns worldwide have been tentatively identified as indirect effects of El Niño.

Another mechanism controlling short-term climate changes as well as being involved in long-term variations is albedo, or the reflectance of a surface. The higher the albedo, the more incoming radiation is reflected and can pass through the "greenhouse" gases and out of the atmosphere. The lower the albedo, the more radiation is absorbed, reradiated as heat and trapped in the atmosphere. Snow and ice have a very high albedo; i.e., they are efficient reflectors of solar energy (45%–85%). Bare ground, fields and forests have intermediate albedos ranging from 3%–25%. Unlike land, the oceans (and water in general) have a variable albedo; very low (2%) for radiation striking from low angles of incidence (i.e., with the sun high in the sky), but high for that striking from high angles (i.e., with the sun low on the horizon). This is caused by the growing proportion of the light that is transmitted into the water at decreasing angles of incidence. Thus the equatorial seas at midday are good absorbers of solar energy, but the arctic seas are not. The significance of this in the Panhandle is that coastal waters receive more heating through insolation in summer, not only because of the increase in sunlit hours from the longer day, but also from an even greater increase of the time the radiation strikes from high angles. Other local effects of albedo differences are common, as anyone who has stood on an asphalt parking lot on a clear summer day can attest.

Another difference between the effects of insolation on land and water is caused by the difference in the specific heat of dry soil or rock and that of water. Water requires nearly five times as much heat energy as does rock to raise its temperature the same amount. This, coupled with the increased evaporative cooling found at the surface of water bodies, explains the more extreme diurnal and seasonal temperature regimens found over land as compared to that over or near large bodies of water.

3.4.2 Anthropogenic Influences

Human activities increasingly influence climate, although the line dividing natural and anthropogenic influences is not always clear. Global warming due to changes in the atmospheric greenhouse effect is one of the most notable results of human activities (Hansen et al. 1981, Weiss et al. 1981, Broecker and Peng 1982, Edmonds and Reilly 1982). This change is primarily a result of increasing concentrations of atmospheric carbon dioxide from combustion of fossil fuels as well as from the logging of enormous areas of forest, with the resultant release of CO_2 through the burning or decomposition of the carbon bound up in the organic matter (Charney 1979); of atmospheric methane (Rasmussen and Khalil 1981a, 1981b, Kerr 1984); of atmospheric nitrous oxides (Donner and Ramanathan 1980); and of chlorofluorocarbons (Ramanathan 1975). There was a 9% increase in atmospheric carbon dioxide between 1958 and 1985 (Figure 33).

A conference was held in 1982 in response to articles in popular literature (Boyle and Mechum 1982) concerning a theory ascribing recently reduced rainfall and increased temperature in south Florida to reduced albedo and evapotranspiration resulting from the draining of area wetlands. The results of this conference are summarized in Gannon (1982). Though evapotranspiration from land masses may account for only 5% of the precipitation in south Florida (the bulk arriving with air masses from over the Atlantic), evapotranspiration increases the buoyancy of the continental air masses. It is probable that this increases mass convergence, bringing in more moisture from the adjacent oceans and acts as a trigger to increase convection and, therefore, the convection-induced rains. Rainfall of this nature is found year round but is especially common in summer. A 70 inch rainfall deficit which accumulated between 1962 and 1982 along the St. Johns River in northeast Florida has also been attributed to the draining by 1972 of approximately 72% of the once vast wetlands through which the river flowed (Barada 1982). If this relationship between evapotranspiration and rainfall is confirmed, a similar mechanism probably exists in the Panhandle, where similar patterns of convective rainfall are found. Future development which reduces wetland and vegetated areas might induce similar reductions in summer rainfall.

Short-term cooling trends have been attributed to insolation screening by dust, smoke, and debris thrown into the upper atmosphere by large volcanic eruptions such as Krakatoa in 1883 (Humphries 1940) and Mount St. Helens in 1980 (Searc and Kelly

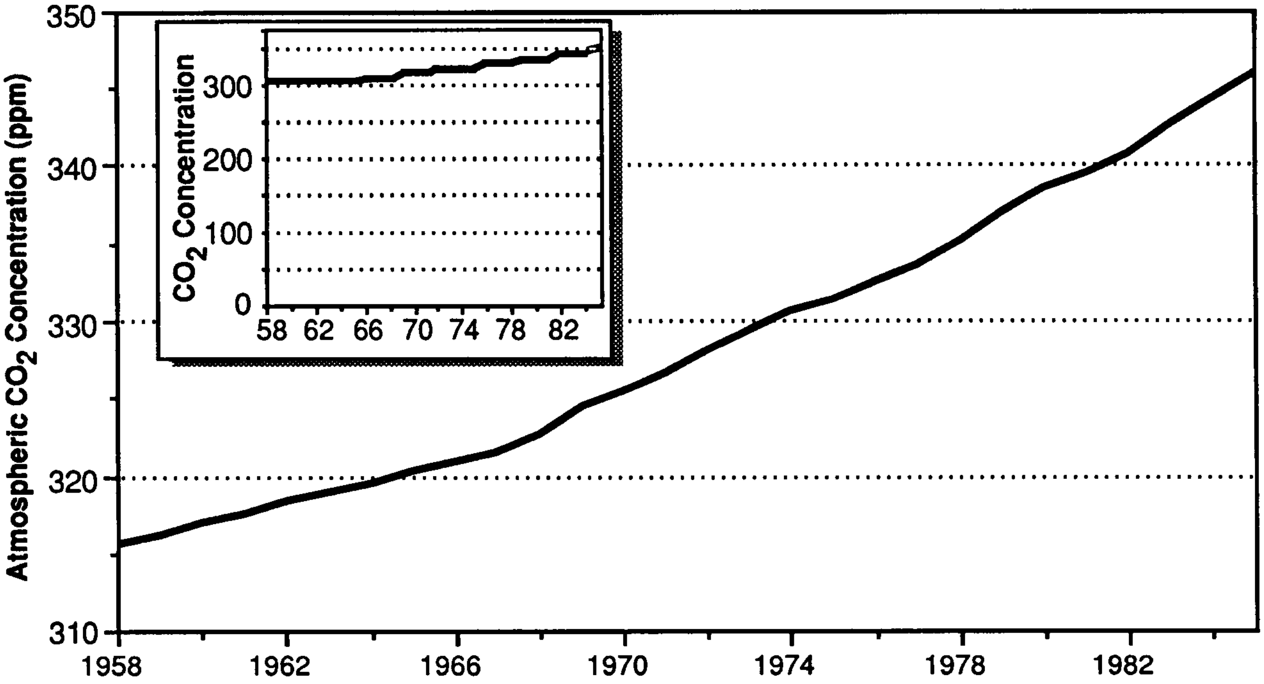


Figure 33. Increasing atmospheric carbon dioxide as measured atop Mauna Loa, Hawaii (data from Charles Keeling, Scripps Inst. of Oceanography).

1980). Smaller eruptions have a weaker cooling effect. It is thought that this short-term cooling may be partially masking the long-term global warming caused by increasing concentrations of atmospheric CO_2 (Bell 1980).

3.5 Summary of Climatic Concerns

The Florida Panhandle has three present and near-future climatological concerns. Two of these result from the present global warming trend. While all effects of this warming are not predictable with our present understanding of the ecosystem, certain effects in the Panhandle are probable. A major impact resulting from global warming is a predicted substantial rise in sea level, significant effects of which are expected within 25 years. This impact is discussed more fully in section 4.8. The second concern relating to atmospheric warming is a probable change in weather patterns. A possible 5 °F increase in the mean global temperature by the latter part of the next century is projected to yield a similar increase in mean Panhandle temperature and a few percent increase in local precipitation (Revelle 1982, National Research Council 1983). The present understanding of meteorology is not, however, sufficient to permit reliable prediction of these changes. This is particularly true of climate changes over a relatively small area the size of the Panhandle.

A final climatic concern for the future is the possibility of reduced summer (convective) rainfall. Unlike the previous two problems, the causes have not yet been widely initiated and are preventable. Convective summer thundershowers provide the majority of summer rainfall. Summer rains, in turn, supply the majority of the total annual rainfall (Figure 17). The convective mechanism causing these rains is similar to that found in south and east Florida. Since the "rain machine" in these regions may have been weakened by extensive wetland draining, it is possible that future terrain alteration in the Panhandle—including drainage and development of large wetland areas—could cause a similar effect.

Predicting the occurrence and effect of climate changes is very difficult since the understanding of the meteorological and oceanographic systems that provide climatic feedback and checks-and-balances is incomplete. With these constraints, even the sea level predictions, which are based on an intensive program of study, include necessarily wide margins for error. Unexpected or unexpectedly strong feedback mechanisms may exist to damp the warming trend. One possible example of such feedback is that the increase in size taking place in our deserts (especially the Sahara) may be a result of global warming; however, the increased dust blown into the atmosphere from the larger desert area may be increasing insolation screening and therefore tending to reduce that warming. The possible existence and "strength" of similar feedback mechanisms make accurate prediction of future climate difficult; however, the National Academy of Sciences (Charney 1979) was unable to find any overlooked physical effect that could reduce the estimated temperature increase to negligible proportions. The accuracy of the predictions is increasing through research into the major climatic factors.

3.6 Areas Needing Research

Research on numerous aspects of the Panhandle climate is needed concerning questions which, of course, affect much wider areas, but are applicable to this area. Research is especially needed on the changing greenhouse effect; the effects of increasing world-wide average temperatures on area climate; the mechanisms controlling coastal convective rainfall; and rates of evapotranspiration and their connection to rainfall and runoff.

Chapter 4. HYDROLOGY AND WATER QUALITY

4.1 Introduction

Water quality is, in many ways, dependent on hydrology and frequently the forces affecting one also affect the other. This chapter will discuss each of these areas, their interrelationships, and their status in the Florida Panhandle. An excellent source of general information on the water resources of the Panhandle and all of Florida is the *Water Resources Atlas of Florida* (Fernald and Patton 1984). The *Hydrologic Almanac of Florida* (Heath and Conover 1981) has very good discussions of different hydrologic and water quality factors as well as containing good, if occasionally dated, records on Florida.

Panhandle surface water supplies and its ground water supplies are normally inseparable. In many places water flows from the surface into the ground and back again many times as it makes its way to the coast. Any changes in the hydrology or the quality of one is likely to affect the other. The entire supply of potable ground water in Florida floats on deeper layers of saline ground water that are connected with the Atlantic Ocean and the Gulf of Mexico. This layer of fresh water floats because it is ~2.5% less dense than the salt water. As water is removed from the fresh-water aquifer, the underlying salt water tends to push the upper surface of the fresh-water aquifer higher as the aquifer gets lighter. As a result, "permanently" lowering the upper surface of the freshwater aquifer by 1 ft over a broad area requires withdrawing a volume of water equal to nearly 40 ft of the aquifer thickness. Thus, simplistically, for every foot our pumping of the fresh-water aquifers lowers the upper surface and is not replaced in a reasonable period of time by rainwater, the deeper saline layers rise 40 ft. The Florida Panhandle, and all of Florida, has tremendous volumes of fresh water stored beneath the ground; however, it cannot be used at a rate greater than the average rate at which it is replaced by rainfall. Otherwise, saltwater intrusion will render the coastal wells useless because the depth to the underlying saline layer is much less near the oceans.

4.1.1 Hydrology

Hydrology is the study of the water cycle, including atmospheric, surface, and ground waters. The basic hydrologic cycle (Figure 34) includes water vapor entering the atmosphere as a result of evaporation, transpiration, and sublimation. This vapor condenses to form fog, clouds, and, eventually, precipitation. In the Florida Panhandle precipitation normally reaches the ground in the form of rain. Snow and hail occur infrequently. Upon reaching the ground, the water either evaporates, soaks into the soil and thence into the groundwater system, or (if the ground is saturated or the rate of rainfall exceeds the ground's ability to absorb it) runs off or pools, forming streams, rivers, lakes and other wetlands.

The fundamental organizational unit of surface hydrology is the drainage basin. In its most basic form, a drainage basin, or watershed, consists of that area which drains surface runoff to a given point. Thus the mouth of a river has a drainage basin that includes the basins of its tributaries. The drainage areas discussed in this document are based upon the basins described by the U.S. Geological Survey (Conover and Leach 1975) (Figure 35). Most of these consist of the Florida portion of the drainage basin of a single coastal river. A large portion of many of these basins actually extends well into Georgia and Alabama (Figure 36). Some, however, represent coastal drainage areas where lands drain to coastal streams and marshes on a broad front rather than to a single discharge point.

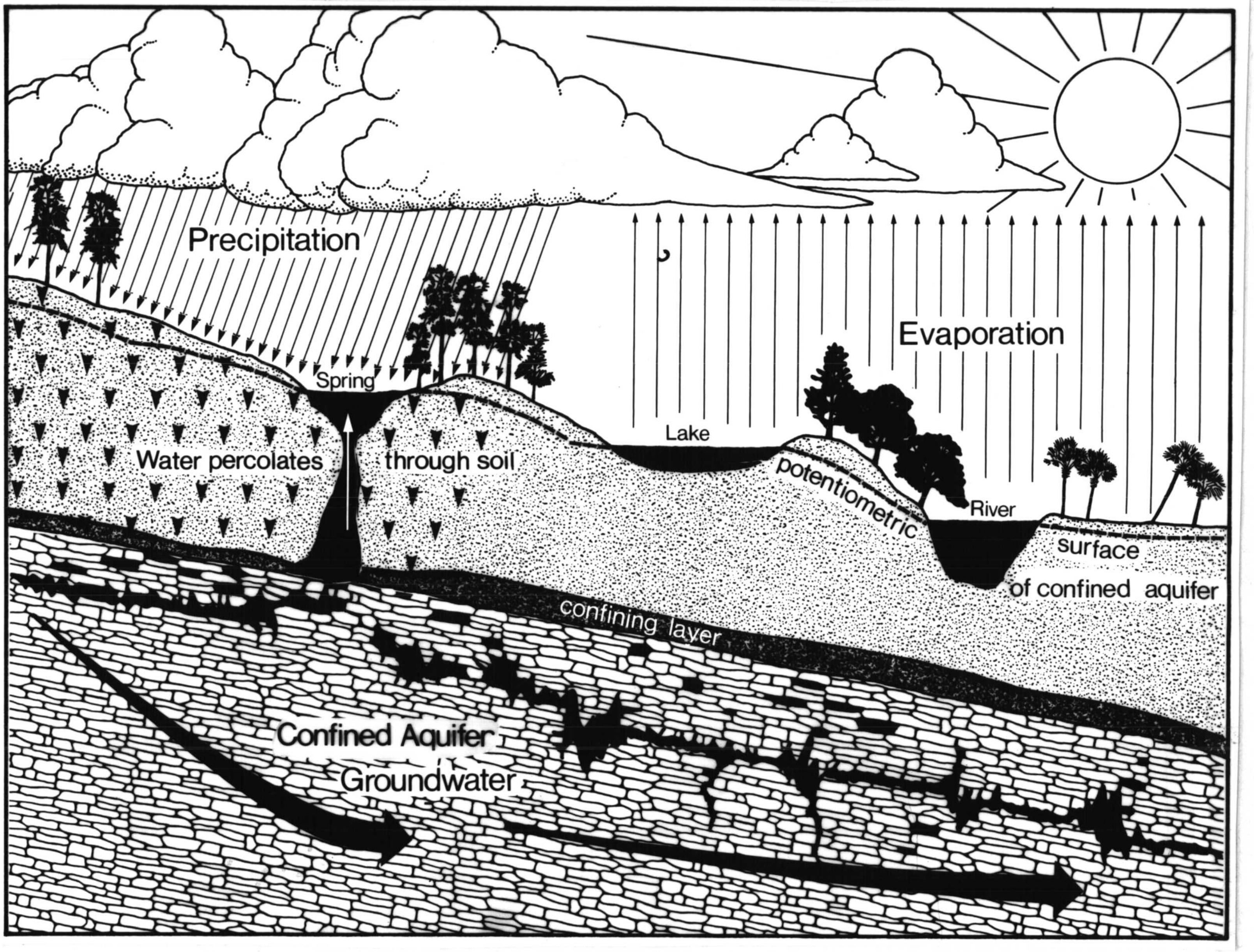


Figure 34. The basic hydrologic cycle.

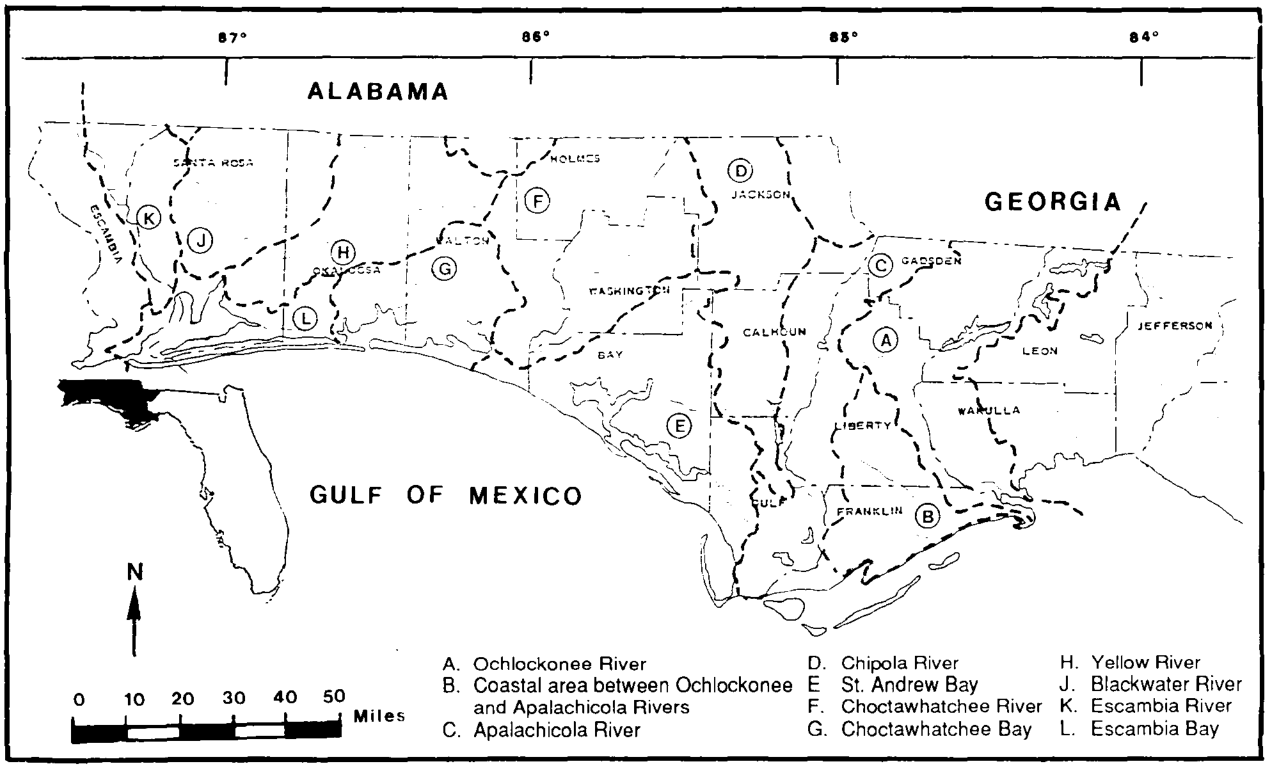


Figure 35. Panhandle drainage basins discussed in this document (after Conover and Leach 1975).

Ground water in the Florida Panhandle is contained primarily within two overlapping reservoirs: the Floridan aquifer underlying the entire Panhandle; and the Sand and Gravel aquifer which overlies the Floridan west from Okaloosa County (Figure 37). A shallow surficial aquifer is found overlying the Floridan aquifer in many parts of the eastern Panhandle (Figure 38).

Panhandle aquifers are recharged by five means: (1) drainage of surface runoff into areas where the aquifer is unconfined (i.e., not overlain with a low-permeability stratum) and located at or near the ground surface; (2) drainage of surface runoff into sinkholes and other natural breaches into the aquifer; (3) percolation of rainfall and surface water through the upper confining beds; (4) percolation through the confining layers of water from aquifers overlying or underlying the one in question but with a greater potentiometric surface ("pressure"); and (5) lateral transport from areas within the aquifer with a higher potentiometric surface (Figure 39). Areas within the Panhandle recharging the Floridan aquifer are presented in Figure 40.

4.1.2 Water Quality

The availability of water has always been an important factor in selection of sites for human activities. The primary concern of the past—securing needed quantities of water—has, in recent years, increasingly been replaced by concerns about the quality of that water. Water quality affects people directly by influencing water's suitability for drinking, cooking, bathing and recreation, and indirectly by its effect upon the ecosystem within which humanity exists. Factors affecting water quality include the physical makeup of the local ecosystem (e.g., the presence of limestone generally prevents acidic water), seasonal changes in that ecosystem, direct discharges from human sources, and indirect discharges from human sources (e.g., acid rain).

Society judges water quality based upon its usefulness to people and those animals and plants

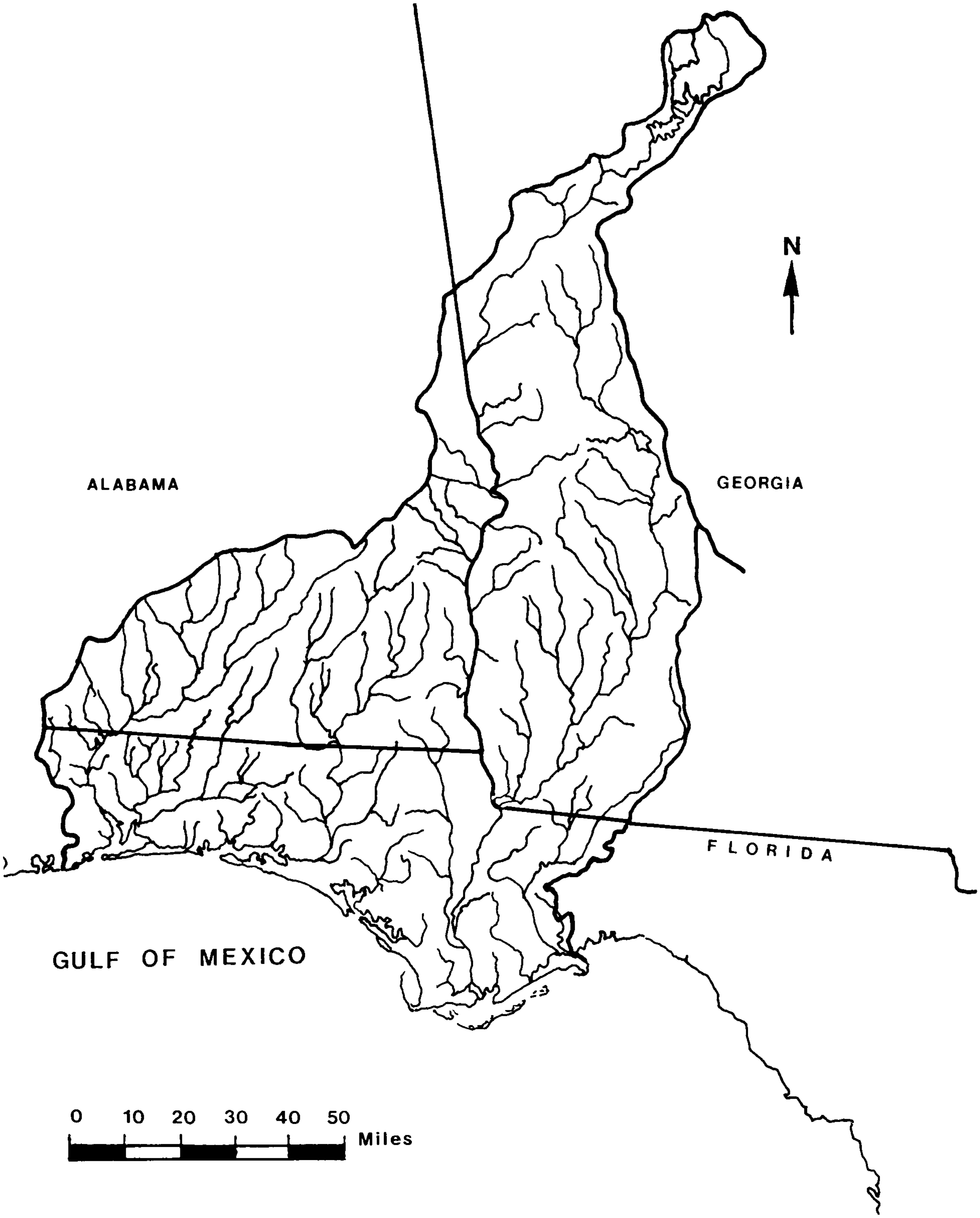


Figure 36. Out of state drainage basins of Panhandle rivers (after Palmer 1984).

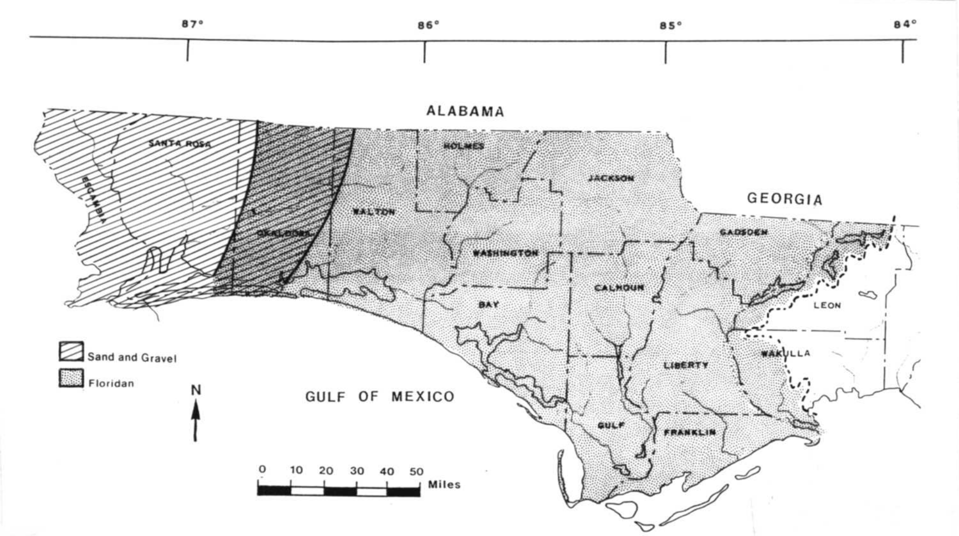


Figure 37. Primary Panhandle aquifers used as water sources (after Hyde 1975).

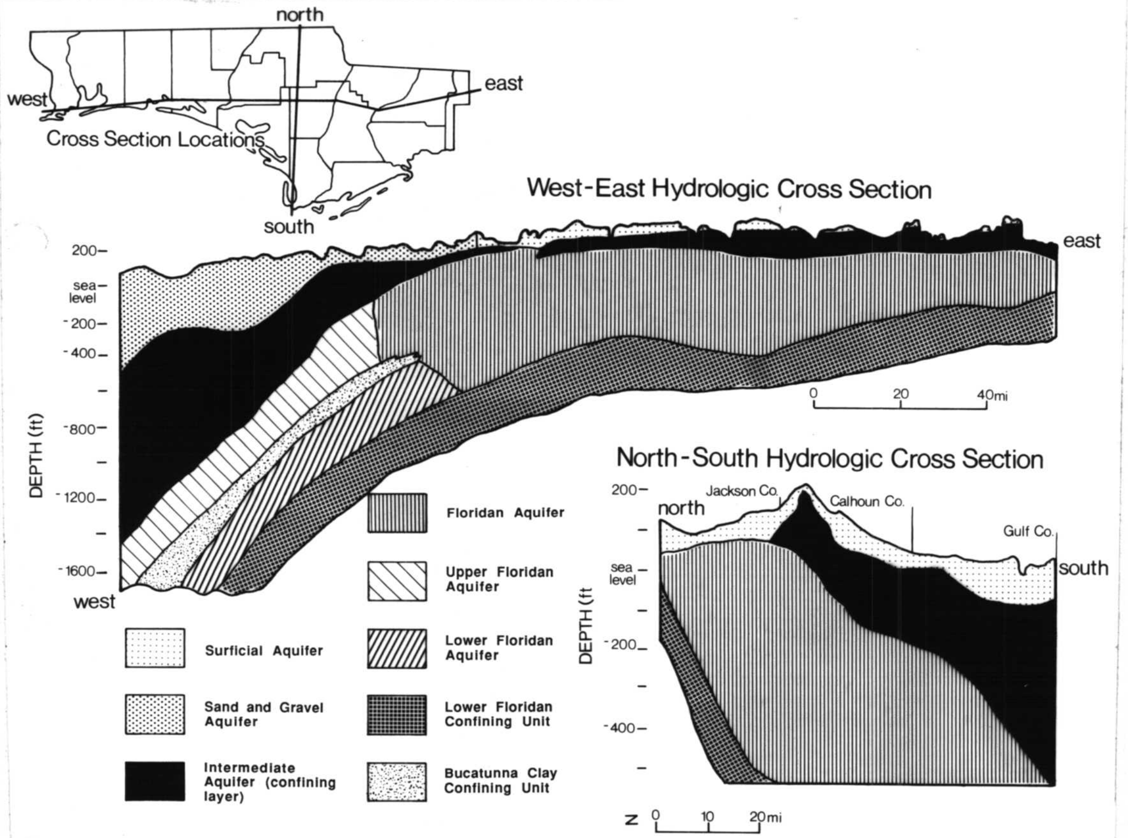


Figure 38. Hydrologic cross sections of the Panhandle (after Wagner et al. 1984).

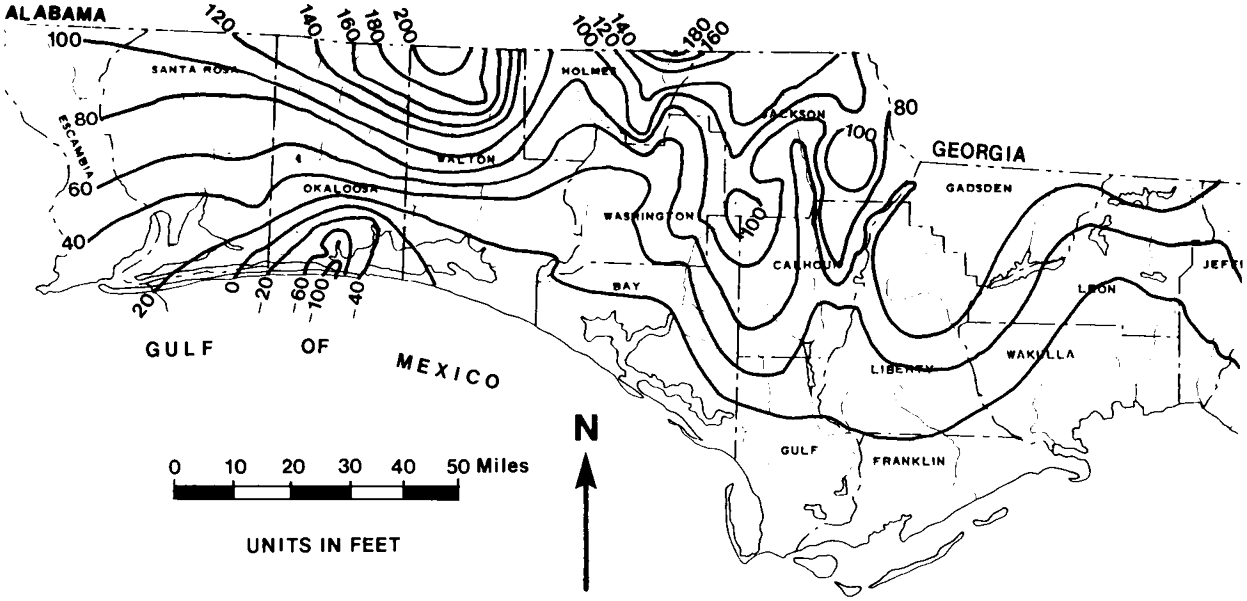
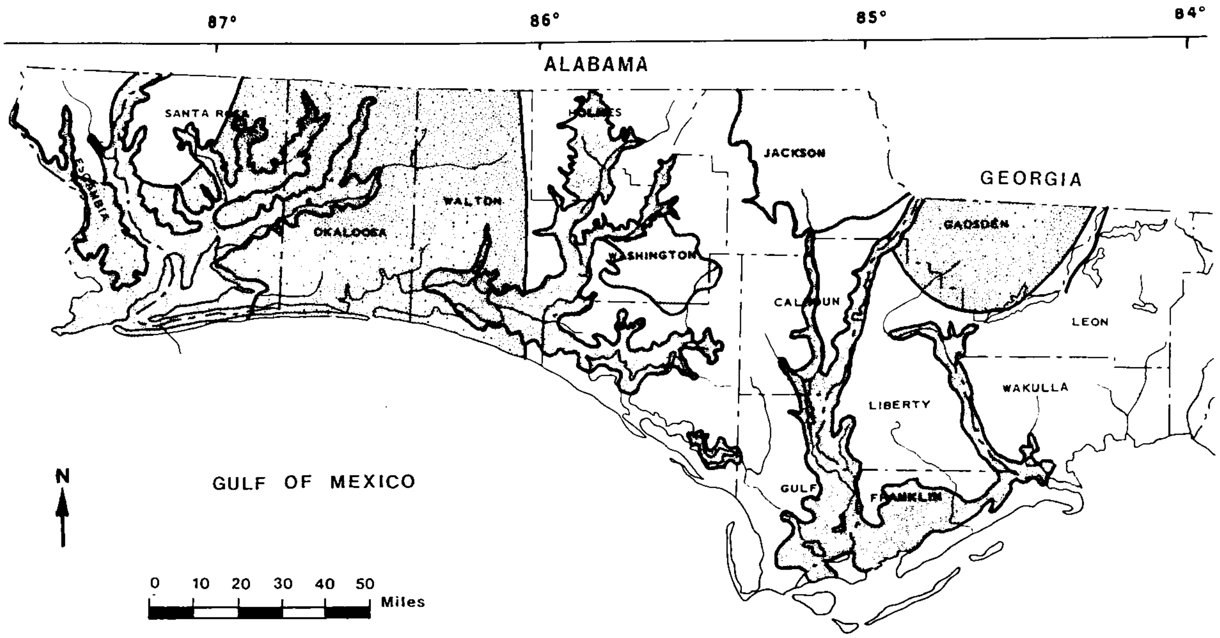


Figure 39. Potentiometric surface of the Floridan aquifer in the Panhandle in May, 1980 (after Healy 1982).



▒ **Generally No Recharge** Natural discharge areas. Heavy pumpage may reverse gradient and induce limited local recharge.

░ **Known Very Low Recharge** Floridan known to be overlain by relatively impermeable and unbreached confining beds.

▓ **Very Low to Moderate Recharge** Floridan overlain by thinner or breached confining beds; water table higher than potentiometric surface.

☐ **High Recharge** Well-drained upland areas characterized by poorly developed stream drainage systems.

Figure 40. Recharge areas to the Floridan aquifer in the Panhandle (after Stewart 1980).

we value. Since our society has come to recognize the value of a healthy ecosystem, we try to measure this health in addition to the physical and chemical water quality parameters. Increasingly this is done by examining the number and diversity of the species and individuals present in the water body. Various indices have been developed and used including numerous species diversity indices and what are known as biotic indices, which measure the presence of key species judged to be indicators of high water quality. Combinations of these indices aid in quantifying the degree of ecological health, but results from any one index must be viewed with caution. Each method, because of the manner with which it weighs different factors, generally has situations in which it gives a poor representation of the actual conditions.

a. Direct Importance. The first concerns about water quality were directed toward the transmission of disease through drinking water. Even this concern is relatively new. The desirability of separating human wastes from sources of water for drinking and food preparation was not understood in western civilizations until the mid-1800's and this separation was not effected on a wide scale until the early 1900's.

Until the early 1970's, drinking water was routinely examined and treated primarily for disease pathogens. Only recently has an awareness of the health and environmental impacts of toxicants become widespread. The majority of these substances are metals or synthetic organic compounds. Metals from natural sources in sufficient concentrations to cause problems are uncommon. Most of the organic hydrocarbons contaminating waters do not occur naturally. The vast majority of toxic substances found in the planet's waters are anthropogenic, products of modern industrialized society.

Efforts to locate, identify, and remove these substances from our waters are greatly hindered by their enormous number and variety, their difficult detection, and the lack of knowledge concerning both their short- and long-term effects. Some are toxic at levels below which their concentrations can be reliably measured. Increasing the problem of controlling these hazards is the daily discovery or synthesis of additional chemical compounds, many of which are a potential threat to water supplies. In addition to exposure through contaminated drinking water, some of these substances are being found in human foods following uptake by food plants or animals.

A secondary problem is the need for water of sufficiently high quality to meet industrial needs. Though most industrial water uses are for cooling, steam generation, material transportation, and similar tasks not requiring potable water, preventing scale buildup in steam and cooling equipment and using water for product makeup and certain chemical processes may require that specific aspects of the water quality be high.

b. Indirect Importance. The quality of water, both the physical characteristics and the presence or absence of toxic components, is a factor controlling ecosystem constituents (e.g., productivity, species diversity). Just as climate and water availability exert control upon floral and faunal composition, so does the quality of the available water. An area of poor water quality may support little or no life or, alternatively, populations of undesirable species.

Humanity is at the apex of a food web pyramid and is, therefore, dependent upon the soundness of the base of that pyramid for existence. If pressed, we may be capable of treating sufficient quantities of contaminated water to supply humanity's direct water needs; however, water of the quality necessary to support all levels of the ecosystem must be available, otherwise the food web pyramid may erode from beneath us.

4.1.3 Hydrology and Water Quality Regulation and Management

Though attempts are being made to treat drinking waters for contaminants, the removal of contaminants from the natural surface waters to which people are exposed during work or recreation is much more difficult to manage. It is impractical to treat surface waters to remove contaminants or alter physical parameters; rather, contaminant removal and physical changes must be performed prior to discharge of domestic or industrial effluents. To this end, State and Federal regulations have been enacted in an attempt to control effluent discharges into surface waters. Under the Federal Clean Water Act, point source discharges into surface waters of the United States are regulated by the National Pollutant Discharge Elimination System (NPDES). Under this system dischargers are given permits to discharge effluents meeting certain standards based upon the types of waste generated. The discharger is required to monitor the effluents and report periodically. In Florida, all NPDES permit applications and reports are reviewed by the Florida Department of Environmental Regulation (FDER). Under NPDES regulations, effluents should meet State water quality standards. The NPDES program, however, does not regulate dischargers in such a way that cumulative impacts are controlled. Hence, while a river may have numerous discharges into it, each meeting water-quality standards, the cumulative effect of all the discharges upon the river may cause its water quality to fail to meet standards. The NPDES program primarily is aimed at conventional pollutants, including bacteria, nutrients, and materials decreasing dissolved oxygen (DO) concentrations.

Surface waters have been monitored by the FDER since 1973 using Permanent Network Stations (PNS), though this monitoring network has been substantially reduced in recent years. The responsibility for management of regional water resources is held by the Northwest Florida Water Management District (NWFWMD). This responsibility includes regulation of water consumption and long-range planning to help ensure the continuing availability of high quality water. The water management district also has its own network of monitoring stations. At the request of the State Legislature, the NWFWMD in 1979 formulated a water resources management plan (NWFWMD 1979a) and a regional water supply development plan for the Panhandle coast (Barrett, Daffin and Carlan, Inc. 1982).

Waste load allocation studies have been performed by the FDER and, in earlier years, the U.S. Geological Survey to attempt to determine the amount of effluent discharges, including those of sewage treatment plants and private sources, that can be discharged into water bodies without degrading them. It should be pointed out that present methods of wasteload allocation rely primarily on models of DO and nutrient concentrations, are aimed at allocation of nutrient loads from public and private sources to maintain DO levels necessary for a healthy aquatic system, and are therefore incapable of predicting or allowing for effects from toxic discharges. The FDER conducts a program of acute and chronic toxicity bioassay testing on selected private and municipal effluent discharges that are recommended to them. Results of the tests are available as reports from the FDER Biology Section, Tallahassee.

Primarily because of cost considerations, most data collected from the various monitoring networks and stations is physical or chemical in nature. The biological baseline studies and monitoring needed to enable accurate determination of the overall "goodness" of the water quality of a particular water body is generally lacking. Additionally, all the large Panhandle rivers are interstate rivers originating in Georgia or Alabama. Thus, their hydrology and water quality is influenced by factors outside their Florida drainage basins. With the notable exception of Apalachicola Bay, data limitations due to changing sampling methods and uncharacterized ambient conditions have prevented long-term trend analysis in these river basins (FDER 1986c). Lack of baseline data in most instances and lack of continuing data collection in many instances prevent accurate detection of changes in surface-water quality and hinders interpretation of data gathered in short-term studies and laboratory simulations performed to predict effects on area ecology (e.g., chronic toxicity bioassays) (FDER 1985a, Livingston 1986a).

Following the discovery in the early 1980's of the toxic pesticides aldicarb (Temik®) and ethylene dibromide (EDB) in Florida ground waters, the Florida Legislature passed the Water Quality Assurance Act of 1983 which included steps to address the ground-water contamination problem. One major aspect of this act was the institution of a ground-water quality monitoring network to be administered by the FDER. This consists of a network of existing wells plus new wells where existing ones are insufficient to permit adequate ground-water sampling,each sampled on a regular basis. In its first phase, nearing completion at the time of this writing, the FDER's Bureau of Ground Water Protection performed extensive chemical testing of ground-water samples as a pilot operation to establish the necessary locations for the monitoring wells, to gather mapping and water quality information (aquifer locations and water flow, areas of saline intrusion, ambient ground-water chemistry), and to help locate the main areas with water quality problems. Upon completion of this step, the preliminary locations of permanent monitoring wells and the frequency of sampling needed will be determined. The ensuing program will be altered as dictated by sampling results. The ground-water monitoring network was envisioned as the source of a computerized data base helping to (1) determine the quality of water provided to the public by major well fields in the state, (2) determine the background or unaffected ground-water quality, and (3) determine the quality of ground water affected by sources of pollution. A biennial report describing Florida's ground-water quality will be made available to the public and governmental bodies to help in decision making.

4.2 Water Quality Parameters

4.2.1. Dissolved Oxygen

a. DO capacities. The amount of oxygen dissolved in water can be a limiting factor for aquatic life. Dissolved oxygen levels below approximately 3–4 ppm are insufficient for many species to survive. Alternatively, supersaturated levels of DO can result in embolisms (bubbles forming within the animal's tissues) and death. The amount of oxygen necessary to saturate water is temperature dependent. Higher temperatures reduce the saturation concentration (amount of oxygen the water can hold) and lower temperatures increase it (Figure 41). At 2 °C, freshwater (at sea level) is saturated at a DO of 13.8 ppm. At 30 °C, saturation occurs at 7.5 ppm. Another major factor influencing saturation levels is salinity; high salinities reduce saturation concentrations and low salinities increase them (Figure 42). While freshwater at 2 °C is saturated at 13.8 ppm, seawater (35 ppt) at the same temperature is saturated at 9.9 ppm. To provide a clearer picture of the ability of a water body to absorb more oxygen, the concentration is sometimes expressed as percent saturation—the percentage of that DO concentration at which the water would be saturated.

b. Oxygen uptake—respiration. As a result of these factors, during hot weather, when the metabolic rates of aquatic lifeforms are highest and their oxygen demands greatest, the oxygen carrying capacity of water is lowest. This situation is accentuated in confined water bodies, such as canals, where poor circulation minimizes aeration and maximizes water temperature.

The problem of the reduced oxygen capacity of warm water is compounded by two factors: algal respiration and biochemical oxygen demand (BOD). "Fish kills" caused by low DO (which may include many organisms other than fish) generally occur at night or during periods of cloudy weather. The net oxygen production by the algal population during sunlit hours changes to a net oxygen consumption during dark hours when algal photosynthesis ceases but respiration by the algae and other sources continues.

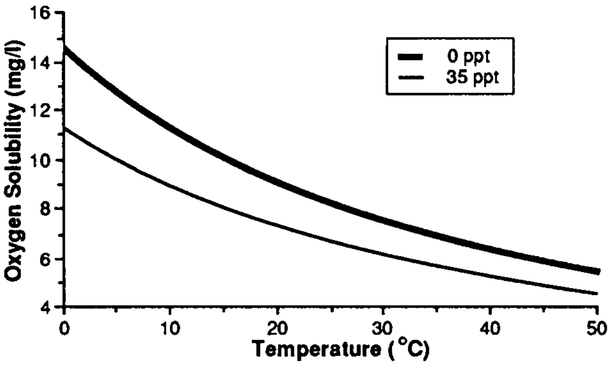


Figure 41. Oxygen solubility as a function of temperature.

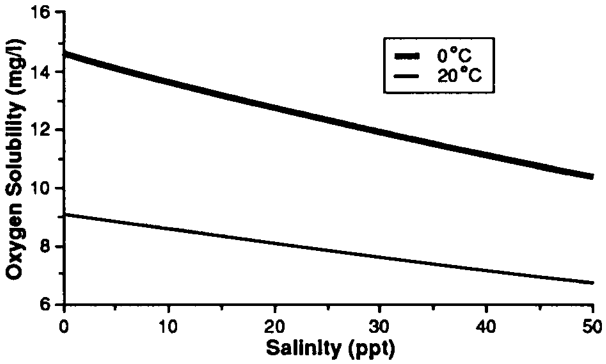


Figure 42. Oxygen solubility as a function of salinity.

c. Oxygen uptake—Biochemical Oxygen Demand (BOD). BOD results from microbial and chemical consumption of oxygen during the degradation of organic compounds in the water column and bottom sediments. BOD becomes a problem when excessive organic wastes enter an aquatic system. Oxygen uptake from high BOD can reduce DO levels to near zero. Even relatively low levels of BOD can contribute significantly towards low DO levels and resulting problems if that BOD combines with floral and faunal respiration and temperature-salinity interactions. As a result, fish and invertebrate kills from low DO are not uncommon, especially during summer months. Most of the oxygen dissolved in water results from gas exchange with the atmosphere except during periods of heavy algal growth. The rate at which a water body absorbs oxygen from the atmosphere is influenced by its circulation. If the oxygen must diffuse through the entire water column to reoxygenate depleted bottom waters (i.e., the water body is stagnant) then this rate is very slow. Bottom waters in canals and other enclosed water bodies, particularly those with a high ratio of depth to width and having organic bottom sediments, are especially vulnerable to oxygen depletion. If the depleted waters are circulated to the surface, the rate of oxygen uptake from the atmosphere is greatly enhanced and pockets of anaerobic water are less likely to develop.

4.2.2 pH

The concentration of hydrogen ions in water is measured in pH units. Waters of low pH (<7) are acidic, those with pH = 7 are neutral,and those with high pH (>7) are basic. The pH scale is inverse (in terms of H^+ ions) and logarithmic; hence water of pH 6 has 100 times as many H^+ ions as does that of pH 8. The pH of water is important biologically and chemically. Below a pH of approximately 6 harmful biological effects are felt, especially in sensitive life stages such as eggs. Below a pH of about 4, only a few specialized species can survive.

The biological effects of low pH are strongly linked to other factors, particularly the nonhydrogen ionic content of the water. Thus pH exerts a strong effect on the form of many of the other contents in the water. Ammonia, for instance, is found in the form of ionized ammonia (NH_4^+) and unionized ammonia (NH_3). The ionized form in which most ammonia is found in acidic waters is several orders of magnitude less toxic than the unionized form found in basic water. This is the reverse of the general rule of thumb that the ionic forms of substances (which often form in low pH waters) tend to be more toxic (Cairns et al. 1975).

Biologically, most of the direct effects of low pH upon aquatic fauna appear to be related to problems with disruption of osmoregulation (regulating blood and tissue fluids) and control of the ionic balance of blood and vascular fluids (Leivestad et al. 1976,1980, McWilliams and Potts 1978). The pH of blood (as well as plant vascular fluids) exerts strong effects on the ionic speciation of its components (i.e., the form in which the ion is found—e.g., CO_2 may be found in solution as CO_2, carbonic acid, carbonate, and/or bicarbonate, depending upon several factors, the major one being pH). Since pH exerts strong effects on metabolic chemistry, blood and vascular pH must be maintained within relatively narrow ranges. The blood of aquatic fauna is typically separated from the surrounding water by a thin semipermeable cell wall in their gills. Species or life stages that have a high ratio of gill (or in the case of eggs, chorion) surface area to body volume generally have the most difficulty compensating for ambient pH outside the nominal range for their blood chemistry (Lee and Gerking 1980).

In the Florida Panhandle, surface waters of low pH are generally found in swamps and swamp drainages. Figure 43 gives the normal pH levels of Panhandle surface waters. Rain water is generally slightly acidic due to the presence of dissolved CO_2 (forming carbonic acid) picked up from the atmosphere. Rainwater is, however, poorly buffered (i.e., possesses few ions that tend to stabilize pH levels). Concerned that Panhandle rainwater may be becoming more acidic due to powerplant emissions, the State and the Florida Electric Power Coordinating Group (an organization formed by the powerplants within Florida) have undertaken broad-scope acid rain studies. These studies are attempting to determine whether the unique conditions found in Florida increase or decrease the likelihood of acid rain formation, whether these conditions increase or decrease the sensitivity of the ecosystem to acid rain stress, and areas in or out of the State where the effects of Florida-caused acid rain may be felt (FDER

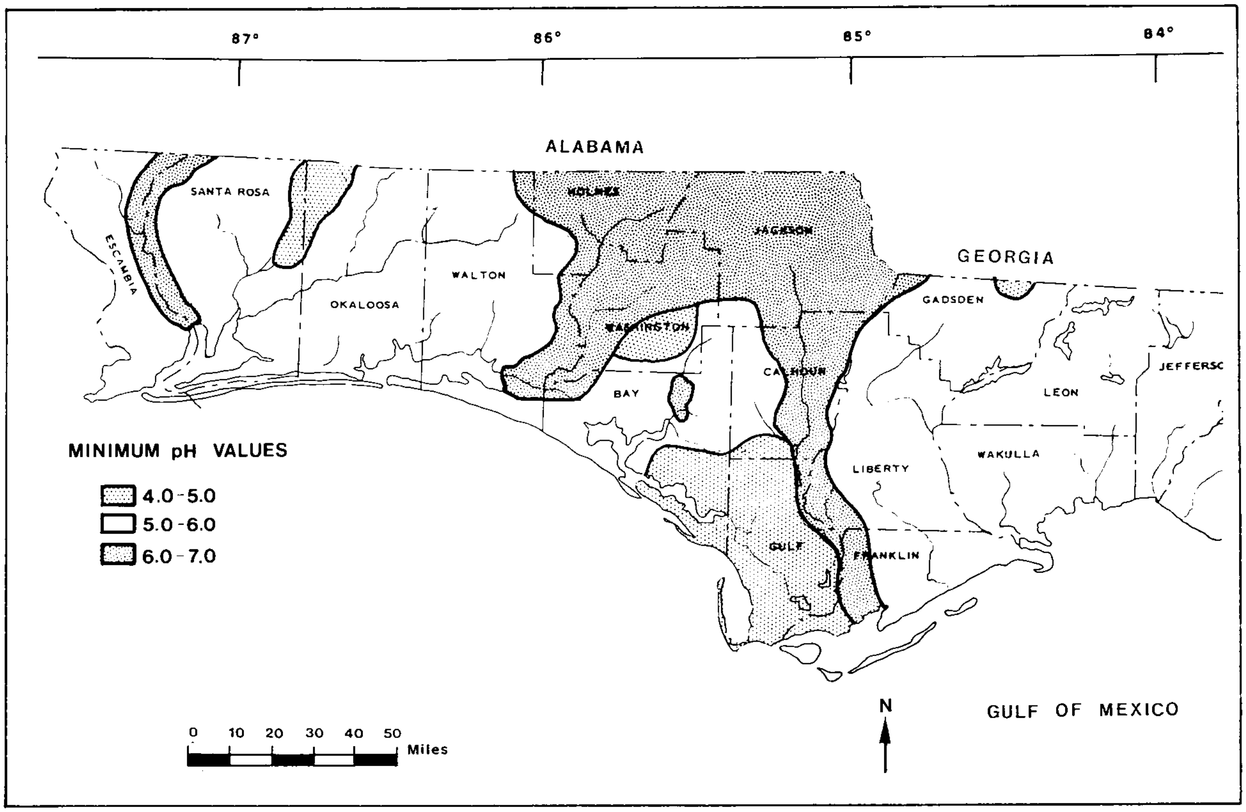


Figure 43. Minimum pH of Panhandle surface waters (after Kaufman 1975a).

1985b). If the rainwater contacts a substrate composed of a buffering material (in the Panhandle this is usually limestone—calcium carbonate, $CaCO_3$), then the pH moves toward what is known as the equilibrium pH for that buffering reaction, that is, toward the pH at which water in contact with that particular buffer will eventually stabilize. However, if the water contacts only organic and insoluble substrates (e.g., swamps and marshes), then it becomes quite acidic (pH 4 or below) from the organic acids created by the decomposition of the vegetation, and the entire system stabilizes at a low pH. These conditions yield community structures entirely different from those found in water of higher pH, since many species are excluded by their lack of tolerance for the acidic conditions.

The pH of water bodies originating in these organic wetlands often increases downstream because of the input of buffering ground water or surface drainage (or both) or from contact with a buffering streambed. Carbonate buffering in north Florida ground water is sufficiently strong that the addition of 5%–10% of a moderately alkaline ground water (pH approximately 8.0, alkalinity approximately 120 mg/l) has been shown to raise swamp water with a pH of 4.0 and an alkalinity of 0 mg/l to a pH of 6–6.5 and alkalinity of 6–12 mg/l (FDER 1985a). Since the pH scale is inverse logarithmic, the 5%–10% ground-water addition, as a result of chemical buffering reactions, reduced the concentration of hydrogen ions by 99% or more. In the Florida Panhandle, pH is almost entirely controlled by the water's carbonate concentration (Kaufman 1975a).

Because of the substantial buffering effect of the high ion content of saltwater, marine pH levels are generally near 8. Thus problems from low pH are rare in estuarine and marine waters.

4.2.3 Turbidity and Sediments

Turbidity is the result of particulate and colloidal solids suspended in the water and is measured as the proportion of light that is scattered or absorbed rather than transmitted by a water sample. High levels of turbidity are found in streams that carry heavy sediment loads. This sediment is derived from runoff and much of it, particularly that present during periods of light to moderate rainfall, is commonly the result of human influences on the terrain along the tributaries (e.g., land clearing, urban stormwater drainage, farming without erosion control). In the absence of these anthropogenic influences, heavy rains may still temporarily increase turbidity by washing larger particles into streams, rivers, and lakes. These, however, tend to settle rapidly.

High levels of turbidity may kill aquatic organisms by clogging gill structures, causing suffocation. Hard-bottom benthos can lose habitat if settling sediment creates a mud bottom. Aquatic plants are often affected by increases in turbidity by being buried in deposited sediments or by reduced light levels. Turbidity is a concern in drinking water because it can harbor pathogens and protect them from sterilizing efforts (e.g., chlorination). High turbidity in drinking water sources, therefore, usually necessitates that the particles be removed prior to sterilization.

4.2.4 Dissolved Solids

The term "dissolved solids" refers to the total amount of organic and inorganic materials in solution. The dissolved materials found in Florida surface and ground waters are primarily the carbonate, chloride, and sulfate salts of calcium, sodium, and magnesium. Dissolved solids in both surface and upper ground waters are usually below 200 mg/l except for ground water along the coast (Shampine 1975a, Swihart et al. 1984) (Figure 44). Deeper

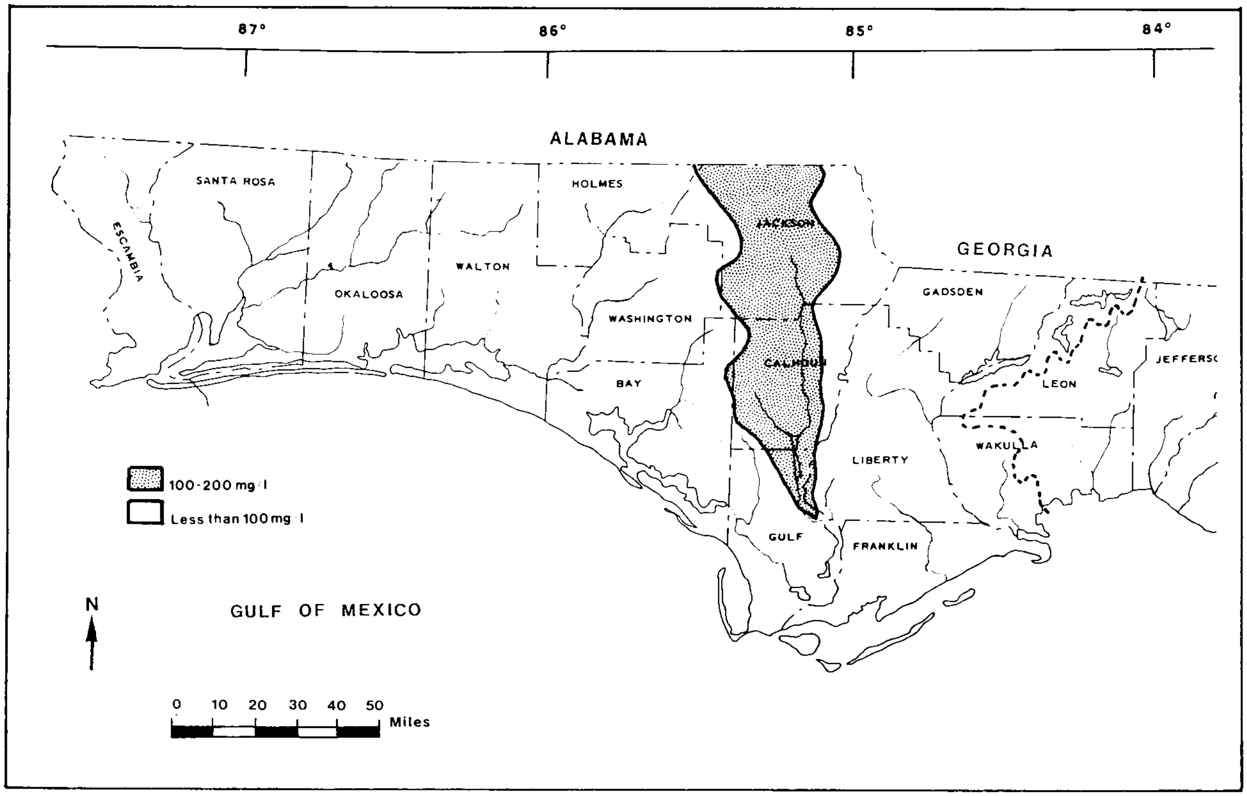


Figure 44. Concentrations of dissolved solids in Panhandle surface waters (after Dysart and Goolsby 1977).

ground-water layers usually contain more dissolved solids than the upper layers.

The major ions commonly found in Panhandle waters are those often measured as alkalinity (HCO_3^- and $SO_4^=$, bicarbonate and sulfate ions), hardness (Ca^{++} and Mg^{++}, calcium and magnesium ions), and salinity. The total dissolved-solids concentration in surface water is generally highest during low-flow conditions (Kaufman 1975b, Dysart and Goolsby 1977).

Conductivity is a commonly used measurement which is indicative of the concentration of dissolved solids. Distilled water is a very poor electrical conductor and ions in the water improve this conductivity. Dissolved solids concentrations can usually be reliably estimated by multiplying the conductivity in µmhos by a factor ranging from 0.55 to 0.75, depending on the water body (Dysart and Goolsby 1977).

a. Alkalinity. The concept of alkalinity is simple, though the chemistry involved can be quite complex. Alkalinity is a measure of the ability of a water sample to neutralize acid, in terms of the amount of H^+ (acid) that can be added to the water before the pH is lowered to some preset value (depending upon which type of alkalinity measurement is being performed). For the most common type of alkalinity measurement (total alkalinity), this pH is 4.5. Ions in the water that tend to keep the pH high increase alkalinity and thus "buffer" the pH.

Buffering ions commonly found in Panhandle surface and ground waters include carbonate (usually as bicarbonate) and sulfate. These components are generally the result of the dissolution of the limestone matrix with which the water has been in contact. The ready solubility of limestone and the frequent input of ground water (which has generally had significant contact with limestone) to the surface waters tends to result in Panhandle surface waters of at least moderate alkalinity.

As mentioned in the discussion of pH, alkalinity in Panhandle water is very highly correlated to pH. The various forms of carbonate found in the waters are by far the predominant pH buffering agent; sulfate and other buffering ions are substantially less common (Kaufman 1975a,b, Shampine 1975a).

Since the alkalinity of Panhandle waters is overwhelmingly a function of the carbonate concentrations, many studies (particularly of ground water) do not measure alkalinity as such, but rather record bicarbonate concentrations. In surface waters total alkalinity is more commonly measured because of the increased likelihood that they may contain additional buffering ions caused by surface drainage and input of human effluents. Alkalinity is not a water quality factor of importance in marine waters because, though high, it is constant.

b. Hardness. The hardness of water, like the alkalinity, is generally of concern in freshwater only. Hardness is a measure of the cation (positive ion) content of water. In the Panhandle the major freshwater cation is Ca^{++}, with Mg^{++} a distant second. Since calcium carbonate (limestone) supplies most of the dissolved ions in surface and ground waters, total dissolved solids, alkalinity, and hardness are often highly correlated. The hardness of natural Panhandle waters can be reliably estimated from the total dissolved-solids values (Figure 44). Hardness is usually reported as equivalent concentrations of calcium carbonate (e.g., 120 mg/l as $CaCO_3$). High levels of hardness (> approximately 2,000 mg/l) are unpalatable but not generally harmful, except for a laxative effect in first time users (Shampine 1975c). One aspect of hardness that is of interest is its relationship to soap and detergent usage. Soap combines with and precipitates hardness ions until they are removed. Only then do lathering and cleansing occur. Harder water, therefore, requires use of more soap than does soft water. Hard water also increases the rate of lime formation within plumbing and heating equipment and, where high, may necessitate the use of chemical softening techniques to minimize maintenance.

c. Salinity. Salinity is the concentration of "salts" dissolved in water. This term is generally used to describe estuarine and marine waters, though very low concentrations of salts are present in freshwaters. Sodium (Na^+) and chloride (Cl^-) ions provide about 86% of the measured salinity; magnesium (Mg^{++}) and sulfate ($SO_4^=$) account for another 11%, with the remaining 3% consisting of various minor salts (Quinby-Hunt and Turekian 1983). Technically, the measurement of salinity has been defined based upon the chlorinity, or chloride

(Cl^-) content of seawater. This was done because of the ease and accuracy with which Cl^- concentrations can be measured, and because the proportions of all the different salts present in seawater are very constant. The total concentrations of these salts are approximately 10^3 to 10^4 times those found in freshwaters. As a result, the chemistry of the freshwater flowing into an estuary does not significantly affect the proportions of the salts in the estuarine waters.

Salinity is a factor in water quality since salinity tolerance can limit the species found in a given salinity regime. Additionally, sudden or large changes in salinity can be stressful or fatal to the biota. The salinity tolerances of aquatic biota separate them into three main groupings: freshwater (salinities below 0.5 ppt), estuarine (0.5 to 30 ppt), and marine (greater than 30 ppt) (Cowardin et al. 1979).

In general, the freshwater and marine species have narrow salinity tolerances while estuarine species are characterized by their tolerance to changing environmental conditions, including salinity. Estuaries, where fresh river waters mix with salt water, regularly present rapidly changing salinity conditions. As a result, this habitat has lower species diversity than do more stable ones, although this does not imply fewer individuals. Despite the harsh physical regime, abundant dissolved nutrients promote high primary productivity that can support a large number of individuals of tolerant species. Separation of populations based on salinity tolerance applies equally to coastal wetlands.

The salinity of Panhandle coastal and estuarine waters is extremely variable. These waters function as a mixing zone for freshwater runoff from surface and ground waters (0 ppt) and the offshore marine waters (35 ppt). In general, estuarine salinities range from 0 ppt throughout the estuary during high river stages, to 32–35 ppt within the estuary (but away from the river mouth) during periods of low river discharge. The coastal waters between the estuaries often receive some freshwater runoff during rainy periods; however, the salinity regime is much more stable than that of the estuaries, and diurnal salinity changes are minimal or nonexistent.

d. Nutrients. The nutrient content of water primarily affects water quality when high concentrations promote excessive growth of algae and higher plants. Too much eutrophication (i.e., nutrient enrichment) causes excessive plant growth and the resulting increased organic load depletes dissolved oxygen, rendering the water less suitable for species considered desirable to people. The primary limiting nutrients (i.e., those that, when lacking, commonly limit algal and plant growth) are nitrogen (as ammonia, nitrite, and nitrate), phosphate, and, for diatoms (which often constitute the majority of fresh and salt water phytoplankton), silica. There are many more required nutrients; however, their availability is normally such that they do not prevent growth. In addition to excessive plant and algal growth, high concentrations of nitrates in drinking water also cause a serious and occasionally fatal poisoning of infants called methemoglobinemia (Slack and Goolsby 1976, Phelps 1978a).

In a natural surface-water system, nitrogen as a nutrient is derived from organic debris that is carried by runoff from surrounding terrain and from aquatic species of nitrogen-fixing plants and bacteria, and is regenerated within the system through the decay of dead plants and animals. These sources are often augmented, sometimes heavily, by human effluent discharges. The most common of these are sewage treatment plants, septic tanks, and runoff from fertilized fields.

Phosphate and silica are derived, in an undisturbed system, from the weathering of continental rock. They are both recycled repeatedly through the cycle of death, decay, and subsequent uptake. Florida has extensive areas of phosphorus rich limestone matrix deposited during periods when the State was covered by shallow seas. The dissolution of this rock and its transport into both ground and surface waters provide a ready source of this nutrient in many Florida waters. The major anthropogenic contributors include municipal sewage treatment discharges (less of a problem since the mandatory reduction of phosphate concentrations in detergents), runoff from fertilized agricultural fields, and effluent from phosphate mining operations. There is little input of anthropogenic silica.

The limiting nutrients are not needed by algae and plants in equal proportions. While the proportions utilized vary widely between species and depend upon environmental conditions, an average ratio of N:P = 10:1 for higher plants and algae and N:P:Si = 15:1:50 for diatoms can be used.

4.2.5 Temperature

Temperature affects water quality by acting as a limiting factor if too high or too low for survival of a specific organism, and by influencing the rate of many biological and chemical processes including metabolism. In general, higher temperatures increase the rate of metabolic functions (including growth) and the speed of other chemical reactions. This tends to increase the toxicity and rate of metabolic uptake of toxicants (Cairns et al. 1975). Therefore, for those toxicants which are bioconcentrated (accumulated within the tissues), higher temperatures will result in higher concentrations in living organisms.

Depending upon the size of the water body and how well mixed it is, the water temperature may take minutes or weeks to adjust to the average air temperature. This lag time damps water temperature fluctuations relative to air temperature fluctuations and helps minimize the stress on aquatic lifeforms.

In addition to the seasonal fluctuations, there are often diurnal fluctuations, particularly where turbid or dark, tannic swamp waters are exposed to sunlight. When the angle of incidence is small, water, as well as many of its contents, absorbs solar energy very efficiently. Dark coloration improves the efficiency slightly, but restricts light penetration, and therefore heating of the water, to near the surface. As a result, surface water can become quite warm, while much cooler water may exist below a shallow thermocline. Freshwater surface temperatures vary depending upon season and the volume, depth, and location of the water body. Estuarine areas show the most complex and rapid variations in water temperatures. The dynamics of freshwater inflow temperatures, coastal marine water temperatures, density stratification, tide, and wind determine the proportions of fresh water and saltwater present at a site within an estuary and may expose the inhabitants to very rapid temperature fluctuations.

Locally, surface-water temperatures may be strongly influenced by ground-water input. Ground-water temperatures tend to remain very near the mean annual temperature of the above-ground climate. This is another example of temperature damping on a larger scale, the result of the slow rate at which the earth changes temperature. Where ground water flows into surface waters, the temperature of the water near the ground-water input will be relatively stable.

Temperature becomes a water quality problem when it is too cold or warm to support a normal ecosystem. Low-temperature kills are almost exclusively a natural product of winter cold spells and are of short duration and temporary effect. High temperatures, however, can become a long-term problem when large quantities of water used to cool power plants and other industrial operations are discharged into surface waters. It is not uncommon for thermal effects to be felt over a large area where substantial quantities of heated water are discharged.

4.2.6 Other Contents

This catchall grouping includes many parameters of great concern. Among these are: toxic substances such as ammonia, pesticides, and metals (e.g., lead, mercury); carcinogens (cancer-causing agents), mutagens (DNA-altering agents), and teratogens (agents causing abnormal growth or structure); and infectious agents (bacteria and viruses). Many substances fit within two or more of these categories.

Metals and many of the toxic compounds in water are often found in ionic forms. Most pesticides and toxic organic compounds, however, do not require ionization to be toxic. Many toxicants, ionic or not, interfere with normal metabolic processes by displacing critical metabolites and thereby blocking reactions necessary for the maintenance of life.

While many ions are not toxic (at least at the concentrations at which they are normally found), the ionic forms of many elements and compounds are generally more reactive than are the nonionic forms. Additionally, different ions of the same substance may vary in their toxicity. Generally, the higher the valence number (i.e., the number of charges on the ion), the more toxic the ion. As a rule, low pH increases ionization and, therefore, the toxicity of many substances.

The total concentration of the subject compound, along with other factors such as pH, temperature, ionic strength (i.e., the concentration of all ionic forms present), and the presence of natural (and anthropogenic) chelating agents such as tannins and lignins, combine to determine the concentrations at which the various ionic and nonionic forms of a compound will be found. Since the toxicity (if any) of that compound is affected by its exact form and availability for uptake, and since the mode of that uptake varies widely between species, predicting the toxicity of effluents being discharged to surface and ground waters is very difficult. The conditions found in the area of each discharge play an important role in determining the effect of an effluent on area ecology. This is further complicated by the long period after exposure which may elapse before the onset of symptoms, especially common in the carcinogens, teratogens, and mutagens. Since these conditions typically fluctuate, sometimes widely, during the year, it can be seen that predicting pollutant impacts can be very difficult.

4.3 Major Influences on Surface Water

4.3.1. Major Influences on Surface-Water Hydrology

a. Natural factors affecting inland surface-water hydrology. In drainage basins not subjected to major human alterations, such factors as climate, season, geology, and surface features control the hydrology. In the Florida Panhandle, climate and season combine to control precipitation, evaporation, and evapotranspiration rates, thereby determining the proportion of water contained in each step of the hydrologic cycle. The geology and topography control flow rates by determining surface porosity, slope, and erosion features. These flow rates are further modified by the presence and types of vegetation that impede runoff.

Flooding is one of the most striking hydrologic events. Panhandle rivers flood primarily during the frontal rainfalls of late winter and early spring (February–May) (Palmer 1984) (Figure 45). While this difference is partially due to the winter rainy period, Figure 17 in the climate chapter shows that the total rainfall during the summer is much greater. The vast quantities of water evaporating from the warm surface waters and transpired from the lush foliage return most of summer rainfall to the atmosphere (Mather et al. 1973), thereby minimizing flood-inducing runoff. While the large Panhandle rivers show this relationship (Figure 46), they also show reduced flow during the summer rainy season because much of their drainage basins are sufficiently far inland that they receive little of the convection-induced summer rains. The reduced foliage present in winter and early spring allows a greater proportion of the rain falling during the winter rainy season of the northern regions to run off and may result in flooding.

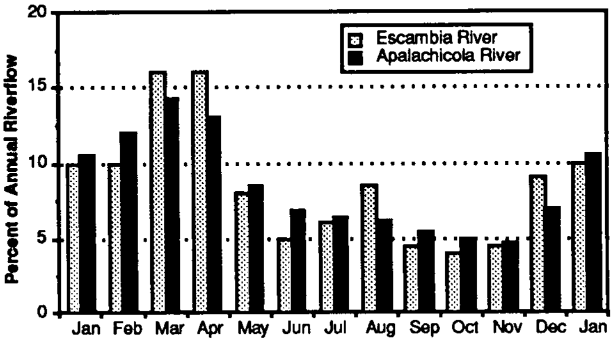


Figure 45. Seasonal riverflow in two Florida Panhandle rivers (data from Livingston 1983, Palmer 1984).

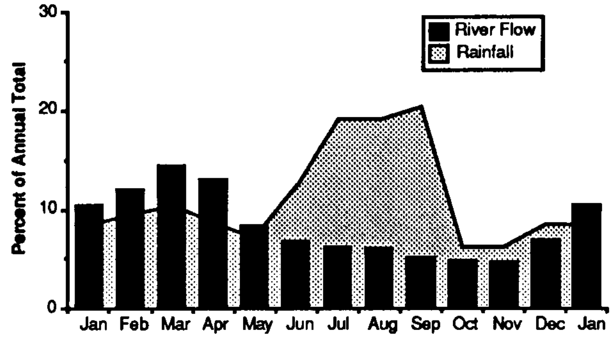


Figure 46. Apalachicola River flow and rainfall at city of Apalachicola (data from Livingston 1983).

Periodic floods are a necessary and important part of wetland energetics. Seasonal inundation of river flood plains and coastal marshes flushes organic matter produced by these wetlands into streams, rivers, and estuaries where it provides a substantial portion of the energy driving the food chain. The goal of minimizing property damage from flooding while maintaining high water quality in surface waters is best achieved by discouraging development in river flood plains and controlling construction of what development does take place to minimize damage to the resulting structures and to the flood plain (e.g., requiring that buildings be constructed on pilings above flood levels and that flood plain terrain and vegetation be maintained).

Maps delineating the 100-year flood plains in Florida were drawn by the U.S. Geological Survey and are currently distributed by the Florida Resources and Environmental Analysis Center (FREAC) at Florida State University. These maps are based upon the USGS topographic quadrant maps and have too much detail to present here. It is probable that, because of changes from continuing development and other factors, these maps underestimate the areas that would be inundated by 100-year floods.

Panhandle springs moderate the flow of those rivers and streams receiving their waters. The ground-water levels controlling the rates of spring flow and ground-water seepage tend to respond slowly to rainfall changes, thereby establishing a minimum streamflow ("base flow") when surface runoff is minimal. This moderating tendency is less noticeable during periods of high runoff and streamflow. However, many springs become siphons under these conditions and carry surface water directly to the aquifers (Ceryak et al. 1983), thereby reducing the peak streamflow somewhat. First and second magnitude springs (>30 m^3/s and 3–30 m^3/s, respectively) (Figure 47) are most numerous in the

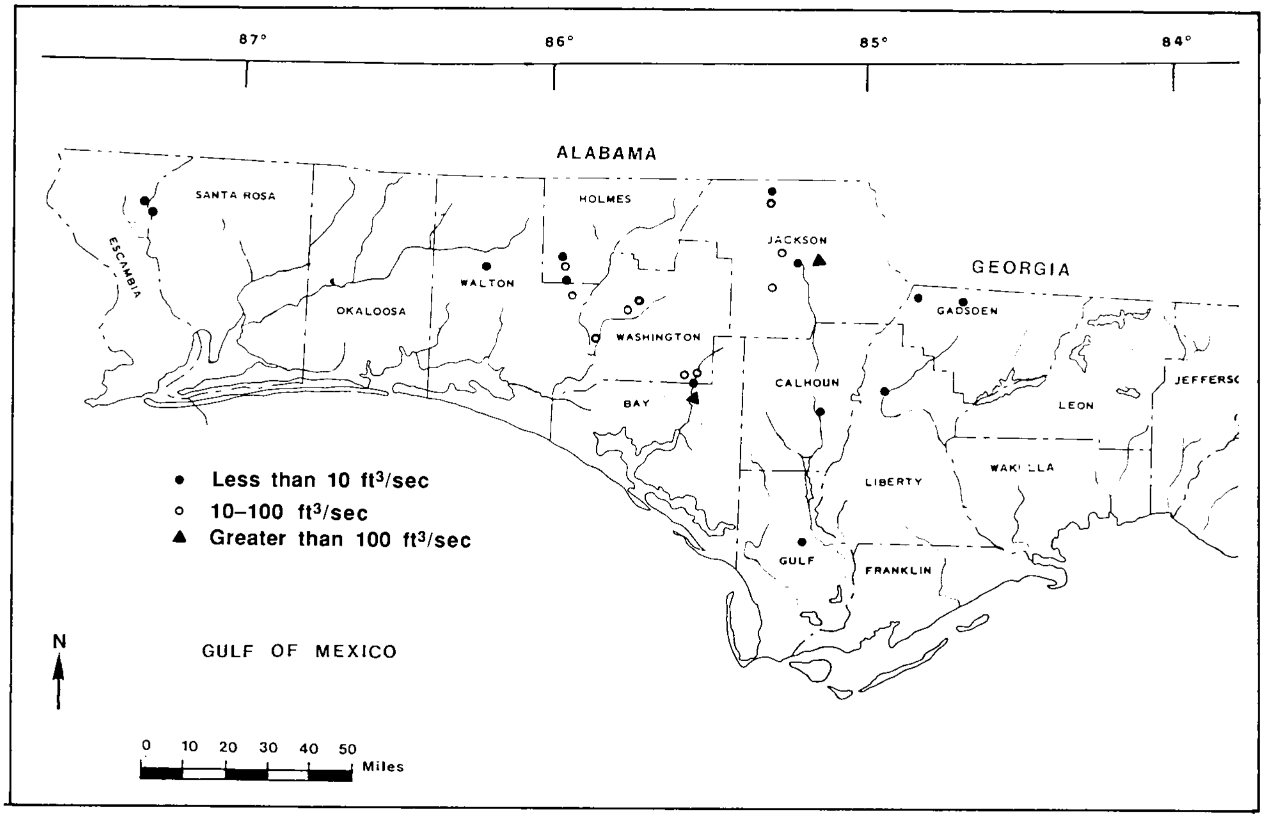


Figure 47. Locations and magnitudes of major Panhandle springs (after Rosenau and Faulkner 1975).

central Panhandle and are located primarily along the Choctawhatchee and upper Chipola Rivers and Econfina Creek. Third magnitude springs (<3 m^3/s) are less concentrated but are generally more common east of Walton County.

b. Natural factors affecting coastal surface-water hydrology. Coastal waters are affected by several forces that have little affect on the freshwaters inland. In shallow nearshore areas such as those common along the eastern Panhandle coast and in estuaries, wind is the major factor driving water circulation (Williams et al. 1977, Livingston 1983). This results in a net long-term movement of water west along the coast during the late spring, summer, and early fall and east along the coast during the winter months. Short-term currents are quite variable and depend primarily upon: (1) local wind direction, (2) tide-induced currents, (3) proximity to river mouths and the estuarine currents resulting from the density differences of the mixing fresh and salt water, and (4) the possible presence of eddies spun off of the Loop Current in the Gulf of Mexico.

(1) During much of the year, local wind direction is affected by the convective phenomenon driving the land breeze and sea breeze. Wind strength and direction and the resulting force exerted on the surface waters often changes over short periods of time. Chapter 3 contains more information on seasonal changes in wind strength and direction.

(2) The Panhandle coast experiences unequal semidiurnal tides; i.e., two high and two low tides daily, each of different magnitude. This pattern is the result of a complex combination of forces, the gravitational pull of the Moon and the Sun being the primary ones. The period of the tides is such that they are approximately one hour later each day. The net tide-induced current is weakly west along the coast (Battisti and Clark 1982). Of more importance to the nearshore hydrology and water quality, the (normally) four times daily change of direction of this movement of water induces substantial mixing of the nearshore and offshore waters.

(3) A number of current-producing and -affecting forces are in action at the mouths of rivers. Among them are (a) the friction of the riverflow upon the salt water it enters, (b) salt-wedge circulation, and (c) geostrophic forces. The friction of the flow exiting the river mouth attempts to "drag" adjacent salt water along with the body of river water, inducing eddies along the transition zone between the two water masses. A salt wedge forms because fresh water flowing out of the rivers is less dense than the salt water into which it flows; thus the fresh water tends to form a layer flowing over the top of the denser salt water (Figure 48a). This underlying layer of salt water is called a salt wedge, and since the upstream end of this wedge has a lower salinity (is less dense) from mixing with the overlying river water, pressure from the denser salt water behind it forces the wedge upstream. In shallow, so-called well-mixed estuaries (the type found along the Panhandle coast), turbulence and other mixing forces tend to minimize the distance over which these two water masses remain unmixed. However, the mechanism is still functioning and an important part of estuarine hydrology. As the saltwater mixes with the overlying fresh water at their interface, the brackish water formed is less dense than the salt water and is caught up in the outward flow of fresh water and carried out toward the gulf. This loss of saltwater from the wedge induces a flow of saltwater from the gulf to replace it. Thus the estuary experiences a net outflow in the surface waters, and a net inflow in the bottom waters. This inflow can be several times the volume of the riverflow before it enters the estuary (Knauss 1978). What are perceived as small changes in river flow can result in large changes in estuarine and nearshore circulation.

Others factors in estuarine circulation are those caused by Coriolis and geostrophic forces. The Coriolis "force" in the northern hemisphere is felt as a force directed to the right of the direction of water flow. The result of this force, when applied to an estuary exhibiting stratified salinity, is that inflowing fresh surface water tends to collect on the right side (relative to the direction of flow) of the estuary (Figure 48b). In the Panhandle, the resulting thicker layer of fresh water is then forced west along the coast by geostrophic forces caused by the pressure from the denser, more saline waters to the south or east. These two forces, in the absence of strong coastal currents, cause the outflow of rivers in the Panhandle to tend to curve to the right once they reach

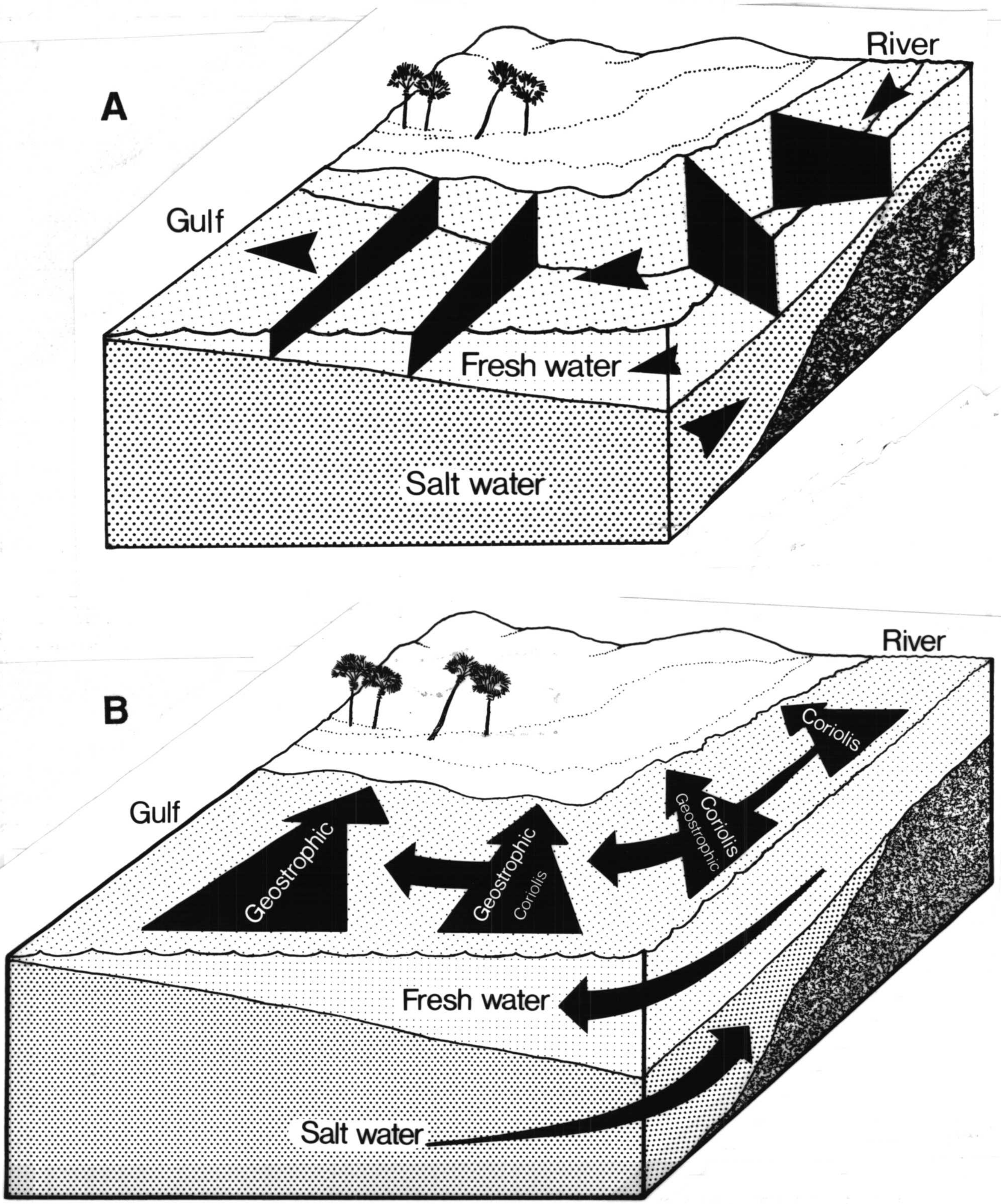


Figure 48. (A) Formation of a salt wedge and "stacking" of freshwater layer to right of flow direction at river mouths. (B) Coriolis and geostrophic forces affecting fresh water flowing from river mouths.

the ocean (Knauss 1978). Once free of the river banks, these forces will tend to keep the surface layer of freshwater "pinned" to the coast and force it west along the coast until mixing destroys the stratification. The magnitude of the effect of these forces on coastal and estuarine circulation depends strongly on the presence or absence of mixing forces at the time, thus they are continually in a state of flux.

A final influence on coastal hydrology is wave mixing and erosion. Wave motion does not result in significant lateral movement of water; however, vertical mixing takes place to a depth approximately twice the wave height. In shallow areas such as the eastern Panhandle nearshore region, large storm-induced waves caused the waters to be well mixed top to bottom. During periods of wave heights greater than approximately 1 m, therefore, the eastern Panhandle coastal waters would be expected to exhibit very little temperature or salinity stratification.

c. Anthropogenic factors affecting inland surface-water hydrology. Development often substantially alters surface drainage. In the Panhandle these alterations include river damming, streamflow diversion, river channelization, dredge-and-fill activities, "terraforming," increasing runoff (e.g., stormwater drainage), wetland draining, floodplain development, and extensive landclearing activities. The most common results of these alterations are increased magnitude and duration of flooding and the decreased water quality of runoff. Undeveloped uplands in drainage basins act as a buffer to runoff, absorbing the initial rainfall and impeding the rate at which excess water runs off. Developed lands generally have a much reduced ability to absorb rainfall due to the reduced amount of absorptive "litter," reduced permeability of the land surface, and reduced evapotranspiration due to lower foliage densities. In addition, most development includes measures such as regrading of the terrain and installation of drainage ditches and culverts, all aimed at speeding the rate of runoff. As a result, the streamflow in developed basins following periods of rainfall tend to peak rapidly and at a much higher level than it does in undeveloped basins. This is caused by a greater total volume of water draining into the stream or river over a shorter total period of time. This problem is further exacerbated by the tendency of developed drainage basins to restrict the area through which the stream or river flows during high water conditions. This area, the floodplain, is the width of river channel required to carry the runoff during periods of heavy rainfall in the basin. After this floodplain is developed, which commonly includes reducing its width by dumping fill along its borders, the increased runoff resulting from the development must now flow through a more restricted channel. As a result the height of flooding is increased even more. The increased rate of runoff in developed basins also increases erosion, which further reduces landcover and retention of rainwater.

d. Anthropogenic factors affecting coastal surface-water hydrology. Human alteration of freshwater input can also alter coastal estuarine systems. Diversion of surface waters to different drainage basins and alteration of the dynamics of the hydrologic cycle by anthropogenic activities (e.g., consumptive water use) can cause profound changes in patterns of freshwater flow to estuaries and coastal marshes, with potentially devastating results. It has been previously described how river outflow induces circulation and mixing in water masses many times greater than the volume of water discharged. Thus the size of an estuary is controlled by the volume of fresh water inflow, but any decrease of inflow causes a much larger decrease in the volume of the estuary. If average flow into an estuary decreases, then decreases in estuarine productivity disproportionate to the volume of fresh water diverted can be expected.

4.3.2 Major Influences on Surface-water Quality

a. Natural factors affecting inland surface-water quality. The major natural influence governing surface water quality is the progression of the seasons. Surface waters are commonly composed of some mixture of excess rainwater drained from surrounding lands, flow from the Surficial Aquifer, and artesian flow from the Floridan Aquifer. Seasonal factors which affect surface water quality include rainfall, air temperature, and nutrient sources.

"Normal" rainwater is slightly acidic with a very low concentration of dissolved minerals (i.e., soft water). The water is poorly buffered and the pH is easily changed by the materials it contacts. During the rainy seasons, surface streams, rivers, and lakes are composed primarily of rainfall runoff, with ground water constituting a relatively small proportion. The rainwater picks up tannic and other organic acids through contact with organic debris during runoff, particularly that encountered during the relatively long periods of retention provided by swamps and marshes. This swamp runoff is acidic (pH 4–5) and highly colored, with a relatively low DO and a very low concentration of dissolved minerals.

During periods of low rainfall, ground water makes up an increased proportion of most surface waters. Since ground waters are frequently highly filtered and have spent time in contact with the minerals composing the aquifer matrix (primarily limestone), they are generally colorless, moderately alkaline, and contain moderate to high levels of dissolved minerals. Since surface runoff often has weak organic acids acting as buffers, the pH of surface water mixed with a small amount of ground water can change radically. As a result of these factors, surface water chemistry (especially pH) tends to reflect seasonal rainfall patterns.

In addition to the direct correlation between air temperature and water temperature, air temperature has many indirect influences on surface water. As discussed previously, ambient temperatures affect chemical reaction rates and equilibria reactions in water. As a result, rates of bioconcentration of toxics are higher in warmer water, as are rates of nutrient production and utilization. Another factor influenced by air temperature is plant growth.

Seasonal change in ambient temperature is one of the primary factors controlling plant and often animal growth and reproduction, both in the drainage basin and within water bodies. The growth and death of biota are major factors in nutrient cycling and in the levels of dissolved nutrients found in surface waters. Nutrient levels tend to decrease during periods of maximal population growth and increase during periods when deaths (and therefore nutrient regeneration) exceed reproduction and growth.

Surface runoff leaches nutrients from upland litter, which are then carried to downstream water bodies. Additionally, some of the litter is carried into the water, where it settles to the bottom and decays, providing shelter and food for detrital feeders as well as nutrients for primary production.

b. Natural factors affecting coastal surface-water quality. The water quality of nearshore waters is subject to many of the same climate induced changes that affect inland waters; however, by virtue of their volume, the coastal waters are more resistant to change. Nearshore water quality is primarily determined by the mixing dynamics resulting from the previously discussed hydrologic factors. These factors control the mixing of the fresh water draining off the land and the marine waters offshore. One relatively common event which is harmful to the ecology occurs when conditions encourage plankton blooms. The exact causes triggering these blooms are not fully understood; however, the dense blooms introduce metabolic byproducts that are toxic to many species and can produce fish kills. The BOD from these kills, along with the enormous respiratory oxygen demand of the plankton at night and during overcast periods, can result in low levels of dissolved oxygen, increasing the kill. These problems are worst in constricted waters near shore.

c. Anthropogenic factors affecting inland surface-water quality. Until recently, point-source pollutant discharges have been the major human-induced cause of water quality changes. In the Panhandle, much of which is relatively undeveloped, private and municipal sewage and discharges are the most common point-source effluents. Industrial activity is generally found in the western portions of the area. These sources, fewer in number but which may have substantial local impact, include discharges from powerplants, chemical factories, paper mills, and mining operations. Discharges from powerplants are primarily in the form of thermal effluents, i.e., water that has been used to cool the generators.

