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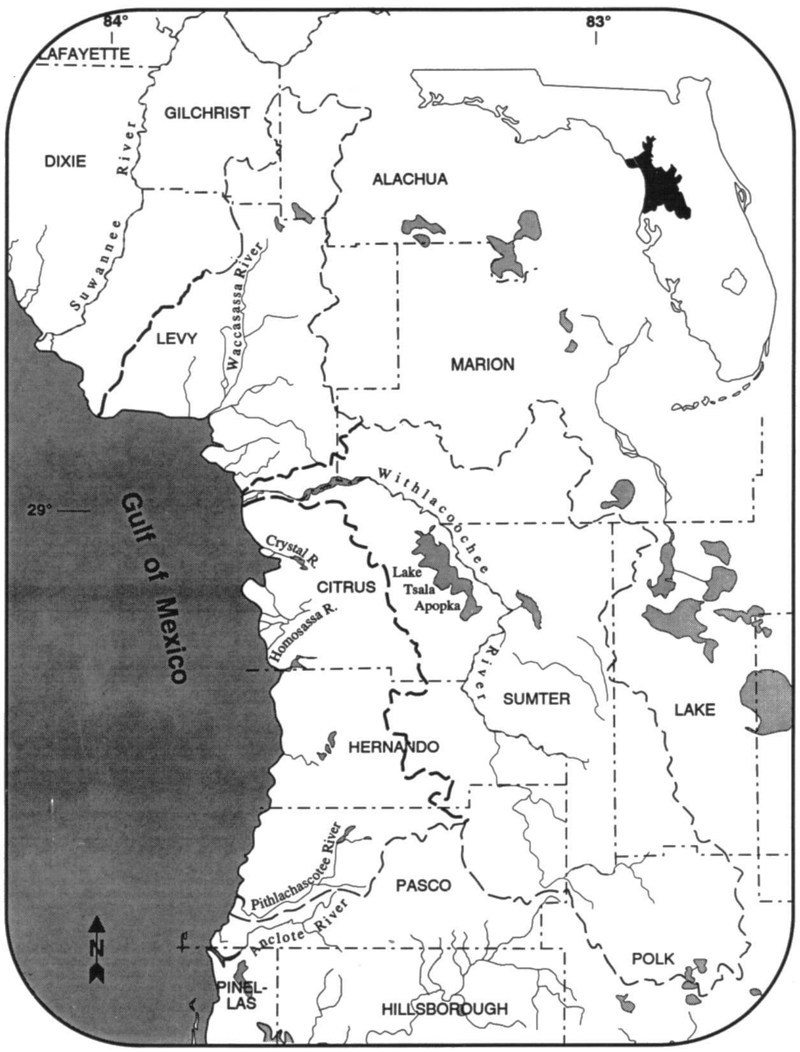
AN ECOLOGICAL CHARACTERIZATION
of the
FLORIDA SPRINGS COAST:
Pithlachascotee to Waccasassa Rivers



Fish and Wildlife Service and
Minerals Management Service

In cooperation with the
Southwest Florida
Water Management District

U.S. Department of the Interior

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An Ecological Characterization of the Florida Springs Coast: *Pithlachascotee to Waccasassa Rivers*

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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 communities, produce many benefits. 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:

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CONVERSION FACTORS

Metric to U.S. Customary

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

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	0.0929	square meters
acres	0.4047	hectares
square miles	2.590	square kilometers
gallons	3.785	liters
cubic feet	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
British thermal units	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F –32)	Celsius degrees

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of the numerous people who contributed to the preparation of this document. Many people were consulted during the preparation of this work, and many more contributed knowledge over the years that enabled the authors to write these descriptions of biological communities. Many public and private agency representatives cooperated with our search for published and unpublished data sources. Noteworthy among these were the staffs and libraries of the Southwest Florida Water Management District and the Florida Department of Natural Resources' Marine Research Institute.

The final product was greatly improved by the generous reviewing efforts of: Eric Shaw and Mark Friedemann, Florida Department of Environmental Regulation; Lorna Patrick of the U.S. Fish and Wildlife Service; Jim Buckner, David Hall, Paul Moler, and Barbara Muschlitz for review of the terrestrial and fresh water chapter; as well as Loretta Wolfe and Bonnie Boynton for review and editing. Extra thanks to the U.S. Fish and Wildlife Service's Beth Vairin for editing assistance and review and Sue Lauritzen for review of and assistance with graphics.

We would especially like to thank Lawrence Handley and the late Millicent Quammen of the U.S. Fish and Wildlife Service for review, review coordination, and general assistance...and persistence.

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Chapter 1. INTRODUCTION

1.1 Purpose and Organization of the Document

For many years, Florida has been experiencing rapid growth that shows no signs of slowing. The areas of the state that have received the main population influx to date are experiencing severe problems with environmental degradation and loss of the very features that attracted the people in the first place. Urbanization, draining of wetlands, sewage and industrial-effluent discharges, contaminated surface runoff, and alterations of the hydrologic regime controlling the ground-water supplies all have caused and are causing loss of wildlife habitat and wildlife populations. In many areas, contamination of ground water through seepage from surface contaminants and saline intrusion cause water shortages that are aggravated by prolonged dry spells. "Reclamation" of wetlands has damaged nature's ability to keep the ground-water aquifers full and may be affecting the rainfall patterns themselves.

Many of the actions that have caused environmental damage were done out of ignorance. The people of Florida are realizing that the expense to the taxpayer of trying to undo past errors far exceeds the cost of requiring that initial development take place in such a way as to minimize damage. While continued growth may be inevitable, we can maintain much of the physical and aesthetic natural attributes that make Florida one of the finest areas in the country.

The authors have dubbed the area covered in this document the Springs Coast because of the need to refer to it in terms briefer than "the upper coast of west-central Florida" or other similar descriptions. This region includes the drainage basins and nearshore waters of the west coast of Florida between, but not including, the Anclote River basin and the Suwannee River basin. The name Springs Coast was chosen because this area of coast contains a multitude of springs, both named and too small or inaccessible to have been named. Much of the area is karstic limestone where the Floridan aquifer is flowing onto the surface of the land, helping to provide the extensive marshlands along the coast. Most recognizable among the springs are the famous Crystal River, Weeki Wachee, and Homosassa springs.

This document is a summary of the available information on the Springs Coast area of Florida, for use by planners, developers, regulatory authorities, and other interested parties. An understanding of the factors affecting their plans and the possibly unexpected impacts of their actions on others will, it is hoped, promote intelligent development in areas capable of supporting it. We have tried to provide a clear, coherent picture of what is currently known about how the physical, chemical, and biological factors of the environment interact. Extensive references are provided so that those wishing more detail on any aspect will know where to find it. Many of the sources cited are among the so-called "grey literature," studies and reports that are not published or are not widely circulated. Much valuable information is available in these documents. We have also tried to identify those aspects of the local environment that are most susceptible to damage or most likely to cause damage. Finally, we have tried to identify the direction of future development and locate those areas needing study prior to developmental pressure.

The report is divided into two main sections. Chapters 2–4 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 much of the environmental pressure affecting the biological habitats. These habitats and their inhabitants—terrestrial, freshwater, and marine—are described in Chapters 5 and 6. Chapter 7 summarizes the main points and identifies present and potential problems.

1.2 The Florida Springs Coast

The Springs Coast of Florida as defined for this report extends from the Pithlachascotee River basin located north of Tampa Bay to the Waccasassa River area south of the mouth of the Suwannee River (Fig. 1). It includes one of Florida's largest rivers, the Withlacoochee, as well as several of the state's largest springs.

Within the Springs Coast are included the coastal drainage basin between the Anclote and Withlacoochee Rivers, the Withlacoochee River basin, and the coastal area between the Withlacoochee and Suwannee Rivers including the Waccasassa River basin. This territory includes large expanses of marsh and wetland and, along its shores, the southern end of the largest area of seagrass beds in the state—the Florida Big Bend Seagrass Beds Preserve. It also possesses numerous spring-fed rivers and streams along the coast, whose constant discharges provide unique, relatively stable estuarine environments.

The northern half of the Springs Coast is just beginning to feel growth pressures; the southern portion along the coast has recently experienced heavy development, but the area is still relatively small. Virtually the entire coastline is low-energy, i.e., mangrove and salt marsh. This enormous coastal wetland, often extending kilometers inland, is the primary reason for limited human inhabitation. Though the population pressures from the more popular southern areas of the state are now moving to the north, the delay has allowed us to gain an understanding of the irreplaceable value of these areas. The wetlands of the Big Bend and the Springs Coast support much of the gulf fishery, acting as a nursery and food source. In addition, many areas are important for recharging the underground aquifers upon which much of the state depends for its water supplies.

The Springs Coast, which is beginning to receive heavy development, stands a good chance of maintaining its environmental and ecological quality through that development. We hope this document helps in achieving that result.

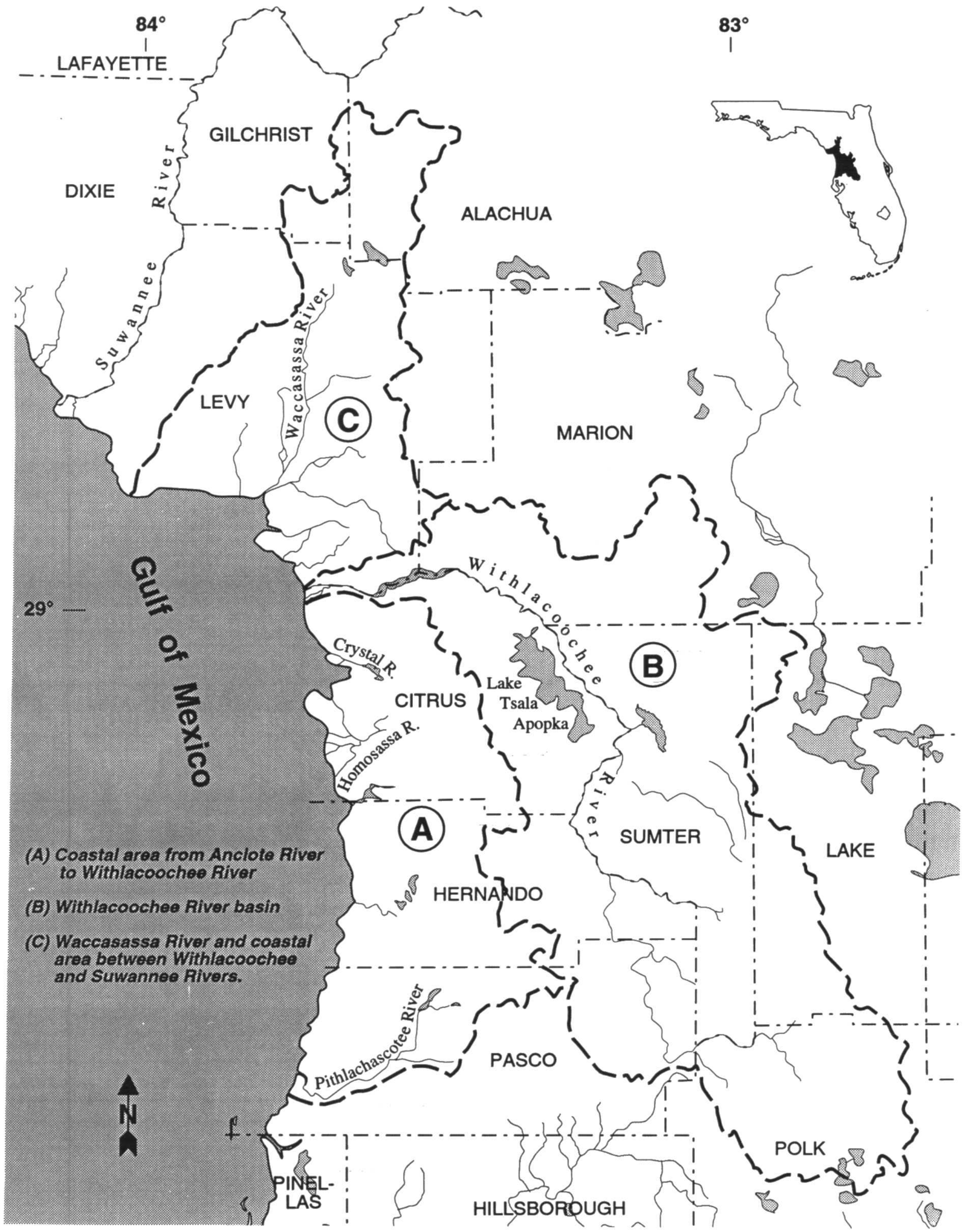


Figure 1. Drainage basins and features of the Springs Coast region of Florida.

Chapter 2. GEOLOGY AND PHYSIOGRAPHY

by Reed E. Noss and Michael J. Bland

2.1 Introduction

The geology of any region determines to a great extent the habitats available to plants and animals. Rocks near the surface are the "parent material" from which soils are formed, and clastics such as sands and clays are the primary inorganic components of soils. The chemical composition, texture, and other properties of a particular parent material and soil will favor some plant species over others. Surface limestone, for example, produces soils with abundant calcium compared to most sandy soils or organic mucks. Certain "calciphilous" plant species are found most frequently, or perhaps only, where limestone outcrops or is very near the surface.

Geology also determines landform. To the lay person, the influence of landform on ecology might be most obvious in mountainous regions, where cliffs, screes, and climatic changes related to elevation and slope aspect have profound effects on species distributions. In Florida, geological influences on habitat are more subtle, but just as important. Variations in elevation in Florida, ranging from 0 to 105 m above sea level, are not enough to create any noticeable differences in climate. But Florida's modest slopes are extremely important in determining soil moisture levels. The slope moisture gradient, interacting with fire and other abiotic factors, produces a corresponding gradient in species composition. Xeric ecosystems with low soil-moisture levels and high fire frequencies are found at the top of the slope moisture gradient, and wetlands are found at the bottom. In the middle are mesic habitats such as mixed species hardwood forests.

A prominent landform of our study region, and over much of Florida, is karst. Karst topography is a regional landform that has been modified by the solution of subsurface limestone. Rainwater, charged with carbonic acid from the solution of atmospheric CO_2, percolates through the crevices of limestone and dissolves it, creating caves, sinkholes, many solution valleys and depressions, and other karst features. Karst features provide habitats that would otherwise be absent from the regional landscape, such as prairies, lakes, and poorly drained depressions, that support diverse assemblages of species.

What we know as Florida is the emergent part of a large peninsular platform called the Floridan Plateau (Fig. 2) that extends southward from the continental mass and separates the deep waters of the Atlantic Ocean and the Gulf of Mexico. The Floridan Plateau is composed of thousands of feet of sedimentary rocks covered by clastic sediments (including sand, clay, silt, shell marl, rock fragments, and other materials) of varying thickness (from 0 to several hundred feet). Episodically, at times in the past, the entire Floridan Plateau has been submerged beneath the sea, while at other times it has been almost entirely emergent. At one time of emergence the land area of the peninsula was over twice its present size. The limestone and dolomite bedrock that underlies all of our study region was deposited in shallow seas from about 58 to 25 million years ago (from middle Eocene to Miocene epochs; still older sediments and igneous rocks are found beneath these Tertiary sediments, but will not be considered further in this report). The clastics that overlie the bedrock were deposited from about 25 million years ago to the present (from Miocene to Holocene epochs). Some

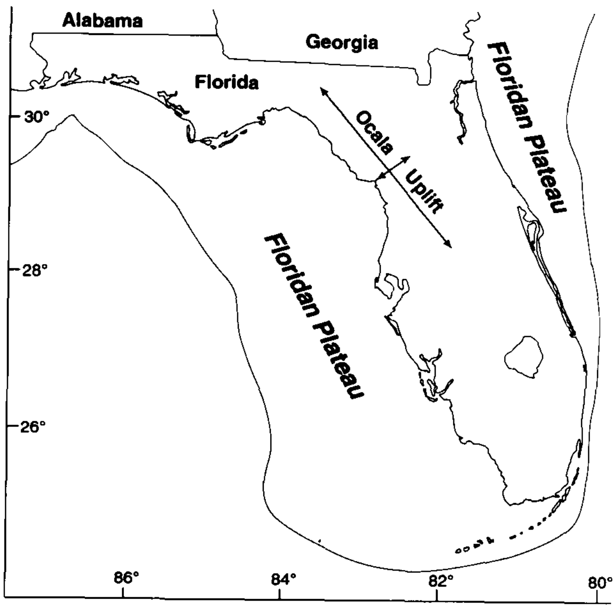


Figure 2. The Floridan Plateau and its present day emergent part, Florida. The Ocala Uplift has an important influence on spring occurrence in the state.

of these clastics are sediments of near-shore marine origin, some are fluvial deposits transported by rivers, some are lacustrine (lake-bottom) deposits, and some represent aeolian (wind-blown) sediments such as dunes.

One of the most prominent geomorphological features of Florida is the step-like series of terraces that progress in elevation from the coast to the interior (Fig. 3). The interior (landward) edges of these terraces, called scarps, represent the beach dunes and ridges of ancient shorelines. Many of these scarps are associated with variations in sea level that parallel the glacial and interglacial periods of the Pleistocene epoch (Walker and Coleman 1987). During glacial maxima, when much of the earth's water was frozen in glaciers and polar ice, sea level was as much as 41 m below its current level. During warm, moist interglacial periods, seas rose to levels higher than today's. Florida terrain higher than 30–52 m above present sea level may not represent terrace deposits associated with Pleistocene sea levels, but rather older deposits of Pliocene and upper Miocene age (Healy 1975a). In fact, some recent evidence (reviewed by Clewell 1981) suggests that sea level rose to a maximum height of only 8–11 m above present mean sea level (m.s.l.) during Pleistocene interglacial stages. If this is true, then with the exception of brief interglacial warm periods, Florida has been continuously emerging from the sea since the Miocene. Some recent authors still consider all marine terraces as Pleistocene in age. Much of the uncertainty about terrace age is due to the fact that differential warping and subsidence of the land surface, the latter due to solution weathering of limestone, has resulted in terraces of the same age (same shoreline) being found today at different heights in different areas (Walker and Coleman 1987). Geological change and climate-induced fluctuations in sea level will undoubtedly continue to be important processes in Florida's future.

2.2 *Physiography and geomorphology*

Physiography is the study of physical geography, and geomorphology is the geological study of the configuration and evolution of landforms. Together, they refer to what commonly is called "the lay of the land." All habitats and biological communities exist in a physiographic and geomorphological context.

Because of Florida's low relief, delineation of geomorphic features has not been as straightforward as in mountainous areas. Although terraces created during past high sea levels are often easily recognized, higher terraces are older and have been subjected to more erosion and sagging due to solution of underlying limestones. Hence, contour lines representing terrace scarps are not necessarily good delineators of physiographic features (White 1970). Rather, one must look directly to the landforms of the region as they exist today.

White (1970) divided Florida into three general physiographic zones (Fig. 4). All of our study region is within the Central or Mid-Peninsular Zone. This zone is characterized by discontinuous, subparallel ridges separated by broad valleys. Broad, shallow lakes are prominent features of the valley floors, and

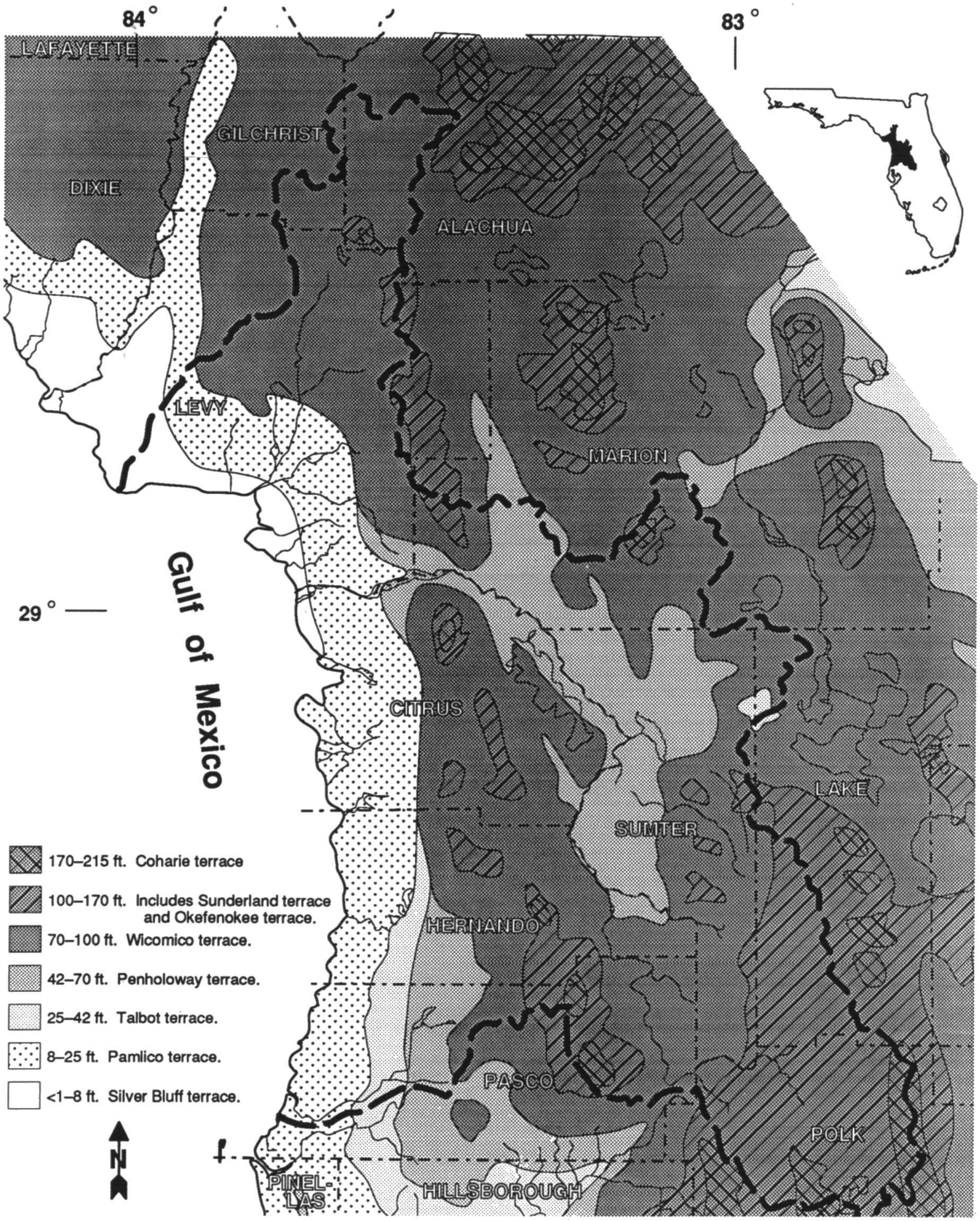


Figure 3. Terraces and shorelines of Florida (after Healy 1975a).

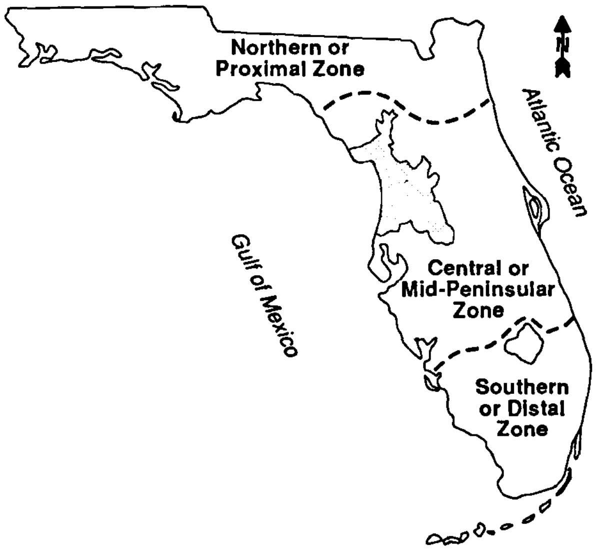


Figure 4. Major transpeninsular physiographic divisions of Florida; Springs Coast region shaded (after White 1970).

some deep lakes with complex geological histories occur on the ridges (White 1970). The following is a description of some of the most prominent physiographic features of our study region. These features can be identified on White's (1970) physiographic map of North Peninsular Florida (Fig. 5).

2.2.1 The Brooksville Ridge

One of the most striking physiographic features of this region is the Brooksville Ridge, which extends some 177 km from eastern Lafayette County (north of our study region) southward to the Zephyrhills area of southern Pasco County. The Withlacoochee River, flowing through the Dunnellon Gap between the towns of Dunnellon and Inglis where Levy, Marion, and Citrus Counties come together, divides the ridge into two unequal parts. The larger southern part is about 97 km long and from 16 to 24 km wide. The smaller part to the north is about 80 km long and varies in width from 6 to 10 km. In contrast to the near sea-level elevations of the adjacent Gulf Coastal Lowlands, the Brooksville Ridge ranges from about 21 m m.s.l. to over 75 m m.s.l.. The surface is highly irregular, with elevations varying 30 m or more over short distances. The Brooksville Ridge is often considered a western part of a larger physiographic region of Florida, the Central Highlands.

The deep sands of the Brooksville Ridge were probably deposited as dunes at the Wicomico shoreline at an elevation of about 30 m (Knapp 1978). The elevations at the toe of this scarp are variable, however, suggesting that certain parts of the scarp have been shores at more than one sea level (White 1970). Underlying the surficial sands are clayey phosphatic sands and sandy clays (mostly of the Miocene Hawthorn Formation), which overlie limestones and dolomites of Oligocene and Eocene age. The higher elevations of the carbonate rock under the Ridge, relative to the adjacent lowlands, has been attributed to the less permeable overlying sands and clays as compared to the more porous sands of the lowlands (Vernon 1951). The clayey sands of the Brooksville Ridge reduce downward percolation of surface waters and resultant dissolution of the underlying carbonates. Hence, the Brooksville Ridge is a relatively persistent landform which supports important upland community types such as longleaf pine sandhills and sand pine and oak scrub. Dependent on these uplands are many threatened and endangered species of our region, including the gopher tortoise (which finds excellent burrow sites in the deep sands), red-cockaded woodpecker, indigo snake, and Sherman's fox squirrel.

2.2.2 The Ocala Hills and the Cotton Plant Ridge

Forming the western edge of the Central Highlands, the Ocala Hills extend 9 mi southwestward from the city of Ocala and range in elevation from 23 to 53 m above m.s.l.. These hills, at most 8 km wide, are part of a series of uplands that separate the Western Valley from the Central Valley and form a line paralleling other prominent ridge systems in Florida, including Trail Ridge and the Lake Wales Ridge (White 1970). Like the Brooksville Ridge, the Ocala Hills are thought to be relict coastal features composed of predominantly clayey sands that have protected underlying carbonate rocks from solution.

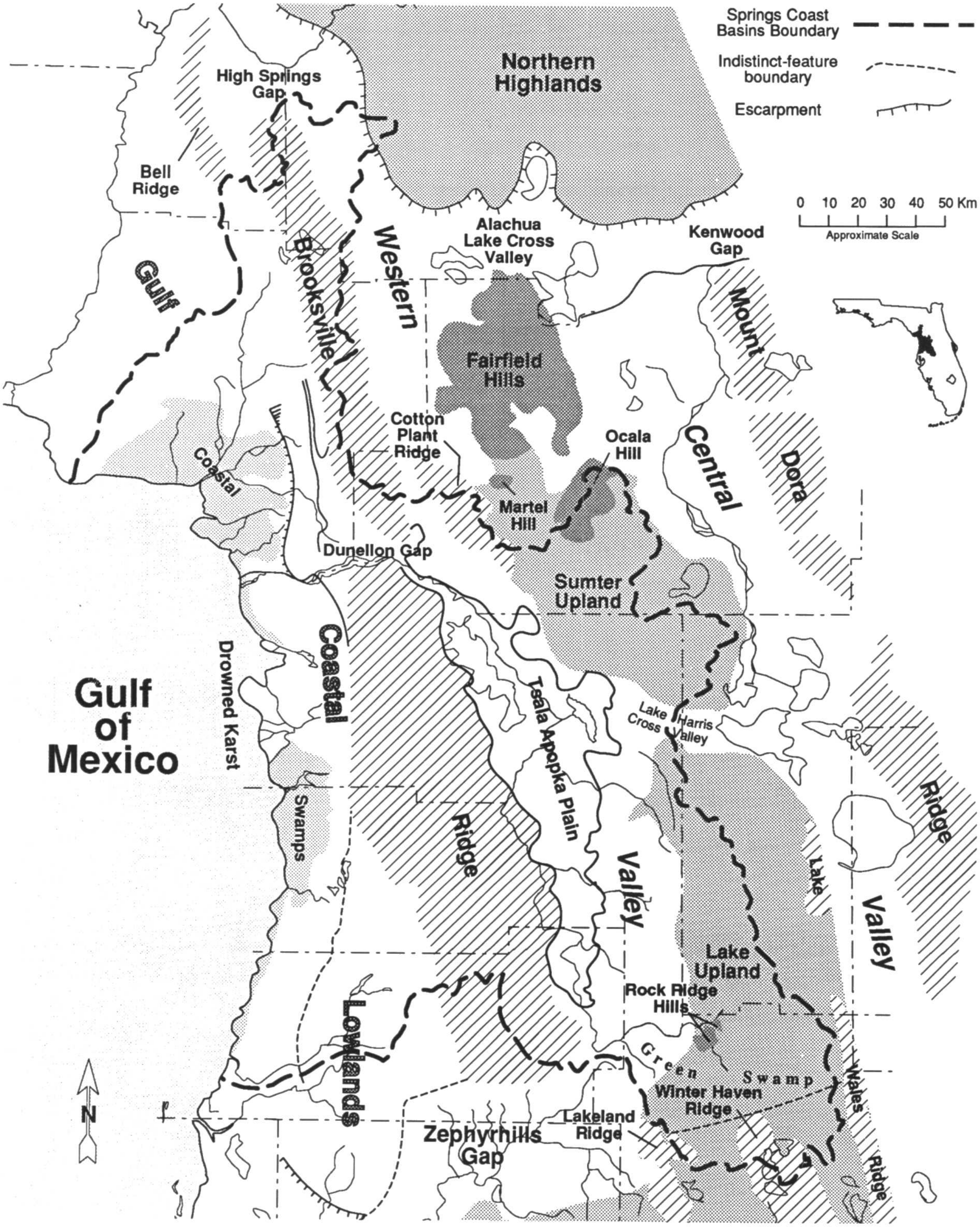


Figure 5. Physiography of the Florida Springs Coast and adjacent areas (after White 1970).

West of the Ocala Hills, and separated from them by Martel Hill (which is just outside our study region), is Cotton Plant Ridge. This sandy ridge is about 26 km long and 8 km wide, with a distinct northwest-southeast orientation relative to the other ridges of the Central Highlands. Maximum elevation is about 30 m m.s.l., and sediments are predominantly white sands. The unusual orientation of Cotton Plant Ridge suggests a derivation different from the supposed shoreline origin of other ridges in this region (Knapp 1978). Superimposed on Cotton Plant Ridge are hills with a surface pattern that suggests an aeolian origin, which may explain their orientation perpendicular to the dune-forming southwest winds (White 1970).

2.2.3 The Lake and Sumter Uplands

The Lake and Sumter Uplands are two highland areas named for Lake and Sumter Counties, respectively, and separated by the Lake Harris Cross Valley in the vicinity of Leesburg. Each of the two uplands is about 56 km long and 24 km wide. They lie generally between the Western and Central Valleys, but are partly bounded by higher lands such as the Lake Wales Ridge on the eastern side of the Lake Upland and the Ocala and Fairfield Hills and Cotton Plant Ridge at the northern edge of the Sumter Upland. The Lake and Sumter Uplands gradually decline in elevation from north to south, from 38 to 45 m m.s.l. at the southern end of the Lake Upland to 23–30 m at the northern end of the Sumter Upland (White 1970).

The Lake and Sumter Uplands are similar in composition to the Brooksville Ridge: sands and clayey sands overlying limestone bedrock. The Lake Upland is dominated by relict beach ridges with limited but differential solution of the underlying limestones. As the beach ridges and intervening swales decline in elevation northward, a series of many small lakes appears, which gives Lake County its name (most of these lakes lie to the east of our study region, however). With the exception of the large Lake Weir (in Marion County, and just outside our study region), the Sumter Uplands contain few lakes.

2.2.4 The Western Valley and Tsala Apopka Plain

The Western Valley is a large, irregularly shaped area of low relief and poor drainage bounded on the west by the Brooksville Ridge and on the east by the Lake and Sumter Uplands and other highlands to the north (including the Ocala Hills, Cotton Plant Ridge, and Fairfield Hills). The Western Valley extends about 225 km from the High Springs Gap in western Alachua County (just north of our study region) to the Zephyrhills Gap in Pasco and Hillsborough Counties (just south of our study region). It is connected to the Central Valley (east of our study region) by the Lake Harris Cross Valley (which separates the Lake and Sumter Uplands) and by the Alachua Lake Cross Valley in southern Alachua County (east of our study region).

With elevations ranging generally from about 15 to 30 m above m.s.l., the Western Valley contains many swamps and lakes. The largest of the swamps, the Green Swamp, lies in parts of Lake, Sumter, and Polk Counties (Deuerling and MacGill 1981). The Green Swamp is one of the most significant natural landscapes of our region, although it is being increasingly modified by human activities.

The Tsala Apopka Plain is a lower (from 12 to 23 m above m.s.l.) and flatter portion of the Western Valley located in eastern Citrus, Hernando, and Pasco Counties, and western Sumter County. It is bounded on the east by the Withlacoochee River and on the west by the Brooksville Ridge. The Tsala Apopka Plain contains a number of lakes, including present-day Lake Tsala Apopka, Lake Panasoffkee, and many smaller lakes, all of which are believed to be remnants of a much larger lake that once occupied all of the Tsala Apopka Plain (White 1970). The larger ancestral lake apparently found a new, lower outlet through a solution opening (the Dunnellon Gap) in the confining Brooksville Ridge to the west. This escape seems to have reversed the flow of the Withlacoochee River between Zephyr Hills and Dunnellon, partially draining the ancestral lake and leaving the smaller lakes we see today in lower areas. These lower areas are probably old sinks dating back to before the impounding of the ancestral lake

(White 1981). Alluvial deposits of variable thickness on the plain overlie limestone, and much of the local relief is a highly irregular low topography that resembles dunes (White 1970).

2.2.5 The Gulf Coastal Lowlands

The Gulf Coastal Lowlands is a poorly drained area of low relief (from 0 to about 30 m above m.s.l.) that extends inland from the Gulf of Mexico to the Brooksville Ridge, throughout the length of our study region. Located within the Gulf Coastal Lowlands are coastal swamps, river valley lowlands, and marine terraces of Pleistocene age (10,000–1.6 million years ago) and possibly older. A marine terrace is a gently sloping or nearly horizontal surface that was formed by an ancient sea, the inland edge of which is usually marked by a seaward-facing escarpment representing ancient shoreline features such as dunes. Terraces are usually covered by sands or clayey sands. As mapped by Healy (1975a; see Fig. 3), seven marine terraces occur in our region. Starting with the presumed oldest, they are the Coharie, Sunderland (or Okefenokee), Wicomico, Penholoway, Talbot, Pamlico, and Silver Bluff Terraces. The older three terraces extend above the Gulf Coastal Lowlands as defined by White (1970), but are discussed here for convenience.

The Coharie Terrace is found in our region only in small areas of Pasco County. Standing at 52–65 m above m.s.l., the Coharie Terrace was considered by Cooke (1931) to have been formed when the Pleistocene shoreline was at 65 m above m.s.l.. If, however, Pleistocene seas were never this high (a more recent view), then this terrace may be much older (of Pliocene or even Miocene age). The Sunderland Terrace, which also may be older than Pleistocene times, stands at 30–52 m above m.s.l. (with a shoreline at 52 m) in much of our study region. The other possibly pre-Pleistocene terrace in our region is the Wicomico, standing at 21–30 m above m.s.l. (shoreline at 30 m). The Brooksville Ridge is associated with this terrace over much of its area.

The four remaining terraces are within the Gulf Coastal Lowlands, except for the Penholoway, which extends from the lowlands through gaps into the Western Valley. These four terraces (except possibly the Penholoway) are generally agreed by modern authors to represent Pleistocene deposits and shorelines. The Penholoway Terrace, at 13–30 m above m.s.l. (shoreline at 30 m), occupies the most inland portion of the Gulf Coastal Lowlands in much of our region and also is found in the Tsala Apopka Plain and surrounding lowlands. The Talbot Terrace, at 8–13 m above m.s.l. (shoreline at 13 m), is not well developed in our region, but occupies a strip of land in Hernando and Pasco Counties between the Penholoway and Pamlico Terraces.

The Pamlico Terrace is the best developed of the Pleistocene Terraces in our region, and occupies most of this part of the Gulf Coastal Lowlands at 2–13 m above m.s.l. (shoreline at 13 m). Many dunes are associated with the Pamlico Terrace, which seems to indicate that much more sand was available for the building of dunes and beaches than is present today (Deuerling and MacGill 1981). The source of these sands may have been the Brooksville Ridge (White 1970). Signs of an ancient barrier island-lagoon system in the Crystal River area also indicate a greater supply of sand in the past than today (Deuerling and MacGill 1981). Underlying the Pamlico Terrace are a number of karst features, including sinkholes and depressions that are masked by a thin veneer of sand, marls, and coquina deposited during the Pleistocene. The Waccasassa Flats, which occupy the Pamlico Terrace in central Levy County north of the town of Gulf Hammock, is a swampy area composed of varying amounts of clayey sands (4–5.5 m thick) overlying limestone. The origin of the Waccasassa Flats is uncertain; Vernon (1951) and White (1970) pointed to a fluvial source, whereas Puri et al. (1967) thought marine processes were responsible.

The Silver Bluff Terrace, at 0.3–3 m above m.s.l. (shoreline at 3 m), is the most recent of the terraces, and is found in the region only in Levy County and extreme northwest Citrus County. The Silver Bluff Terrace is associated with a coastal marsh belt and is composed primarily of Pleistocene to Holocene (Recent) marine sediments underlain by limestones and dolomites quite close to the surface.

Puri and Vernon (1964) and White (1970) designated the westernmost and lowest area of the Gulf Coastal Lowlands, occupying much of the Pamlico and Silver Bluff Terraces in the region, as a physiographic subregion called the Coastal Swamps. This area is recognized as a low-energy coast where there is a dearth of sand for building beaches, and includes many lagoons, salt marshes, freshwater swamps, and hydric hammocks. Some of the most important natural areas of our region, such as the Chassahowitzka Swamp and much of Gulf Hammock, fall into the Coastal Swamps subregion.

2.3 *Surface and Subsurface Geological Formations*

The surface and subsurface geologic formations of our study region (Figs. 6 and 7, Table 1) are mostly limestones and dolomites deposited in Tertiary seas from the Eocene epoch (from 58–36 million years ago) through the Oligocene epoch (36–25 million years ago), overlain by clastics that include quartz sands, silts, clayey sands, and clays. These clastics were deposited from the Miocene epoch, through the Pleistocene to the Holocene (from 25 million years ago to the present). The study of rock strata, especially their distribution, deposition, and age, is called stratigraphy. The following discussion will concern only surface and near-surface stratigraphy, and not the pre-Eocene sediments and igneous basement rocks that occur in our area below about 1,200 m.

The surface and near-surface stratigraphy and outcrop patterns of our region are controlled by a dominant structural feature, the Ocala Uplift. Puri and Vernon (1964) described the Ocala Uplift as "a gentle anticlinal flexure about 230 miles long and about 70 miles wide exposed near the surface in west-central Florida." The Ocala Uplift is not expressed topographically (i.e., it does not produce a hill or ridge), but can be seen in the outcrop patterns of the rocks. Rocks previously deposited and lithified were uplifted relative to rocks of the same strata in surrounding areas, so that a particular stratum will occur at different elevations in different parts of our study region.

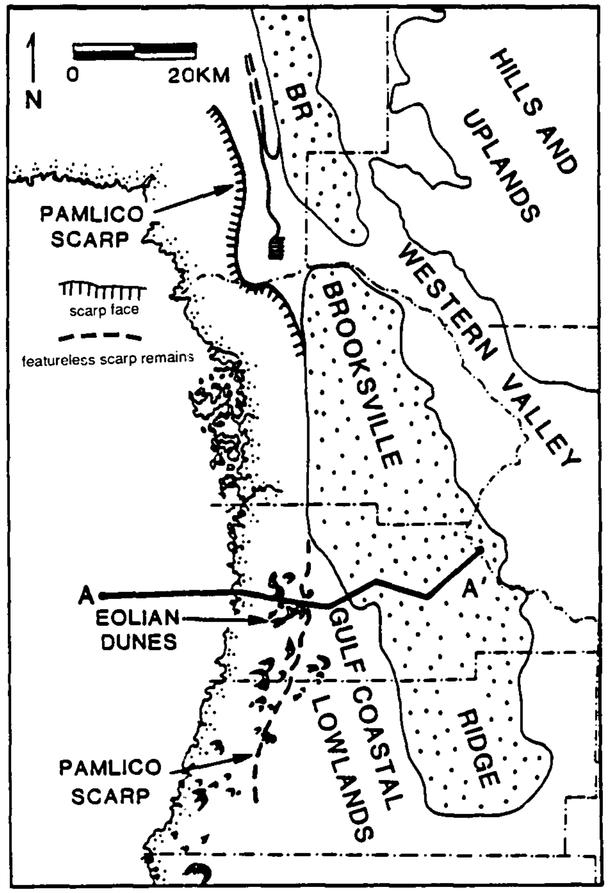


Figure 6. Location of major geomorphological features in west-central Florida (White 1970).

2.3.1 Eocene Series

The middle Eocene Avon Park limestone, which was deposited about 45 million years ago, is the oldest formation to outcrop in Florida. The Avon Park limestone is present in the subsurface throughout most of our study region, but is exposed only in two small areas of Levy, Marion, and Citrus counties. These two outcrops occur near Dunnellon and Lebanon Station and along the Withlacoochee River, and in the vicinity of the towns of Gulf Hammock and Otter Creek. The Avon Park formation was deposited in "shallow coastal bays, beaches, and marine shelves where almost no clastic material was being deposited" (Vernon 1951). The upper sediments of

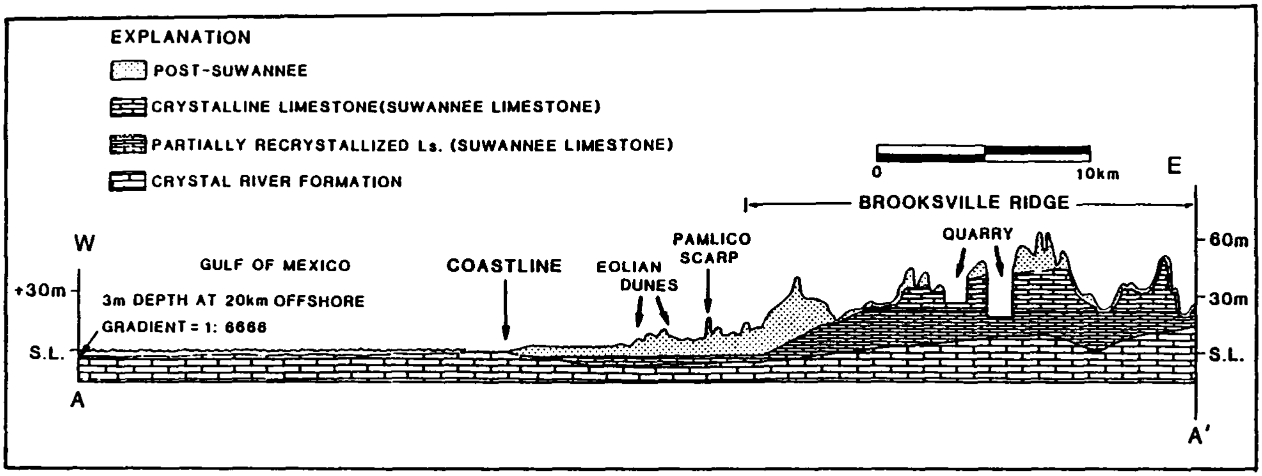


Figure 7. Cross-section across Hernando County (line "A" on Figure 6) illustrating low, flat gradient near the present coastline. Also shown are the Pleistocene sands of the Pamlico Terrace deposited on the west flank of the erosionally resistant limestones of the Brooksville Ridge (Hine and Belknap 1986).

the Avon Park limestone were apparently dolomitized subsequent to deposition, thus making it difficult to recognize fossils and other features indicative of a particular environment (Knapp 1978). The exposed sediments generally appear as a brown to dark-brown to tan very fine-grained soft to relatively hard dolomite containing numerous black carboniferous plant fossil impressions. Interbedded limestone consists almost entirely of small foraminiferan microfossils.

Overlying the Avon Park formation are late Eocene limestones of the Ocala Group, named for exposures of this limestone in quarries near the city of Ocala. These limestones, which were deposited in a shallow marine environment about 40 million years ago, form the major surface and near-surface bedrock over most of our study region. The limestones of the Ocala Group were considered by Puri (1953) to consist of three formations, which in ascending order are the Inglis Formation, Williston Formation, and Crystal River Formation. Puri's three formations cannot be mapped or definitely recognized lithologically. As a result many modem authors have abandoned these terms (Miller 1986). The lower strata of the Ocala Group consist of cream to white generally fine-grained soft or semi-indurated micritic limestone containing abundant miliolid remains and scattered large foraminiferans.

The upper part of the Ocala Group, which is the typical Crystal River Formation of the literature, is a white, generally soft and somewhat-friable porous coquina composed of large foraminiferans, bryozoan fragments, and whole to broken echinoids, all loosely bound by a matrix of micritic limestone (Miller 1986). The Ocala limestone is one of the most permeable rock units in the Floridan aquifer system. The surface of the formation is very irregular because of solution of the limestone by acidic ground water. This solution has resulted in a distinctive karst topography over most of our region, with numerous caves, sinkholes, and other features. The karst surface has apparently been developing from Miocene to Holocene times when the limestone surface was above sea level and exposed to weathering and solution agents.

2.3.2 Oligocene Series

The Suwannee Limestone was deposited as marine sediments during the Oligocene (about 30 to 37 million years ago). In our study region, the Suwannee limestone is found at or near ground surface in small parts of Citrus and Hernando

Table 1. Surface and near-surface geologic formations in the Florida Springs Coast (all Quaternary-period).

Epoch	Formation	Years ago	Characteristics
Holocene	______	0 to 10,000	Thin sand and gravel deposits; mostly adjacent to present streams, estuaries, lagoons, and the coast.
Pleistocene	______	10,000 to 2.5 million	Sand and clayey sand on terraces and ancient shorelines, often in dunes.
Pliocene	______	2.5 to 7 million	Terrace deposits.
	Alachua Formation		Gray to bluish-gray clayey sand; weathers red to reddish brown.
	Bone Valley Formation		Highly phosphatic sand and clay beds; mostly fluvial origin.
Miocene	Hawthorne Formation	7 to 25 million	Phosphatic clayey sand or sandy clay; dolomites or dolomitic limestones in lower beds.
	Tampa Limestone		White to light gray, sandy or locally clayey limestone; fossiliferous.
Oligocene	Suwannee Limestone	30 to 37 million	Cream to tan-colored limestone, granular to chalky, hard, partially silicified; highly fossiliferous.
Eocene	Ocala Group (Crystal River Formation, Williston Formation, Inglis Formation)	40 to 45 million	White, generally soft, coquina limestone; highly fossiliferous; cream to white, soft to fairly hard micritic limestone in lower beds.
	Avon Park Limestone		Brown to dark brown to tan, very fine-grained soft to relatively hard dolomite.

Counties, in the south-central region of the Brooksville Ridge. The general lithology is a cream to tan-colored limestone, granular to chalky, moderate to well-indurated (hard), variably recrystallized, partially silicified (forming chert), and highly fossiliferous, containing many mollusks and several distinctive foraminiferans. The Suwannee Limestone in this region may be 36 m thick (Vernon 1951). The Suwannee Limestone unconformably rests upon the Ocala Group limestones (Crystal River Formation), meaning that the stratigraphic record is incomplete and intervening sediments may have been present and subsequently eroded.

2.3.3 Miocene Series

The limestones of the Eocene and Oligocene series in our region are commonly overlain by sediments of Miocene age. The oldest of these Miocene sediments in our region, which occur at or near the surface over much of Pasco County, compose the Tampa Formation. The Tampa Limestone is a sandy limestone of early Miocene age. It is a white to light-gray sandy soft to hard locally clayey fossiliferous (mostly pelecypod and gastropod casts and molds) limestone with local occurrences of phosphate and chert (Miller 1986).

Covering a major portion of our study region is the Hawthorne Formation, the most widespread and thickest Miocene unit in the southeastern United States. The Hawthorne is a complexly interbedded, highly variable sequence that consists primarily of clay, silt, and sand beds containing little to abundant phosphate. Fossils in the Hawthorne Formation include sharks' teeth, ray dental plates, and silicified heads of colonial corals (K.E. Williams et al. 1977). Where it is present, the Hawthorne Formation comprises most of the upper confining unit of the Floridan Aquifer system. Although the upper Hawthorne sediments are entirely clastics or a variable mixture of clastics and carbonate fragments, the lower sediments are often phosphatic dolomites or dolomitic limestone beds, usually brown but locally cream to white (Miller 1986). Sediments of the Hawthorne Formation are thought to have been deposited in a near-shore marine environment, and probably constitute residual sediments eroded from the Brooksville Ridge. The phosphate minerals in the Hawthorne were probably deposited from upwelling cold marine waters (Miller 1986). The Hawthorne Formation probably covered most of our study region, but in places has been eroded away to expose older sediments. Hawthorne phosphorites are mined over a large area in central Florida.

2.3.4 Pliocene Series

The Bone Valley Formation, a highly phosphatic sequence of sand and clay beds containing vertebrate remains of Pliocene Age (about 2.5–7 million years ago), is at or near the surface in several parts of our region, including portions of Levy, Gilchrist, Marion, Hernando, Pasco, Sumter, Lake, and Polk Counties. The Bone Valley Formation is mostly of fluvial origin and is composed largely of material reworked from underlying Miocene rocks (Puri and Vernon 1964). The extent and thickness of the Bone Valley Formation is uncertain and difficult to distinguish from the underlying Hawthorne Formation (Miller 1986). Some authors (e.g., Cooke 1945; Vernon 1951; K.E. Williams et al. 1977) identify a Middle Pliocene deposit, the Alachua Formation, in parts of our study area. This unit is a generally nonfossiliferous (but with local vertebrate fossils) gray to bluish-gray clayey sand that weathers red to reddish brown on exposure. It contains residual silicified boulders of late Eocene, Oligocene, and Miocene age and locally heavy concentrations of secondary hard-rock phosphate (K.E. Williams et al. 1977). Later authors generally consider these sediments to be residual material of the Hawthorne group (Campbell 1984). The Alachua Formation was not mapped as a separate unit by Brooks (1981).

2.3.5 Pleistocene to Holocene (Recent) Series

The Pleistocene epoch was the time of the glacial advances and retreats, from about 2.5 million to 10,000 years ago. None of the Pleistocene glaciers or their melt-water deposits came into Florida, but Florida was greatly affected by fluctuating sea levels during this epoch. Because of the uncertainty about whether all the marine terraces of Florida represent Pleistocene shorelines and associated dune systems (e.g., the Brooksville Ridge), or whether all but the lower three terraces are older than Pleistocene, it is difficult to delineate Pleistocene deposits today. At least some of the sand and clayey sand deposits on the higher terraces and shorelines (such as the Wicomico, including the Brooksville Ridge) may be Pleistocene sediments. Brooks (1981) mapped Pleistocene sand dunes in the Western Valley to the east of the Tsala Apopka Plain and north of Lake Panasoffkee, and in portions of the Gulf Coastal Lowlands in Pasco, Hernando, and southern Citrus Counties. Localized examples of Pleistocene fossils (including land vertebrates and marine and nonmarine invertebrates) occur throughout most of our study region.

The Holocene epoch began about 10,000 to 12,000 years ago and continues today. Holocene deposits in our study region include thin sand and gravel deposits that are mostly adjacent to present-day streams, and dune, estuarine, and lagoonal sediments next to the modern coast. Holocene deposits also include residual materials from the weathering of older sediments and local windblown sediments (Miller 1986). Brooks (1981) did not map Holocene deposits in our region.

2.4 Marine Geology

The Springs Coast comprises about 193 km of the west coast of Florida and includes the coastal portions of Levy, Citrus, Hernando, and Pasco Counties. This portion of the Florida coast is often termed the "zero energy" coast (Tanner 1960) because of the extremely low energy levels found here, with a mean annual wave height of 30 cm and a spring tidal range of 90 cm (Hine and Belknap 1986). The major reasons for the low-energy conditions are (1) weaker and less common extratropical storms; (2) the dominant storm winds from the north and east, making them offshore winds on this coast; (3) the wide, low-gradient adjacent Continental Shelf, protecting the coast from any large waves formed in the Gulf of Mexico; and (4) the small fetch of the Gulf of Mexico (Hine and Belknap 1986).

A complex area of salt marsh, mangrove swamp, and oyster reefs with little to no natural sand accumulations, this portion of the Florida coast has seen far less real estate development than other parts of the Florida coast. The only natural sandy beaches in the study area are located on Seahorse and Cedar Keys; however, several artificial beaches, such as those at Pine Island-Bayport in Hernando County and at Hudson and Floramar in Pasco County, are present. These beaches are small, only 60–610 m long and 9 m wide, and need periodic nourishment (Bruun et al. 1962). Several dredge-and-fill developments are also present along the coast in the study area.

South from the Suwannee River, the marsh coast is cut by numerous tidal creeks and extends into a wide expanse of swamp with flooded topographic highs, producing numerous isolated islands with elevations of up to 4.5 m. The highest elevations along the coast in this area are found on the islands in the Cedar Keys group. Seahorse Key rises to 15.8 m. Many of the islands have a mangrove fringe that protects them from erosion. South from Cedar Keys many communities are located in areas where elevations are less than 3 m or even 1.5 m in many places. These low elevations make most of the coastal portions of Levy, Citrus, Hernando, and Pasco Counties unsuitable for development, as they are prone to flooding during even a moderate storm event (Doyle 1984).

2.4.1 Regional Marine Geology

Beginning in the lower Cretaceous and continuing on up through late Oligocene time, the Florida platform was the site of continuous carbonate deposition (McKinney 1984). This formed a low-gradient carbonate platform separated by the Suwannee Channel from terrigenous clastic input from the Appalachians via the Apalachicola River (Chen 1965).

Extensive amounts of clastic material were deposited as shore-parallel beach ridges during subsequent high stands of sea level during the Miocene and Pliocene and several fluctuations in the Pleistocene (Cooke 1945; Alt and Brooks 1965) (Figs. 3 and 6). The Pleistocene shoreline at 7.6–9.1 m above present sea level is believed to have been occupied repeatedly and may represent the predominant interglacial stand of sea level (Alt and Brooks 1965). The terrace formed at this elevation is called the Pamlico Terrace (Cooke 1945) and is present in Levy County and along the coast in Citrus, Hernando, and Pasco Counties at elevations of 2.4–7.6 m above present sea level (Healy 1975a). This terrace is the best developed landform feature because it has been the least modified by erosion (Healy 1975a). The Pamlico Terrace has its eastern edge at the Brooksville Ridge (Fig. 6), while to the west the terrace extends into the Gulf of Mexico to a submerged scarp at about 18.3 m below sea level (Wetterhall 1964). This submerged portion of the terrace is pocked by sinkholes and springs which retain many of the features of those found on land. A northward-flowing longshore current has filled in many of these sinkholes and sluggish springs with sand, but they can be seen from the air as subrounded areas of different color or texture on the gulf bottom (Wetterhall 1964).

The sand deposited during these Pleistocene high stands of sea level was deposited well inland of the present coastline (Fig. 7). Because there is no transport of this material westward to the gulf, this portion of the coast is sediment starved, and the bedrock topography is the main factor controlling the shoreline (Hutton et al. 1984). These sandy terraces are located closer to shore farther south. The sand from these terraces is transported to the gulf, helping in the formation of the barrier islands in northern Pinellas County (Hutton et al. 1984).

The landform development in the region is controlled by several factors, according to Vernon (1951) these are (1) a warm, humid climate with a high annual rainfall; (2) a bedrock composed of carbonates easily soluble in freshwater but highly resistant to marine erosion; (3) low surface elevations; (4) flat to gently dipping porous rock covered by limited porous sand and phosphatic beds; (5) heavily charged phosphoric, humic, and carbonic acid waters; (6) fracturing along the crest of the Ocala Uplift; and (7) certain ground-water conditions.

The study area is underlain by a thick section of Eocene, Oligocene, and Miocene limestones. The upper few hundred feet of this section forms a gross hydrologic unit called the Floridan aquifer, which supplies almost all the freshwater to the area (Wetterhall 1964). These limestones are near the surface and exposed around the axis of the Ocala Uplift, which is a broad flexure of these limestones of uncertain origin (Vernon 1951; Winston 1976). The axis of the Ocala Uplift trends northwest-southeast; its crest is located in Citrus County (Vernon 1951). This feature controls the outcrop pattern of the rocks in this area, with older rocks to the north (the oldest exposed rocks in Florida are Eocene in age and located in Levy County) and younger rocks to the south and southwest (Deuerling and MacGill 1981). The Ocala Uplift caused a regional northwest-southeast trending fracture system to develop, with faulting along its crest and flanks (Yon and Hendry 1972) establishing a secondary northeast-southwest fracture system (Vernon 1951). These fracture systems have served as loci of surficial karst topography through the solution of the underlying limestone, leading to the highly irregular limestone bedrock topography found underlying the study area today (Hutton et al. 1984).

The larger rivers—the Waccasassa and Withlacoochee, as well as the Suwannee at the northern border of the Springs Coast—and smaller streams and creeks in the study area carry no sediment other than fine muds and dissolved solids to the Gulf of Mexico (Vernon 1951). During floods the Suwannee River does carry fine to medium sand reworked along the river banks and deposited as sand bars along the flood plain. Some of this sand reaches the mouth, but the majority of sediments deposited at the mouth and into the gulf are muds and dissolved solids that precipitate as the river mixes with salt water (Vernon 1951). The reason for this lack of sediment load is that the rivers and streams cut through carbonate rocks with only a thin veneer of clastic cover.

The Withlacoochee River is the largest in the study area and discharges at the apex of a minor salient in the coastline (White 1958). The lower reach of the river seems to have escaped from its former longer route parallel to the coast via the valley of what was once a coast-perpendicular stream (White 1958). West of the Brooksville ridge streams tend to run perpendicular to the coast (Fig. 1) because the land surface there was formed essentially by simple emergence of the sea bottom. No structural features, such as the offshore bars or beach ridges, interpose there, because there are no large accumulations of sand (White 1958). The Withlacoochee River valley seems to have formed originally as a lagoon behind an offshore bar at the level of the Okefenokee Terrace, 45.7 m above present sea level (MacNeil 1949). It has only lately acquired its present course through the Brooksville Ridge as a result of solution (White 1958).

The Waccasassa River reaches the coast at the head of a bay, Waccasassa Bay. The river is believed to have been an outlet for a much larger drainage area than it now possesses (White 1958) and now drains a broad area of delta plain (Vernon 1951), which extends nearly to its headwaters and in which the limestone is buried by a thin layer of fluvial sediments (White 1958).

The other smaller rivers and streams in the study area, such as the Crystal, Halls, Homosassa, Wecki Wachee, Mud, and Pithlachascotee Rivers all flow over and drain a predominantly carbonate terrain. As a result, these rivers carry very little, if any, sediment to the gulf, and all have drowned and marshy mouths.

2.4.2 Local Marine Geology

This complex portion of the Florida coast is one of the least studied areas in Florida, there having been only one extensive study of the geologic history and marine geology here. This study, conducted by Hine and Belknap (1986), covered the coastal areas of Citrus, Hernando, and Pasco Counties. From this study they found that the area could be divided into four coastal sectors (Fig. 8). Although Levy County was not included in their study, the sectors discussed below can be extended northward to include those portions of Levy County that resemble the Hine and Belknap coastal sectors. The remainder of this discussion is based on the Hine and Belknap study.

The first sector Hine and Belknap discuss is their Berm-Ridge Marsh sector, which is found in the southern portion of the study area (Fig. 8). This area lies closest to the ancient Pleistocene relict-shoreline deposits located a few miles inland, but is still far enough away from these sand deposits so that no barrier islands or sandy beaches could form as they did in northern Pinellas County, which has direct access to these deposits. Because of this proximity to these deposits and reduced influence of the bedrock topography which increases to the north, however, this area of the marsh coast is the least irregular. It is essentially a slowly eroding marsh dominated by *Juncus roemerianus* and supports a narrow sandy beach and berm-ridge at the marsh-water interface. A core through this sandy layer, which is only about 50 cm or less in thickness, reveals an organic-rich, rooted mud-marsh deposit up to 1 m thick underlying the sand. This mud in turn overlies an irregular limestone weathering residuum up to 1 m thick. The berm-ridge shoreline thins seaward as a result of nearshore erosion. Offshore of the berm-ridge shoreline, no more than 1 m of the marsh deposits—beneath 10–30 cm of muddy, carbonate or quartz sand—are preserved.

Hine and Belknap found a series of tidal creeks criss-crossing this berm-ridge and marsh system. The creeks are controlled by the underlying bedrock topography and provide the drainage for the interior. They started out as small ponds formed from solution of the limestone. As sea level rose, these ponds connected, forming the meandering tidal creeks. Also present in this system are a large number of hammocks, which are areas of topographic highs that support a thin, sandy soil with less salt-tolerant trees and shrubs.

Farther north, the berm-ridge marsh coast grades into the Marsh Peninsula portion of this coast (Fig. 8). Hine and Belknap describe this portion of the coast as being more irregular due to the absence of sand cover and the increased influence of the underlying bedrock topography. The marsh peninsulas, points of land, promontories, or marsh headlands are more common here and represent rock outcroppings stranded as sea level rose. The same sort of deposits as found in the berm-ridge marsh sector are found here. However, the sand cover becomes thinner and less continuous.

Continuing northward, we find the two most complex portions of the marsh coast, according to Hine and Belknap. The first of these are their Shelf Embayment sectors (Fig. 8), which are microtidal, low-wave energy, freshwater influenced shallow depositional basins. These shelf estuarine systems are rimmed by marshes and have been formed by long-term exposure to mixed salt and fresh waters, causing a lowering of the bedrock surface. The embayments are all associated with large springs or rivers, the magnitude and duration of whose freshwater flow determines their size. In Hine and Belknap's study area, these embayments include the Bayport embayment at the mouth of the Weeki Wachee and Mud Rivers, Chassahowitzka Bay, Homosassa Bay, and Crystal Bay. Withlacoochee Bay, Waccasassa Bay, and Suwannee Sound in Levy County would most likely fall into the shelf embayment category, but further study in this area is needed to see if these embayments display the same types of characteristics

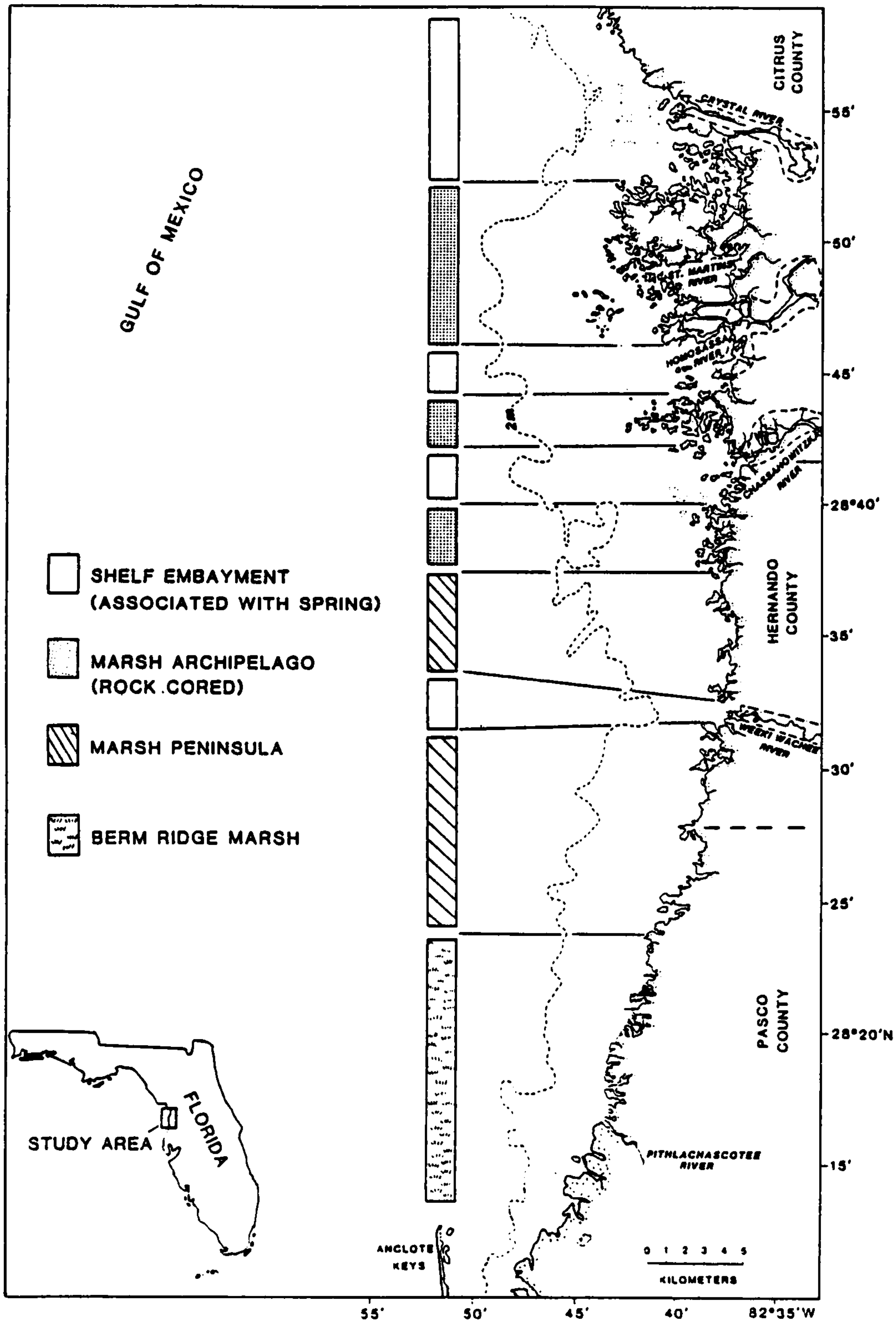


Figure 8. Distribution of the four main morphologic sectors in Citrus, Hernando, and Pasco Counties (Hine and Belknap 1986).

found by Hine and Belknap farther south. Narrow channels extending seaward under water represent the river beds during lower stands of sea level. Seaward of the rivers, such as Homosassa River, a single row of sinkholes may be found aligned with these channels within the shelf embayment. Offshore, a number of springs are present, indicating that subterranean karstification is still going on.

Hine and Belknap divide their shelf embayment into two sections, a nearshore section and an inner shelf section. The nearshore section includes the marshes, oyster bioherms, and interbioherm lows, while the inner shelf consists of the area seaward of the oyster bioherms. The division of these two sections is one of wave energy caused by the shore-parallel orientation of the oyster reefs.

Six sedimentary environments were found in the shelf embayment system, these include (1) a limestone weathering zone; (2) Pleistocene and eolian sands; (3) marsh consisting of peat and peaty muds; (4) interbioherm lows consisting of muddy, shelly sands; (5) oyster bioherms consisting of the shells of *Crassostrea virginica*; and (6) an inner shelf environment consisting of poorly sorted quartz and carbonate sands.

The oyster reefs in the embayments were found to flourish seaward in response to higher freshwater flow. The reefs are associated with bedrock highs and accumulate vertically with sea-level rise. The oysters nucleate on local rocky knobs or drowned hammocks and extend laterally into coast-parallel features.

The final and most complex of the sectors discussed by Hine and Belknap is their Marsh Archipelago sector (Fig. 8). These are areas of partially drowned and exposed karstic bedrock with numerous rock-cored marsh islands separated by tidal creeks. They found that these areas were so complex because of several factors: (1) the age, lithology, and diagenetic history of the bedrock; (2) the degree of fracturing in the bedrock; (3) the volume of the freshwater discharge; (4) lack of quartz sand veneer; and (5) vegetative cover.

The marsh archipelagos are found bounding the shelf embayments and are located just south of Chassahowitzka Bay, at Chassahowitzka Point between Homosassa and Chassahowitzka Bay, and—the largest one—at Ozello. Outside of Hine and Belknap's study area in Levy County, Turtle Creek Point between Withlacoochee and Waccasassa Bays most probably represents this type of coast. Cedar Keys may also represent this type of coast in part, but other things that will be discussed later also affect this area. Again, further study in Levy County and areas farther north is needed in order to better characterize these areas.

Hine and Belknap found the marsh archipelago sector to be divided into three subenvironments: (1) a westward mangrove swamp, (2) an eastward salt marsh, and (3) a north-south trending belt of hardwood hammocks. Overall, the marsh archipelago is an area of regionally elevated bedrock located between the lower shelf embayments. The reason for the elevated conditions is that the archipelagos are outside the influence of the freshwater from the rivers and springs that lead to the lowering of the shelf embayments.

The controlling factor in this sector and the entire Springs Coast is the development of karst in the underlying bedrock. Hine and Belknap discuss three orders of karst development present in the study area. First-order karst operates on a regional scale, with fracturing and solution of the carbonate strata forming the major features of the area. Second-order karst then relates to the solution and modification of first-order features through corrosion by acid ground water and other factors. Finally, third-order karst is local, small-scale solution as a result of plant roots and other biological, chemical, biochemical, and physical degradation. Figure 9 displays the order of events leading to the type of features found in the study area. Where fractures are more numerous, undersaturated ground waters dissolve more material creating more topographic irregularities on the surface and voids in the subsurface, which collapse to form surface low areas. The low areas accumulate acid-forming marsh sediments, which enhances the process. The final diagram shows the modern distribution of hammocks, marshes, and tidal creeks.

As stated earlier, Cedar Keys may represent a marsh archipelago-type section of the coast, as it is

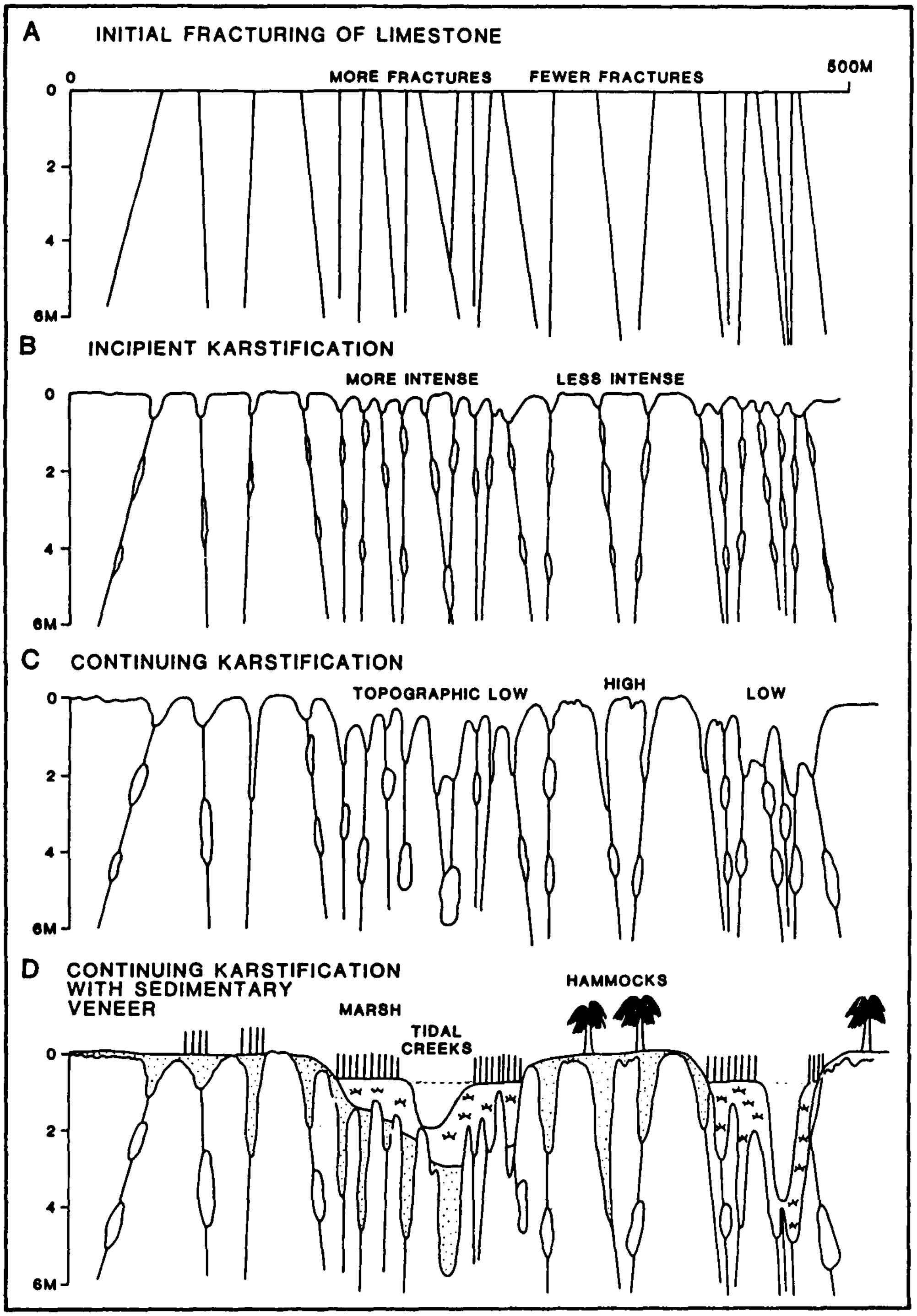


Figure 9. Diagrams showing the evolutionary stages of karstification (Hine and Belknap 1986).

situated on a topographically high area between Waccasassa Bay and Suwannee Sound, and many of the islands are composed of limestone. The keys do differ from the marsh archipelago coast in that many of the islands are composed of quartz sand (Vernon 1951) and have natural sandy beaches. The sand for the islands at Cedar Keys was supplied from a beach that existed at a time when sea level was much lower. These islands were once dunes formed by winds blowing the sand landward from this ancient beach. As sea level rose, these dunes were partially submerged and modified into their present state by wave and tidal action (White 1970). Sand shoals that are several meters in relief and come within 50 cm of the sea surface at low tide have also been found well offshore of Hernando County in the St. Martins Reef vicinity (Hine and Belknap 1986). Dune fields are also found a short distance inland in Hernando and Pasco Counties (White 1970) (Fig. 3) and, where found, form an important local supply of sand and provide higher elevations that help prevent coastal flooding.

2.5 Economic Geology

The geologic deposits of our study region are economically valuable in many ways. The useful commodities include limestone, dolomite, phosphate, sand, clayey sand, and a small amount of peat (Vernon 1951; Knapp 1978; Deuerling and MacGill 1981).

Much of our region has large reserves of high-quality limestone and dolomite, and all of the counties in our region where limestone is exposed have had limestone quarrying (open pit) operations. Most of the limestone is mined from the Avon Park Limestone, the Ocala Group Limestones (Williston and Crystal River Formations), and the Suwannee Limestones. Some of the limestone found in the Crystal River Formation is over 99.5% calcium carbonate (Deuerling and MacGill 1981). Most of the mined limestone is used as road-base material, and many small quarries are adjacent to major highways. Other uses include cement aggregate, soil conditioners, asphalt filler material, solvents and neutralizers, erosion control structures (rip-rap), and as a basic ingredient of Portland cement. The dolomite in our region, which contains about 36% magnesium carbonate (Vernon 1951), is used primarily as a soil conditioner. Quarrying of limestones and dolomites is usually by the use of draglines and occasionally by blasting (such as in the Suwannee Limestone, which has interbedded hard and soft layers and requires blasting to shatter the quarry face).

Sand and clayey sand are abundant in our region, particularly near the coast and on the Brooksville Ridge. These sediments are mined in many areas and used for construction purposes, fill material, road base materials, and in asphalt production. Clay, present as fuller's earth, is mined in some areas for use as absorbents and in other products.

Phosphate occurs as hard-rock phosphate, soft-rock phosphate, and land-pebble phosphate. Hard-rock phosphate deposits in our region are part of a linear belt called the Hardrock Phosphate District, which extends from eastern Hernando County northward through Citrus, Levy, Marion, Gilchrist, and Suwannee Counties. Hard-rock deposits consist of boulders; pebbles; and small grains of phosphate, clay, sand, chert, and silicified limestone lying upon a limestone surface, which is irregular due to solution (Vernon 1951). No hard-rock phosphate is being mined in our region today, but it was mined extensively between 1883 and 1966 (Deuerling and MacGill 1981). Quartz sand and a tan-to-gray soft phosphatic clay known as soft phosphate were separated as waste products during the process of washing hard-rock phosphate (Vernon 1943). The separated waste clay and sand were discharged to settling areas from which the clay is available for later recovery. Soft-rock phosphate is now being recovered from old settling areas in the Withlacoochee State Forest, and is being used for direct application to soil and, if the fluorine content is low enough, as an animal dietary supplement.

Land-pebble phosphate is found in a large area known as the Central Florida Phosphate District and is mined from the Bone Valley, Hawthorne, and Alachua Formations. This phosphate occurs as particles ranging from clay size to pebbles over an inch in diameter. Florida phosphate production in 1978 supplied over 80% of the national output and 30% of the world's output (Sweeney and Windham 1979). Most of the phosphate is used in the production of fertilizer. Phosphate is also an ingredient of detergents, water softeners, and metal polishes (Deuerling and MacGill 1981). Uranium is also separated as a by-product of phosphate production (Sweeney and Windham 1979).

Peat from Holocene-age deposits is being mined in small boggy areas in Sumter County. Mining is accomplished by clearing the surface of vegetation, pumping to dewater the peat, then excavating the peat by dragline. All of the peat produced from these areas is utilized for horticultural purposes such as landscaping and potting soils.

No oil or gas has been produced from any of the exploratory wells in this region.

2.6 Important Natural Geologic Sites

Geologic features, in and of themselves, are as much a part of our natural heritage as the biotic communities which they underlie and help determine. Geologists customarily travel to human-created sites such as quarries and road cuts to observe exposed strata and fossils. But other natural features are obviously of great interest as well. Knapp (1978) and Deuerling and MacGill (1981) discussed outcrops of interest in our study region, focusing on stream cuts and river beds as well as mined areas. White (1981) discussed a number of potential Geological Natural Landmarks in Florida. These sites are natural in origin, but unfortunately all have been degraded to various extents by human activities. The following is mostly a condensation of White's (1981) descriptions of the Natural Landmark sites proposed for our study region.

2.6.1 Chassahowitzka Springs

Located in southwestern Citrus County by the town of Chassahowitzka, Chassahowitzka Springs is a large spring complex with an average discharge of 201 X 10^6 L per day, comprising a cluster of large springs separated enough to have branching spring runs. Like all the springs in the region, water from the Floridan aquifer is discharged. They are located at the eastern edge of the Gulf Coastal Swamps subregion of the Gulf Coastal Lowlands, at the foot of a zone of relict coastal dunes of probable Pamlico age. While the environs below the springs have not yet been heavily developed, there is considerable development at the springs themselves.

2.6.2 Homosassa Springs

Located in Citrus County at the southern edge of the town of Homosassa Springs, Homosassa Springs is a developed tourist facility but a good example of a very large Florida spring. Its flow is 326 X 10^6 L per day, emanating visibly from solution-enlarged fissures in Eocene limestone bedrock (Ocala Group). The head pool is some 24 m wide, and one of the fissures has been measured at 13.3 m in depth.

2.6.3 Weeki Wachee Springs

Located in Hernando County 21 km west of the city of Brooksville, this very large spring has been developed into a commercial attraction. There is also some development on the lower part of the river, much of it on canals off the river itself. Like Chassahowitzka and Homosassa Springs, Weeki Wachee Springs lies along the western edge of a zone of relict coastal dunes that were apparently deposited at the Pamlico or Talbot shoreline when sea level was 9 to 12 m higher than it is today. The springs have a headpool some 45 m in diameter, with a bottom sloping downward to a depth of about 4 m, below which it drops precipitously to 15 m. The deeper cavity is about 15 m wide. Thus, the spring may be a relict funnel-shaped sink that received surface drainage during low glacial sea levels and is now discharging artesian water during the present period of higher sea level. The springs discharge up to 428 X 10^6 L per day (Yobbi 1983).

2.6.4 Chunky Pond

Located in Levy County just south of the town of Bronson, Chunky Pond is a series of small lakes and ponds at the foot of a relict marine-terrace (probably Wicomico) scarp where soluble limestone underlies the insoluble shoreline sands at the western edge of the Brooksville Ridge. The slope of the water table steepens behind the face of the scarp with the increased gradient of water flow, bringing the water table closer to the ground surface immediately below the scarp. The increased water flow tends to dissolve the buried surface of the limestone, creating sag ponds along the toe of the scarp. The scarp is of interest in itself as an example of a relict marine shoreline formed by extensive shoreline erosion at the crest of a marine transgression.

2.6.5 Diffluence of the Withlacoochee River, and Lake Tsala Apopka

Whereas most fluvial diffluences result from aggradation, as in deltas built of fluvial sediment or upgrowth of peat, the diffluence of the upper Withlacoochee River into the Hillsborough and lower Withlacoochee Rivers apparently results from a reversal of flow direction in the present lower Withlacoochee River caused by stream piracy. The present Hillsborough River was probably the ancestral trunk stream with two major tributaries: the present upper Withlacoochee and a smaller stream arising in Rainbow (Blue) Springs and flowing southward along the present Blue Spring River into the larger ancestral Lake Tsala Apopka (see physiographic description, above, of the Tsala Apopka Plain). Apparently this stream system was disrupted by leakage of lake water through cavernous openings in the limestone of the Brooksville Ridge, at the present Dunnellon Gap near the town of Inglis. This new outlet drained the ancestral Lake Tsala Apopka and reversed the flow of the north branch of the ancestral river from southward to northward.

2.7 Problems Affecting the Coast

The three most important factors affecting the coast in the study area are sea-level rise, anthropogenic impacts, and severe storms such as hurricanes. It is a fact that sea level is rising. The rate at which it is rising, however, is the subject of much debate at present. Scholl et al. (1969) have shown that sea level has risen 40 cm/1000 years for the past 3,000 years. This equals a landward retreat of the shoreline of 2.7 km/1,000 years (Hine and Belknap 1986). Data indicate that sea level is rising much more rapidly today than it was in the past few thousand years. An 8.2-cm rise in sea level for the period from 1914 to 1980 is seen in the tide gauge records at Cedar Keys (Hicks et al. 1983). A sea-level rise of 4.8–17.1 cm by the year 2000 and 56–345 cm by the year 2100 has been demonstrated to be a very good possibility (Titus et al. 1984). More recent estimates suggest a rise of 70–100 cm within the next 100 years (Hine and Belknap 1986).

The cause for this expected acceleration in the rate of sea-level rise is the greenhouse effect. Increasing concentrations of carbon dioxide and other gases due to the combustion of fossil fuels; deforestation; cement manufacture; and the release of chlorofluorocarbons from refrigerants, propellants, and other sources are expected to warm the Earth several degrees in the next century. This warming could cause sea-level rise by expanding ocean water, melting mountain glaciers, and eventually, melting substantial portions of the polar icecaps.

If sea level does rise the expected 70–100 cm, the effects on this low-gradient portion of the Florida coast would be drastic. Hine and Belknap (1986), using a sea-level rise of 180 cm by the year 2100, show in Figs. 10 and 11 what would happen to the coastline. From this it is evident that much of the coast could be submerged by the year 2100. The coastal towns of Port Richey, Hudson, Aripeka, Chassahowitzka, Paradise Point, Homosassa, Crystal River, Ozello, Pine Island, and Bayonet Point may all be under water, leaving Bayport a small island surrounded by water (Hine and Belknap 1986).

With sea-level rise and landward retreat of the shoreline, this portion of the coast will be exposed to a sand source as it approaches the Brooksville Ridge (Fig. 5). Hine and Belknap (1986) propose that this exposure to a new source of sand would initiate the formation of a beach, with straightening of the shoreline occurring as the sand cover subdues the underlying limestone bedrock surface. In time, a low-energy

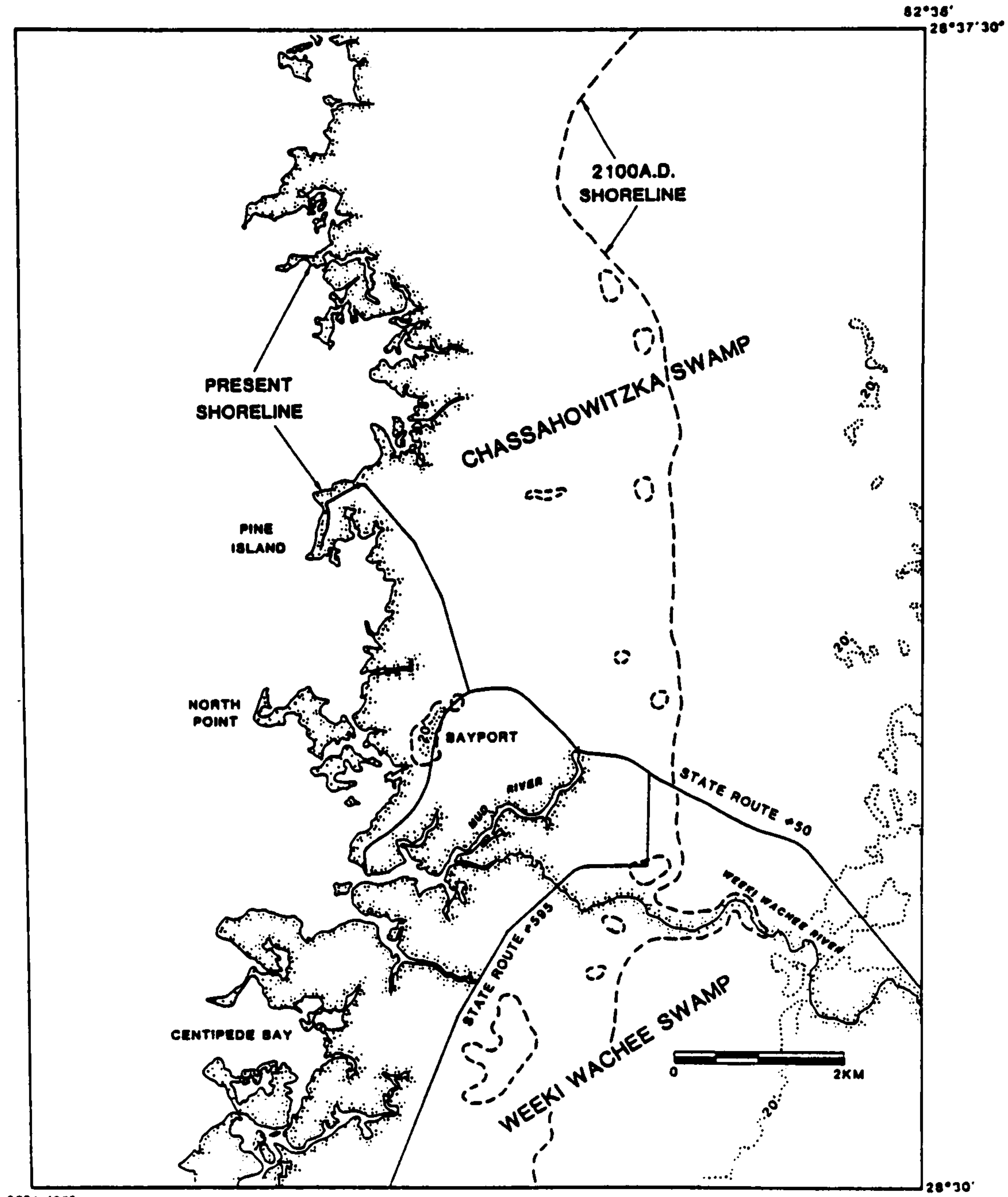


Figure 10. Present shoreline and a predicted shoreline in the year 2100 in the Bayport area of Hernando County, based on a 180-cm rise in sea level (Hine and Belknap 1986).

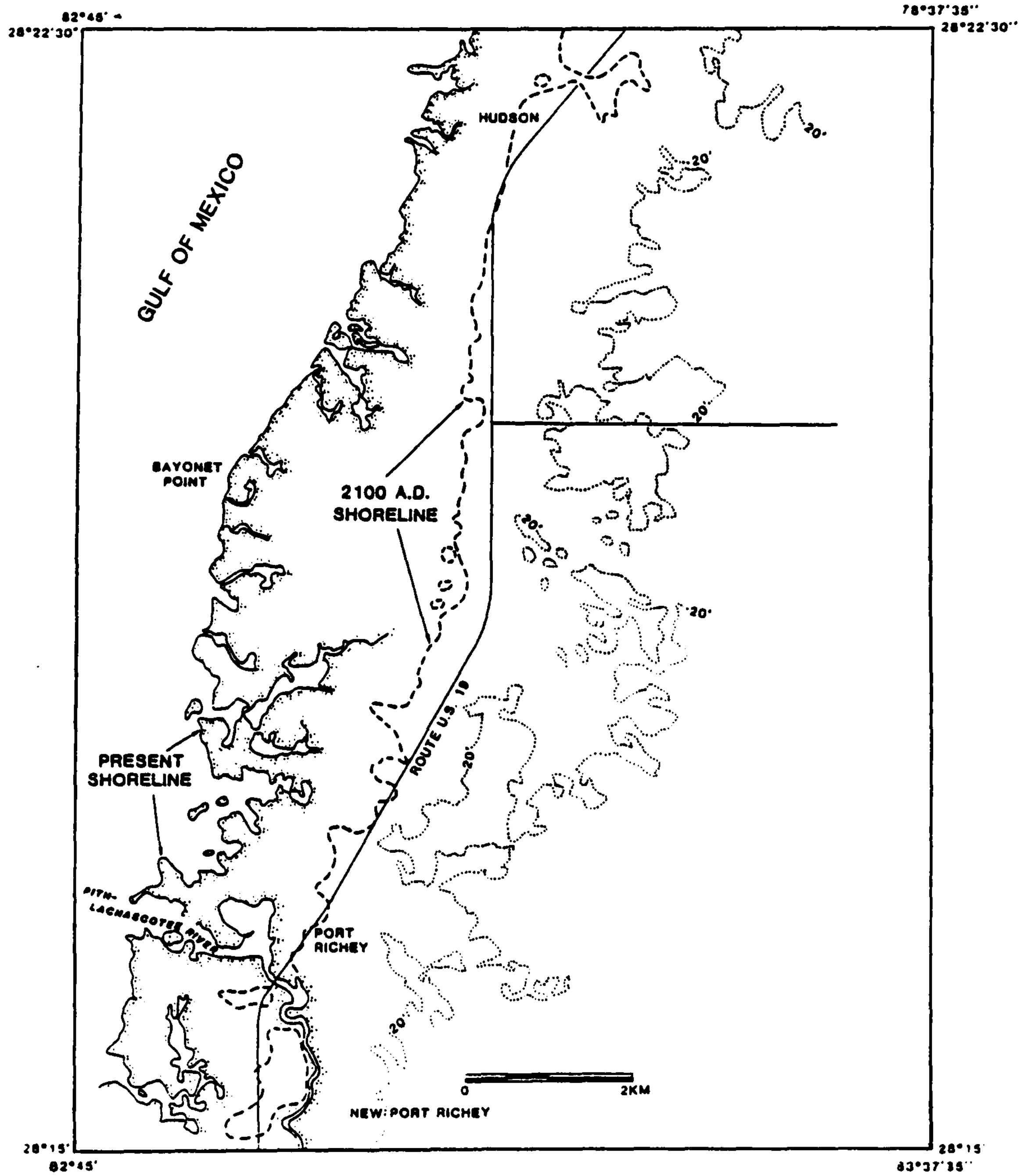


Figure 11. Present shoreline and a predicted shoreline in the year 2100 in the Bayonet Point area of Pasco County, based on a 180-cm rise in sea level (Hine and Belknap 1986).

barrier-island coast similar to that found in northern Pinellas County would develop. They also indicate that because of the extremely low sedimentation rates found in this area of the coast, the marshes are barely able to keep up with the present 1.24 mm/year rise in sea level and that any increase in this rate would lead to widespread marsh drowning.

Coastal erosion in the study area is slow as compared to other marsh areas in the United States because of the rock underpinnings nearshore. However, several marsh islands have completely disappeared in the period from 1944 to 1982 (Hine and Belknap 1986). The most exposed outer islands and areas exposed to boat traffic with resulting net increases in wave energy (such as at Shell Island at the mouth of the Crystal River) are the most prone to shoreline instability (Hine and Belknap 1986).

The U.S. Army Corps of Engineers (1971) indicate that no severe erosion occurs along the Springs Coast, with the exception of a few areas such as the beach at Pine Island-Bayport in Hernando County, which has been stabilized with groins, and at Seahorse Key in the Cedar Keys area of Levy County, where severe beach erosion is occurring. In areas where erosion is taking place, the rates are 33–58 cm/year (Hine and Belknap 1986).

Several dredge-and-fill developments are taking place along the coast in the study area. Hine and Belknap (1986) indicate that, where present, these dredge-and-fill operations equal or exceed natural processes as causes of shoreline change.

Severe storms such as hurricanes are probably the most important influences on the shoreline today. Sea-level rise and changes brought on by human activity take time to change the shoreline, but a single hurricane can have disastrous effects over one or two days. Because of the low gradient of this area and because most of the development is on areas of low elevation, a storm surge of 3–3.7 m during a hurricane would flood most of the study area. Most of the coastal portions of Levy, Citrus, Hernando, and Pasco Counties have elevations below 3 m and are the sites of developments or individual cottages and houses. Thus, storm-surge flooding is the main threat to this area (Doyle 1984).

Very little short-term coastal change is taking place along this portion of the Florida coast. Except for dredging activity or a severe storm causing flooding, the low energy conditions and protected nature of this marsh coast insure that it will change very little. The long-term changes as a result of sea-level rise and coastal subsidence from limestone solution are what coastal planners in this area of the Florida west coast should be concerned with as much of this low-lying coastal area begins to disappear under water.

Chapter 3. CLIMATE

by Steven H. Wolfe

3.1 Introduction

The Florida Springs Coast experiences a mild, subtropical climate as a result of its latitude (28°10'–29°20' 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. Gulf influence is strongest near the coast, weakening inland. Fairly detailed long-term climatological summaries are available only for sites just south and east of the Springs Coast (e.g., Ocala, Lakeland, Tampa) (Jordan 1973). More limited data are available for Cedar Key to the north and certain other Springs Coast locations where U.S. Weather Service stations collecting less complete data are located (Fig. 12).

3.2 Climatological Features

3.2.1 Temperature

The Springs Coast encompasses an area of substantial climatic difference. The annual average of the mean daily temperature is approximately 70 °F. Mean summer temperatures are in the low 80's, and mean winter temperatures are in the upper 50's. Annual and seasonal temperatures vary widely (Figs. 13 and 14) with summer highs generally in the low to mid 90's and infrequent occasions of 100° or higher. The summer heat is tempered by sea breezes along the coast and up to 50 km inland, as well as the 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 25–30 °F, with single-digit lows almost unknown. Temperatures rarely remain below freezing during the day anywhere within the region, and the cold weather from a front generally lasts only 2-3 days. Temperatures in the 60's and 70's °F often separate the cold fronts. This weather pattern results in average low temperatures near 50 °F during the coldest months (December through February).

3.2.2 Rainfall

The Florida Springs Coast receives rainfall from three types of systems: frontal, convective, and tropical cyclonic. The frontal systems dominate the winter rainfall; convective showers and thunderstorms are common during the remainder of the year. The tropical storms, including hurricanes, resulting from tropical cyclonic activity are more sporadic, and years frequently occur with no activity.

The region experiences two peak rainfall periods: a primary one during summer (June through September) and a secondary one during late winter and early spring (February through April) (Fig. 15). The Springs Coast lies in a transition zone between the annual patterns of two wet/two dry seasons of north Florida and one wet/one dry season of south Florida. This transition results from the weakening of winter cold fronts arriving from the north. Most of these fronts stall out before reaching south Florida, or are

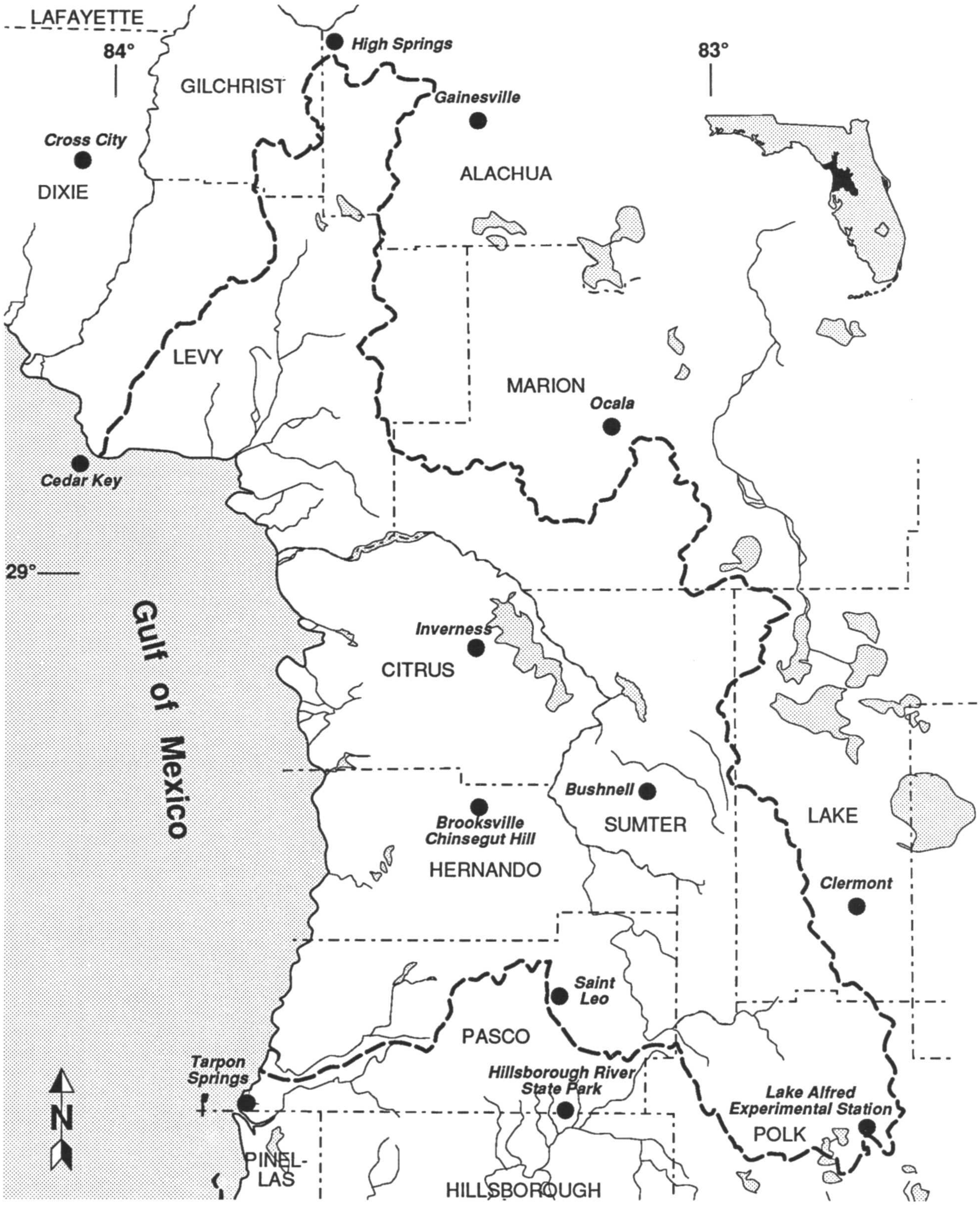


Figure 12. Locations of NOAA climatological stations near the Florida Springs Coast (after Jordan 1984).

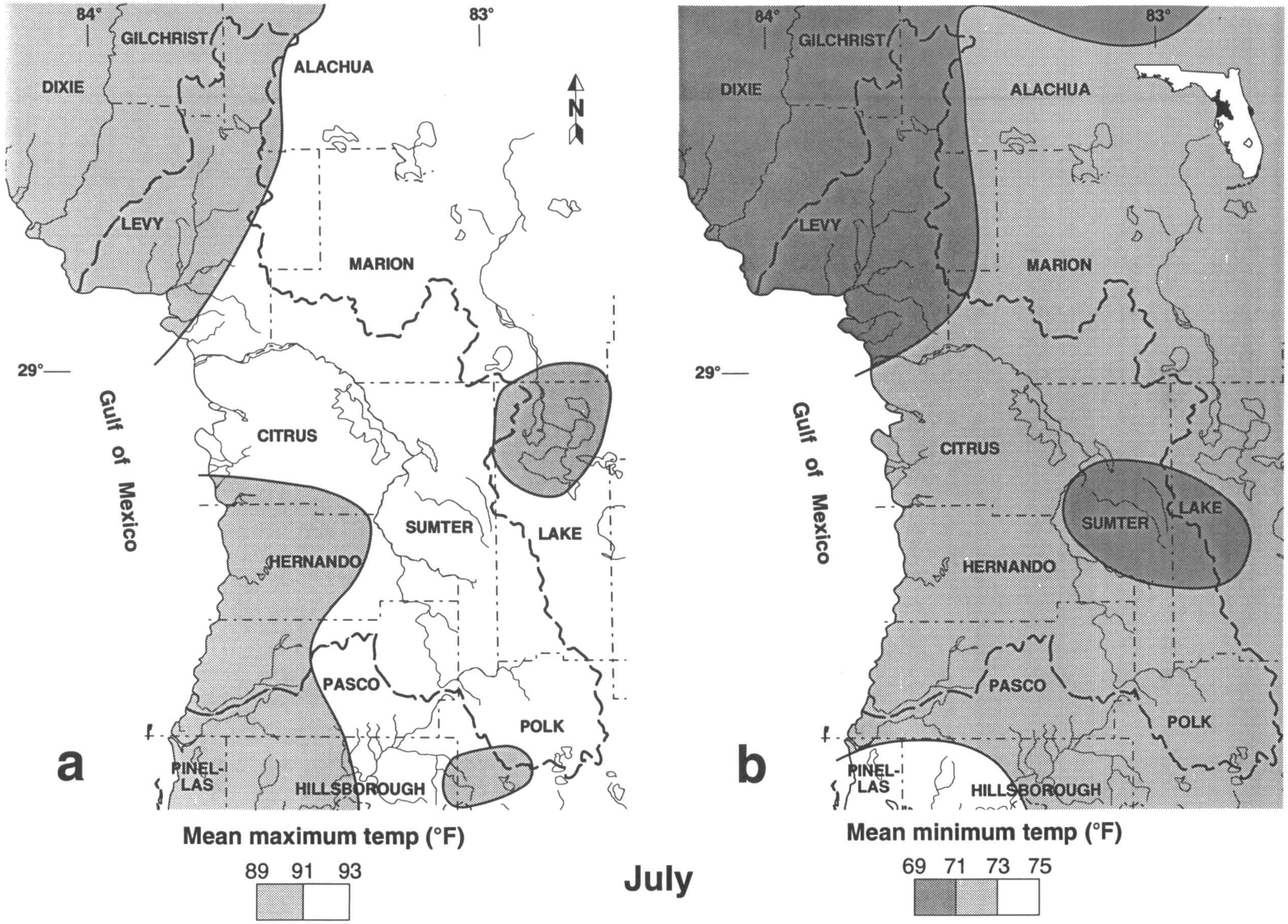


Figure 13. Isotherms for July temperatures in the Florida Springs Coast, 1959-1979 (after Fernald 1981).

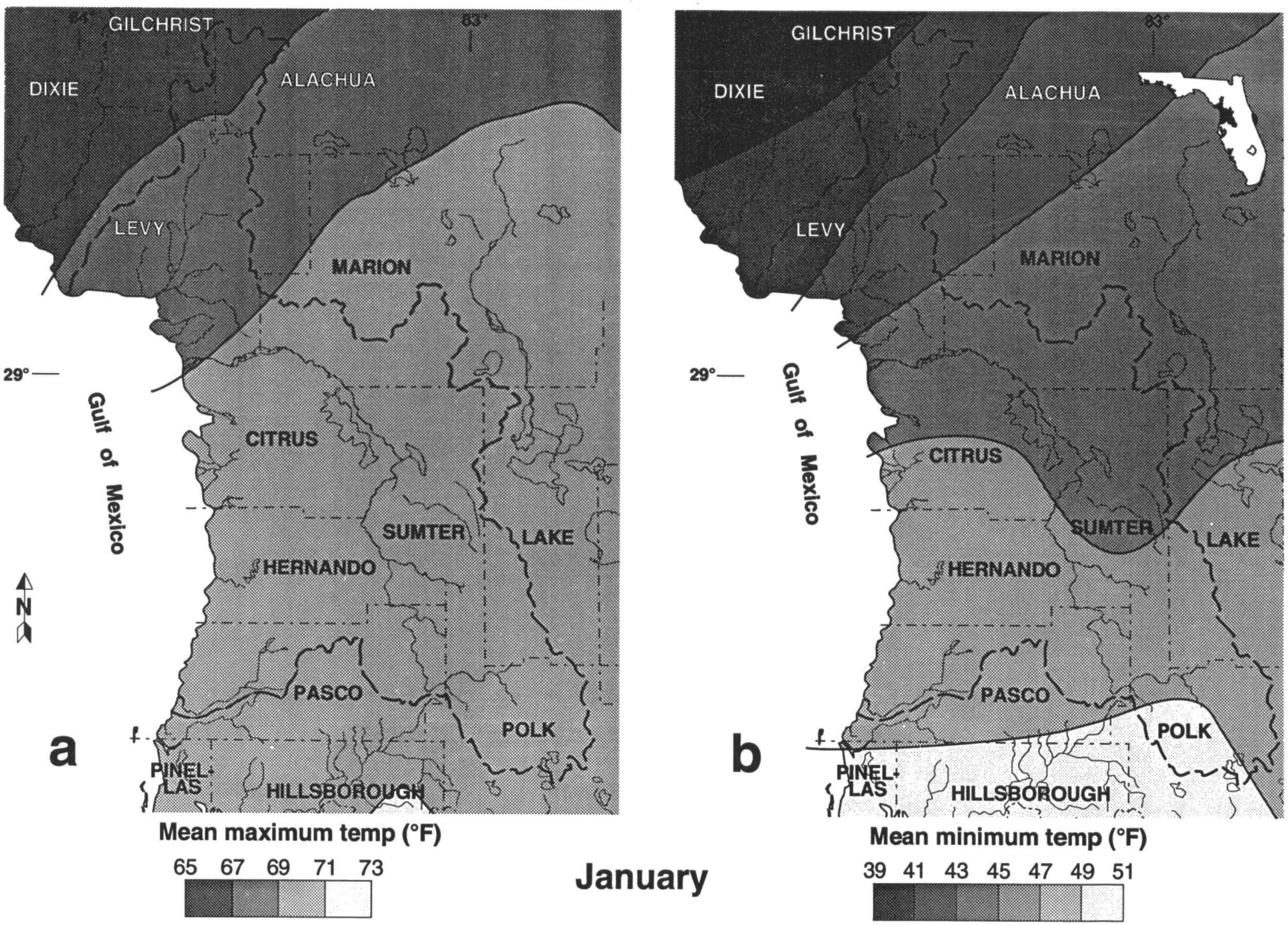


Figure 14. Isotherms for January temperatures in the Florida Springs Coast, 1959-1979 (after Fernald 1981).

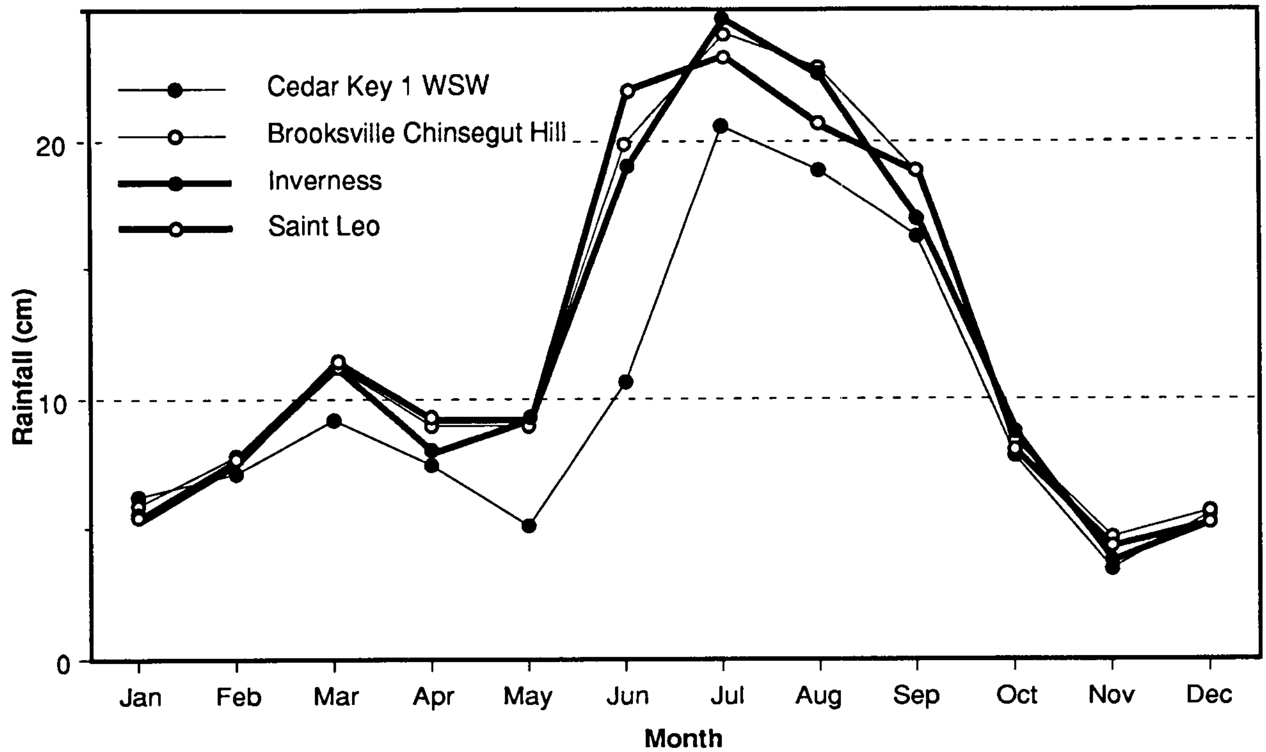


Figure 15. Seasonal rainfall variation at selected sites in the Florida Springs Coast (data from Bradley 1972).

"rained-out" and reach south Florida as dry fronts, resulting in cooler weather but little precipitation. As a result, the dry seasons and the secondary wet season are drier in the Springs Coast than to the north, but because of the greater convective heating in the south, the primary wet season is wetter (Fig. 15). Average annual rainfall across the Springs Coast is approximately 147 cm across the north of the region, decreasing to approximately 137 cm in the south (Jordan 1984) (Fig. 16). The average rainfall varies widely and has ranged in any single 12-month period since 1951 from less than 75 cm to 215 cm (Fig. 17). Maximum annual rainfall values tend to be about 40 inches above the annual mean (Jordan 1984). National Weather Service data compiled in Hafer and Palmer (1978) show that while the eastern Springs Coast edge can expect to receive the average rainfall in any given year, the rest can expect only a 40%–45% chance of receiving rainfall equal to or greater than the average annual precipitation. In other words, it is normal for the annual rainfall to be below average. The occasional very wet years, which result in the median rainfall values being significantly less than the mean values, are probably the result of tropical storm activity.

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 Tampa and with the results supported by corresponding studies at Apalachicola, 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

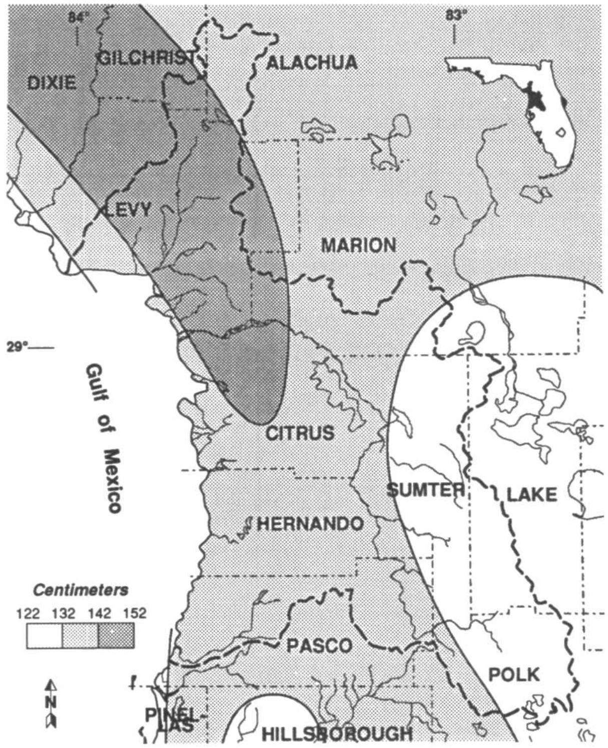


Figure 16. Average annual rainfall in the Florida Springs Coast, 1951–1980 (after Jordan 1984).