Nonpoint-source pollution is considered by the FDER to be a major, but largely uncontrolled, cause of surface water degradation. It is estimated from studies that nonpoint sources contribute 450 times more suspended solids, 9 times more oxygen-depleting materials, and 3.5 times more nitrogen than point sources (FDER 1986c). The major nonpoint-source pollutants in Panhandle rivers are pesticides, animal wastes, nutrients, and sediments. The major causes of nonpoint-source pollution in southeastern U.S. river basins are agriculture (affecting 62% of basins) and urban stormwater runoff (affecting 57% of basins), with silviculture (tree farming), landfills, and septic tanks affecting 33% of the basins (U.S. EPA 1977). Nonpoint-source pollution is expanding and has the potential to nullify water-quality gains being made through the reduction of point-source emissions.

d. Anthropogenic factors affecting coastal surface-water quality. The primary impact of human activities on coastal water quality results from the restriction of water circulation in dredged or otherwise altered areas. This may result in high temperatures, low DO, and salinity alterations. One of the greatest effects of human activities results from salinity alterations caused by the changes in hydrology previously described in 4.3.1(d). The factors affecting inland surface-water quality may affect local coastal water quality, particularly in the estuaries.

4.4 Major Influences on Ground Water

4.4.1 Major Influences on Ground-water Hydrology

a. Natural factors affecting ground-water hydrology. In the absence of cultural impacts, ground-water levels are a function of rainfall. Ground-water levels respond to area-wide rainfall with a lag time of up to several weeks (Ceryak 1981). Since substantial lateral transport is possible, levels tend to follow fluctuations in rainfall averaged over substantial areas (up to thousands of square kilometers). Ground water movement is from areas of high to those of low potentiometric surface (Figure 39).

Recharge of the Floridan Aquifer from rains and infiltration of surface water depends on the permeability and thickness of the overlying strata and, where there is a surficial aquifer, depends upon the difference in head pressure between this overlying aquifer and the Floridan Aquifer as well as on the permeability of the confining layer separating them. During periods when the Floridan Aquifer's potentiometric surface is locally low, rains may cause the Surficial Aquifer's pressure to be greater than that of the Floridan, with subsequent downward percolation to the Floridan. At other times, however, the potentiometric surface of the Floridan may be greater than that of the Surficial Aquifer and no recharge to the Floridan takes place. In this situation, water from the Floridan Aquifer may seep upward into the Surficial Aquifer. In instances where the Floridan Aquifer is confined and its potentiometric surface is above the land surface or above the level of overlying surface water, springs and seeps may flow from the aquifer and find their way into surface waters. High surface water levels (i.e., floods) and/or low ground-water levels may convert the springs into siphons, thereby draining surface waters directly into the aquifer (Ceryak et al. 1983) (Figure 49). This is common for the springs along many rivers and, in the instances of springs flowing through large underground passages, may allow substantial volumes of surface water to mix with ground waters, increasing the opportunity for large-scale contamination of ground waters with surface pollutants.

b. Anthropogenic factors affecting ground-water hydrology. Ground-water levels are affected, often extensively, by human activities. Four major impacts presently exist in the Panhandle: (1) ground water withdrawal; (2) drainage wells; (3) pressure injection wells; and (4) surface hydrology alterations.

(1) Ground water withdrawal tends to lower the potentiometric surface in the immediate vicinity of a well. As a result, ground water tends to flow laterally toward the pumped well to fill the potentiometric "hole," or cone of depression. The rate of this flow depends upon the local permeability of the aquifer and the pressure gradient between the well and the surrounding aquifer. Another factor affected by ground-water pumping is the depth to the saline layer underlying the fresh-water aquifers. Especially near the coast, excessive pumping of ground water results in saline intrusion into the potable aquifer. Because the density difference between the fresh-water aquifers and the deeper saline ground waters is minimal, the permanent lowering by 1 ft of the upper surface of the Floridan fresh water indicates that approximately 40 ft of of the fresh water was removed and that the upper surface of the underlying saline aquifer rose nearly 40 ft.

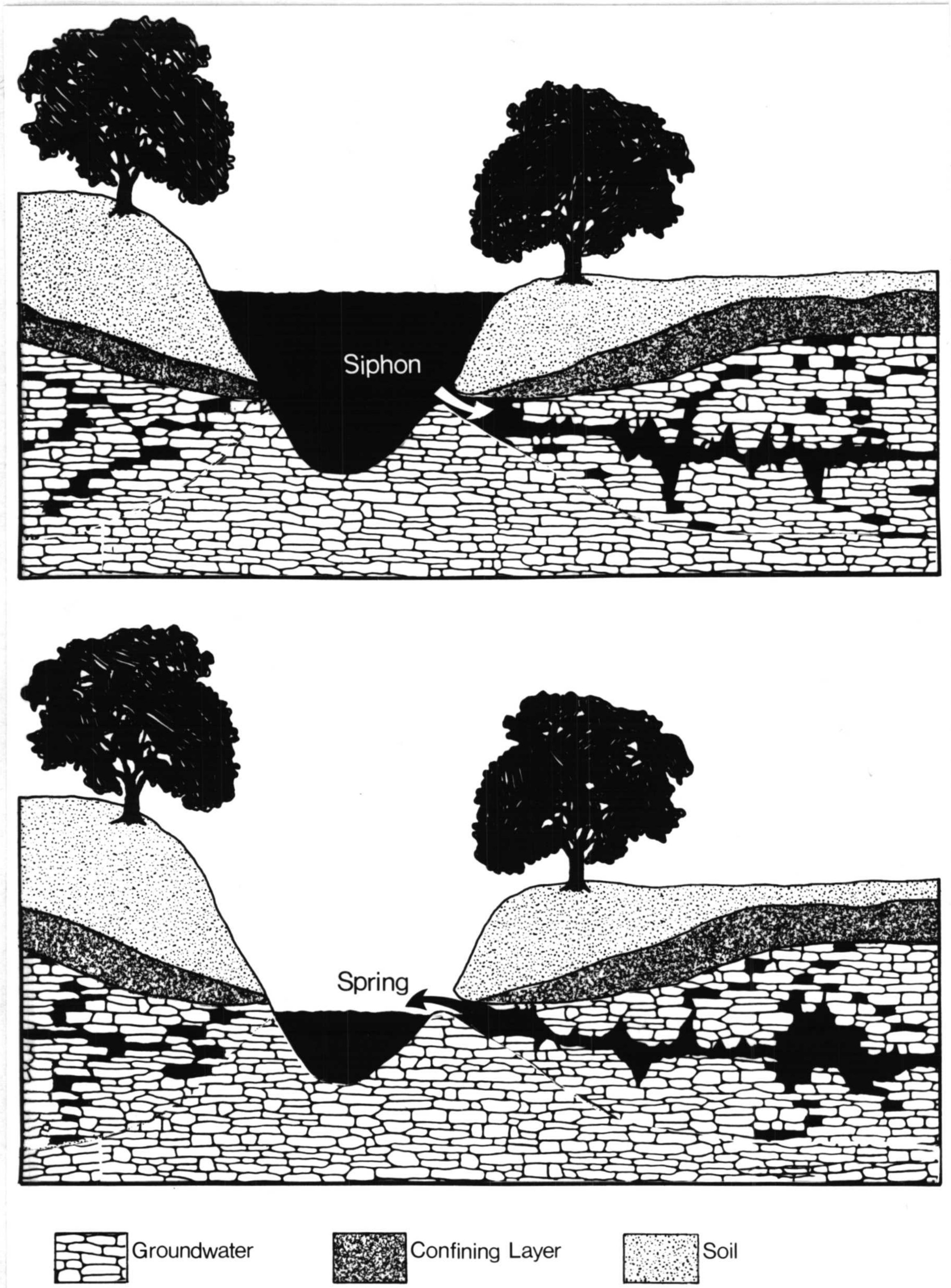


Figure 49. Generalized relationship of surface water to ground water for springs and siphons.

(2) Drainage wells have been used extensively in some areas to drain perennially-wet or flood-prone areas. These wells are drilled into an aquifer and the boreholes left open. "Excess" surface drainage is then directed to the holes. It is also common, in suitable areas, that sink holes connecting to ground water are used in place of drilled wells. The use of drainage wells has decreased markedly because of concerns about the poor quality of water draining into the aquifers. Attempts by the water management districts to locate these wells to help in water management planning have been hindered by the age of many of them and by poor records of their existence. At the time of this writing the USGS is preparing a map of known drainage wells (Kimrey, in prep). It is unlikely that most of the drainage wells in the Panhandle and in the State will be located.

(3) Pressure injection wells are used in various locations throughout the State as a means of wastewater and storm-water disposal. These techniques, when used with storm water and with appropriate caution towards their potential for ground-water contamination, may help recharge the aquifer with water that would otherwise evaporate or run off. Pressure injection wells are of two primary types, those injecting into the fresh-water aquifers and those injecting into the saline-water aquifers. Injection into many potable water zones yields little increase in storage since the artesian aquifers are already full, so this type of injection well is little used.

Liquid wastes are being injected into saline waters in the deeper zones of the Floridan Aquifer as a storage and disposal method. There is evidence that this use is expanding, especially in storing or disposing of secondarily treated sewage effluent (Hickey 1984). The USGS has mapped the general locations of deep saline aquifers that might be suitable for liquid waste disposal (Miller 1979). Waste water is also injected into nonpotable areas of saline intrusion to create a back pressure and slow further intrusion (Stewart 1980). Because of concern over the long-term effects of this practice, the USGS is involved in extensive investigations into this practice (e.g., Kaufman 1973; Pascale 1976; Pascale and Martin 1978; Ehrlich et al. 1979; Hull and Martin 1982; Vecchioli et al., in press; Merritt, in press) and chemical changes in the wastes following injection. Temporary storage of freshwater (storm water) in saline aquifers is being evaluated by the USGS in south Florida.

(4) The surface hydrology of aquifer recharge areas serves to channel water to or away from recharge areas (Figure 40). Recharge through sinkholes and other breaches of the confining layer, and by percolation through porous soils can be easily altered by human activities. Wetlands may serve to hold water over areas of low porosity, thereby increasing the amount of water percolating to the aquifer. Diversion of surface drainage to, or away from, sinkholes and wetlands, as well as speeding surface drainage away from recharge areas as a flood prevention measure, affects the amount and quality of water recharging the aquifer. Development activities, especially in recharge areas, must be performed carefully to ensure protection of ground-water supplies.

4.4.2 Major Influences on Ground-water Quality

a. Natural factors affecting ground-water quality. Many areas in the Panhandle function as recharge areas for the Floridan Aquifer (Figure 40), and the Floridan Aquifer, being unconfined in much of the Panhandle, is recharged throughout most of the area where it exists. There is often a general perception that surface water contacts ground water only after it has very slowly percolated through purifying layers of soil and rock. In Florida, including the Panhandle, this perception is generally incorrect. In many ground-water recharge areas, the surface bodies of water and surface runoff are directly connected to the ground water by channels through the intervening rock. Below the surface of the land, Florida is largely a sponge of karstic limestone penetrated by innumerable solution channels and sand beds. Though these porous layers of limestone are often separated by confining layers of clay and rock, their connections to the surface and to surface waters is evident in the numerous springs and sinkholes which dot Florida's landscape. Many sinkholes act as drainage gutters, providing direct contact between contaminated or uncontaminated surface runoff and the ground-water aquifers. The Sand and Gravel aquifer is just a layer of fine-to-coarse quartz sand sometimes mixed with small quartz or chert gravel (Hyde 1975) lying on top of a confining layer and exposed at the ground's surface.

Percolation of surface waters into this aquifer is fast and relatively unobstructed.

Ground water from the Floridan Aquifer is characterized by high pH, alkalinity, and hardness. This results from contact with the limestone within which the Floridan is found. Water from the Sand and Gravel Aquifer is acidic and has low concentrations of dissolved solids. The normal ground water characteristics in the shallower aquifers are affected by surface water hydrology. During periods of high surface water, substantial quantities of often dark, acidic swamp runoff find their way into and mix with (or replace) the ground water, rendering the quality of water from shallow wells similar to that of the surface waters.

b. Anthropogenic factors affecting ground-water quality. Anthropogenic effects on ground-water quality takes three forms: (1) contamination via surface waters and leaching of surface contaminants; (2) contamination via direct means, i.e., drainage wells and injection wells; and (3) increasing intrusion of saline waters into potable aquifers through excessive pumping of ground waters.

(1) The Surficial Aquifer, the Sand and Gravel Aquifer, and the Floridan where it is unconfined (not covered by a stratum of low permeability) are often at or near the surface and are by their proximity easily contaminated. Even where beds of low permeability overlie the aquifer (Figure 50), surface contaminants are relatively easily introduced. The terms "confining beds" and "low permeability" were drafted by hydrologists describing the movement of ground water. For purposes of water consumption, an overlying or surrounding stratum of low permeability may slow local ground-water recharge sufficiently to prevent large withdrawals of water from an area. Percolation rates measured in inches per day are very slow in terms of aquifer recharge, but all too fast in terms of movement of contaminants toward potable aquifers.

(2) Drainage wells have been in use for some time, sometimes for the disposal of sewage and other effluents, usually for the disposal of unwanted surface water. Concerns have been raised over the possible health effects of such activities, and their use is being actively discouraged. Injection wells are relatively new and, as is discussed in 4.4.1(b), their effects are being studied intensively by the USGS and they are heavily regulated by the U.S. Environmental Protection Agency (EPA) and the FDER.

(3) Salt water intrusion is becoming an increasing problem, especially in coastal areas. Withdrawal of excessive volumes of ground water increases intrusion of saline waters, as discussed in 4.4.1(b). One aspect of this that is often overlooked is that intrusion of saline waters into the shallow ground waters along the coasts (where the potable aquifers are thinnest) can change the makeup of overlying vegetation by killing species that are not salt tolerant.

4.5 Area-wide Surface-water Hydrology and Water Quality

The seven major Panhandle coastal rivers originate in Georgia or Alabama. Changing land use in these States, as well as in the Panhandle, is directly affecting the rivers' hydrology and water quality (FDER 1986c). There has been some successful cooperation among the States in investigating the interstate drainage basins (e.g., U.S. Dept. of Agriculture 1977), but less in instituting interstate corrections to problems.

Table 3 gives major drainage basin and waterbody sizes as well as streamflows for Panhandle lakes and rivers. Foose (1980) gives drainage basin, river, and lake areas for Florida including the Panhandle. His later work (Foose 1983) includes further statistics concerning flow characteristics of Florida rivers. The Northwest Florida Water Management District (NWFWMD) has published reports on the flood damage potential of the district (NWFWMD 1977); on the availability of water for industrial uses within the district (NWFWMD 1980a); on the availability of water resources in the peninsula area of southern Santa Rosa County (NWFWMD 1979b) and southern Okaloosa and Walton Counties (Barr et al. 1981); summarizing available rainfall data for the Panhandle (Kennedy 1982); and an exhaustive statistical summary and inventory of Panhandle lakes and streams which should answer most questions concerning hydrologic regimes and the frequency with which a given hydrologic condition occurs (Maristany et al. 1984).

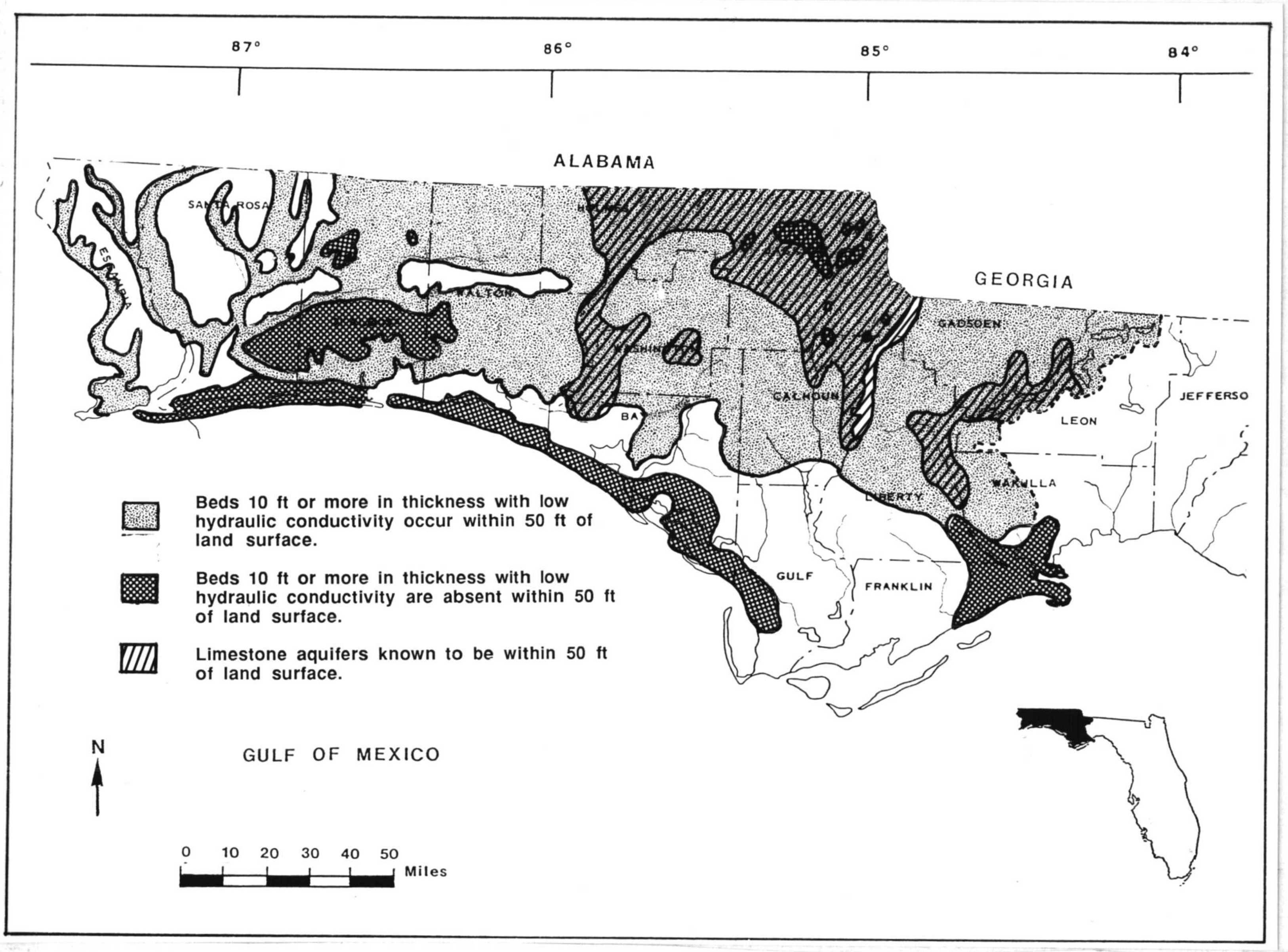


Figure 50. Location of limestone aquifers known to be within 50 ft of land surface and of surficial beds of low water permeability (after Healy and Hunn 1984).

Table 3. Drainage basin statistics for Florida Panhandle.

Basins	Main tributaries	Length (km)	Drainage area (km^2)	% of basin by state			Discharge gauging site and distance above mouth (km)	Mean annual discharge (m^3/s)	Mean annual Runoff (cm)
				Fl	Al	Ga			
Ochlockonee River	Telogia Creek (FL) Sopchoppy R. (FL) Crooked R. (FL)	331	5,830	48	0	52	Bloxham (105)	51	36.47
Coastal Area between Ochlockonee and Apalachicola Rivers	New R. (FL) Crooked R. (FL)	—	1,440	100	0	0	—	—	—
Apalachicola River	Flint R.(GA) Chattahoochee R.(AL,GA) Chipola R. (FL) Jackson R. (FL)	843	50,765	13	14	73	Blountstown (126)	701	48.54
Chipola River	Dry Creek (FL)	115	3,205	82	18	0	Altha (87)	42	65.99
St. Andrew Bay Coastal Area	Wetappo Creek (FL) Sandy Creek (FL) Bear Creek (FL) Econfina Creek (FL) Big Cedar Creek (FL)	—	3,500	100	0	0	—	—	—
Choctawhatchee River	Pea R. (AL) Wrights Creek (AL,FL) Sandy Creek (FL) Holmes Creek (AL,FL) Pine Log Creek (FL)	370	12,033	31	69	0	Bruce (34)	204	56.62
Choctawhatchee Bay Coastal Area	Lafayette Creek (FL) Alaqua Creek (FL) Rocky Creek (FL) Turkey Creek (FL)	—	1,190	100	0	0	—	—	—
Yellow River	Shoal R.(FL)	177	3,540	63	37	0	Milligan (64)	33	65.23
Blackwater River	Panther Creek (FL) Big Juniper Creek (FL) Big Coldwater Creek (FL) Pond Creek (FL)	100	2,230	81	19	0	Baker (56)	10	57.56
Escambia River	Murder R. (AL) Conecuh R. (AL) Canoe Creek (FL) Pine Barren Creek (FL)	386	10,960	10	90	0	Century (84)	178	56.97
Escambia Bay Coastal Area	East Bay River (FL)	—	1,410	100	0	0	—	—	—

The FDNR formulated a beach protection and preservation plan which also addresses hurricane protection (Henningsen and Salmon 1981). Panhandle water resources are discussed in a report by the U.S. Army Corps of Engineers (1978).

In the Florida Panhandle, pH is almost entirely controlled by the water's carbonate concentration (Kaufman 1975a). Almost all bodies of surface water have a maximum pH of 8–8.5. The minimum pH levels, however, vary substantially, ranging from 4–5 to over 7 (Figure 43). Most natural waters with a minimum pH of 4–5 are upstream of alkaline ground-water input, drain noncarbonate lands, and/or receive drainage from swamps (especially during periods of high flow). Natural waters of low pH tend to be characterized by low alkalinity (buffering capacity), low conductivity, low calcium concentrations (soft water), and some iron content. In the eastern portion of the Panhandle, they also have a greater tendency to be highly colored. Additionally, they tend to be corrosive and unstable, exhibiting wide, rapid fluctuations in pH. The pH of most Panhandle surface waters varies with rainfall and ground-water levels. Periods of heavy rainfall correlate with generally lower pH levels while periods of drought allow a higher proportion of ground water to increase the pH of most surface waters. Research into the possible existence of acid rain effects in the State suggest that rainfall in some parts of the State may be more acidic than could be expected because of powerplant and other emissions, but effects on the ecosystem have not yet been identified. The Panhandle and north-central Florida have the most acidic rainfall in the state, the pH averaging below 4.65 (Environmental Science and Engineering, Inc. 1984). The Panhandle stations tend to have a slightly higher pH than did those to the east.

Surface water temperatures across the Panhandle tend to follow seasonal patterns reflecting the air temperatures (Figure 51). The changes in water temperatures lag changes in air temperature. Freshwater surface temperatures in the Panhandle may vary from freezing in the winter to near 40 °C in the summer, depending upon the volume, depth, and location of the water body. Nearshore marine surface temperatures generally reach minimum

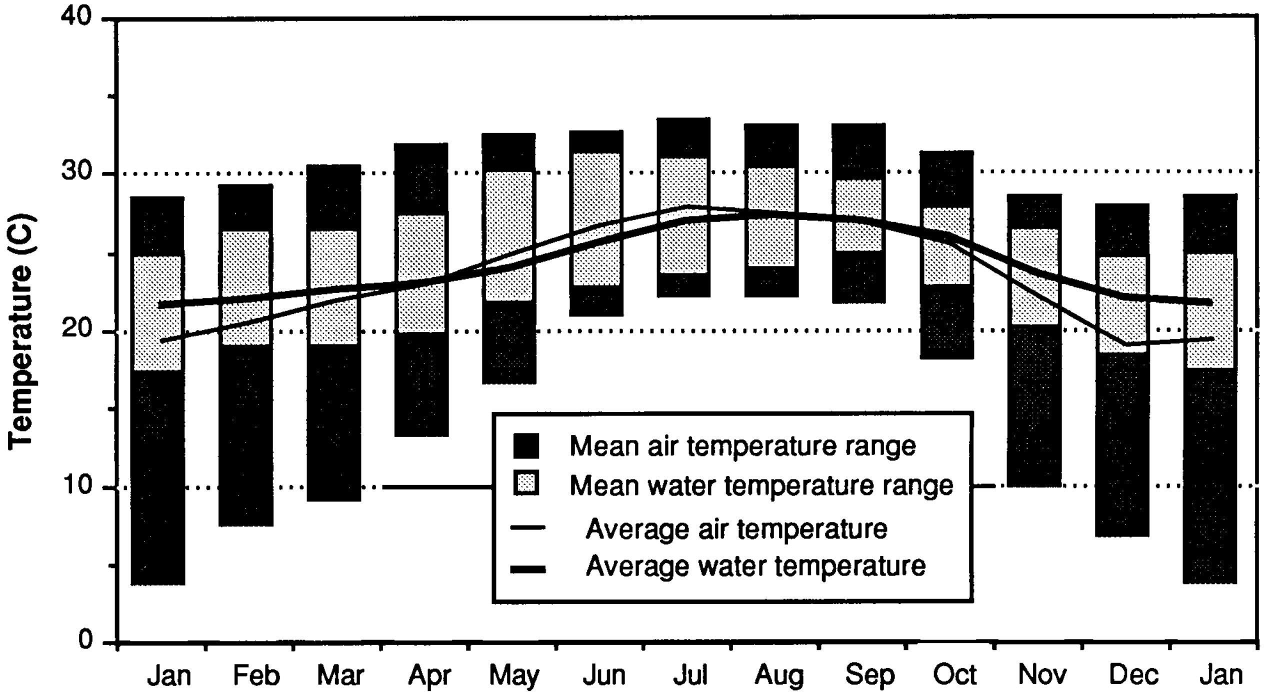


Figure 51. Seasonal fluctuations in air temperature at Tallahassee and Sanford Fire Tower and in water temperature of Sopchoppy River, June 1964 to September 1968 (after Anderson 1975).

temperatures near 10 °C in winter and maximum temperatures near 30 °C in summer. Shallow sheltered embayments and other areas with minimal mixing with offshore waters may, however, have greater temperature ranges than these.

The FDER ranked Florida lakes, based primarily upon their trophic state, in an effort to objectively determine those most in need of restoration and those most in need of preservation (Myers and Edmiston 1983). This ranking was based largely upon a report by the University of Florida, Department of Environmental Engineering Sciences (1983). Results pertaining to the Panhandle drainage basins are included in the following sections; however, since this ranking was performed on lakes where prior studies provided sufficient data, and since public interest was a factor weighed in assigning rank, it is not a definitive statement of the relative conditions of all lakes in Florida.

4.6 Area-wide Ground-water Hydrology and Water Quality

Ground water within the Florida Panhandle is influenced by the hydrology and water quality of the overlying surface water; however, the flow of ground water is little affected by the flow constraints of the overlying drainage basins. As a result the discussion of some aspect of ground water often includes factors from more than one drainage basin. Although ground water is discussed in the following drainage basin sections, each discussion is largely restricted to the effects of the surface waters in that particular basin upon the ground water. Studies looking at the aquifers on a larger scale and across more than one drainage basin are covered in this section.

The Floridan Aquifer contains most of the nonsaline ground water in the eastern portion of the Panhandle and is the primary potable water source in this area. Beginning in Okaloosa County and continuing westward, the Floridan is located deeper and its water becomes highly mineralized; therefore the Sand and Gravel Aquifer is more commonly used in these areas (Figure 37). The approximate thickness of the potable-water zone in the Floridan is shown in a USGS map (Causey and Leve 1976). Parts of Bay County use Deer Point Lake as a water source since the Floridan in that area has relatively low transmissibility and does not support large well fields (U.S. Army Corps of Engineers 1980a).

The Surficial Aquifer consists of a porous, sandy surface layer recharged locally and is separated from the underlying Floridan Aquifer by a clay-containing layer of low permeability—a confining layer or aquitard. The Surficial Aquifer varies in thickness and, where the underlying Floridan or the confining layer are at the surface, may not exist at all. To the west the Surficial Aquifer thickens and deepens and becomes the Sand and Gravel Aquifer (Figure 38). Additional small but usable quantities of water exist in some areas within the clay and sandy-clay confining layer separating the aquifers; however, except in rural areas with small requirements, these are little used because of the larger volumes available in the major aquifers. Because of the occurrence of this ground water within the confining layer, it is sometimes called the Intermediate Aquifer. Its primary action, however, is to restrict the movement between the Surficial or Sand and Gravel Aquifers and the underlying Floridan Aquifer.

The average temperature of the top 25 m of ground water in the Panhandle range is approximately 21 °C, varying about 4 °C throughout the year (Heath 1983). The shallow aquifers vary more than the deeper ones.

The USGS has conducted numerous investigations of the water resources of the Panhandle (Table 4). These include an examination of ground-water levels and water quality along the coast from Walton to Escambia Counties (Barraclough and Marsh 1962) and a later more detailed look at the water resources of Walton County (Pascale 1974). Both the Sand and Gravel Aquifer and the Floridan Aquifer are important in this county, with the Sand and Gravel storing water for stream baseflow and recharging the underlying Floridan. The Sand and Gravel is also used as a rural water supply. The Floridan is the primary water supply in the county. Transmissivity within the aquifer is highly variable. The Floridan is exposed in Alabama north of the Walton County where it is recharged by rainfall. Ground water within the Floridan moves south, discharging by springs and seeps along the Choctawhatchee River and by leakage to Choctawhatchee Bay and the gulf.

Table 4. U.S. Geological Survey Maps for the Florida Panhandle

Surface-water Hydrology

1. Runoff from hydrologic units in Florida (Hughes undated).
2. Runoff in Florida (Kenner 1966).
3. Annual and seasonal rainfall in Florida (Hughes et al. 1971).
4. Surface water features of Florida (Snell and Kenner 1974).
5. Water-level fluctuations of lakes in Florida (Hughes 1974).
6. Low streamflow in Florida—magnitude and frequency (Stone 1974).
7. Seasonal variation in streamflow in Florida (Kenner 1975).
8. The difference between rainfall and potential evaporation in Florida (Visher and Hughes 1975).
9. Average flow of major streams in Florida (Kenner et al. 1975).
10. An index to springs of Florida (Rosenau and Faulkner 1975).
11. River basin and hydrologic unit map of Florida (Conover and Leach 1975).
12. Florida: Satellite image mosaic (U.S. Geological Survey 1978).
13. Long-term streamflow stations in Florida, 1980 (Foose and Sohm 1983).
14. Hurricane Frederic tidal floods of September 12–13, 1979 along the Gulf coast, Oriole Beach, Garcon Point, Holley, south of Holley, and Navarre quadrangles, Florida (Franklin and Bohman 1980).
15. Hurricane Frederic tidal floods of September 12–13, 1979 along the Gulf coast, Gulf Breeze-Fort Barrancas quadrangles, Florida (Franklin and Scott 1980).
16. Hurricane Frederic tidal floods of September 12–13, 1979 along the Gulf coast, Perdido Bay quadrangle, Florida (Scott and Franklin 1980).
17. Wetlands in Florida (Hampson 1984).
18. Sinkhole type and development in Florida (Sinclair and Stewart 1985).

Surface-water Chemistry

1. The pH of water in Florida streams and canal (Kaufman 1975a).
2. Specific conductance of water in Florida streams and canals (Slack and Kaufman 1975).
3. Dissolved solids in water from the upper part of the Floridan aquifer in Florida (Shampine 1975a).
4. The chemical type of water in Florida streams (Kaufman 1975b).
5. Color of water in Florida streams and canals (Kaufman 1975c).
6. Generalized distribution and concentration of orthophosphate in Florida streams (Kaufman 1975d).
7. Temperature of Florida streams (Anderson 1975).
8. Nitrogen loads and concentrations in Florida streams (Slack and Goolsby 1976).
9. Dissolved-solids concentrations and loads in Florida surface waters (Dysart and Goolsby 1977).

Ground-water Hydrology

1. Top of the Floridan artesian aquifer (Vernon 1973).
2. The observation-well network of the U.S. Geological Survey in Florida (Healy 1974).
3. Piezometric surface and areas of artesian flow of the Floridan aquifer in Florida, July 6–17, 1961 (Healy 1975).
4. Principal aquifers in Florida (Hyde 1975).
5. Estimated yield of fresh-water wells in Florida (Pascale 1975).
6. Potentiometric surface of the Floridan aquifer in the Northwest Florida Water Management District, May 1976 (Rosenau and Meadows 1977).

(continued)

Table 4. Concluded

Ground-water Hydrology (concluded)

7. Potential subsurface zones for liquid-waste storage in Florida (Miller 1979).
8. Areas of natural recharge to the Floridan aquifer in Florida (Stewart 1980).
9. Estimated pumpage from ground-water sources for public supply and rural domestic use in Florida, 1977 (Healy 1981).
10. Potentiometric surface of the Floridan aquifer in the Northwest Florida Water Management District, May 1980 (Rosenau and Milner 1981).
11. Potentiometric surface of the Floridan aquifer in Florida, May 1980 (Healy 1982).

Ground-water Chemistry

1. Quality of water from the Floridan aquifer in the Econfina Creek basin area, Florida, 1962. (Toler and Shampine 1965).
2. Fluoride content of water from the Floridan aquifer of northwest Florida, 1963. (Toler 1965).
3. Chloride concentration in water from the upper part of the Floridan aquifer in Florida (Shampine 1975b).
4. Hardness of water from the upper part of the Floridan aquifer in Florida (Shampine 1975c).
5. Sulfate concentration in water from the upper part of the Floridan aquifer in Florida (Shampine 1975d).
6. Depth to base of potable water in the Floridan aquifer (Klein 1975).
7. Thickness of the potable-water zone in the Floridan aquifer (Causey and Leve 1976).
8. Chemical quality of water used for municipal supply in Florida, 1975 (Phelps 1978a).
9. Quality of untreated water for public drinking supplies in Florida with reference to the National Primary Drinking Water Regulations (Hull and Irwin 1979).

Water Use

1. Estimated water use in Florida, 1965 (Pride 1975).
2. Principal uses of freshwater in Florida, 1975 (Phelps 1978b).
3. Freshwater use in Florida, 1975 (Leach 1978).
4. Estimated water use in Florida, 1980 (Leach 1982a).
5. Consumptive use of freshwater in Florida, 1980 (Leach 1982b).
6. Estimated irrigation water use in Florida, 1980 (Spechler 1983).
7. Projected public supply and rural (self-supplied) water use in Florida through year 2020 (Leach 1984).

The USGS also carried out similar investigations of water resources in Okaloosa County in a study which included portions of western Walton County (Trapp et al. 1977). This study was prompted by the declining level of the upper Floridan Aquifer within the area. This area depends almost entirely upon this aquifer for its water supply. The study concluded that levels would continue to decline until wells were better distributed, and alternate water sources, such as the Sand and Gravel Aquifer or surface waters, were placed into operation. This report includes a good description of the drainage conditions throughout the region. These conditions vary widely because a number of different physiographic regions and soil types are found within the area.

These USGS studies on the western Panhandle were updated by later publication of a hydrologic budget for Escambia County (Trapp 1978), of hydrologic and water quality data for Okaloosa, Walton, and southeastern Santa Rosa Counties (Wagner et al. 1980) and in a study of the hydrology of the coast of Okaloosa and Walton Counties (Barr et al. 1985).

The USGS has produced many maps depicting ground-water hydrology and water quality in the Panhandle. These are listed in Table 4. In addition to the USGS studies, the NWFWMD has performed ground-water studies of the quality and availability of water from the Sand and Gravel Aquifer in southern Santa Rosa County (Pratt and Barr 1982), the hydrogeology of the Sand and Gravel Aquifer in southern Escambia County (Wilkins et al. 1985), and the hydrogeologic effects of solid-waste landfills in northwest Florida (Bartel and Barksdale 1985). The NWFWMD has also compiled a ground-water bibliography with geological references for the district (Wagner 1985).

The lack of separation between surface and ground water in most of the Panhandle, especially in those areas where springs abound, cannot be over emphasized. The direct connections can easily be verified by observing local wells and springs during moderate to high water periods. At these times, well waters and springs are often brown from the tannic acid of surface waters, and some springs can be seen to be acting as siphons, draining surface waters to the underlying aquifer (Figure 49).

Within the Panhandle, ground-water pumping has lowered the potentiometric surface of the Floridan Aquifer significantly only in coastal Okaloosa County (Figure 52). In this region, the surface of the aquifer declined approximately 27 m between 1940 and 1961 (Barraclough and Marsh 1962) and another 12 m between 1961 and 1972 (Healy 1982). This permitted saltwater intrusion and contamination of area water supplies. Relocation of wells farther inland and other measures reducing the withdrawal of ground water have resulted in a partial rise in the surface of the aquifer in this area. However, water levels in 1980 were still as much as 33.5 m below 1940 levels (Wagner et al. 1984). Ground-water pumping for irrigation in southwest Georgia increased 500% between 1973 and 1980 (U.S. EPA 1983); this withdrawal has been documented as affecting nearby wells and surface water flow, including that of Panhandle rivers with basins in that area (FDER 1986c).

Ensuring continuing water supplies requires regulation by governmental authorities because the hydrology and water quality of Panhandle ground waters are wide-reaching phenomena which do not respect private boundaries. We encourage the continuing public purchase of major ground-water recharge areas as the best long-term solution to maximizing recharge while protecting water quality.

4.7 Basin Hydrology and Water Quality

4.7.1 Ochlockonee River Basin (Figure 53)

The Ochlockonee River and its numerous tributaries drain approximately 5,830 km^2, of which 52% (3,030 km^2) is in Georgia and 48% (2,800 km^2) in Florida (Foose 1980). Within Florida, the Ochlockonee River basin cuts through two physiographic divisions, the red clay of the Tallahassee Red Hills in the north and the sandy Gulf Coastal Lowlands in the south (Puri and Vernon 1964). The Ochlockonee and its major Florida tributary, the Sopchoppy, have been designated Outstanding Florida Waters (OFW—no significant degradation permitted).

Approximately 105 km down the river's 180-km course through Florida, the Jackson Bluff Dam backs the river up to form Lake Talquin. This dam was operated as a hydroelectric generation plant from 1930 to 1970 and was reactivated in 1985. The operation of the powerplant turbines can cause substantial drops in lake level over short periods of time; as a result their use is being limited to that producing drops of less than 1 ft below normal (nongenerating) levels. Lake Talquin is listed by Myers and Edmiston (1983) as one of the top 50 lakes in the State needing preservation and protection. The river drops about 27 m from the Georgia border to the coast (Pascale and Wagner 1982). Above the dam the river is characterized by sharp bends and low banks with an average fall of 0.14 m/km. Below the dam the river widens and passes through wide bottomlands and marshes, becoming tidal 19 km from the mouth. Much of the river basin below the dam (about 910 km^2) is contained in the Apalachicola National Forest and a portion (about 65 km^2) near the mouth is in the St. Marks National Wildlife Refuge.

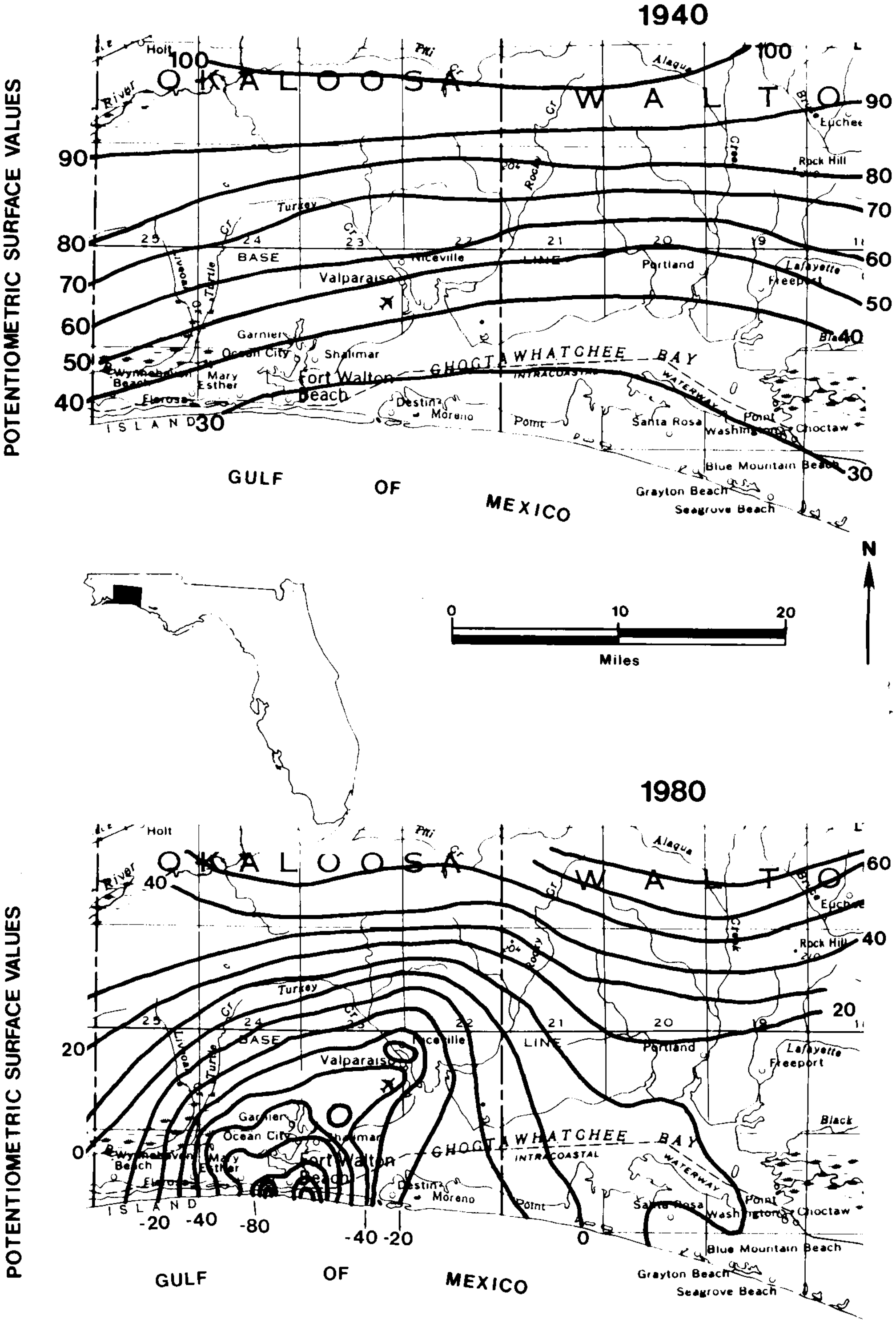


Figure 52. Potentiometric surface of the Floridan aquifer (in ft above MSL) in 1940 and 1980, before and after increased ground-water pumping in the area of western Choctawhatchee Bay (after Wagner et al. 1984.)

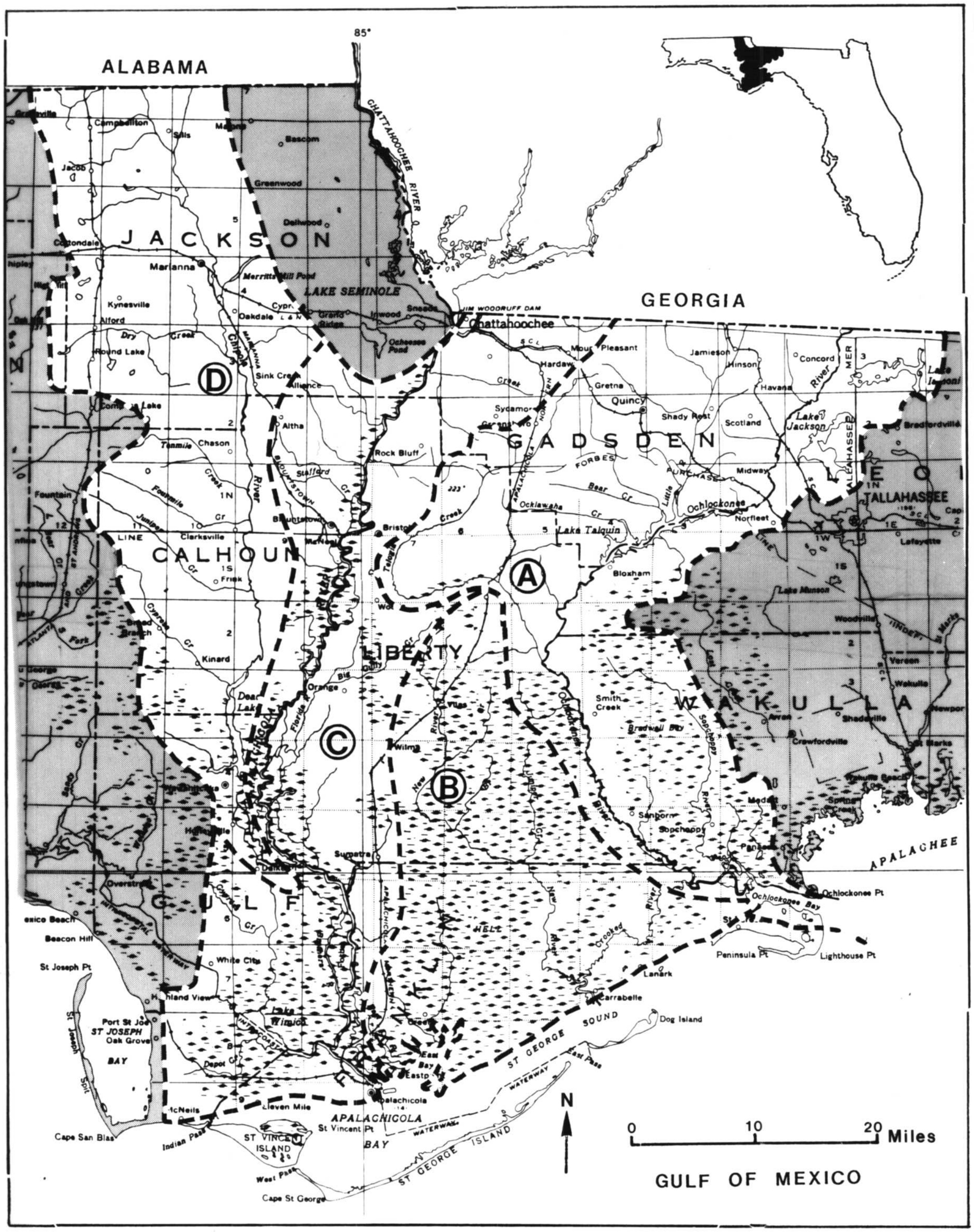


Figure 53. Eastern Panhandle drainage basins—(A) Ochlockonee River, (B) Coastal area between Ochlockonee River and Apalachicola River, (C) Apalachicola River, and (D) Chipola River (after Conover and Leach 1975).

East of the river near the Florida-Georgia border lie two large lakes whose water level is loosely affected by ground-water levels (Sellards 1917, Hendry and Sproul 1966). Lake Iamonia and Lake Jackson were formed by the the coalescence of sinkholes caused by solution and collapse of the area limestone (Hutchinson 1957). The lakes are poorly connected to the Floridan Aquifer through numerous completely or partially plugged sinkholes in their lake beds. Lake levels normally are 11–14 m above the potentiometric surface of the Floridan Aquifer (Pascale and Wagner 1982) and, as a result, leak to the aquifer, thereby recharging it. They sometimes drain completely following extended dry spells when the aquifer has dropped several feet. Lacking the ground water's support of the overlying limestone and sediments, either sinkholes form as the lake bed collapses into the now air-filled cavities, or the sediment plugs which block pre-existing sinkholes collapse. The remaining lake water may then rush "down the drain" over a few days or weeks. The last two occurrences in Lake Iamonia were in 1931 and 1981; the last two in Lake Jackson were in 1956 and 1982. The lakes refill when the water table returns to normal levels, and the sinkholes eventually plug with new sediments. The hydrologic significance of flooding in Lake Jackson during 1960 was reported on by the USGS (Hughes 1969). A hydrologic assessment of the 1982 draining was performed by the NWFWMD (Wagner 1984).

Until recently Lake Iamonia was connected to the Ochlockonee River by a natural channel which allowed river flood waters to flow to the lake and lake flood waters to flow to the river's flood plain. A structure was built to regulate this flow in 1976 (Pascale and Wagner 1982). Since 1977 efforts have been underway to drain the lake through a sink located on the north shore in an effort to control the growth of aquatic vegetation. A hydrologic assessment of the lake and the sink was performed by the NWFWMD (Wagner and Musgrove 1983).

The Lake Jackson basin has been increasingly developed with the resulting sediment and nutrient input accelerating eutrophication and degrading the lake's water quality and habitat (Babcock and Rousseau 1978). Harris and Turner (1974) studied the lake's water quality and characterized the northern sections of the lake from good to excellent while the southern sections, including Megginnis Arm, Ford's Arm, and a small part of the open lake, were fair to poor and highly variable. Following Harris and Turner's study, the water quality was monitored by the Florida Game and Fresh Water Fish Commission (Babcock 1977) and then by the FDER. Algal assays were performed by FDER on two occasions to determine the nutrients limiting algal growth in Megginnis and Ford's Arms and in the northern mid-lake (FDER 1980). They found that, at the times of sampling, the water of Megginnis Arm was primarily phosphate limited and secondarily nitrogen limited. The water in Ford's arm and the mid-lake north station were nitrogen and phosphate colimited. In all instances the growth was below that expected. This was tentatively attributed to the phosphate available for biological uptake being less than the orthophosphate concentrations found by chemical analysis. In an effort to slow this degradation, a number of local, State, and Federal agencies cooperated in the installation in 1984 of a stormwater retention and treatment facility using some relatively untried methods (NWFWMD 1984). The facility's use of retention ponds and aquatic plants for sediment and nutrient removal is still being evaluated and adjustments are still being made, but initial results show improved water quality in the water being discharged to Megginnis Arm (Tuovila et al. in press). However, substantial improvement in the overall water quality of the arm has not been demonstrated, possibly because of the release of nutrients bound up in lake bottom sediments.

West of the river and away from the coasts, surface runoff forms myriad tributary streams. Many of these, including Little River, Bear Creek, and Ocklawaha Creek, drain into Lake Talquin. The land east of the river in this area is a porous karstic limestone that provides a quick path for rainfall to recharge the aquifer. As a result, the familiar dendritic pattern of stream runoff is absent. The ground and surface water resources of the Little River basin have been examined by the NWFWMD (Wagner 1982, Maristany 1983).

The Ochlockonee River receives very little ground water contribution in its upper reaches (Pascale and Wagner 1982), thus its flow is dependent on rainfall patterns and is highly variable. Ochlockonee Bay and possibly the lower river receive ground-water flow as the rocks of the Floridan Aquifer outcrop and the aquifer potentiometric surface is above the surface of the river. Cray's Rise, on the north shore of Ochlockonee Bay, is an example of aquifer discharge. Bradwell Bay, a large marsh east of the river's lower reaches, has formed because of poor soil permeability and lack of a sufficient relief to promote drainage. The Sopchoppy River flows alongside and east of the lower Ochlockonee River into the Ochlockonee Bay estuary. The Sopchoppy River is often considered a tributary of the Ochlockonee River (NWFWMD 1979); however, the USGS feels that the flows are sufficiently separated to merit listing them as independent rivers (Pascale and Wagner 1982). Hand and Jackman (1984) reported naturally low pH levels in several of the basin tributaries, particularly the Sopchoppy River, caused by the swampy drainage lands. Hydrologic, geologic, and water quality data for the Ochlockonee River basin was compiled by Pascale et al. (1978). The USGS reported on severe flooding in Gadsden County during 1969 (Bridges and Davis 1972).

The water quality of the upper river has been deteriorating in recent years (Hand and Jackman 1984, FDER 1986a). Forestry and agriculture are the predominant land uses in the basin; however, fuller's earth (clay) is mined in Georgia and Florida near the border and sedimentation from the mining has reduced benthic community diversities in the upper section of the river. Bacteria and nutrients from point sources in Georgia have historically damaged the quality of the river water entering Florida. In Florida, Attapulgus and Willacoochee Creeks are the major contributors of sediment-laden water to the Ochlockonee (FDER 1986c). The Little River and its upstream tributary Quincy Creek have historically shown bacteria, nutrient, and turbidity problems from upstream sources including the City of Quincy Sewage Treatment Plant and Fuller's earth mining at the Floridan strip mine (Hand and Jackman 1984). Additionally, below the Georgia-Florida border the river water quality has historically had DO, bacteria, nutrient, and turbidity problems. Twenty-three major permitted point source dischargers operate in the basin. Thirteen of these are sewage-treatment plants (eight in Georgia and five in Florida) and ten are industrial dischargers. High bacteria and nutrient concentrations and low macroinvertebrate diversity continue to be problems. The water quality of the Ochlockonee River improves downstream from this area. Hand and Jackman (1984) and FDER (1986a) attributed these problems to Georgia point sources. According to Georgia's 1982 305(b) report (reporting status of the State's water quality to EPA) these problems should decrease because of treatment plant upgrading.

Five stations within the basin were examined during 1973–78 for biological indications of water quality (Ross and Jones 1979). A station in the Ochlockonee River near the Georgia border was sampled only a few times. Macroinvertebrate species diversities appeared high, though Biotic Index values suggested the possibility of problems with low dissolved oxygen during summer low flow. At a station below the Talquin Dam, too few macroinvertebrate samples were taken to make judgments, but bacteria counts were occasionally high, probably from runoff. A station in Lake Jackson appeared to improve during the study period; however, nutrient and silt inputs from urban and residential runoff had degraded apparent water quality and contributed to nuisance growth of aquatic weeds. A station in the Sopchoppy River at SR 375 was in an area primarily of swamp drainage; macroinvertebrate diversity was high from the three samples taken. The final station in Ochlockonee Bay west of Bald Point had consistently high macroinvertebrate diversity.

The water resources in the area from Quincy in Gadsden County southeast to the Ochlockonee River above Lake Talquin have been studied for their ability to support industry (NWFWMD 1980a). This study showed that the water quality of the Surficial and Intermediate Aquifers is generally good, but bacterial levels in the Surficial Aquifer, caused by its proximity to the surface, require that the water be treated before use. The Surficial Aquifer in this basin is presently important primarily for its water storage capacity (approximately 1.25×10^9 m^3), its maintenance of streamflow, and its recharge of the Intermediate and Floridan Aquifers (Pascale and Wagner 1982). The Intermediate Aquifer (which is also known as the water bearing zone of the upper confining unit of the Floridan) in the northern basin consists of a low-permeability layer of sandy clay and sandy limestone of variable thickness (from 0 to a maximum of about 60 m in the Greensboro-Quincy area) confined above and below by layers of clay. The extent of this aquifer diminishes southward through Gadsden County and is discontinuous south of Lake Talquin. These shallow aquifers are suitable only for very small demands. The clay layer separating the Intermediate Aquifer from the Floridan is approximately 6 m thick in Gadsden County (NWFWMD 1980a). The Floridan at this location is of relatively low porosity and is recharged locally by leakage through the confining layer. The low rate of recharge allowed by the confining layer has prevented thorough flushing of the Floridan locally, and residual sea water from the last period during which the area was below sea level is still present at relatively shallow depths within the aquifer. The water quality of this aquifer is acceptable, with the concentration of dissolved solids increasing rapidly with depth. Wells tapping the Floridan yield as little as 75 l/min in Gadsden County to as much as 17,000 l/min in Leon County.

The USGS has mapped the flood-prone areas (i.e., those inundated by a 100-year flood) of Gadsden County (Rumenik et al. 1975). As would be expected most of these areas are along the rivers and streams of the county; however, numerous spots are unattached to these drainageways.

Ground-water pumping for the town of Panacea from two wells drilled in 1965 resulted in saltwater intrusion by 1970. Subsequent investigation by the USGS determined that the aquifer discharges to the bay and river, and that the upward movement of aquifer flow in the area tends to bring deeper salty water into the upper zone of the aquifer (Pascale and Wagner 1982).

Ground-water movement in the northern part of this basin tends to be towards the southeast west of the river and to the south east of the river toward Wakulla Springs, 16 km south of Tallahassee.

4.7.2 Coastal Area between Ochlockonee and Apalachicola Rivers (Figure 53)

This 1,440 km^2 area is poorly drained and consists of two main regions. The eastern portion of the basin (830 km^2) is the area drained by the New River and its tributaries, which discharge into St. George Sound at the town of Carrabelle. The western portion is Tate's Hell Swamp, a large, densely wooded and vegetated swamp which drains to East Bay in Apalachicola Bay. Whiskey George Creek is the stream within Tate's Hell with significant flow to East Bay.

The construction within the swamp during the early 1970's of logging roads and drainage ditches to direct surface water to the Apalachicola River is reported to have altered the drainage patterns sufficiently to result in dry areas, substantially altering wildlife habitat and increasing fire hazard (Bruce Means, Coastal Plains Institute, pers. comm.).

The major causes of water quality problems in this basin are the discharges to the coast from the sewage treatment plants in Carabelle and Eastpoint and surface runoff from forest clearcutting by Buckeye Cellulose Corporation. The City of Eastpoint Water and Sewage District Waste and Treatment Facility is being upgraded and the system expanded to replace many of the septic tanks in the area. The City of Carabelle Wastewater Treatment Plant is the only plant in northwest Florida providing only primary treatment (Florida Rivers Study Committee 1985). The highly chlorinated sewage which is discharged degrades the water in the vicinity of the outfall to St. George Sound and settles to form putrescent sludge deposits. Overly enriched waters produce plankton blooms and excessive growth of filamentous algae, bacteria, viruses, and fungi that are pathogenic to the sea grasses of St. George Sound. This plant has been under some form of enforcement action for years.

The effects of runoff from forest clearcutting operations upon the New and Crooked Rivers was investigated by Hydroscience, Inc. (1977). They calculated minimal long-term effects upon the rivers and the bay into which they discharge, but felt that short-term nutrient, turbidity, and color spikes could be a problem. Their investigation was, however, aimed at effects in the rivers, and not at the effects upon the wetland hydrology in the swamps. The purposeful draining of the wetlands to ease timber harvesting was the source of changes documented by their study.

This basin has been studied very little. No stations examining the biological indications of water quality were located in this basin during the period analyzed by Ross and Jones (1979).

4.7.3 Apalachicola River Basin (Figure 53)

The Apalachicola River is the 21st largest river in flow in the conterminous United States and is by far the best studied river system in the Panhandle. The Apalachicola, together with its main out-of-State tributaries, the Chattahoochee and Flint Rivers (together often called the A-C-F basin) and its main in-state tributary, the Chipola River (separately addressed in 4.7.4), drains approximately 51,000 km^2 of Georgia, Alabama, and Florida. Of this basin only 13% (~6,500 km^2) is in Florida, and the Florida portion, excluding the Chipola River basin, is less than 8% (~3,830 km^2) of the total. The majority of the remaining 44,500 km^2 consists of Georgia's Flint River watershed, which drains into Lake Seminole on the Georgia-Florida border. River flow normally varies from 250 to 2,800 m^3/s (FDER 1984a) and the mean flow from 1958 to 1980 was 690 m^3/s (Leitman et al. 1983). The river width at mean discharge varies from 75 to 300 m (FDER 1984a). Seasonal river stage fluctuations are 3 times greater in the upper river than in the lower and peak floods are most likely to occur during January through April (Leitman et al. 1983). Low flows are usually found during September through November. Georgia rainfall has much greater influence on flow in the upper Apalachicola than does Florida rainfall. Georgia rainfall is slightly higher in winter and much lower in summer than is Florida rainfall. Both experience similar quantities of rain in spring and minima in October–November.

When the Apalachicola is high the Chattahoochee River contributes most of the flow as it is steeper than the Flint River and has abundant rainfall in its upper basin. This results in large pulses in the Chattahoochee contribution. The Flint River basin is flatter and receives much spring flow, providing a more stable flow regime. During low flow conditions in the Apalachicola, these two tributaries contribute more equal flow. During extreme low flow the Flint is the major contributor (Leitman et al. 1984). The Chattahoochee contribution is becoming more stable because of the Army Corps of Engineers' dams and flow regulation. During the next 20 to 30 years growth of the Atlanta area and the resulting increased use of the Chattahoochee River as a water supply could reduce the volume of its contribution to the Apalachicola River and Bay (Livingston 1983). This has the potential to seriously alter the salinity regime within the bay, thus reducing the fisheries potential. The Apalachicola River discharge peaks in winter and early spring and declines until fall (Figures 45 & 46). The average winter–early spring flow is 2 to 3 times the average summer flow. The Florida basin rainfall averages 147 cm while the mean annual potential evaporation is 99–114 cm (U.S. Dept. Agriculture 1969).

From Chattahoochee to Blountstown the river has long straight stretches and gentle bends. This part of the basin is characterized on the east side by steep bluffs backed by relatively high and rugged terrain. Small tributary streams have incised deep channels producing the most hilly area of Florida. On the west side the basin consists of gently rolling, lower land containing a 1.5–3 km wide flood plain (Leitman et al. 1983). Ocheesee Pond, west of the river in Jackson County, is the largest natural lake in the area. From Blountstown to Wewahitchka the river channel meanders with large loops and many small tight bends to the south, and the flood plain is 3–4.5 km wide. Below Wewahitchka the river has long straight stretches with a few small bends and the flood plain widens to 4.5–8 km. A map of the Apalachicola River flood plain and data on the associated hydrologic conditions are presented in Leitman (1984).

At the Chipola Cutoff (just below Dead Lake), approximately 25% of the Apalachicola flow diverts to the Chipola River (Ager et al. 1983). The Chipola River flow measured above the Chipola Cutoff averaged 10% of that of the Apalachicola River during 1979–80 at Sumatra (Leitman et al. 1983). A similar situation exists farther downstream where the Brickyard Cutoff diverts Apalachicola flow to near the head of the Brothers River. This diversion involves sufficient quantities of water that the water chemistry of the Brothers River is controlled by that of the Apalachicola River (Ager et al. 1983).

Lake Wimico is located in the southern part of the basin west of the Apalachicola and receives runoff from numerous streams draining the southwestern portion of the Apalachicola River Basin. From here the water flows 5.5 km via the Jackson

River to the Apalachicola River, near its mouth. Lake Wimico is one of the 50 lakes in the State listed in Myers and Edmiston (1983) as most in need of preservation and protection.

Land use in the basin is diverse and includes agriculture, forestry, and manufacturing. The basin hydrology has been substantially altered by dredging, spoil disposal, and construction of navigational aids. The Corps of Engineers constructed four cutoffs in 1956–57 and three more in 1968–69, straightening oxbow river bends to ease barge traffic. These cutoffs have shortened the river by 3 km. About 765,000 m^3/yr are dredged from the river and placed in and along the river in an effort to maintain the Federally authorized 9 ft by 100 ft channel (Eichholz et al. 1979). Effects on water quality within the river were felt for only a short distance below the dredging activity and impacts were minor because the dredging usually takes place in areas with unstable bottoms and hence low productivity. Additionally, much of the dredged material is medium to coarse sand, the suspension of which produces little and short lived turbidity (Leitman et al. 1984). The Corps of Engineers reported that turbidity in the dredging plumes dropped to ambient within 18 m of the discharge pipe.

Dredge material disposal sites along the lower river have been studied to assess their effects (Eichholz et al. 1979, Leitman et al. 1984). Army Corps of Engineers dredging of the river shipping channel has affected river and floodplain hydrology and biota. Effects from dredging extend into habitats beyond the river bed. Spoil deposited in floodplains adjacent to the river, in addition to killing the trees and other plant growth within the spoil area, altered the hydrologic flow patterns in the floodplain and therefore, in some instances, the habitat. Eichholz et al. (1979) recommended spoil disposal between the river banks in areas where the bottom was unstable already and therefore low in productivity. Leitman et al. (1983) found that the river stage at Chattahoochee was lower than before channel alterations. Lake Seminole serves as a sediment trap and tends to adsorb metals and other potential pollutants from upriver and prevent their migration downriver. It is estimated that Lake Seminole traps 65%–70% of the sediment flowing into it. Heavy metals in dredged sediments were low except for iron, which was primarily in an insoluble form (Leitman et al. 1984). Pesticides in the sediments were generally below detection levels and those detected—Archlor 1254 (a DDT breakdown product) and 2-4 D—were in the upper river.

The bed of the Apalachicola River is undergoing degradation, whereby it erodes away, lowering its elevation and exposing bedrock outcroppings. The rate of this process in the upper river has been increased by the construction of the Jim Woodruff Dam (Leitman et al. 1984). The State of Florida, after many conflicts over the A-C-F basin with Alabama and Georgia, entered into a Memorandum of Agreement with those States in 1979 to cooperate in a long range water budget and management plan. As part of the Agreement, required by the other States prior to their consenting to having Apalachicola Bay designated a National Estuarine Sanctuary, Florida promised to cooperate in efforts to increase the availability of a 9-ft channel, and subsequently gave the Corps of Engineers permission in 1984 to remove a number of rock outcroppings (USACE 1984). Removal of outcroppings, which slow river flow, destroys valuable fishery habitat (Eichholz et al. 1979). Before this work was completed the Corps suggested other areas for removal (Florida Rivers Study Committee 1985). Navigation projects in the Apalachicola are incrementally altering the river ecosystem. Each project since 1954 has been justified as maintaining the Federally permitted 9-ft deep channel. To date, little overall improvement has been noted. The 9-ft controlling depth is available an average of 80% of the time and in 1981 (a dry year) was available less than 10% of the time (Florida Rivers Study Committee 1985). It appears that this depth will also be available very little during 1986 following the record spring drought. It seems that during some portions of the year a 9-ft by 100-ft channel in the Apalachicola River requires a greater volume of water than the river can provide without sacrificing the river basin habitat, and that the goal of 95% availability of this depth is not realistic.

Water resource projects (dams and other flow-control structures) are common. The Corps of Engineers has constructed and operates a network of five large dammed impoundments in the Chattahoochee River subbasin alone. Sixteen dams exist in the river basin, including those in Georgia and

Alabama; the five largest influence seasonal, weekly, or daily flows; the other eleven have no effect on flow (Leitman et al. 1983). The southernmost dam in the Apalachicola watershed, the Jim Woodruff Lock and Dam, which became operative in 1954, is located near the Florida-Georgia border and marks the beginning of the Apalachicola River. Lake Seminole, formed behind the dam, is located at the Florida-Georgia border and receives flow from the Chattahoochee and Flint Rivers. The dam was constructed primarily to aid upstream navigation and to generate power, and secondarily to regulate streamflow and for recreation and conservation (Maristany 1981). Normal dam operations restrict lake level fluctuations to 1 ft. Maristany (1981) concluded that the dam has practically no flood control capability because its working storage is equal to approximately 1 day of average river flow. Additionally, it has limited use for low flow regulation because the working storage could only augment downstream river flow by 10% of the average river flow for 10 days. He further concluded that the dam has exhibited practically no effect on annual mean flows. More detailed information on the Chattahoochee and Flint Rivers is available in a comprehensive report compiled by the States of Alabama, Georgia, and Florida in cooperation with the Mobile District of the Army Corps of Engineers (USACE 1984). The Florida Department of Administration (1977) prepared a report on the Apalachicola River and Bay System prior to the State's designating it an Area of Critical State Concern. This report examines the potential impacts of various basin alterations including additional dams and locks, channelization, and levees.

The Florida portion of the Apalachicola River and Apalachicola Bay have been designated Outstanding Florida Waters (OFW); that portion below the northern Gulf County line since 1979 and that above it since 1985. The Florida Defenders of the Environment wrote a persuasive report describing the upper Apalachicola basin and nominating it for OFW status (Florida Defenders of the Environment 1982). One mile of the 107 river miles in Florida was not designated OFW because of preexisting industry: one-half mile adjoining the Jackson County Port Authority and one-half mile below SR 20 (FDER 1984a). The OFW designation was further altered to exempt Army Corps of Engineers' maintenance of a shipping channel. The effects on the hydrology and ecology of the basin from the dredging and rock removal planned and carried out as part of this maintenance are discussed in Leitman et al. (1984). Following the Federal purchase of substantial quantities of surrounding lands, the lower river and Apalachicola Bay was named a National Estuarine Sanctuary. They have also been designated a State Aquatic Preserve and an International Biosphere Reserve. The head of the river basin is north of Atlanta in the Blue Ridge Mountains and parts of the Georgia and Alabama portions of the basin are urbanized. These areas include Gainesville, Atlanta, Columbus, Thomaston, and Albany in Georgia, and Phoenix City, Eufaula, and Dothan in Alabama. The Florida portion is sparsely populated with four population centers: Chattahoochee, Marianna, Blountstown, and Apalachicola. However, runoff from steep terrain in Chattahoochee, Sneads, Blountstown, and Bristol could be the source of future problems (FDER 1984a).

Apalachicola Bay is dependent upon the transport of nutrients from the river's flood plain (Livingston 1981, Mattraw and Elder 1983). This transport takes place as both dissolved nutrients and detritus, with detritus playing the most important role. The Jim Woodruff dam stops detrital transport from further upriver; therefore Apalachicola Bay depends upon its floodplain in Florida for most of its nutrient input. The water flowing from Lake Seminole does not contain a substantial nutrient load, either dissolved or as detritus (Elder and Cairns 1982). The height of natural river bank levees and the size and distribution of breaks in the levees have a major controlling effect on the floodplain hydrology (Leitman et al. 1983). Much of the lower river floodplain is permanently or semipermanently flooded; Leitman et al. (1983) and Leitman (1984) detail floodplain locations and descriptions. Nutrient and detritus transport in the Apalachicola River has been analyzed (Mattraw and Elder 1980, Elder and Mattraw 1982, Mattraw and Elder 1983). Annual floods cause appreciable surges in nutrient transport, especially as detritus. In an 86 day flood in 1980 they found that half of the annual outflow of organic carbon, nitrogen, and phosphorus, along with 60% of the annual detritus load, passed their sampling station closest to the bay. The total organic carbon outflow at this station was 50% greater than the inflow to the river at Jim Woodruff Dam and 25% greater than the increase in streamflow. The nitrogen and phosphorus increases were proportional to the streamflow increase. On an areal basis, they found the Apalachicola basin to export greater quantities of carbon and phosphorus than most watersheds. In an earlier study it was found that the Apalachicola floodplain produces dissolved nutrients at approximately the same rate it consumes them, but that it is an exporter of detrital matter (Elder and Cairns 1982). The Apalachicola wetlands produce some net increases in organic carbon and phosphate transport, but no net change in nitrogen concentrations (Mattraw and Elder 1983). Elder and Cairns (1982) discuss in detail the quantities and nutrient makeup of the floodplain detritus. The FDER (1984a) concluded that "Significant alterations in the form or amount of substances which reach the [Apalachicola] estuary could influence productivity of the bay. Alterations which would block the transport of detritus and nutrients out of the floodplain or which limit the variations in flow volume of the river could have negative impacts on Apalachicola Bay."

Best et al. (1983) investigated the feasibility of using Apalachicola wetlands for wastewater recycling beginning in 1981. They investigated various aspects of the wetland ecology and attempted to model the system so as to enable calculation of the effects of wastewater effluents released into the wetlands.

Little information has been gathered to address impacts of toxic substances or nonpoint-source pollutants. The Apalachicola River has been found by researchers from Florida State University to have higher concentrations of germanium than most of the rivers in the world (Froelich and Mortlock 1984). Little is known of germanium toxicology. The major source of germanium in water is coal-fly ash from upwind coal-burning powerplants (FDER 1984b). High nutrient levels in Lake Seminole have caused problems with eutrophication and resulted in excess growth of aquatic plants. This growth is controlled with herbicide applications, which contributes to water quality degradation in the lake. The U.S. Army Corps of Engineers (1982) completed a comprehensive study of water quality in Lake Seminole and part of the Apalachicola. Numerous Federal- and State-permitted point sources discharge into the Apalachicola, Chipola, and Flint Rivers and their tributaries. These include municipal sewage treatment plants, industrial and agricultural facilities,and nuclear and fossil-fueled powerplants. In addition, large agricultural areas contribute nonpoint-source discharges. Nutrient enriched water pumped from and running off of grazing lands resulted in M/K Ranches being the only nonpoint discharger in the basin which has been regulated by the FDER (Esry 1978, FDER 1984a). This drainage from the M/K canal system reduced visibility in the river as measured by a secchi disk to 30–45 cm (USACE 1981). Streams with the greatest amount of degradation include Double Bayou, Clark Creek, Murphy Creek, and Scipio Creek.

Agriculture within a drainage basin often contributes nutrients, coliform bacteria, sediments, and pesticides to the river system. The FDER established a nonregulatory nonpoint source management program for agricultural interests that is administered by the Florida Department of Agriculture and Consumer Services in cooperation with the U.S. Department of Agriculture and the Soil and Water Conservation Districts. While this program has been fairly successful in parts of Florida, the largest resistance to it has occurred in northwest Florida, including the Apalachicola watershed (Florida Rivers Study Committee 1985). The effects of silviculture in the basin upon the water quality and biota of Apalachicola Bay were investigated in a report to Buckeye Cellulose Corporation (Hydroscience, Inc. 1977).

The primary problems detected by monitoring stations along the river are high fecal coliform counts and low DO below sewage treatment plants and industrial discharges. Before entering Florida, Apalachicola River tributaries receive numerous discharges from Atlanta and other urban areas, from textile mills, paper mills, sewage treatment plants, steam powerplants, a nuclear powerplant, and extensive agriculture areas of Alabama and Georgia (Hand and Jackman 1984). The USGS has examined the effects of flooding on the sources of pathogenic bacteria in the Apalachicola River and Estuary from 1982 to 1985 and is analyzing their data for publication in the near future (Elder, in prep). The Florida State Hospital at Chattahoochee discharges to Mosquito Creek, then to the Apalachicola. High phosphate concentrations from detergents (Doherty

1980) and high fecal coliform counts (Nicol 1979) have historically been continuing problems in the creek. The Hospital failed static acute toxicity bioassays performed by the FDER in 1982 and 1983 (FDER 1982, 1983). A 1984 FDER study of Mosquito Creek showed low total phosphorus levels but fecal and total coliform concentrations much above standards (McKnight 1984). Additionally, 5-day BOD could not be determined due to some bacterial inhibitor in the effluent. Sutton Creek, an Apalachicola River tributary, has experienced DO violations caused by the Blountstown sewage treatment plant (Kobylinski 1981). While this problem is expected to improve with scheduled plant upgrades, there remains the need to eliminate hydraulic overloads during wet weather. Apalachicola Bay has experienced problems with high coliform bacteria levels, which sometimes cause the bay to be closed to fishing. Much of this results from septic tank seepage in coastal communities and from poorly treatment discharges from area sewage treatment facilities. The City of Apalachicola Wastewater Treatment Plant has a long history of poor performance and environmental problems. New facilities are under construction and are expected to solve problems of poor discharge quality.

During 1982–83, DO concentrations were above 4.0 ppm at all sites sampled by the Florida Game and Freshwater Fish Commission, but a summer (July–August) depression was noted between navigation mile 75 and 100 (Ager et al. 1983). Cox and Auth (1971) had similar findings; no explanation was offered in either instance. All water quality parameters examined during the Game and Freshwater Fish study met State standards.

The only major point-source discharge to the Apalachicola River is the Gulf Power Scholz Electric Power Plant near Blountstown. This coal-burning plant uses once-through cooling water from the river. The FDER and EPA have permitted outfalls which include noncontact cooling water, ash pond water, low volume wastes, boiler blowdown, metal cleaning wastes, construction runoff, coal pile runoff, and sanitary waste. NPDES pH violations were noted in 1982 and illegal sanitary waste discharges were found in 1983 (FDER 1984a). A limited study of the plant's thermal discharge was performed in 1977 (Wieckowicz 1977) and also as a research project by the University of Florida. Winger et al. (1984) investigated river biota for residues of organochlorine insecticides, PCB's, and heavy metals. Elder and Mattraw (1984) looked at the accumulation of trace elements, pesticides, and polychlorinated biphenyls in river sediments and in the clam *Corbicula manilensis.*

This basin was sampled at four sites for biological indicators of water quality during 1973–78 (Ross and Jones 1979). The upper station was near the Bristol boat landing and, though only sampled a few times, it showed good macroinvertebrate diversity. This was also true of a station downstream, 2.5 km below the Chipola River cutoff (a connection above the confluence of the Chipola and Apalachicola Rivers where water from the Apalachicola flows into the Chipola; the Chipola below the cutoff consists primarily of Apalachicola water). The next station was in the Brothers River about 1.5 km above its confluence with the Apalachicola River. This area was basically undeveloped swamp, which was reflected in the good macroinvertebrate diversity. The next station, at Buoy No. 40 in the lower Apalachicola River, showed a marginal Biotic Index and generally high diversity. Occasional high coliform bacteria counts were attributed to runoff. The final station was at the mouth of Lake Wimico (the head of the Jackson River). Here the macroinvertebrate diversity was generally high and the introduction of estuarine forms into the lake from the Intracoastal Waterway to the west was noted.

The watershed south of Lake Seminole (i.e., the portion of the basin in Florida) is relatively pristine, and water quality in the river recovers during its transit. However, heavy-metal bearing sediments are being deposited in Apalachicola Bay from the Apalachicola and Chipola Rivers (FDER 1986c). Fishery studies suggest that, despite the alterations, the Apalachicola River is relatively productive (Bass 1983).

Leitman et al. (1983) examined shallow groundwater movement in parts of the basin. They found that ground-water flow at Sweetwater, approximately 7 km north of Blountstown, was generally toward the river at low river stages and away from the river at high stages, but that ground-water flow from the uplands east of the floodplain showed constant flow to the floodplain. At Brickyard, near Sumatra, ground-water flow was away from the river at low and medium river stages, but the ground-water level was essentially equal to that of the river at high river stages. They felt that ground-water flow at Brickyard was possibly toward the river at extremely low stages, but could not document this since these conditions did not occur during the study.

Apalachicola Bay is a highly productive estuary, providing most of Florida's oysters and a nursery area supporting a substantial shrimp, crab, and finfish fishery. The bay is nevertheless suffering from developmental pressures and from the lack of cohesive plans to handle area wastes. These problems are being addressed by State and local governments through establishing the river and bay as an Area of Critical State Concern. This designation allows the local governments to enlist the aid of State planning experts in developing methods to deal with area problems and requires them to follow a State management plan. The Area of Critical State Concern designation remains in effect until the State is satisfied that the local government has established programs capable of dealing with the problems. The Apalachicola River is believed to be the dominant factor controlling the seasonal changes of nutrient levels and salinity, which drive the estuary and keep the fisheries potential of the estuary extremely high (Florida Rivers Study Committee 1985).

The U.S. Army Corps of Engineers studied the Apalachicola River basin's water resources and discussed ground-water supplies (USACE 1981). Apalachicola Bay is not further discussed here since it has been thoroughly covered in a recent profile by Livingston (1984). In addition, further information may be found through Banks et al. (1983), a thorough (as of the date of its publication) bibliography of literature concerning the Apalachicola River basin.

4.7.4 Chipola River Basin (Figure 53)

The Chipola River, a major tributary of the Apalachicola, drains a 3,200 km^2 area into the lower Apalachicola River. Eighty-two percent of this basin (2,640 km^2) lies in Florida, with the remaining 18% (560 km^2) lying in Alabama. The Chipola emerges from subterranean streams in southeast Alabama, flows generally south, then goes underground for a short distance north of Marianna, Florida. It reappears and flows south another 65 km to its confluence with the Apalachicola River near Wewahitchka. The Dead Lake area is formed where the natural levees of the Apalachicola River impound the Chipola above their confluence and produce a usually-flooded area. A low dam was constructed to enlarge the lake, stabilize the lake level, and enhance fishing access. Dead Lake, along with Lake McKenzie, Mirror Lake, Turkey Pen Pond, and Merrits Mill Pond farther north in this basin, is among the 50 lakes in the State listed in Myers and Edmiston (1983) as most in need of preservation and protection. At the Chipola Cutoff above the confluence, approximately 25% of the Apalachicola River flow diverts to the Chipola River (Ager et al. 1983), where it constitutes the bulk of the Chipola River water below that point (Leitman et al. 1983). The largest spring in the basin is Blue Spring, located about 10 km northeast of Marianna. Blue Springs Creek flows from the spring into the Chipola River.

The Chipola generally has good water quality (Hand and Jackman 1984) but was, in recent years, receiving indirect discharges via Dry Creek from a battery reclamation plant, Sapp Battery Company. Extensive damage has occurred to the wetlands near the Sapp plant site because of runoff contaminated with battery acid (sulfuric acid) and heavy metals. In 1970 Sapp employed five people to crack used automotive batteries and recover lead. By 1978, 85 people were employed, cracking 50,000 batteries per week (Watts 1984). Acid from the batteries was dumped outside the plant building where it drained into a cypress swamp on company property. Water from this swamp drained south into a shallow lake named Steele City Bay, then through a series of cypress swamps into Little Dry Creek about a mile from the factory. Little Dry Creek is a tributary of the Chipola River via Dry Creek. By 1977 the acid had started to kill the cypress trees in Steele City Bay and beyond and, upon receiving complaints, the FDER became involved. After taking some unsuccessful steps to alleviate the off-site discharge and coming under legal action by FDER, Sapp abruptly closed down in 1980 (Watts 1984). In 1982 FDER began investigating the contamination under the U.S. EPA Superfund program. Contamination included lead, manganese, aluminum, and sulfuric acid. Approximately 17,500 m^3 of battery casings were buried on site to a depth of over 1.5 m with another 2,600 m^3 piled on the surface.

High levels of lead were found in most of the upper soils, the concentration generally decreasing with depth. At certain sites, which proved to be sinkholes, concentrations increased with depth to approximately 30 m. Sampling wells drilled in the bottom of one sink proved to be the most contaminated of any taken on the site, with extremely high levels of lead, manganese, aluminum, and sulfate, and somewhat lower levels of cadmium and nickel. It was concluded that water from these sinks was seeping into the Floridan Aquifer, and that concentrations of lead, cadmium and aluminum in samples taken from this aquifer under the Sapp site represented maximum theoretical solubilities for the metals (Watts 1984). It was further concluded that the shallow aquifer was most likely to suffer widespread contamination; subsequent testing identified moderate to high levels of lead and aluminum contamination of this aquifer in a zone east of the site.

Surface waters were also sampled for contamination. The on-site pond and cypress swamp proved to be heavily contaminated with lead, manganese, and aluminum, with concentrations decreasing irregularly downstream until levels were indistinguishable from background concentrations at the most distant stations on Little Dry Creek. Concentrations measured in this study during 1983 proved to be significantly less than those obtained in an U.S. EPA study three years earlier (Watts 1984). This contamination is now being cleaned up using State and Federal funds.

The U.S. Fish and Wildlife Service (USFWS) examined the fish, clams, and sediment in the Chipola River in 1982 for possible effects from the Sapp site contamination (Winger et al. in press). They found that while the levels of trace elements in samples of biota and sediments demonstrated no serious contamination in the Chipola River, metal concentrations generally increased downstream from the two stations located above the rivers confluence with Dry Creek. This increase was particularly noticeable for arsenic, cadmium, chromium, lead, and zinc in clam and sediment samples, though the arsenic and cadmium levels in the downstream biota were similar to those found in the biota of the Apalachicola River in a 1978 study (Winger et al. 1984). The levels of lead in clams were, however, greater than those found in Apalachicola River clams. They speculate that Dead Lake may be serving as a sink for contaminants flowing down the Chipola, as the metal concentrations in sediments from the lower part of the lake were higher than those downstream of the Dead Lake dam near the Chipola's confluence with the Apalachicola River. Additionally, the only organochlorine pesticides found in the sediment samples were from those taken at Dead Lake.

Simultaneously with the FDER study of the Sapp site, Little Dry Creek and Dry Creek were investigated as part of an EPA sponsored study attempting to define similarities and differences between laboratory and field toxicity data (Livingston 1986a). The ecological effects of the gradient of contamination found downstream from the Sapp site provided a comparison to effects projected from similar toxicity gradients used in normal laboratory bioassay testing. At the same time the information concerning the effects of the Sapp contamination on the ecosystems of the creeks was documented.

The Florida Department of Health and Rehabilitative Services (HRS) in 1983 reported levels of lead in the introduced clam *Corbicula* above FDA levels for removal of food from the market place (Ager et al. 1983). Investigation of mercury contamination in the Chipola is addressed by the FDER (1984b). A study in 1982 showed that the Chipola below the Dead Lakes Dam had moderately hard, very clear, and slightly acid water, but that the DO indicated an unusually high BOD upstream (Ager et al. 1983). The constant water level provided by the dam is killing trees and is allowing the growth of excessive aquatic plants. The dam is presently scheduled for removal (Banks 1983, Cason et al. 1984). There has been concern expressed about the potential for the release of substantial concentrations of heavy metals from the sediments trapped behind the Dead Lakes Dam when the structure is removed as planned (Bob Patton, FDER, Tallahassee; pers. comm.). This potential release would be the result of the anaerobic reaction of sulfur and iron.

Four stations within the Chipola Basin were sampled for biological indications of water quality during 1973–78 (Ross and Jones 1979). The uppermost station was downstream from Waddell's Mill Creek in Jackson County. Macroinvertebrate diversities were fairly high, but lower than expected; numbers of species collected were somewhat low, and the Biotic Index was marginal. These results were attributed to heavy silt loads and subsequent degraded water quality from farming along the stream banks. The next station in the Chipola River at SR 274, east of Chason and upstream of Tenmile Creek, had high macroinvertebrate diversities and Biotic Index values and showed a significant improvement during the study period. Occasionally, Class III (i.e., suitable for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife) bacteria standards were exceeded. This was possibly caused by the Marianna sewage treatment plant, though it was felt that it might be too far upstream to be the source of the fecal coliform bacteria. A third station was in Juniper Creek near Frink. This station showed high macroinvertebrate diversity and high Biotic Index values during the three times it was sampled. High bacteria counts were attributed to runoff. The last station was just downstream of the dam which forms Dead Lake. It was sampled only twice but had high macroinvertebrate diversities both times.

4.7.5 St. Andrew Bay and Coastal Area (Figure 54)

The St. Andrew Bay drainage basin encompasses approximately 3,500 km^2 and includes St. Andrew, West, North, and East Bays, St. Andrew Sound, and, to the east, St. Joseph Bay. There are no large rivers within the watershed; the largest inflow to the St. Andrew Bay system comes from Econfina Creek, which most of the year is composed predominantly of ground water from springs fed by the Floridan Aquifer (Musgrove et al. 1964). Much of the terrain is very porous sands, which allow quick infiltration of rainfall. Stream baseflow within much of the area is maintained from the shallow sandy aquifer. The Deadening Lakes area (not to be confused with Dead Lake at the confluence of the Chipola and Apalachicola Rivers) at the northern end of the basin contains numerous sinkhole lakes formed by the collapse of solution holes in underlying limestone. Most of the lakes in this area have no surface outlets (Musgrove et al. 1964) and have subterranean connections.

Econfina Creek flows into Deer Point Lake, formed by the construction in 1961 of a dam across North Bay (USACE 1980a). This dam maintains the lake level approximately 1.5 m above sea level and provides the primary water source for Panama City.

The water in the streams and lakes within the basin is low in dissolved solids because they are generally fed from surface runoff or from the shallow sand aquifer. This aquifer has little buffering effect, and as a result the surface waters have about the same mineral concentration as rainwater; this concentration changes little between periods of high and low flow (Musgrove et al. 1964). Color and pH change with stream and lake stage as the proportion of water having contacted decayed organic materials increases. The pH normally ranges from 6.0 to 7.0 but falls below 6.0 during high flow. The exception to these generalities occurs in an area along Econfina Creek downstream of a point east of Porter Lake, where springs from the Floridan Aquifer flow to the Econfina and increase dissolved solids concentrations in proportion to the concentration of spring water (Musgrove et al. 1964).

The St. Andrew Bay system was studied in 1974 in order to calculate a waste load allocation (i.e., the amount and quality of waste that can be discharged to the system based upon its calculated ability to assimilate that waste without damage to its ecosystem) (Johnson et al. 1974). During this study St. Andrew Bay had the poorest water quality of the four bays in this drainage. Some locations, particularly Watson Bayou and the International Paper Company outfall, did not meet DO, turbidity, or bacterial standards for Class III waters (i.e., recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife) . The other bays generally met Class II standards (i.e., shellfish propagation or harvesting). The model produced in this study showed Watson Bayou to be quite sensitive to storm-water runoff, resulting in significant DO reductions.

Ten years later, Hand and Jackman (1984) reported that of 400 km^2 of estuary in this basin, all but 14 km^2 has good water quality. The major urban development in the area centers around Panama City. Major point sources of pollution include two large paper-pulp processing plants: the International

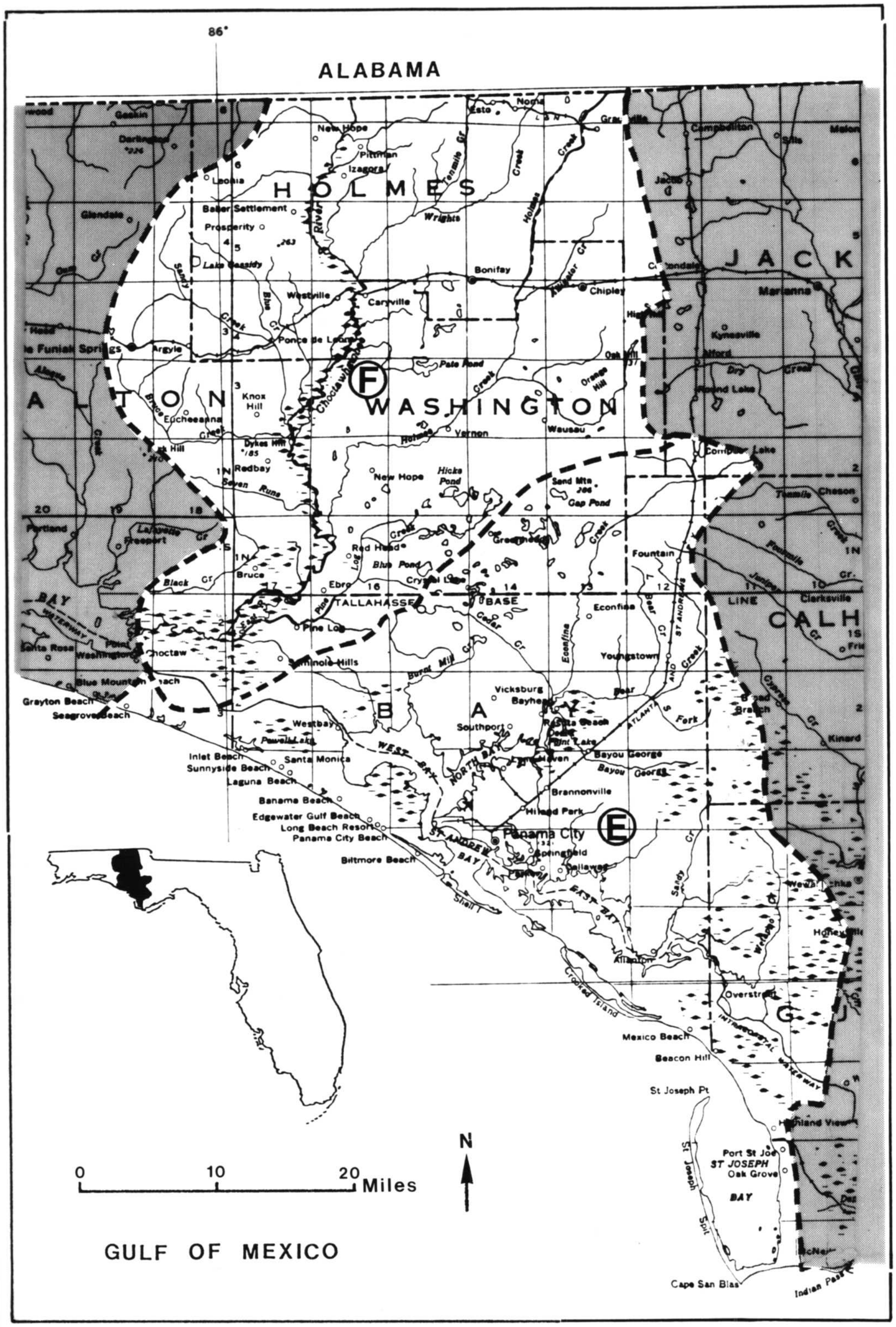


Figure 54. East-central Panhandle drainage basins—(E) St. Andrew Bay and (F) Choctawhatchee River (after Conover and Leach 1975).

Paper Company, discharging to St. Andrew Bay after treatment at the Bay County Regional sewage treatment plant, and the St. Joe Paper Company, discharging directly to St. Joseph Bay. Historically, problem areas include Watson Bayou, Martin Bayou, the area which used to receive the International Paper Co. discharge, and Deer Point Lake at the head of North Bay. Hand and Jackman (1984) report no data since 1981. Watson Bayou had DO, bacteria, and nutrient problems. The bayou received discharge from the Millville Sewage Treatment Plant, which has since been diverted to the regional treatment plant. Martin Bayou had pH, nutrient, and aesthetic problems caused, in part, by a limited assimilative capacity, discharge from two small sewage package plants, and urban runoff. The area around the International Paper Co. discharge into St. Andrew Bay had low DO, high bacteria, and aesthetic problems; these discharges are now diverted to the regional plant. Deer Point Lake had low DO but is now, along with Crystal Lake and Gap Pond in Washington County, among the 50 lakes in the State listed in Myers and Edmiston (1983) as most in need of preservation and protection.

Biological sampling of water quality during 1973–78 was performed at six stations within this basin (Ross and Jones 1979). A station in fast flowing Econfina Creek near the town of Econfina showed the stream supporting an excellent macroinvertebrate community with high diversity and very high Biotic Index values. Occasional high bacteria counts were attributed to runoff. Stations in East Bay east of the mouth of Burnt Mill Creek and in West Bay on the gulf side south of Calloway exhibited good diversity and no trends were evident. Bacteria counts in West Bay exceeded Class II (i.e., shellfish propagation or harvesting) water quality standards. This was attributed to the greater development surrounding West Bay than is found around East Bay. A station in St. Andrew Bay near the entrance to West Bay and two stations in St. Joseph Bay, one off the T.H. Stone State Park on Cape San Blas and one off Port St. Joe, all had very high macroinvertebrate diversities and only occasional high bacteria counts. None of these three stations appeared to have been degraded by pollution during this study period.

Ground water in this basin, particularly near Panama City, lies in an area of the Floridan Aquifer of relatively low transmissibility. By 1963 groundwater levels had been lowered 61 m by pumping since the first deep well was drilled in 1908 (Musgrove et al. 1964). In 1964 pumping from one well field of 21 wells was stopped and water levels rose 50 m within 51 days.

The aquifer east of East Bay was tested in order to estimate pumping drawdown and determine consequences of increased use as a source of irrigation water (Barr and Pratt 1981). This investigation dealt with the multilayered nature of the aquifer in order to provide a more realistic estimate than that given by the simpler conventional methods. They found that the aquifer could be considered to be a low permeability layer about 90 m thick and a high permeability layer about 40 m thick. They concluded that heavy pumping from an irrigation well would be felt for several miles and that multiple wells would lead to substantial general water table decline. The NWFWMD also performed a reconnaissance of ground-water resources in southwestern Bay County (Barr and Wagner 1981).

Area water resources and their potential for fulfilling future demands, flooding problems, and area navigation problems are addressed in a U.S. Army Corps of Engineers study (USACE 1980a).

4.7.6 Choctawhatchee River Basin (Figure 54)

The Choctawhatchee River drains 12,030 km^2, of which 31% (3,700 km^2) lies in Florida and 69% (8,330 km^2) lies in Alabama. It is one of the four largest rivers in terms of flow in Florida and is second only to the Apalachicola River in floodplain area. In Florida the river is vigorous, slightly meandering, and heavily loaded with sediment. The Floridan Aquifer provides a major source of inflow to the river system (Hand and Jackman 1984). It travels 143 km from the Alabama border through an extremely swampy floodplain to Choctawhatchee Bay. At the mouth the flood plain is over 5 km wide and the river flows into the bay over shoals. The major Florida tributary is Holmes Creek, which flows approximately 80 km from southeastern Alabama to its Choctawhatchee confluence near the town of Ebro. The river has been designated an Outstanding Florida Water (OFW), in part because its forested floodplain is virtually undeveloped and its basin is the least developed major river corridor in Florida. Numerous streams, springs, and lakes characterize this basin. Two lakes, Lake Victor in Holmes County and Smith Lake in Washington County, are listed by Myers and Edmiston (1983) as among the 50 lakes in the State most in need of preservation and protection.

The Choctawhatchee River is presently undergoing a State-funded baseline study under the direction of Dr. Robert Livingston of Florida State University.

The Federal government authorized a navigable channel from the mouth of the Choctawhatchee River to Geneva, Alabama, just north of the Florida-Alabama border. However, commercial navigation was abandoned by the mid-1930's and Corps of Engineers maintenance ceased in 1942 (Florida Rivers Study Committee 1985). The strategic plan for regulating development within the basin was developed by the Florida Rivers Study Committee (1985).

Six cities with populations greater than 5,000 are located in this basin, five in Alabama and one (Chipley) in Florida. The largest Florida cities are Chipley, Bonifay, and Defuniak Springs. Some development in the river flood plain is beginning near Freeport and Caryville, primarily in the form of second homes.

Caryville is the major community along the Choctawhatchee River in Florida experiencing flooding problems. The town was almost totally inundated in 1975 after 45 cm of rain fell in 21 hours in the upper Pea River basin 1 month after a storm dropped 23 cm in 24 hours (U.S. Dept. of Agriculture 1975). This storm caused severe erosion damage to cropland as well. The severity of flooding was blamed on sediment deposition (Florida Rivers Study Committee 1985). To date the Corps of Engineers has concluded that the costs of flood control measures for the river would far outweigh the reduction in flood damage and the increased navigability. The NWFWMD also performed a study of sedimentation in the river (Musgrove 1983) and a flood reconnaissance (NWFWMD 1978a).

Forestry and agriculture constitute the major land use in this largely undeveloped basin. Large timber companies own most of the land along the river. The Choctawhatchee is a moderately fertile, alluvial river and is the richest in nitrogen and phosphorus of the Panhandle rivers, a result of the high clay content of basin soils and the runoff-promoting relief, as well as from anthropogenic nutrient inputs. The majority of sedimentation originates in the agricultural land of Alabama along the Choctawhatchee and Pea Rivers (Florida Rivers Study Committee 1985).

The water quality of the river in Florida is generally good except for its high sediment load. The river is probably the only economical source of potable water for the massive coastal development predicted for southern Walton County (Florida Rivers Study Committee 1985). Twenty-four sewage treatment plants discharge into the Alabama portion of the drainage basin, eight into the major tributary Pea River and sixteen into the Choctawhatchee and its smaller tributaries. In addition, nine industrial sites discharge into the Alabama portion, four into the Pea River and five into the Choctawhatchee and its tributaries. Nonpoint sources throughout the basin, particularly in Alabama, include extensive agriculture, including dairy and hog farms. Florida discharges causing water quality problems include sewage treatment plants in Chipley discharging to Alligator Creek, in Graceville discharging to Holmes Creek via Little Creek, and in Bonifay discharging to Holmes Creek via Camp Branch. These plants have caused bacteria, DO, and nutrient problems in the Florida portion of the basin (Hand and Jackman 1982, 1984); however, Graceville and Bonifay are upgrading their plants which should improve the water quality in this area. Additional water quality problems are caused by the Defuniak Spring sewage treatment plant discharging to Sandy Creek and a chicken processing plant discharging to Bruce Creek via Carpenter Creek (Hand and Jackman 1984).

Improper logging methods in Washington County, primarily clearcutting near surface streams and rivers, are increasing the sediment problems in the river. Because timber is the dominant industry in the area, any regulation to curb the practice is expected to be slow to occur (Florida Rivers Study Committee 1985). Holmes County is aware of sedimentation originating in the county and is working with the Soil Conservation Service to construct watershed projects to reduce it.

Biological sampling was performed at stations within the basin during 1973–78 for indications of water quality (Ross and Jones 1979). Stations in the Choctawhatchee River at SR 2 near the Alabama border and at SR 20 near Ebro had high Biotic Indices from qualitative macroinvertebrate sampling. Quantitative macroinvertebrate sampling showed high diversity at the SR 20 station. Both stations characterized the river as clean and fast flowing. Both stations also had rather high bacteria counts, especially the one at SR 2. Stations in Holmes Creek, at SR 2 near Graceville and at SR 79 near Vernon, both had moderately high macro-invertebrate diversities and occasional problems with bacteria. Showell Farms, an industrial point source, has been identified by the FDER district office as a significant polluter of Bruce Creek, a Choctawhatchee tributary. Fish communities in the Florida portion of the basin are considered healthy (Bass 1983).

Leaking gasoline from a small service station in northwestern Holmes County has contaminated the Floridan and Claiborne aquifers underlying the site (Busen et al. 1984). Corrective actions have been taken by FDER.

Flooding problems, area navigation problems, and area water resources and their potential for fulfilling future demands are addressed in a U.S. Army Corps of Engineers study (USACE 1980a).

4.7.7 Choctawhatchee Bay and Coastal Area (Figure 55)

This 1,190 km^2 coastal basin is drained by Lafayette, Magnolia, Alaqua, Rocky, Turkey, and Juniper Creeks. The largest stream is Alaqua Creek which drains 324 km^2. These streams have a high base flow (i.e., minimum flow) which is attributed to seepage from the Sand and Gravel Aquifer (USACE 1980a). In 1978–79 baseflow constituted 92%–98% of the total runoff from Turtle, Juniper, and Turkey Creeks in southern Okaloosa County (Barr et al. 1985). Choctawhatchee Bay, 40 km long by 5 km wide, averages 3 m in depth at the eastern end where the highly alluvial Choctawhatchee River flows into the bay (Musgrove 1983), and 9 m in the remainder of the bay. It receives flow from a watershed which includes the Choctawhatchee River and which totals approximately 13,830 km^2. The bay is characterized by its minimal connection with the Gulf of Mexico. East Pass, a narrow channel west of Destin and east of Santa Rosa Island, is the only connector and is often shoaled to a depth of 2 m (Collard 1976) requiring maintenance dredging to keep a 4 m channel open (USACE 1975). Fort Walton Beach, Destin, and Valparaiso are the largest cities in the basin, and the area around these cities along the gulf coast is undergoing rapid urban development.

A State-funded, in depth ecological baseline study of Choctawhatchee Bay during 1985–86 was recently completed (Livingston 1986b). Forty eight stations were monitored to provide information for preserving the bay in the face of expected massive development of surrounding lands. This study was prompted by plans to construct a bridge over the middle of the bay between White Point and Piney Point. Similar bridges were constructed in other bays without proper understanding of the factors controlling the estuary ecosystem, causing marked damage to the fisheries in parts of those estuaries (e.g., the St. George Island bridge in Apalachicola Bay). This study concluded that the proposed bridge can be constructed with minimal environmental damage if (1) observed seagrass beds in the vicinity of White Point and Piney Point were protected during the varous stages of bridge construction and operation, (2) storm-water runoff from the completed structure was processed adequately to prevent water quality deterioration in the bay, and (3) causeway construction was kept to a minimum to avoid direct habitat destruction and possible changes in the flushing rates of the areas at depth in western sections of the bay.

According to long-term area residents, during heavy flooding in the late 1920's, East Pass formed due to a "blow-out" of bay water (Livingston 1986b). Resulting higher salinity levels within the bay were associated with losses of the well-developed emergent and submergent vegetation, and a reduced fishery. Vertical salinity stratification was found in the deeper portions of the bay. These areas (especially in the central and western bay) also had vertical stratification of DO and were hypoxic at depth during various times of the year.

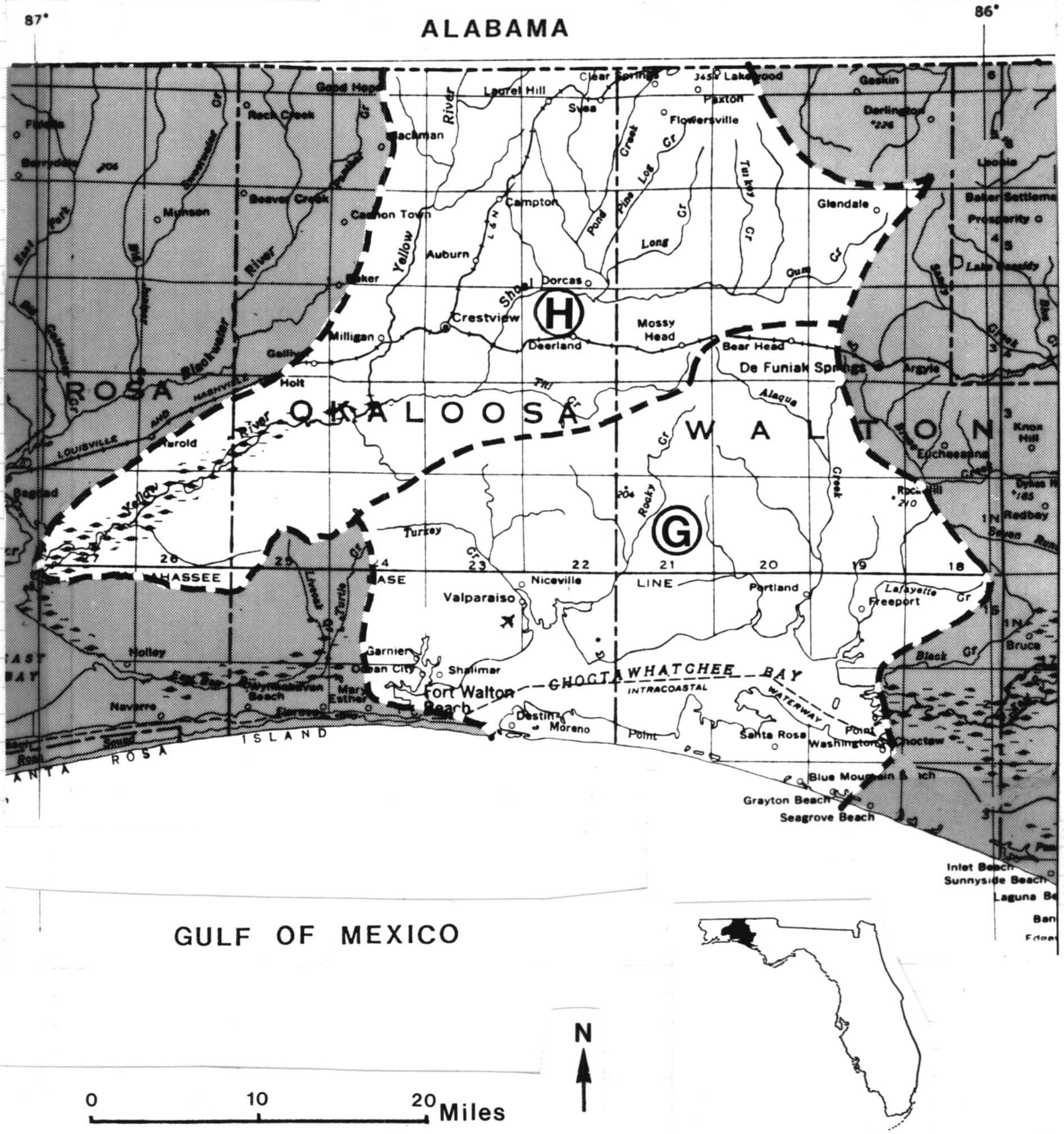


Figure 55. West-central Panhandle drainage basins—(G) Choctawhatchee Bay and (H) Yellow River (after Conover and Leach 1975).

Oyster Lake and Lake Stanley, located on the coastal spit south of Choctawhatchee Bay, are listed by Myers and Edmiston (1983) as among the 50 lakes in the State most needing preservation and protection. Surface waters within the basin had a pH varying from 4.2 to 7.4 and averaged 5.5 during 1978–79 (Barr et al. 1985). Water quality is good but would be corrosive to water distribution systems.

The low range of tides (averaging 0.2 m within the bay and 0.4 m in the adjacent gulf) produces minimal tidal flushing. This, combined with the fact that the salt water input is at the opposite end of the major source of freshwater input, results in poor mixing of bay waters. Bay salinity gradients followed river flow fluctuations; lowest salinities were found from December through April at the bay surface and highest salinities were found during summer-fall. As a result of these factors, the deeper water of Choctawhatchee Bay is some of the most stratified in the Panhandle, with the western two-thirds being sharply stratified and the eastern third weakly stratified (Collard 1976, Livingston 1986b). These conditions tend to produce a situation where the underlying high salinity water stagnates. Collard (1976) found that in summer the bottom of the bay was "biologically barren." Livingston (1986b) found that low DO levels associated with the salinity gradients in the deeper portions of the bay were life-limiting to various estuarine forms during certain months of the year. Low DO was most evident during summer months and by August the entire bay was hypoxic to anoxic at depth.

The baseline study also found that nitrogen levels were highest in the western sections of the bay (Cinco, Garnier, lower Rocky , and Boggy Bayous). Phosporus levels were also highest in the western end (Old Pass Lagoon, lower Rocky and Boggy Bayous). This was attributed to storm-water runoff from the Destin peninsula and adjacent developed areas. Pesticide and heavy-metal analyses were not performed in the study, but it is suggested that improved management of the Choctawhatchee River basin (e.g., regulation of pesticide use, municipal waster disposal, etc.) might improve the relatively low productivity found in the eastern portions of the bay.

A tabulation of past data and an excellent bibliography on the Choctawhatchee Bay system was compiled by the Northwest Florida Water Management District as it began development of an area management program (Northwest Florida Water Management District 1980b). This report cites a 1978 study of the bay (Taylor Biological Co. 1978) as being one of the most useful as a guide for policy and decision making.

The NWFWMD has compiled all their studies of the bay into one report (NWFWMD 1986). Included in the compilation is an investigation of the extremely high temperatures found below the halocline during 1984 sampling (Maristany and Cason 1984). The cause of this has not been resolved.

A waste-load allocation study was performed on the bay using a water-quality model from the University of South Florida (Johnson et al. 1974). This model examined the salinity, DO, N, and P concentrations, and the 5-day BOD. Water quality was found to be generally good with the exceptions of the Cinco, LaGrange, Boggy, and Alaqua Bayous, and nutrient levels in most of the bay indicated no eutrophication processes in existence. Their model indicated that conditions in Cinco and LaGrange Bayous could be improved by requiring secondary treatment for all discharges to the bay. They also expressed concern for the effects of urban runoff from future land development along the shores.

Stations in the basin were sampled for biological indications of water quality during 1973–78 (Ross and Jones 1979). A station a few kilometers up Lafayette Creek showed consistently high Biotic Index values from qualitative macroinvertebrate samples. Nutrient-enriched runoff from a large nearby farm contributed to the lush growth of aquatic plants. At a station in Choctawhatchee Bay near Fort Walton Beach macroinvertebrate diversities suggested a fairly healthy community. A station in the bay near Piney Point showed a significant decline in macroinvertebrate diversity during the sampling period. Both the bay stations were being influenced by the rapid development in the west end of the bay. Occasional occurrences of bacteria levels in excess of Class II (i.e., shellfish propagation or harvesting) water quality standards were noted at the Piney Point station, though counts were generally low.

According to Hand and Jackman (1984) the Choctawhatchee Bay basin has historically had good water quality in all areas and at present Old Pass Lagoon, which drains the coastal area of Destin, is the only area exhibiting poor water quality. This small lagoon is in the process of becoming a landlocked salt lake due to the natural shifting of coastal sand, and a channel is maintained by dredging. The lagoon has poor circulation and receives nutrients from surrounding housing developments and possibly from the drainage of nutrient-enriched shallow ground water from a nearby sewage treatment plant spray field (Donald Esry, Northwest Florida Water Management District; pers. comm.). The circulation problems are aggravated by the presence of numerous dredge-and-fill constructed finger canals. As a result Old Pass Lagoon suffers from low DO levels and frequent fish kills. The Northwest Florida Water Management District is planning to install a large pump to transfer water from the Gulf of Mexico into the lagoon to enhance the circulation and ease the water quality problems.

The NWFWMD examined the ground water conditions around Choctawhatchee Bay (Barr 1983). Additionally, they investigated the ground water near the wastewater percolation ponds in Destin for increased nutrients (Barr and Bowman 1985).

Area water resources and their potential for fulfilling future demands, flooding problems, and area navigation problems are addressed in a USACE study (USACE 1980a). The USACE also prepared a report concerning coastal storm flooding in the Destin area (USACE 1970). The highest flood tide reported occurred in 1926 and was 3–3.5 m above mean sea level on the beach. The most severe storm tide expected, given area conditions, was predicted to be 4.25 m above sea level. These calculations did not take into consideration the predicted, relatively rapid rise in world-wide sea level (Hoffman et al. 1983) (see section 4.8.1).

4.7.8 Yellow River Basin (Figure 55)

The Yellow River drains 3,540 km^2, of which 63% (2,220 km^2) is in Florida and 37% (1,320 km^2) is in Alabama, and drains into Blackwater Bay. This river, along with its only major tributary, the Shoal River, and the neighboring Blackwater River are considered classic sand-bottom streams (Beck 1965). The waters are clear and of relatively low primary productivity. In this basin, Lake Jackson, Juniper Lake, and Oyster Lake are listed by Myers and Edmiston (1983) as among the 50 lakes in the State most needing preservation and protection.

Forestry is the predominant land use with agriculture second. Milligan and Crestview are the largest towns in the basin. The main sources of pollution in the area include agricultural and urban runoff and domestic sewage discharge (Hand and Jackman 1984). The only problem area in the basin is Trammel Creek, which receives treated sewage from the Crestview sewage treatment plant. This discharge caused nutrient and bacterial problems in the creek, but assimilation is complete and water quality good by the time the creek reaches the Yellow River. Crestview is in the process of upgrading their plant. A 1979 train derailment spilled anhydrous ammonia into the Yellow River just below its confluence with Trammel Creek. Hand and Jackman (1984) reported that the river benthos in the area of the spill still showed reduced diversity.

The Yellow River exhibits only fair to good water quality in Alabama because of DO, nutrient, and bacterial violations associated with sewage treatment plant discharges. The Yellow River has not been extensively sampled, though indications are that the river in Florida is relatively unspoiled (FDER 1986c). Sampling at a station in the Shoal and in the Yellow Rivers during 1973–78 showed healthy macroinvertebrate communities and no signs of DO deficiencies (Ross and Jones 1979). Occasionally high total coliform bacteria counts from the Shoal River station east of Crestview were attributed to agricultural runoff. Higher fecal coliform counts from the Yellow River station south of Holt were attributed to the Crestview sewage treatment plant.

4.7.9 Blackwater River Basin (Figure 56)

The Blackwater River drains 2,230 km^2 of which 81% (1,810 km^2) is in Florida and 19% (420 km^2) is in Alabama. The river originates north of Bradley, Alabama and flows south to Blackwater Bay. Groundwater seepage from the Sand and Gravel Aquifer provides much of the riverflow (USACE 1980b, Hand and Jackman 1984). Most of the watershed is contained within two State forests, the Conecuh in Alabama and the Blackwater in Florida. Thus forestry is the predominant land use, with agriculture of secondary importance. The river's major tributaries include Panther, Big Juniper, Big Coldwater, and Pond Creeks. The Blackwater River, a clear, sand-bottomed stream, has been designated an OFW (i.e., no significant degradation allowed) and receives heavy recreational use. Within the basin, Hurricane Lake, Lake Karick, and Bear Lake are listed by Myers and Edmiston (1983) as

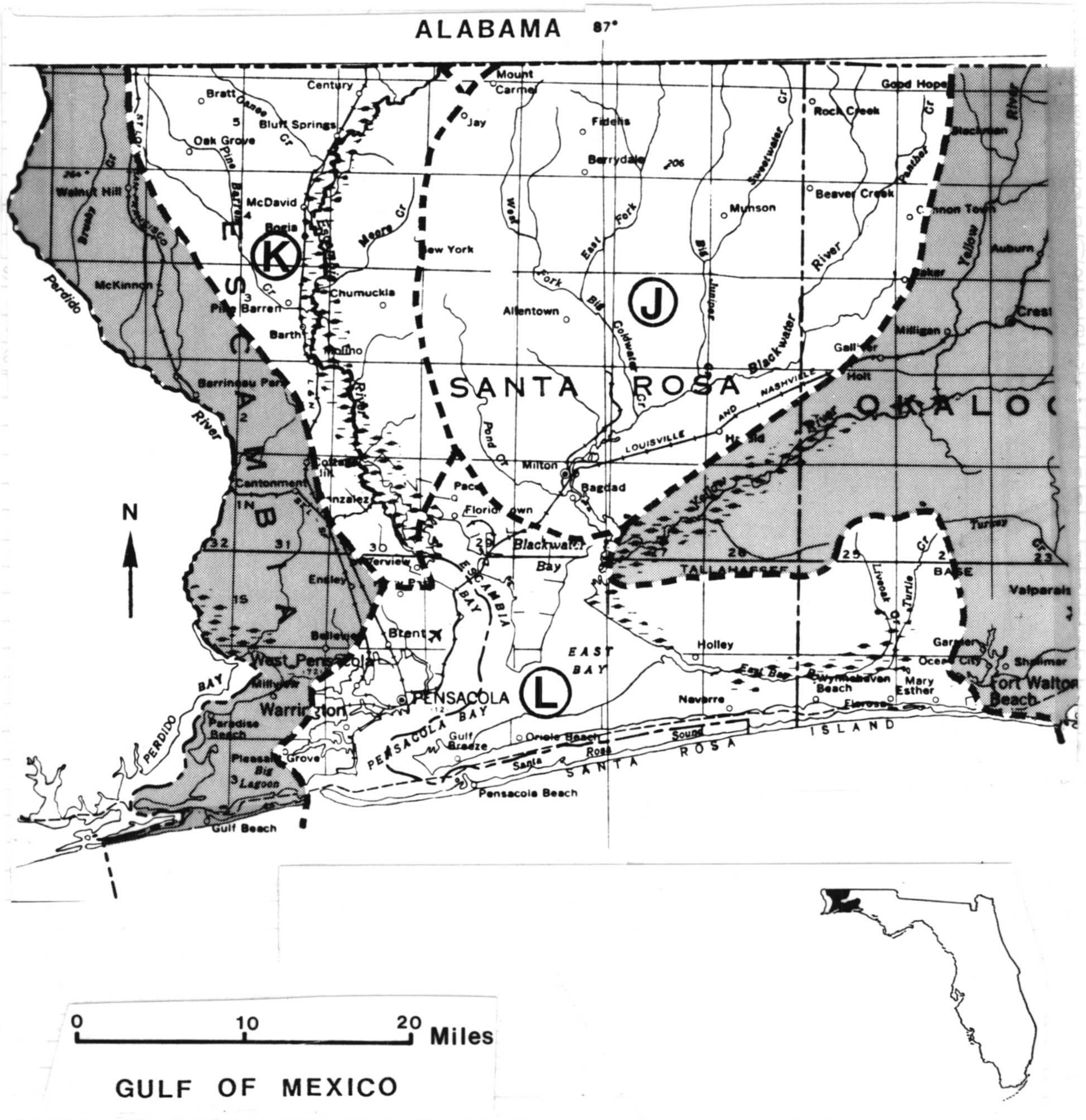


Figure 56. West Panhandle drainage basins–(J) Blackwater River, (K) Escambia River and (L) Escambia Bay (after Conover and Leach 1975).

among the 50 lakes in the State most needing preservation and protection.

This river basin is sparsely developed and populated; most of the population is located near Milton.

Water quality problems in the Blackwater River are limited to the stretch at the mouth of the river below Milton. Here, chronically high bacteria and nutrient levels have been recorded because of the discharges from the Milton sewage treatment plant

(Hand and Jackman 1982, 1984). Below this point, macroinvertebrates have been reduced to fewer than ten pollution-tolerant species. The Milton plant is being extensively upgraded, which is expected to improve the area water quality. Fish and macroinvertebrate populations in the remainder of the river are considered exceptionally healthy (Bass 1983) despite agricultural runoff and several point-source effluent dischargers.

Biological water-quality stations in the basin were sampled during 1973–78 (Ross and Jones 1979). A station in Big Coldwater Creek had a high Biotic Index from qualitative sampling, indicating no significant organic pollution. A station in the upper Blackwater River near SR 4 exhibited high macroinvertebrate diversities for two types of quantitative sampling and a high Biotic Index for qualitative samples. Occasionally high total and fecal coliform counts were attributed to pasture and other agricultural runoff. These numbers sometimes exceeded Class III (i.e.,recreation, propagation and maintenance of a healthy , well-balanced population of fish and wildlife) water quality standards. A station at the mouth of the river in East Bay had a moderate species diversity and a low number of species per sample, which was attributed to the estuarine conditions. The occurrence of frequently high total coliform bacteria counts were attributed to the Milton sewage treatment plant upriver and to area runoff.

The USGS is monitoring a waste injection well near Milton for potential ground-water contamination (Pascale and Martin 1977).

4.7.10 Escambia River Basin (Figure 56)

The Escambia River drains 10,960 km^2 of which approximately 10% (1,080 km^2) is in Florida and 90% (9,880 km^2) is in Alabama. The river is formed by the confluence of Escambia Creek and Conecuh River at the Florida border. The basin has a limestone base with poorly drained organic surface soils near the coast, such that the river flows through a generally low, swampy area with many sloughs and backwaters from Molino, Florida, to Escambia Bay (Hand and Jackman 1984). These conditions change to well-drained sandy soils in the northern portions of the drainage. Despite these well-drained soils, topographic relief is sufficient to render this area susceptible to erosion (FDER 1986c).

The basin is lightly populated with only two cities, Cantonment and Century, having populations greater than 5,000. Most of the basin is forested and, together with some agriculture, this constitutes the major land use. There are approximately 260 km^2 of floodplain crop and pasture land. Flood peaks occur primarily in April and May, with high river stages also common in December. It is recommended that crops be planted and construction take place at least 7 m above the mean river stage to minimize flood damage (USACE 1980b).

Historic baseline water quality data for the Escambia River includes a study by Patrick (1953). Thirteen point-source dischargers have State or Federal permits to discharge into this basin. Five sewage treatment plants and five industrial sources (primarily paper and chemical companies) discharge into the basin in Alabama including the Container Corporation of America—Brewton Mill (U.S. EPA 1971a). In Florida, Monsanto Chemical discharges inorganic effluents into the Escambia River, and two small towns near the Alabama-Florida border, Jay and Century, discharge effluent from sewage treatment plants. The Escambia River has a history of water quality problems (U.S. Dept. of the Interior 1970b). U.S. EPA water-quality index values for DO, color, and bacteria downstream of Alabama point sources in the past have been fair to poor (Hand and Jackman 1984).

Recent samplings show that bacterial standards for Florida Class III waters (i.e., recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife) are not being met in the Escambia River near the Alabama border (Hand and Jackman 1984). Fish communities are recovering from past degradation; however, they remain less healthy than expected (Bass 1983). Fishery investigations by the Florida Game and Fresh Water Fish Commission suggested that the river was in an intermediate stage of recovery from the past pollution (Bass and Hitt 1978, Bass 1983). Effluent from the sewage treatment plant for the Florida town of Century causes bacterial violations downstream in the Escambia River. The recent reduction in monitoring activity has made it impossible to distinguish between river impacts originating in Alabama and in Florida. At the lower end of the Escambia River at the mouth of Governors Bayou three of five DO measurements taken during 1981–83 were below 3 mg/l (Hand and Jackman 1984).

Canoe Creek, a tributary of the Escambia River, has experienced some water quality problems from nonpoint source runoff (FDER 1978). The 1978 study noted increasing bacterial levels, decreasing pH, and relatively high nitrate concentrations from 1975 to 1978. Only one point source discharges to the stream, Bluff Springs Campground sewage treatment plant. FDER concluded that this source was not responsible for the problems and tentatively attributed the low pH to substantial input of the unbuffered water of the Sand and Gravel Aquifer and the bacteria and nitrate levels to pasture and woodland runoff. The creek demonstrated bacterial violations in 1983, attributed by the FDER district office to dairy and other agricultural stormwater runoff. In addition, siltation and turbidity remain problems in Canoe Creek, especially after rainfall.

In the central part of this basin, near the town of Jay, the University of Florida operates an IFAS (Institute of Food and Agricultural Sciences) agricultural research center. The FDER investigated the site in 1984 following complaints that the pesticides and herbicides tested at the center were being improperly disposed of (Busen et al. 1985). Three separate sampling trips confirmed pesticides at high levels as deep as 4.5–6 m in the soil at the pesticide mix-wash area, in the drainage ditch, and in the field to which the runoff was diverted. Leftover pesticides and wash water were dumped into the drainage ditch, which flowed to gravel-filled pits built to increase percolation. An on-site dump in which pesticide containers containing chemicals were found also showed soil contamination from pesticides. No ground-water contamination, however, was detected. The deep water table and numerous clay layers in the soil limit the potential for pesticide migration into the ground water. This incident raised concerns about the other 22 IFAS centers where similar disposal methods and the normal sandy soils of the State might pose a hazard to area ground water.

Macroinvertebrate diversity was monitored at three stations in the Escambia River from 1973 to 1978 (Ross and Jones 1979). These data suggested that the river was recovering from the massive pollution present during the 1950's and 1960's (FDER 1986c). The station in the river near the Alabama border showed significant improvement during the study period. Diversity indices and the Biotic Index indicated a fairly healthy, stable macroinvertebrate community. However, the combination of very high total coliform bacteria populations and low fecal coliform populations suggested a marked impact from a large paper mill upstream. A second station at Upper Bluffs, approximately 18 km upriver from the river's mouth had high macroinvertebrate diversities, high Biotic index values, and also showed a significant trend of improvement. Occasionally high bacteria counts were attributed to runoff. The salt wedge from Escambia Bay reaches this station during low flow conditions and estuarine forms are found here. The third river station was at the mouth at US 90. It was tentatively concluded that the estuarine conditions found there, combined with thermal effluents, oil and grease spills, and PCB-containing sediments, may have lowered macroinvertebrate diversities. Occasional high coliform counts were apparently caused by runoff.

4.7.11 Escambia Bay and Coastal Area (Figure 56)

The Escambia Bay coastal area (including Pensacola, Escambia, East, and Blackwater Bays and Santa Rosa Sound) drains approximately 1,410 km^2. The bay system receives flow from a watershed including the Yellow, Blackwater, and Escambia Rivers and totalling some 18,130 km^2, of which 6,525 km^2 (36%) is located in Florida and 11,605 km^2 (64%) in Alabama. Major inflows to the bay system are from the Escambia River (185 m^3/s) and the Blackwater River (11 m^3/s). The bay is relatively shallow, ranging from less than 1 m to 6 m deep and averaging 2.5 m at mean low water (U.S. EPA 1971a). Water depth increases from the northern end southward. Ellis (1969) described some of the basic dynamics of the estuary and labeled it a low energy estuary.

Escambia Bay was studied during a period of low river flow in 1969 (U.S. Dept. of the Interior 1970a) with a follow up during high river flow in 1970 (U.S. EPA 1971b). These studies found that Escambia Bay sediments are highly organic and that tidal circulation in upper Escambia Bay is poor. Therefore, disturbing the sediments (e.g., dredging) can cause severe oxygen depletion and massive fish kills. These studies reported unconsolidated bottom sediments ranging from approximately 0.5 m to greater than 2 m, with about one-third of the bay covered to a depth greater than 2 m. Circulation in the bay is generally clockwise during high and low river stages. Water flows out the west side of the bay and saline water flows into the east side. During low flow periods the small creeks in the extreme northern end of the bay do not discharge sufficient water to flush the area, and pollutants are effectively trapped. The studies further determined that the pilings (most of which were unused and unnecessary) of the railroad bridge across the middle of the bay restricted circulation between the upper and lower bay. An investigation of bottom benthos (U.S. EPA 1971b) suggested that wastes discharged along the eastern shore from American Cyanamid and Escambia Chemical companies were generally swept northwestward and deposited along with wastes from Monsanto and Container Corporation in the central and western portions of the upper and lower bay.

An enforcement conference in the late 1960's (U.S. Dept. of the Interior 1970b) led to bay recovery studies by U.S. EPA during 1972–73. These studies resulted in more stringent controls on municipal and industrial discharges. In 1975, following a study of the area's capability to deal with the pollutant loads it was generating (Henningson, Durham & Richardson, Inc. 1975, Olinger et al. 1975), it was concluded by the West Florida Regional Planning Council that (1) there should be no additional nutrient loads discharged to Pensacola Bay, and (2) all domestic sewage discharges should be removed from: Perdido Bay, Big Lagoon, Escambia Bay, East Bay, Blackwater Bay, and Santa Rosa Sound. Hand and Jackman (1984) report that most of the bay system has good water quality; however, several of the bayou areas which receive treated sewage, industrial wastes, and urban runoff exhibit significant water quality problems.

Bayou Chico drains part of the Pensacola urban area, receives treated industrial waste and treated sewage from Warrington Sewage Treatment Plant via Jones Creek and until recently from Pen Haven Sewage Treatment Plant via Jackson Creek, and has bacteria and nutrient problems (Hand and Jackman 1984). The Pen Haven plant has been closed and its waste load diverted to the Main Street Plant. As a result Jackson Creek is improving.

Bayou Texar drains the center of Pensacola and, though there are no permitted point sources in its drainage, has shown bacteria and low DO problems. This bayou is on the western side of Escambia Bay and the only stream flowing into it is Carpenter Creek. The creek and bayou are over 13 km long but the bayou varies in width from about 30 m to a maximum of about 425 m. (NWFWMD 1978b). The creek is intermittent in some sections and apparently receives little base flow, depending on runoff to maintain flow. Bayou Texar undergoes wide fluctuations in depth depending on local weather conditions, experiencing "flooding" caused by water pile-up as well as exposure of large expanses of bottom when water is blown away. In 1974 a restoration study was prepared for the State (Henningson, Durham & Richardson 1974). This study concluded that the major cause of water quality degradation was sediment deposits on the bottom resulting from uncontrolled development in the basin. Further studies ensued to determine the nature and extent of siltation in the bayou and the effect of the siltation on local hydrology (NWFWMD 1978b). This study detailed changes in the bayou since 1893 and described erosion problems of surrounding lands and subsequent transport of the eroded sediments through the bayou. Hand and Jackman (1984) report no recent (since 1981) data on this area. Water quality problems exist in the northern part of Escambia Bay with reduced DO concentrations and bacteria problems around the mouth of the Escambia River. The University of West Florida Sewage Treatment Plant effluent and Monsanto industrial effluents are discharged to the river just upstream of the mouth.

Mulatto Bay, on the east side of Escambia Bay, has had DO, nutrient and bacteria problems but Hand and Jackman (1984) report no data since 1981. Blackwater Bay exhibits water quality problems primarily attributable to nutrients at the Blackwater River mouth. These are attributed to the nutrient loads carried by the river.

Pensacola Bay, particularly the area near Pensacola, was monitored as part of an investigation of the effects of discharges from the Main Street

Wastewater Treatment Plant (McAfee 1984). This study showed the bay to be highly stratified and poorly flushed. They reported improved conditions from studies taking place in the mid-1970's.

The western half of Santa Rosa Sound was studied for its potential for reclassification as a shellfish harvesting water (Florida Department of Health and Rehabilitative Services 1970). The study concluded that, at that time, the western part of the Sound should be reclassified for shellfish harvest since it had excellent water quality, no sources of industrial pollutants, and a watershed little larger than the area of the Sound. Five sewage treatment plants did, however, discharge into the Sound. It was recommended that these be forced to find alternative discharge points outside this area.

Santa Rosa Sound was studied again in 1977–79 (Moshiri et al. 1980). The researchers concluded that the Sound exhibited serious degradation of water quality relative to other local estuarine systems; during warm months red tide outbreaks were possible. Additionally, Little Sabine Bay, on the western end of the gulf side of Santa Rosa Sound, exhibited signs of eutrophication evidenced by high nutrient concentrations, low water transparency, increased algal populations, and low DO. They recommended no further discharges be allowed to Little Sabine Bay.

A biological station sampled in Escambia Bay during 1973–78 showed macroinvertebrate diversities ranging from near zero (very poor) to 3.3 (good) with no trend of improvement evident (Ross and Jones 1979). The apparent instability was attributed to the estuarine environment and stresses from variable industrial discharges into the bay. A similar station in Pensacola Bay was well flushed with marine waters and population and species diversity values suggested a fairly stable macroinvertebrate community. A final station in Santa Rosa Sound at Upper Pritchard Point generally exhibited moderate macroinvertebrate diversities with no significant trend and no notable bacteria problems. This last station is probably more closely associated with Choctawhatchee Bay than with the Escambia Bay system.

The American Creosote Works, Inc. has treated wood at a site in Pensacola for 70 years and discharged effluents into two unlined surface impoundments which are in direct contact with the Sand and Gravel Aquifer, the principal source of water in the area. The USGS chose this site in particular for further study because it is typical of other industrial storage impoundments, the phenols involved are very toxic, and it gave ease of access for sampling (Troutman et al. 1984). They have placed monitoring wells surrounding the site and are sampling the nearby area in Pensacola Bay (Troutman et al. 1984, USGS 1984). Total phenol concentrations in water samples from a test well 30 m south of the impoundment were 36,000 µg/l at a depth of 12 m but less than 10 µg/l at a depth of 27 m (Troutman et al. 1984). Other test wells indicated that contaminated ground water may not be discharging directly into Pensacola Bay. However, phenol concentrations in samples from a drainage ditch discharging directly in Bayou Chico exceeded 20 µg/l.

Deep-well waste injection is used by several of the industries in the Pensacola area. The USGS has been doing substantial investigations of this method, studying movements of the injected wastes (Pascale 1976, Pascale and Martin 1978, Hull and Martin 1982, Merritt in press) and chemical changes in the wastes following injection (Ehrlich et al. 1979, Hull and Martin 1982, Vecchioli et al. in press) to ensure that it will not contaminate area ground water. These programs are ongoing.

The USGS performed an early ground-water investigation near Gulf Breeze in Santa Rosa County, identifying two shallow aquifers separated by a clay confining layer (Heath and Clark 1951). They have also constructed maps showing flooding along the coast during Hurricane Frederick in 1979 (Franklin and Bohman 1980, Franklin and Scott 1980, Scott and Franklin 1980) and published a summary of ground water and surface water data for Pensacola and Escambia County (Coffin 1982).

4.8 Potential Hydrology and Water Quality Problems

4.8.1 Hydrologic Concerns

The frequency and magnitude of floods usually increase as drainage basins are developed. Flooding is a necessary and desirable part of the river basin ecosystem's energy flow; however, their frequency and magnitude can easily exceed levels needed to maintain the ecosystem if improper development takes place. Enforcement of prudent construction practices designed to retain or slow runoff can minimize this increase and its effects on human development. Minimizing vegetation removal (especially trees), prohibiting ditch-and-drain operations as well as dredge-and-fill construction (particularly in wetland areas), and preventing, or tightly controlling, construction and development in river flood plains are all necessary to minimize excessive flooding.

Summer rainfall may be reduced if future development increases the area's albedo (surface reflectivity). It has been proposed that convective rainfall has been reduced by albedo changes from extensive wetland draining in south and east Florida (Gannon 1982). The Panhandle has a lower percentage of wetlands than did these regions originally, yet summer rainfall patterns are similar, with afternoon seabreezes reacting with updrafts from the heated land mass to form thunderheads. The potential for human alterations of Panhandle albedo causing altered rain patterns seems likely; however, programs underway by State and Federal agencies appear to be minimizing those alterations.

A hydrologic change certain to have substantial impact in at least the coastal areas of the Panhandle is the rising sea level. Projections in reports published by the U.S. EPA (Hoffman et al. 1983, 1986) and the National Academy of Sciences (Revell 1983) predict a global sea level rise ranging from as little as 38 cm to as much as 211 cm over the next 100 years. The most recent estimates (Hoffman et al. 1986) predict a global rise of between 57 and 368 cm by 2100. This rise, coupled with coastal subsidence in the Panhandle from tectonic activity totalling approximately 13 cm would result in a net sea level increase along the Panhandle coast of from 70 to 381 cm (roughly 2.3 to 12.5 ft). This compares to a net increase over the last century of approximately 10–15 cm (Gornitz et al. 1982, Barnett 1983). The rate of rise increases with time; the 25-year estimates and cumulative totals through the year 2100 are given in Table 5 and Figure 57.

Impacts from sea level rise will be manifold but can be placed in three broad categories: shoreline retreat, temporary flooding, and salt intrusion. Besides inundating lowlying coastal areas, coastal erosion will progress inland a great distance. Statewide, average horizontal encroachment by the oceans in the next 100 years is expected to be approximately 100 times the vertical rise (i.e., 51–224 m) (Bruun 1962). The actual encroachment experienced will be strongly dependent on the local terrain. This high ratio is an effect explained by the Bruun Rule. Briefly, this rule states that beach erosion occurs to provide sediments to the shore bottom so that the shore bottom can be elevated in proportion to the rise in sea level. Thus sufficient beach will erode to provide the same shore bottom-beach slope from some distance offshore that was stable prior to the sea level rise (Figure 58).

The current trend of sea level rise may be responsible for serious erosion taking place in many coastal resorts (New Jersey Department of Environmental Protection 1981, Pilkey et al. 1981). Most of the Panhandle can probably expect a ratio lower than the Florida average since maintaining the relatively steep nearshore slope of the mostly high energy coastline will result in somewhat less lateral encroachment. However, the barrier islands along much of the Panhandle will be strongly affected, migrating landward where possible and experiencing heavy erosion on the seaward faces.

Table 5. Scenarios of future sea-level rise (in cm) (Hoffman et al. 1986).

Scenario	2000	2025	2050	2075	2100
High	5.5	21	55	191	368
Low	3.5	10	20	36	57

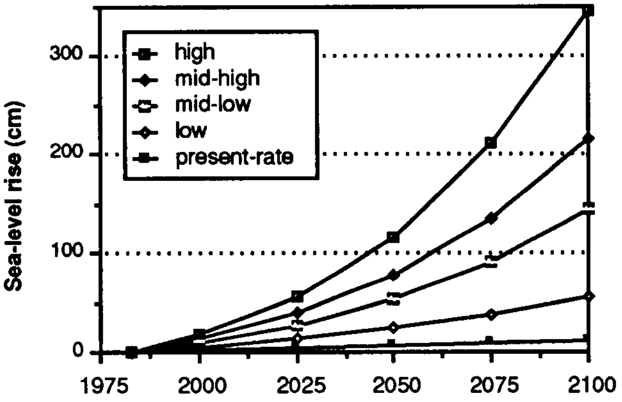


Figure 57. Projected sea-level rise using different scenarios (data from Hoffman et al. 1983).

The increased depth of the water near shore in those areas where artificial or natural structures prevent sediment erosion from the beach, according to the Bruun Rule, will allow more energetic waves to strike the coastline. Areas suffering temporary flooding will increase behind these structures since storms, including hurricanes, will result in higher "storm surge" levels. Many present coastal developments and cities will be much more vulnerable to storm damage. Impact scenarios have been developed for Galveston, Texas, and Charleston, South Carolina (Barth and Titus 1984). These models indicate that substantial damage will occur in these two cities, but that the extent can be ameliorated and substantial losses prevented by taking anticipatory actions.

Although buildings are frequently designed assuming a 30 year life, the patterns of development resulting from construction of roads and certain key commercial property (e.g., factories, utilities, airports) may determine patterns of development for centuries. Consideration of the changing sea level should be made a part of planning and permitting, particularly for these key structures. Barrier island development is probably foolish in nearly all instances.

The rising sea level will, by increasing the hydraulic pressure of the saltwater, increase saltwater intrusion into the aquifers in coastal areas. The potentiometric pressures in the aquifers along the coast suggest that the saltwater intrusion will be felt along the entire Panhandle near-coastal area and will have the greatest effect in those areas where the aquifer potentiometric pressures have already been reduced to levels near or below sea level (Figure 52). Southern Okaloosa county is presently the most extreme case of ground water over-pumping in the Panhandle.

Areas in the Panhandle most affected by sea-level rise may be the barrier islands, coastal wetlands, and those coastal areas with present elevations less than a few meters above sea level. The wetlands will tend to migrate inland except where development prevents it.

4.8.2 Water Quality Concerns

a. Surface water. The further reduction of point-source, surface-water pollutants from Panhandle

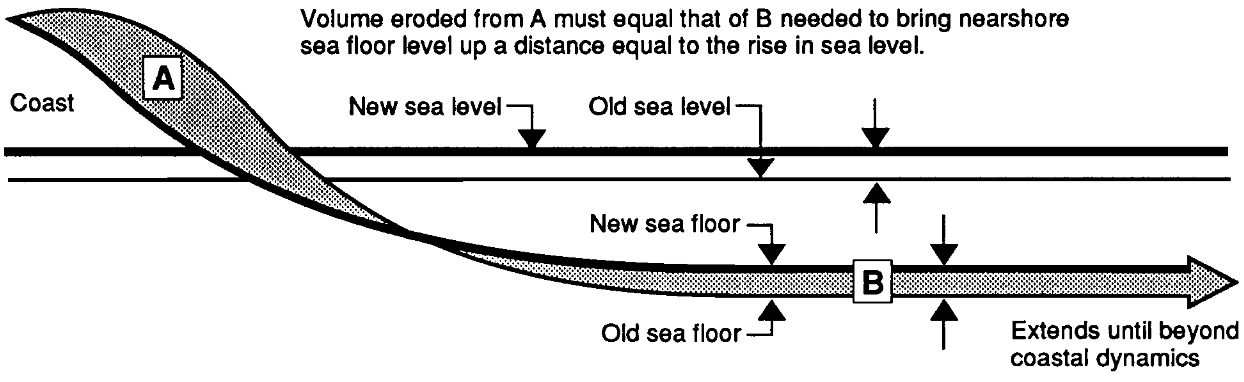


Figure 58. Diagram showing Bruun Rule for beach erosion following increase in sea level.

sources through State and Federal efforts looks promising; however, the water quality of Panhandle rivers is presently most affected by out-of-state pollution. Any improvements in this problem will result from either improvement in the regulatory programs of Alabama and Georgia or efforts by Federal authorities. The State of Florida has been carrying on negotiations with these States for several years in an efforts to encourage their help.

The outlook for control of nonpoint-source pollutants is not as promising. Nonpoint-source pollution is generally the result of rainfall runoff carrying dilute amounts of polluting agents such as petroleum products and nutrients. Since runoff almost invariably increases with development, nonpoint-source pollution also increases with development. The problems with nonpoint-source pollution have less to do with the concentration of the pollutants in the runoff than with the total pollutant load that is carried to our waters each year by the enormous volume of rainfall that runs off the Panhandle. The impacts of this type of pollution tend to be less noticeable than those of point sources because they lack the localized nature of the sometimes massive effects which bring a point-source site to the attention of the public. The nonpoint-source pollutants are nevertheless important and their area of effect often widespread. Detecting and preventing their proliferation will require that regulating agencies establish baseline and monitoring biological and chemical studies in area waters and that future development be planned and controlled to minimize creation of nonpoint-source pollution.

Acid rain is potentially damaging to the surface waters of parts of the Panhandle. Studies are presently underway to determine the sources, amounts, and effects of acid rain (Environmental Science and Engineering, Inc. 1982a, 1982b, 1984; FDER and Florida Public Service Commission 1984; FDER 1985b). Preliminary findings suggest that acid rain results from sulfate emissions by powerplants and other industry, that it tends to be concentrated over land by the sea-breeze/land-breeze phenomenon, and that it develops most strongly during the summer when it is transported northward by the prevailing winds. The already acidic and unbuffered streams and lakes formed by swamp drainage are probably the most likely surface water bodies to be affected. The Panhandle seems to be receiving rainfall that is more acidic than the rest of the State receives except for the area immediately to the east.

Metal-containing sediments are a possible source of water quality problems. Some anaerobic sediments have been identified as potential sources of heavy metal pollution. When iron and sulfur are present in anaerobic sediments (they are especially common in marine sediments) pyrite is formed. When disturbed and exposed to aerobic conditions (e.g., dredging and disposal of resulting spoil), the pyrites rapidly oxidize, forming sulfuric acid. Interstitial porewater pH's as low as 2–3 occur and these conditions can release substantial quantities of any metals bound in the sediments into surrounding waters. This problem has been identified in European harbors (harbor sediments commonly have substantial metal loads [FDER 1986b]) and its potential is being investigated in the Mississippi delta. Possible Panhandle sites where this could be a problem include Pensacola Bay, Apalachicola Bay, and the Dead Lakes along the Apalachicola River.

b. Ground water. The single greatest concern for ground water is contamination from landfills. Panhandle ground-water supplies are very easily contaminated by toxic substances percolating from the surface through the porous ground. With growth comes the necessity of disposing of increasing amounts of waste. Many old landfills were established without regard to their potential for ground-water contamination. These must be located and, where necessary, closed and their contents disposed of safely. New landfills and other forms of surface disposal must be established and managed to prevent contamination of ground water.

The intrusion of saline ground water into the potable aquifers is the second greatest future problem. The increasing consumption of ground-water supplies by a growing population will cause this to be increasingly common. Historically in south Florida, this type of water problem was addressed by local governments with temporary improvements which were not cures and which often simply increased the size of the area of saline contamination. Comprehensive plans have not been instituted until the situation bordered on collapse. In the western Panhandle a water distribution system to prevent this nearly irreversible contamination needs to be instituted before the intrusion increases.

Degraded water quality may occur in Panhandle areas where ground water is pumped for irrigation. The water in excess of plant needs percolates back through the ground to the shallow aquifer from which it was pumped, carrying residual concentrations of the fertilizers used on the crops. It is pumped and used repeatedly and the fertilizer residuals tend to increase in the aquifer. The constant percolation increases the porosity of the ground, minimizing the time before more irrigation is necessary and therefore speeding the cycle. As a result of this process, places in west-central Florida south of Weeki Wachee are unfit for farming. Care must be taken in areas where this recycling might occur to limit irrigation to levels necessary for good crop growth, thereby minimizing the amount percolating back to the underlying ground water.

The direct forms of waste water disposal to the aquifers (e.g., drainage wells and injection wells) which are being used must be investigated carefully and instituted with great caution. The opportunity for large scale pollution of ground water with these methods is very real.

The problems of the future stem largely from the need to balance the pressure for "progress" against the maintenance of those factors necessary to support that progress. Given the near inevitability of the growth, it is sensible to pay extra attention to maintaining the ecosystem.

Chapter 5. TERRESTRIAL HABITATS

5.1 Introduction

Animals and plants are directly affected by the physical nature of the environment. All of Florida's habitats can be ordinated along one or more physical gradients. Among the most important are (1) slope, (2) soil moisture, (3) soil particle size, (4) soil pH, (5) fire frequency, (6) stream order (e.g., Strahler 1964), (7) temperature, (8) light intensity, (9) duration of inundation, and (10) humidity. Each physical factor varies in intensity or quality, often determining the presence, absence, or numbers of individuals in a species population. Groups of species can be found together in a community or habitat more or less predictably over a geographic region, wherever the same physical aspects of the environment occur.

The plant communities that develop in response to background physical and chemical conditions are integrating links between the watershed as a physical unit and the watershed as a habitat for fish and wildlife. Plants and animals possess a wide variety of adaptive mechanisms to reduce competition with one another and for responding to changes in their local environment. They may in turn induce changes in their surroundings that shift the competitive balance in their favor and lead to the succession of one community into another. In plants, such changes include the production of flammable plant parts to promote the probability of fire (Mutch 1970), the production of secondary plant compounds that inhibit the growth of other plant species (allelopathy), local control of microclimate, local erosion control, the alteration of topographic patterns, and the accumulation and recycling of organic matter, as well as many others. In animals, such changes include altering the environment by their behavior such as territoriality, grazing, burrowing, or excavating holes in trees. The outcome of all these interactions is that biotic communities are dynamic rather than static systems.

The watersheds of Panhandle Florida, because of their unique geographical position and geological and hydrological history, have a diverse array of habitats supporting a variety of vegetative communities. Bottomland hardwoods predominate in the river floodplains, and pines mixed with a variety of other tree species and shrubs prevail in the uplands. Wetlands dominate the coastal fringe of the bay systems and large parts of the river floodplains. Dune vegetation and salt marshes are common and important habitats of the barrier islands, beaches, and spits that border the coastline. Seagrass meadows and oyster reefs provide habitat diversity to the intertidal and subtidal areas within the bays.

For more than 400 years northern Florida has been explored by naturalists. Some of the reports and writings of the early naturalists (LeMoyne in DeBry 1591, Catesby 1743, Bartram 1791, Williams 1827, Muir 1917) provide numerous descriptions of plant species, but surprisingly few details of habitats and community types. Although considerable surveys and observations have been made on the flora of the region, until recently a general lack of understanding of the delineation of plant communities and of the factors that control their structure, distribution, and successional relationships has prevailed. According to Clewell (1971), the reasons for this lack of understanding include (1) the general complexity and diversity of Panhandle flora; (2) the subtle patterns of vegetation associations and the dramatic shifts that occur with little obvious change in physiochemical conditions; (3) the lack of information on the effects of fire and flood on vegetation; and (4) the lack of information on the environmental tolerances and reproductive strategies of many important species.

Past and present land use also affect distributions. Although sparsely populated and industrialized compared to the rest of Florida, the watersheds of the Panhandle already have experienced severe environmental modifications affecting plant communities and will continue to do so. Among the impacts are forestry, logging, agriculture, and land and waterway development for commerce and urbanization. Nonetheless, knowledge of the factors which affect the processes important for these communities is necessary to predict the future changes that will be induced by human alterations and provide information to employ proper management practices.

The Panhandle is richly endowed with animals and plants. A general map of the distribution of vegetative communities (habitats) discussed is shown in Figure 59. Aquatic organisms, understandably, are limited in their geographic ranges by the continuity, or lack thereof, of the water in which they live. Therefore, all of the larger stream basins of Panhandle Florida have their aquatic endemics. Terrestrial animals and plants are not so limited by drainage divisions as they are by water in the stream courses of the drainage basin. Even so, numerous terrestrial species are restricted by, or at least have ranges terminating in, a specific Panhandle drainage.

Florida's richest region of endemicity is located in the Apalachicola Bluffs and Ravines, but other parts of the Panhandle have their own distinctive identities also. Between the Apalachicola and Ochlockonee Rivers, and between Telogia Creek on the north and the Gulf of Mexico on the south, lies another region of endemicity (Means 1977), and the vicinity of western Eglin Air Force Base seems also to be emerging as an area having narrowly restricted species, including a frog new to science (*Rana okaloosae*), a darter (*Etheostoma okaloosae*), a cyprinid minnow (*Notropis* new species), possibly a desmognathine salamander, the Panhandle lily (*Lilium iridollae*), and others.

Table 6 lists all the known Panhandle endangered, threatened or commercially exploited plants listed by the State of Florida and USFWS (Wood 1986) and the Panhandle counties in which they are found (Ward 1978). Table 7 lists the endangered or threatened animals (Wood 1986).

5.2 Native Habitats

5.2.1 Longleaf Clayhill Uplands

Harper (1906) recognized the biological distinctiveness of the red hill country in the Coastal Plain of Georgia, calling it the Altamaha Grit Region. In Panhandle Florida, this same physiographic region reaches coastward from the Georgia border to its termination at Cody Scarp and is called the Tallahassee Red Hills (Harper 1914), a subdivision of the Northern Highlands (Puri and Vernon 1964). At least half of the terrestrial environments of Panhandle Florida are developed on red clay soils of the Northern Highlands (Figure 59 and Figure 5).

a. Flora. Longleaf pine (*Pinus palustris*) was the principal tree species on upland soils (valley slopes and ridges) of the Coastal Plain in pre-Columbian times. At least 70 million acres (Wahlenberg 1946) were reported to have supported longleaf, or yellow pine. Typically the canopy is sparse or open, allowing direct or weakly filtered sunlight to the forest floor. This condition fosters a species-rich groundcover flora, containing more than 200 species of forbs and grasses per hectare (Clewell 1971, 1978). One grass particularly, pineland three awn, or wiregrass, (*Aristida stricta*) is a groundcover dominant that is always present. Other wiregrasses (*Aristida* spp., *Sporobolus* spp. and bluestems *Andropogon* spp.) are common herbs, and bracken fern (*Pteridium aquilinum*) is always present and often abundant. Forbs include numerous species of composites (*Aster* spp., *Eupatorium* spp., *Solidago* spp., etc.), legumes (*Desmodium* spp., *Lespedeza* spp., *Tephrosia* spp., etc.), and heaths (*Vaccinium* spp., *Gaylussacia* spp.). Woody low shrubs such as the runner oaks (*Quercus pumila* and *Q. minima*), chinquapin, (*Castanea pumila*), and others are common. See Clewell (1978) for a full list of the plants found on three longleaf clayhill habitats near Thomasville, Georgia. On ridges and high slopes in clayhill country where rains have leached clays from the topsoil, the scrub oaks *Quercus laevis, Q. marilandica*, and *Q. incana* are found. These were suppressed by the frequent natural fires of these communities in pre-Columbian times, and occurred

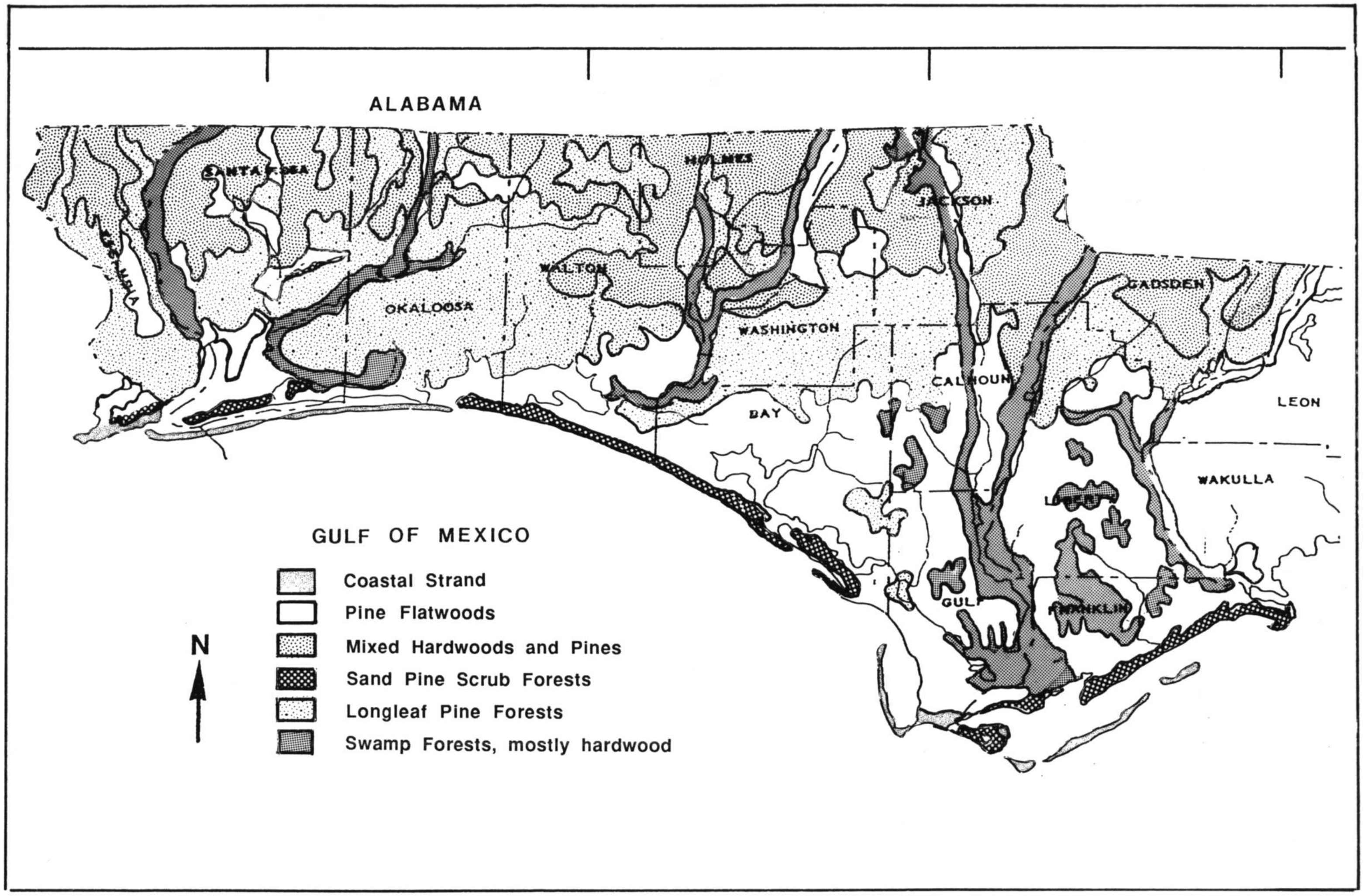


Figure 59. Vegetative communities of the Florida Panhandle (after Davis 1967).

Table 6. Panhandle plants listed as Endangered (E), Threatened (T), Commercially Exploited (C), and Under Review (UR) by the State of Florida (FDA) and USFWS (from Wood 1986) and counties where they are found (from Ward 1978).

			Bay	Calhoun	Escambia	Franklin	Gadsden	Gulf	Holmes	Jackson	Leon	Liberty	Okaloosa	Santa Rosa	Walton	Washington
Actaea pachypoda	T															
Adiantum capillus-veneris	E		●	●		●	●	●		●						●
Aquilegia canadensis	E	UR								●						●
Baptisia hirsuta	T	UR							●				●	●	●	
Baptisia megacarpa	T	UR		●			●		●	●						
Brickellia cordifolia	T	UR								●						
Bumelia lycioides	T			●												
Callirhoe papaver	T															
Cheilanthes microphylla	T															●
Chrysopsis cruiseana	E	UR											●	●		
Conradina glabra	T	UR														
Cornus alternifolia	T			●			●									
Croomia pauciflora	E	UR					●									
Cryptotaenia canadensis	T						●									
Drosera intermedia	T		●	●	●	●		●					●	●	●	●
Epigaea repens	E				●								●	●		
Erythronium umbilicatum	T						●									
Gentiana pennelliana	E	UR	●	●		●	●	●							●	
Harperocallis flava	E	E				●										
Hedeoma graveolens	E	UR	●													
Hepatica nobilis obtusa (=americana)	E						●									
Heterotheca (=Chrysopsis) cruiseana	E	UR			●								●	●	●	
Hexastylis arifolia	T				●		●						●	●	●	●
Hydrangea arborescens	T															
Hypericum lissophloeus	E	UR	●													●
Juncus gymnocarpus		UR													●	
Kalmia latifolia	T			●	●		●		●	●			●	●	●	●
Liatris provincialis	E	UR				●		●								
Leitneria floridana	T	UR				●										
Lilium iridollae	E	UR			●								●	●	●	
Linum westii	T	UR		●		●		●		●						
Litsea aestivalis	T	UR											●			

(continued)

Table 6. Concluded

	FDA	USFWS	Bay	Calhoun	Escambia	Franklin	Gadsden	Gulf	Holmes	Jackson	Leon	Liberty	Okaloosa	Santa Rosa	Walton	Washington
Lupinus westianus	E	UR	●			●		●					●	●	●	
Macbridea alba	E	UR	●			●		●								
Magnolia acuminata	T								●						●	
Magnolia ashei	E	UR					●				●	●	●	●	●	●
Malaxis unifolia	T						●					●				
Matelea alabamensis	E	UR										●				
Medeola virginiana	T						●				●			●		
Melanthium (=Veratrum) woodii	E						●			●						
Nolina atopocarpa	E	UR				●						●				
Oxypolis greenmanii	E	UR	●	●				●								
Pachysandra procumbens	E									●						
Parnassia grandifolia	E					●										
Polygonella macrophylla	T	UR	●		●	●		●					●	●	●	
Polygonum meisnerianum	T										●					
Rhapidophyllum hystrix	C	UR					●			●	●	●			●	
Rhexia salicifolia		UR	●								●				●	●
Rhododendron austrinum	E	UR	●	●	●		●	●	●	●	●	●	●	●	●	●
Rhododendron chapmanii	E	E					●	●				●				
Salix floridana	T	UR								●						
Sarracenia leucophylla	E		●	●	●	●		●	●	●		●	●	●	●	●
Sarracenia rubra	E	UR	●		●								●	●	●	
Schisandra glabra	T	UR					●			●		●				
Staphylea trifolia	T											●				
Stewartia malacodendron	E		●	●	●		●		●	●		●	●	●	●	●
Taxus floridana	E	UR					●					●				
Thalictrum(=Anemonella) thalictroides	T						●									
Torreya taxifolia	E	E					●			●						
Trillium lancifolium	E						●									
Verbesina chapmanii	T	UR	●					●				●				
Viola hastata	E						●									
Xyris longisepala	E	UR	●								●				●	

Table 7. Vertebrate animals of Panhandle Florida whose status is threatened (T), endangered (E), under review (UR), or of special concern (SSC) (after Wood 1986).

Scientific name	Common name	Status State	Status Federal
Fish			
Acipenser oxyrhynchus desotoi	Atlantic sturgeon	SSC	UR
Ammocrypta asprella	Crystal darter	T	UR
Etheostoma histrio	Harlequin darter	SSC	
Etheostoma okaloosae	Okaloosa darter	E	E
Fundulus jenkinsi	Saltmarsh topminnow	SSC	
Micropterus notius	Suwannee bass	SSC	
Micropterus sp. (undescribed)	Shoal bass	SSC	
Notropis callitaenia	Bluestripe shiner	SSC	UR
Notropis sp. (undescribed)	Blackmouth shiner	E	UR
Amphibians			
Ambystoma cingulatum	Flatwoods salamander		UR
Haideotriton wallacei	Georgia blind salamander		UR
Hyla andersonii	Pine barrens treefrog	SSC	
Rana areolata	Gopher frog	SSC	UR
Rana okaloosae	Bog frog	SSC	UR
Reptiles			
Alligator mississippiensis	American alligator	SSC	T (S/A)[a]
Caretta caretta caretta	Atlantic loggerhead turtle	T	T
Chrysemys (=Pseudemys) concinna suwanniensis	Suwannee cooter	SSC	UR
Dermochelys coriacea	Leatherback turtle	E	E
Drymarchon corais couperi	Eastern indigo snake	T	T
Gopherus polyphemus	Gopher tortoise	SSC	UR
Graptemys barbouri	Barbour's map turtle	SSC	UR
Lepidochelys kempii	Atlantic ridley turtle	E	E
Macroclemys temmincki	Alligator snapping turtle	SSC	UR
Pituophis melanoleucus mugitus	Florida pine snake	SSC	UR
Birds			
Aimophila aestivalis	Bachman's sparrow		UR
Ammodramus maritimus juncicolus	Wakulla seaside sparrow	SSC	UR
Aramus guarauna	Limpkin	SSC	

(continued)

Table 7. Continued

Scientific Name	Common Name	Status State	Status Federal
Birds (continued)			
Buteo swainsoni	Swainson's hawk		UR
Campephilus principalis	Ivory-billed woodpecker	E	E
Charadrius alexandrinus tenuirostris	Southeastern snowy plover	T	UR
Charadrius melodus	Piping plover	T	T
Cistothorus palustris marianae	Marian's marsh wren	SSC	
Dendroica dominica stoddardi	Stoddard's yellow-throated warbler		UR
Dendroica kirtlandii	Kirtland's warbler	E	E
Egretta caerulea	Little blue heron	SSC	
Egretta thula	Snowy egret	SSC	
Egretta tricolor	Tricolored heron	SSC	
Elanoides forficatus	Swallow-tailed kite		UR
Falco peregrinus tundrius	Arctic peregrine falcon	E	T
Falco sparverius paulus	Southeastern kestrel	T	UR
Grus canadensis pratensis	Florida sandhill crane	T	
Haematopus palliatus	American oystercatcher	SSC	
Haliaeetus leucocephalus	Bald eagle	T	E
Lanius ludovicianus migrans	Migrant loggerhead shrike		UR
Mycteria americana	Wood stork	E	E
Pelecanus occidentalis	Brown pelican	SSC	
Picoides borealis	Red-cockaded woodpecker	T	E
Rostrhamus sociabilis	Snail kite	E	E
Sterna antillarum	Least tern	T	
Vermivora bachmanii	Bachman's warbler	E	E
Mammals			
Felis concolor coryi	Florida panther	E	E
Mustela vison lutensis	Florida mink		UR
Myotis austroriparius	Southeastern bat		UR
Myotis grisescens	Gray bat	E	E
Myotis sodalis	Indiana bat	E	E
Neofiber alleni	Round-tailed muskrat		UR
Peromyscus floridanus	Florida mouse	SSC	UR
Peromyscus polionotus allophrys	Choctawhatchee beach mouse	T	E
Peromyscus polionotus leucocephalus	Santa Rosa beach mouse		UR
Peromyscus polionotus peninsularis	St. Andrews beach mouse		UR
Peromyscus polionotus trissyllepsis	Perdido Bay beach mouse	E	E
Plecotus rafinesquii	Southeastern big-eared bat		UR

(continued)

Table 7. Concluded

Scientific Name	Common Name	Status State	Status Federal
Mammals (continued)			
Tamias striatus	Eastern chipmunk	SSC	
Trichechus manatus latirostris	West Indian manatee	E	E
Ursus americanus floridanus	Florida black bear	T	UR

[a]S/A = similarity of appearance

mostly as woody herbs in the groundcover. At best they were small trees of the understory, probably rarely attaining 30 years of age.

The second-growth forests of this community type today are somewhat different from their presettlement prototypes in several important ways. First, the age-class composition of clayhill longleaf forests is truncated; most stands are less than 60 years old, containing no trees 350–400 years old as is possible for longleaf pine (Wahlenberg 1946). Second, the cycle of summer fires has been halted or, in the case of controlled burning, shifted to winter burns. Alteration of the fire cycle has had a dramatic effect upon the reproduction of many of the species of plants in longleaf communities. Because many plants require fires in summer to stimulate flowering (Parrott 1967, Davis 1985, Means and Grow 1985), the absence of fire or the shifting of fire to the season of plant dormancy has prevented these species from reproducing. Moreover, many of these same species, and others that do not require summer fires for flowering, have vastly diminished recruitment because their seeds require a bare mineral soil on which to germinate. Longleaf pine itself has this requirement; summer burns open the rank groundcover and create bare mineral soil which lies exposed when longleaf seeds normally fall to the ground during fall and winter.

b. Ecology. The life cycle of the longleaf pine is important to the ecology of the clayhills, sandhills, and flatwoods ecosystems it inhabits and will be discussed to provide an understanding of the functioning of these ecosystems. Even though fully grown specimens of most of the species of southern pines can withstand fire, they are killed in the seedling and sapling stage. Longleaf pine alone, is physically adapted to tolerate fire when young. Instead of growing upward right away as most saplings do, longleaf seedlings stay flat on the ground for periods of 3 to 15 years (Croker and Boyer 1975).

During the "grass stage," the young tree grows a long, heavy taproot that probably helps it reach far down into the sandy soil toward moisture; this tap root also serves as a nutrient storage organ. When the young plant finally starts to grow tall, the stored food in the taproot helps it shoot rapidly upward. At the same time that it is racing skyward, the tree delays putting out branches, giving young saplings of this species a distinctive bottlebrush appearance. By growing rapidly upward in a single spurt, the young tree minimizes the amount of time its growing tip is vulnerable to destruction by ground fires. A young tree growing steadily year by year and putting out multiple branches would be vulnerable to ground fires over a far longer period of time. Moreover, longleaf pines have thick, corky bark and dense tufts of needles surrounding its apical buds. These two characteristics insulate the young longleaf pine and are obvious adaptations for resisting heat.

Like many conifers, the seeds of the longleaf require open sunlight and bare mineral soil on which to germinate. Beneath longleaf pines, however, the ground is densely carpeted with wiregrass and many other native grasses and forbs. The only open places readily available to longleaf seeds are very small bare patches of soil created by burrowing animals (e.g., gopher tortoise, *Gopherus polyphemus*; pocket gopher, *Geomys pinetus*) and the tip-up mounds of wind-thrown longleaf trees. More than any other single agent, it is fire that creates the bare mineral soil conditions necessary for the germination of longleaf seeds. In the longleaf pine belt, summertime is the season of natural fires. The pines drop their seeds in the autumn and those seeds germinate when other plants are dormant from October to March, a timing that is adapted to the yearly cycle of the fires.

The periodicity of natural fires depends mainly upon two major factors: (l) number of local lightning ignitions, and (2) the occurrence of broad, sweeping fires. It is obvious that summers with more lightning storms also had more fires. The amount of lightning, however, varies considerably from summer to summer, as meteorological data for the past half century show. About once every decade, summer lightning reaches a peak. During those peak summers, there are enough lightning storms to set enough local fires to burn off most of the longleaf pine sites in the Coastal Plain.

There is good reason to believe that the original longleaf forests typically burned every 2 to 3 years, but sometimes they burned annually and, during periods of low lightning incidence and wet summers, sometimes as seldom as once in 5 years (Clewell 1971, Means and Grow 1985, Christensen, in press).

Lightning is usually attracted to older, larger pines. Older pines are more likely to have heart-rot, a fungal infection that makes the heartwood porous and more flammable, and to have more resins in their heartwood than younger trees. Even when alive, the older trees are more likely than younger trees to be set afire, or to be set smouldering, even during heavy rains. A smouldering tree can ignite a ground fire days later, when the storm is past and the ground is dry again. Dead trees may start groundfires more readily than live ones do. The original longleaf forest not only was able to survive fire, it even depended upon fire, and it may actually have helped start and sustain the fires that regularly burned it (Mutch 1970).

Old-growth trees—living or dead—are exceedingly rare in the Coastal Plain today because almost all of the original timber has been cut. Furthermore, the present generations of longleaf pines are destined to be harvested when their commercial value peaks out at 40–50 years, and there will be very few forests, indeed, that contain old longleaf pines, living or dead.

In the original forests of the Coastal Plain, longleaf communities dominated the uplands and spread downslope from ridgetops all the way to the saturated soils. Longleaf pine forests have been labeled as fire "disclimax" or "subclimax" forest, because, to survive, they need fires to suppress the scrub oaks and other hardwoods that would otherwise take over. Most hardwoods are thin barked and fire tender, and in the original forests, they could only survive in the Coastal Plain in areas that were naturally fire protected, such as valley bottoms and lower down on the moist soils of valley sidewalls.

There still are many places where the pine woods grade naturally into the hardwoods. As one travels downslope from the dry uplands, the first hardwoods one sees are typically shrubby, small-leaved evergreen species. Further downslope, these grade into more substantial hardwood trees at the toe of the valley sidewall and thereafter, the species composition changes according to the hydrology of the stream course.

c. Soils. The soils of the clayhills are developed from the Miocene Miccosukee Formation in the Tallahassee Red Hills subdivision of the Northern Highlands, and from the Citronelle Formation in the Western Highlands. Clayhills soils tend to hold moisture over a long period of time. On ridgetops, rain leaches the clay particles from the top 6 inches of soil, creating slightly more xeric soil conditions for plants and animals. Hilltops are the sites in the clayhills communities of the Tallahassee Red Hills, Grand Ridge, New Hope Ridge, and the Western Red Hills where the best agricultural lands lie, and the lands that have been most impacted by agriculture and development.

d. Trophic dynamics. Although no measures have been found in the literature, the primary productivity in longleaf clayhill associations is probably about equally divided between the overstory and the groundcover. Primary consumers of the longleaf pines are mostly insects, but there is some consumption of young longleaf seedlings and saplings by grazing and browsing vertebrates. Feral hogs are known to be particularly damaging to young longleaf pines by digging and eating the long tap roots. (Wahlenberg 1946).

The high primary productivity and species richness of the plants support a rich consumer community. In addition to leaf-, stem-, and root-consuming insects (i.e., lepidoptera, orthoptera, coleoptera, diptera, hemiptera) and other invertebrates, the many species of flowering forbs attract numerous species of pollinating insects. Because the groundcover plants bring their insect consumers close to the ground surface, insectivores abound there and include predaceous beetles (coleoptera), dragonflies (odonata), bugs (hemiptera), mantises (mantida), and spiders (arachnida). The invertebrates are also the food base for dozens of vertebrate insectivores including lizards, frogs, mammals and birds.

e. Fauna. The following animals are principal species found in open, longleaf pine forests: red-tailed hawk *(Buteo jamaicensis)*, great horned owl (*Bubo virginianus*), fox squirrel (*Sciurus niger*), eastern diamondback rattlesnake (*Crotalus adamanteus*), pine snake (*Pituophis melanoleucus*), gopher tortoise (*Gopherus polyphemus*), Bachman's sparrow (*Aimophila aestivalis*), and bobwhite (*Colinus virginianus*).

In a drift-fence study of the amphibians and reptiles inhabiting a 200-acre tract of old growth longleaf pine in the Tallahassee Red Hills (Means and Campbell 1981), 20 different species were recorded in over 6,000 trap weeks during one 2-year period (Table 8). Engstrom (1982) reported the largest number of breeding birds from any known Florida habitat from the same site (Table 9).

f. Rare and endangered species. Panhandle Florida longleaf clayhill communities support a large number of species that are rare, endangered, threatened, or of special concern. The gopher tortoise, a species of special concern, is found in clayhills from the Perdido to the Ochlockonee drainages, but does not do as well in clayey soils as it does in sandy soils. The gopher tortoise is a keystone species (Eisenberg 1983) whose presence is vital to the existence of other species. The burrows of the gopher tortoise are a haven for dozens of vertebrates and invertebrates, including a few strict obligate commensals that are totally dependent upon the gopher tortoise. More about the interdependencies of the tortoise and its commensals is discussed under sandhills habitat. The federally endangered red-cockaded woodpecker (*Picoides borealis*) once was common in clayhills longleaf forests, but most of the native longleaf forest has been replaced in clayhills habitats by the mixed shortleaf-loblolly pine hardwood community in which the red-cockaded woodpecker does very poorly. Mature longleaf pine forests such as those that originally clothed the clayhills habitats of the Northern Highlands are nearly nonexistent today. Their absence is the principal reason why the red-cockaded woodpecker is endangered. Because so much of the original longleaf pine clayhills communities have been converted into ruderal communities, the native biota of longleaf clayhills has been severely reduced or fragmented.

5.2.2 Longleaf Sandhill Uplands

The term "sandhills" has been applied to this community by a long list of its students (Laessle 1958, Bozeman l971, Campbell and Christman 1982, Means and Campbell 1981, Christensen in press). Other common names that have been applied to this community are high pinelands (Clewell 1971), longleaf pine, and xerophytic oaks (Davis 1967), and dwarf oak forests (Wharton 1977). In Panhandle Florida, sandhills habitats can be roughly classed into two types: (1) the longleaf sandhill uplands in the interior, especially those occurring as a broad band of deep sand deposits below Cody Scarp, including Eglin Air Force Base, Greenhead Slope, Fountain Slope, and Beacon Slope; and (2) sandhills along the coast that are vegetated with coastal scrub vegetation (overstory of either slash pines or sand pine, and understory of coastal scrub oaks). The former are discussed here, the latter in 5.2.7.

a. Soils. The well-drained white-to-yellowish sands usually are 100 cm (40 inches) or more deep above finer textured subsoils. They are relatively sterile, nearly flat to strongly sloping, acidic, moderately to excessively well drained, and coarsely textured. Water moves so rapidly through the soil that shortly after rains and in the interim between

Table 8. Numbers of amphibians and reptiles captured on two annually burned pine stands and an unburned hardwood stand in north Florida (Means and Campbell 1981).

Species	Longleaf pine clayhills[a]	Shortleaf loblolly clayhills[b]	Beech magnolia[c]
Ambystoma opacum	0	3	264
Ambystoma talpoideum	0	0	22
Ambystoma tigrinum	99	13	0
Notophthalmus viridescens	4	0	1
Eurycea bislineata	0	0	1
Eurycea quadridigitata	1	0	0
Plethodon glutinosus	0	3	18
Scaphiopus holbrooki	41	21	24
Bufo quercicus	294	0	0
Bufo terrestris	38	66	28
Acris gryllus	0	0	8
Hyla cinerea	0	0	2
Hyla crucifer	0	0	2
Hyla gratiosa	2	0	0
Hyla chrysocelis	0	0	1
Pseudacris nigrita	3	0	0
Pseudacris ornata	152	0	0
Rana catesbeiana	0	3	2
Rana clamitans	0	1	6
Rana sphenocephala	4	4	9
Gastrophryne carolinensis	39	22	20
Kinosternon subrubrum	3	0	0
Terrapene carolina	3	1	0
Deirochelys reticularia	2	0	0
Anolis carolinensis	0	2	12
Sceloporus undulatus	0	3	0
Cnemidophorus sexlineatus	16	2	4
Eumeces inexpectatus	2	0	0
Eumeces laticeps	7	14	2
Leilopisma laterale	0	0	1
Ophisaurus ventralis	7	0	0
Cemophora coccinea	2	0	0
Coluber constrictor	0	0	2
Elaphe guttata	0	1	0
Elaphe obsoleta	0	0	1
Heterodon platyrhinos	0	1	0
Thamnophis sauritus	2	0	0
Thamnophis sirtalis	0	4	0
Total	**721**	**164**	**430**
Total number species	**20**	**17**	**21**

[a] 64 traps running continously 16 March 1979–6 Feb 1981 = 6,272 trap weeks.

[b] 16 traps running continously (except 11 Apr–24 Sep 1978) 1 Feb 1976–6 Feb 1981 = 2,760 trap weeks.

[c] 3 traps running continously 14 Apr 1976–18 Apr 1978, then 16 traps 12 Oct 1978–6 Feb 1981 = 1,840 trap weeks.

Table 9. Breeding birds of clayhill longleaf old-growth forest (from Engstrom 1982). The number of individuals per trip in Winter Bird Population Study (WBPS-79, 58.3 ha), the number of breeding pairs per tract in Breeding Bird Censuses (BBC-79, 58.3 ha; BBC-80, 20 ha), and residency status.

Species	WBPS-79[a]	BBC-79	BBC-80	Status[b]
Wood duck (*Aix sponsa*)	+	2	2	WB
Bobwhite (*Colinus virginianus*)	-	2.5	2.5	BO
Mourning dove (*Zenaida macroura*)	2	10.5	3	WB
Great horned owl (*Bubo virginianus*)	1	1	-	WB
Common flicker (*Colaptes auratus*)	4	5	1.5	WB
Pileated woodpecker (*Dryocopus pileatus*)	+	1	+	WB
Red-bellied woodpecker (*Melanerpes carolinus*)	8	8.5	3.5	WB
Red-headed woodpecker (*M. erythrocephalus*)	-	13.5	3.5	BO
Yellow-bellied sapsucker (*Sphyrapicus varius*)	3	-	-	W
Red-cockaded woodpecker (*Picoides borealis*)	17	5	1.5	WB
Hairy woodpecker (*Picoides villosus*)	+	1	1	WB
Downy woodpecker (*Picoides pubescens*)	+	1	+	WB
Eastern kingbird (*Tyrannus tyrannus*)	-	3	+	B
Great crested flycatcher (*Myiarchus crinitus*)	-	13	4	B
Eastern wood pewee (*Contopus virens*)	-	8.5	4.5	B
Blue jay (*Cyanocitta cristata*)	2	8	2	WB
Common crow (*Corvus brachyrhynchos*)	-	2	-	WB
Tufted titmouse (*Parus bicolor*)	-	1	-	WB
White-breasted nuthatch (*Sitta carolinensis*)	7	5	2.5	WB
Brown-headed nuthatch (*Sitta pusilla*)	7	7	4.5	WB
House wren (*Troglodytes aedon*)	9	-	-	W
Carolina wren (*Thryothorus ludovicianus*)	4	4	2.5	WB
Northern mockingbird (*Mimus polyglottos*)	-	1	-	BO
Brown thrasher (*Toxostoma rufum*)	-	3	1	BO
American robin (*Turdus americanus*)	8	-	-	W
Eastern bluebird (*Sialia sialis*)	3	3	2	WB
Loggerhead shrike (*Lanius ludovidianus*)	1	1	+	WB
Solitary vireo (*Vireo solitarius*)	2	-	-	W
Yellow-throated vireo (*Vireo flavifrons*)	-	1.5	+	B
Yellow-rumped warbler (*Dendroica coronata*)	2	-	-	W
Pine warbler (*Dendroica pinus*)	11	10	6.5	WB
Palm warbler (*Dendroica palmarum*)	2	-	-	W
Common yellowthroat (*Geothlypis trichas*)	12	14	4.5	WB
Yellow-breasted chat (*Icteria virens*)	-	11.5	2.5	B
Eastern meadowlark (*Sturnella magna*)	5	7.5	3	WB
Red-winged blackbird (*Agelaius phoenicus*)	60	2	-	WB
Common grackle (*Quiscalus quicala*)	-	1	-	BO
Brown-headed cowbird (*Molothrus ater*)	-	5	4	BO
Orchard oriole (*Icterus spurius*)	-	2	1	B

(continued)

Table 9. Concluded

Species	WBPS-79	BBC-79	BBC-80	Status*
Summer tanager (*Pirangra rubra*)	-	4	1.5	B
Cardinal (*Cardinalis cardinalis*)	1	4	-	WB
Blue grosbeak (*Guiraca caerulea*)	-	11	3.5	B
American goldfinch (*Carduelis tristis*)	1	-	-	W
Indigo bunting (*Passerina cyanea*)	-	14.5	6.5	B
Rufous-sided towhee (*Pipilo erythrophthalmus*)	16	30	11	WB
Bachman's sparrow (*Aimophila aestivalis*)	-	16.5	8	B
Swamp sparrow (*Melospiza georgiana*)	1	-	-	W
Total species	**25**	**39**	**27**	
Total estimated density	**189**	**245**	**94.5**	

[a] averaged <1

[b] WB = permanent resident, winter and breeding season; BO = permanent resident, breeding season only; W = winter resident only; B = breeding resident only.

rains, the soil is dry and often hot. Only plants adapted for such xeric conditions can survive in sandhills. One botanist has described the sandhills community as a desert in the rain (Wells 1967).

b. Flora. The community has a distinctively open canopy with widely spaced longleaf pines comprising the overstory and smaller (dwarf or scrub) oaks in the understory. The scrub oaks are turkey oak (*Quercus laevis*), blackjack oak (*Q. marilandica*), and bluejack oak (*Q. incana*). Turkey oak and bluejack oak are almost universally found together. Blackjack oak and often sand post oak (*Quercus stellata margarettae*) are more often found with turkey oak and bluejack oak on the moister and loamier soils of the clayhills. In addition, particularly near the coast, the understory may also contain live oak (*Q. virginiana*). Ground cover is usually dominated by wiregrass and bracken fern plus a variety of low woody shrubs, such as ground huckleberries (*Gaylussacia* spp.), dwarf blueberries (*Vaccinium* spp.), runner oaks (*Quercus pumila, Q. minima*), gopher apple (*Licania michauxii*), and blackberry (*Rubus cuneifolius*). Important herbs are *Dichanthelium* spp., *Tragia* spp., *Andropogon* spp., *Heterotheca graminifolia*, and numerous legumes and composites.

c. Ecology. The combination of longleaf pine and wiregrass indicates that fire plays a dominant role in maintaining this community (Greene 1931, Garren 1943, Clewell 1971, Vogl 1973, Christensen in press). Dry during much of the year, the water table remains 4 ft or more below the surface except after heavy rains. Longleaf communities depend upon fire (Clewell 1971, Komarek 1974, Christensen 1986). This is nowhere more evident than in the sandhills, which are the driest, most fire prone of all Panhandle habitat types. Fire mediates the dominance relationship between pines and hardwood species that live in this, Florida's most xeric ecosystem. The above ground parts of turkey oak, blackjack oak, and bluejack oak are highly vulnerable to fire, which readily kills the stems and branches. But their roots, like the roots of many hardwoods, survive to throw up other stems. Moreover, most of these scrub oaks produce underground runners that put up stems in every direction, so that what appears to be 50 or more separate trees growing over areas as large as an acre may actually be separate stems of a single, cloning plant. This may be one way that these oaks cope with fire.