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. On the average in Tampa (the nearest site with available data), thunderstorms occur on 91% of days; 66% of the storms occur in the summer (June-September), while only 5% occur in winter (November-February).

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 that 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 beginning in the 1940's and ending in the 1970's demonstrate these different diurnal patterns of the summer and winter rains (Fig. 18). Few stations collected this data, so data from Orlando are presented, though it lies just outside the Springs Coast area. Snowfall occurs at rare intervals across the Springs Coast, approximately 1 year in 15 (U.S. Dept. of Commerce 1980a,b,c).

Despite large average annual rainfalls, droughts occur (Fig. 19). 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 increased 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 Springs Coast 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) (Fig. 20). 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 Fig. 20) changes substantially during spring and summer. From October through February, a western anticyclonic cell separates from the Bermuda anticyclone and establishes itself in the Gulf of Mexico (Fig. 20). 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 Springs Coast.

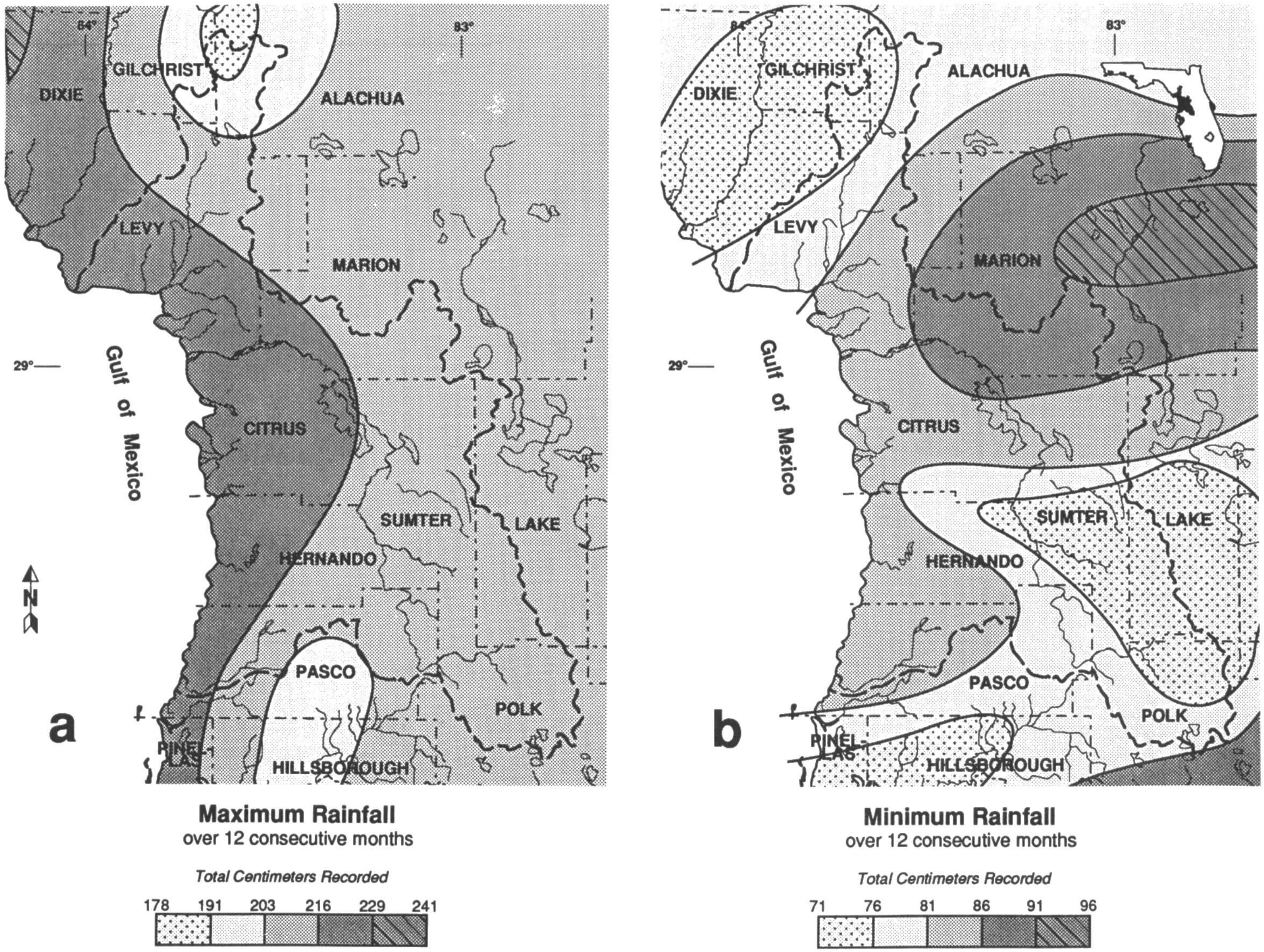


Figure 17. Springs Coast 12-month rainfall 1951-1980 (after Jordan 1984).

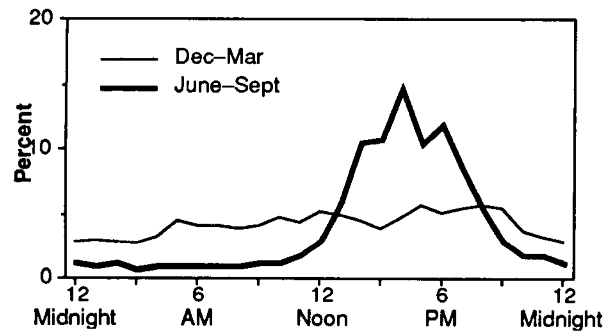


Figure 18. Percent of total daily rainfall during individual hours of the day at Orlando (after Jordan 1984).

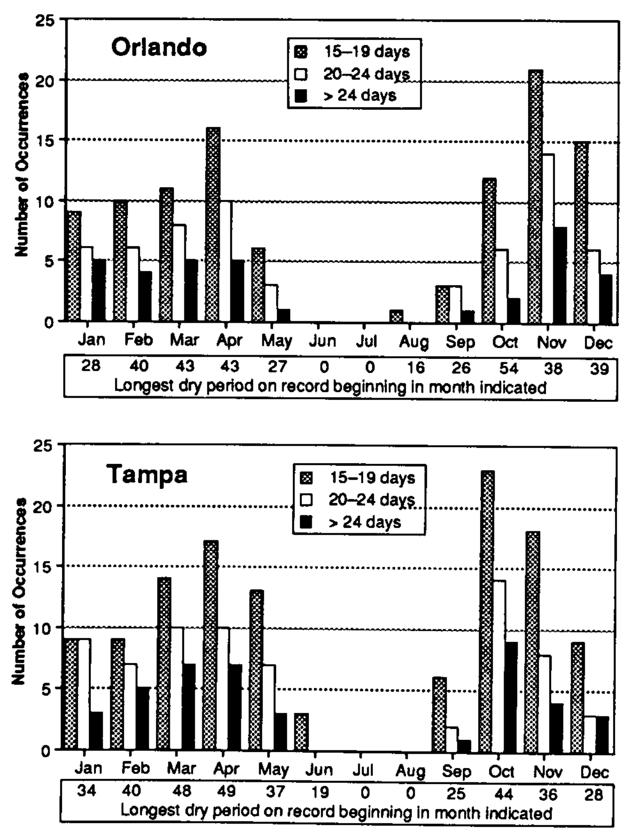
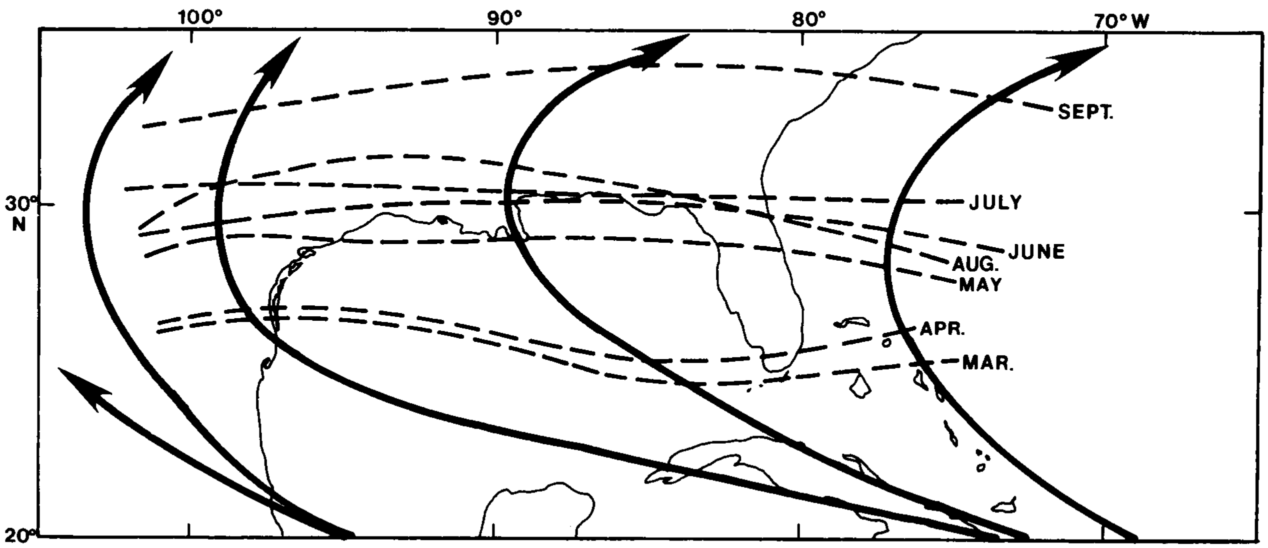


Figure 19. Occurrence of extended dry periods at Orlando and Tampa, 1950–1980 [no day over 0.25 cm] (after Jordan 1984).

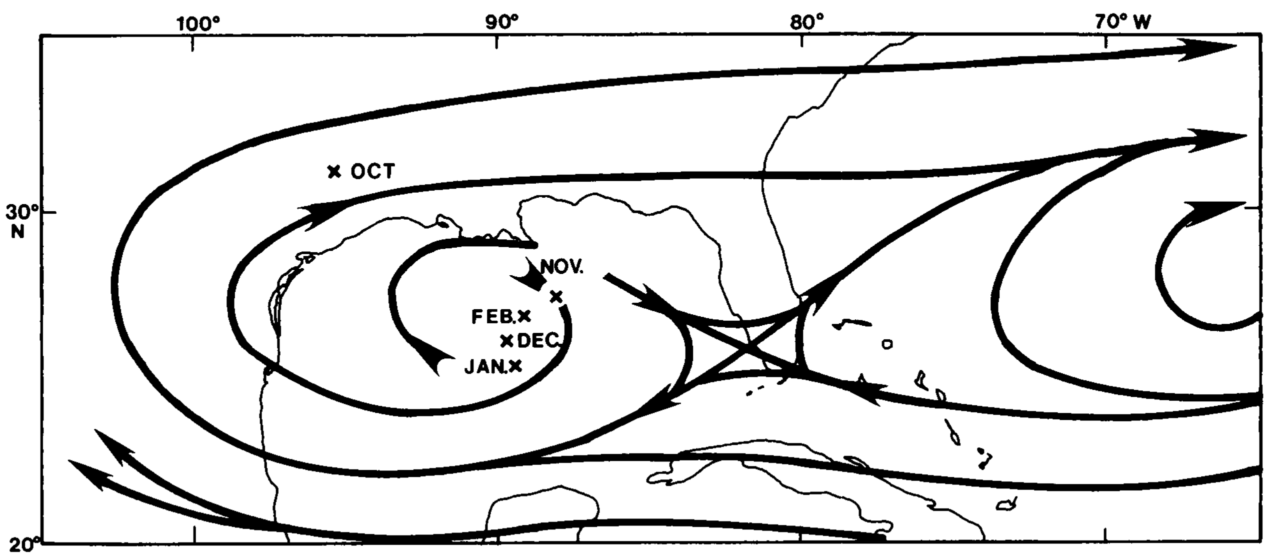
These circulatory patterns indicate that the Springs Coast is primarily influenced by tropical air masses in the spring and summer and by continental (cold) air masses during the fall and winter. The prevailing winds in the Florida Springs Coast are from a southerly direction during the spring and summer. Figure 21 shows seasonal windroses for Tampa, the nearest site collecting this information. Locally, wind directions may be determined by 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 from a southerly direction, rapidly changes direction with a clockwise progression ("clocks") through the west, then usually 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. As a result, the most prevalent winds from September through February (the season of frontal passages) are out of the northern half of the compass (following the fronts) with less frequent and weaker winds from the southern half of the compass (before the fronts) (Fig. 21). The annual average resultant wind (i.e., the vector sum of the monthly wind speed and direction) in the Springs Coast is from the north. This is because the wind speeds that follow the winter fronts are greater than those that 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 than during the fall, winter, and spring



March–September



October–February

Figure 20. Low level (600-900 m) winds (after Atkinson and Sadler 1970).

(Fig. 22). Since no data from within the Springs Coast is available, those for Tampa are given in the figure to suggest the seasonal wind strength in the Springs Coast. Inland stations exhibit somewhat lower 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).

b. Hurricanes, tornadoes, and waterspouts. Hurricanes pose a major threat to the Florida Springs Coast. A hurricane is a cyclonic storm (i.e., the winds rotate counterclockwise in the northern

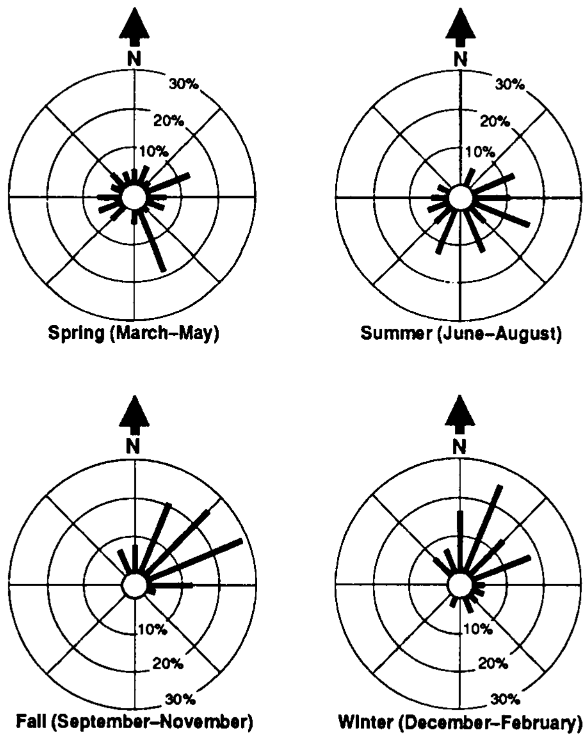


Figure 21. Percentage of time wind blew from different directions at Tampa (nearest data site) during different seasons, 1959–1979 average (after Fernald 1981).

hemisphere) with sustained wind speeds in excess of 120 km/h. Six hurricanes have come ashore in this region from 1885 to 1985. Figure 23 shows the tracks for hurricanes hitting near the Florida Springs Coast during this period. Of 48 hurricanes and tropical storms that struck or came within 150 miles of the Florida coast from Tampa Bay to the Ochlockonee River, including the Springs Coast, 5 were in June, 3 in July, 11 in August, 15 in September, 12 in October, and 2 from November through May.

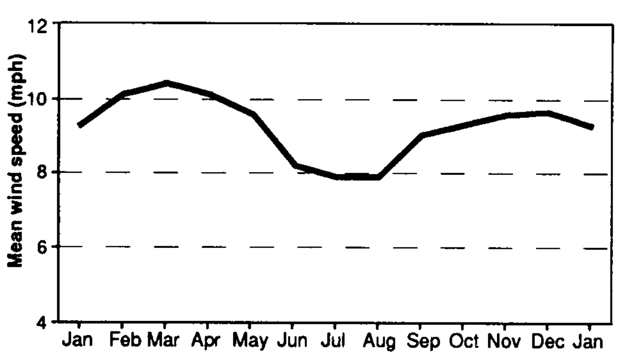


Figure 22. Seasonal windspeed at Tampa (nearest data site) (after Jordan 1973).

Much of the damage done by hurricanes is caused by the local rise in sea level known as storm surge. For hurricanes striking the Springs Coast 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. Embayments help contain this water and can increase storm-surge magnitudes substantially when a hurricane strikes the northern or western side. Tidal stage and phase, bottom topography, coastline configuration, and especially wind strength combine to 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 (insolation) reaching the Florida Springs Coast 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

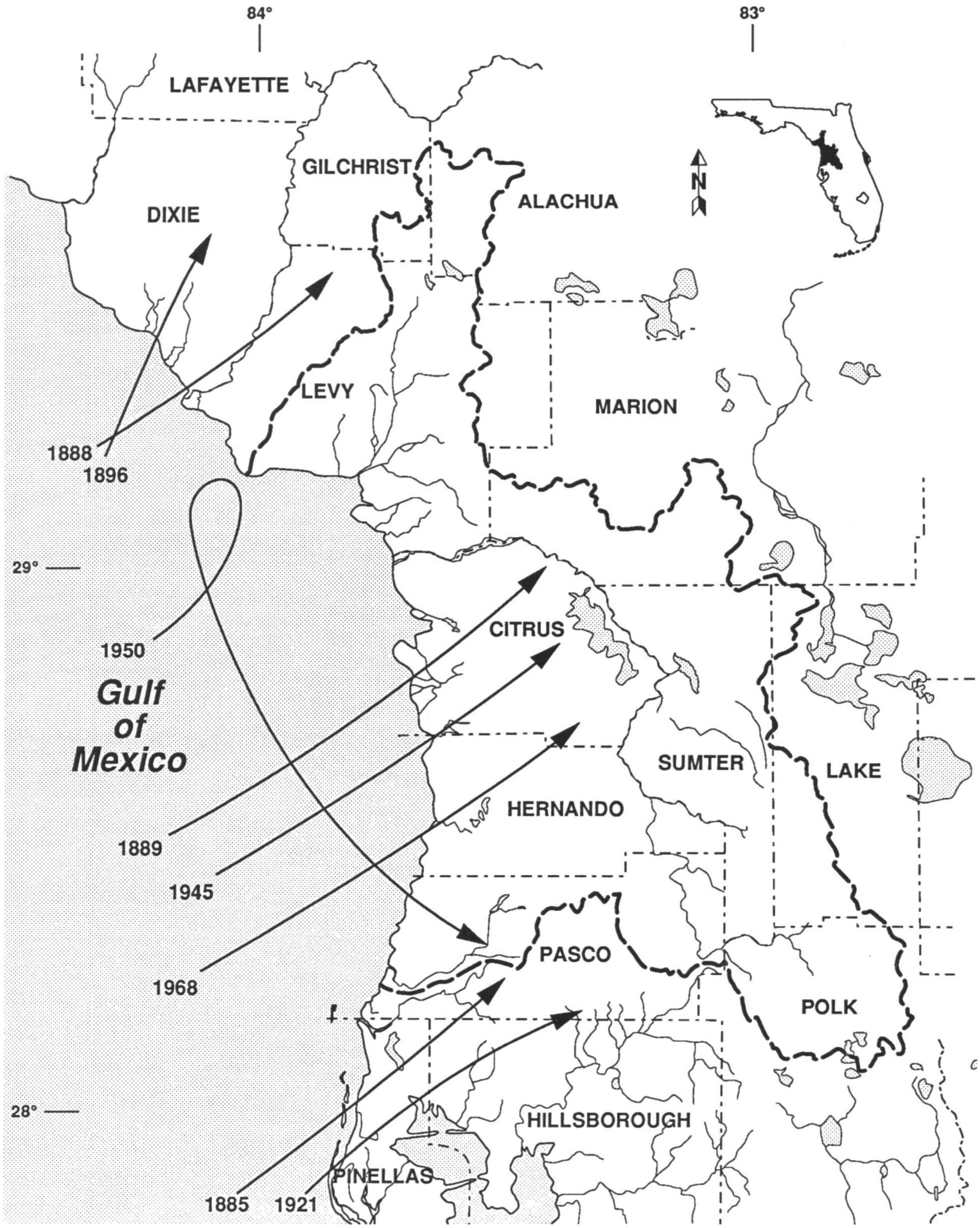


Figure 23. Paths of hurricanes striking the Springs Coast 1885-1990 (after Jordan 1984; Case 1986).

atmosphere through which the solar rays must travel to reach the Earth's surface at points north or south of the orbital plane (Fig. 24); (3) the reduced density of rays striking an area on Earth's surface north or south of the orbital plane (Fig. 25); (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 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.

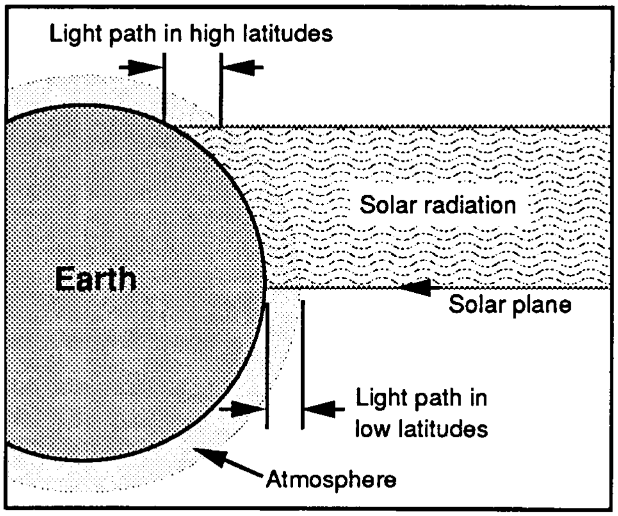


Figure 24. Change in length of atmospheric light path with change in distance above or below orbital plane.

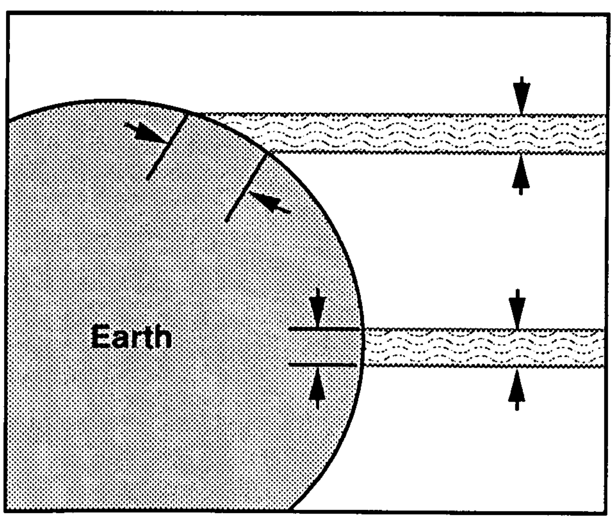


Figure 25. Change in light intensity at Earth's surface with change in distance above or below orbital plane.

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, as well as its patterns, varies seasonally (Fig. 26). 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. The types of clouds and rainfall patterns are different under each of these systems. Daily cloud cover variations are considerably greater in summer than in winter. That is, in summer many days have partial cloud cover, while in winter the days tend to be

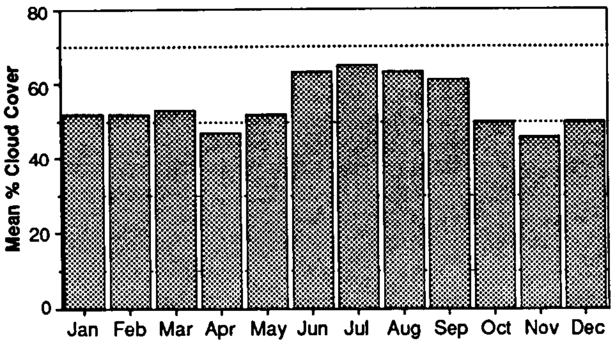


Figure 26. Mean daytime sky cover at Lakeland (data from U.S. Dept. of Commerce 1980c).

entirely overcast or entirely clear. In the Springs Coast and increasingly as one progresses into south Florida, where winter cyclones and fronts are less frequent, the amounts of cloud cover differ greatly in winter and summer.

The maximum insolation striking Earth's atmosphere at the latitude of Springs Coast Florida is approximately 925 langleys/day (Strahler 1975). Figure 27 shows the seasonal variation of the daily insolation striking the atmosphere over the Springs Coast region. The monthly average of the daily insolation amounts actually received at several sites in the Springs Coast are presented in Fig. 28. In addition, the percent of possible sunshine measured at several sites in the Springs Coast is presented in Fig. 29.

Atmospheric clarity over the Springs Coast 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 Springs Coast 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. 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 Springs Coast 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 Springs Coast is minimized, 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 $\leq$ 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). Little data on Springs Coast fog frequencies is available, but Tampa, just south of the Springs Coast, experiences heavy fog on an average of 14% of 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 influences the regional ecology through two major mechanisms. The normal climate of the

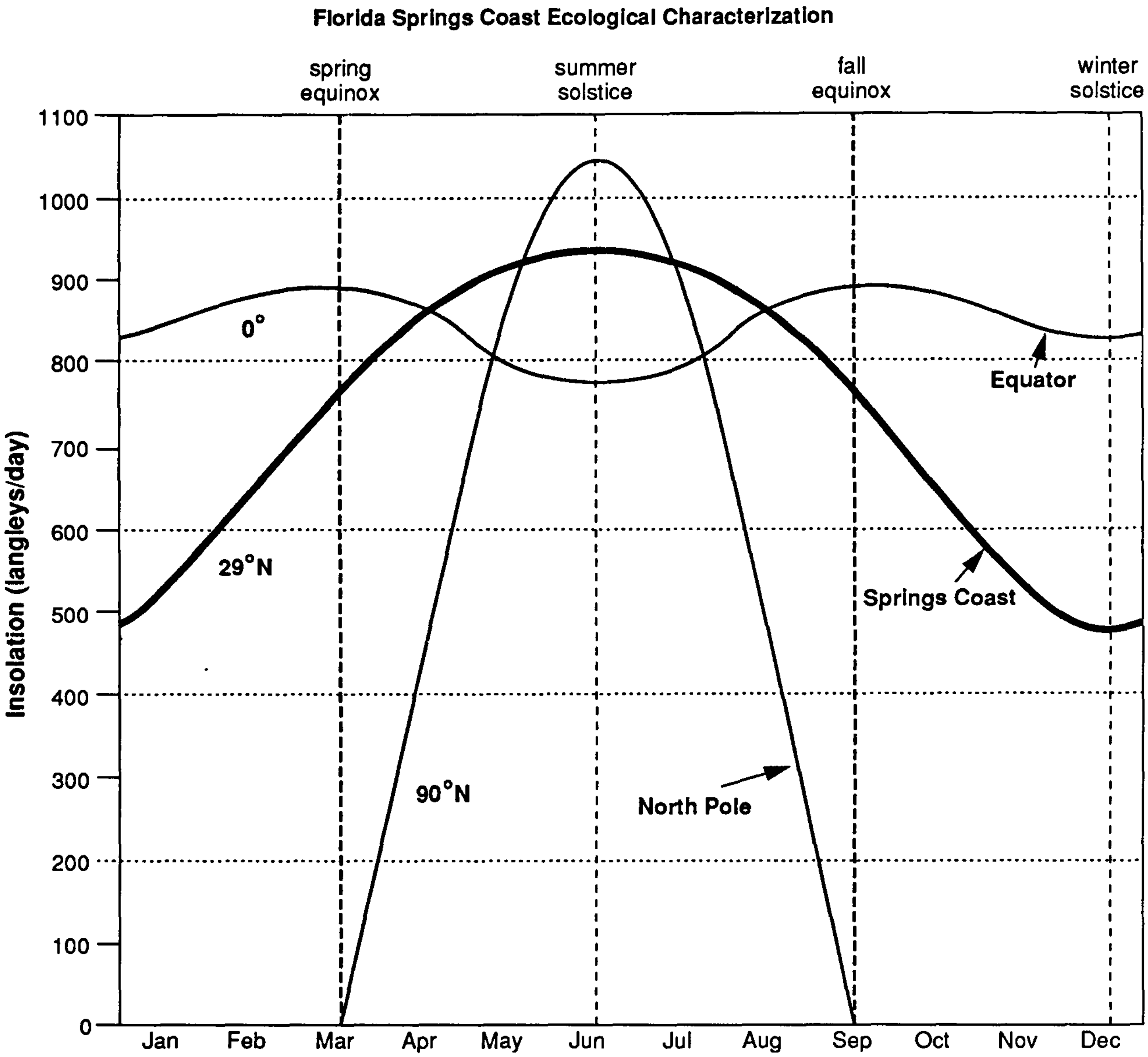


Figure 27. Variations in insolation striking the atmosphere, depending on latitude and season (after Strahler 1975).

Springs Coast 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 rarely-occurring 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. An example is the mangrove. A dominant coastal species on the southwest Florida coast, mangroves become increasingly scarce as one progresses north along the Springs Coast coast and are nearly nonexistent north

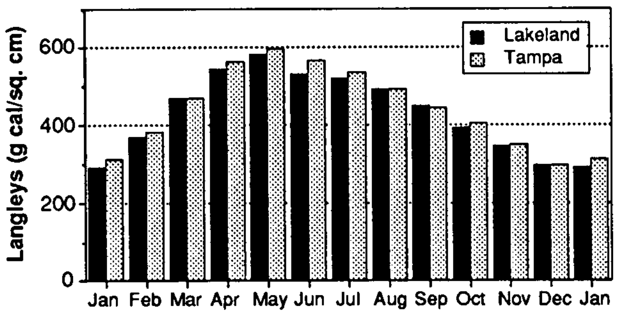


Figure 28. Monthly insolation at selected sites near the Florida Springs Coast (data from Bradley 1972).

of Cedar Key. In conditions otherwise conducive to mangrove growth, the occasional cold winters limit their northward expansion. 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

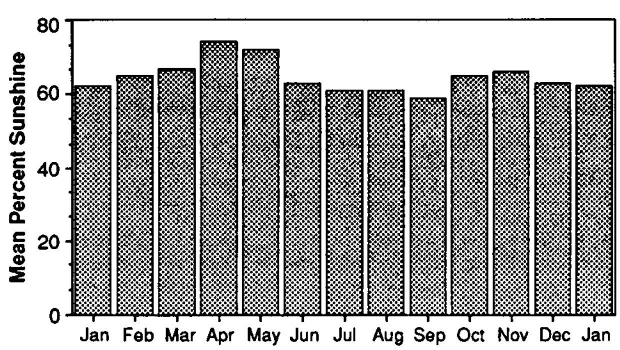


Figure 29. Percent of possible sunshine at Lakeland (nearest site to Springs Coast for which such data is available) (data from U.S. Dept. of Commerce 1980c).

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. 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. 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 Springs Coast, 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 Springs Coast and elsewhere 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 that 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 Springs Coast 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 Springs Coast, 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 Springs Coast is that coastal waters are heated more 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 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,b; 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 (Fig. 30).

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 off the Atlantic), evapotranspiration increases the buoyancy of the continental air masses. This probably increases mass convergence, bringing in more moisture from the adjacent oceans, thereby acting as a trigger to increase convection and convection-induced rains. Rainfall of this nature is found year round but is especially common in the summer. A 70-inch rainfall deficit that 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 Springs Coast, where similar patterns of convective rainfall are found. Future development that 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 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).

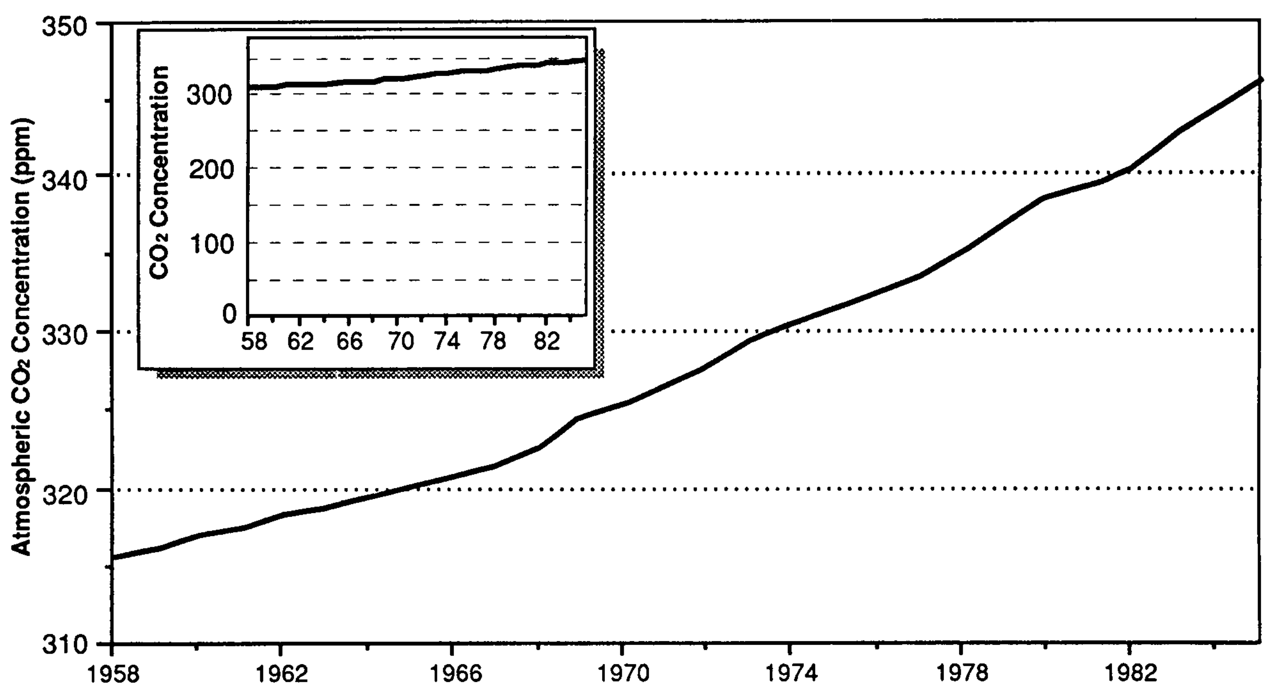


Figure 30. Increasing atmospheric carbon dioxide as measured atop Mauna Loa, Hawaii (data from Charles Keeling, Scripps Inst. of Oceanography).

3.5 Summary of Climatic Concerns

The Florida Springs Coast 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 Springs Coast 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 Springs Coast 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 Springs Coast.

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, which, in turn, supplies the majority of the total annual rainfall (Fig. 15). 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 Springs Coast—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, although 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 Springs Coast climate is needed concerning questions which, of course, affect much wider areas, but are applicable to this area, especially 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

by Steven H. Wolfe

Water quality is, in many ways, dependent on hydrology, and often the forces affecting one also affect the other. This chapter will discuss each of these areas, their interrelationships, and their status in the Florida Springs Coast. Excellent sources of information on the water resources of the Springs Coast are *Rivers of Florida* (Livingston 1991) and *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.

The Springs Coast surface-water and 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 freshwater floats because it is ~2.5% less dense than the salt water. As water is removed from the freshwater aquifer, the pressure of the underlying salt water tends to push the salt/freshwater interface higher, while nearly maintaining the level of the upper surface of the freshwater aquifer. 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 (1 ft = 2.5% of 40 ft). Thus, simplistically, every foot by which our pumping of the freshwater aquifers lowers the upper surface and which is not replaced in a reasonable period of time by rainwater, results in a 40-ft rise in the deeper saline layers. The Florida Springs Coast, and all of Florida, has tremendous volumes of freshwater 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, salt-water intrusion will render the coastal wells useless because the underlying saline layer is much closer to the surface nearer the oceans.

4.1 Hydrology

Hydrology is the study of the water cycle, including atmospheric, surface, and ground waters. The basic hydrologic cycle (Fig. 31) includes water vapor entering the atmosphere as a result of evaporation, transpiration, and sublimation. This vapor condenses to form fog, clouds, and, eventually, precipitation. Along the Florida Springs Coast, 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 surface and ground water of Florida is divided into two distinct areas delineated by a line crossing the state along the northern edge of the Springs Coast (Fig. 32). There is almost no net movement of surface water or ground water across this line; rainfall north of the line recharges the northern part of the area, and that south of the line recharges the southern portion. The southern region in particular needs to

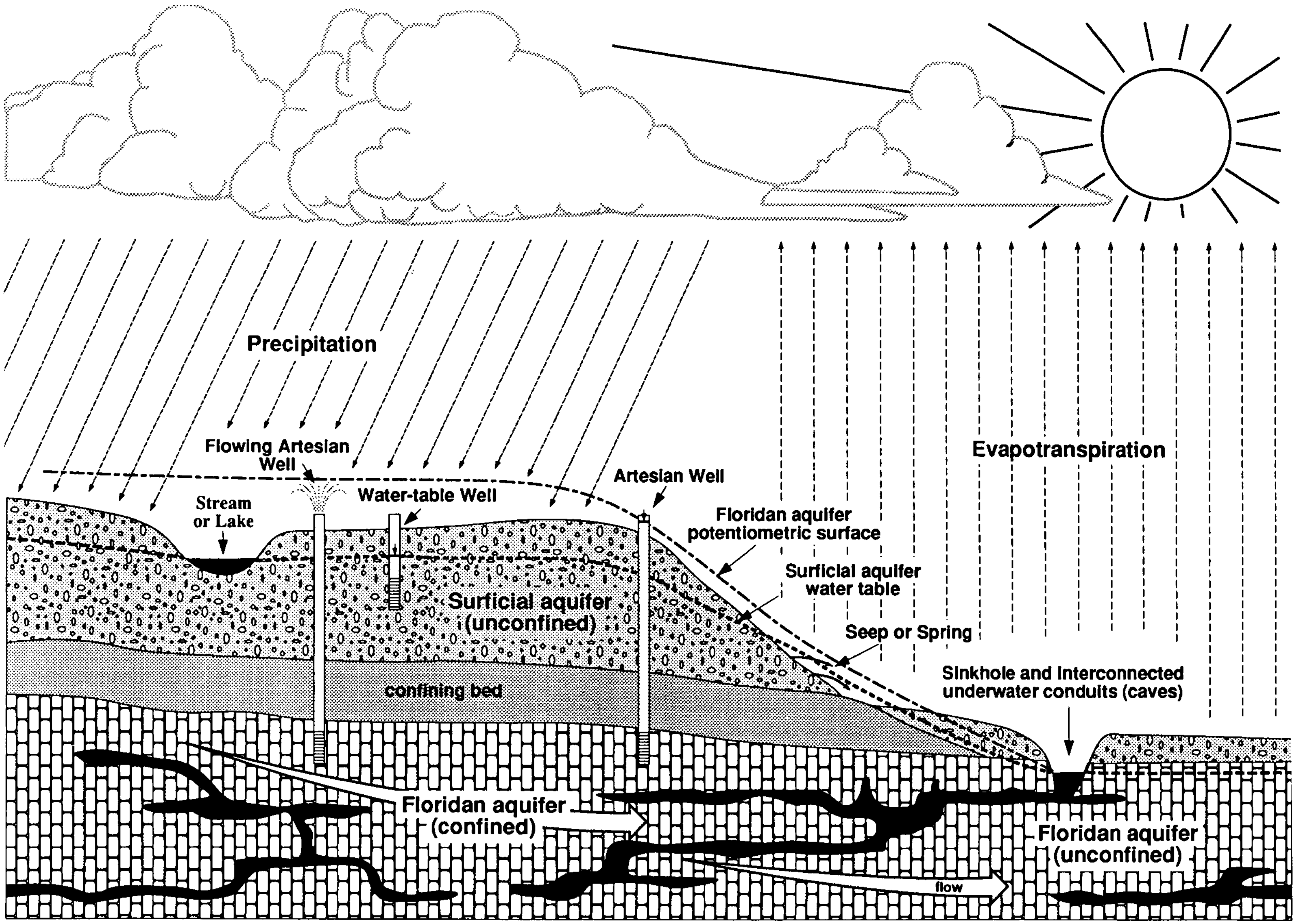


Figure 31. The basic hydrologic cycle.

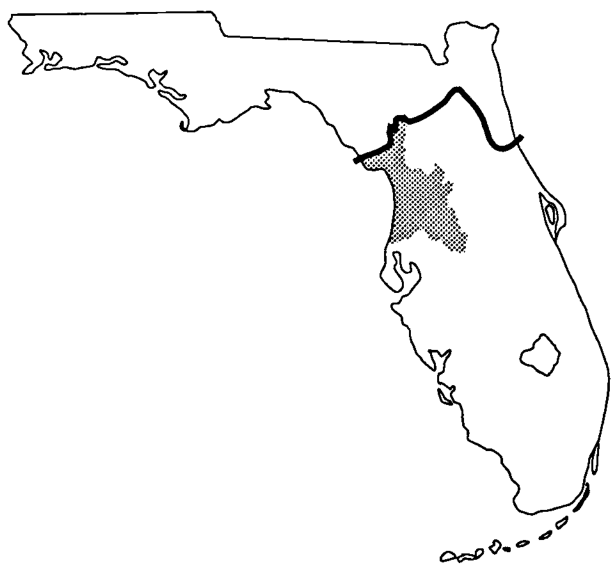


Figure 32. The Florida hydrologic divide (after Heath and Conover 1981).

manage its water budget based upon the rainfall it receives since there is no potential for recharge of the aquifers from ground-water supplies or rainfall to the north.

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) (Fig. 33). Most of these consist of the Florida portion of the drainage basin of a single coastal river. 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.

Ground water in the Springs Coast is contained primarily within the Floridan aquifer, which underlies the entire region. This aquifer is found in a characteristic limestone matrix. A shallow surficial aquifer contained in sand beds overlying the Floridan may be found in much of the Springs Coast. Additionally, small but usable quantities of water exist in some areas within the clay and sandy clay confining layer separating the aquifers; however, except for rural areas with small requirements, these are little utilized because of the larger volumes available in the Floridan.

Local areas of aquifers in the Springs Coast 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 (Fig. 34). Areas within the Springs Coast recharging the Floridan aquifer are presented in Fig. 35.

4.2 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 it values. 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

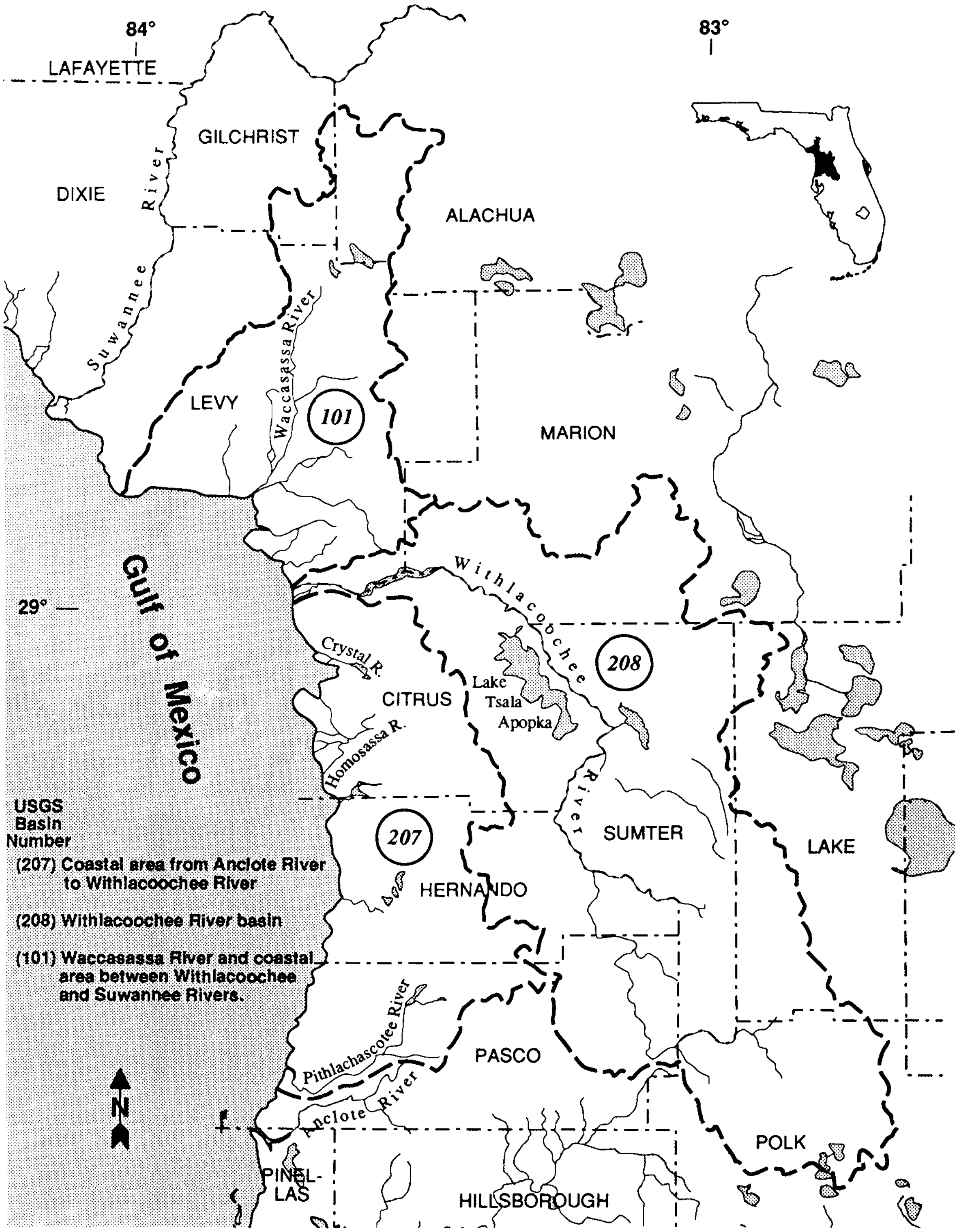


Figure 33. Major drainage basins and surface-water features of the Springs Coast region of Florida.

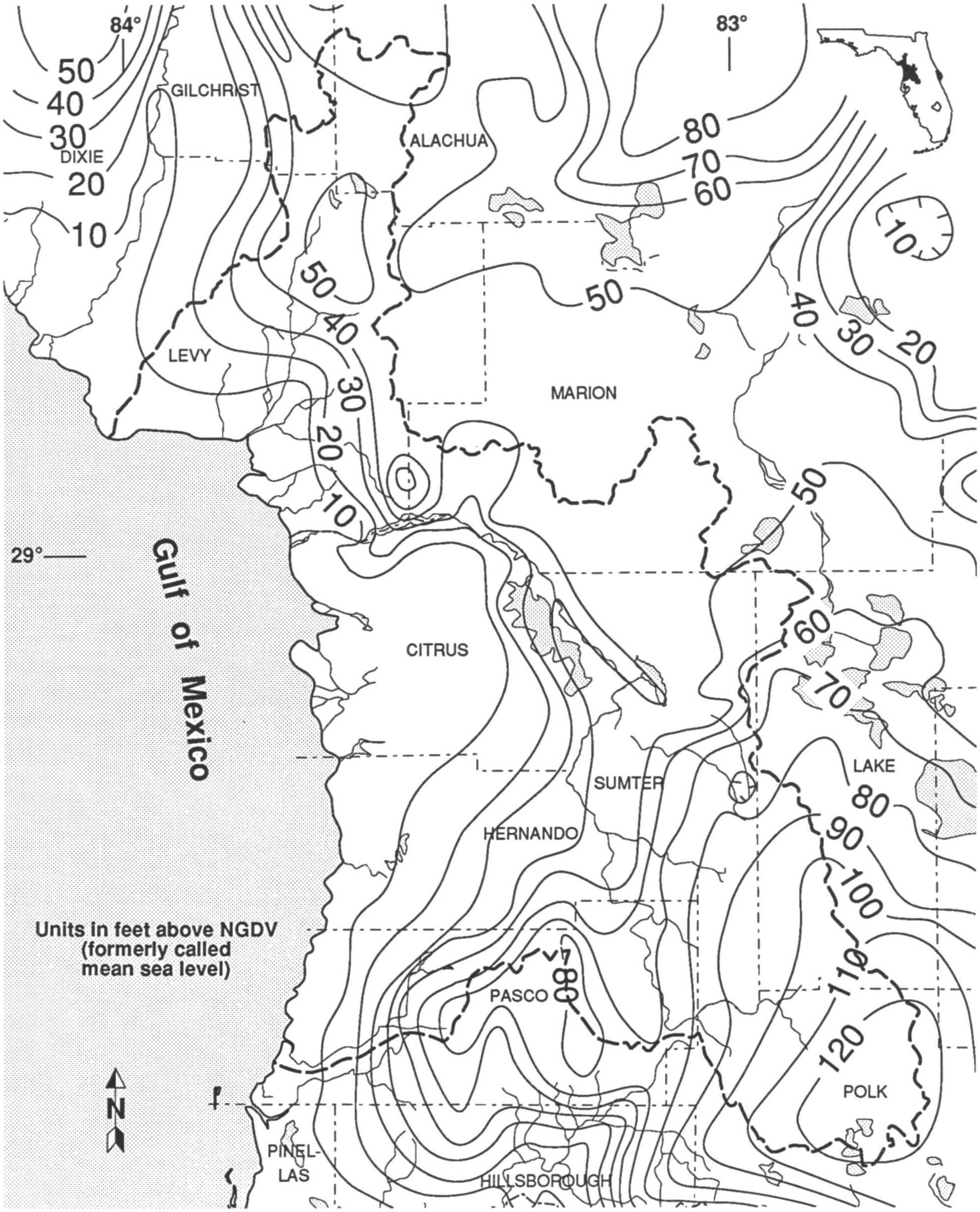


Figure 34. Potentiometric surface of the Floridan aquifer in the Springs Coast in May 1980 (after Healy 1982).

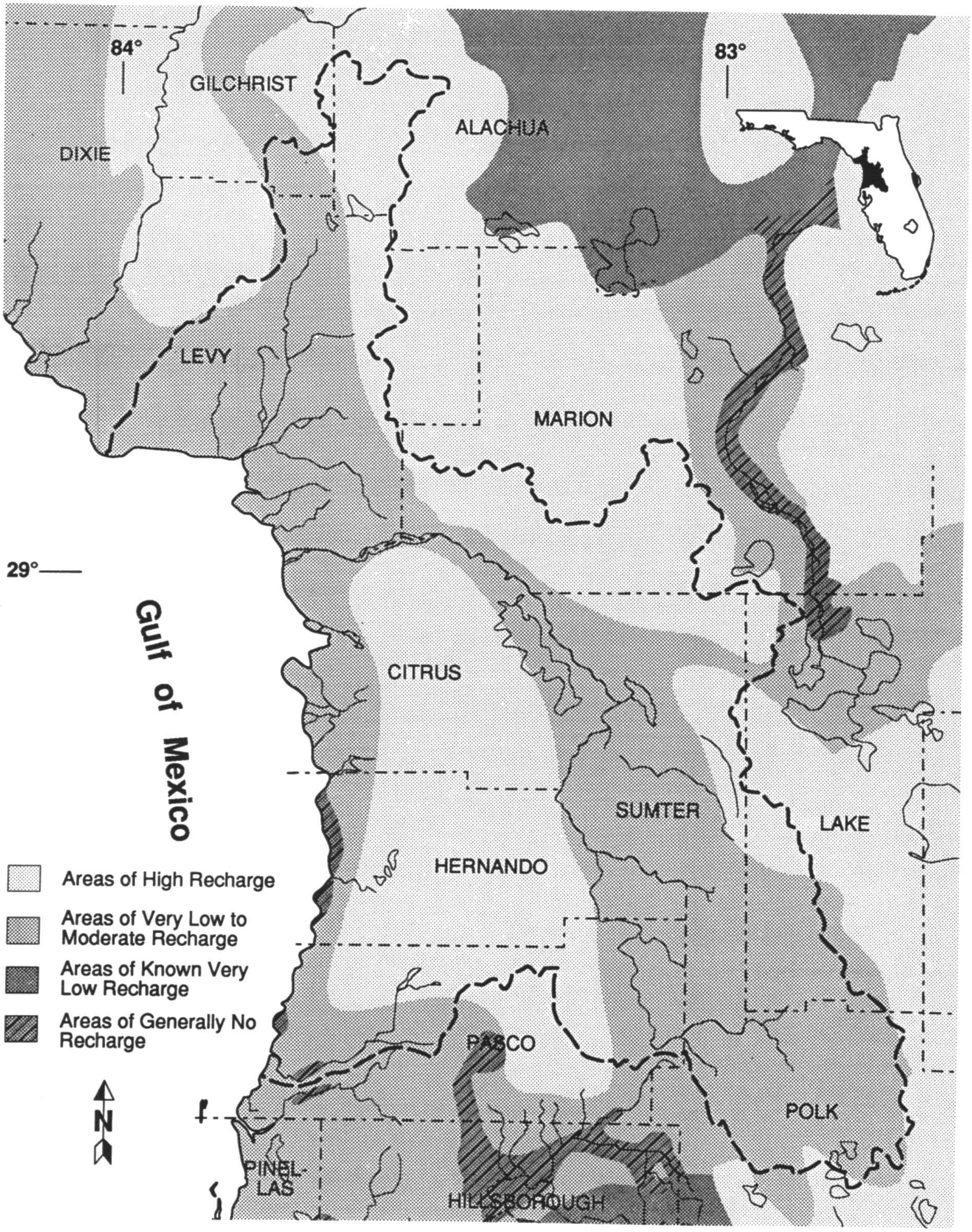


Figure 35. Recharge areas to the Floridan aquifer in the Springs Coast region (after Stewart 1980).

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. Few of the organic hydrocarbons contaminating waters 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.

4.3 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.

The responsibility for management of the water resources on a regional level is held by two agencies within the Springs Coast. The Southwest Florida Water Management District (SWFWMD) is responsible for the coastal drainage basins south of and including the Withlacoochee River basin (there are two Withlacoochee Rivers within the state of Florida; the other one is in north central Florida and is a tributary of the Suwannee River). The Suwannee River Water Management District (SRWMD) is responsible for the coastal drainage basins north of the Withlacoochee River basin, including the "other" Withlacoochee River which flows to the Suwannee River!

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 Southwest Florida Water Management District (SWFWMD). This responsibility includes regulation of water consumption and long-range planning to help ensure the continuing availability of high quality water.

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 waste-load 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. Data limitations due to changing sampling methods and uncharacterized ambient conditions have prevented long-term trend analysis in these river basins (FDER 1986a). Lack of baseline data in most instances and lack of continuing data collection in many instances prevents 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 1986).

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 administered by the FDER. This consists of a network of existing wells plus new wells where existing ones were insufficient to permit adequate ground-water sampling, each sampled on a regular basis. In its first phase, 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 locations of permanent monitoring wells and the frequency of sampling were determined. The ground-water monitoring network is the source of information for 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 is made available to the public and governmental bodies to help in decision making.

4.4 Water-Quality Parameters

The major water-quality parameters are dissolved oxygen (DO), acidity (pH), turbidity and sediments, dissolved solids, temperature, and "other" substances.

4.4.1 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, supersaturation levels of DO can result in embolisms (bubbles forming within the animal's tissues) and death. The amount of oxygen necessary to saturate water depends on temperature. Higher temperatures reduce the saturation concentration (amount of oxygen the water can hold) and lower temperatures increase it (Fig. 36). 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 (Fig. 37). While freshwater at 2 °C is saturated at 13.8 ppm, sea water (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.

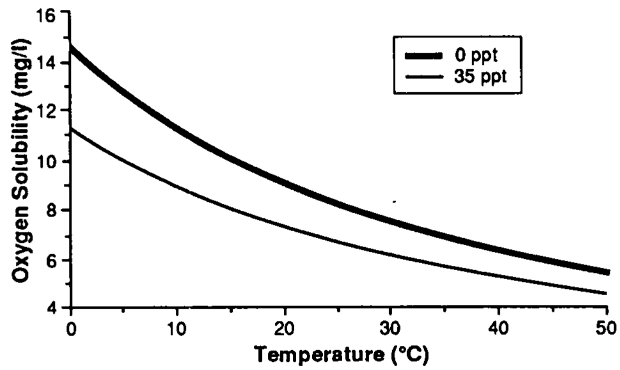


Figure 36. Oxygen solubility as a function of temperature.

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.

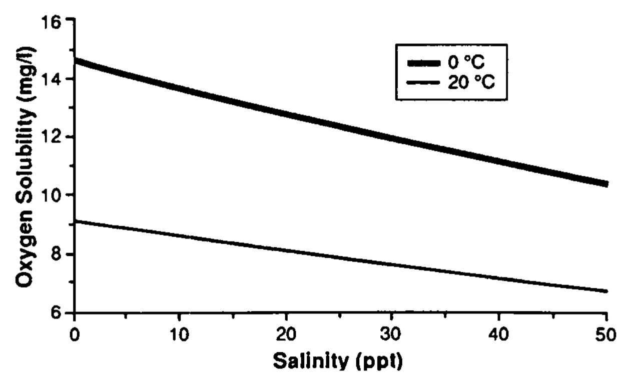


Figure 37. Oxygen solubility as a function of salinity.

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.

c. Oxygen uptake—Biochemical Oxygen Demand (BOD). Biochemical oxygen demand results from microbial and chemical consumption of oxygen during the degradation of organic compounds in the water column and bottom sediments; it 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.

4.4.2 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 may be 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, since 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 un-ionized ammonia (NH_3). The ionized form in which most ammonia is found in acidic waters is several orders of magnitude less toxic than the un-ionized 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 (that is, the form in which the ion is found—for example, CO_2 may be found in solution as CO_2 gas, 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 Springs Coast, surface waters of low pH are generally found in swamps and swamp drainages. Figure 38 gives the normal pH levels of Springs Coast 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 Springs Coast 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 in what areas in or out of the State the effects of Florida-caused acid rain may be felt (FDER 1985a). If the rain water contacts a substrate composed of a buffering material (in the Springs Coast 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, marshes, some flatwoods), 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 intolerance for the acidic conditions.

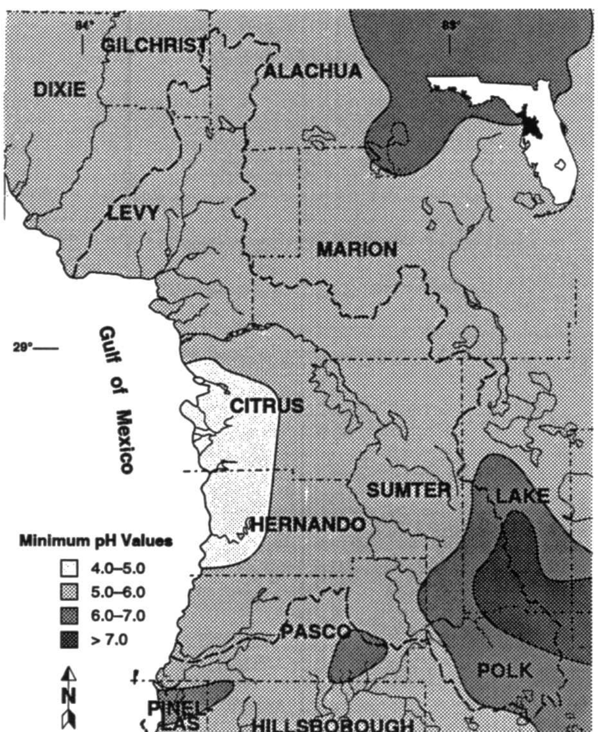


Figure 38. General distribution of minimum pH in Springs Coast surface waters (after Kaufman 1975a).

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 to a pH of 6–6.5 and alkalinity of 6–12 mg/L (FDER 1985b). Since the pH scale is inverse and 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 Springs Coast, 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.

4.4.3 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 storm-water 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.

4.4.4 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) (Fig. 39). Deeper ground-water layers usually contain more dissolved solids than the upper layers.

The major ions commonly found in Springs Coast 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. Concentrations of dissolved solids 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).

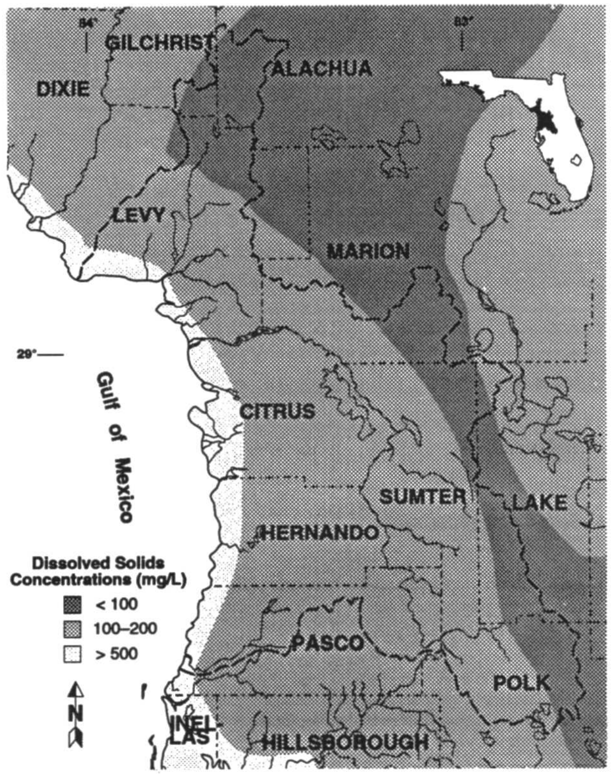


Figure 39. Estimated average dissolved solids concentrations in surface waters of the Florida Springs Coast (after Dysart and Goolsby 1977).

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 Springs Coast 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 Springs Coast surface waters of at least moderate alkalinity.

As mentioned in the discussion of pH, alkalinity in Springs Coast 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 Springs Coast 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 Springs Coast 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 Springs Coast waters can be reliably estimated from the total dissolved-solid values (Fig. 39). 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 saltwater, regularly present rapidly changing salinity conditions. As a result, this habitat has lower species diversity than 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 Springs Coast coastal and estuarine waters is extremely variable. These waters function as a mixing zone for freshwater runoff from surface and ground waters (0 salinity) and the offshore marine waters (35 ppt). In general, estuarine salinities range from near 0 throughout the estuary during high river stages, to near 30 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 affects water quality primarily 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 limit 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, 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 used 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.

4.4.5 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 freshwater 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 low 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. In the Springs Coast, the most notable instance of hot-water effluent is the cooling water discharge from the nuclear power plant at Crystal River.

4.4.6 Other Contents

This catchall grouping includes many materials 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 fall 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.

4.5 Major Influences on Surface Water

4.5.1 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 Springs Coast, 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. 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. Many Springs Coast rivers have very stable flow regimes, since they are primarily spring fed and receive little runoff. However, those with appreciable drainage basins flood primarily from the convective rainfalls of late summer and early fall (August–October) (Palmer 1984) (Fig. 40). Figure 15 shows that the total rainfall during the summer is much greater than that of winter. The vast quantities of water evaporating from the warm surface waters and transpired from lush summer foliage, however, return most of this rainfall to the atmosphere (Mather et al. 1973), thereby minimizing flood-inducing runoff.

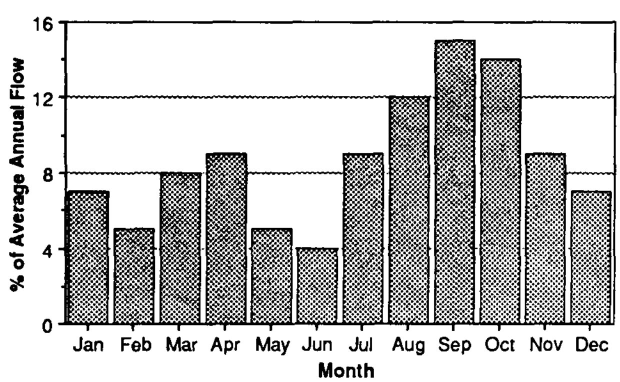


Figure 40. Seasonal riverflow in the Springs Coast Withlacoochee River (after Palmer 1984).

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). In the Springs Coast area, dams and other water control structures are used to minimize flooding in populated and agricultural areas. Secondary problems with area hydrology that were induced by these structures, however, have shifted the emphasis away from these types of permanent structures and toward the use of wetland areas for flood-water retention. This is accomplished primarily by setting these areas aside and leaving them in a relatively natural state. The use of dikes to create flood detention areas, where flood waters are held temporarily, helps damp out flooding of inhabited areas downstream while providing relatively normal conditions in the wetland area.

Maps delineating the 100-year flood plains in Florida have been 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, they underestimate the areas that would be inundated by 100-year floods.

Springs Coast springs moderate the flow of rivers and streams receiving their waters. The groundwater 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. Springs can become siphons under these conditions and carry surface water directly to the aquifers (Ceryak et al. 1983), thereby reducing the peak streamflow somewhat. However, the relatively high potentiometric pressures of the springs in most of this region, coupled with the flat terrain that minimizes changes in river stage, probably minimize or prevent siphoning in much of the region. First- and second-magnitude springs (>30 m^3/s and 3-30 m^3/s, respectively) are clustered primarily in coastal Citrus and Hernando County (Fig. 41). Third-magnitude springs (<3 m^3/s) also tend to cluster about these areas but are found throughout the region.

Springs of Florida (Rosenau et al. 1977) includes flow data for the springs and *An index to springs of Florida* (Rosenau and Faulkner 1975) shows the locations of those springs in the Springs Coast. The USGS (1970) reported on the large springs of Citrus and Hernando Counties.

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 Springs Coast coast and in estuaries, wind is the major factor driving water circulation (J. Williams et al. 1977; Livingston 1983). This results in a net long-term movement of coastal waters north and west during the late spring, summer, and early fall, and south and east 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 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 Springs Coast 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 40 minutes later each day. In research carried out along the west coast of Florida, tides on the Springs Coast coastal shelf were found to generate modest primarily onshore and offshore currents (averaging 0.16 m/s) which, because of the shallow topography, are stronger than those found along the southern gulf coast of Florida (Battisti and Clarke 1982). This wide, shallow coastal shelf was also found to be resonant with the principal lunar tide, adding a shelf-induced cycle of amplification and damping to this portion of the tidal cycle (Battisti and Clarke 1982). Of more importance to the nearshore hydrology, the (normally) four-times-daily change of direction of this movement of water induces substantial mixing of the near-shore 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 river flow upon the saltwater it enters, (b) salt-wedge circulation, and (c) geostrophic forces. The friction of the flow exiting the river mouth attempts to "drag" adjacent saltwater along with the body of river water, inducing eddies along the transition zone between the two water masses. A salt wedge forms because freshwater flowing out of the rivers is less dense than the saltwater into which it flows; thus the freshwater tends to form a layer flowing over the top of the denser saltwater (Fig. 42a). This underlying layer of saltwater 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 saltwater behind it forces the wedge upstream. In shallow, so-called well-mixed estuaries (the type found along the Springs Coast 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 hydraulics. As the saltwater mixes with the overlying freshwater at their interface, the

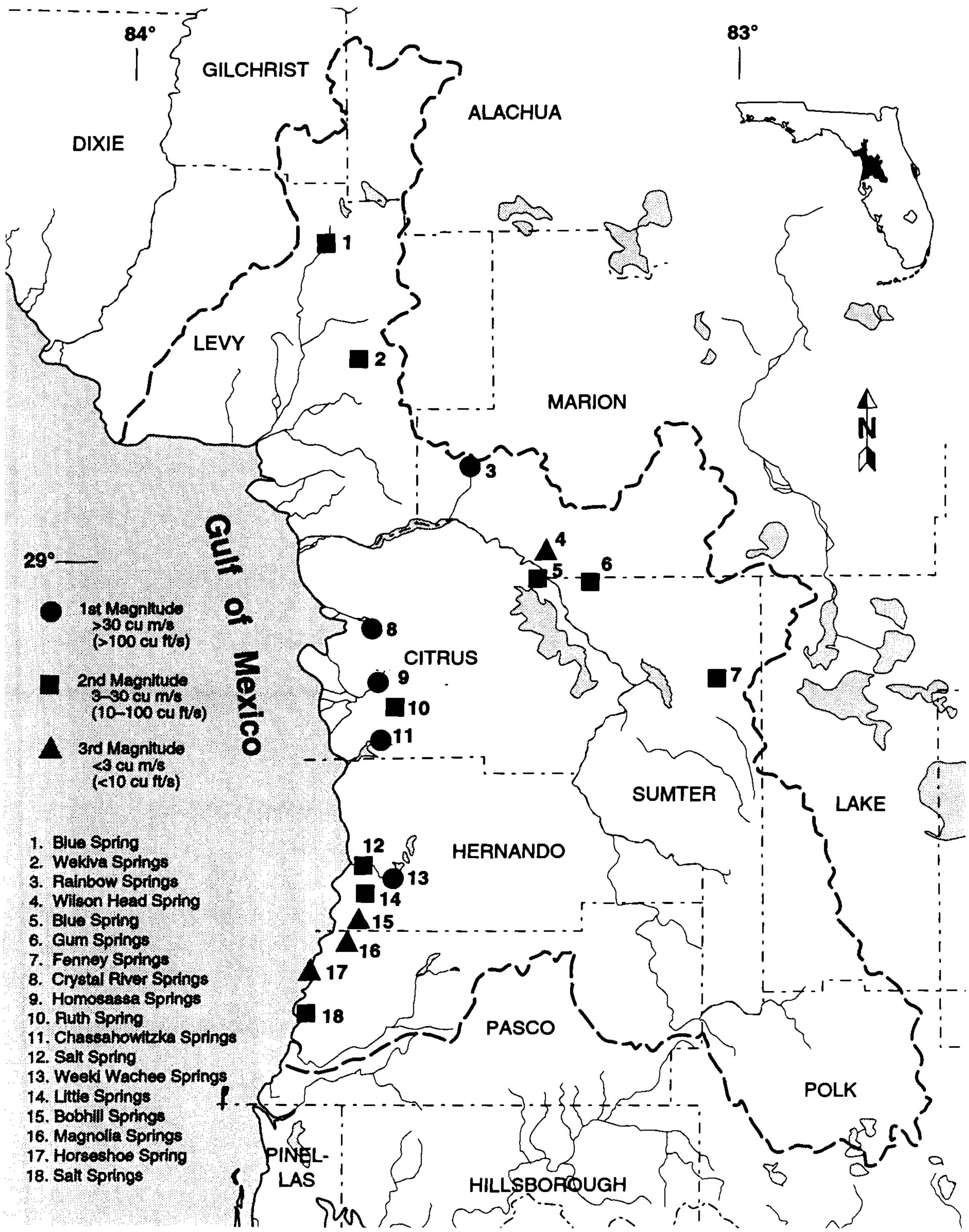


Figure 41. Locations and magnitudes of major springs in the Florida Springs Coast (after Rosenau and Faulkner 1975).

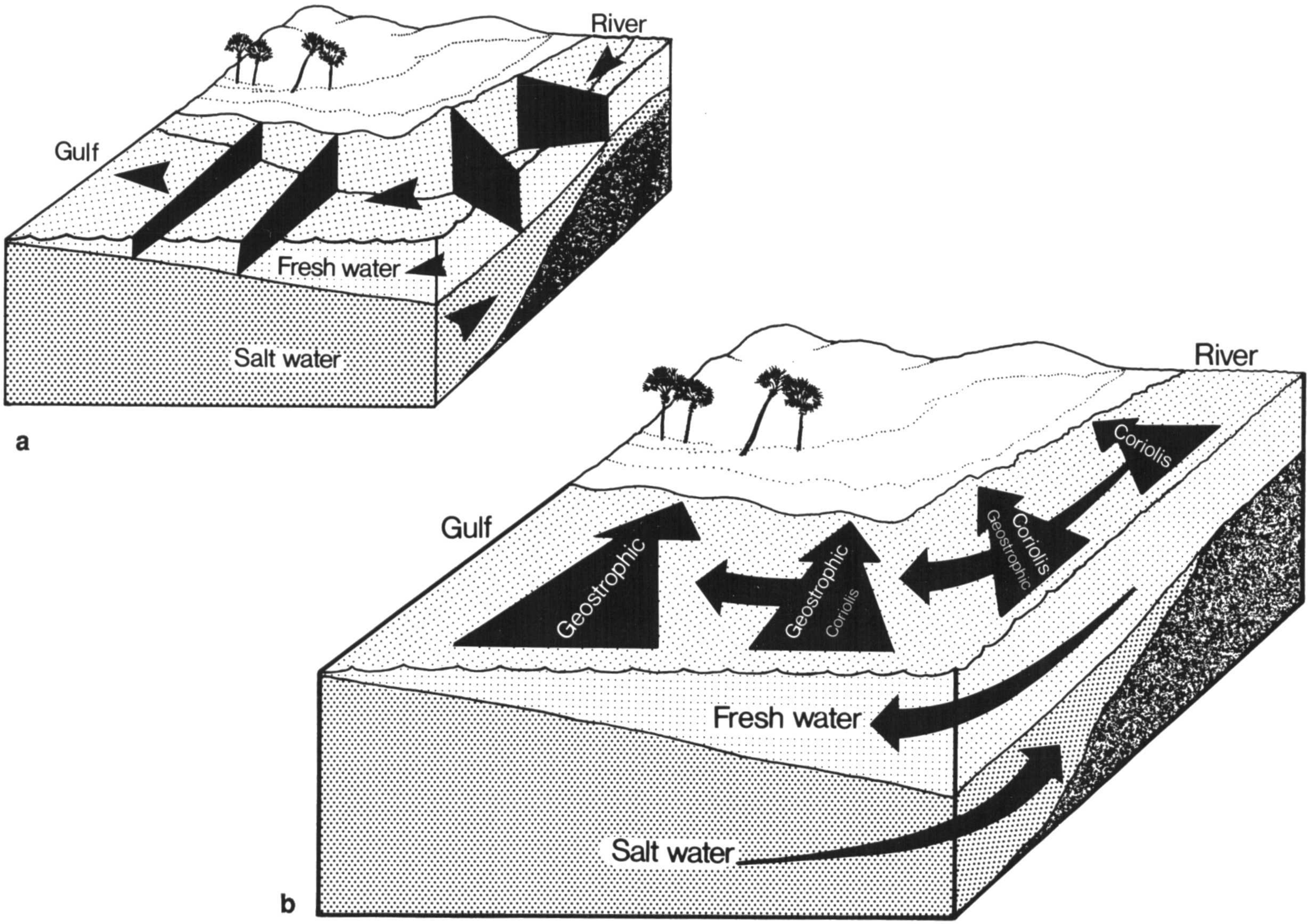


Figure 42. River-mouth flow phenomena: a— Formation of a salt wedge and "stacking" of freshwater layer to right of flow direction at river mouths; b—Coriolis and geostrophic forces affecting fresh water flowing from river mouths.

brackish water formed, less dense than the saltwater, is caught up in the outward flow of freshwater 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 (Fig. 42b). In the Springs Coast, the resulting thicker layer of freshwater 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 Springs Coast to tend to curve to the right once they reach 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 continuously 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 Springs Coast 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 Springs Coast 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 Springs Coast 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 land-clearing activities. The most common results of these alterations is 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 tends to peak rapidly and at a much higher level than it does in undeveloped basins. The 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, increasing the height of flooding 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. Since river outflow induces circulation and mixing in water masses many times greater than the volume of water discharged, the size of an estuary is controlled by the volume of freshwater inflow, but any decrease of inflow causes a much larger decrease in the volume of the estuary. If average flow into an estuary is reduced, then decreases in estuarine productivity disproportionate to the volume of freshwater diverted can be expected.

4.5.2 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 that 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 equilibrium 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. Dissolved 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 freshwater draining off the land and the marine waters offshore. One relatively common event that is harmful to the ecology occurs when conditions encourage plankton blooms. The exact conditions 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 Springs Coast, much of which is relatively undeveloped, private and municipal sewage and discharges are the most common point-source effluents. Sources that are fewer in number but which may have substantial local impact include discharges from powerplants 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. The only power plant in the Springs Coast is located at Crystal River (Crystal River Nuclear Power Plant) in Citrus County.

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 as much suspended solids, 9 times as much oxygen-depleting materials, and 3.5 times as much nitrogen as point sources (FDER 1986a). The major non-point-source pollutants in Springs Coast rivers are pesticides, animal wastes, nutrients, and sediments. The major sources of nonpoint-source pollution in southeastern U.S. river basins are agriculture (affecting 62% of basins) and urban storm-water 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. The factors affecting inland surface-water quality may affect local coastal-water quality, particularly in the estuaries.

4.6 Major Influences on Ground Water

4.6.1 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 (Fig. 34).

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 can convert springs into siphons, thereby draining surface waters directly into the aquifer (Ceryak et al. 1983) (Fig. 43). This is common for the springs along many rivers in the state and, in the instances of springs flowing through large underground passages, may allow substantial volumes of

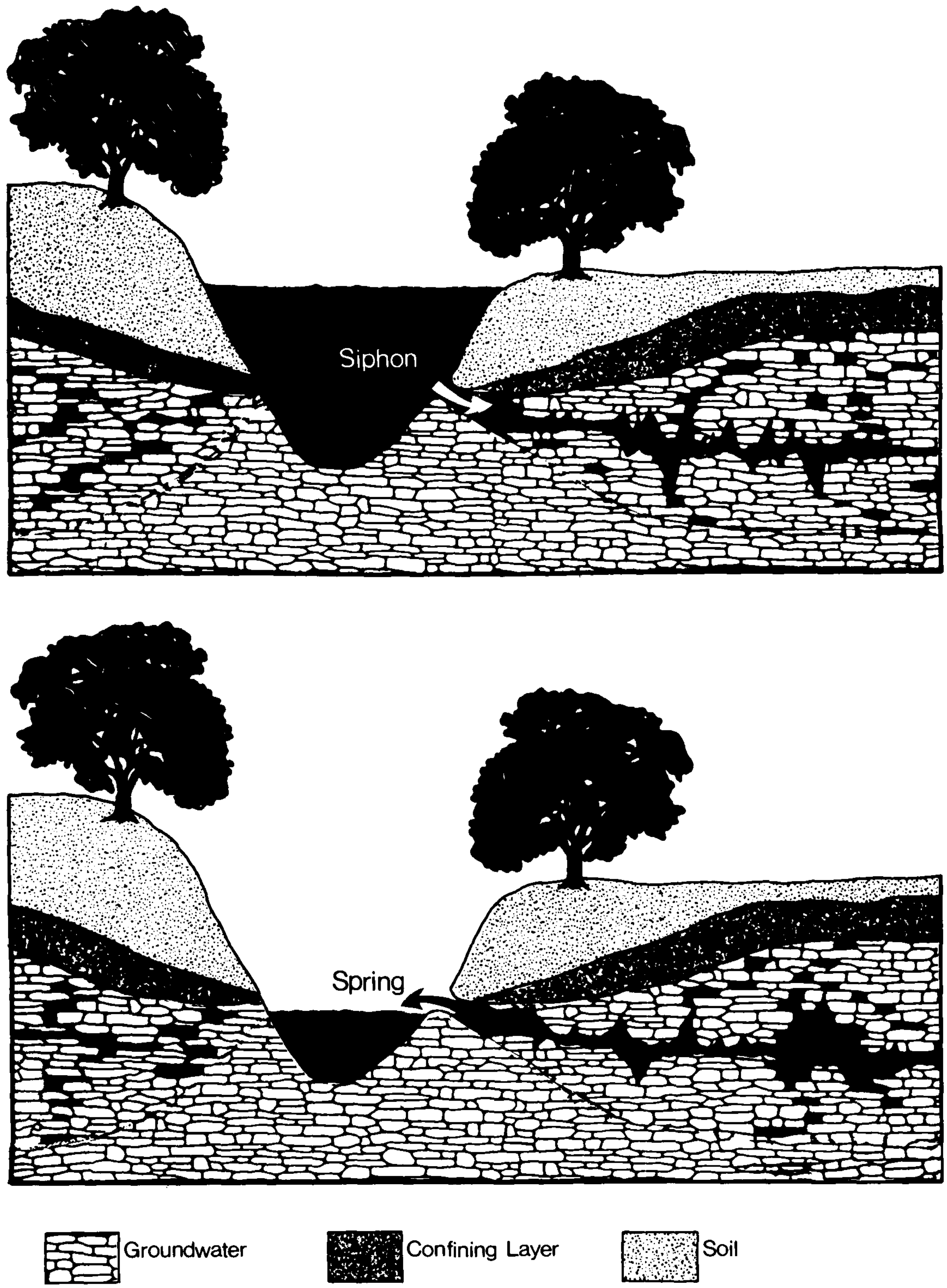


Figure 43. Generalized relationship of surface water to ground water for springs and siphons.

surface water to mix with ground waters, increasing the opportunity for large-scale contamination of ground waters with surface pollutants. The existence of siphons in Springs Coast rivers is undocumented. However, the combination of high potentiometric pressure springs and low-relief terrain (minimizing changes in river stage) may minimize or prevent conditions causing siphoning. The Pithlachascotee River is the most likely to have siphons form, since it is known that the river frequently loses water to the underlying aquifer.

b. Anthropogenic factors affecting ground-water hydrology. Ground-water levels are affected, often extensively, by human activities. Three major impacts presently exist in the Springs Coast: (1) ground water withdrawal; (2) drainage wells; (3) and 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 freshwater aquifers. Especially near the coast, excessive pumping of ground water results in saline intrusion into the potable aquifer. Because the density difference between the freshwater aquifers and the deeper saline ground water is minimal, the permanent lowering by 1 ft of the upper surface of the Floridan freshwater indicates that approximately 40 ft of the freshwater was removed and that the upper surface of the underlying saline aquifer rose nearly 40 ft. Investigations of seawater intrusion along the Springs Coast have been carried out, including that of Reichenbaugh (1972).

(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 1990). Most of the drainage wells in the Springs Coast and in the state will probably not be located.

(3) The surface hydrology of aquifer recharge areas serves to channel water to or away from recharge areas (Fig. 35). 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 managed carefully to ensure protection of ground-water supplies.

In addition, while not presently used in the Springs Coast, pressure-injection wells are used in various locations throughout the state as a means of waste-water 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 freshwater 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. 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 its long-term effects, 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. 1984; Merritt 1984), 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.

4.6.2 Ground-Water Quality

a. Natural factors affecting ground-water quality. Large areas in the Springs Coast function as recharge areas for the Floridan aquifer (Fig. 35). There is often a 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 Springs Coast, this perception is often 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 that dot Florida's landscape. Many sinkholes act as drainage gutters, providing direct contact between surface runoff and the ground-water aquifers. The surficial aquifer, where it exists, is just a layer of permeable strata laying on top of a confining layer and exposed at the ground surface. Percolation of surface waters into this aquifer is fast and relatively unobstructed. *Springs of Florida* (Rosenau et al. 1977) includes representative water quality data from the springs and *An Index to Springs of Florida* (Rosenau and Faulkner 1975) shows the locations of those springs in the Springs Coast.

Ground water from the Floridan aquifer is characterized by high pH, alkalinity, and hardness, resulting 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 take three forms: (1) contamination by surface waters and leaching of surface contaminants; (2) contamination by 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. These effects are further explained below.

(1) The surficial aquifer and the Floridan aquifer 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 (Fig. 44), 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 discussed above, their effects

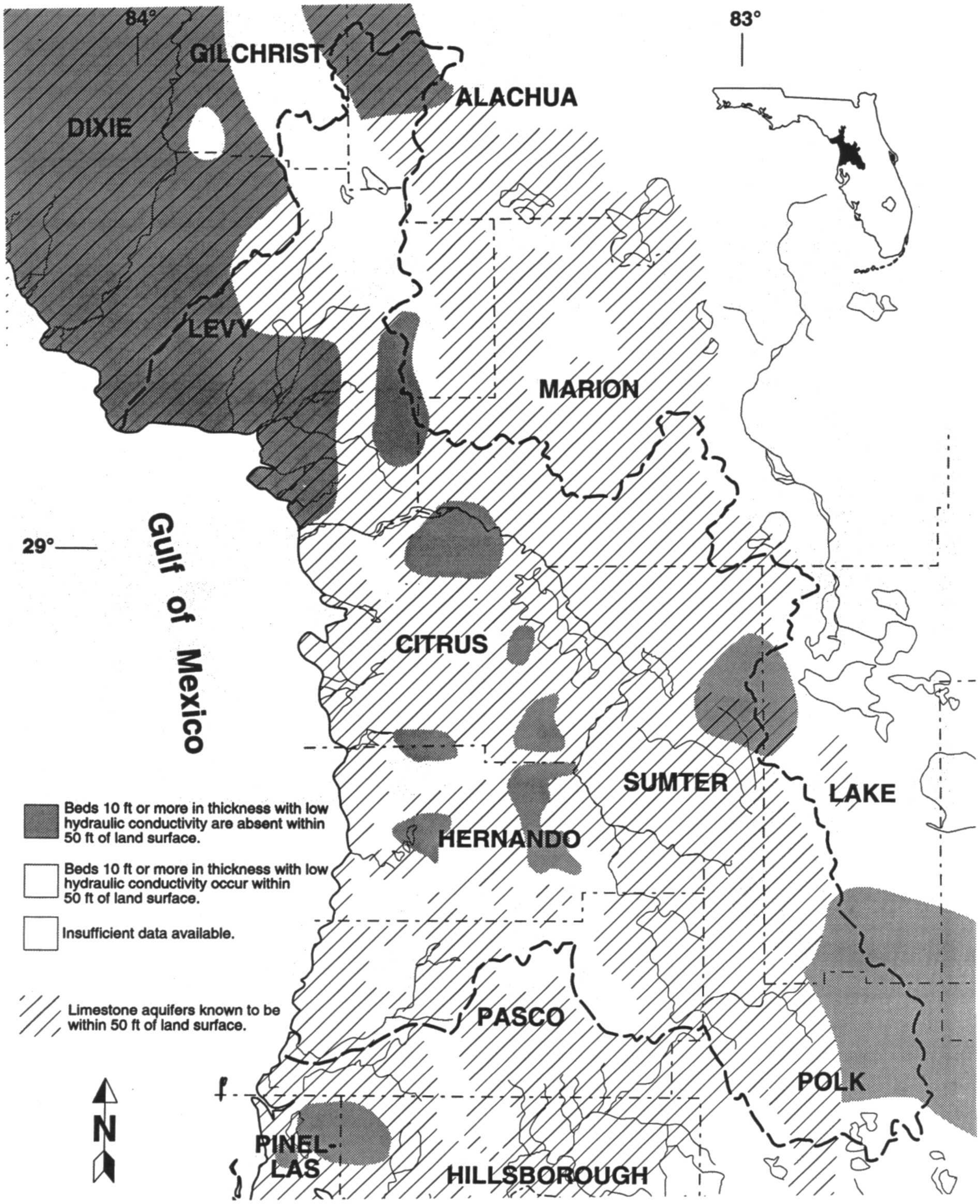


Figure 44. Location of limestone aquifers known to be within 50 ft of land surface and of surficial beds of low water permeability (after Healy and Hunn 1984).

are being studied intensively by the USGS and they are heavily regulated by the U.S. Environmental Protection Agency (EPA) and the FDER.

(3) Saltwater intrusion is becoming an increasing problem, especially in coastal areas. 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.

4.7 Area-wide Surface-Water Hydrology and Water Quality

The Springs Coast contains one of Florida's major coastal rivers, the Withlacoochee and six first-magnitude springs. Table 2 gives major drainage basin and waterbody sizes as well as streamflows for Springs Coast lakes and rivers. Foose (1980) gives drainage basin, river, and lake areas for Florida including the Springs Coast. His later work (Foose 1983) includes further statistics concerning flow characteristics of Florida rivers. Figure 45 shows the general land usage in the Springs Coast, which affects runoff and the water-quality characteristics of downstream water bodies. Surface waters have been monitored by the Florida Department of Environmental Regulation (FDER) since 1973, using Permanent Network Stations (PNS), though this monitoring network has been substantially reduced in recent years.

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. Data limitations due to changing sampling methods and uncharacterized ambient conditions have prevented long-term trend analysis in Florida river basins (FDER 1986a). Lack of baseline data in most instances, and absence of continuing data collection in many instances, prevents accurate

Table 2. Statistics for Florida Springs Coast rivers (data from Foose 1980, 1983; Rosenau et al. 1977).

Main rivers	Major tributaries	Length (km)	Drainage area (km^2)	Discharge gauging site and distance above mouth (km)	Mean annual discharge (m^3/s)
Pithlachascotee River	—	29	507	near New Port Richey–15	0.88
Weeki Wachee River	—	11	spring run	below Weeki Wachee Springs–10	4.98
Chassahowitzka River	—	8	spring run	below springs cluster–1	3.92
Homosassa River	Halls River	10	spring run	below junction of SE fork	4.96
Crystal River	—	11	spring run	town of Crystal River–6.4	27.6
Withlacoochee River	Little Withlacoochee River	260	5,230	near Holder–61	31.01
	Jumper Creek Canal			at Inglis Dam[a]–18	11.97
	Lake Panasoffkee			through Bypass channel[b]–18	32.05
	Rainbow Springs				
Waccasassa River	Wekiva River	35	1,580	near Gulf Hammock–5.8	8.92
	Otter Creek				

[a] flow at Inglis Dam (below Lake Rousseau) is directed to the Cross Florida Barge Canal
[b] flow through Bypass channel (also below Lake Rousseau) is directed to lower Withlacoochee River

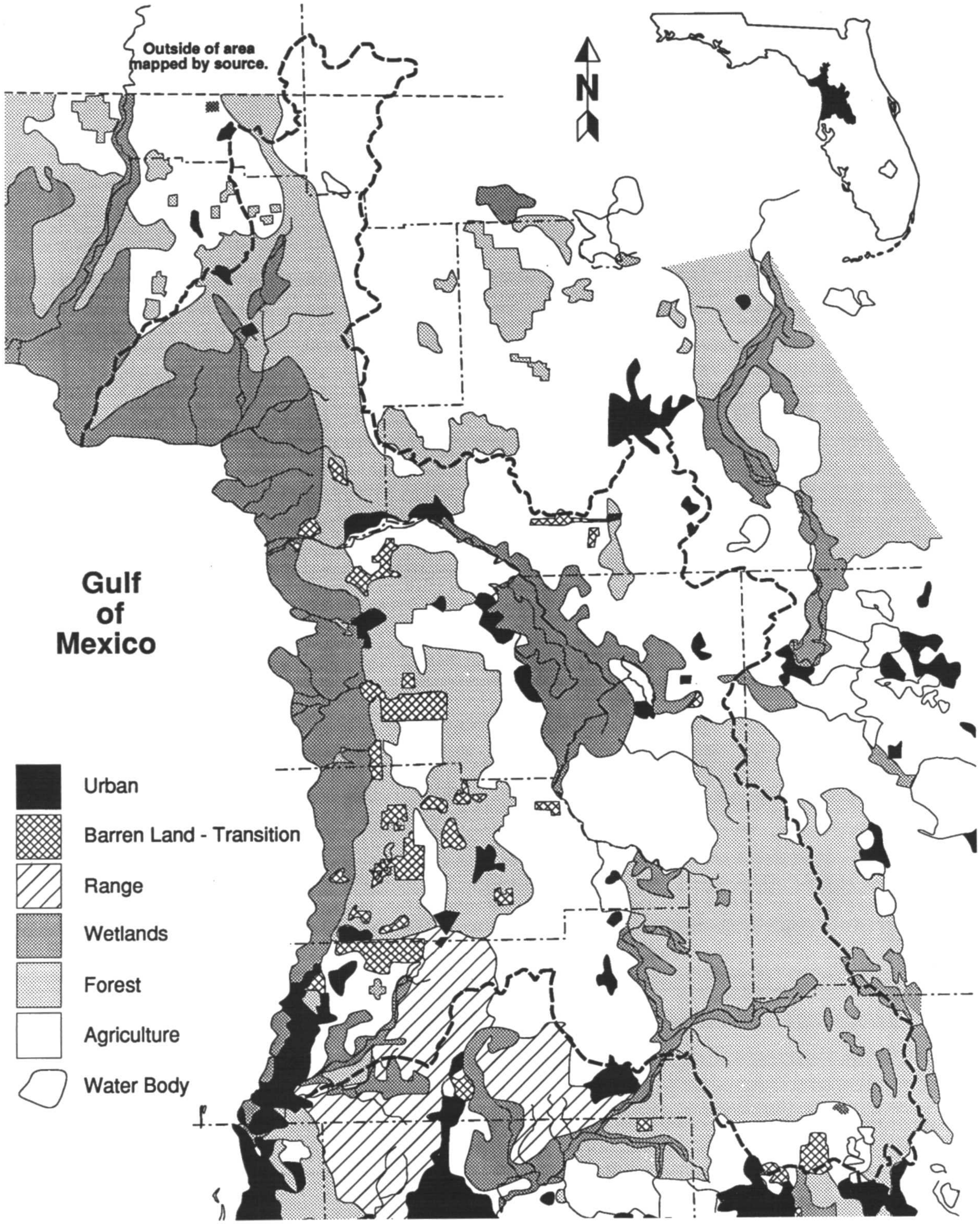


Figure 45. Generalized land use and vegetation map of the Florida Springs Coast (after SWFWMD 1978).

detection of changes in surface-water quality and hinder 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 et al. 1985).

In the Florida Springs Coast, 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 (Fig. 38). 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). The Green Swamp area in the southeast Springs Coast is the only area exhibiting these conditions. 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. The pH of most Springs Coast 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 possible 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.

Surface-water temperatures across the Springs Coast tend to follow seasonal patterns reflecting the air temperatures. The changes in water temperature lag changes in air temperature; however, the many springs and spring-fed streams are much more stable than the surface-runoff features. Freshwater surface temperatures in the Springs Coast average 20–22 °C (Anderson 1975), but non-spring-derived water bodies may vary from freezing in the winter to near 40 °C in the summer, depending upon their volume, depth, and location. During a two-year study, nearshore marine surface temperatures were observed to range from near 8 °C in winter to near 30 °C in summer (SWFWMD 1986). These temperature extremes are moderated somewhat in coastal areas near the mouths of the larger spring-fed rivers by the relatively constant temperature of the ground water flowing from them. Shallow, sheltered embayments and other areas with minimal mixing with offshore waters, may, however, have greater temperature ranges than these. Estuarine areas show the most complex variations in water temperature.

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 Springs Coast 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.

Low-flow frequency analyses were conducted for streams in west-central Florida (Hammett 1985). The low-flow levels of streams and rivers are related to their suitability as wildlife habitat and their capability to support an estuary. Low-flow characteristics also affect the suitability of the stream as a reliable water supply and determine the capacity of the water body to assimilate a continual waste load without unacceptable drops in water quality (Seaman and McLean 1977). In studies co-sponsored by the Southwest Florida Water Management District, the USGS investigated the effects of freshwater inflow rates on salinity distributions in five gulf coast estuaries, including the Weeki Wachee, Homosassa, Crystal, Chassahowitzka, and Withlacoochee estuaries (Yobbi and Knochemus 1988a,b). The water quality and ecological characteristics of three of these estuaries (Weeki Wachee, Crystal, and Withlacoochee), plus Hammock Creek and the Waccasassa River, were studied by Mote Marine Laboratory and the SWFWMD during the same times as the USGS studies (SWFWMD 1986). All the studies were commissioned, in part, to examine the effects of potential freshwater withdrawals from rivers flowing to those estuaries and the establishment of regulations to protect the estuarine resources.

In a thesis by Wyllie (1981), the monthly evapotranspiration rates for 1-km^2 quadrants of the SWFWMD (including the Springs Coast) were computer modeled and a verification study performed. Figure 46 shows the potential (modeled) average evapotranspiration in the water-management district, using four different methods.

The Springs Coast coast experiences unequal semidiurnal tides; i.e., two high and two low tides daily, each of different magnitude. The range between the high-high and the low-low tides is approximately 0.6–1.4 m (Yobbi and Knochemus 1988a,b)

4.8 Area-wide Ground-Water Hydrology and Water Quality

Ground water within the Florida Springs Coast 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 underlies the entire Springs Coast and dominates area aquifer hydrology. This aquifer supplies most of the water used in the Springs Coast. The approximate thickness of the potable-water zone in the Floridan is shown in a USGS map (Causey and Leve 1976). Ground-water movement is from areas of high potentiometric pressure to those of low (Fig. 40).

The surficial aquifer consists of a porous, sandy surface layer, recharged locally and 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

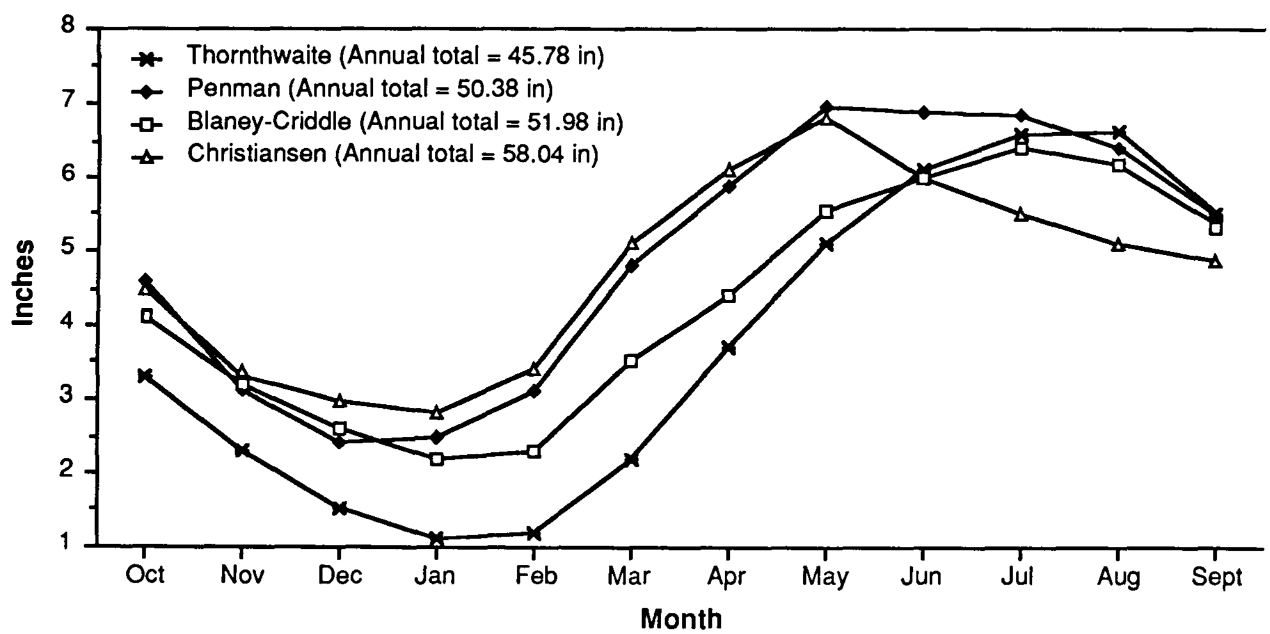


Figure 46. Comparative average potential evapotranspiration in the middle gulf area as calculated by four models (after Wyllie 1981).

layer are at the surface, may not exist at all. Where the surficial aquifer exists, the water is usually of lower mineral content than the underlying Floridan.

Average ground-water temperature in the top 25 m of the Springs Coast is approximately 23 °C, varying about 3-4 °C throughout the year (Heath 1983). The shallow aquifers, however, vary more than the deeper ones.

Research by Harada et al. (1989) has found substantial concentrations of the highly radioactive element polonium in the surficial aquifer in areas of west-central Florida. While this aquifer is not a common water source, there is some usage, and further work is being performed under the aegis of the FDER to identify the source, the extent of the area involved, and degree of hazard associated.

The U.S. Geological Survey, under contract to the Southwest Florida Water Management District (SWFWMD) and Suwannee River Water Management District (SRWMD), is involved in numerous studies of hydrology and water quality in the Springs Coast, among them investigations of ground water in several of the southern Springs Coast counties (Fretwell 1983, 1985, 1988), the potentiometric surface of the Floridan aquifer (e.g., Barr and Schiner 1982,1983; Yobbi 1983), the potential for saline contamination of the Floridan through its lower confining bed (Duerr and Enos 1991), and the potential of any intermediate aquifer as a water supply (Duerr et al. 1988). Realizing that the present picture of the Springs Coast aquifer system is inadequate, they are attempting to further define the systems and subsystems present in ground water in the SWFWMD. Semiannual potentiometric surface maps of the Floridan aquifer in the SWFWMD have been published by the U.S. Geological Survey since 1975 (e.g., Barr and Schiner 1982,1983). Appendix Table A lists selected U.S. Geological Survey maps for the Springs Coast.

Within the Springs Coast, ground-water pumping has lowered the Floridan aquifer significantly, primarily in the southern region. In some places (Pasco County), overlying wetlands are drying up as a result of pumping. Heavy withdrawal near the coasts has also permitted saltwater intrusion and contamination of area water supplies, especially along coastal Pasco, Hernando, and Citrus Counties.

During an investigation of the effect of the completed portion of the Cross-Florida Barge Canal on nearby ground-water salinity, The Earth Technology Corporation (1986) concluded that poor water quality in the vicinity of Yankeetown was caused by the presence of anhydrite deposits ($CaSO_4$) and not primarily by saltwater intrusion.

An evaluation of the hydrogeologic resources of the "Four Rivers Basins Area" (Geraghty and Miller, Inc. and Reynolds, Smith and Hills 1977), that area containing the rivers arising in or near the Green Swamp, (including the Pithlachascotee and Withlacoochee Rivers in the southern Springs Coast) shows much higher recharge rates in the northern portions of the study area. Additionally, the transmissivity (i.e., rate of transmission of ground water through the aquifer substrate) in the Floridan becomes much higher as one progresses northward (Missimer and Associates 1978). This, coupled with greater rates of withdrawal in the southern portion, result in abundant fresh ground water in the north and shortages in the south. Enough total water is available to provide overall needs for growth projected through the year 2035; however, means to transport the water from areas of abundance to areas of shortage will be necessary.

Ensuring continuing water supplies requires regulation by governmental authorities because the hydrology and water quality of Springs Coast 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.

4.9 Basin Hydrology and Water Quality

4.9.1 Coastal Area between the Anclote and Withlacoochee Rivers (Fig. 47)

This 2,725-km^2 area is predominantly poorly drained marsh with the Floridan aquifer occurring at or near the surface. With one exception, the major

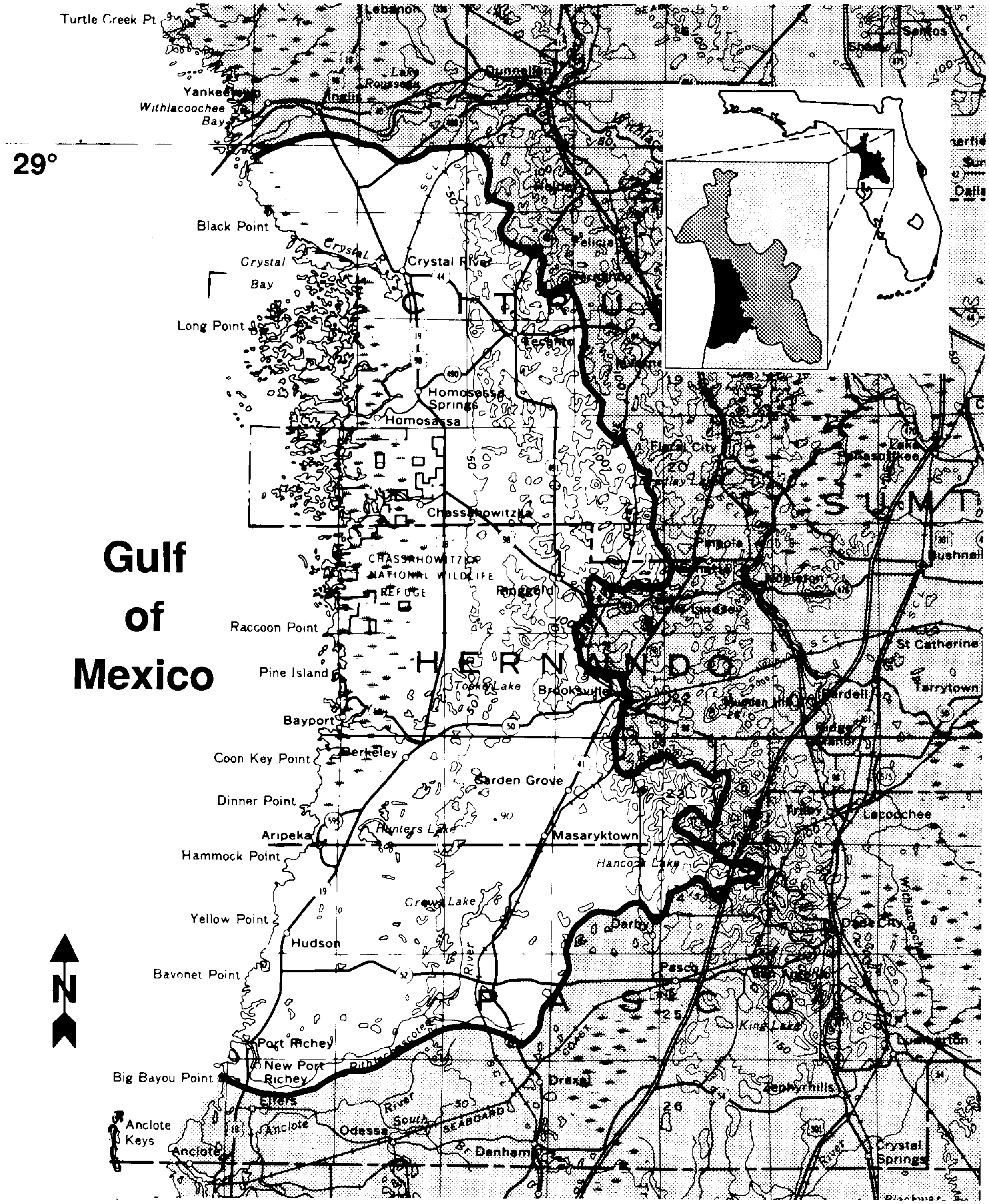


Figure 47. Coastal Area drainage basin—the area between the Anclote River and the Withlacoochee River.

point discharges to the Gulf of Mexico are spring fed rather than derived from surface drainage. First-magnitude (average flow >30 m^3/s) springs include Weeki Wachee, Chassahowitzka, Homosassa, and Crystal River. The hydrology of the spring complexes providing the flow of these rivers is being addressed in a study by the U.S. Geological Survey (Yobbi 1989). The flow of the springs varies seasonally and the flows of all but Weeki Wachee are affected by tidal fluctuation. The total flow of these four spring complexes averages over one billion gallons per day. Innumerable smaller springs are located along the coast, particularly in the northern half of the basin. Some of these were described and characterized by Wetterhall (1965). Surface runoff is confined to these coastal springs except at the southern boundary and is derived from rainfall's charging of the Floridan aquifer east and south of the springs area (Fretwell 1983; Yobbi 1989). Commonly, sinkholes act as collection points for surface runoff and divert it into the Floridan aquifer.

a. Pithlachascotee River. At the southern boundary of this area, where the relief is sufficient to form a river, the Pithlachascotee River drains 508 km^2 of Hernando and Pasco Counties. The hydrology of the river basin and the area north along the coast to beyond Weeki Wachee springs was studied by Missimer and Associates, Inc. (1978). This river originates in an area of interconnected lakes and sinkholes in south-central Hernando county, connected by surface and subsurface channels to Crews Lake, which is divided by an earthen dike into north and south segments connected by a culvert. According to the Florida Water Quality Index (FWQI) (FDER 1984), Crews Lake exhibited good water quality historically, but no recent EPA STORET data was available. The northern part is connected directly to the Floridan aquifer by a sinkhole and the lake level drops faster in this part when the lake stage drops below the connecting culvert. The lake level varies seasonally, has done so since at least the mid-1800's (Wharton 1984), and has been completely drained through the sinkhole during very dry years (Cherry et al. 1970). The rate of drainage into the sinkhole is probably at least 18 m^3/sec much of the time. The poorly defined river channel runs approximately 29 km to the coast, during which substantial flow is lost due to infiltration through the river bed into the underlying Floridan aquifer (Wharton 1984). This river has very low base flow, and during low-flow conditions most of the river's water originates as ground-water seepage. During high flow, most of it comes from surface runoff (Courser and McLean 1977).

The numerous wetlands located in the Pithlachascotee River basin as well as Crews Lake are water-table marshes and lakes, frequently having direct connection to the aquifer via sinkholes. The surface-water levels follow fluctuating ground-water levels, and prolonged dry spells cause the lakes and marshes to dry completely. Heavy ground-water pumping causes the levels in those lakes directly connected to the aquifer to recede rapidly. Northern and eastern portions of the Pithlachascotee drainage basin receive 3–4 in more rainfall than the southwestern coastal area. Staff from the SWFWMD collected baseline salinity data in the river during 1980–81 and 1985–87. Sampling during the 1985 drought found the toe of the salt wedge 11.3 km up the river from the mouth, which was close to the theoretical maximum penetration estimated by the USGS (Coble 1973). Ross and Jones (1979) report that macroinvertebrate sampling at two sites, twice near the SR 518 bridge and once about 1.5 km upstream of it, showed greater diversity upstream. The bridge site receives residential runoff, the upstream site, pasture runoff. The difference in diversity was attributed to the upstream station's receiving less pollutant material and, being entirely freshwater, without salinity stress. The Water Quality Inventory for the State of Florida (Hand and Jackman 1984), which utilizes the EPA STORET computer data, reports that the Pithlachascotee is heavily impacted by urban growth, especially in the lower segments where it receives runoff from New Port Richey and Port Richey. A recent water quality study of the Pithlachascotee River found that nutrients and coliform bacteria were within acceptable limits in upstream areas, but were high in the downstream, urban portions of the river due largely to stormwater runoff (Dames and Moore

1991). Dissolved-oxygen levels have improved in 1981-83 compared to historic records, but turbidity readings have increased.

b. Hammock Creek. Hammock Creek, near Aripeka at the Hernando-Pasco County border, is fed from a number of small springs (Fig. 48). The water is brackish nearly to the headsprings; Fig. 49 shows the salinity regime. The water quality and ecological characteristics of Hammock Creek were studied by the Mote Marine Laboratory and the SWFWMD (SWFWMD 1986).

c. Weeki Wachee River. The Weeki Wachee River is about 11 km long and located entirely within Hernando County. Its channel is well defined, cutting through bedrock and thereby creating numerous small springs. Considerable damage may have been done by extensive nonpermitted dredge-and-fill operations during which the Weeki Wachee river bottom was dredged to depths 10 ft below the natural bottom elevation, connecting canals cut into a half-mile of the river bank, and vegetation and trees clear cut (Fig. 50).

Ross and Jones (1979) report that three samplings during 1976–78 at a station north of the mouth of the river near Bayport showed very good macroinvertebrate diversity. Hand and Jackman (1984) report that Weeki Wachee Springs has an elevated bacterial count from unknown sources. Ross and Jones (1979) report that bacterial concentrations were normally low, with exceptions probably related to runoff. Macroinvertebrate sampling at the springs showed very variable diversities ranging from poor to very good. This was attributed to sampling error induced by the varying substrate found in the springs. Biotic Index numbers indicated only fair water quality. The water quality and ecological characteristics were studied by Mote Marine Laboratory and the SWFWMD (SWFWMD 1986). The salinity regime of the estuary is presented in Fig. 51.

d. Chassahowitzka River. The 8-km run of the Chassahowitzka River in Citrus County is fed by numerous springs and fluctuates seasonally with ground-water levels. Hand and Jackman (1984) report that limited EPA STORET data for the period prior to 1981 show the water quality of the river to be good. No STORET data collected after 1981 is available. The Chassahowitzka was not sampled for macroinvertebrate diversity.

e. Homosassa River. The Homosassa River runs 10 km through Citrus County from its headwaters at Homosassa Spring to Homosassa Bay. Halls River, another spring-fed stream, is the only freshwater tributary of consequence. The Homosassa, like most of these spring-fed coastal rivers, receives little surface runoff. Hand and Jackman (1984) report that both the historic and recent water quality of the river is good and that the macroinvertebrate diversity is fair. A recent study of the river by Florida Land Design and Engineering (1989), however, found significant water-quality degradation in the uppermost reaches of the river due primarily to the effects of septic tanks and treated-wastewater effluents. A macroinvertebrate sampling station below the confluence with Halls River showed good diversity during three samplings in 1976–78 (Ross and Jones 1979), but a lower number of species than expected. The presence of several estuarine taxa at this station indicated the presence of a salt wedge reaching upstream from the gulf. It was postulated that the salinity variation plus the relatively low DO common to spring waters was responsible for the limited number of species.

f. Crystal River. The Crystal River runs approximately 11 km from Crystal River Springs near the town of Crystal River to the Gulf of Mexico (Fig. 52). Crystal River Springs is a first-magnitude cluster of at least 30 springs. Examination of EPA STORET data (Hand and Jackman 1984) showed records of good water quality during the period before 1981. No STORET later data is available to determine if the substantial development taking place in the area has affected the river and springs. A study of the water quality and ecological characteristics in the river was performed by Mote Marine Laboratory and the SWFWMD (SWFWMD 1986). The salinity regime of the estuary is presented in Fig. 53. Crystal River was not covered by Ross and Jones (1979).