Because of their large root systems and elaborate runners, scrub oaks are constantly ready to grow, and the absence of fire provides them the opportunity they need. Stems sprout, new stems grow, leaves proliferate, and trees shoot up into the bright sunlight between the widely spaced pines. Normally, fires kill this growth back every few years. But when there are no fires, the oaks keep growing until their branches touch to form a closed canopy. The ground under dense scrub oaks is shaded from light and covered with leaf litter. Longleaf seeds and seedlings cannot sprout there. Without fire to remove the oaks, the towering longleaf is conquered by a mass of scrub oaks. Carried to the extreme by selective logging or long-term fire exclusion, the big pines die of age, no little ones replace them, and the prolific scrub oaks inherit the forest.

There is good reason to believe that natural fires kept the scrub oaks under tight control in the original longleaf forests, pruning them back, keeping most of them as small shrubs, and some no bigger than herbs. Photographs of virgin longleaf sites at the turn of the century corroborate this, as do recent experiments in control burning. All over the Coastal Plain today there are dense, 30 ft high stands of scrub oaks, which took over after people cut the longleaf pines and disrupted natural fires. In essence, those scrub oak forests are a human creation.

d. Fauna. The fauna of the sandhills communities of Panhandle Florida have not been studied per se, and what is known about sandhills ecology comes mostly from studies located in central Florida. There, a well developed endemic fauna exists, including half a dozen or more vertebrates. It appears that the fauna of the Panhandle sandhills is depauperate when compared to central Florida. Nevertheless, there are animals that flourish in the Panhandle sandhills that are not generally found in other habitats. These are the red-tailed skink (*Eumeces egregius*), gopher frog (*Rana areolata*), pine snake, and pocket gopher.

The gopher tortoise, recognized by most Coastal Plains States as threatened or a species of special concern (State of Florida), is the most important native grazing animal in the pineland forests it inhabits. It is a keystone species whose extirpation would have dire consequences for a whole community of other animals. The long and persistent gopher burrows excavated by tortoises are homes for up to almost 40 commensal species of vertebrates and invertebrates. Many of these species are obligate commensals, requiring tortoise burrows for their survival. Some have been associated with the gopher tortoise burrows so long that they have become partly cave-adapted, losing pigment. A threatened species, the indigo snake (*Drymarchon corais*), is heavily dependent upon gopher burrows, as is the gopher frog, whose common name reflects its dependence upon the gopher tortoise, and possibly the pine snake.

Other notable vertebrate animals occurring in Panhandle sandhills are the eastern spadefoot toad (*Scaphiopus holbrookii*), efts of the newt (*Notophthalmus viridescens*), eastern tiger salamander (*Ambystoma tigrinum*), eastern diamondback rattlesnake, six-lined racerunner (*Cnemidophorus sexlineatus*), southern fence lizard (*Sceloporus undulatus*), fox squirrel, old field mouse (*Peromyscus polionotus*), cotton mouse (*P. gossypinus*), short-tailed shrew (*Blarina brevicauda*), mole (*Scalopus aquaticus*), least shrew (*Cryptodus parva*), cotton rat (*Sigmodon hispidus*), cottontail (*Sylvilagus floridanus*), and numerous other species that occur over a wide range of habitats. Significant rare, endangered, or threatened species are red-cockaded woodpecker, gopher tortoise, indigo snake (*Drymarchon corais*), pine snake, and gopher frog. See Table 7 for status details.

5.2.3 Gully-eroded Ravines

Small first and second order (Strahler 1964 classification) streams with steep valley walls have a unique physiography and microclimate and should be recognized as a separate community type in the Panhandle, considering their extensive occurrence. The valley floors of such streams are wetlands, quite different in vegetation, hydrology, and fauna from the valley slope beginning at a sometimes sharply defined toe. Many of Florida's rarest animals and plants, as well as numerous endemics and relicts, occur in ravines.

a. Soils. Most of the gully eroded stream valleys in the Panhandle were developed in the Hawthorn, Miccosukee, and Citronelle Formations of the Northern Highlands and, as a consequence, soils of the valley sidewalls are coarse clastics, usually sand, clayey sand, or sandy clay, well drained, and moderately-to-steeply sloping. Occasionally Tertiary limestones are exposed and the stream channel may even be etched into hard limestone bedrock (as above Aspalaga Landing on the Apalachicola River).

The soils of the stream valley bottom in its first and second order (Figure 60) reaches are eroding and are composed of the same materials of the valley sidewalls immediately upslope. Soils of the floodplain of the third and higher orders are alluvial, contain more silts and clays, and are distinguished by the presence of partially decomposed vegetation in the form of fluid muck or fibrous peat.

b. Ecology. Rainwater works its way to the sea by (1) evaporation off the land surface and direct transport to the sea via precipitation; (2) by percolation downward and seaward through underground passageways ranging in size from the interstitial spaces between sand or clay particles to 30-m diameter tunnels dissolved in limestone; and (3) over the top of the ground as surface runoff. This latter means by which water moves to the sea is extremely important to plants and animals because the erosive power of surface runoff sculpts the physical topography of the land. Where soil particle size (clays and silts) is so small as not to allow much percolation, surface runoff is proportionally higher than where soils are coarser grained and more friable. Gullying of the land surface, therefore, is more extensive in tighter soils. The tightly packed soils of the Western Highlands, Grand Ridge, New Hope Ridge, and the Tallahassee Red Hills physiographic regions are the most susceptible to gullying of all the Panhandle soils. Combined with the greatest elevations in the Panhandle, the highlands contain some of the most deeply entrenched ravine valleys in Florida. Gully-eroded ravines are most abundant and deepest along the valley wall escarpments of the larger river systems. Those along the eastern valley wall of the Apalachicola River are among the very best examples of deeply incised small-tributary ravine valleys in the entire Coastal Plain, and have been famous the world over for their biological uniqueness for 140 years (Gray 1846, James 1961, Graham 1964). The Apalachicola Bluffs and Ravines area is recognized as biologically distinct (Means 1977, 1985c).

Other ravines in the Northern Highlands are clustered along the Holmes Valley Scarp (see Figure

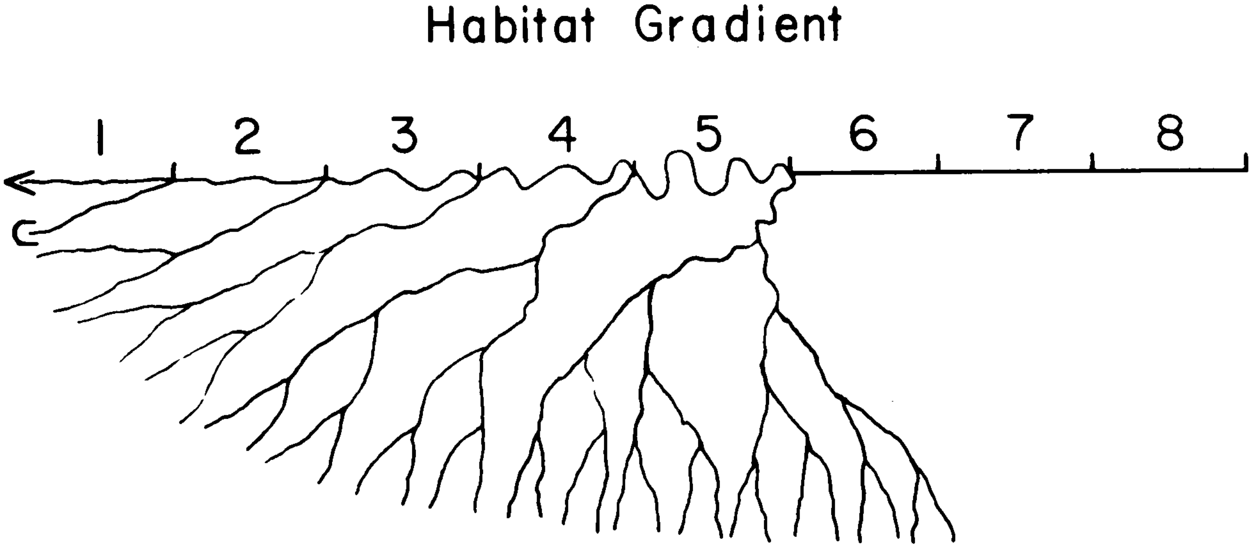


Figure 60. Stream habitat classification (Strahler 1964): (1) order 1 streams including gully erosion (V-shaped) and steephead (U-shaped) ravines; (2) order 2 streams; (3) order 3 streams; (4) order 4 streams; (5) order 5 streams; (6) streams greater than order 5, but less than about order 8; (7) large river floodplain sloughs and alluvial swamp habitats; (8) lake and pond margins.

5), along parts of the southern and western valley wall of the Choctawhatchee River, along the southwestern valley escarpment of the Escambia River, the western tributaries of the Escambia River, and along the Yellow River system and its major tributaries. All these ravine systems are poorly explored, but offer considerable promise of being biologically interesting (Means and Longden 1970; Means 1974a,b, 1975, 1985c).

The heads of gully-eroded stream systems are hydrologically similar throughout the Panhandle. From catchment divides downslope for some distance, the water channels in catchment bottoms are subject to extreme fluctuations in streamflow. Typically, water flows only during and shortly after a rainfall. The persistence of flowing water is strictly dependent upon the regularity and amount of rainfall. During normal dry periods and particularly during extended drought, these stream channels are quite dry, and are inhospitable to aquatic or wetland plants and wildlife.

At some point down the stream gradient, the moisture in the catchment soils upslope becomes great enough, notwithstanding the relatively impermeable clay soils, to slowly leak into the stream bottom, creating a more mesic to hydric condition. This usually is along portions of the creek gradient of Strahler order 2 or 3 (Figure 60). During a drought, even in these reaches streamflow dries up, but the soil moisture remains high enough to support a wetland vegetation of evergreen shrubs and hardwoods. These parts of headwater catchments are clearly erosional, showing little alluviation in the valley bottom, and having relatively steep valley sidewalls. Further downstream, when the slope of the stream bottom becomes shallower, stream flow slows down and loses its scouring ability. The stream drags its sediments along and spreads them all over the valley bottom (alluviation), creating a more or less flat surface with minor depressions. A low-water channel develops that carries stream water during low water stages, but during heavy rains, the water rises out of the meandering channel and flows over the entire flat surface of the floodplain. When the water recedes, it is trapped in the shallow basins where partially decomposed organic debris builds up as muck or peat. This portion of the Strahler gradient is characterized by a stream channel incised into the floodplain floor with clayey-sandy-organic banks that rise sometimes 2 to 3 ft above the channel bed. During dry weather the alluvial portions of ravine streams are mesic, and support many of the members of the beech-magnolia community. During wet weather, however, water flows or stands in the floodplain long enough that a number of hydric trees often are found here too. One value of gully-eroded ravines is to preserve the terrestrial habitat gradient from longleaf pine clayhills to beech-magnolia mesic forest. Where slopes are gentle, ravines are not present because people have replaced the natural forest types with agriculture, silviculture, and urban and suburban developments. The steep slopes of ravine valleys preserve some of the natural terrestrial communities from gross alteration by human activities. Ravines also have a higher and more continuous humidity during summer because of the greenhouse effect under the closed canopies and confining valley sidewalls of ravines. The variety in slope shading, results in north-facing effects (protection from direct sunfall), south facing effects (dryer microclimates because of more direct year-round sunfall), and combinations of these.

c. Flora. Generally, the lower valley sidewalls support a beech-magnolia community (see Section 5.2.5). In the saturated soils of the alluvial floodplain on both sides of the stream channel, one finds hydric species such as the star anise (*Illicium floridanum*), sweet bay magnolia (*Magnolia virginiana*), tulip tree (*Liriodendron tulipifera*), and sweetgum (*Liquidambar styraciflua*). A classic example of a gully eroded ravine in reasonably undisturbed condition is located just north of the city limits of Tallahassee.

The gully-eroded Apalachicola ravines between Sweetwater Creek in Liberty County and the Florida-Georgia border are replete with northern relicts and species endemic to the ravines. Leonard and Baker (1982) reported 52 species of trees, shrubs, and herbs that were endemics, relicts, or rare.

d. Fauna. Wildlife that utilize gully eroded ravines include species tolerant of a wide range of moisture fluctuations. At the heads of gullies near the catchment divides, the vegetation and animal life are characteristic of the longleaf pine clayhills, but shortly downstream woody evergreen shrub species appear, then grade into the beech-magnolia forest with its characteristic wildlife (see sections on longleaf pine clayhills and beech-magnolia forest). The stream itself is the beginning of a developing aquatic gradient, and the water column has its own peculiar wildlife associated with it (see Chapter 6.3.1).

The fauna of the uppermost reaches of gully-eroded ravines is typical of that found in the upland vegetation clothing the watershed (see longleaf clayhills and beech-magnolia sections). When soil moisture increases, and gully-eroded stream valleys begin to have some permanence of flow, a stream side litter fauna is found. The highly distinctive fauna of these streamsides features dozens of species of invertebrates found only in ravines, including earthworms (*Diplocardia* spp., *Sparganophilus* spp.), crayfish (*Procambarus* spp.), trap-door spiders (*Cyclocosmia torreya*), and plethodontid salamanders (*Eurycea bislineata, Pseudotriton ruber, Plethodon glutinosus,* and *Desmognathus* spp.). When studied systematically, the ravines across Panhandle Florida should reveal a great deal of biological diversity presently unrecognized.

5.2.4 Steepheads

Steepheads are highly distinctive stream valley habitats (Means 1975, 1981, 1985c) known presently only from Florida, where they first were discovered and named in the Panhandle (Sellards and Gunter 1918). They are found in the deep sands of the Citronelle Formation and in younger deposits below Cody Scarp (Puri and Vernon 1964, Brooks 1981b) and are aligned east-west (Figure 61) in a manner suggesting an old shoreline (Means 1981, 1985c).

Steepheads and their stream valleys are formed when ground water leaks out on a sloping surface through porous sand at the head of a stream catchment. If the volume of escaping ground water is substantial, sand will be carried away downstream, creating a semicircular horizontal nick in the sloping sand body. Over time, as more sand is carried away, a U-shaped (in vertical cross-section) valley forms as the steep, amphitheatre-shaped valley head migrates headward into the sand. It is this process of lateral sapping of the water table and the resulting headward undercutting that makes steepheads and the valleys they form fundamentally different from typical gully eroded stream valleys. Stream valleys normally are formed as the surface of the land is carried away by the scouring action of rainwater surface runoff, a process called gully erosion. Steephead-origin streams are the same as the seepage streams listed by the Florida Natural Areas Inventory.

Proceeding east across the Panhandle, steepheads first occur in the Panhandle in the deep sands of western Eglin Air Force Base. Large stream valleys cut deeply into the Citronelle sands there and

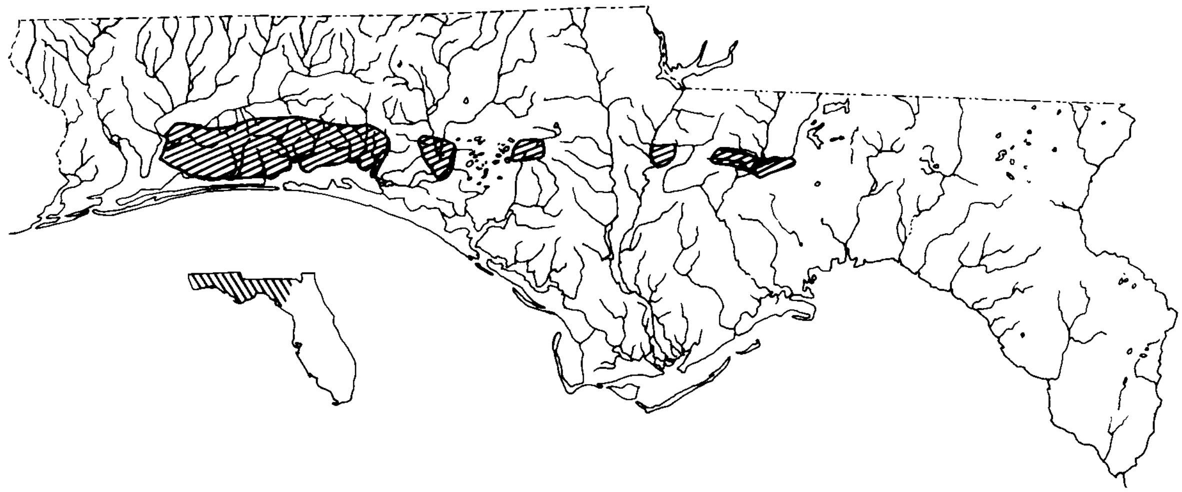


Figure 61. Distribution of known steepheads in the Florida Panhandle (Means 1981).

drain north into the lower reaches of the Yellow River, and south into East Bay River and Choctawhatchee Bay. A few have been etched into the landform along the eastern side of Econfina Creek in Washington County, and into sinkholes in northern Bay County. Below the main axis of Big Sweetwater Creek in Liberty County, every stream valley feeding into Big Sweetwater Creek was formed by steephead migration, and each stream supports a magnificent steephead that is still actively eroding its way headward. A few steepheads are found in the Telogia Creek drainage and along Ocklawaha and Bear creeks draining into the west side of Lake Talquin on the Ochlockonee River. Going east across north Florida, the last steepheads are found along the east side of Lake Talquin in the short tributaries etched into the western end of Beacon Slope.

a. Soils. Soils of steephead valley slopes are exceedingly porous, coarse sands whose angle of repose is about 45°. They are between 25 and 100 ft deep, depending upon geographical location. The soils of steephead valley bottoms are the same Citronelle and Recent sands of the valley walls, but have an occasional veneer of organic deposits along the stream margin and the lower, seepage slope of the valley wall. Downstream in third order portions of steephead valleys, alluvial matter and organic sediments become more prevalent as substrates for plants and animals to live on, or burrow in.

b. Ecology. The physical and chemical characteristics of steepheads are the result of their special hydrological conditions. Steephead waters are filtered through tons of sand, and emerge relatively neutral in pH. Waters of gully-eroded streamheads take on chemical characteristics of the substrate over which the waters flow. Runoff waters characteristically are turbid with suspended clays and silts picked up from the parent material of the soil, and they contain leachates and organic particulates that sweep into the stream course. Since the porous sands soak up rainwater, there is little opportunity for surface runoff to deliver organic or inorganic materials downslope into the stream. Steephead springs usually are continuously flowing, giving a perennial nature to the watercourse at and downstream from spring sources. The bottom of a steephead valley at its head can be up to 30 m deeper than the top of the uplands it drains.

Water chemistry is not the only quality of steephead streams that is different from runoff streams. The temperature of steephead waters is thermally buffered because it emerges from subterranean perched aquifers. Steephead waters have ground--water temperatures at all times of the year, but warm up by ambient processes progressively downstream. Even so, the temperature of steephead-origin streams such as Sweetwater Creek in Liberty County and Liveoak and Turtle Creeks in Okaloosa County are much cooler than the waters of surface runoff streams. Runoff waters are subject to considerable temperature fluctuation seasonally because of the air temperature on the catchment, but ground water tends to track the annual average temperature of the surface of the ground; in the Panhandle, steephead spring-water temperatures are 68–72 °F, year around.

Because steepheads are highly localized phenomena and have formed de novo in each of the larger Panhandle drainages in which they are found, they are rather isolated environments, separated by drainage divides upstream and by changing lotic environments downstream. Biologically, steepheads are natural laboratories providing a potential for ecological and evolutionary processes. Some populations of animals and plants in steepheads may differ from regional populations genetically because of the founder effect or strong local selection; populations of other species demonstrate ecological release in steepheads where more competitive congeners are precluded from immigration for some reason (Means 1975).

c. Flora. Steepheads throughout the Panhandle generally possess a similar cross-sectional gradient of vegetation along a vertical transect running from the top of the basin or watershed they drain to the stream bed. Xeric longleaf pine-scrub oak (*Pinus palustrus, Quercus laevis, Q. incana, Q. marilandica*, and often *Q. virginiana*) communities are found on drainage divides surrounding steepheads. From about where the crest of the slope breaks to about halfway down the transect, the forests are a closed-canopy assemblage of xeric, deciduous trees commonly containing *Carya tomentosa, Quercus hemisphaerica, Q. nigra*. In this xeric zone, are sometimes found stumps and cut logs—signs of a once more extensive occurrence of northern red cedar, *Juniperus virginiana*.

About halfway down steephead slopes one enters a mesic forest containing many elements of the beech-magnolia climax type including *Magnolia grandiflora, Fagus grandifolia, Quercus nigra, Pinus glabra, Carya glabra, Ostrya virginiana, Quercus michauxii*, and *Q. alba*. In this zone in steepheads of the Apalachicola River basin, *Magnolia pyramidata, M. ashei*, and *Stewartia malacodendron* also occur.

On the lower one-third of steephead slopes that are protected from the sun (north-faces or particularly deep cuts), an evergreen shrub zone is developed. This zone contains shrubby species such as *Vaccinium arboreum, Kalmia latifolia, Lyonia lucida, Rhododendron austrinum*, and others.

In steepheads of the Apalachicola River basin, the evergreen shrub zone is especially well-developed and contains many of Florida's endemic and rare northern plants. Among these are *Kalmia latifolia, Rhododendron austrinum, Torreya taxifolia, Taxus floridana, Asarum arifolium, Croomia pauciflora*, and others.

The valley floor of steepheads is a wetland community as demonstrated by an abrupt change to wetland plants and animals. *Illicium floridanum* and *Magnolia virginiana* are indicator species that are almost invariably found rooted in the inundated to saturated soils of steephead bottoms across the entire Panhandle.

d. Fauna. The fauna of steepheads is mostly confined to the litter of the valley bottom, where a detritus-cycling community of litter arthropods feeds a number of small vertebrates on the moist valley floor. Almost every steephead across the Panhandle supports breeding populations of three species of lungless salamanders of the family Plethodontidae. Two of these species are always found: the two-lined salamander, *Eurycea bislineata*, and the red salamander, *Pseudotriton ruber*. One of three species of dusky salamanders completes the trio: *Desmognathus auriculatus* is found in a few steepheads on Eglin Air Force Base and in the steepheads of Econfina Creek in Bay County; *D. fuscus conanti* is found in all others west of the Chipola River basin (Means 1974a,b). An undescribed species is endemic to the Apalachicola-Chipola and Ochlockonee river basins (Karlin and Guttman 1986). The creek chub, *Semotilus atromaculatus*, often is found within a few meters of the sapping waters of steepheads when the volume is large as it is on Eglin Air Force Base. Downstream from the steephead proper, in streams at the western end of Eglin Air Force Base, a frog new to science, *Rana okaloosae*, was just described as occurring in bogs along the margins of streams (Moler 1985). When Panhandle steepheads are thoroughly investigated, numerous relict or endemic invertebrates and possibly some nonvascular plants will be found.

5.2.5 Beech-Magnolia Climax Forests

In the long-term absence of fire, hardwood forests eventually replace the fire-perpetuated longleaf pine ecosystems on all the upland soils of Panhandle Florida. One particular association, in which American beech (*Fagus grandifolia*) and southern magnolia (*Magnolia grandiflora*) are among the dominant trees, is composed of about 40 hardwoods and a few conifers just downslope from the fires in the pinewoods and just upslope from places where the soil is permanently wet (Figure 62). This forest type has been widely touted as the climax forest of the Gulf Coastal Plain (Delcourt and Delcourt 1977), even though old-growth stands are patchily distributed, rather rare, and confined to small areas protected by slopes.

a. Soils. The beech-magnolia forests of the Panhandle are capable of growing in a wide range of soils, ranging from the loamy soil at the bases of slopes, on the higher reaches of floodplains, and on the overflow zones of small creeks to xeric, sandy soils. Because fires keep the species of the beech-magnolia forest off of ridge crests and the upper slopes of stream valleys, the actual soils on which the beech-magnolia forests are rooted are not so variable as they might otherwise be. Usually, soils of beech-magnolia forests are moderately to well-drained sandy loams, which become clayey within a few feet of the surface. On flat, small stream terraces, organic and clay content is higher than on steep slopes of steephead ravine valleys. In the Marianna Lowlands, the Apalachicola Bluffs and Ravines region, and the Coastal Lowlands where limestone is close to the surface of the ground, beech-magnolia forests seem to be especially well developed.

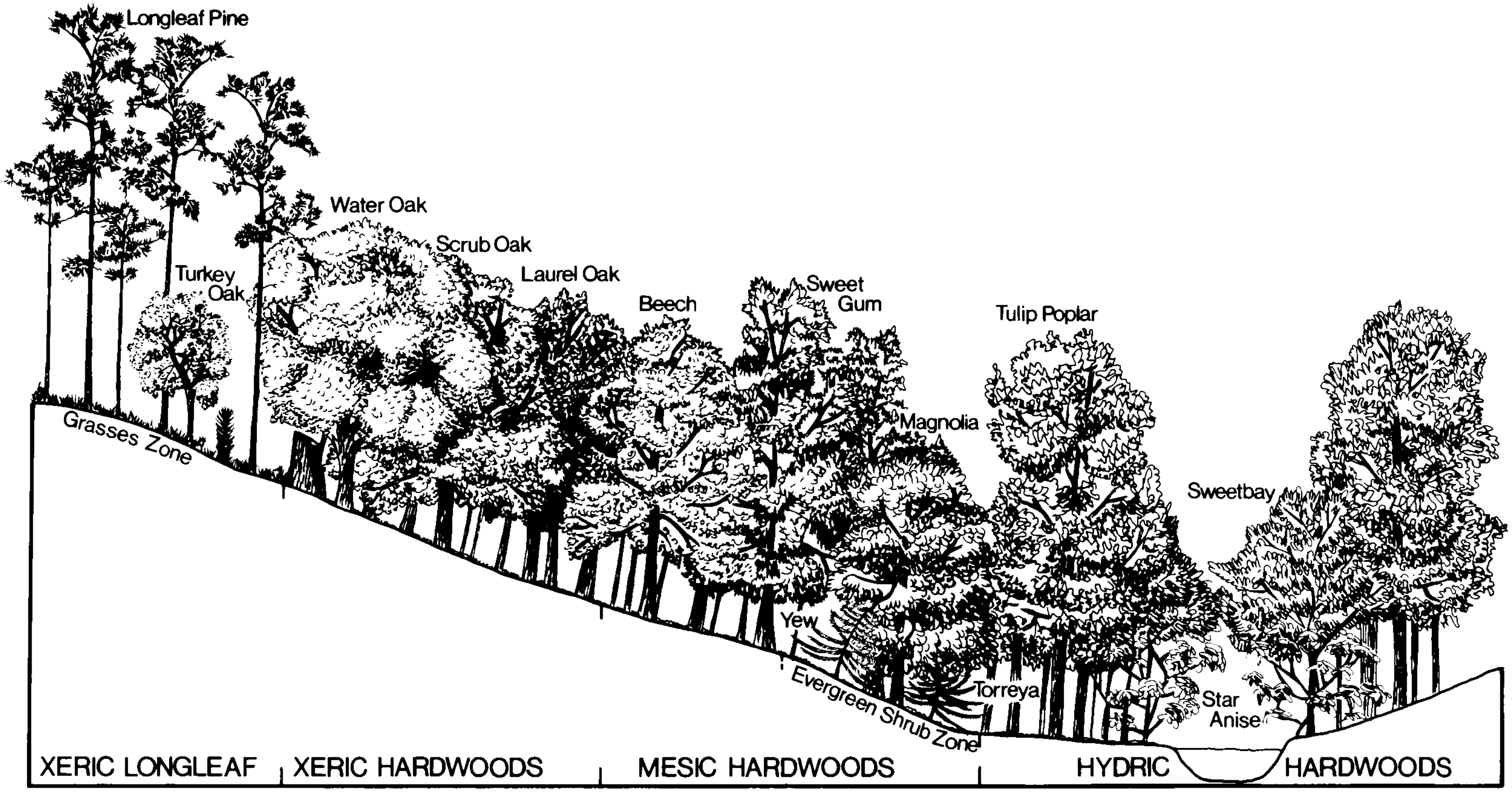


Figure 62. Pine–hardwood continuum developed over a steep slope/moisture gradient.

b. Ecology. Experimental studies of beech-magnolia forests at Tall Timbers Research Station near Tallahassee, Florida have demonstrated that the regular fires that sweep downslope from longleaf forests in clayhill regions of the Coastal Plain keep elements of the beech-magnolia forest downslope in mesic soil zones where fires are naturally retarded by soil and litter moisture. They also indicate that the mixed pine-oak-hickory forests of Quarterman and Keever (1962) are ruderal successional forests involving elements of the beech-magnolia forest mixed with shortleaf and loblolly pines and other colonizing vegetation. The latter forest type, one of the most common habitat types in the Panhandle today, is human-created, and is discussed in Chapter 5.3.1.

When fires are eliminated from the native longleaf pine forests, the hardwoods begin to encroach in an upslope direction (Mutch 1970). Among the hardwoods that are first able to get a roothold in the wiregrass community are sweetgum, laurel oak (*Quercus laurifolia*), and water oak (*Q. nigra*). In the absence of natural fire, the hardwood forest moves slowly up toward the ridgetops. The drier, sandier soils on ridgetops are less suitable for these species; nevertheless, most species of the beech-magnolia forest can, in time, grow in even the highest, driest sites.

This displacement has happened both naturally and experimentally. There are places in north Florida where an unusual configuration of steep slopes has naturally kept broad, sweeping fires away from isolated ridgetops. Under natural circumstances, longleaf pines would occur on those dry ridgetops but instead, beech-magnolia forests occur there—in a continuous transect from the moist valleys to the high, dry hilltops. Apparently there are not enough lightning fires on such ridges to kill back the new hardwood growth. Once established, this forest is self-perpetuating. The beech-magnolia forest, therefore, is the climax forest type on the Coastal Plain uplands, even though those high places are usually the domain of the pines.

The term "hammock" broadly refers to any grouping of hardwood trees. Where it occurs on clayey-loamy soils, it is termed a mesic hammock, and the beech-magnolia climax is often found in these environments. Mesic hammocks are particularly rich in numbers of species of trees. Most mesic hammocks in the Panhandle occur on the lower slopes of stream valleys throughout the Western Red Hills and Tallahassee Red Hills regions. Hammocks can also be found on sandy, or xeric, soils.

Xeric hammocks are often found within sandhill or pine flatwoods communities or on the fringes of lakes and ponds. Clewell (1971) notes that hardwood hammock vegetation often surrounds high pineland depressions especially along the steep slopes of lime sink holes. Overstory trees consist of a mixture of mockernut (*Carya tomentosa*) and pignut hickory (*C. glabra*), persimmon (*Diospyros virginiana*), and southern red oak (*Quercus falcata*) on drier sites.

Hydric hammocks are on the wet end of the soil moisture scale and consequently intergrade imperceptibly with swamp forests. For this reason they are treated in 6.2.2.

Two of the more prominent characteristics of beech-magnolia associations are their overall diversity as a floristic unit and their compositional variation from site to site. In seeking to determine why different tree species were more prominent in one stand than another, Monk (1965) examined species composition in terms of soil moisture, calcium, phosphorus, potassium, and magnesium. His conclusions, summarized in Wharton (1977, p. 167) are as follows:

"(1) Calcium is extremely important; soils high in calcium produce the maximum diversity;

(2) Soils low in calcium, potassium, phosphorus, and moisture support a community dominated by evergreen trees;

(3) Some trees, such as water oak [*Quercus nigra*], swamp chestnut oak [*Q. prinus*], sugarberry [*Celtis* sp.], spruce pine [*Pinus glabra*], and blackgum [*Nyssa sylvatica*], favor wetter environments;

(4) Some trees such as sweetgum [*Liquidambar styraciflua*] and live oak [*Q. virginiana*] do well at both extremes of wet and dry [meaning that factors like fire and longevity may be more important when these trees do or do not appear in the forest];

(5) American holly [*Ilex opaca*] and wild olive [*Osmanthus americanus*] prefer dry areas, dogwood [*Cornus* spp.] and hop hornbeam [*Ostrya virginica*]

prefer dry to mesic conditions, and ironwood [*Carpinus caroliniana*] prefers more hydric soils;

(6) Some shrubs and herbs also prefer xeric conditions (sparkleberry [*Batodendron arboreum*], *Elephantopus* [elephant's foot], horse-sugar [*Symplocos tinctoria*], sarsaparilla vine [*Smilax pumila*]);

(7) Of the 49 tree species, Monk found only four; cabbage palm [*Sabal palmetto*], red bay [*Persea borbonia*], wild olive, and buckthorn [*Bumelia temax*], to be of subtropical affinities."

c. Flora. Dominant trees include southern magnolia (*Magnolia grandiflora*), American beech, sweet gum, spruce pine (*P. glabra*), pignut hickory (*Carya glabra*), American holly (*Ilex opaca*), laurel oak (*Quercus laurifolia*), white oak, swamp chestnut oak (*Q. michauxii*), hop-hornbeam (*Ostrya virginiana*), ironwood (*Carpinus caroliniana*), dogwood (*Cornus florida*), and a host of others. Table 10 lists the tree species found in several unpublished studies of mesic hardwood forests in the eastern Panhandle (Means, unpubl. data).

Common shrubs include wild olive (*Osmanthus americanus*), sparkleberry (*Vaccinium arboreum*), witch hazel (*Hamamelis virginiana*), fringe tree (*Chionanthus virginicus*), horse sugar (*Symplocos tinctoria*), strawberry bush (*Euonymus americanus*), red bay (*Persea borbonia*), and others. Woody vines are abundant in the beech-magnolia forest. The giant vines of the muscadine (*Vitis rotundifolia*), smeared with the orange slime mold (*Dictyostelium* sp.) in the spring, the spiked catbrier (*Smilax bona-nox*), and the distinctive leaves of poison ivy (*Toxicodendron radicans*) are always present. Partridge berry (*Mitchella repens*), trillium (*Trillium underwoodii*), violet (*Viola floridana*), Indian pipe (*Monotropa uniflora*), and ferns (*Polystichum acrostichoides*, *Thelypteris* spp., *Asplenium* spp. and others) are common herbs in these forests.

d. Fauna. Hardwood forests are quite different from the open pine forests of the Panhandle in ways very important to animals. Most of the photosynthesis in hardwood forests goes on high in the lofty canopy where new buds, leaves, flowers, fruits, and nuts abound. The animals that are primary consumers, therefore, are generally arboreal. Lepidopteran larvae in the canopy and a host of sucking and chewing insects are the base of the food web comprised of arboreal insectivores. These mostly are birds, including vireos, warblers, woodpeckers, and other foliage and bark gleaners. The gray squirrel (*Sciurus carolinensis*) is the most prominent mammal in the canopy.

The forest floor food web in hardwood forests is litter driven. The leaves, sticks, twigs, flower parts, and seeds of the trees accumulate on the forest floor and are immediately eaten by a host of terrestrial invertebrates. Among the more important groups

Table 10. Species of trees in the beech-magnolia forest association over 100-m transects compared among selected old-growth forests in Panhandle Florida (from reports on beech-magnolia forests on file with the Florida Natural Areas Inventory, Tallahassee). o = overstory; u = understory.

	Marianna Caverns State Park	Timberlane Hammock	Woodyard Hammock	McBride's Slough Hammock	Indian Lake Hilltop Hammock	Sweetwater Hill Hammock
Acer barbatum	o			o		
Acer rubrum		u	u	u		
Aesculus pavia	u					
Amelianchier arborea						u
Broussonetia papyrifera		u				
Carpinus caroliniana	u	u	u	u		

(continued)

Table 10. Concluded

	Marianna Caverns State Park	Timberlane Hammock	Woodyard Hammock	McBride's Slough Hammock	Indian Lake Hilltop Hammock	Sweetwater Hill Hammock
Carya glabra	o	o	o	o	o	
Carya pallida						o
Carya sp.	o					
Celtis laevigata	u					
Cercis canadensis			u			
Cornus florida	u	u	u	u		u
Crataegus sp.				u		
Fagus grandifolia	o	o	o	o	o	o
Fraxinus caroliniana	o					
Fraxinus pennsylvanica			u			
Halesia diptera	u					
Hamamelis virginiana	u					
Ilex opaca	u		u	u	u	
Juglans nigra	o					o
Juniperus nigra	u					
Liquidambar styraciflua	o	o	o	o	o	
Liriodendron tulipifera		o	o			
Magnolia grandiflora	o	o	o	o	o	u
Magnolia virginiana			u	o		
Morus rubra	u		u			
Myrica cerifera				u		
Nyssa sylvatica		o	o	o		
Osmanthus americana						u
Ostrya virginiana	u	u	u	u	u	u
Oxydendrum arboreum			u			o
Persea borbonia	u	u		o	o	o
Pinus echinata	o					
Pinus glabra	o	o	o	o	o	o
Pinus taeda		o	o			
Prunus caroliniana			u			
Prunus serotina	o	o	u	o		o
Quercus alba		o	o	o	o	
Quercus hemisphaerica	o	o	o	o	o	o
Quercus michauxii	u	u	o	o	o	
Quercus nigra		o	o	o	o	
Quercus phellos	u		o			
Quercus shumardii	o		o			
Quercus stellata	o					
Quercus virginiana			o			o
Sabal palmetto				u		
Symplocos tinctoria		u	u			o
Tilia americana	o				o	
Ulmus alata	u					
Ulmus americana	o		o			
Vaccinium arboreum						u
Viburnum dentatum						u

are springtails, mites, harvestmen, beetles, hemipterans, millipedes, dipterans, isopods, orthopterans, and earthworms. Spiders, feeding on the detritivores, create another source for the higher consumer levels. The rich litter infauna drives a surprisingly complex predator community. Table 8 lists the terrestrial vertebrates captured in a drift-fence sampling of an old growth beech-magnolia forest (Woodyard Hammock) on Tall Timbers Research Station in northern Leon County. Many other primary and secondary consumers visit the beech-magnolia forest ecosystem, but are not restricted to it. In fact, there seems not to be a single vertebrate that is strictly found in the hardwood habitats. However, a suite of highly visible, large vertebrates are more characteristic of hardwood forests than the pine forests further upslope. These are the gray squirrel, the red-shouldered hawk (*Buteo lineatus*), and barred owl (*Strix varia*)—ecological analogs of the fox squirrel species, red-tailed hawk (*Buteo jamaicensis*), and great horned owl (*Bubo virginianus*) in the open pine forests.

5.2.6 Longleaf Flatwoods

Longleaf pine flatwoods are open woodlands that lie between the drier sandhill community upslope and the evergreen shrub dominated wetlands downslope. A drop of only 5 ft in elevation over a distance of 200 m in the Coastal Lowlands will have a longleaf-turkey oak-gopher tortoise sandhills xeric community at the high end, a broad, flat, longleaf flatwoods with no understory over 90% of the transect, and an evergreen shrub bog appearing abruptly at the lower end. Standing anywhere along the slope-moisture gradient, however, the casual observer would be unable to visually detect the elevational drop. Flatwoods often are much broader than 200 m.

The longleaf pine-wiregrass association was undoubtedly the presettlement dominant forest type of the southeast Coastal Plain. It is estimated to have originally covered about 24 million acres from Mobile Bay, Alabama, eastward throughout Florida and then northward through the Coastal Plain in Georgia, South Carolina, and southern North Carolina. Vast flatwood acreages still stretch across the Gulf Coastal Lowlands between the Choctawhatchee River and the Ochlockonee River, and between Cody Scarp and the coast. Scrub oaks, common in the sandhills, are absent from this community and the grassy aspect of the ground cover is sometimes obscured by saw palmetto.

a. Soils. The soils in pine flatwoods are sandy, ground-water podzols with much organic matter in the upper few inches associated with the roots of the dominant ground cover, wiregrass. An organic pan is usually present a foot or two into the soil profile. Soils are generally moist at shallow depths with the water table at or near the surface to about 4 ft deep under drier conditions.

b. Ecology. Working in the Apalachicola National Forest, Clewell (1971) identified four variants of the pine flatwoods based on dominant species. These include: (1) a longleaf pine phase, (2) a slash pine (*P. elliottii*) phase, (3) a longleaf-slash pine phase, and (4) a pond pine (*P. serotina*) phase. The pond pine phase usually contains a compliment of cypress and blackgum and is a true wetland ecosystem. It will be discussed in Chapter 6.2.2.

Before the influence of people, longleaf pine was far more common in the overstory of Coastal Plain flatwoods than it is today. Before about 1920, pond and slash pine were generally restricted to wetter areas, as were some of the brush species characteristic of present-day bay swamps. Reasons for the increase in these species in the flatwoods are still largely unresolved, but are probably related to the disruption of the longleaf pine and wiregrass association by logging practices, silviculture, and most of all, by the interruption of the natural fire cycles. The key to deciding whether a Gulf Coastal Lowlands site is a low sandhill or a flatwood site is the water table. When it is between 0 and 4–5 ft beneath the surface, a flatwoods prevails.

As noted in Clewell (1971, p. 35), "Notes of early naturalists indicated that these pinelands contained nearly pure stands of longleaf pine, as many still do today. Only during recent decades of fire suppression have loblolly, pond, and particularly slash pine invaded some of these pinelands. Longleaf pine, which is the only southeastern tree able to survive fire as a seedling and sapling, owes its existence to the highly flammable wiregrass. Wiregrass and the needle-drop from the longleaf pine comprise a highly combustible fuel that is ignited by lightning and more recently by people. The density of wiregrass and the overlap of the blades of adjacent bunches assures that a fire, once ignited, will spread for miles over that flat or gently rolling pinelands with nothing to stop its course. In pre-colonial days these fires must have burned at intervals of every 3–4 years in order to have destroyed the seedlings and saplings of all other tree species that had seeded in the pineland since the previous fire."

Both species, longleaf pine and wiregrass, have adaptive competitive abilities to maintain their mutual existence. Beside their tolerance to fire, these include an ability to acquire and maintain moisture and nutrients in poor, well-drained soils, the ability to eliminate competitive plants via growth patterns, and the ability to perpetuate themselves under adverse conditions.

Longleaf pine depends upon the dense carpet of wiregrass for the elimination of competitive tree species that would otherwise replace the pine and prevent its future reproduction, while the pine provides an open canopy (light) and soil conditions (pH and nutrients) conducive to wiregrass cover and associated plants (e.g., yellow fox glove [*Aureolaria pedicularia*], dwarf huckleberry [*Gaylussacia dumosa*], and blazing star [*Liatris* spp.]).

Wiregrass does not readily become reestablished once uprooted because it does not reproduce sexually or asexually except under the most exacting environmental conditions (Clewell 1974). These include temperature, photoperiod, moisture, and fire. According to the picture drawn by Clewell (1974, p. 45), the required conditions may no longer exist, leaving the theory that the wiregrass left today "may have germinated from seeds centuries ago when earlier, post-Pleistocene climates provided the environmental conditions needed for reproduction." Once disrupted by logging or agricultural practices, this shallow-rooted grass is eliminated from the ground cover, resulting in a permanent successional change to other forest conditions.

c. Flora. In addition to the wiregrass and saw palmetto (*Serenoa repens*), gallberry (*Ilex glabra*), runner oaks (*Quercus minima, Q. pumila*), a low blueberry (*Vaccinium myrsinites*), a ground huckleberry (*Gaylussacia dumosa*), and bracken fern are dominant ground cover plants in the pine flatwoods. According to Clewell (1971), there may be 200 or more species of ground cover, with 75 or more found in any given stand of a few acres. A list of groundcover species found in four Panhandle flatwood sites is given in Table 11.

d. Fauna. The flatwoods of the Gulf Coastal Lowlands, especially in the Apalachicola National Forest, support a robust population of native earthworms of the genus *Diplocardia*. One species, particularly, *D. mississippiensis*, is the focus of a large fishing bait industry. Many local residents of Calhoun, Liberty, and Wakulla counties make a good living by gathering this species by means of the technique called "grunting." A wooden stake is driven into the ground and vibrated by drawing an ax handle, shovel handle, or similar device across it. The vibrations in the ground agitate the earthworms, driving them to the surface where they are collected. Bait collectors like to "grunt" recently burned flatwoods, where densities of *D. mississippiensis* are on the order of thousands per acre. This species, alone, must do a considerable job in recycling organic nutrients back into the soil.

The groundcover of flatwoods is usually quite luxuriant because water is readily available during rains which do not percolate far into the soil to local water tables. Furthermore, under the natural conditions of regular fires, nutrients tied up in dead and slowly decomposing organic litter are quickly made available to the plants of flatwoods by the rapid oxidation and nutrient-cycling effect of fire.

Because the primary productivity of the groundcover vegetation is so high, flatwoods support a rich invertebrate fauna of herbivores. These, in turn, drive a surprisingly rich vertebrate insectivore fauna, comprising salamanders (*Ambystoma talpoideum, A. tigrinum, A. cingulatum, Notophthalmus viridescens, N. perstriatus, Eurycea quadridigitata*), frogs (*Gastrophryne carolinensis, Bufo terrestris, B. quercicus, Hyla squirella, H. femoralis, H. gratiosa, Pseudacris ornata, P. nigrita, Limnaoedus ocularis, Rana sphenocephala, Scaphiopus holbrookii*), and lizards (*Eumeces inexpectatus, Scincella lateralis, Cnemidophorus sexlineatus, Ophisaurus ventralis*). Snakes that feed upon the herbivores are abundant also (*Coluber constrictor, Lampropeltis getulus, L.*

Table 11. Comparison of floral diversity among four flatwoods sites in Panhandle Florida. Site 1=Liberty County flatwoods; site 2=Tate's Hell Swamp; site 3=grass-sedge savannah, Liberty County; site 4=Buckhorn Hunt Camp (from research summaries 6, 7, 9, & 5, respectively, in Clewell 1981).

Species	Site 1	Site 2	Site 3	Site 4
Agalinis aphylla	•		•	
Agalinis filicaulis			•	
Agalinis linifolia		•		
Agalinus purpurea		•	•	
Ageratina aromatica	•			
Aletris aurea	•		•	
Aletris lutea	•	•	•	
Aletris obovata	•			
Angelica dentata	•			•
Andropogon virginicus	•			•
Andropogon sp.			•	
Anthaenantia rufa			•	
Aristida affinis			•	
Aristida stricta	•		•	•
Arnoglossum ovatum			•	
Aronia arbutifolia		•		
Asclepias cinerea	•			•
Asclepias convivens			•	
Asclepias lanceolata			•	
Asclepias longifolia	•		•	
Asclepias michauxii	•			
Ascyrum (=Hypericum) hypericoides				•
Asimina longifolia	•			•
Aster adnatus	•		•	•
Aster chapmanii		•	•	
Aster concolor	•			
Aster dumosus	•			
Aster eryngiifolius	•		•	•
Aster linariifolius	•			
Aster reticulatus	•		•	•
Aster tortifolius	•			•
Aureolaria pedicularia	•			
Balduina uniflora		•	•	•
Baptisia lanceolata	•			
Baptisia simplicifolia	•			•
Bartonia paniculata		•		
Berlandiera pumila	•			
Bigelowia nudata			•	
Callicarpa americana	•			
Calopogon pallidus		•	•	
Calopogon tuberosus (=C. pulchellus)			•	
Carphephorus pseudoliatris	•	•		•
Cassia fasciculata	•			•
Cassia nictitans	•			
Chamaecyparis henryae		•		
Chaptalia tomentosa			•	
Chondrophora nudata		•		
Chrysopsis mariana	•			•
Cirsium horridulum	•			
Cirsium lecontei	•		•	
Cleistes divaricata				•
Clethra alnifolia		•	•	
Cliftonia monophylla		•		
Cnidoscolus stimulosus	•			
Coreopsis gladiata			•	
Coreopsis leavenworthii		•		
Coreopsis nudata			•	
Crotalaria purshii	•			•
Ctenium aromaticum	•		•	
Cuscuta compacta		•		•
Cyrilla racemiflora parvifolia		•	•	
Cyrilla racemiflora		•		•
Desmodium ciliare	•			
Desmodium lineatum	•			•
Desmodium paniculatum	•			•
Dichanthelium acuminatum	•		•	•
Dichromena colorata			•	
Dichromena latifolia		•	•	
Diospyros virginiana			•	
Drosera capillaris		•	•	•
Drosera filiformis		•		
Dyschoriste oblongifolia	•			
Elephantopus elatus	•			
Erianthus giganteus			•	
Erigeron vernus	•		•	
Erigeron tomentosum	•			
Eriocaulon compressum			•	
Eriocaulon decangulare		•	•	
Eryngium yuccifolium	•		•	•
Eupatorium album	•			
Eupatorium compositifolium	•			•
Eupatorium leucolepis			•	
Eupatorium recurvans	•	•	•	
Eupatorium rotundifolium	•		•	

(continued)

Table 11. Continued

Species	Site 1	Site 2	Site 3	Site 4
Eupatorium semiserratum	•	•		
Euphorbia inundata	•		•	
Euthamia minor		•	•	
Fraxinus caroliniana			•	
Fuirena squarrosa			•	
Galactia erecta	•			
Gaylussacia dumosa	•		•	
Gaylussacia frondosa	•			•
Gaylussacia mosieri		•		
Gelsemium rankinii		•		
Gelsemium sempervirens	•			
Gnaphalium purpureum falcatum	•			
Heleanthemum carolinum	•			
Helenium pinnatifidum	•		•	
Helianthus floridanus		•		
Helianthus heterophyllus	•		•	
Helianthus radula	•			•
Heterotheca (=Pityopsis) aspera	•			
Heterotheca (=Chrysopsis) gossypina	•			
Heterotheca (=Pityopsis) graminifolia	•			•
Heterotheca (=Pityopsis) oligantha	•		•	•
Hibiscus aculeatus	•			
Hieracium gronovii	•			
Houstonia (=Hedyotis) procumbens	•			
Hypericum brachyphyllum		•	•	
Hypericum fasciculatum	•	•	•	
Hypericum microsepalum	•		•	
Hypericum myrtifolium	•		•	
Hypericum tetrapetalum	•			
Hypericum stans	•			
Hypoxis hirsuta		•	•	•
Hyptis alata			•	
Ilex coriacea		•	•	•
Ilex glabra	•	•	•	•
Ilex myrtifolia		•	•	•
Iris tridentata			•	
Justicia crassifolia	•			
Kalmia hirsuta				•
Lachnanthes caroliana		•		

Species	Site 1	Site 2	Site 3	Site 4
Lachnocaulon anceps	•	•		
Lespedeza capitata	•			
Lespedeza repens	•			•
Liatris chapmanii				•
Liatris gracilis	•			
Liatris spicata		•	•	
Liatris tenuifolia	•			
Licania michauxii	•			•
Lilium catesbaei		•	•	
Lobelia brevifolia			•	
Lobelia floridana	•	•	•	
Lobelia paludosa	•		•	•
Lophiola americana		•	•	
Ludwigia linearis		•		
Ludwigia pilosa		•		
Lycopodium alopecuroides		•	•	
Lycopodium carolinianum		•		
Lycopodium prostratum			•	
Lygodesmia aphylla	•			
Lyonia ferruginea				•
Lyonia fruticosa		•		
Lyonia lucida		•	•	•
Magnolia virginiana		•	•	
Muhlenbergia capillaris			•	
Myrica cerifera	•	•	•	•
Myrica heterophylla	•		•	
Myrica inodora	•	•		
Nolina atopocarpa	•			
Nyssa sylvatica biflora		•	•	
Onosmodium virginianum	•			
Osmanthus americanus	•	•		
Osmunda cinnamomea			•	•
Oxypolis filiformis		•	•	
Panicum anceps				•
Panicum rigidulum			•	
Parnassia caroliniana			•	
Paspalum plicatulum			•	
Paspalum sp.	•			
Persea palustris		•	•	
Petalostemon albidum	•			
Phoebanthus tenuifolia	•			
Physostegia leptophylla			•	
Pieris phillyreifolia		•		
Pinguicula sp.			•	
Pinus elliottii	•	•	•	•

(continued)

Table 11. Continued

Species	Site 1	Site 2	Site 3	Site 4
Pinus palustris	•			•
Plantanthera ciliaris		•		
Plantanthera nivea		•	•	
Pleea tenuifolia		•	•	
Pluchea camphorata		•		
Pluchea foetida		•		
Pluchea odorata		•		
Pluchea rosea		•		
Pogonia ophioglossoides			•	
Polygala baldwinii			•	
Polygala crenata	•		•	
Polygala cruciata		•	•	
Polygala cymosa		•	•	
Polygala grandiflora	•			
Polygala harperi			•	
Polygala incarnata	•			
Polygala lutea	•	•		
Polygala nana	•			•
Polygala ramosa			•	
Polygala setacea				•
Proserpinaca pectinata		•		
Pteridium aquilinum	•			•
Pterocaulon pycnostachyum (=P. virfatum)	•			•
Quercus falcata	•			
Quercus incana	•			
Quercus laevis	•			
Quercus minima	•			•
Quercus nigra	•		•	
Quercus pumila	•			•
Rhexia alifanus	•	•	•	•
Rhexia lutea			•	
Rhexia petiolata			•	
Rhexia virginica		•		
Rhododendron serrulatum		•		
Rhynchospora chapmanii			•	
Rhynchospora corniculata			•	
Rhynchospora globularis			•	
Rhynchospora microcephala			•	
Rhynchospora mollissima	•			
Rhynchospora plumosa			•	
Rhynchospora sp.	•			
Rubus argutus			•	
Rubus cuneifolius	•			
Rudbeckia graminifolia			•	
Rudbeckia mohrii			•	
Ruellia pedunculata			•	
Sabatia bartramii			•	
Sabatia brevifolia	•			
Sabatia difformis				•
Sabatia quadrangula		•		
Sabatia stellaris			•	
Sagittaria graminea		•		
Salvia azurea	•			
Sarracenia flava		•	•	
Sarracenia psittacina		•	•	
Schrankia microphylla	•			
Scleria baldwinii			•	
Scleria hirtella	•		•	
Scleria nitida				•
Scleria reticularis			•	
Scleria triglomerata				•
Scutellaria integrifolia	•			
Serenoa repens	•			•
Seymeria cassioides	•		•	•
Sisyrinchium arenicola	•		•	
Smilax auriculata	•			•
Smilax glauca			•	•
Smilax laurifolia		•	•	
Smilax pumila	•			•
Solidago odora	•			
Solidago stricta	•			
Spiranthes praecox			•	
Stylisma patens	•			
Stillingia sylvatica	•			•
Stylosanthes biflora	•			
Styrax americana		•		
Syngonanthus flavidulus		•		•
Taxodium distichum nutans (=T. ascendens)		•	•	
Tephrosia hispidula				•
Tephrosia virginiana	•			
Tofieldia racemosa			•	•
Tragia urens	•			•
Trichostema dichotomum	•			
Trilisa (=Carphephorus) odoratissimus	•		•	•
Trilisa (=Carphephorus) paniculatus	•			
Utricularia cornuta		•		

(continued)

Table 11. Concluded

Species	Site 1	Site 2	Site 3	Site 4
Utricularia juncea		•	•	
Vaccinium darrowi	•			•
Vaccinium fuscatum		•		
Vaccinium myrsinites	•			•
Verbesina chapmanii			•	
Viola septemloba	•			
Viola sp.	•			
Vitis rotundifolia	•		•	•
Vitis sp.		•		
Woodwardia virginica		•		
Xyris ambigua		•		
Xyris baldwiniana		•	•	
Xyris caroliniana	•		•	•
Xyris elliottii		•		
Xyris stricta		•	•	
Zigadenus densus	•		•	•
Zigadenus glaberrimus		•	•	
Total species	**134**	**87**	**127**	**71**

triangulum, L. calligaster, Masticophis flagellum, Drymarchon corais, Sistrurus miliarius, Elaphe guttata, E. obsoleta).

Mammals of the flatwoods are most of the same species found in sandhills. They include the mammalian insectivores: shrews (*Blarina brevicauda, Cryptodus parva, Sorex longirostris*) and the mole (*Scalopus aquaticus*). Mammalian herbivores are abundant: cottontail and marsh rabbit (*Sylvilagus floridanus, S. palustris*), cotton rat and cotton mouse (*Sigmodon hispidus, Peromyscus gossypinus*), harvest mouse (*Reithrodontomys humulis*), pine vole (*Microtus pinetorum*), white-tailed deer (*Odocoileus virginianus*), and others. Most of the mammalian carnivores (skunk, opossum, raccoon, bobcat, gray fox) not strictly associated with water are found in flatwoods. Since watercourses meander through the flatwoods, the aquatic mammals (otter, mink, beaver) occasionally enter the piney woods. The threatened black bear is found in small numbers in deep swamps like Bradwell Bay Wilderness Area located in the flatwoods of the Apalachicola National Forest.

The avifauna of flatwoods is of four feeding guilds: an arboreal, needle and bark gleaning suite of species; a flycatching group that sallies out from their perches to catch insects in the air; a seed-eating terrestrial assemblage; and a group of aerial predators. Preeminent among the birds of the first guild is the federally endangered red-cockaded woodpecker (*Picoides borealis*).

The last strong bastion of this species is the Coastal Lowlands of Panhandle Florida. Eglin Air Force Base and the Apalachicola National Forest probably harbor more than 50% of the remaining individuals of this species. The aerial predators are nocturnal and diurnal, including the great horned owl (*Bubo virginianus*), red-tailed hawk (*Buteo jamaicensis*), and chuck-will's-widow (*Caprimulgus carolinensis*). The Bachman's Sparrow (*Aimophila aestivalis*) is a fully terrestrial bird that requires the open, shrubless prairie groundcover typical of flatwoods.

5.2.7 Beach, Dune, and Scrub

The beach and dune coastal strand vegetative associations are restricted to the high energy shorelines along the seaward boundary of the spits and barrier islands of Panhandle Florida. The barrier islands are Santa Rosa, Shell, St. George, St. Vincent, and Dog Island; the larger spits are Moreno Point, Crooked Island, St. Joseph Spit, and Alligator Peninsula. One small stretch of mainland exposed to the open gulf, from Alligator Point to Dog Island, has a small amount of strand vegetation. Coastal marshes and salt flats found along low-energy coastlines are not considered components of the strand community, nor are the upland communities, such as the pine flatwoods found inland of the dune system and along shorelines being eroded by the sea.

a. Soils. Soils of the coastal strand, as the beach, dune, and coastal scrub are often called, are sandy, grading from unsorted, mixed grain sizes and shells thrown up as berms by storms to finely graded and sorted grain sizes on aeolian dunes. These latter dunes occur perched on the interdune flats or are developed on top of the berms thrown up by storms.

b. Ecology. The scrub community, which is unique to the southeastern Coastal Plain and especially to Florida, has two variants, one dominated by sand pine (*P. clausa*), and one dominated by slash pine (*Pinus elliottii*). On Panhandle barrier islands, treeless scrub occurs just behind the foredunes in the lee of winds heavily laden with salt spray off the Gulf of Mexico. Going inland, the treeless scrub changes to scrub with a slash pine canopy. Further back from the first or second beach-dune ridge, one encounters sand pine scrub. This transect is obvious on St. Joseph Spit, St. George Island, and St. Vincent Island.

As in peninsular Florida, pine scrub of the Panhandle is also found on relict sand dunes and beach ridges created when sea level was higher than at present. Soils on such relict dunes are well-washed, well-drained sterile white-to-yellowish sands. Unlike peninsular Florida scrub communities, however, the Panhandle scrub community tends to be closer to the coast, positioned between the coast and the pine flatwoods. The pine scrub habitats of Panhandle Florida are isolated from those in the north central peninsula by the low-energy coastline of the Florida Big Bend region, where few dunes have been formed.

c. Flora. Though variable from site to site, dune and beach vegetation can have three distinguishable zones: (1) the shifting beach sands; (2) the produne vegetation; and (3) the scrub zone.

The shifting beach sand zone is, by definition, devoid of living, rooted vegetation. The primary energy sources for the often numerous consumers that frequent this zone are imported by wind and wave action or brought down from more inland areas. Seagrasses washed onto the shoreline by storm tides and waves, drifting plant debris, shells, and carcasses of fish and other marine life, collectively called seawrack, serve as food for the primary consumers that include many insects and their larvae, amphipods, ghost crabs (*Ocypode* sp.), and other burrowing invertebrate species. These, in turn, provide food for gulls, terns, and probing shorebirds.

Inland from the shifting beach sand zone, the produne zone is the first large dune. Produne vegetation is characterized by pioneer plants that are able to establish themselves in the shifting, arid sands and to tolerate salt spray and intense heat. Examples include sea oats (*Uniola paniculata*), railroad vine (*Ipomoea pes-caprae*), beach morning glory (*I. stolonifera*), evening primrose (*Oenothera humifusa*), sand spur (*Cenchrus tribuloides*), grasses (*Paspalum vaginatum, Schizachyrium maritimum, Panicum amarum*), sand cocograss (*Cyperus lecontei*), and sea purslane (*Sesuvium portulacastrum*) (Kurz 1942; Clewell 1971). Limited quantitative data on the density of these dune plants on St. George Island are provided by Carlton (1977).

The produne affords limited protection to the interior dune system from wind and salt spray and is crucial for the establishment of subsequent plant communities. On the backsides of these dunes Spanish bayonet (*Yucca aloifolia*), myrtle oak (*Quercus myrtifolia*), green brier (*Smilax auriculata*), saw palmetto (*Serenoa repens*), and other plants characteristic of the interior dunes may grow.

Farther inland from the foredunes is the "scrub" zone, characterized by stunted, wind and salt spray-pruned scrubby oaks and other evergreen, small-leaved shrubs. This area is referred to as the "scrub" zone by Kurz (1942), because of its similarity to scrub oak growing on relict sand dunes of interior Florida. The scrubby, gnarled, thick-leaved evergreen oaks that are characteristic of the scrub community almost always include sand-live oak (*Q. virginiana geminata*), Chapmans oak (*Q. chapmanii*), fetterbush (*Lyonia lucida*), and very rarely in the Panhandle, myrtle oak (*Quercus myrtifolia*). Other common shrubs include different types of rosemary (*Ceratiola ericoides, Conradina canescens*) and gopher apple (*Licania michauxii*). Ground cover is usually sparse, leaving large patches of bare white sand interspersed with reindeer moss (*Cladonia rangifera*) and other lichens. The scrub community is typically two layered, with slash or sand pine in the canopy and the scrub oaks and shrubs in the understory.

Scrub communities are quite variable. The coastal scrub forest is dominated by a mixture of sand and slash pine in most locations (Carlton 1977). However, according to Clewell (1971), sand pine was represented by a single tree in his survey of St. George Island. Comparable dunes near Carrabelle and on St. Joseph Spit have dense forests of sand pine (*Pinus clausa*). Sand pine seems to be less tolerant of salt spray than slash pine. Therefore, it is common to find sand pine on the interior dunes or bayside beach ridges and dunes on the Panhandle's barrier islands. Across the lagoon, where sand pine is somewhat better sheltered from heavy winds and salt spray, it occurs in dense stands on relict dunes and beach ridges along the continental margin. Eglin Air Force Base is noted for a variety of sand pine having open, rather than serotinous cones, such as the sand pine has in central Florida. Sand pine forests include monospecific stands of uniform age, indicating regeneration about the same time. This coincides with theories about natural replacement of sand pine by fires in central Florida (Laessle 1958). It is common to find sand pine growing with other pines, such as longleaf pine on Eglin Air Force Base. Apparently sand pine will encroach under the canopy of longleaf pine in the absence of fire. In stands of old sand pine, wind seems to be able to blow over large individuals, opening the sand pine forest up for invasion by hardwoods, other pines, and shrubs. The successional relationships of Panhandle sand pine have yet to be fully studied.

Open areas of the scrub zone are sometimes occupied by lichens, St. Johns wort (*Hypericum reductum*), nettles (*Cnidoscolus stimulosus*), stunted sea oats, and jointweed (*Polygonella polygama*). Swales between dunes may occasionally retain water after heavy rains. These shallow interdunal depressions may be distinguished from sloughs in that they drain surface runoff vertically into the soil, whereas sloughs hold surface runoff or carry it into the bay (Clewell 1971).

On St. George Island, sloughs are generally flanked by pine flatwoods and are delineated by a dense zone of medium-sized oaks. These mesic to xeric-like hammock communities are composed primarily of laurel oak (*Quercus laurifolia*) and live oak with some sand-live oak (*Q. virginiana geminata*), as well (Clewell 1971). A variety of woody plants form an understory in this more protected habitat, including gallberry (*Ilex glabra*), wax myrtle (*Myrica cerifera*), greenbrier, bamboo vine (*Smilax laurifolia*), poison oak (*Toxicodendron quercifolia*), muscadine (*Vitis rotundifolia*), wild olive (*Osmanthus americanus*) yaupon (*Ilex vomitoria*), buttonwood (*Cephalanthus occidentalis*), royal fern (*Osmunda regalis*), and sawgrass (*Cladium jamaicense*). Where standing water remains nearly all year pond habitat may form, supporting freshwater marsh plants such as sawgrass, water lilies (*Nymphaea odorata*), and umbrella grass (*Fuirena scirpoidea*).

The vegetation of the coastal community is subjected to harsh conditions. High winds, shifting sands, intense heat, and salt spray are chronic stress factors which define not only species composition, but growth form as well. Many plants found in the coastal region appear to be gnarled and stunted, perhaps as adaptations to or consequences of environmental stress.

Despite the fact that many plants may appear stunted or small, they are frequently quite old. Clewell (1971) reports a myrtle oak 2 m in height to be at least 11 years old; a 2.3 m sand live-oak to be 25 years old; a 1.3 m rosemary bush to be 15 years old; and a 25.4 cm diameter slash pine to be 75 years old. Though they appear stressed, many of the scrub species survive quite well under such conditions. Their success is essential to the stabilization of the dune system, which is constantly subjected to the eroding force of onshore winds and storms.

Although fire tends to be infrequent in the coastal community, it does occur (Clewell 1971) and is important in maintaining other more typically inland community types on barrier island systems (i.e., pine flatwoods, pine scrub). Because of the openness of the scrub zone and the lack of fuel in the ground cover, fewer fires occur and they rarely spread very far in the dune system.

The slash pine scrub community described by Clewell (1971) in the Apalachicola National Forest possesses more than just scrub oak understory. Sand-live oak (*Quercus virginiana geminata*), sweet bay magnolia (*Magnolia virginiana*), southern magnolia (*Magnolia grandiflora*), and stagger bush (*Lyonia ferruginea*) were common stunted trees, 10–30 ft tall. Others included black titi (*Cliftonia monophylla*), wild olive (*Osmanthus americanus*), water oak (*Quercus nigra*), and others. The overstory, which has been cut, was solely slash pine (*Pinus elliottii*), up to 120 years in age before logging. The scrub layer in this community contains fetterbush (*Lyonia lucida*), stagger bush, gallberry (*Ilex glabra*), dwarf huckleberry (*Gaylussacia* spp.), dangleberry (*Vaccinium erythrocarpum*), and sand-live oak (*Quercus virginiana geminata*). Saw palmetto (*Serenoa repens*) grows sparsely. Only 51 species are recorded from this upland site.

On St. George Island, a slash pine dominated scrub community lies behind the dune system, often intergrading into sand pine scrub and pine flatwoods (Clewell 1971). In this particular location, myrtle and sand-live oak form large patches and saw palmetto covers up to 15% of the ground. Chapmans oak and rosemary were also reported.

Two trends in this community's distribution have been noted: (1) the invasion of sand pine into sandhill sites as fire is eliminated (Gatewood and Hartman 1977); and (2) the establishment of a slash pine overstory at sites formerly dominated by sand pine as the sand pines reach old age and begin to fall down and thin out (Clewell 1971). Fire suppression in sandhill communities may slow the recycling rate of organic nutrients in the forest litter and eliminate wiregrass, lowering overall soil fertility and thus favoring the invasion by sand pine. The deliberate planting of slash pine may promote its invasion into adjacent scrub communities by increasing the relative numbers of seeds reaching available sites. Fire suppression may also play a role in promoting slash pine. In south Florida sand pine scrub is recycled by catastrophic fire (Laessle 1958, Bozeman 1971). Much less is known about the role of fire in north Florida scrub communities, and extrapolation from the ecology of central Florida scrub may be invalid.

d. Fauna. The dunes are so arid and hot that few amphibians can tolerate the severely stressful conditions. Southern toads (*Bufo terrestris*) occasionally take refuge in burrows and forage at night at the base of dunes, especially in the interdune flats. Toads can be abundant in coastal strand environments as can the southern leopard frog (*Rana sphenocephala*) because both breed in temporary ponds of the interdune flats.

Coastal strand environments are well endowed with reptiles. Reptiles are the vertebrates best adapted for dry terrestrial environments, and the kinds of foods eaten by most reptiles (insects, small vertebrates) are themselves abundant in the highly productive coastal habitats. The garter snake (*Thamnophis sirtalis*), black racer (*Coluber constrictor*), coachwhip (*Masticophis flagellum*), cottonmouth (*Agkistrodon piscivorus*), and pygmy rattlesnake (*Sistrurus miliarius*) are also exceedingly abundant along strands. Mammals of the coastal strand include the eastern mole (*Scalopus aquaticus*), shrews, beach mice (*Peromyscus polionotus* sbspp.), rice rat (*Oryzomys palustris*), cotton rat (*Sigmodon hispidus*), cottontail (*Sylvilagus floridanus*), and marsh rabbit (*S. palustris*).

Panhandle scrub communities are depauperate in animals when compared to the central Florida interior scrubs. Apparently the Panhandle scrubs are only as old as the barrier islands and the coastline where it is confined geographically. Present coastal features are only about 6,000 years old, but interior scrubs in central Florida are relicts stranded from higher stands of the sea, possibly as long ago as late Pliocene, and may be up to 2 million years old.

Coastal scrub communities from Santa Rosa Island to St. Joe Spit have populations of light-colored beach mice that burrow in the sand. These, cotton rats, and rice rats probably are eaten by the coachwhip and black racer, common snakes in the scrub that actively hunt their prey. They also eat the six-lined racerunner (*Cnemidophorus sexlineatus*), one of the commonest scrub vertebrates. Southern toads are the most common frog, but the southern leopard frog is also abundant. Many of the animals encountered in scrubs are visitors from adjacent wetlands, forests, or grassland vegetation. Two federally listed endangered subspecies, the Choctawhatchee beach mouse (*Peromyscus polionotus allophnys*) and Perdido Key beach mouse (*P. polionotus trissyllepsis*) are found on some of these barrier islands.

5.2.8 Caves

Caves filled with air rather than water are generally rare in Florida but are more prevalent in the Panhandle than in the peninsula. This type of habitat is found in regions with limestone formations. Two distinct limestone (karst) regions exist in north Florida west of the Suwannee River, each biologically and geologically distinct from the other: the Woodville Karst Plain in the Florida Big Bend region and the Marianna Lowlands in the Panhandle. Air-filled caves are virtually nonexistent in the subterranean limestone passageways of the Woodville Karst Plain, but they are abundant in the Marianna Lowlands. The reason seems to be that the water table in the Marianna Lowlands is lower than the general elevation of the upper limestone passageways, allowing air, rather than water, to fill the caves. The air-filled passageways are connected by vertical shafts to water-filled passageways in horizontal cave systems at lower levels. The biological resources of water-filled caves are described in the chapter on freshwater wetlands (Chapter 6.5.1).

The Marianna Lowlands physiographic region of Panhandle Florida is the southwestern end of a large karst plain known in Georgia as the Dougherty Plain. This limestone region extends northeast from Marianna, Florida, to about 25 mi beyond Albany, Georgia. The Tertiary limestones which lie close to the ground surface, mantled with a thin veneer of sand, have been subject to erosion by dissolution for millions of years, and both vertical and horizontal solution channels are extensive in them. Vertical shafts dissolve as surface waters percolate downward through joints, cracks, fissures, and faults; horizontal caves are formed as ground water flows downhill underground along bedding planes between limestone terranes (sediment layers). Over millions of years, horizontal tunnels can widen to become 30–50 ft in diameter, or even larger in places.

When in time sea levels drop, as they periodically do in Florida in response to the waxing and waning of continental glaciation, ground water levels also fall. When ground water drops, it abandons upper horizontal cave systems through vertical interconnecting shafts and occupies horizontal systems at lower levels in the limestones. Once the water in the passageways is replaced with air, they are available for colonization and use by terrestrial animals and plants.

Because light is always a limiting factor in food webs (except some deep sea ones), it is no surprise that light, or the lack of it, plays a role in cave ecosystems. Light intensity declines as the square of distance, so that the intensity of light available for photosynthesis falls off very rapidly back from the cave mouth. Very few caves exist into which sunlight falls directly. The area near the mouth of a cave where any amount of light falls is called the "twilight" zone. This is not an abstract category; animals and plants that use and/or need light are specifically found in this zone in caves, and their distributions in the twilight zone are quite demonstrable on inspection. The dark portions of caves are, of course, just as well-defined by the absence of any light at all, and the simplified food webs in the dark (troglobitic) zones of caves are driven entirely by detritus.

Most of the caves of biological importance in the Marianna Lowlands are privately owned, but two systems now belong to the State of Florida. The caves in the Marianna Caverns State Park include a few thousands of feet of passageways. None of these caves is particularly important biologically, and the main commercial cavern is disturbed daily by the tourist traffic. Some of the park's smaller caves, such as Indian Cave, are being managed in hope of the return of the endangered grey bat (*Myotis grisescens*), which is known to have once used them. One of the most important caves in the region, biologically, is known as Judge's Cave. This cave now is owned by the Florida Game and Fresh Water Fish Commission. It is the major maternity cave for the grey bat, whose pregnant females seem to require a roost over water in caves (Tuttle 1974, Humphrey and Tuttle 1978).

Other privately owned caves that are important biological resources are known by the following names: Bump Nose Cave, Honey Comb Hill Cave, Stoney Cave, Fears Cave, Sam Smith's Cave #1 (also known as Gerard's Cave), Sam Smith's Cave #2, and Baxter Cave, all in Jackson County. Many more occur in Jackson County. Some are clustered along the Chipola River valley between Marianna Caverns State Park and U. S. Highway 90, and others are found to the west in the direction of the town of Cottondale. Another cluster of caves lies along Waddell's Mill Creek and its tributaries west of the Chipola River. The Florida State Cave Club, a grotto (branch) of the National Speleological Society and operating out of Florida State University in Tallahassee, maintains records on the caves of the Panhandle and has maps of many.

a. Flora. It may come as some surprise that the twilight zones of caves in the Panhandle have a distinctive flora. Cave plants are mostly microscopic species, and in the Panhandle are limited to algae, fungi, and bacteria. While cave flora have not yet been thoroughly investigated in Florida caves, at least two species of algae have already been described as endemic to Panhandle caves (Friedmann and Ocampa 1974). Liverworts and fungi are common about the mouths of caves, and fungi occur far back in the dark zones, especially on bat guano.

b. Fauna. There are many animals that use caves casually because they provide shelter and buffered air temperatures. For many animals caves may seem to be no more than just larger cracks and burrows that they normally inhabit. The Florida wood rat (*Neotoma floridana*) commonly builds its stick nests just inside caves in the twilight zone, usually under large rocks or in fissures in the walls. The slimy salamander (*Plethodon glutinosus*), two-lined salamander (*Eurycea bislineata*), and long-tailed salamander (*Eurycea longicauda*) are three common casual visitors to the Marianna caves. The camel cricket (*Ceuthophilus* spp.) is found abundantly in Panhandle caves, in the twilight zone and throughout the dark zone. *Cambala annulata* is a cave millipede found in Marianna caves, along with the cave spider, *Islandia* sp.

5.3 Human-created Habitats

5.3.1 Fallow Lands, Succession, and Mixed Hardwood Forests

Today, most of the pine forests in the Coastal Plain are very different from the native longleaf communities they have replaced. First, the pines themselves are different. Shortleaf (*Pinus echinata*), loblolly (*P. taeda*), and slash pine (*P. elliottii*) have replaced longleaf pine. Second, these areas are as much hardwood communities as they are pine forests. These replacement forests are old field successional communities, and they result from the most serious of human impacts to longleaf forests: soil disturbance.

a. Soils. The soils of fallow lands are usually the richest and the highest in elevation—those that are naturally best suited for agriculture. In the Panhandle, the best agricultural soils are the loamy soils of the Northern Highlands. The sediments of the Miccosukee and Citronelle Formation in the Northern Highlands, and the nutrient rich calcareous soils of the Marianna Lowlands attracted the first settlers and consequently, have been disturbed by the plow the longest. In the Coastal Lowlands cultivated and, later, fallow land have always been less abundant because the sandy soils are poor for agricultural use. Site preparation for silviculture has had similar impacts in the Coastal Lowlands (see Section 5.3.3).

b. Ecology. At one time or another, most of the naturally richer soils of the Coastal Plain have been farmed. In the pre-Civil War South agriculture was the primary industry of the Coastal Plain, and it still is important today. Until the 1940's and 1950's, when commercial fertilizers began to be used on a grand scale, farmers had to rotate their crops from site to site and let fields lie fallow for a few years to restore their fertility naturally.

But in the Coastal Plain no land lies unclaimed for long. Many plants spread seeds using the wind, water, animals, or birds for distribution. Soon a rich flora develops on the old field sites. Several species of hardwoods from beech-magnolia forest may take root. The first of these are usually sweet gum, laurel oak, and water oak. A pine from that same forest, the loblolly pine, may recruit and establish itself provided that it can escape death by fire in the first decade of its life. The shortleaf pine also invades the old fields. It followed settlers coastward from its natural habitat in the Piedmont.

Today, many of the pine forests of the southeast grow on former longleaf sites that were cleared, farmed, and abandoned. Where these forests are burned each year, the hardwoods are suppressed, and an open, parklike panorama of large old field pines can be produced. When these stands are 40 to 80 years old, they begin to resemble the native longleaf vistas, but a closer look reveals that the replacement forests contain a very different mix of plants than the original longleaf forests. For one thing, hardwoods that grow up with the replacement pines are rarely eliminated, because their persistent roots keep putting up new shoots. If fire is kept out long enough, the large hardwood roots can thrust up stems very rapidly and grow big enough to survive the next fire.

With infrequent fires, old fields inevitably become hardwood stands. The hardwoods make it even more difficult for fire to sweep through, and young shortleaf and loblolly pines cannot survive under the dense shade of the hardwoods. The old field site eventually changes into a hardwood community as the original shortleaf and loblolly individuals age and die.

The strong dependency of many native groundcover plants (and longleaf pines as well) on summer fires for sexual reproduction is probably a major reason that fallow land does not recruit the same mix of species that make up a virgin forest, even if adjacent to one. Another reason, however, is that among the species of any community, some are better adapted for colonizing bare soil than others. Bare soil of the sizes left by humans following agriculture or other artificial soil disturbance are unusual site conditions that probably never existed in presettlement times. Large patches of bare soil are quickly colonized, not by a random sample of the native flora, but by a highly biased subset of the native flora involving mostly the good colonizers (sometimes called "weeds"). These species naturally occur at very low densities under normal conditions. Broomsedge (*Andropogon virginicus*) and dog fennels (*Eupatorium* spp.), whose density on old fields can be almost impenetrable, are good examples of native species that in longleaf ecosystems are relatively rare because they are found on a few bare patches of soil that exist only for short periods. Such bare patches are created by tree tip-up mounds when trees fall over, or consist of soil pushed up by burrowing animals such as the gopher tortoise or pocket gopher. Because these patches are small and rare, the plants that are adapted for finding and utilizing them usually have high fecundity and high dispersability. Lots of seeds, produced every year and carried by the wind, ensure that these species will find the rare and fleeting bare soil sites in native longleaf communities. Fallow soil, however, is selectively colonized by these species, creating vast instead of normally tiny populations.

Weeds introduced from Asia, Europe, Africa, South and Central America, and elsewhere in North America by people have also invaded the Coastal Plain. These join with native weeds and are called ruderal "communities."

c. Flora. The mixed pine-oak-hickory forests of Quarterman and Keever (1962) are not, as they believed, the natural climax community. These communities are late successional stages of fallow lands. Numerous grasses and forbs dominate the early stages of field abandonment. Woody perennials succeed the succulent annuals, and include *Eupatorium* spp., *Rubus* spp., sassafras (*Sassafras albidum*), winged sumac (*Rhus copallina*), beautyberry (*Callicarpa americana*), and young stems of several hardwood species, including sweet gum (*Liquidambar styraciflua*), water oak (*Q. nigra*), laurel oak (*Q. laurifolia*), black cherry (*Prunus serotina*), pignut hickory (*Carya glabra*), mockernut hickory (*Carya tomentosa*), southern red oak (*Quercus falcata*), occasional live oak (*Quercus virginiana*), persimmon (*Diospyros virginiana*), and others. When these tree species begin to rise above the perennials, they are in a race skyward with the old field pines (shortleaf and loblolly). At first the pines win the race, establishing a canopy above the slower growing hardwoods. If regular fires sweep these forests after about 7 or 8 years, the hardwoods will be pruned back to rootstocks after every burn, allowing the pines to dominate the site. If no fires sweep the site, or they come at great intervals, the hardwoods will reach the canopy and share it a while with the pines. The hardwoods, however, can replace themselves with new recruits when an opening occurs in the closed canopy; the pines, being intolerant of shade, can not. Eventually, as the old-field pines die, the mixed pine-oak-hickory forest becomes an exclusively hardwood community. Most of the arable land of the Panhandle, if not presently under cultivation, is in some stage of successional recovery from it or has been totally converted into living space for people.

d. Fauna. Many of the animals that inhabit the longleaf pine clayhills uplands are found in the short leaf loblolly pine woodlands, if these are burned regularly (annually). But dense stands of young hardwoods and pines were not present in the Panhandle in pre-Columbian times, and few animals are preadapted to do well in this now common community type. A recent study of the breeding birds of an 80-year old, annually burned old-field community showed two things: (1) The fauna of the forest, which was similar physiognomically, to a longleaf pine forest, was not too different from that habitat; and (2) when the annual burning ceased, there was a measurable decline in the presence and abundance of birds that favor open, prairie-like pinelands. (Engstrom et al. 1984). In a drift-fence study comparison of an original growth longleaf pine forest with an 80-year old, annually burned shortleaf loblolly pine forest, Means and Campbell (1982) showed little difference between the terrestrial herpetofauna (Table 8). It is not known, however, what happens to the suite of species if annual fires are stopped.

5.3.2 Silvicultural Communities

Probably as much of the terrestrial environment of the Panhandle is devoted to silviculture as comprises all other terrestrial habitat types combined. The largest timber growers are private pulp and lumber corporations who have holdings in every county. Next in total area are the State and Federal lands devoted to tree farming, including the Blackwater River State Forest, Apalachicola National Forest, Eglin Air Force Base, and St. Marks National Wildlife Refuge. Tree farming by small private land owners is also extensive and may approach, in sheer acreage, the sum of the large corporate holdings.

a. Soils. Soils range from ultisols to spodisols to entisols. Pine tree silviculture is carried out on the sandiest soils throughout the Panhandle, the loamy soils of the Western Red Hills and Tallahassee Red Hills, and the acid wetland soils of flatwoods.

b. Ecology. Most of the silviculture in the Panhandle involves monospecific stands of one of three kinds of native pines: slash pine (*Pinus elliottii*), loblolly pine (*P. taeda*), and sand pine (*P. clausa*). About as much acreage in the clayhill regions of the Northern Highlands is devoted to pine tree farming as in the flatwoods country of the Coastal Lowlands. Therefore, many community types, ranging from the driest longleaf and scrub oak forests downslope to the evergreen shrub wetlands bordering flatwood streams, have been replaced by uniform silviculture. This has erased natural beta diversity and simplified site-specific community structure.

c. Flora. Usually slash pine (*Pinus elliottii*) is found on flatwoods soils or sandhill soils of the Gulf Coastal Lowlands; slash or loblolly pine (*P. echinata*) on clayey loamy soils of the Northern Highlands; and, sometimes, sand pine (*P. clausa*) on sandy soils in the Gulf Coastal Lowlands. Other trees that may occur in silvicultural stands are native hardwood species that either resprout from rootstocks or seedstocks left after site preparation, or seed into the site in the early years after planting with trees. In the clayhill regions of the Panhandle these are colonizing members of the beech-magnolia forest, including especially sweet gum (*Liquidambar styraciflua*), laurel oak (*Quercus laurifolia*), black cherry (*Prunus serotina*) and water oak (*Q. nigra*). Later, if fires are kept out of silviculture stands, even the slower colonizers such as pignut hickory (*Carya glabra*), dogwood (*Cornus florida*), and southern magnolia (*Magnolia grandiflora*) will encroach if stands are left alone for 40 to 50 years.

In flatwoods regions, silvicultural stands become rapidly invaded by many of the evergreen shrub species that attain small tree stature, such as black titi (*Cliftonia monophylla*), swamp cyrilla (*Cyrilla racemiflora*), and sweetbay magnolia (*Magnolia virginiana*). Often a plethora of shrubby evergreen species encroaches as well, including fetterbush (*Lyonia lucida* and *Leucothoe racemosa*), stagger bush (*L. ferruginea*), large gallberry (*Ilex coriacea*), pepperbush (*Clethra alnifolia*), and St. Johnswort (*Hypericum* spp.). As one approaches the coast in the Panhandle, the water table rises nearer to the surface of the ground. The increased moisture greatly stimulates the groundcover, producing rank growth. Scarified wet flatwoods soils in the Panhandle are dominated by a luxuriant growth of St. Johnswort.

On sandhills, site preparation does not eliminate species of scrub oaks that occur in the original xeric longleaf pine communities. Usually the cloning species resprout from root fragments, these are turkey oak (*Quercus laevis*), blackjack oak (*Q. marilandica*), and bluejack oak (*Q. incana*).

Some shrubs found in silvicultural areas are sparkleberry (*Vaccinium arboreum*) and plums and cherries (*Prunus* spp.), but the closed canopy in pine tree forests after about 5–8 years of growth usually shades out most of the shrub species.

Several herb species are common to all silviculture sites. Some of these are species of bluestem grasses (*Andropogon* spp.) and blackberry (*Rubus* spp.). It is notable that vines of the genus Smilax are also invariably present in pine tree farms.

Succession of a limited sort is obvious in pine silviculture. At first, the planted pines grow in an open prairielike environment with grasses and forbs abundant. After 8–15 years, however, depending on soils, the pine canopy closes and shades the ground so severely that often only a brown carpet of pine needles is visible on the forest floor.

d. Fauna. The pine trees of pine tree farms produce resinous, acid litter that neither decomposes readily nor is readily eaten by many primary consumers. Among those that do eat the dead needles are harvestmen, which are reasonably numerous in silvicultural sites. Other insects are generally restricted to lepidopteran larvae adapted to eating pine needles or beetle larvae and adults that eat the cambium of trees.

Amphibians are restricted to those species that enter silviculture sites from adjacent communities. Most notable is the southern toad (*Bufo terrestris*): others are the oak toad (*B. quercicus*), and, usually, the pinewoods tree frog (*Hyla femoralis*). These eat the insects and other arthropods found in the litter or on boles of trees.

Lizards are scarce because of the paucity of insects, but usually the ubiquitous anole (*Anolis carolinensis*) can be found at least near the edges of silvicultural sites. Sometimes the eastern glass lizard (*Ophisaurus ventralis*) is present, and in pine tree farms in sandhills, the fence swift (*Sceloporus undulatus*) can be found. Snakes are almost nonexistent in pine tree farms because they feed at higher trophic levels than insects, but if a snake is to be found it most likely is the black racer (*Coluber constrictor*), which feeds on lizards. It is common to see the gopher tortoise (*Gopherus polyphemus*) dig out of its burrow after site preparation, and gopher tortoise populations flourish after replanting on silvicultural sites; invariably after about 10 years, when the canopy closes and shades out the valuable herbaceous groundcover food of the tortoise, the species becomes locally extinct. This holds true for the entire community of herbs, shrubs, vines, insects, and vertebrates. For the first 5 to 10 years, a productive groundcover flourishes and forms the basis for a rich animal food web. After canopy closure, and until clearcutting 20–40 years later, the entire understory community nearly vanishes.

Before canopy closure, grassland birds are common and do well as both winter visitors and summer residents. After canopy closure, very little bird life visits pine tree farms except those that glean foliage, and feed in the canopy. Few species breed in silvicultural sites.

Mammals are restricted to low density populations of those species that normally inhabit the natural pine forest lands on which a given site is developed. Species usually include the cotton rat (*Sigmodon hispidus*), cotton mouse (*Peromyscus gossypinus*), short-tailed shrew (*Blarina brevicauda*), and the least shrew (*Cryptodus parva*). White-tailed deer (*Odocoileus virginiana*) use pine tree farms in early successional stages when forage is close to the ground and abundant. After canopy closure, whitetail use falls off dramatically. Other mammals usually are transients.

In drift fence studies on silvicultural plots on the Apalachicola National Forest, Means (unpubl. data) trapped the rare southeastern shrew (*Sorex longirostris*) in a flatwood slash pine forest that was bedded. Generally, no rare, endangered, or threatened species are restricted to pine tree farms, or even commonly found there.

Chapter 6. FRESHWATER HABITATS

6.1 Introduction

We define the freshwater habitats of Panhandle Florida as beginning where the water table first rises to the elevation of the soil surface. This usually happens at the lower sides of catchment slopes, somewhere near the stream valley bottom. Habitats that are neither strictly aquatic nor strictly terrestrial are called wetlands. Downslope, water from wetlands flows in an ever increasing volume as it works its way to the sea. As it joins other water to form larger and larger channels, the increasing volume of water and its changing physical attributes create a continuum of changing aquatic habitats. These habitats as well as ponds, swamps, and lakes are all considered in this chapter.

The U. S. Fish and Wildlife Service (USFWS) (Cowardin, et al. 1979, p. 3) defines wetlands to be "...lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water...wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soils; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Under the unpublished classification scheme of the Florida Natural Areas Inventory (FNAI), communities in Florida having these characteristics are classified as "palustrine." These are "...lands regularly inundated or saturated by freshwater and characterized by wetland vegetation." The FNAI list contains 19 palustrine community types of which all are found in Panhandle Florida. Below we use the FNAI designations, expand upon them where we believe it warranted, or at least mention them under our own heading.

The terms "lotic" and "lentic" are usually used in aquatic systems to refer to bodies of open water either running (lotic), such as rivers, creeks and streams; or standing (lentic), such as ponds and lakes. Wetlands that are periodically or ephemerally covered with water may be incorporated into this scheme depending on their source and period of inundation. In this particular case the term lotic is expanded to include not only the aquatic portions of streams but their associated floodplain wetlands as well. Likewise, standing water wetlands such as swamps, marshes, and savannas which may fringe the margin of lakes and ponds are called lentic systems.

The treatment of freshwater habitats will follow the same pattern as that in the section on terrestrial habitats: freshwater habitats are considered to be aligned along a soil moisture and stream gradient. The first freshwater habitats discussed are those immediately downslope from dry ground, called wetlands, or palustrine habitats. Next, we will discuss streams and rivers that form as water flows downhill from palustrine habitats into channels sculpted by water in the landform.

It is important to note that the slope of the catchment valley sidewalls has a very strong influence upon the type of wetland or stream encountered. In catchments with steep slopes cut by gully erosion, streams and the adjacent wetlands are confined to a narrow band where the two slopes intersect. The hydrology and biology of such streams is very different from streams with gently sloping valley walls. When stream catchments are not deeply etched into the landform, such as those in the flatwoods of the Coastal Lowlands, the wetlands adjacent to the stream form very broad fringing zones.

6.2 Native Palustrine Habitats

6.2.1 Herb Bogs and Savannahs

Much of the geological structure underlying the Florida Panhandle is deep, porous sand often containing relatively impermeable clay lenses. In combination with the high annual rainfall, this condition causes the buildup of small reservoirs of perched groundwater. Where slopes are very steep, such as those in steepheads that characteristically are 45° or more, seepage escapes into a well-defined stream channel, and little boggy wetland exists. But where the sloping ground surface is very gentle, such as in the Gulf Coastal Lowlands (Figure 5), it intersects the horizontal water table over a fairly broad zone. Here the water seeps laterally, forming wetlands called bogs (Figure 63).

The first of the wetland zones normally encountered downslope from longleaf pine forests in stream valleys with gentle slopes, is called a "seepage bog," or a "herb bog." Panhandle Florida and the adjacent lower Gulf Coastal Plain of Alabama and Mississippi were once nearly continuous bogs (Bartram 1791, Harper 1914), containing one of North America's most unusual assemblages of animals and plants, including many that are rare, endangered, or endemic. Calculations by Folkerts (1982) indicate that nearly 97% of the original herb bog habitat has been destroyed throughout the Gulf Coastal Plain. The largest acreage and some of the best remaining examples of this unique wetland type are found in the Coastal Lowlands areas in Panhandle drainage basins from the Perdido to the Ochlockonee Rivers. Seepage bogs decline rapidly in both acreage and number to the east of the Ochlockonee, and are not a particularly important habitat type in the Florida Big Bend.

Although defined as wetlands, seepage bogs of various types are sometimes quite dry. During periods of wet weather when the perched aquifers are fully charged, seepage is continuous and the soil of herb bogs is moist and difficult to walk in because of sinking into the wet organic deposits. At the other extreme, during seasonal or extended droughts, the soil of herb bogs tends to dry out and sometimes crack. In order to tolerate the drastic soil moisture changes animals and plants must have specific adaptations to resist death or physiological stress.

Because of the activity of the mineral components of the soils, bog soils typically are low in pH. Values range from 3.4 to 5.0 (Wharton 1977, Clewell 1981, Folkerts 1982). This, coupled with low-nutrient soils, makes bogs home to only those plants that can tolerate such extreme conditions.

a. Flora. Typically, Panhandle seepage bogs contain insectivorous plants, including two or more species of *Drosera*, the sundews; two or more species of *Sarracenia*, the pitcher-plants; two or more of *Pinguicula*, the butterworts; and occasionally *Utricularia*, the bladderworts. Because the distinctive leaves of some species of pitcher plants are so conspicuous, these bogs are often called "pitcher plant bogs." Many other genera of forbs characteristic of highly acid sites are associated with the carnivorous plants, including *Sphagnum*, *Eriocaulon*, *Calopogon*, *Habenaria*, and *Burmannia*. Wiregrass (*Aristida stricta*), beaked rushes (*Rhynchospora*), panic-grasses (*Panicum*), and sedges are among other dominant herbs.

When the seepage slopes of flatwoods stream valleys are extremely gently inclined, the herb bog zone can be hundreds of meters wide (Figure 64). In this case, the open, treeless plain often is called a savannah. The region located in the western half of the Apalachicola National Forest between the settlements of Wilma and Sumatra is particularly noted for extensive seepage bog savannahs developed on fine clays and silts (Clewell 1971).

Clewell (1971) has studied these savannahs and believes there are four variations:

(1) *Verbesina* phase. This is an open savannah with loamy surface soils. The indicator species is Chapman's crownbeard, *Verbesina chapmanii*, a summer flowering composite.

(2) *Pleea* phase. This too is an open savannah, but with sandy soil. The indicator species in the ground cover is an autumn flowering lily, rush featherling (*Pleea tenuifolia*).

(3) Hatrack phase. This is a less open savannah with one to many stunted slash pines (*Pinus elliottii*) with spindly trunks and abbreviated limbs.

(4) Pine-titi phase. This is an even less open savannah with some *Pleea* and larger slash pine, pond pine (*Pinus serotina*), titi (*Cyrilla* spp., *Cliftonia monophylla*), cypress (*Taxodium distichum* var. *nu-*

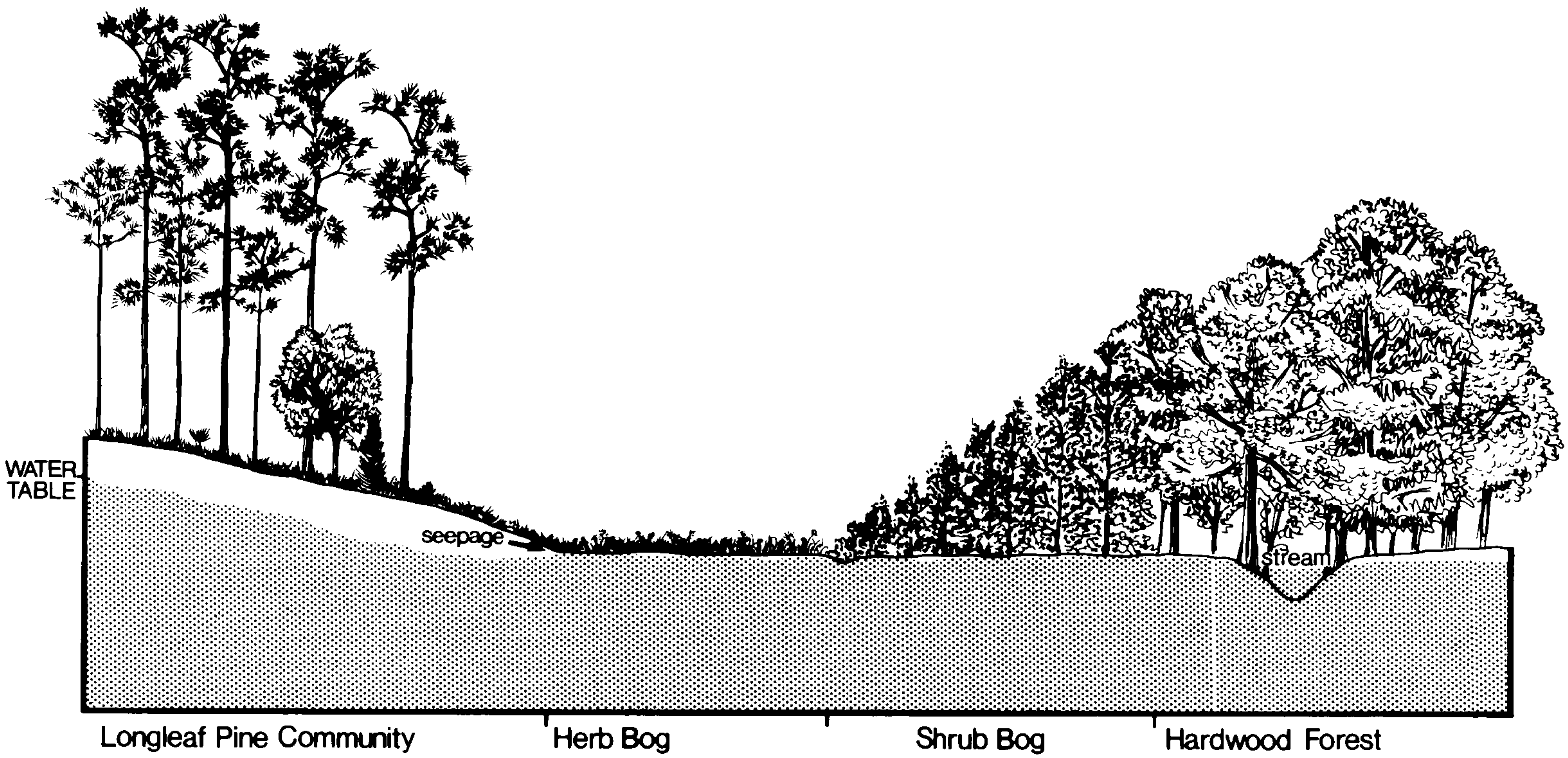


Figure 63. Flatwoods seepage bog developed along a gentle slope/moisture gradient.

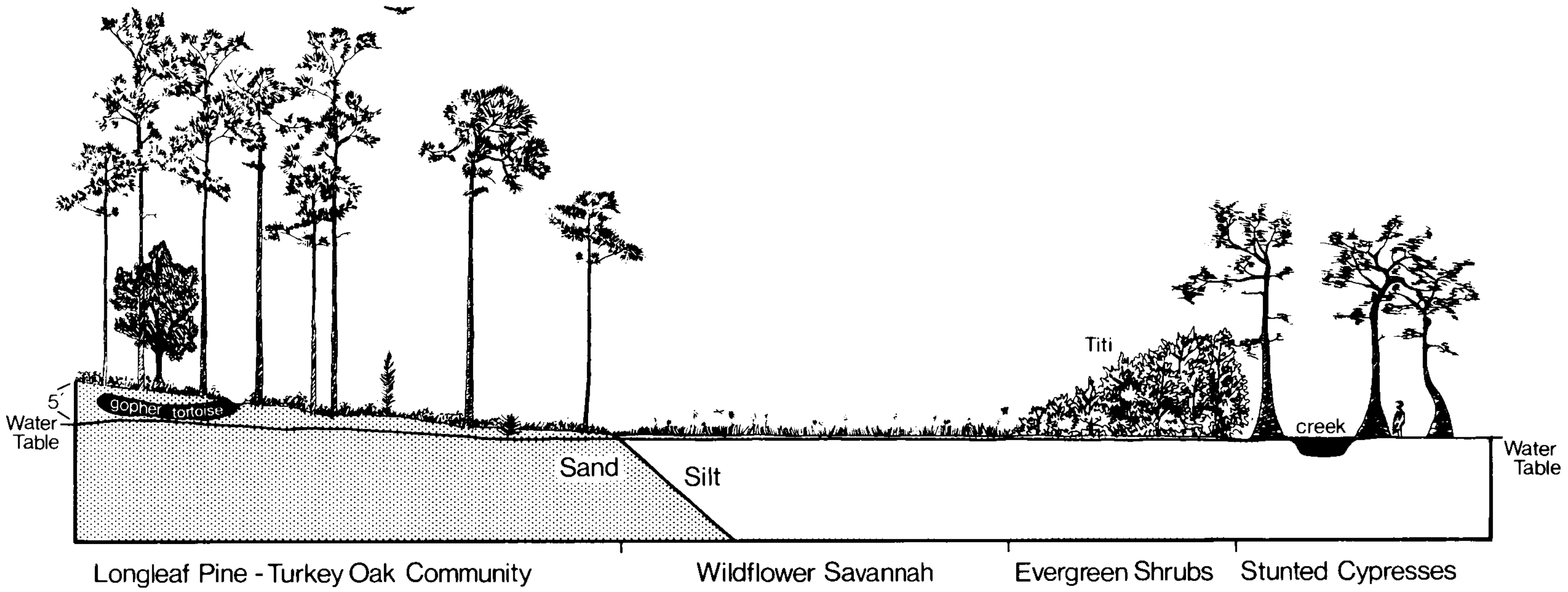


Figure 64. Flatwoods savannah, a special case of a seepage bog that is underlain by silt and has a nearly level slope.

tans), sweet bay (*Magnolia virginiana*), wax myrtle (*Myrica cerifera*), fetter-bush (*Lyonia lucida*), myrtle-leaf holly (*Ilex myrtifolia*), and large gallberry (*Ilex coriacea*).

This fourth phase is regarded as continuous with titi swamps. Were it not for the lack of saw palmetto (*Serenoa repens)* and the presence of pitcher-plants and other characteristic savannah species, the pine-titi phase could be considered transitional to titi swamps.

These communities are noted for their dense growth of grasses and sedges interspersed with an abundance of wild flowers numbering well over a hundred species. Among these are many orchids and insectivorous plants. Wiregrass usually dominates although it may be absent from the *Pleea* phase. Species of *Panicum* are also important. Beak rush (*Rhynchospora chapmanii, R. plumosa*) and several nut rushes (*Scleria baldwinii, S. reticularis*) are among the more important sedges. A pseudocanopy of St. Johnswort (*Hypericum* sp.) often covers the entire community. The needlelike leaves apparently allow considerable light to reach the ground cover below.

The level of soil moisture in savannahs is consistently higher than in pine flatwoods and even in some bay communities. The heavy loams and highly organic sands are indicative of a perched water table. After heavy rains the soils may be totally saturated for extended periods, giving rise to the name herb bog.

In addition to the ecotone between the pine-titi phase and the titi swamps, savannahs also intergrade with savannah swamps and longleaf pine flats. Clewell (1971) summarizes the ecological relationships of savannahs to other vegetation and theories on their origin and maintenance. According to Clewell, *Verbesina chapmanii* grows only in heavy soils and *Pleea tenuifolia* only in sands or sandy loams; they do not grow together. Barbara's-buttons (*Marshallia graminifolia*) may also be a good indicator of the *Pleea* phase. Several other species seem to be associated only with *Verbesina* savannahs. The *Verbesina* phase is generally freer of shrubs and does not contain black titi, fetterbush, or large gallberry. The clays underlying the *Verbesina* phase extend downward at least 8 ft. The proximity of these clays to the Apalachicola River suggests that they represent alluvial deposits, which accumulated as the river shifted course during the Pleistocene. Ripples of sand on top of these clays provide the elevated knolls upon which longleaf pines grow.

The curious hat rack slash pines may have become established during periods of fire suppression. The poorly adapted pines were able to grow sufficiently to withstand the next fire. Pritchett (1969) studied slash pine growth in a savannah having a weston fine sandy loam, which is a humic gley soil. He found that the poor drainage caused by a sandy clay substrate within 25 cm of the surface, reduced the aeration needed for growth in pine roots. He also found that low levels of phosphorus restricted growth. Applications of phosphate on an unditched site with minimal site preparation raised the site index (a numerical evaluation of the quality of a habitat for plant productivity used by the U.S. Forest Service) from 28 to 68 .

The question has been raised whether southeastern savannahs are successional, permanent, or artifactual communities. Penfound (1952) suggested that savannahs could be created by excessive fire or logging. Wells and Shunk (1928, 1931) in a classic study on a savannah in North Carolina noted that nearly all savannah vegetation grew on hammocks which they believed to be the soil around former root systems in a shrub-bog of blackgum (*Nyssa sylvatica*) and swamp titi (*Cyrilla racemiflora*). With a drop in the water table in post-Pleistocene times, the savannah replaced the shrub-bog, at least in part because of increase in the incidence of fire associated with a drier habitat.

Pessin and Smith (1938) noted that the logging of longleaf pines resulted in a higher water table in successive years and in a subsequent invasion of pitcher-plants and other savannah species which had been absent previously. They suggested that removing the trees reduced the evapotranspiration sufficiently to raise the water table, or rather to prevent its being lowered. Wahlenberg (1946) expressed the same opinion on savannah formation.

Quintus A. Kyle (pers. comm. to Clewell 1971) added substance to that theory. He said that some of the present savannahs west of Bradwell Bay in the Apalachicola National Forest (ANF) were formerly low, wet longleaf pine flatwoods that were not as densely stocked as pine-palmetto flatwoods usually are. These pines were cut in about 1915, and thereafter the water table rose and savannah vegetation became evident. It seems likely that the acreage of savannahs has increased since the initial logging in the ANF. If so, much of the *Pleea* phase may have once been low flatwoods, which are now being converted to savannah because of a rise in the water table. The pine-titi phase would then represent additional areas being converted to savannahs, but lack of fire has allowed the invasion of brush.

Of course the reduction in evapotranspiration is not necessarily the only mechanism for raising water tables and thereby creating savannahs. Clewell (1971) suggested that slumping of the surface could be creating wet depressions as organic acids dissolve calcareous deposits in underlying Miocene clastics.

The *Verbesina* savannahs lack pine stumps, but adjacent longleaf pine flats still retain stumps remaining from the original timber harvest. This observation suggests that the *Verbesina* phase is a permanent, edaphic vegetation type, and was not created via recent reductions in evapotranspiration. The heavy soils probably retain water much more effectively than sands. Evidence for this comes from a somewhat loamy savannah of the *Pleea* phase near Fort Gadsden (SW 1/4 Sec. 29, T6S R7W), where the savannah is actually a foot or so higher in elevation than the adjoining, sandier, drier pine-palmetto flatwoods (Clewell 1971).

Changes in savannahs in northwest Florida resulting from disturbance were indicated by Pullen and Plummer (1961). They resurveyed a savannah studied in 1906 by R. M. Harper, which had since been drained and intensively grazed. They counted 98 species not listed by Harper, many of them weedy, that were introduced because of disturbance. They also said that about 50 species had been eliminated, including spectacular species of pitcher-plants (*Sarracenia* spp.), sundew (*Drosera* spp.), *Agalinis, Aster, Coreopsis*, colic-root (*Aletris* spp.), meadow-beauty (*Rhexia* spp.), cone-flower (*Rudbeckia* spp.), *Sabatia* spp., and *Balduina* spp.

Wells and Shunk (1928) noted the complete lack of legumes in a savannah in North Carolina. Legumes are rare or absent in savannahs of the ANF, although many species are represented, some abundantly, in adjacent pinelands. Perhaps the nitrogen-fixing bacteria in leguminous roots cannot survive the long hydroperiods of savannah soils.

Wells (1967) remarked on the large number of species with leaves appressed against their stems, which he interpreted as a mechanism to prevent transpiration. Plants of savannahs may be physiological xerophytes, even though they grow in wet soils, because high acidity prevents the rapid absorption of water.

b. Fauna. As expected in a plant community lacking trees and shrubs, no arboreal fauna is present. The herb-dominated bogs and savannahs of the Panhandle support a rich diversity of insects that feed upon the numerous species of groundcover plants. These in turn feed a small group of vertebrate insectivores, including most notably the pine woods tree frog (*Hyla femoralis*), the ornate chorus frog (*Pseudacris ornata*), and the Florida chorus frog (*P. nigrita*). Burrowing crayfishes of the genera *Cambarus* and *Procambarus* (Hobbs 1942) can be unusually abundant in herb bogs. Although never studied, it appears quite probable that burrowing crayfishes have a strong beneficial influence upon other animals that use the burrows for protection from enemies and the elements. Among these species are the two-toed amphiuma (*Amphiuma means*), southern dusky salamander (*Desmognathus auriculatus*), and the mud salamander (*Pseudotriton montanus*).

In the western Panhandle from Washington to Santa Rosa Counties, the pine barrens tree frog (*Hyla andersonii*) seems to be exclusively dependent upon herb bog seepage sites for breeding (Means and Longden 1976, Means and Moler 1979).

Reptiles that use herb bogs include the garter, ribbon, and mud snakes (*Thamnophis sirtalis, T. sauritus, Farancia abacura*). The mud turtle (*Kinosternon subrubrum*) and box turtle (*Terrapene carolina*) are also common herb bog inhabitants.

Grassland birds like the meadow lark (*Sturnella magna*) and the red-winged blackbird (*Agelaius* *phoeniceus*) are visitors in herb bogs occasionally and the common yellowthroat (*Geothlypis trichas*) is found along shrubby edges. The rice rat (*Oryzomys palustris*) and cotton rat (*Sigmodon hispidus*) are important and common small mammals that live in herb bogs, the rice rat being more at home during wet weather when the bogs are wet, and the cotton rats more so during drought.

6.2.2 Shrub Bogs, Titi Swamps, and Bay Swamps

Downslope from herb bogs, a dense growth of evergreen shrubs is encountered in Panhandle flatwoods. When fire cycles are operating normally, the transition from open herbaceous prairie to dense, small- and leathery-leaved shrubs is often abrupt (Figure 63). Predominant among these shrubs are the titis of the family Cyrillaceae, with either black titi (*Cliftonia monophylla*) or swamp titi (*Cyrilla racemiflora*), or both, present. Other evergreen shrubby species usually present with the titis are the fetterbushes (*Lyonia lucida* and *Leucothoe racemosa*), myrtles (*Myrica cerifera* and *M. inodora*), dahoon holly (*Ilex cassine*) and large gallberry (*I. coriacea*), sweet pepperbush (*Clethra alnifolia*), and others. In Panhandle Florida evergreen shrub communities of this type usually fringe swamp forests of several types. The shrub zones are rarely extensive, but form a very distinctive transition from the dry soil uplands or moist soil herb bogs to the stream or pond gallery forests described below.

Pine flatwoods are frequently dotted with swampy depressions and minor drainageways occupied by shrub-bog species and small trees, mostly evergreens. Such systems are loosely referred to as "bays" or "bay swamps." These swamps may support primarily titi (*Cyrilla racemiflora, Cliftonia monophylla*), in which case they are called titi swamps. Titi swamps may contain scattered pond pines (*Pinus serotina*) or slash pine (*P. elliottii*) extending above a dense growth of titi. Small, round bay or titi swamps of a few acres or less are locally called ponds, even if they contain no standing water.

Larger bay swamps usually contain taller trees toward the center and are fringed with titi. Sweetbay magnolia (*Magnolia virginiana*) and slash pine are common species. Where such swamps form the headwaters of a small creek, they are known as "bayheads." Intermittent streams lined with elongated bay swamps are known as bay branches. Where Atlantic white-cedar (*Chamaecyparis thyoides*) grows conspicuously within bay or titi swamps the area is locally called a juniper swamp.

Large bay swamps may also encircle moister sites occupied by cypress or blackgum swamps. Cypress swamps that are circular in shape are known as cypress domes or heads because the trees in the center tend to be taller than those along the margins, giving a circular dome shape to the canopy. The center trees may be taller because conditions there are more optimum for cypress growth than the margins. Elsewhere in Florida, researchers have noted that the taller trees in the center may or may not be older than the fringing trees (Duever et al. 1976). Kurz (1933b) hypothesized that the shape of cypress domes was created by the pruning effect of fires. Shorter, younger trees would be produced at the margins by more frequent fires there, and larger, taller trees would result from fewer fires as one moved toward the deeper water in the center of domes. Cypress swamps that are elongated along a slough or other small drainageway are called cypress strands.

Within large areas of bay, cypress, or blackgum swamps, small patches of pine flatwoods may occur. These pine islands usually occupy the more elevated sites.

The ecotonal changes from pineland to titi, bay, cypress, and blackgum swamps usually involve an elevation drop of less than 4 m (12 ft). The horizontal distance may be as small as 16–66 m (50–200 ft). Below this point or as the size of the swamps increase, the community type changes to bottomland hardwood forest or cypress-gum swamp forest.

a. Bay swamps. Clewell (1971) identified four phases of bay swamps: (1) Sweetbay phase where sweetbay (*M. virginiana*) is dominant with a few slash pines, swamp bay (*Persea borbonia*) and loblolly bay (*Gordonia lasianthus*); (2) Slash pine phase, with sweetbay present but slash pine dominant; (3) Mixed swamp phase, with dominance shared by sweet bay, blackgum, cypress, sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), water oak (*Quercus nigra*), and diamond-leaf oak (*Q.*

laurifolia); and (4) Atlantic white cedar phase, as mentioned above; Atlantic white cedar (*Chamaecyparis thyoides)* is a conspicuous member of the community.

The patchy, often dense understory of bay swamps contains a mixture of switch cane (*Arundinaria gigantea*), wax myrtle (*Myrica cerifera*), swamp titi (*Cyrilla racemiflora*), sweet pepperbush (*Clethra alnifolia*), and black titi (*Cliftonia monophylla*). Other common species include wild azalea (*Rhododendron canescens*), fetter-bush (*Lyonia lucida*), large gallberry (*Ilex coriacea*), muscadine (*Vitis rotundifolia*), myrtle leaf holly (*I. myrtifolia*), odorless wax myrtle (*Myrica inodora*), climbing fetterbush (*Pieris phyllyreifolia*), an epiphytic shrub on pine or cypress, red chokeberry (*Aronia arbutifolia*), highbush blueberry (*Vaccinium corymbosum*), odorless yellow jessamine (*Gelsemium rankinii*), and poison ivy (*Toxicodendron radicans*).

Ground cover consists of patchy beds of peat moss (*Sphagnum* spp.), Virginia and netted chain ferns (*Woodwardia virginica, W. areolata*), sedges (e.g., *Carex glaucescens*), and grasses (e.g., *Panicum tenerum*). Cane (*Arundinaria gigantea*) may occur in openings.

The soil in bay swamps is highly organic sand often overlain by peat. The peat may erode into hammocks and hollows giving some microrelief to the terrain. The soil is usually moist and at times may be inundated with several inches of water. The water table seldom lies more than 1 m below the ground level. Pines are not common in bay swamps primarily because of the wetness and the buffer provided by fringing titi swamps.

b. Titi swamps. Titi swamps come in five varieties, three of which have a pine overstory: (1) A titi phase with no overstory of pines, (2) A pond pine phase, (3) A slash pine phase, (4) A pond pine-slash pine phase, and (5) A holly phase with neither a pine overstory nor titi, having myrtle-leaf holly as the dominant shrub. Atlantic white cedar may be locally common.

This community is distinguished by its understory of dense shrubbery. The dominant species include one or more of two titi species, black titi (*Cliftonia monophylla*) and swamp titi (*Cyrilla racemiflora*). Black titi is the most common and tends to occur on higher sites than swamp titi. Other common species of shrubs include fetter-bush, large gallberry, and switch cane. Less common but still frequent species include staggerbush (*Lyonia ferruginea*), sweet pepperbush (*Clethra alnifolia*), and odorless wax myrtle. Ground cover is generally absent. Saplings of swamp bay or sweet bay may be present.

Soils in titi swamps are similar to those in bay swamps: highly organic sand overlain by peat. Generally the roots of the shrubs bind the peat soils, but under the influence of fire and intense rainfall erosional channels may develop, leaving little islands of thicker peat between swales burned down to mineral soils. As in bay swamps the water table is always close to the surface. During wet periods standing water pockets are common.

Titi swamps often border on pine flatwoods and may form along the borders between bay swamps and pine communities as well. Titi swamps tend to be poor fuel for the frequent fires that maintain pine dominance in neighboring flatwoods. Usually no more than the outer fringes of titi swamps burn. Thus they act as a protective buffer between pine communities and more fire sensitive bay swamps. In places the titi swamp may also border cypress or blackgum swamps, affording them the same buffer.

During prolonged summer droughts when humidity is low and the water table depressed, fire may spread into the titi swamps or be started there by lightning. Clewell (1971) estimated these conditions could occur once every 5 to 10 years. Wharton et al. (1976) estimated that the fire period in titi swamps was 20–50 years in monospecific stands of black titi. When such fires do ignite, they tend to be very hot and hard to contain. Usually all aerial stems are destroyed and some or all of the peat may also burn. Larger pines if present may survive, but most of the trees and shrubs will be killed if fires burn deeply into the peat and kill their roots.

Subsequent to fires that do not burn into the peat, the titi and other shrubs resprout from root crowns, directly regenerating the swamp without going through successional stages. Often several sprouts may arise from each crown, creating trees and bushes with multiple trunks. It has been suggested that the root crowns of these multitrunk resprouted trees and shrubs may be centuries old (Clewell 1971).

Titis (Cyrillaceae) are but one group of evergreen shrubs or small trees that in the pre-Columbian Coastal Plain naturally occurred downslope from the fire-frequent longleaf pine forest in places where soil moisture was high enough to preclude fires in most normal years. The titis and the other evergreen woody species associated with them are fire-tender hardwoods that die when their stems are heated. The evergreen shrub zone naturally occurs just upslope along the margin of stream hardwood forests occupying creek bottoms where stream valley soils usually are saturated. This was the narrow, original zone of slash pine, also.

When fires are kept out of the flatwoods in the Coastal Lowlands for long periods of time, as they have been in Florida National Forests by anthropogenic factors, the evergreen shrub species of stream hardwoods migrate upslope by seeding and root propagation. This has a twofold effect upon the ecology of the herbaceous wetlands. First, the vegetative species composition obviously changes, and so too does the vegetative structure. Instead of a grass-forb meadow habitat, the herb bog sites become closed-canopied forests of small-diameter, densely stocked evergreen trees. Because woody plants have higher evapotranspiration rates than grasses and forbs, the sheet flow that occurs in herb bogs due to seepage from the intercepted water table is depressed, changing the hydrology of the site. In flatwoods where drainage valley slopes are so gentle that they often cannot be perceived by the naked eye, the woody evergreens and other stream hardwoods expand their distribution well upslope into the longleaf-wiregrass zone. Site preparation probably is more damaging ecologically in titi areas that are to be reclaimed than in any other soil type because the delicate, gentle slope and moisture gradients are severely interrupted by chopping, disking, and bedding, and by running a fire plow through them, channelizing the water flow.

c. Fauna. The animal life of shrub bogs has not been the target of specific studies, but many Panhandle animals are known to use shrub bogs. Two frogs seem to be restricted almost exclusively to shrub bogs and the adjacent herb bogs. One is the pine barrens tree frog, *Hyla andersonii*, which uses the stems of evergreen shrub plants as foraging habitat (Means and Longden 1976, Means and Moler 1979). The other is the bog frog (*Rana okaloosae*), known from wetlands along the margins of the steephead streams of Eglin Air Force Base and a few localities in Santa Rosa, Okaloosa, and Walton counties (Moler 1985 and P. Moler, Florida Game and Fresh Water Fish Commission, Gainesville; pers. comm.).

When enough water is present for breeding, shrub bogs also support populations of the bronze frog (*Rana clamitans*), southern leopard frog (*R. sphenocephala*), green tree frog (*Hyla cinerea*), pine woods tree frog (*H. femoralis*), and spring peeper (*H. crucifer*). The five-lined skink (*Eumeces fasciatus*) and sometimes the coal skink (*E. anthracinus*) are common lizards while the green anole (*Anolis carolinensis*) and ground skink (*Scincella lateralis*) are sometimes abundant at the margins of shrub bogs. Garter snakes (*Thamnophis sirtalis*) and ribbon snakes (*T. sauritus*) forage in shrub bogs for frogs, as does the black racer (*Coluber constrictor*) and the endangered indigo snake (*Drymarchon corais*).

6.2.3 Bottomland Hardwood Forests

The forested floodplain of the Apalachicola watershed is the largest in Florida, covering approximately 450 km^2 (173 mi^2) (Wharton et al. 1976). The predominant species in terms of cover include water tupelo (*Nyssa aquatica*), ogeechee tupelo (*N. ogeche*), baldcypress (*Taxodium distichum*), carolina ash (*Fraxinus caroliniana*), swamp tupelo or blackgum (*Nyssa sylvatica biflora*), sweetgum (*Liquidambar styraciflua*), and overcup oak (*Quercus lyrata*). These species are typical of alluvial floodplains in the southeastern United States and occur in such areas partially because of their ability to withstand saturated and inundated soils (Wharton et al. 1976).

The distribution of floodplain trees in the Apalachicola basin has been described in detail by Leitman (1978, 1984) and Leitman et al. (1983). In these studies vegetative composition was shown to be

Table 12. Types, species composition, and distinguishing characteristics of bottomland hardwood forests of the Apalachicola River (from Leitman et al. 1983).

Name	Definition	Chief associates	Common associates
Type A: Sweetgum–sugar-berry–water oak.	Sweetgum, sugarberry, water oak, American hornbeam, possumhaw, are predominant.[a]	Diamond-leaf oak, green ash.	American elm, American sycamore, water hickory.
Type B: Water hickory–green ash–overcup oak–diamond-leaf oak.	Water hickory, green ash, overcup oak, diamond-leaf oak, sweetgum, American elm are predominant.[a]	Sugarberry, red maple.	Water oak, possumhaw, American hornbeam, water tupelo, Ogeechee tupelo, baldcypress.
Type C: Water tupelo–Ogeechee tupelo–baldcypress.	Water tupelo, Ogeechee tupelo, baldcypress, swamp tupelo, Carolina ash, planertree are predominant but not pure.[a]	Overcup oak, pumpkin ash, red maple.	Water hickory, American elm, green ash, diamond-leaf oak, sweetbay.
Type D: Water tupelo–swamp tupelo.	Water tupelo, swamp tupelo, Ogeechee tupelo, baldcypress, Carolina ash, pumpkin ash, planertree, sweetbay are pure[a, b]	—	—
Type E: Water tupelo–baldcypress.	Water tupelo, baldcypress, Ogeechee tupelo, Carolina ash, planertree are pure.[a]	—	—

[a] Predominant: comprising 50% or more of basal area; pure: comprising 95% or more of basal area.
[b] Swamp tupelo, pumpkin ash, or sweetbay serve as indicator species to distinguish this type from type E.

highly correlated with depth of water, duration of inundation and saturation, sediment grain size, and water level. These hydrologic conditions are, in turn, controlled by the height of natural riverbank levees and the size and distribution of levee breaks along the river. A description of forest types, their species composition, and distinguishing characteristics is presented in Table 12 from transect plots surveyed by Leitman et al. (1983).

Alluvial rivers have broad floodplains that are dominated by two very important hydrological processes: high water and low water. During low water stages, the water flows in a meandering channel that, with time, wanders back and forth across the floodplain and continually resculpts it. The scouring action of water at the outside bends of meander loops continually undercuts the channel bank, causing the stream channel to migrate in the direction of the meander loop. Sediment eroded from the outside bends of meander loops is deposited downstream on the inside of the next bend in the river, on the advancing end of the point bar. Point bars have successional stages of plant communities developing on them from the youngest pioneer stages on new sand berms at water's edge to stable hardwood forests farther back from the water.

When rising water leaves the low-water channel, it loses its velocity—and thus its sediment carrying power—creating piles of coarser sediments called levees, or berms, along the channel banks. The coarser sediments are dropped first, and finer sediments such as silts and clays are carried farther out into the floodplain. It is not uncommon for silt and clay several inches to a few feet deep to be deposited on the floodplain floor away from the low water channel after every high water rise.

Each Panhandle river has its great annual rise sometime between midwinter and midspring (January to April), when water volume may exceed 100 times or more the normal volume in the low water channel (Foose 1983). During this 3-month period, water extends across the entire floodplain from one valley sidewall to the other. Only flood-tolerant species of plants and animals can survive in floodplains. Floodplain communities, therefore, are true wetlands, characterized by specialized wetlands species. True terrestrial vegetation is found above the level of the annual high water at the extreme lateral margins of the floodplain. The inundated floodplain of the Apalachicola River during the annual high water levels ranges from 2300 m (1.4 mi) to 6500 m (4.0 mi) wide (Leitman et al. 1983). The Apalachicola River floodplain remains inundated annually for periods ranging from 1 to 5 months (Foose 1983).

a. Ecology. A sweetgum-water oak-loblolly pine (*Liquidambar styraciflua-Quercus nigra-Pinus taeda*) association is found in dry to damp soils on elevated slopes. This forest association is most prevalent in the middle reach of the river, decreasing in area as the water hickory-overcup oak-sugarberry (*Carya aquatica-Quercus lyrata-Celtis laevigata*) association increases. This association covers approximately 43% of the floodplain, mainly in the upper and middle reaches of the river basin, and becomes increasingly uncommon in the lower reaches of the river valley where it occupies a narrow band along the river. Dominant in the lower reaches of the river basin is a tupelo-cypress-mixed hardwood association covering over 38% of the lower floodplain. Found in dry to saturated soils, this association is concentrated along existing and relict waterways just upland from the water hickory-overcup oak-sugarberry association. A somewhat similar tupelo-baldcypress (*Nyssa aquatica-Taxodium distichum*) association is located in damp to saturated soils along the entire length of the river. In addition to these major forest associations a pioneer community, dominated by black willow (*Salix nigra*), occupies a narrow zone in areas inundated more than 25% of the time.

When all forest types are considered, tupelo, baldcypress, and ash (*Fraxinus* spp.) are the three most abundant species in descending order (Table 13). Total leaf production follows the same general ranking with only a few exceptions (Elder and Cairns 1982). It is surprising, however, that relative leaf production per stem biomass of individual tree species displays a different trend. Low abundance trees such as sugarberry, overcup oak, American hornbeam (*Carpinus caroliniana*), and elm (*Ulmus* spp.) are high in relative leaf productivity while tupelo, cypress, and ash are low (Figure 65). Although no explanation for this has been advanced, it seems possible that trees occurring in saturated (and anaerobic) soils such as tupelo, cypress, and ash may be nutrient limited or may be investing energy in stem and trunk biomass. The expanded basal areas of these trees relative to other tree species strongly suggest that they invest more than an average amount of energy into stem and trunk biomass production, perhaps to aid in stabilization. This may be done at the cost of leaf production. In contrast, the more upland species can afford greater leaf production which may improve their competitive ability for light and canopy space. The higher rates of leaf production may result from investing less energy in stem and trunk biomass and perhaps from higher nutrient concentrations.

A plot of total leaf production versus hydroperiod would yield a bell-shaped curve according to productivity data of Elder and Cairns (1982). At the peak of this curve is a forest characterized by high tree species diversity and low to moderate inundation. Although speculative, this peak in leaf production

Table 13. Species abundance for all forest types combined (from Leitman et al. 1983). Species are ranked in order from most important to least important in terms of basal area. Absolute basal area and density upon which these percentages are based are 201 ft^2/acre (46.2 m^2/ha) and 623 trees /acre (1.540 trees/ha), respectively. Because of rounding, percentages given will not necessarily total 100.

Species	Relative basal area (%)	Relative density (%)
Water tupelo (*Nyssa aquatica*)	29.9	12.8
Ogeechee tupelo (*Nyssa ogeche*)	11.0	6.6
Baldcypress (*Taxodium distichum*)	10.6	5.5
Carolina ash (*Fraxinus caroliniana*)	5.4	11.5
Swamp tupelo or blackgum (*Nyssa sylvatica biflora*)	5.0	2.0
Sweetgum (*Liquidambar styraciflua*)	4.8	3.2
Overcup oak (*Quercus lyrata*)	3.2	2.0
Planertree[a] (*Planera aquatica*)	2.9	9.4
Green ash (*Fraxinus pennsylvanica*)	2.9	2.7
Water hickory (*Carya aquatica*)	2.9	0.8
Sugarberry or hackberry (*Celtis laevigata*)	2.8	2.1
Diamond-leaf or laurel oak (*Quercus laurifolia*)	2.5	1.4
American elm (*Ulmus americana*)	2.4	1.2
American hornbeam (*Carpinus caroliniana*)	2.0	4.7
Pumpkin ash (*Fraxinus profunda*)[b]	1.9	4.4
Water oak (*Quercus nigra*)	1.8	0.5
Red Maple (*Acer rubrum*)	1.5	4.8
Sweetbay (*Magnolia virginiana*)	1.0	0.5
River birch (*Betula nigra*)	0.8	0.7
Possumhaw (*Ilex decidua*)	0.8	10.5
American sycamore (*Platanus occidentalis*)	0.6	0.3
Swamp cottonwood (*Populus heterophylla*)	0.4	0.4
Black willow (*Salix nigra*)	0.4	0.4
Swamp chestnut oak (*Quercus prinus*)[c]	0.3	0.1
Box elder (*Acer negundo*)	0.3	0.8

Other species found:

Green haw (*Crataegus viridus*)
Cabbage palmetto (*Sabal palmetto*)
Water locust (*Gleditsia aquatica*)
Red mulberry (*Morus rubra*)
Swamp-privet (*Forestiera acuminata*)
Winged elm (*Ulmus alata*)
Slippery elm (*Ulmus rubra*)
Cherrybark oak (*Quercus falcata* var. *pagodaefolia*)
Stiffcornel dogwood (*Cornus foemina*)[d]
Chinaberry (*Melia azedarach*)[e]
Black tupelo or sourgum (*Nyssa sylvatica*[f])
Buttonbush (*Cephalanthus occidentalis*)
Spruce pine (*Pinus glabra*)
Loblolly pine (*Pinus taeda*)
Buckthorn bumelia (*Bumelia lycioides*)
Parsley haw (*Crataegus marshallii*)
Common persimmon (*Diospyros virginiana*)
Black walnut (*Juglans nigra*)
Titi (*Cyrilla racemiflora*)
Witherod viburnum (*Viburnum cassinoides*)
Little silverbell (*Halesia parviflora*)
Plus a total of 22 additional species.

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[a] Water elm according to Little (1979).

[b] Some trees identified as pumpkin ash may have been Carolina ash or green ash. Samaras (winged seeds) had dropped from the trees and seeds of all three species were mixed on the ground beneath the trees.

[c] *Quercus michauxii* according to Little (1979).

[d] Swamp dogwood (*Cornus stricta*) according to Little (1979).

[e] Introduced exotic species.

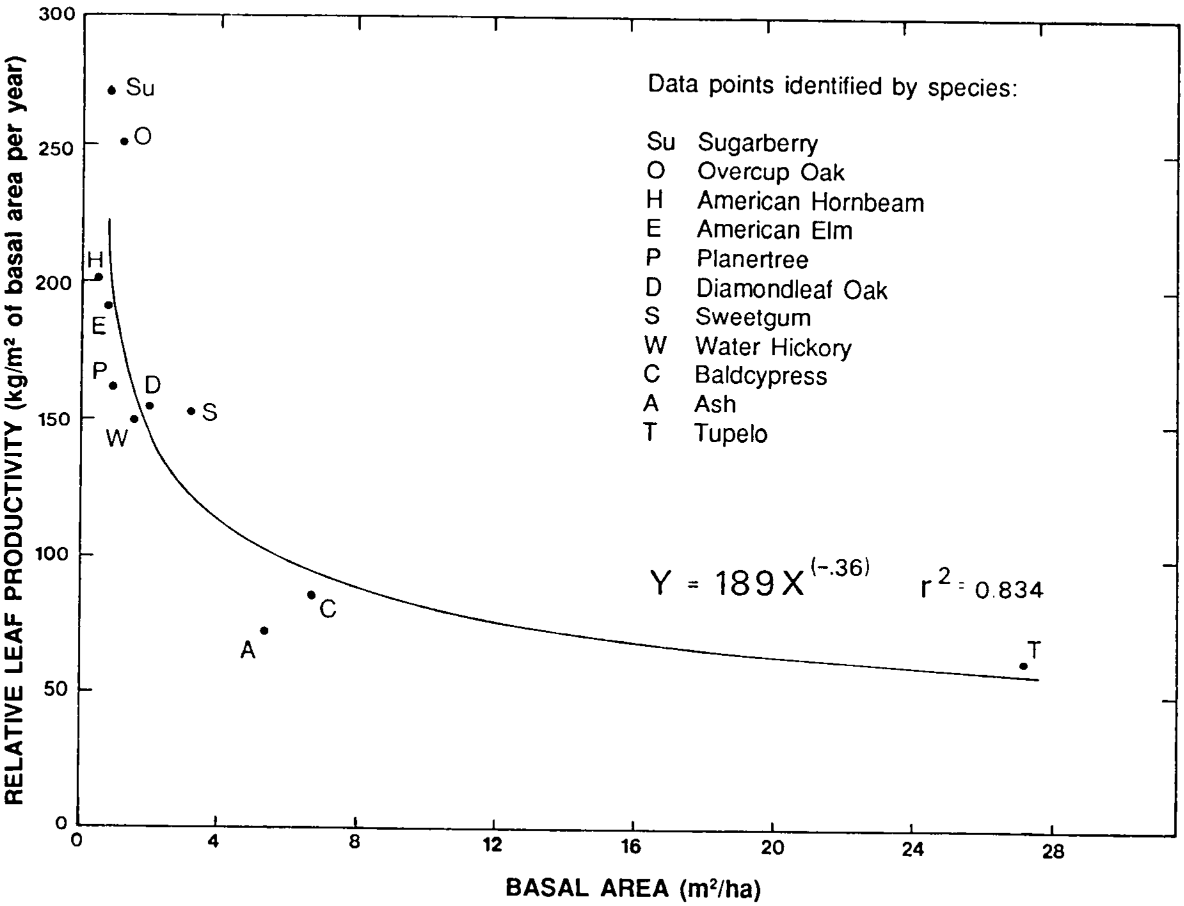


Figure 65. Relative leaf productivity per stem biomass of 11 major leaf-fall producers (trees) in the Apalachicola River flood plain (Elder and Cairns 1982).

may reflect the location of optimum conditions for floodplain forest growth. Further upland, forest productivity may be limited by competition for canopy space, nutrients, and less than optimum hydroperiod; closest to the river, productivity may be limited by the physical and chemical stresses of the increasing hydroperiod. This possibility is reminiscent of the theoretical maximum proposed for mangrove forest productivity within the freshwater to saline gradient (Carter et al. 1973).

The rate of leaf and litter production varies not only seasonally, but also as a function of forest type, individual species, and background conditions. Three patterns of seasonality are identified by Elder and Cairns (1982). The first pattern is one of high rates of leaf fall in September through December, followed by no leaf fall through late spring and only minimal rates in summer. Representative species exhibiting this pattern include water hickory, baldcypress, ash, American elm, grape (*Vitis rotundifolia*), and American hornbeam. A second pattern of leaf fall is represented by tupelo and sweetgum. These trees begin to shed leaves in the early spring and steadily increase the rate through late fall. By midwinter no leaves are falling. The third pattern is exemplified by diamond-leaf oak (*Quercus laurifolia*), overcup oak, sugarberry, and planer tree (*Planera aquatica*). These species start shedding leaves in early fall followed by a sustained release that peaks in December and January. During spring the rate decreases and by May or June leaf fall has ceased. Examples of these seasonal leaf fall patterns for three representative species are shown in Figure 66.

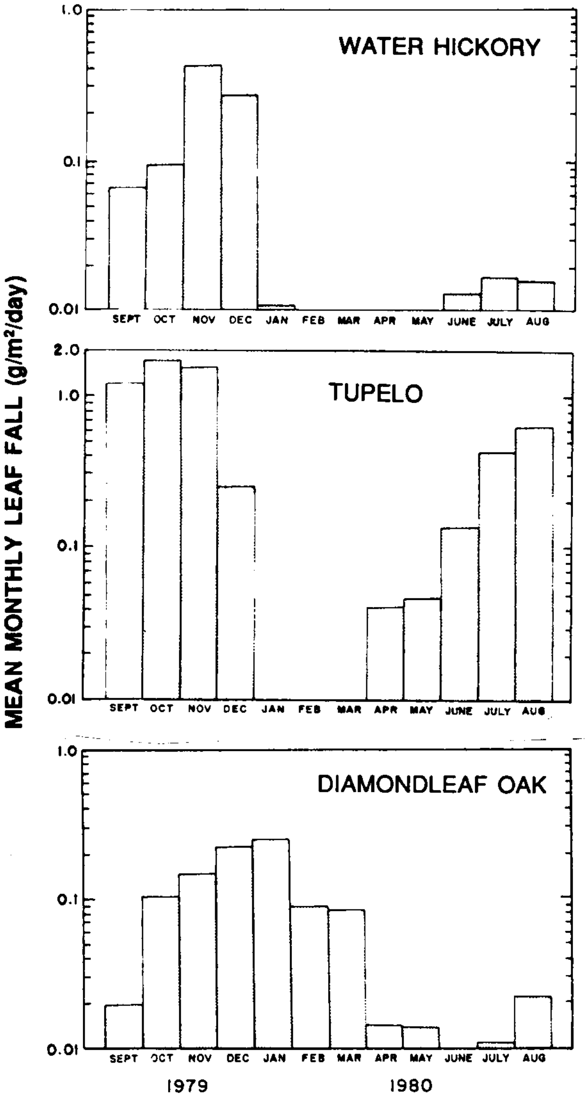


Figure 66. Mean monthly leaf fall of three representative species of intensive–transect plots in Apalachicola River flood plain (Elder and Cairns 1982).

Once on the forest floor, the rate of decomposition varies with species, environmental conditions, and the supply of chemical substance (i.e., nitrogen, phosphorus, carbon). Of five tree species monitored on continuously flooded sites, tupelo and sweetgum leaves degrade the fastest, losing essentially all of their biomass in 6 months. Baldcypress and diamondleaf oak degrade the slowest losing only 40% of their biomass in the same time period. Water hickory is intermediate in decomposition rate, and it is the most variable, with 25%–30% remaining after 6 months. On dry sites, decomposition rates are considerably lower, though the relative species rankings remain the same. The fast decomposers have approximately 60% remaining after six months, the slow ones 90%. It appears that inundation by flood waters increases the decomposition rate, a finding similar to that reported by Heald (1969) for red mangrove leaves.

Another factor controlling decomposition rate is the physical-chemical nature of the water and soil. The rate of loss of carbon, nitrogen, and phosphorus from litter are slowest in the floodplain, higher in river water, and highest at submerged locations influenced by estuarine waters. Phosphorus and nitrogen decline exponentially, with phosphorus being lost more rapidly. Carbon and total leaf material show a linear rate of decrease (Figure 67).

Apalachicola floodplain forests are an important source of energy to the river and estuary. The quantity of nutrients generated from litterfall is more than that from any other source except the upstream drainage basin (i.e., Flint and Chattahoochee Rivers). What makes the floodplain source even more important is the form in which it supplies nutrients, as particulate matter. Although the upstream basin may supply a greater load of nutrients, the bulk of this energy is in the dissolved form. Lake Seminole acts as a large settling basin for particulate matter, lowering the load delivered downstream. This causes partially decomposed leaves and other forest litter from floodplain forests to take on a relatively more important role in the metabolism of the estuary (Elder and Cairns 1982). Considerable evidence indicates that detritus in particulate form is essential to maintaining high levels of estuarine productivity (Livingston 1984).

b. Fauna. The floodplains across the Panhandle are richly endowed with animal life to match their plant species-richness. Productivity available to herbivores in floodplain forests is mostly in the canopy overstory. There, a wealth of consumer insects abounds that feed on the many kinds of leaves, mostly of palatable hardwood species. Feeding on the insects is a rich avifauna dominated by wood

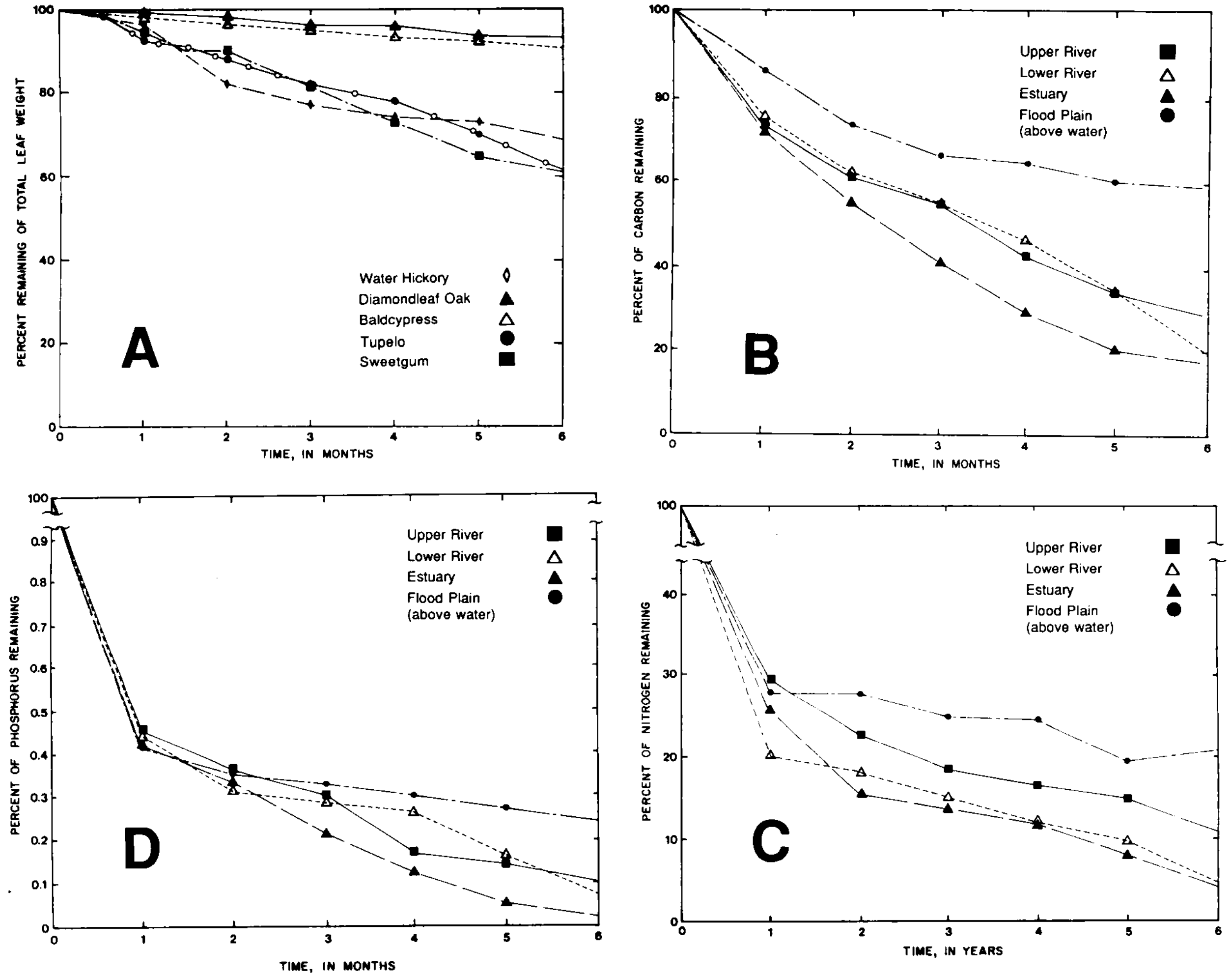


Figure 67. Decline in carbon, phosphorus, nitrogen, and total leaf mass during decomposition in Apalachicola River system (Elder and Cairns 1982).

warblers, many of which breed in these bottomland forests and in no other terrestrial habitats. The parula warbler (*Parula americana*) is one example. The only reptile that capitalizes on the canopy insects is the ubiquitous broad-headed skink (*Eumeces laticeps*).

On the floodplain floor, notwithstanding the lack of primary productivity, a rich fauna exists which is based on (1) decomposing litter from the canopy above, (2) imported litter from tributary streams, (3) nut and seedfall from overstory trees such as sweetgum, water hickory, tupelo gum, blackgum, diamondleaf oak, overcup oak, and others, and (4) the sparse herbaceous groundcover that exists on heavily filtered sunlight. Harvestmen, millipedes, springtails, isopods, and other macroinvertebrates feed directly on the detritus and are themselves food for litter-inhabiting insectivores.

Panhandle floodplains are the home of some vertebrate insectivores that are found only in floodplains. These species eat both litter consuming invertebrates and the surprising number of canopy-inhabiting invertebrates that fall to the forest floor. Among these are Fowler's toad (*Bufo woodhousii fowleri*), upland chorus frog (*Pseudacris triseriata*), northern cricket frog (*Acris crepitans*), southern dusky salamander (*Desmognathus auriculatus*), mud salamander (*Pseudotriton montanus*), one-toed salamander (*Amphiuma pholeter*), and coal skink (*Eumeces anthrocinus*).

The American beaver (*Castor canadensis*), once nearly extirpated from Florida, now is found throughout Panhandle floodplains. Its diet consists of loblolly pine, sweetgum, silverbell (*Halesia diptera*), sweetbay, and ironwood (*Carpinus caroliniana*, predominantly, but other plants employed to one degree or another are tupelo (*Nyssa* spp.), box elder (*Acer negundo*), wax myrtle (*Myrica cerifera*), witch-hazel (*Hamamelis virginiana*), spruce pine (*Pinus glabra*), and others. Beavers are responsible for damming up small streams by creating stick and mud dams across them. In the Panhandle, beaver ponds are commonly found in the abundant water in backswamps, floodplain creeks, and sloughs of the larger river bottomlands.

The eastern wood rat (*Neotoma floridana*) is common in hardwood bottomlands (Lowery 1974), building large stick and debris nests often on bare ground at the base of a tree, in a hollow log, or especially under tangles of muscadine vines (*Vitis spp.*). This rodent is one of the commonest herbivores in bottomland hardwood forests, eating buds, seeds, tubers, roots, nuts, succulent herbs, grasses, berries, and especially oak mast.

6.3 Native Riverine Habitats

There has been very little effort to make comparative studies of the streams and rivers of Florida. Furthermore, there are very few intensive studies of the ecology and limnology of any Panhandle Florida river. We have been unable to find any ecological characterization of the physical, chemical, and biological properties of Panhandle rivers. What knowledge is available resides in many separate studies of single species or specific water quality and hydrology studies.

Beck (1965) made an admirable early attempt to analyze Florida streams and delineate the natural categories he felt they represented. For our purposes, the streams and rivers of Panhandle Florida are loosely organized into three categories, following Beck (1965): (1) alluvial streams, (2) blackwater streams, and (3) spring-run streams. Streams and rivers of the Panhandle, however, while mostly exhibiting the characteristics of one of the above categories, in fact also possess characteristics of the other two stream types. The large, alluvial Apalachicola River for instance, blends its waters with the Chipola River, its largest Florida tributary and a spring-run stream. Another example is the alluvial upper Ochlockonee River which joins the blackwater stream, Telogia Creek.

Unfortunately no student of Florida's streams has made a study of the changes that occur with increasing water volume, showing, for instance, how the ecology of streams may change and be classified along a water volume gradient. Clearly the limnology at the source of a steephead seepage stream differs in the extreme from that of the middle of the Apalachicola River.

When speaking of the size of a stream, we refer to the same stream classification scheme (Figure 60) we referred to when describing the upland vegetation along a stream valley gradient (Strahler 1964).

6.3.1 First-order Ravine Streams

Just as the vegetation and animal life in the terrestrial portion of ravine valleys is distinctive from all other types of upland habitats, the biota of the water column in ravines is very different from other types of aquatic systems. No specific comparative studies of the limnology of Panhandle Florida ravine waters has been carried out, but numerous studies of aquatic invertebrates, and a few studies of aquatic vertebrates, indicate that ravine streams form a special class of aquatic habitats. Moreover, there may be different types of ravine streams as well.

Studies of crayfish (Hobbs 1942), freshwater snails (Thompson 1984), mayflies (Berner 1950), dragonflies (Byers 1930), water beetles (Young 1954), caddisflies (Franz 1982), stoneflies (Stark and Gaufin 1979), and salamanders (Means 1974a,b, 1975; Means and Karlin, in press) indicate that ravine-type headwater streams in the Panhandle are unique aquatic habitats having a specialized fauna of their own. There are good reasons also why ravines of a special type called steepheads (see Chapter 5.2.4) may have entirely different aquatic life than ravines formed by gully erosion (Chapter 5.2.3) (Means 1981, 1985c).

a. Flora. Little is known of the aquatic submerged vegetation of Panhandle ravine streams, but algae and diatoms are commonly visible to the naked eye or using a hand lens, growing on the pea-sized gravels and coarse sands in steephead stream beds. Primary productivity in these streams is most likely somewhat limited because the streams are almost always heavily shaded by a closed hardwood canopy. Productivity derives mostly from litter that falls or washes into ravine streams from the productive hydric hardwood forests of the stream valley bottom (*Magnolia virginiana, Illicium floridanum, Smilax bona-nox)*, and the mesic hardwood forests clothing the lower valley sidewalls. These latter forests usually are the beech-magnolia type (see Chapter 5.2.5 for a description).

b. Fauna. The aerated, cool (65–70°F) clear spring water of steepheads flows over sandy-gravelly substrates from the point on the valley sidewall where ground water seeps laterally. Many of these streams originate from an amphitheatre-shaped valley head where spring sapping takes place along a 270° arc. Water in some Panhandle steepheads has so much volume that fishes such as the creek chub (*Semotilus atromaculatus*), mosquitofish (*Gambusia affinis*), and darters (*Etheostoma* spp.) can be seen within 3–5 m of the spring source. Steephead streams flowing into western Choctawhatchee Bay from Eglin Air Force Base contain the entire distribution of the federally endangered Okaloosa darter (*Etheostoma okaloosae*). All across the Panhandle in first-order streams, Means (1974a,b) discovered a specific suite of plethodontid salamanders that are not found in any other habitats. The larva of these three species live in benthic habitats in ravine streams from 6 months in the case of the central and Apalachicola dusky salamanders (*Desmognathus fuscus conanti, D.* n. sp.) to 3 years in the case of the two-lined salamander and the red salamander (*Eurycea bislineata, Pseudotriton ruber*).

Among the many crayfishes that inhabit Panhandle ravine streams, species of *Procambarus* and *Cambarus* are the diet of the queen snake (*Regina septemvittata*), a crayfish-eating specialist that is relatively rare in Florida, and which lives mostly in Panhandle ravine streams. Occasionally, banded water snakes (*Nerodia fasciata*) find their way into ravine streams, probably to eat fish. The mud turtle (*Kinosternon subrubrum*), loggerhead musk turtle (*Sternotherus minor*), and juvenile snapping turtles (*Chelydra serpentina*) all forage in ravine stream waters (Means, personal observation). Panhandle Florida ravine streams apparently have no aquatic mammals or birds that use aquatic habitats as their homes, but the opossum (*Didelphis virginiana*) and raccoon (*Procyon lotor*) are common visitors. The raccoon, adroit fisher that it is, possibly has the most impact on the system. Raccoon tracks in the wet sands and organic soils adjacent to ravine streams attest to their presence.

6.3.2 Alluvial Streams and Rivers

Four Panhandle streams are noteworthy for their alluvial character. They are the Escambia, Choctawhatchee, Apalachicola, and Ochlockonee Rivers. All four have blackwater tributary streams, and the Choctawhatchee and Apalachicola have substantial inputs from spring-run tributaries. The alluvial character of these rivers derives from the fact that the greatest portions of their stream catchments are north of the Florida boundary in clastic-dominated sediments of the Coastal Plain or, in the case of the Apalachicola River, in the southern Appalachian Mountains.

The development of rooted aquatic vegetation in the rivers of the Panhandle is limited by the influence of one or more of four factors: (1) current velocity, (2) water depth, (3) turbidity and color, and (4) fluctuating water levels. Factors 1 and 2 tend to be limiting in channels where water flow and depth are greatest. Rainfall runoff, into the larger Panhandle rivers particularly, is usually quite turbid, limiting light penetration. The only suitable areas for the development of rooted aquatic species are narrow shelves between the floodplain vegetation and the main channel.

Where the Panhandle rivers drain sandy swampy lowlands, the water flowing in the turbulent areas has a brown color. The water in these streams is frequently high in organic acids, tannins, and lignins leached from the decomposing plant litter, giving the water the look of tea. Many Panhandle rivers and streams cut steepsided ravines beneath the closed canopies of their mature floodplain forests. Light penetration is limited first by the forest canopy, second by the dark color. Also, the steep sides of stream channels generally insure that water depth fluctuates widely in response to rainfall and runoff, creating an unstable background environment, especially for submergent plants. These conditions act together to limit the growth of submergent, emergent, and floating aquatic vegetation.

In contrast, the Panhandle rivers and their tributaries support a rich and varied assemblage of aquatic animals (Means 1977, Yerger 1977, Swift et al. 1977). This situation underscores the close interdependence between the streams and their floodplains. Detritus from upland runoff and leaf fall appears to be the major energy source for the Panhandle rivers as well as for their estuaries. The highly diverse animal community appears to result from the diversity provided by bank vegetation and regularly flooded swamp forests rather than by instream plant communities.

a. Flora. The aquatic habitats of the alluvial streams of Panhandle Florida can be classified by the water column and by different types of substrates. In the water column, the free-swimming aquatic organisms are plankton (microscopic plants and animals) and nekton (macroscopic motile organisms such as crayfish and true fish). Benthic substrates are masses of attached algae, compact clay, sand, mud, fixed organic debris (submerged brush, logs, roots, leaf packs), and rock and gravel (Gold et al. 1954). Because alluvial rivers are turbid with fine suspended sediments, and because river waters continually move and fluctuate in volume, phytoplankton levels often are quite low in this type of coastal plain aquatic habitat compared to those in standing water (Patrick et al. 1967).

Wharton (1977) lamented that "general descriptions of Coastal Plain streams are rare...I could find few studies of submerged, floating, or emergent higher plants in Georgia rivers." While scientists are beginning to generate considerable knowledge about the ecology of Panhandle estuaries (see Chapter 7), few detailed studies are available on Panhandle rivers. Information on the ecology of the Savannah River in Georgia may not be strictly applicable to Panhandle rivers, but a few generalities may be extrapolated.

Most algae are common in summer and fall, others in the spring, and a few in winter. A few green algae (*Oedogonium* spp.), red algae (*Compsopogon* spp., *Batrachospermum* spp.), and filamentous diatoms form long streamers in faster water. Some blue-green algae (*Lyngbya* spp.) form long filaments in still water. The green algae *Vaucheria* and *Oedogonium* form algal mats on sand or mud in shallow water, while *Spirogyra* exists a little deeper.

b. Fauna. The animal life of large Panhandle alluvial rivers is extensive and more well known than the plants. Each river system across the Panhandle has a core of wide-ranging species shared by all the rivers, but each system also possesses many species of invertebrates and fish not found in the other rivers. The Escambia River, farthest west of the alluvial streams, is most abundantly endowed with the animal life typical of the western Gulf of Mexico streams such as the Mississippi River. The Escambia has its headwaters in the upper Coastal Plain of southern Alabama, adjacent to the much larger Alabama-Tombigbee drainage on its west. The Ochlockonee River, by contrast, receives a large share of its species from the Atlantic Coastal Plain. This may be a result of a shared drainage divide with the Withlacoochee River (a tributary of the Suwannee River) as well as a possible connection with the Suwannee on the exposed Continental Shelf during the Pleistocene. The Apalachicola River is distinctive because it is the only Florida drainage whose headwaters originate outside the Coastal Plain in the southern Appalachian Mountains.

The wide variety of animal life in alluvial rivers is related to the diversity of the physical environments of these streams. For instance, the 68 species of freshwater fishes in the Ochlockonee River (Swift et al. 1977) are distributed among diverse habitats: shallow swift water and slow deep pools, sandy riffles and organic muck, under cut banks and in midstream, ravine tributaries and main channels. A severe change takes place in these streams annually that affects much of the wildlife. Runoff of rainwater falling on the catchments during winter and spring tends to be greater than at any other time of the year (Foose 1983, Means 1986), causing water to spill out of the low water channel into extensive floodplains. Many riverine species such as catfishes

(*Ictalurus* spp.), centrarchids, bowfin (*Amia calva*), gars (*Lepisosteus* spp.), and minnows (*Notropis* spp.) benefit by moving into the expanded aquatic environment during the 1–5 months that annual high waters stand in the floodplain. In addition, species that live in the backwaters of floodplains benefit by the high annual rises which rejuvenate the backwater aquatic systems by providing them with nutrients and water. During winter and spring high water periods, for instance, some species of riverine amphibians breed in the floodplain and spend their larval life in the receding waters outside the main low water channel. These are the upland chorus frog (*Pseudacris triseriata*), Fowler's toad (*Bufo woodhousii fowleri*), and southern leopard frog (*Rana sphenocephala*). Others breed in the same floodplain backwaters during the summer. Among these are the river swamp frog (*Rana heckscheri*), bronze frog (*Rana clamitans*), bird-voiced tree frog (*Hyla avivoca*), gray tree frog (*Hyla chrysoscelis*), green tree frog (*Hyla cinerea*), southern dusky salamander (*Desmognathus auriculatus*), mud salamander (*Pseudotriton montanus*), long-tailed salamander (*Eurycea longicauda*), and dwarf four-toed salamander (*Eurycea quadridigitata*).

Alluvial rivers of the Panhandle, while not possessing a great deal of primary productivity in the water column for filter feeding animals, compensate by being rich in nutrients supplied by litter that washes into the system from floodplain forests and from tributary streams. Thus alluvial rivers are replete with benthic organisms that attack the litter and, in turn, feed a robust food web of higher feeding levels. Among the many important invertebrate groups are caddisflies (Wiggins 1977), mayflies (Berner 1950), crayfish (Hobbs 1942), freshwater snails (Thompson 1984), bivalves (Clench and Turner 1956), stoneflies (Stark and Gaufin 1979), and carnivorous groups such as dragonflies (Byers 1930) and water beetles (Young 1954).

The invertebrates are the food base, in turn, for a wealth of fish species. Some fish groups feed on the bottom, such as the sturgeons (*Acipenser* spp.), suckers (*Catostomus, Minytrema, Erimyzon*), darters (*Etheostoma* and *Percina*), and catfishes (*Ictalurus, Noturus*). Some feed at or near the water's surface, such as many species of the Cyprinodontidae, Poeciliidae, and Centrarchidae, and others feed in the water column, such as species of those families just mentioned plus the gars, bowfin, pickerels (*Esox* spp.), minnows, shad (*Dorosoma* and *Alosa*), and others.

Alluvial rivers support a great wealth of reptile life beginning with large numbers of many species of turtles. The world's largest freshwater turtle, the alligator snapping turtle (*Macroclemys temminckii*), is largely confined to the deep waters of alluvial streams, and Panhandle Florida rivers are one of the important holdouts of their populations. The Mississippi River and other western Gulf of Mexico drainages have had severe fishing pressure brought to bear on the alligator snapper for use in commercial production of turtle soup. Common omnivores in alluvial rivers are the large river cooters and sliders, most notably the Suwannee and Mobile cooters (*Pseudemys concinna* sspp.), the peninsula cooter (*P. floridana*), and the yellowbelly slider (*P. scripta*). Other important turtles are species of map turtles (*Graptemys* spp.) found exclusively in large rivers, including a species endemic to the Apalachicola River system, Barbour's map turtle (*G. barbouri*), species of musk turtles (*Sternotherus odoratus* and *S. minor*), and mud turtles (*Kinosternon subrubrum*).

Alligators (*Alligator mississippiensis*) are very common in the large alluvial rivers where they have not been harassed or killed out. They eat mostly fish, but turtles are next in importance. While no lizard is specialized for aquatic life in Florida Panhandle rivers, several snakes are. The most abundant snake seen along overhanging branches and along the banks of alluvial rivers is the brown water snake (*Nerodia taxispilota*) usually mistaken for the cottonmouth (*Agkistrodon piscivorus*). The latter rarely is found in the main channel of alluvial streams, but it flourishes in the backwater slough and swamps in the floodplain. The red-bellied water snake (*Nerodia erythrogaster*) is also a common riverine species, often seen at the water's edge where it feeds on fish.

Otter (*Lutra canadensis*) and beaver (*Castor canadensis*) are the only truly aquatic mammals sometimes seen in the main channel of alluvial rivers, but both are more common in the tributary streams and backwaters. Historically, the manatee (*Trichechus manatus*) apparently made forays up into the alluvial rivers of the Panhandle, but this is probably rare or nonexistent today.

Alluvial rivers are the feeding grounds for many species of wading and aquatic birds. Wading birds such as the great blue heron (*Ardea herodias*), great egret (*Casmerodius alba*), and little blue heron (*Egretta caerulea*) are commonly seen feeding along the banks of alluvial rivers. Diving birds such as the anhinga (*Anhinga anhinga*), double-crested cormorant (*Phalacrocorax auritus*), and species of ducks use alluvial rivers extensively. The osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*) are common raptors that grab fish from the surface of river waters.

Although no definitive study of the fauna of alluvial rivers has been done, Means (1977) has surveyed the significance of the Apalachicola River basin to vertebrates, and more information, including a vertebrate species list, is available in the publication.

6.3.3 Blackwater Streams

The most widely distributed type of stream in Panhandle Florida we call here the blackwater stream. We combine Beck's (1965) sand-bottomed stream with his swamp-and-bog stream because the latter is merely a slower moving, lower volume version of the former; the swamp-and-bog stream dominated by organic sediments in its bed, grades downstream into a sand-bottomed stream if the drainage system is large enough. The Perdido River, Blackwater River, Shoal River, Titi Creek, Pine Log Creek, Bear Creek, Telogia Creek, New River, and others are examples of blackwater streams that have organic-bottom tributary streams that come together to form the sand-bottomed, blackwater master stream.

The highly acid, sluggish swamp-and-bog streams are found throughout Panhandle Florida, and are particularly common in the Gulf Coastal Lowlands (Figure 5). They originate in herb bogs and shrub bogs and show a definite relationship to the sand-bottomed streams in that all chemical differences are functions of velocity (Beck 1965). An increase of gradient would convert them to the sand-bottomed type by increasing turbulence, which in turn increases reaeration, reduces carbon dioxide, increases pH and alkalinity, and removes the finer bottom sediments of organics and silt, replacing them with sand.

The swamp-and-bog version of blackwater streams has the following characteristics: pH 3.8 to 6.5, alkalinity and hardness both normally well below 40 mg/l, color sometimes as high as 750 units, turbidity low, and carbon dioxide at times above 100 mg/l. The velocity of these streams is slow to moderate. The larger volume, sand-bottomed version of the blackwater stream is mildly acid to circumneutral (pH 5.7–7.4), has alkalinity ranging from 5 to 100 mg/l, hardness from 2 to 120 mg/l, color moderate to high, and moderate to swift velocity (Beck 1965).

a. Flora. Plant life in blackwater streams has not been studied across the Panhandle. While diatoms and algae no doubt make up a considerable portion of the phytoplankton of blackwater streams, the primary productivity of blackwater streams is lower than a typical spring-run stream because of the differences in light levels. One emergent that catches the eye in shallow blackwater streams is golden club (*Orontium aquaticum*), whose green emergent leaves accentuate the golden-tipped spathe rising from dark, sometimes inky, waters.

b. Fauna. Blackwater streams support a surprising fish and amphibian fauna, with many species present that are normally considered sensitive to high carbon dioxide values, e.g., sunfishes (*Lepomis* spp.) and darters (*Etheostoma* spp.), waterdogs (*Necturus* spp.), and plethodontid salamanders.

According to Beck (1965), the invertebrate fauna of the organic-bottomed blackwater streams differs little from acid ponds. Running water forms and species that thrive in running water are universally lacking. Mollusks are represented only by *Physa pumilia*, and the general fauna give the impression of being composed almost totally of species highly resistant to organic pollution, even though the streams are not polluted by anthropogenic sources. Typical elements are hydropsychid and philopotamid caddisflies, mayflies of the genera *Stenonema* and *Isonychia*, simuliid larvae, Plecoptera, orthocladiine chironomids, elmid beetles, and *Corydalis cornutus* (Beck 1965). The fishes are an exception.

Farther downstream in sand-bottom reaches of the catchment, flowing water species dominate.

The floodplains of blackwater streams, particularly where there is seepage, are the breeding sites of several salamanders found more commonly in blackwater streams than anywhere else. These are the long-tailed salamander (*Eurycea longicauda guttolineata*), southern dusky salamander (*Desmognathus auriculatus*), and mud salamander (*Pseudotriton montanus*). Other salamanders living in the water column as adults are the two-toed amphiuma (*Amphiuma means*), lesser siren (*Siren intermedia*), and the gulf coast waterdog (*Necturus beyeri*).

Common reptiles of blackwater streams are the alligator (*Alligator mississippiensis*), common snapping turtle (*Chelydra serpentina*), peninsula cooter (*Pseudemys floridana*), stinkpot (*Sternotherus odoratus*), mud turtle (*Kinosternon subrubrum*), glossy water snake (*Regina rigida*), banded water snake (*Nerodia fasciata*), and cottonmouth (*Agkistrodon piscivorus*).

Wading and diving birds tend to use blackwater streams infrequently for two possible reasons: less food may be available because of the reduced productivity or visibility in black water, and the danger from subsurface attack from alligators and other aquatic predators is greater than in alluvial rivers and spring-run streams. No aquatic or semiaquatic mammals are known exclusively from blackwater streams, but the raccoon, beaver, and otter use blackwater streams extensively.

6.3.4 Spring-fed Streams

Panhandle Florida is not so well endowed with large springs as is central Florida and the Florida Big Bend region, but Rosenau et al. (1977) mapped 37 different springs in Panhandle Florida ranging in discharge from under 5 ft^3/s to more than 250 ft^3/s. Panhandle Florida has only two first order magnitude springs (having a discharge of more than 64.6 million gallons per day), Gainer Springs in Bay County and Blue Springs in Jackson County (Fernald and Patton 1984). Most of the Panhandle springs average in the range of 15–35 ft^3/s.

Spring-fed streams are very different from other Panhandle stream types in several important ways. First, spring waters are usually clear because they have been filtered through limestones. Second, spring-fed streams have relatively constant temperatures at their spring-heads, that persist to a diminishing extent downstream, making them somewhat thermally buffered. Third, they are chemically different from other rivers because they issue from carbonate terranes (limestone sediments) where the waters have picked up ions of calcium, magnesium, iron and other minerals. Spring-fed rivers and streams are notably less acidic than other rivers because of their high mineral ion content and seem to be heavily populated with mollusks, possibly because of the high levels of available calcium in the water.

Only two major streams of the Panhandle can be classed as spring-run streams, but both are also heavily influenced by inputs from blackwater stream tributaries. The Chipola River of Jackson, Calhoun, and Gulf Counties receives a large percentage of its flow from springs discharging the Floridan Aquifer from limestones in the southern Marianna Lowlands physiographic region. Many springs discharge directly into the floodplain of the Chipola River north of Marianna, but other springs have outlets into smaller spring-run stream courses that join the Chipola, such as Blue Springs Run. The Floridan Aquifer also discharges into Econfina Creek in Bay County through limestone conduits. A substantial portion of each stream catchment above the zone of the springs receives water as runoff from the surrounding landform, so that immediately below the springs, the waters of both rivers are a blend of calcareous spring waters and acid blackwater stream waters. Holmes and Wright Creeks in Washington and Holmes Counties are also fed by spring waters. During droughts, the waters of Chipola River, Holmes, Wright, and Econfina creeks become clear and dominated by spring-flow. At these times, these streams are more like the classic spring-flow streams of the Big Bend (Wakulla and Wacissa Rivers). During normal rainfall periods, however, all four streams can be so dominated by runoff that their waters are quite dark, and the streams appear superficially as blackwater streams.

According to Beck (1965), spring-run streams (called calcareous streams by Beck) typically are alkaline (pH 7.0–8.2), the alkalinity ranging from 20 to 200 mg/l, hardness from 25 to 300 mg/l, water normally clear, and velocity ranging from slow to swift. The beds of Panhandle spring-run streams consist of sand and limestone in the vicinity of springs, changing to sand, clay, pebbles, mollusk shells (of the introduced clam *Corbicula manilensis*), and organic detritus downstream.

a. Stream flora. The clear waters allow much more light to penetrate at depth, and therefore spring-fed streams have the highest primary production of all Panhandle streams. This is manifest more in macrophytic plants rooted in the subaquatic stream bed than in the water column. Diatoms and filamentous algae also abound but are attached to the physical substrate and the macrophytes. Thermal buffering prevents both low temperatures that slow down plant and animal metabolism and high temperatures that lead to anoxic conditions during summer.

Unfortunately, there are no ecological studies of the flora of Panhandle spring-fed streams, so that quantitative information about the roles of different species in primary productivity, and therefore their role as food and cover for aquatic wildlife, is lacking.

b. Stream fauna. According to Beck (1965), the invertebrate fauna of spring-run streams is less current-loving than sand-bottomed blackwater streams. The most obvious benthic faunal feature is their high mollusk populations, originally consisting of native genera *Goniobasis, Campeloma, Viviparus*, and *Pomacea*. Today, because of the overwhelming dominance of the introduced clam *Corbicula manilensis*, the bottom sediments are full of the living and dead shells of this bivalve, to the literal extirpation of many of the native species. Other current-loving invertebrates listed by Beck (1965) are hydropsychid caddisflies, mayflies of the genus *Stenonema*, a great variety of chironomid midges, *Corydalis cornutus*, and occasionally Simuliidae and Plecoptera.

Spring-run streams of the Panhandle are noteworthy for their mollusk-eating turtles. Females of Barbour's map turtle (*Graptemys barbouri*) are several times larger than males, but differ even more in possessing powerful crushing jaws and jaw musculature, enabling them to feed upon the abundant mollusks. A similar adaptation has taken place in the loggerhead musk turtle (*Sternotherus minor*). Both sexes, however, feed upon mollusks and show enlarged feeding apparatus. Omnivorous turtles are also very common, possibly because light penetrates deeply in spring-run streams and there is much more aquatic plant productivity than in the other two types of Panhandle streams. Commonly found are the Suwannee Cooter (*Pseudemys concinna*), peninsula cooter (*P. floridana*), and sometimes the yellowbelly slider (*Pseudemys scripta*).

The brown water snake (*Nerodia taxispilota*) is by far the most common aquatic snake encountered in Panhandle spring-run streams, but the red-bellied water snake (*N. erythrogaster*), and the cottonmouth (*Agkistrodon piscivorus*) are also found regularly, the latter more often off the main open-water channel in the fringing river swamps. The spectacularly colored rainbow snake (*Farancia erytrogramma*), specialized to eat freshwater eels (*Anguilla rostrata*), seems mostly to be found in spring-run streams.

Two freshwater fishes are known almost exclusively from spring-fed stream waters in the Panhandle. These are the redeye chub (*Notropis harperi*) and the bluefin killifish (*Lucania goodei*). Other fishes common to Panhandle spring-run streams include: bowfin (*Amia calva*), spotted sucker (*Minytrema melanops*), blacktail redhorse (*Moxostoma poecilurum*), pugnose minnow (*Notropis emiliae*), sailfin shiner (*N. hypselopterus*), coastal shiner (*N. petersoni*), blacktail shiner (*N. venustus*), longnose shiner (*N. longirostris*), weed shiner (*N. texanus*), silverjaw minnow (*Ericymba buccata*), bigeye chub (*Hybopsis amblops*), speckled madtom (*Noturus leptacanthus*), tadpole madtom (*N. gyrinus*), golden shiner (*Notemigonus chrysoleucas*), mosquitofish (*Gambusia affinis*), least killifish (*Heterandria formosa*), blackbanded darter (*Percina nigrofasciata*), spotted sunfish (*Lepomis punctatus*), bluegill (*L. macrochirus*), spotted bass (*Micropterus punctulatus*), largemouth bass (*M. salmoides*), brook silversides (*Labidesthes sicculus*), and others.

6.4 Native Lacustrine Habitats

The Panhandle has less water-bearing limestone near the surface of the ground than the rest of the State, so lakes formed by solution subsidence of the ground surface to levels below the piezometric surface of ground water are less common. Most of these lakes are in northern Bay and southern Washington Counties. Lake Wimico may represent a depression in a relict sea bottom. The second most common type of lake is formed by the natural meandering processes of Panhandle streams and rivers, and we will call them floodplain lakes.

The two largest lakes of the Panhandle (Lakes Seminole and Talquin) are impoundments of the Apalachicola and Ochlockonee rivers, respectively. The three largest natural lakes, Dead Lake, Ocheesee Pond and Lake Wimico, are associated in one way or another with the Apalachicola River.

Lakes are not very long lived geological phenomena because they receive sediment-laden water from the surrounding uplands, and eventually are filled in. The filling process involves both inorganic sediments that are washed in by streams and other surface runoff and organic sediments that accumulate from the incomplete decomposition of plant matter. Organic lake sediments are derived mostly from primary productivity in the lake itself and to a lesser degree from imported litter. Young, recently formed Florida lakes usually are relatively deep, sand-bottomed, and possess open surface waters. Later in the filling cycle these lakes become shallow, with deep organic sediments in their beds, and begin to support a highly productive macrophyte community of emergent aquatic grasses, forbs, shrubs, and trees. We classify young, deep, sand-bottomed lakes as karst lakes and the shallow, peat-dominated lakes as swamp lakes. The latter usually are simply late successional stages of the former.

6.4.1 Karst Lakes

Panhandle Florida has fewer natural lakes than the adjacent Florida Big Bend region or peninsular Florida, but where lakes are found in the Panhandle, they usually have a limestone solution origin similar to those in the peninsula. Most of the natural lakes in the Panhandle are located in Bay and Washington Counties on the sandy uplands called Greenhead Slope between the Choctawhatchee River and Econfina Creek (Puri and Vernon 1964). These lakes and a few others such as De Funiak Springs Lake, Lake Mystic, Camel Pond, Wright Lake, Moore Lake, and Silver Lake are all of karst origin.

The karst lakes of the Panhandle seem to fit the FNAI Sandhill Upland Lake category better than their Sinkhole Lake type. These generally are rounded solution depressions in deep sandy uplands, usually without surface inflows or outflows. A few lakes on both sides of Econfina Creek in Bay County, however, have or had a steephead stream develop from their margins at the time the sink lake depression formed. In one case, a steephead stream flows over more than a mile into a sinkhole lake . The sand resulting from erosion of the steephead valley partially fills these lakes. They typically have a sandy substrate with organic accumulations near their deeper portions. They are characteristically clear, circumneutral to slightly acidic, and moderately free of minerals.

a. Flora. Little research on Panhandle lakes has been published. The karst lakes in Bay and Washington Counties are known to have several interesting plants, and a systematic investigation may discover more. Smooth-barked St. Johnswort (*Hypericum lissophloeus*) is an endangered species endemic to Lake Merial and one other sinkhole lake nearby (Ward 1978). One of the Bay County lakes is a known locality of the threatened karst pond xyris (*Xyris longisepala*), which is also found in karst lakes in southern Leon County and Walton County (Ward 1978). Other rare plants are known from these lakes, and a pine barrens sundew, *Drosera*, may be disjunct in the bed of Lake Merial and other Bay County lakes; other populations of this species are known only from North Carolina to New Jersey (R. K. Godfrey, Florida State Univ., Tallahassee; pers. comm.).

The phytoplankton of Panhandle karst lakes has not been described. Many karst lakes have sandy, treeless shores with zones of successional herbaceous vegetation fringing the waterline. Other lakes have a scattering of cypress around their margins.

b. Fauna. Almost nothing is known about the fauna of Panhandle karst lakes. Plankton, benthic algae, and submerged aquatic plants are the basis of the food web, which consists of turtles (*Pseudemys scripta, P. floridana*) and invertebrates. Macroscopic predators are fish (centrarchids, topminnows (*Fundulus* spp.), poeciliids, catfishes (*Ictalurus* spp.), bowfin (*Amia calva*), two-toed amphiuma

(*Amphiuma means*), bullfrog (*Rana catesbeiana*), bronze frog (*R. clamitans*), southern leopard frog (*R. sphenocephala*), pig frog (*R. grylio*), snapping turtle (*Chelydra serpentina*), mud turtle (*Kinosternon subrubrum*), green water snake (*Nerodia cyclopion*), mud snake (*Farancia abacura*), black swamp snake (*Seminatrix pygaea*), and alligator (*Alligator mississippiensis*).

6.4.2 River Floodplain Lakes

The low water channels of rivers migrate over their floodplains through the centuries in wandering loops. These loops eventually are cut off during high water by newly eroded channels, forming the familiar oxbow lakes that are dammed up at both ends by levees thrown up by subsequent high water stands. Thereafter, following each high rise of the river, the fine particles settle out of the turbid waters that refill the oxbow lake. Over time, oxbow lakes fill in with silt and clay.

a. Flora. At first, a newly cut off oxbow lake is only a portion of the river with standing, rather than flowing water in its channel. As the oxbow lake fills in, floodplain vegetation grows in from its sides, eventually closing the open water channel with a canopy of baldcypress (*Taxodium distichum*), and gum trees (*Nyssa aquatica, N. ogeche*).

b. Fauna. While the lotic river channel and lentic oxbow lake faunas may differ somewhat because of differences in current, Panhandle Florida oxbow lakes have not been intensively studied and compared. The species of aquatic vertebrates in oxbow lakes is a subset of those of deeper, slower waters in the main river channel, including the bowfin (*Amia calva*), alligator, spotted, and longnose gars (*Lepisosteus spatula, L. oculatus, L. osseus*), chain pickerel (*Esox niger*), suckers (*Moxostoma* spp.), catfishes (*Ictalurus* spp.), pirate perch (*Aphredoderus sayanus*), flier (*Centrarchus macropterus*), largemouth bass (*Micropterus salmoides*), warmouth (*Lepomis gulosus*), bluegill (*L. macrochirus*), dollar sunfish (*L. marginatus*), black crappie (*Pomoxis nigromaculatus*), siren (*Siren lacertina*), two-toed amphiuma (*Amphiuma means*), larvae of the river swamp frog (*Rana heckscheri*), alligator (*Alligator mississippiensis*), alligator snapping turtle (*Macroclemys temminckii*), Florida softshell turtle (*Trionyx ferox*), river cooter (*Pseudemys concinna*), peninsula cooter (*P. floridana*), and yellowbelly slider (*Pseudemys scripta*).

6.4.3 Swamp Lakes

Large swamp lakes such as Lakes Miccosukee, Iamonia, and Tsala Apopka of the Florida Big Bend are rare in the Florida Panhandle. Most of the Panhandle lakes are relatively deep limestone solution lakes that have not yet reached an advanced stage of filling in with sediments. There are, however, a number of small swamp lakes in Holmes and northern Walton Counties that appear to be nearly filled in solution basins. In addition, two large lakes in the middle stages of filling in and becoming swamps are of river origin and are not solution basins. Dead Lake on the lower Chipola River is an interesting example of a small river (Chipola) that is naturally impounded by the alluvial sediments of a larger river (Apalachicola) at the confluence of the two rivers. The waters of the Chipola have been backed up long enough for the lake margin to have accumulated massive organic deposits that ultimately will fill in at least the backswamps in time. Ocheesee pond is an even better example of a swamp created by the filling in of a lake. This wetland lies in an abandoned bed of the Apalachicola River, and the lake basin may later have been enlarged partially by downward and lateral solution of limestone.

There is virtually no scientific literature on the biota of the swamp lakes of Panhandle Florida, and we have no insights as to how Ocheesee Pond and Dead Lake differ from river floodplain lakes.

6.4.4 Ponds

Panhandle Florida possesses hundreds of small (less than 1 acre) ponds scattered throughout all the physiographic provinces. These water bodies collectively deserve mention as a major lotic type because they are the breeding sites of so many animals. No comparative studies of these ponds have ever been made for the eastern United States so far as we are able to determine, even though these ponds are known to field biologists as the only places to find certain invertebrates and vertebrates in larval and even adult stages.

We are also unable to subclassify ponds into natural groups, but we do recognize that there are major physical differences in their properties. Some are deep woods ponds formed in the hardwood forests of bottomlands that are not inundated by annual high rises of a large stream. Some are flatwoods ponds, and these may be marshy with no trees, or only a thin scattering of cypress or gum, or both. Some are just depressions in sandy flatwoods, with sandy bottoms that grass over during dry spells, and some have organic sediments perched on sand. The water cycle of most of these ponds is ephemeral, but some are permanent or nearly so.

a. Flora. The truly ephemeral ponds sometimes have very little distinctive flora except diatoms and other one-celled algae in the water column when water is present. Sometimes these temporary ponds form in depressions in wiregrass flatwoods or in low places in sandhills where little difference is notable in the groundcover between the rare times when the site is wet and when it is dry. As the hydroperiod increases, plant response increases, and often a low swale is evident by its herbaceous distinctiveness, indicating the beginnings of a true wetland. Certain grasses and many sedges seem to be the first indication that the hydroperiod is longer on some sites than on others. All degrees of plant response, depending upon hydroperiod, are evident among the many Panhandle ponds, including those with cypress (*Taxodium*) and gum (*Nyssa*) fringing them. In those ponds with a longer hydroperiod, organic sediments build up, and are obvious underfoot during drought periods. A study of small ponds and their physical and biological characteristics would begin to provide an understanding of an important, and often overlooked, habitat type.

b. Fauna. A great many unusual species of invertebrates and vertebrates use ephemeral ponds to complete their life cycles. A major reason may be the absence of fish predators. Several rarely seen crustacean groups become dense in these ponds after rains, including the fairy shrimps (Anostraca) and clam shrimps (Conchostraca). Other crustaceans that bloom in ephemeral ponds are species of isopods, amphipods, and decapods, including grass shrimps (Penaeidae) and crayfishes (*Procambarus*).

The invertebrate life and algae form a rich food resource and a number of amphibian vertebrate carnivores have evolved to take advantage of it. Ephemeral ponds are often the only places larvae of ambystomatid salamanders can be found. Panhandle Florida has four: the marbled salamander (*Ambystoma opacum*) is found in ephemeral ponds in hardwood bottomlands, breeding in river floodplain temporary standing water bodies or temporary ponds in low lying woodlands along smaller stream courses; the flatwoods salamander (*A. cingulatum*) uses temporary ponds in flatwoods, usually temporary cypress or cypress-gum ponds; the tiger salamander (*A. tigrinum*) also breeds in flatwoods ponds, especially deeper ones with slightly longer water cycles, including ponds with fish; and the mole salamander (*A. talpoideum*) which has a catholic preference, using almost any temporary pond, in any major terrestrial habitat.

Another group of salamanders that depend upon ephemeral ponds for their larval life is the Salamandridae, or newts. *Notophthalmus viridescens* commonly breeds in ponds and the larvae spend one or more years of their life in the ponds. Newts metamorphose into terrestrial salamanders called efts, and migrate away from ponds to take up a fossorial life in adjacent woodlands of various types. Later, when the breeding urge comes upon them, they migrate back to ponds and undergo another series of morphological changes that assist them with aquatic life. Both newts and the mole salamander mentioned above have the unique life history strategy of retaining their larval morphology (process of neoteny) until sexually mature and breeding if water levels remain substantial for one or more years. If water levels recede or the pond dries up, however, they quickly metamorphose and wander off to live on land until water returns and they are able to migrate back to the pond and breed.