The nearshore area where the Crystal River Nuclear Power Plant cooling-water intake and

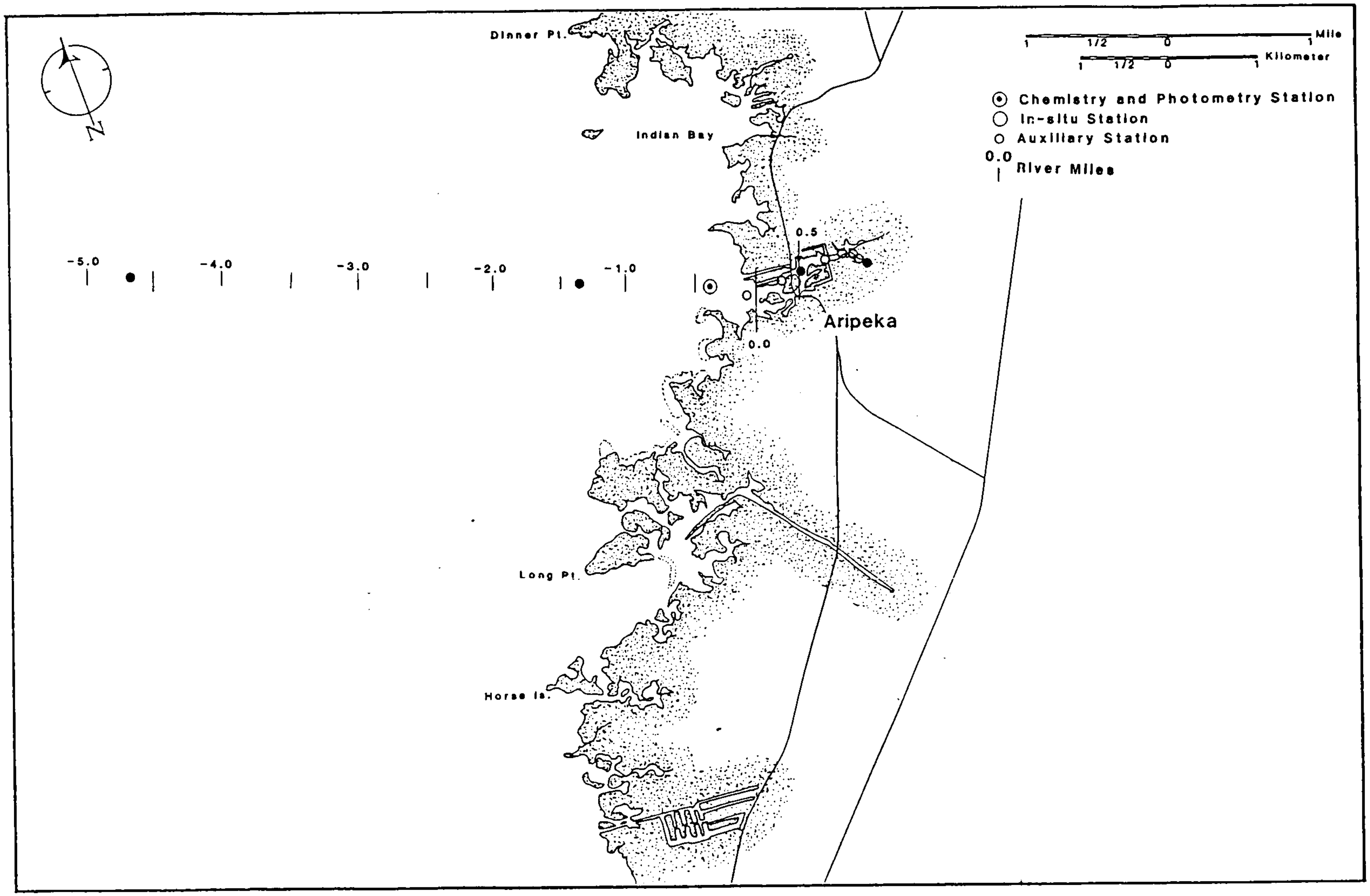


Figure 48. Hammock Creek estuary and sampling stations from SWFWMD study (Dixon 1986).

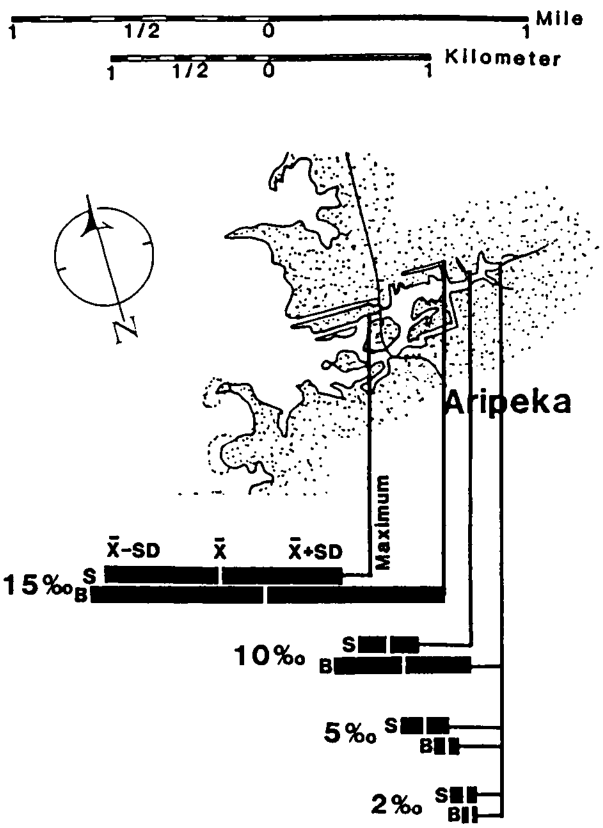


Figure 49. Hammock Creek: surface and bottom, high-tide isohaline positions; mean, standard deviation, and maxima of penetration during 1984 (Dixon 1986).

discharge and the entrance to the Cross-Florida Barge Canal are located has been studied. This area lies along the coast between the mouths of the Crystal and Withlacoochee Rivers. During 1969–1971, before the startup of the nuclear reactor while the plant was operating two coal-fired generators, a environmental baseline study was performed recording extensive population data, temperature regimes, and trace-metal levels in oysters (Mountain 1972). Records were also kept on air temperature, DO, and pH at the 27 sampling stations. This study showed an increasing bottom salinity gradient proceeding offshore and from the canal entrance to south of the power plant cooling water channels. No temperature gradient was evident proceeding offshore, but an increase of about 1 °C was evident proceeding towards the power-plant channels. Periodic peaks of low-level copper concentrations in the oysters were attributed to runoff from stored coal near the canals. Twelve other metals were monitored, including mercury, lead, cadmium, and zinc. No troublesome levels were noted.

g. Other. The annual flow regimes of the spring-fed rivers fluctuate less than those of surface-drainage rivers. This creates unusual estuaries along this part of the Florida coast that have more stable physical conditions than is common in the estuaries formed by surface-drainage rivers. The freshwater, however, is much lower in dissolved nutrients (especially nitrogen) and detritus than are drainage rivers. Preliminary results from studies on the Weeki Wachee, Homosassa, and Crystal River estuaries commissioned by the Southwest Florida Water Management District indicate that, as a result, the overall phytoplankton standing crop may also be lower, though seagrass biomass may be substantial (SWFWMD 1986). Additional USGS studies were performed to gather physical and chemical data to aid in predicting salt-wedge movement in the coastal rivers under various flow conditions and the effects of possible withdrawals of surface or ground water on the estuary salinity (Yobbi and Knochemus 1988a,b).

Waste-load allocation studies were performed on the Cross Bayou (near New Port Richey), Homosassa River, and Crystal River estuaries (Seaburn and Jennings 1976). This study predicted no change in DO or total Kjeldahl nitrogen (TKN) levels for wasteloads projected through 1985 in the Crystal and Homosassa Rivers. Cross Bayou was projected to experience lower DO and increased TKN. Myers and Edmiston (1983) concluded that this basin had no lakes ranking in the top 50 needing restoration, and one, Moon Lake in Pasco County, ranking in the top 50 needing preservation. The USGS has investigated certain lakes in the basin to describe their physical, chemical, and hydrologic characteristics and to examine their relation to the surrounding hydrologic system. To date, these include Lake Padget, Saxon Lake, and the adjacent area in Pasco County

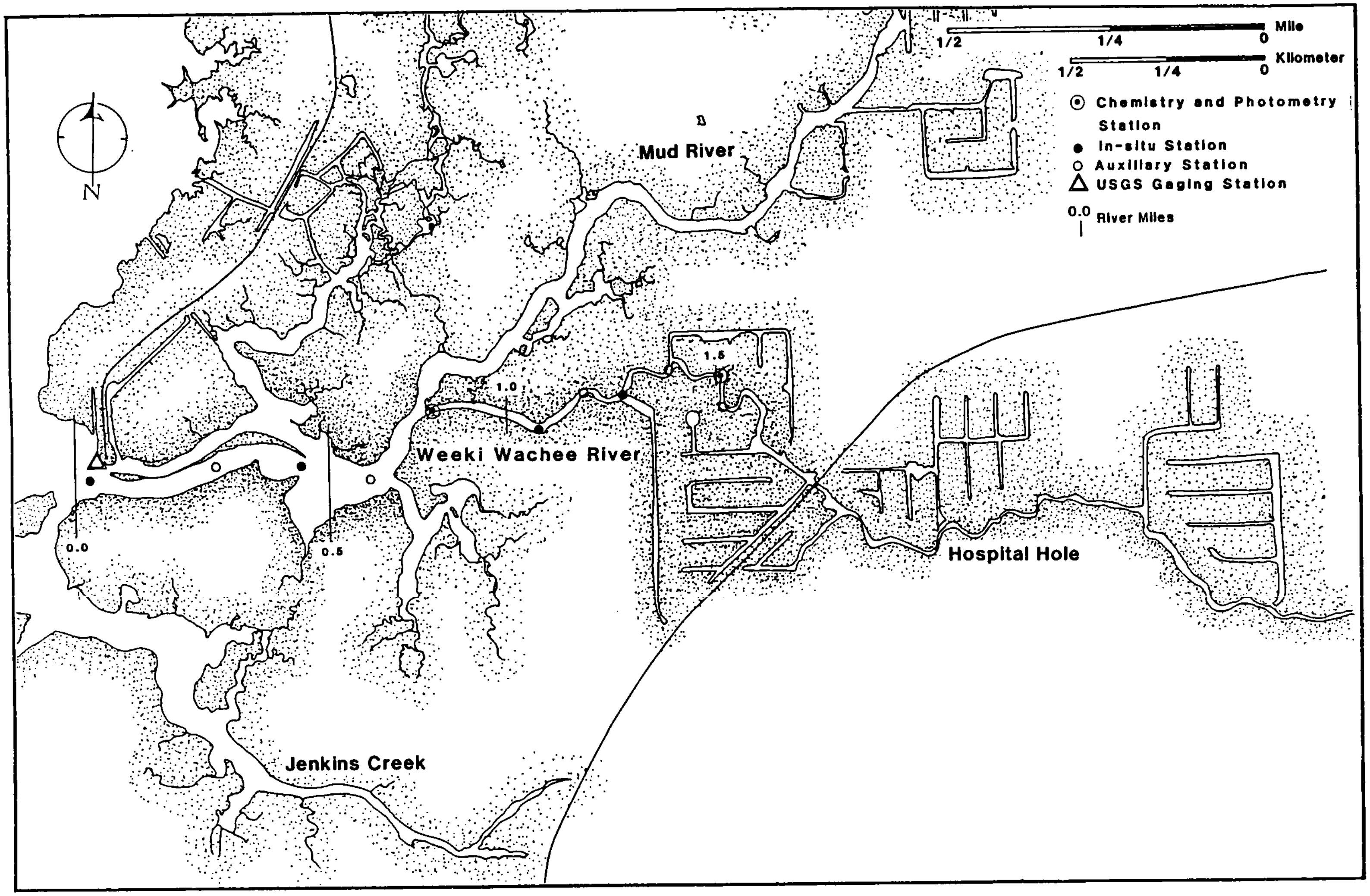


Figure 50. Weeki Wachee River estuary showing sampling stations from SWFWMD study and results of extensive dredge-and-fill activity (Dixon 1986).

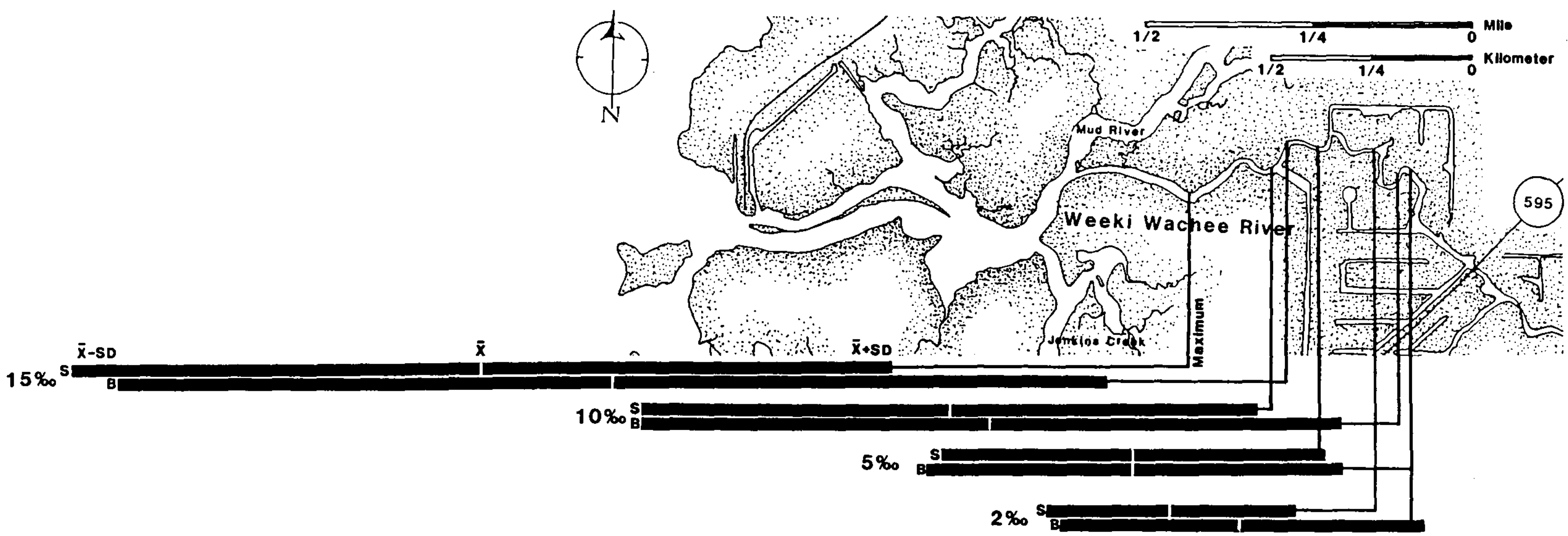


Figure 51. Weeki Wachee River: surface and bottom, high-tide isohaline positions; mean, standard deviation, and maxima of penetration during 1984–1985 (Dixon 1986).

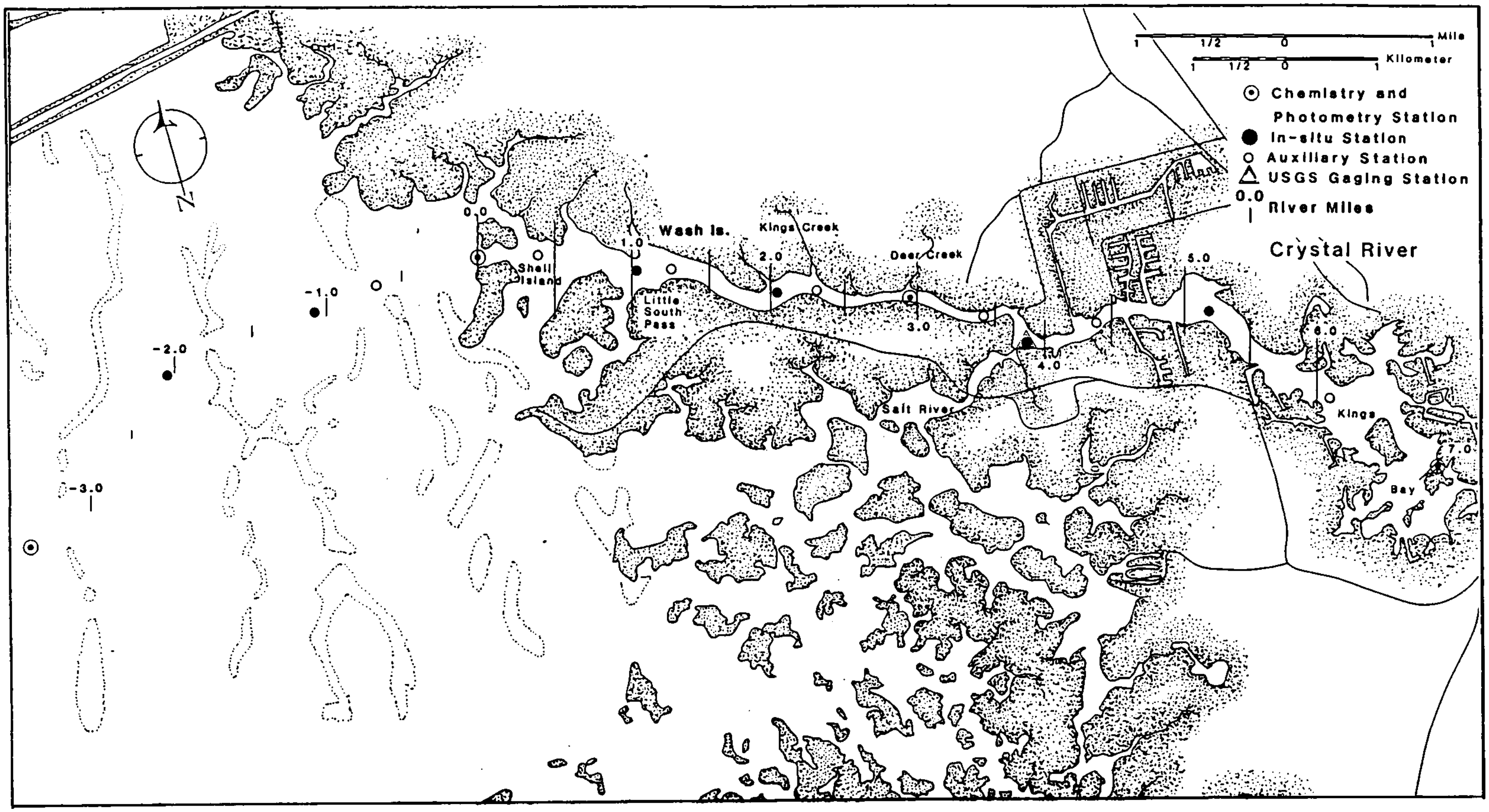


Figure 52. Crystal River estuary and sampling stations from SWFWMD study (Dixon 1986).

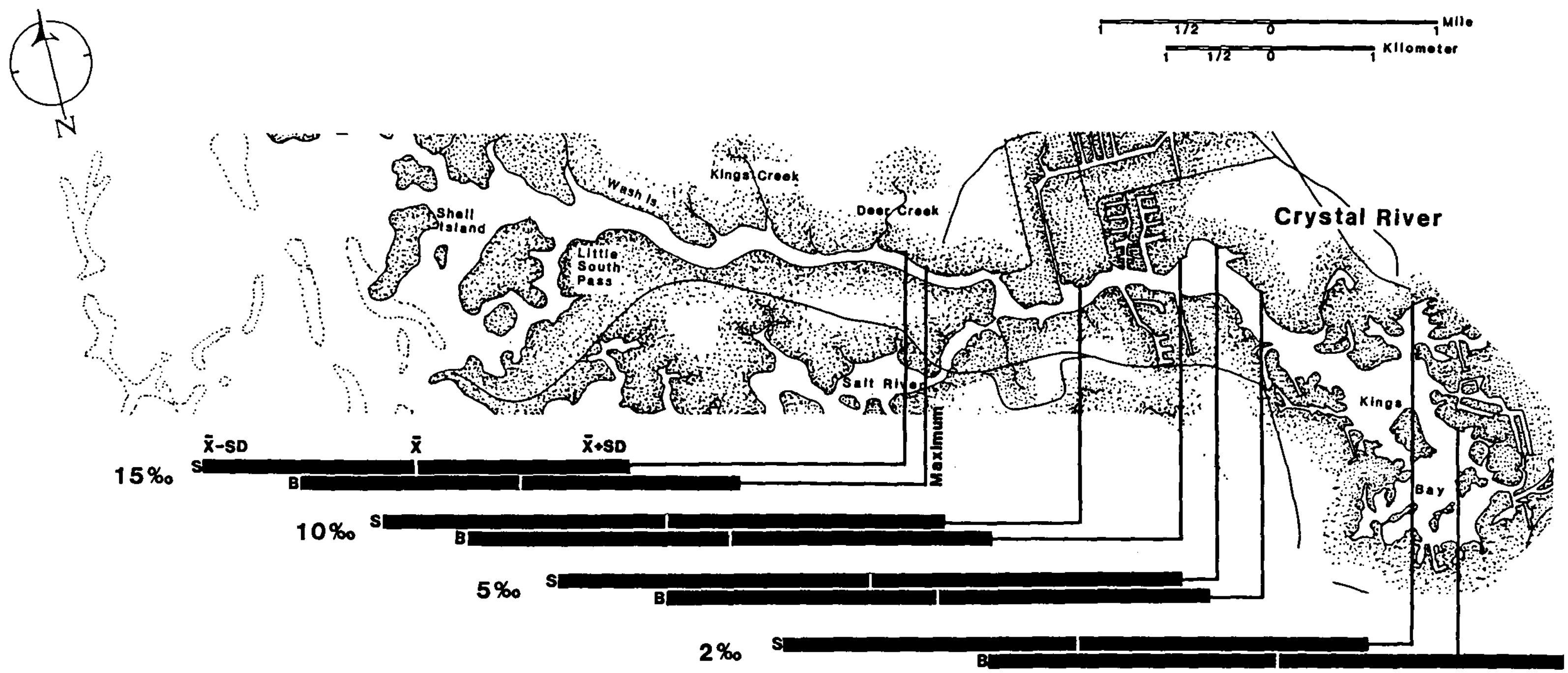


Figure 53. Crystal River: surface and bottom, high-tide isohaline positions; mean, standard deviation, and maxima of penetration during 1984-1985 (Dixon 1986).

(Henderson 1983), and Lake Tsala Apopka in Citrus County (Rutledge 1977).

The extensive well fields supplying water to the heavily populated areas in the southernmost Springs Coast and to areas south have lowered the level of the surficial aquifer (Guyton and Associates 1974), with the result that some overlying wetlands have dried up. This has occurred in part of the Jay B. Starkey Wilderness Park in Pasco County from pumping at the Starkey wellfield located within it. Monitoring by the SWFWMD has documented a vegetation shift from wetland to upland vegetation (Rochow 1982, 1984, 1985) in the far western portion where the most pumping took place before to 1983. The SWFWMD is now monitoring the central portion, the area to which the pumping effort has shifted in an effort to minimize saltwater intrusion. The hydrology and water quality of Pasco County are currently under investigation by USGS (Fretwell 1988), with emphasis on the effects of proposed ground-water pumping on the hydrologic system.

The progress of saltwater intrusion into the ground waters of coastal Hernando and Citrus counties (USGS 1977) showed intrusion farther inland in Citrus County. This was attributed to direct recharge of saltwater to the Floridan aquifer along canals and rivers during periods of low freshwater flow and to large amounts of ground-water pumping to supply the heavily urbanized coastal area of Citrus County. Sinclair (1978) examined the Weeki Wachee spring-river system and the lower Withlacoochee River including Rainbow Springs for water-supply potential. These were felt to be the only two systems in the SWFWMD (southern Springs Coast) suitable for development that were not tidally affected, topographically low, or located near the zone of the ground water's fresh/salt interface. The ground-water flow was generally from the topographic highs in the southeast toward the coastal discharges along the coast in the northwest. Sinclair gives estimates of the volumes of water that could be withdrawn from the various sites and the impacts upon the hydrologic system of those withdrawals. Similar investigation of coastal Pasco County (Reichenbaugh 1972) showed the saltwater interface paralleling the Gulf Coast one to two miles inland. A subsequent well-monitoring program by SWFWMD in Pasco County reported that chloride levels in two coastal wells had increased at an average annual rate of over 250 mg/L per year between 1971 and 1982 (SWFWMD 1983). The study was unable to point to any single dominant cause of the increase.

The USGS is examining the hydrology and ground-water quality in Hernando County (Fretwell 1985; Mahon 1989), to look at the effects of proposed ground-water withdrawals on the hydrologic system, particularly impacts on flow to the coastal springs and saltwater intrusion.

4.9.2 Withlacoochee River Basin (Fig. 54)

Two rivers in Florida bear the name Withlacoochee: one is a tributary of the Suwannee River in north Florida; the other, located in the Springs Coast region, starts in central Florida and runs northward to the gulf coast. The latter Withlacoochee River is about 260 km long, drains approximately 5,230 km^2 and originates in the extensive wetland known as the Green Swamp, which constitutes the upstream half of the drainage. Downstream, the Withlacoochee receives water primarily from Lake Panasoffkee, Lake Tsala Apopka (a large area of shallow, interconnected lakes), and Rainbow Springs. A major portion of the river flow is contributed by the Floridan aquifer. The Withlacoochee River basin was examined prior to many of the drainage alterations for the Sumter County Recreation and Water Conservation and Control Authority (Gee & Jenson 1958). The study documented rainfall and river-flow correlations and flooding patterns and recommended construction of various flood-control structures, many of which are now in place. The Withlacoochee River basin is a relatively highly controlled watershed with numerous artificial flow-control structures in both the river and the surrounding tributaries and wetlands. The only structure in the river itself above Inglis is the Wysong Dam just downstream of the Lake Panasoffkee inflow. The Inglis Structural Complex includes Inglis dam and the various locks and spillways of the abandoned Cross-Florida Barge Canal.

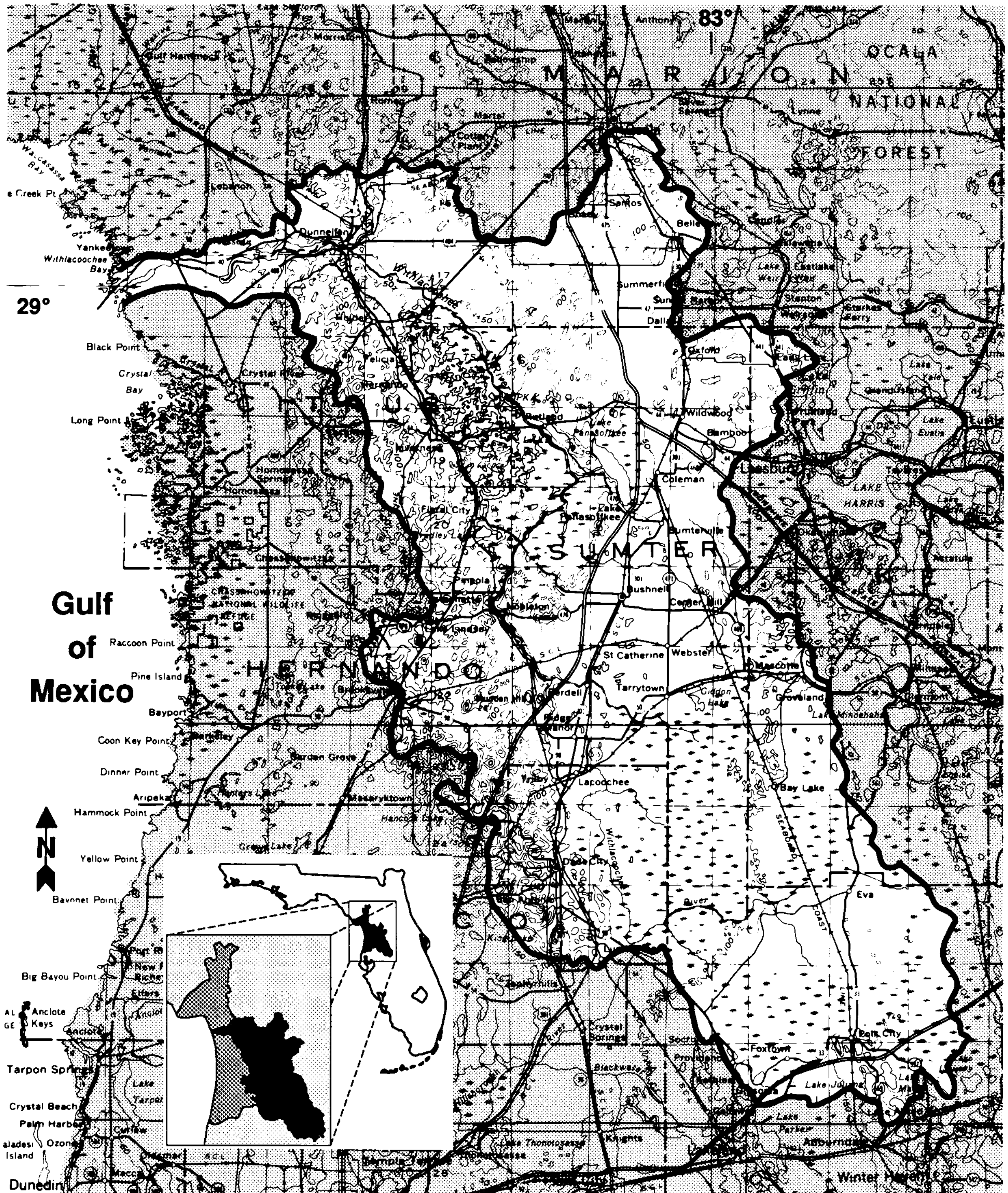


Figure 54. Withlacoochee River drainage basin.

The Green Swamp is possibly the second most significant hydrologic and environmental area in Florida after the Everglades. A committee appointed by the governor chose this area as one of six in Florida for which they devised strategic plans to help preserve and/or restore the systems as important to the State (Florida Rivers Study Committee 1985). Due to increasing "improvement" of areas along the edges for agriculture and the beginning realization that similar efforts in the Everglades were causing unexpected problems, the State of Florida contracted with USGS to examine the area hydrology (Pride et al. 1961, 1966). The Four River Basins Project was initiated to protect urban and agricultural areas from severe flooding (U.S. Army Corps of Engineers 1962, 1980; SWFWMD 1979). The name refers to the four rivers that originate in the Green Swamp; the Withlacoochee is the only one of the four in the Springs Coast; however, it drains the majority of the swamp (Pride et al. 1961, 1966; Parker 1973). In 1974 portions of the swamp were declared Areas of Critical State Concern by the Florida Legislature in recognition of the area's unique hydrologic and environmental values and the realization that State aid was necessary for their preservation. This designation places strict standards on zoning and construction in the floodplain and remains in effect until the State is satisfied that local governments will enact necessary ordinances to maintain the natural integrity of the system (SWFWMD 1984).

The Green Swamp is located on a sandy ridge in central Florida; it contains many marshes, some which are interconnected, but many of which are separated by ridges, hills, and upland plains. The elevation of the land surface within the Green Swamp varies from about 60 m above sea level in the eastern part to about 23 m in the river valleys of the northwestern part. The Withlacoochee River drains over 80% of the approximately 2,250 km^2 Green Swamp, the southern part via a network of small streams that flow generally north to the river. Here the Withlacoochee River-Hillsborough River Overflow, a unique natural saddle where a portion of the Withlacoochee flow diverts to the Hillsborough River when the Withlacoochee reaches a stage of approximately 24 m above mean sea level, is located. The Little Withlacoochee River and Gator Hole Slough drain the northern part of the Green Swamp westward into the Withlacoochee, the Little Withlacoochee alone increasing the flow by 20%.

The Floridan aquifer outcrops in the western part of the swamp, but is approximately 60 m below the land surface in the eastern, which functions as a Floridan recharge area. There is no flow of surface water into the Green Swamp, and rainfall, as well as Floridan baseflow to streams during dry periods, is the only source of water in the area. Due to the sluggish surface flow, much of this rainfall evaporates; transpires; or, in the eastern part, percolates into the ground, recharging the underlying surficial and Floridan aquifers. The area is a potentiometric high for the Floridan aquifer, and portions of the swamp are thought to be areas of great potential recharge (Fig. 35) (SWFWMD 1984). Since the Floridan in this area is locally recharged, the stream base flow is still of local rainfall origin, but the marshes and aquifer function as a sponge to moderate the rate of surface drainage to the Withlacoochee and its tributaries, thus evening out flood peaks and periods of low flow. Drainage canals have been constructed in many places within the Green Swamp area, connecting adjacent swamps, reducing the circuitous route by which the surface water drains, and generally speeding the drainage of area water. The SWFWMD and the U.S. Army Corps of Engineers (1962) have been engaged in a program to regulate occasionally severe flooding. The emphasis of this program has shifted in recent years from construction of permanent impoundments to control through the use of flood detention areas (Waldron et al. 1984). These areas store waters for short periods of time during periods of peak rainfall, but do not form permanent lakes or pools. This method is believed to accomplish the goal of reducing flooding at minimal environmental damage. Corps of Engineers interest has been reduced, since their justification for involvement was based upon the value of the impoundments as sources of water supply.

The strata below the Green Swamp contain a number of faults which, if within the Floridan aquifer, probably increase the permeability of the aquifer unless they have filled with sediments of low permeability. Where these faults cut confining beds, they may increase the circulation of ground water between aquifers (Pride et al. 1966).

North of the Green Swamp and east of the Withlacoochee, Jumper Creek Canal drains a 215-km^2 wetland area which is now used for truck farming, cattle raising, and several limestone mines. This watershed has one of the most stable flow regimes in west-central Florida due to its above- and below-ground storage capacity, and was examined in 1978 to determine if proposed drainage alterations would be beneficial (Anderson 1980).

Lake Panasoffkee is a large (2.5 km^2), shallow (maximum depth ≈ 3 m) lake located in the north-central portion of the drainage basin. The lake is an exposed portion of the Floridan aquifer (Taylor 1977) and receives runoff from a surrounding large, marshy watershed (Greiner Engineering Sciences 1978). It contributes about four times the flow of the Little Withlacoochee to the river. A 1-year baseline study of algal biomass, productivity, and nutrient concentrations in the lake (Bays and Crisman 1981) determined that it was mesotrophic but that water quality, based on these criteria, was not a problem. Earlier, Moody (1957) conducted a fisheries study of the lake. The lake vegetation was mapped during 1974, 1975, 1978, and 1980 (Dooris 1982). These maps suggest that the plant diversity is good, though there have been changes in species dominance, and show that the lake is eutrophic and aging rapidly. The lake is listed in Myers and Edmiston (1983) as one of the 50 lakes in Florida most in need of preservation and protection.

Lake Tsala Apopka is in the west side of the Withlacoochee River valley in Citrus County and consists of a large area of numerous interconnected shallow ponds and wetlands (Attardi 1983a). The pools in the western part of the lake are comparatively deep; the lake grows progressively shallower and melds into marsh on the east side (Rutledge 1977). Wetlands cover 40% of the area, but cypress trees do not inhabit the marshes because water currents and a lack of dry periods prevent their establishment. Although there was no open-water connection between the lake and river prior to the late 1800's, and what flow there was went through the marshes, a system of canals and flow-control structures now govern the generally northerly movement of water through the lake and into the Withlacoochee. Water quality in the southern reaches of the lake system is most closely related to water quality in the river (Buickerood et al. 1990). The lake is connected hydraulically with the Floridan aquifer (Bradner 1988). The aquifer is near the surface and overlain with a permeable sand bed. The configuration of the potentiometric surface shows that the lake is a recharge area for the Floridan (Bradner 1988). Open water in the lake is basically confined to three pool areas: the Floral City Pool in the south, the Inverness Pool, and the Hernando Pool in the north.

North of Lake Tsala Apopka, the river bends and flows west to the gulf. Just above the impounded Lake Rousseau, Rainbow Springs discharges to the river. Rainbow Springs is a first-magnitude spring whose average flow is exceeded by only three other springs in the state. A hydroelectric-power dam built across the river near Inglis in 1909 formed the long, narrow Lake Rousseau, approximately 18 km long and covering some 16 km^2 (Heath and Conover 1981). The power station has since been shut down. The lake is in a state of advanced eutrophication approaching senescence (German 1978) and is listed in the FDER lake classification project (Myers and Edmiston 1983) as one of the 50 lakes in the state most in need of restoration. German (1978) found that organic detritus had accumulated to a depth of one or more meters over much of the bottom and that the surface was covered by mats of thick vegetation. The lake did not appear to have high nutrient levels, though abundant plant growth caused occasional low DO. A more recent analysis of Lake Rousseau by the SWFWMD (Downing et al. 1988) also concluded that restoration efforts were warranted and that these efforts should include periodic extreme drawdowns of reservoir water levels. Currently, the reservoir has severe problems with excessive aquatic vegetation, especially hydrilla and large floating islands of mixed vegetation. The SWFWMD concluded that nutrient levels in Lake Rousseau were closely related to the inflowing Withlacoochee River, and the principal water-quality problem in the reservoir was periodic low DO levels. It was suggested that the excessive aquatic weeds worsened dissolved oxygen conditions by restricting vertical mixing and lateral circulation. They also found that organic-rich sediments of up to 1 m in depth have accumulated over much of the reservoir, probably increasing sediment oxygen demand.

Concentrations of toxic substances such as metals and pesticides are low (Lamonds and Merritt 1976), and EPA STORET data show occasions of low DO in 7 of 11 areas sampled (primarily near the dams) as the only water-quality problem (Hand and Jackman 1984). The river pH increases downstream from the source, averaging approximately 5.1 near the Green Swamp, increasing to 7.7 near Jumper Creek Canal, and remaining there to the gulf. Average nitrogen levels have increased in the river below the Jumper Creek Canal when compared with average levels from 1960–1977 (Hand 1980). A large kill of the Asiatic clam *Corbicula manilensis* was reported in July 1983 (Attardi 1983b) but was tentatively attributed to a natural die-off following spawning in an exceptionally large year class.

Ross and Jones (1979) reported on biological aspects of water quality at six stations along the Withlacoochee River covering data from 1974–78. They found that at a sampling station near the head of the river east of Dade City, natural substrate macroinvertebrate populations sampled during 1976–78 showed good diversities, with pasture runoff the only significant pollution source. Downstream near Lacoochee, the river is subject to citrus-processing and domestic wastes as well as pasture runoff. Macroinvertebrate diversity data indicated a fairly healthy community, but conflicting data made interpretation of trends uncertain. Bacteria counts were within the standards for recreational waters. Near Holder the river exhibited generally good macroinvertebrate diversity, but trend data here were also conflicting. Data inconsistencies at both stations were attributed to wide variations in stream flow at these sites. A station in Blue Run, which flows from Rainbow Springs and the Rainbow River to the Withlacoochee River, suggested good water quality and showed acceptable bacterial levels. A station in the Withlacoochee downstream of the confluence with Blue Run also showed generally good macroinvertebrate diversity and fairly low bacterial counts. A final station in the Withlacoochee River below the dam at Inglis showed good macroinvertebrate diversities. The Biotic Index showed significant decline during the sampling period. It was suggested that this might be the result of a loss of habitat diversity due to the stable water levels supplied by the dam. Bacterial levels were usually low.

The Withlacoochee River from Inglis to its mouth has been greatly affected by the completion in 1969 of the first stage of the Cross-Florida Barge Canal. The lower Withlacoochee–Cross-Florida Barge Canal Complex is the name given to the area between Inglis dam and the Gulf of Mexico. Lake Rousseau was to have been part of the halted Cross-Florida Barge Canal and is connected by a lock with the completed section of the canal. The construction of this portion of the now-discontinued canal changed the hydrological regime of the lower river channel by limiting the maximum flow rate to approximately the previous average. Since this regime prevents the periods of high flow, the long-term average dropped from approximately 45 m^3/s to 32 m^3/s. The remainder of the flow serves to minimize the salinity of water in the canal (Bush 1972). This reduction in flow to the Withlacoochee estuary is probably somewhat offset by the nearby canal discharge; however, the channel dredged through the estuary to the canal entrance probably caused substantial change in the estuary hydrography.

The SWFWMD and Mote Marine Laboratory studied the salinity and water quality characteristics of the Withlacoochee estuary from January 1984 through February 1986 (SWFWMD 1986; Dixon 1986). The Withlacoochee was the most stratified of the five estuaries studied, with the top and bottom salinity differing an average of 7–9 ppt in the lower 2.5 km of the river, and occasionally reaching between 15 and 20 ppt (Fig. 55). At high tide, the salt wedge frequently penetrated 5.5 km upriver. From the pattern of the salt wedge in the lower river, it was speculated that high points in the river bed at East

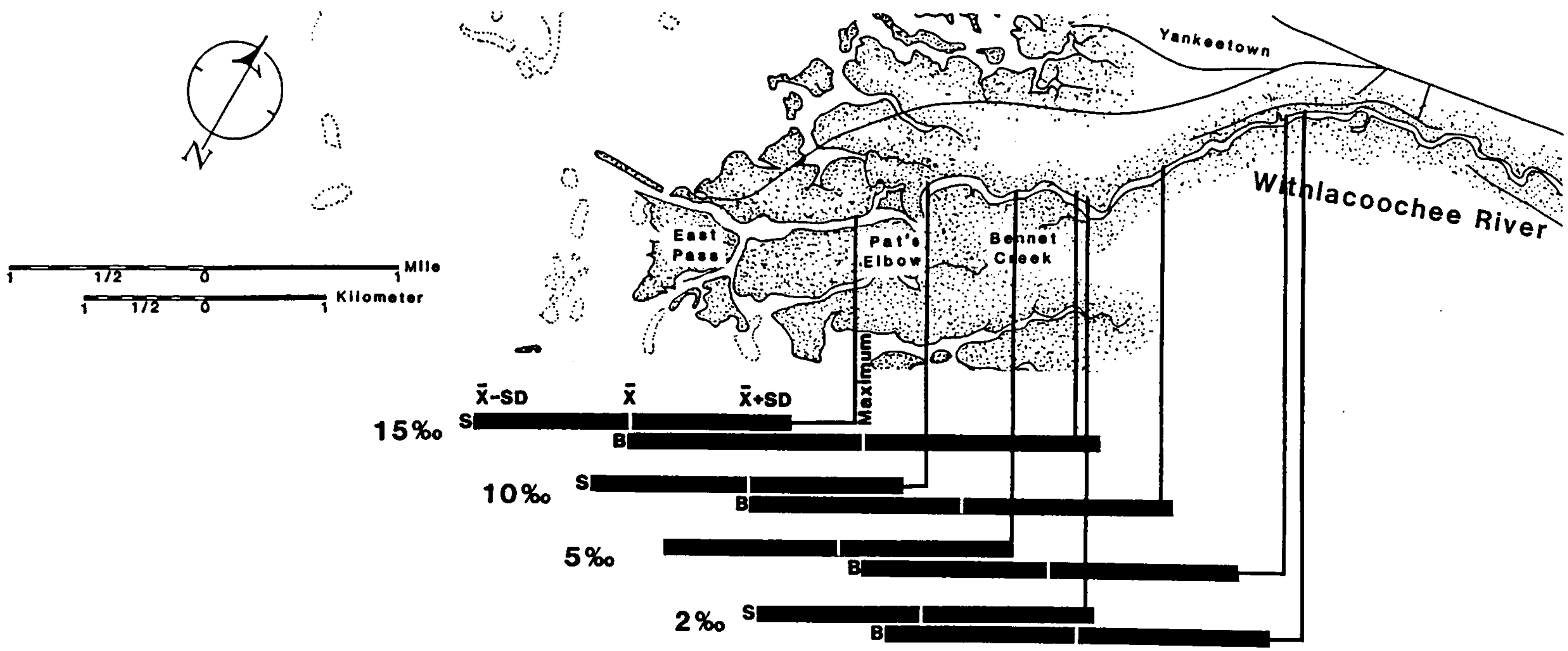


Figure 55. Withlacoochee River : surface and bottom, high-tide isohaline positions; mean, standard deviation, and maxima of penetration during 1984-1985 (Dixon 1986).

Pass and at points approximately 2 km and 5.5 km upstream might be acting as barriers to salt-wedge penetration.

The canal's effects on area ground water was a subject of great concern, and several studies were performed (e.g., Faulkner 1973a, 1973b; German 1978). The construction of the canal lowered the surrounding ground-water surface by approximately 4.5 m over some 40 km^2 (Faulkner 1973b).

The Governor's Florida Rivers Study Committee (1985) found these problems in the basin:

(1) Water-quality degradation as a result of runoff and dumping of trash at major bridge and highway crossings.

(2) Contaminated inflow from septic tanks in flood-prone areas and cottage development along the river floodplain.

(3) Dade City Canal transporting contaminated inflow (urban, industrial, and agricultural discharge) to the Withlacoochee River upstream of Dobe's Hole.

(4) Pasco and Hernando County landfills located near the river have the potential to degrade water quality.

(5) From Dunnellon downstream to Lake Rousseau, the river loses velocity and becomes more lakelike. Low DO and high BOD are associated with the eutrophication of these portions of the river.

(6) Aquatic weed problems resulting from hydrilla and water hyacinth compound water quality problems and impede recreational navigation as far upstream as Lacoochee in northern Pasco County.

(7) Land-use and development practices such as filling within the floodplain, ditching, and draining are common.

(8) Flood-plain encroachment degrades and produces losses in habitat and associated wildlife and recreational resources along the river.

4.9.3 Waccasassa River Basin and Coastal Area between Withlacoochee and Suwannee Rivers (Fig. 56)

This basin drains a 2,425-km^2 area north between the Withlacoochee and Suwannee Rivers into Waccasassa Bay. The main dischargers to the bay are the Waccasassa River and Cow Creek. Major tributaries of the Waccasassa River are the Wekiva River, carrying water from Wekiva Springs, and Otter Creek. Tenmile Creek is the main tributary of Cow Creek. Neither Cow Creek nor Otter Creek contributes much freshwater to the bay except during periods of above-average rainfall (Saville 1966).

Flow from several springs, including Blue and Wekiva Springs, helps maintain flow during the drier times of the year (Saville 1966; Burnson et al. 1984) The mean flow between 1964 and 1985 was 4.8 m^3/s, but the Waccasassa River is perennial only below Blue Spring. Maximum and minimum flows during this period were 345 m^3/s and –51 m^3/s, respectively. The negative flows were recorded during extreme high tides. Stelzenmuller (1965) reported the effects of local winds on water levels.

The SWFWMD and Mote Marine Laboratory studied the Waccasassa River during 1985 and early 1986, a drier-than-normal year which included a major drought (SWFWMD 1986; Dixon 1986). Figure 57 shows Waccasassa Bay and associated rivers and streams. Figure 58 shows the salinity regime of the estuary as defined by 10 sampling runs made during this period.

Historical data from EPA STORET shows good water quality and, though there is no recent STORET data, it was concluded that the quality was still good since there are no major urban areas in this basin and no development has taken place (Hand and Jackman 1984). One station on the Waccasassa was sampled for macroinvertebrates three times between 1975 and 1978 (Ross and Jones 1979). The diversities were fairly good but lower than expected for an unpolluted river. This was considered typical of a natural community associated with a slow-flowing swamp drainage.

4.10 Hydrology and Water-Quality Concerns

4.10.1 Hydrologic Concerns

The frequency and magnitude of floods usually increase as drainage basins are developed. Flooding

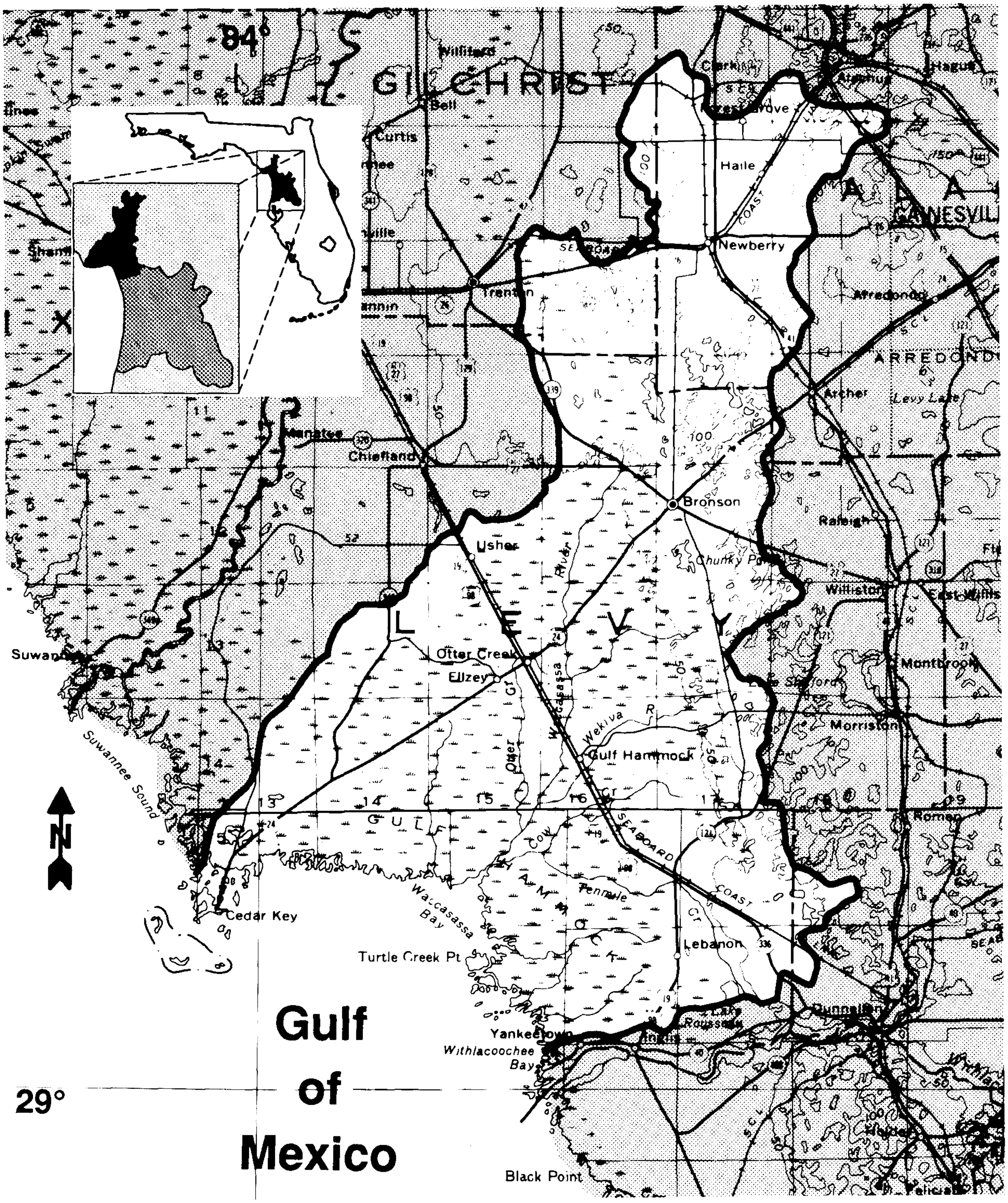


Figure 56. Waccasassa River Basin and coastal area between Withlacoochee and Suwannee Rivers.

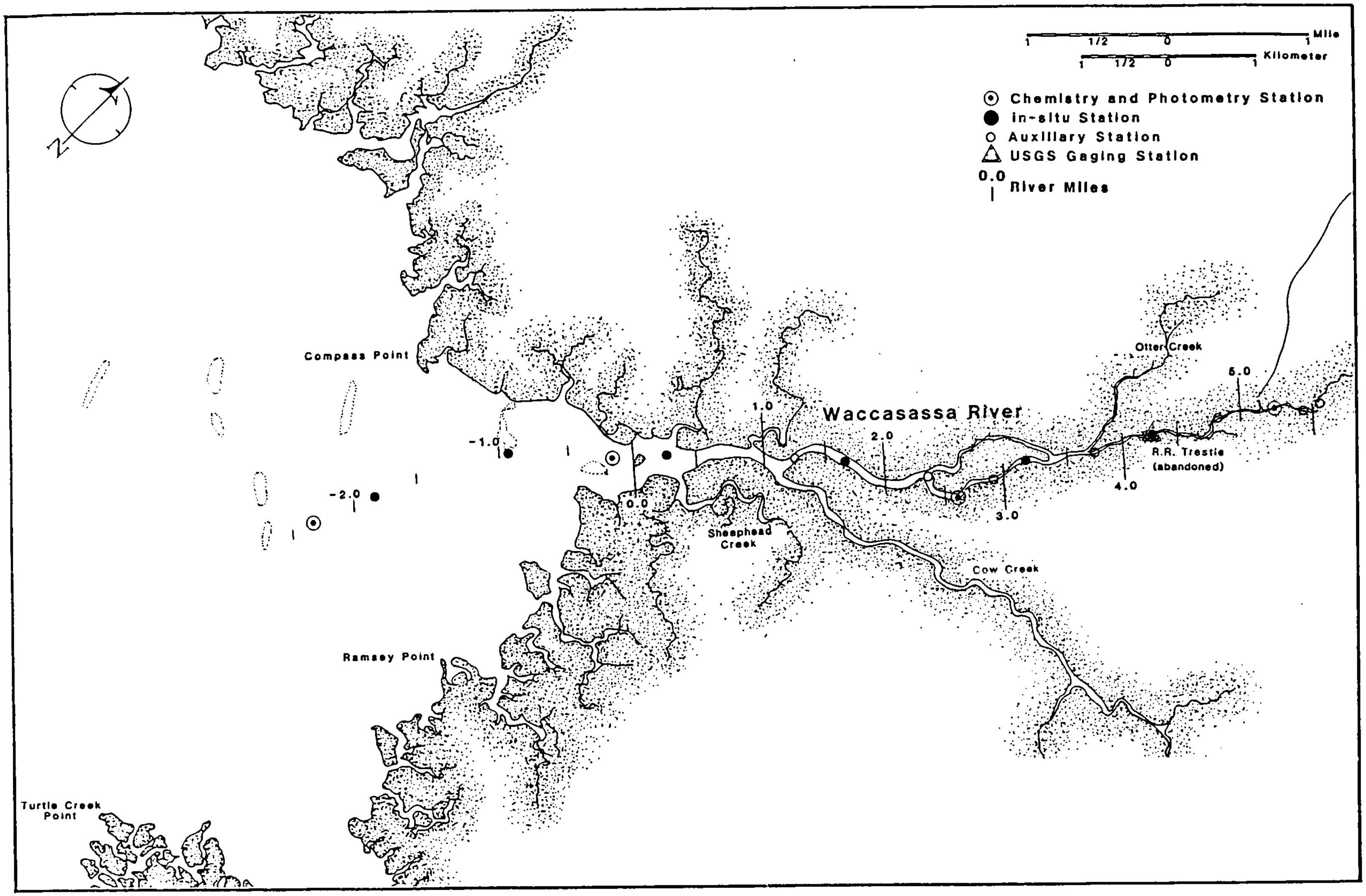


Figure 57. Waccasassa River estuary and sampling stations from SWFWMD study (Dixon 1986).

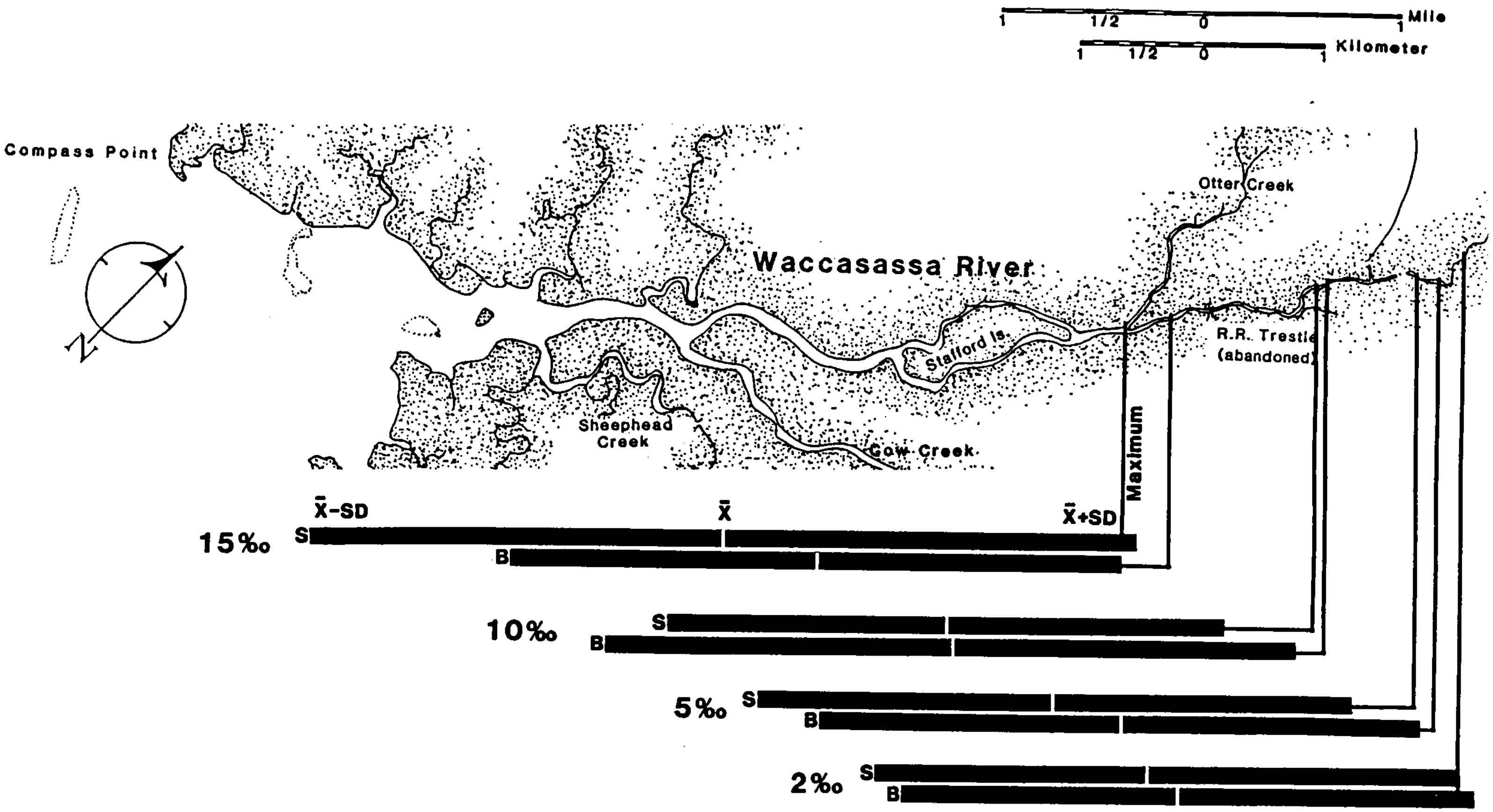


Figure 58. Waccasassa River: surface and bottom, high-tide isohaline positions; mean, standard deviation, and maxima of penetration during 1985 (Dixon 1986).

is a necessary and desirable part of the river basin ecosystem's energy flow; however, the frequency and magnitude of floods 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 floodplains are all necessary to minimize excessive flooding.

One conclusion that is clear at this time is that the surface and ground-water hydrology of the Springs Coast will be substantially affected by the rapidly expanding demand for sources of freshwater. While present plans call for more and expanded well fields and transportation of water to areas of demand (U.S. Army Corps of Engineers 1980), the Withlacoochee and especially Suwannee River have long been viewed as potential sources (e.g., Ross et al. 1978; U.S. Army Corps of Engineers 1980). The water management districts, as well as other agencies that are presently involved in planning the development of the regional water supplies, are attempting to proceed in such a way as to minimize the impacts of the withdrawals, including saline ground-water intrusion and lost estuarine productivity. During any period of drought in southwest Florida, letters to the editors of local newspapers appear demanding that the "wasted" freshwater discharging into the Gulf of Mexico from the rivers to the north (the Withlacoochee and the Suwannee) be diverted south. Public opinion holding the power that it does, it must be emphasized to the public and the politicians representing these constituencies that the repercussions of large surface- or ground-water withdrawals, in the form of saline intrusion, dried-up wetlands and lost fisheries, are very great. The apparent "waste" of freshwater is deceptive. The southern Springs Coast is well into a period that will determine the habitats surviving in this area in the near future. In the past, wetlands in many areas of Florida disappeared through dredging and filling. While this activity is much reduced with present regulations, the wetlands are now beginning to be lost through ground-water withdrawals.

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 Springs Coast 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 Springs Coast albedo causing altered rain patterns seems significant; 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 Springs Coast is the rising sea level. Ho and Tracey (1975) present data concerning the frequency of past storm tides for the Gulf of Mexico of Florida from Cape San Blas to St. Petersburg beach. Their data can be used to help predict the increased effect of storm tides as the sea level rises. Projections in reports published by the U.S. EPA (Hoffman et al. 1983, 1986) and the National Academy of Sciences (Revelle 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 Springs Coast totalling approximately 13 cm, will result in a net sea-level increase along the Springs Coast of 84–150 cm. This compares to a net increase over the last century of about 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 Fig. 59.

Impacts from sea-level rise will be manifold, but can be placed in three broad categories: shoreline retreat, temporary flooding, and salt intrusion. Besides inundation of low-lying coastal areas, there will be coastal erosion progressing inland a great distance. Statewide, average horizontal encroachment by the oceans in the next 100 years is expected

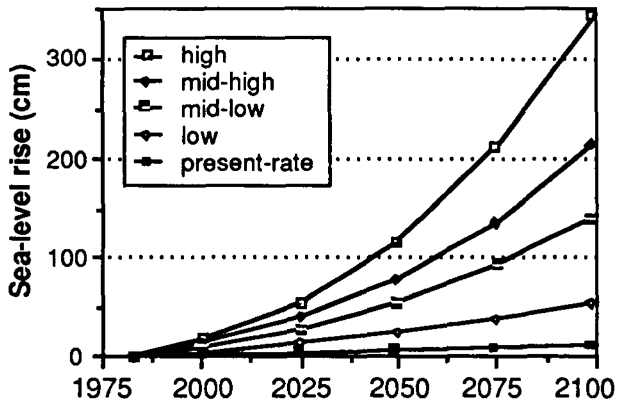


Figure 59. Projected sea-level rise using different scenarios.

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, which briefly, 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 (Fig. 60).

The current trend of sea-level rise may be responsible for serious erosion now taking place in many coastal resorts (New Jersey Department of Environmental Protection 1981; Pilkey et al. 1981). Most of the Springs Coast can probably expect a higher level than the Florida average, since maintaining the relatively shallow nearshore slope of the low-energy coastline will result in more lateral encroachment.

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 often 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

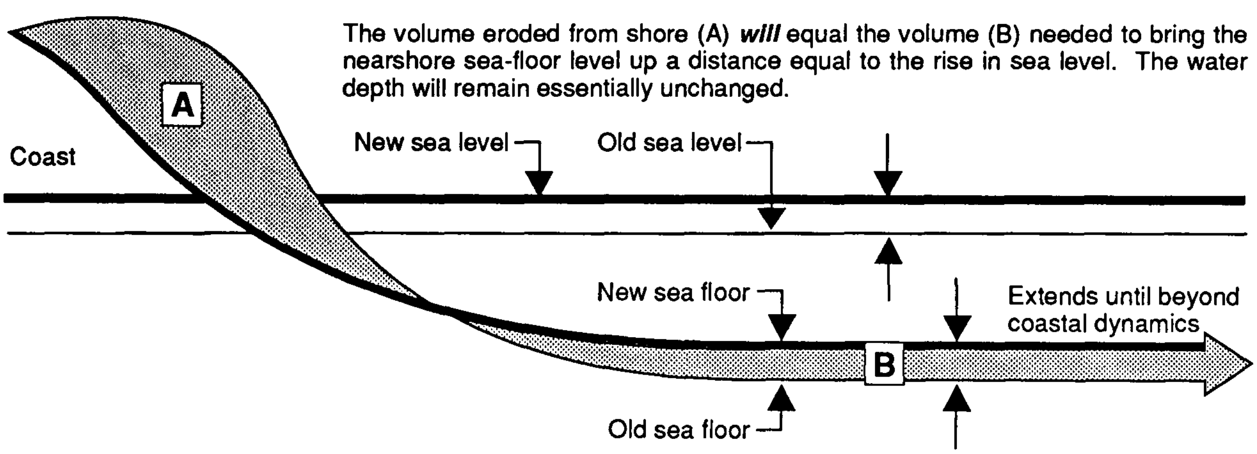


Figure 60. Diagram showing Bruun Rule for beach erosion following increase in sea level.

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 Springs Coast near-coastal area (Fig. 34). The Springs Coast, where ground water is heavily used to supply the substantial populations located here and especially to the south, is the most likely area to feel the effects of rising sea level in the form of increased saline intrusion .

Areas in the Springs Coast most affected by sea-level rise may be the coastal wetlands (which constitute nearly the entire coastline), and those coastal areas with present elevations less than a few meters above sea level (e.g., the Withlacoochee River at Inglis is 1.5 m above sea level with the city itself little higher). The wetlands will tend to migrate inland except where development prevents this.

4.10.2 Water-Quality Concerns

a. Surface water. The further reduction of point-source surface-water pollutants from Springs Coast sources through State and Federal efforts looks promising. The same cannot be said for the outlook for control of nonpoint-source pollutants. 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 Springs Coast. 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 Springs Coast. 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 1985a). Preliminary findings suggest that acid rain results from sulfate emissions by power plants and other industry, that it tends to be concentrated over land by the sea-breeze/land-breeze phenomenon, 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.

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 pore-water 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.

b. Ground water. The single greatest concern for ground water is contamination from landfills. Springs Coast 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 that were not cures and often simply increased the size of the area of saline contamination. Comprehensive plans have not been instituted until the situation bordered on collapse.

Degraded water quality may occur in Springs Coast 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 accelerating the cycle. As a result of this process, some places 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 AND FRESHWATER HABITATS

by Robert W. Simons

5.1 Introduction

The landscape of this gulf-coastal watershed area of north central Florida is at once monotonous and diverse. There are no mountains, or even hills more than 200 ft in elevation, no raging rivers, no deserts, no scenic rock outcrops, and not even any extensive sandy beaches. On the other hand, the fauna and flora of this nearly flat coastal plain area are diverse and inhabit a remarkable array of assemblages known variously as habitat types, vegetation types, ecosystems, or biological communities.

The major native biological communities are, for the most part, distinct from one another and often coexist side by side, with an abrupt line of transition from one community to the next (Nash 1895). This diversity of communities has been noticed and described by many observers. William Bartram (1791) was the first naturalist to visit this area and write an extensive description. He wrote at length about rivers, small streams, aquatic caves, lakes, ponds, swamps, marshes, savannas (prairies), sandhills or high, open pine forest (high pine), baygalls (bayheads), and hommocks (hammocks), describing many of the plants and animals he found in each place. Over 100 years later, Nash (1895) described the uplands around Eustis, Florida, which is just east of our area. His categories include scrub, high pine, flatwoods, bayhead, and hammock. These same general categories of Bartram and Nash have been used, with minor variations, ever since (Harper 1915; Laessle 1942; Monk 1968).

The main factors determining which community will occur in a particular location are topography, soil, flooding, and fire (these factors are often interrelated). Topographic factors include proximity to saltwater, water seepage, and surface drainage (the latter two affected by slope). The most significant soil characteristics are particle size (sand vs. clay), organic content, calcium (lime) content, pH, and internal drainage (subsoil permeability). The most important flooding factors are depth, duration, and motion (flowing vs. still). For streams and ponds, size, pH, fertility, calcium content, and whether they are ephemeral or permanently flooded are the important factors. Finally, fire frequency, intensity, and timing are very important in shaping many terrestrial communities.

Although it would seem that the physical characteristics of the site, coupled with the regional climatic characteristics, would completely determine the resulting biological community, this is not entirely true. Some plant species have the ability to alter such factors as surface drainage; soil pH; and fire frequency, timing, and intensity. In addition, some plants produce chemicals that are toxic to other plants, and some plants are beneficial to other plants.

The interactions between plants and animals and among the various animal species are even more complex. Flower pollination, seed dispersal, nest cavity construction, and burrow construction are examples of animal activities which can profoundly shape biological communities.

The activities of humans have now become the overriding factor in shaping Florida's landscape. This is true even in this least affected part of the Florida peninsula. Vast areas have been cleared of native flora and fauna and converted to fields, pastures, groves, residential areas, or cities. Other areas have been partially cleared and converted to pine plantations. The wild areas that remain have often been altered by drainage, protection from fire, elimination of important native species, introduction of exotic species, livestock grazing, and/or logging. Aquatic habitats have often been polluted and/or have had the water level stabilized.

The classification system used here consists of 15 general categories of native biological communities and another three of human-dominated habitat types, for a total of 18 (see table of contents). The main reason for choosing these particular categories is that they are the ones that are in common usage among foresters, farmers, ranchers, land use planners, naturalists, and wildlife managers, who are forced to think and talk about the different landscapes they work with and have, therefore, developed a workable language, over a broad range of time and experience, to deal with the situation. Another reason for choosing this classification system is that it is very similar to the one used in the Cross Florida Barge Canal Restudy Report, Wildlife Study, by the Florida Game and Fresh Water Fish Commission (1976). This study is by far the most comprehensive investigation into the habitat types of north central Florida. Its area of study and application includes the gulf-coast region of north central Florida, and it is the primary reference used in making many of the lists of animal species by habitat type in this publication. Although the main references used are cited with each table, the combined information from many other publications and unpublished reports were used in adjusting the species lists for the area covered in this publication, and in estimating abundance ratings and habitat preferences. Published sources and theses that were used are Ansley (1952); Attardi (1983a,b); Bohall-Wood and Collopy (1986); Brown (1963); Conant (1975); Edmisten (1963); Florida Game and Fresh Water Fish Commission (1976); Harper (1915); Hearld and Strickland (1949); Humphrey et al. (1985); Kurz (1942); Laessle (1942); Lee et al. (1980); Lopez et al. (1981); Marion and O'Meara (1982); Moler and Franz (1987); Monk (1965, 1966, 1968); Pearson (1954); Pritchard (1979); Repenning and Labisky (1985); Rochow et al. (1976); Schnoes and Humphrey (1987); Simons et al. (1984); Simons et al. (1989); Snedaker (1963); Terres (1980); Thompson (1980); U.S. Dept. of Agriculture (1981); Vince et al. (1989); Wharton et al. (1982); and Woolfenden and Rohwer (1969). Unpublished sources include Moler (1985); Southwest Florida Water Management District (SWFWMD 1985); U.S. Fish and Wildlife Service (1978); Florida Park Service species lists for Cedar Key Scrub Preserve and Waccasassa Bay Preserve; consulting job reports and species lists from the files of the author; Florida Natural Areas Inventory Reports (Nature Conservancy) for several sites in the area; and field data from the Comprehensive Inventory of Ecological Communities in Alachua County (Duever et al. 1987).

For some purposes, the general categories are not specific enough. Therefore, some of the major habitat types are divided into subunits. Again, these are organized and named, for the most part, according to common usage, and generally correspond to habitats studied in the Cross Florida Barge Canal Restudy Report (Florida Game and Fresh Water Fish Commission 1976). With this sort of organized classification system, both the general and the more specific user of the system can be accommodated. It also seems to fit the real situation better than a lengthy list of unorganized, specific habitat types.

Of course, no classification system fits the real situation perfectly. There are always plots of land, or water, that don't fit any category, or seem to fit two categories equally well. Although there are many examples of discrete vegetation types in northern peninsular Florida, there are also many instances of gradual transition from one type to another. Communities also change with time. Figure 61 shows some hypothetical relationships of some of the biological community types of this area. The lines show potential changes by succession over long time periods, or with changes in drainage, fire frequency, or other factors. Finally, different people think differently and have various objectives, so that a system well suited for one person, organization, or purpose may not suit another very well. By following general usage, this system will, we hope, be as broadly applicable as is possible.

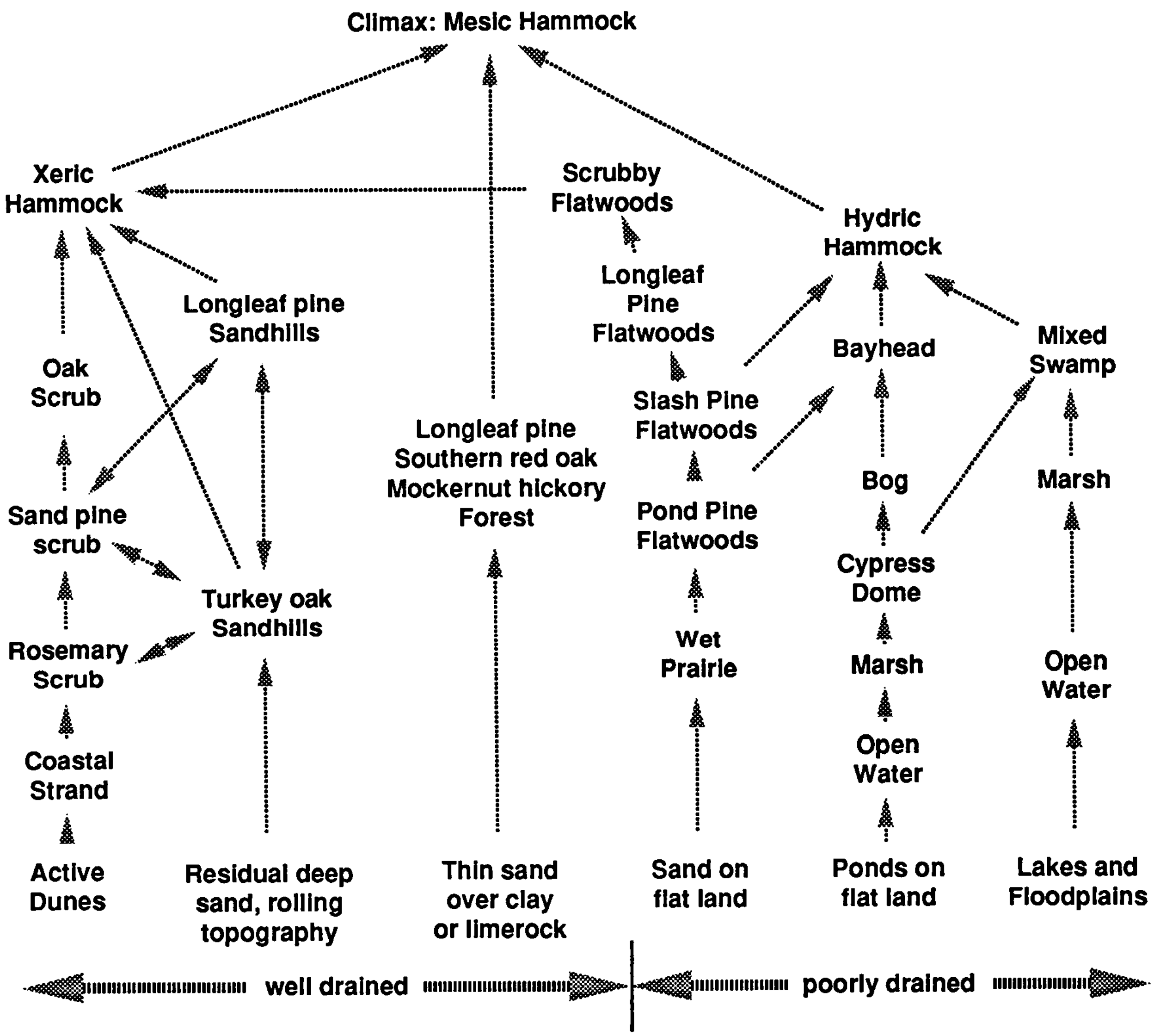


Figure 61. Generalized successional and edaphic relationships among the main biological community types of northern peninsular Florida including the Springs Coast (mostly after Laessle 1942).

Area wetland associations and communities are described by the U.S. Army Corps of Engineers (1978) and an additional source for much information on species distributions and habitats in the Springs Coast is the U.S. Fish and Wildlife Service's Gulf Coast Ecological Inventory map series (Beccasia et al. 1982). Information specific to Springs Coast rivers is available in the Estevez et al. (1991) chapter of the *Rivers of Florida* (Livingston 1991).

5.2 Coastal Strand

The gulf coast of the north half of the Florida peninsula is very flat, sloping imperceptibly from low, flat uplands through a level tidal zone and into the very shallow waters of the Gulf of Mexico. This coast is also relatively sheltered from wave action and has very small vertical tidal fluctuations (though they are some of the largest along the Florida gulf coast). However, the horizontal tidal fluctuation is quite large because of the very flat land surface. Consequently, most of this low-energy coast line is bordered by a band of salt marsh which gives way inland to forest. In only a very few spots, mostly on offshore islands, are there any beaches, sand dunes, or coastal strand forests. The best examples are on the islands of the Cedar Keys and Anclote Keys.

The only reason that there are even these few beaches is because the islands and sand spits on which they occur are ancient sand dunes that were formed when coastal conditions were different. Now, with the slow rise in sea level (Gornitz et al. 1982) and the slow subsidence of this coastline (Holdahl and Morrison 1974) (both elevation changes have been in the order of 4 or 5 inches in the last 100 years), these old, stabilized dunes are eroding and supplying fine, wind-sorted sand for the narrow, white beaches.

Beaches support no living vascular-plant community, so the food chain is based mainly on detritus washed up from the sea. Seagrasses washed onto shore by storm tides and waves, along with other plant debris, shells, carcasses of fish, jellyfish, crabs, and other marine life make up the movable feast referred to as seawrack. Insects, amphipods, ghost crabs, fiddler crabs, and sea gulls are some of the most common detritus feeders. The insects, amphipods, and crabs are, in turn, fed upon by gulls, sandpipers, and other shore birds.

There are almost no areas of dune or coastal-strand scrub vegetation in this part of Florida. Some of the islands support coastal-strand forest (maritime hammock) dominated by sand live oak (*Quercus geminata*) and live oak (*Quercus virginiana*) in association with cabbage palm (*Sabal palmetto*), southern redcedar (*Juniperus silicicola*) and other trees (the vast majority of coastal live oak, cabbage palm, redcedar forest in this region is on low land subject to flooding, and is classified as hydric hammock. On Seahorse Key off Cedar Key, this sort of forest supports breeding rookeries of brown pelicans (*Pelecanus occidentalis*) and white ibis (*Eudocimus albus*). On the ground, perhaps because of the rookeries, water moccasins (*Agkistrodon piscivorus*) are abundant. Both water moccasins and eastern diamondback rattlesnakes (*Crotalus adamanteus*) are also found on some of the other islands. An endemic lizard, the Cedar Key mole skink (*Eumeces egregius insularis*), is found in this and adjacent habitats on Cedar Key and Seahorse Key (Christman 1979). The peninsula crowned snake (*Tantilla relicta relicta*) is also found here, whereas the Florida crown snake (*Tantilla relicta neilli*), occurs elsewhere in this region (Conant 1975). The gray kingbird (*Tyrannus dominicensis*) is another species found at Cedar Key as an isolated population, and black-whiskered vireos (*Vireo altiloquus*) also occur in this habitat in spots scattered along the coast (Florida Game and Fresh Water Fish Commission 1976).

5.3 Scrub

The most uniquely Floridian biological community is the scrub. It is almost completely restricted to Florida, and there are many endemic scrub plants and animals that only occur on the Florida peninsula in this habitat (Pritchard 1979). It is, on average, the most xeric (dry and hot) of Florida's communities, and is adapted to the most disastrous fires. The vegetation is almost entirely evergreen, and it is often fairly uniform in density from the ground up to the top of the canopy, with the exception of mature sand pine scrub, in which the sand pines (*Pinus clausa*) form a distinct canopy above the rest of the plants.

The ancient scrubs, where most of the rare endemic species occur (Christman 1988) occupy small areas in this region on the Coharie terrace (above 170 ft above mean sea level). Most of the scrub in the Florida Springs Coast is of recent origin and contains few scrub endemics.

There are four or five scrubs in the range of 1,000 to 2,000 acres in size (Fig. 62) and several more small scrubs in the Florida Springs Coast region. One of the larger ones, located about 7 mi northeast of Cedar Key, is largely contained within the Cedar Key Scrub State Preserve. Other small, but ecologically significant, areas exist in Citrus County and elsewhere.

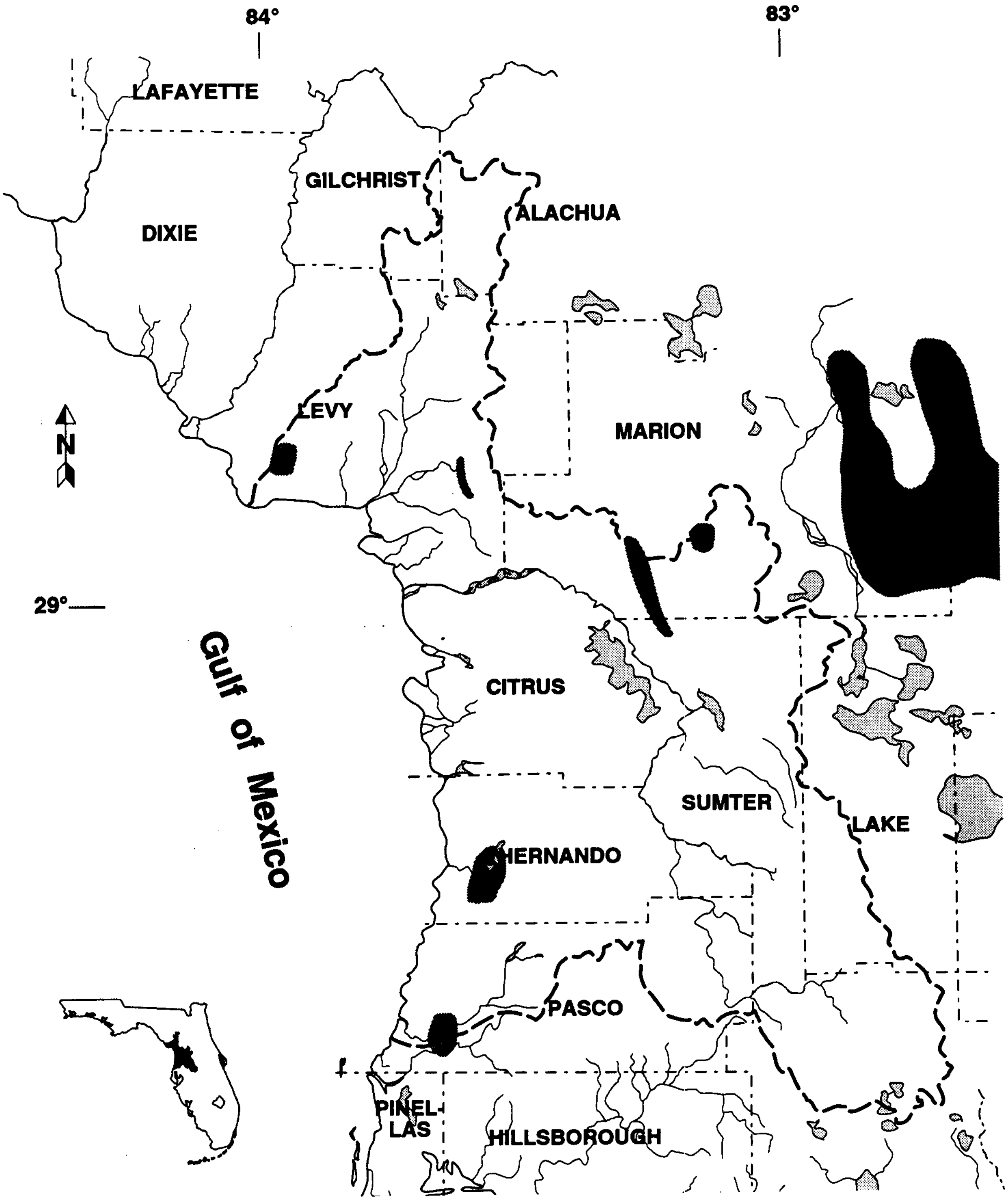


Figure 62. Approximate location of the largest areas of scrub in and near the Florida Springs Coast (after U.S. Dept. of Agriculture 1981).

5.3.1 General Scrub Information

a. Soil. Scrub occurs only on well-drained sand. The sand may be either white throughout or yellow with some white sand at the surface (Laessle 1958). The plant species composition seems to be somewhat related to sand color. The sand is of oceanic origin, having been deposited along ancient shorelines. Several lines of sandhills paralleling the coast were formed in this manner during periods when the sea level was higher than it is now (Laessle 1958).

Scrub typically inhabits sands that have resulted from the washing and sorting actions of water and wind (Laessle 1958). The nutrient content of the sandy soil is quite low (Kalisz and Stone 1984).

b. Ecology. It often seems that the soils supporting scrub are too nutrient poor or too xeric to support any other inland community (Laessle 1958). However, at least in some cases, there appears to be no difference between the soils occupied by scrub and the soils occupied by high pine vegetation (Kalisz and Stone 1984). In situations where the soil could support either, it is clear that fire frequency and intensity play a strong role in determining which community occurs on a particular site. Occasional disastrous crown fires strongly favor scrub, whereas frequent ground fires strongly favor the high pine community. The vegetative structure and composition of each of these two communities tends to promote the type of fire that helps maintain that community.

Scrub favors crown fires over ground fires by having a continuous thicket of flammable living vegetation from just above the ground up to the tree canopy, or, in the case of mature sand pine scrub, up nearer the canopy than in other fire-adapted forests. At the same time, scrub has almost no flammable fuel on the ground. The lack of fuel on the ground is due to a combination of the scrub plants having leaves that lack rosin and decay quickly, and the fact that there are very few grasses or other flammable plants growing on the ground (see section on high pine for comparison). The natural fire frequency for scrub is probably quite variable, both in terms of the time between fires at any one site and the average frequency for different scrubs. Before 1900, it probably averaged about once every 10–50 years.

When fires do occur in scrub, they usually kill all the vegetation that is above ground. However, head fires that have developed to the stage of being a fire storm often progress in a rolling or swirling motion, leaving periodic small strips of vegetation that is not completely killed. These fire storms can be quite spectacular. The Ocala scrub fire of 1935 burned about 22,000 to 35,000 acres in about 4 hours, starting from a single ignition point, before being stopped first by Lake George and then by a rain storm (data from the files of the Lake George Ranger District, Ocala National Forest, U.S. Forest Service). This may be the all-time national record for rapid development of a forest fire.

Most of the scrub vegetation responds to a fire by sprouting back from the base or roots. The two common palms, saw-palmetto (*Serenoa repens*) and scrub palmetto (*Sabal etonia*), have their stems underground, so that only the leaves are lost to the fire. However, at least two common scrub plants are completely killed by intense fires. These are sand pine (*Pinus clausa*) and Florida rosemary (*Ceratiola ericoides*). The less common woody mints (*Calamintha* spp. and perhaps *Dicerandra* spp.) are also in this category. Sand pine is usually able to reproduce prolifically after a fire, because most of the cones produced by most of the trees on the Florida peninsula remain closed after they mature. They are sealed shut by rosin. When exposed to fire, the rosin melts, allowing the cone to partially open, and then dry out and open fully a day or two after the fire. Thus, several years' supply of sand pine seed are released a few days after the fire, when conditions are ideal for survival and growth of the young pines due to the temporary elimination of all competing vegetation and the release of nutrients from the ash. The seeds of rosemary (and presumably the woody mints) are stored in the soil waiting to respond in much the same way (Johnson 1982). Periodic fire or disturbance of similar magnitude is necessary to maintain rosemary in sand pine scrub or oak scrub, because rosemary becomes senescent after about 35 years and cannot reproduce under itself or the other scrub vegetation (Johnson 1982).

In the absence of disastrous fires, the best way to perpetuate scrub seems to be to have occasional clearcuts followed by fire or mechanical disturbance to simulate the destruction of such a fire. In the absence of fire or any other disturbance, most scrubs would become xeric (dry) hammocks (Laessle 1958).

Scrub is very distinct from high pine habitat, both visually and ecologically, because it is a dense growth of evergreen shrubs and small trees without much herbaceous ground cover, usually beneath sand pine, whereas high pine (sandhill) is an open savanna of grasses and other herbs, deciduous oaks, and longleaf pine (Laessle 1958).

c. Fauna. The scrub is well known for its endemic animals. Although they are occasionally found in high pine or scrubby flatwoods, the following species are largely restricted to scrub: scrub jay (*Aphelocoma coerulescens*), scrub lizard (*Sceloporus woodi*), sand skink (*Neoseps reynoldsi*), blue-tailed mole skink (*Eumeces egregius lividus*), and several species of invertebrates including the red widow spider (*Latrodectus bishopi*), rosemary wolf spider (*Lycosa ericeticola*), and rosemary grasshopper (*Schistocerca ceratiola*). Of these endemics, only the scrub jay is known to occur in the gulf-coast scrubs. It prefers a mixture of low oak scrub (with or without scattered sand pine) and patches of bare sand. The patches of bare sand are used to store acorns, which make up a large part of the scrub jay's diet (Terres 1980, Woolfenden 1978). The scrub must be kept low and open by periodic fire or some other disturbance if it is to remain suitable habitat for this species. The scrub jay is fairly common in the Cedar Key scrub and adjacent scrubby flatwoods.

The loose sand of the gulf-coast scrubs is ideal habitat for several sand-swimming reptiles that are endemic to the scrub and high pine habitats of the Florida peninsula. These are the short-tailed snake (*Stilosoma extenuatum*), worm lizard (*Rhineura floridana*), peninsula mole skink (*Eumeces egregius onocrepis*), and central Florida crowned snake (*Tantilla relicta neilli*) (Conant 1975). The short-tailed snake is considered to be a threatened species in Florida (Wood 1990).

The loose sand is also ideal habitat for the pushup beetle (*Peltotrupes* spp.), which excavates a vertical tunnel 1 m or more in depth, resulting in a small sand mound on the surface. Grasshoppers of many kinds are quite abundant in scrub, and are an important food source for many of the scrub animals. However, the most abundant insect is probably the Florida harvester ant (*Pogonomyrmex badius*), which builds a very noticeable flat-topped, circular mound around the colony's single entrance hole. The ants clear the sand of vegetation around the mound and decorate the mound with large grains of sand and bits of charred plant material.

Other animals commonly inhabiting scrub are listed in Appendix Table B. The Springs Coast scrubs are often better fall mast producers, due to the abundance of oaks and saw-palmetto, than adjacent habitats, and, therefore, often support increased numbers of Florida black bear (*Ursus americanus floridanus*), raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), wild hog (*Sus scrofa*), gray squirrel (*Sciurus carolinensis*), Sherman's fox squirrel (*Sciurus niger shermani*), and wild turkey (*Meleagris gallopavo*), which move in from other habitats at this time of year.

d. Flora. There are many plant species endemic (or nearly so) to Florida scrub habitat. However, most of these endemics do not occur in the gulf-coast scrubs. The ones that do occur in one or more of the gulf-coast scrubs are sand pine, long-spurred mint (*Dicerandra cornutissima*), scrub pawpaw (*Asimina obovata*), rosemary, garbaria (*Garbaria heterophylla*), palafoxia (*Palafoxia feayi*), scrub palmetto, and silkbay (*Persea humilis*). Some of these plants, most notably rosemary, now also occur in high pine habitat, because of fire suppression. Many additional plant species occur more commonly in scrub than in any other habitat. These two categories of plants are indicated in Appendix Table C by an '*'. Other plants commonly found in scrub are also listed in Appendix Table C.

5.3.2 Sand Pine Scrub

The most common form of scrub is sand pine scrub (Fig. 63). In the region covered by this publication, sand pine forms a scattered to dense overstory reaching 30–60 ft in height. Beneath the pines is a dwarfed evergreen forest dominated by myrtle oak

Figure 63. Mature sand pine scrub with sand pine overstory and understory of sand live oak, myrtle oak, crooked-wood, and rosemary and a ground cover of deermoss.

(*Quercus myrtifolia*), sand live oak (*Quercus geminata*), and crooked-wood (*Lyonia ferruginea*). Other common small trees include redbay (*Persea borbonia*) or silkbay, devilwood (*Osmanthus americanus*), and Chapman oak (*Quercus chapmanii*). The most common shrubs beneath the small trees are saw-palmetto and rosemary. Finally, on the ground, there is often a dense growth of lichens and sometimes gopher-apple (*Licania michauxii*). There is usually a scattering of scrub beakrush (*Rhynchospora megalocarpa*), prickly-pear cactus (*Opuntia humifusa*), and bracken fern (*Pteridium aquilinum*).

The composition of this community varies considerably from one scrub to the next. Since the scrub of the Ocala National Forest is the best known, it might help to compare it to the small, isolated scrubs of this region. One difference is that scrub palmetto, which is the dominant palm in the Ocala scrub, is largely replaced by saw-palmetto in the Springs Coast scrubs. The woody mint of the Ocala scrub is lavender basil (*Calamintha ashei*), whereas the woody mint in scrubs in southwest Marion County and northern Sumter County is scrub balm (*Dicerandra cornutissima*), which is listed as an endangered species (Wood 1990), and the woody mint in scrub in Citrus County is scarlet lady (*Calamintha coccinea*). Several more scrub plants, such as scrub hickory (*Carya floridana*), scrub holly (*Ilex opaca* var. *arenicola*), scrub milkwort (*Polygala lewtonii*), and Florida bonamia (*Bonamia grandiflora*), occur in the

Ocala scrub but not the gulf-coast scrubs, just as there are several endemic species that occur in the scrubs on the south end of the central (Lake Wales) ridge that do not occur in the Ocala scrub.

There is also considerable variation among the Springs Coast scrubs. One of the largest of these is the Cedar Key scrub, yet the only scrub endemics it contains are sand pine and rosemary. This paucity of endemic species is an indication that this and similar scrubs are very young in comparison to those that contain an abundance of endemics (Christman 1988).

With fire suppression and infrequent or no prescribed burning in adjacent high pine communities, sand pine scrub has been rapidly expanding into and replacing high pine habitat in some places. However, real estate development is eliminating scrub at an even greater rate.

5.3.3 Oak Scrub

A second form of scrub is called oak scrub (Fig. 64). The oaks and other small trees and shrubs are generally denser than in sand pine scrub, but, otherwise, this is essentially sand pine scrub without sand pine. It occurs intermixed with sand pine scrub in spots that for some reason failed to regenerate to sand pine. Factors that may cause sand pine to be eliminated from an area are severe drought in the year following a fire, two fires within a 5-year period, or

Figure 64. Oak scrub, showing sand road through a thicket of myrtle oak, sand live oak, crooked-wood, and saw-palmetto with one sand pine in right background.

no fire within a period of 100 or more years. In large scrubs, sand pine may be eliminated from a portion of the area by one of these factors, but may later recolonize from adjacent seed sources. In very small, isolated scrubs, however, once the sand pine disappears, it cannot easily return. Perhaps for this reason, or perhaps because sand pine never got to some of the isolated scrubs to begin with, most of the isolated scrubs less than 100 acres in size lack sand pine.

5.3.4 Rosemary Scrub

Another form of scrub that is rather common on parts of the Brooksville Ridge between Archer and Bronson is rosemary scrub (Fig. 65). This originally occurred as small, isolated colonies on the tops of some of the highest, driest sand hills, and consisted of nearly pure stands of Florida rosemary bushes on bare sand. Associated plants include scrub live oak, turkey oak, and deermoss. These spots of scrub were surrounded by high pine forest that burned frequently, but they were able to survive because there was no fuel between the rosemary bushes to carry a fire. With fire suppression in the region, Florida rosemary has rapidly invaded the cut-over high pine habitat, thus greatly expanding the area of most of these rosemary scrubs. In winter, the American robin (*Turdus migratorius*) and migrating warblers (mostly *Dendroica* spp.) are sometimes abundant in rosemary scrub, apparently feeding at least to some extent on the rosemary fruits which are ripe then. The subsequent scattering of seed by the migrating birds

Figure 65. Rosemary scrub, showing pure stand of rosemary with no herbaceous ground cover.

would explain the ability of Florida rosemary to rapidly invade vast areas of new territory.

5.4 *High Pine Forest (Sandhill)*

The vast majority of the well-drained uplands of this region were originally open forests of longleaf pine (*Pinus palustris*) with a scattered subcanopy of deciduous oaks and a ground cover of wiregrass (*Aristida stricta*), other grasses, and broad-leaved herbs. Much of this community, particularly the areas on moderately fertile soil, has been cleared for agriculture or real estate development. However, several hundred thousand acres remain, mostly on the Brooksville Ridge, but also scattered throughout the rest of the region as shown in Fig. 66.

5.4.1 General High Pine Forest Information

a. Soils. The soils supporting this community were all derived from noncalcareous marine deposits and are all well drained. Most of the high pine forest in this region is on deep sands of the Lakeland soil series. These sands have a grayish-brown to dark-brown topsoil 4 to 6 inches thick over yellow to brownish-yellow sand. The Blanton series, which is less severely drained sandy soil, also supports this community. In some areas of western Alachua and Marion Counties, there is only a foot or two of sandy soil over chert and limerock. In this same area, and even more commonly further north, some of the high pine forest was (and a very small fraction still is) on soils of the Norfolk series. The Norfolk soils are derived from deposits of sand and clay, and have grayish-brown to dark-gray topsoil over yellow to yellowish-brown subsoil, which, in turn, overlies friable sand-clay loam or sandy clay subsoils at depths of 14 to 30 inches (Laessle 1958). In some parts of western Alachua and Marion Counties, the red clay is at the surface, sometimes capped with a thin layer of black topsoil.

b. Ecology. Although the soils vary widely in texture and fertility, the high pine community was originally surprisingly uniform in structure, function, and fauna. This is because of the strong effect of fire, which plays a dominant role in maintaining this community (Garren 1943, Clewell 1971, Clewell 1981, Vogl 1973, Christensen in press). Because of the structure of the forest, these fires are almost entirely ground fires, although the heat of the fire will often scorch the crowns of the trees. There is good reason to believe that these original forests burned mostly in summer at an average frequency of 2 to 3 years (Clewell 1971, 1981; Christensen 1981; Means and Grow 1985).

Many of the plants and animals of this community are adapted to fire in some way. Most of the grasses, herbs, and small woody plants sprout back from their bases or roots following a fire. Longleaf pine and the fire-adapted hardwoods such as turkey oak (*Quercus laevis*), southern red oak (*Quercus falcata*), and mockernut hickory (*Carya tomentosa*) have thick bark, stems, branches, and buds in order to withstand fire, and the hardwoods all sprout prolifically. Longleaf pine also has a "grass stage" during the first 3 to 20 years of its life, during which it makes no significant height growth (Fowells 1965). At this stage, the visible above ground portion of the plant resembles a dense clump of wiregrass, hence the name grass stage. The delayed height growth enables the young pine to increase the size and number of needles, the diameter of its stem, and, most importantly, the size and depth of its root system, while the stem and bud remain at the ground surface below the most intense heat of the periodic ground fires. Once sufficient size and energy reserves are obtained, the young pine grows in height very rapidly, and with a very thick stem. Some will be killed if fires occur during this most vulnerable sapling stage, but many will survive. Once fully grown, longleaf pine is exceptionally fire resistant (Fowells 1965). Another interesting trait of longleaf pine is its long, resinous needles. These needles are very flammable once they are shed, are sufficiently rot-resistant to remain on the ground for several years, and are long and stiff enough to keep them from packing flat on the ground. In fact, they tend to become draped in and on all the understory and ground-cover vegetation. This accumulation of pine straw in combination with an accumulation of the similarly shaped and easily ignited wiregrass straw creates a ground cover that will burn on practically any day of the year when it

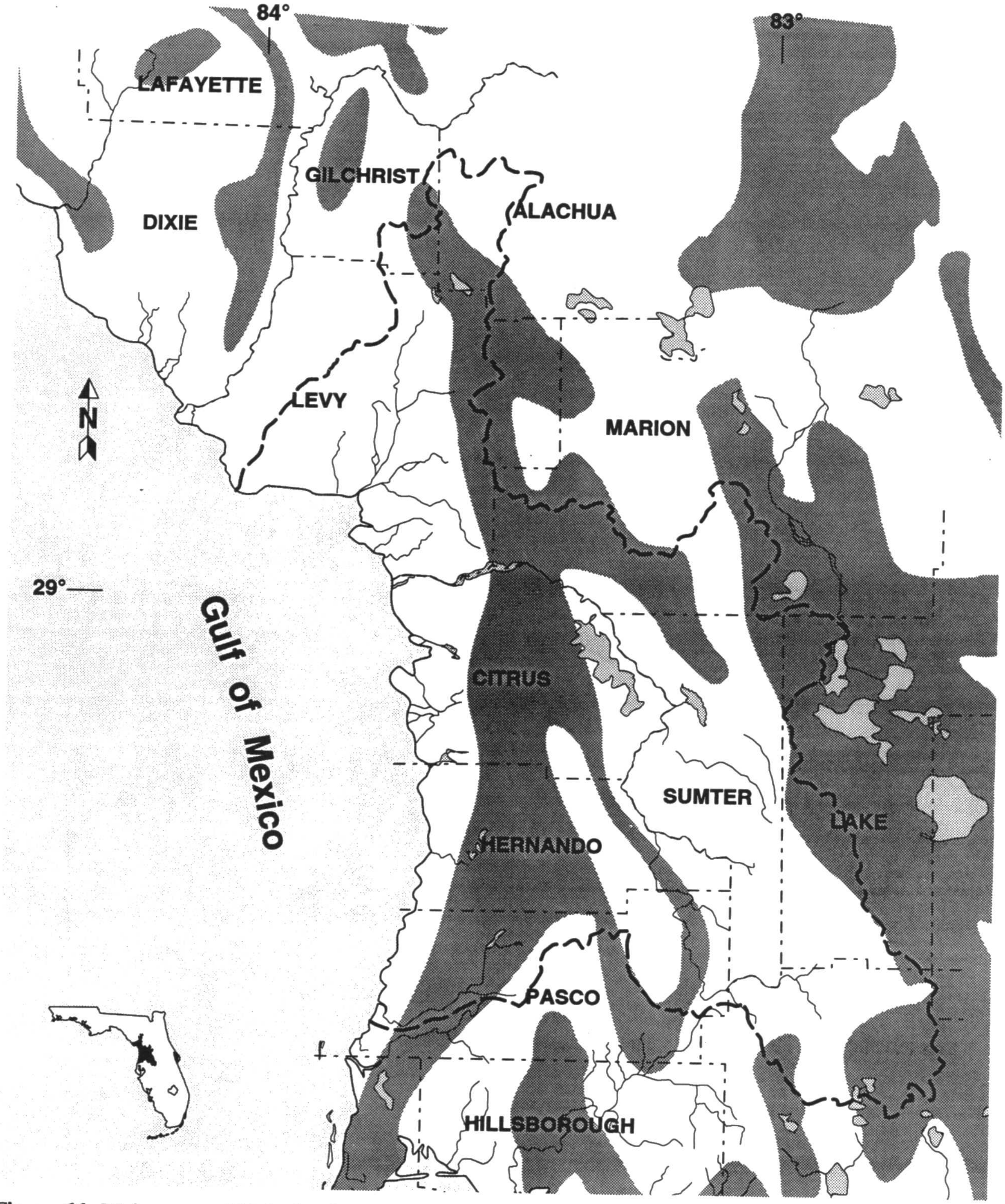


Figure 66. Major areas of high pine forest in the Florida Springs Coast (after U.S. Dept. of Agriculture 1981).

isn't actually raining. Thus, the community creates a condition favoring the frequent, low-intensity ground fires required for its long-term survival.

Besides being able to withstand the fires, most of the plants and many of the animals of the high pine forests actually need the fires to survive. For instance, longleaf pine cannot reproduce unless fires keep the understory vegetation thin enough for its seedlings to get enough sunlight to survive and grow. Also, a fire within a year and preferably within a few months prior to a good seed-fall is needed to get a good crop of seedlings. Without the fire, most of the seed will be trapped on top of leaf litter or ground-cover vegetation where it cannot get established. Wiregrass (*Aristida stricta*) will not reproduce at all without fire (Clewell 1981).

Without sufficiently frequent fire, this community quickly begins to change. First, the fire-adapted hardwoods that are naturally present in the community become much more abundant, and those that had been kept down as shrubs by the fires grow into trees. At the same time, the wiregrass becomes much less vigorous. As this process continues, all the ground-cover vegetation becomes less dense and abundant, and pine and hardwood species from outside the community begin to seed in and grow. It is interesting that blue jays (*Cyanocitta cristata*) play a large role in this invasion by storing acorns under the leaf litter in widely scattered locations (Darley-Hill and Johnson 1981). If there is an adjacent scrub, then sand pine (*Pinus clausa*), Florida rosemary (*Ceratiola ericoides*), and the evergreen scrub oaks may be the first invaders. On the most fertile high pine sites, loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), and black cherry (*Prunus serotina*) may be important invaders. However, on most sites, even in the early stages, and on all sites if the process continues long enough, laurel oak (*Quercus hemisphaerica* or *Q. laurifolia*) becomes the dominant and most damaging invader. At this point, animals such as the Sherman's fox squirrel (*Sciurus niger shermani*), southeastern kestrel (*Falco sparverius paulus*), and red-cockaded woodpecker (*Picoides borealis*), which are specifically adapted to the open woodland structure, are eliminated. If the process continues for 100 years or so, almost all of the high pine flora and much of the fauna is completely eliminated. The forest that replaces it is generally a xeric (dry) to mesic (moist) hammock of low diversity.

Unfortunately, this gradual destruction of the high pine community through fire suppression is in progress in virtually all the remaining areas of this habitat type. Of course, prescribed burning can substitute for the natural fires of old, but it is necessary to burn at least part of the time in the late spring or summer, and it is necessary to burn more often than most landowners are willing or able to do.

One additional threat to this biological community is the invasion by exotic species (exotic in the sense of being from some other region of the world and not native to Florida). Ever increasing numbers of mimosa (*Albizia julibrissin*), camphor (*Cinnamomum camphora*), and other exotic trees are adding to the invasion of the native trees from other habitats. As with the native invaders, these can be controlled with prescribed burning. Of more concern, however, is the introduction of cogongrass (*Imperata* sp.) to many high pine sites. This grass often grows in a solid, dense, ever-expanding stand that eliminates the native herbs and most of the wildlife associated with them. It is well adapted to fire and mechanical disturbance, and is difficult to control with herbicides. In fact, it is so well adapted to fire and builds up such a large amount of highly flammable fuel that its presence may cause the eventual elimination of most of the high pine woody plants as well. At present, its spread in Florida is progressing unchecked.

c. Fauna. The high pine community supports a great number of mammal, bird, reptile, and amphibian species (Appendix Table D), and is the best habitat in Florida for many of them. The gopher tortoise (*Gopherus polyphemus*) is perhaps the most important one. Populations of one to two "gophers" per acre are not uncommon where the habitat is fire maintained and human predation is not a serious problem. The gopher tortoise is considered important because its 15–20 ft-long burrow is home for nearly 40 commensal species of vertebrates and invertebrates, including a few strict obligate commensals that are totally dependent upon the gopher tortoise (Eisenberg 1983). Some vertebrates that benefit from the burrows are the Florida mouse (*Podomys floridanus*), gray fox (*Urocyon cinereoargenteus*), indigo snake (*Drymarchon corais*), coachwhip (*Masticophis flagellum*), eastern diamondback rattlesnake (*Crotalus adamanteus*), and gopher frog (*Rana capito*). Unfortunately, the gopher tortoise has been declining due to overharvesting and habitat destruction (see Chapter 7).

Another burrowing animal whose native habitat is largely restricted to this community is the southeastern pocket gopher (*Geomys pinetis*). The Florida pine snake (*Pituophis melanoleucus mugitus*) is largely dependent on this animal for food and spends most of its life in pocket gopher burrows (Richard Franz, Florida State Museum, pers. comm.). Coachwhips also use these burrows. The mounds of sand on the surface are important winter refuges for mole skinks (*Eumeces egregius*) and several other species of burrowing reptiles (Florida Game and Fresh Water Fish Commission 1976).

Three animals of this community that are currently threatened with extinction are the red-cockaded woodpecker, southeastern kestrel, and Sherman's fox squirrel (see Section 5.20). The red-cockaded woodpecker requires mature pines, preferably longleaf, for nesting and an open woodland forest structure throughout its feeding territory (Jackson 1986; Ligon et al. 1986). The logging of virtually the entire virgin forest of this region in the late 19th and early 20th centuries, coupled with the logging of most second-growth forests before they reach an age suitable for nesting, is the main problem for this species, but forest fragmentation and failure to keep the woods open with sufficiently frequent fires are also significant factors. The southeastern kestrel has virtually the same problems. It requires large, dead pines for nesting, and fields or very open woodland with short ground cover for feeding (Bohall 1984; Hoffman 1983; Wiley 1978). Sherman's fox squirrel is less demanding, but needs open woodland with both pines and oaks (Ehrhart 1978). Of these three species, the fox squirrel is the latest to show a decline. It has declined drastically in the last 40 years (Reed F. Noss, Landscape Ecosystems, Inc., pers. comm.).

Other animals which appear to be declining in this habitat are the red-headed woodpecker (*Melanerpes erythrocephalus*), common ground dove (*Columbina passerina*), loggerhead shrike (*Lanius ludovicianus*), Bachman's sparrow (*Aimophila aestivalis*), northern bobwhite (*Colinus virginianus*), coachwhip, and indigo snake. Most are declining because their requirement of an open habitat with a healthy herbaceous ground cover is not being met. An additional problem for the indigo snake is that it is often killed by people or their pet cats and dogs. Many cavity-nesting birds, such as the red-headed woodpecker, eastern bluebird (*Sialia sialis*), tufted titmouse (*Parus bicolor*), great crested flycatcher (*Myiarchus crinitus*), and screech owl (*Otus asio*), are less common than they would be if there were more snags to provide cavities.

d. Flora. There are relatively few species of woody plants native to this community. The most common trees are longleaf pine and turkey oak. Dwarf blueberry (*Vaccinium myrsinites*), gopher apple (*Licania michauxii*), and showy pawpaw (*Asimina incarna*) are common shrubs. In contrast, there are many kinds of grasses, composites, and other herbs. Appendix Table E does not reflect this dominance of herbs, because only a fraction of the herbs are listed in comparison to almost all the woody plants.

Without periodic fire, this community is invaded by many woody species not originally native to it, and, at the same time, the herbaceous ground cover begins to lose species. The list in Appendix Table E is primarily based on healthy, fire-maintained habitat. However, some common invaders are also listed.

There are three main phases of this community. One is dominated by longleaf pine and various herbs including wiregrass. The second is dominated by a mixture of longleaf pine, turkey oak, and, again, various herbs including wiregrass. These first two are on deep sands. The third grows on richer soils and was originally dominated by longleaf pine in association with southern red oak, sand post oak (*Quercus margaretta*), bluejack oak (*Quercus incana*), and mockernut hickory over a diverse ground cover of chinquapin (*Castanea pumila*), poison oak (*Rhus toxicodendron*), wiregrass, and many other species.

5.4.2 Longleaf Pine Sandhill

The early naturalists wrote about vast open woodlands of longleaf pine through which one could see for a mile (Bartram 1791). Bartram (1791) wrote: "This plain is mostly a forest of the great long-leafed pine (*P. palustris* Linn.); the earth covered with grass, interspersed with an infinite variety of herbaceous plants,...". To get an idea of what these forests were like, one must go to the Wade Tract or the one or two other bits of virgin longleaf pine forest that still stand on quail-hunting plantations in southwest Georgia. There is no forest like this left in Florida. However, there are some areas of younger, denser longleaf forest in the Withlacoochee State Forest and elsewhere on the Brooksville Ridge in central Citrus and Hernando Counties, which, if burned often enough and left to grow long enough, might eventually become forest of this kind.

The second-growth longleaf-dominated sandhills (Fig. 67) are not yet as good habitat for most of the native fauna as was the older and more open virgin forest. In particular, the red-cockaded woodpecker, southeastern kestrel, and eastern kingbird (*Tyrannus tyrannus*) clearly do better in older forests. When compared to the turkey-oak-dominated sandhills, the longleaf-dominated sandhills are better habitat for some animals and poorer for others. Animals favoring the longleaf sandhills include the red-cockaded woodpecker, bobwhite, pine warbler (*Dendroica pinus*), and brown-headed nuthatch (*Sitta pusilla*) (Florida Game and Fresh Water Fish Commission 1976). The southeastern kestrel needs very open

Figure 67. Longleaf pine sandhill, showing longleaf pine, wiregrass, and occasional turkey oaks.

foraging habitat and a sufficient population of large pine trees to provide the dead pines with cavities it prefers for nesting (Hoffman 1983; Bohall 1984). Animals favoring the turkey-oak-dominated sandhills, provided they are still open woodland, are fox squirrel, Florida mouse, blue jay, great crested flycatcher, short-tailed snake (*Stilosoma extenuatum*), Florida crowned snake (*Tantilla relicta*), coral snake (*Micrurus fulvius*), eastern fence lizard (*Sceloporus undulatus*), mole skink, and Florida worm lizard (*Rhineura floridana*) (Florida Game and Fresh Water Fish Commission 1976). A reasonable conclusion is that the high pine faunal community as a whole would do best with about an even mix of oak and pine, scattered widely enough and burned often enough to have an open forest structure and a vigorous herbaceous ground cover.

The vegetation of longleaf pine sandhill forest is predominantly longleaf pine and wiregrass, but includes some turkey oak and a scattering of most of the species listed in Appendix Table E. The ground cover is usually strongly dominated by wiregrass, but most of the other herbs do better here than in turkey oak sandhill forest. There has been some speculation that the wiregrass domination may have been increased by the open-range cattle (*Bos taurus*) grazing of the 19th and first half of the 20th century. Certainly, the practice of annual burning combined with cattle grazing will favor wiregrass over most of its competitors in the ground cover, although the winter and early spring burning that was done is much less favorable to wiregrass than summer fire.

5.4.3 Turkey Oak Sandhill

Sandhills dominated by turkey oak (Fig. 68) are common today on the Brooksville Ridge and elsewhere in north Florida. Clearly, most of these areas once supported much more longleaf pine. The old resinous stumps of the original pines were clear evidence of this before they were removed and sold to the rosin industry (primarily the Hercules Powder and Cabot Carbon Companies). However, an understory of turkey oak, and often bluejack oak, was not uncommon. Nash (1895) explored the area around Eustis, Florida, before the virgin timber was logged and before the advent of fire suppression, and described the forest: "Of these the high pine land is the greatest in extent. The tall timber is composed entirely of the long-leafed or yellow pine, *Pinus palustris*. The trees have perfectly straight trunks, rising to a height of 50 to 75 feet, the branches all being borne near the top, leaving the trunks entirely naked. The two other prevailing trees are *Quercus catesbaei* [*Q. laevis*] and *Quercus cinerea* [*Q. incana*], the shining bright green deeply cut leaves of the former making a strong contrast to the narrow entire and grayish-green foliage of *Q. cinerea*." In 1774, William Bartram observed a sandhill somewhere between Gainesville and the Suwannee River and described it as follows: "... we ascended a sandy ridge, thinly planted by nature with stately pines and oaks,..." (Bartram 1791, pg. 180). With the logging of the virgin forest and subsequently the second-growth pines, it was inevitable that the oaks would increase in dominance. Cattle grazing and annual late-winter burning on the open range further contributed to this by ensuring that fires would be mild due to little fuel accumulation. Since the forest would usually have already been burned, fires would not occur in summer when more damage would be done to the oaks.

5.4.4 Longleaf Pine-Southern Red Oak Forest

This community originally covered large areas in western Alachua and Marion Counties. The soil was mostly a thin layer of sandy topsoil over either clay or limerock (Harper 1915). In some cases, the clay was at the surface. Most of this forest was cleared years ago for farms, pasture, and other purposes. The little that remains has been changed by hardwood invasion to the point that it is hard to imagine the original longleaf pine forest. This original forest grew in well-stocked but open stands of large longleaf pine. Trees associated with longleaf pine in this forest, or in the ecotone between this forest and mesic hammock, were southern red oak (*Quercus falcata*), mockernut hickory, post oak (*Quercus stellata)*, sand post oak, bluejack oak, and flowering dogwood (*Cornus florida*). In north-central Florida, southern red oak and mockernut hickory are largely confined to this

Figure 68. Turkey oak sandhill, showing turkey oak and wiregrass with one young longleaf pine left of center.

community (Harper 1915). Other plants characteristic of or somewhat restricted to this community in this area are sassafras (*Sassafras albidum*), chinquapin, New Jersey tea (*Ceanothus americanus*), poppy mallow (*Callirhoe papaver*), and white indigo (*Baptisia alba*). Dogwood, poison oak, and skullcap (*Scutellaria integrifolia*) were more abundant in this community than elsewhere. Botanically, this was the most diverse and interesting phase of high pine. The ground cover was particularly diverse and dense.

5.5 Pine Flatwoods

As with the preceding major habitat types, pine flatwoods, in its natural state, is a distinct and easily recognized (Fig. 69) biological community. As its name implies, it occurs on very flat land which is poorly drained. Where fire is still a significant factor, the community is strongly structured in two layers. The tree layer is a tall forest of pine (*Pinus* spp.) trees. The second layer of vegetation is 5 ft or less in height and is dominated by evergreen shrubs, mostly saw-palmetto (*Serenoa repens*), gallberry (*Ilex glabra*), and fetterbush (*Lyonia lucida*). Areas not dominated by these large shrubs have a mixture of very small evergreen shrubs (*Quercus pumila*, *Q. minima*, *Vaccinium myrsinites*, *Kalmia hirsuta*, and others), grasses (*Andropogon* spp., *Aristida* spp., *Panicum* spp., and others), and wildflowers. In midwinter, this is the greenest community in the southeastern United States.

Figure 69. Pine flatwoods, showing longleaf pine, saw-palmetto, and openings containing mix of herbs and dwarf shrubs.

Pine flatwoods is one of the major forest types of the Springs Coast region, occupying over 100,000 acres of land in the Green Swamp area in the southeast part of the region (Lopez et al. 1981) and perhaps an equal amount surrounding Gulf Hammock and extending northward in the Waccasassa River drainage west of Bronson, as shown in Fig. 70.

5.5.1 General Pine Flatwoods Information

a. Soils. Pine flatwoods soil is generally poorly drained, sandy, acid, and low in nutrients. The upper 2 or 3 inches are often high in organic content, below which is a layer of strongly leached white sand. There is usually an organic hardpan (spodic horizon) 6 in to 3 ft below the surface. A clay hardpan often lies below the organic hardpan. These are called ground-water podzol soils (aquods). Areas of typical pine flatwoods forest also grow on flat, poorly-drained sandy soils over limerock with no hardpans (or a weakly formed spodic horizon) in west-central Levy County and probably elsewhere. The water table generally varies with the season from at or near the surface to 1–4 feet below the surface.

b. Ecology. During periods of wet weather, flatwoods soils may remain saturated with water for several months. During droughts, the water table may drop below the root zones of most plant species, which are often restricted in depth by the organic and/or clay hardpans (or limerock). Both of these conditions can severely stress plant and animal species and serve to restrict the species composition of the

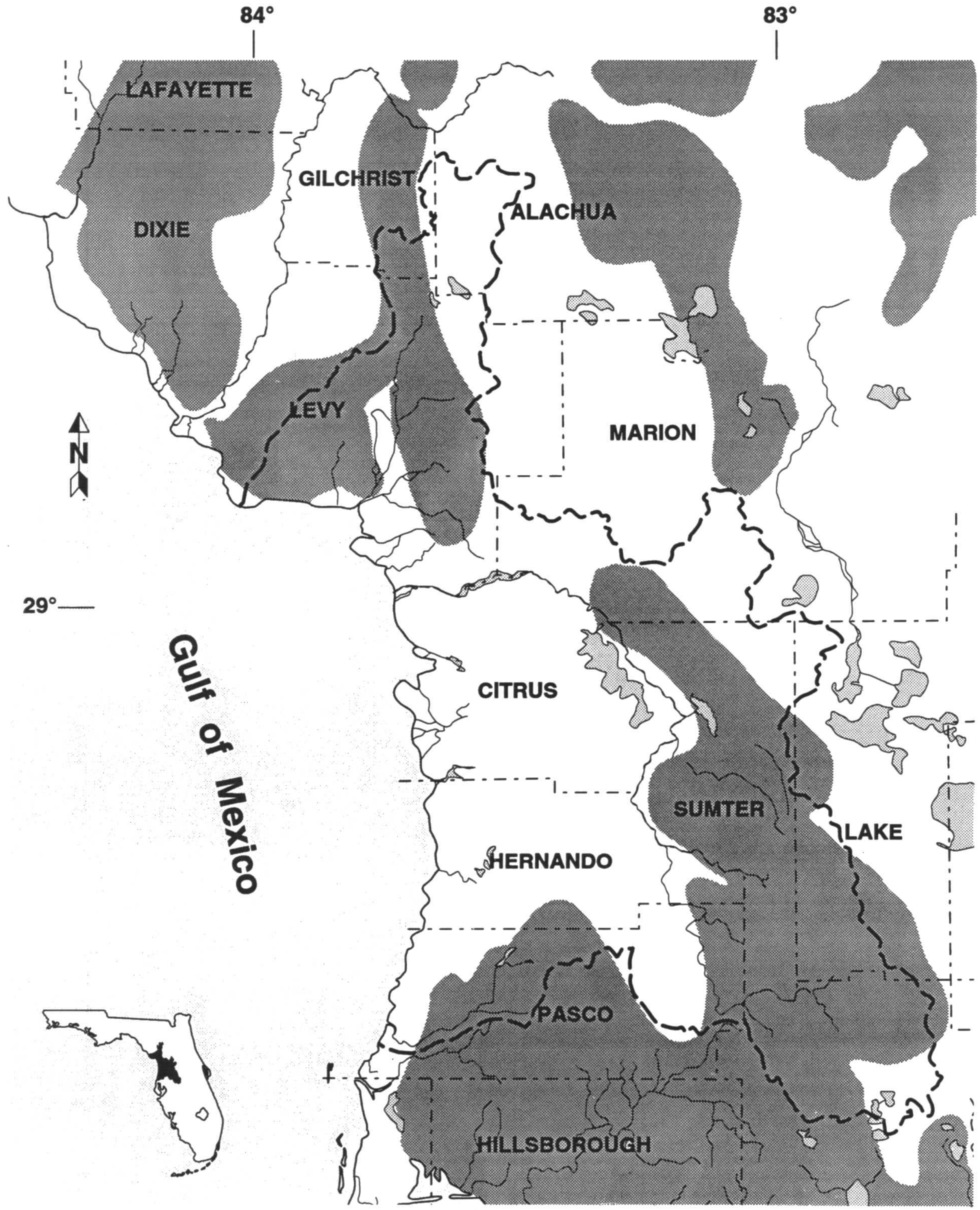


Figure 70. Major areas of pine flatwoods in the Florida Springs Coast (after U.S. Dept. of Agriculture 1981).

flatwoods. Nutrient limitations and soil acidity further restrict species composition.

Fire also plays a strong role in determining species composition of the flatwoods. The typical pine flatwoods habitat of today, with its dense pine stands and evergreen shrub-dominated understory, is the result of frequent mild winter fires. Bartram (1791) described flatwoods with widely scattered pines and a short understory containing saw-palmetto and other shrubs, but with more grasses and wildflowers than we see today. This was, no doubt, the result of a much more diverse fire regime, which probably included a majority of summer fires. With infrequent winter fires or complete protection from fire, flatwoods is invaded by hardwood trees, and some wet flatwoods areas have become hydric hammocks dominated by water oak (*Quercus nigra*), blackgum (*Nyssa sylvatica* var. *biflora*), and red maple (*Acer rubrum*).

The role of fire in the pine flatwoods is very similar to its role in the high pine community, and some of the dominant plants are the same, i.e., longleaf pine (*Pinus palustris*) and wiregrass (*Aristida stricta*) (see high pine section). The main difference is the shrub understory in the flatwoods, which provides taller and more abundant fuel that does not ignite quite as easily, but that burns hotter and with taller flames. Under natural conditions, this probably resulted in somewhat less frequent fires that were more intense. The average frequency under natural conditions might have been every 2 to 5 years with considerable variation over time and from place to place. The less frequent burning and winter burning commonly practiced now have shifted the dominance in favor of the large shrubs. More frequent burning and summer burning can be used to shift the dominance back toward the dwarf shrubs, grasses, and wildflowers. However, much care must be taken if the pine overstory is to remain undamaged, due to the high fuel concentrations in the flatwoods.

c. Fauna. As with the preceding major habitat types (i.e., coastal strand, scrub, and high pine) the pine flatwoods community supports a unique fauna, some members of which do better in this habitat than anywhere else, and some of which do well in a broad range of habitats including this one (Appendix Table F). The flatwoods earthworm, *Diplocardia mississippiensis*, is quite abundant and supports a commercial bait industry. Because of the luxuriant ground cover, high water table, and numerous wetland depressions, this is particularly good habitat for a number of amphibian species, of which the pine woods tree frog (*Hyla femoralis*) is probably the most noticeable, characteristic, and abundant. Two of the most notable and common reptiles are the southern black racer (*Coluber constrictor priapus*) and eastern diamondback rattlesnake (*Crotalus adamanteus*), both of which occur in a wide range of habitats. The eastern indigo snake (*Drymarchon corais couperi*) was originally rather common in the Springs Coast pine flatwoods, but is becoming less so, perhaps in part due to the removal of the old pine stumps, which served as den sites.

The birds of the Springs Coast flatwoods include all the longleaf-pine-dwelling species such as the pine warbler (*Dendroica pinus*), brown-headed nuthatch (*Sitta pusilla*), and even a few red-cockaded woodpeckers (*Picoides borealis*). Of these, the pine warbler is the most abundant. Some of the more generalized crown dwellers like the summer tanager (*Piranga rubra*) and the blue-gray gnatcatcher (*Polioptila caerulea*) are also quite common. The eastern wood-pewee (*Contopus virens*) is a characteristic summer bird of the flatwoods, though patchy in its occurrence. The northern bobwhite (*Colinus virginianus*) and Bachman's sparrow (*Aimophila aestivalis*) are common where the understory is kept open by burning. Most abundant as a group, however, are the dense shrub dwellers, i.e., the rufous-sided towhee (*Pipilo erythrophthalmus*), white-eyed vireo (*Vireo griseus*), Carolina wren (*Thryothorus ludovicianus*), northern cardinal (*Cardinalis cardinalis*), and common yellowthroat (*Geothlypis trichas*).

The mammals of the pine flatwoods are all species that occur in other habitats at least as frequently. White-tailed deer (*Odocoileus virginianus*), wild hog (*Sus scrofa*), hispid cotton rat (*Sigmodon hispidus*), and nine-banded armadillo (*Dasypus novemcinctus*) are the most common and important of these.

Appendix Table F lists vertebrates of the pine flatwoods of this region.

d. Flora. Longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii*) make up well over 90% of the tree canopy of the Springs Coast flatwoods. There are a few small areas of pond pine (*Pinus serotina*) and some loblolly-bay (*Gordonia lasianthus*), and, due to fire suppression, there are varying amounts of invading sand live oak (*Quercus geminata*), water oak (*Quercus nigra*), loblolly pine (*Pinus taeda*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), swamp-bay (*Persea palustris*), and red maple (*Acer rubrum*) in most pine flatwoods forests. Although tree species are few, the flatwoods contains many kinds of shrubs, of which saw-palmetto (*Serenoa repens*), runner oak (*Quercus pumila*), dwarf live oak (*Quercus minima*), shiny blueberry (*Vaccinium myrsinites*), gallberry (*Ilex glabra*), fetterbush (*Lyonia lucida*), and waxmyrtle (*Myrica cerifera*) are the most common. Though shrubs usually dominate the understory, the number of shrub species pales in comparison to the vast diversity of grasses and wildflowers, which is so great that only a few of the most common can be listed in Appendix Table G. Wiregrass (*Aristida stricta*) is the most common, although it is not nearly as dominant here as in the high pine community.

There are several variants of pine flatwoods in the Springs Coast region. Pond pine occurs in pure stands or mixed with slash pine or loblolly bay on a few areas of very wet, very acid soil. On most wet flatwoods sites, slash pine dominates over a dense thicket of gallberry and other shrubs. Longleaf pine originally dominated the dry or mesic flatwoods, which was the most common type of flatwoods. In a few areas there are flatwoods soils with a layer of sand on top that support a community known as scrubby flatwoods, consisting of slash or longleaf pine over a mixture of scrub and flatwoods shrubs.

5.5.2 Pond Pine Flatwoods

Pond pine flatwoods occurs very sparingly in the Springs Coast region. It is somewhat intermediate between wet pine flatwoods and bayhead in composition and ecology. Pond pine can be in pure stands, but is more commonly mixed either with slash pine or loblolly-bay or both. There is usually a dense shrub layer of fetterbush (*Lyonia lucida*), gallberry (*Ilex glabra*), large gallberry (*Ilex coriacea*), red chokeberry (*Aronia arbutifolia*), huckleberry (*Gaylussacia* spp.), and saw-palmetto.

5.5.3 Wet Flatwoods (Slash Pine Flatwoods)

There are areas of wet flatwoods scattered throughout the flatwoods, particularly in the Green Swamp area and in the upper parts of the Waccasassa River basin. Slash pine often occurs in pure, dense stands, although longleaf pine also grew here originally to some extent. The understory is quite variable. Some places have dense thickets of gallberry or saw-palmetto or fetterbush. Waxmyrtle is sometimes abundant. Often, there are openings dominated by Virginia chain fern (*Woodwardia virginica*) or redroot (*Lachnanthes caroliniana*) or maidencane (*Panicum hemitomon*). The fauna of the wet flatwoods is very similar to that of the flatwoods in general, although many species are less abundant, particularly those associated with herbaceous ground cover. When adjacent to hardwood forest, the tall pines afford ideal nest sites for swallow-tailed kites (Florida Game and Fresh Water Fish Commission 1976), which are moderately common west of U.S. Highway 19.

5.5.4 Mesic Flatwoods (Longleaf Pine Flatwoods)

Also called high flatwoods or typical flatwoods or longleaf pine flatwoods, this is the most common form of flatwoods. However, it is only slightly more common than wet flatwoods in this region. Longleaf pine originally dominated the canopy except near the coast, where slash pine was the dominant tree. The slash pine on the coast, particularly on islands like Cedar key, is genetically distinct, being more robust and presumably more salt-tolerant than the inland pines. It is generally considered to be south Florida slash pine (*Pinus elliottii* var. *densa*). Today, nearly all of the mesic flatwoods on private land has been clearcut and replanted to slash pine. The Withlacoochee State Forest is the only place in this region where much of this community is still in longleaf pine, and even here, much has been converted to slash pine plantation. The flora and fauna of pine plantations established on these forest sites is similar to the original flatwoods, but there are significant differences that are related to intensity of site preparation and rotation length (see section on plantations).

Mesic pine flatwoods forest is generally more open and not as tall as the wet pine flatwoods forest. Saw-palmetto is almost always the dominant shrub, but there are usually openings that have a low ground cover of wiregrass, runner oak, dwarf live oak, silkgrass (*Pityopsis graminifolia*), shiny blueberry, and various other small plants. Although very similar to wet flatwoods in wildlife values, mesic flatwoods is generally better habitat for most of the ground-dwelling fauna, with the possible exception of the amphibians. Certainly, bobwhite, wild turkey (*Meleagris gallopavo*), and deer benefit from the openings. The key to maintaining these openings is frequent fire, which can reduce or even reverse the encroachment of saw-palmetto.

5.5.5 Scrubby Flatwoods

The natural tree canopy of scrubby flatwoods is usually a rather widely scattered stand of either longleaf or slash pine. This is usually converted by forest managers to a dense plantation of slash pine. The shrub layer is usually a dense thicket of sand live oak, myrtle oak (*Quercus myrtifolia*), saw-palmetto, huckleberry, fetterbush (*Lyonia lucida*), crookedwood (*Lyonia ferruginea*), and various other flatwoods and scrub shrubs. If the natural, open scrubby flatwoods is burned periodically to keep the shrubs low, this is good scrub jay (*Aphelocoma coerulescens*) habitat. It also supports gopher tortoises (*Gopherus polyphemus*). Indeed, the flora and fauna are intermediate between flatwoods and scrub, although tarflower (*Befaria racemosa*), pennyroyal (*Piloblephis rigida*), and flatwoods pawpaw (*Asimina reticulata*) are more abundant here than in other types of flatwoods or in scrub. Thus Appendix Tables F and G listing flatwoods species are not entirely appropriate for this community. Appendix Tables B and C, listing scrub species, should also be consulted.

There are several areas of this vegetation type, including a fairly extensive one northeast of Cedar Key. There are also small spots of this habitat, some less than an acre in size, scattered about in the mesic flatwoods. These small spots are interesting and valuable, because they are often heavily used by deer and often contain gopher tortoise colonies.

5.6 Hammocks

The uplands of Florida were originally dominated by vast pine forests. Scattered about in a few spots in this sea of pines were islands of dense hardwood forest. These were, and still are, called hammocks. Loblolly pine (*Pinus taeda*), southern redcedar (*Juniperus silicicola*), and cabbage palm (*Sabal palmetto*) often occur in these hammocks, but the dominant trees are generally a mixture of oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), pignut hickory (*Carya glabra*), and many other hardwood species.

Hammocks occur in places with more fertile soil due to deposits of limerock, phosphate, or clay; or they occur in places protected to some degree from wildfire by bodies of water or swamps (Harper 1911, 1915; Platt and Schwartz 1990).

By far the single largest hammock in Florida is Gulf Hammock in western Levy County. It originally covered more than 100,000 acres from Florida Highway 24 south to the Withlacoochee River between U.S. Highway 19 and the gulf. Much of this hammock has been destroyed in the past 20 years, mostly by conversion to pine plantations. The largest remaining portion of Gulf Hammock is the coastal fringe that is within Waccasassa Bay State Preserve. However, this part is slowly disappearing due to a combination of coastal subsidence and sea level rise (Simons et al. 1989). A large-scale die-off of cabbage palms (and to some extent live oak [*Quercus virginiana*] and redcedar) on the coastal edge of this hammock has been occurring in the last six years (1985–1991), perhaps caused by the gradually accelerating sea-level rise predicted by the greenhouse effect theory. If the current projections of a sea-level rise of 84–104 cm for the next century

(Titus et al. 1984) come to pass, almost all of the hammock and swamp forest within the Waccasassa Bay State Preserve, the lower Suwannee National Wildlife Refuge, and the Chassahowitzka National Wildlife Refuge will die and become salt marsh.

The other hammocks of the Springs Coast are now mostly 1,000 acres or less in size and are scattered along the coast south of Levy County, along the Withlacoochee River and its tributary streams and lakes, and in other areas indicated in Fig. 71. The large area delineated as hammock in Fig. 71 in Alachua and Marion Counties was originally mostly the southern red oak phase of high pine forest with a scattering of hammocks. Now, the high pine is mostly gone, but some hammocks remain. Much hammock forest was associated with Lake Tsala Apopka, and there is still some, but most of it has been cleared for pasture.

5.6.1 General Hammock Information

a. Soils. Hammocks occur on a wide variety of soil, from flat, poorly drained, fertile clay soil of neutral pH to hilly, xeric, infertile acid sands. In general, however, hammocks are on relatively fertile soil with either clay or limerock near the surface.

b. Ecology. Two main factors determine whether or not an upland site will be a hammock. One is protection from fire, and the other is soil fertility. Almost any area of upland will become hammock if protected long enough from fire (Veno 1976). Indeed, many areas of high pine, pine flatwoods, and scrub are now becoming hammocks. There are some apparent exceptions, such as the Florida rosemary (*Ceratiola ericoides*) scrubs on the hilltops at the north end of the Brooksville Ridge, which may be so sterile and xeric that no hammock vegetation can grow there, but these are only very small areas. Most uplands could support some sort of hammock. Further evidence for this assumption is that many of the original hammocks occur next to bodies of water or wetlands where there is some natural protection from fire. Good examples of this were the many small hammocks that were restricted to islands and peninsulas on the west side of Lake Tsala-Apopka (Harper 1911).

However, it is also true that many hammocks occur on areas of fertile soil or limerock outcrop, and that the original boundary of the hammock followed the boundary of the "hammock" soil without any apparent relation to fire. Harper (1915) noted that the low (hydric) hammocks of the Gulf Hammock region corresponded approximately with soils of mixed marl, clay, sand, and humus, whereas the adjacent flatwoods are on acid sands, often with an organic hardpan. The boundaries between hammock and flatwoods here are quite irregular, and generally have no fire barriers other than the differences in vegetation. Similarly, the high (mesic) hammocks near Ocala were closely associated with fertile soil, often on slightly higher ground than the adjacent pine forests (Harper 1915). Finally, there is evidence of past fire in most hammocks, including hydric (wet) hammocks (Vince et al. 1989).

Apparently, both fire and soil quality play strong roles in determining where hammocks occur, and either factor, by itself, if expressed strongly enough (total fire protection or very fertile soil), is sufficient to create a hammock. Most cases probably reflect a combination of factors, i.e., a hammock on moderately fertile soil can endure more assault by fire than one on less fertile soil, but still needs some protection from fire to become or remain a hammock.

Topography also plays a role in the location of hammocks. The Springs Coast region is generally flat, and most of the hammocks are on very flat terrain. However, there are some slopes along rivers and their tributaries and on the sides of sink holes. These slopes often support hammocks. This may be, in part, because the soil on the slope is kept moist by seepage from the adjacent upland and is therefore better able to grow hammock vegetation. Or a more fertile soil may be exposed or develop on the slope. However, another part of the answer is certainly that the increased moisture and the slope itself offer some protection from fire. Fire burns less vigorously downhill than on level ground or uphill, and less vigorously when fuels are moist.

Water mediates the existence of hammocks in other ways. Hydric hammocks flood occasionally, but are usually not flooded more than about 10% of

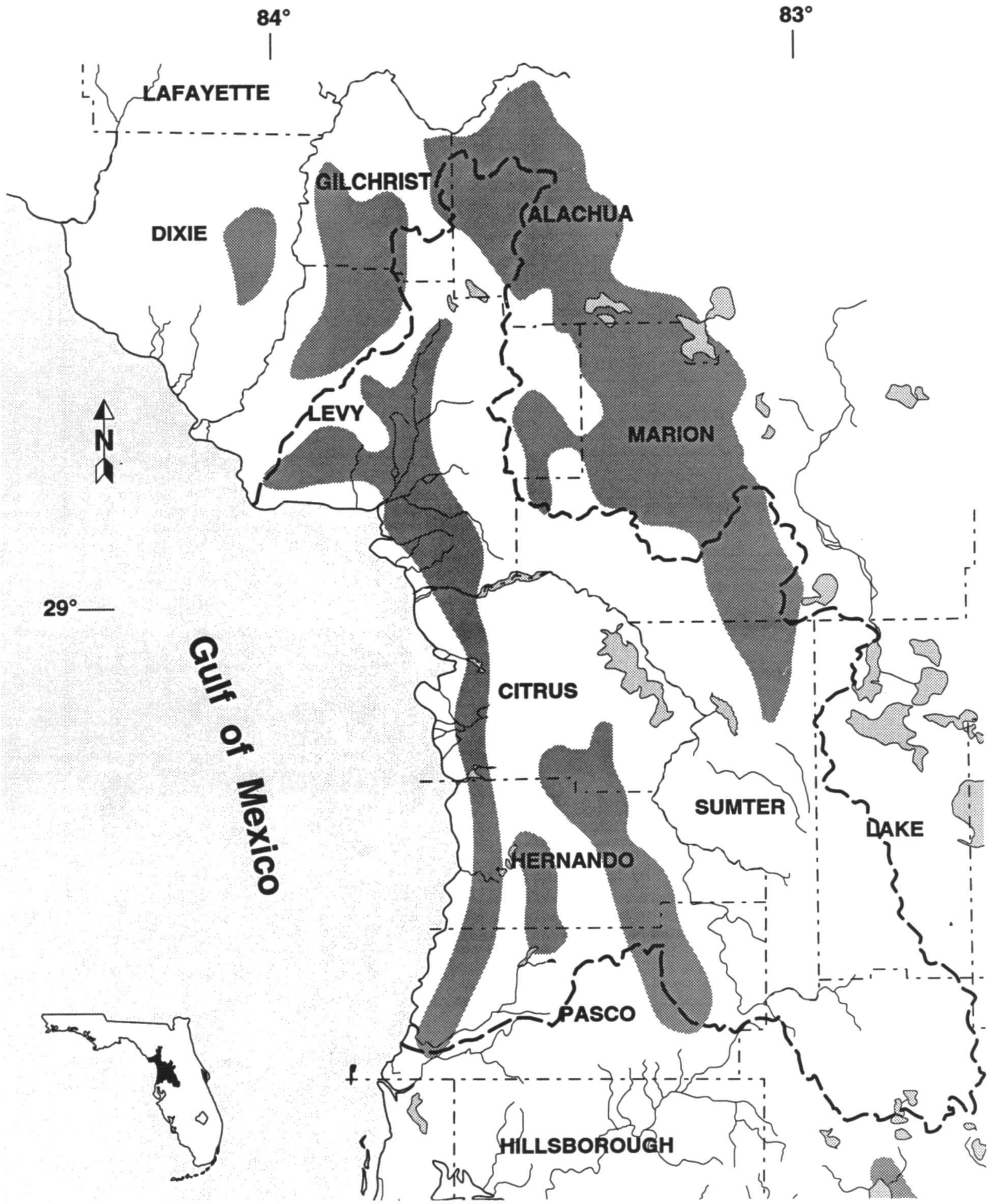


Figure 71. Major areas containing hammock forest in the Florida Springs Coast (after U.S. Dept. of Agriculture 1981).

the time. Swamps may be flooded for much more of the time. Differences in flood frequency and duration are the major factors determining the boundaries between these two communities. The hydrologic distinction between hammock and bayhead is somewhat different. Bayhead soil rarely floods, but seepage keeps it saturated, or nearly so, throughout the year. Hydric hammocks may flood, but they also dry out. Also, bayhead soils are usually quite acidic, whereas hammock soils are rarely very acidic (Monk 1968).

Because hammocks are the climax vegetation of this region, they are not being changed by invasion of other native species due to changes in fire frequency. However, logging and cattle grazing do alter hammocks, making them less diverse in structure and composition. In addition, several exotic species have invaded some hammocks. Skunk vine (*Paederia foetida*), which is covering a small area of hammock in the Withlacoochee State Forest the way kudzu (*Pueraria lobata*) covers trees in the piedmont, is a new introduction that seems to have the potential to do serious damage. It is readily spread by seeds carried by birds.

c. Fauna. Few species of vertebrates are restricted to hammock habitat, but there are many that do better in hammocks than in any other Springs Coast habitat (Appendix Table H). The fauna of hammocks is quite distinct from that of the preceding communities, although not so distinct from the fauna of swamps and bayheads. The hammock canopy dwellers, in particular, are different from those of the pine forests, with the gray squirrel (*Sciurus carolinensis*) and red-eyed vireo (*Vireo olivaceus*) being abundant. The bird most nearly restricted to hammock is probably the shrub-dwelling hooded warbler (*Wilsonia citrina*). The raptors are also different, with the red-shouldered hawk (*Buteo lineatus*) and barred owl (*Strix varia*) replacing the red-tailed hawk (*Buteo jamaicensis*) and great horned owl (*Bubo virginianus*) of the open pine woods.

Perhaps the most distinctive feature of the hammocks is the invertebrate fauna of the forest floor, which includes snails, earthworms, millipedes, isopods, springtails, harvestmen, mites, beetles, orthopterans, dipterans, and hemipterans. These, in turn, support a diversity of spiders, predatory insects, amphibians, reptiles, birds, and a few mammals. One introduced mammal, the nine-banded armadillo (*Dasypus novemcinctus*), is now exploiting this food web to such an extent that it may be seriously impacting some of the other species (Archie F. Carr, Jr., University of Florida, pers. comm.). The armadillo would probably not be nearly so abundant if its potential predators, the black bear (*Ursus americanus*), red wolf (*Canis rufus*), and panther (*Felis concolor*) still roamed the hammocks.

Old-growth hammocks provide good habitat for several kinds of woodpeckers and many cavity-nesting or cavity-dwelling species. They also produce large mast crops in the fall of most years, benefiting white-tailed deer (*Odocoileus virginianus*), wild hogs (*Sus scrofa*), gray squirrels, wild turkeys (*Meleagris gallopavo*), raccoons (*Procyon lotor*), blue jays (*Cyanocitta cristata*), common grackles (*Quiscalus quiscula*), woodpeckers, and other animals from nearby habitats as well as those that live part-time or full-time in hammocks. The hammocks along the Springs Coast are of particular importance to the fauna of much of the eastern United States, because they support very large populations of overwintering songbirds (Florida Game and Fresh Water Fish Commission 1976) and provide important habitat for migrants that winter farther south (Cox 1988).

d. Flora. The diversity of trees and shrubs reaches its peak for the continental United States in the hammocks of north Florida. In addition, there are a number of kinds of epiphytes and vines and a surprising number of herbaceous species. As with other major community types, part of the diversity of hammocks is due to differences between the different types of hammock, each with its own slightly different set of species. However, the old, original hammocks are also very diverse per unit area within any one type of hammock.

The concept of a mature hardwood forest having a dense canopy, but little vegetation otherwise, is true in this region only for hardwood forests that endure considerable flooding, logging, or cattle grazing, or are the result of recent hardwood invasion into old fields or former pine lands. The old, undisturbed areas of hammock, particularly on limerock outcrops and in the mix of mesic and hydric hammock along the gulf coast, often have a lush and diverse ground cover of grasses, sedges, wildflowers, and ferns. Above this is a variable growth of scattered bushes, vines, and young trees. Between the shrub layer and the main canopy, there is often a distinct subcanopy of hornbeam (*Carpinus caroliniana*) and other small trees. Finally, the canopy of old-growth hammocks is a dense but irregular mixture of many species.

The plant list in Appendix Table I is more complete for the woody plants than for herbaceous plants. As with the preceding lists, the relative abundance of the species is given, and those species particularly abundant in hammocks relative to other community types are marked.

There are several kinds of hammock that are quite distinct from one another in some instances, but that often blend together in other situations. Hammock on deep, well-drained sand is called xeric hammock. Mesic hammock occurs on fertile, well-drained soil with good moisture-holding capacity and/or a water table near the surface. Hydric hammock occurs in places that flood occasionally. Each of these three types of hammock is different when near the coast than when farther inland.

5.6.2 Xeric Hammock

The most distinctive type of hammock, the one least like the others, is xeric hammock (Fig. 72). Some of the dominant plants, i.e., sand live oak (*Quercus geminata*), saw-palmetto (*Serenoa repens*), crookedwood (*Lyonia ferruginea*), sparkleberry (*Vaccinium arboreum*), and deerberry (*Vaccinium stamineum*), are generally not common in the other types of hammock. Similarly, this is the only type of hammock that normally has gopher tortoises (*Gopherus polyphemus*), Florida crowned snakes (*Tantilla relicta*), or fence lizards (*Sceloporus undulatus*). The spadefoot toad (*Scaphiopus holbrookii*) and the southern hognose snake (*Heterodon simus*) are much more common in this habitat than in the other hammock types. Conversely, some of the moisture-dependent animals common in the other types of hammock are absent here, i.e.: Florida box turtle (*Terrapene carolina*), ribbon snakes (*Thamnophis sauritus*), slimy salamander (*Plethodon glutinosus*), and little grass frog (*Limnaoedus ocularis*).

Xeric hammock is less diverse vegetatively than the other types of hammock. The overstory is typically made up of sand live oak, live oak (*Quercus virginiana*), laurel oak (*Quercus hemisphaerica*), and pignut hickory (*Carya glabra*) with perhaps some black cherry (*Prunus serotina*), southern magnolia (*Magnolia grandiflora*), and redbay (*Persea borbonia*). The shrub layer is usually dominated by saw-palmetto with some sparkleberry, deerberry, flatwoods plum (*Prunus umbellata*), carolina holly (*Ilex ambigua*), tallow-wood (*Ximenia americana*), winged sumac (*Rhus copallinum*), beautyberry (*Callicarpa americana*), wild olive (*Osmanthus americanus*), and crookedwood. Bullace grape (*Vitis rotundifolia*) and yellow jessamine (*Gelsemium sempervirens*) vines are often abundant. There are usually few herbs, although bracken fern (*Pteridium aquilinum*), scrub beakrush (*Rhynchospora megalocarpa*), partridgeberry (*Mitchella repens*), sarsaparilla vine (*Smilax pumila*), coralbean (*Erythrina herbacea*), and elephant's-foot (*Elephantopus* spp.) may be present. Coontie (*Zamia floridana*) is sometimes common.

On the coast, live oak (*Quercus virginiana*) and cabbage palm (*Sabal palmetto*) are often abundant in this forest type. Some of the unusual animals found in xeric hammock on the Cedar Key group of islands are discussed in the section on coastal strand.

5.6.3 Mesic Hammock

Of the various types of forest in this region, mesic hammock (Fig. 73) is the one most similar to the oak-hickory forest found farther north. It is the ultimate climax vegetation type for this region, according to some theories of plant succession (see Fig. 61 and Quarterman and Keever 1962). Species composition is not limited by lack of soil moisture or fertility, or by flooding, or by fire. Indeed, the species diversity is highest here, although only a few of the species

Figure 72. Xeric hammock with sand live oak, saw-palmetto, and Spanish moss.

associated with limerock outcrops (see next paragraph) are strictly limited to mesic hammock. This is partly because the distinctions between mesic, xeric, and hydric hammock are difficult to determine precisely. In addition to the limerock outcrop species, trees that are primarily mesic hammock species in this region are swamp chestnut oak (*Quercus michauxii*), shumard oak (*Q. shumardii*), white ash (*Fraxinus americana*), winged elm (*Ulmus alata*), southern magnolia (*Magnolia grandiflora*), Eastern hophornbeam (*Ostrya virginiana*), Eastern redbud (*Cercis canadensis*), American plum (*Prunus americana*), and Carolina basswood (*Tilia caroliniana*). However, the most common trees in mesic hammock are often laurel (or diamondleaf) oak (*Quercus hemisphaerica* or *laurifolia*) and pignut hickory. In Gulf Hammock, swamp chestnut oak, in association with a great diversity of other trees, shrubs, vines, and herbs, was the dominant tree on the slightly elevated ridges of mesic hammock locally known as white oak ridges. Another abundant tree on these ridges was Florida maple (*Acer barbatum*). The past tense is used in this case, because most of this magnificent hammock has been cleared in the past 20 years. The coastal end of these ridges, which is now in the Waccasassa Bay State Preserve, is a much simpler community dominated by live oak, cabbage palm, and redcedar. This coastal form of the hammock is still found on the slightly elevated ridges, but is occasionally flooded by brackish water during hurricanes. It is nearly identical in composition to the hammock near the gulf that is not on the ridges, and, since they both flood occasionally, they are considered here as the coastal form of hydric hammock.

Figure 73. Mesic hammock, showing mixed hardwood forest with dense overstory and understory in December.

Mesic hammocks are not only diverse, but they are also quite variable from one place to the next. The single most important factor influencing variability is the presence or absence of limerock. Monk (1968) noted that hammocks growing on limerock outcrop soils are primarily deciduous, whereas those on soils low in calcium, phosphorus, or potassium are primarily evergreen. Sweetgum (*Liquidambar styraciflua*), pignut hickory, swamp chestnut oak, shumard oak, redbay (*Persea borbonia*), sugarberry (*Celtis laevigata*), winged elm, Florida maple, and basswood often dominate the calcium-rich hammocks, whereas laurel oak often dominates the less fertile situations, and live oak and southern magnolia may also be more common. The calcareous mesic hammocks are the most diverse hammocks. Besides the trees already mentioned, virtually the entire list of species in Appendix Table I, and many herbaceous plants not listed, occur in the larger stands. Some plants that are entirely restricted to calcareous hammocks are bluff oak (*Quercus austrina*), wingleaf soapberry (*Sapindus saponaria*), virgin's bower (*Clematis catesbyana*), climbing buckthorn (*Sageretia minutiflora*), Godfrey's privet (*Forestiera godfreyi*), wild coffee (*Psychotria nervosa*), and rouge plant (*Rivina humilis*). Cooley's justica (*Justicia cooleyi*) is a herbaceous plant endemic to the floristically rich limestone hill hammocks in the vicinity of Brooksville in Hernando County (Ward 1978).

Mesic hammock is a very fertile and productive habitat, and many of the animals that do well in hammock do best in mesic hammock or a combination of mesic and hydric hammock. Thirty to forty years ago, Gulf Hammock had one of the highest combined densities of deer, cattle, and hogs of any one area in Florida (Harlow 1959), and also high wild turkey (Swindell 1949) and gray squirrel (Jennings 1951) populations.

5.6.4 Hydric Hammock

Hammocks subject to flooding (Fig. 74) are called hydric hammocks. They are generally less diverse than mesic hammocks, because many of the mesic-hammock species cannot endure any significant amount of flooding. The typical dominant trees of hydric hammocks inland more than a mile from the coast are sweetgum, laurel oak, live oak, red maple (*Acer rubrum*), Florida elm (*Ulmus americana* var. *floridana*), sugarberry, cabbage palm, and loblolly pine (Simons et al. 1989). American hornbeam (*Carpinus caroliniana*) is a common understory tree. Hydric hammocks that are on ground that rarely floods for long, but that remains moist most of the time, usually have a dense ground cover of ferns, grasses, sedges, and other herbs. Hammocks that occasionally flood for a month or more may have little ground cover other than leaves and patches of greenbriar (*Smilax* spp.).

Near the coast, well-drained hydric hammock becomes strongly dominated by cabbage palm (Fig. 75) in association with redcedar and live oak

Figure 74. Hydric hammock (flooded), showing live oak and loblolly pine with some smaller sweetgum and red maple in the background.

Figure 75. Coastal hydric hammock dominated by cabbage palm with some southern redcedar.

(Vince et al. 1989). A scattering of cedar elm (*Ulmus crassifolia*) occurs along the broad transition area between the inland and coastal forms of hydric hammock. There are low areas of marsh and small ponds scattered about in this coastal hammock, some of which contain corkwood (*Leitneria floridana*) around the edges. These provide habitat for wood ducks (*Aix sponsa*), alligators (*Alligator mississippiensis*), wading birds, and many other species. In wetter areas of hydric hammock near the coast, red maple, redcedar, cabbage palm, and sweetbay (*Magnolia virginiana*) form an open forest over sawgrass (*Cladium jamaicense*) and various other marsh plants. On the coast, the cabbage palm-live oak-southern redcedar forest breaks up into peninsulas and islands interspersed with the salt marsh to form one of Florida's most scenic landscapes.

5.6.5 Pioneer Hammock

Many areas that were formerly high pine forest have now become hardwood forests due to protection from fire and, of less significance, logging of the pines. Similar hardwood forests have also developed from mesic flatwoods forests, old field forests, and pine plantations. This new community has been called upland mixed forest (Duever 1985) and high hammock (Platt and Schwartz 1990), or has been lumped in with xeric hammock (Laessle 1942) or southern mixed hardwood forest (Monk 1968). Pioneer hardwood forest is the most abundant type of hardwood forest in the piedmont and coastal plain of the southeastern United States and in the Florida panhandle, but, although rapidly increasing, it is still less common than mesic and hydric hammock in this region, where it did not begin to develop in any abundance until about 50 years ago.

In this region, pioneer hammocks can be distinguished from high pine forest by the closed canopy of hardwood trees and by the abundance of laurel oak. They can be distinguished from the other types of hammocks by remnants of the high pine community and by the scarcity of many of the characteristic hammock species. Of the various woody plants mentioned as characteristic of xeric hammock, only the oaks are likely to be common in pioneer hammock. The late successional mesic hammock trees such as basswood, pignut hickory, swamp chestnut oak, hornbeam, and hop-hornbeam are also scarce or absent.

Not all pine forests become pioneer hammock if protected from fire. Scrub succeeds directly to xeric hammock without going through the pioneer hammock stage, and wet pine flatwoods succeeds directly to hydric hammock. Pond pine flatwoods often succeeds to bayhead.

Pioneer hammock forest does not contain the diversity and abundance of either plant or animal species or the overall abundance of wildlife that the older hammocks have. However, in time, pioneer hammocks develop into xeric hammock if on deep, well-drained sandy soil; mesic hammock if on more fertile, well-drained soil; and hydric hammock if on poorly drained, occasionally flooded ground. The mesic and hydric hammocks thus formed will probably still be less productive and diverse on average than the original hammocks, because they will, on average, be on less fertile soil. This is because the location of the original hammocks was often due to limerock outcrops or areas of particularly fertile soil, whereas pioneer hammocks have usually formed, by chance, on less fertile sites.

5.7 Sinkholes and Terrestrial Caves

Caves are common in this region, particularly in central Citrus and Hernando Counties and in the vicinity of Newberry in Alachua County and south of Ocala in Marion County. There is no vascular flora in the caves, but there is often an interesting community of calcareous (mesic) hammock plants in sink holes or on the rock outcrops associated with caves. Many species of ferns in this region are largely confined to sinkholes with limerock outcrops (often called "grottoes"; Small 1920), and central Citrus and Hernando Counties contain the best known populations of some of these, which include two species of maidenhair fern (*Adiantum tenerum* and *Adiantum capillus-veneris*), two species of brake fern (*Pteris vittata* and *Pteris cretica*), several species of spleenwort (*Asplenium heterochroum, A. resiliens, A. cristatum, A. pumilum, A. verecundum, A. auritum,* and *A. subtile*), southern lip fern (*Cheilanthes microphylla*), and sinkhole fern (*Blechnum occidentale*). Several species of wood fern (*Thelypteris* spp.) are the most common ferns in these situations. In addition, several kinds of mosses and liverworts often grow on moist, shaded rock surfaces in these grottoes. Twenty-four species of pteridophytes (ferns and fern allies), perhaps more than for any other site of similar size in North America, have been recorded from Pineola Grotto in Citrus County (Lakela 1964; Noss 1984).

The only plants in the interior of the caves are algae, fungi, and an occasional tree root. Animal life is also reduced compared to surface habitats, but caves frequently harbor a few deer mice (*Peromyscus* spp.), eastern woodrats (*Neotoma floridana*), rat snakes (*Elaphe* spp.), and salamanders. Their main habitat value, however, is for bats. Breeding colonies of the southeastern myotis bat (*Myotis austroriparius*), sometimes numbering in the thousands, occupy some of the caves here in the summer. Several other species of bats also use caves in this region.

Where there are bats, there is bat guano, and it is bat guano that is often the base of the food chain for the cave invertebrates. Species of invertebrates at least to some extent restricted to the dry cave habitats in this region are two spiders (*Gaucelmus augustinus*) and (*Nesticus pallidus*), two springtails (*Isotoma notabilis*) and (*Tomocerus dubius*), and a cave cricket (*Ceuthopilus latibuli*) (Peck 1970). There are also mites (Acarina), harvestmen (Phalangida), and a number of invertebrates not noticeably restricted to this habitat. Where dry and aquatic habitats meet in caves, the organic production in the dry cave often supports an additional community of aquatic invertebrates (see par. 5.19).

5.8 Pine Plantations and Old Field Forests

Pine plantations are today one of the major forest types in the Springs Coast region. The most common type of pine plantation is slash pine (*Pinus elliottii*) planted in the pine flatwoods after the original forest has been clearcut and some site preparation has been done. The photo in Fig. 76 shows two such plantations, a new one in the foreground and an old one in the background. Other types of areas that are now pine plantations are high pine sites which were clear cut and site prepared, former hammock sites that have been harvested and site prepared, and former agricultural lands (old fields). In addition, some of the old fields that were left fallow seeded to pines naturally.

5.8.1 Pine Flatwoods Plantations

Pine plantations on pine flatwoods sites that have always been forested are very similar to the natural pine flatwoods forests (see pine flatwoods section). The main differences relate to the effects of logging and site preparation, and the youth and high density of the planted trees. The logging of the original forest results in all the trees being removed and nearly all the other vegetation being mashed to the ground by the heavy logging machinery. The site preparation that follows usually consists of one or several of the

Figure 76. Pine plantation on flatwoods site, showing a 2-year-old slash pine plantation with grass-dominated ground cover in the foreground and a 20-year-old slash pine plantation with shrub understory in the background.

following: chopping by rolling a drum with blades on it over the site; a hot fire; the bulldozing of all remaining trees, logs, and old stumps into piles or rows (windrows); harrowing; and the plowing of the soil into raised beds alternating with shallow ditches, with the tops of the beds being about 10 ft apart (bedding). Several months later, young pines are planted at a density of about 600 to 800 trees per acre. Cattle are often grazed on the area while the trees grow.

The effect of logging and site preparation on the pine flatwoods biological community is dramatic. Initially, all the tree- and shrub-dwelling animals and most of the ground dwellers are eliminated from the site along with the woody vegetation that was their habitat. The site initially becomes wetter due to a reduction in transpiration, but is also better drained if bedded, so that, after the planted trees form a canopy, the site becomes drier than it was originally (Williams 1979). Small natural depressions are reduced or eliminated. The den sites of the old stumps are eliminated. If significant windrows are piled up, then a new shrub and den habitat is created. Moler (1985) found that indigo snakes (*Drymarchon corais*) den in these windrows. The newly cleared ground is good feeding habitat for crows (*Corvus* spp.), common grackles (*Quiscalus quiscula*), brown-headed cowbirds (*Molothrus ater*), and cattle egrets (*Bubulcus ibis*). Before the plant growth becomes too dense, killdeer (*Charadrius vociferus*) and ground doves (*Columbina passerina*) will often move in to take advantage of a few months of good habitat. Then, within a few months, the shrubs, grasses, and wildflowers spring up, and a brand new habitat is formed.

This new pine-plantation habitat has a diverse and vigorous herbaceous ground cover that is much greater in biomass and diversity than the now much-reduced woody plant component of the habitat (Conde et al. 1983). The vegetative diversity is much greater than in the original forest (Swindell et al. 1983), although much of this increase is due to a short-term population explosion of weedy species at the expense of some of the more sensitive native species (Noss 1983; Harris 1984). Plant genera that increase dramatically 1 year after site preparation relative to the original forest are *Panicum, Andropogon, Cyperus, Eleocharis, Rhynchospora,* and *Scleria*; forbs in general also increase dramatically (Swindell et al. 1983). Shrubs are reduced, but not eliminated, with the exception of blackberry (*Rubus* spp.), and sometimes St. John's wort (*Hypericum* spp.), which increase. Marion and O'Meara (1982) made the following observations on wildlife effects. New pine plantations in the flatwoods benefit eastern meadowlarks (*Sturnella magna*) and northern bobwhite (*Colinus virginianus*) to some extent year-round, and robins (*Turdus migratorius*), red-winged blackbirds (*Agelaius phoeniceus*), and sparrows dramatically in winter. Small mammals and white-tailed deer (*Odocoileus virginianus*) are not benefited. Amphibians, reptiles, and tree-dwelling birds are all reduced in abundance. The more severe the site preparation, the greater is the reduction in overall wildlife that is observed. On the other hand, the more intense the cattle grazing, the better the habitat for some animals, particularly northern bobwhite (Marion and O'Meara 1982). Wintering bird densities are also increased markedly for eastern bluebird (*Sialia sialis*), common ground dove (*Columbina passerina*), and American goldfinch (*Carduelis tristis*), and year-round densities are increased for mourning dove (*Zenaida macroura*) (Repenning and Labisky 1985).

By 5 years after establishment, the native shrubs and planted pines are the dominant vegetation of the plantation, and it is no longer good habitat for the species that were benefited by clearing. The shrubs that increase the most with intense site preparation, becoming much more abundant than in the original forest, are gallberry (*Ilex glabra*), waxmyrtle (*Myrica cerifera*), and blackberry (White et al. 1976). Saw-palmetto is dramatically reduced in abundance in direct correlation with the intensity of site preparation (White et al. 1976). The habitat value for deer is at its maximum between 5 and 15 years after planting (Harris and Skoog 1980). The same is probably true for eastern phoebe (*Sayornis phoebe*), yellow-rumped warbler (*Dendroica coronata*), and rufous-sided towhee (*Pipilo erythrophthalmus*) (Repenning and Labisky 1985). On the other hand, the habitat value for most other animals is at a minimum during the second decade. Eventually, if the pines are grown long enough, thinned, and burned frequently enough, the habitat will return to nearly its former condition (see section on pine flatwoods). Some impacts would require very long rotations to overcome and are therefore permanent alterations when short rotations are used. One of these is the reduction and eventual elimination of wiregrass (not necessarily a detriment to wildlife). Another is the reduction in terrestrial den sites (the windrows rot away in 5 to 10 years and the old stump holes are gone). Habitat for cavity nesters is reduced, because the size and durability of snags (standing dead trees) increases with stand age. Similarly, the stand must get past 60 years in age before it begins producing potential den trees for red-cockaded woodpeckers (*Picoides borealis*) (Hooper at al. 1980). Other potentially permanent changes are a reduction in breeding sites for amphibians resulting from the lowered water table and the draining and filling of small depressions if the site was bedded, and a reduction in tree-dwelling animals if slash pine has replaced longleaf pine. The density, species richness, species diversity, and biomass of breeding birds are depressed in all age classes of slash pine plantation compared to mature longleaf pine flatwoods (Repenning and Labisky 1985). The same is probably true for the other classes of animals, and the reduction in wildlife habitat value is directly correlated with intensity of site preparation (Harris et al. 1975).

5.8.2 High Pine Plantations

High pine habitats have often been cleared and planted to slash pine. The results are similar, in terms of habitat changes, to what happens in the flatwoods. The main differences are that no bedding is done, and, usually, no windrows are created. Another difference is that the small mammal populations, particularly oldfield mouse (*Peromyscus polionotus*), hispid cotton rat (*Sigmodon hispidus*), and eastern cottontail rabbit (*Sylvilagus floridanus*), seem to be increased considerably during the first few years of the plantation (Umber and Harris 1975). This, in turn, benefits some predators such as the red-tailed hawk (*Buteo jamaicensis*), northern harrier (marsh hawk) (*Circus cyaneus*) (in winter), great horned owl (*Bubo virginianus*), and gray fox (*Urocyon cinereoargenteus*). Gopher tortoises (*Gopherus polyphemus*), southeastern pocket gophers (*Geomys pinetis*), and the associated fauna also do well the first few years, as do sparrows, mourning dove, ground dove, and northern bobwhite. On the other hand, fox squirrels (*Sciurus niger*), Florida mice (*Podomys floridanus*), and most bird species of the original forest are greatly reduced (Umber and Harris 1975).

When the pines reach crown closure, at about age 10 to 15, the plantation returns to a high pine type of habitat (see section on high pine), but with all the wildlife habitat values dropping to well below the original condition. The combination of the dense pine canopy and an often dense subcanopy of oaks nearly eliminates the ground cover and all the animals that depend on it. However, a few gopher tortoises, pocket gophers, and associated fauna usually survive, often taking advantage of small openings in the pine canopy such as those created by lightning strikes and associated bark beetle (*Dendroctonus* spp. and *Ips* spp.) attacks. As with flatwoods plantations, the habitat values would eventually increase to near their original condition with sufficient time, thinning, and fire, but short rotation lengths and infrequent burning usually prevent this. Again, the more intense the site preparation and successful the plantation, the lower the habitat values during the life of the plantation after age 10. The elimination of wiregrass is more serious in high pine, because it is more dominant in the original forest. The overall effect of slash pine plantations in the sandhills is much the same as in the flatwoods, i.e., a general reduction in wildlife habitat value.

An alternative to planting slash pine is the planting of sand pine (*Pinus clausa*). This is being done more now than in the past. Site preparation is usually less intense for establishing sand pine, and sometimes it is planted with no site preparation. In either case, the result is the same. The high pine community is almost completely eliminated if the plantation is successful, due to the very dense crown cover. Even the oak species of the high pine community are greatly reduced by the intense competition. The habitat value of such sand pine plantations is near zero for birds (Humphrey et al. 1985), and is zero for gopher tortoises, pocket gophers, and most other terrestrial animals. This is clearly much worse for wildlife in general than plantations of the other species of southern pines.

The wildlife habitat value is inversely proportional to the crown density of the plantation. Therefore, longleaf pine plantations are best, slash pine second, loblolly pine third, and sand pine a distant fourth. Planting density is also important with initial survival of 200 to 400 trees per acre being much better for wildlife than higher densities.

Beginning with the second crop of planted slash or longleaf pine, blackberry (*Rubus cuneifolius*), broomsedge-type grasses (*Andropogon* spp.), bracken fern (*Pteridium aquilinum*), and various oaks usually increase in abundance. If the oaks are controlled with herbicides, the other species may form a moderately dense ground cover capable of supporting gopher tortoises, cottontail rabbits, and other animals.

5.8.3 Hammock and Old-Field Pine Plantations

Plantations of slash pine or loblolly pine (*Pinus taeda*) are often established on old fields and former hammock sites. Loblolly pine will also seed in naturally on these sites, creating what are commonly referred to as old-field forests. These pine forests and plantations have an initial 5- to 10-year stage that is generally quite good for cotton rats, cottontail rabbits, and associated predators. Indigo buntings (*Passerina cyanea*) often reach high population levels during this period in southwestern Alachua County and farther north, but are rare farther south. The habitat then changes dramatically at about age 10 when the crowns of the trees grow large enough to make a closed canopy. On these more fertile sites, the pine canopy is usually very dense after crown closure, shading out most or all of the ground cover. There may be a massive amount of hardwood sprouting on hammock and second-generation old-field plantations. The site may still be used to some extent by ground skinks (*Scincella lateralis*), squirrels (*Sciurus* spp. and *Glaucomys volans*), and migrating birds. Crows and blue jays (*Cyanocitta cristata*) may nest in these stands, and blue jays use the pine plantations for acorn storage beneath the pine straw. If there isn't already an abundance of hardwood sprouts, acorn storage by blue jays will ensure the establishment of a laurel oak (*Quercus hemisphaerica*) understory (after Darley-Hill and Johnson 1981). Black cherry (*Prunus serotina*) and water oak (*Quercus nigra*) are also frequent invaders, and sweetgum (*Liquidambar styraciflua*) is often common on old fields and former hammock sites. Without frequent burning or the use of herbicides, these sites quickly begin succeeding to hammock forest.

5.8.4 Summary

All the plantations and old-field forests have several things in common. If they continue to be managed as pine plantations for several rotations, the flora will become increasingly dominated by blackberry (*Rubus* spp.) and oaks in association with the pine crop, and the flora and fauna associated with the original community type will become increasingly scarce with few exceptions. Two of the exceptions are cottontail rabbits and cotton rats if the blackberry patches get thick enough. If the pine management stops, and the site is not actively changed or managed in some way, the site will become a hammock, again often at the expense of the original flora and fauna, unless the site happened to be a hammock to begin with. Since pine plantations dominate large areas in this region, this has the effect of reducing diversity on a regional scale (Noss 1983). On the other hand, the frequently observed alternatives of no forest management, including no burning, or of rural subdivisions, are also detrimental in this regard.

5.9 Cleared Rural Upland

Substantial areas of land have been cleared in the Springs Coast region. Land which is only partially cleared, where native shrubs like saw-palmetto (*Serenoa repens*) are still common, is called native pasture or range land and covers nearly 100,000 acres in the Green Swamp region (Lopez et al. 1981). Most of the cleared land in the Springs Coast region is improved pasture that has been more completely cleared and on which cultivated pasture grasses are established. There are also cultivated fields used to produce row crops, grain, or hay, and fields that were once used but are now fallow. Finally, there are some citrus groves.

Most native pasture is on sites that were originally pine flatwoods. Where the shrub and ground cover is still intact, the fauna and flora is much the same as in pine flatwoods (Appendix Tables F and G) minus the trees and tree-dwelling mammals and birds. Appendix Table J shows the common animals characteristic to cleared rural lands. Habitat for some animals is improved over that of the pine flatwoods. Hispid cotton rat (*Sigmodon hispidus*), cotton mouse (*Peromyscus gossypinus*), eastern cottontail rabbit (*Sylvilagus floridanus*), marsh rabbit (*Sylvilagus palustris*), gray fox (*Urocyon cinereoargenteus*), black vulture (*Coragyps atratus*), turkey vulture (*Cathartes aura*), red-tailed hawk (*Buteo jamaicensis*), northern harrier (marsh hawk) (*Circus cyaneus*) (in winter), American kestrel (*Falco sparverius*), great horned owl (*Bubo virginianus*), crows (*Corvus* spp.), northern bobwhite (*Colinus virginianus*), mourning dove (*Zenaida macroura*), ground dove (*Columbina passerina*), eastern meadowlark (*Sturnella magna*), eastern bluebird (*Sialia sialis*), northern mockingbird (*Mimus polyglottos*), cattle egret (*Bubulcus ibis*), common grackle (*Quiscalus quiscula*), several kinds of sparrows, green anole (*Anolis carolinensis*), black racer (*Coluber constrictor*), eastern king snake (*Lampropeltis getulus*), pigmy rattlesnake (*Sistrurus miliarius*), and eastern diamondback rattlesnake (*Crotalus adamanteus*) all do well here. The kestrel and bluebird need cavities for nesting and are, therefore, associated with standing dead trees (snags) containing cavities. Snags are also important to many of the birds for perching, and, unfortunately, in most cases, they are left over from a time when these areas were forest, and gradually disappear. Therefore, native pasture with a sufficient growth of scattered pine trees to provide a continuous supply of snags is better habitat for many bird species than are treeless areas.

Improved pastures are usually dominated by one species of grass. Bahia grass (*Paspalum notatum*) is the most common species, but several other grasses are used. There may be scattered trees, and some pastures have scattered pawpaw bushes (*Asimina* spp.) and some blackberry briars (*Rubus* spp.). Improved pastures are often nearly devoid of wildlife, but some species can survive in them in small numbers. Animals found in almost all pastures, including the middle of large areas of pure grass, are cattle egret, killdeer (*Charadrius vociferus*), meadowlark, American crow (*Corvus brachyrhynchos*), common grackle, mourning dove, red-winged blackbird (*Agelaius phoeniceus*), American goldfinch (*Carduelis tristis*) (in winter), savannah sparrow (*Passerculus sandwichensis*) (in winter), and European starling (*Sturnus vulgaris*). The presence of most other animals depends on some adjacent cover or place to perch. Species that make use of the combination of pasture and fence-row thicket or pasture and scattered trees and shrubs are cotton rat, cottontail rabbit, nine-banded armadillo (*Dasypus novemcinctus*), eastern kingbird (*Tyrannus tyrannus*), loggerhead shrike (*Lanius ludovicianus*), American kestrel, eastern bluebird, red-tailed hawk, northern bobwhite, northern mockingbird, blue grosbeak (*Guiraca caerulea*), black racer, and southern toad (*Bufo terrestris*). Most pastures could support good populations of gopher tortoises (*Gopherus polyphemus*) and southeastern pocket gophers (*Geomys pinetis*). The few that do have these species may also be suitable habitat for several additional species, including pine snakes (*Pituophis melanoleucus*), Florida mice (*Podomys floridanus*), gopher frogs (*Rana areolata*), and even burrowing owls (*Athene cunicularia*).

Cultivated fields, fallow fields, and groves with weeds and grasses between the rows of trees contain a more diverse flora composed of a mixture of native and exotic weeds in combination with the cultivated plants. Some common plants are sand blackberry (*Rubus cuneifolius*), broomgrass (*Andropogon virginicus*), poorjoe (*Diodia teres*), Florida pusley (*Richardia scabra*), ragweed (*Ambrosia artemisiifolia*), horseweed (*Conyza canadensis*), daisy fleabane (*Erigeron strigosus*), dogfennel (*Eupatorium capillifolium*), scratch daisy (*Haplopappus divaricatus*), camphorweed (*Heterotheca subaxillaris*), toad-flax (*Linaria* sp.), partridge pea (*Chamaecrista fasciculata*), and hairy indigo (*Indigofera hirsuta*), to name a few. The fauna is similar to that of the pasture areas described above, but some species may be much more abundant, particularly in fallow fields. Cotton rat and cottontail rabbit may be very abundant and support good populations of predators such as gray fox, red-tailed hawk, northern harrier, and great horned owl. Other species much more common here than in pasture include indigo bunting (*Passerina cyanea*), blue grosbeak, northern bobwhite, and several kinds of sparrows. The presence of fence-row thickets benefits the same set of species it did in pasture areas.

The hedgerows also support a fauna of their own that includes the blue jay (*Cyanocitta cristata*), northern cardinal (*Cardinalis cardinalis*), rufous-sided towhee (*Pipilo erythrophthalmus*), orchard oriole (*Icterus spurius*), and brown thrasher (*Toxostoma rufum*). A wide assortment of plants are found in the fence-row thickets. Some of the most common are blackberry (*Rubus* spp.), black cherry (*Prunus serotina*), chickasaw plum (*Prunus angustifolia*), flatwoods plum (*Prunus umbellata*), waxmyrtle (*Myrica cerifera*), greenbriar (*Smilax auriculata*), hercules club (*Zanthoxylum clava-herculis*), persimmon (*Diospyros virginiana*), live oak (*Quercus virginiana*), and laurel oak (*Quercus hemisphaerica*).

5.10 Developed Areas

There are no large cities in the Springs Coast region except for part of southeastern Ocala in Marion County. However, there are a number of small cities and towns, and large areas of sprawling suburban and rural residential development.

The flora associated with these developed areas is highly varied, usually including small patches of the original biological communities mixed in with pasture, fallow fields, and more intensely developed areas. On the more intensely developed areas, there is usually a remnant of the original tree cover scattered about in association with exotic trees, lawns of exotic grasses, and various ornamental landscape plants. The fauna of these residential areas varies according to the relative amounts and types of native habitats, cleared rural land, and developed sites, and according to the overall density of development as estimated in Appendix Table K. A discussion of the low-density rural development follows.

There are many areas with widely scattered houses on lot sizes from 5 to 40 acres. This sort of development has the most wildlife. The rural, "ranchette" type of residential area also has a lot of open and forest land left within and around the development. This type of area generally has nearly the full range of wildlife species associated with the native habitats and rural cleared habitats. The exceptions are a few kinds of animals that cannot survive in close association with people and their pets and guns. The Florida panther (*Felis concolor coryi*) and Florida black bear (*Ursus americanus floridanus*) are two animals that need so much wild land and are so likely to be shot if found that they have been eliminated from most (in the case of the panther, perhaps all) of the region. The larger game animals, such as white-tailed deer (*Odocoileus virginianus*), wild hog (*Sus scrofa*), and wild turkey (*Meleagris gallopavo*), can and do survive in some such areas, but are usually eliminated by shooting or by being repeatedly chased by dogs. Some very visible species, such as the indigo snake (*Drymarchon corais*), coachwhip snake (*Masticophis flagellum*), and American swallow-tailed kite (*Elanoides forficatus*), may be reduced or eliminated by indiscriminate killing. Cats and dogs are usually abundant and unrestrained in such areas, and help reduce or eliminate some species. Birds nesting in natural areas surrounded by suburbs often suffer higher rates of nest predation than those whose habitats are surrounded by agricultural land (Wilcove 1985). On the other hand, some animals, such as northern mockingbirds (*Mimus polyglottos*), mourning doves (*Zenaida macroura*), blue jays (*Cyanocitta cristata*), and European starlings (*Sturnus vulgaris*), benefit from this low-density development.

The habitat for animals changes as the density of development increases. Areas of vegetation become islands surrounded by well-traveled roads. The dominant vegetation becomes exotic grasses and shrubs both of which may often be sprayed, thus reducing their already low value to wildlife. The scattered tree cover is the most productive remaining part of the habitat. Many wildlife species are eliminated with increasing density of development, but, at the same time, some species are benefited and a few new ones are added. Appendix Table K shows the habitat preferences for most of the animals common in developed areas.

The animals that do best at the highest density of development are exotic species, i.e., Norway rat (*Rattus norvegicus*), black rat (*Rattus rattus*), house mouse (*Mus musculus*), rock dove (*Columba livia*), and house sparrow (*Passer domesticus*). However, some native species do very well at moderate densities of development. The four most abundant native bird species in residential areas, i.e., the mourning dove, blue jay, northern mockingbird, and northern cardinal (*Cardinalis cardinalis*), achieve higher population levels in these areas than in native habitats (Woolfenden and Rohwer 1969). Two others, the chimney swift (*Chaetura pelagica*) and purple martin (*Progne subis*), do much better in association with people than in native habitats if their specific nesting requirements are met, i.e., unblocked and unused chimneys for the swift and martin houses for the martin. The southern toad (*Bufo terrestris*) and green and squirrel tree frogs (*Hyla cinerea* and *Hyla squirella*) also must have a place to breed, such as a small pond, if they are to inhabit any area. Other species benefited by development include the ring-billed gull (*Larus delawarensis*), which benefits by raiding the landfills that result from development; the gray squirrel (*Sciurus carolinensis*), which feeds primarily on the mast of oaks (*Quercus* spp.), hickories (*Carya* spp.), pines (*Pinus* spp.), elms (*Ulmus* spp.), and other native trees; and the Mediterranean house gecko (*Hemidactylus turcicus*) (an exotic), which lives in cracks and crevices of buildings by day and climbs about the outside walls at night feeding on insects.

One reason some species develop high population densities in developed areas is that they find supplemental food sources there. Bird feeders benefit the gray squirrel, house sparrow, northern cardinal, blue jay, mourning dove, rock dove, tufted titmouse (*Parus bicolor*), Carolina chickadee (*Parus carolinensis*), American goldfinch (*Carduelis tristis*), red-bellied woodpecker (*Melanerpes carolinus*), common grackle (*Quiscalus quiscula*), and brown-headed cowbird (*Molothrus ater*). Outside feeding of dogs and cats benefits the Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), Norway rat, black rat, gray squirrel, blue jay, common grackle, northern mockingbird (*Mimus polyglottos*), and brown thrasher (*Toxostoma rufum*). Garbage receptacles with open tops, such as some dumpsters, often benefit the house sparrow, fish crow (*Corvus ossifragus*), and common grackle.

Unfortunately, the vast majority of native plants and animals in this region are being either reduced in number or eliminated in many areas by development, including most of the animals in Appendix Table K.

5.11 Bayhead

This biological community is variously known as bay, bayhead, baygall, bay swamp, seepage swamp, and bog forest. It is generally defined as a forest dominated by any one or combination of three different species of broad-leaved evergreen trees known as bay trees, although swamp tupelo (*Nyssa sylvatica* var. *biflora*), a deciduous tree, is also generally a codominant. There is usually a moderately dense shrub layer that is also dominated by broad-leaved evergreen species. Ferns are often abundant in the ground cover. This evergreen community contrasts sharply with the various swamp communities, which are dominated by deciduous plants (compare Appendix Tables L and M with the species lists of other communities; also compare the photo in Fig. 77 showing the interior of a mature bayhead with the photo of the interior of a mixed swamp in Fig. 78).

There are not as many bayheads in this region as in the other parts of north Florida. Neither is there the diversity of seepage communities, such as shrub bogs and herb bogs, that are so common in the Florida panhandle and, to a lesser extent, in Clay County. Bayheads in this region occur mostly as small, scattered patches of a few acres to perhaps 100 acres in area. A discussion of the characteristics of the bayhead follows.

Figure 77. Bayhead, showing evergreen shrub layer and trunks of sweetbay (left center), loblolly-bay (right center), and swamp tupelo (right edge) in January.

a. Soil. The soil at the surface is usually peat or organic muck, which may vary from a few inches to many feet in depth. It is often quite acidic. Under the organic soil is usually sand; on seepage slopes, the sand may be under a few inches of organic soil or it may be at the surface.

b. Ecology. Bayhead is a wetland community. The soil is usually organic, at least on the surface, and is saturated, or nearly so, with water throughout the year. But bayheads are not subject to much, if any, flooding above their normal water level. This is because bayheads lie at the head or side of drainage systems where water seeps out of the ground around and beneath the bayhead and, at the same time, drains off downstream. Bayheads may either be on seepage slopes or on peat bogs with good outlet drainage. The seepage slopes are kept moist by continuous seepage and are the last areas in a drainage system to dry out. They always have good surface drainage by virtue of the sloping topography. Peat bogs are kept moist by a combination of continuous seepage from underground and the large water supply stored in the peat, which continues to reach the surface by capillary action during droughts. Furthermore, the forested surface of the peat bog floats on the semiliquid peat underneath, so that the surface will adjust up or down somewhat in response to the water table. It is possible to jump up and down in the middle of peat bogs and create waves on the surface, such that large trees may begin swaying gently back and forth. The surface drainage of peat bogs is not as good as that of on seepage slopes, but, if it is too poor, allowing for

Figure 78. Mixed swamp, showing mixed hardwoods, buttresses, cypress knees, one old cypress stump in center background, and one baldcypress (second from left behind looping vine).

prolonged flooding, the bog will support a marsh or swamp rather than a bayhead.

Bayhead is not a fire-adapted community, at least not in the same sense that the pine communities are. However most bayheads are exposed to fire under a natural fire regime, because they are usually adjacent to pine forest, at least on one side, and because they will burn when conditions are dry and windy. The bayheads that are most subject to fire are often dominated by loblolly-bay (*Gordonia lasianthus*), usually in association with slash pine (*Pinus elliottii*) or pond pine (*Pinus serotina*). Loblolly-bay has moderately thick bark, and all the bay trees sprout prolifically when killed back by fire.

The most important factor determining whether an area is bayhead as opposed to some other community seems to be water-level fluctuation. Areas that flood significantly and/or dry out are not bayheads. However, soil pH and fertility are also factors. Monk (1966) states that relative to mixed swamps, bayheads occur on sites that are more acidic, less fertile, and subject to minimum flooding.

c. Fauna. Bayheads do not have a particularly abundant or diverse fauna of their own (Appendix Table L). However, they occur mostly as small areas scattered among other, often very different, habitats, and so have considerable value by increasing the overall habitat diversity. Small bayheads surrounded by another community such as mesic hammock will often have higher bird densities than the surrounding habitat (Noss 1991). They provide good habitat for some amphibians and reptiles, and the swamp tupelo, sweetbay (*Magnolia virginiana*), gallberry (*Ilex glabra*), dahoon (*Ilex cassine*), and greenbriar (*Smilax* spp.) fruits provide seasonal food for some birds and mammals. Most bayheads also provide a permanent water source. Finally, the dense evergreen vegetation provides good escape and nesting habitat for some species. Large bayheads in other regions that have good black bear populations are of great value to that species as escape cover (Williams 1978), and the smaller bayheads of this region may benefit to some extent the few black bears that remain here.

d. Flora. Four tree species dominate the tree canopy of bayheads. Three are broad-leaved evergreens: loblolly-bay, which is in the tea family; sweetbay, which is in the magnolia family; and swamp-bay (*Persea palustris*), which is in the laurel family. Swamp-bay is often mistakenly called redbay (*Persea borbonia*), a species in the same genus that has very different habitat requirements. The fourth species, which is equally important and dominant in bayheads, is swamp tupelo, which is also called blackgum. These four species are often the only trees in the center or main part of a bayhead. However, red maple (*Acer rubrum*), pond pine, and slash pine will also grow in bayheads. There are often some additional trees from the adjacent community mixed in on the edge of the bayhead. The understory vegetation is usually a dense thicket of evergreen shrubs, greenbriar, and ferns.

In this region, bayheads are of two general types. Those on deep peat tend to be strongly dominated by loblolly-bay, fetterbush (*Lyonia lucida*), greenbriar (*Smilax laurifolia* with some *Smilax glauca*), and sometimes slash pine. Most bayheads are not on deep peat and are more diverse, containing many of the other species in Appendix Table M as well.

5.12 Mixed Swamp

Swamps are wetland forests that are often flooded for months at a time. There are several types of swamp in the Springs Coast region of north central Florida, all but one of which are considered here to be a part of the mixed-swamp major community type. The one type of swamp that is not considered to be a part of this community is the cypress dome, which is the subject of a separate section. Most large swamps in this region, and many small ones, contain a mixture of ash (*Fraxinus* spp.), red maple (*Acer rubrum*), willow (*Salix* spp.), buttonbush (*Cephalanthus occidentalis*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), and other hardwoods in association with a variable abundance of baldcypress (*Taxodium distichum*) or, occasionally, pond-cypress (*Taxodium ascendens*); hence the name mixed swamp. Variations of this composition include swamps dominated by different mixtures of the species or, in some cases, nearly pure stands of one or another of these species. Mixed swamps are generally tall, dense forests with an open, deeply shaded understory and sparse ground cover (Fig. 78). However, some of the most deeply flooded swamps and most swamps right on the coast have an open canopy of shorter trees and much more shrub and ground-cover vegetation.

Mixed swamps generally occur as strands or sloughs, or as the deep-water part of the floodplain forests beside rivers, creeks, or lakes. There are large areas of mixed swamp all along the gulf coast, with some of the largest and best examples being in and around the Chassahowitzka National Wildlife Refuge and Gulf Hammock. Other large areas of swamp lie along the Waccasassa and Withlacoochee Rivers and their tributaries, around Lake Panasoffkee, and in the Green Swamp. A discussion of the characteristics of mixed swamp follows.

a. Soil. Some of the swamp soils are alluvial, but most are on sandy or clay soil over limerock. They have varying amounts of organic muck on top. In contrast to cypress domes, the pH and levels of such nutrients as calcium and phosphorus are relatively high in mixed swamps. (Monk 1968).

b. Ecology. Mixed swamps are generally connected hydrologically to an established drainage system during all but the very lowest water levels. This means that the water is generally flowing, (slowly) except at times of very low water (and except for the lake-edge swamps). On average, mixed swamps are flooded a little more than half the time, probably varying from about 20% to 90% of the time.

Although the surface water disappears completely on occasion, the soil in mixed swamps never dries out much below the surface. This is due to their position in the middle or lower part of the watershed where there is always at least some subsurface flow of water.

In contrast to cypress domes and most upland communities, mixed swamps rarely, if ever, burn. There is evidence of fire in some swamps, but it is usually associated with only one tree. Large, hollow trees, particularly cypress trees, will sometimes catch fire and burn on the inside if struck by lightning.

Mixed swamps usually join hydric hammock on the upland edge. These two forest communities are very similar structurally and share several species (compare Appendix Tables N and O with the hammock species lists). However, there is usually a rather sharp break between the two. The oaks (*Quercus*), elms (*Ulmus*), sweetgum (*Liquidambar styraciflua*), Carolina basswood (*Tilia caroliniana*), southern redcedar (*Juniperus silicicola*), pine (*Pinus* spp.), and herbaceous ground cover of the hydric hammock are abruptly replaced by the ash (*Fraxinus*), tupelo (*Nyssa*), cypress (*Taxodium*), and sparse ground cover of the swamp. However, there are also areas where the two blend together over a wide ecotone. It is not uncommon to find areas where swamp laurel oak (*Quercus laurifolia*) and sweetgum mix with the ash, tupelo, and baldcypress at the shallow edge of the swamp. It is particularly difficult to define the boundaries where red maple (*Acer rubrum*) and cabbage palm (*Sabal palmetto*), which can grow well in both communities, are common. Duration of flooding determines the ecotone between these two floodplain communities.

c. Fauna. Mixed swamps are very fertile and productive communities, but they are not particularly diverse. The major habitats are the crowns of the tall trees, the hollow trunks and branches of the old trees, the muck, and the water. Many of the crown-dwelling animals are the same ones that live in hammocks, although the mast crop is not as abundant or varied and does not support many of the acorn-eaters that are so common in hammocks. The paucity of shrubs and herbs means poor habitat for browsers and grazers. On the other hand, the muck is habitat for a whole new suite of animals not found in hammocks, and the deeper and more permanent water also supports an additional community of animals.

Some of the abundant invertebrates of the muck and water are mud-dwelling earthworms, several kinds of crayfish and shrimp, several kinds of snails, including the Florida applesnail (*Pomacea paludosa*), and many kinds of insects and their larvae. These provide a food source for many of the swamp vertebrates listed in Appendix Table N.

The cavities in the tree trunks and branches are particularly important here, because there is little shelter on the ground for nonaquatic creatures. Ash, tupelo, and cypress are all good cavity producers, and the occasional huge old hollow cypress trees provide shelter for bats, chimney swifts, and medium-sized mammals that don't often find sufficiently large cavities elsewhere. Some swamp-dwelling birds requiring cavities for nesting are the wood duck (*Aix sponsa*), barred owl (*Strix varia*), great crested flycatcher (*Myiarchus crinitus*), Carolina chickadee (*Parus carolinensis*), tufted titmouse (*Parus bicolor*), and prothonotary warbler (*Protonotaria citrea*) (Terres 1980). Many other animals benefit to some extent from cavities, including the gray squirrel (*Sciurus carolinensis*), flying squirrel (*Glaucomys volans*), Eastern woodrat (*Neotoma floridana*), cotton mouse (*Peromyscus gossypinus*), Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), and most of the snakes and lizards.

d. Flora. By definition, swamps are wetlands subject to prolonged flooding and vegetated by woody plants. However, the woody plant composition is severely restricted by the prolonged flooding. Four genera of trees dominate the swamps on the coastal plain of the southeastern United States: *Taxodium* (cypress), *Nyssa* (tupelo), *Fraxinus* (ash), and *Acer* (maple). The mixed swamps of this region are made up mostly of baldcypress, green ash (*Fraxinus pennsylvanica*), pumpkin ash (*Fraxinus profunda*), swamp tupelo, and red maple. Other trees mixed in to some degree, usually in the shallower areas or edges of the swamp, are cabbage palm, swamp laurel oak, sweetbay (*Magnolia virginiana*), sweetgum, American hornbeam (*Carpinus caroliniana*), and Florida elm (*Ulmus americana* var. *floridana*). Some early successional swamps contain or are dominated by coastal plain willow (*Salix caroliniana*) or pop ash (*Fraxinus caroliniana*). Buttonbush (*Cephalanthus occidentalis*) is often the only shrub, except in the more open forests, where waxmyrtle (*Myrica cerifera*) may also be common.

The diversity of herbaceous plants is restricted by a combination flooding and shade. The more open deep-muck swamps may have an abundance of bamboo vine (greenbriar) (*Smilax laurifolia*) and a number of herbaceous species. Densely forested mixed swamps may have very few herbaceous plants, although during prolonged droughts, when the soil surface is exposed above water for several months, an abundance of herbs may spring up from stored or transported seed, only to disappear again when the water returns. The most common and characteristic plants of mixed swamps are listed in Appendix Table O.

5.13 Cypress Dome

There are several types of swamps in the Springs Coast region of north-central Florida. One of these is quite distinct from the others in terms of ecology, flora, and fauna. This is the cypress dome, otherwise known as cypress head, cypress pond, and pondcypress swamp. It is interesting that pondcypress (*Taxodium ascendens*), the tree that characterizes this type of swamp and strongly dominates its tree canopy, is often considered to be of the same species as baldcypress (*Taxodium distichum*), which sometimes strongly dominates swamps of a similar appearance but very different ecology and species composition.

Cypress domes occur as isolated swamps (Fig. 79) in depressions scattered throughout the pine flatwoods community, the range of which is shown in Fig. 70. They generally constitute about 30% of the total area of the north Florida flatwoods (Marion and O'Meara 1982), although, in the Green Swamp, the percentage is much higher (Lopez et al. 1981). Most of these domes are between 1 and 100 acres in area, except in the Green Swamp, where they are often larger (Lopez et al. 1981). The smaller ones are mostly round to oval in shape when viewed from above, and, when viewed from the side or in crosssection, are often dome-shaped, due to the tallest trees being in the center of the swamp. Larger cypress domes are often irregular in shape, but still often have the largest trees in the middle. On the other hand, some larger domes are open in the middle, either with an open-water pond, or, more commonly, with a small marsh in the middle. There is usually a very dense ring of shrubs around the outer edge of cypress domes. A discussion of the characteristics of cypress domes follows.

a. Soil. Two major differences between this kind of swamp and the other kinds are the soil pH and phosphorus levels, which are much lower for cypress domes than for the other swamp types (Monk 1968). Brown (1963) found the pH of the surface soil to vary between 3.6 and 4.0. Cypress domes occur on the acid, nutrient-poor sands of the flatwoods. They have clay hardpans at varying depths, so that they are rather like large, shallow saucers that hold water (Brown 1963). There is usually some organic topsoil or sediment on the soil surface which is deepest near the center and gets progressively shallower toward the edges of the dome (Brown 1963), although Davis (1946) observed that many domes have no organic deposit.

b. Ecology. Another distinction of the cypress domes is that they are at the extreme upstream end or side of the drainage system. They are each isolated hydrologically except at high water, when they overflow through poorly defined channels from one dome to the next. The drainage has often been altered somewhat by the construction of small ditches (often with a fireline plow) from one wetland to the next, so that the domes do not get quite as full before overflowing. If the drainage system is followed downstream, a swamp will eventually be reached that is connected to the downstream part of the drainage at moderate to low water conditions, and, from this point on, the forest will be a mixed baldcypress-hardwood swamp or some other kind of wetland instead of a cypress dome. What this means

Figure 79. Cypress dome, showing a nearly pure stand of pondcypress (the two dark crowns are slash pine) surrounded by a young pine plantation on a pine flatwoods site.

hydrologically is that the domes are more poorly drained. The downstream swamps, which occur either along well-defined channels or in long strands or sloughs, have flowing water most of the time, whereas domes have still water. During dry periods, the downstream swamps have a continuous supply of water which seeps through the drainage system below ground. Domes, on the other hand, have only the water stored within the dome above the clay pan plus a limited amount of seepage from the immediately surrounding flatwoods. As in other swamps, many domes lose their surface water almost every year during the dry season, but, unlike other swamps, during severe droughts the water stored in the soil above the clay lens may also disappear, subjecting the dome vegetation to severe drought stress.

Another major distinction separating domes from other swamps is that they are a fire-adapted community. One of the main distinctions between pondcypress and baldcypress is bark thickness, with pondcypress having bark averaging at least twice as thick. Indeed, pondcypress is much more fire-tolerant than the swamp hardwood trees (Ewel and Mitsch 1978) and seems to have about the same fire tolerance as slash pine or perhaps even longleaf pine. It also sprouts vigorously from the stump and trunk. Cypress domes that have been burned occasionally often have a dense ground cover of maidencane (*Panicum hemitomon*) and/or virginia chain fern (*Woodwardia virginica*) as shown in Fig. 80.

Although few of the other species listed for this community in Appendix Tables P and Q are regarded

Figure 80. Cypress dome interior showing a dense ground cover of Virginia chain fern stalks in January. The trees in the foreground are pondcypress; the edge of a pine plantation on a pine flatwoods site is in the background. Note cypress knees left of center.

as fire adapted, the habitat itself is. When protected from fire, there is a steady increase in the density of fetterbush (*Lyonia lucida*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) throughout the dome, and a similar increase in various hardwood tree species around the edges. As the shrub and hardwood densities increase, the ground-cover vegetation decreases, often disappearing completely.

The shrub thicket around the edge of the cypress dome is an important feature. It supports much of the plant and animal diversity (Marion and O'Meara 1982) and helps maintain a moist microclimate within the dome. Whether this thicket is a natural feature or the result of fire suppression in any particular case, or in general, is a matter for speculation.

c. Fauna. Cypress domes are good habitat for a number of reptile and amphibian species, but have few mammals and no unique bird species (Florida Game and Fresh Water Fish Commission 1976). However, they add an important element of diversity to the flatwoods areas, support a higher density and diversity of animals than the surrounding flatwoods, and are particularly important as a refuge for the flatwoods fauna when the pine forests are harvested (Marion and O'Meara 1982). The dense thicket at the boundary between the pine flatwoods and the cypress dome is particularly valuable, having much higher densities and diversity of reptiles, amphibians, and birds than either adjacent community (McElveen 1977; Marion and O'Meara 1982). Bird densities in both the center of the domes and on the edges are highest in winter (Marion and O'Meara 1982). Cypress domes, and particularly the edge thickets, are an important white-tailed deer habitat (Harlow 1959). Most of the species listed for this habitat in Appendix Table P are either broadly adapted upland species that also occur in the pine flatwoods, or they are broadly adapted wetland species. Some exceptions to this are the chicken turtle (*Deirochelys reticularia*), glossy crayfish snake (*Regina rigida*), and dwarf siren (*Pseudobranchus striatus*), all of which do particularly well in the more permanently flooded cypress domes containing abundant marsh vegetation.

d. Flora. The most characteristic and dominant plant is pond-cypress, which usually occurs in dense, nearly pure stands. Except for the edges, many cypress domes have very little in the way of other trees, shrubs, or ground cover. Many others, however, have a dense thicket of shrubs or a dense ground cover of marsh plants or a mixture of the two. Even here, a few species strongly dominate the flora, making cypress domes one of Florida's least diverse and most distinctive plant communities. Fetterbush (*Lyonia lucida*) is by far the most abundant shrub and Virginia chain fern the dominant ground cover species. These and other plants often found in this habitat are listed in Appendix Table Q.

5.14 Freshwater Marshes and Prairies

Marshes and prairies are treeless wetlands. They are mostly open expanses of tall grasses, sedges, and herbs that emerge above the water, together with various floating-leaved and submerged plants (Fig. 81). Many of the freshwater marshes and prairies of this area are nearly pure stands of maidencane (*Panicum hemitomon*). By far the largest expanse of marsh in this region, totaling several thousand acres, covers the shallow waters around and between the many bodies of open water at Lake Tsala Apopka in eastern Citrus County. Another significant area of marsh and prairie is associated with Watermelon Pond on both sides of the Levy County - Alachua County border. There are many smaller marshes and wet prairies scattered throughout the region, some in flatwoods areas, some in low spots on the Brooksville Ridge, some near the coast. They vary in size from less than an acre to several hundred acres. A discussion of the characteristics of freshwater marsh and prairie follows.

a. Soil. The marshes at Lake Tsala Apopka and Watermelon Pond are on varying depths of sand over limerock, as are most of the marshes within and on either side of the Brooksville Ridge. Marshes in the flatwoods are generally on varying amounts of organic muck over sand with a clay layer somewhere underneath. Other marshes, such as that on the east side of Lake Panasoffkee in Sumter County and the one at the head of Gad's Bay in Levy County, are on deep organic muck, probably over marl or limestone (Harper 1915).

b. Ecology. Freshwater marshes occur in areas of permanent shallow water, in areas that are flooded most of the time and are subject to fire, in newly created wetlands or where wetlands are expanding into open water, and in areas that flood less than half the time, but have some other factor preventing woody plant invasion, such as frequent fire and/or occasional very prolonged flooding.

The term prairie is used in north Florida to signify large, shallow marshes that are dry a significant part of the time and burn, or at least used to burn, fairly often. The term wet prairie is used in central and south Florida to signify areas in the pine flatwoods that are very shallow marshes that also are often dry and burn frequently. (The term dry prairie is used in south Florida for areas that are not marshes in any sense of the word.)

Some marshes are clearly pioneer communities invading either disturbed sites or open water. In these situations, the marsh is sometimes, in turn, invaded by woody vegetation and eventually becomes a swamp. Marshes that are invading the open water of lakes are generally able to do so because the lake bottom is gradually filling up. As the open-water areas near shore get shallower, the marsh vegetation is better able to grow there. The marsh vegetation itself often aids this process by trapping sediment and by producing organic matter that is added to the

Figure 81. Freshwater marsh and prairie with cordgrass (*Spartina bakeri*) in the foreground, bluestem (*Andropogon* spp.) in the near background, and maidencane (*Panicum hemitomon*) in the far background.

growing muck deposits on the lake bottom. Increasing the fertility of the lake, for example by installing septic tanks nearby, fertilizing lawns or crops, or grazing cattle on the lake shore, hastens this process. Water-level stabilization also hastens this process.

Water-level fluctuation holds back this process as follows: when lake levels recede, organic muck that is exposed is consolidated and oxidized to some extent, depending on how long it is exposed; when water levels rise above normal, the deep-water edge of the marsh may be killed back.

Although it is generally considered undesirable for marsh vegetation to invade open water, some marsh vegetation on the edge of lakes is highly desirable. The deep-water parts of the marsh, which are often patches of white water lilies (*Nymphaea odorata*), bonnets (spatterdock) (*Nuphar luteum*), or thin stands of maidencane, provide good habitat for large fish such as largemouth bass (*Micropterus salmoides*) and bream (bluegill) (*Lepomis macrochirus*). The denser marsh vegetation in shallower water harbors large numbers of smaller fish, thus providing a nursery area and a habitat that supports an important part of the food chain. Marshes also support many other animals (Appendix Table R), help remove nutrients from the lake, and trap sediment washed from the shore into the lake.

Most areas of marsh are not invading or colonizing new territory and are not turning into swamps. There are several different kinds of situations where this occurs. One is permanently flooded shallow water that is low enough in nutrients and high enough in dissolved oxygen so that no muck accumulates on the bottom. In this situation, marshes will not expand into deeper water, because no sediment is accumulating to make the water shallower; and they will not be invaded by woody plants unless they go dry occasionally or have a muck buildup.

Most marshes produce some organic muck buildup, and most dry out at least occasionally. Therefore, without some mechanism to prevent it, they would be invaded by woody plants. A few marshes, like those around Watermelon Pond, turn into temporary lakes or ponds for several years at a time on rare occasion. This kills all the rooted vegetation and gives the marsh a fresh start when the water recedes. However, most marsh communities are maintained by fire. When a marsh goes dry, the vegetation dries and becomes very flammable. At the same time, the woods around the marsh are also dry, so that, under natural conditions, if a fire starts anywhere within several miles of the marsh, it may well burn up to and across the marsh. The rapidly moving grass fire that crosses a dry marsh will often be hot due to the large amount of fuel that is usually there, but it will only kill most woody plants to the ground, allowing them to resprout after the fire, and it may not be hot enough to kill back large pondcypress. However, if the marsh is dry enough, the muck may also catch fire and burn slowly but deeply. When this happens, all vegetation is eliminated, giving the marsh a fresh start. It is muck fires that often determine whether an area will be a fire-adapted swamp, i.e., a cypress dome, or whether it will be a marsh. It is interesting that there are marshes in the centers of some large cypress domes, where the most muck accumulates due to more permanent flooding and less frequent fire. In a few of these, the remains of old, burned-out pondcypress show that swamp can sometimes change back to marsh. It is also interesting that here again we have a fire-adapted community that provides for a type of fire that serves to maintain the community.

c. Fauna. The prairies and marshes are habitat for a number of broadly adapted aquatic species and a few terrestrial species. In addition, there are certain animals that are specifically adapted to this habitat (see Appendix Table R). Marshes and prairies are often very productive habitat for a few abundant species like the hispid cotton rat (*Sigmodon hispidus*), red-winged blackbird (*Agelaius phoeniceus*), peninsula newt (*Notophthalmus viridescens piaropicola*), frogs of several kinds, and a number of small fish species. Insects, crayfish, snails, and other invertebrates are also quite abundant in most marshes. The abundance of these small animals provides a good food source for wading birds, raptors, and other predators. Marshes that go dry periodically are particularly important feeding habitat for wood storks (*Mycteria americana*). Animals that would probably not exist in Florida without this habitat include the wood stork, sandhill crane (*Grus canadensis*), American bittern (*Botaurus lentiginosus*), king rail (*Rallus elegans*), Florida green water snake (*Nerodia floridana*), and round-tailed muskrat (*Neofiber alleni*). A number of others do best in marshes, but also live in other habitats, and some marsh dwellers require other habitats, usually uplands, to complete some phase of their life cycle. For instance, turtles must lay eggs on dry land, and some of the birds must nest in trees.

The small, isolated marshes, like isolated ponds, have very high per-acre habitat value, particularly as breeding sites for amphibians (Moler and Franz 1987) (see section on ponds for further discussion).

d. Flora. Marshes and wet prairies are defined as wetlands without trees. However, sometimes a few widely scattered trees may grow on the edge or in a spot or two out in the marsh or prairie. Shrubs may also be present in marshes and are sometimes abundant. However, in general, the marshes and wet prairies here are strongly dominated by herbaceous plants.

Marshes and wet prairies are often dominated by one species of tall grass, sedge, or other herb in any one spot, although many marshes have a number of species intermixed. The predominance often changes with water depth, sometimes producing a series of bands of different vegetation from the edge to the deepest part of the wetland. Other marshes may be nearly pure stands of one type of plant throughout. In this area, maidencane is the most abundant plant of both marshes and prairies, and it often occurs in pure stands. Appendix Table S contains a list of the plants commonly found in marshes in this region. In general, the emergent plants are more common in the shallower water and the floating-leaved and submerged plants are more common in deeper water, but there are many exceptions to this. Algae may be an important part of the total vegetative biomass in marshes, and may be even more important than its mass would indicate in supplying the base of the food chain for the marsh fauna.

Many quite different prairie and marsh plant communities occur in this region, in part because the plant species tend to form nearly pure stands, and in part because of the different soils, water depths, and hydroperiods of the different wetlands. The following are some of the most common types.

There are extensive areas of pure maidencane. When flooded, these provide good duck habitat and are the only habitat for the round-tailed muskrat. Some of these, as at Lake Tsala Apopka, are in fairly deep and permanent water. At the other extreme, maidencane forms pure stands on prairies that are only occasionally flooded and are ideal habitat for the sandhill crane. It is also frequently the only emergent plant in shallow pine-flatwoods depressions. It generally grows on inorganic soil, usually sand, and in situations that are moderately, but not overly, fertile.

Pickerelweed (*Pontederia cordata*) also frequently grows in pure stands, usually on muck, often in a zone between maidencane and the floating-leaved plants in deeper water. Its low, dense growth provides good habitat for a number of reptiles and amphibians and is sometimes used as nesting habitat by sandhill cranes.

In deep-water marsh, floating-leaved plants such as water lilies and submerged plants such as bladderwort (*Utricularia* spp.) are the dominant vegetation. This is the most aquatic type of marsh and supports the most fish. It is also good habitat for ducks and other swimming birds, alligators (*Alligator mississippiensis*), and several kinds of turtles.

In the Green Swamp, and to some extent in the other areas of pine flatwoods, there are many areas in the flatwoods called wet prairies that have mixtures of maidencane, Virginia chain fern (*Woodwardia virginica*), redroot (*Lachnanthes caroliniana*), meadow beauties (*Rhexia* spp.), yellow-eyed-grass (*Xyris* spp.), broomgrass (*Andropogon* spp.), pipeworts (*Eriocaulon* spp.), and many other species of flatwoods grasses and wildflowers. Some are pure stands of one kind of plant, such as redroot or Virginia chain fern, but most are mixtures. There are also areas of marsh in and around small ponds in the flatwoods. Laessle (1942) gives a good account of the various marsh associations in the pine flatwoods at Welaka, which are very similar to those found in this region.

Cattail marsh grows in areas of high fertility, and often replaces other forms of marsh when fertilizer runoff or sewage effluent enters. This is usually followed by an invasion of coastal plain willow (*Salix caroliniana*) and other woody plants, which makes ideal cottonmouth (*Agkistrodon piscivorus*) habitat.

Sawgrass forms pure stands on deep organic muck subject to prolonged flooding. In fairly deep and permanent water it is often mixed with lanceleaf arrowhead (*Sagittaria lancifolia*). Sawgrass is particularly common near the coast, even on inorganic soils, where the water is mildly brackish at times. Cottonmouths are more common here than in most of the other kinds of marsh.

Sand cordgrass (*Spartina bakeri*) is another plant that likes mildly brackish situations, where it often grows in mixture with other marsh plants. One of these is swamp hibiscus (*Hibiscus grandiflorus*), which grows to over 6 ft tall. These marshes near the coast intergrade with the salt marshes, and contain some salt-marsh species. They are maintained as marsh, at least in part, because of the occasional flooding by brackish water that occurs during severe storm tides. In fact, it is clear from the many stumps and dead trees on the edges of these occasionally brackish marshes that they are expanding inland at the expense of forest land because of the gradual rise of sea level (Gornitz et al. 1982) and lowering of the land (Holdahl and Morrison 1974) over the past century. Sand cordgrass is also sometimes found as the uppermost band of marsh vegetation around isolated ponds and wet prairies in the flatwoods and sandhills in this region (see Fig. 81).

5.15 Ponds

Ponds are small bodies of open, nonflowing water (Fig. 82). The distinction between ponds and lakes is not always clear. One reason is that a small body of deep, permanent water is more similar to a lake than a somewhat larger, shallow, temporary one. Therefore, we are defining ponds as all permanent bodies of open water under 5 acres and all temporary bodies of open water of any size. Temporary refers to a water body that dries out completely at least once per decade on average.

There are literally thousands of ponds 5 acres or less in area in the Springs Coast region, and dozens more larger ones that go dry frequently. Most of these ponds have been formed by the collapse of solution caves in the underground limestone aquifer. Cavern collapses near the surface sometimes cause sinkholes that result in deep ponds if the water table is near the surface. Shallow depressions may be old, partly eroded and filled sinkholes, or may have resulted from deeper collapses or more diffuse collapses within the aquifer; or they may be old depressions left over from when this part of Florida was under the sea. In any case, the result is a diversity of pond sizes, depths, and locations. A discussion of the characteristics of ponds follows.

Figure 82. Small, ephemeral pond less than half full of water.

a. Ecology. Ponds are the most temporary of aquatic habitats. Even the deepest, clearest, sand-bottomed pond is slowly filling up with sediment, and the more fertile ponds fill much more quickly with organic sediment. Ponds with outflows are also slowly being drained by the continual erosion of the outfall stream bed. This means that most ponds are relatively young compared to large lakes and very young compared to most rivers. Ponds are also generally at least somewhat isolated from larger aquatic systems. For these reasons, there are generally fewer kinds of aquatic organisms in ponds than in lakes and streams. However, the most important factor determining both the diversity and the set of species that inhabit a pond is whether or not it is permanent.

Permanent ponds invariably contain fish, although how they got to some of the remote and isolated ponds is puzzling. Even most ponds that go dry only briefly on rare occasions have fish. And ponds that have fish don't have certain kinds of amphibians and invertebrates. Therefore, the ephemeral (temporary) ponds that go dry every few years and sometimes stay dry for a while have a very different fauna than those that contain water permanently. These ephemeral ponds also generally lack many of the aquatic plants that thrive in more permanent water. To be a truly ephemeral pond, the whole pond must go completely dry. If there is one deep hole that always contains water, then the fish can survive.

Another factor influencing the ecology of a pond is the surrounding upland soil and biological community. A pond in the sandhills or pine flatwoods will have soft, acid water that is low in fertility, and it will be a breeding place for the amphibians that live in the sandhills or flatwoods. A pond within a fertile mesic hammock will have water that is much higher in pH, hardness, and fertility, and will be a breeding place for a somewhat different set of amphibians. Ponds near the coast that are flooded on rare occasion by brackish water are quite different from any of these.

Another important factor is whether the pond is isolated or is part of a drainage system. The former generally have clearer water of lower fertility and a somewhat different set of species than the latter (Moler and Franz 1987). Also, ponds that are directly connected to the stream system are different from those in the floodplain, but not otherwise connected. One difference between isolated and connected ponds is that ephemeral connected ponds have fish, and so are more like permanent ponds with regard to fauna.

b. Fauna. The habitat value of ponds per unit of area is generally much higher than that of lakes, and it increases with increased isolation and separation from other wetlands. This is because ponds are breeding sites for a number of insects, amphibians, and birds. In the most extreme case, where there is only one wetland in a large upland area, one temporary pond of less than an acre in extent may be used by all the toads (*Bufo* spp. and *Scaphiopus holbrookii*), tree frogs (*Hyla* spp.), gopher frogs (*Rana capito*), and dragon flies for a distance of more than a mile in all directions. Thus, a very significant part of the terrestrial fauna of an area in excess of 2,000 acres may depend on less than one acre of ephemeral, isolated pond (Moler and Franz 1987). A single, isolated pond may also have great importance as a source of drinking water for some animals. Doves (*Columbina passerina* and *Zenaida macroura*), nighthawks (*Chordeiles minor*), and other birds will fly long distances to get water, and many other animals need to drink daily. No other habitat has such a high value per acre.

Animals listed in Appendix Table T are those commonly inhabiting the open part of ponds, either when flooded or dry, for at least part of their lives. Some of the animals listed don't stay at ponds for long, but often come to feed or breed. Those that come only to drink are not listed, although this is an important value. There is often a border of marsh or swamp around or beside a pond. For the animals inhabiting these areas, refer to the sections on these communities.

c. Flora. The plants around the edges of ponds are mostly the swamp, marsh, and wet prairie plants listed in previous sections. Some of the submerged marsh plants grow in the open parts of some ponds. In addition, duckweeds (*Lemna* spp. and *Spirodela* spp.), water spangles (*Salvinia minima*), or mosquito fern (*Azolla caroliniana*) are common on the surface of some ponds in fertile situations. Several low-growing types of *Sagittaria* grow on the bottom of some clear ponds in shallow water. Near the coast in Gulf Hammock, corkwood (*Leitneria floridana*) grows on the margins of some ponds. However, algae are the most important plants in ponds in terms of importance to wildlife.

5.16 Lakes

Lakes are large, permanently flooded bodies of nonflowing, open water like the one shown in Fig. 83. They form and disappear by the same processes that affect ponds (see pond section), but on a grander scale. Like ponds, lakes are not very permanent features of the landscape from a geological perspective. Lake Tsala Apopka is clearly the largest lake in this region, covering from 19,000 to 24,000 acres, although it was once much larger (see chapter 2). Most of this area is marsh, some is swamp, and only about 10% (2 to 3 thousand acres) is open water (Attardi 1983a). Lake Panasoffkee has the second largest total area (4,460 acres), but, because of its higher percentage of open water, it has a similar total amount of open-water habitat. Both of these lakes are connected to the Withlacoochee River. Lake Rousseau, a man-made reservoir on the lower Withlacoochee River, is also about this size at 3,657 acres (Florida Board of Conservation 1969). There are several hundred smaller lakes scattered throughout the region with areas of 5 to 1,000 acres. Bodies of open water covering less than 5 acres, or larger ones

Figure 83. Medium-sized lake.

that go dry regularly, are considered ponds. A discussion of the characteristics of lakes follows.

a. Ecology. Factors influencing the ecology of lakes include size, depth, type of bottom, water quality, water-level fluctuation, water inflow and outflow, and the adjacent wetland and upland ecosystems.

The swamps and marshes that are often on the edges of the open water are quite important to the ecology of lakes. They are generally more productive of small fish, insects, crayfish, amphibians, and other small animals than the open water, and so are quite beneficial in supplying an abundant food source for the larger fish and other predators of the open water. They also serve as nursery areas for some of the open water species. In addition, adjacent wetlands help remove excess nutrients and some other pollutants from lakes and buffer the wave action that otherwise erodes the shore and deposits sediment in the deeper parts of lakes, eventually filling them.

The source of water varies considerably and strongly affects the ecology of lakes. Lake Panasoffkee, for example, has aquifer-fed springs that supply the lake with calcium-rich water high in pH, hardness, and inherent fertility. This fertility, combined with a water level stabilized by dams on the outlet stream and on the Withlacoochee River, have caused Lake Panasoffkee to become very eutrophic (fertile, filling with muck, and rapidly aging). Lake Rousseau has water quality similar to Lake Panasoffkee, but, being a river reservoir, has trapped a lot more sediment and nutrients, making it even more eutrophic. Many lakes in this region are isolated, with no stream flow. Watermelon Pond in southwestern Alachua County is an example. If located in the sandhills, as this one is, or in the flatwoods, such a lake will be naturally low in fertility, but will be quite vulnerable to greatly increased fertility if impacted by human development. Such lakes usually have a more variable (fluctuating) water level, which is important and valuable in that it helps reduce muck and fertility buildup in the lake and rejuvenates the marsh and bottom vegetation. This also benefits many animals that feed in the shallow water or on exposed lake bottom.

Water quality is important for several reasons. The chemical character of the water determines to a large extent the kinds and abundance of life that it supports. The factors most often influencing species composition are pH, hardness, salinity, dissolved oxygen, and fertility (available nitrogen and/or phosphorus are usually the limiting elements). Of these, fertility is the one most often influenced by human activities. Indeed, the fertility of almost all lakes in Florida has been and continues to be increased by the presence of septic tanks, fertilized lawns, and/or agricultural operations on or near the lake shore.

This increased fertility affects many other things. It increases the productivity of the lake, increasing the growth of algae, which, in turn, can lead to decreased dissolved oxygen at times when the decomposition rate of dead algae is high and photosynthesis is reduced by cloudy weather or other factors. If the fertility goes high enough, the aquatic community becomes less diverse and less stable, leading to algal blooms, fish kills, and very rapid muck accumulation.

b. Fauna. This discussion is restricted to open-water areas of lakes. Many lakes have significant associated areas of marsh and/or swamp that are very important from a habitat and ecological perspective. The fauna and flora found in these areas are covered in the sections on marsh and swamp. However, these areas affect the biota of the open water, too. For instance, Lake Tsala Apopka has good water quality and is a very good producer of bream (*Lepomis macrochirus*), bass (*Micropterus salmoides*), and chain pickerel (*Esox niger*), in part because of the extensive marsh areas that take up nutrients and produce invertebrates and small fish that are food for the larger fish. Animals that make use of the shallow waters on the edges of lakes and the exposed lake shore and bottom during low water are included in the lake fauna list (Appendix Table U).

Many animals living in or utilizing the open water of lakes also require another habitat for nesting or some other purpose. Therefore, when "lake" is denoted as the best habitat for an animal, this does not mean that no other habitats are also required.

The fauna of the habitats adjacent to a lake is invariably enriched by the presence of the lake, both in terms of the species that are there and the numbers of individuals. The main reason for this is the abundant supply of additional food provided by the lake in the form of turtle and alligator eggs, fish, crayfish, and the amphibians and insects that come ashore in droves after spending their juvenile stages in the water. Some of the obvious beneficiaries of this enrichment, such as raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), king snakes (*Lampropeltis getulus*), and garter snakes (*Thamnophis sirtalis*) are listed in Appendix Table U as lake-dwellers even though they spend most of their lives on shore. However, there are many other animals, particularly insect-eaters, that benefit but are not listed.

One oddity of this region is that the Suwannee cooter, which normally lives exclusively in spring-fed rivers, is listed as living in lakes, too. This is because it is common in Lake Panasoffkee, which, being spring fed, has a biota similar in many respects to these rivers, and it is abundant in Lake Rousseau, which is a dammed-up portion of a river.

c. Flora. The plants commonly found in the marshes and swamps on the margins of lakes are discussed in the sections on these two communities. The flora of the open-water habitat in lakes is dominated by single celled algae, mostly diatoms and green algae. However, Lake Rousseau and large areas in some other lakes have become dominated in recent years by the introduced weed hydrilla (*Hydrilla verticillata*). In the past, waterhyacinth (*Eichhornia crassipes*) has covered large areas as well, but it is less of a problem now due to several insect and disease species that have been released for the biological control of this exotic plant. Hydrilla is currently controlled by using herbicides, which often damage beneficial plants while controlling hydrilla only temporarily. Hopefully, a means of biological control can be found for this plant as well.

5.17 Blackwater Streams

Most of the small to medium-sized streams in this area, like the one pictured in Fig. 84, are tributaries or parts of the headwaters of the Waccasassa and Withlacoochee Rivers. The Waccasassa watershed includes the pine flatwoods, hammock, and swamp forests of central Levy County, while the Withlacoochee begins in the pine flatwoods and swamps in and around the Green Swamp. There are also the Pithlachascotee River and a number of smaller streams that flow directly to the gulf. In this flat terrain, the soft, acid water that flows gently through the shallow channels of these streams is stained brown by organic acids. In the midreaches of the two main rivers, springs add greatly to the volume of flow and change the water characteristics of these streams dramatically. These lower spring-fed sections of river, as well as the many spring runs of this region, are discussed in the next section. A discussion of the characteristics of blackwater streams follows.

a. Ecology. The water of the tea-colored blackwater streams may be very acidic, with a pH as low as 4.0. The soft water is not very fertile and is shaded by the overhanging forest, so that there are few aquatic plants and little biological productivity. In addition, most of these streams cease flowing and many go dry during severe, prolonged droughts. Even so, some species live permanently in and along these streams, and many more utilize them part time.

The small streams in the coastal hammocks that drain directly to the gulf are somewhat different. These are more fertile and less acid than the inland streams and become tidal creeks as they approach the coast.

The ecology of the dark-water streams varies according to size, permanence, type of bottom, and the adjacent biological community. Of these factors, the adjacent community is the most important. This is because these streams are so small that they are literally encircled by the adjacent forest. Not only does the tree canopy close over the top, but the tree roots stretch across most of the stream bottom. In addition, there are usually sections where the channel disappears completely, with the stream diffusing through an area of swamp and re-forming again at the other side. It is no surprise, then, that the ecology of the extreme upper end of these streams is similar to that of a small cypress dome, while downstream, and

Figure 84. Medium-sized blackwater stream during a wet period.

for most of the blackwater stream's length, the ecology resembles that of the mixed swamp community that usually occupies the immediately adjacent floodplain. Other habitats that occur occasionally along blackwater streams and add somewhat to the fauna are bayhead, hammock, and pine flatwoods.

b. Fauna. The fauna of the blackwater streams is primarily a mixture of swamp and river species. There are a few benthic invertebrates, mostly oligochaetes in areas with muck bottom and chironomids in the most permanently flowing areas (SWFWMD 1985). The only common mollusk is *Physa pumilia.* Downstream from seeps and small dark-water springs in channels filled with loose organic sediment, the one-toed amphiuma (*Amphiuma pholeter*) and lesser siren (*Siren intermedia*) may be abundant. The vertebrates inhabiting blackwater streams include all the swamp species, although with somewhat different patterns of abundance, plus some additional species of fish. Since a list of blackwater stream animals would be essentially the same as Appendix Table N, which lists the animals in mixed swamps, with a few additions from Appendix Table P on cypress domes and a few additional fish, only those species that are more abundant in and along creeks than in swamps in general are listed in Appendix Table V.

c. Flora. The flora of blackwater streams is primarily the flora of the plant community beside the stream. This community is most often mixed swamp. In situations where streams flow through pine flatwoods, bayhead, or hammock forest, there is usually some mixed swamp flora along the stream bank.

Therefore, the list of flora in Appendix Table O is also an appropriate list for blackwater streams.

5.18 Springs, Spring Runs, and Spring-fed Rivers

This region is famous for its big, beautiful, clear-water springs. Table 3 lists the largest ones along with some discharge and water temperature data. See also Fig. 41 for major spring locations. In addition to these, there are many smaller springs such as Blue Spring on the Waccasassa River, Wekiva Spring on a tributary of the Waccasassa, and the springs in Lake Panasoffkee. Just to the north of this area in the Suwannee River basin is one of the greatest concentrations of clear-water springs in the world.

Although not entirely spring fed, the lower ends of the Withlacoochee and Waccasassa Rivers are strongly influenced by water coming from springs in their middle to lower regions. The ecology and species composition of these stretches of river (such as the one shown in Fig. 85) are much more similar to spring runs than to blackwater streams, and therefore they are included in this section. A discussion of the characteristics of springs, spring runs, and spring-fed rivers follows.

a. Ecology. In this region, the characteristics of spring runs contrast sharply with those of blackwater streams. The flow is permanent and much less variable. The water temperature remains nearly constant year round. The water is very clear, between pH 7 and 8, and high in dissolved solids such as calcium carbonate. The spring-fed parts of the two main rivers of this region are not as clear or constant in flow or temperature, but are nearly so during low-flow periods. As with the spring runs, the spring-fed rivers are permanent and always contain an abundance of dissolved solids. Finally, in this region, the spring runs and spring-fed streams are much larger than the blackwater streams.