Temporary ponds of the Panhandle are quite important to frogs and a couple of turtles. The chicken turtle (*Deirochelys reticularia*) is known almost exclusively from small ponds. It and the mud turtle (*Kinosternon subrubrum*) are among the most common turtles seen crossing roads. The ability to disperse from one drying pond to another is certainly an important adaptation found in animals that live in drying ponds. But frogs, among the vertebrates, seem to use temporary ponds the most, possibly because of the absence of predaceous fishes. Frogs rely on temporary ponds so much that several species in Panhandle ponds even breed only during cold weather in the middle of the winter.

The spring peeper (*Hyla crucifer*), ornate chorus frog (*Pseudacris ornata*), and Florida chorus frog (*P. nigrita*) use these ponds from November to February when there is ample winter rain. A definite spring breeding burst occurs in these ponds from February–April during very heavy rains, when the southern toad (*Bufo terrestris*), gopher frog (*Rana areolata*), and southern leopard frog (*R. sphenocephala*) breed, sometimes with huge numbers of the spadefoot (*Scaphiopus holbrookii*). But it is the summer rains that bring out the largest number of breeding species. Beginning in May and continuing until September, ponds in the Panhandle are teeming with breeding activity and tadpoles. The following are species of frogs that mostly depend upon small ephemeral summer ponds for the larval portion of their life cycle: oak toad (*Bufo quercicus*), narrowmouth toad (*Gastrophryne carolinensis*), pinewoods tree frog (*Hyla femoralis*), barking tree frog (*H. gratiosa*), squirrel tree frog (*H. squirella*), little grass frog (*Limnaoedus ocularis*), cricket frog (*Acris gryllus*).

Other frog species which are more catholic in the selection of their breeding habitats such as the green tree frog and gray tree frog (*H. cinerea, H. chrysoscelis*), also breed in these ponds.

When fish are found in ephemeral ponds, they almost always include the following: pygmy sunfishes (*Elassoma* spp.), pirate perch (*Aphredoderus sayanus*), mosquitofish (*Gambusia affinis*), and often the banded topminnow (*Fundulus cingulatus*).

No aquatic mammals are known to use ponds exclusively, but opportunistic predators such as raccoon and opossum are common, especially when water levels begin to go down and the large numbers of larvae are concentrated. These ponds support one of Florida's endangered birds, the wood stork (*Mycteria americana*), which feeds on small fish and amphibian larvae when ponds are drying up.

The fact that so many animals are found only in ponds, or have special adaptations for pond life, indicates that the pond is a very important true habitat type, and not an artifact of human attempts to define nature. Studies on Panhandle ponds are urgently needed.

6.4.5 Coastal Ponds

Between sets of aeolian dunes or wave-created sandy berms along the coastal barrier islands and the mainland lie interdune depressions, or flats. Often these depressions have water standing in them for periods ranging from a few days to nearly always. The FNAI designation for these water bodies is Coastal Dune Lake. These ponds are very important to the wildlife of coastal strands, and we single them out here for recognition.

The bottoms of coastal ponds are predominantly composed of sand, with some organic matter. The amount of organic matter depends upon hydroperiod—short hydroperiods allow faster decomposition of organic sediments, so that some interdune flats that have water standing for only a few days to weeks after rains have almost no organic sediments at all. The salinity of coastal ponds is variable and subject to saltwater intrusion from beneath during drought, from storm surges, and from salt spray transported by the wind. Coastal ponds are slightly acidic, but often have hard waters with high mineral content (especially sodium chloride).

Coastal ponds, occurring at the continental margin and on barrier islands, are very young geologically. Those on Panhandle barrier islands such as St. George, St. Vincent, and Dog islands are no more than 6,000 years old. Because the barrier island ponds have formed in isolation from the mainland, each pond is likely to have its own distinctive subset of waif plants and animals in it. On St. Vincent Island, for instance, almost no titis (Cyrillaceae) fringe the coastal ponds in the manner that they do on the mainland. Instead, the evergreen shrubs in many St. George Island ponds are replaced with persimmon, *Diospyros virginiana*. No studies are available comparing coastal pond biota. Many species typical of ephemeral water bodies can be expected in coastal ponds, partly because of the dearth of fish in them. Ostracods, amphipods, anostracans, conchostracans, and isopods should be looked for after rains. A few frogs and toads use coastal ponds, including the southern toad (*Bufo terrestris*), southern leopard frog (*Rana sphenocephala*), and pig frog (*Rana grylio*). The first fish to appear in these ponds usually are the mosquitofish (*Gambusia affinis*), but some larger, permanent ponds on St. Vincent Island contain the spotted gar (*Lepisosteus osseus*), bowfin (*Amia calva*), lake chubsucker (*Erimyzon sucetta*), brown bullhead (*Ictalurus nebulosus*), golden topminnow (*Fundulus chrysotus*), pygmy killifish (*Leptolucania ommata*), least killifish (*Heterandria formosa*), sailfin molly (*Poecilia latipinna*), tidewater silverside (*Menidia beryllina*), everglades pygmy sunfish (*Elassoma evergladei*), warmouth (*Lepomis gulosus*), bluegill (*L. macrochirus*), redear sunfish (*L. microlophus*), largemouth bass (*Micropterus salmoides*), striped mullet (*Mugil cephalus*), and the fat sleeper (*Dormitator maculatus*) (Christman 1984).

Coastal ponds are very important to wildlife, especially on barrier islands, because usually they provide the only water available. For this reason they are extremely important to incoming migrant birds that are returning from cross-Gulf migration.

6.5 Subterranean Habitats

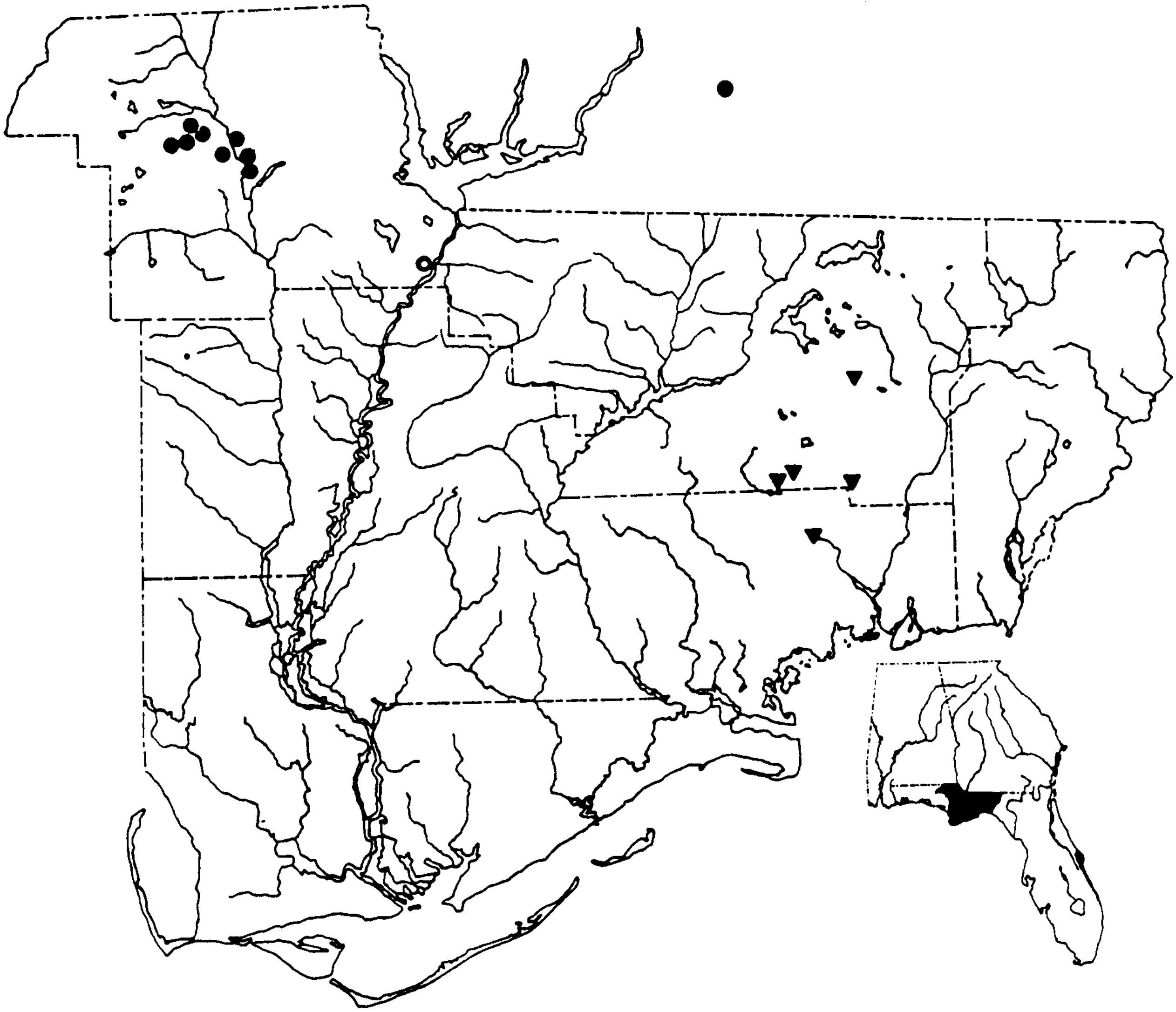
6.5.1 Water-filled Caves

Beginning with Lonnberg (1894a, 1894b), studies of the animal life of caves and sinkholes in Florida and adjacent parts of the Coastal Plain of Georgia and Alabama have revealed a number of cave-adapted organisms that are endemic in the Apalachicola River drainage basin. Because Panhandle Florida solution cavities are presently filled with water, the number of aquatic troglobites (phreatobites) is large in contrast with the number of troglobites (cave-adapted animals) in air-filled cave ecosystems of the Appalachian region of the eastern United States.

Means (1977) recognized three groups of troglobites in Florida and Georgia by the following names: the Chattahoochee fauna, named for the anticline which brought limestone terranes to the surface in the Marianna Lowlands-Dougherty Plain physiographic region (same as Pylka and Warren's (1958) northern region); the Woodville fauna, named for the Woodville Karst Plain of the Gulf Coastal Lowlands physiographic region (Hendry and Sproul, 1966); and the Ocala fauna, named for the Ocala Uplift in peninsular Florida. These last two areas plus sinkholes breaching the Hawthorne Formation along the Peninsular Arch.

In Panhandle Florida only one fauna, the Chattahoochee fauna, is present. At least eight caves in the Marianna Lowlands-Dougherty Plains region share the Chattahoochee fauna (Figure 68). A number of springs and subterranean water-filled passages which probably contain the Chattahoochee fauna are located along the west bank of the Apalachicola River for several miles south of Sneads. The nature of the barrier isolating the Chattahoochee fauna from other troglobites is now better known because of geological and hydrological studies carried out in the past decade (Figure 69). A faulted syncline complementary to the Chattahoochee anticline is present between the Apalachicola and Ochlockonee Rivers, and contains clastic sediments of low permeability (Veatch and Stephenson 1911, Applin and Applin 1944, Herrick and Vorhis 1963, Sever 1964, Kaufman et al. 1969). Also, limestone underlying the clastic sediments in the trough does not show evidence of significant solution or secondary permeability (Hendry and Sproul 1966). This geomorphic feature has been called the Gulf Trough (Hendry and Sproul 1966). The eastern edge of the Gulf Trough contains another structure, the Ochlockonee fault (Kaufman et al. 1969), which may also serve as an impediment to hydrologic flow to the southeast (Figure 69). Recent studies of disequilibrium patterns of naturally occurring uranium isotopes demonstrate that "...the Gulf Trough and Ochlockonee Fault act as a hydrologic barrier that prevents any significant southeastward flow of groundwater" (Kaufman et al. 1969, p. 384).

Much of what is known about phreatobites of the eastern gulf region came from studying specimens brought up from wells which penetrate cavities in the Floridan aquifer (Carr 1939; Hobbs 1942, 1971; Hobbs and Means 1972). In many cases, the nearest entrance to the aquifer is through sinkholes or springs several miles from the well. After Carr (1939) described the Georgia blind salamander (*Haideotriton wallacei* Carr) from a deep well in Albany, Georgia, specimens were discovered in caves in Jackson County, Florida (Pylka and Warren 1958). All troglobitic salamanders presently known from this karst region are *Haideotriton wallacei*.



● Localities of the Chattahoochee Fauna

○ Unexplored cave likely to contain *Haideotriton wallacei* or *Cambarus cryptodytes*

▼ Localities of the Woodville Fauna

Figure 68. Distribution of caves and phreatobites in Panhandle Florida (after Means 1977).

Haideotriton wallacei is not closely related to any known troglobitic salamanders, but several species of troglobitic salamanders whose epigean (living on ground surface) ancestry probably belongs to the same genus occur in the Balcones Escarpment (Edwards Plateau) region of Texas. The epigean ancestors of all these species probably belonged to the genus *Eurycea*. *Haideotriton* probably evolved from this genus independently and is similar morphologically to the most cave-adapted species, *Typhlomolge rathbuni* from the Balcones Escarpment, by evolutionary convergence.

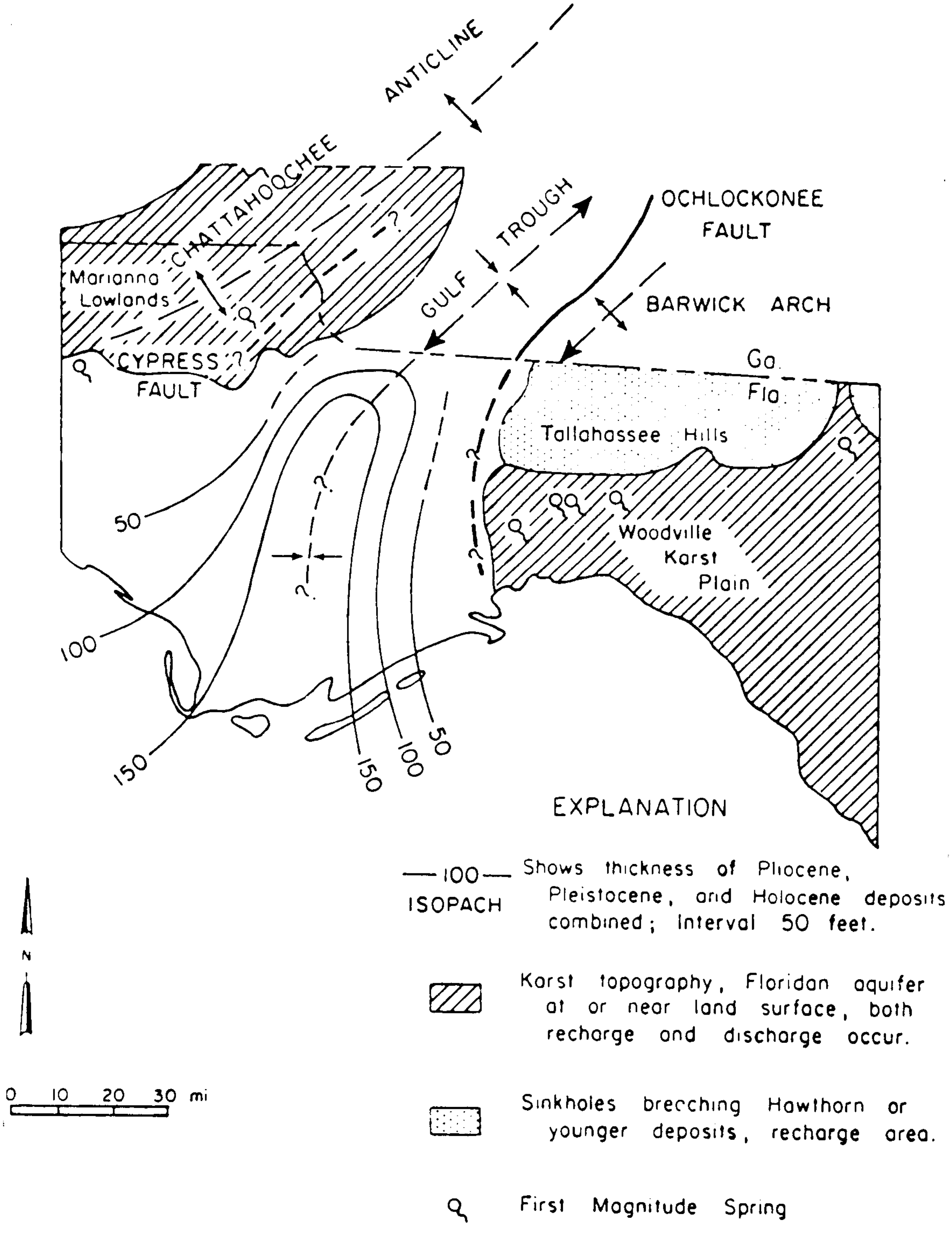


Figure 69. Regional structure of eastern Panhandle Florida showing the Gulf Trough putative barrier to dispersal between the Chattahoochee and Woodville phreatobite faunas. (Kaufman et al. 1969).

Two epigean species (*Eurycea bislineata, E. longicauda*) are known troglobites in caves of the Marianna Lowlands and in Climax Cave, Georgia. Larvae of both species have been found in and near the mouths of caves in pools and streams issuing from the underground water system (Means, personal observation). Both of these species of *Eurycea* are typically northern animals. It is not known whether either gave rise to *Haideotriton wallacei*, but they or their ancestors are the most likely candidates. The species *H. wallacei* and *T. rathbuni* of Texas share the distinction of being the most highly cave-adapted salamanders in North America.

The endemic crayfish, *Cambarus cryptodytes*, was also described from the specimens obtained from a well; they, too are now known to be abundant in caves in Jackson County. Both *Cambarus cryptodytes* and *Haideotriton wallacei* live together in the water column, especially near nutrient inputs such as subterranean streams beneath bat roosts in caves. Gerard's Cave (Pylka and Warren 1958) in Jackson County has several vertical cracks in the cave floor under bat roosts where these species are common year around. Apparently the crayfish forage on detritus from bat excreta and carcasses, and on other aquatic life that feeds on the same fare. Middle-sized and large crayfishes are capable of capturing and feeding upon *Haideotriton wallacei.* The crayfish probably also feed upon some of the food items that have been identified in the diet of the cave salamander, including ostracods, amphipods, isopods, copepods, insects and a species of mite (Lee 1969).

The troglobitic isopod, *Asellus hobbsi* is found in the Marianna Lowlands in the Panhandle and in cave waters of peninsular Florida. However, its occurrence in crayfish burrows in Calhoun County south of Blountstown (Maloney 1939) and the tendency for other subterranean isopods to occur in epigean waters (Minckley 1961) indicates surface dispersal and would not require continuous limestone connection between the two regions in the study area. Peck (1973) identified an amphipod (*Crangonyx floridanus*) and a copepod (*Macrocyclops albidus*) from guts of *Haideotriton wallacei.*

The extensive system of subterranean waters and solution cavities drained by the upper Apalachicola basin contains an isolated and unique ecosystem of cave-adapted aquatic organisms. Major threats to this ecosystem are impacts from pollution (municipal waste effluents, siltation, and turbidity due to surface erosion in open recharge areas) and alteration of the water table (by impounding local streams, including the Apalachicola and Chipola Rivers, or from heavy drawdown by wells). Serious consideration should be given to influences on the local water table.

6.6 Human-Created Lacustrine Habitats

People have created numerous lotic environments over Panhandle Florida, mostly of the small, ephemeral type along roadsides and railroad rights-of-way. Roadside ditches are so common that biologists commonly use them for collecting and teaching, yet almost no studies of the biota of roadside ditches, per se, are available. The closest natural lotic environments to roadside ditch ponds are the ephemeral ponds described in Chapter 6.4.4. Somewhat larger than roadside ditches are the borrow pits created by roadbuilders for road construction. These water bodies are quite sterile, even more so than roadside ditches, because they usually are deeper. In the Panhandle, particularly the Coastal Lowlands region, borrow pits are characterized by the dense growths of St. Johnswort (*Hypericum* spp.) that flourish after mechanical disturbance to a wetland.

6.6.1 Impoundments

The largest of all human-created lotic environments, however, are the impoundments of streams and rivers. These are numerous over the entire Panhandle. Many are fish management areas maintained by the Florida Game and Fresh Water Fish Commission. Some of the small- to medium-sized impoundments are Bear Lake (107 acres) in Santa Rosa County, Hurricane Lake (400 acres) in Okaloosa County, Juniper Lake (665 acres) in Walton County, Lake Stone (130 acres) in Escambia County, Lake Victor (134 acres) in Holmes County, Merritt's Mill Pond (202 acres) in Jackson County, and Smith Lake (160 acres) in Washington County. There are surprisingly few impoundments of the larger rivers, however, even when compared to the upstream reaches of these rivers north of the Florida State line. The three largest are Lake Talquin on the Ochlockonee River (4,004 acres), Deer Point Lake (5,000 acres) on Econfina Creek north of Panama City, and Lake Seminole (37,000 acres).

The Florida Department of Environmental Regulation recently completed a 1-year study of water quality in Panhandle impoundments (FDER 1986d). This investigation included the monitoring of benthic macroinvertebrate and periphyton populations upstream of, in, and downstream of 17 Panhandle impoundments. This study found that the nutrient enrichment in the impoundments resulted in oxygen depletion, depauperate populations of benthic macroinvertebrates, and enhanced growth of algae. Not only were there effects within the impoundments, but there were profound adverse effects downstream of the impoundment that resulted in reduced macroinvertebrate populations.

The largest lake in Panhandle Florida is Lake Seminole, an artificial impoundment of the Chattahoochee and Flint rivers, backed up behind Jim Woodruff Dam exactly at their point of confluence at the beginning of the Apalachicola River. This large lake, with a surface area of 152 km^2 and a total volume of 9,439 km^3, is the last of 16 impoundments in the drainage basin, and the only one on the Florida reaches of the river.

a. Flora. Phytoplankton in Lake Seminole are dominated by diatoms (*Melosira distans, Asterionella formosa*), which during the cooler months make up as much as 77% of the population. During the warmer months, blue-green algae become dominant, making-up 76% of the total numbers. Coincident with this seasonal pattern is a switch in limiting nutrients from phosphorus in the cool months to inorganic nitrogen in the summer and fall. Cell numbers also vary seasonally, averaging lowest in winter months (1,951 cells/ml) and highest in September (14,729 cells/ml). An average of 37.5 taxa (13 to 51) of phytoplankton were reported from 17 stations in the lake over a 6-month period (USACE 1981).

Aquatic macrophytes cover approximately 40% of the surface area of Lake Seminole and virtually 100% of the area less than 2 m in depth (USACE 1981). Over 700 taxa of macrophytes have been identified, with 73 being reported as common to abundant (Table 14).

b. Fauna. We were unable to find comparative studies of the trophic relationships within Panhandle impoundments, although various lakes have been monitored for various periods by the Florida Game and Fresh Water Fish Commission. The fauna of impounded lakes derive mostly from the native faunas of the rivers in question, and partly from lentic water species that find their way into the lake by means of chance dispersal and by human transport. All of the impoundments in the Panhandle have been stocked with game fishes, mostly bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and channel catfish (*Ictalurus punctatus*), and with other species on a more limited basis (Gatewood and Hartman 1977). The fish, mammal, and waterfowl recreational values of these impoundments were summarized by Gatewood and Hartmann (1977).

Table 14. Aquatic macrophytes noted to be common to abundant in Lake Seminole during 1978–79 field surveys by the Army Corps of Engineers (USACE 1982). S = Submersed; E = Emergent; F = Floating.

Algae	S	E	F	Vascular	S	E	F
Chara spp.; chara	•			*Justicia americana*; water willow		•	
Lyngbya/Spirogyra; algal mat			•	*Sagittaria latifolia*; common arrowhead		•	
Nitella spp.; nitella	•			*Alternanthera philoxeroides*; alligator-weed		•	
				Colocasia esculenta; wild taro		•	

(continued)

Table 14. Continued

Vascular (continued)	S	E	F
Orontium aquaticum; golden club		•	
Alnus serrulata; speckled alder		•	
Betula nigra; river birch		•	
Brasenia schreberi; watershield		•	
Cabomba caroliniana; fanwort	•		
Sphenoclea zeylandica; chicken spike		•	
Ceratophyllum demersum; common coontail	•		
Ceratophyllum echinatum; prickly coontail	•		
Mikania scandens; climbing hempweed		•	
Carex spp.; sedges		•	
Cyperus spp.; sedges		•	
Eleocharis acicularis; slender spikerush		•	
Eleocharis cellulosa; spikerush		•	
Eleocharis equisetodes; knotted spikerush		•	
Hydrochloa carolinensis; water grass		•	
Leersia hexandra; cutgrass		•	
Panicum hemitomum; maidencane		•	
Panicum repens; torpedograss		•	
Zizaniopsis miliaceae; giant cutgrass		•	
Hypericum spp.; St Johnsworts		•	
Myriophyllum brasiliense; parrotfeather	•		
Myriophyllum spicatum; Eurasian watermilfoil	•		
Egeria densa; elodea	•		
Hydrilla verticillata; hydrilla	•		
Vallisneria americana; eelgrass	•		
Juncus effusus; soft rush		•	
Juncus spp.; rushes		•	
Lemna perpusilla; common duckweed			•
Spirodela polyrhiza; giant duckweed			•
Utricularia floridana; giant bladderwort	•		
Utricularia inflata; floating bladderwort	•		
Utricularia purpurea; purple bladderwort	•		
Mayaca fluviatilis; bog moss	•		
Nymphoides aquaticum; banana lily		•	

Vascular	S	E	F
Myrica cerifera; wax myrtle		•	
Najas guadalupensis; southern naiad	•		
Najas minor; naiad	•		
Nelumbo lutea; American lotus		•	
Nuphar luteum, spatterdock			
Nymphaea odorata; fragrant waterlily		•	
Nyssa aquatica; swamp tupelo		•	
Nyssa ogeche; ogeche tupelo		•	
Ludwigia decurrens; singed water primrose		•	
Ludwigia leptocarpa; water primrose		•	
Ludwigia palustris; water purslane		•	
Ludwigia peruviana; water primrose		•	
Platanus occidentalis; sycamore		•	
Polygonum spp.; smartweeds		•	
Eichhornia crassipes; water hyacinth			•
Pontederia cordata; pickerelweed		•	
Pontederia lanceolata; southern pickerelweed		•	
Potamogeton diversifolius; snailseed pondweed		•	
Potamogeton illinoiensis; Illinois pondweed	•		
Potamogeton nodosus; American pondweed		•	
Cephalanthus occidentalis; buttonbush		•	
Salix caroliniana; coastal plain willow		•	
Salix nigra; black willow		•	
Saururus cernuus; lizard's tail		•	
Bacopa caroliniana; water mint	•		
Sparganium americanum; burreed		•	
Taxodium ascendens; pond cypress		•	
Taxodium distichum; bald cypress		•	
Typha domingensis; southern cattail		•	
Typha latifolia; cattail		•	
Hydrocotyle ranunculoides; splitleaf pennywort			•
Xyris spp.; yellow-eyed grass.		•	

Chapter 7

ESTUARINE, SALTWATER WETLAND, AND MARINE HABITATS

7.1 Introduction

Classification of the saltwater habitats follows the scheme of Cowardin et al. (1979) as closely as possible (Table 15). Two systems, estuarine and marine, make up the saltwater environment. Included within each system are two subsystems— subtidal and intertidal. It is not possible to classify many of the Panhandle habitats as strictly subtidal or intertidal. For example, oyster reefs are primarily intertidal, but some are entirely intertidal and some may have both intertidal and subtidal regions. Given these problems, most habitats within the two systems are not subdivided further into strict subsystems. Class (henceforth "habitat") definitions are maintained and are based upon substrate composition (e.g., oyster reef) or primary vegetation (e.g., seagrass bed). In this document, the water column is treated as a separate habitat—open water—and includes fish and truly planktonic forms that cannot be assigned to specific habitats.

The short and very arbitrary naming and delineation of habitats are made with the following caveats: (1) the environment is a continuum of habitats, each one unique (e.g., not all oyster reefs are exactly the same) and each one dependent to varying degrees upon the others, and (2) many organisms use multiple habitats during different times of the day or different life stages and, therefore, cannot be assigned precisely to a single habitat. Wherever possible, major discrepancies in the classification are underscored.

A gross-level classification of the fauna is made according to the size of the organism, especially the benthos (bottom-dwelling organisms), for which size categories have traditionally been based upon retention on various sieve sizes: macrofauna (>0.500 mm), meiofauna (0.500–0.062 mm), and microfauna (<0.062 mm). This scheme has limitations. Some macrofaunal organisms are included as meiofauna early in their development, hence both temporary and permanent meiofauna distinctions are made. Nevertheless, the categories roughly follow taxonomic lines such that the macrofauna generally includes echinoderms, polychaetes, bivalves, oligochaetes, and crustaceans, such as decapods, amphipods, and isopods. The meiofauna includes harpacticoid copepods, nematodes, ostracods, kinorynchs, polychaetes, and gastrotrichs. The microfauna includes ciliates, fungi, and bacteria. Within this overall organization, there are trophic (i.e., deposit feeders and suspension feeders) and life-position (i.e., epifaunal and infaunal) distinctions.

The classification of flora is also based roughly on size: macrophytes (e.g., seagrasses and salt marsh grasses) and microphytes (e.g., phytoplankton and benthic diatoms). The boundaries, however, are less rigidly defined.

Given the large area of coast covered in the Panhandle region, it is unrealistic to report every species present or the small, albeit interesting, differences among watersheds. Primarily, dominant and ecologically important organisms are reported. An attempt has been made to highlight general patterns and interactions observable throughout the different locales. In addition, the role and natural history of some commercially important organisms are reported.

Within each habitat description, assessments and projections were made on potential and realized human impacts. Because they are semienclosed and have limited circulation, coastal estuaries and lagoons are very sensitive to pollution impacts, even though they ordinarily possess much higher nutrient concentrations than the marine or freshwater areas.

Table 15. Definition of estuarine and marine systems (after Cowardin et al. 1979).

Estuarine System	Marine System
Consists of deepwater tidal habitats and adjacent tidal wetlands that are semienclosed by land but have open, partly obstructed, or sporadic access to the open ocean. It contains ocean water that is at least occasionally diluted by freshwater runoff from the land. The salinity may periodically increase above that of open ocean due to evaporation.	Consists of the open ocean overlying the Continental Shelf and its associated high-energy coastline. Salinities exceed 30 ppt with little or no dilution except outside the mouths of estuaries. It includes habitats exposed to the waves and currents of the open ocean.
Limits—extends: (1) upstream and landward to where salinities do not fall below 0.5 ppt during the period of average annual low flow; (2) to an imaginary line closing the mouth of a river, bay, or sound; (3) to the seaward limit of wetland emergents, shrubs, or trees where they are not included in (2).	**Limits**—extends from the outer edge of the Continental Shelf shoreward to one of three lines: (1) the landward limit of tidal inundation (extreme high water of spring tides), including the splash zone from breaking waves; (2) the seaward limit of wetland emergents, trees, or shrubs; (3) the seaward limit of the Estuarine System.
Subsystems— (1) Intertidal—substrate exposed and flooded by tides; includes the splash zone; (2) Subtidal—substrate continuously submerged.	**Subsystems**— (1) Intertidal—substrate exposed and flooded by tides; includes the splash zone;

Estuaries act as nutrient and pollutant sinks through three major mechanisms: (1) sediment adsorption—the abundant clay-sized sediment particles tend to adsorb nutrients and other chemicals; when concentrations in the water column decline, sediments release their nutrients; (2) the basic circulation pattern of the estuaries—there are usually only limited tidal- and wind-generated currents in estuaries, and retention times are generally long; (3) biodeposition—large numbers of suspension-feeding mollusks (e.g., oysters) and crustaceans remove suspended materials and package them into feces and pseudofeces. These act as large particles that sink to the bottom and are buried; the nutrients and pollutants contained in them may later be released by erosion, sediment reworking by the benthos, and dredging.

In this document, human perturbations are generally grouped into two broad classes. The first includes those destructive impacts (usually the most easily detected), such as dredging and construction, that result in changes in habitat quantity. The second includes those impacts, such as excessive organic loading, that alter and degrade habitat quality. In some instances, the classes overlap. In many cases, specific impact studies on Panhandle sites are lacking and projected effects were derived from examples outside the immediate area.

7.1.1 Tides and Salinity Ranges

There are two types of tides along the Panhandle coast: semidiurnal from Ochlockonee Bay to Apalachicola Bay and diurnal (daily) from Apalachicola Bay westward to Perdido Bay. The semidiurnal tides are mixed (i.e., have unequal highs and lows) and range from 0.67 m to 1.16 m (Stout 1984). Diurnal tides have smaller amplitudes, ranging from 0.37 m to 0.52 m. Local daily tidal conditions are highly dependent upon meteorological conditions such as wind speed and direction.

Nearby gulf coastal water salinities are characteristically marine and stable through the year, averaging between 34 and 35 ppt. On the other hand, the bays and estuaries demonstrate fluctuating salinities that depend on a variety of physical factors such as river flow, rainfall, and tidal and wind conditions. The bays, except for St. Joseph and Alligator Harbor, which do not have rivers and streams supplying freshwater inputs, usually have definable haloclines that intensify during heavy rainfalls and dissipate during droughts. The interface between brackish bay water and saline gulf water approaches the surface on incoming tides and falls during outgoing tides. Northerly winds (especially strong in the winter) can cause the surface water of bays to move gulfward and can lower salinities up to 7 ppt (Salsman and Ciesluk 1978). Bay water salinity is low near river mouths and ranges between 20 and 38 ppt through most of their area.

7.2 Estuarine Habitats

7.2.1 Introduction

The discussion of the estuarine habitats follows a general format: first, the habitat is introduced with general background information; second, the flora, fauna, or both typically found in the habitat is discussed; third, the distribution of the habitat is provided; fourth, the trophic interactions within the habitat are given; and last, the natural and human impacts are presented. Sections will not be included where information was not available.

7.2.2 Brackish Marshes

a. Introduction. The brackish vegetation habitat includes both emergent and submergent forms. The habitat is primarily limited to salinities in the range of approximately 0 to 15 ppt and is generally located along river mouths subject to tidal influence.

b. Vascular species. Clewell (1978) investigated the extensive brackish marshes (i.e., emergent vegetation) at the mouth of the Apalachicola River. The marshes were primarily dominated by sawgrass (*Cladium jamaicense*). However, large patches of black needlerush (*Juncus roemerianus*) interrupted the sawgrass in places, particularly near the river channels and its distributaries. Other herbs were also common within a few meters of the banks of the channels, especially *Cicuta maculata, Ipomoea sagittata* (morning glory), *Rumex verticillatus, Sagittaria lancifolia* (arrowhead), *Spartina patens* (saltmeadow cordgrass), and *Teucrium canadense*. These and others are generally incidental or absent in the interior expanse of the sawgrass meadow.

The dominant brackish-water submergent vegetation includes three species: *Vallisneria americana, Potamogeton* sp., and *Ruppia maritima*.

East Bay in the Apalachicola Bay system has been the most extensively studied (Livingston 1980, 1984). Harper (1910) published the only other account of emergent brackish marshes in the Panhandle (specifically the Apalachicola).

Brackish vegetation is perennial, with annual diebacks starting in the fall and continuing at low biomass through the winter. This vegetation probably serves as an important source of detrital material providing energy for the species in the area.

c. Associated fauna. McLane (1980) described 33 species of benthic infauna from an area of East Bay (north Apalachicola Bay) brackish vegetation (Table 16). The dominant macrophytes were *Vallisneria americana* and *Ruppia maritima*. The six most abundant macrofaunal organisms (in descending rank) were *Grandideriella bonneroides* (amphipod), *Dicrotendipes* sp. (insect larva), *Laeonereis culveri* (polychaete), a nematode, *Mediomastus californiensis* (polychaete), and *Amphicteis gunneri* (polychaete). The number of macrofauna ranged from approximately 1,000 to 10,000 individuals/m^2. Peak numbers were recorded from September through March. Lowest densities were recorded from May through August. Biomass peaked in February to March and August to September.

Purcell (1977) described the epibenthic fauna associated with tape weed (*Vallisneria americana*) beds in East Bay and discussed that this habitat is an important nursery area especially for blue crabs (*Callinectes sapidus*).

d. Human Impacts. Timber clear cutting increases runoff and sediment load in streams leading

Table 16. Common benthic macroinvertebrates found in brackish vegetation in the Panhandle (McLane 1980).

Type	Species	Type	Species
Crustaceans	*Cerapus* spp. (amphipod) *Corophium lousianum* (amphipod) *Gammarus macromucronatus* *Grandideriella bonneroides* (amphipod) *Callinectes sapidus*	Polychaetes	*Amphicteis gunneri* *Laeonereis culveri* *Mediomastus californiensis* *Streblospio benedicti*
Insects	*Dicrotendipes* sp.	Mollusks	*Littorina sphictostoma* *Mactra fragilis* *Spisula solidissima*

into the estuaries. The increased turbidity and sediments and lower pH (i.e., higher acidity) cut down on light for photosynthesis. The increased sedimentation also smothers plants and animals.

7.2.3 Salt (or Tidal) Marshes

a. Introduction. Salt marshes are plant communities of the intertidal zone that represent a transition between terrestrial and marine ecosystems. Generally, marshes develop along low-energy coasts under stable or emergent conditions (Chapman 1960). Salt marshes develop in estuaries, behind the shelter of spits, offshore bars, and islands, in protected bays, and along very shallow seas. All these environments provide the marsh with protection from high-energy waves and allow for sediment accumulation and plant community expansion.

Numerous factors influence the areal extent of salt marshes. The most important of these are:

(1) the relation of land to sea level (i.e., whether the coastline is stable, emerging or submerging);

(2) the composition of the substrate;

(3) the amplitude of local tide;

(4) winds, currents, and waves—through their effects on sedimentation and aggradation (i.e., detrital loading)—and;

(5) the nature of the body of water facing the marsh.

The coastal marsh system is highly productive, exceeding natural upland vegetation and in some cases even agricultural crops (Odum et al. 1974). The high productivity is generally attributed to a large input of nutrients and particulate organic matter (of freshwater and marine origin), river flow and rainfall fluxes, tidal energy input, and basic physiographic and biological features. Three groups of organisms are responsible for the high productivity: phytoplankton, algae (on sediments and plants), and vascular plants. Both the above- and below-ground productivity make very important contributions.

The detrital food web appears the most important in salt marshes (Odum and de la Cruz 1967). Very few animals feed directly upon *Spartina* or *Juncus*.

Salt marshes perform four major ecological functions:

(1) They produce relatively large quantities of organic matter per unit area per time. Some of this organic matter is stored in the marsh in the form of peat, some is recycled in the marsh through a variety of food chains, and some is transported out of the marsh and dissipated into the estuaries.

(2) They are the exclusive habitat of a few species of algae and seed plants, of a large variety of invertebrates, of a large number of birds, and of a few reptiles and mammals.

(3) They provide substantial protection to adjacent low-lying uplands from saltwater intrusion, coastal erosion, and quantities of drifting debris, and, in expansive marshes, from salt spray.

(4) They are important nursery grounds and refuges for commercial and sport species.

Three different plant communities can be delineated within salt marshes (Stout 1984):

(1) saline marshes that experience tidal waters of marine salinity;

(2) brackish marshes where tidal waters are routinely diluted before flooding of the marsh; and

(3) transitional communities between brackish and freshwater marshes (also called "intermediate marshes"). Note: the brackish marshes were discussed in the previous section.

Salt marshes are usually characterized by large, homogeneous expanses of dense grasslike plants. Typically, the marshes are dominated by one plant species and named accordingly (e.g., *Juncus* marsh). The marsh community is usually low in macrophyte species diversity (see Table 17) with incidental species having a patchy occurrence and represented by only a few species.

b. Major physiographic features. Three types of surface irregularities occur in Panhandle salt marshes: tidal creeks, natural levees, and barrens.

Tidal creeks form when minor irregularities in marsh substrate cause the tidal water to be guided into definite channels (Chapman 1960). Once channels are formed, tides cause further scouring and prevent recolonization by vascular plants. Channels also deepen by accretion on their banks of sediments trapped around the roots of plants bordering the creek. As sedimentation increases and the marsh floor builds, creeks may lengthen and branch. Where the surface slope is gradual, creeks are less branched and the main channels are sinuous. The sinuosity of tidal-creek channels facilitates flooding and drainage, and promotes extension of the marsh by reducing the time required for the inward movement of seawater with each rising tide. Creek banks often support different vegetation from that immediately beyond the bank.

Natural levees develop from sand deposited on upper beaches by very high tides. Most natural levees slowly move landward through the action of tides. Very high tides continually remove sand from the seaward side and redeposit it on the landward side of levees.

Barrens (or salt barrens and salt pans) develop during the initial stages of marsh formation because of the irregular colonization patterns of salt marsh "pioneer" plants, which surround low bare areas and cause them to lose their outlets for tidal waters. These areas fill during spring tides and hold water for long periods of time. In summer, evaporation causes the salinity to rise and plants cannot invade the area. The characteristic round shape of salt pans may result from eddies that form on their borders during flooding. Barrens can also form by deposition of sand and silt in irregularly flooded areas (Kurz 1953, Kurz and Wagner 1957) and from debris tossed up on the marshes by tides and storms that sometime smother the marsh vegetation. In addition, they may

Table 17. Common vascular plants (in order of abundance) present in Panhandle salt marshes (Stout 1984).

Species	Common name	Species	Common name
Juncus roemerianus	Black needlerush	*Scirpus robustus*	Leafy sedge
Spartina alterniflora	Smooth cordgrass, oystergrass	*Salicornia bigelovii*	Annual glasswort
Spartina patens	Saltmeadow hay, saltmeadow cordgrass	*Salicornia virginica*	Perennial glasswort
Spartina cynosuroides	Giant cordgrass, rough cordgrass	*Batis maritima*	Saltwort
Distichlis spicata	Salt grass	*Phragmites australis*	Common cane, Roseau cane
Scirpus olneyi	Three-square sedge	*Baccharis halimifolia*	Sea myrtle
		Iva frutescens	Marsh elder

form behind a levee as a narrow strip devoid of vegetation. Most are temporary and usually recolonize within a few years, depending on salinity levels and depth of the barren (Kurz 1953).

c. Distribution. The marshes in the Panhandle are developing on the seaward edge of the Pamlico terrace of the late Pleistocene (Kurz 1953, Coultas 1980). The Pamlico terrace is a low upland with an elevation up to 8 m.

The Ochlockonee and Apalachicola Rivers supply alluvium downdrift to the west that results in the development of a system of beaches, spits, and barrier islands, as well as bars at the river mouths. Within these low-energy zones, marshes are located in the lee of barriers and within bays protected from wave action (Tanner 1960b, Kwan 1969). No barriers are found in the region west of St. Joseph Bay. Moderate-energy waves from the Gulf of Mexico strike the beaches; marshes protect shores only in major bays such as St. Andrew Bay and Choctawhatchee Bay. Steep mainland bluffs along the western shore of Escambia Bay in the Pensacola system do not support broad salt marshes.

Marshes occur sporadically along the lagoonal interface of Alligator Point peninsula, especially at the extreme east end of Alligator Harbor (Livingston 1984). Marshes are limited along the mainland east and west of the Apalachicola River mouth. In areal coverage, East Bay marshes dominate the system with lesser marsh development along St. Vincent Sound and the landward portions of Dog Island and St. George Island. The marshes of the Apalachicola Bay system cover approximately 14% of the surface (Livingston 1984).

d. Vascular plants present. The saline marshes of the Panhandle are dominated by halophytic monocotyledonous grass or rushlike plants, primarily *Juncus roemerianus* (black needlerush), *Spartina alterniflora* (saltmarsh cordgrass), *Spartina patens* (saltmeadow hay or cordgrass), and *Distichlis spicata* (salt grass). Fleshy, dicotyledonous plants—*Salicornia*, *Batis*, and *Borrichia*—are commonly present but less abundant. Table 17 gives a list of dominant plant species in Panhandle salt marshes. Tidal marshes of the northwest Florida coast are dominated by *Juncus roemerianus*. Thirty-one percent of the marsh area in the Panhandle is dominated by this species (Eleuterius 1976).

The vascular plants form distinctive patterns of species zonation within the salt and brackish marshes of the Panhandle. Four zones are discernible: *Spartina alterniflora*, *Juncus roemerianus*, salt flat or barren, and high meadow (Stout 1984) (Figure 70A).

The *Spartina alterniflora* zone is closest to sea level in the intertidal zone and experiences regular or daily inundation. Since this zone is regularly flooded, substrate salinity is approximately that of tidal concentration. The zone lies typically within an elevation from -0.24 m to 0.54 m MLW. If the shore topography is broad and gently sloping, *S. alterniflora* can exhibit differences in morphology and flowering. Taller plants with flower heads occur in the lower elevations of the zone, while shorter sterile plants occupy the upper area (Stout 1984). The zone is usually monospecific. On shores with greater slope, *S. alterniflora* may be found mixed with *Juncus roemerianus*. Shores with greater wave energy may form a levee upslope from the *Spartina* (Figure 70B). The vegetation of the levee is usually typical of higher elevations.

The *Juncus roemerianus* zone is at a slightly higher elevation and subjected to less flooding than the *Spartina alterniflora* zone (Figure 70A). *Juncus* comprises the bulk of the biomass in most Panhandle marshes. There is usually a sharp demarcation between the *Spartina* and *Juncus* zones. The *Juncus*-demarcation zone generally corresponds to the MHW mark, but edaphic conditions and biotic factors may also be important. The *Juncus* zone occupies a more restricted elevation range (0.54 m–0.75 m MLW) but spans greater horizontal distances than *Spartina*. The *Juncus* zone can reach several kilometers in width.

Tidal flooding of this zone is irregular and higher elevations may be flooded only during spring or storm tides. Because of longer more frequent periods of exposure and evaporation, interstitial water salinities may be higher in *Juncus* than *Spartina alterniflora* zones. The high organic content (and associated acid conditions) of *Juncus* soils may impede percolation of tidal water and rainwater into the substrate.

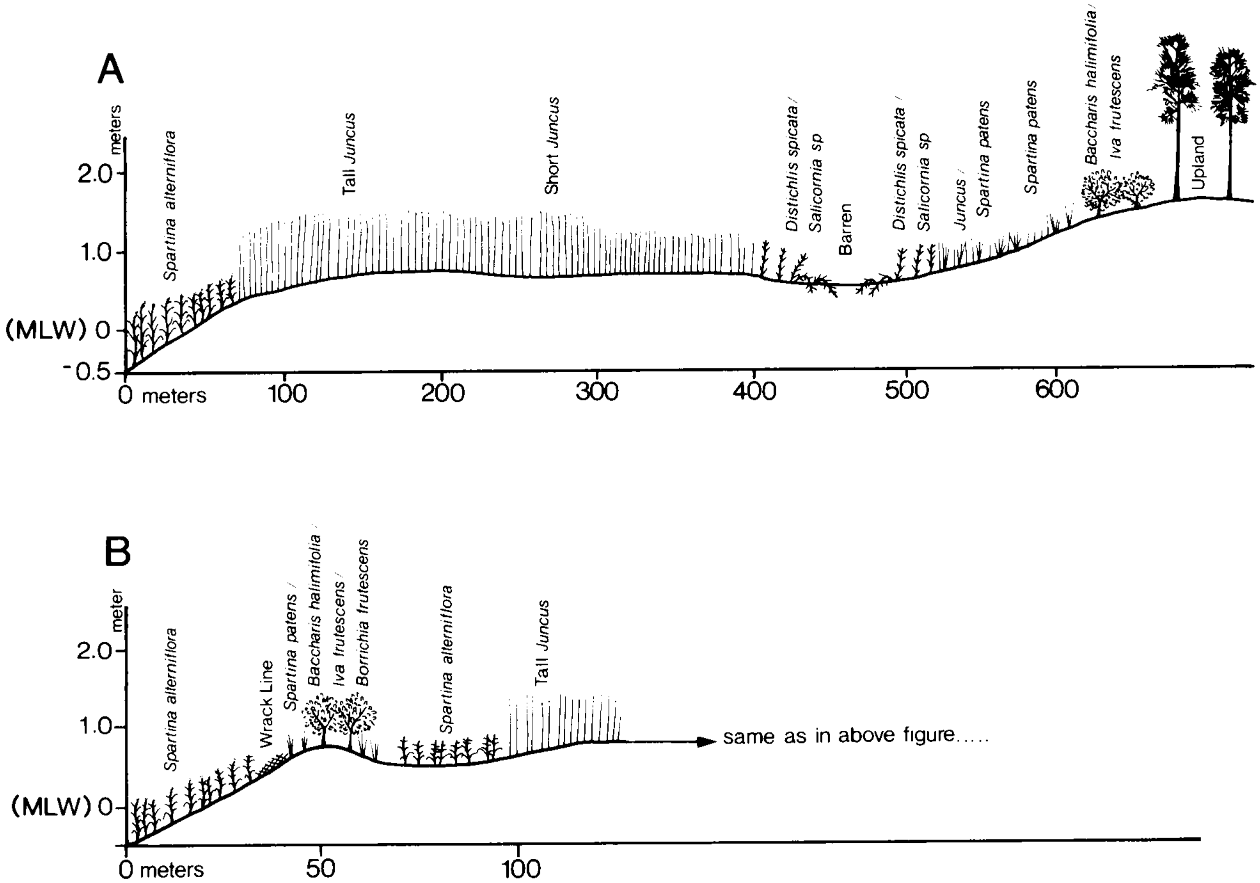


Figure 70. Schematic views of gulf coast salt marshes on protected low-energy shorelines (A) and open moderate energy shorelines (B) (after Stout 1984).

A *Juncus* marsh community may be represented by two or more height forms that possibly reflect microhabitat differences in the zone. The tallest plants are nearest the tidal source and so are more frequently flooded. Stem height and diameter decrease with distance from shore, while stem densities and new leaf production increase. Soil texture and salinity gradients may a play role in morphology (Coultas 1980).

There is a decline in sexual reproduction in *Juncus* and *Spartina alterniflora* plants at higher elevations in a marsh. The shortest *Juncus* plants (height ≤0.5 m) are usually sterile and are found adjacent to salt flats. Unlike most of the other marsh grasses, *J. roemerianus* grows throughout the year and represents a climax vegetational type (Eleuterius 1976).

The salt flat zone, just upland from the *Juncus* zone, has a sandy, hypersaline soil and includes portions of the zone vegetated by halophytic species. These ecotonal areas are called "barrens" because they are devoid of plants. This zone is rarely inundated by tidal water and when it is flooded, water quickly percolates through the coarse substrate. Interstitial water salinities are extremely high.

The seaward and upland margins of the salt flat are usually mirror images of plant communities on either side of the barrens (Stout 1984). Salt grass

(*Distichlis spicata*) extends in parallel stands from the upper edge of the *Juncus* and the lower edge of the high meadow into the salt flat. As salinities increase toward the barrens, *Distichlis* no longer grows. Interior to the *Distichlis* margins of the salt flats only three species occur: *Salicornia virginica* (perennial); *S. bigelovii* (annual) and *Batis maritima*. All three species are obligate halophytes.

The size of the barrens varies with local conditions and may change over short periods of time (i.e., days) with rainfall fluctuations and tidal flooding, and over long periods of time with changes in elevation. If salinity decreases within the barrens, seedlings of the annual *Salicornia bigelovii* and rhizomes of other salt flat species rapidly colonize the area.

The extent of the high meadow zone (or high marsh) varies greatly from a narrowly vegetated fringe between the salt flat and upland vegetation to a broad meadow of grasslike vegetation. *Juncus* is usually very abundant and shares dominance with *Spartina patens*, the latter being most common upland. This zone contributes most to the diversity of the marsh with numerous incidental species present in the shrub-forest ecotone. Species common in this zone include: *Fimbristylis caroliniana*, *Scirpus robustus*, *Aster tenuifolius*, *Phragmites australis*, *Cynanchum angustifolium*, *Pluchea* sp., and various shrubs (e.g., *Baccharis halimifolia*, *Iva frutescens*, and *Myrica cerifera*).

e. Nonvascular (and microbial) plant community. The highest density of nonvascular plants is always found on other plants above the soil surface. Twenty-five species of filamentous fungi occur on *Spartina*, all of which are on the aboveground parts of the plant. Two infectious fungi occur on *Spartina*: the ergot fungus *Claviceps purpurea* and the rust fungus *Puccinia sparganiodes*.

Of the algal communities found in Panhandle marshes, only diatoms and blue greens of *Juncus*-dominated marshes have been examined (Stout 1984). The epiphytic algae *Bostrychia* spp. and *Enteromorpha* spp. are the most frequently encountered (Table 18). Diatoms constitute a continuous benthic marsh cover in areas with and without a spermatophyte canopy. The most abundant diatom species is *Navicula tripuncata*. The greatest number of diatom species is found on *Distichlis spicata*, the lowest on *Juncus*. Diatom distributions are primarily

Table 18. Zonal relationship of algae with spermatophyte community in Panhandle marshes (from Kurz and Wagner 1957, Stout 1984).

Dominant algae	Location
***Spartina alterniflora* community**	
Bostrychia spp.	attached to culms
Enteromorpha flexuosa	attached to culms
Melosira spp.	attached to culms
Microcoleus chthonoplastes	channel bottom
Phormidium fragile	attached to oyster shells
Lyngbya confervoides	attached to oyster shells
soil diatoms	sediment
Chondria spp.	drift fragments
Digenia spp.	drift fragments
Enteromorpha spp.	drift fragments
Sargassum spp.	drift fragments
Polysiphonia spp.	drift fragments
Champia spp.	drift fragments
Fosliella spp.	drift fragments
***Juncus roemerianus* community**	
Bostrychia spp.	attached to culms
Cladophora spp.	attached to culms
Chaetomorpha spp.	attached to culms
Enteromorpha spp.	attached to culms
Lyngbya aestuarii	attached to culms
***Distichlis spicata* community**	
Bostrychia spp.	attached to culms
Cladophora spp.	attached to culms
Chaetomorpha spp.	attached to culms
Enteromorpha spp.	attached to culms
Lyngbya aestuarii	attached to culms

regulated by marsh surface elevation and canopy height.

f. Marsh-associated fauna. Animal members of the marsh ecosystem fall into three broad categories: (1) permanent residents that spend their entire lives in the marsh; (2) transitory residents that spend only part of their lives (e.g., foraging) in the marsh; and (3) animals that spend only the juvenile portion of their lives in the marsh (Shipp 1977). The third category emphasizes the importance of the role of salt marshes as "nursery ground" for many species.

Salt marsh organisms are frequently exposed to harsh and variable conditions. Waters within the marsh change daily with the tide, resulting in salinity, temperature, oxygen, and pH fluctuations. Salinity can also vary from one area to another with temperature, wind, freshwater inflow, rainfall, and evaporation. The marsh fauna change along the gradient from the low marsh to the upper marsh (Figure 71).

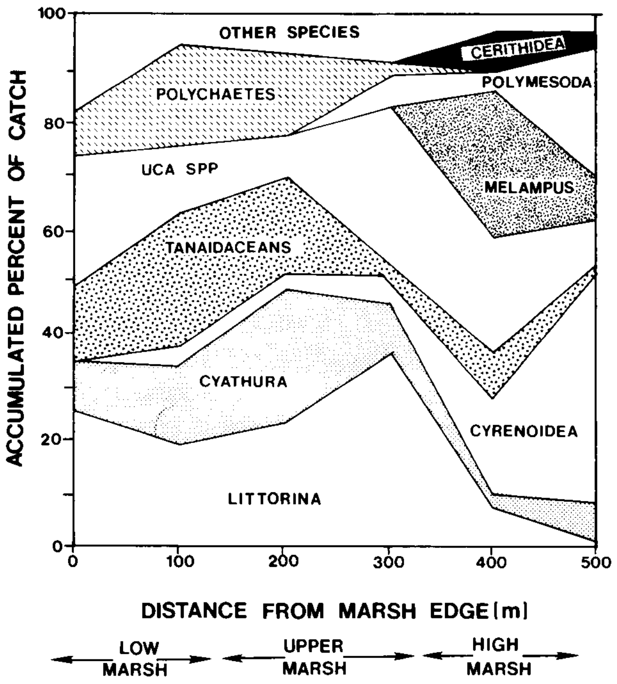


Figure 71. Horizontal distribution of macrofauna in a typical Panhandle tidal marsh (after Stout 1984).

Of the marsh invertebrates (Table 19), insects are very abundant, with all major orders being recorded (McCoy 1977). The insects can be divided into aquatic, subterranean, and surface-living groups. Diptera, Coleoptera, and Hemiptera dominate. Gastropods and fiddler crabs (*Uca* spp.) are the most common visible mollusks and crustaceans, respectively.

Fish are seasonally very abundant and diverse. Over 80 fish species have been reported from the creeks, ponds, and open water of salt marshes in the Panhandle. Table 20 shows those that are most common. Fish community structure is influenced by (1) season and tides, (2) species breeding activity, (3) species feeding behavior, (4) habitat diversity

Table 19. Common invertebrates of Panhandle salt marshes (Stout 1984).

Group	Species or order
Zooplankton	*Uca* spp.
Meiofauna	Nematoda Harpacticoid copepods
Insects	Diptera Coleoptera Hemiptera
Polychaetes	*Scoloplos fragilis* *Neanthes succinea* *Amphicteis gunneri* *Laeonereis culveri*
Mollusks	*Littorina irrorata* (marsh periwinkle) *Polymesoda caroliniana* (bivalve) *Neritina usnea* (gastropod) *Melampus bidentata* (gastropod) *Cerithidea scalariformis* (gastropod) *Detracia floridana* (gastropod) *Succinea ovalis* (gastropod)
Crustaceans	*Halmyrapseudes bahamensis* (tanaid) *Cyathura polita* (isopod) *Palaemonetes pugio* (grass shrimp) *Palaemonetes intermedius* *Callinectes sapidus* (blue crab) *Uca* spp.

Table 20. Common fishes of Panhandle salt marshes (Stout 1984).

Species	Common name	Residence status
Menidia beryllina	Tidewater silverside	permanent
Fundulus similis	Longnose killifish	permanent
Fundulus grandis	Gulf killifish	permanent
Fundulus confluentus	Marsh killifish	permanent
Cyprinodon variegatus	Sheepshead minnow	permanent
Adinia xenica	Diamond killifish	permanent
Poecilia latipinna	Sailfin molly	permanent
Leiostomus xanthurus	Spot	nursery user
Lucania parva	Bluefin killifish	permanent
Anchoa mitchilli	Bay anchovy	nursery user
Mugil cephalus	Striped mullet	nursery user
Lagodon rhomboides	Pinfish	nursery user

and available space, and (5) proximity to estuarine and nearshore waters. Panhandle marshes, like other Gulf of Mexico marshes, are dominated by cyprinodont species (Stout 1984).

A number of reptile species are commonly encountered in the marsh, but amphibians are not as well represented. Common reptiles are shown in Table 21.

Birds are an important component of the marsh system. Over 60 species are reported to use habitats within Panhandle salt marshes. Table 22 lists those species that are common, however, only a few are permanent residents. The marsh offers food sources, nesting areas, and refuges. Wading birds and shore birds often feed near the marsh intertidal zone and creeks. Only clapper rails and seaside sparrows nest in the *Juncus* marshes. The majority of others nest in small trees and shrubs growing on shell and sand berms or spoil deposits within the marsh. Snowy and great egrets are the most abundant nesting species within the brackish marshes. Tricolored herons are the most abundant species in the salt marshes (Stout 1984).

Table 21. Common reptiles of Panhandle salt marshes (Stout 1984).

Species	Common name
Malaclemys terrapin pileata	Mississippi diamond back terrapin
Pseudemys alabamensis	Alabama red-bellied turtle
Pseudemys floridana floridana	Florida cooter
Alligator mississippiensis	America alligator
Nerodia fasciata clarkii	Gulf salt marsh water snake

Mammals can be categorized into three major groups: (1) marsh residents, (2) inhabitants of the marsh-upland interface, and (3) upland mammals entering the marsh to feed (Table 23).

g. Species of special concern. The American bald eagle (*Haliaeetus leucocephalus*) is listed as federally endangered and occurs in Panhandle salt marshes.

h. Trophic dynamics/interactions. Marshes are characterized by an extremely high level of primary productivity and, subsequently, serve as the base of the detrital food web for the entire estuarine ecosystem. Few animals feed directly upon live *Juncus* or *Spartina*, but marsh detritus that results from the decomposition (both biological and mechanical) of plant material is a rich food source for many marsh and estuarine organisms.

Table 22. Common birds of Panhandle salt marshes (Stout 1984). Note for Occurrence: P = permanent resident; B = breeding population; M = migrant; W = winter visitor; S = summer resident; C = casual; T = threatened species (State of Florida).

Order	Species name	Common name	Occurrence
Gruiformes	*Rallus elegans*	King rail	PB
	Rallus longirostris	Clapper rail	PB
	Rallus limicola	Virginia rail	MW
	Porzana carolina	Sora	MW
	Coturnicops noveboracensis	Yellow rail	W
	Laterallus jamaicensis	Black rail	PB
	Fulica americana	American coot	PB
Charadriiformes	*Sterna nilotica*	Gull-billed tern	M
	Sterna forsteri	Forster's tern	PB
	Sterna caspia	Caspian tern	W
	Charadrius semipalmatus	Semipalmated plover	W
	Pluvialis squatarola	Black-bellied plover	WM
	Catoptrophorus semipalmatus	Willet	MB
	Calidris minutilla	Least sandpiper	WM
	Calidris alpina	Dunlin	WM
	Limnodromus griseus	Short-billed dowitcher	SM
	Calidris himantopus	Stilt sandpiper	M
	Calidris pusilla	Semipalmated sandpiper	M
	Calidris mauri	Western sandpiper	WM
Ciconiiformes	*Ardea herodias occidentalis*	Great white heron	CS(T)
	Ardea herodias	Great blue heron	PB
	Butorides striatus	Green-backed heron	SB
	Egretta caerulea	Little blue heron	PB
	Casmerodius albus	Great egret	PB
	Egretta thula	Snowy egret	PB
	Egretta tricolor	Tricolored heron	SB
	Nycticorax nycticorax	Black-crowned night heron	PB
	Eudocimus albus	White ibis	S
Anseriformes	*Anas rubripes*	American black duck	PB
	Anas strepera	Gadwall	W
	Anas americana	American wigeon	W
	Aythya americana	Redhead	MW
	Aythya affinis	Lesser scaup	MW
	Branta canadensis	Canada goose	MW
Passeriformes	*Tachycineta bicolor*	Tree swallow	M
	Corvus ossifragus	Fish crow	PB
	Cistothorus palustris	Marsh wren	PB
	Cistothorus platensis	Sedge wren	W
	Agelaius phoeniceus	Red-winged blackbird	PB
	Ammodramus caudacutus	Sharp-tailed sparrow	PB
	Ammodramus maritimus	Seaside sparrow	PB

Table 23. Common mammals of Panhandle salt marshes (Stout 1984).

Species	Common name	Species	Common name
Sylvilagus palustris palustris	Marsh rabbit	*Mustela vison mink*	Southern mink
Oryzomys palustris palustris	Rice rat	*Lutra* cf. *canadensis*	Otter
Sigmodon hispidus	Cotton rat	*Vulpes fulva*	Red Fox
Ondatra zibethicus rivalicius	Louisiana muskrat	*Mustela frenata*	Long-tailed weasel
Myocastor coypus bonariensis	Nutria	*Lynx rufus*	Bobcat
Procyon lotor varius	Raccoon	*Odocoileus* sp.	Deer

Decomposition rates vary among the different plant species. The available detritus is usually lowest in winter months and increases through the spring and early summer to maximum values in August and September (Stout 1984).

i. Natural Impacts. Several natural factors such as sea level rise, extreme climatic events, tidal scour, and fire have affected the ability of marsh habitats to remain functional.

The current and future sea level rise (and coastal subsidence) may represent the most important potential long-range impact on salt marshes. Estimates of sea-level rise in the Panhandle (i.e., Pensacola) range from 84 to 104 cm in the next 100 years (including local subsidence rate and water-level increase) (Titus et al. 1984).

Sea-level rise will affect salt marshes in two ways: (1) increased tidal flooding and (2) wave-induced erosion (Titus et al. 1984). Since tidal flooding is an essential component of salt marsh functioning, any alteration can substantially change the system. With increased flooding, the system tends to migrate upward and landward. When insufficient organic sediment or peat is added to the marsh to keep up with the sea-level rise, the seaward zone becomes flooded so that the vegetation drowns and the soil erodes; the high marsh zone eventually becomes the low marsh or open water.

Sedimentation from rivers can offset some of the sea-level rise, but probably only for marshes in major river deltas (e.g., the Apalachicola). Other marshes will have a tendency to move inland. If there is human development just inland from the salt marshes, however, the marshes will have no room to migrate and will eventually disappear.

Sea-level rise may increase wave-induced erosion by allowing larger waves to hit the shoreline. A rise in sea level deepens bays and, depending upon bottom topography, would allow larger locally formed waves and ocean waves to strike the marsh. In addition, the protective barrier islands will rapidly erode and no longer buffer the wave energy before it strikes the coast.

j. Human Impacts. Marshes are extremely sensitive and susceptible to oil pollution. Given their location, they can be affected by oil residue running off the land as well as by oil spilled in the Gulf of Mexico and estuarine waters. Primary productivity can be severely reduced for months after a spill (Stout 1984). Contamination is usually restricted to the outer fringes of the marsh unless storms or extreme high tides drive water higher than usual. Usually, contamination will be apparent on the surface of the soil, plant stems, and leaves. The extent of an oil spill impact depends upon the amount and type of petroleum spilled, the proximity of the spill to the marsh, and other factors. The sublethal effects may be chronic or acute. The trophic effect on marsh birds and other animals higher in the food chain is not well known.

Pulp-mill effluents in the Apalachee Bay to the east of the study area have been found to severely reduce both the number of species and of individuals of marsh fishes. In addition, community structure was altered (Livingston 1975). Bird populations also exhibited reduced abundances and species numbers in pulp-mill polluted areas (Weiser 1973).

Sediment diversions such as dams, canals, and levees (e.g., fill roads) impact wetlands by decreasing the supply of fine sediment essential for the maintenance of marsh substrate. If an area is naturally subsiding, a reduced sediment supply from the land magnifies the problem.

The extraction of ground water, oil, and gas may cause subsidence of the local area. Also, impounding a marsh causes consolidation and oxidation of dewatered sediments.

Other human activities with more localized effects include: using pesticides (Tagatz et al. 1974), erosion from boat-wakes, canal dredging, using marsh buggies and other wetland transportation vehicles, and waste disposal.

k. Conclusions. The salt marsh is a critical nursery, refuge, and feeding area for many commercially important estuarine organisms such as fish and crabs. The plants protect the juvenile forms of many of the estuarine organisms against predation. They also supply the bulk of the detritus for the estuarine system. They have the important function of buffering coastal regions from the erosional effects of storms. The balance between a rising sea level and the necessary sediment supply is being upset by human encroachment in nearby habitats that directly and indirectly affects the marsh. This habitat is one that requires very stringent monitoring for future protection.

7.2.4 Intertidal Flats

a. Introduction. Intertidal flats are those portions of the unvegetated bottoms of estuaries, bays, lagoons, and river mouths that lie between the high and low tide marks as defined by the extremes of spring tides (Peterson and Peterson 1979). Intertidal flats are composed of sandy and muddy sediments in a wide range of relative proportions. Usually the distinction between intertidal "sand" flats and "mud" flats (as nearly all intertidal flats are traditionally misnamed) is made upon percentage of silt-clay in the sediment:

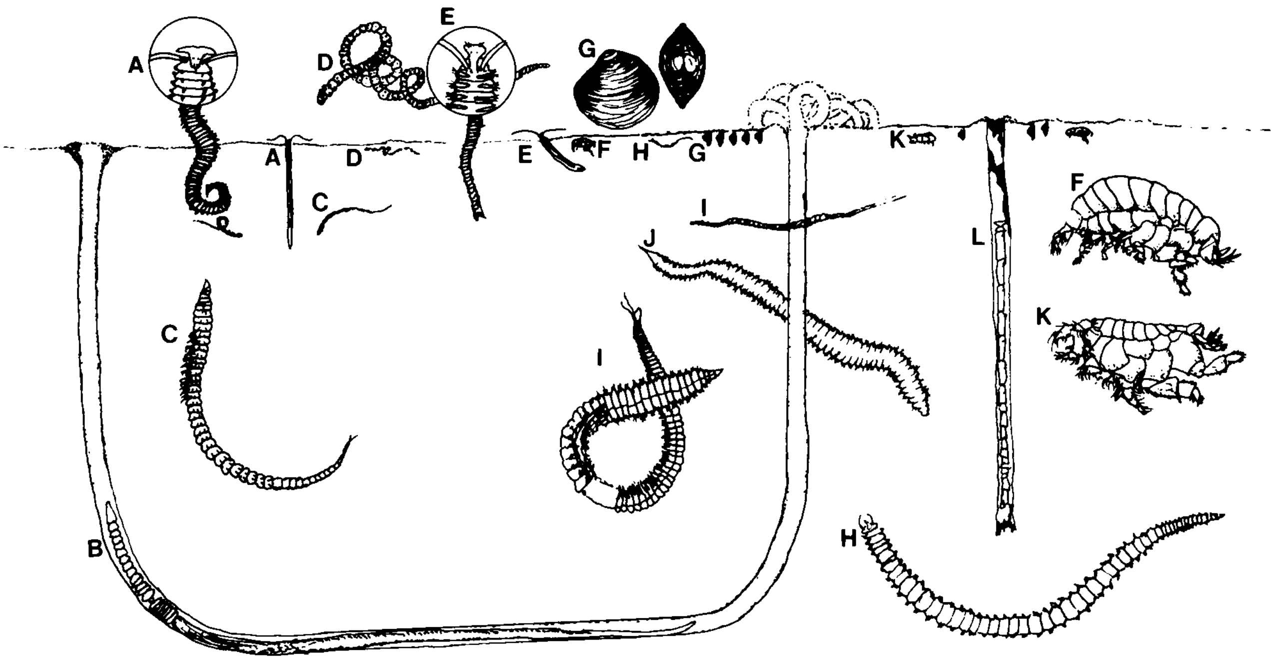
sediment	silt-clay fraction (dry wt.)
clean sands	< 5%
muddy sands	5–50%
sandy muds	50–90%
true muds	> 90%

The sediment type is indicative of the energy level of the coastline (i.e., a muddy sediment usually means a low-energy shore).

Intertidal flats appear barren and unproductive because of the absence of macrophytes such as marsh grass or seagrass. However, benthic microalgae are very abundant and productive, but do not accumulate the great biomass that, for example, marsh grasses do. Microalgae are nutritious and highly palatable to many herbivores; they are therefore rapidly used and maintain a low standing stock. Benthic microalgae generally do not go through intermediate bacterial or fungal food chains but are consumed directly by benthic invertebrates. For these reasons, intertidal flats contribute a substantial amount of primary productivity to an estuarine system which is, in turn, converted into consumer biomass. The benthic invertebrates are preyed upon by larger predators such as shorebirds, crabs, and bottom-feeding fishes. Intertidal flats play a critical role in the functioning of the entire estuarine system (Peterson 1981).

b. Flora. Microalgae, bacteria, and fungi are locally abundant on intertidal flats. The generally small sediment particles present in the intertidal habitat can support large populations of these organisms. Occasionally, the bacteria form visible purplish-red mats on the sediment surface (Reidenauer, personal observation). Bacteria are an important food source for the meiofaunal community (Carman 1984) and are the primary transformers of detritus into inorganic nutrients.

c. Faunal composition. Two groups of benthic fauna are present on the intertidal flats: epifauna (forms that live on top of the substrate) and infauna (forms that live within the substrate) (Figure 72). Mobile epifauna, such as crabs, are found most commonly during high tides. Infaunal organisms, however, are more abundant at both low and high tides.



Surface deposit feeders
A = *Spiophanes bombyx* (spionid polychaete)
B = *Ptychodera bahamensis* (protochordate)
E = *Prionospio steenstrupi* (spionid polychaete)

Suspension Feeders
F = *Protohaustorius* sp. (haustorid amphipod)
G = *Gemma gemma* (venerid bivalve)
K = *Acanthohaustorius* sp. (haustorid amphipod)

Conveyor-belt deposit feeder
L = *Clymenella torquata* (maldanid polychaete)

Burrowing deposit feeders
C = *Aricidea cerrutii* (paraonid polychaete)
D = oligochaete
H = *Exogone dispar* (syllid polychaete)
I = *Haploscoloplos* fragilis (orbiniid polychaete)
J = *Nephtys picts* (nephtyid polychaete)

Figure 72. A cross-sectional view through a typical intertidal sand-flat community in the Panhandle showing representative invertebrates (adapted from Whitlatch 1982).

The infaunal microfauna are dominated by protozoans, with foraminifera and ciliates being the dominant forms. The group has been little studied.

The meiofauna differ between sand and mud tidal flats because of the difference in interstitial space (i.e., space between sediment particles) available to the organisms in each sediment type. Sand sediments have larger interstitial spaces and the majority of the meiofauna are adapted to living within these spaces (i.e., infaunal). In muddy sediments, the meiofauna are generally restricted to living on the sediment surface (i.e., epifaunal).

The macrofauna are the most dominant group of infauna in terms of biomass present. Polychaetes, amphipods, enteropneusts, and bivalve and gastropod mollusks dominate the community (Figure 72 and Table 24).

d. Trophic dynamics and interactions. Microalgae, primarily the diatoms, dinoflagellates, filamentous greens, and blue-greens, are the primary products in the tidal flat system. Typically, these forms demonstrate a high turnover rate. Herbivores are usually deposit-feeding or grazing macroinvertebrates. Many of the common species are given in

Table 24. Commonly encountered macroinvertebrates of Panhandle intertidal flats (Abele 1970, LeBlanc 1973, Abele and Kim 1986).

Group	Species	Habitat
Crustacea	*Alpheus heterochaelis*	epifaunal
	Callianassa jamaicensis	infaunal
	Eurytium limosum	epifaunal
	Uca longisignalis	epifaunal
	Callinectes sapidus	epifaunal
Mollusca	*Mercenaria mercenaria*	infaunal
Polychaeta	*Amphicteis gunneri floridus*	infaunal
	Diopatra cuprea	infaunal
	Glycera americana	infaunal
	Glycera dibranchiata	infaunal
	Haploscoplos fragilis	infaunal
	Heteromastus filiformis	infaunal
	Laeonereis culveri	infaunal
	Notomastus latericeus	infaunal
	Onuphis eremita oculata	infaunal
	Pectinaria gouldii	infaunal
Enteropneusta	*Ptychodera bahamensis*	infaunal
Merostomata	*Limulus polyphemus*	epifaunal

Table 25. Common birds of Panhandle intertidal flats (Stout 1984).

Guild	Common name
Waders	Herons Egrets Ibises Yellowlegs
Shallow-probing, surface-searching	Sandpipers Plovers Knots
Deep-probing	Godwits Willets Curlews
Aerial-searching	Terns Gulls Skimmers Pelicans
Floating/diving	Ducks Geese Grebes Cormorants
Birds of prey	Osprey Eagles

Table 24. Shorebirds (Table 25), crabs, and fishes are the primary consumers of the herbivores.

The infauna of Panhandle intertidal flats are generally less abundant than that of adjacent salt marshes, even at similar tidal heights. The difference is usually pronounced and approaches two orders of magnitude (Stout 1984). The pattern appears to be a result of higher predation on organisms living in the flat areas (Naqvi 1968).

Large, mobile epibenthic predators are common on intertidal flats, especially during the warm summer months when most infaunal organisms are low in numbers. Predators can be divided into two general groups. One group, dominated by fiddler crabs (*Uca* spp.), roams the intertidal zone at low tide foraging for epibenthic algae and detritus. Most of the members in this group are herbivores or detritivores. The other group of predators includes organisms that forage on the flat when the tide is in. These species are mostly carnivorous. The most important species are the blue crab, *Callinectes sapidus*, the stingray, *Dasyatis sabina*, and the horseshoe crab, *Limulus polyphemus*. These species prey on bivalves and polychaetes. The tolerance of blue crabs to reduced salinities makes them effective predators under a variety of conditions. Blue crabs cannot forage efficiently for infauna in the presence of shell debris, which inhibits their digging; therefore, the abundance of many bivalves and other infauna is higher at the margins of structures such as oyster reefs. Smaller biological structures, such as *Diopatra cuprea* tubes, may also offer infaunal organisms a refuge from predation or disturbance (Woodin

1978). In addition to the invertebrate predators, birds are important predators on infaunal organisms.

In addition to removing organisms by predation, blue crabs, horseshoe crabs, and birds can be a source of infaunal mortality by disrupting the sediment surface. Blue crabs dig up to 6–8 cm deep in the sediments to forage and hide. Their pits are sites of decreased infaunal densities (Woodin 1978). Horseshoe crabs dig broad, shallower pits (less than 4 cm deep) that have slightly less impact on the infauna (Peterson and Peterson 1979). Birds disturb the infauna in a variety of ways depending on their feeding mode.

Additional food resources are supplied to the intertidal flats by grass wrack (dead fragments of seagrass and marsh grass) that are deposited on the flat during outgoing and incoming tides.

7.2.5 Hard Substrates

a. Introduction. Most of the habitat represented in this category is artificial. There is little naturally occurring hard substrate along the Panhandle coast. In addition to larger surfaces such as jetties, bridges, and pier pilings, mollusk shells and trash offer suitable microhabitats for some sessile organisms.

b. Community structure. Panhandle estuarine fouling communities demonstrate a dramatic decrease in larval settlement and population growth during the winter (November–March) (Salsman and Ciesluk 1978). The entire fouling community appears to be affected except the bacteria and associated slime film (including algae) that is usually present.

During the summer, when water temperatures are greater than approximately 20 °C, a complete biofouling community is present. The most abundant organisms are barnacles, with the species *Balanus eburneus* dominant in the upper tidal zone. Polychaetes (serpulids and spirorbids—calcareous tube builders) and bryozoans are also abundant. Later in community development, tunicates (ascidians) become important. Tunicates, or sea squirts, (e.g., *Ectenascidia turbinata* and *Styella partita*) can eventually dominate a substrate, forming a homogenous layer 30–40 mm thick.

The first macrofaunal colonizers onto a new hard substrate are usually the American oyster *Crassostrea virginica* or the barnacle *Balanus* spp. The barnacle can eventually replace the oyster.

c. Trophic dynamics and interactions. Predators on the initial colonizers of hard substrates appear quickly after settlement. Oyster predators include the American oystercatcher (*Haematopus palliatus*), the decapods—blue crab, stone crab (*Menippe mercenaria*), and mud crab (*Eurypanopeus depressus*), and the mollusk—oyster drill (*Thais haemastoma*). Barnacle predators include the decapods *Pachygrapsus transversus*, *Mithrax forceps*, and *M. pleuracanthus*. Decapods are common on Panhandle jetties (Table 26).

K. Sherman (Florida Department of Health and Rehabilitative Services, Tallahassee; pers. comm.) has investigated the epifauna of live scallop shells from St. Joseph Bay. The epifaunal assemblage is similar to the nearby *Thalassia* epifauna but is dominated by different species. There is a strong seasonality, and competition for food may be an important factor in controlling abundances (especially meiofauna). The two-dimensional nature of the hard substrate may result in spatial competition among the various residents (K. Sherman, pers. comm.).

7.2.6 Oyster Reefs

a. Introduction. The biology of the oyster has been extensively studied because of economic interests (e.g., meat and shell industries). However, the ecology of the oyster reef ecosystem, despite recognition that it is a separate community (Mobius 1877), has not been nearly as intensively investigated. Most information comes from research performed outside the Panhandle region. Oysters are typically reef organisms, growing on the shell substrate accumulated from generations of oysters (Chestnut 1974). The term oyster reef is often used interchangeably with other terms for estuarine regions inhabited by oysters, including oyster bar, oyster bed, oyster rock, oyster ground, and oyster planting. Bahr and Lanier (1981, p. 3) define oyster reefs as "the natural structure found between the tide lines that are [sic] composed of oyster shell, live oyster, and other organisms and that are discrete, contiguous, and clearly distinguishable (during the ebb tide) from scattered oysters in marshes and mud flats, and from wave-formed shell windrows."

Table 26. Common decapods found on Panhandle jetties (Abele 1970, Abele and Kim 1986).

Species name	Species name	Species name
Acanthonyx petiverii	*Hexapanopeus quinquedentatus*	*Periclemenes americanus*
Alpheus armillatus	*Hippolysmata wurdemanni*	*Portunus sayi*
Alpheus formosus	*Mithrax forceps*	*Sicyonia laevigata*
Calcinus tibicen	*Mithrax pleuracanthus*	*Stenorhynchus seticornis*
Dromidia antillensis	*Pagurus miamensis*	*Synalpheus fritzmuelleri*
Hexapanopeus paulensis		*Xantho denticulata*

Oyster reefs influence estuaries physically by removing suspended particulate matter and changing current patterns, and biologically by removing phytoplankton and other particles and producing large quantities of oyster biomass and pseudofeces. In addition, the structure of the reef provides habitats for many estuarine organisms. One square meter of a typical oyster reef actually represents approximately 50 m^2 of surface area or potential habitat (Bahr and Lanier 1981).

The oyster reef is a strongly heterotrophic system using tidal energy to bring in food and carry away waste material. The majority of energy or matter entering or leaving the oyster reef is surficial (filter feeders, detritus, and predator components) and not contained within complex food web networks (Dame and Patten 1981). Overall, filter feeders (e.g., the oysters) affect nutrient cycling and energy flow in the ecosystem through translocation and transformation of matter (Dame 1976).

b. Distribution. Oyster reefs are present in many of the Panhandle estuaries (Table 27). In the Apalachicola Bay system, oyster reefs cover an estimated 7% of the bottom area (Livingston 1984a). Newly constructed artificial reefs are located primarily in the eastern portions of St. Vincent Sound. The natural reefs of St. Vincent Sound and western St. George Sound represent the largest concentrations of commercial oysters in the Panhandle. It is estimated that 40% of Apalachicola Bay is suitable for growing oysters, but that substrate type is a major limiting factor (Whitfield and Beaumarriage 1977).

Table 27. Area of oyster reefs (beds) in the Florida Panhandle (from (a) McNulty et al. 1972, (b) Livingston 1984).

Area	Oyster reef coverage (ha)	Source	Area	Oyster reef coverage (ha)	Source
Ochlockonee Bay	?		East Bay (St. Andrew)	46	a
Alligator Harbor	36.7	a	St. Andrew Bay	0	a
St. George Sound (East)	2.6	b	West Bay	7	a
St. George Sound (West)	1,488.8	b	North Bay	6	a
East Bay	66.6	b	Choctawhatchee Bay	4,695	a
Apalachicola Bay	1,658.5	b	Santa Rosa Sound	0	a
St. Vincent Sound	1,096.5	b	East Bay (Pensacola)	3,395	a
St. Joseph Bay	0	a	Escambia Bay	81	a
St. Andrew Sound	0	a	Pensacola Bay	0	a

The system is characterized by very rapid oyster reproduction and growth, accounting for approximately 90% of Florida's and 8%–10% of the nation's annual oyster production.

Choctawhatchee Bay also possesses a fairly extensive coverage of oyster reefs (Burch 1983b). The oyster beds are harvested in Walton County west of the U.S. Highway 331 causeway along the southern shore of the bay.

c. Oyster autecology. The primary reef-building, commercial oyster found in the Panhandle is the Eastern or American oyster. The species *Ostrea equestris* is also present. Both species grow in a wide salinity range (10–30 ppt). Optimal growth occurs at a water temperature of approximately 25 °C.

The oyster is dioecious (i.e., having separate sexes), but once a year some members can undergo protandry (change from male to female) or protogyny (female to male). It has been postulated that under certain types of stress a population may develop a higher proportion of males than females. For instance, the harsh conditions in the higher portions of the oysters' intertidal range (the upper reef zone) may produce or regrow predominantly male colonies that would contribute little to the reproductive success of the population.

Temperature or salinity shock usually triggers the emission of sperm from mature males in a local population. The threshold temperature or salinity can vary among geographic locations. Emission of the sperm from male oysters stimulates the females in the area to release eggs via a chemical cue (protein pheromone). A mass "chain reaction" spawning can occur in dense populations. Fertilization occurs in the water column through the chance meetings of egg and sperm. This begins the planktonic, free-living phase of the oyster life cycle. When the larva first secretes a pair of shells, it reaches the veliger stage. Depending on water temperature and food availability, the larval stages usually lasts 7 to 10 days, but in some cases may last up to two months.

Hayes (1979) studied the reproductive cycle of the American oyster in intertidal areas off Turkey Point and in Alligator Harbor along the Panhandle coast. He reported that oysters 1 year of age and older undergo two major spawning periods per year with renewed gonadal development between these events. In addition, oysters that set early in the spawning season reach sexual maturity and spawn before the end of the same reproductive season.

The gonadal condition of established oyster populations depends on ambient water temperatures. In the eastern part of the Panhandle, gonadal development begins before the temperature reaches 20 °C (usually in April), probably sometime in late February or March (Hayes 1979). The majority of spawning does not occur until a minimum temperature of 25 °C is reached. Spawning can also be induced by temperature fluctuations of 5–10 °C. Gamete-containing gonads in established oysters are still present in late October and probably remain active until late November when most gonadal activity ceases (Hayes 1979).

Most of the setting occurs in the spring (late May). This peak can be attributed solely to the spawning of those oysters that attached in previous years (i.e., at least 1 year old). Setting that takes place later in the season may be due to additional spawning by older oysters and spawning of the sexually developed young-of-the-year oysters. The contribution of the young oysters to population recruitment, however, is minimal.

A number of physicochemical and biological factors influence the settlement of larval oysters. Light, salinity, temperature, and current velocity are of primary importance. In addition, oyster larvae are highly gregarious and settle in response to a waterborne pheromone or metabolite that is released by the oyster after metamorphosis. Larvae are also attracted to a protein on the surface of oyster shells. The gregariousness is critical since the reproductive scheme of the oyster requires settlement in proximity for successful fertilization.

Oyster growth occurs throughout the year in the Panhandle (Menzel et al. 1966). Maximum size (total shell length) is usually not much greater than 100 mm. Oysters reach a marketable size within 2 to 3 years after settlement.

Oysters are filter-feeders. The specific diet is not clearly known. The gills are reported to selectively retain diatoms, dinoflagellates, and graphite particles from 2 to 3 microns (Bahr and Lanier 1981). Feeding activity is highest at low food concentrations and there is a negative correlation between pumping rate and surrounding turbidity. Because they filter the water to feed, oysters can concentrate pathogenic bacteria and viruses along with food particles.

d. Oyster reef development and zonation. Oyster reefs in the Panhandle range in size from small scattered clumps to massive solid mounds of living oysters and dead shells. Reef development is usually limited to the middle portion of the intertidal zone, where minimum inundation time determines the maximum elevation of reef growth. Predation and siltation (which determines available substrate) are the main factors that often limit oyster populations in the lower intertidal and subtidal zones to scattered individuals and small clumps.

An oyster reef may begin its development with the attachment of a single oyster to some solid substrate. Succeeding generations of oysters attach to the earlier colonizers and a gradual increase in length, width, and height eventually forms a reef. In shallow intertidal water, such development can form a marsh island with a fringe of live oysters. In deeper water, a reef may form a shoal rising several feet above the bottom.

There is a difference in the size of oysters from the various parts of a reef. Individuals along the edge are usually larger (i.e., longer shell length) than those in the center (Menzel et al. 1966). This difference in growth can be as high as two-fold.

During exposure to the atmosphere (at ebb tide), the surface of a reef dries and turns gray, but, upon wetting, the thin film of algae covering the shells appears greenish-brown. Only the upper layer (5–10 cm) of oysters and dead shells actually dries out. The underlying shell layer remains moist. The reef consists of three "horizons" (Bahr and Lanier 1981): (1) pale greenish-gray (the exposed portion); (2) reddish-brown; and (3) silver-black. The reddish-brown section derives its characteristic color from the detritus covering each shell. It lacks the film of algae characteristic of the upper layer. The silver-black zone is characteristic of shells buried in an anaerobic environment high in ferrous sulfide. Mud crabs (e.g., *Panopeus herbstii* and *Eurypanopeus depressus*) graze on the organic film in the top two horizons.

A section through a typical Panhandle oyster reef shows that it has relatively distinct strata (Bahr and Lanier 1981). The moist upper portion is level, but the reef slopes steeply at the edges. The living portion of the reef is thicker at the perimeter than in the center, where mud trapped by biodeposition and sedimentation may smother oysters. This sedimentation results from suspended matter settling out as turbid water slows down while passing over the reef.

Oysters in the top (green) layer have sharper growing edges than those in the reddish-brown zone, indicating faster growth. This is a result of crowding and sediment deposition on lower oysters.

e. Associated fauna. Vertical zonation in oyster reef macrofauna is caused by the differing tolerance to desiccation of the various species rather than by their differing requirements for inundation in order to feed (Bahr and Lanier 1981). Some of the same zonation patterns are reflected on artificial pilings. In a manner similar to that of the reef, single shell or live oyster on that reef maintains a microcosm of sessile and mobile epifauna.

The reef provides a solid substrate for sessile organisms that require an attachment surface. These include algae, hydroids, bryozoans, barnacles, mussels, and polychaetes. Some forms also bore into the shell: boring sponges and mollusks, perforating algae, and burrowing polychaetes. Many organisms find refuge in the crevices of the reef. Organisms typically found on Panhandle oysters reefs are given in Table 28 (Menzel and Nichy 1958, Menzel et al. 1966, Abele 1970, Livingston 1984, Abele and Kim 1986).

The stone crab is a commercially important inhabitant of oyster reefs. Stone crab densities on oyster reefs are highest during the summer, decline over the late fall, and remain low throughout the winter (Hembree 1984) (Figure 73). Seasonal residency patterns suggest that the reefs may provide a

Table 28. Common fauna of a Panhandle oyster reef (Menzel and Nichy 1958, Menzel et al. 1966, Abele 1970, Livingston 1984, Abele and Kim 1986).

Group	Species
Microfauna/Meiofauna	
Fungus	*Perkinsus marinus*
Macrofauna	
Porifera	*Cliona vastifica*
Coelenterata	*Astrangia* spp.
Bryozoa	*Mebranipora* sp.
Platyhelminthes	*Bucephalus cuculus*
	Stylochus frontalis
Insecta	*Anurida maritima*
Annelida (Polychaeta)	*Neanthes succinea*
	Polydora websteri
	Sabellaria spp.
Arthropoda	*Balanus eburneus*
	Callinectes sapidus
	Clibinarius vittatus
	Eurypanopeus depressus
	Menippe mercenaria
	Neopanope packardi
	Neopanope texana
	Panopeus herbstii
	Petrolisthes armatus
	Synalpheus minus
Mollusca (Gastropoda)	*Anachis obesa*
	Busycon contrarium
	Crepidula plana
	Epitonium sp.
Gastropoda (cont.)	*Kurtziella* sp.
	Melongena corona
	Mitrella lunata
	Murex pomum
	Odostonia impressa
	Pleuroploca gigantea
	Polinices duplicatus
	Seila adamsi
	Thais haemastoma
	Triphura nigrocincta
Mollusca (Pelecypoda)	*Abra aequalis*
	Anadara transversa
	Anomia simplex
	Branchidontes exustus
	Branchidontes recurvus
	Chione cancellata
	Crassostrea virginica
	Corbicula sp.
	Martesia smithi
	Mulinia lateralis
	Noetia ponderosa
	Ostrea equestris
	Semele bellastriata
	Trachycardium muriacatum
Fishes	*Hypleurochilus germinatus*
	Hypsoblennius hentzi
	Hyspoblennius ianthus
	Opsanus beta
Birds	*Haematopus palliatus*

valuable site for reproductive activities. Juvenile crabs are abundant on reefs, which act as shelters from predation and offer food resources in the form of reef-associated organisms (i.e., bivalves, gastropods, and crustaceans). Hembree (1984) reported that the adult inshore residency peaked in the fall (Figure 74) and that adult heterosexual pairing of stone crabs on the oyster reefs coincides exclusively with the fall mating season, and suggested that oyster reefs provide a valuable resource for the stone crab, e.g., a high density of potential mates and suitable shelter for molting.