Because the large size of these streams produces a break in the forest canopy, the clear water allows the light to penetrate deeply, and the high pH and dissolved-solid content provide a fertile medium, the spring-connected streams have a diverse and productive aquatic plant community. The dense growths of eelgrass (*Vallisneria americana*) and other submerged plants, which are in turn covered with algae, provide both dense cover and a productive foundation for the food chain. In particular, the plants, in combination with the high calcium content of the water, enable snails to flourish. Clams are also abundant.

The relatively constant temperature and flow of these streams enable this productivity to continue year round. Specifically, both low winter temperatures that would slow metabolism and high summer temperatures that would lower the oxygen content of the water to restrictive levels are avoided. And, of course, the streams don't go dry. These are the only streams in most of this region that never cease flowing, so they are particularly important during severe droughts as refugia for the aquatic animal species that

Table 3. First-magnitude springs and spring groups of the gulf-coast region of north central Florida (adapted from Rosenau et al. 1977).

Spring	County	Average Discharge (ft^3/s)	Range of Discharge (ft^3/s)	Average Temperature in °C	Average Temperature in °F
Chassahowitzka	Citrus	163	131–185	23.5	74
Crystal River	Citrus	916	not avail.	25.0	75
Homosassa	Citrus	175	125–257	23.0	73
Rainbow	Marion	763	487–1230	23.0	73
Weeki Wachee	Hernando	176	101–275	23.5	74

Figure 85. Spring-fed river showing mixed hardwoods and baldcypress on the banks.

quickly repopulate the intermittent streams when water levels rise again. In fact, these rivers are the most permanent surface-water environment, both ecologically and geologically. They ultimately serve as refuges for most freshwater aquatic species.

b. Fauna. The spring-connected rivers are the most diverse and productive wildlife habitat in this region. They vie with the isolated ephemeral ponds for first place in importance to wildlife on a per-acre basis. They are the only riverine habitat in this region and support the greatest diversity and abundance of fish. Several species are restricted to this habitat, and a great number of species either prefer this habitat or are benefited by making some use of it. Appendix Table W is a list of vertebrates for this community. As with blackwater streams, but to a lesser extent, the adjacent upland or wetland community influences the fauna found in and along the river. Species common in these communities that do not increase in numbers or particularly benefit from the river habitat are not included in the list, even though they may be common along some stretches of some of these rivers. To get a complete species list, the list for these spring-connected streams must be combined with the list for the adjacent community or communities. Mixed swamp is the community that is most commonly adjacent, and so the fauna is often a combination of mixed-swamp and river species.

There are high population levels and a good diversity of invertebrates in these streams. Large numbers of aquatic snails support snail predators such as the loggerhead musk turtle (*Sternotherus minor minor*), which is restricted to this habitat, and the limpkin (*Aramus guarauna*), which feeds mostly on the

Florida applesnail (*Pomacea paludosa*). The exotic clam *Corbicula manilensis* reaches very high densities in these streams. Crayfish and aquatic insects are also abundant.

Several marine species invade the spring runs on occasion, and the striped mullet (*Mugil cephalus*), hogchoker (*Trinectes maculatus*), and Atlantic needlefish (*Strongylura marina*) do so routinely. No doubt the most noteworthy marine visitor to this habitat is the West Indian manatee (*Trichechus manatus latirostris*), which takes advantage of the constant temperature of the springs to escape cold water in midwinter. Crystal River and its spring boils harbor one of the largest winter concentrations of this endangered mammal (Packard 1983).

c. Flora. The flora along spring runs and spring-fed rivers is usually mixed swamp on shore and freshwater marsh in some scattered shallow water areas. Hammock forest reaches the banks of these streams in some places. Climbing aster (*Aster carolinianus*), red hibiscus (*Hibiscus coccineus*), annual wild rice (*Zizania aquatica*), and climbing hempweed (*Mikania scandens*) are more abundant on the river edge than in other habitats. However, the only vegetation that is markedly different from communities already described in the preceding sections is the submerged flora on the stream bottom.

Eelgrass (*Vallisneria americana*) and several species of *Sagittaria* are the most abundant stream-bottom plants, often forming extensive pure stands. Other areas support diverse communities of the submerged aquatic plants that are listed in the section on freshwater marsh. Of perhaps equal or greater importance are the diatoms and filamentous algae that are attached in great abundance to the submerged macrophytic plants, sunken logs, rocks, and other structures.

Heavy motorboat traffic has reduced the abundance of submerged plants in most spring runs. An even greater problem in some spring runs and in the lower part of the Withlacoochee River is hydrilla (*Hydrilla verticillata*). This introduced plant has completely taken over some areas, smothering out native macrophytic plants and filling open water areas.

5.19 Aquatic caves

There is a thick bed of limerock under the Springs Coast region, containing many cracks, joints, fissures, and caves filled with water. The limerock and the water, together, are known as the Floridan aquifer. The cracks, joints, and fissures inherent to the limerock have permitted slightly acidic water originating on the surface to slowly, over many thousands of years, dissolve continually larger horizontal and vertical passageways. These underwater or aquatic caves are as well developed here as they are in any region in North America or perhaps the world. A discussion of the characteristics of aquatic caves follows.

a. Ecology. The water in these aquatic caves is generally very clear, with a constant temperature of around 70 °F, a pH between 7 and 8, and a high content of dissolved calcium carbonate (limerock). It may be still or have a considerable current. The caves are often interconnected, forming a complex and extensive maze of passageways beneath much, or perhaps all, of the region. There are distinct layers in the limerock bed, each with its own maze of caves, and the caves of the different layers are interconnected by occasional vertical shafts. The Crystal River Formation in the upper Eocene is the most cavemiculous.

Most of the water added to the aquifer seeps down through layers of soil that filter out most of the organic matter. Where a vertical shaft reaches the surface or a terrestrial cave, there is an avenue for surface water and organic matter to enter the system directly. In some cases, an entire watershed will drain into a sinkhole and directly into the aquifer.

In cases where surface water, open vertical shafts, sinkholes, or, especially, dry caves with bat colonies, connect directly with aquatic caves, a source of food provides the possibility for life in this otherwise nearly sterile environment. Given sufficient time, one might expect a unique and specialized fauna to evolve to take advantage of this unique habitat, and, indeed, one has.

This region may have more species of blind aquatic cave-dwelling animals than any other region in the world. As with dry caves, invertebrates are the primary consumers in this detrital food chain, and, certainly, no other region of the world has more species of blind cave crayfishes. McLane's cave crayfish (*Troglocambarus maclanei*) is the most specialized cave crayfish in the world (Franz 1982). In addition, there are at least two amphipods, two isopods, and one shrimp confined to this habitat (see Table 4). Several species of surface-dwelling fish also use this habitat to some extent. Much of this is probably incidental dispersal, but aquatic caves seem to be an important habitat for the American eel (*Anguilla rostrata*), the redeye chub (*Notropis harperi*), and possibly the yellow bullhead (*Ictalurus natalis*).

5.20 Endangered and Threatened Species

The Springs Coast contains numerous threatened and endangered species. Appendix Table X lists these species by county. The lists from which this table is compiled are often very incomplete. For instance, the Florida pine snake is listed for only one county, yet it actually occurs in all the counties.

Table 4. Animals exclusive to the aquatic caves in the Springs Coast region (Franz 1982).

Common Name	Scientific Name
Invertebrates	
Florida cave amphipod	*Crangonyx grandimanus*
Hobb's cave amphipod	*Crangonyx hobbsi*
Hobb's cave isopod	*Caecidotea hobbsi*
Little Florida isopod	*Remasellus parvus*
Florida cave shrimp	*Palaemonetes cummingi*
Leitheuser's cave crayfish	*Procambarus leitheuseri*
Light-fleeing cave crayfish	*Procambarus lucifugus*
Pallid cave crayfish	*Procambarus pallidus*
McLane's cave crayfish	*Troglocambarus maclanei*

Chapter 6. SALTWATER WETLAND, ESTUARINE, AND MARINE HABITATS

by Steven H. Wolfe, Jeffrey A. Reidenauer, and Michael S. Flannery

6.1 Introduction

The Springs Coast occupies a zone of transition in coastal vegetation, changing from mangrove-dominated coastal habitats in the south to salt-marsh-dominated habitats in the north. The entire coastline, however, discharges substantial quantities of freshwater from myriad streams, springs, and areas of sheet flow. This, coupled with the low-energy regime, yields a coastline that generally has salinities below those considered marine (>30 ppt) and that is heavily vegetated. The inshore waters of the Springs Coast exhibit typical estuarine salinity patterns, and the flora and fauna found therein are characteristically estuarine (SWFWMD 1986).

6.1.1 Estuarine System Classification

Classification of the saltwater habitats follows the scheme of Cowardin et al. (1979) as closely as possible.

a. Estuarine System. This system consists of deepwater tidal habitats and adjacent tidal wetlands that are semi-enclosed 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.

The limits of the system are as follows:
(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).

The subsystems are as follows:
(1) intertidal—substrate exposed and flooded by tides; includes the splash zone;
(2) subtidal—substrate continuously submerged.

b. Marine System. This system 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.

The system 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.

The subsystems are as follows:
(1) intertidal—substrate exposed and flooded by tides; this includes the splash zone;
(2) subtidal—substrate continuously submerged.

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 Springs Coast 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 other specific habitats.

The short and very arbitrary naming and delineation of the habitats is 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 emphasized.

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, benthic diatoms, and epiphytic algae). The boundaries, however, are less rigidly defined.

Given the area of coastline covered within the Springs Coast region, it is not possible to report every species present, or small, albeit interesting, differences among watersheds; reporting is confined to dominant and ecologically important organisms. An attempt has been made to highlight general patterns and interactions observable throughout different sites. In addition, the role and natural history of some commercially important organisms are reported.

Within each habitat description, assessments and projections are made of potential and realized human impacts. Because of the shallow, wide Continental Shelf region of the Springs Coast area, the coastal habitats are very sensitive to pollution impacts. The areas at the mouths of the rivers in the Springs Coast are not classical estuaries in that they are not semi-enclosed water bodies; however, they are functional estuaries in the sense that they are heavily influenced by freshwater inputs and some have somewhat restricted circulation.

Cedar Key and the nearby islands are not covered in this chapter because, while offshore of a coastline that is technically part of the Waccasassa River drainage basin, the main factor controlling the marine and estuarine habitats is the Suwannee River, which is not covered in this document.

In this document, human perturbations are generally grouped into two broad classes. The first includes those destructive effects (usually the most easily detected), such as dredging and construction, which result in changes in habitat quantity. The second includes those effects, such as excessive organic loading, which alter and degrade habitat quality. In some instances, the classes overlap. In many cases, specific impact studies on Springs Coast sites are lacking and projected effects were derived from examples outside the immediate area.

6.1.2 Tides and Salinity Ranges

The tides in the Springs Coast region are predominantly semidiurnal and are mixed, with unequal highs and lows and a tidal range between 0.6 and 1.4 m (Yobbi and Knochenmus 1988a,b).

Estuaries and bays within the Springs Coast region include the mouths of the following streams:

1. Pithlachascotee River
2. Hammock Creek
3. Weeki Wachee River
4. Chassahowitzka River
5. Homosassa River
6. Crystal River
7. Withlacoochee River
8. Waccasassa River

The bays, estuaries, and most of the coastline demonstrate fluctuating salinities that depend on a variety of physical factors such as river flow, rainfall, and tide and wind conditions. The salinity is low near river mouths and ranges between 5 and 25 ppt over most of their area. Under normal conditions, only offshore waters have truly marine salinities (>30 ppt).

6.2 Estuarine Habitats

Estuaries play an important role in the life cycles of many species of fish and invertebrates. It is well documented that the early stages of sport and commercial species use the estuaries as nursery grounds (Skud and Wilson 1960; Smith et al. 1966; Sykes and Finucane 1966; Carr and Adams 1973; Copeland and Bechtel 1974). It is estimated that 90%–97% of the total commercial fisheries catch of the Gulf of Mexico states use estuaries during some phase of their life cycle (Gunter 1967; Durako et al. 1985).

By far the most studied area of the Springs Coast is the Crystal River and estuary because of studies performed as part of environmental impact statements for the nuclear power plant constructed nearby, which uses the estuary for cooling water. Lyons et al. (1971) and Adams et al. (1977) list species found in the Crystal River estuary, and Yockey (1974a) lists the sponges found therein. Studies of the effects of entrainment and entrapment through the intake of the large volumes of cooling water were performed on larvae of the blue crab, *Callinectes sapidus* (Adams et al. 1974), on fishes (Grimes 1975), and on copepods (Alden 1976). Studies of the effect of the thermal discharge were performed on chaetognaths (Benkert 1980) and seagrasses (Grimes 1971; Van Tine 1977). Additional studies have been performed on the ecology of the Florida manatees in the Crystal River and estuary (Hartman 1971; Powell 1981; Kochman et al 1983), on blue-crab ecology (Oesterling 1976a), and on zooplankton ecology (Maturo 1974; Ingram 1980). The metabolic rate of the Crystal River estuary and salt marsh has been measured (Knight and Coggins 1982). Much information on species distributions, both terrestrial and aquatic, can be found in the Gulf coast ecological inventory (Beccasia et al. 1982).

Stancyk (1970) studied the biology and ecology of ophiuroids at Cedar Key. In addition, Wagner-Memer and Jones (1976) investigated fungi occurring in coastal habitats in Hernando County, and Pierce (1952) studied the chaetognatha of the west coast of Florida. Maturo's (1982) review of biological studies on the Waccasassa Bay–New Port Richey, Florida, area includes biological and hydrological bibliographies.

Along the Springs Coast, there are five dominant intertidal estuarine habitats—brackish marshes, salt marshes, intertidal flats, oyster reefs, and to a lesser extent, the intertidal mangrove forests. The discussion of each habitat follows a general format: first, the habitat is introduced with general background information; second, the flora, fauna, or both, typically found in the habitat are discussed; third, the distribution of the habitat is given; fourth, the trophic interactions within the habitat are given; and last, the natural and human impacts are presented. Sections are omitted where information pertaining to the Springs Coast was not available.

6.2.1 Brackish Marshes

a. General. The Springs Coast comprises one of the largest and most spectacular mixtures of salt and brackish marshes found in Florida. In contrast to coastal areas where marshes largely form on deposited alluvium, the Springs Coast area is alluvium poor. Instead, this area is characterized by intense karstification, and numerous karst features such as creek channels, circular ponds, bedrock highs, and freshwater springs are common. This low-energy karstic coastline gives rise to an intricate mosaic of marshes and coastal hammocks, where small changes in elevation, tidal inundation, soil characteristics, and freshwater flow control vegetation zonation. The work of Hine and Belknap (1986) provides an excellent description of the geologic and sedimentary processes that affect plant zonation in the region. Figure 86 depicts the generalized shift in dominant marsh plant species that occurs along the salinity gradient from fresh to salt marshes. The brackish vegetation habitat is primarily limited to areas where salinities range between 0 and 15 ppt, and includes both emergent and submergent forms. Figures 49, 51, 53, 55, and 58 show the approximate locations of these salinity conditions in some of the rivers.

b. Vascular species. The marshes are primarily dominated by sawgrass (*Cladium jamaicense*), but *Typha* spp. are a codominant or dominant in many areas. Large patches of black needlerush (*Juncus roemerianus*) interrupt the sawgrass in places, particularly near the river channels and their distributaries. Other herbs are also common within a few meters of the banks of the channels, especially *Ipomoea sagittata* (morning glory), *Scirpus validus, Spartina patens* (saltmeadow cordgrass), *Phragmites australis, Aster tenuifolius,* and *Acrostichum danaeifolium* (Hussey 1986). These and others are generally incidental or absent in the interior expanse of the marsh meadow.

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.

The dominant brackish-water submergent vegetation includes *Vallisneria neotropicalis, Potamogeton pectinatus,* and *Ruppia maritima,* which are actually freshwater plants that are tolerant of low salinities. A smaller submergent species, *Sagittaria subulata,* is very common along brackish creeks, creating lawn-like mats that are often exposed at low tides. Another submergent species, the exotic weed *Myriophyllum spicatum,* has recently been found in brackish waters in the Springs Coast. The distribution of this species should be monitored to see if it replaces native plant communities.

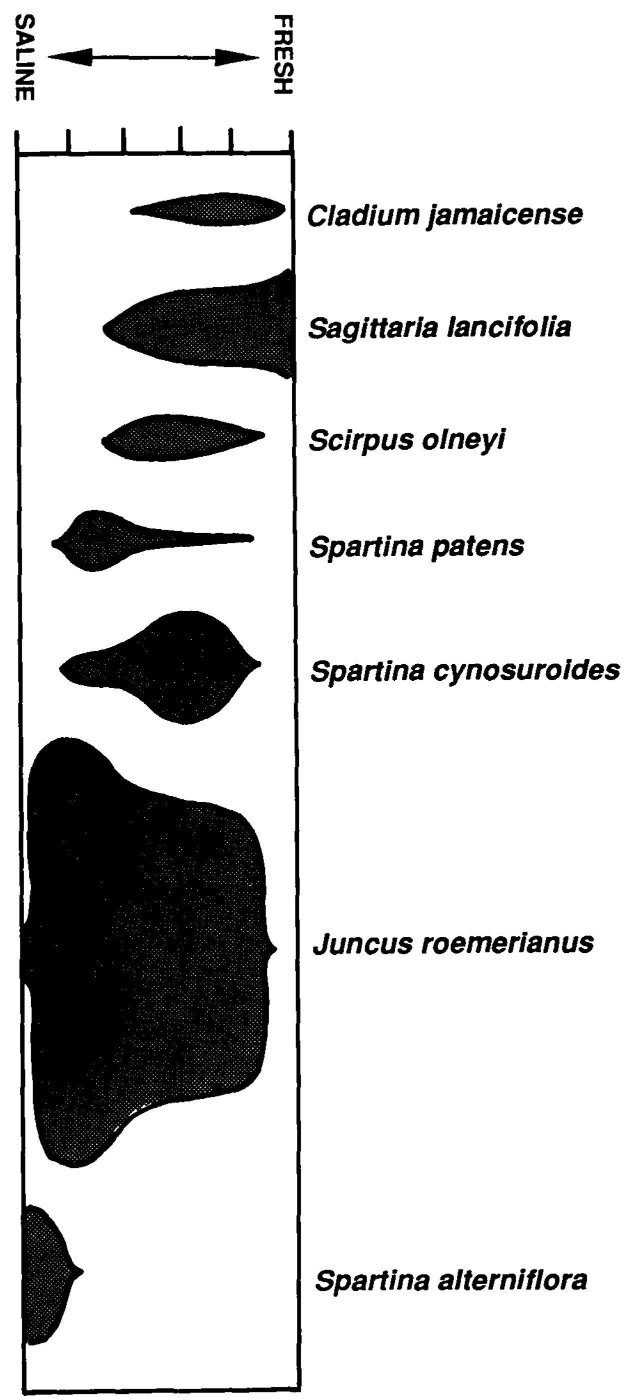


Figure 86. Changes in macrophyte populations found along the marsh salinity gradient from fresh to salt (Stout 1984).

c. Associated fauna. In studies sponsored by the SWFWMD, Mote Marine Laboratory described 65 species of fish (Appendix Table Y) and 13 species of macroinvertebrates (Appendix Table Z) found by trawling, seining, or cast-netting in the streams of Springs Coast brackish marshes (Phillips 1986). The normally freshwater species listed were found primarily near the headsprings of Crystal River. The very low-salinity tidal creeks along the north shore of Crystal River do not appear to be used as nursery areas by estuarine or marine species, but are primarily inhabited by freshwater species (Phillips 1986).

d. Human impacts. Timber clear cutting and urbanization increases runoff and sediment load in streams leading 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.

6.2.2 Salt Marshes

a. General. Salt marshes are intertidal-zone plant communities that represent a transitional zone 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 promote sediment accumulation and plant-community expansion. The Springs Coast region represents an ideal situation for salt-marsh growth which is reflected in the dominance of the habitat along the coastline. Nevertheless, little research has been performed in this area, and much of what follows is taken from work done north of Cedar Key and along the Florida panhandle.

Numerous factors influence the areal extent of salt marshes. The primary ones include:

(1) the relation of land to sea level (i.e., is the coastline stable, emerging, or submerging);
(2) the composition of the substrate;
(3) the amplitude of local tides;
(4) winds, currents, and waves—through their effects on sedimentation and aggradation (i.e., detrital loading);
(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. Knight and Coggins (1982) examined Springs Coast salt-marsh metabolism. Dawes et al. (1978) compared the productivity of epiphytic algae on salt marshes and on mangroves. 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 on per-unit-area and per-unit-time bases. 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, a large number of birds, and a few reptiles and mammals.

(3) They provide adjacent low-lying uplands with substantial protection 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").

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, with patchy occurrence of a few incidental species.

The coastline of the Springs Coast region is dominated by salt marshes (Fig. 45). The primary type of vegetation is black needlerush (*Juncus roemerianus*) (Carlton 1975; Eleuterius 1976; Darako et al. 1985; SWFWMD 1986). An important factor in determining the dominance of *Juncus* in the Springs Coast appears to be the small tidal range, resulting in a relatively small amount of the marsh area being frequently flooded for long periods. The entire Springs Coast region is classified as a "zero energy" coast (Tanner 1960) in which wave energy is dampened over the wide, shallow west Florida Continental Shelf. This allows *Juncus* to develop larger stands near the coastline, despite its apparent intolerance of flooded soils (Kurz and Wagner 1957).

The geology of the region is primarily responsible for the extensive marshland present in the Springs Coast region (Hine and Belknap 1986). This region of the Gulf of Mexico is underlain by Tampa Bay limestone of the Miocene Formation. This erosion-resistant limestone is present very close to the surface and accounts for the reduced slope of the area. The very low profile of the shoreline permits extensive marsh development.

b. Major physiographic features. Four types of surface irregularities occur in Springs Coast salt marshes: tidal creeks, natural levees, barrens, and islands (Rey 1978).

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 vegetation different 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 1942; Kurz and Wagner 1957) and from debris tossed up on the marshes by tides and storms that sometimes smother the marsh vegetation. In addition, they may 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 1942).

Many small, low-profile islands are present near the shoreline. These are typically dominated by *Spartina alterniflora*.

c. Distribution. Salt marshes are found in an almost continuous band from the east shores of Ochlockonee Bay to Anclote Keys, including the Springs Coast (Fig. 45). In the Springs Coast, the coastal salt marshes grade into brackish and fresh marshes as one travels inland, and the combined marsh is up to 10 km wide (USFWS undated). The proportion of this band that is salt marsh varies with the local hydrologic conditions, but can be well over 1 km wide.

d. Soil characteristics. Coultas and Gross (1975) described three major soil groups in Springs Coast areas. The upper marsh zone adjacent to the uplands is dominated by psammaquents. The lower marsh areas are dominated by sulfaquents (with an accompanying strong hydrogen sulfide gas odor). Organic matter and clay content decrease from lower elevation to higher elevation soils. With high organic carbon content in their surface horizons, the sulfaquents are characterized by highly reduced conditions and high iron sulfide concentrations. The psammaquents and haplaquods are predominantly sandy.

Overall, more than 90% of the inorganic sediment component is silt-sized to medium-sized quartz. The second most abundant inorganic mineral is pyrite.

Eighty percent of the organic matter in the sediment is humic material that originated from inland swamps and was deposited by streams flowing into the marsh. The remaining portion of the organic matter is also humic, primarily derived from stalks and roots of *Juncus* and offshore seagrasses.

Sediment pH and Eh are directly related to organic content—the greater the organic matter, the lower the pH and Eh. In general, the marsh soils are very acidic and highly reducing. Because of the reducing environment and high organic content, some metals are enriched: iron, manganese, cobalt, chromium, copper, molybdenum, and nickel. Iron sulfide is abundant and generally increases with sediment depth.

e. Vascular plants present. Springs Coast salt marshes are typically dominated by black needlerush, *Juncus roemerianus*. The smooth cordgrass *Spartina alterniflora* is usually restricted to the narrow fringes bordering the coastline, the edges of tidal creeks, and channels, and to small islands formed by the high points of oyster bars and elevations in the local mudflat. The *Spartina* fringes usually comprise monotypic stands of *Spartina alterniflora*; plants such as *Aster tenuifolius*, *Batis maritima*, and *Juncus roemerianus* often are interspersed, though seldom extremely abundant within the zone.

The *Juncus roemerianus* stands occur at slightly higher elevations than the *Spartina* zone and are subjected to shorter and less frequent tidal flooding. In the Springs Coast, pure stands of *Juncus* can extend for miles and can be found all the way up to the pine flatwood borders and on top of levees, next to live oaks and other higher ground species.

Other plant species present, usually in small isolated patches, include *Spartina patens* (saltgrass), *Distichlis spicata* (marsh spike grass), and *Salicornia perennis* (glasswort). *Distichlis spicata* and *Salicornia perennis* patches are usually located above the *Juncus* zones, typically in mixed stands with species such as *Batis maritima* and *Borrichia frutescens* also present. *Spartina patens* often forms a narrow zone between *Juncus* and *Distichlis*.

The natural levees occurring throughout the Springs Coast region are usually formed as a result of sediment deposition by above-normal high tides. They are usually found in two locations: on beaches just above the mean high water (m.h.w.) mark and on the borders off offshore islands. Several plant species occur on the levees, with specific composition varying with location and levee height. Typically, the most common species on the crests of levees are *Baccharis halimifolia*, *Myrica cerifera*, *Iva frutescens*, *Yucca gloriosa*, and *Lycium carolinianum*. On older, more stable levees, *Ilex vomitoria*, *Sabal palmetto*, and *Juniperus silicicola* become common. *Quercus virginiana* is present on the oldest and highest levees (i.e., elevation approximately 2 m above m.h.w.). The levee slopes contain a different species assemblage. *Spartina alterniflora* occurs only at the levee bases on the seaward side. Proceeding up the slope, *Salicornia* and *Batis* are present. *Spartina patens* is sometimes found near the crest on the seaward side, but is more common on the landward side, mixed with *Juncus* and *Distichlis*. On the

Springs Coast, the Waccasassa River is notable for the natural levees along its tidal channel (Hussey 1986).

Figure 87 presents a generalized schematic of salt-marsh zonation; however, zonation may be complicated by several factors (Clewell et al. 1976). Irregularities in shoreline elevation may cause atypical zonation. Within the *Juncus* zone, shallow, ovoid depressions may be present. Sheet flow during higher-than-normal tides fills a depression but is unable to drain from it. As a result of evaporation, a salt flat may be formed at a lower elevation than that of the surrounding *Juncus* marsh. The lack of relief along the Springs Coast results in marsh zones that may be considerably wider than the distances given in Fig. 87. Also, because of the sheet-flow runoff and freshwater discharge from springs and seeps common along much of the Springs Coast, it is common for the salt marsh to grade into brackish and then freshwater marsh before upland habitats are reached.

Another distinctive feature regarding plant zonation in the coastal marshes of the region are frequent coastal hammock islands that occur on limestone outcrops. These small hammock communities are usually dominated by cabbage palm, redcedar, and live oak (see Section 5.6.4). The hammocks are widely scattered among both salt and brackish marshes, and in these cases the transition from hammock to open-marsh vegetation is generally very abrupt.

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 (Fig. 88).

Fish are seasonally very abundant and diverse. Fable (1973) reported on the fish fauna of Springs Coast salt marshes.

Birds are an important component of the marsh system. Over 60 species are reported to use habitats within Springs Coast salt marshes (Woolfenden and Schreiber 1973; Stout 1984). Appendix Table AA 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

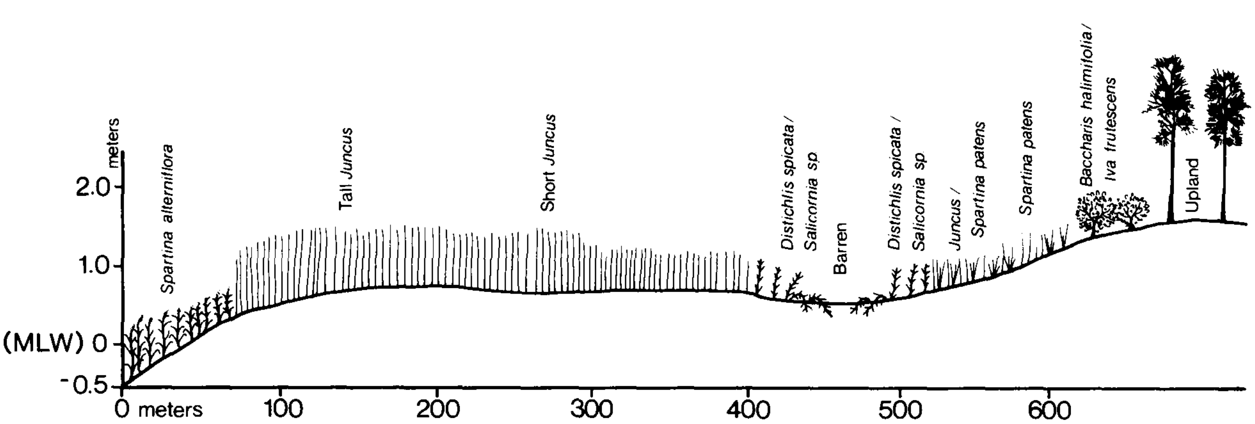


Figure 87. Generalized schematic view of gulf-coast salt marshes on protected low-energy shorelines (after Stout 1984).

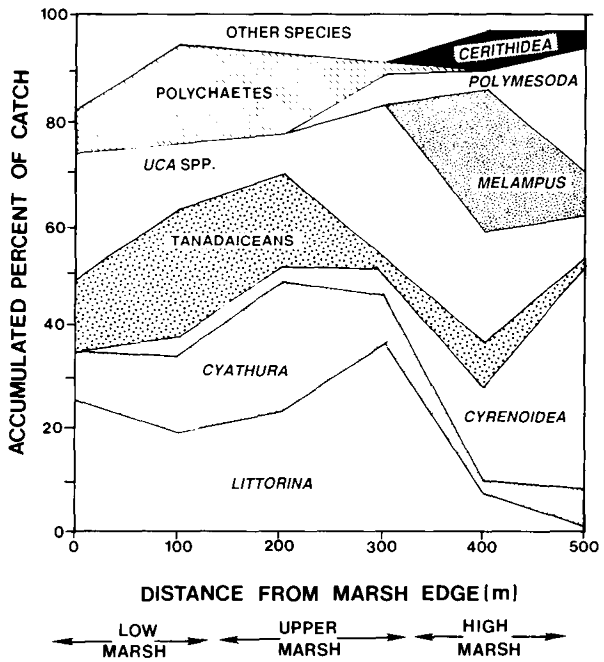


Figure 88. Horizontal distribution of macrofauna in a typical Springs Coast tidal marsh (after Stout 1984).

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).

The marshes are also an important wintering area for the largest concentration of redhead ducks in the Southeastern United States and are sites of bald eagle feeding.

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 5).

The gulf salt marsh snake (*Nerodia clarkii clarkii*) and the ornate diamondback terrapin (*Malaclemys terrapin macrospilota*) are common and characteristic of the Springs Coast brackish marsh. The American alligator (*Alligator mississippiensis*) and Florida cottonmouth (*Agkistrodon piscivorus conanti*) are also common here.

g. Trophic Dynamics and 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 system. 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. Decomposition rates vary among the different plant species. The available detritus is usually lowest in the winter months and increases through the spring and early summer to maximum values in August and September (Stout 1984). In studies of freshwater flows in the Springs Coast sponsored by the Southwest Florida Water Management District, Mote Marine Laboratory investigated salt-marsh standing crop in sites ranging from Hammock Creek to the Waccasassa River (Mote Marine Laboratory 1986).

h. 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 Springs Coast area 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 change the system substantially. 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 the proximity of major river deltas (none occur in the

Table 5. Some mammals of Springs Coast salt marshes (after Stout 1984).

Species	Common name
Sylvilagus palustris	Marsh rabbit
Oryzomys palustris	Marsh rice rat
Sigmodon hispidus	Hispid cotton rat
Procyon lotor	Raccoon
Mustela vison mink	Southern mink
Lutra canadensis	River otter
Mustela frenata	Long-tailed weasel
Lynx rufus	Bobcat
Odocoileus virginianus	White-tailed deer
Microtus pennsylvanicus dukecampbelli	Duke's saltmarsh vole

Springs Coast). 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.

i. 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 extremely 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. Research Planning Institute, Inc. (1984) investigated the sensitivity of the Springs Coast to oil spills and reported that salt marshes, along with mangroves, are the most oil-sensitive type of coastline. They found that the entire Springs Coast is predominantly *Spartina/Juncus* marsh which is very sensitive to oil spills and nearly impossible to clean up following a spill.

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.

Clewell et al. (1976) studied seven sites within five marshes in Wakulla, Taylor, and Dixie Counties north of the Springs Coast. They reported the following results: (1) if tidal flow is unaffected by the presence of a fill road, the marsh will be unaffected except where the road was constructed; (2) if tidal sheet flow is severely restricted, saltwater mollusks will disappear within days or weeks and salt-intolerant plants will invade within approximately 4 years; (3) if sheet flow is precluded for many years, the biota and habitat will change radically and salt-intolerant plants will replace salt-marsh species; and (4) if a tidal marsh that is isolated from the gulf by a fill road does not contain a tidal creek that flows through a culvert, dredging may facilitate flow even though dredging itself produces effects.

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 use of pesticides, erosion from boat-wakes, canal dredging, use of marsh buggies and other wetland transportation vehicles, and waste disposal.

j. 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 and adjacent inland habitats require very careful monitoring and control if salt marshes are to continue playing their important roles.

6.2.3 Intertidal Flats

a. General. 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 denotes a low-energy shore). In the case of the Springs Coast, the intertidal flats are predominantly sandy muds or muds because of the very low energy levels along the coast.

Intertidal flats appear barren and unproductive because of the absence of macrophytes such as marshgrass or seagrass. Benthic microalgae, while very abundant and productive, do not accumulate the great biomass that marshgrasses 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 to an estuarine system a substantial amount of primary production 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, pers. observ.). 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). Mobile epifauna, such as crabs, are found most commonly during high tides. Infaunal organisms, however, are more abundant at both low and high tides.

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.

d. Trophic dynamics and interactions. Microalgae, primarily the diatoms, dinoflagellates, filamentous greens, and blue-greens, are the primary producers 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 Appendix Table AB. Shorebirds (Table 6), crabs, and fishes are the primary consumers of the herbivores.

The infauna of Springs Coast 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).

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 of 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

Table 6. Common birds of Springs Coast intertidal flats (Stout 1984).

Guild	Common Name	Guild	Common Name
Waders	Herons	Aerial-searching	Terns
	Egrets		Gulls
	Ibises		Skimmers
	Yellowlegs		Pelicans
Shallow-probing surface-searchers	Sandpipers	Floating/diving	Ducks
	Plovers		Geese
	Knots		Grebes
Deep-probing	Godwits		Cormorants
	Willets	Birds of prey	Osprey
	Curlews		Eagles
			Owls

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.

6.2.4 Oyster Reefs

a. General. The biology of the oyster has been extensively studied for economic reasons (i.e., meat and shell industries). Most information comes from research performed outside the Springs Coast region. 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. Investigations have been performed recently into the ecology of several oyster reefs located along the Springs Coast (Gorzelany 1986; Sprinkel 1986).

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 reef 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."

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 found primarily in the areas outside the many river mouths along the Springs Coast. Dawson (1955) found that the oyster reefs extend up to 5.5 km into the open Gulf of Mexico off the Crystal River, and that these reefs roughly parallel the shore to the Withlacoochee estuary. The Crystal River reefs are now separated from the Withlacoochee reefs by the dredged intake channel and resulting spoil banks of Florida Power Corporation's Crystal River Nuclear Power Plant. Mote Marine Laboratory studied the oyster reefs associated with Hammock Creek (near Aripeka), and the Weeki Wachee, Crystal, Withlacoochee, and Waccasassa Rivers (Gorzelany 1986; Sprinkel 1986). They found that the reefs of the Crystal and Withlacoochee Rivers were fully developed (according to the stages of development of Hine and Belknap (1986)), while the Weeki Wachee estuary had only incipient reef growth. The Waccasassa reefs were less numerous and narrower than those of the Crystal and Withlacoochee Rivers.

c. Oyster autecology. The primary reef-building and commercial oyster found in the Springs Coast is the Eastern or American oyster, *Crassostrea virginica*. The crested oyster, *Ostreola equestris*, is also present. Both species grow in a wide salinity range (10–30 ppt), with optimal growth occurring at a water temperature of approximately 25 °C (FDNR 1971).

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.

A number of physiochemical and biological factors influence the settlement of larval oysters. Light, salinity, temperature, and current velocity are the most important parameters. In addition, oyster larvae are highly gregarious and settle in response to a water-borne 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 strategy of the oyster requires settlement in proximity for successful fertilization.

Oyster growth occurs throughout the year. Maximum size (total shell length) is usually not much greater than 100 mm. Oyster reach a marketable size within 2 to 3 years after settlement. Sprinkel (1986) reported that larger oysters (i.e., in terms of heights from umbo to shell edge) are generally most abundant near river mouths along the Springs Coast.

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 in diameter (cite). Feeding activity is highest at low food concentrations, and there is a negative correlation between pumping rate and surrounding turbidity. Since 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 throughout the Springs Coast region range in size from small, scattered clumps to massive solid mounds of living oysters and dead shells. Reef development is generally restricted to the middle portion of the intertidal zone, where minimum inundation time determines the maximum elevation of reef growth. Predation and siltation may limit oyster populations in the lower intertidal and subtidal zones to scattered individuals or small clumps in some locations.

An oyster reef may begin its initial development with the attachment of a single oyster to some solid isolated substrate. Succeeding generations of oysters attach to the earlier colonizers and a gradual increase in length, width, and height eventually result in the formation of a reef. In shallow intertidal water, such development can form a marsh island with a fringe of live oysters. This is more common in the north sections of the Apalachee Bay (north of the Springs Coast area), where numerous oyster islands are located off the coast.

During exposure to the atmosphere (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" (or layers): (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.

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. Grinnell (1971, 1974) described the structure and development of oyster reefs in the Suwannee River delta (adjacent to the northern Springs Coast) and also reported on the vertical orientation of individual oysters within the reef.

e. Associated fauna. Vertical zonation observed in oyster reef macrofaunal distributions is a result of interspecific tolerance to desiccation rather than a feeding limitation resulting from reduced inundation time (Bahr and Lanier 1981). Oyster reefs typically contain a large number and a very diverse faunal assemblage. Gorzelany and Lowers (1985) and Gorzelany (1986) examined faunal communities at 13 oyster reef stations located between Aripeka and the Waccasassa River. A total of 248 taxa were identified in that study (Appendix Table AC), but only 21 taxa were found at all of the stations (Table 7). Table 8 lists the common oyster-associated invertebrate fauna; the relative abundances of these fauna by season and by location are listed in Table 9 and Appendix Tables AD and AE. Table 10 lists the relative abundance of common oyster-associated species, and Table 11 gives a list of species that are indicative of the salinity regime of the oyster reef on which they occur. Gorzelany (1986) observed a general trend, with total numbers of species and individuals increasing with distance offshore, and concluded that salinity was a dominant factor controlling species composition, as community similarity analyses (Morisita 1959) had found greater similarity between like stations from different estuaries (e.g., inshore or offshore) than between different stations from the same estuary.

There is an interesting association between oyster reefs and the insect *Anurida maritima* (a true marine insect). This organism feeds on recently dead macrofauna, including oysters. *Anurida* appears to be a true oyster associate (Bahr and Lanier 1981). Its highest concentrations are found in dead pairs of oyster shells. It has a nonwettable cuticle that makes it extremely buoyant. Individuals would be washed away were it not for the numerous crevices among the oyster shells that allow masses of the insects to cling together.

The Springs Coast is relatively free of oyster predators and parasites (Lehman 1974; Florida Power Corporation 1985; Gorzelany 1986). Two species common on oyster reefs result in oyster mortality, the boring sponge *Cliona* spp. and *Melongena corona*, the crown conch (Gorzelany 1986).

Crustaceans and mollusks are common on the oyster reef. Gorzelany (1986) reported that there is a

Table 7. Oyster-associated fauna collected from each of 13 oyster stations (after Gorzelany 1986).

Species	Common name or type	Species	Common name or type
Anurida maritima	Insect	*Hyale plumuiosa*	Amphipod
Balanus improvisus	Barnacle	*Ischadium recurvum*	Hooked mussel
Boonea impressa	Impressed odostome (snail)	*Melita* "complex"	Polychaete worms
Brachidontes exustus	Scorched mussel	Mytilidae spp.	Bivalve
Capitella capitata	Polychaete	Nematoda spp.	Nematode worm
Crassostrea virginica	Oyster	Nereidae spp.	Polychaete worm
Eurypanopeus depressus	Flatback mud crab	Oligochaeta spp.	Oligochaete worm
Fabriciola trilobata	Polychaete	Platyhelminthes spp.	Flatworm
Genetyllis castanea	Polychaete	*Polydora* "complex"	Polychaete worms
Gitanopsis sp.	Amphipod	Xanthidae spp.	Xanthid crab
Hargeria rapax	Tanaid		

Table 8. Common invertebrate species associated with Springs Coast oyster reefs (adapted from Gorzelany 1986).

Phylum/Class	Species	Phylum/Class	Species
Coelenterata	*Anthozoa* spp.	Gastropoda	*Boonea impressa*
Porifera	*Cliona* spp.		*Crepidula plana*
Polychaeta	*Capitella capitata*	Arthropoda	
	Ehlersia cornuta	Insecta	*Anurida maritima*
	Fabriciola trilobata		Chironomidae spp.
	Genetyllis castanea	Amphipoda	*Corophium* spp.
	Neanthes succinea		*Cymadusa compta*
	Phyllodoce castanea		*Gitanopsis* sp.
	Polydora spp.		*Grandidierella bonneroides*
	Streblospio benedicti		*Hyale plumuiosa*
	Syllidae spp.		*Melita "nitida"* complex
Oligochaeta	various spp.	Isopoda	*Cassidinea lunifrons*
Mollusca		Tanaidacea	*Hargeria rapax*
Bivalvia	*Brachidontes exustus*		*Tanais cavolini*
	Crassostrea virginica	Decapoda	*Eurypanopeus depressus*
	Geukensia demissa		Xanthidae spp.
	Ischadium recurvum		

noticeable shift in these two groups with salinity in the estuaries. The Crustacea were the dominant group at low-salinity stations, while the mollusks were most abundant at high-salinity stations. Overall, abundances of these two groups were highest in the summer and lowest in the winter.

Crabs are abundant members of the community. Mud crabs such as *Eurypanopeus depressus* and *Panopeus herbstii*, very abundant among the cracks and crevices of the oysters, are omnivores that feed during high tides. The amphipoda is another well-represented group. They are more numerous and diverse in sublittoral oyster beds than on intertidal portions of a reef. The most common are *Melita nitida* and closely related species.

The stone crab (*Menippe mercenaria*) is a commercially important inhabitant of oyster reefs (Savage et al 1975; Bert et al 1978; Zuboy and Snell 1982). Stone-crab densities are highest during the summer, decline over the fall, and remain low throughout the winter. Seasonal residency patterns suggest that the reefs may be a site for the crab's 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 (e.g., bivalves, gastropods, and crustaceans). Inshore residency and adult heterosexual pairing of stone crabs on the oyster reef coincides exclusively with the fall mating season. Oyster reefs provide a valuable resource for the stone crab—a high density of potential mates and/or suitable shelter during molting.

The stone-crab fishery is concentrated in the nearshore areas of the Springs Coast coast, with the commercial stone-crab season running from October 15 to May 15. Only the claws with a minimum size of 7-cm propodus length or 10.8-cm overall length may be kept.

Table 9. Ten most abundant oyster-associated fauna by quarter, listed by rank (after Gorzelany 1986).

Species	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
(B) *Brachidontes exustus*	1	5	9	8	1	2	5	1
(P) *Polydora* "complex"	2	6	1	2	2	8	6	3
(T) *Hargeria rapax*	3	2	3	6	8	9	—	10
(B) *Crassostrea virginica*	4	7	10	—	4	5	—	—
(I) *Diptera* spp.	5	1	4	4	6	3	8	—
(P) *Fabriciola trilobata*	6	10	7	1	10	—	4	5
(G) *Boonea impressa*	7	—	2	3	3	4	1	2
(A) *Melita* "complex"	8	3	6	7	5	1	7	6
(D) *Eurypanopeus depressus*	9	8	5	—	7	—	—	7
(P) *Syllidae* spp.	10	—	—	10	—	—	10	8
(G) *Crepidula plana*	—	4	8	5	—	—	—	—
(D) *Xanthidae* spp.	—	9	—	—	—	6	—	—
(P) *Capitella capitata*	—	—	—	9	—	—	—	—
(I) *Anurida maritima*	—	—	—	—	9	10	9	—
(B) *Ischadium recurvum*	—	—	—	—	—	7	—	9
(O) *Anchozoa* spp.	—	—	—	—	—	—	2	4
(A) *Hyale plumuiosa*	—	—	—	—	—	—	3	—

B = Bivalve, G = Gastropod, A = Amphipod, P = Polychaete, D = Decapod, I = Insect, T = Tanaid, O = Other

Many other organisms are found within the oyster reef. Bryozoans, flatworms, and hydroids are common and often most abundant in subtidal regions.

f. Associated flora. Sprinkel (1986) reported on macroalgal species that are commonly found in clumps on Springs Coast oyster reefs (Appendix Table AF). For the more northern estuaries (Crystal, Withlacoochee, and Waccasassa), macroalgae occurred in small quantities and did not appear important to reef ecology. In the Weeki Wachee and Hammock Creek estuaries, macroalgae were more

Table 10. Percentage abundance of taxonomic groups of sedentary oyster-associated fauna (Gorzelany 1986).

Taxon	Taxa Identified	% of total	Taxon	Taxa Identified	% of total
Polychaeta	73	27.9	Tanaidacea	3	6.7
Bivalvia	23	16.9	Decapoda	14	6.2
Gastropoda	30	13.9	Anthozoa	1	4.2
Amphipoda	36	13.9	Platyhelminthes	5	0.9
Insecta	6	9.2	Isopoda	17	0.6

Table 11. Selected oyster-associated fauna which may be used as salinity indicators (after Gorzelany 1986).

Species	Salinity Commonly Found	Species	Salinity Commonly Found
Melongena corona	**High**	***Platyhelminthes* spp.**	**Intermediate to High**
Crepidula plana	**High**	***Melita* "complex"**	**Intermediate to Low**
Brachidontes exustus	**High**	***Diptera* spp.**	**Intermediate to Low**
***Anthozoa* spp.**	**High**	***Hargeria rapax***	**Intermediate to Low**
Hyale plumuiosa	**High**	***Gitanopsis* sp.**	**Intermediate to Low**
Cerithiopsis emersonii	**Intermediate to High**	***Geukensia demissa***	**Low**
***Polydora* "complex"**	**Intermediate to High**	***Gammarus mucronatus***	**Low**
Fabriciola trilobata	**Intermediate to High**	***Ischadium recurvum***	**Low**

abundant, and mixed mats of *Digenia simplex*, *Polysiphonia* spp., and *Laurencia* spp. may have restricted reef development.

g. Commercial aspects. Potential harvest areas are classified as follows: (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 runoff that may temporarily lower water quality. Prohibited areas consistently fail to meet water quality standards and harvesting is prohibited. Unclassified areas are unsurveyed and unmonitored sites and are not officially approved for harvesting. Water-quality testing is performed continuously on approved and conditionally approved sites and site classifications are changed with sufficient frequency that listing them here would be meaningless.

Some commercial oyster harvesting is done in the northern part of the Springs Coast. Joyce (1981) reported 149,454 lb of oysters landed in Levy County and 1,007 lb landed in Citrus and Pasco Counties combined. Since these figures report landings, it can only be assumed that they were harvested in nearby waters. None of the recreational harvest is represented in these figures.

h. Natural impacts. Under normal conditions, the natural environment controls population growth and regulates the distribution and density of oyster reefs.

Predation does not seem to be a limiting factor in Springs Coast oyster reefs (Gorzelany 1986). *Melongena corona*, the crown conch, is common but is apparently not a serious oyster predator, though it may be locally important at certain times (Gorzelany 1986).

There are four primary commensals associated with oysters: the boring sponge *Cliona celata*, the polychaete *Polydora websteri*, several species of flatworm (Platyhelminthes), and the oyster pea crab *Pinnotheres ostreum*. All three produce stress on the oyster. The boring sponge is found more commonly on oyster reefs in the southern estuaries of the Springs Coast and can cause severe damage to oyster shells (Gorzelany 1986). It is primarily found in subtidal regions of the reef. Oysters infested by *Cliona* are particularly vulnerable to predation. Erosion of the shell by the boring sponge and polychaete induce additional shell deposition. Though the flatworms are potentially detrimental to oysters (Finucane and Campbell 1968), they do not occur in quantities large enough to be considered a serious nuisance (Gorzelany 1986). The pea crab lives within the oyster's mantle cavity, removing food and mucus from the gills and possibly feeding on developing gametes.

Other important invertebrate predators upon Springs Coast oysters include the stone crab, *Menippe mercenaria*, and the blue crab, *Callinectes sapidus*. These two organisms are heavy predators on small, recently settled oysters, but not large adults. Crabs are most numerous on the reefs during incoming tides. As is common elsewhere, low salinity is the main factor controlling the populations of oyster predators and commensals and preventing them from becoming sufficiently numerous to harm the reef.

The most important vertebrate predator on Springs Coast oysters besides humans is a bird, the American oystercatcher (*Haematopus palliatus*). This predator feeds on clumped oysters more than solitary individuals. It feeds by cracking the oyster valves with its beak to reach the inner tissue. Another vertebrate predator on intertidal oysters is the raccoon; however, the extent of its impacts is not well known.

Storms and hurricanes, in particular, produce widespread damage to oyster reefs. Three factors cause mortality: (1) breakage of live oysters from the reef and deposition onto soft sediments where they are not able to feed properly, (2) increased turbidity that smothers the oysters, and (3) physical crushing of attached oysters by floating debris carried in the water column. Other factors include decreased salinities due to stormwater runoff from heavy rains.

Other natural fluctuations in the ambient physical conditions can affect the health of oyster reefs. Low dissolved-oxygen concentrations, high temperatures, excessive turbidity, overabundance or shortage of appropriate food, and crowding reduce oyster viability.

i. 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 normal 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 cultch 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) that reduces clearing efficiency.

(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 (increased mortality).

(5) Physical impairment of feeding structures by oil contributes to eventual mortality.

(6) Thermal effluents, primarily from power plants such the Crystal River plant, contribute to decreased community diversity and enhanced oyster predation (FDNR 1971; Lehman 1974).

(7) Overharvesting results in the depletion of breeding stocks and culch and a decrease in bottom stability.

(8) Wetland loss caused by development, especially in the southern areas of the Springs Coast region, decreases the wetland-water interface that is prime reef habitat, and the source of primary production that contributes to oyster-reef growth.

j. Conclusions. Oysters in the Springs Coast region are a common feature along the shallow coastline. They represent a potentially 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.

6.2.5 Intertidal Mangrove Forests

a. General. The term "mangrove" denotes more than 50 species of tropical halophytic trees and shrubs and in some cases encompasses the associated plant community (Chapman 1970). Mangroves are facultative halophytes (i.e., saltwater is not a physical requirement) and can grow well in freshwater. However, mangrove ecosystems normally develop only in saline environments where competition from other vascular plant species is reduced (Kuenzler 1974).

Mangroves are primarily found fringing the outer marsh islands along the coast (Shines 1979; Research Planning Institute, Inc. 1984). Mangrove forests offer little direct benefit for human use (tannin, construction timber, and charcoal) and historically have even been considered a "nuisance" (Lugo and Snedaker 1974). In recent years, the increasing demand for waterfront property for residential and commercial development has increased the value and demand for mangrove land simply because of its coastal location.

b. Mangrove species present. Three mangrove species are present in the Springs Coast region (Fig. 89): the black mangrove *Avicennia germinans*, the red mangrove *Rhizophora mangle*, and the white mangrove *Laguncularia racemosa*. The black mangrove is found throughout Florida's gulf coastline and is the most cold resistant; the red mangrove is found north along the gulf coast to Levy County; and the white mangrove is present as far north as Hernando County (Savage 1972; Lewis et al. 1985). The Springs Coast is north of the main concentrations of mangroves along the Florida Gulf coast and, though they can be found as far north as the Florida panhandle, they are generally not a major habitat north of Tampa Bay.

Mangrove forests provide habitat surface for algae (Taylor 1954, Humm 1973) and free-living and sessile invertebrates.

c. Species description/autecology. Areas south of the Springs Coast generally provide better conditions for growth of the mangrove species; the maximums sizes listed below are for those areas. Sizes reached by mangroves in the Springs Coast are generally substantially less.

(1) Red mangrove (*Rhizophora mangle*)—The tree may reach 25 m in height; has thin gray bark and dark red wood. The leaves are 2–12 cm long, broad, and bluntly pointed. They are shiny, deep green above and paler below. The tree is characterized by the prop roots that grow from its trunk and branches. The propagules are pencil-shaped and, after germination, reach 25–30 cm in length . Flowering occurs in the spring and early summer.

(2) Black mangrove (*Avicennia germinans*)—The tree reaches a maximum height of 20 m and has dark, scaly bark. The leaves are 5–10 cm long, narrowly elliptic or oblong, shiny green above and covered with short, dense hairs below. The leaves are frequently salt-encrusted. The tree is characterized by long, horizontal or "cable" roots with short vertical pneumatophores (aerating branches) that protrude out of the ground below the tree. The propagules are lima-bean shaped, dark green while on the tree, and several centimeters long. The tree flowers in the spring and summer.

(3) White mangrove (*Laguncularia racemosa*)—The tree or shrub reaches a height of 15 m or more. The leaves are broad, flattened ovals up to 7 cm long and are rounded at both ends. Two salt glands are located at the apex of the petiole. The propagules are only 1.0–1.5 cm long and are broadest at their apex. The tree flowers in the spring and early summer.

d. Mangrove forest physiognomy. Six major mangrove community types are recognized from different geological and hydrological processes (Lugo and Snedaker 1974; Odum et al. 1982). The zones are most clearly defined where there is a steep topographic shoreline gradient and not in large areas with very flat topographic slopes (e.g., 1 cm/km) (Lugo and Snedaker 1974). In flat regions such as those in the southern regions of the Big Bend, varying mixtures occur in the five major community types. All of the six communities except the scrub or dwarf forest are found in the Springs Coast. The five zones present (Fig. 90) include:

(1) Overwash mangrove forest is frequently present on inundated low islands that experience high rates of organic export (i.e., tidal velocities are high enough to carry away any loose debris). All three mangrove species may be present, with the red mangrove dominant. A dense prop-root system is present. Maximum tree height is approximately 7 m.

(2) Fringe mangrove forest forms a fringe along waterways in which the shoreline is elevated above the mean high water mark and along the edge of protected shorelines and islands. Because of open exposure along some shorelines, this type is occasionally affected by storms that cause breakage. Maximum tree heights approach 10 m.

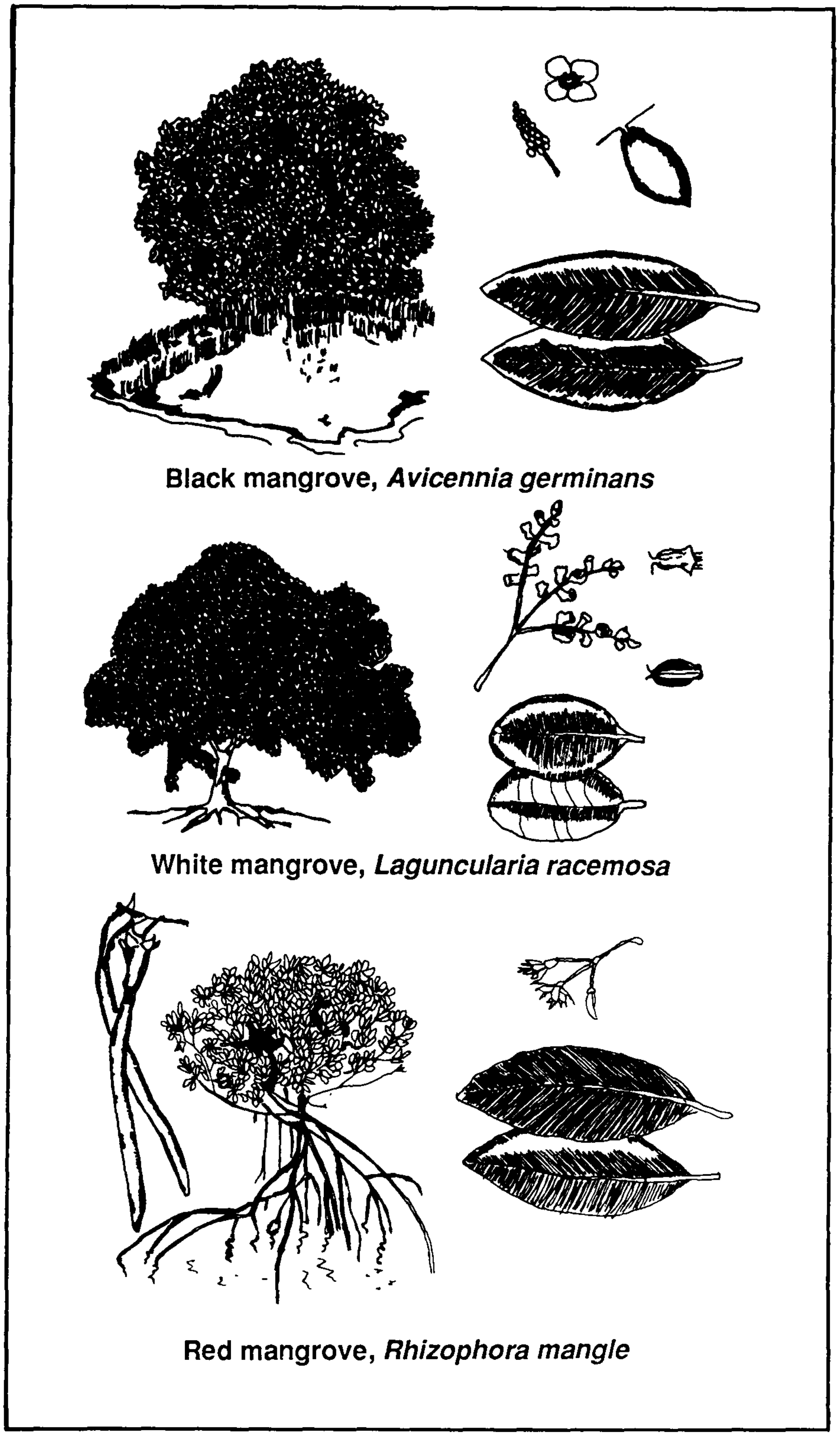
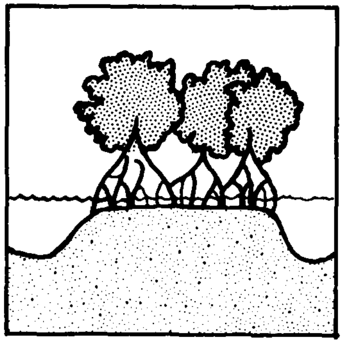
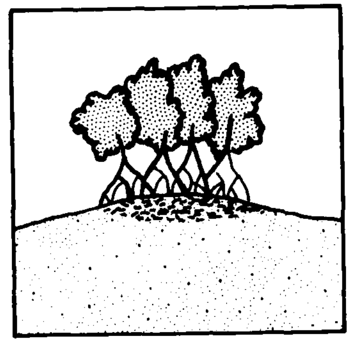


Figure 89. Mangrove species found in the Springs Coast (after Odum et al. 1982).



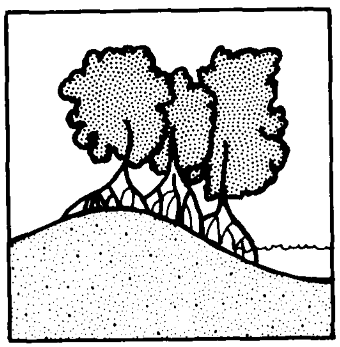
Overwash Mangrove Islands

1. Overwashed by daily tides.
2. High rate of organic exports.
3. Dominated by red mangroves but all species may be present.
4. South Florida, south coast of Puerto Rico.
5. Sensitive to ocean pollution.



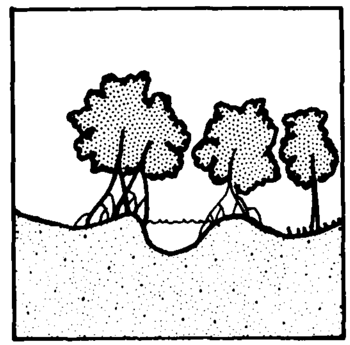
Hammock Mangrove Wetlands

1. On land rises in south Florida.
2. Low export of organic matter.
3. All mangrove species.
4. South Florida everglades.
5. Sensitive to fire and drainage.



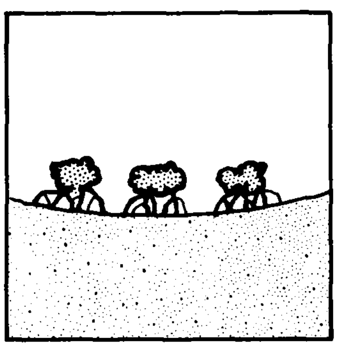
Fringe Mangrove Wetlands

1. Line waterways.
2. High rate of organic exports.
3. Dominated by red mangrove.
4. Throughout south Florida, Puerto Rico, and Florida's east and west coast.
5. Sensitive to ocean pollution.



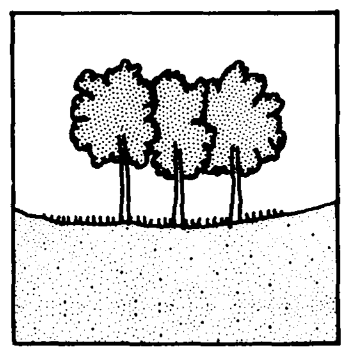
Riverine Mangrove Wetlands

1. Along flowing waters.
2. High export of organic matter.
3. All mangrove species, reds predominate.
4. South Florida, north coast of Puerto Rico.
5. Sensitive to alterations of water flow.



ScrubMangrove Wetlands

1. On extreme environments.
2. Low organic exports.
3. Usually red or black mangroves.
4. Southeast Florida, south coast of Puerto Rico, high latitudes on west coast of Florida..
5. Sensitive to further stress.



Basin Mangrove Wetlands

1. In depressions or areas of slow water movement.
2. High seasonal export of organic matter.
3. Black mangroves predominate.
4. Inland locations in south Florida and Puerto Rico.
5. Sensitive to alteration of sheet flow, sea-water input, and prolonged high water.

Figure 90. Mangrove forest types represented in the Springs Coast (after Wharton et al. 1977).

(3) Riverine mangrove forest includes flood-plain forests along tidal creeks and rivers. The forest is usually flushed by daily tides. It is often fronted by a fringe forest that occupies the edge of the drainage way. All three species of mangrove are present, with the red mangrove predominating (with few, short prop roots). Tree height reaches a maximum of 18–20 m.

(4) Basin mangrove forest occurs just inland in depressions that channel upland runoff to the coast. It is influenced by daily tides and typically dominated by red mangroves. Landward, as tidal influence diminishes, black and white mangroves begin to dominate. Maximum tree heights approach 15 m.

(5) Hammock forest is similar to basin forest except that it occurs on slightly elevated ground (5–10 cm). All tree species are present. Tree heights are usually less than 5 m.

e. Mangrove zonation. Three dominant theories using succession, competition, and physical factors have been proposed to explain mangrove zonation. The first and most classical view (Fig. 91) was advanced by Davis (1940), who suggested that mangrove zonational patterns were analogous to seral stages in a successional sequence (Odum et al. 1982). The seaward-most areas were considered pioneer and dominated by red mangroves. Advancing landward, the zones were viewed as progressively later stages in the successional process. This gradient of forests was dominated by white mangroves, black mangroves, buttonwoods, and the tropical forest that was considered the community climax. The ecosystem was believed to be advancing seaward through a process of sediment accumulation and colonization. A major basis of the theory was derived from sediment cores that apparently consistently showed that red mangrove peat underlaid black mangrove peat, which occurred under terrestrial plant communities.

The second theory proposes that mangrove zonation is merely a response to external physical forces, rather than a successional sequence (Egler 1952; Thom 1967, 1975). The sediment deposition was not always found and in some locations, the mangrove forests appeared to be migrating landward. In addition, red mangroves were not always the sole first colonizers on recent sediment deposits. In the southern regions of the Springs Coast region, it is common to see black mangroves and white mangroves together with *Spartina patens* on, for example, dredge spoil (Lewis and Dunstan 1975). In the northern regions, black mangrove is the only species present and occurs with the major salt-marsh grasses.

A third theory implicated interspecific competition (Ball 1980). It may not be an important process early in mangrove forest development, but it probably becomes influential as the trees reach maturity with increased resource requirements (i.e., space, nutrients, etc.). Contributing to this view are the differential competitive abilities of the individual mangrove species with different physical conditions. Succession may occur independently within each physical zone. Disturbance, such as lightning strikes and strong winds, may produce a mosaic of patches within a zone that is made up of different successional stages.

f. Mangrove forest substrata. Primary mangrove soils in the Springs Coast are calcareous marl muds or calcareous sands in the southern regions and siliceous sands in the northern portions (Kuenzler 1974).

Mangroves often modify the substrate through peat formation and alteration of sedimentation processes. Although present on a variety of substrate types, they flourish on muds and fine-grained siliceous sands. Sediment distribution and mangrove development is controlled by wave and current energy. Mangrove forests modify the substrate through peat deposition. Red mangroves produce the most easily recognizable peat. Its recent deposits are spongy, fibrous, and primarily composed of fine rootlets (0.2–3.0 mm dia). Longer (3–25 mm) root pieces, wood, and leaves are present. Inorganic materials such as pyrite, carbonate minerals, and quartz are present in varying amounts (Davis 1946). Recently excavated peat is reddish-brown but rapidly changes to brown-black after exposure to air.

Peats are usually acidic and capable of dissolving underlying limestone layers. The most acidic conditions are found in the center of the peat layer. The acidity results from the release of organic acids during the anaerobic decomposition and oxidation of reduced sulfur.

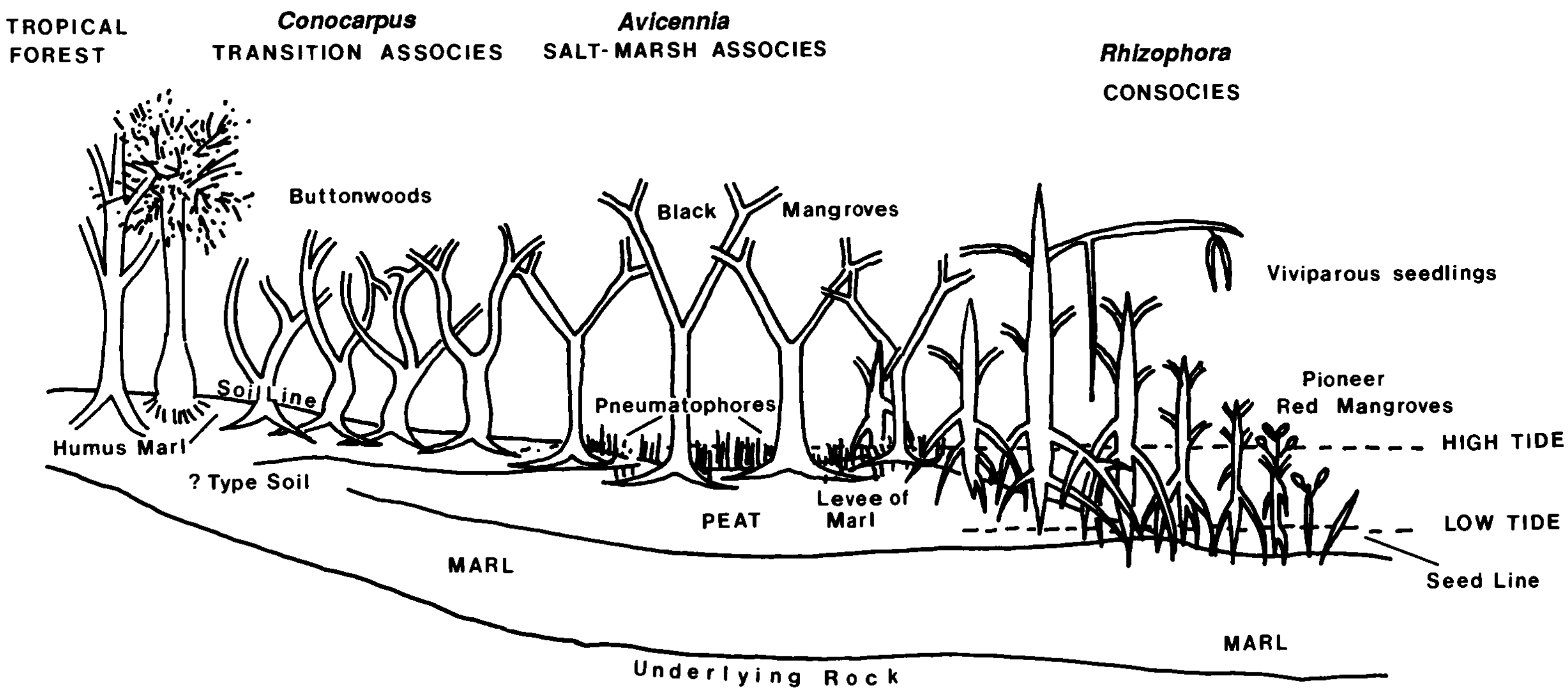


Figure 91. Diagrammatic transect of the mangrove community from the pioneer red mangroves to the tropical hammock forest (after Davis 1940).

g. Associated microorganisms. The fungi or mycoflora from mangrove forests are well described (Kohlmeyer and Kohlmeyer 1979; Fell et al. 1980; Odum et al. 1982). The fungi are important in the conversion of mangrove leaf material into digestible forms for the detritivores. Extensive populations are present on the submerged portions of the prop roots, stems, and branches and on living and dead leaves. Ahearn et al. (1968) have published a survey of aquatic yeasts from south Florida mangroves. The mycoflora undergo a succession of species on decaying red mangrove leaves (Fell et al. 1980). Species of *Nigrospora*, *Phyllostica*, and *Pestalotica* colonize the senescent leaves. After the leaves have fallen and decay has begun, *Phytophthora, Drechslera*, and *Gleosporium* are dominant. *Calso, Gliocidium*, and *Lulworthia* are dominant in the latter stages of decay.

h. Associated plants. Mangrove root systems are attachment sites for diverse algal assemblages. Red-mangrove prop roots and black-mangrove pneumatophores harbor the most conspicuous algae because of their location in the intertidal zone. Productivity is highest at the edge of the forest, where shading is minimal, and declines towards the center of the forest. Dawes et al. (1978) compared the productivity of epiphytic algae of salt marshes and mangroves. The algae are vertically distributed on the prop roots (Taylor 1961; Rehm 1974) (Fig. 92), with the Rhodophyta (red algae) contributing the largest biomass in the system. Three other phyla are generally present: Chlorophyta, Phaeophyta, and Cyanophyta.

Algal zonation on the prop roots is usually very predictable. Near the high-water mark, a green band is present that is dominated by species of *Rhizoclonium*. Below this is a region dominated by species of *Bostrychia, Catenella*, and *Caloglossa*. A large amount of mud is generally associated with the *Bostrychia-Catenella-Caloglossa* complex and appears as a gray band (Odum et al. 1982). In brackish and nearly freshwater areas of a mangrove forest, these three species are replaced by species of *Batophora, Chaetomorpha, Cladophora*, and *Penicillus*. The pneumatophores of *Avicennia* are often colonized by species of *Bostrychia, Monostroma*, and *Rhizoclonium*.

A permanently submerged algal assemblage is often present on the prop roots. Common species include *Acanthophora, Caulerpa, Hypnea, Laurencia, Spyridia, Valonia*, and *Wrangelia*. In addition, epiphytic diatoms and filamentous blue-green and

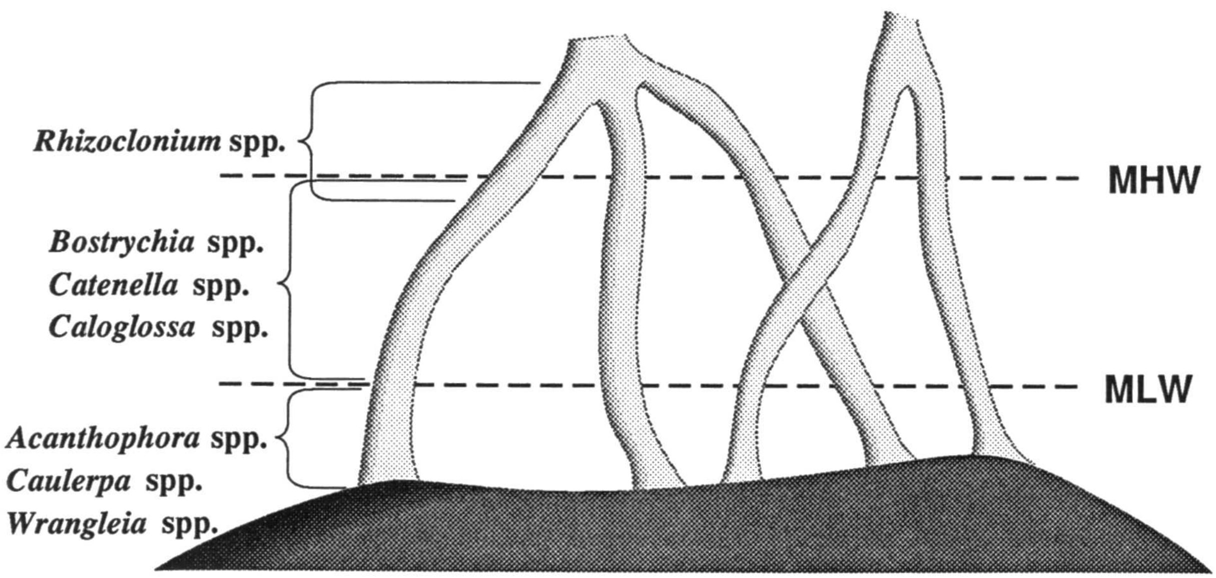


Figure 92. Algal zonation on mangrove prop roots (after Odum et al. 1982).

green algae of a variety of genera are present on any wet surface of the prop roots.

The muddy sediments near the mangrove prop roots harbor a diverse assemblage of algae. Commonly present species include *Cladophoropsis*, *Enteromorpha*, *Vaucheria*, and *Boodleopsis*. Also present is an abundant microscopic community of benthic diatoms and dinoflagellates and other filamentous green and blue-green algae.

A number of salt-tolerant vascular plants are found within mangrove stands (Carlton 1977). For example, the following are usually present: leather leaves (*Acrostichum aureum* and *A. danaeifolium*), chaff flower (*Alternanthera ramosissima*), Spanish bayonet (*Yucca aloifolia*), spider lily (*Hymenocallis latifolia*), sea blite (*Suaeda linearis*), samphire (*Philoxerus vermicularis*), blood leaf (*Iresine celosia*), prickly pear cactus (*Opuntia stricta*), marsh elder (*Iva frutescens*), rubber vine (*Rhabdadenia biflora*), lianas (*Ipomoea tuba* and *Hippocratea volubilis*), and a variety of bromeliads.

i. Associated fauna. The mangrove forest is a highly heterogeneous and structurally complex system that offers a wide variety of habitats for many organisms. It serves as a permanent home and nursery ground for many creatures. Mangroves have both a vertical and a horizontal zonation pattern to faunal distributions.

Mangroves can be characterized as having a moderately high invertebrate species diversity (e.g., Abele 1974). Invertebrates typically demonstrate vertical and horizontal zonation within a mangrove forest. Invertebrate biomass in a red mangrove section at the edge of a forest is often very high, while as one moves towards the center of a forest where there is less flooding, biomass is on the order of a magnitude less.

Mangrove invertebrates can be classified into four general trophic groups (Odum et al. 1982): (1) direct grazers such as insects and the mangrove tree crab, *Aratus pisonii*, which feed in the mangrove canopy; also a group of small invertebrates that graze upon the prop-root algae; (2) filter feeders such as sessile invertebrates which feed on phytoplankton and detritus; (3) deposit feeders such as mobile invertebrates that consume detritus, algae, and small organisms from the sediment surface; and (4) carnivores such as highly mobile invertebrates that feed upon all the other groups.

A distinctive and highly diverse arboreal arthropod assemblage exists within the mangrove forest, for which the mangrove canopy provides camouflage and refuge. The dominant group is the insect fauna. Over 200 species of mangrove-associated insects have been described from the Florida Keys (Simberloff and Wilson 1969). The mangrove tree crab is also a common member of the canopy. It is omnivorous and feeds on mangrove leaves and insects. Other invertebrates present include pulmonate gastropods such as the mangrove periwinkle (*Littorina angulifera*), the ladder hornsnail (*Cerithidea scalariformis*), and *Melampus coffeus*, the isopod *Ligea exotica*, and numerous species of decapods.

The prop-root system and adjacent sediment contain a large number of invertebrate species. Courtney (1975) described a prop-root community from Marco Island that lies south of the Springs Coast region. Typical species include *Crassostrea virginica*, *Littorina angulifera*, *Crepidula plana*, *Urosalpinx perrugata*, *Brachidontes exustus*, and numerous polychaete and decapod species; and, in the intertidal sediments near the mangrove forests, the fiddler crabs *Uca pugilator*, *Uca speciosa*, and *Uca thayeri*.

The mangrove system is a nursery for the Florida spiny lobster *Panulirus argus*. Juveniles are especially abundant within the prop-root system. The puerulus larvae of spiny lobsters apparently settle in macroalgae clumps, particularly Rhodophyta. When they outgrow these habitats they migrate to the mangrove-root mazes and spend a majority of their juvenile life there. The roots provide protection and food.

The different mangrove communities (e.g., basin mangrove and riverine mangrove forests) contain distinct fish assemblages (Odum et al. 1982). Common permanent resident species found throughout most of these habitats are killifish such as *Fundulus* *confluentus* and poecillids such as *Poecilia latipinna* and *Gambusia affinis*. Pinfish, silver perch, pigfish, and anchovies are very abundant. Also present are numerous piscivorous fish such as snook, ladyfish, tarpon, gars, and mangrove snappers.

Amphibians and reptiles are also part of the mangrove ecosystem. Common freshwater species (see Chapter 5) are found in the headwaters that enter the forest. All four species of marine turtles found along the west coast of Florida are associated with the mangrove system during some part of their life cycles. Three species of lizards from the genus *Anolis* are reported from mangroves: the green anole, the Cuban brown anole, and the Bahamian bank anole. The American alligator is also a relatively common member of the Springs Coast mangrove community.

Mangroves harbor a diverse bird assemblage (see Odum et al. 1982 for summary). As with the invertebrate fauna, the structural complexity of the forest provides a wide range of possible habitats for birds. The availability of the trunks, limbs, and foliage offers passerine and nonpasserine birds a surface to feed and live upon. Odum et al. (1982) divided the mangrove bird assemblage into six groups based upon similarities in feeding method. Wading birds such as herons, egrets, ibises, bitterns, and spoonbills and are the most conspicuous group. Probing shorebirds are represented by clapper rails, willets, and black-necked stilts. Floating and diving birds include ducks, grebes, loons, cormorants, and gallinules. Aerially searching birds include gulls, terns, kingfishers, black skimmers, and the fish crow. Birds of prey that utilize the forest include hawks, falcons, vultures, and owls. Arboreal birds are the largest and most diverse group and include pigeons, cuckoos, woodpeckers, flycatchers, thrushes, vireos, warblers, blackbirds, and sparrows.

j. Natural impacts.

(1) Fires have an important influence on mangrove succession (Ball 1980; Taylor 1980; Odum et al. 1982). Most fires in Springs Coast mangrove stands are started by lightning and result in small circular openings in the forest canopy. These can be sites of secondary succession within the forest. Fire may limit the inland spread of mangroves (Taylor 1981).

(2) Storms (e.g., hurricanes) can damage mangrove forests in three general ways:

- (a) wind shearing of trunks;
- (b) overwash mangrove islands swept away;
- (c) trees dying months after the storm in response to prop-root damage caused by the coating of fine organic matter and sediments.

(3) Wood borers. The isopod *Sphaeroma terebrans* burrows into living roots, especially in the southern regions of the Springs Coast area. The organism is capable of nearly severing roots, and coupled with storms, can be responsible for the demise of entire trees.

(4) Cold stress is particularly important to the northernmost mangrove forests.

k. Human impacts.

(1) Direct destruction by cutting or removal of trees for development.

(2) Land filling, road construction, and diking/impounding.

(3) Herbicides. In general, mangroves are very sensitive to defoliation by herbicides. Red mangrove species are the most sensitive. Once defoliated, the forests are very slow to regenerate.

(4) Petroleum is extremely harmful to mangroves (Table 12). It injures and kills mangroves in several ways:

- (a) by coating roots, rhizomes, and pneumatophores and therefore impeding oxygen transport to the underground roots;
- (b) by being absorbed by the surface of the mangroves, which in turn, alters metabolic functions;
- (c) by affecting all the associated flora and fauna, which are highly sensitive to petroleum pollution.

It can be years before the most severe responses to the impacts are felt. Seedlings and pneumatophores are very sensitive.

(5) Freshwater runoff alteration causes an increase in salinity in estuaries, with associated flora and fauna changes. Impact by the boring isopod *Sphaeroma terebrans* may increase.

Table 12. General response of a mangrove ecosystem to severe oil spills (Odum et al. 1982).

Stage	Observed impact
Acute	
0 to 15 days	Deaths of birds, turtles, fishes, and invertebrates
15 to 30 days	Defoliation and death of small mangroves, loss of aerial root community
Chronic	
30 days to 1 year	Defoliation and death of medium-sized mangroves (1-3 m), tissue damage to aerial roots
1 year to 5 year	Death of large mangroves (greater than 3 m), loss of oiled aerial roots, and regrowth of new roots (often deformed)
1 year to ~10 years	Reduction in litter fall, reduced reproduction, and reduced survival of seedlings
	Possible death or reduced growth of young trees colonizing spill site
	Possible increased insect damage
~10 to ~50 years	Complete recovery

6.2.6 Marine Algae

a. General. Marine macroalgae are present in all of the habitat types, both intertidal and subtidal, described from the Springs Coast. Accordingly, species that are unique to those areas are discussed within the appropriate sections. There are, however, algal habitats (attached and drifting) that form unique environments harboring distinct animal communities.

There are five major phyla of algae present along the Springs Coast: (1) Cyanophyta—blue-greens, (2) Rhodophyta—reds, (3) Phaeophyta—browns, (4) Chlorophyta—greens, and (5) Chrysophyta—golden browns. The Springs Coast algae are generally considered an impoverished and undiverse group in comparison to more tropical communities just to the south (e.g., Tampa Bay and Florida Bay) (Taylor 1965). The flora as a whole is considered warm temperate with many eurythermal tropical species represented.

b. Major algal species present. Red and brown algal abundances are usually limited by the availability of a hard substrate for attachment such as oyster shells or rock. One major group of green 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*, and *Udotea*.

Several investigators have published algal species lists from regions within the Springs Coast (e.g., Taylor 1954; Phillips 1960b; Humm and Taylor 1961; Earle 1969; Humm 1973; Mangrove Systems, Inc. 1986; Sprinkel 1986). Appendix Table AG gives a composite of the most common species encountered throughout the region.

Humm (1973) reported that the following genera in the Springs Coast region were generally restricted to more open gulf waters: the reds, *Euchema* and *Halymenia*, and the greens, *Caulerpa*, *Codium*, *Halimeda*, *Penicillus*, and *Udotea*. The following red algal genera are euryhaline and most common in the estuaries and inshore areas of the Springs Coast region that are subject to periodic salinity fluctuations: *Chondria*, *Digenia*, *Jania*, *Laurencia*, *Neoagardhiella*, *Polysiphonia*, and *Spyridia*. The brown alga *Sargassum pteropleuron* is most tolerant of varying environmental parameters in the Springs Coast region. The brown alga *Padina vickersiae* was found epiphytic on the red alga *Digenia simplex* and was present only during the summer months when salinities were high and color and turbidities were low.

Mangrove Systems, Inc. (1986) reported the algal species present in the inshore areas of the Withlacoochee to Aripeka rivers of the Springs Coast region. The green algae *Caulerpa prolifera, Caulerpa paspaloides,* and *Udotea conglutinata* were periodically abundant during the sampling period (in terms of biomass). Rhizophytic algal species demonstrated the highest biomass at the offshore sampling stations, while drift algal abundances were variable with no clear trends present. The green algal genera *Caulerpa, Halimeda,* and *Udotea* were reported to be pioneer species in disturbed regions in the Springs Coast area.

Phillips (1960b) reported 46 algae species present in the Crystal Bay region: 5 blue-green, 7 green, 8 brown, and 26 red species. Twenty five of the species were epiphytes. Many of the species were characteristic of Caribbean tropical-zone flora. The "kelp grass" *Sargassum pteropleuron* was a characteristic, persistent species of the region that was commonly found attached to oyster shell debris scattered on the bottom. Other dominants included *Caulerpa prolifera, Caulerpa paspaloides typica, Gracilaria verrucosa, Polysiphonia echinata, Polysiphonia ramentacea,* and *Rosenvingea intricata.*

Steidinger and Van Breedveld (1971) reported 106 species of marine algae in the Crystal River region in a more intense sampling program. There were 19 species of green algae, 24 species of brown algae, and 63 species of red algae. Wintertime was the season of the lowest species diversity.

Mathieson and Dawes (1975) found that the species diversity of algae changed over the course of a year at Homosassa. Peaks in diversity occurred during the winter and spring months. The peaks were believed to be correlated with high nutrient availability and low temperatures during these months. A total of 68 species were reported from their site. Because of large fluctuations in temperature and salinity, fewer perennial and tropical species were found compared with sites further south.

In intertidal regions, the filamentous blue-green alga *Calothrix crustacea* is broadly distributed on many substrates. It appears as a black band that is often mistaken for an oil stain on seawalls and pilings. It is also present on the basal portion of salt-marsh grasses. Several species of red algae are present below the *Calothrix* band: *Bostrychia, Caloglossa, Catenella,* and *Murrayella.* The green alga *Enteromorpha* is also conspicuous in the intertidal.

In general, the Springs Coast region contains fewer algal species than warmer areas to the south. The phylum having the most species is Rhodophyta (the red algae), which is an abundant drift form. The green algae are typically present in the highest biomass throughout the region. A definite seasonality is observed in most species, with the summer months seeing the highest densities and diversities.

c. Associated fauna. The organisms present in the drifting red algal clumps of the Springs Coast region have been the most thoroughly examined. Hooks et al. (1976) give an overview of such a fauna from the Apalachee Bay region to the north. Generally, the clumps contained a large abundance of organisms that are often cryptic and not easily detectable. The algae act both as an attachment surface for sessile forms and a refuge for free-living organisms. Ophiuroids (brittle stars) are present in large numbers. In addition, large numbers of the Florida grass shrimp *Palaemon floridanus* and the hermit crab *Pagurus bonairensis* are present. Caprellid amphipods and phytal harpacticoid copepods are also extremely abundant, and early juveniles of the spiny lobster *Panulirus argus* are found. These clumps of algae have proven to be the primary habitat for newly settled spiny lobster postlarvae and for the early juveniles (Marx and Herrnkind 1985). The algae provides protection from predation for most of these forms.

d. Natural impacts. Severe salinity and temperature fluctuations and grazing by herbivores are the major natural impacts on benthic microalgae.

e. Human impacts. Steidinger and Van Breedveld (1971) reported the effects of the Crystal River Power

Plant on benthic marine macroalgae. Generally, the temperature elevations did not appear to cause significant alterations in the algae communities. However, siltation from dredging operations in the immediate area, with heavy particulate loads and alterations of substrates, were postulated to have effects.

6.2.7 Open Water

a. General. 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 it exhibits. Much of the patchiness is due to a myriad of physical factors such as local salinity and temperature 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 includes 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 squamatus*) 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.

Open water proves one of the most difficult habitats 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 has been 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 Springs Coast have been described by Grice (1957, 1960), and species amenable to capture by trawl or seine formed part of a SWFWMD study (Phillips 1986). Because of the tremendous diversity of the habitat and the paucity of local data, only dominant species are discussed.

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 Springs Coast estuaries (Steidinger 1973). Many of the estuarine phytoplankton—*Skeletonema costatum*, *Chaetoceros* spp., and *Gonyaulax* spp., among others—form resting spores or cysts and are considered meroplanktonic because a portion of their life is spent on the estuarine floor.

Appendix Table AH lists common fish species found in the water column in Springs Coast estuaries. Table 13 lists those species found in greatest abundance during each of two sampling years. Manatees are often found within the estuaries, as well as in nearby brackish and freshwater areas (Moore 1951; Husar 1977; Irvine and Campbell 1978; Irvine et al. 1981; Powell and Rathbun 1984).

c. Recreationally and commercially important species. The Springs Coast estuarine open-water habitat contains numerous species that are of

Table 13. Most abundant fish and invertebrates trawled from sampling stations in Springs Coast estuaries (Phillips 1986).

1984		*1985*	
Species	**No. captured**	**Species**	**No. captured**
Menidia sp.	1433	*Penaeus duorarum*	816
Eucinostomus sp.	888	*Anchoa mitchilli*	719
Anchoa mitchilli	740	*Menidia* sp.	665
Cyprinodon variegatus	374	*Eucinostomus* sp.	428
Fundulus similis	257	*Cynoscion arenarius*	321
Penaeus duorarum	212	*Diapterus plumieri*	258
Elops saurus	157	*Bairdiella chrysoura*	217
Arius felis	138	*Arius felis*	102
Melongena corona	86	*Fundulus similis*	93
Bagre marinus	81	*Floridichthys carpio*	50
Floridichthys carpio	64	*Cyprinodon variegatus*	49
Fundulus grandis	62	*Melongena corona*	47
Brevoortia smithi	53	*Trachypenaeus constrictus*	44
Bairdiella chrysoura	38	*Bagre marinus*	41
Cynoscion arenarius	38	*Callinectes sapidus*	35

commercial and recreational importance (Mathis et al. 1978). 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*), ladyfish (*Elops saurus*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), silver perch (*Bairdiella chrysoura*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), southern kingfish (*Menticirrhus americanus*), gulf menhaden (*Brevoortia patronus*), striped mullet (*Mugil cephalus*), and sheepshead (*Archosargus probatocephalus*). Descriptions of the most important species follow.

(1) Striped mullet. The striped mullet 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 Springs Coast 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 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 Springs Coast. Highest landings are generally recorded in the fall and early winter. Recreational fishermen generally find shrimp, the Atlantic brief squid (*Lolliguncula brevis*), 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, commercial and recreational take of red drum in Florida is restricted and the regulations in effect should be checked.

(3) Spotted seatrout. The spotted seatrout is a nonmigratory euryhaline estuarine species that is most abundant in the confines of semi-landlocked lagoons and quiet estuaries. It has a protracted spring and summer spawning season that peaks in late 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 shorter than 30 mm. Larger crustaceans are important prey for fish shorter than approximately 300 mm. Larger specimens predominantly eat fish.

Recreational spotted-seatrout fishing includes bridge, skiff, and shoreline fishing. Live bait, including shrimp, sailors choice, pinfish, mullet, and Atlantic needlefish (*Strongylura marina*), is generally used as are lures. Seatrout fishing usually is a year-round activity in the Springs Coast, this species being 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.

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 Springs Coast. 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 Springs Coast waters. Both species feed primarily on zooplankton such as calanoid copepods, mysids, and cladocerans (Sheridan 1978).

d. Species of special concern. Two species of turtle are occasionally present in the Springs Coast estuaries: the Atlantic loggerhead *Caretta caretta* and Atlantic leatherback *Dermochelys coriacea* (Huff et al 1981).

e. Natural impacts. Red-tide outbreaks occasionally occur within estuarine waters in the Springs Coast. The primary components are dinoflagellates, especially *Ptychodiscus brevis* (formerly *Gymnodinium breve*) and *Gonyaulax monilata*. In addition, storms and localized temperature and salinity fluctuations affect the water column organisms.

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, and pulp-mill effluent.

6.2.8 Subtidal Soft Bottoms

a. Introduction. Subtidal unconsolidated bottom environments (e.g., mud and sand) form an extensive habitat area in the Springs Coast estuarine system. 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 high turbidity and poor visibility often encountered.

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, myriad 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. 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. 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.

b. Physical description. Unvegetated soft-bottom environments in the Springs Coast are generally made up of quartz sand, fine silt, and biologically derived carbonates. 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 high may be present for a few days. Culter (1986) examined sediment grain-size distribution at 17 locations along the Springs Coast. All stations were associated with a spring-fed or river estuary, and stations were arrayed from inside the stream channel out to the Gulf. The presence of oyster-shell material was found to be a major influence on the physical structure of sediments outside the Waccasassa, Withlacoochee, and Crystal Rivers. The sediments in the Weeki Wachee and Hammock Creek estuaries were found to be much more uniform, consisting primarily of clean quartz sands.

c. Distribution. Because of the shallow waters and generally nonalluvial character of Springs Coast rivers, much of the bottom area of the bays and estuaries is vegetated. Unvegetated soft bottoms cover are found primarily between oyster bars and grass beds and at the mouths of the rivers, particularly the surface-draining (and therefore more highly colored) Waccasassa, Withlacoochee, and Pithlachascotee Rivers.

d. Faunal composition. The organisms of 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., blue crab—*Callinectes sapidus* and spider crabs—*Libinia* spp.), various gastropods, benthic fish, and skates and rays (Appendix Tables AI and AJ). 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.

Culter (1986) examined benthic infaunal communities along salinity gradients in four estuaries located between Aripeka and the Waccasassa River. Appendix Table AK lists the insects, oligochaetes, and leeches found during the study. Generally, species richness and diversity were highest at the most offshore stations. Polychaetes were the dominant group at the offshore stations (Appendix Table AL), while oligochaetes and chironomids were abundant at most upstream river stations that only occasionally experienced brackish conditions (Appendix Table AM). Intermediate mesohaline stations supported large populations of microcrustaceans, particularly amphipods (Appendix Table AN). 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.

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. 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.

(2) Northern quahog (*Mercenaria mercenaria*) and sunray venus (*Macrocallista nimbosa*). Both clam species are found in the estuaries and nearshore coastal waters of the Springs Coast from the mean high tide level to 15-m depth, with highest abundances on shallow flats. The Florida Department of Natural Resources searched along the Florida gulf coast for beds containing commercial quantities of sunray venus clams (Jolley 1972). The Cedar Keys area in the vicinity of Seahorse Reef yielded some of the highest concentrations found.

(3) Blue crab (*Callinectes sapidus*). Juvenile blue crabs are commonly found in shallow seagrass beds (Oesterling 1976b). 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 Springs Coast, but they must be 7.7 cm across the carapace and females must not be egg bearing.

f. Human impacts. The effects of human activity on soft-bottom communities has not been extensively studied within the Springs Coast.

The most important human influences on soft-bottom communities are dredging, boat traffic, petroleum pollution, and toxic substances such as pesticides. Disturbances from boat traffic are not documented for the Springs Coast and probably represent only localized impacts.

6.2.9 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 (Williams 1984; Iverson and Bittaker 1986). The importance of this habitat to the region is reflected in the State's designation of the grass beds of the Florida Big Bend (including those around the Cedar Keys) as the Big Bend Seagrasses Aquatic Preserve. Unfortunately, the dense seagrass beds found along the rest of Springs Coast were not included in this preserve, though some are already protected (e.g., St. Martins Marsh Aquatic Preserve and Chassahowitzka National Wildlife Refuge in Citrus County).

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 (Fig. 93). The combination of shelter and food makes seagrass meadows one of the richest and most critically important nursery grounds in Florida Springs Coast coastal waters.

Two types of food webs are associated with seagrass communities: (1) a "grazing" food-chain

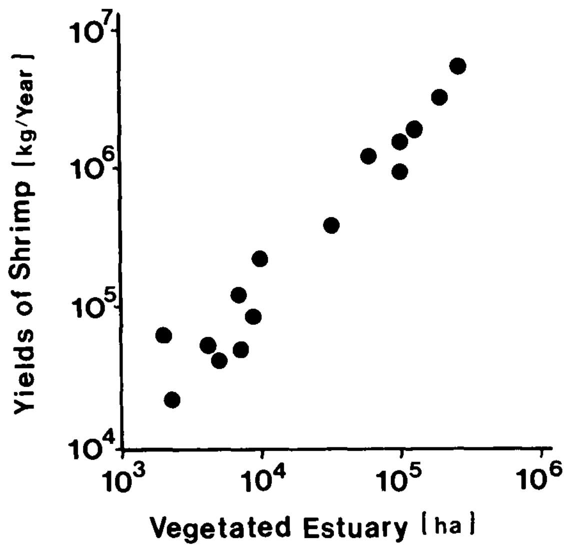


Figure 93. Yield of penaeid shrimp and vegetation coverage in an estuary (after Turner 1977).

component composed 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 composed of herbivores that feed on dead material, together with their associated predators. Only a few species of animals in the Springs Coast 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).

Seagrasses function in many critical roles in the coastal environment. Among the most important are:

(1) serving as a sediment trap and stabilizer of bottom sediments;

(2) contributing 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 sometimes termed meadows. Like many terrestrial systems, the seagrass meadow is defined by a visible boundary grading from an unvegetated to vegetated substrate. Meadows can be composed of a single species (usually turtlegrass, *Thalassia testudinum*) or multiple species (*Thalassia*, shoalgrass (*Halodule*), and manateegrass (*Syringodium*) are commonly found together).

Along the Springs Coast, with only a few isolated breaks in coverage, seagrasses form essentially one bed extending from the north to the open-sand areas along the southern-most reaches (Figs. 94 and 95). Where grasses are present, bottom coverage averages 80% (Iverson and Bittaker 1986).

The seagrasses of the Springs Coast region have remained relatively stable over time partly because of the extensive, undisturbed tidal marshes and swamps of the adjacent shoreline that act as natural filters for sediment carried from upland sources. This region and the Big Bend coast to the north are one of the least perturbed and most pristine areas in the entire Gulf. The inshore marsh systems are partly a result of the same conditions leading to the extensive grass beds (i.e., a low-energy, shallow coastline). However, the success of the subtidal seagrass beds is enhanced by the protective filtering of the marshes and may stand as an example for the preservation of coastal habitats in other regions.

b. Seagrass species present. Of the approximately 50 recognized species of seagrasses worldwide, 5 are present in the Springs Coast region, the most common 4 of which are depicted in Fig. 96. Iverson and Bittaker (1986) give the following descriptions.

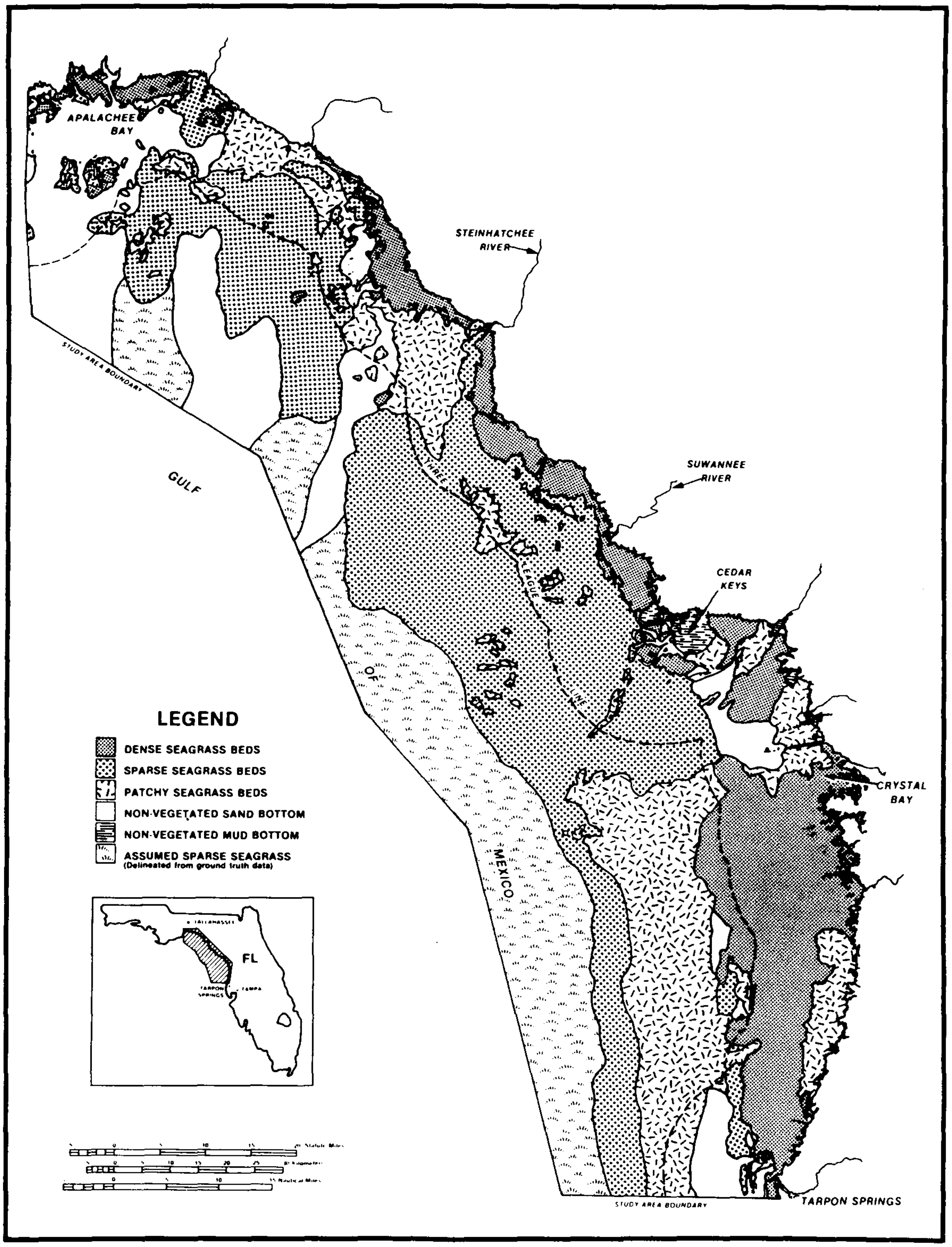


Figure 94. Location of grassbeds along the Florida Big Bend and Springs Coast (after Continental Shelf Associates, Inc. and Martel Laboratories, Inc. 1985).

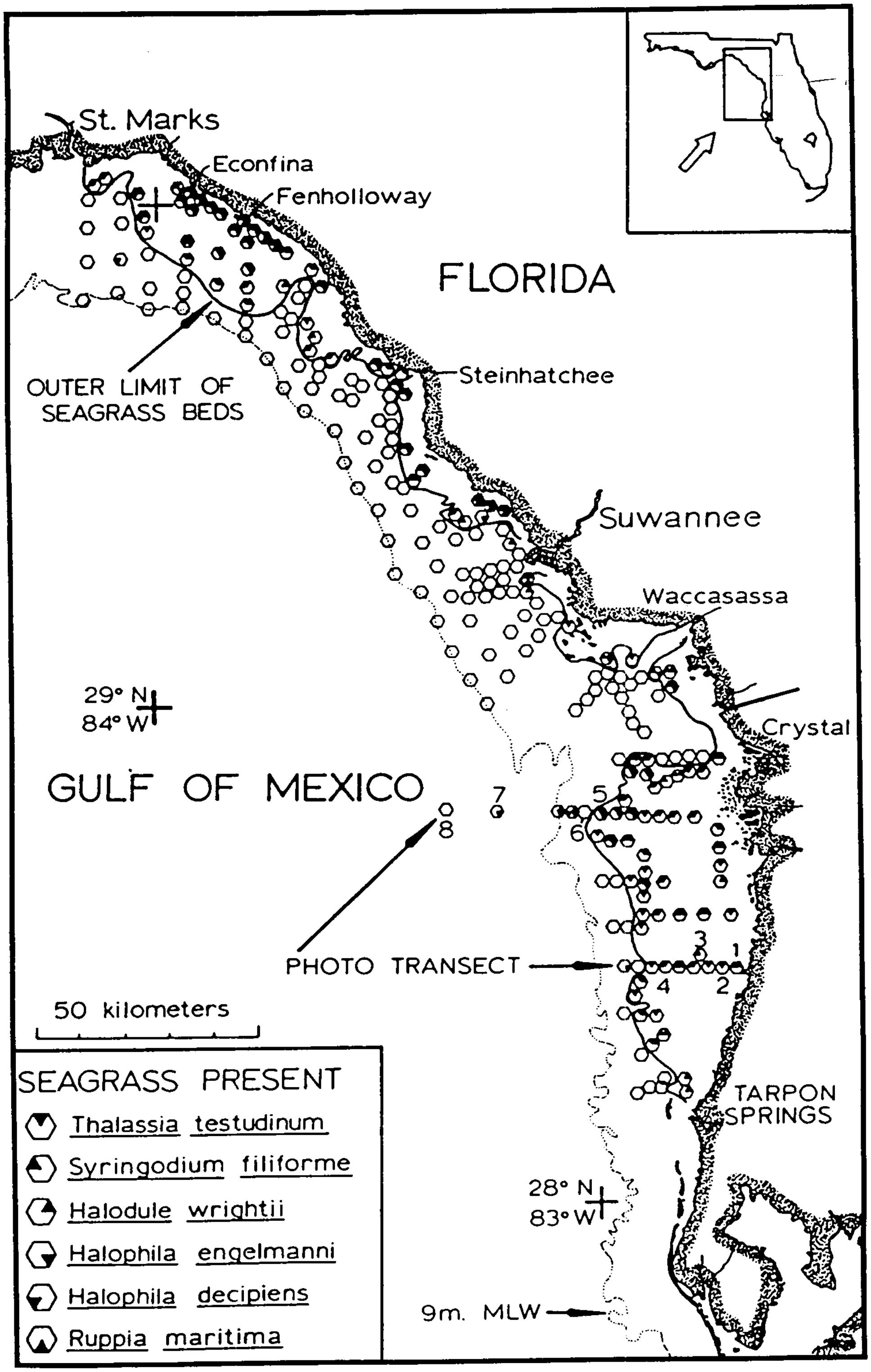


Figure 95. Composition of grassbeds along the Florida Big Bend and Springs Coast (Iverson and Bittaker 1986).

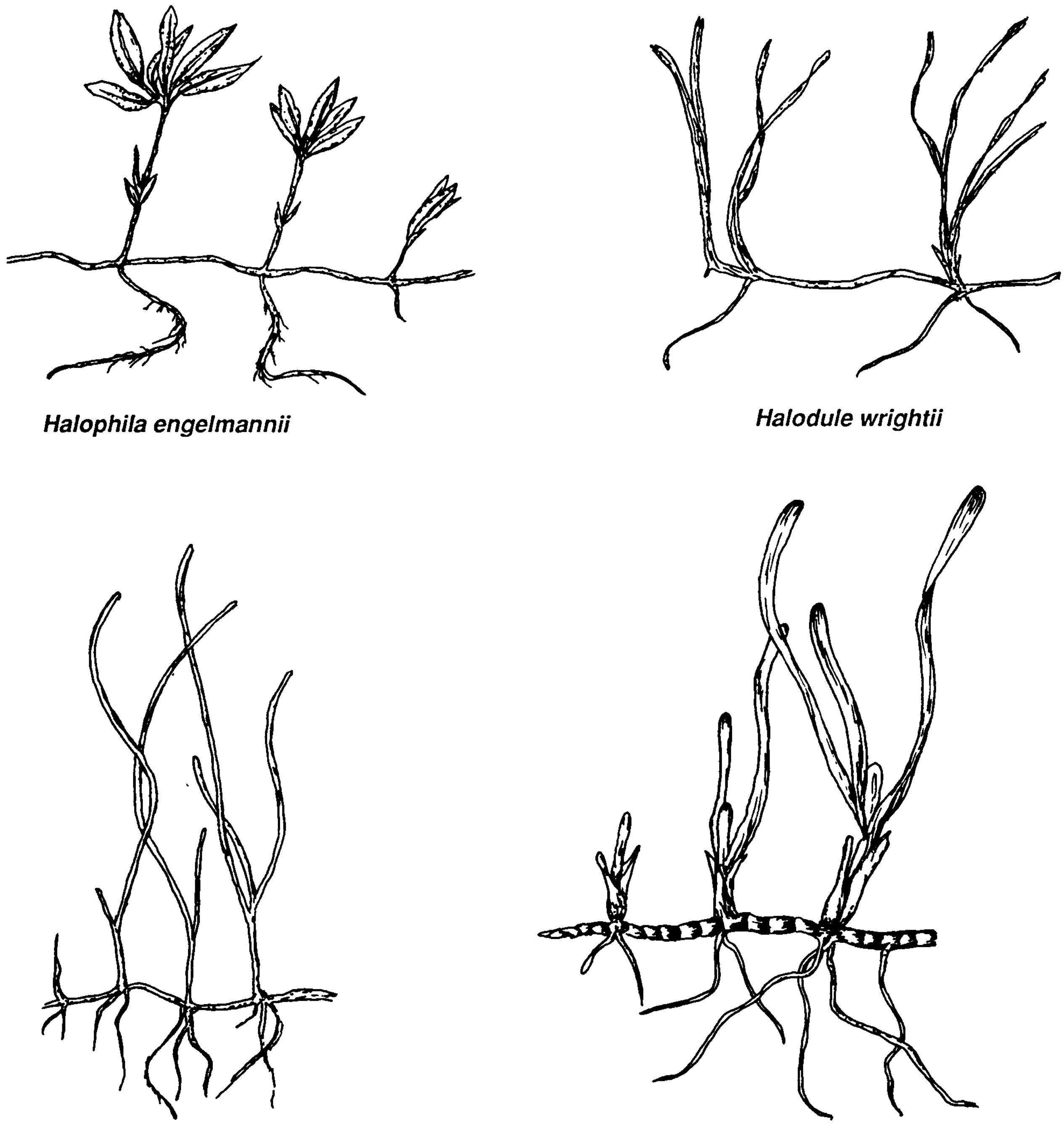


Figure 96. Four common seagrass species present in Springs Coast waters (after Zieman 1982).

1) *Thalassia testudinum*, turtlegrass, is the largest of the five species. Its leaves are ribbon-like, up to 14 mm wide, and reach a maximum length of approximately 75 cm. Leaf tips are rounded. There are 2–5 leaves present per shoot (Fig. 97). Rhizomes reach 1 cm in diameter and extend up to 10 cm below the sediment surface. The roots can extend several meters into the sediment. It is most abundant in 1–4 m of water, with maximum densities in 1- to 2-m depths (Fig. 98). Typically, it is the dominating bed-forming (meadow) seagrass species. It usually colonizes the coarsest grained sediments.

2) *Syringodium filiforme*, manateegrass, has leaves that are circular in cross-section and can grow 75 cm long. It commonly has 2–4 leaves per shoot. Leaf diameters average several millimeters. The rhizomes are several millimeters in diameter and are located within the top several centimeters of the sediment. They are not as robust or deep growing as *Thalassia*. Roots extend approximately 10 cm into the sediment. It inhabits the same water-depth range as *Thalassia*, but its maximum biomass is located deeper (Fig. 99). It is commonly found mixed with other seagrasses and rarely forms extensive monospecific beds like *Thalassia*. Generally, *Syringodium* is found in widely varying sediment types.

3) *Halodule wrightii* (=*Diplanthera wrightii*), shoalgrass, is an important early colonizer of disturbed sediments. In the Springs Coast region, two morphotypes are recognized: (1) a shallow-water form—portions of the leaves are often exposed at low tide, leaves are typically short (5–20 cm) and narrow (0.5–1.0 mm); and (2) a deep-water form—generally longer (20–40 cm), wider leaves (1–3 mm). The leaves are flat with two or three small points at the tips. It occasionally forms the innermost and outermost (depth-wise) monotypic seagrass stands. Biomass versus water depth is given in Fig. 99. It cannot tolerate salinities lower than 3.5 ppt (McMahan 1968). It is found in widely varying sediment types.

4) *Halophila engelmannii* is a sciophilous ("shade-loving") species that is often intermixed with *Thalassia, Syringodium*, and occasionally *Halodule*. It is also abundant outside main beds to depths of at least 20 m, where it can occur in monotypic stands. Populations are usually present in sediments with a mean phi size greater than 2.5 which reflects its preference for low-energy areas.

5) *Halophila decipiens* is a deep-water form. It is not very abundant, but typically occurs in small monotypic stands or is mixed with sparse *Halodule* distributions and the alga *Caulerpa* in areas deeper than 5 m.

Of the five species, the first three are the most common in the Springs Coast. In addition, *Thalassia* and *Syringodium* comprise the majority of seagrass leaf biomass. Their combined biomass is approximately 84% of the total (*Thalassia*, 58% and *Syringodium*, 26%) with *Halodule wrightii* comprising the remainder (Iverson and Bittaker 1986).