The stone crab fishery is concentrated in the nearshore areas of the coast. The commercial stone crab season is from October 15 to May 15. Only claws with a minimum of 7 cm propodus length or 10.8 cm overall length may be kept.

f. Commercial aspects. In the Panhandle (as well as in the entire State) oyster reefs are considered public unless yearly leases are obtained from the Department of Natural Resources. The primary advantage of leasing is the ability to designate an area and plant oyster shells or other culch material

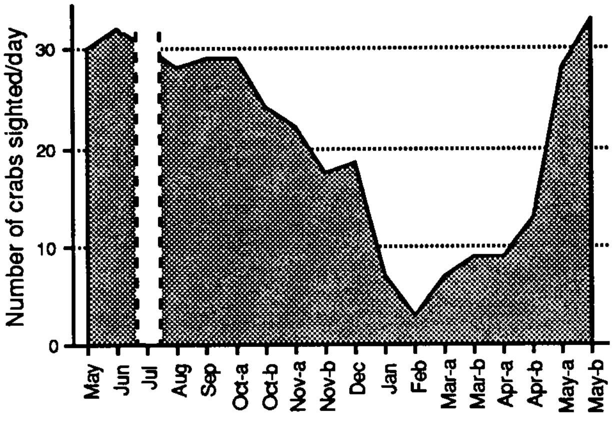


Figure 73. Seasonal stone crab densities on a Panhandle oyster reef (Hembree 1984).

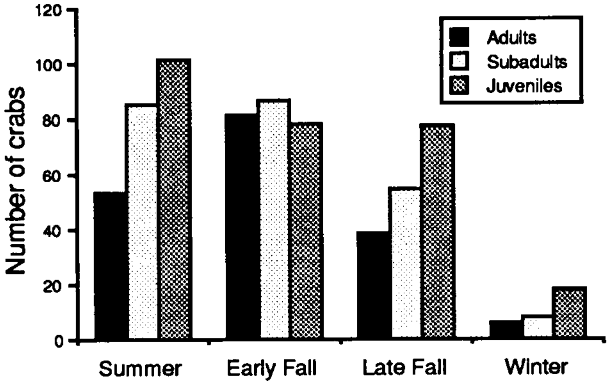


Figure 74. Stone crab age-group occurrence on a Panhandle oyster reef (Hembree 1984).

and expect that it will remain undisturbed (Burch 1983b). All leased reefs are artificial.

Potential harvest areas are classified: (1) approved; (2) conditionally approved; (3) prohibited; and (4) unclassified. Approved areas meet water-quality criteria. Conditionally approved areas normally meet water-quality standards but are subject to localized flooding or urban runoff that may temporarily lower water quality. Prohibited areas consistently do not meet water-quality standards and harvesting is prohibited. Unclassified areas are unsurveyed and unmonitored sites and are not officially approved for harvesting.

The most important oyster harvesting region in the Panhandle is the Apalachicola Bay system, which contains 83% of the State's public reefs. In 1982, 1,884,000 kg of oysters worth an estimated $4,150,366 were harvested from the system (Snell 1984). Also in 1982, Choctawhatchee Bay recorded its highest oyster landing ever (Table 29).

g. Natural Impacts. Under normal conditions, the natural environment controls population growth and regulates the distribution and density of oyster reefs.

The pathogen *Perkinsus marinus* is responsible for up to 50% of the annual mortality in adult oysters

Table 29. Oyster landings (kgs of meat) from Choctawhatchee Bay, 1965–82 (Burch 1983b).

Year	Walton County	Okaloosa County	Year	Walton County	Okaloosa County
1965	3,981	0	1974	3,529	262
1966	2,115	0	1975	1,868	799
1967	3,009	0	1976	123	0
1968	3,290	0	1977	147	0
1969	6,118	0	1978	803	0
1970	5,538	0	1979	0	1,356
1971	2,896	0	1980	36	49
1972	7,424	617	1981	0	0
1973	5,505	1,416	1982	18,196	50

in Panhandle oyster reefs. Young oysters are apparently unaffected.

Predation is a limiting factor in the growth of Panhandle oyster populations, especially in high-salinity subtidal regions (Menzel and Nichy 1958, Menzel et al. 1958). On reefs in Alligator Harbor, Menzel and Nichy (1958) found several important oyster predators. Lightning whelks, *Busycon contrarium*, are primary predators and are usually very numerous throughout the reef. These kill individual oysters by chipping away shell edges or by forcibly opening the valves to gain entry. Apple murexes, *Murex pomum*, and oyster drills, *Thais haemastoma*, are important predators of oysters below the water surface and were not found on exposed portions of reefs. In some locations, they were very abundant. They drill holes in the oyster valves to reach the meat. Another very common predator is the stone crab. Blue crabs are heavy predators of small oysters but not of large individuals. The crabs are very numerous on the reefs during incoming tides. The American oystercatcher is also a very common predator on the reef (Menzel and Nichy 1958).

There are three primary commensals associated with oysters: the boring sponge *Cliona celata*; the polychaete *Polydora websteri*, and the pea crab *Pinnotheres ostreum*. All three produce stress in the oyster. The boring sponge and polychaete induce additional shell deposition. The pea crab lives within the oyster's mantle cavity, removing food and mucus from the gills and possibly feeding on developing gametes.

Hurricane Elena (August 30–September 1, 1985) produced widespread damage to the oyster reefs in Panhandle waters. Three factors were primarily responsible for the mortality: (1) live oysters were broken from the reef and deposited onto soft-sediments where they could not feed properly; (2) increased turbidity smothered the oysters; and (3) attached oysters were crushed. Another damaging factor was decreased salinity.

Low dissolved oxygen concentrations, high temperatures (Quick 1971), excessive turbidity (sedimentation), an overabundance or shortage of appropriate food, and crowding also have an impact on oyster populations.

h. Human Impacts. Human perturbations can be lethal or sublethal for oysters but, even when sublethal, the oysters may be unfit for consumption (human or otherwise). Like most suspension feeders, oysters may concentrate suspended and dissolved constituents of the water column (including human pathogens, pesticides, and heavy metals) to levels several orders of magnitude above background concentrations. There are eight types of impacts:

(1) Physical disturbances, especially sedimentation resulting from dredging and excessive boat traffic, result in burial and anoxia of adult oysters and the reduced availability of culch for spatfall.

(2) Salinity changes caused by freshwater diversion or local hydrologic alteration increase predation and fouling.

(3) Eutrophication results in oxygen depletion in bottom water, toxic effects of blue-green algae and certain other algae, and excessive POC (Particulate Organic Carbon), which reduces clearance efficiency. A specific example is the 1971 oyster kill in Escambia Bay. Ninety percent of the commercial size oysters were destroyed by a fungus (*Perkinsus marinus = Labyrinthomyxa marina*), whose growth was promoted by increased nutrients from industrial waste discharges (Little and Quick 1976).

(4) Toxins, including pulp mill sulfites, heavy metals, chlorinated hydrocarbons, organophosphates, radionuclides, and petroleum hydrocarbons can have such sublethal effects as reduced resistance to natural stress, subtle changes in the entire community structure, and reduced gametogenesis as well as lethal effects such as increased rate of mortality.

(5) Physical impairment of feeding structures by oil contributes to eventual mortality.

(6) Thermal effluents, primarily from powerplants, contribute to decreased community diversity and enhanced oyster production.

(7) Overharvesting results in the depletion of breeding stocks, culch, and a decrease in bottom stability.

(8) Wetland loss caused by development decreases the wetland-water interface that is a prime reef habitat, and the source of primary production that contributes to oyster reef growth.

i. Conclusions. Oysters in the Panhandle represent a valuable commercial resource as well as an ecologically important habitat. Because oysters filter water to feed, they are extremely sensitive to many water quality perturbations, both natural and artificial.

7.2.7 Marine Algae

a. Introduction. There are five major phyla of algae in the Panhandle estuaries: (1) Cyanophyta—blue-greens; (2) Rhodophyta—reds; (3) Phaeophyta—browns; (4)Chlorophyta—greens; and (5) Chrysophyta—golden browns. Approximately 525 species occur in the Panhandle (Earle 1972, Humm 1973). Marine algae provide habitat for many organisms and may be found in nearly all habitats from subtidal soft bottoms to intertidal salt marshes. Hence, the habitat category was not given a strictly intertidal or subtidal designation.

Red and brown abundance is usually limited by the availability of a hard substrate for attachment. An extensive development of benthic algae can usually be found on submerged artificial structures such as jetties, seawalls, and pilings, and on natural surfaces such as oyster reefs, scattered bivalve shells, and seagrass blades.

One major group of algae is able to colonize unconsolidated sediments and may compete with seagrasses for space (Humm 1973). These algae belong to the order Siphonales, many of which have developed the ability to anchor themselves in soft sediment by means of clusters of rhizoids. Members of the genus *Caulerpa*, with their horizontal "stems," erect "leaves," and rhizoids, cover the greatest area of sandy bottom of any of the Siphonales. Other genera present include *Halimeda*, *Penicillus*, *Udotea*, and *Avrainvillea*.

b. Major algal species present. The common algal species found throughout the Panhandle are listed in Table 30. The filamentous blue-green alga *Calothrix crustacea* is a ubiquitous Panhandle species that produces a black band (often mistaken for an oil stain) high in the intertidal zone on seawalls, pilings, and other intertidal, hard surfaces. It also occurs on the basal portions of *Spartina alterniflora* and *Juncus roemerianus* in Panhandle salt marshes and is present less conspicuously in the subtidal regions.

Below the *Calothrix* band in the intertidal zone are several genera of red algae, *Bostrychia*, *Caloglossa*, *Catenella*, and *Murrayella*. The first three are nearly exclusively intertidal. The green alga *Enteromorpha* is also conspicuously abundant in the intertidal zone. Various species of *Vaucheria* are reported from the littoral sand flats on the Florida west coasts (Dawes 1974), and are probably present in the Panhandle.

In deeper water, the red algae *Digenia simplex*, *Gracilaria verrucosa*, *G. folifera*, *Acanthophora spicifera*, *Hypnea musciformis*, and *Laurencia poitei* are frequently present in large, seasonally abundant drift clumps on the bottom or in windrows on the water surface.

c. Associated fauna. The red algal clumps that occur periodically in the Panhandle contain an abundant fauna (Hooks et al. 1976). The algae provide protection from predation and the firm branches provide an attachment surface for sessile organisms. Ophiuroids and caprellid amphipods are common. Large numbers of harpacticoid copepods are usually present.

Red algae may provide refuge from predation for sediment-dwelling organisms (Hooks et al. 1976). Large numbers of the caridean shrimp *Palaemon floridanus* are occasionally present within the clumps.

7.2.8 Open Water

a. Introduction. The open water (or water column) habitat contains plankton (i.e., organisms that are passively carried by the currents) and nekton (i.e., organisms that actively swim) that cannot be associated with and assigned to particular substrate types. The habitat includes species that cover a wide size spectrum ranging from diatoms and copepods (microns in length) to fish and porpoises (meters in length). This habitat contains the phytoplankton that play a major role in the primary productivity of the estuaries.

A characteristic of the estuarine water column habitat is the extreme spatial variability present.

Table 30. Common algal species in the Panhandle (Menzel 1971, Earle 1972, Humm 1973, Dawes 1974).

Class	Species
Cyanophyta	*Calothrix crustacea*
	Dichothrix penicillata
	Entophysalis conferata
	Entophysalis deusta
	Lyngbya confervoides
	Lyngbya majuscula
	Lyngbya semiplena
	Microcoleus tenerrimus
	Plectonema calothrichoides
Rhodophyta	*Bostrychia radicans*
	Botryocladia uvaria
	Ceramium fastigiatum
	Chondria cnicophylla
	Chondria littoralis
	Chondria sedifolia
	Eucheuma acanthocladium
	Fosliella farinosa
	Gelidium corneum
	Gelidium crinale
	Halymenia pseudofloresia
	Jania rubens
	Laurencia intricata
	Laurencia obtusa
	Laurencia poitei
	Lithothamnium occidentale
	Polysiphonia echinata
	Polysiphonia howei
	Polysiphonia subtilissima
Phaeophyta	*Dictyota dichotoma*
	Ectocarpus coinfervoides
	Ectocarpus mitchellae
	Padina vickersiae
	Sargassum filipendula
	Sargassum linifolium
	Sporochnus pendunculatus
Chlorophyta	*Acetabularia crenulata*
	Acetabularia farlowii
	Caulerpa prolifera
	Chaetomorpha linum
	Cladophora gracilis
	Cladophora fulginosa
	Cladophoropsis membranacea
	Codium decoratum
	Enteromorpha clathrata
	Enteromorpha flexuosa
	Enteromorpha lingulata
	Enteromorpha plumosa
	Entocladia viridis
	Halimeda tridens
	Monostroma latissimum
	Penicillus lamourouxii
	Protoderma marinum
	Udotea conglutinata
	Ulva lactuca

Much of the patchiness is due to a myriad of physical factors such as local salinity and temperatures fluctuations and wind and tidal mixing (on daily and seasonal scales). In addition, many organisms, especially fish, are migratory and spend only a portion of their lives in the estuary.

This habitat contains a "permanent" fauna (holoplankton) that live in the water column for an entire life cycle and also a "temporary" fauna (meroplankton) that include the larval forms of many nonplanktonic organisms (e.g., polychaetes, fish, bivalves, and crabs) that use the currents to disperse to different habitats. Some organisms traditionally classified as benthic (e.g., the polychaetes, *Polydora ligni* and *Scolelepsis squamata*) are present in the water column at night. They may use the water column to feed, to disperse to a new habitat area, or to reproduce.

Phytoplankton and zooplankton abundances usually demonstrate strong seasonal peaks that track nutrient inputs (primarily nitrogen and phosphorus from land runoff), temperature, and light levels. The phytoplankton standing crop is usually low at any particular time, but overall productivity is high because of a rapid turnover rate.

The nekton (e.g., fishes and sharks) are extremely patchy and generally unpredictable in their spatial distribution. This group, however, constitutes the primary commercial catch from the coastal environment.

This habitat proves one of the most difficult to characterize. The large diversity of organisms, wide range of physical conditions, and extreme spatial and temporal patchiness of the flora and fauna are the primary causes of the problem. An attempt was made to report the major groups and species present, concentrating on commercially and ecologically important species.

b. Species present. Estuarine water column organisms in the Panhandle have been described in a number of investigations (phytoplankton—Curl 1956, Estabrook 1973, Myers 1977; zooplankton—Grice 1960, Hopkins 1966, Cosper 1969, Edmiston 1979; squid—Laughlin and Livingston 1982; fish—Parrish 1966, Hansen 1969, Irby 1974, Nakamura 1976, Naughton and Saloman 1978, Pristas and Trent 1978, Nall 1979, and many others). Because of the tremendous diversity of the habitat, only dominant species are discussed; over 180 fish species are reported from the Pensacola estuary alone (Cooley 1978).

Diatoms tend to dominate the phytoplankton, while copepods are the dominant zooplankton form. Phytoplankton abundances demonstrate distinct seasonal peaks, but there are resident assemblages that characterize Panhandle estuaries (Steidinger 1973). Many of the estuarine phytoplankton—for example *Skeletonema costatum*, *Chaetoceros* spp., *Gonyaulax* spp., and others—form resting spores or cysts and are considered meroplanktonic because a portion of their life is spent on the estuarine floor.

Tables 31 and 32 list the common planktonic and nektonic species in the Panhandle.

c. Recreationally and commercially important species. The Panhandle estuarine open water habitat contains numerous species of commercial and recreational importance. Additionally, juvenile and larval forms of marine organisms use the estuarine areas as "nursery grounds." These include three shrimp species (brown—*Penaeus aztecus*, white—*P. setiferus*, and pink—*P. duorarum*) (Brusher and Ogren 1976), ladyfish (*Elops saurus*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), silver perch (*Bairdella chrysoura*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), southern kingfish (*Menticirrhus americanus*), gulf menhaden (*Brevoortia patronus*), striped mullet (*Mugil cephalus*), and sheepshead (*Archosargus probatocephalus*). In addition, several anadromous species, e.g., Alabama shad (*Alosa alabamae*) and Atlantic sturgeon (*Acipenser oxyrhynchus*), pass through the Apalachicola Bay system on their way to spawning grounds in the Apalachicola River (Wooley and Crateau 1982). The Atlantic sturgeon also migrates into the Pensacola Bay system. Descriptions of the most important species follow.

(1) Striped mullet. The striped mullet is one of the most important commercial fish species along the Panhandle coast. It spawns from October through February, with peak activity from November through January. Mullet form large schools before spawning and migrate from their normal estuarine habitat into offshore water. Growth rate and age to maturity are highly correlated with water temperature (Cato and McCullough 1976).

(2) Red drum. Within Panhandle estuaries young red drum are generally found in quiet shallow waters with grassy or slightly muddy bottoms that are not greatly affected by tides. Most juvenile or immature red drum (<720 mm total length (TL)) remain in the estuaries throughout the year but move into deeper bay waters in winter. They move from the estuaries into the gulf at maturity (>700 mm TL). After spawning, some adults may move back into bays for a short time but, on the whole, less time is spent in the estuaries after maturity. Their longevity is probably more than 12 years.

Crustaceans, especially crabs and shrimp, and fish are the most important items in the red drum diet. Food habits change with age. Gut contents indicate that red drum feed over sandy to muddy bottoms in both shallow and moderately deep water. Most

Table 31. Common planktonic organisms found in Panhandle estuarine open waters (Estabrook 1973, Edmiston 1979).

Group	Species
Phytoplankton	
Diatoms	*Bacteriastrum delicatulum*
	Bacteriastrum varians
	Cerataulina pelagica
	Chaetocerus deciphens
	Chaetocerus lorengianum
	Coscinodiscus radiatus
	Hemiaulus hauckii
	Hemiaulus sinensis
	Melosira sulcata
	Nitzschia closterium
	Rhizosolenia alata
	Rhizosolenia stolterfothii
	Skeletonema costatum
	Thalassionema nitzschioides
	Thalassiothrix frauenfeldii
Dinoflagellates	*Ceratium tripos*
	Gonyaulax balechii
	Peridinium depressum
Coccolithophores	*Pontosphera* spp.
Zooplankton	
Copepods	
(Calanoids)	*Acartia tonsa*
	Anomalocera ornata
	Labidocera aestiva
	Paracalanus crassirostris
	Paracalanus parva
(Cyclopoids)	*Corycaeus americanus*
	Oithona brevicornis
	Oithona nana
	Oithona simplex
Crab zoeae	
Larvacean	*Oikopleura dioica*
Polychaeta larvae	Spionidae
	Phyllodocidae
Rotifer	*Synchaeta* sp.
Cladocerans	
Chaetognaths	*Sagitta helenae*
	Sagitta hispida
	Sagitta tenuis
Echinoderm larvae	*Mellita quinquiesperforata*
Ctenophores	*Beroe ovata*
	Mnemiopsis mccradyi
Coelenterates	*Aurelia* spp.
	Chrysaora spp.
	Stomolophus spp.
Mysids	
Various fish eggs and larvae	

feeding takes place in the early morning or evening. Red drum have been observed "tailing" in shallow areas, rooting about with heads lowered and tails occasionally out of the water.

Red drum are harvested in a mixed-species fishery, using a variety of gear including haul seines (common and long), fish trawls, pound nets, gill nets, hand lines, trammel nets, and shrimp trawls. Runaround gill nets are the predominant gear used in the Panhandle. Highest landings are generally recorded in the fall and early winter. Recreational fishermen generally find shrimp, squid (*Loliguncula* spp.), cut mullet (*Mugil* spp.), spot, herring (Clupeidae), or menhaden good bait for red drum. An 18-inch limit is set by the State of Florida for red drum. Currently the commercial take of red drum in Florida is banned and the recreational take restricted by the State and regulations regarding take should be checked.

(3) Spotted seatrout. The spotted seatrout is a nonmigratory euryhaline estuarine species that is most abundant in the confines of semilocked lagoons and quiet estuaries. It has a protracted spring and summer spawning season that peaks in late

Table 32. Common nektonic forms found in Panhandle estuarine open waters.

Group	Species	Common name
Squid	*Lolliguncula brevis*	Brief squid
Fish	*Anchoa hepsetus*	Striped anchovy
	Anchoa mitchilli	Bay anchovy
	Archosargus probatocephalus	Sheepshead
	Arius felis	Sea catfish
	Bagre marinus	Gafftopsail catfish
	Bairdiella chrysoura	Silver perch
	Brevoortia patronus	Gulf menhaden
	Cynoscion arenarius	Sand seatrout
	Cynoscion nebulosus	Spotted seatrout
	Echeneis naucrates	Remora
	Elops saurus	Ladyfish
	Leiostomus xanthurus	Spot
	Menidia beryllina	Silverside
	Menticirrhus americanus	Southern kingfish
	Menticirrhus littoralis	Gulf kingfish
	Micropogonias undulatus	Atlantic croaker
	Monocanthus hispidus	Planehead filefish
	Mugil cephalus	Striped mullet
	Pogonias cromis	Black drum
	Sciaenops ocellatus	Red drum
	Urophycis floridana	Southern hake
Sharks	*Carcharhinus acronotus*	Blacknose shark
	Carcharhinus isodon	Finetooth shark
	Carcharhinus leucas	Bull shark
	Carcharhinus limbatus	Blacktip shark
	Rhizoprionodon terraenovae	Atlantic sharpnose shark
	Sphyrna lewini	Scalloped hammerhead
	Sphyrna tiburo	Bonnethead
Turtles	*Caretta caretta*	Loggerhead
	Dermochelys coriacea	Leatherback
Porpoise	*Tursiops truncatus*	Bottlenose dolphin

April to July. Young-of-the-year spotted seatrout are generally associated with seagrass beds in estuaries.

Spotted seatrout are carnivorous, feeding primarily on crustaceans (penaeid shrimp and crabs) and fish (anchovies (*Anchoa* spp.), menhaden, mullet, pinfish (*Lagodon rhomboides*), and silversides (*Menidia beryllina*)). Food habits change with age. Copepods are important prey for fish less than 30 mm TL. Larger crustaceans are important prey for fish less than approximately 275 mm SL (standard length). Larger specimens predominately eat fish.

There are seasonal changes in the types of commercial gear used in the Panhandle. Trammel nets and haul seines are primarily used near river mouths during the winter months. Hook and line fishing is productive throughout most of the year, whereas trolling is usually best in the fall. The best gill- and trammel-net fishing is from mid-November to mid-February when the fish congregate in deep holes.

Recreational spotted seatrout fishing includes bridge, skiff, and shoreline fishing. Live bait, including shrimp, sailors choice, pinfish, mullet, and needlefish (*Strongylura marina*), is generally used with greater success than are lures. Fishing usually takes place year round in the Panhandle. It is one of the most sought after and most frequently caught species of sportfish. A 12-inch minimum size limit is set by the State of Florida for spotted seatrout.

(4) Gulf menhaden. The gulf menhaden supports a large fishery in the gulf and its young are prey for many other species of sport or commercial importance (Tagatz and Wilkens 1973). Spawning occurs in the open gulf. Larvae spend 3–5 weeks offshore before moving into estuaries at 9–25 mm SL. After transformation, juveniles remain in low-salinity nearshore areas where they travel in dense schools near the surface. The schooling behavior is retained throughout life. Feeding behavior changes from selective, particulate-feeding carnivory to filter-feeding with age. Adult and mature juveniles emigrate from estuaries to gulf waters primarily from October to January.

Gulf menhaden is a short-lived species. Individuals rarely exceed 2 years of age. The fishery season runs from mid-April to October when the fish are inshore and sexually inactive.

(5) Atlantic croaker. The Atlantic croaker is a target species of the industrial groundfish fishery and is often dominant in inshore and offshore sport catches. The species is considered estuarine dependent because all stages from larvae to adults are known to occur in abundance in estuarine waters. Postlarvae and juveniles grow rapidly in estuarine nursery grounds and are subject to predation by several other species (Kobylinski and Sheridan 1979).

The species has a protracted spawning season from October to March with a peak in November. After hatching, larvae and postlarvae may spend some time as plankton, but eventually become demersal. The schooling behavior is maintained throughout life. The heaviest concentrations of adult Atlantic croaker are found at river mouths. Marshes are very important to juvenile development.

(6) Sea catfish and gafftopsail catfish (*Arius felis* and *Bagre marinus*). The sea catfish and gafftopsail catfish are not favored sport or food fishes, but their widespread abundance and distribution cause them to rank high in trawl and angler catches in the Panhandle. Commercial and sport fishermen consider both species to be nuisances and dangerous. Toxic substances from sea catfish spines are quite virulent. Copious slimy mucus secreted by the gafftopsail catfish is a problem in nets and to humans handling the fish. The oral gestation behavior of the two species is of scientific interest. The male carries the fertilized eggs, larvae, and small juveniles in its mouth.

The distribution and abundance of the two species in gulf coastal and estuarine waters is related to spawning activities, as well as water temperatures and salinities. Adults avoid lower temperatures by migrating offshore in winter and returning inshore in spring.

Both species are opportunistic feeders over submerged mud and sand flats. Stomach contents generally include algae, seagrasses, coelenterates, holothurians, gastropods, polychaetes, crustaceans, and fish. Scavenging may also be indicated, since large fish scales and human garbage have been reported from some individuals.

(7) Bay anchovy and striped anchovy (*Anchoa mitchilli* and *Anchoa hepsetus*). Both species are important prey species that spawn in the estuaries. They are not of direct commercial importance (as human food). The months of peak abundance vary, but anchovies are generally common from spring through early winter in Panhandle waters. Both species primarily feed on zooplankton such as calanoid copepods, mysids, and cladocerans (Sheridan 1978).

d. Species of special concern. The saltmarsh topminnow *Fundulus jenkinsi* (Everman) is found in Escambia, East, and Blackwater Bays of the Pensacola estuarine system (Gilbert 1978). It is known to live in salt, fresh, and brackish water (salinity range 3.4–24 ppt). It prefers protected tidal ponds, creeks, and marsh areas near river mouths and possibly soft mud substrates. It has been recorded only a few times in Florida waters, and the aforementioned bays may represent the species' easternmost occurrence.

Two species of turtle are occasionally present in the Panhandle estuaries: the Atlantic loggerhead *Caretta caretta* and Atlantic leatherback *Dermochelys coriacea*. Loggerhead turtles nest yearly during summer months on many Panhandle beaches (Harris et al. 1984).

e. Natural Impacts. Red tide outbreaks occasionally occur within estuarine waters in the Panhandle. The primary components are dinoflagellates, primarily *Ptychodiscus brevis* (formerly *Gymnodinium breve*) and *Gonyaulax monilata*. In addition, storms and localized temperature and salinity fluctuations affect the water column organisms (Bortone 1976).

f. Human Impacts. Petroleum pollution is a primary artificial impact. The input of an oil spill is usually considered less severe on open water organisms (at least adult forms) since many can avoid the spill itself (i.e., the nektonic forms can swim away). The effect on planktonic forms is not well established. Productivity is reported to decline immediately after a spill. A possible important indirect effect may be the incorporation of carcinogenic and potentially mutagenic or teratogenic chemicals into lower food chain organisms, such as the plankton, and subsequent ingestion by higher trophic forms.

Though adult fish are usually capable of avoiding spilled floating oil, other life stages such as eggs and larvae are more susceptible. Because the estuaries are spawning and nursery grounds for many species, an oil spill could cause serious damage to future commercial and noncommercial stocks.

Other impacts include sewage inputs, pesticides (Nimmo et al. 1971) and pulp mill effluent.

7.2.9 Subtidal Soft Bottoms

a. Introduction. Subtidal unconsolidated bottom environments (e.g., mud and sand) make up the most extensive habitat area in the Panhandle estuarine system, approximately 75% of the total submerged bottom area. In many ways, they are the least understood (e.g., in terms of governing processes) and most difficult to study of all the habitats. Problems arise from (1) limited access to the habitat for direct observation of and experimentation on processes important to the system and (2) the commonly bad visibility (high turbidity) often encountered. Except in the extremely shallow areas, field work often requires SCUBA gear.

A cursory inspection of the sediment surface gives an impression of a homogeneous, desert-like habitat without much physical structure (e.g., vegetation or rocks) and with few organisms. Upon closer investigation, however, a myriad of small burrow openings and projecting tubes can be observed. The overwhelming majority of organisms in this habitat live within the substrate (infauna), concealed from view. This habitat is three dimensional, and vertical (depth into the sediment) distances are important, as opposed to the two dimensionality of hard substrate environments. Microscopic inspection of a scoop of sand or mud reveals hundreds to thousands of organisms, most of which are important prey items in the ecosystem.

Abiotic factors play an important role in determining the distribution of the benthos, especially in the upper regions of the estuaries near the river mouths (Livingston et al. 1976). Sediment characteristics, such as grain size and organic content, and physical factors, such as salinity and temperature, are most important. Grain size appears to be the single most critical factor because many organisms have specific requirements for feeding and tube building (e.g., White 1971). Deposit feeders (i.e., animals that ingest sediment particles) usually dominate in fine-grained muddy sediments because of the increased availability of detrital material and microorganisms as food. Suspension feeders require contact with the sediment-water interface to feed and are usually present in more stable sedimentary environments where there is less sediment movement and suspended material to clog their feeding structures.

Of all the water bodies in the Panhandle, the eastern half of St. George Sound, Apalachicola Bay, and Alligator Harbor have been the most intensively studied, primarily because of the Florida State University Marine Laboratory facilities (e.g., SCUBA equipment, boats, and eager graduate students) at Turkey Point.

b. Physical description. Unvegetated soft-bottom environments in the Panhandle are generally made up of quartz sand and fine silt. Ray feeding-pits, crab pits, horseshoe crab trails, gastropod trails, and sand dollar trails, and enteropneust (i.e., acorn worm) fecal mounds and cones are prominent microtopographic features on the surface. After rough weather, wave-formed ripple marks up to 3 cm tall may be present for a few days.

c. Distribution. Because of the reduced light penetration and the siltation from the large amounts of sediments deposited by rivers, the majority of the bottom area of Panhandle bays and estuaries is unvegetated. Unvegetated soft bottoms cover more than 75% of the total bottom area in the Panhandle.

d. Faunal composition. The organisms in soft-bottom communities can be categorized into various functional groups based upon life positions (i.e., infaunal or epifaunal) and feeding (or trophic) group (i.e., deposit feeder, suspension feeder, carnivore, etc.). Infaunal organisms include most polychaete, bivalve, amphipod, and isopod species. Typical epifaunal organisms are asteroids (e.g., starfish—*Astropecten articulatus* and *Luidia clathrata*), echinoids (e.g., sand dollars—*Mellita quinquiesperforata* and *Encope mitchelli*), decapods (e.g., *Libinia* spp.), various gastropods, benthic fish, and skates and rays (Table 33). Trophic group classification is less taxon specific, but requires natural history information on the specific organism. Such information is too detailed for inclusion in this document. Ray (1986) has compiled heavily referenced life histories for most of the polychaete species in the Panhandle.

The most abundant metazoan constituents of soft-bottom habitats are the meiofaunal nematodes and harpacticoid copepods (Table 34). In terms of biomass, however, polychaetes, mollusks, and macrocrustaceans dominate (Table 35). These groups are especially abundant in higher salinity

Table 33. Demersal fish, skates, and rays commonly encountered in Panhandle soft-bottom habitats (Hoese and Moore 1977).

Group	Species	Common name
Fish	*Paralichthys albigutta*	Gulf flounder
	Paralichthys lethostigma	Southern flounder
	Prionotus scitulus	Leopard sea robin
	Synodus foetens	Lizardfish
Skates and Rays	*Aetobates narinari*	Spotted eagle ray
	Dasyatis americana	Southern stingray
	Dasyatis sabina	Atlantic stingray
	Dasyatis sayi	Bluntnose stingray
	Gymnura micrura	Smooth butterfly ray
	Narcine brasiliensis	Lesser electric ray
	Pristis pectinata	Smalltooth sawfish
	Raja eglanteria	Clearnose skate
	Raja texana	Roundel skate
	Rhinobatus lentiginosus	Atlantic guitarfish
	Rhinoptera bonasus	Cownose ray

Table 34. Abundant or common benthic meiofauna in Panhandle soft-bottom habitats (Reidenauer and Thistle 1981; Sherman et al. 1983; D. Thistle, Florida State University, Tallahassee, unpublished data; Carman 1984).

Group	Species	Group	Species
Nematoda	*Chromadorella* sp.	Copepoda	
	Chromaspirina sp.	Harpacticoida	*Amphiascus* spp.
	Desmodora sp.		*Ectinosoma* spp.
	Innocuonema spp.		*Enhydrosoma littorale*
	Metachromadora (*Metachromadoroides*) spp.		*Halectinosoma* spp.
	Microlaimus spp.		*Leptastacus* cf. *aberranus*
	Monoposthia sp.		*Mesochra* cf. *pygmaea*
	Sabatieria sp.		*Pseudobradya* cf. *exilis*
	Theristus spp.		*Robertgurneya rostrata*
	Viscosia brachylaimoides		*Zausodes arenicolus*

Table 35. Abundant or common benthic macroinvertebrates in Panhandle soft-bottom habitats (Hartman 1951, Carpenter 1956, Trott 1960, Griffin 1983, Reidenauer 1986).

Group	Species	Group	Species
Polychaetes	*Aricidea cerrutii*	Polychaetes (continued)	*Scololepsis squamata*
	Aricidea taylori		*Typosyllis* sp.
	Axiothella mucosa	Crustaceans	*Acanthohaustarius* spp. (amphipod)
	Capitella capitata		*Apanthura magnifica* (isopod)
	Eteone heteropoda		*Corophium louisiana* (amphipod)
	Haploscoloplos fragilis		*Kalliapseudes bahamensis* (tanaid)
	Haploscoloplos robustus	Mollusks	*Anodontia alba*
	Heteromastus filiformis		*Tellina* spp.
	Laeonereis culveri	Cephalochordata	*Branchiostoma floridae*
	Mediomastus californiensis	Echinodermata	*Astropecten articulatus*
	Paraonis fulgens		*Luidia clathrata*
	Paraprionospio pinnata		
	Prionospio heterobranchia		
	Prionospio pygmaea		
	Spio benedictii		

areas of the estuaries (Winternitz 1936, Yentsch 1953, Wass 1955, Trott 1960, Borror 1961, Griffin 1983). In the lower salinity regions near river mouths, insect larvae and oligochaete worms become more important. Soft-bottom benthic communities are characterized by a high degree of spatial variability at nearly all scales (centimeters, meters, and kilometers), yet individual populations are usually highly persistent and, in many instances, seasonal. Also included as part of this habitat are demersal fish (e.g., flounders), skates, and rays, that spend a majority of their life and feed on the bottom.

Most infaunal members of the soft-bottom community are concentrated within the upper few centimeters of the sediment surface. This is the depth of the aerobic zone. The aerobic zone can be extended deeper within the sediment by animal tubes and burrows, which bring oxygenated water to otherwise anoxic sediments. Meiofaunal organisms are concentrated along these structures and are therefore capable of existing deeper within the sediment.

The total number of species and individual organisms observed at any particular site is a function of many different factors. Among these are the time of year that samples are taken, the sampling gear used, and the physical conditions (e.g., tide stage, weather, and time of day) at the time of sampling.

Many organisms demonstrate not only seasonal differences in abundance, but year-to-year variations that are not, at present, readily predictable (Figure 75). For example, the five-slotted sand dollar is a common visible member of the subtidal soft-bottom habitats in the Panhandle, which can undergo periods of extremely high population densities, with 200–800 individuals/m² (Salsman and Tolbert 1965, Reidenauer, in prep. a) (Figure 76). These periods of high density are short-lived and most times densities are around 20/m². The high densities are apparently the result of appropriate conditions for the successful recruitment of juveniles. Many benthic species, such as *Mellita*, have planktonic larval forms that require specific physical conditions and low predator densities for successful recruitment.

e. Recreationally and commercially important species.

(1) Southern flounder (*Paralichthys lethostigma*). The southern flounder migrates and spawns offshore in the fall and winter (Nall 1979). Larvae eventually move inshore into the estuaries. Juveniles (10–15 cm) are abundant in shallow soft sediments during the late spring and early summer (Reidenauer, personal observation). Juveniles feed on a variety of polychaetes and crustaceans. Adults feed almost exclusively on fish and crustaceans. An 11-inch minimum size is placed by the State of Florida on landed flounders.

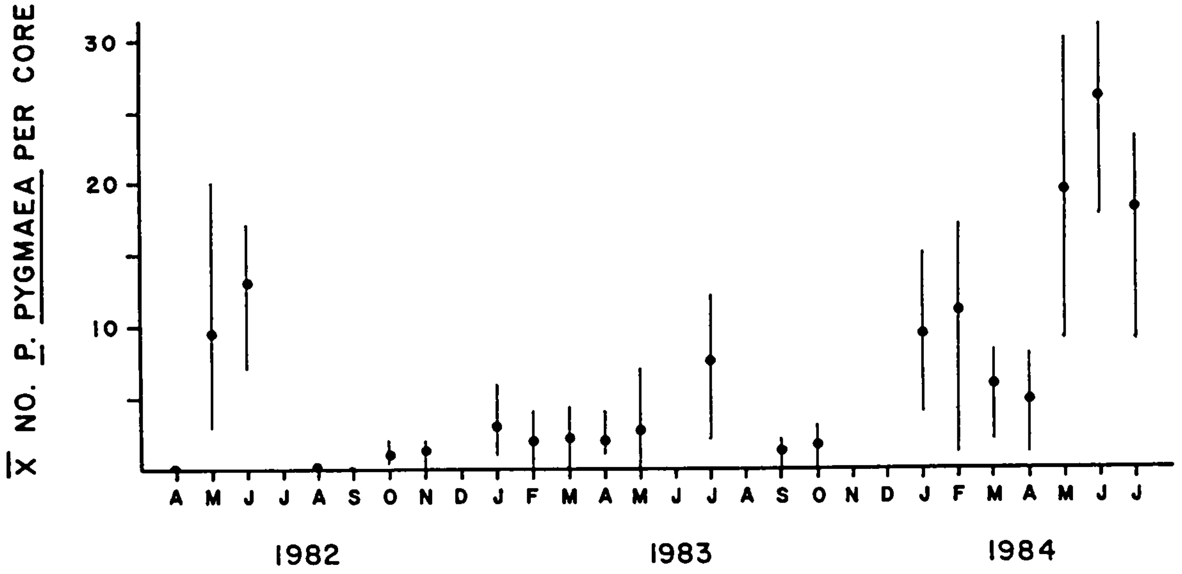


Figure 75. Seasonal variation of the spionid polychaete *Prionospio pygmaea* in a St. George Sound subtidal soft-bottom habitat (Reidenauer 1986).

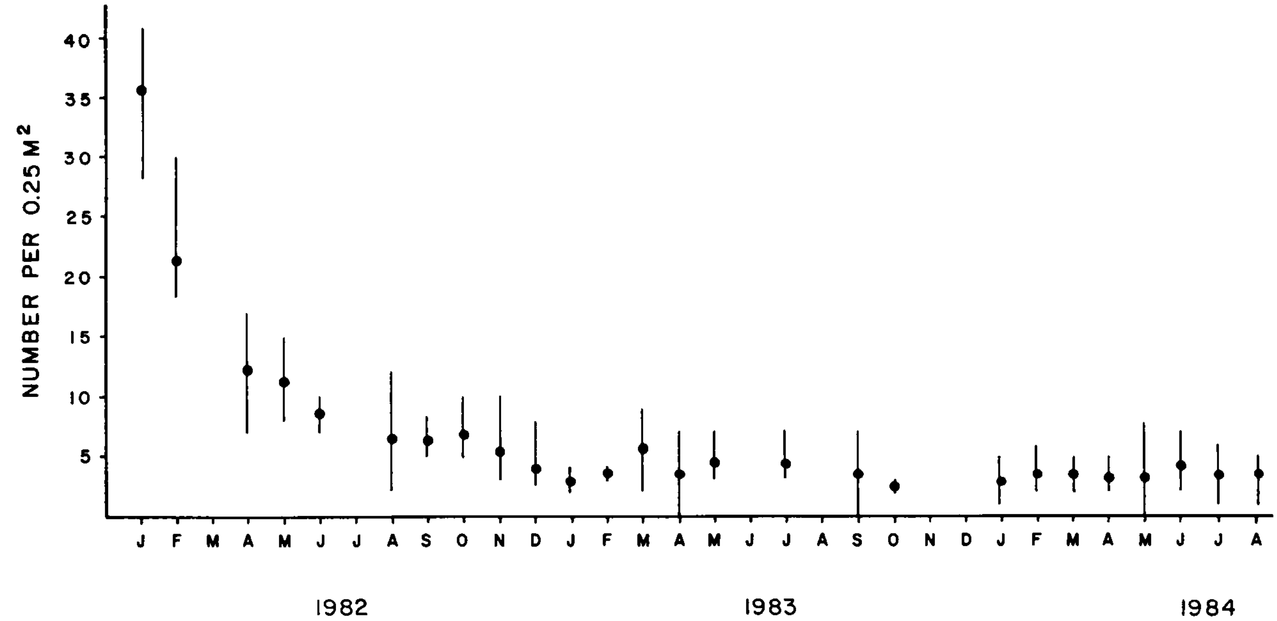


Figure 76. Variation in a five-slotted sand dollar *(Mellita quinquiesperforata)* population from St. George Sound (Reidenauer 1986).

(2) Northern quahog (*Mercenaria mercenaria*), and sunray venus clams (*Macrocallista nimbosa*). Both species are found in the estuaries and nearshore coastal waters of the Panhandle from the mean high tide level to 15 m depth with highest abundances on shallow flats (Akin and Humm 1959, Menzel 1961, Haines 1975). Harvesting is limited in the Panhandle although maricultural and commercial attempts have been made (Joyce 1970, Menzel et al. 1976).

f. Trophic dynamics and interactions. The majority of benthic species are prey for higher trophic organisms. The meiofauna, especially harpacticoid copepods, are important prey for juvenile fishes such as pinfish (*Lagodon rhomboides*) and southern flounder. Polychaetes and bivalves are important in the diet of many fish and crabs.

In general predation appears to be an important, if not the single most important, process governing soft-bottom benthic community dynamics (Mahoney and Livingston 1982). Historically, competitive interactions have been difficult to demonstrate in the soft-bottom environment given the hydrodynamic problems of predator exclusion pens (i.e., increased siltation due to current baffling) and the nearly invisible nature of the benthic inhabitants (i.e., hidden in the sediment or of a small size). In most regions, population densities are usually too low for competition to be an important process. Spatial competition (as in hard substrate communities) is rare in soft sediments, and competition for food is extremely difficult to demonstrate conclusively.

Mutualism is present in a variety of forms in the soft-bottom environment. The pea crab, *Dissodactylus* spp., (approximately 6 mm carapace width) lives among the spines of the five-slotted sand dollar and apparently selects food particles as the echinoid burrows through the sediment. In addition, other pea crabs (Family Pinnotheridae), use the burrows of various burrowing shrimp, such as *Callianassa* and *Upogebia,* as shelter.

g. Natural impacts. The soft-bottom subtidal environment appears more resilient to natural impacts than most marine habitats. A primary reason may be the planktonic larval dispersal characteristic of many of its residents. Furthermore, many benthic species traditionally categorized as sessile organisms are now known to disperse some distances as adults, especially at night, through the water column.

Natural disturbances such as ray feeding pits and enteropneust fecal mounds have been intensively examined in St. George Sound (Thistle 1980, Reidenauer and Thistle 1981, Griffin 1983, Sherman et al. 1983). Generally, the benthic communities, both meiofaunal and macrofaunal, initially decrease in abundance immediately after the disturbance but return to predisturbance levels within hours or a few days. Apparently these types of disturbances are either not on spatial scales large enough to produce long-lasting effects, or the community as a whole has adapted to them. Natural disturbances such as sand-dollar burrowing are apparently a source of mortality for newly settled polychaete, especially spionids (Reidenauer in prep. b). The most important effect of disturbance, therefore, may be on juvenile or larval members of the community and not on adult members that can more easily disperse.

Storm-induced waves often form ripple marks on the estuarine floor. In investigations performed outside the Panhandle, it was found that the troughs of the ripple field tend to collect fine particles and therefore food, which is attractive for a variety of organisms such as meiofaunal nematodes and harpacticoid copepods. Storms in general appear to disrupt the distribution of benthic organisms temporarily.

Duncan (1977) has reported on the effects of stormwater runoff on benthic communities in the Panhandle. An influx of silt or fine-grained sediment may decrease the number of sedentary or sessile members of a benthic community through suffocation. On the other hand, small burrowing deposit-feeding forms, such as capitellid and opheliid polychaetes, usually increase in abundance because of their planktonic larval stage.

h. Human Impacts. The effects of human activity on soft-bottom communities has not been extensively studied within the Panhandle. Some of the studies that have been done were not well designed or executed, so the results are not reliable. Problems have included samples taken without proper controls or without regard to season and use of improper sieve sizes to ensure that the majority of the community was sampled.

The most important human influences on the soft-bottom communities are dredging, boat traffic, petroleum pollution, and toxic substances such as pesticides. Dredging and the offshore collection of sediment for beach renourishment have been reported to have minimal but long-term effects on the benthic community (Water and Air Research, Inc. 1975, Saloman et al. 1982a). Apparently, natural seasonal variations are so great that short-term isolated perturbations are not permanently damaging. However, the evidence is limited and the problem is one that should be more thoroughly addressed in terms of implications for the higher trophic group organisms. Disturbances from boat traffic are not documented for the Panhandle and probably represent only localized impacts. Byrne (1976) has reported on the effects of petroleum pollution on larvae of the quahog clam (*Mercenaria* sp.) found in Alligator Harbor. The effects of various pesticides on the benthic community have been examined by Duke et al. (1970), Hansen and Wilson (1970), Livingston et al. (1978), Tagatz and Iver (1981), and Winger et al. (1984).

7.2.10 Seagrass Beds

a. Introduction. Seagrasses represent one of the most important habitats in the nearshore coastal zones of Florida. Of the approximately 12,000 km^2 of seagrass present in the Gulf of Mexico over 9,100 km^2 lie in Florida gulf coast waters (Iverson and Bittaker 1986).

Seagrasses are marine angiosperms that possess all the structures of their terrestrial counterparts (i.e., a root system, a vascular system, and vegetative and sexual reproduction). Seagrasses are obligate halophytes, living fully submerged and carrying out their entire life cycle in seawater. Seagrass meadows are highly productive and rich in organisms. Total productivity of dense beds (which may consist of more than 4,000 individual plant shoots per square meter) including the plants themselves and the attached flora can reach 20 g C/m^2 per day, making them more productive on a per unit basis than either tropical coral reef systems (10 g C/m^2 per day) or the upwelling regions off Peru (11 g C/m^2 per day).

The physical structure provided by seagrass blades and rhizomes increases available habitat surface area for surrounding organisms as much as 15–20 times compared to unvegetated bottoms. In addition, it offers refuge from predators to many large juvenile populations of commercially important species of invertebrates and fish. For example, the commercial yield of shrimp in an estuary is directly related to the amount of seagrass habitat present (Figure 77). The combination of shelter and food makes seagrass meadows one of the richest and most critically important nursery grounds in Florida Panhandle coastal waters.

Two types of food webs are associated with seagrass communities: (1) a "grazing" food chain component comprised of herbivores that feed on living plants (both the seagrass blade itself and the associated algae) and their predators; and (2) a detrital food chain component comprised of herbivores that feed on dead material, together with their associated predators. Only a few species of animals in the Panhandle graze directly on living seagrasses (e.g., urchins, fishes, and some ducks and geese at low tide) and only a small fraction of the energy and nutrients in a seagrass bed is channeled through these herbivores (Thayer et al. 1984). For the vast majority of the herbivores (e.g., gastropods) in the seagrass ecosystem, the epiphytic algae constitute their primary food source (Kitting et al. 1984).

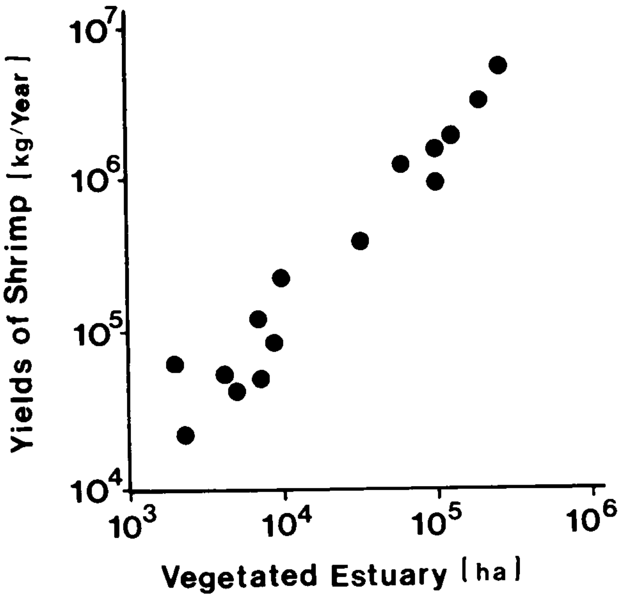


Figure 77. Yield of penaeid shrimp and vegetation coverage in an estuary (after Turner 1977).

Seagrasses have many critical functional roles in the coastal environment. Some of the most important include:

(1) serving as a sediment trap and stabilizer of bottom sediments;

(2) providing primary productivity to the sea;

(3) serving as a direct food source for herbivorous organisms;

(4) serving as a source of large quantities of detritus and dissolved organic matter;

(5) providing an attachment substrate for epiphytic algae that is a primary food source for many seagrass herbivores;

(6) providing a refuge from predators for many juvenile forms of fish and invertebrates, including economically important species;

(7) providing a habitat for a certain assemblage of invertebrate species that burrow or grow attached to leaves and that would otherwise be uncommon or absent, and;

(8) possibly serving as a major link in the main biochemical cycles of coastal areas.

Like terrestrial grasses, seagrasses form recognizable biological and physical entities that are often termed meadows. Like many terrestrial systems, the seagrass meadow is defined by a visible boundary grading from an unvegetated to vegetated substrate. In the Panhandle, meadows vary in size from small isolated patches of plants <1 m across, to continuous distributions of grass over many square kilometers. Meadows can be composed of a single species (usually turtle grass—*Thalassia testudinum*) or multiple species (*Thalassia*, shoal grass (*Halodule*), and manatee grass (*Syringodium*) are commonly found together).

Although still a conspicuous feature of the shallow-water coastal areas of the Panhandle, seagrass coverage appears to have suffered significant declines in many of the major bays over the last few decades. The primary reason appears to be the increased impacts (e.g., from dredging and pollution) of a growing coastal population.

b. Seagrass species present. For this report, *Ruppia martima* is not considered a true seagrass because it is not an obligate halophile and can grow in fresh water. It is found in the brackish vegetation habitat. Of the approximately 50 worldwide species of seagrass, 5 occur in the Panhandle region (Figure 78 shows the four most common):

Thalassia testudinum, turtle grass, is the largest, most robust of the seagrasses. Its ribbon-like leaves are 4 to 12 mm wide and 10 to 35 cm long with rounded tips (Figure 79). Two to five leaves are commonly present per shoot. Rhizomes, or roots, are found 2–5 cm deep in the sediment. Undisturbed, *Thalassia* is capable of forming extensive meadows. It grows at a minimum water depth of 0.5 m and rarely grows in water deeper than 11–12 m (Moore 1963). Bittaker and Iverson (1976) and Bell (1979) reported on the productivity of *Thalassia* in St. George Sound, which averaged 500 mg C/m^2 per day and was linearly proportional to the light energy.

Syringodium filiforme, manatee grass, has leaves that are circular in cross-section and typically has 2 to 4 leaves per shoot. Leaf diameters range from 1.0 to 1.5 mm. Blade length is highly variable but can exceed 50 cm. The rhizome system is less robust than that of *Thalassia* and not as deeply rooted. It is commonly found mixed with other seagrasses or in small, dense monospecific patches. It rarely forms extensive meadows like those of *Thalassia*.

Halodule wrightii (=*Diplanthera wrightii*), shoal grass, is extremely important as an early colonizer of disturbed areas where *Thalassia* and *Syringodium* are excluded. It commonly grows in water either too shallow or too deep for other species. The leaves are flat, typically 1 to 3 mm wide, 10 to 20 cm long, and arise from erect shoots. The tips of the leaves have two to three small points. It is the most tolerant of all seagrasses to variations in temperature and salinity.

Halophila engelmannii is a shade-loving species. It is an initial colonizer of newly available substrate and is extremely pollution tolerant. It is almost never present in monospecific beds, except in areas offshore. In the Gulf of Mexico it grows up to 30 m deep.

Halophila decipiens is known from isolated areas of the Panhandle region at least 6–7 m deep in the open gulf off Alligator Point and Pensacola (Humm 1956). It is a tropical species which may be limited to deeper water in the Panhandle where temperatures are not as extreme as those in the shallows.

Of the five species, the first three are the most commonly encountered in the Panhandle. A diagram of distributional ranges (i.e., salinity and depth) for 4 species is given in Figure 80.

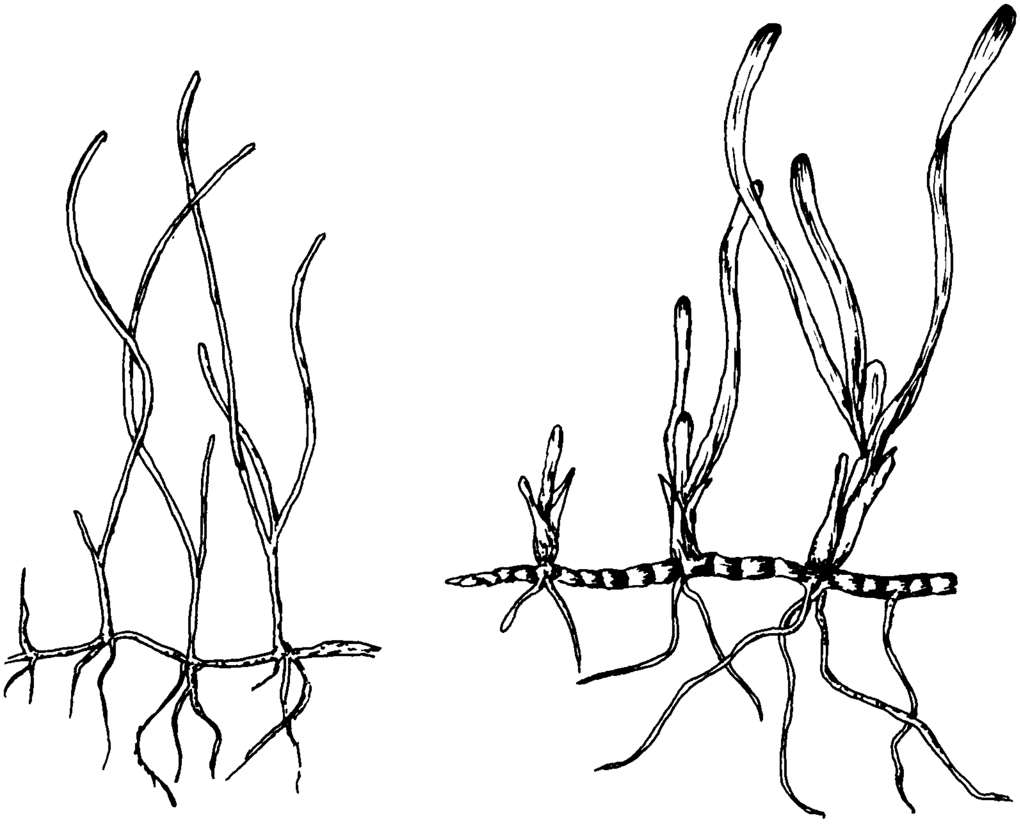
c. Seasonality. Seagrasses in the Panhandle are perennial and reach a peak in biomass in the summer. New short-shoot production occurs only during the spring and summer. *Thalassia* leaf biomass in St. George Sound and St. Joseph Bay reaches a seasonal maximum during August (Iverson and Bittaker 1986). Seagrasses grow at a very reduced rate during the winter months. Each winter the seagrass blades of all species die back to within several centimeters of the sediment-water interface (Iverson and Bittaker 1986).

d. Species succession. Seagrass beds in the Panhandle go through an orderly process of succession, if left undisturbed. See Zieman (1982) for a discussion of the successional theory of seagrasses. Since there are only a few species present, the sequence is fairly simple (Figures 81 and 82). Algae are usually the first to colonize a disturbed area. Their primary contribution to the successional process is the accumulation and binding of sedimentary particles. The pioneer grass species is *Halodule*, which colonizes either by seed or rapid vegetative branching. It further stabilizes and protects the substrate surface. *Syringodium* appears next and as development continues, *Thalassia* becomes established. The time required for the recovery of a damaged bed depends upon the magnitude of the initial disturbance and on local wave and current intensity. However, even small patches take 2 to 5 years to recolonize (Zieman 1982). If the entire bed is removed, recovery may never occur since the source of potential colonizers is gone.

Seagrass bed morphology is believed to denote maturity and successional stages (Hartog 1970,

Halophila engelmannii

Halodule wrightii



Syringodium filiforme

Thalassia testudinum

Figure 78. Four common seagrass species present in Panhandle waters (after Zieman 1982).

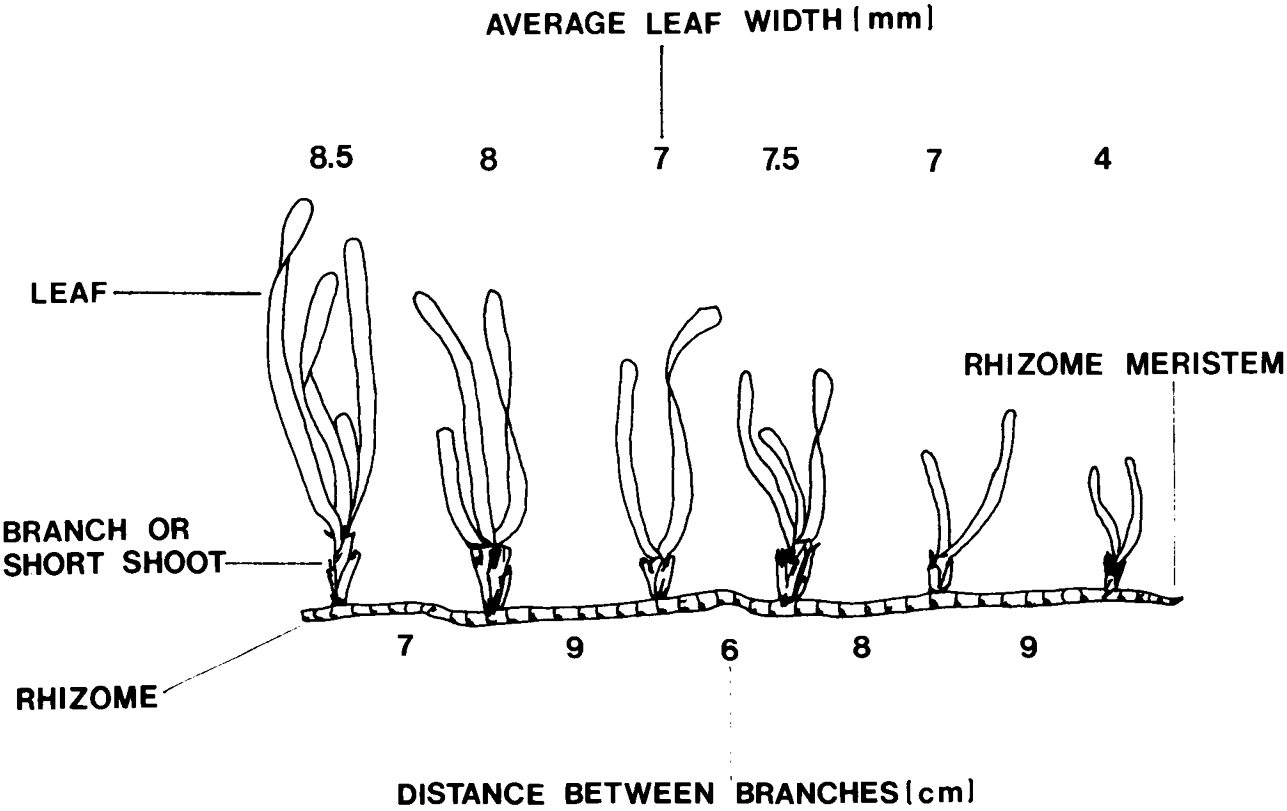


Figure 79. Diagram of a typical *Thalassia* shoot showing oldest leaves to left and new growth on right (after Zieman 1982).

Winter 1978). A pure *Halodule* bed is considered pioneer. A nearly equal mix of all three species is considered intermediate in development. Core-fringe morphology with a central core of intermixed *Thalassia* and *Syringodium* surrounded by a fringe of *Halodule* indicates mature beds.

e. Distribution. The most recent estimate of total coverage of seagrass beds in the Panhandle is approximately 637 km^2 (Table 36).

The data that exist for the 1970's and 1980's show an accelerated decline of grassbeds in many bays, especially in the Pensacola estuary system where Escambia Bay grassbeds are nearly entirely absent. Generally, there is no documentation of areal extent prior to the last few decades, so it is not known how much has been lost. The following discussion documents the most recent account of seagrass distribution in each major bay system in the Panhandle and discusses changes in the system if such information was available at the time of writing.

(1) Ochlockonee Bay. Only a few scattered patches containing some *Thalassia* have been reported near the opening of the bay into Apalachee Bay (Phillips 1960, McNulty et al. 1972).

(2) Alligator Harbor and St. George Sound. Alligator Harbor has large beds in its eastern one-third, along the northern shore, and on Bay Mouth Bar at the entrance of the harbor. There are extensive, continuous beds along the northern shores of St. George Sound. These beds are concentrated in the eastern one-half of the Sound.

(3) Apalachicola Bay System (i.e., East Bay, Apalachicola Bay, and St. Vincent Sound). The

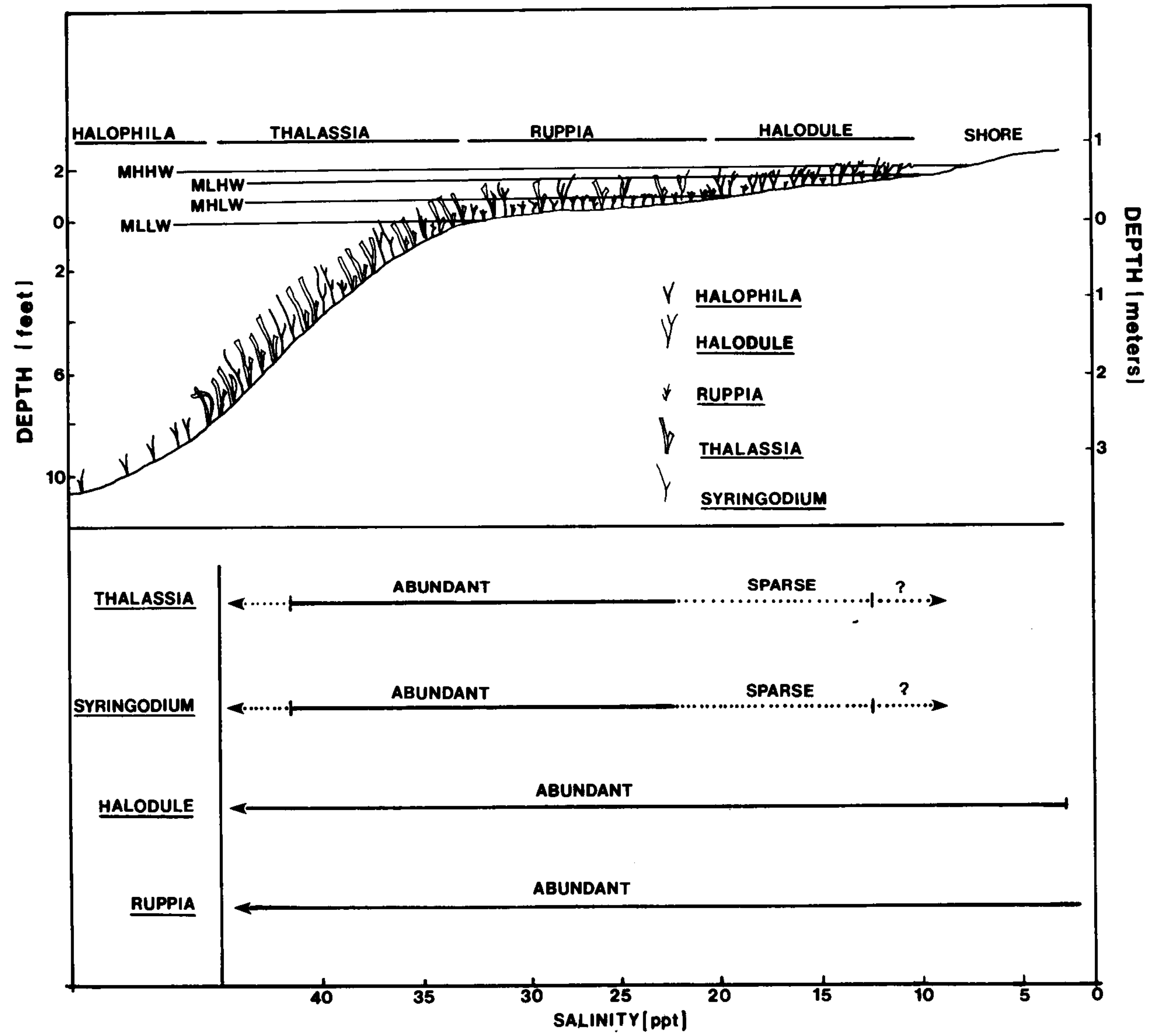


Figure 80. Diagram showing typical depth distributions of three seagrass species and a common brackish species *Ruppia maritima* (after McNulty et al. 1972). MHHW = mean higher high water; MLHW = mean lower high water; MHLW = mean higher low water; and MLLW = mean lower low water.

seagrass distribution in the Apalachicola Bay System is not very extensive given the large area of the estuary (30,480 ha). High turbidity and sedimentation from river input decrease light levels and produce an unsuitable substrate for seagrass growth in most areas. Seagrasses are primarily concentrated along the fringes of the estuary in less than 1 m of water in upper East Bay, inside St. George Island in Apalachicola Bay, and in western St. George Sound (Livingston 1984). *Halodule* and *Syringodium* dominate most areas. Grassbeds are nearly absent from St. Vincent Sound but some small isolated beds do exist (H. Bittaker, Florida Department of Community Affairs, Tallahassee; pers. comm.).

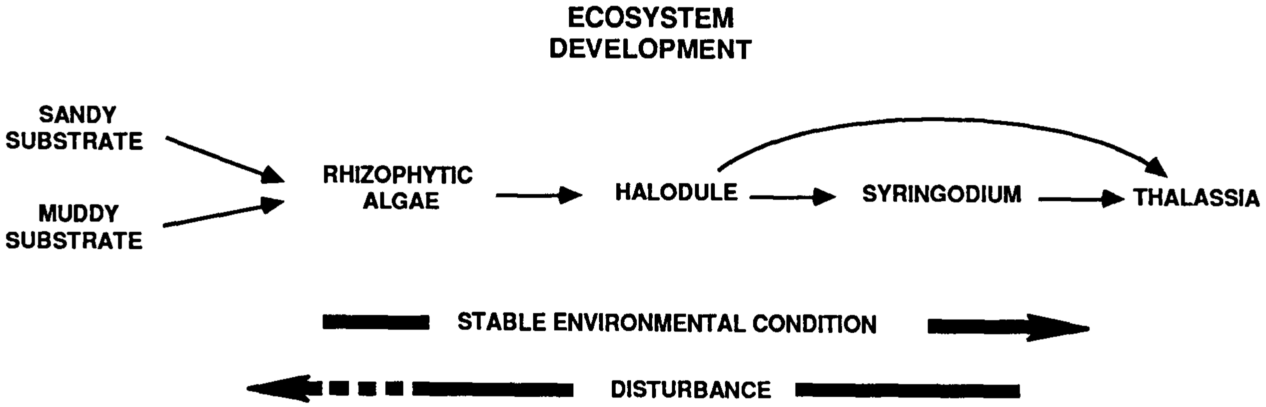


Figure 81. Ecosystem development in seagrasses. Without disturbance a Thalassia climax is reached (modified from Zieman 1982).

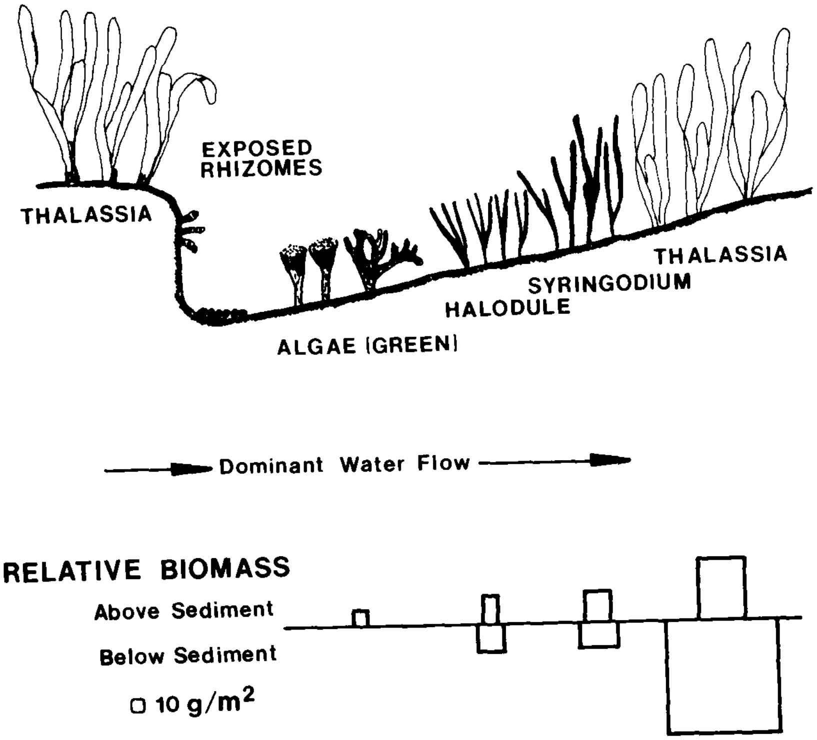


Figure 82. Idealized sequence of seagrass recolonization and growth in a large disturbance (after Zieman 1982).

Table 36. Surface area of major water bodies and most recent seagrass distribution estimates for the Panhandle water bodies (a = McNulty et al. 1972, b = Savastano et al. 1984).

Water body	Bottom area (ha)	Grassbed area (ha)	Source
Alligator Harbor	1,637	261	a
St. George Sound	30,762	3,392	a
East Bay	3,981	1,434	a
Apalachicola Bay	20,960	1,125	a
St. Vincent Sound	5,540	10	a
St. Joseph Bay	17,755	2,560	b
St. Andrew Sound	1,906	151	a
East Bay (St. Andrew)	7,557	464	a
St. Andrew Bay	10,615	1,029	a
West Bay	7,118	626	a
North Bay	2,704	417	a
Choctawhatchee Bay	34,949	1,252	a
Santa Rosa Sound	9,947	1,897	a
East Bay (Pensacola)	14,906	0	a
Escambia Bay	9,754	0	a
Pensacola Bay	16,435	627	a

(4) St. Joseph Bay (Figure 83). The seagrasses nearly circumscribe the entire inner shore of the bay. The figures of McNulty et al. (1972) show that it contains the most seagrass coverage (on a per area basis) of any single bay in the Panhandle. A more recent aerial survey and reported local observations (Savastano et al. 1984) reveal that seagrass distribution has remained unchanged from 1972–78 with apparent stability of community species types.

(5) St. Andrew Bay System (includes St. Andrew Sound, East Bay, St. Andrew Bay, West Bay, and North Bay). In total acreage this system contains the largest seagrass stock in the Panhandle (McNulty et al. 1972). Unfortunately, there have been no published reports since 1972 giving precise seagrass areas in the system, and therefore it is impossible to document any change that may have recently occurred in the bay. Seagrass composition has been noted at certain stations in a more recent study (Grady 1981). *Halodule* was the dominant species at intertidal stations on the shore of the East Arm of St. Andrew Bay. The north shore of the East Arm was nearly devoid of seagrasses, except for *Halodule* near Pitt Bayou. *Halodule* was predominant on the north shore of the West Arm, while a few stations dominated by *Thalassia* were found on the south shore. Since this system is offshore of the fast-growing Panama City area, it would be prudent to take an inventory as soon as possible in order to assess current damage and provide a base for the future assessment of impact on the system.

(6) Choctawhatchee Bay. The vegetation of the bay was studied most recently by Burch (1983a), who documented changes in coverage over the past 30 years. The only seagrass species present is *Halodule wrightii.* Beds are concentrated in the western section of the bay (Okaloosa County) and grow primarily at depths of 1 to 2 m and in areas of abrupt depth change from 2 to 5 m. Six major areas support significant seagrass populations (i.e., bottom coverage greater than 40%): Hogtown Bayou, Moreno Point from the Okaloosa-Walton County line to Joe's Bayou, East Pass, the Santa Rosa Sound entrance, Black Point, and, White Point. Five major areas contain beds with less than 40% bottom coverage: Far Mile Point, east of the Okaloosa-Walton

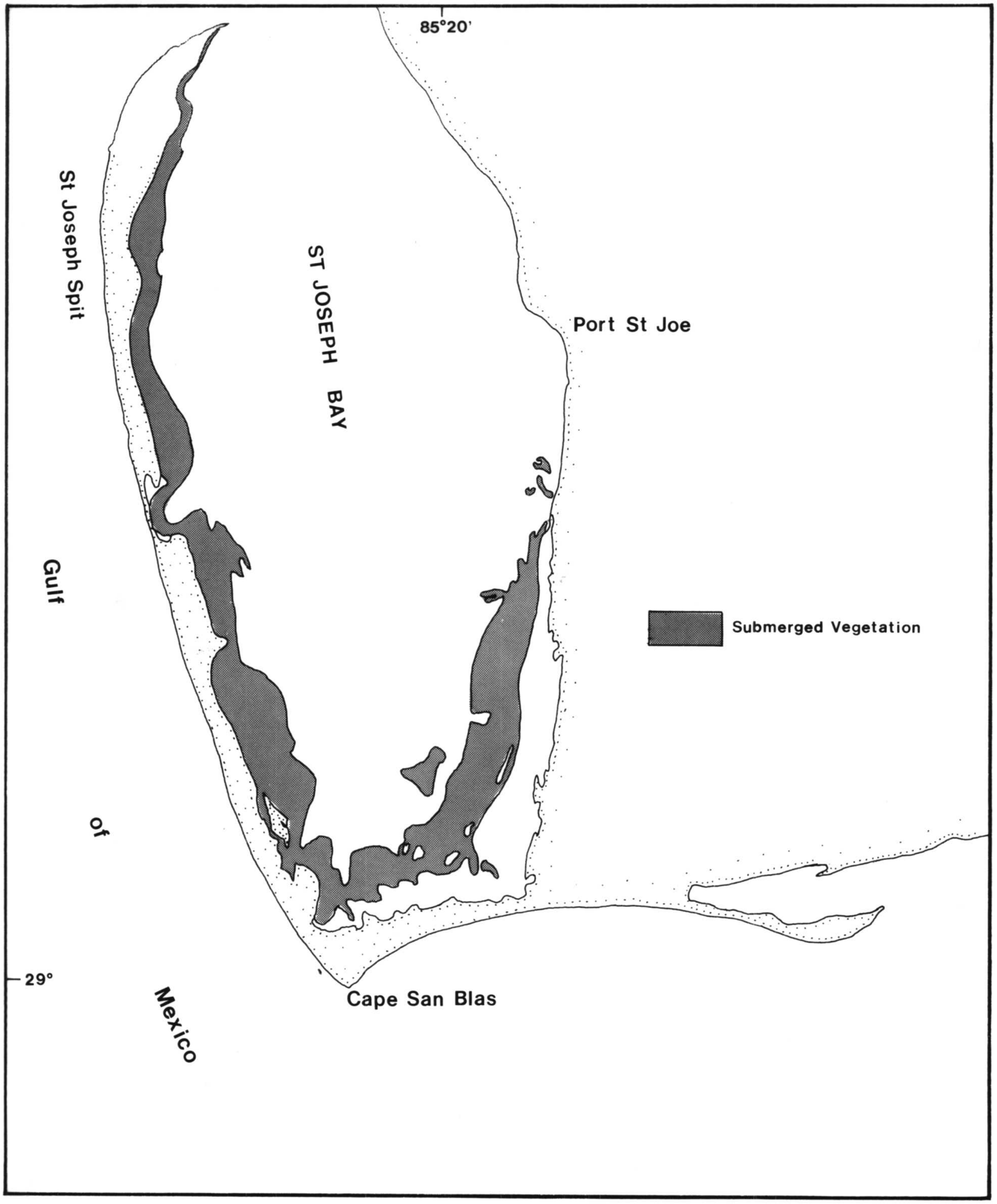


Figure 83. Seagrass distribution in St. Joseph Bay in 1981 (after Savastano et al. 1984).

County line, northwest of Destin, Smack Point, and, Eglin Village north to Rocky Bayou. No submerged vegetation is present west of Stake Point on the north shore or west of Live Oak Point on the south shore. In general, the western part of the bay appears more favorable for seagrass growth in terms of salinity, temperature, and light levels than does the eastern portion.

Burch (1983a) concluded there has been little change in submerged vegetation coverage in the past 10 years since McNulty et al. (1972) reported their findings. However, there were significant declines from 1949 to 1982 (Burch 1983a). A formerly dense patch off White Point is no longer present. Declines were noted around the east end of East Pass Bridge, out from Destin, southwest of Buccaroo Point and west of Starke Point. One major dieback was noted in 1982 in the area of Ben's Lake, which had been dredged since 1955 and another around Bear Creek to the northeast.

(7) Pensacola Bay System (includes Pensacola Bay, Escambia Bay, East Bay, and Santa Rosa Sound, Figure 84). This system is the most impacted by human activity of all the watersheds in the Panhandle. Escambia Bay, which in 1949 had extensive seagrass beds along all shores except for sparse areas along the southwest shore (Rogers and Bisterfield 1975), has been decimated of seagrass over the past 25 years (Olinger et al. 1975). There was a gradual loss between 1949 and 1966 and by 1974 all of the seagrass had disappeared (Rogers and Bisterfield 1975).

East Bay was reported to contain one major stretch of seagrass in the northeast area between Escribano Point and Miller Point. However, recent reports from local residents reveal that this bed disappeared approximately 2 years after Rogers and Bisterfield concluded their study.

Seagrass disappearance has been noted in Pensacola bay since 1951 (Rogers and Bisterfield 1975). Several small beds near the north side of the Pensacola Bay Bridge were gone by 1960, probably because of the dredging for enlargement of the Port of Pensacola; Phase I involved extensive dredging and filling. Other beds adjacent to the bridge and nearby Bayou Texar had disappeared by 1961.

The south shore of Pensacola Bay west of the Bay Bridge has not been historically mapped, but the area east of the bridge was sporadically mapped. East of the bridge, a nearly continuous 22.5 km long grassbed extended to Tom King Bayou in 1960. The dominant species was *Thalassia testudinum*, beginning in Butcherpen Cove and extending eastward 1

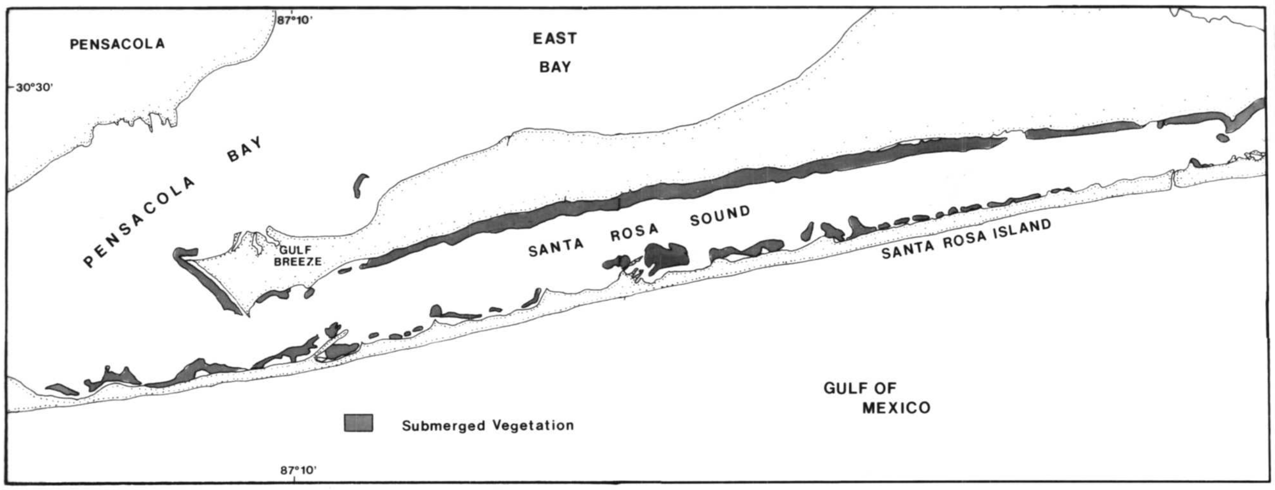


Figure 84. Seagrass distribution in a portion of the Pensacola Bay system (from McNulty et al. 1972 and Williams 1981).

km. At some point eastward toward Tom King Bayou, *Halodule* replaced *Thalassia* as the dominant species. From 1949–66, seagrass coverage declined by approximately 50%. From 1966–74, losses accelerated, and in 1974 no significant stands were left.

The Santa Rosa Sound was most recently surveyed by Winter (1978) and Williams (1981). Using divers, Winter surveyed beds between the sewage treatment plant and Range Point on Santa Rosa Island along five transects at 610, 457, 304, and 153 m from shore and along the 1 m depth contour. A total of 26.1 ha of viable seagrasses were located. Three species, *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii*, were present. Near development on the shore, seagrass coverage was severely reduced and only immature beds were identified . This was interpreted as resulting from disturbances caused by heavy boat traffic and by a fill project that may have covered over some of the beds. Turbidity was postulated as a primary cause of the decline because deeper beds were dead whereas deep beds off Fort Pickens and the National Seashore, where there is no development, were still present and viable. A further increase in water turbidity was identified as the most serious potential impact to the future success of seagrasses in the Sound (Winter 1978).

f. Associated flora and fauna. The classification of the biotic components of the seagrass meadow habitat follows Kikuchi (1980). In this scheme, the flora and fauna are divided into the following three categories on the basis of the microhabitat structure and the mode of existence of the organisms.

(1) epiphytic organisms that grow on the seagrass blades (Table 37) including:

(a) micro- and macroalgae and the micro- and meiofauna associated with these algae.

(b) sessile fauna attached to the leaves.

(c) mobile fauna crawling on the leaves.

(d) swimming fauna which rest on the leaves.

(2) highly mobile fauna that swim within and over the leaf canopy (Table 38)—decapod crustaceans and fishes that may be either diurnal or seasonal transients or permanent residents.

Table 37. Dominant epiphytic organisms (flora and fauna) that grow on the seagrass blades (Dennis 1981, K. Sherman pers. comm.).

Group	Species
Microalgae	
Macroalgae	
Nematoda	*Chromadora nudicapitata* *Epsilonema* sp. *Sphiliphera paradoxa* *Syringolaimus striatocaudatus* *Viscosia macramphidia*
Copepoda	*Altheotha* spp. *Ectinosoma* spp. *Idomene* spp. *Laurinia* spp. *Metis* spp. *Parategastes* spp. *Pholetiscus* spp. *Porcellidium* spp. *Tegastes* spp. *Zaus* spp.
Polychaeta	Serpulidae
Porifera	*Haliclona permollis* *Halicometes perastra* *Mycate cecilia*

(3) epibenthic and infaunal invertebrates that dwell on or within the sediments (Table 39). Many of these species may display nocturnal vertical migration patterns between the sediment and the blades of the seagrasses. Rather than being endemic to the seagrass habitat, they appear to be an extension of the benthic community that lives on and in the adjacent unvegetated substrate.

The functional categories are all intimately linked to the seagrass and exhibit shifts in abundance in response to changes in seagrass density as well as to seasonal fluctuations in environmental parameters. Thus, within any specific meadow, there is considerable temporal variation in the composition and density of associated flora and fauna.

Table 38. Dominant mobile fauna within the seagrass leaf canopy (Abele 1970, Eidemiller 1972, Sheridan and Livingston 1983).

Group	Species name
Decapoda	*Alpheus heterochaelis*
	Callinectes sapidus
	Clibanarius vittatus
	Epialtus dilatatus
	Eurypanopeus depressus
	Hippolyte pleuracantha
	Hippolyte zostericola
	Libinia sp.
	Neopanope packardii
	Neopanope texana texana
	Pagurus bonairensis
	Pagurus longicarpus
	Palaemon floridanus
	Palaemonetes intermedius
	Palaemonetes pugio
	Palaemonetes vulgaris
	Pelia mutica
	Penaeus duorarum
	Tozeuma cardinense
	Upogebia affinis
Tanaidacea	*Hargeria rapax*
Isopoda	*Lironeca ovalis*
Fish	*Bairdiella chrysoura*
	Cynoscion nebulosus
	Lagodon rhomboides
	Orthopristis chrysoptera

There are also horizontal variations within the structure of the seagrass meadow. Silt-clay content, organic matter, and nitrogen pools are lowest outside the meadows and increase in magnitude toward the center of the bed. Shoot density and the standing crop of leaves and of root-rhizomes also increase from the edge to the inside. The faunal community may reflect this edge to center gradient, but existing data are inadequate to prove that hypothesis.

Table 39. Dominant epibenthic and infaunal invertebrates that live on or within the sediments of seagrass meadows (Shier 1965, Kritzler 1971, Osborne 1979, Saloman et al. 1982b, Sherman, personal communication).

Group	Species name
Nematoda	*Chromaspirinic* spp.
	Theristus spp.
Polychaeta	*Aricidea taylori*
	Axiothella mucosa
	Ceratonereis mirabilis
	Exogone dispar
	Heteromastus filiformis
	Hobsonia florida
	Neanthes acuminata
	Nereis pelagica
	Onuphis nebulosa
	Platynereis dumerilii
	Scyphoproctus platyproctus
	Spio filicornis
	Streblosoma hartmanae
	Syllis cornuta
Mollusca	*Caecum floridanum*
	Cardita floridana
	Crepidula maculata
	Mitrella lunata
	Modiolus americanus
	Modiolus demissus
	Neritina reclivata
	Ostrea frons
Crustacea	*Ampelisca vadorum*
	Ampelisca spp.
	Cymadusa compta
	Cymadusa sp.
	Lysianmopsis sp.
Oligochaeta	
Hydroids	

g. Trophic dynamics and interactions. Seagrasses with their attached flora (i.e., epiphytes—macroalgae attached to the blade; periphyton—microalgae such as diatoms, algal sporelings, and bacteria that coat the blade) provide food for other organisms through (1) direct herbivory, (2) detrital food webs within the beds, and (3) exported material—macroplant material or detritus—(Zieman

1982). The primary energy pathway appears to be direct herbivory on the algal epiphytes rather than the detrital food web (Kitting et al.1984). However, detritus is still a major energy pathway. Grazing on the more refractory seagrass blades is not extremely important and is limited to only a few organisms (Montfrans et al. 1984).

Annual epiphyte production can approach 20% of the seagrass production. Several factors control seagrass epiphytic communities (Figure 85). Epiphytic grazers include a wide diversity of organisms: gastropods (the most prominent), amphipods, isopods, decapods, echinoderms, and fish. Some organisms (e.g., sea urchins and fish) remove large portions of the seagrass blade along with the attached algal epiphytes. Periphyton grazers, in most cases, remove only loosely adhered diatoms and algal sporelings, but leave the grass blade intact.

The organisms that live among the epiphytic algae may be an important food source (Alvis 1971). Crustaceans and nematodes are the dominant forms.

A number of fish feed on the infauna living in the sediment in the grassbed. Stingrays actually excavate the sediment, creating pits during feeding. Rays have been noted to concentrate their feeding along the seagrass meadows fringe where the rhizome mat is not as heavily developed (Reidenauer, pers. observ.).

Many fish feed on epifaunal organisms as juveniles and are piscivores as adults, for example the bonnethead shark (*Sphyrna tiburo*) and the lizardfish (*Synodus foetens*).

Besides predation and grazing, other interactions among seagrass and its associated community

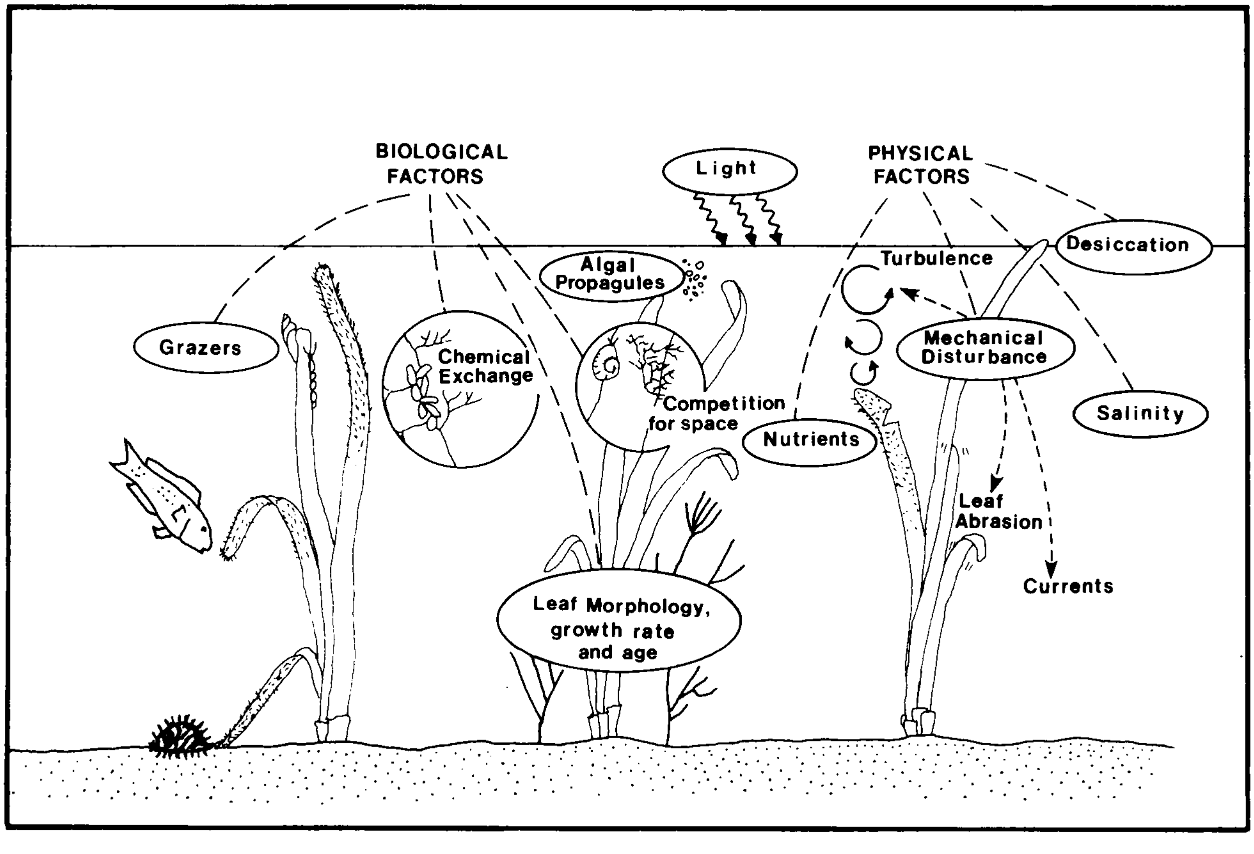


Figure 85. Schematic view showing the numerous seagrass epiphyte interactions that occur in a seagrass bed and the important physical factors affecting the interactions (after Montfrans et al. 1984).

have been examined. The epiphyte-seagrass association is a complex one (Figure 85). Epiphytes may benefit seagrass in a number of ways: reduction of desiccation during low water through entrapment and retention of moisture, protection against damage from ultraviolet radiation, and selective removal of the highly epiphytized and senescent leaf tips, which causes minimal damage to the plant itself and increases light penetration through the seagrass canopy. The distal portions of the blades are the oldest and generally most heavily epiphytized.