Two distinct seagrass associations, separated by a stretch of unvegetated sand, may be present on the shelf: an inshore one consisting of *Thalassia testudinum, Syringodium filiforme*, and *Halodule wrightii* (generally in less than 9 m of water) and an offshore one characterized by overlapping mixtures of algae, seagrass, and live-bottoms (e.g., hard substrates such as algal nodules and rocky outcroppings). *Halophila decipiens* and *H. engelmannii* are the only vascular plant species present (Continental Shelf Associates, Inc. and Martel Laboratories, Inc. 1985).

c. Seasonality. The biomass of Springs Coast seagrasses displays a distinct seasonality (Fig. 100). Contrary to outward appearances, the seagrasses grow year round in the region, but at a much reduced rate in winter. In the winter, the plants lose their leaves. Generally, highest growth rates occur between April and November (Dawes and Lawrence 1980). For example, *Thalassia testudinum* leaf biomass reaches a seasonal maximum during August. New short-shoot production occurs during the spring and summer but not during late fall and winter (Phillips 1960a; Iverson and Bittaker 1986). From quarterly sampling over two years, Mangrove Systems (1986) found seagrass standing crop was highest during summer and fall at inshore locations near the Weeki Wachee, Crystal, and Withlacoochee Rivers and Hammock Creek.

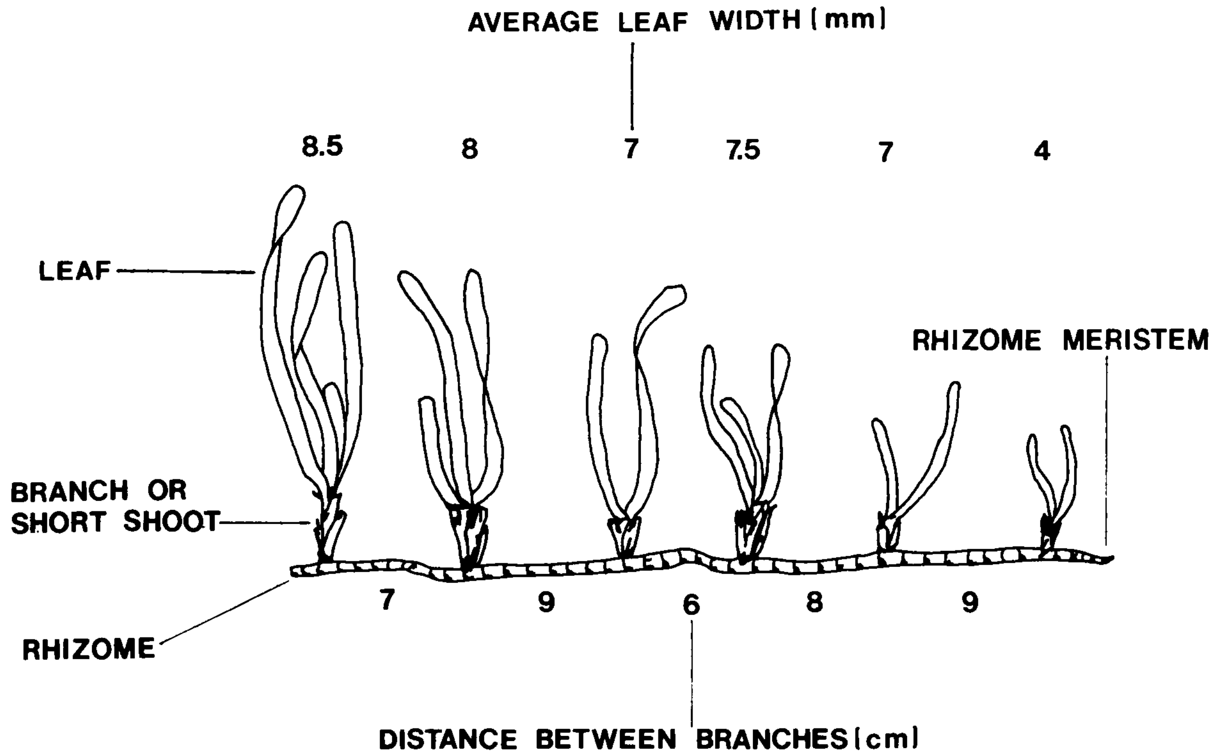


Figure 97. A typical *Thalassia* shoot, showing oldest leaves to left and new growth on right (after Zieman 1982).

d. Species succession. Seagrass beds in the Springs Coast 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 (Figs. 101 and 102). 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 on 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; 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 seagrasses along the Florida Big Bend and Springs Coast essentially form one extensive inshore bed that covers approximately 3,032 km^2 (Iverson and Bittaker 1986). They occur in an offshore band 10–35 km wide between St. Marks and Tarpon Springs. Iverson and Bittaker (1986) give a demarcation line to the grassbed. Within their boundary, the bottom is at least 80% covered with seagrasses. Grasses, primarily monotypic stands of *Halophila engelmannii*, are present to depths of at least 20 m.

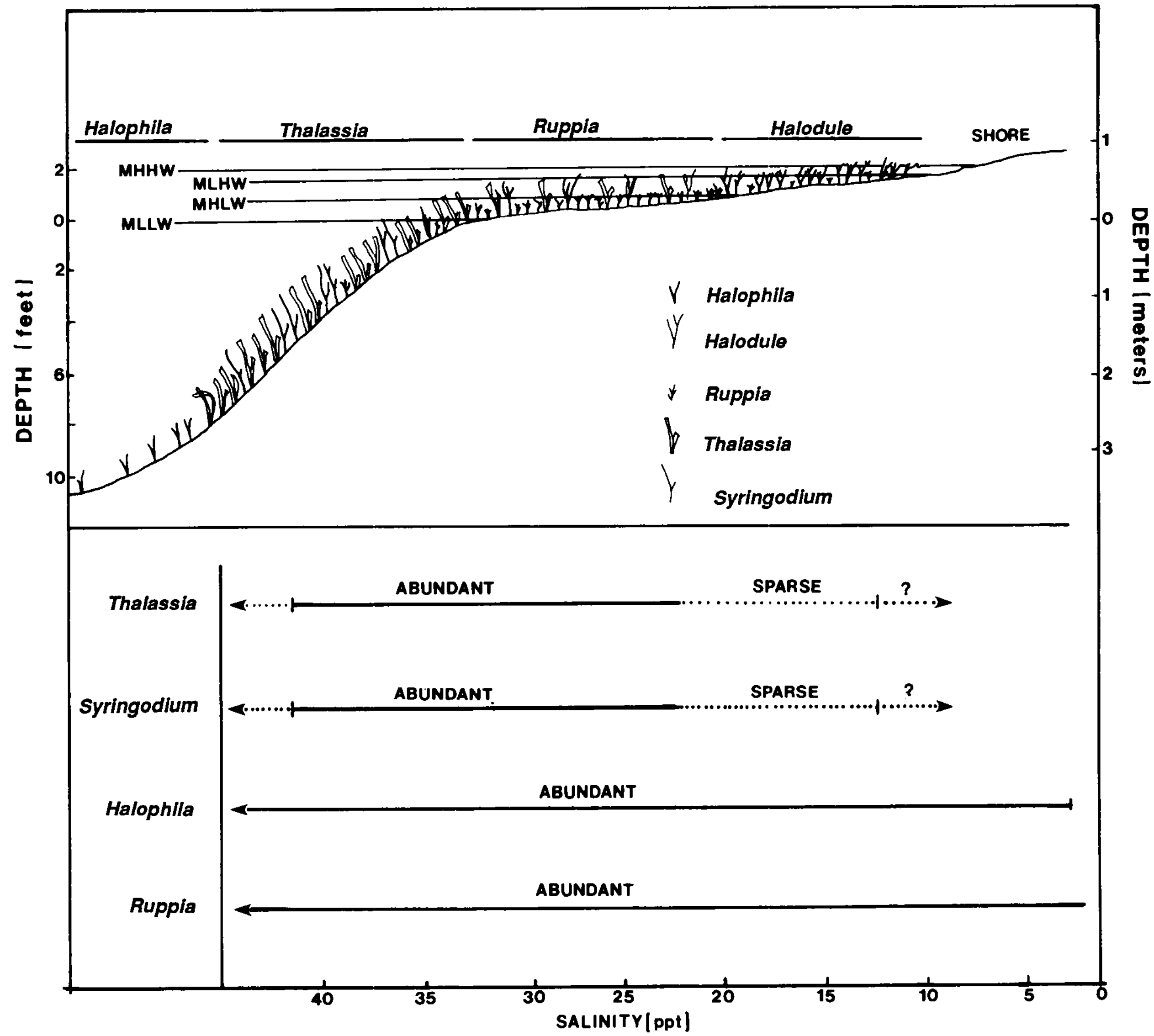


Figure 98. Typical depth distributions of three seagrass species and a common brackish species *Ruppia maritima* (after McNulty et al. 1972).

Seagrass distribution along the Springs Coast may be dependent upon salinity (Phillips 1960a, 1960b), and the nearshore configuration and species composition of beds near the river mouths reflect the influence of the freshwater discharge. The major bed-forming species, *Thalassia* and *Syringodium*, do not grow in these low-salinity areas where values fall below 17 ppt. *Halodule wrightii* does not tolerate salinities lower than 3.5 ppt. Mangrove Systems (1986) monitored seagrass populations in estuaries associated with the Weeki Wachee, Crystal, and Withlacoochee rivers. At each of these systems, a distinct gradient in species composition was found between plant communities near the river mouths and communities offshore. Assemblages near the river mouths were dominated by *Ruppia maritima*, and brackish-tolerant freshwater species such as *Vallisneria neotropicalis* and *Myriophyllum spicatum* were also

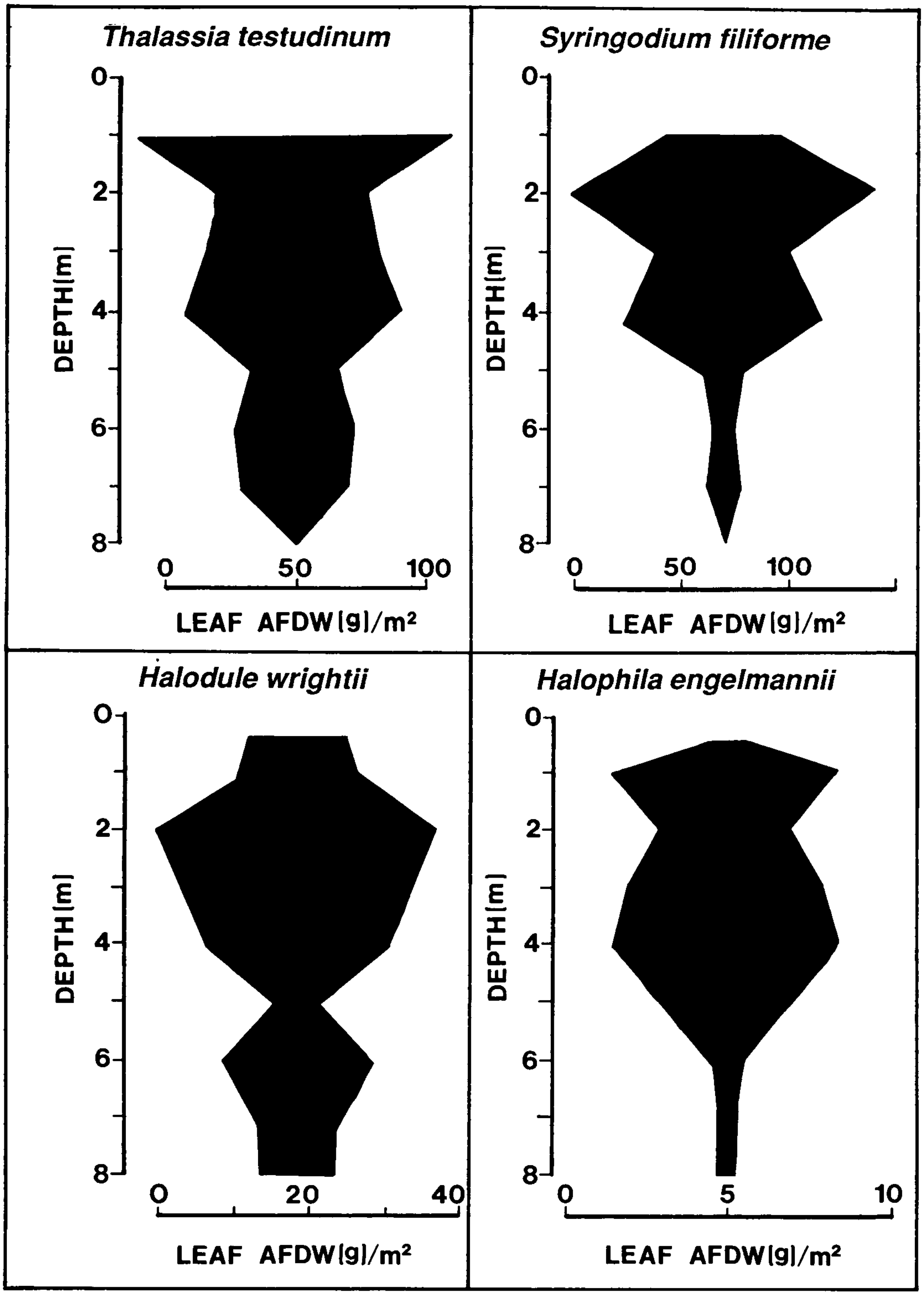


Figure 99. Biomass versus water depth for four seagrasses (data from Iverson and Bittaker 1986).

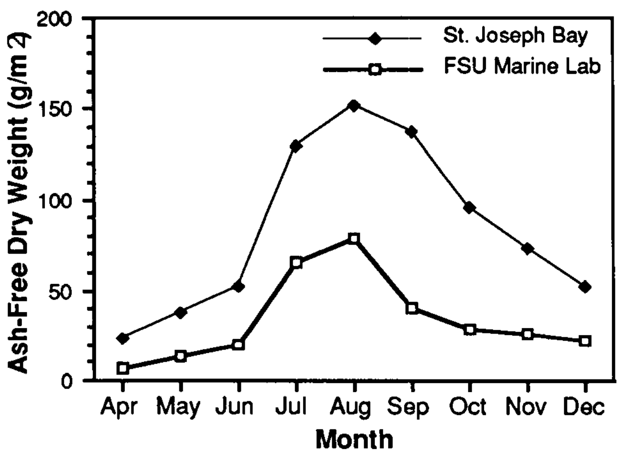


Figure 100. Seasonal cycle of *Thalassia testudinum* leaf ash-free dry weight from stations at two locations (after Iverson and Bittaker 1986).

found. Intermediate stations had the greatest species diversity, with *Halodule wrightii* and *Thalassia testudinum* becoming more abundant. It was noted that many *Thalassia* plants appeared stressed, possibly due to low salinity. *Syringodium filiforme* was found in its greatest abundance at the most offshore stations. Overall, seagrass standing crop was highest for the Weeki Wachee estuary and lowest for the Withlacoochee, indicating that excellent water clarity in the spring-fed system may be responsible for the higher seagrass biomass found there. Also, seagrass distributions were least patchy for the Weeki Wachee estuary where the bottom morphology is relatively smooth, while grassbeds at the Crystal and Withlacoochee estuaries were intermixed with shoals and bars.

f. Depth distribution. Throughout the Springs Coast region, *Thalassia* ranges to about 7.5 m in depth with leaf biomass maximum between 0 and 2 m. *Syringodium* ranges to a depth of about 7 m. Leaf biomass reaches a maximum at middepth ranges. *Halodule* is the only Springs Coast seagrass species capable of withstanding air exposure during low tides. As such, it is the most common species on shoals such as those around Cedar Key (Humm and Taylor 1961). In addition, the leaf biomass of *Halodule* is more variable with depth.

The maximum depth distribution of the Springs Coast seagrasses north of the Crystal River is less than that of more southern beds. The river runoff north of Crystal River is colored by organic compounds that increase the extinction coefficients in the area (Bittaker 1975; Zimmerman and Livingston 1979). The average depths to which 10% of sea surface light penetrates is 7 m between Crystal River and Tarpon Springs and 4.5 m north of Crystal River (Iverson and Bittaker 1986). In contrast, an average value for Florida Bay is 9 m (Iverson and Bittaker 1986). It appears that light energy may be the most important factor controlling the depth distribution of seagrasses in the Springs Coast region.

g. Epiphytic algae. Seagrasses provide a solid substrate for the attachment of a diverse assemblage

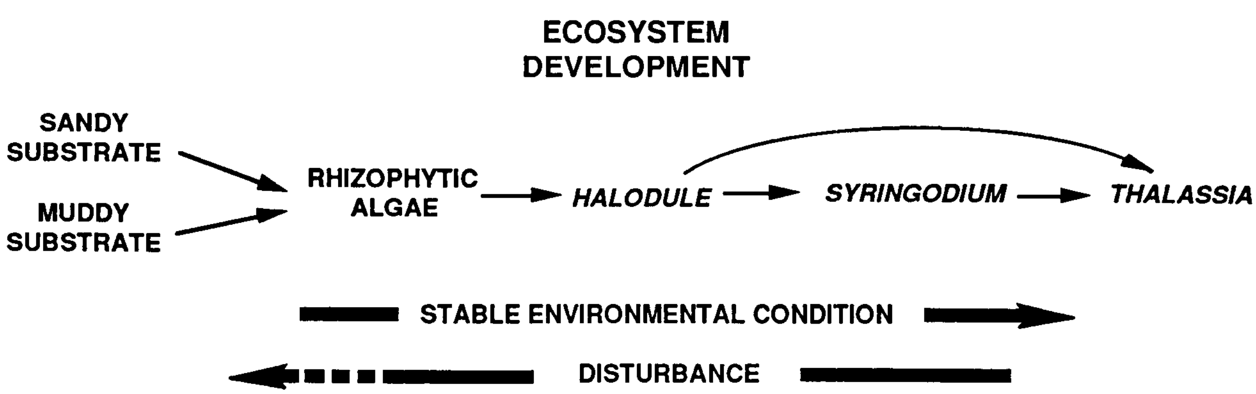


Figure 101. Ecosystem development in seagrasses. Without disturbance, a *Thalassia* climax is reached (after Zieman 1982).

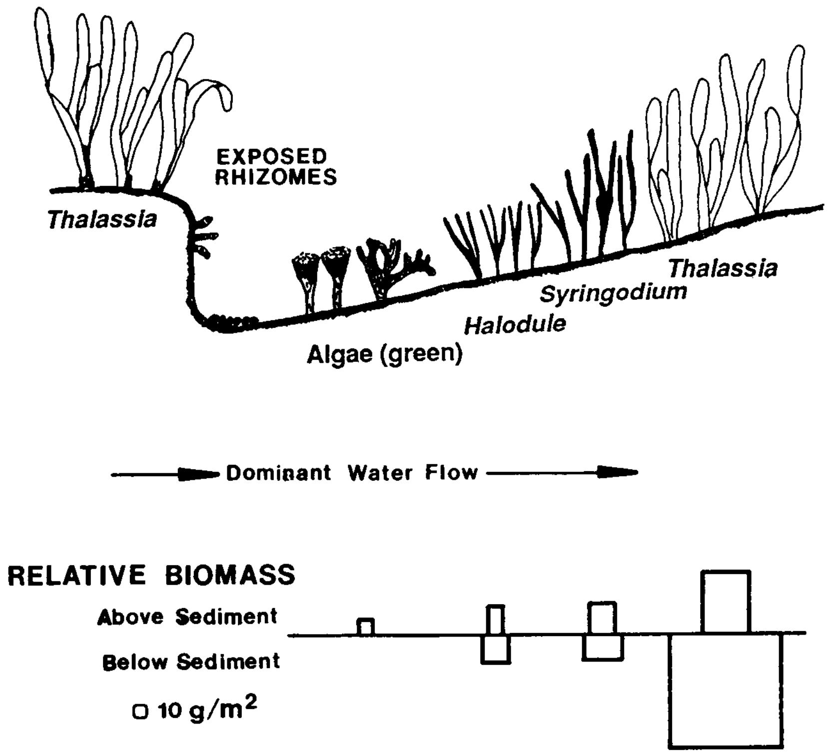


Figure 102. Idealized sequence of seagrass recolonization and growth after a large disturbance (after Zieman 1982).

of algae. The algae are an important food resource for many of the herbivores, as well as an additional source of primary productivity in the seagrass ecosystem. Ballantine and Humm (1975) reported 66 species of benthic algae that were epiphytic on the seagrasses of Florida's west coast. The Rhodophyta (or red algae) comprised 45% of the total species, Chlorophyta and Cyanophyta 21% each, and Phaeophyta 12%. Harlin (1980) produced a compilation of work on seagrass epiphytes that includes research in the Springs Coast area.

Common algal species found attached to Springs Coast seagrass blades include the red algae *Digenia simplex, Gracilaria cervicornis, Gracilaria verrucosa,* and *Laurencia poitei*; the green algae *Anadyomene stellata, Cladophora* spp., and *Cladophoropsis membranacea*; and the brown alga *Padina vickersiae* (Ballantine 1972).

Several factors influence the distribution and abundance of the epiphytic algae:

(1) physical substrate,
(2) access to the photic zone,
(3) motion through the water column (from moving seagrass blades),
(4) nutrient exchange with the host, and
(5) an organic carbon source.

The turnover rate for epiphytes is high because a typical seagrass leaf has a life of about 30 to 60 days. After a new leaf emerges, some time passes before it is colonized by epiphytes. The delay may be due to the relatively smooth surface of the leaf or its production of antibiotic compounds (Zieman 1982). The heaviest coating of epiphytes usually occurs after a leaf is colonized by coralline red algae such as *Fosliella* spp. or *Melobesia* spp. which roughen up the surface and provide an adherent surface.

Seagrass leaves are generally more heavily epiphytized at the tips because the tips are older than the bases and experience more water motion. The shading effect produced by the epiphytes may decrease seagrass photosynthesis by up to 31% (Zieman 1982).

h. Associated fauna. Seagrass beds harbor a large and diverse number of animals. They range from tiny sessile organisms such as spirorbid polychaetes to large commercially important species such as sea trout.

Many organisms are found on the seagrass blades themselves. Common gastropods include *Cerithium muscarum, Cerithium eburneum, Anachis* spp., *Astrea* spp., *Modulus modulus, Mitrella lunata,* and *Bittium varium.* Most of these gastropods feed on the epiphytic algae covering the leaf.

Crustaceans are particularly abundant within the seagrass meadow, both on the blades themselves and in the surrounding sediment. Caridean shrimp are also abundant. Common species include daggerblade grass shrimp *(Palaemonetes pugio),* marsh grass shrimp *(P. vulgaris),* brackish grass shrimp *(P. intermedius),* longtail grass shrimp *(Periclimenes longicaudatus), P. americanus,* arrow shrimp *(Tozeuma carolinense),* false zostera shrimp *(Hippolyte pleuracantha),* green snapping shrimp *(Alpheus normanni),* and bigclaw snapping shrimp *(A. heterochaelis).* Hermit crabs *(Pagurus* spp.) are also numerous on the sediment surface of the seagrass bed.

Fish are very abundant among seagrasses. The permanent residents are typically small and not very mobile. Many of the cryptic species spend their entire life cycle within the grass beds. Members of the families Syngnathidae, Gobidae, and Clinidae are included in this group. The pipefish *Syngnathus scovelli, S. floridae, S. louisianae,* and *Micrognathus criniger* and the seahorses *Hippocampus zosterae* and *H. erectus* are common cryptic species. The lizardfish *Synodus foetens* is a common epibenthic fish predator.

It is well documented that fish are abundant over seagrasses, but knowledge of their within-habitat distributional patterns relative to grassbed characteristics (i.e., structural complexity and prey densities) is poor (Zieman 1982). Many of the fish use the abundant invertebrates as food. Nothing is really known of the relation of typical seagrass-bed fishes and their predators. Livingston and his associates have examined many aspects of the trophic response of fishes to habitat variability in seagrass beds (Livingston 1984).

i. Trophic dynamics and interactions. The trophic relationships of the seagrass fishes in the Crystal River estuary were examined by Adams (1972) and Carr and Adams (1973). They found in examining the juvenile fishes common to the estuary that of the 15 primarily planktivorous species, all fed on zooplankton, with phytoplankton not found in the fishes' guts in measurable amounts. They also found that three species were primarily herbivorous, eight carnivorous (mainly benthic macroinvertebrates), two primarily piscivorous; and six species were detritus feeders to an important extent.

Seagrasses with their attached flora (i.e., epiphytic periphyton—algae and microalgae attached to or coating 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 (Fig. 103). 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.

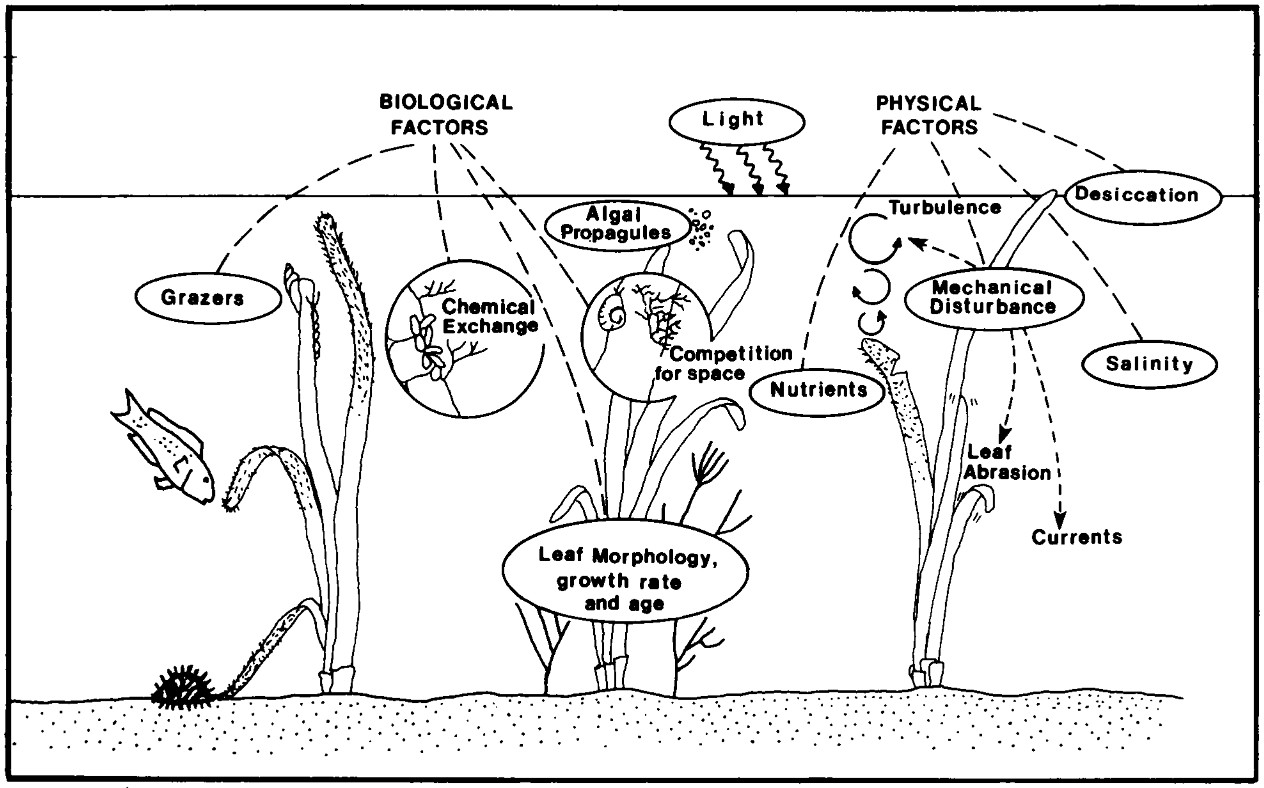


Figure 103. Schematic view showing the numerous seagrass-epiphyte interactions that occur in a seagrass bed and the important physical factors affecting the interactions (after Montfrans et al. 1984).

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*).

Other interactions than predation and grazing among seagrass and its associated community have been examined. The epiphyte-seagrass association is a complex one (Fig. 103). 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.

Seagrasses act as refuges from predation in a variety of ways. For example, a dense rhizome mat protects infaunal organisms from predators, in particular, the blue crab, *Callinectes sapidus*, that digs through the sediment in search for prey. The grass blades themselves provide a structure where many species can hide.

j. Commercially important species. Scallops are common in and around seagrass beds in the Springs Coast. 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 Springs Coast seagrass beds. Scallops spawn in the fall; the larvae are planktonic for a few weeks and then attach to seagrass blades for several weeks before metamorphosing 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 Springs Coast seagrass beds. Juvenile blue crabs are commonly found in shallow seagrass beds (Oesterling 1976b). Adults are generally found in muddy sediments up to 35 m deep. Commercial aspects of this species are further covered in the section on subtidal soft bottoms.

k. Natural impacts. Hurricanes and severe tropical storms occur occasionally along the Springs Coast (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.

l. 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 affecting 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 oxydation-reduction 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).

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., saltmarsh 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.).

The sensitivity of seagrasses to the effects of oil is widely accepted (Getter et al. 1984a,b) and the region has been excluded from OCS lease sales thus far, but unfortunately it has not yet been permanently removed from consideration. Plants exposed to polluting petroleum derivatives generally demonstrate significantly reduced carbon uptakes (McRoy and Williams 1977). From studies thus far, the associated seagrass organisms are most adversely affected by petroleum pollution. The plants themselves, being subtidal, may be buffered from the direct effects of petroleum.

Pollution from toxins and heavy metals has not been implicated in 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.

The effects of heated effluent upon seagrasses has been studied in the regions near the Crystal River power plant (Grimes 1971; Van Tine 1977). Seagrass productivity decreases with increased water temperature and, with a rise of approximately 4 °C above ambient, plant mortality occurs.

In many shallow-water Springs Coast environments, 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.

6.3 Marine Habitats

The Springs Coast marine habitat is confined for the most part to the offshore waters. All nearshore waters are of sufficiently low salinity to be considered estuarine, and traditional marine habitats such as hard substrates and sandy beaches are missing, except for occasional rock outcrops that remain largely unstudied. Carter (1884), Smith (1949), Dawson and Smith (1953), DeLaubenfels (1953) and Yockey (1974b) describe marine sponges found on hard-bottom outcrops offshore of the Springs Coast.

6.3.1 Marine Open Water

a. General. The marine open-water habitat is physically stable compared to that of the estuaries. Salinity varies 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 Springs Coast 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 mackerel (*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, but in smaller numbers. Dinoflagellate diversity may exceed diatom diversity in the marine system.

Phytoplankton demonstrate vertical stratification because of photosynthesis requirements (Steidinger 1973). Grazing zooplankton generally peak in abundance in areas of concentrated phytoplankton patches. They are also seasonal in abundance (Fig. 104).

Marine fish species include those listed in Appendix Table AO.

c. Recreationally and commercially important species. Important commercial and recreational species in this region include brown shrimp, white shrimp (*Penaeus setiferus*), and pink shrimp (*P. duorarum*), sharks, spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), sand seatrout (*Cynoscion arenarius*), gulf menhaden (*Brevoortia patronus*), Spanish and king mackerel, and Atlantic thread herring (*Opisthonema oglinum*).

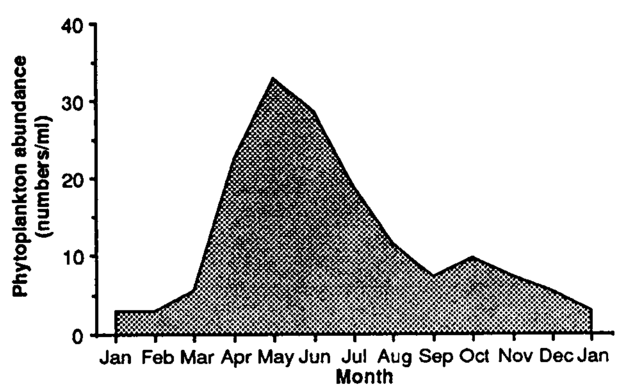


Figure 104. Seasonal phytoplankton abundances in the northeast Gulf of Mexico (after Steidinger 1973).

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 or cigarfish, *Decapterus punctatus*, is the most important prey species in the diet of king mackerel caught in this area. 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.

(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 approximately September to May. Two reproductive peaks may occur in nearshore Springs Coast 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 14) that occasionally occur in Springs Coast waters are threatened or endangered. Additionally, the West Indian manatee (*Trichechus manatus*) is greatly endangered, primarily because of deaths from being struck by boats while lying at or near the surface (Wood 1990).

e. Natural impacts. Some phytoplankton species can cause large fish kills and are toxic to shellfish.

Table 14. Marine turtles with special status that occur in Springs Coast 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
Kemp's ridley	*Lepidochelys kempii*	Endangered

These species cause what are termed red tides because of the discoloration of the waters. Marine coastal red tides in the Springs Coast are primarily associated with population blooms of the dinoflagellates *Ptychodiscus brevis* (formerly *Gymnodinium breve*) and *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. Sea turtles also ingest oil and tar, and die from this directly.

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.

6.3.2 Artificial Reefs

a. General. 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-area 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.

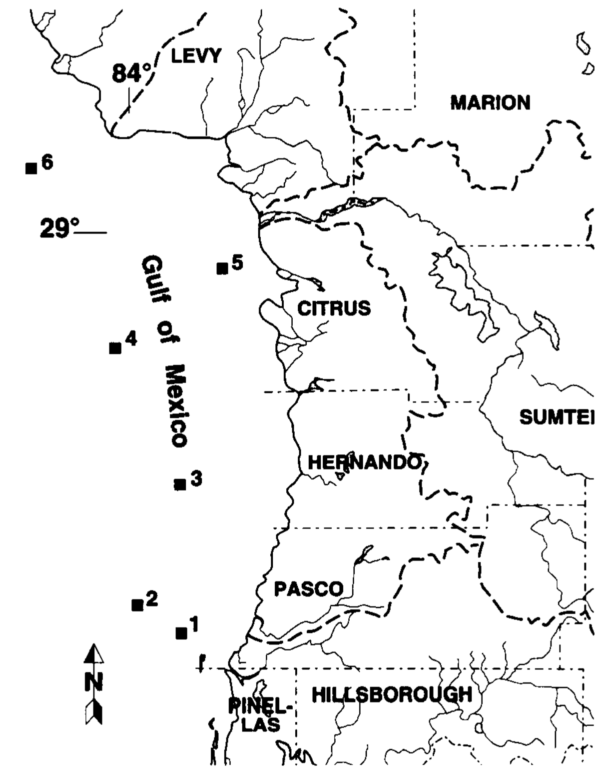
Artificial reefs may be of two types: high profile or low profile. High-profile reefs are usually the most productive because they attract bottom species such as grouper, sea bass, and snapper and also pelagic forms such as Spanish mackerel, cobia, and amberjack. The high profile reefs, however, require 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. Because of the shallowness of the Gulf of Mexico along the Springs Coast, the reefs in these waters are of the low-profile type.

Florida has initiated more reef construction than all the other Southeastern States combined (Seaman 1982). The artificial-reef construction program reflects a number of influences: (1) the vast amount of coastline; (2) an increase in population growth along the coast; and (3) a leisure-oriented population along the coast with a number of party and charter boats, motor-powered boats, and marinas and boatyards. This program in Florida is administered by the Florida Department of Natural Resources, Division of Marine Resources.

Artificial reefs are constructed from very diverse materials. The Springs Coast reefs are composed of sunken barges, automobiles, tires, iron and steel scrap, 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 six verified reefs within the Springs Coasts region (Pybas 1987)(Fig. 105). These artificial reefs have been placed in relatively shallow locations because the nearshore Continental Shelf is shallow. The 9-m depth contour is from 25 to 45 km offshore in the Springs Coast.

Like planned artificial reefs, wrecked ships attract fish by providing structure on an otherwise flat sea floor. The National Ocean Survey maintains updated information on all known wrecks in U.S. coastal waters.



County	#	Year Built	Latitude	Longitude	Depth (ft)
Pasco	1	1981	28°15'19"	82°57'27"	25
	2	1982	28°17'42"	83°01'14"	30
Hernando	3	1977	28°30'00"	82°55'00"	18
Citrus	4	1964	28°53'06"	82°49'42"	22
	5	1983	28°47'24"	83°03'30"	30
Levy	6	1985	29°07'40"	83°12'28"	20-25

Figure 105. Artificial reef locations in Springs Coast waters (after Pybas 1987).

c. Associated fauna. No studies of the fish or other residents, such as the encrusting and free-living invertebrate communities (e.g., sponges, gorgonians, and bryozoans), of Springs Coast artificial reefs have been published.

Fish communities are very diverse on artificial reefs studied elsewhere along the Florida Gulf of

Mexico coast. 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, semiresident 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 semiresident 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) of 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.

d. Trophic dynamics and interactions. Trophic dynamics on artificial reefs 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.

6.3.3 Subtidal Soft Bottoms

a. General. The marine soft-bottom habitat constitutes the largest environment (on an area basis) within its system. This habitat within the Springs Coast is largely unstudied. Most samples in the marine soft-bottom habitat are taken from ships using 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 to the deep ocean and includes practically all the area offshore except rocky outcroppings too deep to support grassbeds. In the Springs Coast, because of the extensive grass beds, large areas of subtidal soft bottom are found mainly around the Cedar Keys (Fig. 94).

b. Physical description. Springs Coast subtidal soft-bottom habitats are undescribed.

c. Fauna present. The offshore Springs Coast marine meiofauna are not documented. However, there is probably some overlap between the nearshore marine assemblages and estuarine ones.

d. Trophic dynamics and interactions. The trophic dynamics of marine soft-bottom communities in the Springs Coast are unstudied. 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. Research specific to the Springs Coast 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 sand for beach renourishment projects (Saloman and Naughton 1984).

Chapter 7. SUMMARY

7.1 The Springs Coast in Review

The Florida Springs Coast has a varied subtropical to warm-temperate climate with hot, humid summers and brief periods of freezing temperatures in winter. Rainfall is abundant, averaging approximately 140 cm per year. Most of this rain falls during the summer rainy season (mid-June through mid-December), with lesser amounts during the late winter-early spring rainy season (February though April). Winter rains are primarily a product of the occasional passing of cold fronts; summer rains are usually in the form of convective thunderstorms. Winds are normally from 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 along the coast.

One major river, the Withlacoochee, is found in the Springs Coast region. Additionally, several spring-fed rivers flow from large springs near the coast. Among these are the Crystal, Homosassa, Chassahowitzka, and Weeki Wachee Rivers. Two small surface-runoff-fed rivers are found at each end of the region, the Pithlachascotee River to the south, and the Waccasassa River to the north.

The floodplains of the three runoff-fed rivers are largely undeveloped at this time, especially those of the Withlacoochee and Waccasassa Rivers. Periodic flooding has been shown to be an important step in recycling nutrients in riverine ecosystems and is responsible for much of the productivity of coastal estuaries. Damming rivers for flood control or other purposes drastically reduces transport of nutrients to the estuaries; the nutrients are trapped in lakes behind the dams, where they lead to eutrophication and eventual lake death. Experience in Florida and elsewhere shows that restricting development in floodplains is the best and most cost-effective means of flood prevention. If development in floodplains is permitted, resulting hydrological alterations cause flooding not only in the floodplain itself, but also in adjoining areas that were not previously flood prone. While substantial flow alterations have already been made to the Withlacoochee drainage basin, these methods are currently being minimized by the Southwest Florida Water Management District.

Most of the ground water used in the Springs Coast is contained within the Floridan Aquifer, a porous limestone matrix characterized by alkaline water with a moderately high level of dissolved solids. Surficial aquifers are used to a limited extent in areas where they occur. Protection of these aquifers and their recharge areas (typically uplands) is a major environmental priority in this region, as elsewhere in Florida.

The presettlement vegetation of the Springs Coast region was dominated by open, fire-maintained pine forests on sandy uplands and coastal terraces. Longleaf pine was the dominant tree, replaced by slash pine in wetter sites and near the coast and by pond pine in the wettest inland sites. Wiregrass was the dominant ground cover, particularly in longleaf pine forests. Other community types were embedded within the pine forest matrix. Patches of sand pine and/or oak scrub occurred on upland sites with reduced fire frequency (such as in the "fire shadow" of a lake), and mesic hammocks occurred on slopes of ravines and sinkholes and on islands and peninsulas, all of which had greatly reduced fire frequencies and generally richer soils. Farther down the slope moisture gradient were hydric hammocks, swamps, marshes, and other wetland communities. Although most of this region has so far escaped the tremendous population growth and associated habitat destruction that characterizes much of Florida, all of the native upland and wetland communities have been drastically altered by human activities. Anthropogenic communities such as pine plantations and various successional, agricultural, and urban habitats now dominate an increasingly large portion of the Springs Coast. The trend, unfortunately, is towards further modification of natural habitats, though increasing environmental awareness on the part of the public is a countertrend that offers us some hope.

The Springs Coast has no classic estuaries where brackish waters are separated from the ocean by physical barriers such as islands. In many ways, however, the whole coastal water body functions like an estuary, as the shallow waters and copious freshwater input along the entire shoreline produce estuarine conditions. The Springs Coast is considered a low-energy coastline because of shallow waters and orientation of the coastline parallel to prevailing winds.

Seagrass beds cover almost the entire nearshore area along the Springs Coast. Salt marshes line the coast and are intermixed with mangroves, particularly in southern portions of the region. Inland from the salt marshes are large areas of brackish marsh dotted with hardwood hammocks. Extensive oyster reefs are found throughout the coastal waters and estuaries, but they are a major fishery only in the northernmost part of the region (i.e., in the Cedar Key area). The reefs south of Citrus County have not been classified by the FDNR because of manpower limitations and therefore are not available for commercial harvest.

The Florida Springs Coast is lightly populated except for much of Pasco County (which has considerable urban sprawl particularly along U.S. Highway 19) and the southern parts of Hernando County along the coast and in the vicinity of Brooksville. This area has continued to develop rapidly since the 1980 census (Fig. 106) and rapid continued growth is probable (Fig. 107). The Brooksville Ridge is currently under considerable pressure from housing developments. The primary land use outside these high-growth areas is forestry and farming. Natural areas are protected to various degrees in Lower Suwannee National Wildlife Refuge, Cedar Key National Wildlife Refuge, Chassahowitzka National Wildlife Refuge, Cedar Key Scrub State Reserve, Waccasassa Bay State Preserve, Green Swamp Wildlife Management Area, and other public lands and private conservation areas. Less consideration is given to natural communities in Withlacoochee State Forest, although important natural areas still remain there which deserve protection.

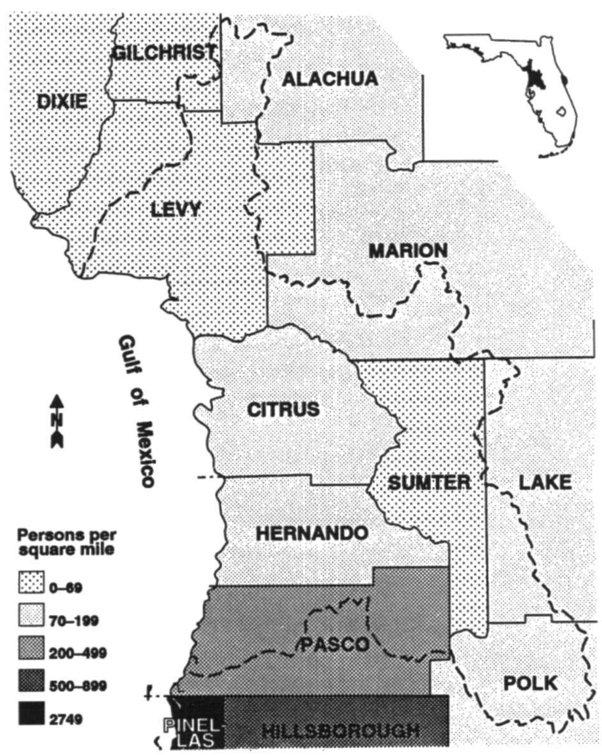


Figure 106. 1980 Florida Springs Coast population by county (after Winsberg and Primelles 1981).

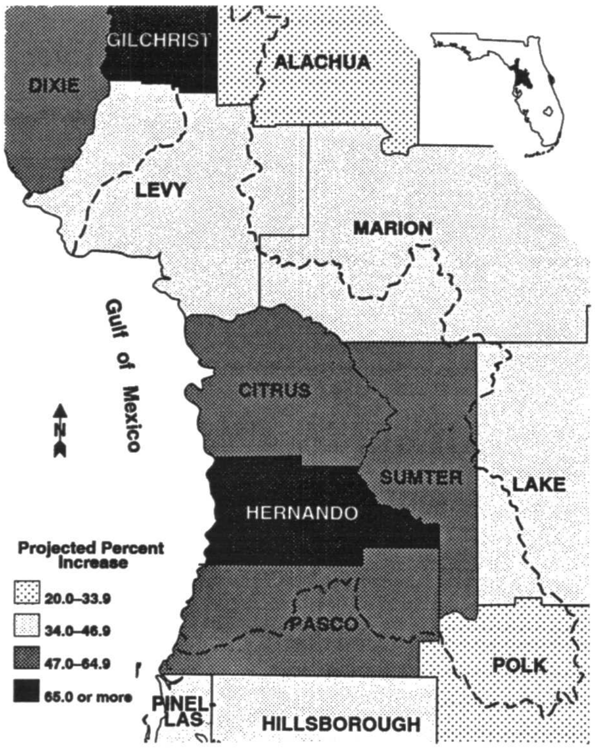


Figure 107. Florida Springs Coast projected population increase 1980-2000 (after Fernald 1981).

7.2 Land-Use Planning and Conservation

This publication focuses on three major watersheds (hydrological units) in the Springs Coast region. The watershed, a "landscape" scale of resolution, is an appropriate scale at which to evaluate many ecological phenomena. One of the most fascinating and rapidly expanding subdisciplines in ecological science is landscape ecology, the study of structure, function, and change in large, heterogeneous land areas (Forman and Godron 1981, 1986; Risser et al. 1984; Urban et al. 1987). Conservation and land-use planning are conveniently and auspiciously directed at the landscape scale (Noss 1983, 1987a, 1987b; Noss and Harris 1986). The landscape, composed of various interacting habitat patches, corridors, and matrix, is the scale at which many ecological processes operate and at which wide-ranging animals such as Florida panthers and black bears fulfill their life histories. It is also a primary scale at which humans live and modify the earth's surface.

Appendix Tables AP and AQ list Federal, State, and local agencies with environmental responsibilities and give locations, addresses, and telephone numbers for the branches responsible for the Springs Coast.

Several investigators have suggested that watersheds are appropriate organizational units for a variety of inventory, planning, and management purposes (e.g., Odum 1971; Young et al. 1983; Noss and Harris 1986). Many ecological processes, including hydrology, erosion, nutrient cycling, and species dispersal, operate within watersheds (Odum 1971). Although many processes also cross watershed boundaries, ecological interactions within watersheds might be expected to be stronger than interactions between components of different watersheds. The Florida Natural Areas Inventory (FNAI: The Nature Conservancy's "heritage program" for Florida) includes a watershed field coded with hydrologic unit numbers on all element records in its computerized data base. This makes the watershed scale convenient for quickly producing lists of endangered and threatened species, community types, and other important natural features in a region of interest.

A major lesson from landscape ecology for the management of large regions is that the structural components of landscapes interact (Noss 1987a). Some examples illustrate this point: (1) in times of drought, fire may spread from a fire-prone habitat to adjacent habitats; (2) edge effects at habitat boundaries include climatological changes from increased sun and wind at forest edges, invasions of xeric-adapted weedy species from disturbed open habitats into forests, and increases in opportunistic predators and higher predation rates on nests of birds near edges; (3) many amphibians require both an aquatic and a terrestrial habitat to complete their life cycles, most terrestrial animals require access to water for drinking, and wide-ranging animals such as bears move among many habitats to meet their seasonal food and cover requirements; and (4) corridors in a landscape facilitate the movement of animals and plant propagules between sites that would otherwise be functionally isolated. Because of landscape-level interactions, too narrow a focus (for example, on single species or single habitat types) inevitably misses many important processes and interactions. Scale of resolution is also a critical consideration for evaluating ecological patterns such as diversity. Increases in diversity at a local scale (for example, from weeds invading a site-prepared clear cut) may lead to decreases in diversity at the regional scale, as sensitive species or species dependent on old growth are eliminated. This has important implications for wildlife management, which often strives to enhance local diversity and edge effect to benefit edge-adapted game species, but may lead to regional declines of more sensitive species (Noss 1983). Consequently, the value of focusing on whole landscapes such as watersheds, or on regions composed of several similar watersheds, is apparent.

Landscape considerations suggest that all habitats that naturally occur in a region have value, both in terms of their inherent qualities and their interactions with other habitats. In looking at the habitat mosaic which composes a landscape, it is immediately evident that the whole is greater than the sum of its parts (Noss and Harris 1986). We often find it easier to focus on parts, for example by devising separate management plans for different species, sites, or habitat types, but in so doing we may fail to maintain the integrity of the landscape as a whole.

As an example of how landscape-level thinking is needed in land-use planning, consider the often arbitrary regulatory distinction made between wetlands and uplands. In recent decades, biologists and concerned citizens have mounted an aggressive campaign to educate the public about the value of wetlands. To a considerable extent, this educational effort has been successful (at least the rate of wetlands destruction has been slowed in many places). Florida's wetland protection regulations (despite unfortunate loopholes such as agricultural exemptions, insufficient protection of small, isolated wetlands, and definitional exclusion of many forested wetlands such as bottomland hardwoods) have led to increased protection and even some partially-successful restorations of wetland communities. Wetlands comprise some 30% of Florida's land area, so their regulatory protection has helped save wildlife habitat in important parts of the landscape mosaic.

But what about uplands, the other 70% of a typical Florida landscape? Data from FNAI (Nature Conservancy 1990) suggests that the most critically endangered community types in Florida are uplands, such as (in our region) scrub. In fact, 15 of 23 Florida upland community-types are ranked 2 (imperilled) or higher at a statewide scale, whereas only 2 of 19 palustrine (wetland) communities are ranked this high (Nature Conservancy 1990). Longleaf pine sandhills and flatwoods have been greatly degraded in the Springs Coast region. Logging, fire suppression, and (historically) turpentining have been major causes of degradation in longleaf pine forests. Fragmentation of remaining uplands by residential and agricultural development is extirpating populations of species such as the red-cockaded woodpecker (federally endangered) and Sherman's fox squirrel (a candidate for Federal listing as threatened). Unfortunately, the FNAI rankings in themselves do not accurately reflect the quality of remaining examples of community types. Considering the poor quality of most remaining examples, longleaf pine communities can certainly be considered endangered (Means and Grow 1985; Noss 1988), perhaps as much as sand-pine scrub. Many threatened and endangered species of the Springs Coast region (Appendix Table X), such as the pygmy fringe-tree (*Chionanthus pygmaeus*), long-spurred mint (*Dicerandra cornutissima*), gopher tortoise, eastern indigo snake, short-tailed snake, red-cockaded woodpecker, Florida mouse, and Sherman's fox squirrel, inhabit these unprotected upland communities.

Wetland protection standards and regulations have actually increased the destruction of uplands. Development is often channeled out of wetlands of marginal quality into more valuable upland habitats, and uplands are destroyed as "mitigation" for development in wetlands (Hart 1987). Interest in uplands preservation is increasing, although it is not known whether the increased interest can catch up with the increased destruction of uplands. The Gopher

Tortoise Council is a private group concerned with saving upland communities as well as the tortoise, a keystone and indicator species for some of our most valuable upland community-types. As shown in Fig. 108, the Brooksville Ridge is one of the most important population centers for the gopher tortoise, and by extension, for the many other upland species associated with it. Unfortunately, the Brooksville Ridge is being developed for housing and other human uses at a rapid pace. Properties that are kept in a more "natural" condition (including public lands such as the Withlacoochee State Forest) often are not burned regularly enough to maintain high pine communities, either because of deliberate fire suppression or

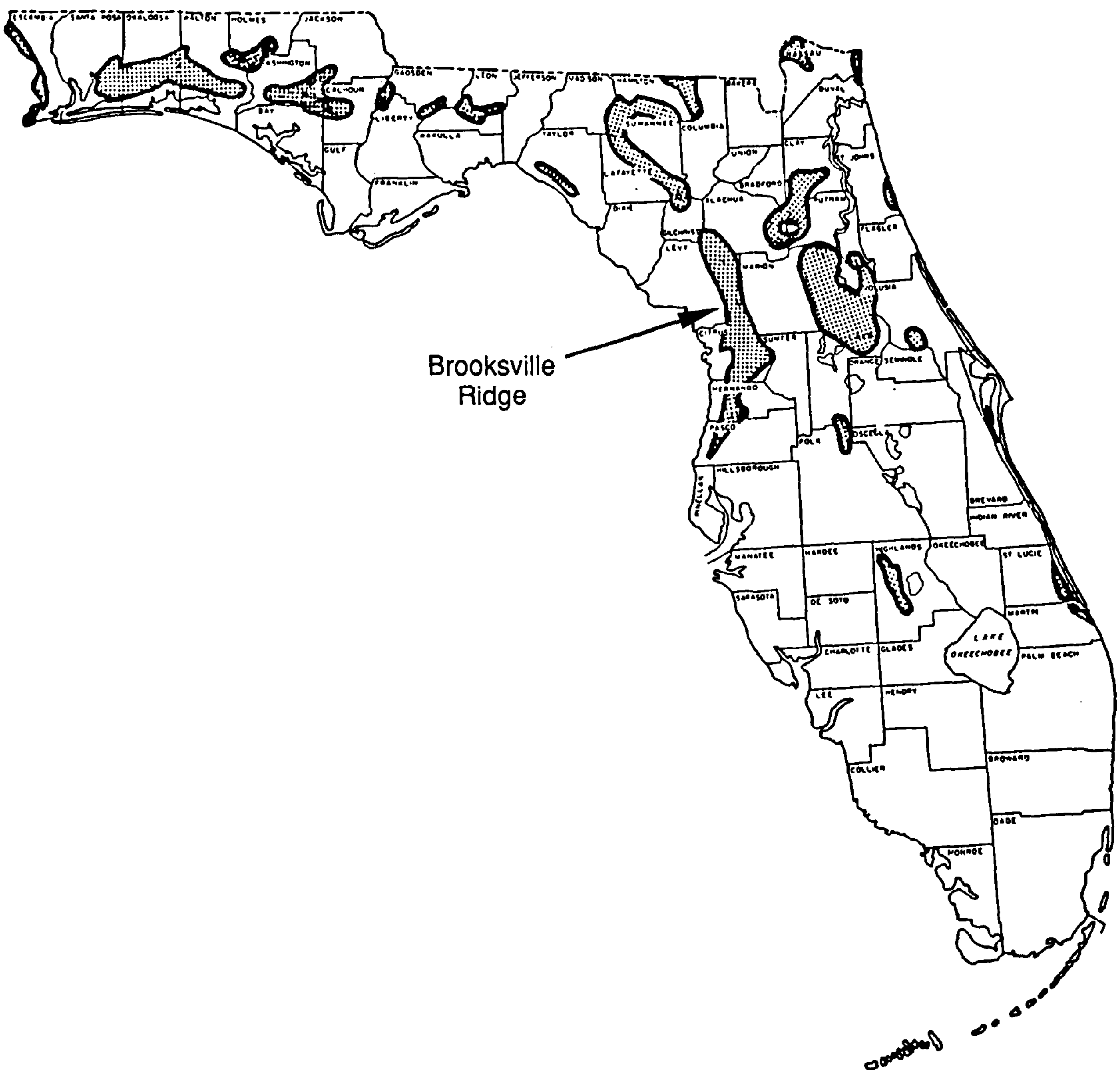


Figure 108. Distribution of major areas with high densities of gopher tortoises (after Auffenberg and Franz 1982).

because of firebreaks such as developments and roads. When prescribed burns are used, they are usually applied in the winter, rather than in the late spring or summer when natural fires occur; this has unfortunate consequences for many of the native flora that require summer burns in order to flower (Means and Grow 1985).

Although wetlands generally receive better regulatory protection than uplands, it would be a mistake to assume that they are safe from destruction. Salt marshes and seagrass beds are a case in point. 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, which affects the marshes both directly and indirectly. This habitat is one that requires 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 *Thalassia* meadow. If seagrasses are destroyed, erosion increases and the associated flora and fauna disappear, including commercially important species such as fish, crabs, and scallops. Primary productivity and detrital production decrease dramatically if seagrasses decline, and this affects other 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 spatial and temporal variability in the composition of seagrass communities, little is known of the general principles of ecosystem function and of the factors controlling persistence of the community. Therefore, subtle changes that may be caused by human activities generally pass unnoticed or are ascribed to natural fluctuation. An example is change in turbidity levels. As turbidity increases, photosynthesis is reduced. Seagrass beds are under constant attack by destructive forces; e.g., storms and erosion, grazing, winter cold snaps. The resulting loss of biomass is balanced by the growth rate of the grass bed. Any reduction in photosynthesis from increasing turbidity levels reduces the bed's ability to maintain itself. Thus turbidity increases, causing relatively minor reductions in photosynthesis that often cause seagrass beds to gradually die off. Subtle but widespread changes in turbidity, related to development along the coast or on banks of rivers that carry sediment to the coast, may have greater long-term impacts on seagrass communities than dredging in concentrated areas, a more obvious impact that is widely reported.

Efforts to protect estuarine resources in the Springs Coast region must be intensified. Approximately 90% of all fish species in Florida coastal waters spend at least a portion of their lives in estuaries. Economic development can become economic disaster if the productivity of estuaries decreases to the point where commercial or sport fish yields decline. For example, filling in salt marshes for development represent economic gain for a few developers, but the economic cost of loss of fish nursery habitat is borne by the public at large. Clearly, planners and decision-makers need to give more attention to the "Big Picture."

It is helpful to identify major sources of environmental impact so that they can be addressed in a holistic rather than piecemeal fashion. Returning to the terrestrial landscape, transportation networks are an overwhelming feature of human-dominated regions that direct the location and intensity of development. Wildlife ecologists recognize that roads are the source of some of the most serious problems for wildlife in the Springs Coast region, as elsewhere. Not only do roads accompany new developments, but they encourage further development, which in turn calls for more roads. This positive-feedback relationship fragments habitats, isolates populations, prevents the natural spread of fires, increases deleterious edge effects, provides access to poachers, and of course, directly kills wildlife. Some 44 bears are known to have been killed on Florida roads in 1989, several in Hernando County on U.S. Highway 19 east of Chassahowitzka Swamp (articles in Gainesville Sun; John Wooding, Florida Game and Fresh Water Fish Commission, pers. comm.). Less heavily traveled roads are still destructive to the extent that they provide access to poachers, developers, off-road vehicles, and other impacts. In order to maintain bear populations in this region, wide corridors of natural habitat will have to be maintained to allow safe movement of bears between large roadless areas. Elevated roadways to allow passage of animals underneath will need to be constructed in key stretches of busy highways such as U.S. Highway 19, and roads should be closed altogether in some sensitive areas. The alternative is to lose sensitive species such as the Florida black bear from the Springs Coast region, which does not speak well for progress.

One strategy to mitigate the habitat fragmentation problem posed by roads and development is implementation of a "Statewide preserve network" of protected areas and habitat corridors. Protected areas would range in size from small parks to huge wilderness landscapes, and wide corridors of natural habitat would allow for natural movement of animals and plant propagules among protected areas. Researchers from the University of Florida and elsewhere are in the process of designing these networks at various scales. One current Statewide design is shown in Fig. 109. Implementation of designs such as this will require increased land acquisition on the part of public agencies, but can rely partially on conservation easements and other cooperative agreements with landowners and among land-managing and regulatory agencies (Noss and Harris 1986). In addition to land and wildlife preservation, a primary goal of the Statewide network is to restore communities to a more natural condition, reestablish extirpated populations (including the Florida panther), and maintain natural processes of disturbance (fire, flooding, etc.). Because the Springs Coast region includes some critical areas in the Statewide network (Fig. 109), efforts towards implementation of the plan, such as land acquisition and construction of elevated highway sections, should begin at once.

Habitat corridors have obvious value for protecting upland and wetland wildlife. But the concept can also be extended to our freshwater and marine habitats. Riparian vegetation, when preserved as a corridor, buffer zone, or "setback" from a river's edge, functions to protect water quality by limiting siltation and input of pollutants (Karr and Schlosser 1978). The spring runs that are so characteristic of our region would benefit from a stricter application of this approach. If we further protect and restore these spring-run "corridors" by prohibiting developments and the use of motorboats in them, the benefits to the endangered West Indian manatee would be enormous. Manatee populations today are in a condition critical enough to warrant strict limitations on human use of their habitats (Packard 1983). Coastal areas that have not yet succumbed to development should also be protected as inviolate natural corridors. In this case, protection should extend as a wide belt including both the terrestrial shoreline and offshore areas.

7.3 The Springs Coast Tomorrow

The Springs Coast is experiencing increasing growth pressures as human migration into Florida continues and as overcrowding in many South Florida areas decreases the desirability of living there (Fig. 107). None of the conservation strategies recommended above can be realized without a drastic reduction in the rate of human population growth and associated development that this region is experiencing. The irony of growth is that it ultimately destroys the quality-of-life factors that originally attracted people to the region. Planners must make tough decisions now to avoid future disasters. One immediate mitigative measure would be to channel development into areas that are already degraded ecologically, such as within existing cities, and away from natural or near-natural habitats. The most critical habitats, sites, and corridors which are discussed in this report and portrayed in the plan in Fig.109, could be fully protected today while still accommodating the same growth in less sensitive areas. Species listed in Appendix Table X and Table 14 should each receive research, habitat acquisition, and management attention, so that their continued existence can be assured.

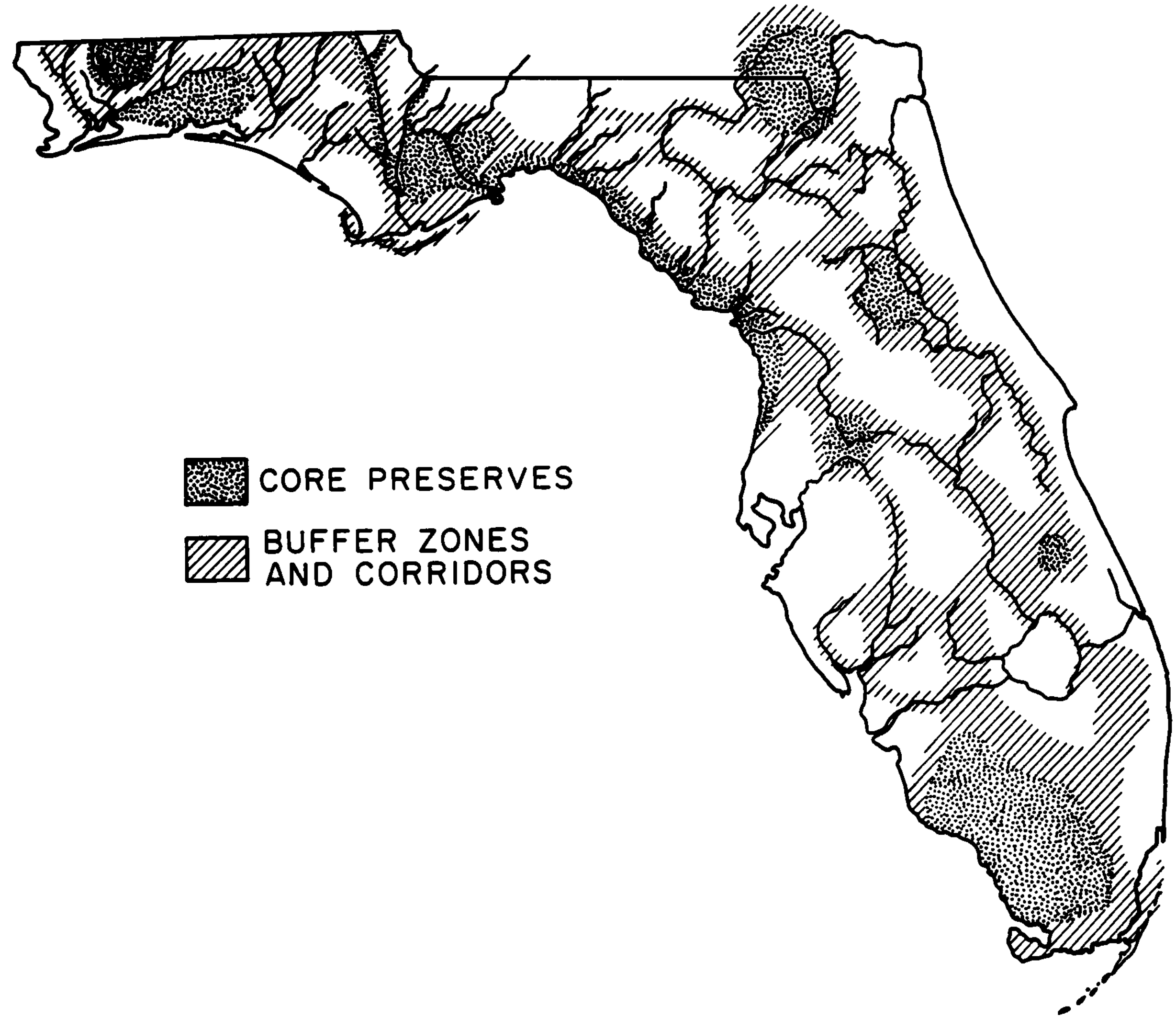


Figure 109. Proposed statewide network of protected areas and corridors (after Noss 1987b).

To leave our descendents a biologically impoverished Springs Coast region would be a crime they would be unlikely to forgive.

In writing this document, it became clear to each of us that far too little is known about the ecology of this area, the status and location of rare species and exemplary natural communities, and appropriate management techniques. Although it should not become an excuse for inaction, lack of baseline information is a serious hindrance to development of effective management plans and regulations. Long-term studies of estuarine ecology, pollutant assimilative capacities of estuaries and other aquatic habitats; fish-stock assessments and fishery research in general; mapping of aquifers; studies of groundwater pollution, acid-rain impacts, effects of rising sea level, population status and dynamics of wildlife (plant as well as animal species); community disturbance and regeneration dynamics; and nature-preserve design, management, and restoration are a few of the research areas which demand increased attention.

Moreover, existing regulations and the relatively small area of protected land are clearly insufficient to safeguard the biological diversity of this region. Government agencies should vastly increase funding for ecological research and protection while we still have something left to study and save. More State and Federal parks, refuges, Outstanding Florida Waters, and aquatic preserves must be acquired and designated before the natural areas of this region deteriorate further. Areas within the Springs Coast region that are most sensitive to development and which should be fully protected include: (1) scrub and high pine (sandhill) communities; (2) springs and spring runs, caves, and sinks; (3) coastal wetlands, estuaries, salt and brackish marshes, and seagrass beds; (4) nonwetland coastal areas where damage from storms and rising seas level is probable; and (5) other sites where rare species and exemplary natural communities of any type occur. Public ownership of these areas is probably the safest option, but will require major shifts in government spending. Aquifer recharge areas and sites prone to ground-water contamination may support some development, but only if carefully regulated. Furthermore, because most habitats in this region have suffered some degree of degradation, restoration of damaged sites (a subject of increasing ecological interest and research) is another priority.

In the long term, a shift away from a purely anthropocentric (human-centered) actions towards a program that takes into account the entire ecosystem will be necessary to ensure the continued existence of the many aspects of the Springs Coast region that make it unique, and to ensure the continued survival of the area ecology. Ideally, this philosophical shift would occur within human society at large, but it must at least occur within a critical mass of leaders, planners, and decision-makers. We need to put the "land ethic" of ecologist Aldo Leopold into action, recognizing in our land-use policies that "a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1949).

LITERATURE CITED

Abele, L.G. 1970. The marine decapod crustacea of the northeastern Gulf of Mexico. M.S. Thesis. Florida State University, Tallahassee. 136 pp.

Abele, L.G. 1974. Species diversity of decapod crustaceans in marine habitats. Ecology 55: 156–161.

Abele, L.G., and W. Kim. 1986. An illustrated guide to the marine decapod crustaceans of Florida. Florida Dep. Environ. Regul. Tech. Ser. 8(1), Parts 1 & 2 (in 2 vols.). 755 pp.

Adams, C.A., II. 1972. Food habits of juvenile pinfish (*Lagodon rhomboides*), silver perch (*Bairdiella chrysoura*) and spotted seatrout (*Cynoscion nebulosus*) of the estuarine zone near Crystal River, Florida. M.S. Thesis. University of Florida, Gainesville. 147 pp.

Adams, C.A., II, G.L. Evink, M.J. Oesterling, W. Seaman, and R. Van Tine. 1977. Appendix A. Phylogenetic listing of estuarine species at Crystal River, Florida. Pages 147–164 *in* Crystal River Power Plant: environmental considerations, final report to Interagency Research Advisory Commission, Vol. III. Florida Power Corp.

Adams, C.A., II, M.J. Oesterling, and S.C. Snedaker. 1974. Effects of impingement and entrapment on the Crystal River blue crab, *Callinectes sapidus* Rathbun, population. Pages 107–146 *in* Crystal River Power Plant: environmental considerations, final report to Interagency Research Advisory Commission, Vol. III. Florida Power Corp.

Ahearn, D.G., F.J. Roth, and S.P. Meyers. 1968. Ecology and characterization of yeasts from aquatic regions of south Florida. Mar. Biol. 1: 291–308.

Alden, R.W. 1976. Growth, reproduction, and survival of some marine copepods subjected to thermal and mechanical stress. Ph.D. Dissertation. University of Florida, Gainesville. 339 pp.

Alt, D., and H.K. Brooks. 1965. Age of Florida marine terraces. J. Geol. 73: 406–411.

Alvis, C.A. 1971. Trophic relationships between significantly associated species of macrobenthos in the shoal grass habitat. M.S. Thesis. Florida State University, Tallahassee. 97 pp.

Anderson, W. 1975. Temperature of Florida streams. Revised edition. U.S. Geol. Surv. Map Ser. 43.

Anderson, W. 1980. Hydrology of Jumper Creek Canal basin, Sumter County, Florida. U.S. Geol. Surv. Water Resour. Inv. 80-208. 41 pp.

Ansley, C.C. 1952. An ecological comparison of the mesic hardwoods forests of central Florida. M.S. Thesis. University of Florida, Gainesville. 83 pp.

Atkinson, G.D., and J.C. Sadler. 1970. Mean-cloudiness and gradient-level-wind charts over the tropics. Air Weather Serv. Tech. Rep. 215. U.S. Air Force. Scott Air Force Base, Ill. 37 pp.

Attardi, V.J. 1983a. An environmental description of Lake Tsala Apopka. Southwest Florida Water Manag. Dist. Tech. Rep. 1983-4, Brooksville. 69 pp.

Attardi, V.J. 1983b. Asiatic clam kill on the Withlacoochee River. Memo. dated 8/10/83, Southwest Fla. Water Manag. Dist., Brooksville. 10 pp.

Auffenberg, W., and R. Franz. 1982. The status and distribution of the gopher tortoise (*Gopherus polyphemus*). Pages 95–126 *in* R.B. Bury, ed. North American tortoises: conservation and ecology. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 12.

Bahr, L.M., and W.P. Lanier. 1981. The ecology of intertidal oyster reefs of the Southern Atlantic coast: a community profile. U.S. Fish Wildl. Serv. Off. Biol. Serv. FWS/OBS-81/15. 105 pp.

Ball, M.C. 1980. Patterns of secondary succession in a mangrove forest of southern Florida. Oecologia 44(2): 226–235.

Ballantine, D.L. 1972. Epiphytes of four Florida seagrass species in the Anclote Anchorage, Tarpon Springs, Florida. M.S. Thesis. University of South Florida, Tampa. 86 pp.

Ballantine, D.L., and H.J. Humm. 1975. Benthic algae of the Anclote estuary I. Epiphytes of seagrass leaves. Fla. Sci. 38: 150–162.

Barada, W.R. 1982. The St. Johns River: an environmental time bomb. Pages 1–8 *in* Enfo report 82–2. Florida Conservation Foundation, Winter Park.

Barnett, T.P. 1983. Global sea level: estimating and explaining apparent changes. Pages 2777–2795 *in* O.T. Magoon, ed. Coastal Zone '83. American Society of Civil Engineering, N.Y.

Barr, G.L., and G.R. Schiner. 1982. Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, September 1982. U.S. Geol. Surv. Open File Rep. 82-1011.

Barr, G.L., and G.R. Schiner. 1983. Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, May 1983. U.S. Geol. Surv. Open File Rep. 83-547.

Barth, M.C., and J.G. Titus. 1984. Greenhouse effect and sea level rise. Van Nostrand Reinhold Co., N.Y. 325 pp.

Bartram, W. 1791. Travels through North and South Carolina, Georgia, East and West Florida. Q.M. van Doren, ed. Dover Publications (1928 reprint). 414 pp.

Battisti, D.S., and A.J. Clarke. 1982. Estimation of nearshore tidal currents on nonsmooth continental shelves. J. Geophys. Res. 87(C9): 7873–7878.

Bays, J.S., and T.L. Crisman. 1981. Results of the Lake Panasoffkee water quality evaluation project, 1980-1981. Report to Southwest Florida Water Management District from University of Florida, Department of Environmental Engineering Science, Gainesville. 32 pp.

Beccasia, A.D., N. Fotheringham, and A.E. Redfield. 1982. Gulf coast ecological inventory: users guide and information base. U.S. Fish Wildl. Serv. Biol. Serv. Prog. FWS/OBS-82/55. 191 pp.

Bell, P. 1980. Volcanic ash could mask global CO_2 effect. EOS, Trans. Am. Geophys. Union 61(29): 537.

Benkert, K.A. 1980. Annual productivity and simulation models of the chaetognath, *Sagitta hispida*, exposed to a thermal plume at Crystal River, Florida. M.S. Thesis. University of Florida, Gainesville. 80 pp.

Bert, T.M., R.E. Warner, and L.D. Kessler. 1978. The biology and Florida fishery of the stone crab, *Menippe mercenaria*. J. Morph. 24: 147–201.

Bohall, P.G. 1984. Habitat selection, seasonal abundance, and foraging ecology of American kestrel subspecies in north Florida. M.S. Thesis. University of Florida, Gainesville. 97 pp.

Bohall-Wood, P., and M.W. Collopy. 1986. Abundance and habitat selection of two American kestrel subspecies in north-central Florida. Auk 103: 557–563.

Boyle, R.H., and R.M. Mechum. 1982. Anatomy of a man–made drought. Sports Illus. 56(11): 46–54.

Bradley, J.T. 1972. Climatography of the United States No. 60–8: climate of Florida. National Oceanic and Atmospheric Administration. 31 pp.

Bradner, L.A. 1988. Hydrology of the Floral City Pool of Tsala Apopka Lake, west-central Florida. U.S. Geol. Surv. Water Resour. Inv. 88-4024.

Broecker, W.S., and T.H. Peng. 1982. Tracers in the sea. Lamont–Doherty Geological Observatory, Columbia University, N.Y. 690 pp.

Brooks, H.K. 1981. Geologic map of Florida. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Brown, T.W. 1963. The ecology of cypress heads in northcentral Florida. M.S. Thesis. University of Florida, Gainesville. 59 pp.

Bruun, P. 1962. Sea level rise as a cause of shore erosion. Am. Soc. Civil Eng. Proc., J. Waterw. Harbor Div. 88(WW1): 117–130.

Bruun, P., T.Y. Chiu, F. Gerritsen, and W.H. Morgan. 1962. Storm tides in Florida as related to coastal topography. Univ. Fla. Eng. Ind. Exp. Sta. Bull. Series 109. Gainesville. 76 pp.

Buickerood, M.J., J.A. Mann, Q.D. Wylupek, and K.F. Romie. 1990. Lake Tsala Apopka environmental assessment. Southwest Florida Water Management District. Brooksville.

Buono, A., and A.T. Rutledge. 1979. Configuration of the top of the Floridan aquifer, Southwest Florida Water Management District and adjacent areas. U.S. Geol. Surv. Water Resour. Inv. 78-34. Map.

Buono, A., R.M. Spechler, G.L. Barr, and R.M. Wolansky. 1979. Generalized thickness of the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District. U.S. Geol. Surv. Water Resour. Inv. Open File Rep. 79-1171. Map.

Burnson, T., J.L. Shoemyen, J.R. Cameron, K.B. Webster, L.C. Oxford, Jr., R. Ceryak, R.E. Copeland, C.J. Leadon, and P. Batchelder. 1984. Suwannee River Water Management District. Pages 218–232 *in* E.A. Fernald and D.J. Patton, eds. Water Resources Atlas of Florida. Florida State University, Tallahassee.

Bush, P.W. 1972. Salt-water movement in the lower Withlacoochee River–Cross-Florida Barge Canal complex. U.S. Geol. Surv. Water Resour. Inv. 5-72. 32 pp.

Cairns, J., Jr., A.G. Heath, and B.C. Parker. 1975. Temperature influence on chemical toxicity to aquatic organisms. J. Water Pollut. Control Fed. 47(2): 267–280.

Campbell, K.M. 1984. Geology of Sumter County. Fla. Geol. Surv. Open File Rep. 7. Tallahassee. 7 pp.

Carlton, J.M. 1975. A guide to common Florida salt marsh and mangrove vegetation. Fla. Dep. Nat. Resour., Mar. Res. Lab, Mar. Resour. Publ. 6. 30 pp.

Carlton, J.M. 1977. A survey of selected coastal vegetation communities in Florida. Fla. Dep. Nat. Resour., Mar. Res. Lab, Mar. Resour. Publ. 30: 1-40.

Carman, K.C. 1984. In situ experimental evidence for dietary difference in four species of co–occurring benthic copepods (Crustacea). M.S. Thesis. Florida State University, Tallahassee. 30 pp.

Carr, W.E.S., and C.A. Adams. 1973. Food habitats of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. Trans. Am. Fish. Soc. 102: 511–540.

Carter, H.J. 1884. Catalogue of marine sponges, collected by Mr. Jos. Willcox, on the west coast of Florida. Proc. Acad. Nat. Sci. Phila. 36: 202–209.

Case, R.A. 1986. Annual summary: Atlantic hurricane season of 1985. Mon. Weather Rev. 114: 1390–1405.

Cato, J.C., and W.E. McCullough, eds. 1976. Economics, biology, and food technology of mullet. Fla. Sea Grant Prog. 15. 158 pp.

Causey, L.V., and G.W. Leve. 1976. Thickness of the potable-water zone in the Floridan aquifer. U.S. Geol. Surv. Map Ser. 74.

Ceryak, R. 1981. Response to recharge in the Principal Artesian aquifer and the Floridan aquifer in the upper Suwannee River basin, south–central Florida. Pages 8–18 *in* B.F. Beck, ed. Studies of the hydrogeology of the Southeastern United States: 1981. Ga. Southwest. Coll. Spec. Publ. 1. Americus.

Ceryak, R., M.S. Knapp, and T. Burnson. 1983. The geology and water resources of the upper Suwannee River Basin, Florida. Fla. Dep. Nat. Resour., Bur. Geol. Rep. Invest. 87. 165 pp.

Chandler, C.R. 1983. Effects of three substrate variables on two artificial reef fish communities. M.S. Thesis. Texas A&M University, College Station. 80 pp.

Chapman, C.R. 1960. Feeding habits of the southern oyster drill, *Thais haemastoma*. Proc. Natl. Shellfish. Assoc. 46: 169–176.

Chapman, V.J. 1970. Mangrove phytosociology. Trop. Ecol. 11: 1–19.

Charney, J. (chairman). 1979. Carbon dioxide and climate: a scientific assessment. National Academy of Science Press, Washington, D.C. Various paging.

Chen, C.S. 1965. The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida. Fl. Geol. Surv. Bull. 45. 105 pp.

Cherry, R.N., J.W. Stewart, and J.A. Mann. 1970. General hydrology of the middle Gulf area, Florida. U.S. Geol. Surv. Rep. 56. 96 pp.

Chestnut, A.C. 1974. Oyster reefs. Pages 171–203 *in* H.T. Odum, B.J. Copeland, and E.A. McMahan, eds., Vol. 2: Coastal ecological systems of the United States. The Conservation Foundation, Washington, D.C.

Christensen, N.L. 1981. Fire regimes in southeastern ecosystems. Pages 112–136 *in* H.A. Mooney, T.M. Bonnickson, N.L. Christensen, J.E. Lotan, and W.A. Reiners, eds. Fire regimes and ecosystem properties. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. WO-26.

Christensen, N.L. 1988. The vegetation of the Coastal Plain of the southeastern United States. Pages 317–363 *in* M.G. Barbour and W.D. Billings, eds. Vegetation of North America. Cambridge University Press.

Christman, S. P. 1979. Cedar Key mole skink. Pages 57–58 *in* R. W. McDiarmid, ed. Amphibians and reptiles. Vol. III. *of* P. C. H. Pritchard, ed. Rare and endangered biota of Florida. University Presses of Florida, Gainesville.

Christman, S. P. [1988.] Endemism and Florida's interior sand pine scrub. Fla. Game Fresh Water Fish Comm. Proj. GFC-84-101. Tallahassee. Unpubl. Ms.

Clewell, A.F. 1971. The vegetation of the Apalachicola National Forest: an ecological perspective. Contract to the U.S. Forest Service. (mimeo.) 152 pp.

Clewell, A.F. 1981. Natural setting and vegetation of the Florida Panhandle. U.S. Army Corps of Eng. Contract No. DACW01-77-C-0104. Mobile, Ala. 773 pp.

Clewell, A.F., L.F. Gainey, Jr., D.P. Harlos, and E.R. Tobi. 1976. Biological effects of fill roads across salt marshes. Florida Department of Transportation. 16 pp.

Coble, R.W. 1973. The Anclote and Pithlachascotee Rivers as water-supply sources. Fla. Dep. Nat. Resour. Bur. Geol. Map Ser. 61.

Conant, R. 1975. A field guide to reptiles and amphibians of Eastern and Central North America. Houghton Mifflin Co., Boston. 429 pp.

Conde, L.F., B.F. Swindel, and J.E. Smith. 1983. Plant species cover, frequency, and biomass: early responses to clearcutting, chopping, and bedding in *Pinus elliottii* flatwoods. For. Ecol. Manage. 6: 307–317.

Conover, C.S., and S.D. Leach. 1975. River basin and hydrologic unit map of Florida. U.S. Geol. Surv. Map Ser. 72.

Continental Shelf Associates, Inc., and Martel Laboratories, Inc. 1985. Florida Big Bend seagrasses habitat study narrative report. Minerals Management Service, Metairie, La. Contract No. 14-12-0001-30188.

Cooke, C.W. 1931. Seven coastal terraces in the southeastern states. Wash. Acad. Sci. J. 21(21): 503–513.

Cooke, C.W. 1945. Geology of Florida. Fl. Geol. Surv. Bull. 29. Tallahassee. 339 pp.

Copeland, B.J., and T.J. Bechtel. 1974. Some environmental limits of six gulf coast estuarine organisms. Contrib. Mar. Sci. 18: 169–204.

Coultas, C.Y., and E.R. Gross. 1975. Distribution and properties of some tidal marsh soils of Apalachee Bay, Florida. Soil Sci. Soc. Am. Proc. 39:914-919.

Courser, D.C., and R.V. McLean. 1977. An overview of the estuaries within the Southwest Florida Water Management District. Pages 19–38 *in* W. Seaman, Jr. and R. McLean, eds. Seminar proceedings: freshwater and the Florida coast: southwest Florida. Fla. Sea Grant Rep. 22.

Courtney, C.M. 1975. Mangrove and seawall oyster communities at Marco Island, Florida. Bull. Am. Malacol. Union Inc. 41: 29–32.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. Larse. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. Off. Biol. Serv. FWS/OBS-79/31. 103 pp.

Cox, J. 1988. The influence of forest size on transient bird species occupying maritime hammocks of northeastern Florida. Fla. Field Nat. 16: 25–34.

Culter, J.K. 1986. Benthic invertebrates and sedimentology. Vol. 2 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 205 pp.

Dame, R.F. 1976. Energy flow in an intertidal oyster population. Estuar. Coast. Mar. Sci. 4: 243–253.

Dame, R.F., and B.C. Patten. 1981. Analysis of energy flows in an intertidal oyster reef. Mar. Ecol. Prog. Ser. 5: 115–124.

Dames and Moore, Inc. 1991. An assessment of the water quality characteristics of the Pithlachascotee River. Southwest Florida Water Management District, Brooksville.

Darley-Hill, S., and W.C. Johnson. 1981. Acorn dispersal by the blue jay (*Cyanocitta cristata*). Oecologia (Berl.) 50: 231–232.

Davis, J.H., Jr. 1940. The ecology and geologic role of mangroves in Florida. Papers from Tortugas Lab 32. Carnegie Inst. Wash. Publ. 517: 305–412.

Davis, J.H., Jr. 1946. The peat deposits of Florida. Their occurrence, development, and uses. Fla. Geol. Surv., Geol. Bull. 30: 1–247.

Dawes, C.J. 1974. Marine algae of the west coast of Florida. University of Miami Press. 201 pp.

Dawes, C.J., and J.M. Lawrence. 1980. Seasonal changes in the proximate constituents of the seagrasses, *Thalassia testudinum, Halodule wrightii*, and *Syringodium filiforme*. Aquat. Bot. 8: 371–380.

Dawes, C.J., R.E. Moon, and M.A. Davis. 1978. The photosynthetic and respiratory rates and tolerances of benthic algae from a mangrove and salt marsh estuary: a comparative study. Estuar. Coast. Mar. Sci. 6: 175–186.

Dawson, C.E., Jr. 1955. A study of the oyster biology and hydrography at Crystal River, Florida. Contr. Inst. Mar. Sci. Univ. Texas 4(1): 279–302.

Dawson, C.E., Jr., and F.G.W. Smith. 1953. The Gulf of Mexico sponge investigation. Fla. State Bd. Conserv. Tech. Ser. 1. Marine Laboratory, University of Miami. 28 pp.

DeLaubenfels, M.W. 1953. Sponges from the Gulf of Mexico. Bull. Mar. Sci. 2: 511–557.

Deuerling, R.J., and P.L. MacGill. 1981. Environmental geology series: Tarpon Springs sheet. Fla. Geol. Surv. Map Ser. 99.

Dixon, L.K. 1986. Water Chemistry. Vol. 1 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 259 pp

Dooris, P.M. 1982. Lake Panasoffkee vegetation map and observations, July, 1980. Memo. dated 1/27/82, Southwest Florida Water Management District, Brooksville. 3 pp.

Donner, L., and V. Ramanathan. 1980. Methane and nitrous oxide: their effect on the terrestrial climate. J. Atmos. Sci. 37: 119–124.

Downing, H.C., Jr., M.S. Flannery, M.J. Buickerood, J.A. Mann, and W.M. Mathieson. 1988. Lake Rousseau operations and management study. Southwest Fla. Water Manage. Dist., Brooksville.

Doyle, L.J. 1984. Living with the west Florida coast. Duke University Press, Durham, N.C. 222 pp.

Duerr, A.D., and G.M. Enos. 1991. Hydrogeology of the intermediate aquifer system and upper Floridan aquifer, Hardy and Desoto Counties, Florida. U.S. Geol. Surv. Water Resour. Inv. 90-4104. 46 pp.

Duerr, A.D., J.D. Hunn, B.R. Lewelling, and J.T. Trommer. 1988. Geohydrology and 1985 water withdrawals of the aquifer systems in southwest Florida, with emphasis on the intermediate aquifer system. U.S. Geol. Surv. Wat. Resour. Invest. Rep. 87-4259. 115 pp.

Duever, L.C. 1985. Element abstract for upland mixed forest. The Florida Natural Areas Inventory, Tallahassee.

Duever, L.C., R.W. Simons, R.F. Noss, and J.R. Newman. 1987. Final report: comprehensive inventory of natural ecological communities in Alachua County. KBN Engineering and Applied Sciences, Gainesville, Florida. 140 pp.

Durako, M.J., J.A. Browder, W.L. Kruczynski, C.B. Subrahamanyam, and R.E. Turner. 1985. Salt marsh habitat and fishery resources of Florida. *In* W. Seaman, ed. Florida aquatic habitat and fishery resources. Florida Chapter, American Fisheries Society. Kissimmee, Fla.

Dysart, J.E., and D.A. Goolsby. 1977. Dissolved–solids concentrations and loads in Florida surface waters. U.S. Geol. Surv. Map Ser. 77.

Earle, S.A. 1969. Phaeophyta of the eastern Gulf of Mexico. Phycologia 7: 71–254.

Earle, S.A. 1975. Dissolved solids, hardness, and orthophosphate of surface-water runoff in the Suwannee River Water Management District, Florida. U.S. Geol. Surv. Water Resour. Inv. 76-15. 3 maps.

Edmisten, J.A. 1963. The ecology of the Florida pine flatwoods. Ph.D. Dissertation. University of Florida, Gainesville. 108 pp.

Edmonds, J.A.E., and J. Reilly. 1982. Global energy and CO_2 to the year 2050. Oak Ridge Associated Universities, Washington, D.C. 34 pp.

Egler, F.E. 1952. Southwest saline Everglades vegetation, Florida, and its management. Vegetatio 3: 213–265.

Ehrhart, L.M. 1978. Sherman's fox squirrel. Pages 17–18 *in* J. N. Layne, ed. Rare and endangered biota of Florida. Vol. I, Mammals. University Presses of Florida, Gainesville.

Ehrlich, G.G., E.M. Godsy, C.A. Pascale, and J. Vecchioli. 1979. Chemical changes in an industrial waste liquid during post–injection movement in a limestone aquifer: Pensacola, Florida. Ground Water 17(6): 562–573.

Eisenberg, J. 1983. The gopher tortoise as a keystone species. Proc. 4th Annu. Meet. Gopher Tortoise Counc., Valdosta, Ga. i-vi, 1-47.

Eleuterius, L.N. 1976. The distribution of *Juncus roemerianus* in the salt marshes of North America. Chesapeake Sci. 17: 289–292.

Environmental Science and Engineering, Inc. 1982a. Florida acid deposition study: phase I summary report. Florida Electric Power Coordinating Group, Tampa. 39 pp.

Environmental Science and Engineering, Inc. 1982b. Florida acid deposition study: source attribution evaluation: phase II summary report. Florida Electric Power Coordinating Group, Tampa. 46 pp.

Environmental Science and Engineering, Inc. 1984. Florida acid deposition study: phase III report. Florida Electric Power Coordinating Group, Tampa. 518 pp.

Estevez, E.D., L.K. Dixon, and M.S. Flannery. 1991. West-coastal rivers of peninsular Florida. Pages 187–222 *in* R.J. Livingston, ed. Rivers of Florida. Ecological Studies Series 83. Springer-Verlag, N.Y.

Ewel, K.C., and W.J. Mitsch. 1978. Effects of fire on species composition in cypress dome ecosystems. Fla. Sci. 41: 25–31.

Fable, W.A., Jr. 1973. Fish fauna of a salt-marsh bayou on the Florida gulf coast. M.A. Thesis. University of South Florida, Tampa. 60 pp.

Faulkner, G.L. 1973a. Geohydrology of the Cross-Florida Barge Canal area with special reference to the Ocala vicinity. U.S. Geol. Surv. Water Resour. Inv. 1-73. 117 pp.

Faulkner, G.L. 1973b. Ground-water conditions in the lower Withlacoochee River-Cross-Florida Barge Canal Comples area. U.S. Geol. Surv. Water Resour. Inv. 4-72. 31 pp.

FDACS. see Florida Department of Agriculture and Consumer Services.

FDER. see Florida Department of Environmental Regulation.

FDNR. see Florida Department of Natural Resources.

Fell, J.W., I.M. Master, and S.Y. Newell. 1980. Laboratory model of the potential role of fungi in the decomposition of red mangrove (*Rhizophora mangle*) leaf litter. Pages 359–372 *in* K.R. Tenore and B.C. Coull, eds. Marine benthic dynamics. Univ. of South Carolina Press, Columbia.

Fernald, E.A., and D.J. Patton, eds. 1984. Water resources atlas of Florida. Florida State University, Tallahassee. 291 pp.

Fernald, E.A., ed. 1981. Atlas of Florida. Florida State University Foundation, Tallahassee. 276 pp.

Finucane, J.H. and R.W. Campbell II. 1968. Ecology of American oysters in Old Tampa Bay, Florida. Q. J. Fla. Acad. Sci. 31: 37-46.

Florida Board of Conservation. 1969. Florida Lakes, Part 3: Gazetteer. Division of Water Resources, Tallahassee. 145 pp.

Florida Department of Agriculture and Consumer Services. 1988. Regulated plant index. Division of Plant Industries, Gainesville. 7 pp.

Florida Department of Natural Resources. Undated. Native plant list: Cedar Key Scrub Reserve. Florida Park Service. 7 pp.

Florida Department of Natural Resources. 1971. A preliminary investigation: the effect of elevated temperature on the American oyster, *Crassostrea virginica* (Gmelin). Fla. Dep. Nat. Resour. Mar. Res. Lab. Prof. Pap. Ser. 15.

Florida Department of Environmental Regulation. 1984. Florida Water Quality Index. Division of Water Quality, Tallahassee. 87 pp.

Florida Department of Environmental Regulation. 1985a. Report of the Florida acid deposition research peer review panel. Tallahassee. 20 pp.

Florida Department of Environmental Regulation. 1985b. Limnology of the Suwannee River, Florida. Tallahassee. 407 pp.

Florida Department of Environmental Regulation. 1986a. An assessment of north Florida river water quality. Tallahassee. 40 pp.

Florida Department of Environmental Regulation. 1986b. Guide for interpreting reported metal concentrations in estuarine sediments. Tallahassee. 28 pp.

Florida Department of Environmental Regulation and Florida Public Service Commission. 1984. An analysis of acid deposition issues: the impacts of proposed national acid deposition control legislation on Florida. Tallahassee. 94 pp.

Florida Game and Fresh Water Fish Commission. 1976. Cross Florida barge canal restudy report. Wildlife study. Vols. I–V. Wildlife Research Laboratory, Gainesville.

Florida Land Design and Engineering, Inc. 1989. Homosassa River water quality study. Citrus County Board of County Commissioners.

Florida Power Corporation. 1985. Crystal River units 1, 2, and 3; 316 demonstration final report. Prepared by Stone and Webster Corp. and Mote Marine Laboratory. 11 sections, 8 appendices.

Florida Rivers Study Committee. 1985. Report to the governor. Florida Rivers Study Committee. Tallahassee. 237 pp.

FNAI. Florida Natural Areas Inventory, see Nature Conservancy.

Foose, D.W. 1980. Drainage areas of selected surface-water sites in Florida. U.S. Geol. Surv. Open File Rep. 80–957. 83 pp.

Foose, D.W. 1983. Selected flow characteristics of Florida streams and canals. U.S. Geol. Surv. Water Resour. Invest. Rep. 83–4107. 265 pp.

Foose, D.W., and J.E. Sohm. 1983. Long-term streamflow stations in Florida, 1980. U.S. Geol. Surv. Map. Ser. 107.

Forman, R.T.T., and Godron, M. 1981. Patches and structural components for a landscape ecology. BioScience 31: 733–740.

Forman, R.T.T., and Godron, M. 1986. Landscape ecology. John Wiley, N.Y. 619 pp.

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S. Dep. Agric. Hand. 271. 762 pp.

Frank, N.L., P.L. Moore, and G.E. Fisher. 1967. Summer shower distribution over the Florida peninsula as deduced from digitized radar data. J. Appl. Meteorol. 6: 309–316.

Franz, R., ed. 1982. Invertebrates. Vol. 6 *in* P.C.H. Pritchard, ed. Rare and endangered biota of Florida. University Presses of Florida, Gainesville. 131 pp.

Fretwell, J.D. 1983. Ground-water resources of coastal Citrus, Hernando and southwestern Levy counties, Florida. U.S. Geol. Surv. Water Resour. Inv. Rep. 83-4079.

Fretwell, J.D. 1985. Water resources and effects of development in Hernando County, Florida. U.S. Geol. Surv. Wat. Resour. Inv. Rep. 84-4320. 83 pp.

Fretwell, J.D. 1988. Water resources and effects of ground-water development in Pasco County, Florida. U.S. Geol. Surv. Wat. Resour. Inv. Rep. 87-4188. 209 pp.

Gannon, P.T. 1982. Meso-scale meteorological modeling in south Florida. Speech summarized *in* K.L. Echternacht. Symposium summary: regional influence of drainage on the hydrologic cycle in Florida: 25–28. Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek–Nubbin Slough Basin, Tallahassee. 42 pp.

Garren, H.K. 1943. Effects of fire on vegetation of the Southeastern United States. Bot. Rev. 9: 617–654.

Gee & Jenson, Consulting Engineers, Inc. 1958. Engineering report of the Withlacoochee River basin. Sumter County Recreation and Water Conservation and Control Authority. Sumter County, Florida. 26 pp.

Geraci, J.R., and D.J. St. Aubin. 1982. Study of the effects of oil on cetaceans. U.S. Dep. Inter., Bur. Land Manage., Contract No. AA551–CT9–29. Washington, D.C.

Geraghty and Miller, Inc. and Reynolds, Smith, and Hills. 1977. Water resources management study: hydrogeologic and engineering evaluation of the Four River Basins area, west-central Florida. U.S. Army Corps of Engineers, Jacksonville, Fla.

German, E.R. 1978. The hydrology of Lake Rousseau, west-central Florida. U.S. Geol. Surv. Water Resourc. Inv. 77-126. Map.

Getter, C.D., J. Michel, and T.G. Ballou. 1984a. Atlas: the sensitivity of coastal environments and wildlife to spilled oil in the north-central Florida region. Fla. Dep. Comm. Aff. Rep. RPI/R/84/8/2-17. 94 pp.

Getter, C.D., J. Michel, and T.G. Ballou. 1984b. Atlas: the sensitivity of coastal environments and wildlife to spilled oil in the Withlacoochee region. Fla. Dep. Comm. Aff. Rep. RPI/R/84/8/2-18. 90 pp.

Gornitz, V., S. Lebedeff, and J. Hansen. 1982. Global sea level trend in the last century. Science 215: 1611–1614.

Gorzelany, J.F., and T.L. Lowers. 1985. Distribution and densities of oyster reef associated fauna along four selected Florida west coast rivers. Fla. Sci. 48 (Suppl. 1).

Gorzelany, J.F. 1986. Oyster-associated fauna. Vol. 5 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 120 pp.

Greiner Engineering Sciences. 1978. Wysong-Lake Panasoffkee resource management study. Southwest Florida Water Management District, Brooksville.

Grice, G.D. 1957. The copepods of the Florida West coast. Ph.D. Dissertation. Florida State University, Tallahassee.

Grice, G.D. 1960. Calanoid and cyclopoid copepods collected from the Florida gulf coast and Florida Keys in 1954 and 1955. Bull. Mar. Sci. Gulf Caribb. 10: 217–226.

Grimes, C.B. 1971. Thermal addition studies on the Crystal River steam electric station. Fla. Dep. Nat. Resour. Mar. Res. Lab. Prof. Paper Ser. 11. 53 pp.

Grimes, C.B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Chesapeake Sci. 16: 172–177.

Grimes, C.B., and J.A. Mountain. 1971. Effects of thermal effluent upon marine fishes near Crystal River steam electric station. Fla. Dep. Nat. Resour., Mar. Res. Lab. Prof. Paper Ser. 17. 64 pp.

Grinnell, R.S., Jr. 1971. Structure and development of oyster reefs on the Suwanee River delta, Florida. Ph.D. Dissertation. State University of New York, Binghampton. 186 pp.

Grinnell, R.S., Jr. 1974. Vertical orientation of shells on some Florida oyster reefs. J. Sediment. Petrol. 44: 116–122.

Gunter, G. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico. Publ. Am. Assoc. Advanc. Sci. 83: 621–638.

Guyton, W.F., and Associates. 1974. Estimated effects of ground water pumping in Pasco County, Florida. Report to Pasco County. 136 pp.

Hafer, F.L., and C.E. Palmer. 1978. Southwest Florida Water Management District Atlas. Southwest Florida Water Management District, Brooksville. 58 pp.

Hampson, P.S. 1984. Wetlands in Florida. U.S. Geol. Surv. Map Ser. 109.

Hand, J. 1980. Multiple station plots: 1980 305b report. Florida Department of Environmental Regulation, Tallahassee.

Hand, J., and D. Jackman. 1984. Water quality inventory for the State of Florida: 305b report. Florida Department of Environmental Regulation, Tallahassee. 235 pp.

Hansen, J.E., A. Lacis, and D. Rind. 1981. Climate impact of increasing atmospheric carbon dioxide. Science 213(4511): 957–966.

Harada, K., W.C. Burnett, P.A. LaRock, and J.B. Cowart. 1989. Polonium in Florida groundwater and its possible relationship to the sulfur cycle in bacteria. Geochem. Cosmochem. Acta 53: 143–150.

Harlow, R.F. 1959. An evaluation of white-tailed deer habitat in Florida. Fla. Game Fresh Water Fish Comm. Tech. Bull. 5. 64 pp.

Harper, R.M. 1911. The relation of climax vegetation to islands and peninsulas. Bull. Torrey Bot. Club 38: 515–525.

Harper, R.M. 1915. Vegetation types. Pages 135–188 *in* E.H. Sellards, R.M. Harper, E.N. Mooney, W.J. Latimer, H. Gunter, and E. Gunter, eds. Natural resources survey of an area in central Florida. Fla. Geol. Surv. Ann. Rep. 7.

Harris, L.D. 1984. The fragmented forest. University of Chicago Press, Chicago. 211 pp.

Harris, L.D., L.D. White, J.E. Johnson, and D.G. Milchunas. 1975. Impact of forest plantations on north Florida wildlife and habitat. Proc. Southeast. Assoc. Game Fish Comm. 28: 659–667.

Harris, L.D., and P. Skoog. 1980. Wildlife habitat implications of forest management practices. Pages 103–119 *in* R.H. Chabreck and R.H. Mills, eds. Integrating timber and wildlife management in southern forests. Proceedings of the 29th Annual Louisiana State University Forest Symposium, Baton Rouge, La.

Hart, R. 1987. The dark side of protecting wetlands. Palmetto 7(3): 10–11.

Hartman, D.S. 1971. Behavior and ecology of the Florida manatee, *Trichechus manatus* (Harden) at Crystal River, Florida. Ph.D. Dissertation. Cornell University, Ithaca, N.Y. 285 pp.

Hartog, C. den. 1970. Seagrasses of the world. North Holland Publishing Co., Amsterdam. 275 pp.

Healy, H.G. 1974. The observation–well network of the U.S. Geological Survey in Florida. U.S. Geol. Surv. Map Ser. 65.

Healy, H.G. 1975a. Terraces and shorelines of Florida. Fla. Bur. Geol. Map Ser. 71.

Healy, H.G. 1975b. Piezometric surface and areas of artesian flow of the Floridan aquifer in Florida, July 6–17, 1961. U.S. Geol. Surv. Map Ser. 4, 2nd ed.

Healy, H.G. 1981. Estimated pumpage from ground–water sources for public supply and rural domestic use in Florida, 1977. U.S. Geol. Surv. Map Ser. 102.

Healy, H.G. 1982. Potentiometric surface of the Floridan aquifer in Florida, May 1980. U.S. Geol. Surv. Map Ser. 104.

Healy, H.G., and J.D. Hunn. 1984. Occurrence of beds of low hydraulic conductivity in surficial deposits of Florida. U.S. Geol. Surv. Water Resour. Invest. Rep. 84–4210.

Hearld, E.S., and R.S. Strickland. 1949. An annotated list of fishes of Homasassa Springs, Florida. Q. J. Fla. Acad. Sci. 11: 99–109.

Heath, R.C. 1983. Basic groundwater hydrology. U.S. Geol. Surv. Water Sup. Pap. 2220. 84 pp.

Heath, R.C., and C.S. Conover. 1981. Hydrologic almanac of Florida. U.S. Geol. Surv. Open File Rep. 81–1107. 239 pp.

Henderson, S.E. 1983. Hydrology of Lake Padget, Saxon Lake, and adjacent area, Pasco County, Florida. U.S. Geol. Surv. Water Resour. Inv. 82-759.

Henningsen, D., and J. Salmon. 1981. Phase one final report of the comprehensive erosion control, beach presentation and hurricane protection plan for the State of Florida. Florida Department of Natural Resources, Division of Marine Resources, Bureau of Beaches and Shores, Tallahassee. 239 pp.

Hickey, J.J. 1984. Subsurface waste storage, Florida. Pages 44–46 *in* Water resources investigations in Florida. U.S. Geological Survey, Tallahassee.

Hicks, S.D., H.A. Debaugh, Jr., and L.E. Hickman. 1983. Sea-level variations for the United States 1855–1980. National Ocean Survey, Rockville, Md. 170 pp.

Hine, A.C., and D.F. Belknap. 1986. Recent geological history and modern sedimentary processes of the Pasco, Hernando and Citrus County coastline: West-central Florida. Fla. Sea Grant Rep. 79. Gainesville. 166 pp.

Ho, F.P., and R.J. Tracey. 1975. Storm tide frequency analysis for the Gulf of Mexico of Florida from Cape San Blas to St. Petersburg beach. Nat. Ocean. Atmos. Admin. Memo NWS HYDRO–20. 34 pp.

Hoffman, J.S., D. Keyes, and J.G. Titus. 1983. Projecting future sea level rise: methodology, estimates to the year 2100, and research needs. U.S. Environ. Protect. Agency, EPA 230–09–007. Revised. Washington, D.C. 120 pp.

Hoffman, J.S., J.B. Wells, and J.G. Titus. 1986. Future global warming and sea level rise. *In* Per Bruun, ed. Iceland Symposium '85. National Energy Authority, Reykjavik.

Hoffman, M.L. 1983. Historical status and nest site selection of the American kestrel (*Falco sparverius paulus*) in Florida. M.S. Thesis. University of Florida, Gainesville. 100 pp.

Holdahl, S.R., and N.L. Morrison. 1974. Regional investigations of vertical crustal movements in the U.S., using precise relevelings and mareographic data. Techonophysics 23: 373–390.

Hooks, T.A., K.L. Heck, Jr., and R.J. Livingston. 1976. An inshore marine invertebrate community: structure and habitat association in the northeastern Gulf of Mexico. Bull. Mar. Sci. 26: 99–109.

Hooper, R.G., A.F. Robinson, Jr., and J.A. Jackson. 1980. The red-cockadad woodpecker: notes on life history and management. U.S. Dep. Agric. For. Serv. Gen. Rep. SA-GR 9. 7 pp.

Huff, J.A., C.J. Grayu, P.R. Witham, and L. Fallow. 1981. Summary of marine turtle activity in Florida, 1980. Florida Department of Natural Resources, Tallahassee.

Hughes, G.H. undated. Runoff from hydrologic units in Florida. U.S. Geol. Surv. Map Ser. 81.

Hughes, G.H. 1974. Water–level fluctuations of lakes in Florida. U.S. Geol. Surv. Map Ser. 62.

Hughes, G.H., E.R. Hampton, and D.F. Tucker. 1971. Annual and seasonal rainfall in Florida. U.S. Geol. Surv. Map Ser. 40.

Hull, R.W., and G.A. Irwin. 1979. Quality of untreated water for public drinking supplies in Florida with reference to the National Primary Drinking Water Regulations. U.S. Geol. Surv. Map Ser. 91.

Hull, R.W., and J.B. Martin. 1982. Data on subsurface storage of liquid waste near Pensacola, Florida, 1963–1980. U.S. Geol. Surv. Open File Rep. 82–689. 179 pp.

Humm, H.J. 1963. Some new records and range extensions of Florida marine algae. Bull. Mar. Sci. Gulf Carib. 14: 306–341.

Humm, H.J. 1973. Benthic algae of the eastern Gulf of Mexico. Pages III B–1 to III B–10 *in* J.I. Jones, R.E. Ring, M.O. Rinkel, and R.E. Smith, eds. A summary of the knowledge of the eastern Gulf of Mexico. State University System of Florida, Institute of Oceanography, St. Petersburg.

Humm, H.J., and S.E. Taylor. 1961. Marine Chlorophyta of the upper west coast of Florida. Bull. Mar. Sci. Gulf Carib. 11: 321–380.

Humphrey, S.R., J.F. Eisenberg, and R. Franz. 1985. Possibilities for restoring wildlife of a longleaf pine savanna in an abandoned citrus grove. Wild. Soc. Bull. 13: 487–496.

Humphries, W.J. 1940. Physics of the air. McGraw–Hill, N.Y. 676 pp.

Husar, S.L. 1977. The West Indian manatee (*Trichechus manatus*). U.S. Fish Wildl. Serv. Rep. 7. 22 pp.

Hussey, E.H. 1986. Shoreline vegetation. Vol. 3 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville.

Hutton, J.G., A.C. Hine, M.W. Evans, E.B. Osking, and D.F. Belknap. 1984. Influence of a karstified limestone surface on an open marine, marsh dominated coastline: west central Florida. Pages 35–42 *in* B.F. Beck, ed. Sinkholes: their geology, engineering, and environmental impact. Proceedings of the first multidisciplinary conference on sinkholes, Orlando, Fla. A.A. Balkema Publishers, Accord, Mass.

Hyde, L.W. 1975. Principal aquifers in Florida. U.S. Geol. Surv. Map Ser. 16.

Ingram, W. 1980. The heuristic analysis of temporal and spatial variation within zooplankton community structure at the Crystal River estuary: a multivariate approach. Ph.D. Dissertation. University of Florida, Gainesville. 640 pp.

Irvine, A.B., and H.W. Campbell. 1978. Aerial census of the West Indian manatee, *Trichechus manatus*, in the Southeastern United States. J. Mammal. 59: 613–617.

Irvine, A.B., J.E. Cuffin, and H.I. Kochman. 1981. Aerial surveys for manatees and dolphins in western peninsular Florida; with notes on sightings of sea turtles and crocodiles. U.S. Fish Wildl. Serv. Off. Biol. Serv. FWS/OBS-80/50.

Iverson, R.L., and H.F. Bittaker. 1986. Seagrass distribution and abundance in eastern Gulf of Mexico coastal waters. Estuar. Coast. Shelf Sci. 22: 577–602.

Jackson, J.A. 1986. Biopolitics, management of Federal lands, and the conservation of the red-cockaded woodpecker. Am. Birds 40: 1162–1168.

Jennings, R.L. 1951. A study of the life history and ecology of the gray squirrel (*Sciurus c. carolinensis* Gmelin) in Gulf Hammock. M.S. Thesis. University of Florida, Gainesville. 151 pp.

Johnson, A.F. 1982. Some demographic characteristics of the Florida rosemary, *Ceratiola ericoides* Michx. Am. Midl. Natur. 108(1): 170–174.

Jolley, J.W. 1972. Exploratory fishing for the sunray venus clam, *Macrocallista nimbosa,* in northwest Florida. Fla. Dep. Nat. Resour. Tech. Ser. 67. 42 pp.

Jordan, C.L. 1973. The physical environment: climate. Pages IIA-1–IIA-22 *in* A summary of knowledge of the eastern Gulf of Mexico 1973. State University System of Florida, Institute of Oceanography, St. Petersburg.

Jordan, C.L. 1984. Florida's weather and climate: implications for water. Pages 18–35 *in* E.A. Fernald and D.J. Patton, eds. Water resources atlas of Florida. Florida State University, Tallahassee. 291 pp.

Joyce, E.A., Jr. 1981. Summary of Florida Commercial Marine Landings. Florida Department of Natural Resources Report, Tallahassee.

Kalisz, P.J., and E.L. Stone. 1984. The longleaf pine islands of the Ocala National Forest, Florida: a soil study. Ecology 65: 1743–1754.

Karr, J.R., and I.J. Schlosser. 1978. Water resources and the land-water interface. Science 201: 229–234.

Kaufman, M.I. 1973. Subsurface wastewater injection, Florida. Am. Soc. Civ. Eng. Proc. Pap. 9598, 99(IRI): 53–70.

Kaufman, M.I. 1975a. The pH of water in Florida streams and canals. U.S. Geol. Surv. Map Ser. 37. Revised.

Kaufman, M.I. 1975b. The chemical type of water in Florida streams. U.S. Geol. Surv. Map Ser. 51. Revised.

Kaufman, M.I. 1975c. Color of water in Florida streams and canals. U.S. Geol. Surv. Map Ser. 35. Revised.

Kaufman, M.I. 1975d. Generalized distribution and concentration of orthophosphate in Florida streams. U.S. Geol. Surv. Map Ser. 33. Revised.

Kenner, W.E. 1966. Runoff in Florida. U.S. Geol. Surv. Map Ser. 22.

Kenner, W.E. 1975. Seasonal variation of streamflow in Florida. U.S. Geol. Surv. Map Ser. 31. Revised.

Kenner, W.E., E.R. Hampton, and C.S. Conover. 1975. Average flow of major streams in Florida. U.S. Geol. Surv. Map Ser. 34. Revised.

Kerr, R.A. 1984. Doubling of atmospheric methane supported. Science 226(4677): 954.

Kimrey, J.O. 1990. Potential for groundwater development in Central Volusia County in Florida. U.S. Geol. Surv. Water Resour. Inv. 90-4010. 31 pp.

Kitting, C.L., B.D. Fry, and M.D. Morgan. 1984. The base of seagrass meadow food webs: inconspicuous algae, not seagrass detritus. Oecologia 62: 145–149.

Klein, H. 1975. Depth to base of potable water in the Floridan aquifer. U.S. Geol. Surv. Map Ser. 42. Revised.

Knapp, M.S. 1978. Environmental geology series: Gainesville sheet. Fla. Bur. Geol. Map Ser. 79.

Knauss, J.A. 1978. Introduction to physical oceanography. Prentice–Hall, Inc., Englewood Cliffs, N.J. 338 pp.

Knight, R.L., and W.F. Coggins. 1982. Record of estuarine and salt marsh metabolism at Crystal River, Florida, 1977–1981. Department of Environmental Engineering, University of Florida, Gainesville. 97 pp.

Kochman, H.I., G.B. Rathbun, and J.A. Powell. 1983. Use of Kings Bay, Crystal River, Florida by the West Indian manatee (*Trichechus manatus*). Pages 60–124 *in* J.M. Packard, ed. Proposed research/management plan for Crystal River manatees. Vol. III. Compendium, Univ. Fla. Coop. Fish Wildl. Res. Unit, Tech. Rep. 7, Gainesville. 346 pp.

Kohlmeyer, J., and E. Kohlmeyer. 1979. Marine mycology: the higher fungi. Academic Press, N.Y.

Kuenzler, E.J. 1974. Mangrove swamp systems. Pages 346–371 *in* H.T. Odom, B.J. Copeland, and E.A. McMahon, eds. Coastal ecological systems. Vol. I. Conservation Foundation, Washington, D.C.

Kurz, H. 1942. Florida dunes and scrub, vegetation and geology. Fla. Geol. Surv. Geol. Bull. 23: 1–154.

Kurz, H., and K. Wagner. 1957. Tidal marshes of the Gulf and Atlantic coasts of northern Florida and Charleston, S.C. Fla. State Univ. Stud. 24. 168 pp.

Laessle, A.M. 1942. The plant communities of the Welaka area. Univ. Fla. Biol. Sci. Ser. 4(1). 143 pp.

Laessle, A.M. 1958. The origin and successional relationship of sandhill vegetation and sand-pine scrub. Ecol. Monogr. 28(4): 361–387.

Lakela, O. 1964. Fewer Florida rarities: changing flora of Pineola Grotto, Citrus County. Sida 1: 299–305.

Lamonds, A.G., and M.L. Merritt. 1976. Proposed cross-Florida barge canal: water quality aspects with a section on waste-assimilative capacity. U.S. Geol. Surv. Water Resour. Inv. 76-23. 189 pp.

Leach, S.D. 1978. Freshwater use in Florida, 1975. U.S. Geol. Surv. Map Ser. 87.

Leach, S.D. 1982a. Estimated water use in Florida, 1980. U.S. Geol. Surv. Map Ser. 103.

Leach, S.D. 1982b. Consumptive use of freshwater in Florida, 1980. U.S. Geol. Surv. Map Ser. 105.

Leach, S.D. 1984. Projected public supply and rural (self–supplied) water use in Florida through year 2020. U.S. Geol. Surv. Map Ser. 108.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. N. C. Biol. Surv. Pub. 1980-12. 854 pp.

Lee, R.M., and S.D. Gerking. 1980. Sensitivity of fish eggs to acid stress. Water Res. 14: 1679–1681.

Lehman, M.E. 1974. Oyster reefs at Crystal River, Florida, and their adaptation to thermal plumes. Ph.D. Dissertation. University of Florida, Gainesville. 197 pp.

Leivestad, H., G. Hendry, I.P. Muniz, and E. Snekvik. 1976. Effects of acid precipitation on freshwater organisms. *In* F.H. Braekke, ed. Impact of acid precipitation on forest and freshwater ecosystems in Norway. Sur Nedbørs virkning på Skog og Fisk FR 6/76, Oslo–Ås, Norway.

Leivestad, H., I.P. Muniz, and B.O. Rosseland. 1980. Acid stress in trout from a dilute mountain stream. Pages 318–319 *in* D. Drabløs and A. Tollan, eds. Ecological impact of acid precipitation. Proc. Int. Conf., Sandefjord, Norway. Sur Nedbørs virkning på Skog og Fisk, Oslo–Ås, Norway.

Leopold, A. 1949. A sand county almanac. Oxford University Press, N.Y. 295 pp.

Lewis, R.R., and F.M. Dunstan. 1975. The possible role of *Spartina alterniflora* Loisel in establishment of mangroves in Florida. Pages 82–100 *in* Proceedings, 2nd conference on the restoration of coastal vegetation in Florida. Hillsborough Community College, Tampa.

Lewis, R.R., R.G. Gilmore, D.W. Crewz, and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida. *In* W. Seaman, ed. Florida aquatic habitat and fishery resources. Florida Chapter, American Fisheries Society. Kissimmee, Fla.

Ligon, J.D., P.B. Stacey, R.N. Conner, C.E. Bock, and C.S. Adkisson. 1986. Report of the American Ornithologists' Union Committee for the Conservation of the Red-cockaded Woodpecker. Auk 103: 848–855.

Livingston, R.J. 1983. Resource atlas of the Apalachicola estuary. Fla. Sea Grant Rep. 55. 64 pp.

Livingston, R.J. 1984. Trophic response of fishes to habitat variability in coastal seagrass systems. Ecology 65(4): 1258-1275.

Livingston, R.J. [1986.] Field verification of bioassay results at toxic waste sites in three southeastern drainage systems. U.S. Environmental Protection Agency, Corvallis, Oreg. 8 vols. Unpubl. Ms.

Livingston, R.J., ed. 1991. Rivers of Florida. Ecological Studies Series 83. Springer-Verlag, N.Y.

Livingston, R.J., C.R. Cripe, R.A. Laughlin, and F.G. Lewis. 1976. Avoidance of estuarine organisms to storm runoff and pulp mill effluents. Estuar. Proc. 1: 313–331.

Livingston, R.J., R.J. Diaz, and D.C. White. 1985. Field validation of laboratory-derived multispecies aquatic test systems: project summary. U.S. Environ. Protect. Agency EPA/600/S4-85/039. Gulf Breeze, Fla. 7 pp.

Lopez, M., P.M. Dorris, and T.F. Rochow. 1981. Green swamp flood detention area environmental assessment. Southwest Florida Water Management District, Brooksville. 70 pp.

Lugo, A.E., and S.C. Snedaker. 1974. The ecology of mangroves. Annu. Rev. Ecol. Syst. 5: 39–64.

Lyons, W.G., S.P. Cobb, D.K. Camp, J.A. Mountain, T. Savage, L. Lyons, and E.A. Joyce, Jr. 1971. Preliminary inventory of marine invertebrates collected near the electrical generating plant, Crystal River, Florida, in 1969. Fla. Dep. Nat. Resour., Mar. Res. Lab Prof. Paper Ser. 14. 45 pp.

MacNeil, F.S. 1949. Pleistocene shorelines in Florida and Georgia. U.S. Geol. Surv. Prof. Pap. 221–F: 95–107.

Mahon, G.L. 1989. Potential for saltwater intrusion into the upper Floridan aquifer, Hernando and Manatee Counties, Florida. U.S. Geol. Surv. Water Resour. Inv. 88-4171. 47 pp.

Mangrove Systems, Inc. 1986. Seagrasses and macroalgae. Vol. 6 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 145 pp.

Marion, W.R., and T.E. O'Meara. 1982. Wildlife dynamics in managed flatwoods of north Florida. Pages 63–67 *in* S.S. Coleman, A.C. Mace, Jr., and B.F. Swindel, eds. Impacts of intensive forest management practices. School of Forest Resources and Conservation Proceedings for the14th Annual Spring Symposium, University of Florida, Gainesville.

Marx, J., and W. Herrnkind. 1985. Macroalgae (Rhodophyta: *Laurencia* spp.) as habitat for young juvenile spiny lobsters, *Panulirus argus*. Bull. Mar. Sci. 36: 423–431.

Mather, J.R., F.J. Swaye, and B.J. Hartmann. 1973. The influence of the climatic water balance on conditions in the estuarine environment. University of Delaware, Newark. 73 pp.

Mathieson, A.C., and C.J. Dawes. 1975. Seasonal studies of Florida sublittoral marine algae. Bull. Mar. Sci. 25: 46–65.

Mathis, K., J.C. Cato, R.L. Degener, P.D. Landrum, and F.J. Prochaska. 1978. Commercial fishing activity and facility needs in Florida: Dixie, Levy, and Taylor counties. Inst. Food Agric. Sci., Indust. Rep. 78-4, Fla. Agric. Market Res. Center, University of Florida, Gainesville.

Maturo, F.J., Jr. 1974. Zooplankton research. Crystal River Power Plant Environmental Considerations. Final report to the Interagency Research Advisory Committee. Florida Power Corporation. 418 pp.

Maturo, F.J., Jr. 1982. A review of biological studies on the Waccasassa Bay–New Port Richey, Florida, area, with biological and hydrological bibliographies. Final Rep. Southwest Fla. Water Manag. Dist. Contract No. 216*B81 (DSR No. 82063mj-2). 50+ pp.

McElveen, J.D. 1977. The edge effect on a forest bird community in north Florida. Proc. Southeast. Game Fish Comm. 31: 212-215.

McKinney, M.L. 1984. Suwanee channel of the Paleocene coastal plain: support for the "carbonate suppression model" of basin formation. Geology 12: 343–345.

McMahan, C.A. 1968. Biomass and salinity tolerance of shoalgrass and manateegrass in lower Laguna Madre, TX. J. Wildl. Manage. 32: 501–506.

McMillan, C. 1979. Differentiation in response to chilling temperatures among populations of three marine spermatophytes, *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii*. Am. J. Bot. 66: 810–819.

McNulty, J.K., W.N. Lindal, Jr., and J.E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study: Florida phase I: area description. Nat. Ocean. Atmos. Admin. Tech. Rep. Circ. 368: 1–126.

McRoy, C.P., and S.L. Williams. 1977. Sublethal effects of hydrocarbons on seagrass photosynthesis. Final report to N.O.A.A. Outer Cont. Shelf Environ. Assess. Pro. Contract 03-5-022-56. 35 pp.

McWilliams, P.G., and W.T.W. Potts. 1978. The effects of pH and calcium on gill potentials in brown trout *Salmo trutta*. J. Comp. Physiol. 126: 277–286.

Means, D.B., and G. Grow. 1985. The endangered longleaf pine community. ENFO 85(4): 1–12.

Means, D.B., and P.E. Moler. 1979. The pine barrens treefrog: fire, seepage bogs, and management implications. Pages 77–83 *in* R. R. Odum and L. Landers, eds. Proceedings of the rare and endangered wildlife symposium, August 3–4, Athens, Georgia. Ga. Dep. Nat. Resour., Game Fish Div. Tech. Bull. WL–4.

Merritt, M.L. 1984. Digital simulation of the regional effects of subsurface injection of liquid waste near Pensacola, Florida. U.S. Geol. Surv. Water Resour. Invest. Rep. 84-4042. 73 pp.

Miller, J.A. 1979. Potential subsurface zones for liquid–waste storage in Florida. U.S. Geol. Surv. Map Ser. 94.

Miller, J.A. 1986. Hydrogeologic framework of the Floridan Aquifer system in Florida, and in parts of Georgia, Alabama, and South Carolina. U.S. Geol. Surv. Pro. Pap. 1403-B. 91 pp.

Missimer and Associates, Inc. 1978. Coastal water management guidelines: Pithlachascotee River basin. Report to Southwest Florida Water Management District. 210 pp.

Mobius, K. 1877. Die Auster und die Austernwistschaft. Wiegundt, Hempel und Parey, Berlin. 126 pp.

Moler, P.E. [1985.] Home range and seasonal activity of the eastern indigo snake, *Drymarchon corais couperi*, in northern Florida. Florida Game and Fresh Water Fish Commission. 25 pp. Unpubl. Ms.

Moler, P.E., and R. Franz. 1987. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pages 234–241 *in* Proceedings 3rd southeastern nongame and endangered wildlife symposium. Ga. Dep. Nat. Resour., Game Fish Comm. Tech. Bull. Atlanta.

Monk, C.D. 1960. A preliminary study on the relationship between the vegetation of a mesic hammock and a sandhill community. Q. J. Fla. Acad. Sci. 23: 1–12.

Monk, C.D. 1965. Southern mixed hardwood forest of north-central Florida. Ecol. Monogr. 35(4): 335–354.

Monk, C.D. 1966. An ecological study of hardwood swamps in north-central Florida. Ecology 47: 649–654.

Monk, C.D. 1968. Successional and environmental relationships of the forest vegetation of north central Florida. Am. Midl. Nat. 79(2): 441–457.

Monk, C.D., and T.W. Brown. 1965. Ecological consideration of cypress heads in north central Florida. Am. Midl. Nat. 74:126-140.

Montfrans, J.V., R.L. Wetzel, and R.J. Orth. 1984. Epiphyte–grazer relationships in seagrass meadows: consequences for seagrass growth and production. Estuaries 7: 289–309.

Moody, H.L. 1957. A fisheries study of Lake Panasoffkee, Florida. Q. J. Fla. Acad. Sci. 20: 21-88.

Moore, J.C. 1951. The range of the Florida manatee. Q. J. Fla. Acad. Sci. 14: 1–19.

Morisita, M. 1959. Measuring the interspecific association and similarity between communities. Mem. Fac. Sci. Kyushu Univ. Ser. E (Biol.) 3(1): 65–80.

Mote Marine Laboratory. 1986. Salt and freshwater marshes. Vol. 7 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 125 pp.

Mountain, J.A. 1972. Further thermal addition studies at Crystal River, Florida with an annotated checklist of marine fishes collected 1969-1971. Fla. Dep. Nat. Resour. Mar. Res. Lab. Prof. Pap. Ser. 20. St. Petersburg. 103 pp.

Myers, V.B., and H.L. Edmiston. 1983. Florida lake classification and prioritization project #S004388: final report. Florida Department of Environmental Regulation, Tallahassee. 78 pp.

Nall, L.E. 1979. Age and growth of the southern flounder, *Paralichthys lethostigma*, in the northern Gulf of Mexico with notes on *P. albigutta*. M.S. Thesis. Florida State University, Tallahassee. 58 pp.

Nash, G.V. 1895. Notes on some Florida plants. Bull. Torrey Bot. Club 22: 141–147.

National Research Council. 1983. Changing climate. Carbon Dioxide Assessment Committee. National Academy of Sciences Press, Washington, D.C. 562 pp.

Nature Conservancy. 1990. Florida natural areas inventory (FNAI). Unpublished lists of special plants, special animals, and community-types. Tallahassee, Fla.

New Jersey Department of Environmental Protection. 1981. New Jersey shore protection master plan. Division of Coastal Resources, Trenton, N.J.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33: 700–706.

Noss, R.F. 1984. Evaluation of Pineola Grotto, Citrus County, Florida, as a potential National Natural Landmark. Report to National Park Service. Florida Natural Areas Inventory, Tallahassee. 13 pp.

Noss, R.F. 1987a. From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). Biol. Conserv. 41: 11–37.

Noss, R.F. 1987b. Protecting natural areas in fragmented landscapes. Nat. Areas J. 7: 2–13.

Noss, R.F. 1988. The longleaf pine landscape of the Southeast: almost gone and almost forgotten. Endangered Species Update 5(5): 1–8.

Noss, R.F. 1991. Effects of edge and internal patchiness on avian habitat use in old-growth Florida hammock. Nat. Areas J. 11(1):34-47.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environ. Manage. 10: 299–309.

Odum, E.P. 1971. Fundamentals of ecology. Saunders, Philadelphia. 574 pp.

Odum, E.P., and A.A. de la Cruz. 1967. Particulate organic detritus in a Georgia salt–marsh estuarine ecosystem. Pages 383–388 *in* G.H. Lauff, ed. Estuaries. American Association for the Advancement of Science, Washington, D.C.

Odum, H.T., H.W. McKellar, W. Smith, M. Lehman, O. Young, M. Kemp, M. Homer, and T. Gayle. 1974. Simulation models of estuarine ecosystems at Crystal River. Progress Report to Florida Power Company. 102 pp.

Odum, W.E., C.C. McIvor, and T.J. Smith III. 1982. The ecology of the mangroves of South Florida: a community profile. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-81/24. 144 pp.

Oesterling, M.J. 1976a. Population structure, dynamics, and movement of the blue crab (*Callinectes sapidus*) Rathbun at Crystal River, Florida. M.S. Thesis. University of Florida, Gainesville. 88 pp.

Oesterling, M.J. 1976b. Reproduction, growth and migration of blue crabs along Florida's gulf coast. MAI-20, Gainesville, Fla. Florida Cooperative Extension Service, Marine Advisory Program.

Packard, J.M., ed. 1983. Proposed research/management plan for Crystal River manatees. Vols. I, II, III. Univ. Fla. Coop. Fish Wildl. Res. Unit, U.S. Fish Wildl. Serv. Tech. Rep. 7. Gainesville.

Palmer, S.L. 1984. Surface water. Pages 54–67 *in* E.A. Fernald and D.J. Patton, eds. Water resources atlas of Florida. Florida State University, Tallahassee. 291 pp.

Parker, G.G. 1973. The Green Swamp: should it be in public ownership? Southwest Florida Water Management District, Brooksville. 3pp.

Pascale, C.A. 1975. Estimated yield of fresh–water wells in Florida. U.S. Geol. Surv. Map Ser. 70.

Pascale, C.A. 1976. Construction and testing of two waste–injection monitoring wells in northwest Florida. U.S. Geol. Surv. Open File Rep. 76–1. 42 pp.

Pascale, C.A., and J.B. Martin. 1978. Hydrologic monitoring of a deep–well waste injection system near Pensacola, Florida, March 1970–March 1977. U.S. Geol. Surv. Water Resour. Invest. 78–27. 61 pp.

Pearson, P.G. 1954. Mammals of Gulf Hammock, Levy County, Florida. Am. Midl. Natur. 51: 468–480.

Peck, S.B. 1970. The terrestrial arthropod fauna of Florida caves. Fla. Entomol. 53(4): 203–207.

Peterson, C.H. 1981. The ecological role of mud flats in estuarine systems. Pages 184–192 *in* R.C. Carry, P.S. Makovits, and J.B. Kirkwood, eds. Proceedings of the USFWS workshop on coastal ecosystems of the Southeastern United States. U.S. Fish. Wildl. Serv. Biol. Serv. Prog. FWS/OBS–80/59.

Peterson, C.H., and N.M. Peterson. 1979. The ecology of intertidal flats of North Carolina: a community profile. U.S. Fish. Wildl. Serv. Biol. Serv. Program FWS/OBS–79/39. 73 pp.

Phelps, G.G. 1978a. Chemical quality of water used for municipal supply in Florida, 1975. U.S. Geol. Surv. Map Ser. 82.

Phelps, G.G. 1978b. Principal uses of freshwater in Florida, 1975. U.S. Geol. Surv. Map Ser. 83.

Phillips, R.C. 1960a. Observations on the ecology and distribution of the Florida seagrass. Fla. Board Conserv. Prof. Papers Ser. 2. 72 pp.

Phillips, R.C. 1960b. The ecology of marine plants of Crystal Bay, Florida. Q. J. Fla. Acad. Sci. 23(4): 328–337.

Phillips, R.C. 1978. Seagrasses and the coastal marine environment. Oceanus 21: 30–40.

Phillips, T.D. 1986. Fishes and macroinvertebrates. Vol. 3 *of* An investigation of the role of freshwater inflows in the ecology of estuaries on the upper coast of west-central Florida. Brooksville. 66 pp.

Pierce, E. 1952. The chaetognatha of the west coast of Florida. Fla. Eng. Ind. Exper. Sta. Eng. Prog. 6: 4–26.

Pilkey, O., J. Howard, B. Brenninkmeyer, R. Frey, A. Hine, J. Kraft, R. Morton, D. Nummedal, and H. Wanless. 1981. Saving the American beach: a position paper by concerned coastal geologists. Results of the Skidaway Institute of Oceanography conference on America's eroding shoreline. Skidaway Institute of Oceanography, Savannah. 43 pp.

Platt, W.J., and M. Schwartz. 1990. Temperate hardwood forests. Pages 194–229 *in* R. Myers and J. Ewel, eds. The ecosystems of Florida. University Presses of Florida. Gainesville.

Powell, J.A. 1981. The manatee population in Crystal River, Citrus County, Florida. Pages 33–40 *in* R.L. Brownell, Jr. and K. Ralls, eds. The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27–29 March, 1978. Florida Department of Natural Resources, Tallahassee.

Powell, J.A., and G.B. Rathbun. 1984. Distribution and abundance of manatees along the northern coast of the Gulf of Mexico. Northeast Gulf Sci. 7: 1–28.

Pride, R.W. 1975. Estimated water use in Florida, 1965. U.S. Geol. Surv. Map Ser. 36. Second edition.

Pride, R.W., F.W. Meyer, and R.N. Cherry. 1961. Interim report on the hydrologic features of the Green Swamp area in central Florida. U.S. Geol. Surv. Inf. Circ. 26. 96 pp.

Pride, R.W., F.W. Meyer, and R.N. Cherry. 1966. Hydrology of Green Swamp area in central Florida. U.S. Geol. Surv. Rep. Inv. 42. 110 pp.

Pritchard, P.C.H., ed. 1979. Rare and endangered biota of Florida. Volumes 1, 2, 3, and 5. University Presses of Florida, Gainesville.

Puri, H.S. 1953. Zonation of the Ocala Group in peninsular Florida. J. Sed. Petr. 23: 130.

Puri, H.S., and R.O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Fla. Bur. Geol. Spec. Publ. 5 (revised). 312 pp.

Puri, H.S., J.W. Yon, and W.R. Oglesby. 1967. Geology of Dixie and Gilchrist Counties, Florida. Fla. Div. Geol. Bull. 49: 1–155.

Pybas, D.W. 1987. Atlas of artificial reefs in Florida. Fla. Sea Grant Ext. Bull. SGEB-13. 26 pp.

Quarterman, E., and C. Keever. 1962. Southern mixed hardwood forest: climax in the southeastern coastal plain, U.S.A. Ecol. Monogr. 32: 167–185.

Quinby-Hunt, M.S., and K.K. Turekian. 1983. Distribution of elements in sea water. EOS, Trans. Am. Geophys. Union 64(14): 130–132.

Randazzo, A.G., and H.G. Saroop. 1976. Sedimentology and paleoecology of middle and upper Eocene carbonate shoreline sequences, Crystal River, Florida. J. Sediment. Geol. 15: 259–291.

Ramanathan, V. 1975. Greenhouse effect due to chlorofluorocarbons: climatic implications. Science 190: 50–52.

Rasmussen, R.A., and M.A.K. Khalil. 1981a. Atmospheric methane (CH_4): trends and seasonal cycles. J. Geophys. Res. 86: 9826–9832.

Rasmussen, R.A., and M.A.K. Khalil. 1981b. Increase in the concentration of atmospheric methane. Atmos. Environ. 15(5): 883–886.

Rehm, A.E. 1974. A study of marine algae epiphytic on prop roots of *Rhizophora mangle* from Tampa to Key Largo. Ph.D. Dissertation. Univ. of South Florida, Tampa.

Reichenbaugh, R.C. 1972. Seawater intrusion in the upper part of the Floridan aquifer in coastal Pasco County, Fl, 1970. U.S. Geol. Surv. Open File Rep. 72-019.

Repenning, R.W., and R.F. Labisky. 1985. Effects of even-aged timber management on bird communities of the longleaf pine forest in northern Florida. J. Wildl. Manage. 49(4): 1088–1098.

Research Planning Institute, Inc. 1984. The sensitivity of coastal environments and wildlife to spilled oil in the Withlacoochee region. Florida Department of Community Affairs, Division of Resource Planning and Management, Tallahassee. 83 pp.

Revelle, R. 1982. Carbon dioxide and world climate. Sci. Am. 247(2): 36–43.

Revelle, R. 1983. Probable future changes in sea level resulting from increased atmospheric carbon dioxide. Pages 433–448 *in* Changing climate—report of the Carbon Dioxide Assessment Committee. National Academy Press, Washington, D.C.

Rey, J.R. 1978. Abundance patterns of terrestrial arthropods in northwest Florida salt marshes. M.S. Thesis. Florida State University, Tallahassee. 187 pp.

Risser, P.G., J.R. Karr, and R.T.T. Forman. 1984. Landscape ecology: directions and approaches. Ill. Nat. Hist. Surv. Spec. Publ. 2. Champaign, Ill. 18 pp.

Rochow, T.F. 1982. Biological assessment of the Jay B. Starkey wilderness park, 1982 update. Southwest Florida Water Management District, Brooksville. 58 pp.

Rochow, T.F. 1984. Photographic survey of the Jay B. Starkey Wilderness Park. Southwest Florida Water Management District, Brooksville. 42 pp.

Rochow, T.F. 1985. Biological assessment of the Jay B. Starkey wilderness park, 1985 update. Southwest Florida Water Management District, Brooksville. 105 pp.

Rochow, T.F., L.F. Bartos, and E.W. Schupp. 1976. Biological assessment of the Jay B. Starkey Wilderness Park. Southwest Fla. Water Manag. Dist. Env. Sect. Tech. Rep. 1976–4. Brooksville. 135 pp.

Rosenau, J.C., and G.L. Faulkner. 1975. An index to springs of Florida. U.S. Geol. Surv. Map Ser. 63. Revised.

Rosenau, J.C., G.L. Faulkner, C.W. Henry, and R.W. Hull. 1977. Springs of Florida. Fla. Bur. Geol. Bull. 31 (revised). 461 pp.

Rosenau, J.C., and R.S. Milner. 1981. Potentiometric surface of the Floridan aquifer in the Suwannee River Water Management District, Florida, May 1980. U.S. Geol. Surv. Water Resour. Inv. Open File Rep. 81-211. Map.

Ross, L.T., and D.A. Jones, eds. 1979. Biological aspects of water quality in Florida: Part III: Withlacoochee, Tampa Bay, Peace, and Kissimmee drainage basins. Fla. Dep. Environ. Reg. Tech. Ser. 4(3), Tallahassee. 597 pp.

Ross, Saarinen, Bolton and Wilder, Environmental Engineers. 1978. Comprehensive study of the regional water supply needs and sources 1980-2020. Engineering report for the West Coast Regional Water Supply Authority. Clearwater, Fla. 761 pp

Rutledge, A.T. 1977. Hydrologic reconnaissance of Tsala Apopka Lake, Citrus County, Florida. U.S. Geological Survey. Water Resour. Inv. 77-89.

Sanders, R.M., Jr. 1983. Hydrologic, diel and lunar factors affecting fishes on artificial reefs off Panama City, Florida. M.S. Thesis. Texas A&M University, College Station. 139 pp.

Saloman, C.H., and S.P. Naughton. 1983. Food of king mackerel, *Scomberomorus cavalla*, from the Southeastern United States including the Gulf of Mexico. Nat. Ocean. Atmos. Admin. Tech. Mem. NMFS–SEFC–126. 25 pp.

Saloman, C.H., and S.P. Naughton. 1984. Beach restoration with offshore dredged sand: effects on nearshore macroinfauna. Nat. Ocean. Atmos. Admin. Tech. Mem. NMFS–SEFC–133. 20 pp.

Sastry, A.M. 1961. Studies on the bay scallop, *Aequipecten irradians concentricus* Say, in Alligator Harbor, Florida. Ph.D. Dissertation. Florida State University, Tallahassee. 118 pp.

Savage., T. 1972. Florida mangroves: a review. Fla. Depart Nat. Resour. Mar. Res. Lab. Ser. 7(1): 1–15.

Savage, T., J.R. Sullivan, and C.E. Kalman. 1975. An analysis of stone crab (*Menippe mercenaria*) landings on Florida's west coast, with a brief synopsis of the fishery. Fla. Mar. Resour. Publ. 13. 37 pp.

Saville, T. 1966. A study of estuarine pollution problems on a small unpolluted estuary and a small polluted estuary in Florida. Engineer. Prog. Univ. Fla. 20(8), Gainesville. 202 pp.

Schnoes, R.S., and S.R. Humphrey. 1987. Terrestrial plant and wildlife communities on phosphate-mined lands in central Florida. Bull. Fla. State Mus. Biol. Sci. 30: 53–116.

Scholl, D.W., F.C. Craighead, Sr., and M. Stuiver. 1969. Florida submergence curve revised: its relation to coastal sedimentation rates. Science 163: 562–564.

Seaburn, G.E., and M.E. Jennings. 1976. Waste load allocation studies for selected west central Florida estuaries - Crystal River, Homosassa River, Cross Bayou, and Anclote River. U.S. Geological Survey, Tallahassee. 80 pp.

Seaman, W., Jr. 1982. Enhancement of Florida marine fisheries using artificial reefs: a review. University of Florida, Florida Sea Grant Program, Gainesville. 33 pp.

Seaman, W., Jr., and R. McLean, eds. 1977. Seminar proceedings: freshwater and the Florida coast: southwest Florida. Fla. Sea Grant Rep. 22; Southwest Fla. Water Manage. Dist. Rep. 1977-1. 244 pp.

Searc, C.B., and P.M. Kelly. 1980. Eruption of Mt. St. Helens: effects on climate. Nature 285(5766): 533–535.

Shampine, W.J. 1975a. Dissolved solids in water from the upper part of the Floridan aquifer in Florida. U.S. Geol. Surv. Map Ser. 14. Revised.

Shampine, W.J. 1975b. Chloride concentration in water from the upper part of the Floridan aquifer in Florida. U.S. Geol. Surv. Map Ser. 12. Revised.

Shampine, W.J. 1975c. Hardness of water from the upper part of the Floridan aquifer in Florida. U.S. Geol. Surv. Map Ser. 13. Revised.

Shampine, W.J. 1975d. Sulfate concentrations in water from the upper part of the Floridan aquifer in Florida. U.S. Geol. Surv. Map Ser. 15. Revised.

Sheridan, P.F. 1978. Trophic relationships of dominant fishes in the Apalachicola Bay system (Florida). Ph.D. Dissertation. Florida State University, Tallahassee. 216 pp.

Shines, J.E. 1979. Distribution of mangrove communities: State of Florida. U.S. Environ. Protect. Agency, Final contract 68-03-2636.

Shipp, L.P. 1977. The vertical and horizontal distribution of decapod larvae in relation to some environmental conditions within a salt marsh area of the north central Gulf of Mexico. M.S. Thesis. University of Southern Alabama, Mobile. 129 pp.

Shokes, F.M., D.W. Gorbet, and G.E. Sanden. 1982. Effect of planting date and date of spray initiation on control of peanut (*Arachis hypogaea*) leaf spots in Florida, USA. Plant Dis. 66(7): 574–575.

Simberloff, D., and E.O. Wilson. 1969. Experimental zoogeography of islands: the colonization of empty islands. Ecology 50: 278–296.

Simonds, E.P., and E.R. German. 1980. Hydrology of the Lake Deaton and Lake Okahumpka area, northeast Sumter County, Florida. U.S. Geol. Surv. Water Resour. Inv. 80-733.

Simons, R.W. 1983. Site survey of Gad's Bay. Florida Natural Areas Inventory. Tallahassee. 4 pp.

Simons, R.W., S.W. Vince, and S.R. Humphrey. 1989. Hydric hammocks: a guide to management. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.26 Supplement). 89 pp.

Simons, R.W., W.R. Marion, and J.H. Hintermister. 1984. Native plant and animal communities, central and south phosphate resource districts. Pages 52–58 *in* H. Hood and R.M. Palmer, eds. Phosphate mining in Florida, a source book. Florida Defenders of the Environment and the Environmental Service Center, Tallahassee.

Sinclair, W.C. 1978. Preliminary evaluation of the water-supply potential of the spring-river system in the Weeki Wachee area and the lower Withlacoochee river, west-central Florida. U.S. Geol. Surv. Water Resour. Inv. 78-74. 40 pp.

Sinclair, W.C., and J.W. Stewart. 1985. Sinkhole type, development, and distribution in Florida. U.S. Geol. Surv. Map Ser. 110.

Skud, B.E., and W.B. Wilson. 1960. Role of estuarine waters in Gulf fisheries. Trans. N. Am. Wildl. Nat. Resour. Conf. 24: 320–326.

Slack, L.J., and D.A. Goolsby. 1976. Nitrogen loads and concentrations in Florida streams. Fla. Dep. Nat. Resour. Bur. Geol. Map Ser. 75. Tallahassee.

Slack, L.J., and M.I. Kaufman. 1975. Specific conductance of water in Florida streams and canals. U.S. Geol. Surv. Map Ser. 58. Revised.

Small, J.K. 1920. A journey to the fern grottoes. J. N.Y. Bot. Gaz. 21: 25–54.

Smith, D.L. 1970. The application of digitized radar data to the prediction of summertime convective activity in coastal regions. Am. Meterol. Soc. Radar Meterol. Conf. 14: 347–352.

Smith, F.G.W. 1949. Report on a survey of the sponge grounds north of Anclote Light. Mimeographed, Florida State Board of Conservation. 29 pp.

Smith, R.F., A.H. Swartz, and W.H. Massman, eds. 1966. A symposium on estuarine fisheries. Am. Fish. Soc., Spec. Publ. 3. 154 pp.

Snedaker, S.C. 1963. Some aspects of the ecology of the Florida sandhills. M.S. Thesis. University of Florida, Gainesville.

Snell,L.J., and W.E. Kenner. 1974. Surface water features of Florida. U.S. Geol. Surv. Map Ser. 66.

Southwest Florida Water Management District. 1978. Generalized land use and vegetation map. D.1.

Southwest Florida Water Management District. 1979. Resolution No. 754, approving, in general, the four river basins, Florida water resources management study performed by the U.S. Army Corps of Engineers and supporting the implementation of specific alternatives. Brooksville. 4 pp.

Southwest Florida Water Management District. 1983. Coastal Pasco chloride investigation. Staff report dated 2/28/83. 12 pp.

Southwest Florida Water Management District. 1984. Technical memorandum: Green Swamp project. 8 pp.

Southwest Florida Water Management District. 1985. The green swamp project—environmental report. Brooksville. 226 pp.

Southwest Florida Water Management District. 1986. A data collection program for selected estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 8 Vols.

Spechler, R.M. 1983. Estimated irrigation water use in Florida, 1980. U.S. Geol. Surv. Map Ser. 106.

Sprinkel, J. 1986. Oyster reefs. Vol. 4 *of* Southwest Florida Water Management District. A data collection program for selected coastal estuaries in Hernando, Citrus, and Levy Counties, Florida. Brooksville. 60 pp.

Stancyk, S.E. 1970. Studies on the biology and ecology of ophiuroids at Cedar Key, Florida. M.S. Thesis. University of Florida, Gainesville, 98 pp.

Steidinger, K.A. 1973. Phytoplankton. Pages IIIE-1 – IIIE-17 *in* J.I. Jones, R.E. Ring, M.O. Rinkel, and R.E. Smith, eds. A summary of knowledge of the eastern Gulf of Mexico. State University System of Florida, Institute of Oceanography, St. Petersburg.

Steidinger, K.A., and J.F. Van Breedveld. 1971. Benthic marine algae from waters adjacent to the Crystal River electric power plant (1969 and 1970). Fla. Dep. Nat. Resour. Mar. Res. Lab. Prof. Paper Ser. 16. 46 pp.

Stelzenmuller, W.B. 1965. Tidal characteristics of two estuaries in Florida. J. Waterw. Harbors Div. Proc. Am. Soc. Civ. Eng. 91(WW3).

Stewart, J.W. 1980. Areas of natural recharge to the Floridan aquifer in Florida. U.S. Geol. Surv. Map Ser. 98.

Stone, R.B. 1974. Low streamflow in Florida—magnitude and frequency. U.S. Geol. Surv. Map Ser. 64.

Stone, R.B., H.L. Pratt, R.O. Parker, Jr., and G.E. Davis. 1979. A comparison of fish populations on an artificial and natural reef in the Florida Keys. Mar. Fish. Rev. 419: 1–11.

Stout, J.P. 1984. The ecology of irregularly flooded salt marshes of the northeastern Gulf of Mexico: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.1). 98 pp.

Strahler, A.N. 1975. Physical geography. 4th ed. John Wiley and Sons, Inc., N.Y. 643 pp.

Sweeney, J.W., and S.R. Windham. 1979. Florida: the new uranium producer. Florida Bur. Geol. Spec. Publ. 22. 13 pp.

SWFWMD. see Southwest Florida Water Management District

Swihart, T., J. Hand, D. Barker, L. Bell, J. Carnes, C. Cosper, R. Deverling, C. Gluckman, W. Hinkley, R. Leins, E. Livingston, and D. York. 1984. Water quality. Pages 68–91 *in* E.A. Fernald and D.J. Patton, eds. Water resources atlas of Florida. Florida State University, Tallahassee.

Swindell, B.F., L.F. Conde, and J.E. Smith. 1983. Plant cover and biomass response to clear–cutting, site preparation, and planting in *Pinus elliottii* flatwoods. Science 219: 1421–1422.

Swindell. D.E., Jr. 1949. Plant communities and other factors affecting deer and turkey populations in Gulf Hammock. M.S. Thesis. University of Florida, Gainesville. 150 pp.

Swindler, J.P., Jr. 1974. Sedimentology of the low-energy coastal region between Withlacoochee and Crystal Rivers, west coast Florida. (Abstract). Geol. Soc. Am. Bull. 6: 406.

Sykes, J.E., and J.H. Finucane. 1966. Occurrence in Tampa Bay, Florida of immature species dominant in Gulf of Mexico commercial fisheries. U.S. Fish Wildl. Serv., Fish. Bull. 65(2): 369–379.

Tagatz, M.E., and E.P.H. Wilkens. 1973. Seasonal occurrence of young Gulf menhanden and other fishes in a northwestern Florida estuary. Nat. Ocean. Atmos. Admin. Tech. Rep. NMFS–SSRF–672. 14 pp.

Tanner, W.F. 1960. Florida coastal classification. Gulf Coast Assoc. Geol. Soc. Trans. 10: 259–266.

Taylor, D.L. 1980. Fire history and man-induced fire problems in subtropical south Florida. Pages 63–68 *in* Proc. fire history workshop. Tech. Rep. RM-81, Rocky Mt. Forest and Range Exp. Stn., U.S.D.A.

Taylor, W.R. 1954. Sketch of the character of the marine algal vegetation of the shores of the Gulf of Mexico. *In* P.S. Galtsoff, ed. Gulf of Mexico—its origin, waters, and marine life. U.S. Fish Wildl. Serv. Fish. Bull. 55: 177–192.

Taylor, G.F. 1977. Hydrology of Lake Panasoffkee, Sumter County, Florida. U.S. Geol. Surv. Water Resour. Inv. 77-88.

Taylor, G.F. 1978. Water resources of the Waccasassa River basin and adjacent areas, Florida. U.S. Geol. Surv. Water Resour. Inv. 77-101.

Taylor, S.E. 1965. Phaeophyta of the eastern Gulf of Mexico. Ph.D. Dissertation. Duke University, Durham, N.C. 312 pp.

Taylor, W.R. 1954. Sketch of the character of the marine algal vegetation of the shores of the Gulf of Mexico. Fish. Bull. 89(55):177-192.

Taylor, W.R. 1961. Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor. 870 pp.

Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf, N.Y. 1,109 pp.

Thayer, G.W., D.A. Wolfe, and R.B. Williams. 1975. The impact of man on a seagrass system. Am. Sci. 63: 288–296.

Thayer, G.W., K.A. Bjorndal, J.C. Ogden, S.L. Williams, and J.C. Zieman. 1984. Role of larger herbivores in seagrass communities. Estuaries 7: 351–376.

The Earth Technology Corporation. 1986. Cross-Florida Barge Canal TDEM survey. Southwest Florida Water Management District, Brooksville. 11 pp. + append.

Thom, B.G. 1967. Mangrove ecology and deltaic geomorphology: Tabasco, Mexico. J. Ecol. 55: 301–343.

Thom, B.G. 1975. Mangrove ecology from a geomorphic viewpoint. Pages 469–481 *in* G.E. walsh, S.C. Snedaker, and H.J. Teas, eds. Proceedings of the interntional symposium on the biology and management of mangroves. University of Florida Press, Gainesville.

Thompson, S.K.S. 1980. Hammock vegetation in the northern Gulf Hammock region of Florida. M.S. Thesis. Florida State University, Tallahassee. 49 pp.

Titus, J.G., T.R. Henderson, and J.M. Teal. 1984. Sea level rise and wetland loss in the United States. Nat. Wetlands Newsl. 6: 3–6.

Turner, R.E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Trans. Am. Fish. Soc. 106: 411–416.

U.S. Army Corps of Engineers. 1962. Four river basins, Florida. U.S. Army, Washington, D.C. 180 pp.

U.S. Army Corps of Engineers. 1971. National shoreline study regional inventory report, south Atlantic and gulf region. Jacksonville, Fla.

U.S. Army Corps of Engineers. 1978. Preliminary guide to wetlands of peninsular Florida. Major associations and communities identified. U.S. Army Eng. Waterw. Exp. Sta., Environ. Effects Lab., Tech. Rep. Y-78-2. Vicksburg, MS. 92 pp.

U.S. Army Corps of Engineers. 1980. Water resources management study: four river basins project, Florida. Jacksonville, Fla. 403 pp.

U.S. Department of Agriculture. 1981. 26 ecological communities of Florida. Soil Conservation Service. Washington, D.C. 263 pp.

U.S. Department of Commerce. 1980a. Local climatological data 1983: annual summary with comparative data—Orlando. National Climatic Center. Asheville, N.C. 4 pp.

U.S. Department of Commerce. 1980b. Local climatological data 1983: annual summary with comparative data—Tampa. National Climatic Center. Asheville, N.C. 4 pp.

U.S. Department of Commerce. 1980c. Local climatological data 1983: annual summary with comparative data—Lakeland. National Climatic Center. Asheville, N.C. 4 pp.

U.S. Environmental Protection Agency. 1977. National water quality inventory report.

U.S. Fish and Wildlife Service. Undated. Wetlands and deepwater habitats of Florida. National Wetlands Inventory Map.

U.S. Fish and Wildlife Service. 1978. A plan for the management of upland wildlife habitat on the St. Marks National Wildlife Refuge. U. S. Fish and Wildlife Service, St. Marks, Fla. 108 pp.

U.S. Geological Survey. 1970. Large springs of Florida's "Sun Coast"—Citrus and Hernando Counties. U.S. Geol. Surv. Leafl. 9. 23 pp.

U.S. Geological Survey. 1977. Saltwater intrusion in the Floridan aquifer, coastal Citrus and Hernando Counties, Florida—1975. U.S. Geol. Surv. Water Resour. Inv. 77-100.

U.S. Geological Survey. 1978. Florida: satellite image mosaic. Reston, Va. Map.

Umber, R.W., and L.D. Harris. 1975. Effects of intensive forestry on succession and wildlife in Florida sandhills. Proc. Southeast. Assoc. Game Fish Comm. 28: 686–692.

University of Florida, Department of Environmental Engineering Sciences. 1983. Technical report: a classification of Florida lakes. University of Florida, Gainesville. 2 Vols., 491 pp.

Urban, D.L., R.V. O'Neill, and H.H. Shugart. 1987. Landscape ecology. BioScience 37: 119–127.

USACE. see U.S. Army Corps of Engineers.

USGS. see U.S. Geological Survey.

Van Tine, R.F. 1977. An ecological comparison of the benthic macroflora of a power plant impacted estuary and an adjacent estuary. M.S. Thesis. University of Florida, Gainesville. 142 pp.

Vecchioli, J., G.G. Ehrlich, E.M. Godsy, and C.A. Pascale. 1984. Alterations in the chemistry of an industrial waste liquid injected into limestone near Pensacola, Florida. Pages 217–221 *in* International Association of Hydrogeologists. Hydrogeology of karstic terrains, case histories, Vol. 1.

Veno, P.A. 1976. Successional relationships of five Florida plant communities. Ecology 57: 498–508

Vernon, R.O. 1943. Florida mineral industry, with summaries of production for 1940 and 1941. Fla. Geol. Surv. Bull. 24: 1–207.

Vernon, R.O. 1951. Geology of Citrus and Levy Counties, Florida. Fla. Geol. Surv. Bull. 33. 256 pp.

Vernon, R.O. 1973. Top of the Floridan artesian aquifer. U.S. Geol. Surv. Map Ser. 56.

Vince, S.W., R.W. Simons, and S. R. Humphrey. 1988. The ecology of hydric hammocks: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.26). 81 pp.

Visher, F.N., and G.H. Hughes. 1975. The difference between rainfall and potential evaporation in Florida. U.S. Geol. Surv. Map Ser. 32. 2nd ed.

Vogl, R. 1973. Fire in the southeastern grasslands. Proc. Tall Timbers Fire Ecol. Conf. 12: 175–198. Tall Timbers Research Station, Tallahassee.

Wagner-Merner, D.T., and R. Jones. 1976. Preliminary observations of fungi occurring in coastal habitats in Hernando County, Florida. Fla. Sci. 39(Suppl.): 7.

Waldron, W.W., L.R. Cannon, G.S. Comp, P.M. Doris, R.J. Evans, A.E. Gilboy, J.W. Heuer, Jr., L. Miller, R.P. Norberg, R.S. Owen, D.K. Parkin-Welz, D.L. Slonena, R.W. Schultz, J.K. Whalen, D.A. Wiley, and B.C. Wirth. 1984. Southwest Florida Water Management District: Pages178-197 *in* E.A. Fernald and D.J. Patton, eds. Water resources atlas of Florida. Florida State University, Tallahassee.

Walker, H.J., and J.M Coleman. 1987. Atlantic and gulf coastal province. Pages 51–110 *in* W.L. Graf, ed. Geomorphic systems of North America. Geological Society of America, Boulder, Colo.

Ward, D. 1978. Plants. Vol. 5 *in* P.C.H. Pritchard, ed. Rare and endangered biota of Florida. University Presses of Florida, Gainesville.

Weiss, B.F., C.D. Keeling, and H. Craig. 1981. The determination of tropospheric nitrous oxide. J. Geophys. Res. 86(68): 7192–7202.

Wetterhall, W.S. 1964. Geohydrologic reconnaissance of Pasco and southern Hernando Counties, Florida. Fla. Geol. Surv. Rep. of Inv. 34. 28 pp.

Wetterhall, W.S. 1965. Reconnaissance of springs and sinks in west-central Florida. U.S. Geol. Surv. Rep. Inv. 39. 42 pp.

Wharton, B.R. 1984. Mid-nineteenth century lake levels for Crews Lake in northwestern Pasco County (Coastal Rivers Basin), Florida. Memo dated 9/18/84 to Environmental Section, Southwest Florida Water Management District.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Sipe. 1982. The ecology of bottomland hardwood forests of the southeast: a community profile. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-81/37. 133 pp.

Wharton, C.H., H.T. Odum, E. Ewel, M. Duever, A. Lugo, R. Boyt, J. Bartholomew, E. Debellevue, S. Brown, M. Brown, and L. Duever. 1977. Forested wetlands of Florida—their management and use. Florida Division of State Planning, Tallahassee. 347 pp.

White, L.D., L.D. Harris, J.E. Johnson, and D.G. Milchunas. 1976. Impact of site preparation on flatwoods wildlife habitat. Proc. Southeast. Assoc. Game Fish Comm. 29: 347–353.

White, W.A. 1958. Some geomorphic features of central peninsular Florida. Fla. Geol. Surv. Bull. 41. 92 pp.

White, W.A. 1970. Geomorphology of the Florida Peninsula. Fla. Bur. Geol. Bull. 51: 1–164.

White, W.A. 1981. Potential geological natural landmarks of the Florida Peninsula. University of North Carolina, Chapel Hill.

Whitlatch, R.B. 1982. The ecology of New England tidal flats: a community profile. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-81/01. 125 pp.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66: 1211–1214.

Wiley, J.W. 1978. Southeastern American kestrel. Pages 32–34 *in* H. W. Kale, ed. Rare and endangered biota of Florida. Vol. II. Birds. University Presses of Florida, Gainesville.

Williams, D.R. 1984. Western Florida coast seagrass inventory (Anclote Keys to Palmetto Island, Florida). U.S. Environ. Protect. Agency, Contract No. 68-93-3049. 113 pp.

Williams, J., W.F. Grey, E.B. Murphy, and J.J. Crane. 1977. Drift bottle analyses of eastern Gulf of Mexico surface circulation. Fla. Dep. Nat. Resour., Mar. Res. Lab. Mem. Hourglass Cruises 4(3). St. Petersburg. 134 pp.

Williams, K.E., D. Nicol, and A.F. Randazzo. 1977. The geology of the western part of Alachua County, Florida. Fla. Bur. Geol. Rept. Invest. No. 85.

Williams, L.E. 1978. Florida black bear. Pages 23–25 *in* J. N. Layne, ed. Rare and endangered biota of Florida. Vol. I. Mammals. University Presses of Florida, Gainesville.

Williams, T.M. 1979. Implications of hydrologic response to the practice of forestry on coastal forests. Pages 93–102 *in* W. H. Smith, ed. Florida's water resources—implications for forest management. Proceedings of the Eleventh SAF-SFRC Spring Symposium, University of Florida, School of Forest Resources and Conservation, Institute of Food and Agricultural Science, Gainesville.

Winsberg, M.D., and D. Primelles. 1981. Population. Pages 74–113 *in* E.A. Fernald, ed. Atlas of Florida. Florida State University Foundation, Tallahassee.

Winston, G.O. 1976. Florida's Ocala Uplift is not an uplift. Bull. Am. Assoc. Petrol. Geol. 60: 992–994.

Winter, P.A. 1978. Evaluation of seagrass resources, Santa Rosa Island, Florida. U.S. Army Corps of Eng. Contract Rep. DACW01-78-C-0103. 26 pp.

Wolansky, R.M., G.L. Barr, and R.K. Spechler. 1979a. Generalized configuration of the bottom of the Floridan aquifer, Southwest Florida Water Management District. U.S. Geol. Surv. Water Resour. Inv. Open File Rep. 79-1490.

Wolansky, R.M., and J.M. Garbade. 1981. Generalized thickness of the Floridan aquifer, Southwest Florida Water Management District. U.S. Geol. Surv. Water Resour. Inv. Open File Rep. 80-1288. Map.

Wolansky, R.M., R.K. Spechler, and A. Buono. 1979b. Generalized thickness of the surficial deposits above the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District. U.S. Geol. Surv. Water Resour. Inv. 79-1071. Map.

Wood, D.A. 1990 Official lists of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission, Tallahassee. 23 pp.

Woodin, S.A. 1978. Refuges, disturbance, and community structure: a marine soft–bottom example. Ecology 59: 274–284.

Woolfenden, G.E. 1978. Florida scrub jay. Pages 45–47 *in* H. W. Kale II, ed. Rare and endangered biota of Florida. Vol. II. Birds. University Presses of Florida, Gainesville.

Woolfenden, G.E., and R.W. Schreiber. 1973. The common birds of saline habitats of the eastern Gulf of Mexico: their distribution, seasonal status and feeding ecology. Pages IIIJ1–IIIJ21 *in* J.I. Jones, R.E.Ring, M.O. Rinkel, and R.E. Smith, eds. A summary of knowledge of the eastern Gulf of Mexico. Florida Institute of Oceanography, St. Petersburg.

Woolfenden, G.E., and S.A. Rohwer. 1969. Breeding birds in a Florida suburb. Bull. Fla. State Museum 13(1): 1–83

Wyllie, M. 1981. Final report: evapotranspiration study for Southwest Florida Water Management District. Florida Resources and Environmental Analysis Center, Florida State University, Tallahassee. 142 pp.

Yobbi, D.K. 1983. Trends and fluctuations in the potentiometric surface of the Floridan aquifer, west-central Florida, 1961-80. U.S. Geol. Surv. Water Resour. Inv. 82-4086.

Yobbi, D.K., and L.A. Knochemus. 1988a. Salinity and flow relations in the Chassahowitska and Homosassa Rivers and adjacent areas of the Gulf of Mexico. U.S. Geol. Surv. Water Resour. Inv. 88-4044.

Yobbi, D.K., and L.A. Knochemus. 1988b. Effects of river discharge and high-tide stage on salinity intrusion in the Weeki Wachee, Crystal River, and Withlacoochee River estuaries, southwest Florida. U.S. Geol. Surv. Water Resour. Inv. 88-4116.

Yobbi, D.K. 1989. Simulation of steady-state groundwater and spring flow in the upper Floridan aquifer of coastal Citrus and Hernando Counties, Florida. U.S. Geol. Surv. Water Resour. Inv. 88-4036. 33 pp.

Yockey, R.H. 1974a. Survey of Crystal River sponge fauna. Pages 104–116 *in* Third Crystal River environmental progress report to the Federal Interagency Research Advisory Committee, April 26, 1974.

Yockey, R.H. 1974b. An ecological survey of sponges from the eastern Gulf of Mexico. M.S. Thesis. University of Florida, Gainesville. 59 pp.

Yon, J.W., and C.W. Hendry. 1972. Suwannee limestone in Hernando and Pasco Counties, Florida. Fl. Geol. Surv. Bull. 54, part 1. 42 pp.

Young, G., F. Steiner, K. Brooks, and K. Struckmeyer. 1983. Determining the regional context for landscape planning. Landscape Plann. 10: 269–296.

Zieman, J.C. 1975. Tropical seagrass ecosystems and pollution. Ch. 4 *in* E.J.F. Wood and R.E. Johannes, eds. Tropical marine pollution. Elsevier Oceanogr. Ser. 12. Elsevier Publishing Co., N.Y.

Zieman, J.C. 1976. The ecological effects of physical damage from motorboats on turtle grass beds in southern Florida. Aquat. Bot. 2: 127–139.

Zieman, J.C. 1982. The ecology of the seagrasses of south Florida: a community profile. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS–82/25. 150 pp.

Zimmerman, M.S., and R.J. Livingston. 1979. Dominance and distribution of benthic macrophtye assemblages in a north Florida estuary (Apalachee Bay, Florida). Bull. Mar. Sci. 29: 27–40.

Zuboy, J.R., and J.E. Snell. 1982. Assessment of the Florida stone crab fishery, 1980–1981 season. Nat. Ocean. Atmos. Admin. Tech. Mem., NMFS-SEFC-79. 21 pp.

Appendix Table A. Selected U.S. Geological Survey Maps for the Florida Springs Coast.

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. Wetlands in Florida (Hampson 1984).
15. Sinkhole type and development in Florida (Sinclair and Stewart 1985).
16. Water resources of the Waccasassa River basin and adjacent areas, Florida (Taylor and Snell 1978).
17. Hydrologic reconnaissance of Tsala Apopka Lake, Citrus County, Florida (Rutledge 1978).
18. The hydrology of Lake Rousseau, west-central Florida (German 1978).

Surface-water Chemistry

1. The pH of water in Florida streams and canals (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).
10. Dissolved solids, hardness, and orthophosphate of surface-water runoff in the Suwannee River Water Management District, Florida (Earle 1975).

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 1975b).

Continued.

Appendix Table A. Concluded.

Ground-water Hydrology (continued)

4. Principal aquifers in Florida (Hyde 1975).
5. Estimated yield of fresh-water wells in Florida (Pascale 1975).
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 Suwannee River Water Management District,Florida, May 1980 (Rosenau and Milner 1981).
11. Potentiometric surface of the Floridan aquifer in the Southwest Florida Water Management District,Florida, May 1980 (Rosenau and Milner 1981).
12. Potentiometric surface of the Floridan aquifer in Florida, May 1980 (Healy 1982).
13. Occurence of beds of low hydraulic conductivity in surficial deposits of Florida (Healy and Hunn 1984).
14. Generalized thickness of the surficial deposits above the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District (Wolansky et al. 1979).
15. Generalized thickness of the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District (Buono et al. 1979).
16. Generalized thickness of the Floridan aquifer, Southwest Florida Water Management District (Wolansky and Garbade 1981).
17. Generalized configuration of the bottom of the Floridan aquifer, Southwest Florida Water Management District (Wolansky et al. 1979).

Ground-water Chemistry

1. Chloride concentration in water from the upper part of the Floridan aquifer in Florida (Shampine 1975b).
2. Hardness of water from the upper part of the Floridan aquifer in Florida (Shampine 1975c).
3. Sulfate concentration in water from the upper part of the Floridan aquifer in Florida (Shampine 1975d).
4. Depth to base of potable water in the Floridan aquifer (Klein 1975).
5. Thickness of the potable-water zone in the Floridan aquifer (Causey and Leve 1976).
6. Chemical quality of water used for municipal supply in Florida, 1975 (Phelps 1978a).
7. 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).

Appendix Table B. Common and characteristic animals of gulf-coast scrub communities (after Florida Game and Fresh Water Fish Commission 1976).

Group	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Least shrew	*Cryptotis parva*	C		
	Northern short-tailed shrew	*Blarina brevicauda*	C		
	Southeastern shrew	*Sorex longirostris*	C		
	Eastern mole	*Scalopus aquaticus*	C		
	Northern yellow bat	*Lasiurus intermedius*	O	W	
	Evening bat	*Nycticeius humeralis*	O	W	
	Marsh rabbit	*Sylvilagus palustris*	O		
	Eastern cottontail rabbit	*Sylvilagus floridanus*	C		
	Cotton mouse	*Peromyscus gossypinus*	C		
	Oldfield mouse	*Peromyscus polionotus*	A		*
	Florida mouse	*Podomys floridanus*	O		@
	Golden mouse	*Ochrotomys nuttalli*	C		*
	Hispid cotton rat	*Sigmodon hispidus*	C		
	Gray fox	*Urocyon cinereoargenteus*	C		@
	Bobcat	*Lynx rufus*	O		
	Striped skunk	*Mephitis mephitis*	C		
	Spotted skunk	*Spilogale putorius*	O		*
	White-tailed deer	*Odocoileus virginianus*	C		
Birds	Sharp-shinned hawk	*Accipiter striatus*	O	W	
	Red-tailed hawk	*Buteo jamaicensis*	O		
	Red-shouldered hawk	*Buteo lineatus*	O		
	American kestrel	*Falco sparverius*	O		
	Common ground dove	*Columbina passerina*	C		
	Mourning dove	*Zenaida macroura*	C		
	Common nighthawk	*Chordeiles minor*	O	S	
	Chuck-will's-widow	*Caprimulgus carolinensis*	O	S	
	Whip-poor-will	*Caprimulgus vociferus*	O	W	
	Downy woodpecker	*Picoides pubescens*	C		
	Red-bellied woodpecker	*Melanerpes carolinus*	C		
	Yellow-bellied sapsucker	*Sphyrapicus varius*	C	W	
	Great crested flycatcher	*Myiarchus crinitus*	C	S	
	Blue jay	*Cyanocitta cristata*	C		
	Scrub jay	*Aphelocoma coerulescens*	C		*
	American crow	*Corvus brachyrhynchos*	C		
	Fish crow	*Corvus ossifragus*	O		
	Tufted titmouse	*Parus bicolor*	C		

(*Continued*)

Appendix Table B. Continued.

Group	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Carolina chickadee	*Parus carolinensis*	C		
	Carolina wren	*Thryothorus ludovicianus*	C		
	House wren	*Troglodytes aedon*	C	W	
	Ruby-crowned kinglet	*Regulus calendula*	C	W	
	Blue-gray gnatcatcher	*Polioptila caerulea*	C		
	American robin	*Turdus migratorius*	O	W	
	Northern mockingbird	*Mimus polyglottos*	C		
	Brown thrasher	*Toxostoma rufum*	C		
	White-eyed vireo	*Vireo griseus*	A		
	Solitary vireo	*Vireo solitarius*	C	W	
	Northern parula warbler	*Parula americana*	O	S	
	Yellow-rumped warbler	*Dendroica coronata*	A	W	
	Yellow-throated warbler	*Dendroica dominica*	C		
	Pine warbler	*Dendroica pinus*	C		
	Prairie warbler	*Dendroica discolor*	O	S	
	Palm warbler	*Dendroica palmarum*	C	W	
	Black-and-white warbler	*Mniotilta varia*	C	W	
	American redstart	*Setophaga ruticilla*	C	W	
	Ovenbird	*Seiurus aurocapillus*	C	W	
	Common yellowthroat	*Geothlypis trichas*	C		
	Summer tanager	*Piranga rubra*	C	S	
	Northern cardinal	*Cardinalis cardinalis*	C		
	Rufous-sided towhee	*Pipilo erythrophthalmus*	A		*
	American goldfinch	*Carduelis tristis*	C	W	
Reptiles	Gopher tortoise	*Gopherus polyphemus*	C		
	Eastern coachwhip snake	*Masticophis flagellum flagellum*	C		*
	Southern black racer	*Coluber constrictor priapus*	C		
	Rough green snake	*Opheodrys aestivus*	C		
	Eastern indigo snake	*Drymarchon corais couperi*	O		
	Eastern hognose snake	*Heterodon platyrhinos*	C		@
	Southern hognose snake	*Heterodon simus*	O		
	Southern ringneck snake	*Diadophis punctatus punctatus*	O		
	Florida scarlet snake	*Cemophora coccinea coccinea*	C		
	Scarlet king snake	*Lampropeltis triangulum elapsoides*	O		
	Short-tailed snake	*Stilosoma extenuatum*	O		@
	Corn snake	*Elaphe guttata guttata*	O		
	Central Florida crowned snake	*Tantilla relicta neilli*	A		@
	Eastern coral snake	*Micrurus fulvius fulvius*	C		

(*Continued*)

Appendix Table B. Concluded.

Group	Common name	Scientific name	Abundance [a]	
Reptiles (cont.)	Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*	C	
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	C	
	Green anole	*Anolis carolinensis carolinensis*	C	
	Six-lined racerunner lizard	*Cnemidophorus sexlineatus sexlineatus*	A	*
	Southern fence lizard	*Sceloporus undulatus undulatus*	A	@
	Peninsula mole skink	*Eumeces egregius onocrepis*	C	*
	Southeastern five-lined skink	*Eumeces inexpectatus*	C	
	Ground skink	*Scincella lateralis*	C	
	Worm lizard	*Rhineura floridana*	A	@
Amphibians	Southern toad	*Bufo terrestris*	C	
	Oak toad	*Bufo quercicus*	C	
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	C	
	Eastern spadefoot toad	*Scaphiopus holbrookii holbrookii*	O	
	Barking tree frog	*Hyla gratiosa*	O	
	Squirrel tree frog	*Hyla squirella*	O	
	Green tree frog	*Hyla cinerea*	O	
	Pine woods tree frog	*Hyla femoralis*	O	
	Florida gopher frog	*Rana areolata aesopus*	O	

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only.
* indicates this is the best habitat for the species; @ indicates this is one of the best habitats.

Appendix Table C. Characteristic and common plants of the gulf coast scrub communities (after Harper 1915; Laessle 1942, 1958; Florida Game and Fresh Water Fish Commission 1976; FDNR undated).

Type	Common name	Scientific name	Abundance [a]	
Trees	Sand pine	*Pinus clausa*	A	*
	Longleaf pine	*Pinus palustris*	O	
	Slash pine	*Pinus elliottii*	O	
	Sand live oak	*Quercus geminata*	A	@
	Myrtle oak	*Quercus myrtifolia*	A	*
	Chapman oak	*Quercus chapmanii*	C	*
	Turkey oak	*Quercus laevis*	O	
	Laurel oak	*Quercus hemisphaerica*	O	
	American (scrub) holly	*Ilex opaca* var. *arenicola*	O	
	Tough bumelia	*Bumelia tenax*	O	
	Silkbay	*Persea humilis*	C	*
	Redbay	*Persea borbonia*	O	
	Devilwood (wild olive)	*Osmanthus americanus*	O	@
Shrubs	Scrub palmetto	*Sabal etonia*	C	*
	Saw-palmetto	*Serenoa repens*	A	
	Florida rosemary	*Ceratiola ericoides*	A	*
	Gopher-apple	*Licania michauxii*	C	@
	Crooked-wood	*Lyonia ferruginea*	A	*
	Fetterbush	*Lyonia lucida*	O	
	Shiny blueberry	*Vaccinium myrsinites*	C	
	Scrub blueberry	*Vaccinium darrowii*	C	*
	Deerberry	*Vaccinium stamineum*	O	
	Dangleberry	*Gaylussacia frondosa*	C	
	Scarlet lady	*Calamintha coccinea*	O	*
	Long-spurred mint	*Dicerandra cornutissima*	O	*
	Scrub pawpaw	*Asimina obovata*	O	*
	Showy pawpaw	*Asimina incarna*	O	
	Pygmy pawpaw	*Asimina pygmaea*	O	
	Carolina holly	*Ilex ambigua*	C	
	Prickly-pear cactus	*Opuntia humifusa*	O	
	Tallow-wood (hog-plum)	*Ximenia americana*	O	*
	Garbaria	*Garbaria heterophylla*	C	*
	Palafoxia	*Palafoxia feayi*	?	*
	Indigofera	*Indigofera caroliniana*	O	

(*Continued*)

Appendix Table C. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Shrubs (cont.)	Coral bean	*Erythrina herbacea*	O	
	Beargrass	*Yucca filamentosa*	O	
Vines	Bullace grape	*Vitis rotundifolia*	C	
	Yellow jessamine	*Gelsemium sempervirens*	C	
	Catbriar	*Smilax auriculata*	O	
Herbs	Florida bluestem	*Andropogon floridanus*	O	
	Corkscrew three-awn	*Aristida gyrans*	O	*
	Panic grass	*Panicum patentifolium*	O	
	Hair sedge	*Bulbostylis ciliatifolia*	O	
	Scrub beakrush	*Rhynchospora megalocarpa*	C	*
	Yellow buttons	*Balduina angustifolia*	O	@
	Lavender paintbrush	*Carphephorus corymbosus*	O	
	White milk-pea	*Galactia elliottii*	C	
	Milk-pea	*Galactia* spp.	O	
	Summer-fairwell	*Dalea feayi*	C	@
	Chapman goldenrod	*Solidago chapmanii*	C	
	Procession flower	*Polygala incarnata*	O	@
	Sand-squares	*Paronychia* spp.	C	*
	Pinweed	*Lechea* spp.	C	*
	Silk-grass	*Pityopsis graminifolia*	C	
	Scrub dayflower	*Commelina erecta*	O	*
	Fine-leaf blazing-star	*Liatris tenuifolia*	O	
	Queen's delight	*Stillingia sylvatica*	O	
	Cottonweed	*Froelichia floridana*	O	
	Dog fennel	*Eupatorium capillifolium*	O	
	Bracken fern	*Pteridium aquilinum*	O	
	Deermoss	*Cladina* and *Cladonia* spp.	A	*

[a] A = abundant, C = common, O = occasional, ? = unknown.
* indicates scrub is the best habitat for the species; @ indicates scrub is one of the best habitats.

Appendix Table D. Animals common in or characteristic of high pine forest (Florida Game and Fresh Water Fish Commission 1976; Rochow et al. 1976; U.S. Fish and Wildlife Service 1978; Simons et al. 1984; Humphrey et al. 1985; Bohall-Wood and Callopy 1986).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Northern yellow bat	*Lasiurus intermedius*	O	S	
	Eastern cottontail rabbit	*Sylvilagus floridanus*	O		
	Sherman's fox squirrel	*Sciurus niger shermani*	O		*
	Southern flying squirrel	*Glaucomys volans*	O		
	Southeastern pocket gopher	*Geomys pinetis*	C		*
	Eastern harvest mouse	*Reithrodontomys humulis*	O		@
	Cotton mouse	*Peromyscus gossypinus*	O		
	Oldfield mouse	*Peromyscus polionotus*	C		@
	Florida mouse	*Podomys floridanus*	C		*
	Hispid cotton rat	*Sigmodon hispidus*	C		@
	Gray fox	*Urocyon cinereoargenteus*	C		*
	Raccoon	*Procyon lotor*	O		
Birds	Red-tailed hawk	*Buteo jamaicensis*	O		
	American kestrel	*Falco sparverius sparverius*	O	W	
	Southeastern American kestrel	*Falco sparverius paulus*	O		*
	Northern bobwhite	*Colinus virginianus*	C		*
	Mourning dove	*Zenaida macroura*	C		
	Common ground dove	*Columbina passerina*	C		@
	Eastern screech owl	*Otus asio*	O		@
	Great horned owl	*Bubo virginianus*	O		
	Common nighthawk	*Chordeiles minor*	C	S	*
	Chuck-will's-widow	*Caprimulgus carolinensis*	C	S	*
	Whip-poor-will	*Caprimulgus vociferus*	O	W	@
	Red-headed woodpecker	*Melanerpes erythrocephalus*	C		*
	Red-bellied woodpecker	*Melanerpes carolinus*	C		
	Downy woodpecker	*Picoides pubescens*	C		
	Red-cockaded woodpecker	*Picoides borealis*	R		@
	Northern flicker	*Colaptes auratus*	C		@
	Great crested flycatcher	*Myiarchus crinitus*	C	S	
	Blue jay	*Cyanocitta cristata*	C		
	American crow	*Corvus brachyrhynchos*	C		
	Carolina chickadee	*Parus carolinensis*	O		
	Tufted titmouse	*Parus bicolor*	C		
	Brown-headed nuthatch	*Sitta pusilla*	O		
	Blue-gray gnatcatcher	*Polioptila caerulea*	C		
	Eastern bluebird	*Sialia sialis*	O		
	American robin	*Turdus migratorius*	C	W	
	Northern mockingbird	*Mimus polyglottos*	O		
	Loggerhead shrike	*Lanius ludovicianus*	O		

(*Continued*)

Appendix Table D. Concluded.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	White-eyed vireo	*Vireo griseus*	O		
	Solitary vireo	*Vireo solitarius*	O	W	
	Yellow-throated vireo	*Vireo flavifrons*	O	S	
	Yellow-rumped warbler	*Dendroica coronata*	C	W	
	Yellow-throated warbler	*Dendroica dominica*	O		
	Pine warbler	*Dendroica pinus*	C		
	Summer tanager	*Piranga rubra*	C	S	*
	Northern cardinal	*Cardinalis cardinalis*	O		
	Rufous-sided towhee	*Pipilo erythrophthalmus*	C		
	Bachman's sparrow	*Aimophila aestivalis*	C		*
	Eastern meadowlark	*Sturnella magna*	O		
	American goldfinch	*Carduelis tristis*	C	W	
Reptiles	Gopher tortoise	*Gopherus polyphemus*	A		*
	Eastern coachwhip	*Masticophis flagellum flagellum*	C		@
	Southern black racer	*Coluber constrictor priapus*	C		
	Rough green snake	*Opheodrys aestivus carinatus*	C		
	Eastern indigo snake	*Drymarchon corais couperi*	O		
	Eastern hognose snake	*Heterodon platyrhinos*	C		@
	Southern hognose snake	*Heterodon simus*	C		@
	Scarlet king snake	*Lampropeltis triangulum elapsoides*	O		
	Short-tailed snake	*Stilosoma extenuatum*	R		*
	Corn snake	*Elaphe guttata guttata*	C		
	Florida pine snake	*Pituophis melanoleucus mugitus*	C		*
	Florida crowned snake	*Tantilla relicta neilli*	C		
	Eastern coral snake	*Micrurus fulvius fulvius*	C		
	Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*	C		
	E. diamondback rattlesnake	*Crotalus adamanteus*	C		@
	Green anole	*Anolis carolinensis carolinensis*	C		
	Six-lined racerunner	*Cnemidophorus sexlineatus sexlineatus*	C		
	Southern fence lizard	*Sceloporus undulatus undulatus*	C		*
	Peninsula mole skink	*Eumeces egregius onocrepis*	O		
	Southeastern five-lined skink	*Eumeces inexpectatus*	O		
	Ground skink	*Scincella lateralis*	C		
	Slender glass lizard	*Ophisaurus attenuatus*	O		*
	Florida worm lizard	*Rhineura floridana*	A		*
Amphibians	Southern toad	*Bufo terrestris*	C		
	Oak toad	*Bufo quercicus*	C		
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	O		
	Eastern spadefoot toad	*Scaphiopus holbrookii holbrookii*	C		
	Florida gopher frog	*Rana capito aesopus*	C		*

[a] * indicates this is the best habitat for the species; @ indicates this is one of the best habitats.
S = summer only, W = winter only.
A = abundant, C = common, O = occasional, R = rare.

Appendix Table E. Common and characteristic plants of high pine forest (after Harper 1915; Laessle 1942; Monk 1965; Florida Game and Fresh Water Fish Commission 1976; Rochow et al. 1976).

Type	Common name	Scientific name	Abundance [a]		
Trees	Longleaf pine	*Pinus palustris*	A		*
	Turkey oak	*Quercus laevis*	A		*
	Bluejack oak	*Quercus incana*	C		*
	Sand post oak	*Quercus margaretta*	O		*
	Post oak	*Quercus stellata*	O		*
	Southern red oak	*Quercus falcata*	O		*
	Sand live oak	*Quercus geminata*	C	I	
	Laurel oak	*Quercus hemisphaerica*	O	I	
	Mockernut hickory	*Carya tomentosa*	O		*
	Persimmon	*Diospyros virginiana*	O		
	Sassafras	*Sassafras albidum*	O		*
	Flowering dogwood	*Cornus florida*	O		
Shrubs	Runner oak	*Quercus pumila*	O		
	Dwarf chinquapin	*Castanea pumila*	O		*
	Florida coontie	*Zamia floridana*	R		*
	Yellow hawthorn	*Crataegus flava*	O		*
	Sand blackberry	*Rubus cuneifolius*	C		
	Showy pawpaw	*Asimina incarna*	C		*
	Shining (= Winged) sumac	*Rhus copallinum*	C		@
	Poison oak	*Rhus toxicodendron*	C		*
	Dwarf blueberry	*Vaccinium myrsinites*	C		
	Deerberry	*Vaccinium stamineum*	C		
	Sparkleberry	*Vaccinium arboreum*	O		
	Gopher-apple	*Licania michauxii*	C		*
	Small-leaved redroot	*Ceanothus microphyllus*	O		*
	Sandhill prickly-pear cactus	*Opuntia humifusa*	O		
	Florida rosemary	*Ceratiola ericoides*	O	I	
	Saw-palmetto	*Serenoa repens*	O		
Vines	Greenbriar	*Smilax auriculata*	O		
Herbs	Beargrass	*Yucca filamentosa*	O		*
	Wiregrass	*Aristida stricta*	A		*
	Three-awn grasses	*Aristida* spp.	C		
	Sandhill dropseed	*Sporobolus junceus (gracilis)*	C		*
	Splitbeard bluestem	*Andropogon ternarius*	O		*
	Bluestem grasses	*Andropogon* spp.	O		
	Lopsided Indian grass	*Sorghastrum secundum*	O		*
	Panic grasses	*Panicum* spp.	O		
	Beard grasses	*Gymnopogon* spp.	O		*
	Sand grasses	*Triplasis* spp.	O		
	Cogon grass	*Imperata* sp.	O	I	
	Dog fennel	*Eupatorium capillifolium*	C		
	Sticky dog fennel	*Eupatorium compositifolium*	O		
	Elephant's-foot	*Elephantopus* spp.	C		
	Milkwort	*Polygala grandiflora*	O		@

(*Continued*)

Appendix Table E. Continued.

Type	Common name	Scientific name	Abundance [a]	
Herbs (cont.)	Milkwort	*Polygala polygama*	O	@
	Sandhill blazing star	*Liatris tenuifolia*	C	@
	Lavender paintbrush	*Carphephorus corymbosus*	O	
	Yellow buttons	*Balduina angustifolia*	O	
	Rosinweed	*Silphium compositum*	O	*
	Greeneyes	*Berlandiera subacaulis*	O	*
	Camphorweed	*Heterotheca subaxillaris*	O	
	Golden-asters	*Chrysopsis* spp.	O	
	Silk-grass	*Pityopsis graminifolia*	C	
	Drooping-leaf aster	*Aster walteri*	C	*
	White-top aster	*Aster tortifolius*	O	
	—	*Stylisma* spp.	O	*
	Indigo	*Indigofera caroliniana*	O	*
	Beggarweeds	*Desmodium* spp.	O	
	Chapman's pea	*Chapmannia floridana*	O	*
	Partridge pea	*Cassia fasciculata*	C	@
	White milk-pea	*Galactia elliottii*	C	
	Butterfly pea	*Centrosema virginianum*	C	*
	Blue pea	*Clitoria mariana*	O	@
	Hoary pea	*Tephrosia* spp.	C	*
	Puckroot	*Psoralea canescens*	O	*
	Dollarweed, etc.	*Rhynchosia* spp.	O	*
	Scurf pea	*Psoralea lupinellus*	O	*
	Bush-clover	*Lespedeza hirta* and *capitata*	C	*
	Summer-farewell	*Dalea feayi* (or *pinnata)*	C	@
	Sensitive briar	*Schrankia microphylla*	O	
	Sandhill lupine	*Lupinus diffusus*	O	*
	Indigo	*Baptisia* spp.	O	*
	Rabbit-bells	*Crotalaria rotundifolia*	O	
	Pencil flower	*Stylosanthes biflora*	O	*
	Innocence	*Hedyotis procumbens*	C	@
	Tall jointweed	*Polygonella gracilis*	C	@
	Blushing sandweed	*Hymenopappus scabiosaeus*	O	*
	Wild foxglove	*Aureolaria pectinata*	O	*
	Dog-tongue	*Eriogonum tomentosum*	C	*
	Sandhill croton	*Croton argyranthemus*	C	*
	Queen's delight	*Stillingia sylvatica*	O	*
	Tread-softly	*Cnidoscolus stimulosus*	O	*
	Blackroot	*Pterocaulon pycnostachyum*	O	
	Sandhill milkweed	*Asclepias humistrata*	O	*
	Butterfly-weed	*Asclepias tuberosa*	O	*
	Blue star	*Amsonia ciliata*	O	*
	Roserush	*Lygodesmia aphylla*	O	*
	Sandhill Indian plantain	*Arnoglossum floridanum*	O	*
	Bracken fern	*Pteridium aquilinum*	A	*

[a] A = abundant, C = common, O = occasional, R = rare.
I = invading species due to fire suppression
* indicates this is the best habitat for the species; @ indicates this is one of the best habitats.

Appendix Table F. Animals common in or characteristic of pine flatwoods (after Conant 1975; Florida Game and Fresh Water Fish Commission 1976; Marion and O'Meara 1982; Repenning and Labisky 1985).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Northern short-tailed shrew	*Blarina brevicauda*	C		
	Least shrew	*Cryptotis parva*	O		
	Nine-banded armadillo	*Dasypus novemcinctus*	A		@
	Eastern cottontail rabbit	*Sylvilagus floridanus*	O		
	Sherman's fox squirrel	*Sciurus niger shermani*	R		
	Gray squirrel	*Sciurus carolinensis*	O		
	Eastern harvest mouse	*Reithrodontomys humulis*	O		@
	Cotton mouse	*Peromyscus gossypinus*	C		
	Golden mouse	*Ochrotomys nuttalli*	O		
	Hispid cotton rat	*Sigmodon hispidus*	A		@
	Raccoon	*Procyon lotor*	O		
	Bobcat	*Lynx rufus*	O		
	Wild hog	*Sus scrofa*	C		
	White-tailed deer	*Odocoileus virginianus*	C		
Birds	Cattle egret	*Bubulcus ibis*	C	S	
	Black vulture	*Coragyps atratus*	C		
	Turkey vulture	*Cathartes aura*	C		
	Sharp-shinned hawk	*Accipiter striatus*	O	W	
	Red-tailed hawk	*Buteo jamaicensis*	O		
	Red-shouldered hawk	*Buteo lineatus*	O		
	American kestrel	*Falco sparverius*	O		
	Wild turkey	*Meleagris gallopavo*	O		
	Northern bobwhite	*Colinus virginianus*	C		
	Mourning dove	*Zenaida macroura*	C		
	Common ground dove	*Columbina passerina*	O		
	Eastern screech owl	*Otus asio*	O		@
	Great horned owl	*Bubo virginianus*	O		@
	Common nighthawk	*Chordeiles minor*	O	S	
	Chuck-will's-widow	*Caprimulgus carolinensis*	O	S	
	Red-headed woodpecker	*Melanerpes erythrocephalus*	O		
	Red-bellied woodpecker	*Melanerpes carolinus*	C		
	Downy woodpecker	*Picoides pubescens*	O		
	Red-cockaded woodpecker	*Picoides borealis*	R		@
	Northern flicker	*Colaptes auratus*	O		
	Pileated woodpecker	*Dryocopus pileatus*	O		
	Eastern wood-pewee	*Contopus virens*	O	S	*
	Eastern phoebe	*Sayornis phoebe*	C	W	@
	Great crested flycatcher	*Myiarchus crinitus*	O	S	
	Tree swallow	*Tachycineta bicolor*	O	W	

(*Continued*)

Appendix Table F. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Blue jay	*Cyanocitta cristata*	C		
	American crow	*Corvus brachyrhynchos*	C		
	Fish crow	*Corvus ossifragus*	C		
	Carolina chickadee	*Parus carolinensis*	C		
	Tufted titmouse	*Parus bicolor*	C		
	Brown-headed nuthatch	*Sitta pusilla*	C		*
	Carolina wren	*Thryothorus ludovicianus*	C		
	House wren	*Troglodytes aedon*	O	W	
	Ruby-crowned kinglet	*Regulus calendula*	C	W	
	Blue-gray gnatcatcher	*Polioptila caerulea*	C		
	Eastern bluebird	*Sialia sialis*	O		
	American robin	*Turdus migratorius*	A	W	
	Gray catbird	*Dumetella carolinensis*	O	W	@
	Northern mockingbird	*Mimus polyglottos*	O		
	White-eyed vireo	*Vireo griseus*	C		
	Yellow-rumped warbler	*Dendroica coronata*	A	W	
	Yellow-throated warbler	*Dendroica dominica*	C		
	Pine warbler	*Dendroica pinus*	A		*
	Prairie warbler	*Dendroica discolor*	O		
	Palm warbler	*Dendroica palmarum*	O	W	
	Common yellowthroat	*Geothlypis trichas*	A		@
	Summer tanager	*Piranga rubra*	O		
	Northern cardinal	*Cardinalis cardinalis*	C		
	Rufous-sided towhee	*Pipilo erythrophthalmus*	A		@
	Bachman's sparrow	*Aimophila aestivalis*	O		
	Eastern meadowlark	*Sturnella magna*	O		
	American goldfinch	*Carduelis tristis*	C	W	
Reptiles	Gopher tortoise	*Gopherus polyphemus*	R		
	Florida box turtle	*Terrapene carolina bauri*	O		
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	O		
	Blue-striped garter snake	*Thamnophis sirtalis similis*	O		
	Southern ribbon snake	*Thamnophis sauritus sackenii*	O		
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	O		
	Southern ringneck snake	*Diadophis punctatus punctatus*	C		
	Pine woods snake	*Rhadinaea flavilata*	O		
	Southern black racer	*Coluber constrictor priapus*	A		@
	Eastern indigo snake	*Drymarchon corais couperi*	O		
	Eastern king snake	*Lampropeltis getulus getulus*	O		
	Scarlet king snake	*L. triangulum elapsoides*	C		*
	Scarlet snake	*Cemophora coccinea*	O		
	Corn snake	*Elaphe guttata guttata*	O		

(*Continued*)

Appendix Table F. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Reptiles (cont.)	Yellow rat snake	*Elaphe obsoleta quadrivittata*	O	
	Gulf hammock rat snake	*Elaphe obsoleta williamsi*	O	
	Eastern coral snake	*Micrurus fulvius fulvius*	O	
	Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*	C	@
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	C	@
	Green anole	*Anolis carolinensis carolinensis*	C	
	Ground skink	*Scincella lateralis*	C	
	Southeastern five-lined skink	*Eumeces inexpectatus*	C	@
	Eastern glass lizard	*Ophisaurus ventralis*	C	
	Island glass lizard	*Ophisaurus compressus*	?	
Amphibians	Slimy salamander	*Plethodon glutinosus*	C	
	Dwarf salamander	*Eurycea quadridigitata*	C	
	Southern toad	*Bufo terrestris*	C	
	Oak toad	*Bufo quercicus*	C	*
	Pine woods treefrog	*Hyla femoralis*	A	*
	Squirrel treefrog	*Hyla squirella*	C	
	Green treefrog	*Hyla cinerea*	C	
	Barking treefrog	*Hyla gratiosa*	C	
	Little grass frog	*Limnaoedus ocularis*	A	*
	Florida cricket frog	*Acris gryllus dorsalis*	C	
	Florida chorus frog	*Pseudacris nigrita verrucosa*	A	*
	Ornate chorus frog	*Pseudacris ornata*	O	*
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	C	

[a] A = abundant, C = common, O = occasional, R = rare, ? = unknown.
S = summer only, W = winter only.
* indicates pine flatwoods is the best habitat; @ indicates this is one of the best habitats.

Appendix Table G. Common and characteristic plants of the pine flatwoods (Harper 1915; Laessle 1942; Edmisten 1963; Florida Game and Fresh Water Fish Commission 1976; Conde et al. 1983).

Type	Common name	Scientific name	Abundance [a]		
Trees	Longleaf pine	*Pinus palustris*	C		@
	Slash pine	*Pinus elliottii*	A		*
	Pond pine	*Pinus serotina*	O		*
	Loblolly pine	*Pinus taeda*	O	I	
	Water oak	*Quercus nigra*	O	I	
	Laurel oak	*Quercus hemisphaerica*	O	I	
	Myrtle oak	*Quercus myrtifolia*	O		
	Sand live oak	*Quercus geminata*	O		
	Swamp-bay	*Persea palustris*	O		
	Swamp tupelo	*Nyssa sylvatica* var. *biflora*	O	I	
	Red maple	*Acer rubrum*	O	I	
	Cabbage-palm	*Sabal palmetto*	O		
Shrubs	Saw-palmetto	*Serenoa repens*	A		*
	Dwarf live oak	*Quercus minima*	C		*
	Runner oak	*Quercus pumila*	C		*
	Waxmyrtle	*Myrica cerifera*	C		
	Gallberry	*Ilex glabra*	A		*
	Large gallberry	*Ilex coriacea*	O		
	Dahoon	*Ilex cassine*	O		
	Fetterbush	*Lyonia lucida*	C		
	Staggerbush	*Lyonia fruticosa*	C		*
	Crooked-wood	*Lyonia ferruginea*	O		
	Hairy-laurel	*Kalmia hirsuta*	O		*
	Huckleberry/dangleberry	*Gaylussacia* sp.	C		*
	Shiny blueberry	*Vaccinium myrsinites*	C		*
	Highbush blueberry	*Vaccinium corymbosum*	O		
	Red chokeberry	*Aronia arbutifolia*	O		*
	Sand blackberry	*Rubus cuneifolius*	O		
	Highbush blackberry	*Rubus argutus*	O		
	Flatwoods pawpaw	*Asimina reticulata*	O		*
	Dwarf pawpaw	*Asimina pygmaea*	O		@
	Tarflower	*Befaria racemosa*	O		*
	Shining (winged) sumac	*Rhus copallinum*	C		
	St. John's wort	*Hypericum* spp.	O		
Vines	Yellow jessamine	*Gelsemium sempervirens*	C		
	Greenbriar	*Smilax* spp.	C		
	Bullace (muscadine) grape	*Vitis rotundifolia*	C		

(Continued)

Appendix Table G. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Herbs	Wiregrass	*Aristida stricta*	A	
	Bottle-brush three-awn	*Aristida spiciformis*	C	*
	Three-awn grasses	*Aristida* spp.	C	
	Curtiss dropseed	*Sporobolus curtissii*	C	*
	Bluestems and broomgrass	*Andropogon* spp.	C	@
	Beaked panicum	*Panicum anceps*	C	@
	Maidencane	*Panicum hemitomon*	C	
	Panic grasses	*Panicum* spp.	C	
	Blue maidencane	*Amphicarpum muhlenbergianum*	O	
	Beak rushes	*Rhynchospora* spp.	C	
	Rush	*Juncus scirpoides*	C	
	Redroot	*Lachnanthes caroliniana*	C	
	Yellow-eyed-grass	*Xyris* spp.	C	@
	Common star-grass	*Hypoxis juncea*	C	*
	Bog button (hatpins)	*Eriocaulon* spp.	C	@
	Shoe-buttons	*Syngonanthus flavidulus*	C	@
	Dog fennel	*Eupatorium* spp.	O	
	Sundew	*Drosera* spp.	C	@
	Pale-blue lobelia	*Lobelia paludosa*	O	@
	Meadow-beauty	*Rhexia* spp.	C	@
	Sabatia	*Sabatia* spp.	C	*
	Milkworts	*Polygala* spp.	C	*
	Butterworts	*Pinguicula* spp.	C	*
	Silk-grass	*Pityopsis graminifolia*	C	*
	Blackroot (rabbit tobacco)	*Pterocaulon pycnostachyum*	C	@
	White milk-pea	*Galactia elliottii*	O	
	Elephant's-foot	*Elephantopus* spp.	O	
	Lavender paintbrush	*Carphephorus corymbosus*	C	@
	Deer's tongue	*Carphephorus odoratissimus*	C	*
	Hairy trilisa	*Carphephorus paniculatus*	C	*
	Blazing star	*Liatris* spp.	C	
	Goldenrod	*Solidago* spp.	C	
	Asters	*Aster* spp.	C	
	Violet	*Viola* spp.	C	
	Bracken fern	*Pteridium aquilinum*	C	
	Cinnamon fern	*Osmunda cinnamomea*	C	
	Virginia chain fern	*Woodwardia virginica*	C	

[a] A = abundant, C = common, O = occasional, R = rare.
I = invading species due to fire suppression.
* indicates pine flatwoods is the best habitat; @ indicates this is one of the best habitats.

Appendix Table H. Common and characteristic animals of hammocks (after Pearson 1954; Florida Game and Fresh Water Fish Commission 1976; Simons et al. 1989; Vince et al. 1989).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	C		@
	Homosassa shrew	*Sorex longirostris eionis*	R		
	Northern short-tailed shrew	*Blarina brevicauda*	C		@
	Nine-banded armadillo	*Dasypus novemcinctus*	A	E	@
	Gray squirrel	*Sciurus carolinensis*	A		*
	Southern flying squirrel	*Glaucomys volans*	A		*
	Cotton mouse	*Peromyscus gossypinus*	C		@
	Golden mouse	*Ochrotomys nuttalli*	O		
	Hispid cotton rat	*Sigmodon hispidus*	O		
	Eastern woodrat	*Neotoma floridana*	O		@
	Raccoon	*Procyon lotor*	O		
	Bobcat	*Lynx rufus*	O		
	Wild hog	*Sus scrofa*	A		*
	White-tailed deer	*Odocoileus virginianus*	A		*
Birds	Wood duck	*Aix sponsa*	O		
	Black vulture	*Coragyps atratus*	O		
	Turkey vulture	*Cathartes aura*	C		
	American swallow-tailed kite	*Elanoides forficatus*	O	S	@
	Sharp-shinned hawk	*Accipiter striatus*	O	W	
	Red-shouldered hawk	*Buteo lineatus*	C		@
	Wild turkey	*Meleagris gallopavo*	C		@
	American woodcock	*Scolopax minor*	O		*
	Yellow-billed cuckoo	*Coccyzus americanus*	C	S	*
	Eastern screech owl	*Otus asio*	O		
	Barred owl	*Strix varia*	C		@
	Ruby-throated hummingbird	*Archilochus colubris*	O	S	*
	Red-headed woodpecker	*Melanerpes erythrocephalus*	O	F	
	Red-bellied woodpecker	*Melanerpes carolinus*	A		*
	Yellow-bellied sapsucker	*Sphyrapicus varius*	A	W	*
	Downy woodpecker	*Picoides pubescens*	C		*
	Northern flicker	*Colaptes auratus*	O		
	Pileated woodpecker	*Dryocopus pileatus*	C		*
	Acadian flycatcher	*Empidonax virescens*	C	S	
	Eastern phoebe	*Sayornis phoebe*	C	W	
	Great crested flycatcher	*Myiarchus crinitus*	C	S	@

(*Continued*)

Appendix Table H. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Tree swallow	*Tachycineta bicolor*	C	W	
	Blue jay	*Cyanocitta cristata*	C		
	American crow	*Corvus brachyrhynchos*	C		
	Fish crow	*Corvus ossifragus*	C		
	Carolina chickadee	*Parus carolinensis*	C		
	Tufted titmouse	*Parus bicolor*	C		
	Carolina wren	*Thryothorus ludovicianus*	A		*
	House wren	*Troglodytes aedon*	C	W	
	Ruby-crowned kinglet	*Regulus calendula*	A	W	*
	Blue-gray gnatcatcher	*Polioptila caerulea*	A		*
	Veery	*Catharus fuscescens*	C	W	*
	Hermit thrush	*Catharus guttatus*	C	W	*
	American robin	*Turdus migratorius*	A	W	@
	Brown thrasher	*Toxostoma rufum*	O		
	Cedar waxwing	*Bombycilla cedrorum*	C	W	*
	White-eyed vireo	*Vireo griseus*	C		
	Solitary vireo	*Vireo solitarius*	C	W	@
	Red-eyed vireo	*Vireo olivaceus*	A	S	@
	Black-whiskered vireo	*Vireo altiloquus*	R		
	Orange-crowned warbler	*Vermivora celata*	O	W	*
	Northern parula warbler	*Parula americana*	A	S	*
	Yellow-rumped warbler	*Dendroica coronata*	A	W	
	Yellow-throated warbler	*Dendroica dominica*	O		
	Prairie warbler	*Dendroica discolor*	O		*
	Black-and-white warbler	*Mniotilta varia*	C	W	*
	American redstart	*Setophaga ruticilla*	O	W	
	Ovenbird	*Seiurus aurocapillus*	O	W	*
	Common yellowthroat	*Geothlypis trichas*	O		
	Hooded warbler	*Wilsonia citrina*	O	S	*
	Summer tanager	*Piranga rubra*	C	S	
	Northern cardinal	*Cardinalis cardinalis*	A		@
	Rufous-sided towhee	*Pipilo erythrophthalmus*	O		
	Common grackle	*Quiscalus quiscula*	C	F,W	
	American goldfinch	*Carduelis tristis*	C	W	
Reptiles	Florida box turtle	*Terrapene carolina bauri*	C		*
	Florida red-bellied snake	*Storeria occipitomaculata obscura*	C		*
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	O		

(*Continued*)

Appendix Table H. Concluded.

Type	Common name	Scientific name	Abundance [a]		
Reptiles (cont.)	Blue-striped garter snake	*Thamnophis sirtalis similis*	O		
	Southern ribbon snake	*Thamnophis sauritus sackenii*	C		
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	C		
	Southern ringneck snake	*Diadophis punctatus punctatus*	C		@
	Pine woods snake	*Rhadinaea flavilata*	O		
	Southern black racer	*Coluber constrictor priapus*	C		
	Rough green snake	*Opheodrys aestivus*	C		
	Eastern indigo snake	*Drymarchon corais couperi*	C		@
	Eastern hognose snake	*Heterodon platyrhinos*	C		
	Southern hognose snake	*Heterodon simus*	O		
	Scarlet snake	*Cemophora coccinea*	O		
	Corn snake	*Elaphe guttata guttata*	O		
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	C		@
	Gulf hammock rat snake	*Elaphe obsoleta williamsi*	C		@
	Eastern coral snake	*Micrurus fulvius fulvius*	C		*
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	O		
	Green anole	*Anolis carolinensis carolinensis*	A		*
	Southern fence lizard	*Sceloporus undulatus undulatus*	O		
	Ground skink	*Scincella lateralis*	A		*
	Broad-headed skink	*Eumeces laticeps*	C		*
	Eastern glass lizard	*Ophisaurus ventralis*	O		
Amphibians	Mole salamander	*Ambystoma talpoideum*	O		*
	Slimy salamander	*Plethodon glutinosus*	C		*
	Dwarf salamander	*Eurycea quadridigitata*	C		
	Southern toad	*Bufo terrestris*	C		
	Eastern spadefoot toad	*Scaphiopus holbrookii holbrookii*	O		
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	C		
	Green tree frog	*Hyla cinerea*	C		
	Squirrel tree frog	*Hyla squirella*	C		
	Barking tree frog	*Hyla gratiosa*	O		
	Pine woods tree frog	*Hyla femoralis*	O		
	Little grass frog	*Limnaoedus ocularis*	C		
	Florida cricket frog	*Acris gryllus dorsalis*	C		
	Greenhouse frog	*Eleutherodactylus planirostris*	O	E	

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, F = fall only, W = winter only; E = exotic.
* indicates that hammock is the best habitat; @ indicates that this is one of the best habitats.

Appendix Table I. Common and characteristic plants of hammocks (Harper 1915; Ansley 1952; Quarterman and Keever 1962; Monk 1965; Florida Game and Fresh Water Fish Commission 1976; Thompson 1980; Simons et al. 1989; Vince et al. 1989).

Type	Common name	Scientific name	Abundance [a]	
Trees	Loblolly pine	*Pinus taeda*	C	@
	Southern redcedar	*Juniperus silicicola*	C	*
	Cabbage palm	*Sabal palmetto*	A	*
	Sweetgum	*Liquidambar styraciflua*	A	*
	Pignut hickory	*Carya glabra*	C	*
	Water oak	*Quercus nigra*	C	*
	Laurel oak (diamondleaf oak)	*Quercus hemisphaerica (laurifolia)*	A	*
	Shumard oak	*Quercus shumardii*	O	*
	Sand live oak	*Quercus geminata*	O	
	Live oak	*Quercus virginiana*	A	*
	Swamp chestnut oak	*Quercus michauxii*	C	*
	Bluff oak	*Quercus austrina*	R	*
	Winged elm	*Ulmus alata*	O	*
	Cedar elm	*Ulmus crassifolia*	R	*
	Florida elm	*Ulmus americana* var. *floridana*	C	*
	Sugarberry	*Celtis laevigata*	C	*
	Wingleaf soapberry	*Sapindus saponaria*	R	*
	Eastern hophornbeam (ironwood)	*Ostrya virginiana*	O	*
	American hornbeam (blue-beech)	*Carpinus caroliniana*	A	*
	Red maple	*Acer rubrum*	C	
	Florida maple	*Acer barbatum*	O	*
	White ash	*Fraxinus americana*	O	*
	Carolina basswood	*Tilia caroliniana*	C	*
	Redbay	*Persea borbonia*	O	@
	Swamp-bay	*Persea palustris*	O	
	Southern magnolia	*Magnolia grandiflora*	C	*
	Sweetbay	*Magnolia virginiana*	O	
	Devilwood (wild olive)	*Osmanthus americanus*	O	
	American holly	*Ilex opaca*	O	*
	Common persimmon	*Diospyros virginiana*	O	@
	Flowering dogwood	*Cornus florida*	O	
	Devil's-walkingstick	*Aralia spinosa*	O	*
	Eastern redbud	*Cercis canadensis*	O	*
	Red mulberry	*Morus rubra*	O	*
	Black cherry	*Prunus serotina*	O	
	Cherry-laurel	*Prunus caroliniana*	O	
	American plum	*Prunus americana*	R	*
	Flatwoods plum	*Prunus umbellata*	O	*
	Fringetree (old-man's-beard)	*Chionanthus virginicus*	O	*
	Wild olive	*Osmanthus americanus*	O	
	Red buckeye	*Aesculus pavia*	O	@

(*Continued*)

Appendix Table I. Continued.

Type	Common name	Scientific name	Abundance [a]	
Trees (cont.)	Camphor tree	*Cinnamomum camphora*	R	E
	Brazilian pepper-tree	*Schinus terebinthifolius*	O	E
Shrubs	Saw-palmetto	*Serenoa repens*	O	
	Bluestem palmetto	*Sabal minor*	O	*
	Needle palm	*Rhapidophyllum hystrix*	R	
	Swamp dogwood	*Cornus foemina*	C	@
	Waxmyrtle	*Myrica cerifera*	C	
	Beautyberry	*Callicarpa americana*	C	*
	Tallow-wood	*Ximenia americana*	R	
	Crookedwood	*Lyonia ferruginea*	O	
	Sparkleberry	*Vaccinium arboreum*	O	*
	Deerberry	*V. stamineum*	O	
	Highbush blueberry	*V. corymbosum*	O	
	Carolina holly	*Ilex ambigua*	O	
	Yaupon	*Ilex vomitoria*	O	@
	Walter viburnum	*Viburnum obovatum*	O	
	Southern arrowwood	*Viburnum dentatum* var. *scabrellum*	O	*
	Upland privet	*Forestiera ligustrina*	O	*
	Godfrey's privet	*Forestiera godfreyi*	R	*
	Hammock pawpaw	*Asimina parviflora*	O	*
	Winged sumac	*Rhus copallinum*	O	
	Wild coffee	*Psychotria nervosa*	R	*
	Coral bean	*Erythrina herbacea*	O	*
	Strawberry bush	*Euonymus americanus*	O	*
	Corkwood	*Leitneria floridana*	R	*
	Glossy privet	*Ligustrum lucidum*	O	E
Vines	Summer grape	*Vitis aestivalis*	A	*
	Bullace grape (muscadine)	*Vitis rotundifolia*	C	*
	Virginia creeper	*Parthenocissus quinquefolia*	C	*
	Pepper vine	*Ampelopsis arborea*	O	*
	Poison ivy	*Toxicodendron radicans*	C	*
	Rattan vine (supplejack)	*Berchemia scandens*	C	*
	Climbing buckthorn	*Sageretia minutiflora*	O	*
	Virgin's bower	*Clematis catesbyana*	R	*
	Climbing hydrangea	*Decumaria barbara*	O	@
	Yellow jessamine	*Gelsemium sempervirens*	O	
	Cross vine	*Bignonia capreolata*	C	*
	Trumpet creeper	*Campsis radicans*	C	*
	Wild yam	*Dioscorea* sp.	O	*
	Milkweed vine	*Matelea* sp.	O	*
	Greenbriar	*Smilax* sp.	C	
	Skunk vine	*Paederia foetida*	R	E

(*Continued*)

Appendix Table I. Concluded.

Type	Common name	Scientific name	Abundance[a]	
Epiphytes	Greenfly orchid	*Epidendrum conopseum*	C	*
	Spanish moss	*Tillandsia usneoides*	C	
	Ball moss	*Tillandsia recurvata*	C	
	Gray needleleaf airplant	*Tillandsia bartramii*	C	
	Red needleleaf airplant	*Tillandsia setacea*	C	
	Resurrection fern	*Polypodium polypodioides*	A	*
	Goldfoot fern	*Phlebodium aureum*	C	*
Herbs	Wood fern	*Thelypteris* spp.	C	*
	Florida shield fern	*Dryopteris ludoviciana*	O	@
	Ebony spleenwort	*Asplenium platyneuron*	O	*
	Giant cane	*Arundinaria gigantea*	O	@
	Spikegrass	*Chasmanthium* spp.	C	*
	Woodsgrass	*Oplismenus setarius*	C	*
	Variable panicum	*Panicum commutatum*	C	@
	Red-top panicum	*Panicum rigidulum*	C	@
	Panic grasses	*Panicum* spp.	C	
	St. Augustine grass	*Stenotaphrum secundatum*	O	E
	Sedges	*Carex* spp.	A	@
	Flat sedge	*Cyperus* spp.	O	
	Tall nut-grass	*Scleria triglomerata*	O	
	Coontie	*Zamia floridana*	R	
	Sarsaparilla vine	*Smilax pumila*	C	*
	Partridgeberry	*Mitchella repens*	C	*
	Scalestem	*Elytraria carolinensis*	O	*
	Cooley's water-willow	*Justicia cooleyi*	R	*
	Purple elephants-foot	*Elephantopus nudatus*	C	*
	Mild water-pepper	*Polygonum hydropiperoides*	O	
	Indian-plantain	*Arnoglossum diversifolium*	O	*
	Indian-plantain	*Cacalia suaveolens*	R	*
	Shadow-witch	*Ponthieva racemosa*	O	*
	Rouge plant	*Rivina humilis*	R	*
	Bear's foot sunflower	*Polymnia uvedalia*	O	*
	Wild petunia	*Ruellia caroliniensis*	O	*
	Lyre-leaf sage	*Salvia lyrata*	O	*
	Butterweed	*Senecio glabellus*	O	*
	Pink-root	*Spigelia loganioides*	R	*
	Bedstraw	*Galium* spp.	C	*
	Spanish needles	*Bidens bipinnata*	O	
	Pony-foot	*Dichondra carolinensis*	O	
	Florida violet	*Viola affinis*	C	*
	Walter violet	*Viola walteri*	O	*

[a] A = abundant, C = common, O = occasional, R = rare; E = exotic invader.
* indicates hammocks are the best habitat; @ indicates this is one of the best habitats.

Appendix Table J. Common and characteristic animals of cleared rural land (after Florida Game and Fresh Water Fish Commission 1976; Lopez et al. 1981; Humphrey et al. 1985).

Type	Common name	Scientific name	Abundance[a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Northern short-tailed shrew	*Blarina brevicauda*	O		
	Nine-banded armadillo	*Dasypus novemcinctus*	C		
	Marsh rabbit	*Sylvilagus palustris*	O		
	Eastern cottontail rabbit	*Sylvilagus floridanus*	C		@
	Southeastern pocket gopher	*Geomys pinetis*	O		@
	Cotton mouse	*Peromyscus gossypinus*	O		
	Hispid cotton rat	*Sigmodon hispidus*	A		@
Birds	Cattle egret	*Bubulcus ibis*	A	E	*
	Black vulture	*Coragyps atratus*	C		@
	Turkey vulture	*Cathartes aura*	O		
	Northern harrier (marsh hawk)	*Circus cyaneus*	O	W	
	Red-tailed hawk	*Buteo jamaicensis*	C		@
	American kestrel	*Falco sparverius*	C	W	@
	Southeastern American kestrel	*Falco sparverius paulus*	R		@
	Northern bobwhite	*Colinus virginianus*	C		@
	Sandhill crane	*Grus canadensis*	R		
	Killdeer	*Charadrius vociferus*	C		@
	Mourning dove	*Zenaida macroura*	C		@
	Common ground dove	*Columbina passerina*	O		@
	Eastern screech owl	*Otus asio*	O		
	Great horned owl	*Bubo virginianus*	O		@
	Barn owl	*Tyto alba*	R		
	Burrowing owl	*Athene cunicularia*	R		*
	Common nighthawk	*Chordeiles minor*	C	S	@
	Eastern phoebe	*Sayornis phoebe*	O	W	
	Great crested flycatcher	*Myiarchus crinitus*	C	S	
	Eastern kingbird	*Tyrannus tyrannus*	O	S	@
	Purple martin	*Progne subis*	C	S	@
	Tree swallow	*Tachycineta bicolor*	O	W	
	Northern rough-winged swallow	*Stelgidopteryx serripennis*	O	S	
	Blue jay	*Cyanocitta cristata*	C		
	American crow	*Corvus brachyrhynchos*	C		@
	Fish crow	*Corvus ossifragus*	O		
	Carolina wren	*Thryothorus ludovicianus*	C		
	House wren	*Troglodytes aedon*	O	W	
	Short-billed marsh wren	*Cistothorus platensis*	R		
	Eastern bluebird	*Sialia sialis*	O		
	American robin	*Turdus migratorius*	C	W	
	Northern mockingbird	*Mimus polyglottos*	C		

(*Continued*)

Appendix Table J. Concluded.

Type	Common name	Scientific name	Abundance[a]		
Birds (cont.)	Brown thrasher	*Toxostoma rufum*	O		
	Loggerhead shrike	*Lanius ludovicianus*	C		*
	European starling	*Sturnus vulgaris*	C	E	@
	White-eyed vireo	*Vireo griseus*	C		
	Yellow-rumped warbler	*Dendroica coronata*	C	W	
	Pine warbler	*Dendroica pinus*	O	W	
	Palm warbler	*Dendroica palmarum*	O	W	
	Northern cardinal	*Cardinalis cardinalis*	O		
	Blue grosbeak	*Guiraca caerulea*	O	S	@
	Indigo bunting	*Passerina cyanea*	O	S	@
	Rufous-sided towhee	*Pipilo erythrophthalmus*	O		
	Savannah sparrow	*Passerculus sandwichensis*	A	W	*
	Chipping sparrow	*Spizella passerina*	C	W	*
	Bobolink	*Dolichonyx oryzivorus*	O	M	
	Red-winged blackbird	*Agelaius phoeniceus*	C		
	Eastern meadowlark	*Sturnella magna*	A		@
	Rusty blackbird	*Euphagus carolinus*	O	W	
	Boat-tailed grackle	*Quiscalus major*	O		
	Common grackle	*Quiscalus quiscula*	A		*
	Brown-headed cowbird	*Molothrus ater*	O		*
	Orchard oriole	*Icterus spurius*	O	S	*
	American goldfinch	*Carduelis tristis*	A	W	@
Reptiles	Gopher tortoise	*Gopherus polyphemus*	R		
	Eastern hognose snake	*Heterodon platyrhinos*	O		
	Southern hognose snake	*Heterodon simus*	O		
	Southern ringneck snake	*Diadophis punctatus punctatus*	O		
	Southern black racer	*Coluber constrictor priapus*	C		
	Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*	O		
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	O		
	Six-lined racerunner	*Cnemidophorus sexlineatus sexlineatus*	O		
	Ground skink	*Scincella lateralis*	O		
	Eastern glass lizard	*Ophisaurus ventralis*	O		
Amphibians	Southern toad	*Bufo terrestris*	C		
	Florida gopher frog	*Rana areolata aesopus*	R		

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only, M = migrant only, E = exotic.
* indicates that cleared land is the best habitat; @ indicates that this is one of the best habitats.

Appendix Table K. Common and characteristic animals of developed areas (in part after Woolfenden and Rohwer 1969; Florida Game and Fresh Water Fish Commission 1976).

Type	Common name [a]	Scientific name	Abundance [b]		
Mammals	Virginia opossum	*Didelphis virginiana*	C	D	@
	Eastern cottontail rabbit	*Sylvilagus floridanus*	C	L	
	Gray squirrel	*Sciurus carolinensis*	A	L,M	@
	Southern flying squirrel	*Glaucomys volans*	C	L,M	
	Southeastern pocket gopher	*Geomys pinetis*	C	L	
	Hispid cotton rat	*Sigmodon hispidus*	C	L	
	Norway rat (E)	*Rattus norvegicus*	C	D	*
	Black rat (E)	*Rattus rattus*	C	D	*
	House mouse (E)	*Mus musculus*	C	D	*
	Gray fox	*Urocyon cinereoargenteus*	C	L	
Birds	Sharp-shinned hawk (W)	*Accipiter striatus*	O	D	
	Red-tailed hawk	*Buteo jamaicensis*	O	L	
	Northern bobwhite	*Colinus virginianus*	C	L	
	Rock dove (city pigeon) (E)	*Columba livia*	C	H	*
	Mourning dove	*Zenaida macroura*	A	M	@
	Common ground dove	*Columbina passerina*	O	L	
	Common nighthawk (S)	*Chordeiles minor*	C	L	
	Chimney swift (S)	*Chaetura pelagica*	A	D	*
	Northern flicker	*Colaptes auratus*	O	L	
	Red-headed woodpecker	*Melanerpes erythrocephalus*	O	L,M	
	Red-bellied woodpecker	*Melanerpes carolinus*	C	L,M	
	Downy woodpecker	*Picoides pubescens*	O	L,M	
	Great crested flycatcher (S)	*Myiarchus crinitus*	C	L,M	
	Eastern phoebe (W)	*Sayornis phoebe*	C	L	
	Purple martin (S)	*Progne subis*	C	D	*
	Blue jay	*Cyanocitta cristata*	A	D	
	Fish crow	*Corvus ossifragus*	C	D	
	Carolina chickadee	*Parus carolinensis*	O	L,M	
	Tufted titmouse	*Parus bicolor*	O	L,M	
	Carolina wren	*Thryothorus ludovicianus*	C	L,M	
	Ruby-crowned kinglet (W)	*Regulus calendula*	O	L,M	
	Blue-gray gnatcatcher	*Polioptila caerulea*	C	L,M	
	American robin (W)	*Turdus migratorius*	C	D	
	Northern mockingbird	*Mimus polyglottos*	A	D	*
	Cedar waxwing (W)	*Bombycilla cedrorum*	O	D	
	European starling (E)	*Sturnus vulgaris*	O	D	*
	Yellow-rumped warbler (W)	*Dendroica coronata*	C	L,M	

(*Continued*)

Appendix Table K. Concluded.

Type	Common name [a]	Scientific name	Abundance [b]		
	Summer tanager (S)	*Piranga rubra*	C	L,M	
	Northern cardinal	*Cardinalis cardinalis*	A	L,M	@
	Rufous-sided towhee	*Pipilo erythrophthalmus*	C	L	
	Boat-tailed grackle	*Quiscalus major*	O	D	
	Common grackle	*Quiscalus quiscula*	C	D	
	American goldfinch (W)	*Carduelis tristis*	C	L,M	
	House sparrow (E)	*Passer domesticus*	A	H	*
Reptiles	Eastern garter snake	*Thamnophis sirtalis sirtalis*	C	L,M	@
	Southern ringneck snake	*Diadophis punctatus punctatus*	C	L,M	
	Southern black racer	*Coluber constrictor priapus*	C	L	
	Rough green snake	*Opheodrys aestivus*	O	L	
	Eastern hognosed snake	*Heterodon platyrhinos*	O	L	
	Corn snake	*Elaphe guttata guttata*	C	L,M	@
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	C	L,M	@
	Florida crowned snake	*Tantilla relicta*	C	L,M	
	Mediterranean house gecko (E)	*Hemidactylus turcicus*	O	M,H	*
	Green anole	*Anolis carolinensis*	A	D	@
	Brown anole (E)	*Anolis sagrei*	O	D	*
	Eastern glass lizard	*Ophisaurus ventralis*	C	L,M	@
Amphibians	Southern toad	*Bufo terrestris*	C	L,M	@
	Green tree frog	*Hyla cinerea*	C	D	
	Squirrel tree frog	*Hyla squirella*	C	D	
	Greenhouse frog (E)	*Eleutherodactylus planirostris*	A	D	*

[a] (S) = summer only, (W) = winter only, (E) = exotic.

[b] A = abundant, C = common, O = occasional.

L = does best in low density development (less then one dwelling per acre); M = does best in medium density development (from one to five dwellings per acre); H = does best in high density development (more than five dwellings per acre or industrial or commercial development); D = no density preference observed.