Epiphytes may also damage seagrasses by competing for similar wavelengths of light, shading, suppressing carbon (HCO_3^-) and phosphorus (PO_4) assimilation, and causing diurnal changes in pH and oxygen content of the surrounding water limiting plant growth and killing seagrass-associated fauna. In addition, light attenuation by epiphytes is thought to cause premature senescence in seagrasses.

The infaunal communities, especially the meiofauna community, in seagrass beds have been examined (e.g., Ruddell 1976); harpacticoid copepod abundances are significantly higher in the sediment surrounding isolated seagrass blades (Thistle et al. 1984). The physical structure of the blade may offer a refuge from fish predation (Dennis 1981). In addition, sediment microbe abundance around the blade is significantly higher than in unvegetated sand, possibly attracting meiofauna to the enriched food source.

h. Commercially important species. Scallops are common in and around seagrass beds in the Panhandle. Two scallop species occur in the region, bay scallops (*Argopecten irradians*) and calico scallops (*A. gibbus*) (Sastry 1961). The bay scallop is the most common species associated with nearshore Panhandle seagrass beds. St. Joseph Bay is a popular scalloping area in the region because of its lush seagrass beds and clear waters. Scallops spawn in the fall in north Florida. The larvae are planktonic for a few weeks and then attach to seagrass blades for several weeks before metamorphosis into adults. Maximum life span is about 2 years. Many die after one spawning season (12–14 months old). Adults are filter feeders on phytoplankton, primarily diatoms. There is no closed season on bay scallops for public harvest. Commercially, they may not be harvested before August 1 because this is when maximum size is attained.

Blue crabs are also abundant in Panhandle seagrass beds. Juvenile blue crabs are commonly found in shallow seagrass beds (Oesterling 1976). Adults are generally found in muddy sediments up to 35 m deep. Females migrate to higher salinity waters offshore to spawn. Juveniles migrate from offshore back into the estuaries. Blue crabs reach commercial size (7.7 cm carapace width) within 1–1.5 years and live up to 3–4 years. Adults feed on live prey such as small fish, oysters, and clams, and they are also scavengers. There is no closed season on blue crabs in the Panhandle, but they must be 7.7 cm across the carapace and females must not be egg-bearing.

i. Natural impacts. Hurricanes and severe tropical storms are common along the Panhandle coast (see Chapter 3). Seagrass beds can withstand hurricane force winds with little sediment erosion and minimal damage (i.e., primarily leaf damage), while adjacent unvegetated areas experience extensive erosion. Damage may occur, however, from indirect effects such as reduced photosynthesis caused by increased water turbidity and heavy sedimentation within the bed from the increased sediment load in the water column.

All seagrass species have an upper and lower temperature tolerance (McMillan 1979) beyond which they may be destroyed. The levels vary with local populations. It appears that seagrasses form photosynthetic and phenological biotopes that are adapted to local temperature ranges and these, in turn, control the entire ecosystem. However, it is difficult to generalize about responses to temperature.

Salinity fluctuations do not appear to have the extreme effects on seagrasses that temperature fluctuations may have, although the species seem to have a range of salinity tolerances.

j. Human impacts. Dredging and filling prove the greatest threat to the seagrass ecosystem (Thayer et al. 1975, Zieman 1975, Phillips 1978). The plants themselves are physically removed and the entire biological, chemical, and physical structure of the ecosystem is changed. The extent of area directly affected by dredging depends on the tidal range, current strength, and sediment texture in the area.

The sediments stirred up by dredging bury plants away from the actual project, but more importantly they also drastically reduce plant density by effecting water clarity (Zieman 1982). During dredging, light penetration through the water column is reduced, and productivity and chlorophyll content of the grasses decreases. The reduction in seagrass density caused by suspended silt increases the erosion of the bottom sediments and further affects additional areas. The redox potential of seagrass sediments is also upset by dredging, which reverses the entire nutrient-flow mechanics of the ecosystem.

Fill produces four major impacts on seagrass meadows: (1) direct covering and smothering of the grass, (2) indirect covering of the grass by drifting sediment, (3) reduced light penetration because of an increase in water turbidity, resulting in a reduction in or cessation of photosynthesis, and (4) damage by depletion of oxygen caused by BOD of the fill materials.

There is evidence that even small-scale dredging projects in some areas may cause a severe perturbation on seagrass ecosystems (Zieman 1975).

Attempts have been made to revegetate dredge spoil areas with seagrass, especially with *Halodule wrightii* plugs in St. Joseph Bay (Phillips et al. 1978). The projects have not been very successful because of physical factors (i.e., cold temperatures and storms) that could not be predicted or controlled. More intensive studies should be conducted on seagrass vegetation because of the great need to restore estuaries in the Panhandle.

Agricultural clearing of uplands, real estate development, logging, and channelizing streams may increase the rate of erosion of sediments, detritus, and mineral nutrients and may cause high inputs of sediments into estuaries and coastal areas (Thayer et al. 1975).

The direct impact from oil on subtidal seagrasses is not as severe as it is on intertidal plants (i.e., salt marsh grasses) because the majority of the oil will float over the beds. However, oil spills can inflict severe damage on grass beds. Direct contact with oil can cause mortality. Probably of greater long-range concern is damage caused when oil-sediment particles that have conglomerated elsewhere accumulate as grass beds reduce current velocity and sediments settle out of the water column. A surface oil sheen can also reduce light penetration and indirectly affect seagrass beds. Laying pipe for oil can directly destroy beds. In areas of low energy, seagrasses are buried and smothered by mud cuttings and fluids and are affected indirectly by turbidity from suspended drilling effluents (John Thompson, Continental Shelf Associates; pers. comm.).

Pollution from toxins and heavy metals has not been implicated in the direct, major destruction of seagrass beds. Evidence exists that roots of seagrasses may accumulate metals such as zinc (Zieman 1982). Concentrated metals may be passed along the food chain through the seagrasses.

In many shallow water Panhandle environments (e.g., St. Joseph Bay and Santa Rosa Sound), the physical destruction of seagrass beds by boat propellers is easily observed. *Thalassia* beds are especially affected since this species does not spread its rhizome mat very rapidly. Propeller cuts can be very persistent features, lasting for 3 years or more (Zieman 1976). If the leaves of *Thalassia*, for example, are slightly damaged rapid regrowth will be unlikely. Rhizome growth is extremely slow and if roots are cut, regrowth may never occur. Trawling by commercial fishermen can tear up grassbeds.

Effluent discharge (particularly nitrogen and phosphorus compounds and suspended solids) can cause a decline in seagrass coverage as a result of heavy growths of phytoplankton and filamentous algae and higher turbidity. These growths reduce the available light and nutrients for seagrasses and also reduce oxygen levels for seagrass respiration during nighttime hours.

7.2.11 Subtidal Leaf Litter

a. Introduction. The leaf-litter habitat in the Panhandle is basically detritus dominated by pine needles and oak leaves. It is generally concentrated near river mouths in the estuaries. The habitat is ephemeral, existing at peak abundance when river flow is great and terrestrial macrophytes are dying off.

Leaf litter contains a unique and definable assemblage of organisms that are closely tied to the decaying vegetation for food and shelter. Omnivorous and detritivorous organisms usually dominate.

Physical factors (e.g., salinity and temperature) are important determinants in the distribution of the leaf-litter faunal community. Biological factors such as predation also appear to play an important role.

b. Associated fauna and flora. Livingston (1984) reported on the common organisms present in Panhandle leaf-litter habitats (Table 40). Abundances of leaf litter macrofauna peak in late winter (March) and early fall (September) (Livingston 1984) (Figure 86). These peaks are strongly correlated to the availability of detritus. Other important factors within the estuaries that affect the leaf-litter fauna are temperature and salinity. Highest abundances are generally associated with higher salinity waters.

The microbial community associated with Panhandle leaf litter has been investigated in depth by Morrison et al. (1977) and White et al. (1979). Microbial biomass correlated strongly with substrate type rather than other physical factors. Bacteria are initial colonizers of the plant litter and are subsequently replaced by more complex forms such as fungi and algae.

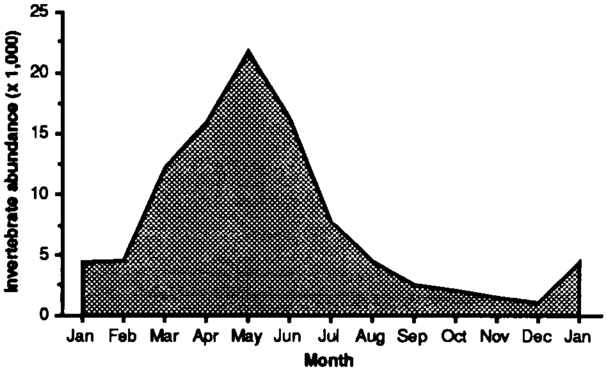


Figure 86. Seasonal abundances of leaf-litter associated invertebrates from the Apalachicola Bay system in 1976 (after Livingston 1984).

Table 40. Common fauna of Panhandle leaf-litter habitats (from Livingston 1984).

Common name	Scientific name
Amphipods	*Corophium louisianum* *Gammarus mucronatus* *Gitanopsis* spp. *Grandidierella bonnieroides* *Melita* spp.
Isopod	*Munna reynoldsi*
Decapods	*Callinectes sapidus* *Palaemonetes pugio* *Palaemonetes vulgaris* *Penaeus setiferus*
Gastropod	*Neritina reclivata*

There are no published reports on the meiofauna of Panhandle leaf-litter communities.

c. Trophic dynamics and interactions. The leaf-litter fauna is primarily omnivorous and detritivorous. Macrofaunal distribution is positively correlated with numbers, biomass, and species richness of the detritus-associated microfauna (Livingston 1984). The macroinvertebrates appear to seek out microbial populations rich in anaerobic or microaerophilic bacteria. Distinct macrofaunal populations may prey upon specific microbes. The macrofaunal detritivores are an important link between the microbial producers living on the leaf litter and commercially important estuarine fish and invertebrates (Livingston 1984).

d. Natural impacts. Storms wash away detritus, making leaf-litter habitat ephemeral and patchily distributed. Temperature and salinity fluctuations affect faunal distributions.

e. Human impacts. Artificial perturbations that affect other estuarine habitats, such as unvegetated soft bottoms, also impact leaf litter. Water quality parameters such as lowered DO, increased nutrients, and heavy metals can produce reductions in fauna.

7.3 Marine Habitats

7.3.1 Hard Substrates

a. Introduction. As in the estuarine system, there are not many naturally occurring hard substrates present in the Panhandle marine intertidal regions. Most of them are artificial (e.g., pilings, jetties, offshore platforms, and boat bottoms). Although limited in area, the habitat is discussed because it contains a unique and ecologically interesting fauna. Community development on structures is economically important because of biofouling problems. For example, marine fouling reduces ship propulsion efficiency by increasing frictional drag and destroys wharf pilings. It is also a problem on buoys and other structures in the marine environment.

b. Associated flora and fauna. Marine algae on platforms tend to be small and inconspicuous. Two colonial forms are present: *Enteromorpha* and *Chaetomorpha*. Generally the dominance follows this order: green, red, blue-green, and brown algae (Salsman and Ciesluk 1978). For photosynthetic reasons, algal biomass is concentrated near the surface waters. Algae are usually one of the first colonizers of new or open solid surfaces.

There is considerable variation in biofouling communities in the type of organisms present and in their size and density (Hastings 1972). The system is dependent on season, water depth, distance from shore, and larval availability (Pequegnat et al. 1967, Pequegnat and Pequegnat 1968). The nature of the substrate also plays a major role. The settlement rate of larvae is often determined by surface contour, texture, composition, and color. Light levels, water currents, and tidal range are also important.

There appears to be a predictable sequence in the development of a Panhandle fouling assemblage (Salsman and Ciesluk 1978): (1) initial settlement and rapid development of pioneer species; (2) a rapid and then more gradual increase in species diversity; (3) an early increase in size and density of nearly all individuals; (4) a decrease in the abundance of some species with the local extinction of others; and (5) the persistence of a few species, which facilitates the settlement of later arriving species.

The pioneer "guild" includes a community of bacteria, diatoms, and blue-green algae that produce a slime-like surface. During the first week of exposure, barnacles, hydroids, and gammarid amphipods usually appear. Most of these are primarily suspension feeders. Other trophic types settle later.

Three species of acorn barnacles (*Balanus venustrus*, *B. improvisus*, and *B. eburneus*) are typically encountered in the Panhandle (Hulings 1961). *Balanus venustrus* is usually the most abundant species.

Five species of gammarid amphipods are also present (Salsman and Ciesluk 1978). Twenty-three species of hydroids are present in the lower intertidal to subtidal range.

The most prominent difference between Panhandle estuarine and marine biofouling communities is the dramatic decrease in organism settlement and growth found in estuaries during the winter months (November–March).

Offshore petroleum structures represent unique artificial habitat areas. They may act as islands of hard substrate in otherwise soft-bottom habitats. Gallaway et al. (1981) delineated three distinct biofouling assemblages that are present in the northern Gulf of Mexico region: coastal (0–30 m), offshore (30–60 m), and bluewater (> 60 m). Coastal platforms are typically dominated by barnacles with hydroids, bryozoans, and sponges also abundant. Oysters may be present too. Offshore communities are similar but are dominated by bivalves instead of barnacles and usually have lush populations of octocorals (e.g., *Telesto* spp.) and algae near the surface. Bluewater biofouling assemblages have the lowest biomass of the three types. Algae and stalked barnacles dominate near the surface with bivalves more abundant at greater depth.

Because of the extensive biofouling communities, petroleum platforms are subjected to increased frictional drag from wave and current action. For economic and structural reasons, biofouling communities are extremely important. They tend to decrease the longevity of the platforms and hence increase the cost of offshore operations. Organisms on platforms are usually restricted to a particular depth range, and communities found in the near-surface intertidal range are similar to those from the nearshore intertidal environment.

7.3.2 Sandy Beaches

a. Introduction. The marine sandy beaches in the Panhandle are located on the gulfward-facing shores of the barrier islands (Dog, St. George, St. Vincent, Shell, and Santa Rosa Islands) and on the mainland shores from Cape San Blas to Pensacola. These intertidal habitats experience the highest wave-energy levels of any habitat type in the Panhandle saltwater environment. This beach habitat includes the swash zone (the sloping surface of the beach face that is created by the runup of water) down to the mean low water (MLW) mark.

Panhandle beach sediments are composed almost exclusively of fine quartz grains with a median diameter of 0.1 to 0.2 mm (Salsman and Ciesluk 1978). Their extreme white color makes them attractive to tourists. The aerobic zone (i.e., depth of oxygenated sediment) in beach sediments is very deep because of tidal flushing and the relatively large interstitial pore spaces. This allows organisms to live far down within the sediment and escape the pounding of the waves. The majority of beach organisms tend to be suspension feeders, using the rushing water to constantly carry food in and waste material away.

b. Beach zonation. Panhandle beaches are typical marine beaches and can be divided into specific zones (Figure 87). Typically, there are two offshore sandbars, the first located approximately 15–25 m offshore at a depth of 0.3–1.0 m, and the second 130–140 m offshore in 2–2.5 m of water.

c. Associated fauna. The macrofauna component has been the most intensively studied (Abele 1970, Hayden and Dolan 1974, Saloman and Naughton 1978, Saloman and Naughton 1984) (Table 41). Polychaetes dominate numerically. Amphipods (also called "sand fleas") and ghost crabs (*Ocypode quadrata*) are also important members of the community.

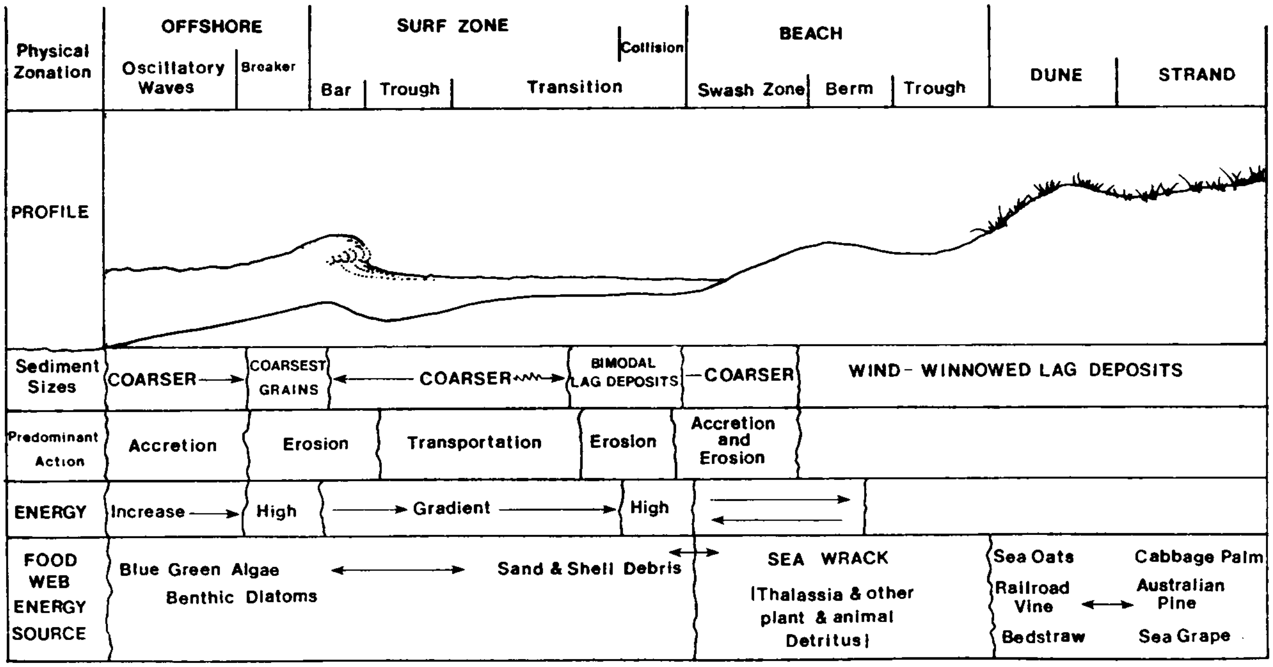


Figure 87. A high-energy beach community, showing major zones relating to sand motion (adapted from Riedl and McMahan 1974).

Table 41. Common macroinvertebrates present on Panhandle beaches (Hayden and Dolan 1974; Saloman and Naughton 1978, 1984).

Species name	Common name
Along wave line:	
Emerita talpoida	mole crab
Lepidopa benedicti	decapod
Callianassa islagrande	decapod
Arenaeus cribrarius	decapod
Scolelepsis squamata	polychaete
Haustorius spp.	amphipod
Upper portion of beach:	
Ocypode quadrata	ghost crab

One meiofauna group, the tardigrades (or "water bears"), are usually very abundant in beach sediments. A common Panhandle species is *Batillipes mirus*.

Birds are conspicuous members of the beach habitat and nearshore gulf waters. Common Panhandle sea- and shorebirds include: pelicans, cormorants, gulls, terns, sandpipers, plovers, stilts, skimmers, and oystercatchers (see Table 42).

d. Species of special concern. The Cuban snowy plover (*Charadrius alexandrinus tenuirostris*) is the only bird species in Florida that relies solely on the sandy beach for nesting and foraging habitat (Kunneke and Palik 1984). It is listed as an threatened species by the Florida Game and Fresh Water Fish Commission. It requires isolated, expansive sandy beaches for nesting. Breeding occurs from April to June. Its eggs (usually three) are laid in a shallow depression, which the parents occasionally line with seashell fragments. The mammals, the Choctawhatchee beach mouse (*Peromyscus polionotus allophrys*) and Perdido Key beach mouse (*P. polionotus trissyllepsis*), were listed as endangered by the Federal government in 1985.

Panhandle beaches are nesting grounds for sea turtles. The Atlantic loggerhead (*Caretta caretta*), nests yearly (August through October) on the beaches from St. George Island to Okaloosa County.

e. Trophic dynamics and interactions. Most of the organisms such as mole crabs (*Emerita talpoida*) are suspension feeders. Some, such as the ghost crab, are also scavengers.

Birds prove an intricate part of beach food-chain dynamics. They represent the top trophic group in the beach system, feeding on crustaceans, polychaetes, mollusks, and fish.

Table 42. Common seabirds and shorebirds present along Panhandle beaches (Lowery and Newman 1954, Sprout 1954).

Common name	Scientific name
American oystercatcher	*Haematopus palliatus*
Black skimmer	*Rynchops nigra*
Common tern	*Sterna hirundo*
Double-crested cormorant	*Phalacrocorax auritus*
Eastern brown pelican	*Pelecanus occidentalis carolinensis*
Laughing gull	*Larus atricilla*
Least tern	*Sterna antillarum*
Royal tern	*Sterna maxima*
Sandwich tern	*Sterna sandvicensis*
Snowy plover	*Charadrius alexandrinus tenuirostris*
Wilson's plover	*Charadrius wilsonia*

f. Natural Impacts. Morton (1976) and Chiu (1977) reported the effects of Hurricane Eloise on Panama City beaches. The storm occurred in September, 1975, and caused extensive beach erosion, primarily by storm surge, wave setup, and beach scour (Figure 88). Wind and flood damage to the beach were minimal. Sediment was transported westward. The effects of Eloise on the benthic beach fauna was reported to be minimal and temporary (Saloman and Naughton 1977). Numbers of benthic individuals were approximately the same before and after the storm. Numbers of species increased just after the storm but rapidly returned to prestorm levels.

Beach erosion is affected by fluctuations in sea level, wave conditions, longshore currents, atmospheric conditions, and human activities. The current sea-level rise of 0.5–1.0 cm/yr corresponds to a rate of shoreline retreat of about 0.3–1 m/yr. Shoreline erosion is not a constant, gradual process but appears to take place most severely during periods of intense wave activity, storm tides, and storm surges such as occur during hurricanes and other tropical storms (Ho and Tracey 1975, Walton 1978).

Dredging navigational channels through inlets below their natural depths may enhance beach erosion by increasing the capability of the channel to flush sand out of a bay system. A channel can also act as a barrier to sand transported along the coast by longshore drift and deplete the supply to downcurrent beaches. In a similar manner, structures such as jetties at inlets can cut off the natural supply of sand and direct it offshore. Beach erosion is a problem in Bay County in areas such as Biltmore Beach and Mexico Beach, where erosion rates of 1 m/yr have been documented.

g. Human Impacts. Trash, noise, and sediment disruption are the major disruptions created by recreational beach users. The Panhandle has over 900,000 linear ft of recreational beach coastline.

The effect on the benthic fauna from sand deposition during beach restoration is reported in only a few instances (Thompson 1973, Hayden and Dolan 1974, Culter and Mahadevan 1982). Results of a study on a Panhandle beach (Panama City Beach) appear consistent with other reports (Saloman and Naughton 1984). The deposition of offshore sand

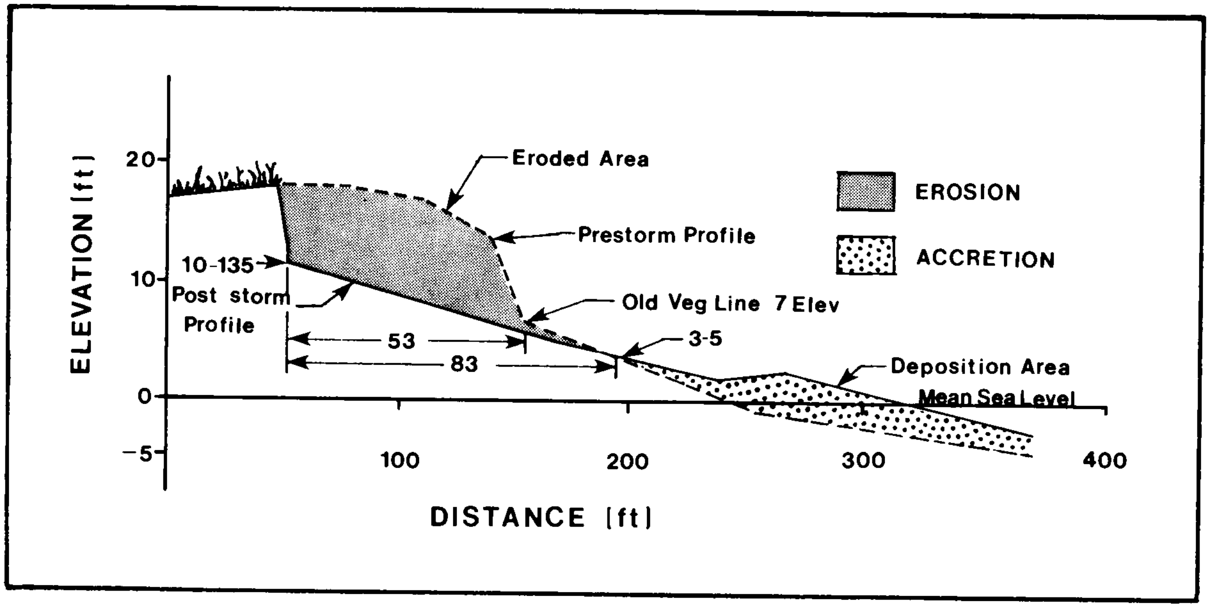


Figure 88. Change in Panama City beach profile after Hurricane Eloise in September 1975 (after Morton 1976).

onto the beach produces only short-term minor effects on the benthic fauna. For five to six weeks after deposition, species numbers and densities decrease in the swash zone. After this period, populations return to pretreatment levels and stabilize. Overall, the beach fauna appear relatively resilient to this type of disturbance. There have been no reports of the effects of beach renourishment on higher trophic organisms such as birds.

Renourishing beaches with offshore dredged sediments costs an estimated $1 million/mi of restored beach initially and requires about $25,000/mi/yr to maintain (Kunneke and Palik 1984).

Artificial structures such as seawalls, offshore breakwaters, groin fields, rock revetments, and jetties tend to aggravate beach erosion rather than slow or stop it.

7.3.3 Marine Open Water

a. Introduction. The nearshore and offshore marine open water habitat is physically stable compared to that of the estuaries. Salinity varies very little throughout the year and temperatures do not fluctuate as much or as quickly in the marine system.

Primary productivity in marine open waters of the Panhandle is lower than that of estuaries since the nutrient input is lower. Trophic dynamics are basically similar. There is overlap in the species present in the two systems. Many fish use the estuaries as nursery areas and migrate to deeper marine waters as adults, eventually to spawn. This habitat includes the prized sport and commercial fish such as grouper (*Mycteroperca* spp.), Spanish mackerel (*Scomberomorus maculatus*), king mackeral (*S. cavalla*), dolphin (*Coryphaena hippurus*), and billfish (Istiophoridae), and invertebrates such as the brown shrimp (*Penaeus aztecus*).

b. Species present. The reduction in primary productivity in marine open waters is accompanied by a higher phytoplankton species diversity (Steidinger 1973) and characterized by more holoplanktonic forms than spore-forming meroplanktonic forms. Many of the diatoms and dinoflagellates that occur in the estuaries are also present in the nearshore marine system (Table 43), but in smaller numbers. Dinoflagellate diversity may exceed diatom diversity in the marine system.

Table 43. Common plankton present in the marine open water habitat of the Panhandle (Steidinger 1973).

Group	Species
Phytoplankton	
Diatoms	*Chaetoceros compressum* *Guinardia flaccida* *Hemiaulus hauckii* *Plagiogramma vanheuckii* *Rhyzarolenia imbricata* *Rhyzarolenia robusta* *Thalassiothrix faruenfeldii*
Dinoflagellates	*Ceratium carriense* *Ceratium furca* *Ceratium fusus* *Ceratium massiliense* *Ceratium trichoceros* *Peridium* spp.
Blue-greens	*Oscillatoria erythraea*
Zooplankton	
Copepods	*Eucalanus monachus* *Nannocalanus minor* *Terma* spp. *Undinula vulgaris*
Chaetognaths	*Sagitta elegans*
Decapod Larvae	
Mysids	*Bowmaniella dissimilis* *Mysidopsis almyra* *Taphromysis bowmanni*

Phytoplankton demonstrate vertical stratification because of photosynthesis requirements (Steidinger 1973). Grazing zooplankton generally peak in abundance in areas of concentrated phytoplankton patches. The plankton are also seasonal in abundance (Figure 89).

c. Recreationally and commercially important species. To the west of Cape San Blas the Continental Shelf is relatively narrow, and numerous pelagic species are found relatively close to shore. Important commercial and recreational species in

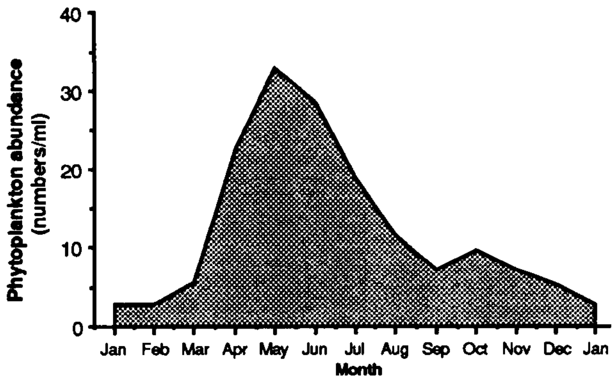


Figure 89. Seasonal phytoplankton abundances in the northeast Gulf of Mexico (after Steidinger 1973).

this region include brown shrimp, white shrimp (*Penaeus setiferus*), and pink shrimp (*P. duorarum*), Atlantic bonito (*Sarda sarda*), greater amberjack (*Serioila dumerili*), crevalle jack (*Caranx hippos*), blue runner (*C. crysos*), sharks, spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), sand seatrout (*Cynoscion arenarius*), gulf menhaden (*Brevoortia patronus*), bluefish (*Pomatomus saltatrix*), Spanish and king mackerel, Atlantic thread herring (*Opisthonema oglinum*), Spanish sardine (*Sardinella anchovia*), and the billfishes—blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus platypterus*) (Pristas 1981) (Table 44). Five marine turtles with special status are also found in this region (Table 45).

Inshore trolling grounds off Panama City are important summer sportfishing areas for Spanish and king mackerel, Atlantic bonito, and dolphin. The area off the entrance to Pensacola Bay is a popular summer sportfishing area for Spanish and king mackerel, bluefish, and cobia (*Rachycentron canadum*)(Trent and Anthony 1978).

In the Panhandle, a number of charter sportfishing boats, numerous private boats, and party boats (also called head boats) fish the nearshore marine waters during the warmer months (Fable et al. 1981, Kunneke and Palik 1984) (Table 46). Trolling techniques are usually used with king mackerel, Spanish mackerel, bluefish, blue runner, little tunny (*Euthynnus alletteratus*), Atlantic bonito, and dolphin. These seven species make up a majority of charter boat catches. Yearly species composition during the 1970's were king mackerel (61%), Atlantic bonito (15%), bluefish (5%), blue runner (5%), little tunny (5%), Spanish mackerel (4%), and dolphin (4%). Trolling effort in the Panhandle is greatest offshore of Panama City and Destin. Historically, the sport fishery has been mostly dependent on king mackerel catches (Brusher et al. 1976, Fisher 1978).

Dramatic changes in the landings, species composition, and sizes of fishes in the summer of 1977 and 1978 in the charter boat pelagic fishery off Panama City have been correlated to large changes in air temperatures during the preceding winters (Fable et al. 1981). During 1970–76 and 1979, king mackerel generally dominated the catch, ranging from 57.2% (1979) to 92.9% (1970) (Figure 90).

Table 44. Common fish species present in marine open waters of the Panhandle.

Species name	Common name	Species name	Common name
Caranx crysos	Blue runner	*Pomatomus saltatrix*	Bluefish
Coryphaena hippurus	Dolphin	*Rachycentron canadum*	Cobia
Epinephelus morio	Red grouper	*Rhomboplites aurorubens*	Vermilion snapper
Euthynnus alletteratus	Little tunny	*Sarda sarda*	Atlantic bonito
Istiophorus platypterus	Sailfish	*Scomberomorus cavalla*	King mackerel
Lutjanus campechanus	Red snapper	*Scomberomorus maculatus*	Spanish mackerel
Makaira nigricans	Blue marlin	*Sphyraena barracuda*	Great barracuda
Mycteroperca microlepis	Gag	*Tetrapturus albidus*	White marlin
Pagrus pagrus	Red porgy	*Thunnus thynnus*	Bluefin tuna

Table 45. Marine turtles with special status that occur in Panhandle marine waters.

Common name	Species name	Status
Atlantic green turtle	*Chelonia mydas mydas*	Endangered
Atlantic hawksbill	*Eretmochelys imbricata imbricata*	Endangered
Atlantic leatherback	*Dermochelys coriacea*	Endangered
Atlantic loggerhead	*Caretta caretta caretta*	Threatened
Atlantic ridley	*Lepidochelys kempi*	Endangered

Table 46. Charter and party boat principal ports of call (Schmied 1982, Waterway Guide, Inc. 1982).

County	Ports of call	Number of charter boats	Number of party boats
Escambia	Pensacola	5	0
Santa Rosa	Gulf Breeze	5	0
Okaloosa	Destin Harbor	51	4
	Ft. Walton Beach Harbor	4	0
	Shalimar Harbor	3	0
	Santa Rosa Beach	2	0
Walton	—	0	0
Bay	Panama City	73	7
	Mexico Beach	6	0
Gulf	—	0	0
Franklin	—	2	0
Total		**151**	**11**

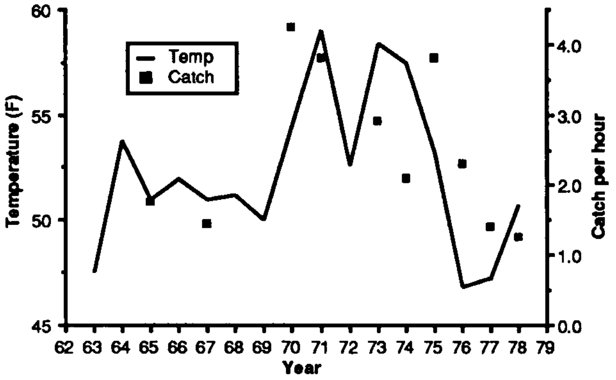


Figure 90. Correlation of pelagic fisheries to changes in air temperatures off Panama City (Fable et al. 1981).

Atlantic bonito ranged from zero to 7.1% during the same time periods. In the summers of 1977 and 1978, king mackerel made up only 38.7% and 18.9%, respectively, of the total catch, while Atlantic bonito comprised 29.5% and 47% of the totals. These changes corresponded to unusually low temperatures during the 1976–77 and 1977–78 winters. Successful king mackerel migration into Panhandle waters, therefore, appears dependent upon water temperatures that are not far below normal.

In general, king mackerel are available to the fishery in the Panama City area in April, are abundant during June to November, and are most abundant, or catchable, in September. The king mackerel in this region winter off the southeast coast of Florida (Sutherland and Fable 1980). Of the remaining six species, Atlantic bonito, blue runner, little tunny, and dolphin have been most abundant in the catches during June or July, while bluefish have been most abundant in May and November, and Spanish mackerel in March (Fable et al. 1981, Goodwin and Finucane 1985).

The size of king mackerel caught off Panama City varies seasonally. Generally, mean lengths are greatest at the beginning of each fishing season, decline to a seasonal low in August, and then increase in September or October.

The billfish sport fishery began in the mid-1950's off the Panhandle. Sportboats originate primarily from Pensacola, Destin, and Panama City. In Destin, sailfish were caught as early as 1955, but the first white marlin was landed in 1959 and the first blue marlin in 1962 (Nakamura and Rivas 1974). An early history of the development of the billfish sport fishery in the Panhandle region is included in Siebenaler's (1965) work.

A major billfish area is located off Pensacola near the Desoto Canyon. Typically, white marlin are more abundant in July and sailfish are more abundant during the latter half of September, while blue marlin do not have an especially abundant period. Usually, the bluer the water, the greater the relative abundance of billfish. Off the Panhandle, blue marlin prefer mullet as bait, sailfish prefer bonito, and white marlin show no preference (Nakamura and Rivas 1974).

The habitat and dietary preferences of the major sport and commercial fishes are summarized below.

(1) King mackerel. The diet of king mackerel includes fish from 31 families (Saloman and Naughton 1983). Clupeidae are the dominant prey. Other families of importance include Carangidae, Sciaenidae, Engraulidae, Trichiuridae, Exocetidae, and Scombridae. The round scad, *Decapterus punctatus*, is the most important prey species in the diet of king mackerel caught in the Panhandle. Squid are the dominant invertebrate prey. King mackerel are primarily piscivorous, feeding heavily on schooling fishes. They are also opportunistic feeders, as evidenced by the nonschooling or nonaggregating species, such as synodontids and triglids, found during gut sampling. Since it usually bites or chops the prey in half, a whole fish is rarely found in a king mackerel stomach.

(2) Dolphin. Dolphin appear in Panhandle waters from April to December with May and August being the peak months. Their maximum lifespan is approximately 4 years. Dolphins tend to form close-knit schools. They are prey to a wide variety of ocean predators and are cannibalistic. When hooked, a dolphin rarely tries to escape by diving downward. Vertical distribution is generally limited from the surface to approximately 30 m.

(3) Brown shrimp. Brown shrimp are reported to spawn primarily in open gulf waters deeper than 18 m and possibly up to 140 m. The spawning season extends from September to May. Two reproductive peaks may occur in nearshore Panhandle marine waters: September–November and April–May. Fishing begins in May, peaks in June and July during their seaward migration, and continues through November in offshore waters.

All feeding stages are omnivorous. Larvae feed in the water column on both phytoplankton and zooplankton. Postlarvae live and feed in the estuaries. Shrimp larger than 65 mm that live in deep water are more predaceous than small individuals, with occasional detritus and algae being ingested. Prey items include polychaetes, amphipods, nematodes, and ostracods. The shrimp itself is prey to a host of fish species, many of which are commercially important.

d. Species of special concern. Five species of marine turtles (Table 45) and three species of whales—finback whale (*Balaenoptera physalus*), sperm whale (*Physeter catodon*), and humpback whale (*Megaptera novaeangliae*)—that occasionally occur in Panhandle waters are threatened or endangered.

e. Natural impacts. Some phytoplankton species can cause large fish kills and are toxic to shellfish. These species cause what are termed red tides because of the discoloration of the waters. Marine coastal red tides in the Panhandle are primarily associated with population blooms of the dinoflagellate *Ptychodiscus brevis* (formerly *Gymnodinium breve*) or *Gonyaulax monilata*. Usually concentrated within 48 km of the coastline, these species produce a neurotoxin that, in sufficient concentration, is capable of paralyzing and killing a number of fish species. The effects on larval invertebrates is not well known. Most major red tides last 2–4 months. In addition to having an effect on nearshore fisheries, red tides can also affect tourism along a coast because of the odor of decaying fish.

f. Human Impacts. Oil drilling activities (i.e., boat traffic, mud cuttings, spills, etc.) can have a variety of effects on water column species. Many larger pelagic species such as fish can avoid oil spills, but small planktonic species are vulnerable to direct effects.

Offshore oil spills pose a potential impact for sea turtles, especially juvenile turtles. Floating oil could increase the mortality rate of turtles directly by contacting the turtles when they surface to breathe and indirectly by affecting food sources.

Dolphins have been observed swimming and feeding in oil slicks and oil apparently does not adhere to their smooth skin (Geraci and St. Aubin 1982). It appears unlikely that dolphins inhale oil into their blowholes while breathing. Some hydrocarbon-contaminated food or water could be ingested; however, the effects of hydrocarbon ingestion by marine mammals is unknown.

7.3.4 Artificial Reefs

a. Introduction. Artificial reefs are objects of human or natural composition that are placed on selected sites in the aquatic environment to attract and stimulate the growth of larger fish and invertebrate populations. The primary purpose is the promotion of sport (and in some cases commercial) fishing by attracting food and game fish to a location easily accessible to fishermen and sport divers (i.e., spear fishermen). Artificial reefs benefit anglers and the economy of the nearby shore community, in the latter case by attracting out-of-city fishermen into the community.

The purpose of the artificial reef is to duplicate conditions of naturally occurring reefs or hard bottom areas. Numbers of fish species and abundances on an artificial reef can mimic those on a natural reef within 8 months of placement (Stone et al. 1979). In addition, they can effectively improve an already existing rough-bottom habitat and provide a functional management tool for reef fish resources. They also are potential nursery grounds for various species because they provide shelter from predators.

The reef provides the inhabitants with a refuge from predation and, in some instances, strong currents. In addition, the fouling organisms that encrust the reef become food items for small foraging fish that, in turn, attract larger predatory fish. If large enough, artificial reefs may increase the primary productivity of an area by creating an upwelling effect that causes nutrient-rich bottom water to mix with upper water layers.

Artificial reefs may be of two types: high profile or low profile. High-profile reefs are usually the most productive because they attract bottom species such as grouper, sea bass, and snapper and also pelagic forms such as Spanish mackerel, cobia, and amberjack. The high profile reefs, however, require greater depths to prevent them from becoming navigation hazards. Low-profile reefs are more useful in shallower inshore areas and are effective in attracting demersal fish.

Florida has initiated more reef construction than all the other Southeastern States combined (Seaman 1982). The Panhandle region is one of the primary artificial reef areas in the State (Seaman and Aska 1985). Artificial reef construction in the area reflects a number of influences; (1) the vast amount of coastline, (2) an increase in population growth along the coast, (3) a leisure-oriented population along the coast with a number of party and charter boats (Table 46), motor-powered boats, and marinas and boatyards. Besides the large number of verified artificial reefs in the Panhandle, there are a number of unauthorized "private" reefs in use.

The artificial-reef program in Florida is administered by the Florida Department of Natural Resources, Division of Marine Resources (Section 370.013 of the Florida Statutes). Panama City has an artificial-reef program directed by the Panama City Marine Institute that began in July 1978.

Establishment of the first documented artificial reef in Florida was in the Panhandle region off Pensacola in 1920 (Seaman and Aska 1985). During the next 50 years there was only sporadic construction. However, in the early 1970's activity greatly accelerated.

Artificial reefs are constructed from very diverse materials. Nearly all Panhandle reefs are comprised of ships (e.g., barges), automobiles, tires, or concrete rubble. Most reefs can be classified on the basis of a single predominant material. In some cases, it is difficult to assign a reef to one category on the basis of composition because some established reefs are being expanded with new and different materials. There is a trend toward longer-lasting, denser materials such as tires and automobiles as well as toward improved methods of placement.

b. Distribution. There are at least 61 verified reefs within the Panhandle region (Kunneke and Palik 1984, Seaman and Aska 1985)(Figure 91). The average distance offshore is approximately 12 km. Average depth is approximately 20 m.

Panhandle artificial reefs have been placed principally in oceanic locations with a few exceptions, such as one in Choctawhatchee Bay near Fort Walton Beach. Depth and distance from shore is variable. Because the Continental Shelf is relatively shallow at great distances from shore, it is not unusual that a reef be placed 24–32 km offshore to approach a 10–20 m depth.

Like planned artificial reefs, shipwrecks attract fish by providing structure on an otherwise flat sea floor. The National Ocean Survey maintains updated information on all known shipwrecks in U.S. coastal waters. Table 47 gives a list of major shipwreck sites in the Panhandle region.

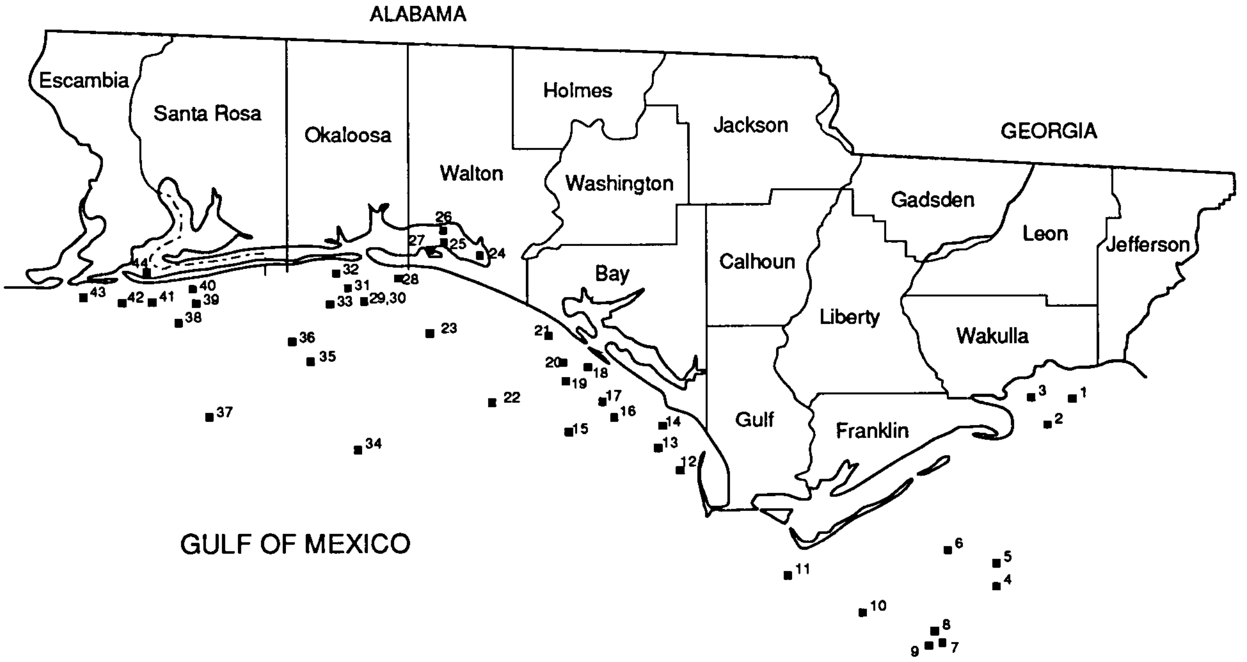
c. Associated fauna. Fish are the most intensively studied group associated with Panhandle artificial reefs (Table 48). Other groups such as the encrusting and free-living invertebrate communities (e.g., sponges, gorgonians, and bryozoans) are not well documented.

Fish communities on artificial reefs are very diverse. Sanders (1983) reported 72 species associated with eight artificial reef sites off Panama City. The fish community can be divided into three classes (Chandler 1983): resident species, semi-resident species, and transient species. Resident species generally make up the largest of the three groups and are dependent upon the reef for food and shelter. The semi-resident group includes fish that are not dependent upon reefs for food and shelter and do not maintain permanent residency on the reef. This group is typically represented by schooling pelagic species (e.g., jacks) or suprabenthic species (e.g., vermilion snapper *Rhomboplites aurorubens*). Semiresident fish generally do not use the reef for protective cover but as a visual reference point or food source. Transient species form a catchall category that includes species found infrequently on the reef and whose dependence on the reef is unknown.

The complexity of a reef surface is an important factor for determining the abundance and diversity of the resident fish community. Chandler (1983) concluded from two artificial reefs (barges) off Panama City that the more complex structure had a larger and more diverse fish assemblage. The primary factors appeared to be the greater availability of space and food resources (i.e., epifaunal invertebrates and biofouling communities) on the more complex structure. Contributing to increased abundance and diversity is the vertical relief of an artificial reef. Greater vertical relief offers additional space, and also represents a stronger visual marker or cue for nonresident or transient species.

Water temperature appears to be the single most important factor that controls species composition in Panhandle artificial reef fish communities (Sanders 1983). Increasing temperatures in the spring and summer usually mark the appearance of typically tropical species such as the white grunt *Haemulon aurolineatum*, cocoa damselfish *Pomacentrus variablis*, and painted wrasse *Halichoeres caudalis*.

Chandler (1983) reported that seasonal changes in the structure of resident fish communities in Panhandle artificial reefs were affected primarily by recruitment of new members during the summer and by higher predation and mortality rates in the winter.



County	#	Year Built	Latitude	Longitude	Depth (ft)
Wakulla	1	1964	30°00'00"	84°09'15"	20
	2	1964	29°55'42"	8413'06"	21–30
	3	1964	3000'06"	8417'06"	15
Franklin	4	–	2924'54"	8421'54"	–
	5	1981	2930'48"	8422'06"	60
	6	1981	2932'12"	8437'06"	70
	7	1982	2931'05"	8439'25"	70
	8	1979	2917'55"	8436'48"	105
	9	1980	2917'06"	8436'48"	105
	10	1973	2924'24"	8451'48"	85
	11	–	2931'12"	8507'36"	45
Gulf	1	1964	29°50'24"	85°29'18"	40
	2	1971	29°53'15"	85°32'00"	44–70
Bay	3	1979	29°54'06"	85°31'55"	54
	4	1979	29°58'07"	85°48'49"	100
	5	1974	29°59'03"	85°42'20"	74
	6	1979	30°02'23"	85°43'18"	71
	7	1978	30°02'49"	86°05'32"	105
	8	1978	30°04'16"	85°48'53"	77
	9	1978	30°05'01"	85°44'02"	65
	10	1980	30°07'05"	85°49'29"	75
	11	1979	30°09'32"	85°53'33"	72
Walton	12	1972	30°24'38"	86°08'48"	9
	13	1972	30°25'56"	86°14'18"	13
	14	1972	30°27'58"	86°14'34"	13
	15	1972	30°24'36"	86°17'35"	7
Okaloosa	16	-	30°09'08"	86°19'07"	102
	17	1977	30°22'00"	86°25'00"	43–71
	18	1976	30°21'00"	86°29'05"	85
	19	1977	30°21'04"	86°29'06"	85
	20	-	29°55'01"	86°34'09"	-
	21	1976	30°22'03"	86°35'04"	65
	22	1977	30°21'04"	86°35'07"	68
	23	1977	30°18'09"	86°36'02"	85
	24	1979	30°09'04"	86°43'06"	118
Santa Rosa	25	1980	30°12'46"	86°48'20"	70–80
Escambia	26	1982	30°00'00"	87°04'00"	175
	27	1978	30°17'02"	87°07'06"	85
	28	1973	30°18'08"	87°07'30"	60
	29	1976	30°16'03"	87°09'07"	67
	30	-	30°19'56"	87°13'12"	20
	31	1974	30°17'25"	87°13'13"	45
	32	1920	30°17'42"	87°18'42"	exposed
	33	-	30°16'54"	87°25'36"	20

Figure 91. Artificial reef locations in Panhandle waters (after Aska and Pybas 1983).

Table 47. Shipwrecks in Florida Panhandle waters (Beccasio et al. 1982).

Ship name	Latitude	Longitude	Depth (ft)
Unknown	30° 15' 00"	87° 34' 00"	-
Unknown	30° 14' 45"	87° 33' 00"	-
Eastern Light	30° 18' 54"	87° 19' 30"	-
Anna Pepina	30° 19' 06"	87° 18'48"	-
Bride of Lorne	30° 17' 30"	87° 18' 42"	-
Unknown	30° 25' 30"	86° 19' 20"	7
Unknown	30° 13' 45"	85° 49' 40"	27
Unknown	30° 17' 35"	85° 51' 20"	55
Unknown	30° 09' 30"	85° 47' 50"	49
Unknown	30° 05' 25"	85° 46' 00"	62
Unknown	30° 06' 30"	85° 41' 00"	24
Unknown	30° 03' 00"	85° 37' 30"	25
Vamar	29° 54' 00"	85° 27' 54"	-

Table 48. Some resident reef fish from eight artificial reefs off Panama City, Florida (Chandler 1983, Sanders 1983).

Common name	Scientific name
Bandtail puffer	*Sphoeroides splengleri*
Black sea bass	*Centropristis striata*
Blennies	Family Blenniidae
Cocoa damselfish	*Pomacentrus variabilis*
Gag	*Mycteroperca microlepis*
Jackknife-fish	*Equetus lanceolatus*
Orange filefish	*Aluterus schoepfi*
Reef butterflyfish	*Chaetodon sedentarius*
Scamp	*Mycteroperca phenax*
Scrawled cowfish	*Lactophyrys quadricornis*
Sheepshead	*Archosargus probatocephalus*
Spotfin butterflyfish	*Chaetodon ocellatus*
Twospot cardinalfish	*Apogon pseudomaculatus*
White grunt	*Haemulon plumieri*
Yellowtail reeffish	*Chromis enchrysurus*

Semiresident species emigrate from a reef as water temperatures drop.

d. Trophic dynamics and interactions. Trophic dynamics on artificial reefs in the Panhandle are not well documented. Most likely they are not much different from those of natural tropical reefs. The biofouling or encrusting community probably represents an important food resource to many reef residents. In turn, top carnivores such as the barracuda (*Sphyraena barracuda*) and jacks feed on the smaller schooling species.

7.3.5 Subtidal Rocky Outcroppings/ Natural Reefs

a. Introduction. Subtidal rocky outcroppings are areas of hard, rugged bottom relief, usually comprised of limestone (Jordan 1952, Salsman and Ciesluk 1978). These areas have been called "live bottoms" by the State of Florida in its designation of regions that are sensitive to oil drilling activities. They are scattered throughout the area in depths of 18–70 m of water; some lie as close as 1.5 km from shore. Most of them protrude less than a meter above the surrounding sediment. Occasional small, isolated outcrops are also known nearshore in the St. George Sound area (e.g., Dog Island Reef).

This habitat represents a contrasting environment to an otherwise soft-sediment dominated system. The hard substrate offers an attachment surface for a variety of organisms such as sponges and algae.

b. Associated flora and fauna. Offshore rocky outcroppings are usually areas of fish concentrations (Saloman and Fable 1981, John E. Chance and Associates, Inc. 1984) (Figure 92). An area known as the Timberholes is an important recreational and commercial red snapper (*Lutjanus campechanus*) ground. Vermilion snapper, red grouper (*Epinephelus moria*), gag (*Mycteroperca microlepis*), and red porgy (*Pagrus sedecim*) are also taken. This ground is the inshore edge of Desoto Canyon, a submarine canyon in open gulf waters. Desoto Canyon is one of the major billfish sportfishing areas in the eastern Gulf of Mexico. Some of the major species caught include blue marlin, white marlin, and sailfish. A diverse sponge fauna is usually present (Little 1958). Red algae are usually attached to the hard substrate. Common species include *Euchema acanthocladum*, *Botrylcladia uvaria*, and *Callithamnion byssoides*.

The relief is sometimes augmented by recent coral growth. Coral growth has been reported on a rocky outcrop 3 to 12 km offshore between Panama City and the Choctawhatchee Bay entrance. Nonhermatypic corals such as *Madracis asperula*, *Cladocora* sp., and *Paracyathus* sp. are common. Red algae are usually attached to the hard substrate. Nonhermatypic corals such as *Madracis asperula*, *Cladocora* sp., and *Paracyathus* sp. are common.

7.3.6 Subtidal Soft Bottoms

a. Introduction. As with the estuarine system, the marine soft bottom habitat constitutes the largest environment (on an area basis) within its system. There have been numerous surveys of the fauna in this habitat (e.g., Salsman and Tolbert 1965 and Loftin and Touvila 1981), but very little experimental work because of access problems. Most samples are taken from ships with remote devices such as box cores, dredges, trawls, and epibenthic sleds. As a result, most reports are descriptive and little is known about the mechanisms and interactions that are important in any given location.

The habitat ranges from the mean low water mark offshore and includes practically all the area offshore except rocky outcroppings. However, for this report, only the region to the Continental Shelf break is covered, with the inshore areas stressed.

b. Physical description. The nearshore zone is comprised of fine quartz sand (0.1–0.2 mm median diameter) that extends out across the shallow barrier bar and to a depth of 15 to 18 m, where the fine sediment becomes interspersed with a coarser brown sand containing shell fragments (Salsman and Ciesluk 1978). The coarser sediment has a median diameter of 0.3 to 0.5 mm. Wave-produced sand ripples with heights up to 2.5 cm and wavelengths of 7.5 to 12.5 cm are present much of the time in the shallow areas directly off the beaches (Salsman and Tolbert 1961). Sand dollars are capable of flattening these ripples less than 24 hours after their formation (Salsman and Tolbert 1965). Large storm waves can produce ripples in the coarser sand found in deeper waters. Sand ripples with heights up to 15 cm and wavelengths of 1 to 1.2 m that persist for up to 2 months may be produced (Salsman and Ciesluk 1978).

c. Fauna present. A number of investigations have reported species collected from offshore soft sediments (e.g., Salsman and Tolbert 1965, Saloman 1976, Saloman 1979, Loftin and Touvila 1981, Saloman 1981, Uebelacker and Johnson 1984). As in the estuarine system, the marine soft-bottom organisms can be classified into a variety of functional groups based upon life-position, motility, and feeding mode. These classifications often make data easier to interpret when taxonomic problems or other constraints arise.

The offshore Panhandle marine meiofauna are not well documented. However, there is probably some overlap between the nearshore marine assemblages and estuarine ones. The meiofauna, especially the polychaetes, have been examined (Uebelacker and Johnson 1984). Common species are given in Table 49 along with other common organisms.

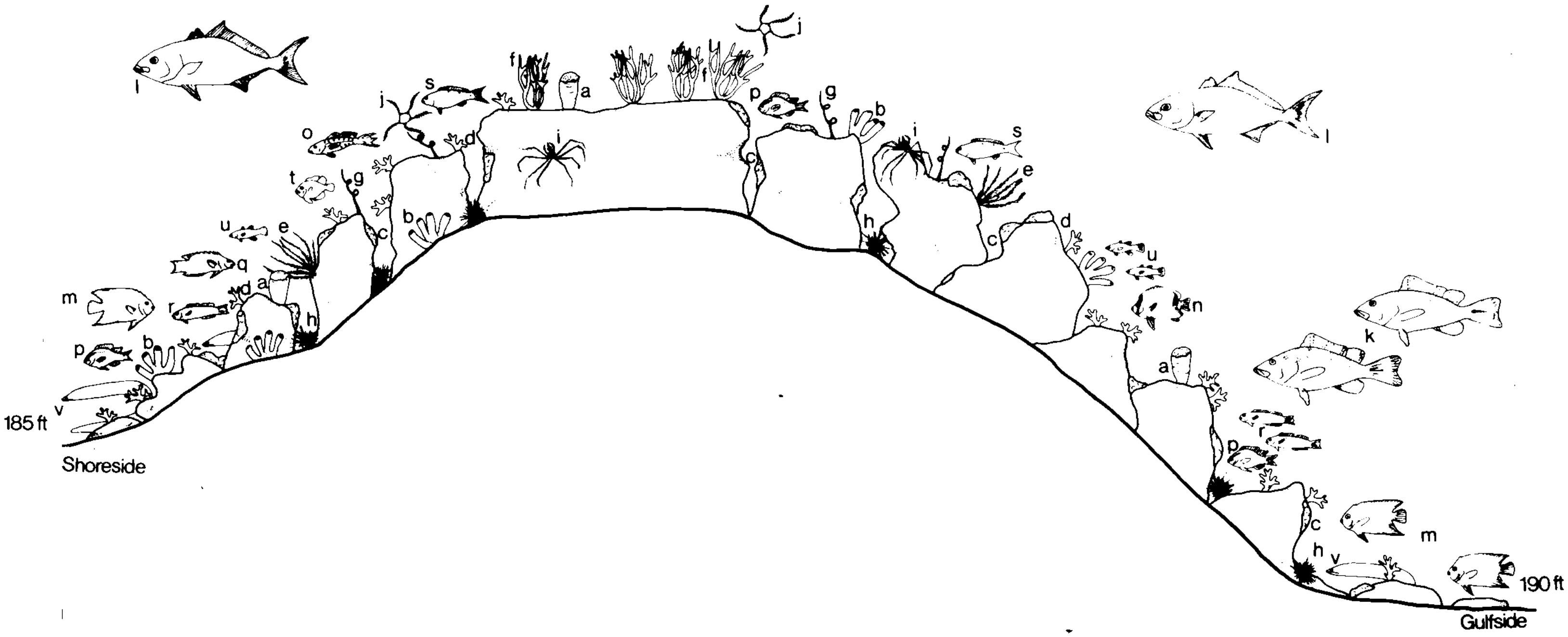


Figure 92. Cross-sectional view through a typical rocky outcropping off the Panhandle coast (John E. Chance and Associates, Inc. 1984).

Table 49. Common invertebrates present in nearshore soft-bottom habitats in the Panhandle (Saloman 1976, Saloman 1979, Loftin and Touvila 1981, Uebelacker and Johnson 1984).

Group	Species name	Group	Species name
Polychaetes	*Aricidea* spp.	Amphipods	
	Armandia agilis		
	Dispio unicinata	Cumaceans	*Spilocuma salomani*
	Microphthalmus spp.	Decapods	
	Nephtys bocera	(caridean shrimp)	*Ambidexter symmetricus*
	Nephtys picta		*Ogyrides alphaerostris*
	Onuphis eremita		*Processa hemphilli*
	Paraonis fulgens		*Processa vicina*
	Prionospio spp.		*Tozeuma cornutum*
	Scolelepsis squamata		
	Spiophanes bombyx	Echinoids	*Encope mitchelli*
	Syllidae		

d. Trophic dynamics and interactions. The trophic dynamics of marine soft-bottom communities in the Panhandle are not well studied, primarily for logistic reasons. The general patterns are probably similar to those of estuarine soft bottoms.

e. Natural impacts. The deeper offshore soft-bottom habitat is relatively free from natural impacts. Only the shallower nearshore areas are subject to occasional storm disruptions. Panhandle-specific research in this area is nonexistent.

f. Human impacts. Localized impacts can occur from oil-drilling rigs placed on the bottom and from dredging, especially dredging for sand for beach renourishment projects (Saloman and Naughton 1984).

Chapter 8. SUMMARY

8.1 The Panhandle In Review

The Florida Panhandle has a varied subtropical climate with hot, humid summers and brief periods of below freezing temperatures in winter. Rainfall is abundant, averaging approximately 152 cm per year. This rain falls primarily during two rainy seasons, late winter and early spring (February through April) and summer (mid-June through mid-September). Winter rains are primarily a product of passing cold fronts; summer rains are primarily in the form of convective thunderstorms. Winds are normally out of the south to southeast during the summer and constantly change in the winter, being most commonly out of the north to northwest or the south to southeast. Tropical storms and hurricanes occasionally cause substantial damage from high winds and storm surge.

Seven major rivers, the Ochlockonee, Apalachicola, Chipola, Choctawhatchee, Yellow, Blackwater, and Escambia, traverse the Panhandle on their way to the coast. The rivers of the western Panhandle tend to be highly colored, of low turbidity, and nutrient poor. Those of the eastern Panhandle are generally alluvial (sediment carrying) and nutrient rich. All originate out-of-State in either Georgia or Alabama. Changing land use and effluent discharges in these states, which practice less stringent water-quality regulation than does Florida, are hindering Florida's attempts to maintain or improve the quality of water in Panhandle rivers. In particular, out-of-State pollutants are affecting the Ochlockonee, Apalachicola, and Escambia Rivers.

The flood plains of Panhandle rivers are largely undeveloped at this time. Periodic flooding has been shown to be an important step in recycling nutrients in riverine ecosystems and to be responsible for much of the productivity of coastal estuaries. Damming rivers for flood control or other purposes prevents the transport of much of these nutrients to the estuaries, the nutrients are trapped in lakes behind the dams where they speed up the eutrophication of the lakes. Experience in other parts of Florida and elsewhere in the United States shows that restricting development in flood plains is the best and most cost effective means of flood prevention. This prevents not only flooding of the developments in the flood plain, but also flooding in areas outside the flood plain which become more flood prone as a result of the altered hydrology associated with development.

Most of the ground water used in the Panhandle is contained within two aquifers: the Floridan Aquifer east of Okaloosa County and the Sand and Gravel Aquifer from Okaloosa County west. The Floridan Aquifer is contained in a porous limestone matrix and is characterized by alkaline water with a moderately high level of dissolved solids. Beginning near Okaloosa County the Floridan Aquifer is increasingly deeper as one proceeds west and it becomes increasingly mineralized. The Sand and Gravel Aquifer is found above the Floridan in this western region and is more commonly used because of its better water quality.

The terrestrial vegetation of the Panhandle was mostly open pine woods on rolling hills and flat lands before human alterations began. In the valley bottoms of the hill lands and along creeks in flatwoods a series of hardwood forest types were found. Regularly occurring natural fires that burned through the pinelands were extinguished downslope where soil moisture increased, keeping the fire-tender hardwood species from seeding under the pines and taking over the uplands. Today, most of the dry land and even all the wetlands have been logged, often more than once. The natural fire cycles have been stopped or severely altered, and the woodlands of most of the Panhandle are second-growth mixtures of pines and encroaching hardwoods, where timber has been cut and allowed to regenerate naturally, or has been converted to pine monoculture, agriculture, and urban and suburban development.

The Florida Panhandle is a crossroads where animals and plants from the Gulf Coastal Plain reach their eastward distributional limits, where others from the Atlantic Coastal Plain reach their southwestern limits, and where northern species, including many Appalachian forms, reach their southern limits. There is also a contribution of species from peninsular Florida. So many species of plants and animals flourish in the wet, temperate climate of the Panhandle that the region may support the highest species diversity of any similar-size area in the U.S. and Canada.

Because the Panhandle has high annual rainfall and low, gently sloping terrain, wetlands abound. The bogs, marshes, swamps, wet prairies, and wet flatwoods provide a diversity of wetland types that support numerous species of animals and plants, including many endemic species and races. Wetlands seem to vary considerably depending upon slope, soil type, water chemistry, and fire cycle and there is a need for a more thorough investigation and classification to understand the significance of the differences.

The seven Panhandle estuaries are, with the exception of Ochlockonee Bay, bar built (i.e., separated from the Gulf of Mexico by a sand bar or barrier island). They are nearly evenly distributed along the coast and are formed at the mouths of rivers, except for the two lagoonal estuaries, St. Joseph Bay and Alligator Harbor. The western Panhandle has a higher energy regime along its coast than the eastern portion as is evidenced by the associated sandy beaches. This situation arises because of the closer proximity of the edge of the Continental Shelf and the longer fetch, allowing the prevailing winds to generate greater wave energy.

Seagrass beds cover a greater area in the eastern Panhandle than in the western. This results from the more suitable conditions for seagrass promulgation provided by the lower energy conditions along the coast in the east. Within the estuaries, this difference is correlated with the greater industrial development in the western Panhandle. Extensive losses in seagrass habitats in the western Panhandle estuaries have been documented and tied to human development (i.e., industrial discharges and dredging). Panhandle salt marshes are prevalent and more evenly distributed than the seagrasses, though they are not nearly as extensive as those formed in the lower energy conditions along the adjacent Florida Big Bend coast.

Oyster reefs are found in all the Panhandle estuaries, but those in the western estuaries tend to be unusable by humans because oysters concentrate the contaminants introduced to the waters by surrounding development. Apalachicola Bay contains the largest concentration of commercially important oyster reefs. These relatively unaffected (by pollution) beds are presently experiencing potential contamination from septic tanks on nearby St. George Island. Oyster reefs in the Choctawhatchee and Pensacola Bay systems have experienced the most impact from industrial development in the nearby coastal regions and the majority of reefs are not harvestable.

The Florida Panhandle is lightly populated except for an intensively developed and increasingly industrialized region along the coast from Pensacola eastward to Panama City. This area has continued to develop rapidly from the densities indicated by the 1980 census (Figure 93). The only other population pressure in the area is from the State Capitol, Tallahassee, alongside the Panhandle's eastern border. The primary land use outside these two areas is forestry and farming. The Apalachicola National Forest, Blackwater River State Forest, Apalachicola Estuarine Sanctuary, St. Vincent Island and St. Marks National Wildlife Refuges, Gulf Islands National Seashore, and the St. Joseph Peninsula (T.H. Stone Memorial) and St. George Island State Parks as well as numerous smaller State forests and parks are located within the Panhandle.

8.2 Panhandle Findings

The estuaries and nearshore marine habitats of the Florida Panhandle are some of the greatest natural and economic assets of the region. There is

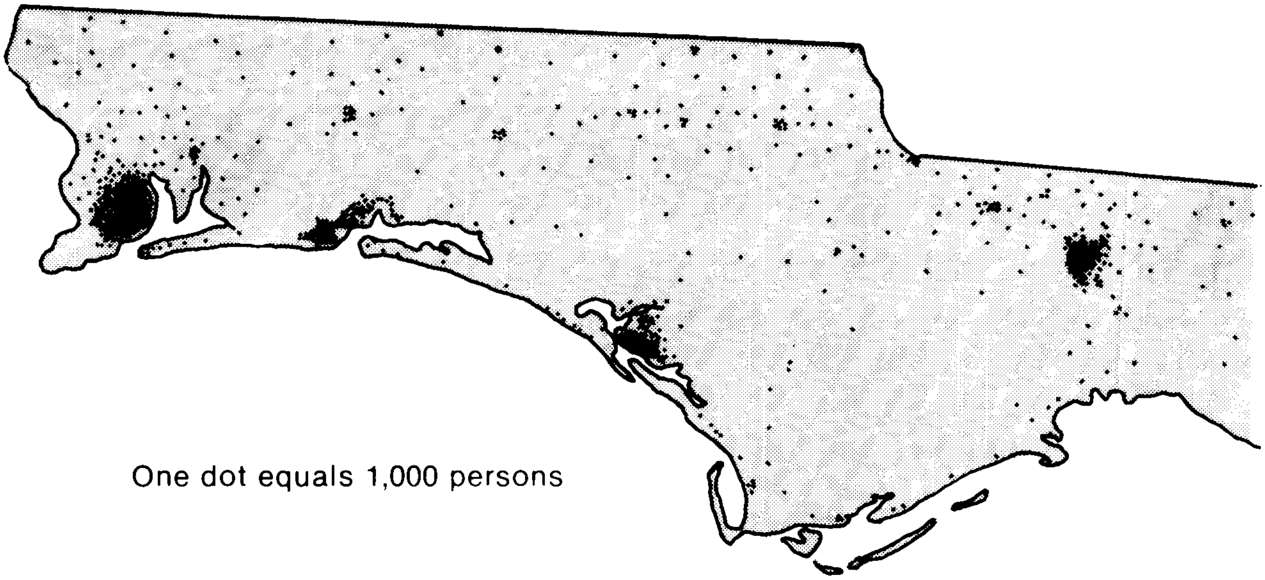


Figure 93. 1980 Florida Panhandle population distribution (Winsberg and Primelles 1981).

little dispute that the majority of the present population growth experienced within the region is concentrated along the coastal zone. People are especially attracted to the clear, blue gulf waters and the white, sandy beaches of the western Panhandle. In addition, many of the estuaries harbor important commercial organisms, such as oysters, fish, and shrimp, that provide a livelihood to Panhandle residents.

Only recently has the importance of viewing a region as a complete entity been realized. It is critical to understand that a far-reaching domino effect exists in the area environment. Terrestrial alterations affect terrestrial habitats and the quality of the surface water and ground water. These changes affect the freshwater and troglobitic (cave) habitats and, in turn, the estuarine and marine water quality and habitats are affected. Because of this chain of interactions, an estuary tends to be the repository for all pollution that occurs in its drainage basin. Estuaries have remarkable assimilative and recuperative abilities. However, their capacity to absorb human perturbation may be approaching a threshold.

There is good evidence that Panhandle Florida may well have more species of animals and plants than any equivalent area of temperate North America. Unfortunately, the region has been poorly studied. New species of plants, invertebrates, and even vertebrates have been described in the past 5 years, and more are known and under investigation. The Florida Panhandle is so biologically diverse that there are at least 4 major centers of endemism containing both relict and indigenous species.

Results of several noncoordinated studies in the western Panhandle have recently revealed that a center of endemism exists in southern Okaloosa and Santa Rosa counties. This region should be explored and inventoried biologically to more fully appreciate its natural resources. A plan should then be developed to insure protection of the endemics through some sort of specific action. The same purposeful effort should be directed to the Apalachicola Lowlands center of endemicity. The Apalachicola Lowlands appear to have more indigenous races, species, and genera than any other area of the State, and possibly more than the entire coastal plain.

The most famous of the Panhandle centers of endemicity is the Apalachicola Bluffs and Ravines area. These have been the focus of conservation activity in the past 5 years and most of the important habitats of this area have been purchased by the State or by nonprofit conservation organizations. One significant area remains, however, that ought to be purchased: the limestone bluffs and ravines in the vicinity of Aspalaga Landing.

The Panhandle has high species richness in acid bog plants; possibly more carnivorous plant species occur in the Panhandle than in any similar size area in the world. These unique wetlands should be specifically inventoried for their biological composition; bogs are so variable that there may be several distinct types of bogs, each of which may need to be brought into the statewide inventory of publicly owned lands.

Lacustrine environments of the Panhandle are diverse and mostly unstudied. They range from temporary ponds in low places and sinkhole depressions to large, permanent lakes with relatively deep water. An inventory, including a census of the animal and plant components, is urgently needed and a categorization based on hydrology, water chemistry, and biota is long overdue.

The Panhandle possesses unique stream valley types called steepheads; these should be recognized for their uniqueness and inventoried for their biological components. It is likely that some, at least, may contain endemic forms of life.

The lands under the influence of the navigable freshwater bodies of the Panhandle are sovereign, belonging to the State, but for almost no navigable river or lake has the boundary between State owned lands and the upland riparian ownership been determined by survey. This causes acute environmental problems. Most of the floodplains of the Panhandle have been logged by the adjacent landowners and continue to be affected. These publicly owned lands should be recognized as such and managed to preserve the riverine ecosystems in their natural state. The detritus that originates in the floodplain forests is one of the main forcing functions of the estuarine productivity that is so important to the Florida Panhandle's seafood industry.

Native upland ecosystems are the most altered ones in the Panhandle because these are the sites on which people live. There is not a good representation of the upland habitat types in public ownership, partly because there are few patches left that are undisturbed, and partly because these sites are targeted for development. We call for a review of the acreage of the important terrestrial communities remaining, and for an effort to set aside a representative selection to maintain species diversity and for posterity to enjoy.

Two habitats of great importance in the Panhandle coastal region are salt marshes and seagrass beds. Salt marshes are critical nursery, feeding, and refuge areas for many commercially important estuarine organisms such as fish and crabs. The economic value of an acre of marsh has been estimated at 4 to 5 times that of the most productive farmland. The balance between a rising sea level and the sediment supply is being upset by human encroachment in nearby upland habitats, thereby directly and indirectly affecting the marshes. This habitat is one that requires very stringent monitoring for future protection.

Seagrasses are vital to the coastal ecosystem because they form the basis of a structurally complex, three-dimensional habitat. Few other systems are so dominated and controlled by a single species as is the climax *Thalassia* meadow. If seagrasses are destroyed, more erosion occurs and the associated flora and fauna disappear, including commercially important species (e.g., fish, crabs, and scallops). Primary productivity and detrital production decrease dramatically, and this affects other habitat systems, such as unvegetated bottoms, that rely on organic import for the basis of their food chain.

Despite extensive studies on seagrass productivity and on temporal and spatial variability in the biological composition of seagrass communities, little is known of the general principles on which the ecosystem functions and of the factors controlling ecological success in the community. Therefore, subtle changes that may be caused by human activities generally pass unnoticed or are ascribed to natural variation. An example is changes in turbidity levels. Light levels are extremely important for the seagrasses and over time, if light is decreasing, grass beds will slowly die off. Only gross damages, such as the tearing up of beds by dredging, are described in the literature. However, it may be subtle changes in light levels that eventually take the largest toll on this habitat.

It became painfully obvious during the writing of this document that intensive studies have often been conducted at great expense, but the resulting recommendations have not been implemented into area management plans or reflected in local ordinances and policies where they would be effective. The regulatory mechanisms in place often are inadequate to protect environmental resources. Additionally, studies sometimes duplicate previous efforts. There should be a more concerted effort toward coordinating research efforts to get the most information for the dollar.

We further note the need to establish further standards for Outstanding Florida Waters (OFW's) and Aquatic Preserves as well as for their adjacent upland areas. Assigning one of these designations to an area without knowledge of its ecological state or the intent to gain this knowledge hinders enforcement of the regulations that are supposed to protect them. In some instances, the protective regulations and enforcement authority are not even in place, rendering the designation token at best.

Though it has been so often repeated that it is sometimes regarded as an excuse, the ability to formulate effective, balanced management plans for the Florida Panhandle is in many instances fatally hindered by the lack of information on which to base the necessary decisions. During our review of Panhandle ecological literature, we noted many areas which have not been investigated. Questions concerning some of these information gaps may safely be answered using studies performed on similar areas elsewhere. However, experience has shown that the operations of ecosystems are so poorly understood that, at present and in the foreseeable future, the ecology of local ecosystems must often be regarded as unique. Even systems that appear identical may have achieved the external similarity in response to the synergy of altogether different driving forces.

Data gaps that were identified include:

(1) biological baseline studies of estuaries (except Apalachicola Bay; a study is also underway of Choctawhatchee Bay), of rivers (one–year studies are underway for the Ochlockonee and Choctawhatchee Rivers), and lakes. These studies need to be several years in duration in order to provide a hint of the natural variability from annual climatic differences. Without these studies, documenting changes in the river habitats caused by pollutants is nearly impossible, a fact that has prevented effective enforcement of no–degradation policies in many instances. Physical baseline studies do not provide the data necessary to determine the effects of most pollutants on the most important aspect of the habitat—the biota;
(2) pollutant assimilative capacities of individual estuaries;
(3) fish stock assessments;
(4) fishery data in general, e.g., habitat and dietary preferences of major species;
(5) mapping of aquifers, transmissibility of confining layers, and movement of water within the aquifers;
(6) ground water pollution into estuaries;
(7) effects from acid rain;
(8) local impacts of rising sea level.

8.3 The Panhandle Tomorrow

Population growth and development and the environment should not be competing forces because they are different parts of one ecosystem. Florida Panhandle growth must be carefully integrated into the ecosystem or undesirable repercussions are certain to occur.

The Panhandle is coming under increasing growth pressures as the population influx to Florida continues and overcrowding in many south Florida areas decreases the desirability of living there (Figure 94). The justifiably famous white sand beaches of the western Panhandle have so far borne the brunt of the development. Belated local and State efforts to control and plan for this growth (e.g., the Resource Management Committees in the Choctawhatchee and Pensacola Bay Systems) are meeting with limited success, but many of the factors which make this region attractive have been severely damaged. Development of most of the barrier islands and beach areas is already far along. Regulation of

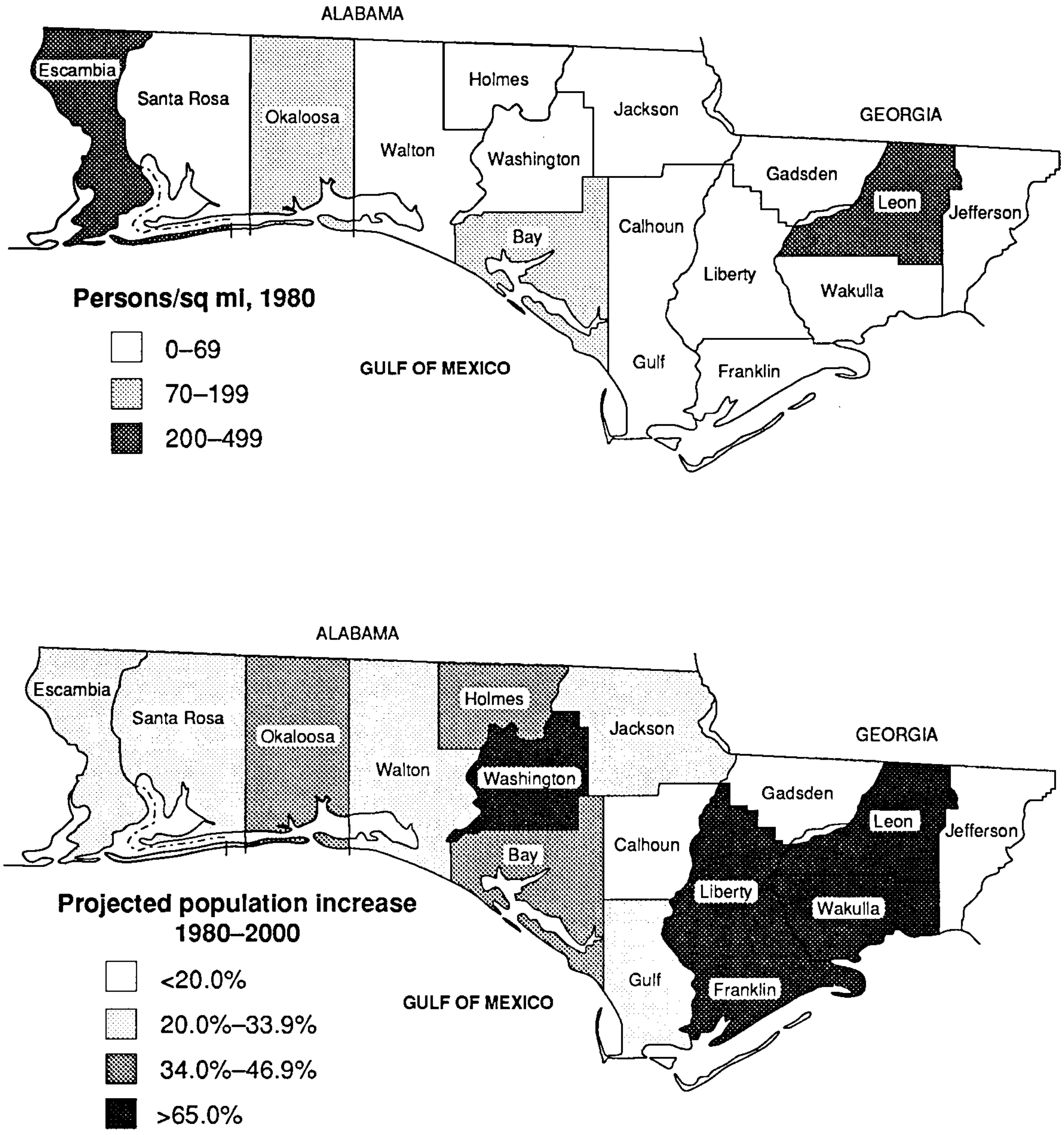


Figure 94. 1980 Florida Panhandle population density by county (after Winsberg and Primelles 1981) and projected population increase 1980–2000 (after Fernald et al. 1981).

growth has been hindered by local groups and governments who see the financial rewards of development as a quick solution to their economic wants or needs. Other parts of the Panhandle will be coming under increasing growth pressure. We hope that the growth management legislation recently adopted by the State Legislature and presently being fine tuned and put into action will work to direct growth in a manner minimizing Panhandle environmental damage.

Efforts should be made to protect the estuarine resources of the State as soon as possible. Approximately 90% of all fish species in Florida coastal waters spend at least a portion of their lives in estuaries. This use can be related directly to commercial and sport fishing dollars. Economic development can become economic loss because of decreased productivity. For example, filling in marshland for development is an economic asset for a few developers while the loss of nursery habitat and subsequent loss in fish production is an economic cost which the general public pays. Maintenance of the fishing sport and industry which attract many people to the coastal region requires that estuarine resources not be lost and that fisheries data (e.g., stock assessments, habitat preferences, etc.) on which to base management decisions be collected.

Areas within the Panhandle which are most sensitive to development and where it should be prevented or minimized include:
(1) river floodplains;
(2) coastal wetlands;
(3) barrier islands and nonwetland coastal areas where damage from the rising sea level and from storms is probable (i.e., most areas within a few hundred meters of the water);
(4) estuaries still in good condition (e.g., Apalachicola Bay, Choctawhatchee Bay, St. Joseph Bay). Subtidal seagrass beds within the various Panhandle estuaries, as well as along the coast, should be protected and preserved to the fullest extent possible.

Areas which can support development if care is used to address ecological "Achilles' heels" include:
(1) Major aquifer recharge areas (e.g., large parts of Jackson and Washington Counties);
(2) Areas where ground water is easily contaminated (studies are underway to help define these areas; they are likely to include much of the Panhandle).

Panhandle areas with unique properties that should be preserved for the future include:
(1) seagrass beds;
(2) salt marshes;
(3) old-growth forest types, including the longleaf pine forest on Eglin Air Force Base, the stunted cypress forest on clay soils in the western half of the Apalachicola National Forest, and floodplain hardwood forests;
(4) steephead areas along Econfina Creek and the Choctawhatchee River;
(5) caves in the Marianna Lowlands, particularly those providing access to ground water filled passages and the various aquatic cave species. Few of the caves within Marianna Caverns State Park provide this access.

In addition to these unique areas, we suggest that locations of the more important common habitat types be identified and that habitat preserves be set aside for each. There is a tendency to overlook the common while it is being developed, only to find later that what was once common can no longer be found, or is found with so many changes that it is functionally different.

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Appendix A
FEDERAL, STATE, AND LOCAL ENVIRONMENTAL CONTROL AGENCIES AND THEIR RESPONSIBILITIES

Federal Agencies

1. **Army Corps of Engineers**

   Concerned with all activities which affect or modify navigable waters of the United States. Primarily concerned with construction in navigable waters and with dredge and fill permits. They are also involved in permitting the placement of dredge and fill material into navigable waters and adjacent wetlands, and they provide some funding for aquatic plant control in navigable and public waters.

2. **Coast Guard**

   They have authority to respond in an emergency to hazardous waste releases and to force responsible parties to clean up.

3. **Department of Commerce—National Oceanic and Atmospheric Administration**

   The administrator of NOAA is currently directing a ten-year effort to develop and implement a program to deal with acid precipitation.

4. **Environmental Protection Agency**

   This is the main Federal agency responsible for "clean water." Areas covered by EPA include: hazardous waste cleanup, public drinking water systems, all point-source pollutant discharges into waters of the United States, and protection and restoration of the environment. EPA also reviews Corps of Engineers permit activities, and sets guidelines for State environmental programs.

5. **Department of Interior**

   Functions performed by this agency include reviewing proposed activities which impact threatened or endangered species, reviewing Corps of Engineers' permits for effect on fish and wildlife, and managing all Federal public lands. Under this department the U.S. Geological Survey conducts research on water resources and the U.S. Fish and Wildlife Service manages and restores sport fish and wildlife populations and conducts research on the effects of pollution on fishery and wildlife resources. The Mineral Managements Service is responsible for the regulation of oil and gas wells on the Outer Continental Shelf.

6. **Department of Agriculture**

   The Soil Conservation Service promotes the use of conservation practices to reduce soil losses, including techniques to reduce runoff and thus improve water quality in waterways. The U.S. Forest Service promotes watershed management, wildlife habitat management, and reforestation programs. The Agricultural Stabilization and Conservation Service, through many programs, helps protect wetlands and helps solve water, woodland, and pollution problems on farms and ranches.

Florida Agencies

1. **Department of Agriculture and Consumer Services**

   This department regulates the purchase and use of restricted pesticides and helps in soil and water conservation through activities of the Soil and Water Conservation Districts and the Division of Forestry.

2. **Department of Community Affairs**

   This department is responsible for reviewing local comprehensive plans and has jurisdiction over "Developments of Regional Impact" (DRI).

These concern developments which could have a substantial effect upon the health, safety, or welfare of citizens of more than one county.

3. **Department of Environmental Regulation**

   The DER is the lead agency involved in water quality, dredge and fill, pollution control, and resource recovery programs. The department sets water quality standards, pollution discharge loadings, and has permit jurisdiction over point- and nonpoint-source discharges, dredge and fill, drinking water systems, powerplant siting, and many construction activities in waters of the State. The department also interacts closely with other Federal and State agencies on water related matters.

4. **Florida Game and Fresh Water Fish Commission**

   The purpose of the Commission is to manage, protect, and conserve wild animal life and freshwater aquatic life. Its efforts include sport and commercial fishing, fishery and habitat management, lake drawdowns, and fish and wildlife stocking.

5. **Department of Health and Rehabilitative Services**

   HRS is responsible for septic tank system permitting through its county health departments, mosquito control coordination, and investigations into threats to the public health.

6. **Department of Natural Resources**

   The DNR is highly involved in water related problems. Besides administering all State lands, including parks and aquatic preserves, DNR serves as the enforcement agency for the Florida Endangered and Threatened Species Act and the Oil Spill Prevention and Pollution Control Act. DNR is also responsible for coordinating aquatic plant research and control in the State. DNR issues permits for transport of aquatic plants, herbicide spraying, and other plant control methods in aquatic environments. DNR also has lake management extension services.

Other Agencies

1. **Water Management Districts**

   The five multipurpose water management districts in the State are concerned with water use, lake levels, dredge and fill, water quality, and other water-related management programs. These districts can hold, control, and acquire land and water bodies which affect water storage.

2. **Regional Planning Councils**

   The 11 regional planning councils in the State act in an advisory capacity to local governments in matters concerning water resources, recreational areas, and Developments of Regional Impact.

3. **Soil and Water Conservation Districts**

   These districts are supervised to a limited degree by the Department of Agriculture and Consumer Services and carry out preventive measures for flood prevention and soil erosion.

4. **Miscellaneous**

   Many local counties and municipalities have environmental and planning agencies which can be involved in environmental management. Local governments can also pass pollution control laws, zoning and land use laws, and many other ordinances which can be effective in preventing environmental problems.

Many of these agencies perform functions which overlap on the State, Federal, and local level. There are also many Memoranda of Understanding between agencies which allow sharing of overlapping functions. Local, State, and Federal agencies interact extensively on programs because of mutual benefits and cost sharing agreements.

Appendix B
PANHANDLE REGULATORY AGENCY LOCATIONS AND ADDRESSES

Florida Department of Environmental Regulation:
Main Office
2600 Blair Stone Rd.
Tallahassee, FL 32399-2400
(904) 488-4805

Northwest District Office
160 Governmental Center
Pensacola, FL 32399-3000
(904) 436-8300

Florida Department of Natural Resources—Regional Biologists
Northwest Region
3900 Commonwealth Blvd., Rm. 304
Tallahassee, FL 32304
(904) 488-5631

Florida Game and Fresh Water Fish Commission
Main Office
620 S. Meridian St.
Tallahassee, FL 32399
(904) 488-1960

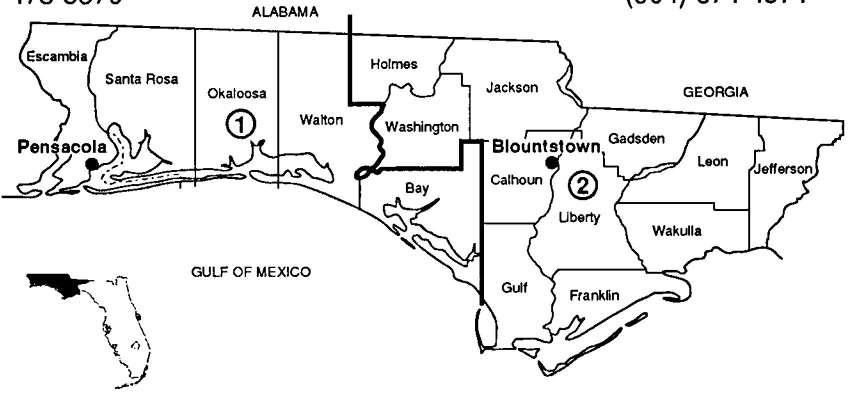
Northwest Regional Office
Rt. 4, Box 759
Panama City, FL 32405
(904) 265-3676

Northwest Florida Water Management District
Rt. 1, Box 3100
Havana, FL 32333
(904) 487-1770

U.S. Army Corps of Engineers
Panama City Field Office
P.O. Box 151
Panama City, FL 32401
(904) 785-9366

Regional Planning Councils
① West Florida RPC
P.O. Box 486
Pensacola, FL 32593
(904) 478-5870

② Apalachee RPC
P.O. Box 428
Blountstown, FL 32424
(904) 674-4571



As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

March 3, 1849

MINERALS MANAGEMENT SERVICE