* indicates developed areas are the best habitat for the species; @ indicates this is one of the best habitats for this species.

Appendix Table L. Common and characteristic animals of bayheads (after Florida Game and Fresh Water Fish Commission 1976).

Type	Common name	Scientific name	Abundance [a]	
Mammals	Virginia opossum	*Didelphis virginiana*	C	
	Marsh rice rat	*Oryzomys palustris*	O	
	Cotton mouse	*Peromyscus gossypinus*	C	
	Golden mouse	*Ochrotomys nuttalli*	O	
	Eastern woodrat	*Neotoma floridana*	O	
	Black bear	*Ursus americanus*	R	@
	Raccoon	*Procyon lotor*	C	
Birds	Green-backed heron	*Butorides striatus*	O	
	Red-shouldered hawk	*Buteo lineatus*	O	
	Yellow-billed cuckoo	*Coccyzus americanus*	C	S
	Barred owl	*Strix varia*	C	
	Chuck-will's-widow	*Caprimulgus carolinensis*	O	S
	Red-bellied woodpecker	*Melanerpes carolinus*	C	
	Downy woodpecker	*Picoides pubescens*	O	
	Pileated woodpecker	*Dryocopus pileatus*	C	
	Great crested flycatcher	*Myiarchus crinitus*	C	S
	Blue jay	*Cyanocitta cristata*	C	
	American crow	*Corvus brachyrhynchos*	C	
	Carolina chickadee	*Parus carolinensis*	O	
	Tufted titmouse	*Parus bicolor*	C	
	Carolina wren	*Thryothorus ludovicianus*	C	
	Ruby-crowned kinglet	*Regulus calendula*	C	W
	Blue-gray gnatcatcher	*Polioptila caerulea*	O	
	American robin	*Turdus migratorius*	C	W
	Cedar waxwing	*Bombycilla cedrorum*	O	W
	White-eyed vireo	*Vireo griseus*	C	
	Solitary vireo	*Vireo solitarius*	O	W
	Red-eyed vireo	*Vireo olivaceus*	C	S
	Northern parula warbler	*Parula americana*	C	S
	Yellow-rumped warbler	*Dendroica coronata*	C	W
	Prothonotary warbler	*Protonotaria citrea*	O	S
	Common yellowthroat	*Geothlypis trichas*	O	
	Summer tanager	*Piranga rubra*	O	S
	Northern cardinal	*Cardinalis cardinalis*	C	
	Rufous-sided towhee	*Pipilo erythrophthalmus*	C	
	Red-winged blackbird	*Agelaius phoeniceus*	O	
	Common grackle	*Quiscalus quiscula*	C	

(*Continued*)

Appendix Table L. Concluded.

Type	Common name	Scientific name	Abundance [a]
Reptiles	Stinkpot	*Sternotherus odoratus*	O
	Striped mud turtle	*Kinosternon baurii*	O
	Florida mud turtle	*K. subrubrum steindachneri*	O
	Florida box turtle	*Terrapene carolina bauri*	O
	Florida banded water snake	*Nerodia fasciata pictiventris*	C
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	C
	Southern ribbon snake	*Thamnophis sauritus sackenii*	C
	Striped crayfish snake	*Regina alleni*	O
	Black swamp snake	*Seminatrix pygaea pygaea*	O
	Southern ringneck snake	*Diadophis punctatus punctatus*	C
	Pine woods snake	*Rhadinaea flavilata*	O
	Eastern mud snake	*Farancia abacura abacura*	C
	Rough green snake	*Opheodrys aestivus*	C
	Southern black racer	*Coluber constrictor priapus*	C
	Eastern indigo snake	*Drymarchon corais couperi*	O
	Scarlet king snake	*Lampropeltis triangulum elapsoides*	O
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	C
	Eastern coral snake	*Micrurus fulvius fulvius*	C
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	C
	Dusky pigmy rattlesnake	*Sistrurus miliarius barbouri*	C
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	O
	Green anole	*Anolis carolinensis carolinensis*	C
	Broad-headed skink	*Eumeces laticeps*	C
	Eastern glass lizard	*Ophisaurus ventralis*	O
Amphibians	Two-toed amphiuma	*Amphiuma means*	O
	Lesser siren	*Siren intermedia*	O
	Narrow-striped dwarf siren	*Pseudobranchus striatus axanthus*	O
	Gulf hammock dwarf siren	*Pseudobranchus striatus lustricolus*	R
	Peninsula newt	*Notophthalmus viridescens piaropicola*	C
	Slimy salamander	*Plethodon glutinosus*	C
	Dwarf salamander	*Eurycea quadridigitata*	C
	Greenhouse frog	*Eleutherodactylus planirostris*	C
	Southern toad	*Bufo terrestris*	C
	Barking tree frog	*Hyla gratiosa*	C
	Squirrel tree frog	*Hyla squirella*	C
	Green tree frog	*Hyla cinerea*	C
	Little grass frog	*Limnaoedus ocularis*	C
	Florida cricket frog	*Acris gryllus dorsalis*	C
	Florida leopard frog	*Rana utricularia sphenocephala*	C

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only; @ = bayhead is one of the best habitats.

Appendix Table M. Common and characteristic plants of bayheads (after Florida Game and Fresh Water Fish Commission 1976; Simons et al. 1984).

Type	Common name	Scientific name	Abundance [a]	
Trees	Pond pine	*Pinus serotina*	O	
	Slash pine	*Pinus elliottii*	C	
	Pondcypress	*Taxodium ascendens*	O	
	Loblolly-bay	*Gordonia lasianthus*	A	*
	Sweetbay	*Magnolia virginiana*	A	*
	Swamp-bay	*Persea palustris*	A	*
	Swamp tupelo	*Nyssa sylvatica* var. *biflora*	A	@
	Red maple	*Acer rubrum*	C	
	Water oak	*Quercus nigra*	O	
	Dahoon	*Ilex cassine*	C	@
Shrubs	Large gallberry	*Ilex coriacea*	C	*
	Gallberry	*Ilex glabra*	C	
	Virginia-willow	*Itea virginica*	A	*
	Fetterbush	*Lyonia lucida*	A	@
	Sweet bells	*Leucothoe racemosa*	O	@
	Swamp azalea	*Rhododendron serrulatum*	O	*
	Highbush blueberry	*Vaccinium corymbosum (fuscatum)*	O	@
	Dangleberry (huckleberry)	*Gaylussacia frondosa*	O	
	Elderberry	*Sambucus canadensis*	C	
	Highbush blackberry	*Rubus argutus*	C	@
	Red chokeberry	*Aronia arbutifolia*	O	
	Wax myrtle	*Myrica cerifera*	C	
	Poison sumac	*Rhus vernix*	O	*
	Arrow-wood	*Viburnum nudum*	O	*
	Saw-palmetto	*Serenoa repens*	O	
	Needle palm	*Rhapidophyllum hystrix*	R	@
Vines	Greenbriar (bamboo vine)	*Smilax laurifolia*	A	*
	Greenbriar	*Smilax glauca*	C	@
	Bullace grape (muscadine)	*Vitis rotundifolia*	C	
	Virginia creeper	*Parthenocissus quinquefolia*	O	
	Rattan vine	*Berchemia scandens*	O	
	Yellow jessamine	*Gelsemium sempervirens*	O	
Herbs	Sphagnum moss	*Sphagnum* spp.	C	*
	Cinnamon fern	*Osmunda cinnamomea*	A	*
	Royal fern	*Osmunda regalis*	O	@
	Netted chain fern	*Lorinseria areolata*	A	*
	Virginia chain fern	*Woodwardia virginica*	C	@
	Florida shield fern	*Dryopteris ludoviciana*	C	@
	Lizard's tail	*Saururus cernuus*	C	@

[a] A = abundant, C = common, O = occasional, R = rare.
* indicates that bayheads are the best habitat; @ indicates bayhead is one of the best habitats.

Appendix Table N. Common and characteristic animals of mixed swamps (after Florida Game and Fresh Water Fish Commission 1976; Simons 1983).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	C		
	Homosassa shrew	*Sorex longirostris eionis*	R		*
	Southeastern myotis	*Myotis austroriparius*	C		@
	Eastern pipistrelle	*Pipistrellus subflavus*	O	S	
	Red bat	*Lasiurus borealis*	C		@
	Seminole bat	*Lasiurus seminolus*	O	S	@
	Evening bat	*Nycticeius humeralis*	C	S	@
	Gray squirrel	*Sciurus carolinensis*	O		
	Cotton mouse	*Peromyscus gossypinus*	C		
	Eastern woodrat	*Neotoma floridana*	O		
	Raccoon	*Procyon lotor*	C		
	River otter	*Lutra canadensis*	O		
	Wild hog	*Sus scrofa*	C		
Birds	Great egret	*Casmerodius albus*	O		
	Green-backed heron	*Butorides striatus*	O		
	White ibis	*Eudocimus albus*	O		
	Wood duck	*Aix sponsa*	C		@
	Black vulture	*Coragyps atratus*	C		
	Turkey vulture	*Cathartes aura*	C		
	American swallow-tailed kite	*Elanoides forficatus*	O	S	
	Sharp-shinned hawk	*Accipiter striatus*	O	W	
	Red-shouldered hawk	*Buteo lineatus*	C		
	Wild turkey	*Meleagris gallopavo*	O		
	Limpkin	*Aramus guarauna*	O		
	Yellow-billed cuckoo	*Coccyzus americanus*	C	S	
	Barred owl	*Strix varia*	C		@
	Belted kingfisher	*Ceryle alcyon*	O		
	Downy woodpecker	*Picoides pubescens*	C		@
	Yellow-bellied sapsucker	*Sphyrapicus varius*	C	W	@
	Red-bellied woodpecker	*Melanerpes carolinus*	A		@
	Yellow-shafted flicker	*Colaptes auratus*	O		
	Pileated woodpecker	*Dryocopus pileatus*	C		@
	Acadian flycatcher	*Empidonax virescens*	A	S	*
	Eastern phoebe	*Sayornis phoebe*	O	W	
	Great crested flycatcher	*Myiarchus crinitus*	C	S	
	Tree swallow	*Tachycineta bicolor*	O	W	
	Blue jay	*Cyanocitta cristata*	O		

(*Continued*)

Appendix Table N. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	American crow	*Corvus brachyrhynchos*	O		
	Fish crow	*Corvus ossifragus*	O		
	Carolina chickadee	*Parus carolinensis*	C		
	Tufted titmouse	*Parus bicolor*	C		
	Carolina wren	*Thryothorus ludovicianus*	C		
	House wren	*Troglodytes aedon*	C	W	
	Ruby-crowned kinglet	*Regulus calendula*	C	W	
	Blue-gray gnatcatcher	*Polioptila caerulea*	C		
	Veery	*Catharus fuscescens*	O	M	
	Hermit thrush	*Catharus guttatus*	O	W	
	American robin	*Turdus migratorius*	C	W	
	White-eyed vireo	*Vireo griseus*	O		
	Solitary vireo	*Vireo solitarius*	C	W	
	Yellow-throated vireo	*Vireo flavifrons*	O	S	
	Red-eyed vireo	*Vireo olivaceus*	A	S	*
	Northern parula warbler	*Parula americana*	C	S	
	Yellow-rumped warbler	*Dendroica coronata*	A	W	
	Yellow-throated warbler	*Dendroica dominica*	C		
	Common yellowthroat	*Geothlypis trichas*	O		
	Black-and-white warbler	*Mniotilta varia*	C	W	
	Prothonotary warbler	*Protonotaria citrea*	C	S	@
	Summer tanager	*Piranga rubra*	C	S	
	Northern cardinal	*Cardinalis cardinalis*	C		
	American goldfinch	*Carduelis tristis*	O	W	
Reptiles	American alligator	*Alligator mississippiensis*	O		
	Striped mud turtle	*Kinosternon baurii*	C		
	Florida banded water snake	*Nerodia fasciata pictiventris*	C		
	Brown water snake	*Nerodia taxispilota*	O		
	Southern ribbon snake	*Thamnophis sauritus sackenii*	C		
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	C		
	Eastern mud snake	*Farancia abacura abacura*	C		
	Southern black racer	*Coluber constrictor priapus*	O		
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	C		
	Gulf hammock rat snake	*Elaphe obsoleta williamsi*	C		
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	A		*
	Green anole	*Anolis carolinensis carolinensis*	C		

(*Continued*)

Appendix Table N. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Amphibians	Two-toed amphiuma	*Amphiuma means*	C	
	One-toed amphiuma	*Amphiuma pholeter*	R	
	Greater siren	*Siren lacertina*	C	
	Lesser siren	*Siren intermedia*	C	
	Southern toad	*Bufo terrestris*	C	
	Green tree frog	*Hyla cinerea*	C	
	Squirrel tree frog	*Hyla squirella*	O	
	River frog	*Rana heckscheri*	C	*
	Bronze frog	*Rana clamitans clamitans*	C	*
	Florida leopard frog	*Rana utricularia sphenocephala*	C	
Fish	Mosquitofish	*Gambusia affinis*	C	
	Dollar sunfish	*Lepomis marginatus*	O	@

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only, M = migrant only.
* indicates that mixed swamp is the best habitat; @ indicates this is one of the best habitats.

Appendix Table O. Common and characteristic plants of mixed swamps (after Florida Game and Fresh Water Fish Commission 1976; Simons 1983).

Type	Common name	Scientific name	Abundance [a]	
Trees	Baldcypress	*Taxodium distichum*	A	*
	Pondcypress	*Taxodium ascendens*	O	
	Cabbage palm	*Sabal palmetto*	C	
	Swamp tupelo	*Nyssa sylvatica* var. *biflora*	A	*
	Green ash	*Fraxinus pennsylvanica*	A	*
	Pumpkin ash	*Fraxinus profunda*	?	*
	Pop ash	*Fraxinus caroliniana*	O	*
	Red maple	*Acer rubrum*	A	*
	Waterlocust	*Gleditsia aquatica*	O	*
	Swamp laurel oak	*Quercus laurifolia*	O	
	Coastal plain willow	*Salix caroliniana*	A	*
	Sweetgum	*Liquidambar styraciflua*	O	
	Florida elm	*Ulmus americana* var. *floridana*	O	
	Sweetbay	*Magnolia virginiana*	O	
	American hornbeam (blue-beech)	*Carpinus caroliniana*	O	
	Dahoon	*Ilex cassine*	O	
Shrubs	Buttonbush	*Cephalanthus occidentalis*	A	*
	American snowbell	*Styrax americana*	O	*
	Virginia-willow	*Itea virginica*	O	
	Wax myrtle	*Myrica cerifera*	C	
	Swamp rose	*Rosa palustris*	O	
	Swamp dogwood	*Cornus foemina*	C	@
	Elderberry	*Sambucus canadensis*	O	
Vines	Climbing hydrangea	*Decumaria barbara*	C	*
	Poison ivy	*Toxicodendron radicans*	C	
	Summer grape	*Vitis aestivalis*	C	
	Rattan vine (supplejack)	*Berchemia scandens*	C	
	Bamboo vine (greenbriar)	*Smilax laurifolia*	C	
Epiphytes	Gray needleleaf airplant	*Tillandsia bartramii*	C	*
	Red needleleaf airplant	*Tillandsia setacea*	C	*
	Green-fly orchid	*Epidendrum conopseum*	O	
Herbs	Water spangles	*Salvinia minima*	O	@
	Swamp fern	*Blechnum serrulatum*	O	@
	Royal fern	*Osmunda regalis*	O	*

(*Continued*)

Appendix Table O. Concluded.

Type	Common name	Scientific name	Abundance [a]	
	Sawgrass	*Cladium jamaicense*	O	
	Savannah panic grass	*Panicum gymnocarpon*	O	
	Beakrush	*Rhynchospora* spp.	C	
	String-lily	*Crinum americanum*	O	*
	Spider-lily	*Hymenocallis crassifolia*	C	*
	Golden club	*Orontium aquaticum*	O	*
	Arrowhead	*Sagittaria* spp.	O	
	Smartweed	*Polygonum hydropiperoides*	O	
	Lizard's tail	*Saururus cernuus*	C	*
	Bog-hemp	*Boehmeria cylindrica*	O	*
	Cardinal flower	*Lobelia cardinalis*	O	*
	Pennywort	*Hydrocotyle* spp.	O	
	Climbing hempweed	*Mikania scandens*	O	
	Climbing aster	*Aster carolinianus*	O	

[a] A = abundant, C = common, O = occasional, ? = abundance unknown due to problems with identification to species.
* indicates that mixed swamp in the primary habitat; @ indicates this is one of the best habitats.

Appendix Table P. Common and characteristic animals of cypress domes (after Florida Game and Fresh Water Fish Commission 1976; Marion and O'Meara 1982).

Type	Common name	Scientific name	Abundance[a]	
Mammals	Virginia opossum	*Didelphis virginiana*	O	
	Marsh rabbit	*Sylvilagus palustris*	O	
	Gray squirrel	*Sciurus carolinensis*	O	
	Marsh rice rat	*Oryzomys palustris*	O	
	Cotton mouse	*Peromyscus gossypinus*	C	
	Eastern woodrat	*Neotoma floridana*	O	
	Raccoon	*Procyon lotor*	C	
	Wild hog	*Sus scrofa*	C	
	White-tailed deer	*Odocoileus virginianus*	C	
Birds	Great egret	*Casmerodius albus*	O	
	Great blue heron	*Ardea herodias*	O	
	Snowy egret	*Egretta thula*	O	
	Little blue heron	*Egretta caerulea*	O	
	Green-backed heron	*Butorides striatus*	C	
	White ibis	*Eudocimus albus*	C	
	Wood duck	*Aix sponsa*	O	
	Hooded merganser	*Lophodytes cucullatus*	O	
	Black vulture	*Coragyps atratus*	O	
	Turkey vulture	*Cathartes aura*	O	
	Sharp-shinned hawk	*Accipiter striatus*	O	W
	Red-shouldered hawk	*Buteo lineatus*	C	
	Wild turkey	*Meleagris gallopavo*	O	
	Barred owl	*Strix varia*	O	
	Belted kingfisher	*Ceryle alcyon*	O	
	Red-bellied woodpecker	*Melanerpes carolinus*	C	
	Pileated woodpecker	*Dryocopus pileatus*	O	
	Great crested flycatcher	*Myiarchus crinitus*	O	S
	Blue jay	*Cyanocitta cristata*	C	
	American crow	*Corvus brachyrhynchos*	C	
	Fish crow	*Corvus ossifragus*	C	
	Carolina chickadee	*Parus carolinensis*	C	
	Tufted titmouse	*Parus bicolor*	C	
	Carolina wren	*Thryothorus ludovicianus*	C	
	House wren	*Troglodytes aedon*	O	W
	Ruby-crowned kinglet	*Regulus calendula*	C	W
	Blue-gray gnatcatcher	*Polioptila caerulea*	O	
	American robin	*Turdus migratorius*	A	W

(*Continued*)

Appendix Table P. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Gray catbird	*Dumetella carolinensis*	O	W	
	Northern mockingbird	*Mimus polyglottos*	O		
	Cedar waxwing	*Bombycilla cedrorum*	O	W	
	White-eyed vireo	*Vireo griseus*	C		
	Red-eyed vireo	*Vireo olivaceus*	C	S	
	Northern parula warbler	*Parula americana*	O	S	
	Yellow-rumped warbler	*Dendroica coronata*	A	W	
	Yellow-throated warbler	*Dendroica dominica*	C		
	Pine warbler	*Dendroica pinus*	O		
	Prothonotory warbler	*Protonotaria citrea*	O	S	
	Common yellowthroat	*Geothlypis trichas*	C		
	Summer tanager	*Piranga rubra*	C		
	Northern cardinal	*Cardinalis cardinalis*	C		
	Red-winged blackbird	*Agelaius phoeniceus*	O		
	Common grackle	*Quiscalus quiscula*	C		
Reptiles	Stinkpot	*Sternotherus odoratus*	O		
	Striped mud turtle	*Kinosternon baurii*	O		
	Eastern mud turtle	*K.subrubrum subrubrum*	C		
	Florida mud turtle	*K.subrubrum steindachneri*	R		
	Florida box turtle	*Terrapene carolina bauri*	O		
	Peninsula cooter	*Pseudemys floridana peninsularis*	O		
	Chicken turtle	*Deirochelys reticularia*	O		
	Florida banded water snake	*Nerodia fasciata pictiventris*	C		
	Striped crayfish snake	*Regina alleni*	O		@
	Glossy crayfish snake	*Regina rigida*	O		*
	Black swamp snake	*Seminatrix pygaea*	C		@
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	O		
	Southern ribbon snake	*Thamnophis sauritus sackeni*	C		
	Southern ringneck snake	*Diadophis punctatus punctatus*	C		
	Pine woods snake	*Rhadinaea flavilata*	C		*
	Eastern mud snake	*Farancia abacura abacura*	O		
	Rough green snake	*Opheodrys aestivus*	C		
	Southern black racer	*Coluber constrictor priapus*	O		
	Eastern indigo snake	*Drymarchon corais couperi*	O		
	Eastern king snake	*Lampropeltis getulus getulus*	O		
	Scarlet king snake	*L.triangulum elapsoides*	O		
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	O		
	Dusky pygmy rattlesnake	*Sistrurus miliarius barbouri*	O		

(*Continued*)

Appendix Table P. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Reptiles (cont.)	Florida cottonmouth	*Agkistrodon piscivorus conanti*	C	
	Green anole	*Anolis carolinensis carolinensis*	C	
	Ground skink	*Scincella lateralis*	O	
	Broad-headed skink	*Eumeces laticeps*	O	
	Southeastern five-lined skink	*Eumeces inexpectatus*	C	
	Eastern glass lizard	*Ophisaurus ventralis*	C	
Amphibians	Two-toed amphiuma	*Amphiuma means*	O	
	Greater siren	*Siren lacertina*	O	
	Lesser siren	*Siren intermedia*	O	
	Slender dwarf siren	*Pseudobranchus striatus spheniscus*	C	*
	Gulf Hammock dwarf siren	*Pseudobranchus striatus lustricolus*	R	*
	Striped newt	*Notophthalmus perstriatus*	O	@
	Peninsula newt	*Notophthalmus viridescens piaropicola*	C	
	Southern dusky salamander	*Desmognathus auriculatus*	O	*
	Slimy salamander	*Plethodon glutinosus*	C	
	Dwarf salamander	*Eurycea quadridigitata*	C	
	Southern toad	*Bufo terrestris*	C	
	Pine woods tree frog	*Hyla femoralis*	C	
	Squirrel tree frog	*Hyla squirella*	C	
	Green tree frog	*Hyla cinerea*	C	
	Barking tree frog	*Hyla gratiosa*	O	
	Little grass frog	*Limnaoedus ocularis*	C	@
	Florida cricket frog	*Acris gryllus dorsalis*	C	
	Florida chorus frog	*Pseudacris nigrita verrucosa*	C	
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	O	
	Bullfrog	*Rana catesbeiana*	O	
	River frog	*Rana heckscheri*	O	
	Pig frog	*Rana grylio*	C	
	Bronze frog	*Rana clamitans clamitans*	O	
	Florida leopard frog	*Rana utricularia sphenocephala*	C	
Fish	Mosquitofish	*Gambusia affinis*	O	

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only.
* indicates cypress domes are the best habitat; @ indicates this is one of the best habitats.

Appendix Table Q. Common and characteristic plants of cypress domes (after Brown 1963; Monk and Brown 1965; Florida Game and Fresh Water Fish Commission 1976).

Type	Common name	Scientific name	Abundance [a]	
Trees	Pond-cypress	*Taxodium ascendens*	A	*
	Bald-cypress	*Taxodium distichum*	O	
	Slash pine	*Pinus elliottii*	C	
	Swamp tupelo	*Nyssa sylvatica* var. *biflora*	C	
	Red maple	*Acer rubrum*	O	
	Water oak	*Quercus nigra*	O	
	Coastal plain willow	*Salix caroliniana*	O	
	Loblolly-bay	*Gordonia lasianthus*	O	
	Sweetbay	*Magnolia virginiana*	O	
	Dahoon	*Ilex cassine*	O	
	Shrubs			
	Gallberry	*Ilex glabra*	O	
	Fetterbush	*Lyonia lucida*	A	@
	Virginia-willow	*Itea virginica*	C	
	Wax myrtle	*Myrica cerifera*	C	
	Highbush blackberry	*Rubus argutus*	O	
	Red chokeberry	*Aronia arbutifolia*	O	
	Buttonbush	*Cephalanthus occidentalis*	O	
	Pond-spice	*Litsea aestivalis*	R	*
	St. John's wort	*Hypericum fasciculatum*	C	
Vines	Poison ivy	*Toxicodendron radicans*	C	
	Greenbriar (bamboo-vine)	*Smilax laurifolia*	C	
Epiphytes	Spanish moss	*Tillandsia usneoides*	C	@
	Ball moss	*Tillandsia recurvata*	C	@
	Gray needleleaf airplant	*Tillandsia bartramii*	C	
	Red needleleaf airplant	*Tillandsia setacea*	C	
Herbs	Sphagnum moss	*Sphagnum* spp.	O	
	Dimorphic chain fern	*Lorinseria areolata*	O	
	Virginia chain fern	*Woodwardia virginica*	A	*
	Swamp fern	*Blechnum serrulatum*	O	@
	Cinnamon fern	*Osmunda cinnamomea*	O	
	Royal fern	*Osmunda regalis*	O	
	Maidencane	*Panicum hemitomon*	C	
	Sawgrass	*Cladium jamaicense*	O	

(*Continued*)

Appendix Table Q. Concluded.

Type	Common name	Scientific name	Abundance [a]
Herbs (cont.)	Sedges	*Carex* spp.	O
	Pennywort	*Hydrocotyle* spp.	O
	Lizard's tail	*Saururus cernuus*	O
	Pickerelweed	*Pontederia cordata*	O
	Arrowhead	*Sagittaria* spp.	O
	Marsh beggar-tick	*Bidens mitis*	O
	Golden canna	*Canna flaccida*	O
	Smartweed	*Polygonum hydropiperoides*	O
	Yellow-eyed grass	*Xyris* spp.	O
	Redroot	*Lachnanthes caroliniana*	O
	Bladderwort	*Utricularia* spp.	O
	Sundew	*Drosera* spp.	O

[a] A = abundant, C = common, O = occasional, R = rare.
* indicates cypress dome is the best habitat; @ indicates this is one of the best habitats.

Appendix Table R. Common and characteristic animals of freshwater marshes and wet prairies (after Florida Game and Fresh Water Fish Commission 1976; Lee et al. 1980)

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Northern short-tailed shrew	*Blarina brevicauda*	O		
	Marsh rabbit	*Sylvilagus palustris*	C		@
	Marsh rice rat	*Oryzomys palustris*	O		@
	Cotton mouse	*Peromyscus gossypinus*	C		
	Hispid cotton rat	*Sigmodon hispidus*	A		@
	Round-tailed muskrat	*Neofiber alleni*	O		*
	Raccoon	*Procyon lotor*	C		@
	River otter	*Lutra canadensis*	O		@
	Wild hog	*Sus scrofa*	O		
	White-tailed deer	*Odocoileus virginianus*	O		
Birds	Pied-billed grebe	*Podilymbus podiceps*	C		
	Anhinga	*Anhinga anhinga*	C		
	American bittern	*Botaurus lentiginosus*	O		*
	Least bittern	*Ixobrychus exilis*	O		*
	Great blue heron	*Ardea herodias*	C		*
	Great egret	*Casmerodius albus*	C		*
	Snowy egret	*Egretta thula*	C		*
	Little blue heron	*Egretta caerulea*	C		*
	Tricolored heron	*Egretta tricolor*	C		*
	Cattle egret	*Bubulcus ibis*	C		
	Green-backed heron	*Butorides striatus*	O		
	Black-crowned night-heron	*Nycticorax nycticorax*	O		*
	White ibis	*Eudocimus albus*	A		@
	Glossy ibis	*Plegadis falcinellus*	O		@
	Wood stork	*Mycteria americana*	R		@
	Wood duck	*Aix sponsa*	O		
	Green-winged teal	*Anas crecca*	O	W	@
	Mottled duck	*Anas fulvigula*	O		*
	Mallard	*Anas platyrhynchos*	O	W	@
	Northern pintail	*Anas acuta*	O	W	@
	Blue-winged teal	*Anas discors*	C	W	@
	Northern shoveler	*Anas clypeata*	O	W	@
	Gadwall	*Anas strepera*	O	W	@
	American wigeon	*Anas americana*	O	W	@
	Ring-necked duck	*Aythya collaris*	O	W	
	Black vulture	*Coragyps atratus*	O		

(*Continued*)

Appendix Table R. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Turkey vulture	*Cathartes aura*	O		
	Northern harrier (marsh hawk)	*Circus cyaneus*	C	W	*
	Sharp-shinned hawk	*Accipiter striatus*	O	W	
	Red-shouldered hawk	*Buteo lineatus*	C		
	Red-tailed hawk	*Buteo jamaicensis*	C		*
	American kestrel	*Falco sparverius*	O	W	
	King rail	*Rallus elegans*	C		*
	Virginia rail	*Rallus limicola*	O	W	@
	Sora	*Porzana carolina*	O	W	*
	Purple gallinule	*Porphyrula martinica*	O	S	*
	Common moorhen	*Gallinula chloropus*	C		*
	American coot	*Fulica americana*	C	W	
	Limpkin	*Aramus guarauna*	O		
	Sandhill crane	*Grus canadensis*	C		*
	Killdeer	*Charadrius vociferus*	C		@
	Common snipe	*Gallinago gallinago*	C	W	*
	Mourning dove	*Zenaida macroura*	O		
	Common ground dove	*Columbina passerina*	O		
	Barn owl	*Tyto alba*	O		@
	Great horned owl	*Bubo virginianus*	O		
	Common nighthawk	*Chordeiles minor*	C	S	@
	Belted kingfisher	*Ceryle alcyon*	O		
	Eastern phoebe	*Sayornis phoebe*	C	W	
	Eastern kingbird	*Tyrannus tyrannus*	O	S	@
	Tree swallow	*Tachycineta bicolor*	C	W	@
	Northern roughwinged swallow	*Stelgidopteryx serripennis*	O	S	@
	Blue jay	*Cyanocitta cristata*	O		
	American crow	*Corvus brachyrhynchos*	C		@
	Fish crow	*Corvus ossifragus*	C		@
	Carolina wren	*Thryothorus ludovicianus*	O		
	House wren	*Troglodytes aedon*	C	W	
	Sedge wren	*Cistothorus platensis*	O	W	@
	American robin	*Turdus migratorius*	C	W	
	Loggerhead shrike	*Lanius ludovicianus*	O		
	Palm warbler	*Dendroica palmarum*	C	W	*
	Common yellowthroat	*Geothlypis trichas*	C		@
	Blue grosbeak	*Guiraca caerulea*	O	S	
	Indigo bunting	*Passerina cyanea*	O	S	
	Rufous-sided towhee	*Pipilo erythrophthalmus*	O		

(Continued)

Appendix Table R. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Savannah sparrow	*Passerculus sandwichensis*	O	W	
	Song sparrow	*Melospiza melodia*	C	W	*
	Swamp sparrow	*Melospiza georgiana*	C	W	*
	Bobolink	*Dolichonyx oryzivorus*	O	M	
	Red-winged blackbird	*Agelaius phoeniceus*	A		*
	Eastern meadowlark	*Sturnella magna*	C		
	Boat-tailed grackle	*Quiscalus major*	C		*
	Common grackle	*Quiscalus quiscula*	O		
Reptiles	American alligator	*Alligator mississippiensis*	O		
	Stinkpot	*Sternotherus odoratus*	O		
	Striped mud turtle	*Kinosternon baurii*	C		*
	Florida mud turtle	*K. subrubrum steindachneri*	C		*
	Chicken turtle	*Deirochelys reticularia*	C		*
	Florida box turtle	*Terrapene carolina bauri*	O		
	Florida red-bellied turtle	*Pseudemys nelsoni*	O		
	Peninsula cooter	*P. floridana peninsularis*	C		
	Florida softshell turtle	*Apalone ferox*	O		
	Florida green water snake	*Nerodia floridana*	A		*
	Florida banded water snake	*Nerodia fasciata pictiventris*	A		@
	Striped crayfish snake	*Regina alleni*	C		*
	Black swamp snake	*Seminatrix pygaea*	C		@
	Florida brown snake	*Storeria dekayi victa*	C		*
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	O		
	Blue-striped garter snake	*Thamnophis sirtalis similis*	O		
	Southern ribbon snake	*Thamnophis sauritus sackenii*	C		*
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	C		*
	Eastern mud snake	*Farancia abacura abacura*	C		*
	Southern black racer	*Coluber constrictor priapus*	O		
	Rough green snake	*Opheodrys aestivus*	O		
	Eastern indigo snake	*Drymarchon corais couperi*	O		
	Eastern king snake	*Lampropeltis getulus getulus*	C		*
	Yellow rat snake	*Elaphe obsoleta quadrivittata*	O		
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	O		
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	O		
	Eastern glass lizard	*Ophisaurus ventralis*	O		
Amphibians	Two-toed amphiuma	*Amphiuma means*	O		
	Greater siren	*Siren lacertina*	C		

(*Continued*)

Appendix Table R. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Amphibians (cont.)	Narrow-striped dwarf siren	*Pseudobranchus striatus axanthus*	O	
	Striped newt	*Notophthalmus perstriatus*	R	
	Peninsula newt	*N. viridescens piaropicola*	A	*
	Southern toad	*Bufo terrestris*	C	
	Green tree frog	*Hyla cinerea*	C	*
	Squirrel tree frog	*Hyla squirella*	C	
	Little grass frog	*Limnaoedus ocularis*	O	
	Florida cricket frog	*Acris gryllus dorsalis*	A	*
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	O	
	Bullfrog	*Rana catesbeiana*	C	
	Pig frog	*Rana grylio*	A	*
	Florida leopard frog	*Rana utricularia sphenocephala*	A	*
Fish	Mudfish (bowfin)	*Amia calva*	O	
	Redfin pickerel	*Esox americanus*	O	
	Chain pickerel	*Esox niger*	O	
	Tadpole madtom	*Noturus gyrinus*	C	*
	Pirate perch	*Aphredoderus sayanus*	C	*
	Golden topminnow	*Fundulus chrysotus*	A	*
	Banded topminnow	*Fundulus cingulatus*	R	*
	Lined (= Starhead) topminnow	*Fundulus notti*	C	*
	Flagfish	*Jordanella floridae*	O	
	Pigmy killifish	*Leptolucania ommata*	C	*
	Bluefin killifish	*Lucania goodei*	O	
	Mosquitofish	*Gambusia affinis*	A	*
	Least killifish	*Heterandria formosa*	C	*
	Sailfin molly	*Poecilia latipinna*	O	
	Pigmy sunfish	*Elassoma* spp.	C	*
	Bluespotted sunfish	*Enneacanthus gloriosus*	O	*
	Warmouth	*Lepomis gulosus*	C	*
	Bream (bluegill)	*Lepomis macrochirus*	C	
	Largemouth bass	*Micropterus salmoides*	C	
	Swamp darter	*Etheostoma fusiforme*	O	@

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only, M = migrant only, E = exotic.
* indicates this is the best habitat; @ indicates this is one of the best habitats.

Appendix Table S. Common and typical plants of marshes and wet prairies (Laessle 1942; Rochow et al. 1976; Attardi 1983a; Simons et al. 1984; Southwest Florida Water Management District 1985).

Type	Common name	Scientific name	Abundance[a]	
Trees	Coastal plain willow	*Salix caroliniana*	R	
	Common persimmon	*Diospyros virginiana*	R	
	Red maple	*Acer rubrum*	R	
	Cabbage-palm	*Sabal palmetto*	R	
	Pondcypress	*Taxodium ascendens*	R	
	Baldcypress	*Taxodium distichum*	R	
Shrubs	Wax myrtle	*Myrica cerifera*	O	
	Elderberry	*Sambucus canadensis*	O	
	Buttonbush	*Cephalanthus occidentalis*	O	
	Saltbush	*Baccharis halimifolia*	O	
	Primrose-willow	*Ludwigia peruviana*	O	
	Water-willow	*Decodon verticillatus*	O	
	Swamp rose	*Rosa palustris*	O	
	St. John's wort	*Hypericum* spp.	O	
Herbs—Emergent	Maidencane	*Panicum hemitomon*	A	*
	Para grass	*Panicum purpurascens*	O	
	Torpedo grass	*Panicum repens*	O	
	Other panic grasses	*Panicum* spp.	O	
	Blue maidencane	*Amphicarpum muhlenbergianum*	O	*
	Southern cutgrass	*Leersia hexandra*	C	*
	Southern water grass	*Hydrochloa caroliniensis*	C	*
	Braided grass	*Paspalidium geminatum*	O	
	Broomgrass	*Andropogon* spp.	C	
	Umbrella-grass	*Fuirena* spp.	O	
	Baldrush	*Rhynchospora nitens*	O	
	Sawgrass	*Cladium jamaicense*	C	*
	Sedges	*Carex* spp.	C	
	Flatsedge	*Cyperus* spp.	C	
	Bulrush	*Scirpus* spp.	O	*
	Spikerush	*Eleocharis* spp.	C	*
	Beak-rush	*Rhynchospora* spp.	C	*
	White-top sedge	*Dichromena colorata*	O	
	Soft rush	*Juncus effusus*	O	*
	Sand cordgrass	*Spartina bakeri*	O	*
	Cattail	*Typha latifolia*	O	*
	Yellow-eyed-grass	*Xyris* spp.	C	

(*Continued*)

Appendix Table S. Concluded.

Type	Common name	Scientific name	Abundance[a]	
Herbs— Emergent (cont.)	Redroot	*Lachnanthes caroliniana*	C	
	Arrowhead	*Sagittaria* spp.	C	*
	Pickerelweed	*Pontederia cordata*	C	*
	Water hyacinth	*Eichhornia crassipes*	O	
	Fire flag	*Thalia geniculata*	O	*
	Water spider orchid	*Habenaria repens*	O	*
	Alligator-weed	*Alternanthera philoxeroides*	C	*
	Coinwort	*Centella asiatica*	O	
	Water pennywort	*Hydrocotyle umbellata*	C	*
	Water primrose	*Ludwigia* spp.	C	*
	Mermaid-weed	*Proserpinaca pectinata*	O	*
	Water hyssop	*Bacopa caroliniana*	C	
	Smartweed	*Polygonum* spp.	C	@
	Marsh beggar-tick	*Bidens mitis*	C	*
	Meadow-beauty	*Rhexia* spp.	O	
	Marsh pink	*Sabatia* spp.	O	
	Milkwort	*Polygala* spp.	O	
	Pipewort	*Eriocaulon* spp.	O	
	Swamp hibiscus	*Hibiscus grandiflorus*	O	*
	Virginia chain fern	*Woodwardia virginica*	C	
Herbs— Floating-leaved	White water lily	*Nymphaea odorata*	C	*
	Bonnets (spatterdock)	*Nuphar luteum*	C	*
	American (yellow) lotus	*Nelumbo lutea*	R	*
	Water-shield	*Brasenia schreberi*	O	*
	Frog's-bit	*Limnobium spongia*	O	@
	Banana-lily	*Nymphoides aquatica*	C	*
	Duckweed	*Lemna* spp. and *Spirodela* spp.	O	
	Mosquito fern	*Azolla caroliniana*	O	
	Water spangles	*Salvinia minima*	O	
Herbs— Submerged	Fanwort	*Cabomba caroliniana*	O	
	Coontail	*Ceratophyllum demersum*	O	
	Muskgrass	*Chara* spp.	O	
	Marsh-purslane	*Ludwigia palustris*	O	
	Watermilfoil	*Myriophyllum* spp.	O	
	Southern naiad	*Najas guadalupensis*	O	
	Pondweed	*Potamogeton* spp.	O	
	Bladderwort	*Utricularia* spp.	C	@

[a] A = abundant, C = common, O = occasional, R = rare.
* indicates that this is the best habitat; @ indicates that this is one of the best habitats.

Appendix Table T. Common and characteristic animals of ponds (after Florida Game and Fresh Water Fish Commission 1976; Lee et al. 1980; Moler and Franz 1987).

Type	Common name	Scientific name	Abundance[a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Raccoon	*Procyon lotor*	C		
	River otter	*Lutra canadensis*	O		@
	Wild hog	*Sus scrofa*	C	T	@
Birds	Pied-billed grebe	*Podilymbus podiceps*	C		
	Anhinga	*Anhinga anhinga*	C	P	
	Great blue heron	*Ardea herodias*	C		@
	Great egret	*Casmerodius albus*	C		@
	Snowy egret	*Egretta thula*	C		@
	Little blue heron	*Egretta caerulea*	C		@
	Tricolored heron	*Egretta tricolor*	O		
	Cattle egret	*Bubulcus ibis*	C		
	Green-backed heron	*Butorides striatus*	A		*
	Black-crowned night-heron	*Nycticorax nycticorax*	O		
	Yellow-crowned night-heron	*Nycticorax violaceus*	O		
	White ibis	*Eudocimus albus*	C		
	Wood stork	*Mycteria americana*	O		@
	Wood duck	*Aix sponsa*	C		@
	Green-winged teal	*Anas carolinensis*	O	W	@
	Mallard	*Anas platyrhynchos*	O	W	@
	Blue-winged teal	*Anas discors*	C	W	@
	Northern shoveler	*Anas clypeata*	O	W	@
	Hooded merganser	*Lophodytes cucullatus*	C	W	@
	Red-shouldered hawk	*Buteo lineatus*	C		
	Sandhill crane	*Grus canadensis*	O		
	Killdeer	*Charadrius vociferus*	O		
	Greater yellowlegs	*Tringa melanoleuca*	C	W	@
	Lesser yellowlegs	*Tringa flavipes*	C	W	@
	Spotted sandpiper	*Actitis macularia*	O		
	Common snipe	*Gallinago gallinago*	C	W	
	Mourning dove	*Zenaida macroura*	C		
	Common ground dove	*Columbina passerina*	O		
	Common nighthawk	*Chordeiles minor*	C	S	@
	Belted kingfisher	*Ceryle alcyon*	O		
	Tree swallow	*Tachycineta bicolor*	C	W	@
	Northern roughwinged swallow	*Stelgidopteryx serripennis*	O	S	@
	American crow	*Corvus brachyrhynchos*	C		@

(Continued)

Appendix Table T. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Fish crow	*Corvus ossifragus*	C		@
	American robin	*Turdus migratorius*	C	W	
	Water pipit	*Anthus spinoletta*	C	W	*
	Palm warbler	*Dendroica palmarum*	C	W	@
	Red-winged blackbird	*Agelaius phoeniceus*	C		
	Boat-tailed grackle	*Quiscalus major*	C		
	Common grackle	*Quiscalus quiscula*	C		
Reptiles	American alligator	*Alligator mississippiensis*	O		
	Stinkpot	*Sternotherus odoratus*	O		
	Striped mud turtle	*Kinosternon baurii*	C		@
	Chicken turtle	*Deirochelys reticularia*	C		@
	Peninsula cooter	*Pseudemys floridana peninsularis*	O		
	Florida softshell turtle	*Apalone ferox*	C		
	Florida banded water snake	*Nerodia fasciata pictiventris*	C		@
	Black swamp snake	*Seminatrix pygaea*	C		@
	Southern black racer	*Coluber constrictor priapus*	O		
	Eastern indigo snake	*Drymarchon corais couperi*	O		@
Amphibians	Two-toed amphiuma	*Amphiuma means*	C		
	Lesser siren	*Siren intermedia*	C		@
	Dwarf siren	*Pseudobranchus striatus*	C		@
	Striped newt	*Notophthalmus perstriatus*	O	T	*
	Peninsula newt	*N. viridescens piaropicola*	C		
	Mole salamander	*Ambystoma talpoideum*	O	T	*
	Tiger salamander	*Ambystoma tigrinum*	R	T	*
	Dwarf salamander	*Eurycea quadridigitata*	C		
	Southern toad	*Bufo terrestris*	A		@
	Oak toad	*Bufo quercicus*	C	T	*
	Eastern spadefoot toad	*Scaphiopus holbrookii*	O	T	*
	Eastern narrow-mouthed toad	*Gastrophryne carolinensis*	C		@
	Green tree frog	*Hyla cinerea*	C		
	Squirrel tree frog	*Hyla squirella*	C	T	*
	Pine woods tree frog	*Hyla femoralis*	C	T	*
	Barking tree frog	*Hyla gratiosa*	O	T	*
	Little grass frog	*Limnaoedus ocularis*	C	T	*
	Florida cricket frog	*Acris gryllus dorsalis*	A		@
	Ornate chorus frog	*Pseudacris ornata*	O	T	*
	Florida chorus frog	*Pseudacris nigrita*	C	T	*

(*Continued*)

Appendix Table T. Concluded.

Type	Common name	Scientific name	Abundance[a]		
Amphibians	Bullfrog	*Rana catesbeiana*	C		*
(cont.)	Pig frog	*Rana grylio*	O		
	Bronze frog	*Rana clamitans clamitans*	O		
	Florida leopard frog	*Rana utricularia sphenocephala*	A		@
	Florida gopher frog	*Rana areolata aesopus*	O	T	@
Fish	Brown bullhead	*Ictalurus nebulosus*	C	P	@
	Golden topminnow	*Fundulus chrysotus*	C	P	
	Banded topminnow	*Fundulus cingulatus*	R	P	@
	Lined (= Starhead) topminnow	*Fundulus notti*	O	P	
	Flagfish	*Jordanella floridae*	C	P	*
	Pigmy killifish	*Leptolucania ommata*	O	P	
	Mosquitofish	*Gambusia affinis*	A	P	@
	Least killifish	*Heterandria formosa*	C	P	@
	Bluespotted sunfish	*Enneacanthus gloriosus*	O	P	@
	Bream (bluegill)	*Lepomis macrochirus*	C	P	
	Dollar sunfish	*Lepomis marginatus*	O	P	
	Largemouth bass	*Micropterus salmoides*	O	P	

[a] A = abundant, C = common, O = occasional, R = rare; S = summer only, W = winter only.
P = prefers permanent water, T = prefers temporary water.
* indicates ponds are the best habitat for the species, @ indicates ponds are one of the best habitats.

Appendix Table U. Common and characteristic animals of lakes (after Florida Game and Fresh Water Fish Commission 1976; Lee et al. 1980).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Virginia opossum	*Didelphis virginiana*	O		
	Southeastern myotis	*Myotis austroriparius*	C		*
	Raccoon	*Procyon lotor*	O		
	River otter	*Lutra canadensis*	O		
Birds	Horned grebe	*Podiceps auritus*	O	W	
	Pied-billed grebe	*Podilymbus podiceps*	C		*
	Double-crested cormorant	*Phalacrocorax auritus*	C		
	Anhinga	*Anhinga anhinga*	C		*
	Great blue heron	*Ardea herodias*	C		@
	Great egret	*Casmerodius albus*	C		@
	Snowy egret	*Egretta thula*	C		@
	Little blue heron	*Egretta caerulea*	C		@
	Tricolored heron	*Egretta tricolor*	C		@
	Cattle egret	*Bubulcus ibis*	C		
	Green-backed heron	*Butorides striatus*	C		@
	Black-crowned night-heron	*Nycticorax nycticorax*	O		@
	Yellow-crowned night-heron	*Nycticorax violaceus*	O		
	White ibis	*Eudocimus albus*	O		
	Glossy ibis	*Plegadis falcinellus*	O		
	Wood stork	*Mycteria americana*	R		
	Wood duck	*Aix sponsa*	O		
	Mottled duck	*Anas fulvigula*	O		
	Ring-necked duck	*Aythya collaris*	C	W	
	Lesser scaup	*Aythya affinis*	O	W	
	Hooded merganser	*Lophodytes cucullatus*	O	W	
	Red-breasted merganser	*Mergus serrator*	O	W	
	Osprey	*Pandion haliaetus*	C		*
	Bald eagle	*Haliaeetus leucocephalus*	O		*
	Common moorhen	*Gallinula chloropus*	C		
	American coot	*Fulica americana*	A	W	*
	Limpkin	*Aramus guarauna*	O		
	Killdeer	*Charadrius vociferus*	C		@
	Common snipe	*Gallinago gallinago*	C	W	@
	Bonaparte's gull	*Larus philadelphia*	O	W	@
	Ring-billed gull	*Larus delawarensis*	C	W	@
	Forster's tern	*Sterna forsteri*	C	W	@
	Common nighthawk	*Chordeiles minor*	O	S	

(*Continued*)

Appendix Table U. Continued.

Type	Common name	Scientific name	Abundance [a]		
Birds (cont.)	Belted kingfisher	*Ceryle alcyon*	C		@
	Purple martin	*Progne subis*	O	S	
	Tree swallow	*Tachycineta bicolor*	C	W	@
	Fish crow	*Corvus ossifragus*	C		@
	Red-winged blackbird	*Agelaius phoeniceus*	C		
	Boat-tailed grackle	*Quiscalus major*	C		*
Reptiles	American alligator	*Alligator mississippiensis*	A		*
	Florida snapping turtle	*Chelydra serpentina osceola*	C		@
	Stinkpot	*Sternotherus odoratus*	C		*
	Striped mud turtle	*Kinosternon baurii*	O		
	Chicken turtle	*Deirochelys reticularia*	O		
	Florida red-belled turtle	*Pseudemys nelsoni*	C		*
	Peninsula cooter	*P. floridana peninsularis*	C		*
	Suwannee cooter	*P. concinna suwanniensis*	O		
	Florida softshell turtle	*Apalone ferox*	C		*
	Florida green water snake	*Nerodia floridana*	C		
	Florida banded water snake	*Nerodia fasciata pictiventris*	C		
	Striped crayfish snake	*Regina alleni*	O		
	Black swamp snake	*Seminatrix pygaea*	O		
	Florida brown snake	*Storeria dekayi victa*	O		
	Eastern garter snake	*Thamnophis sirtalis sirtalis*	O		
	Eastern mud snake	*Farancia abacura abacura*	O		
	Eastern king snake	*Lampropeltis getulus getulus*	O		
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	C		
Amphibians	Two-toed amphiuma	*Amphiuma means*	C		@
	Greater siren	*Siren lacertina*	C		@
	Narrow-striped dwarf siren	*Pseudobranchus striatus axanthus*	C		@
	Peninsula newt	*Notophthalmus viridescens piaropicola*	C		
	Dwarf salamander	*Eurycea quadridigitata*	C		
	Southern toad	*Bufo terrestris*	C		
	Green tree frog	*Hyla cinerea*	C		
	Florida cricket frog	*Acris gryllus dorsalis*	C		
	Bullfrog	*Rana catesbeiana*	O		
	Pig frog	*Rana grylio*	C		@
	Florida leopard frog	*Rana utricularia sphenocephala*	C		
Fish	Longnose gar	*Lepisosteus osseus*	O		
	Florida gar	*Lepisosteus platyrhincus*	C		@
	Mudfish (bowfin)	*Amia calva*	C		*

(Continued)

Appendix Table U. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Fish (cont.)	Gizzard shad	*Dorosoma cepedianum*	A	*
	Threadfin shad	*Dorosoma petenense*	C	*
	Redfin pickerel	*Esox americanus americanus*	O	
	Chain pickerel	*Esox niger*	C	*
	Golden shiner	*Notemigonus crysoleucas*	C	*
	Taillight shiner	*Notropis maculatus*	C	*
	Lake chubsucker	*Erimyzon sucetta*	C	*
	White catfish	*Ictalurus catus*	O	@
	Brown bullhead	*Ictalurus nebulosus*	C	*
	Madtom catfish	*Noturus* spp.	C	
	Pirate perch	*Aphredoderus sayanus*	O	
	Golden topminnow	*Fundulus chrysotus*	C	
	Seminole killifish	*Fundulus seminolis*	C	*
	Bluefin killifish	*Lucania goodei*	O	
	Mosquito fish	*Gambusia affinis*	A	
	Least killifish	*Heterandria formosa*	O	
	Sailfin molly	*Poecilia latipinna*	O	
	Brook silversides	*Labidesthes sicculus*	C	@
	Pygmy sunfish	*Elassoma* spp.	O	
	Bluespotted sunfish	*Enneacanthus gloriosus*	O	
	Redbreast sunfish	*Lepomis auritus*	O	
	Warmouth	*Lepomis gulosus*	C	
	Bream (bluegill)	*Lepomis macrochirus*	A	*
	Dollar sunfish	*Lepomis marginatus*	O	
	Shellcracker	*Lepomis microlophus*	C	
	Stumpknocker	*Lepomis punctatus*	O	
	Largemouth bass	*Micropterus salmoides*	C	*
	Black crappie	*Pomoxis nigromaculatus*	A	*
	Swamp darter	*Etheostoma fusiforme*	C	

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only.
* indicates lakes are the best habitat for the species; @ indicates lakes are one of the best habitats.

Appendix Table V. Animals characteristic of blackwater streams (data from Conant 1975; Lee et al. 1980).

Type	Common name	Scientific name	Abundance [a]	
Mammals	Virginia opossum	*Didelphis virginiana*	C	@
	Raccoon	*Procyon lotor*	A	*
	River otter	*Lutra canadensis*	C	@
Birds	Great egret	*Casmerodius albus*	C	
	Wood stork	*Mycteria americana*	R	
	Wood duck	*Aix sponsa*	C	@
	Limpkin	*Aramus guarauna*	O	
	Belted kingfisher	*Ceryle alcyon*	C	@
Reptiles	Florida snapping turtle	*Chelydra serpentina osceola*	O	
	Florida banded water snake	*Nerodia fasciata pictiventris*	A	*
	Southern ribbon snake	*Thamnophis sauritus sackenii*	C	@
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	C	*
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	A	*
	Broad-headed skink	*Eumeces laticeps*	C	@
Amphibians	One-toed amphiuma	*Amphiuma pholeter*	R	*
	Lesser siren	*Siren intermedia*	O	@
	Bronze frog	*Rana clamitans clamitans*	A	*
	Southern dusky salamander	*Desmognathus auriculatus*	O	@
Fish	Redfin pickerel	*Esox americanus americanus*	O	
	Mosquitofish	*Gambusia affinis*	C	
	Ironcolor shiner	*Notropis chalybaeus*	C	*
	Sailfin shiner	*Notropis hypselopterus*	O	
	Coastal shiner	*Notropis petersoni*	O	
	Yellow bullhead	*Ictalurus natalis*	O	
	Brook silverside	*Labidesthes sicculus*	C	
	Warmouth	*Lepomis gulosus*	O	
	Dollar sunfish	*Lepomis marginatus*	C	*
	Stumpknocker	*Lepomis punctatus*	O	
	Swamp darter	*Etheostoma fusiforme*	O	

[a] A = abundant, C = common, O = occasional, R = rare.
* indicates blackwater streams are the best habitat; @ indicates this is one of the best habitats.

Appendix Table W. Common and characteristic animals of spring runs and spring fed rivers (after Florida Game and Fresh Water Fish Commission 1976; Lee et al. 1980; Lopez et al. 1981).

Type	Common name	Scientific name	Abundance [a]		
Mammals	Southeastern myotis	*Myotis austroriparius*	C		*
	Red bat	*Lasiurus borealis*	C		*
	Seminole bat	*Lasiurus seminolus*	O	S	@
	Evening bat	*Nycticeius humeralis*	C	S	*
	Raccoon	*Procyon lotor*	C		
	River otter	*Lutra canadensis*	O		
	West Indian manatee	*Trichechus manatus latirostris*	R	W	@
Birds	Pied-billed grebe	*Podilymbus podiceps*	O		
	Double-crested cormorant	*Phalacrocorax auritus*	O		
	Anhinga	*Anhinga anhinga*	O		
	Great blue heron	*Ardea herodias*	C		@
	Great egret	*Casmerodius albus*	C		@
	Snowy egret	*Egretta thula*	O		
	Little blue heron	*Egretta caerulea*	C		@
	Tricolored heron	*Egretta tricolor*	O		
	Cattle egret	*Bubulcus ibis*	O		
	Green-backed heron	*Butorides striatus*	C		
	Yellow-crowned night-heron	*Nycticorax violaceus*	O		
	White ibis	*Eudocimus albus*	C		
	Wood duck	*Aix sponsa*	C		@
	American swallow-tailed kite	*Elanoides forficatus*	O	S	@
	Red-shouldered hawk	*Buteo lineatus*	C		@
	Osprey	*Pandion haliaetus*	O		
	Purple gallinule	*Porphyrula martinica*	O		
	Common moorhen	*Gallinula chloropus*	O		
	American coot	*Fulica americana*	O		
	Limpkin	*Aramus guarauna*	C		*
	Barred owl	*Strix varia*	C		@
	Ruby-throated hummingbird	*Archilochus colubris*	O	S	
	Belted kingfisher	*Ceryle alcyon*	C		*
	Acadian flycatcher	*Empidonax virescens*	A	S	@
	Eastern phoebe	*Sayornis phoebe*	C	W	
	Tree swallow	*Tachycineta bicolor*	C	W	
	Prothonotary warbler	*Protonotaria citrea*	A	S	*
Reptiles	American alligator	*Alligator mississippiensis*	C		@
	Florida snapping turtle	*Chelydra serpentina osceola*	C		*

(*Continued*)

Appendix Table W. Continued.

Type	Common name	Scientific name	Abundance [a]	
Reptiles (cont.)	Stinkpot	*Sternotherus odoratus*	C	@
	Loggerhead musk turtle	*Sternotherus minor minor*	A	*
	Florida red-bellied turtle	*Pseudemys nelsoni*	A	*
	Suwannee cooter	*Pseudemys concinna suwanniensis*	A	*
	Peninsula cooter	*Pseudemys floridana peninsularis*	C	
	Florida softshell turtle	*Apalone ferox*	O	
	Brown water snake	*Nerodia taxispilota*	A	*
	Florida banded water snake	*Nerodia fasciata pictiventris*	C	
	Blue-striped ribbon snake	*Thamnophis sauritus nitae*	C	
	Rainbow snake	*Farancia erytrogramma*	R	*
	Florida cottonmouth	*Agkistrodon piscivorus conanti*	C	
Amphibians	Two-toed amphiuma	*Amphiuma means*	C	
	Greater siren	*Siren lacertina*	C	
	Narrow-striped dwarf siren	*Pseudobranchus striatus axanthus*	C	
	Peninsula newt	*Notophthalmus viridescens piaropicola*	C	
	Green tree frog	*Hyla cinerea*	C	
	Squirrel tree frog	*Hyla squirella*	C	
	Florida cricket frog	*Acris gryllus dorsalis*	C	
	Bullfrog	*Rana catesbeiana*	O	
	River frog	*Rana heckscheri*	C	*
	Pig frog	*Rana grylio*	C	
	Florida leopard frog	*Rana utricularia sphenocephala*	C	
Fish	Longnose gar	*Lepisosteus osseus*	C	*
	Florida gar	*Lepisosteus platyrhincus*	C	*
	Mudfish (bowfin)	*Amia calva*	O	
	American eel	*Anguilla rostrata*	O	*
	Threadfin shad	*Dorosoma petenense*	O	
	Redfin pickerel	*Esox americanus americanus*	O	
	Golden shiner	*Notemigonus crysoleucas*	C	@
	Ironcolor shiner	*Notropis chalybaeus*	C	
	Redeye chub	*Notropis harperi*	A	*
	Sailfin shiner	*Notropis hypselopterus*	C	*
	Coastal shiner	*Notropis petersoni*	C	*
	Lake chubsucker	*Erimyzon sucetta*	O	
	White catfish	*Ictalurus catus*	O	*
	Yellow bullhead	*Ictalurus natalis*	O	
	Brown bullhead	*Ictalurus nebulosus*	O	

(*Continued*)

Appendix Table W. Concluded.

Type	Common name	Scientific name	Abundance [a]	
Fish (cont.)	Channel catfish	*Ictalurus punctatus*	O	*
	Tadpole madtom	*Noturus gyrinus*	O	
	Atlantic needlefish	*Strongylura marina*	C	
	Golden topminnow	*Fundulus chrysotus*	O	
	Seminole killifish	*Fundulus seminolis*	C	*
	Bluefin killifish	*Lucania goodei*	C	*
	Mosquitofish	*Gambusia affinis*	C	
	Least killifish	*Heterandria formosa*	O	
	Sailfin molly	*Poecilia latipinna*	C	
	Brook silverside	*Labidesthes sicculus*	C	
	Tidewater silverside	*Menidia peninsulae*	C	
	Pigmy sunfish	*Elassoma* spp.	O	
	Redbreast sunfish	*Lepomis auritus*	O	
	Warmouth	*Lepomis gulosus*	O	
	Bream (bluegill)	*Lepomis macrochirus*	A	@
	Dollar sunfish	*Lepomis marginatus*	O	
	Shellcracker	*Lepomis microlophus*	A	*
	Stumpknocker	*Lepomis punctatus*	C	*
	Largemouth bass	*Micropterus salmoides*	C	@
	Swamp darter	*Etheostoma fusiforme*	O	
	Crevalle jack	*Caranx hippos*	O	
	Striped mullet	*Mugil cephalus*	C	
	Hogchoker	*Trinectes maculatus*	O	

[a] A = abundant, C = common, O = occasional, R = rare.
S = summer only, W = winter only.
* indicates this is the best habitat for the species, @ indicates this is one of the best habitats.

Appendix Table X. Endangered and threatened species in the Springs Coast with watersheds and counties where they are found (compiled by R. Noss from FDACS 1988; Nature Conservancy 1990; Wood 1990).

Species (common name)	USFWS [a] status	State [b] status	FNAI [c] status	Watershed [d] 101	207	208	County [e] Levy	Gilchrist	Alachua	Marion	Citrus	Sumter	Lake	Hernando	Pasco	Polk
Plants																
Adiantum capillus-veneris (Southern maidenhair fern)		E	G5/S3S4	2			•									
Agrimonia incisa (Incised groove-bur)	C2		G3/S2		1	1					•			•		
Anemone berlandieri (Texas anemone)			GU/S2	2			•									
Asplenium auritum (Auricled spleenwort)		E	G?/S2			1								•		
Asplenium pumilum (Dwarf spleenwort)		E	G1?/S1		1	2					•			•		
Blechnum occidentale (Sinkhole fern)		E	G5/S1		1	1								•		
Campanula robinsiae (Brooksville bellflower)	E	E	G1/S1		1	2								•		
Cheilanthes microphylla (Southern lip fern)		T	G?/S3		1						•					
Clitoria fragrans (Pigeon-wing)	C1	E	G3/S3			1							•			
Coelorachis tuberculosa (Piedmont jointgrass)	C2		G3/S3	1	1				•					•		
Dicerandra cornutissima (Long-spurred mint)	E	E	G1/S1			4				•						
Digitaria floridana (Florida crabgrass)	C2		G1?/S1			1								•		
Drosera intermedia (Spoon-leaved sundew)		T	G5/S3	2			•									
Glandularia tampensis (Tampa vervain)	C1		G1/S1		2						•			•		
Justicia cooleyi (Cooley's water-willow)	E	E	G1G2/S1S2	1	3									•		
Leitneria floridana (Corkwood)	3C	T	G3G4/S3	3			•									
Litsea aestivalis (Pondspice)	3C	T	G4G5/S2	2			•									
Monotropsis reynoldsiae (Pigmy-pipes)	C2	E	G1Q/S1			1								•		
Nolina brittoniana (Britton's bear-grass)	C1	E	G2/S2		1									•		
Peltandra sagittifolia (Spoon-flower)			G3G4/S3	2			•									
Pharus parvifolius (Creeping-leaf stalkgrass)			G?/SH			1					•					

(Continued)

Appendix Table X. Continued.

Species (common name)	USFWS[a] status	State[b] status	FNAI[c] status	Watershed[d] 101	207	208	County[e] Levy	Gilchrist	Alachua	Marion	Citrus	Sumter	Lake	Hernando	Pasco	Polk
Phyllanthus leibmannianus (Pine-wood dainties)	3C	T	G3G5T2/S2	2			•									
Pteroglossaspis ecristata (Wild coco)	C2	T	G3G4/S2		1						•					
Pycnanthemum floridanum (Florida mountain-mint)	3C		G3/S3		1	1								•		
Sium floridanum (Florida water-parsnip)	C2		G1Q/S1	1			•									
Spigelia loganioides (Pink-root)	3C	E	G1G2/S1S2	4			•									
Spiranthes polyantha (Green ladies-tresses)	C2	E	G1G3/S1S2		1						•					
Triphora craigheadii (Craighead's nodding-caps)	C2	T	G1/S1			3					•			•		
Ulmus crassifolia (Cedar elm)			G4?/S1	2			•									
Invertebrates																
Aphaostracon xynoelictus (Fenney springs aphaostracon)	C2		G1/S1			1						•				
Caecidotea hobbsi (Hobbs' cave isopod)			G1/S1	2					•							
Caecidotea parva (Little Florida cave isopod)			GU/SU		1						•					
Cincinnatia helicogyra (Crystal siltsnail)	C2		G1/S1		1						•					
Crangonyx grandimanus (Florida cave amphipod)	C2		G2/S2		1									•		
Crangonyx hobbsi (Hobbs' cave amphipod)	C2		G2G3/S2S3	1	1	3			•	•	•			•		
Nemopalpus nearcticus (Sugarfoot moth fly)	C2		GU/SU		1				•							
Palaemonetes cummingi (Squirrel Chimney cave shrimp)	C1		G1/S1	1					•							
Procambarus leitheuseri (Coastal lowland cave crayfish)			G2/S2		4									•	•	
Procambarus lucifugus (Florida cave crayfish)			G3/S3	3		4			•	•	•					
Procambarus pallidus (Pallid cave crayfish)			G2G3/S2S3	1					•							
Troglocambarus maclanei (Spider cave crayfish)			G2/S2	1	1	2			•	•	•			•		
Fishes																
Enneacanthus chaetodon (Blackbanded sunfish)			G3/S3		1										•	

(Continued)

Appendis Table X. Continued.

Species (common name)	USFWS[a] status	State[b] status	FNAI[c] status	Watershed[d] 101	207	208	County[e] Levy	Gilchrist	Alachua	Marion	Citrus	Sumter	Lake	Hernando	Pasco	Polk
Amphibians																
Amphiuma pholeter (One-toed amphiuma)			G3/S3	1			•									
Reptiles																
Alligator mississippiensis (American alligator)	T(S/A)	SSC	G5/S4	(throughout, but records generally not kept)												
Crotalus horridus (Canebrake rattlesnake)			G5/S3	1					•							
Drymarchon corais couperi (Eastern indigo snake)	T	T	G4T3/S3	6	3	3	•		•		•			•	•	•
Eumeces egregius insularis (Cedar Key mole skink)	C2		G4T1/S1	2			•									
Gopherus polyphemus (Gopher tortoise)	C2	SSC	G3/S3	6	5	3	•		•	•	•	•		•	•	
Nerodia clarkii clarkii (Gulf salt marsh snake)			G5T3/S3?	4			•									
Pituophis melanoleucus mugitus (Florida pine snake)	C2	SSC	G5T3?/S?		1										•	
Stilosoma extenuatum (Short-tailed snake)	C2	T	G3/S3		4	2				•	•				•	
Birds																
Accipiter cooperii (Cooper's hawk)			G4/S3?	1			•									
Aphelocoma c. coerulescens (Florida scrub jay)	T	T	G5T3/S3	2	4	8	•		•	•	•	•		•	•	
Athene cunicularia floridana (Florida burrowing owl)		SSC	G5T3/S3		1						•					
Casmerodius albus (Great egret)			G5/S4	3	2	6	•	•			•	•			•	
Egretta caerulea (Little blue heron)		SSC	G5/S4	2	3	4	•	•			•	•			•	
Egretta thula (Snowy egret)		SSC	G5/S4		2	3					•				•	
Egretta tricolor (Tricolored heron)		SSC	G5/S4	1	3	2	•				•				•	
Eudocimus albus (White ibis)			G5/S4	1			•				•	•			•	
Grus canadensis pratensis (Florida sandhill crane)		T	G5T2T3/S2S3		2							•				
Haliaeetus leucocephalus (Bald eagle)	E	T	G3/S2S3	5	10	7	•				•	•		•	•	
Mycteria americana (Wood stork)	E	E	G5/S2			2						•			•	

(Continued)

Appendix Table X. Concluded.

Species (common name)	USFWS[a] status	State[b] status	FNAI[c] status	Watershed[d] 101	207	208	County[e] Levy	Gilchrist	Alachua	Marion	Citrus	Sumter	Lake	Hernando	Pasco	Polk
Nycticorax nycticorax (Black-crowned night-heron)			G5/S3?		2						•					
Nycticorax violaceus (Yellow-crowned night-heron)			G5/S3?		1						•					
Pandion haliaetus (Osprey)			G5/S3S4	2			•									
Pelecanus occidentalis (Brown pelican)		SSC	G5/S3	1	1		•				•					
Picoides borealis (Red-cockaded woodpecker)	E	T	G2/S2		2	2					•			•		
Mammals																
Microtus pennsylvanicus dukecampbelli (Duke's saltmarsh vole)		SSC					•									
Mustela vison lutensis (Florida mink)	C2		G5T3/S3	2			•									
Podomys floridanus (Florida mouse)	C2	SSC	G3/S3			1								•		
Sciurus niger shermani (Sherman's fox squirrel)	C2	SSC	G5T2/S2	1		1	•				•					
Trichechus manatus (West Indian manatee)	E	E	G2?/S2?		5	2					•					
Ursus americanus floridanus (Florida black bear)	C2	T	G5T3/S3	2	?	?	•				•	?	?	•	•	

[a] **USFWS:** E = endangered; T = threatened; T(S/A) = threatened due to similarity of appearance; C1 = candidate for listing, and FWS has substantial evidence supports biological appropriateness of listing; C2 = candidate for listing, but substantial evidence of biological vulnerability and/or threat is lacking; 3C = formerly under review for listing, but has proven to be more abundant or widespread or less subject to threat than previously believed.

[b] **State:** E = endangered; T = threatened; SSC = species of special concern

[c] **FNAI:** G1 (or S1) = critically imperilled globally (or in state) because of extreme rarity (5 or fewer occurrences or less than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor; G2 (or S2) = imperilled globally (or in state) because of rarity (6–20 occurrences or less than 3,000 individuals) or because of vulnerability to extinction due to some biological or man-made factor; G3 (or S3) = either very rare and local throughout its range (or in state) (21–100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction because of other factors; G4 (or S4) = apparently secure globally (or locally) (may be rare in parts of range); G5 (or S5) = demonstrably secure globally (locally); GH (or SH) = of historical occurrence, may be rediscovered; G#? (or S#?) = tentative rank; G#G# (or S#S#) = range of rank (insufficient data to assign specific rank); G#T# (rank of taxonomic subgroup such as subspecies or variety; G#Q = rank of questionable species (ranked as species but questionable whether it is a species or subspecies; GU (or SU) = due to lack of information, no rank or range can be assigned.

[d] USGS watershed numbers, see Fig. 33 for locations. Numbers under watersheds indicate the number of 7.5-minute quadrangles in which a particular species is found in that watershed.

[e] County records refer only to those portions of the counties that are within the study region.

Appendix Table Y. Common and scientific names of fishes of Springs Coast brackish marshes (after Phillips 1986). Nomenclature follows Robins et al. (1980).

Common name	Scientific name	Occurrence [a]
Longnose gar	*Lepisosteus osseus*	F
Gar	*Lepisosteus* sp.	F
Ladyfish	*Elops saurus*	B-F
Alabama shad	*Alosa alabamae*	B-F
Skipjack herring	*Alosa chrysochloris*	B-F
Striped anchovy	*Anchoa hepsetus*	B
Bay anchovy	*Anchoa mitchilli*	B-F
Inshore lizardfish	*Synodus foetens*	B
Golden shiner	*Notemigonus crysoleucas*	F
Shiner	*Notropis* sp.	F
Lake chubsucker	*Erimyzon sucetta*	F
Hardhead catfish	*Arius felis*	B-F
Gafftopsail catfish	*Bagre marinus*	B
Gulf toadfish	*Opsanus beta*	B
Atlantic needlefish	*Strongylura marina*	B-F
Sheepshead minnow	*Cyprinodon variegatus*	B-F
Goldspotted killifish	*Floridichthys carpio*	B
Marsh killifish	*Fundulus confluentus*	B-F
Gulf killifish	*Fundulus grandis*	B-F
Mummichog	*Fundulus heteroclitus*	B-F
Seminole killifish	*Fundulus seminolis*	F
Longnose killifish	*Fundulus similis*	B
Bluefin killifish	*Lucania goodei*	F
Rainwater killifish	*Lucania parva*	B-F
Mosquitofish	*Gambusia affinis*	B-F
Least killifish	*Heterandria formosa*	F
Sailfin molly	*Poecilia latipinna*	B-F
Molly	*Poecilia* sp.	B-F
Silverside	*Menidia* sp.	B
Dusky pipefish	*Syngnathus floridae*	B
Gulf pipefish	*Syngnathus scovelli*	B-F
Bluegill	*Lepomis macrochirus*	F
Sunfish	*Lepomis* sp.	F
Largemouth bass	*Micropterus salmoides*	F
Atlantic bumper	*Chloroscombrus chrysurus*	B
Spotfin mojarra	*Eucinostomus argenteus*	B-F
Silver jenny	*Eucinostomus gula*	B
Mojarra	*Eucinostomus* sp.	B

(*Continued*)

Appendix Table Y. Concluded.

Common name	Scientific name	Occurrence [a]
Pigfish	*Orthopristis chrysoptera*	B-F
Sheepshead	*Archosargus probatocephalus*	B-F
Pinfish	*Lagodon rhomboides*	B-F
Silver perch	*Bairdiella chrysoura*	B-F
Sand seatrout	*Cynoscion arenarius*	B
Spotted seatrout	*Cynoscion nebulosus*	B-F
Spot	*Leiostomus xanthurus*	B-F
Southern kingfish	*Menticirrhus americanus*	B
Drum	*Menticirrhus* sp.	B
Atlantic croaker	*Micropogonias undulatus*	B-F
Black drum	*Pogonias cromis*	B
Red drum	*Sciaenops ocellatus*	M-B-F
Atlantic spadefish	*Chaetodipterus faber*	B
Striped mullet	*Mugil cephalus*	M-B-F
Feather blenny	*Hypsoblennius hentzi*	B
Sharptail goby	*Gobionellus hastatus*	B
Naked goby	*Gobiosoma bosci*	B-F
Code goby	*Gobiosoma robustum*	B-F
Clown goby	*Microgobius gulosus*	B-F
Leopard searobin	*Prionotus scitulus*	B
Bighead searobin	*Prionotus tribulus*	B
Lined sole	*Achirus lineatus*	B
Hogchoker	*Trinectes maculatus*	B-F
Blackcheek tonguefish	*Symphurus plagiusa*	B
Southern puffer	*Sphoeroides nephelus*	B
Puffer	*Sphoeroides* sp.	B
Striped burrfish	*Chilomycterus schoepfi*	B

[a] M = normally found in marine waters; B = normally found in brackish waters; F = normally found in fresh water.

Appendix Table Z. Common and scientific names of macroinvertebrates from Springs Coast brackish marshes (after Phillips 1986).

Common name	Scientific name	Occurrence [a]
—	*Ambidexter symmetricus*	B
Brackish grass shrimp	*Palaemonetes intermedius*	B
Riverine grass shrimp	*Palaemonetes paludosus*	F
Daggerblade grass shrimp	*Palaemonetes pugio*	B
Marsh grass shrimp	*Palaemonetes vulgaris*	B
Estuarine long-eyed shrimp	*Ogyrides alphaerostris*	B
Crayfish	*Procambarus* sp.	F
Flatclaw hermit crab	*Pagurus pollicaris*	B
Green porcelain crab	*Petrolisthes armatus*	B
Blue crab	*Callinectes sapidus*	M-B-F
Flatback mud crab	*Eurypanopeus depressus*	B
Gulf grassflat crab	*Dyspanopeus (=Neopanope) texana*	B
Fiddler crab	*Uca* sp.	B

[a] M = normally marine; B = normally brackish; F = normally fresh water.

Appendix Table AA. Common birds of Springs Coast salt marshes (Stout 1984).

Order	Common name	Scientific name	Occurrence [a]
Gruiformes	King rail	*Rallus elegans*	PB
	Clapper rail	*Rallus longirostris*	PB
	Virginia rail	*Rallus limicola*	MW
	Sora	*Porzana carolina*	MW
	Yellow rail	*Coturnicops noveboracensis*	W
	Black rail	*Laterallus jamaicensis*	PB
	American coot	*Fulica americana*	PB
Charadriiformes	Gull-billed tern	*Sterna nilotica*	M
	Forster's tern	*Sterna forsteri*	PB
	Caspian tern	*Sterna caspia*	W
	Semipalmated plover	*Charadrius semipalmatus*	W
	Black-bellied plover	*Pluvialis squatarola*	WM
	Willet	*Catoptrophorus semipalmatus*	MB
	Least sandpiper	*Calidris minutilla*	WM
	Dunlin	*Calidris alpina*	WM
	Short-billed dowitcher	*Limnodromus griseus*	SM
	Stilt sandpiper	*Calidris himantopus*	M
	Semipalmated sandpiper	*Calidris pusilla*	M
	Western sandpiper	*Calidris mauri*	WM
Ciconiiformes	Great white heron	*Ardea occidentalis*	CS(T)
	Great blue heron	*Ardea herodias*	PB
	Green-backed heron	*Butorides striatus*	SB
	Little blue heron	*Egretta caerulea*	PB
	Great egret	*Casmerodius albus*	PB
	Snowy egret	*Egretta thula*	PB
	Tricolored heron	*Egretta tricolor*	SB
	Black-crowned night heron	*Nycticorax nycticorax*	PB
	White ibis	*Eudocimus albus*	S
Anseriformes	American black duck	*Anas rubripes*	PB
	Gadwall	*Anas strepera*	W
	American wigeon	*Anas americana*	W
	Redhead	*Aythya americana*	MW
	Lesser scaup	*Aythya affinis*	MW
	Canada goose	*Branta canadensis*	MW

(*Continued*)

Appendix Table AA. Concluded.

Order	Common name	Scientific name	Occurrence [a]
Passeriformes	Tree swallow	*Tachycineta bicolor*	M
	Fish crow	*Corvus ossifragus*	PB
	Marsh wren	*Cistothorus palustris*	PB
	Sedge wren	*Cistothorus platensis*	W
	Red-winged blackbird	*Agelaius phoeniceus*	PB
	Sharp-tailed sparrow	*Ammodramus caudacutus*	PB
	Seaside sparrow	*Ammodramus maritimus*	PB

[a] P = permanent resident; B = breeding population; M = migrant; W = winter visitor; S = summer resident; C = casual; T = threatened species (State of Florida).

Appendix Table AB. Common macroinvertebrates of Springs Coast intertidal flats (Abele 1970; Abele and Kim 1986).

Group	Scientific name	Common name	Habitat
Crustacea			
	Alpheus heterochaelis	Bigclaw snapping shrimp	Infaunal
	Callianassa jamaicensis	Estuarine ghost shrimp	Infaunal
	Eurytium limosum	Broadback mud crab	Infaunal
	Uca longisignalis	Gulf marsh fiddler crab	Infaunal/epifaunal
	Callinectes sapidus	Blue crab	Epifaunal
Mollusca			
	Mercenaria mercenaria	Northern quahog	Infaunal
Polychaeta			
	Amphicteis gunneri		Infaunal
	Diopatra cuprea		Infaunal
	Glycera americana		Infaunal
	Glycera dibranchiata		Infaunal
	Haploscoplos fragilis		Infaunal
	Heteromastus filiformis		Infaunal
	Laeonereis culveri		Infaunal
	Notomastus latericeus		Infaunal
	Onuphis eremita		Infaunal
	Pectinaria gouldii		Infaunal
Enteropneusta			
	Eneropneusta spp.		Infaunal
Merostomata			
	Limulus polyphemus	Horseshoe crab	Epifaunal

Appendix Table AC. Springs Coast oyster-associated fauna; phylogenetic species list (after Gorzelany 1986).

PHYLUM PORIFERA
Porifera spp.

PHYLUM CNIDARIA
Anthozoa spp.
Hydrozoa spp.

PHYLUM PLATYHELMINTHES
Platyhelminthes sp. A
Platyhelminthes sp. B
Polycladida sp. A
Polycladida sp. B
Euplana gracilis

PHYLUM RHYNCHOCOELA
Nemertina spp.

PHYLUM NEMATODA
Nematoda spp.

PHYLUM ANNELIDA

CLASS POLYCHAETA
Polychaeta sp. A
Polychaeta sp. B

FAMILY PHYLLODOCIDAE
Phyllodocidae spp.
Phyllodoce spp.
Eteone sp.
Eulalia sanguinea
Genetyllis castanea

FAMILY POLYNOIDAE
Lepidametria commensalis
Lepidonotus variabilis
Lepidasthenia varia

FAMILY SYLLIDAE
Syllidae spp.
Ehlersia cornuta

FAMILY HESIONIDAE
Parahesione luteola
Podarke obscura
Gyptis brevipalpa

FAMILY NEREIDAE
Nereidae spp.
Nereis falsa
Nereis riisei
Ceratonereis mirabilis
Neanthes succinea
Platynereis dumerilli
Laeonereis culveri

FAMILY ONUPHIDAE
Onuphidae spp.

FAMILY EUNICIDAE
Eunicidae spp.
Marphysa sanguinea

FAMILY DORVILLEIDAE
Dorvilleidae sp.
Schistomeringos cf. rudolphi
Ophryotrocha sp. A

FAMILY ORBINIIDAE
Orbiniidae spp.
Leitoscoloplos spp.
Leitoscoloplos foliosus
Naineris spp.
Naineris laevigata
Naineris quadricuspida

FAMILY PARAONIDAE
Aricidea philbinae
Cirrophorus sp.

FAMILY SPIONIDAE
Spionidae spp.
Minuspio cirrifera
Paraprionospio pinnata
Streblospio benedicti
Polydora "complex"

FAMILY CIRRATULIDAE
Cirratulidae spp.
Caulleriella spp.
Tharyx cf. *dorsobranchialis*
Tharyx annulosus

FAMILY OPHELIIDAE
Armandia maculata

FAMILY CAPITELLIDAE
Capitella capitata
Mediomastus ambiseta
Mediomastus spp.
Mediomastus californiensis

FAMILY ARENICOLIDAE
Arenicolidae sp.

FAMILY MALDANIDAE
Maldanidae spp.
Axiothella mucosa

FAMILY SABELLARIIDAE
Sabellaria vulgaris

FAMILY BOGUEIDAE
Boguea enigmatica

FAMILY AMPHARETIDAE
Ampharetidae spp.
Amphicteis gunneri

FAMILY TEREBELLIDAE
Streblosoma hartmanae
Streblosoma verilli

FAMILY SABELLIDAE
Sabellidae spp.
Chone sp.
Chone americana
Demonax microphthalma
Fabriciola sp.
Fabriciola trilobata
Notaulax phaeotania
Pseudobranchioma sp.

FAMILY SERPULIDAE
Serpulidae spp.
Filograna implexa
Hydroides dianthus
Mercierellopsis sp.
Spirorbis sp.

CLASS OLIGOCHAETA
Oligochaeta spp.

CLASS HIRUDINEA
Hirudinea sp.

PHYLUM MOLLUSCA

CLASS GASTROPODA
Gastropoda spp.

FAMILY RISSOINIDAE
Rissoina catesbyna

FAMILY ASSIMINEIDAE
Assiminea succinea

FAMILY VITRINELLIDAE
Vitrinellidae sp.
Solariorbis infracarinata
Solariorbis shimeri

FAMILY DIASTOMIDAE
Diastoma varium

FAMILY CAECIDAE
Caecum pulchellum

FAMILY CERITHIIDAE
Cerithiidae sp.
Cerithiopsis emersonii
Cerithiopsis greeni
Seila adamsi

(*Continued*)

Appendix Table AC. Continued.

FAMILY TRIPHORIDAE
Triphora nigrocincta
FAMILY EPITONIIDAE
Epitonium unifasciatum
FAMILY CALYPTRAEIDAE
Crepidula sp.
Crepidula convexa
Crepidula maculosa
Crepidula plana
FAMILY COLUMBELLIDAE
Anachis obesa ostreicola
Anachis pulchella
Anachis semiplicata
Mitrella lunata
FAMILY NASSARIIDAE
Nassarius vibex
FAMILY OLIVIDAE
Oliva spp.
FAMILY MELONGENIDAE
Melongena corona
FAMILY TURRIDAE
Turridae spp.
FAMILY PYRAMIDELLIDAE
Boonea impressa
Boonea seminuda
FAMILY SCAPHANDRIDAE
Acteocina canaliculata
SUBCLASS OPISTHOBRANCHIA
ORDER NUDIBRANCHIA
Nudibranchia spp.
CLASS POLYPLACOPHORA
Acanthochitona spiculosa
CLASS BIVALVIA
Bivalvia spp.
FAMILY ARCIDAE
Arcidae sp.
FAMILY MYTILIDAE
Mytilidae sp.
Brachidontes exustus
Amygdalum papyrium
Guekensia demissa granosissoma
Ischadium recurvum
Musculus lateralis
FAMILY LIMIDAE
Lima sp.
FAMILY LEPTONIDAE
Mysella planulata
FAMILY OSTREIDAE
Crassostrea virginica
FAMILY LUCINIDAE
Lucinidae spp.
Codakia orbicularis
Linga amiantus
FAMILY CARDIIDAE
Carditamera floridana
FAMILY TELLINIDAE
Tellina sp.
FAMILY PSAMMOBIIDAE
Tagelus plebeius
FAMILY DREISSINIDAE
Mytilopsis leucophaeata
FAMILY SEMELIDAE
Semele proficua
FAMILY CORBICULIDAE
Pseudocryena floridana
FAMILY VENERIDAE
Veneridae spp.
Parastarte triquetra
FAMILY LYONSIIDAE
Lyonsia hyalina floridana
PHYLUM ARTHROPODA
CLASS ARACHNIDA
Arachnida sp. A
Arachnida sp. B
Arachnida sp. C
Arachnida sp. E
Hydracarina sp.
ORDER PSEUDOSCORPIONIDA
Pseudoscorpiones sp.
CLASS PYCNOGONIDA
Pycnogonida sp.
SUBPHYLUM CRUSTACEA
CLASS OSTRACODA
Ostracoda spp.
Myodocopa spp.
Parasterope pollex
CLASS COPEPODA
Calanoid copepoda
Cyclopoid copepoda
Harpacticoid copepoda
CLASS CIRRIPEDIA
Balanus subalbidus
Semibalanus balanoides
Balanus amphitrite
Balanus eburneus
Balanus improvisus
Balanus venustus
CLASS MALACOSTRACA
ORDER MYSIDACEA
Mysidacea sp.
ORDER CUMACEA
FAMILY BODOTRIIDAE
Cyclaspis sp. A
FAMILY LEUCONIDAE
Leucon sp. A
ORDER TANAIDACEA
FAMILY APSEUDIDAE
Halmyrapseudes cubanensis
FAMILY TANAIDAE
Tanais cavolinii
FAMILY PARATANAIDAE
Hargeria rapax
ORDER ISOPODA
FAMILY ANTHURIDAE
Cyathura polita
Apanthura cf. signata
Mesanthura floridensis
Mesanthura decorata
Mesanthura pulchra
FAMILY SPHAEROMATIDAE
Paracerceis cordata
Cassidinidea lunifrons
Cymodoce faxoni
FAMILY IDOTEIDAE
Erichsonella cf. *attenuata*
Erichsonella cf. *filiformis*
FAMILY CIROLANIDAE
Cirolana parva
Cirolana minuta
Eurydice littoralis
FAMILY MUNNIDAE
Munna cf. *hayesi*
Munna cf. *lateralis*

(*Continued*)

Appendix Table AC. Concluded.

Munna reynoldsi
FAMILY ATYLIDAE
Atylus cf. *minikoi*
ORDER AMPHIPODA
Amphipoda sp.
FAMILY AMPHILOCHIDAE
Amphilochus sp.
Gitanopsis sp.
FAMILY AMPELISCIDAE
Ampelisca sp.
Ampelisca abdita
FAMILY AMPITHOIDAE
Cymadusa compta
FAMILY TALITRIDAE
Orchestia grillis
FAMILY AORIDAE
Lembos sp.
Grandidierella bonneroides
FAMILY COROPHIIDAE
Corophium spp.
Cerapus sp. A
Cerapus tubularis
Cerapus benthophilus
FAMILY PHOTIDAE
Photis pugnator
FAMILY PODOCERIDAE
Podocerus brasiliensis
FAMILY GAMMARIDAE
Gammaridae spp.
Gammarus sp.
Gammarus mucronatus
FAMILY COLOMASTIGIDAE
Colomastix halichondriae
FAMILY MELITIDAE
Elasmopus sp.
Elasmopus levis
Elasmopus pocillimanus
Maera sp.
Melita "complex"
FAMILY HYALIDAE
Hyale plumuiosa
FAMILY ISCHYROCERIDAE
Erichthonius brasiliensis
FAMILY BATEIDAE
Batea catharinensis
FAMILY LYSIANASSIDAE
Lysianopsis alba
FAMILY PHOXOCEPHALIDAE
Paraphoxus oculatus
Eobrolgus spinosus
FAMILY STENOTHOEIDAE
Stenothoe minuta
Stenothoe gallensis
FAMILY LEUCOTHOIDAE
Leucothoe spinicarpa
FAMILY CAPRELLIDAE
Caprellidae spp.
Caprella sp.
Paracaprella tenuis
ORDER DECAPODA
Brachyura spp.
FAMILY SERGESTIDAE
Lucifer faxoni
FAMILY PALAEMONIDAE
Palaemonidae sp.
Palaemonetes cf. *intermedius*
FAMILY ALPHEIDAE
Alpheus normanni
FAMILY HIPPOLYTIDAE
Thor dobkini
FAMILY PAGURIDAE
Pagurus sp.
FAMILY PORCELLANIDAE
Petrolisthes armatus
FAMILY XANTHIDAE
Xanthidae spp.
Eurypanopeus depressus
Panopeus simpsoni
Panopeus cf. *obesus*
Rhithropanopeus harrisii
FAMILY GRAPSIDAE
Sesarma cinereum
CLASS INSECTA
Insecta sp.
ORDER COLLEMBOLA
Anurida maritima
Entomobrya sp.
Isotomidae sp.
ORDER COLEOPTERA
Carabidae sp.
ORDER DIPTERA
Diptera spp.
PHYLUM SIPUNCULA
Sipuncula spp.
PHYLUM BRYOZOA
Bryozoa spp.
PHYLUM HEMICHORDATA
CLASS ENTEROPNEUSTA
Enteropneusta spp.
PHYLUM CHORDATA
CLASS OSTEICHTHYES
FAMILY GOBIESOCIDAE
Gobiesox strumosus
FAMILY BLENNIDAE
Chasmodes saburrae

Appendix Table AD. Ten most abundant oyster fauna, with rank, at different Springs Coast estuary sites (after Gorzelany 1986).

	WACCASASSA			WITHLACOOCHEE			CRYSTAL			WEEKIWACHEE			HAMMOCK
Species	**Near[a]**	**Mid**	**Off**	**Near**	**Mid**	**Off**	**Near**	**Mid**	**Off**	**Near**	**Mid**	**Off**	**Mid**
(B)[b] *Ischadium recurvum*	1	2	—	3	7	—	—	—	—	—	—	—	—
(G) *Boonea impressa*	2	4	1	5	5	3	5	4	4	4	2	7	3
(B) *Crassostrea virginica*	3	5	7	8	4	9	7	8	9	7	10	—	—
(A) *Melita* "complex"	4	8	3	4	8	—	3	6	6	1	3	8	6
(P) *Polydora* "complex"	5	6	2	7	1	4	4	2	8	5	1	5	1
(D) *Xanthidae* spp.	6	9	9	—	—	—	—	—	10	—	—	—	—
(D) *Eurypanopeus depressus*	7	7	6	9	6	5	8	7	5	9	9	10	8
(P) *Genetyllis castanea*	8	10	—	—	—	—	—	—	7	—	—	—	—
(A) *Corophium* spp.	9	—	5	6	—	—	9	—	—	—	—	—	—
(B) *Mytilidae* spp.	10	—	—	—	—	—	—	—	—	—	—	—	—
(I) *Anurida maritima*	—	1	8	—	—	—	—	—	—	—	—	—	—
(P) *Fabriciola trilobata*	—	3	4	—	3	—	6	1	—	—	8	4	2
(P) *Neanthes succinea*	—	—	10	—	—	—	—	—	—	—	—	—	—
(P) *Syllidae* spp.	—	—	—	—	—	—	—	—	—	—	5	6	4
(I) *Diptera* spp.	—	—	—	1	2	2	2	3	—	3	7	—	5
(T) *Hargeria rapax*	—	—	—	2	10	6	1	9	—	2	4	—	7
(P) *Capitella capitata*	—	—	—	—	—	10	10	—	—	—	6	9	10
(B) *Brachidontes exustus*	—	—	—	10	9	1	—	—	1	—	—	2	—
(T) *Tanais cavolinii*	—	—	—	—	—	7	—	—	—	—	—	—	—
(O) *Anchozoa* spp.	—	—	—	—	—	8	—	10	3	—	—	3	—
(G) *Crepidula plana*	—	—	—	—	—	—	—	5	2	—	—	—	—
(B) *Geukensia demissa*	—	—	—	—	—	—	—	—	—	6	—	—	—
(X) *Cassidinidea lunifrons*	—	—	—	—	—	—	—	—	—	8	—	—	—
(A) *Gitanopsis* sp.	—	—	—	—	—	—	—	—	—	10	—	—	—
(A) *Hyale plumuiosa*	—	—	—	—	—	—	—	—	—	—	—	1	—

[a] Near = nearshore station; Mid = intermediate-distance station; off = offshore station

[b] B = Bivalve; G = Gastropod; A = Amphipod; P = Polychaete; D = Decapod; I = Insect; X = Isopod; O = Other

Appendix Table AE. Rank order list of oyster associated fauna (after Gorzelany 1986).

Species	Percent	Species	Percent	Species	Percent
Polydora "complex"	10.678	Nereidae spp.	0.084	*Axiothella mucosa*	0.009
Brachidontes exustus	9.347	Arachnida sp. A	0.082	*Amphilochus* sp.	0.008
Boonea impressa	8.508	*Caprella* sp.	0.072	*Gobiosoma bosci*	0.008
Fabriciola trilobata	8.296	*Anachis obesa*	0.060	Turridae sp.	0.008
Melita "complex"	7.579	*Streblosoma hartmanae*	0.053	*Solariorbis infracarinata*	0.008
Diptera spp.	6.841	*Mediomastus californiensis*	0.051	Orbiniidae spp.	0.007
Hargeria rapax	5.853	*Hydracarina* spp.	0.043	*Gobiesox strumosus*	0.007
Eurypanopeus depressus	4.477	*Cerithiopsis greeni*	0.041	*Laeonereis culveri*	0.007
Crepidula plana	4.141	Eunicidae spp.	0.041	*Isotomidae* sp.	0.006
Anthozoa spp.	3.894	*Leucothoe spinicarpa*	0.038	*Lepidametria commensalis*	0.006
Crassostrea virginica	3.395	*Seila adamsi*	0.037	*Cyclaspis* sp. A	0.005
Hyale plumuiosa	3.373	Phyllodocidae spp.	0.034	*Erichsonella* cf. *attenuata*	0.005
Syllidae spp.	3.201	*Nereis riisei*	0.034	*Mytilopsis leucophaeta*	0.005
Capitella capitata	2.471	*Amygdalum papyrium*	0.033	Nudibranchia spp.	0.005
Anurida maritima	2.378	*Paracaprella tenuis*	0.030	Arachnida sp. B	0.005
Ischadium recurvum	2.201	Bivalvia spp.	0.026	Calanoid copepoda	0.005
Xanthidae spp.	1.334	Harpacticoid copepoda	0.026	*Demonax microphthalma*	0.005
Genetyllis castanea	1.260	*Filograna implexa*	0.025	*Leitoscoloplos* spp.	0.005
Mytilidae spp.	1.097	Maldanidae spp.	0.025	*Mercierellopsis* sp.	0.005
Corophium spp.	1.024	*Epitonium unifasciatum*	0.023	*Streblopsio benedicti*	0.005
Geukensia demissa	0.836	Brachyura spp.	0.023	*Cerapus tubularis*	0.004
Tanais cavolinii	0.813	*Caecum pulchellum*	0.023	*Crepidula* spp.	0.004
Platyhelminthes sp. A	0.610	*Elasmopus levis*	0.022	*Entomobrya* sp.	0.004
Gitanopsis sp.	0.584	*Halmyrapseudes cubanensis*	0.021	Vitrinellidae sp.	0.004
Cerithiopsis emersoni	0.575	Gastropoda spp.	0.020	*Eulalia sanguinea*	0.004
Neanthes succinea	0.473	*Mesanthura floridensis*	0.019	*Panopeus* cf. *obesus*	0.004
Cassidinidea lunifrons	0.430	*Crepidula maculosa*	0.018	*Panopeus simpsoni*	0.004
Mediomastus spp.	0.306	*Sabellaria vulgaris*	0.018	Polychaeta sp. A	0.004
Petrolisthes armatus	0.306	*Naineris laevigata*	0.017	*Triphora nigrocincta*	0.004
Platyhelminthes sp. B	0.275	*Boguea enigmatica*	0.017	*Acanthochitona spiculosa*	0.003
Cymadusa compta	0.260	*Ericthonius brasliensis*	0.016	*Anachis semplicata*	0.003
Grandidierella bonneroides	0.241	*Marphysa sanguinea*	0.016	*Chasmodes saburrae*	0.003
Gammarus mucronatus	0.171	*Tagelus plebius*	0.016	*Mesanthura decorata*	0.003
Arenicolidae sp.	0.160	*Munna reynoldsi*	0.015	Spionidae spp.	0.003
Hydroides dianthus	0.157	Sipuncula spp.	0.013	*Chone americana*	0.003
Nereis falsa	0.148	Serpulidae spp.	0.013	*Musculus lateralis*	0.003
Ehlersia cornuta	0.140	*Schistomeringos* cf. *rudolphi*	0.012	*Apanthura* cf. *signata*	0.002
Assiminea succinea	0.129	*Leitoscoloplos foliosus*	0.012	Cerithiidae sp.	0.002
Streblospio benedicti	0.128	*Ampelisca* sp.	0.012	*Euplana gracilis*	0.002
Diastoma varium	0.102	*Erichsonella* cf. *filiformis*	0.011	*Fabriciola* sp.	0.002
Munna cf. *hayesi*	0.097	*Melongena corona*	0.010	*Mediomsatus ambiseta*	0.002
Rissoina catesbyna	0.096	*Paracerceis cordata*	0.010	*Orchestia grillis*	0.002
Mitrella lunata	0.095	*Platynereis dumerilli*	0.010	Ostracoda spp.	0.002

(*Continued*)

Appendix Table AE. Concluded.

Species	Percent	Species	Percent	Species	Percent
Paraprionospio pinnata	0.002	*Elasmopus* sp.	0.001	Enteropneusta spp.	0.001
Porifera spp.	0.002	*Eurydice littoralis*	0.001	*Eteone* spp.	0.001
Stenothoe minuta	0.002	Gobiidae sp.	0.001	*Gammarus* sp.	0.001
Thor dobkini	0.002	*Gobiosoma robustum*	0.001	*Gyptis brevipalpa*	0.001
Ampharetidae spp.	0.002	*Lepidasthenia varia*	0.001	Hiurdinea sp.	0.001
Amphicteis gunneri	0.002	*Lepidonotus variabilis*	0.001	Hydrozoa spp.	0.001
Amphipoda sp.	0.002	*Lysanopsis alba*	0.001	*Lembos* sp.	0.001
Anachis pulchella	0.002	*Minuspio cirrifera*	0.001	*Lima* sp.	0.001
Atylus cf. *minikoi*	0.002	*Mysella planulata*	0.001	*Linga amianthus*	0.001
Carabidae sp.	0.002	Onuphidae spp.	0.001	Lucinidae spp.	0.001
Cirrophorus sp.	0.002	*Opsanus beta*	0.001	*Myodocopa* spp.	0.001
Cyathura polita	0.002	*Palaemonetes intermedius*	0.001	Mysidacea sp.	0.001
Eobrolgus spinosus	0.002	Palaemonidae spp.	0.001	*Naineris quadricuspida*	0.001
Gammaridae spp.	0.002	*Photis pugnator*	0.001	*Naineris* sp.	0.001
Insecta sp.	0.002	*Podocerus brasiliensis*	0.001	*Nassarius vibex*	0.001
Leucon sp. A	0.002	Polycladida sp. A	0.001	*Oliva* spp.	0.001
Lucifer faxoni	0.002	Polycladida sp. B	0.001	*Pagurus* sp.	0.001
Lyonsia hialina	0.002	Sabellidae spp.	0.001	*Paraphoxus oculatus*	0.001
Maera sp.	0.002	*Semele proficua*	0.001	*Parastarte triquerta*	0.001
Mesanthura pulchra	0.002	*Tellina* sp.	0.001	*Parasterope pollex*	0.001
Munna cf. *lateralis*	0.002	Veneridae spp.	0.001	*Podarke obscura*	0.001
Notaulax phaeotania	0.002	*Acteocina canaliculata*	0.001	Polychaeta sp. B	0.001
Ophryotrocha sp. A	0.002	*Alpheus normanni*	0.001	*Pseudobranchioma* sp.	0.001
Parahesione luteola	0.002	Arachnida sp. E	0.001	*Pseudocryena floridana*	0.001
Phyllodoce spp.	0.002	*Arcidae* sp.	0.001	*Pseudoscorpione* sp.	0.001
Pycnogonida sp.	0.002	*Aricidea philbinae*	0.001	*Rhithropanopeus harrisii*	0.001
Sesarma cinereum	0.002	*Armandia muculata*	0.001	*Semibalanus balanoides*	0.001
Shistomeringoes cf. *rudolphi*	0.002	Ascidiacea sp.	0.001	*Solariorbis shimeri*	0.001
Stenothoe gallensis	0.002	*Batea catharinensis*	0.001	*Spirorbis* sp.	0.001
Streblosoma verilli	0.002	Bryozoa spp.	0.001	*Tharyx annulosus*	0.001
Ampelisca abdita	0.001	*Carditamera floridana*	0.001	*Tharyx* cf. *dorsobranchialis*	0.001
Arachnida sp. C	0.001	*Cerapus benthophilus*	0.001	*Balanus amphitrite*	< 0.001
Boonea seminuda	0.001	*Cerapus* sp. A	0.001	*Balanus eburneus*	< 0.001
Caprellidae sp.	0.001	*Ceratonereis mirabilis*	0.001	*Balanus improvisus*	< 0.001
Caullerielia spp.	0.001	*Cirolana minuta*	0.001	*Balanus subalbidus*	< 0.001
Chone sp.	0.001	Cirratulidae spp.	0.001	*Balanus venustus*	< 0.001
Cirolana parva	0.001	*Crepidula convexa*	0.001	Nematoda spp.	< 0.001
Codakia orbicularis	0.001	*Cymodoce faxoni*	0.001	Nemertinea spp.	< 0.001
Colomastix halichondriae	0.001	Dorvilleidae sp.	0.001	Oligochaeta spp.	< 0.001
Cyclopoid copepoda	0.001	*Elasmopus pocillimanus*	0.001		

TOTAL SPECIES = 248

Appendix Table AF. Macroalgae species present on Springs Coast oyster reefs (Sprinkel 1986).

Phylum	Species	Phylum	Species
Chlorophyta	*Acetabularia crenulata*	Rhodophyta (cont.)	*Eucheuma nudum*
	Batophora oerstedi		*Gracilaria* spp.
	Caulerpa prolifera		*Herposiphonia* spp.
	Dasycladus vermicularis		*Laurencia intricata*
	Enteromorpha spp.		*Laurencia obtusa*
	Enteromorpha compressa		*Laurencia papillosa*
	Enteromorpha erecta		*Laurencia* spp.
	Enteromorpha intestinalis		*Polysiphonia* spp.
	Enteromorpha linza		*Polysiphonia ramentacea*
	Monostroma oxysperum		*Polysiphonia subtilissima*
			Sargassum cymosum
Rhodophyta	*Caloglossa leprieurii*		*Sargassum* spp.
	Ceramium spp.		*Spyridea filamentosa*
	Ceramium byssoideum		*Taenioma nanum*
	Champia parvula		
	Chondria spp.	Phaeophyta	*Ectocarpus confervoides*

Appendix Table AG. Common macroalgae species from the Springs Coast region (compiled from Taylor 1955; Humm and Taylor 1961; Phillips 1960b; Humm 1963, 1973; Earle 1969; Dawes 1974; Mangrove Systems, Inc. 1986; and Sprinkel 1986).

Type	Species	Type	Species
Rhizophytic Algae	*Anadyomene stellata*	Drift Algae (cont.)	*Eucheuma nudum*
	Batophora oerstedii		*Giffordia mitchelliae*
	Caulerpa prolifera		*Gracilaria verrucosa*
	Caulerpa paspaloides		*Gracilaria* spp.
	Halimeda incrassata		*Halymenia floresia*
	Penicillus capitata		*Halymenia floridana*
	Udotea conglutinata		*Hummia anusta*
	Udotea spp.		*Jania* spp.
			Laurencia intricata
Drift Algae	*Ceramium fastigiatum*		*Laurencia poitei*
	Champia parvula		*Neoagardhiella ramoissima*
	Chondria tenuissima		*Polysiphonia ramentacea*
	Chondria spp.		*Polysiphonia harveyi*
	Codium taylori		*Sargassum filipendula*
	Digenia simplex		*Sargassum pteropleuron*
	Enteromorpha compressa		*Spyridia filamentosa*
	Enteromorpha intestinalis		

Appendix Table AH. Common water-column-dwelling fishes of Springs Coast estuaries (after Phillips 1986).

Common name	Scientific name	Occurrence [a]
Ladyfish	*Elops saurus*	E-F
Alabama shad	*Alosa alabamae*	E-F
Skipjack herring	*Alosa chrysochloris*	E-F
Shad	*Alosa* sp.	—
Gulf menhaden	*Brevoortia patronus*	M-E
Atlantic thread herring	*Opisthonema oglinum*	M-E
Striped anchovy	*Anchoa hepsetus*	E
Bay anchovy	*Anchoa mitchilli*	E-F
Anchovy	*Anchoa* sp.	—
Hardhead catfish	*Arius felis*	E-F
Gafftopsail catfish	*Bagre marinus*	E
Southern hake	*Urophycis floridana*	M-E
Halfbeak	*Hyporhamphus unifasciatus*	M-E
Atlantic needlefish	*Strongylura marina*	E-F
Silverside	*Menidia* sp.	E
Dusky pipefish	*Syngnathus floridae*	E
Atlantic bumper	*Chloroscombrus chrysurus*	E
Leatherjacket	*Oligoplites saurus*	M-E
Lookdown	*Selene vomer*	M-E
Florida pompano	*Trachinotus carolinus*	M-E
Permit	*Trachinotus falcatus*	M-E
Gray snapper	*Lutjanus griseus*	M-E
Spotfin mojarra	*Eucinostomus argenteus*	E-F
Silver jenny	*Eucinostomus gula*	E
Mojarra	*Eucinostomus* sp.	E
Pigfish	*Orthopristis chrysoptera*	E-F
Sheepshead	*Archosargus probatocephalus*	E-F
Pinfish	*Lagodon rhomboides*	E-F
Silver perch	*Bairdiella chrysoura*	E-F
Sand seatrout	*Cynoscion arenarius*	E
Spotted seatrout	*Cynoscion nebulosus*	E-F
Spot	*Leiostomus xanthurus*	E-F
Southern kingfish	*Menticirrhus americanus*	E
Drum	*Menticirrhus* sp.	—
Atlantic croaker	*Micropogonias undulatus*	E-F
Black drum	*Pogonias cromis*	E
Red drum	*Sciaenops ocellatus*	M-E-F
Atlantic spadefish	*Chaetodipterus faber*	E
Striped mullet	*Mugil cephalus*	M-E-F
Gulf butterfish	*Peprilus burti*	M
Southern puffer	*Sphoeroides nephelus*	E
Puffer	*Sphoeroides* sp.	E
Striped burrfish	*Chilomycterus schoepfi*	E

[a] M = marine; E = estuarine; F = fresh

Appendix Table AI. Common demersal fishes of Springs Coast estuaries (after Phillips 1986).

Common name	Scientific name	Occurrence [a]
Atlantic stingray	*Dasyatis sabina*	M-E
Smooth butterfly ray	*Gymnura micrura*	M-E
Cownose ray	*Rhinoptera bonasus*	M-E
Inshore lizardfish	*Synodus foetens*	E
Hardhead catfish	*Arius felis*	E-F
Gafftopsail catfish	*Bagre marinus*	E
Gulf toadfish	*Opsanus beta*	E
Polka-dot batfish	*Ogcocephalus cubifrons (=radiatus)*	M-E
Leopard searobin	*Prionotus scitulus*	E
Bighead searobin	*Prionotus tribulus*	E
Ocellated flounder	*Ancylopsetta quadrocellata*	M
Fringed flounder	*Etropus crossotus*	M
Gulf flounder	*Paralichthys albigutta*	M-E
Lined sole	*Achirus lineatus*	E
Hogchoker	*Trinectes maculatus*	E-F
Blackcheek tonguefish	*Symphurus plagiusa*	E

[a] M = marine; E = estuarine; F = fresh

Appendix Table AJ. Common demersal macroinvertebrates from Springs Coast estuaries (after Phillips 1986).

Common name	Scientific name	Occurrence [a]
Pink shrimp	*Penaeus duorarum*	M
Roughneck shrimp	*Trachypenaeus constrictus*	M
Shrimp	*Trachypenaeus* sp.	—
Shrimp	*Ambidexter symmetricus*	E
Big-clawed snapping shrimp	*Alpheus heterochaelis*	E
Long-eyed shrimp	*Ogyrides alphaerostris*	E
Longwrist hermit crab	*Pagurus longicarpus*	M-E
Flatclaw hermit crab	*Pagurus pollicaris*	E
Green porcelain crab	*Petrolisthes armatus*	E
Blue crab	*Callinectes sapidus*	M-E-F
Mud crabs	Xanthidae	M-E
Flat mud crab	*Eurypanopeus depressus*	E
Mud crab	*Neopanope texana*	E
Florida crown conch	*Melongena corona*	E
Bivalve mollusks	Bivalvia	—
American oyster	*Crassostrea virginica*	E

[a] M = marine; E = estuarine; F = freshwater

Appendix Table AK. Taxonomic listing the typical habitat of all insects, oligochaetes, and leeches found in Springs Coast estuaries (after Culter 1986).

Class/Order	Species	Occurrence [a,b]
Insecta		
Collembola	*Anurida maritima*	E
Ephemeroptera	Baetidae spp.	F
	Caenis spp.	F
Trichoptera	*Hydroptila* spp.	F
	Nectopsyche spp.	F
	Oecetis spp.	F
	Polycentropus spp.	F
Coleoptera	*Coleoptera* spp.	F
	Dubiraphia spp.	F
	Stenelmis spp.	F
Diptera	*Bezzia/Palpomyia* gp.	E
	Chironomidae spp.	E
	Ablabesmyia spp.	F
	Chironomini spp.	F
	Chironomus spp.	F-E
	Chironomus raparius gp.	F
	Cladopelma spp.	F
	Cladotanytarsus spp.	F
	Coelotanypus spp.	F
	Cricotopus spp.	F-E*
	Cricotopus bicinctus	F
	Cryptochironomus spp.	F-E*
	Cryptotendipes spp.	F
	Dicrotendipes spp.	F-E
	Dicrotendipes neomodestus	F-E*
	Dicrotendipes nervosus	F-E*
	Harnischia complex	F
	Labrundinia spp.	F
	Micropsectra spp.	F
	Microtendipes spp.	F
	Nanocladius spp.	F
	Orthocladiinae spp.	F
	Orthocladius gp.	F
Diptera (cont.)	*Pagastiella* spp.	F
	Paracladopelma spp.	F
	Paralauterborniella spp.	F
	Paratanytarsus spp.	F
	Polypedilum spp.	F
	Polypedilum scalaenum gp.	F-E*
	Polypedilum simulans gp.	F
	Procladius spp.	F-E*
	Pseudochironomus spp.	F
	Rheotanystarsus spp.	F
	Smittia gp.	F
	Stempellina spp.	F
	Stenochironomus spp.	F
	Stictochironomus spp.	F
	Tanypodinae spp.	E*
	Tanypus spp.	F-E
	Tanytarsini spp.	F
	Tanytarsus spp.	F
Oligochaeta		
Enchytraeidae	*Enchytraeus* spp.	E
	Grania postclitellochaeta	M
	Grania roscoffensis	M
	Lumbricilius sp. A	E
Naididae	*Bratislavia unidentata*	F
	Dero digitata	F
	Dero furcata	F
	Dero trifida	F
	Nais communis	F
	Nais elinguis	F
	Paranais grandis	E
	Paranais litoralis	E
	Pristina foreli	F
	Pristina jenkinae	F
	Pristina longiseta leidyi	F

(*Continued*)

Appendix Table AK. Continued.

Class/Order	Species	Occurrence [a,b]
Tubificidae	Unidentified immature w/o capilliform chaetae	F
	Unidentified immature w/ capilliform chaetae	F
Tubificinae	*Aulodrilus pigueti*	F
	Haber speciosus	F
	Ilyodrilus templetoni	F
	Limnodrilus spp.	F
	Limnodrilus angustipenis	F
	Limnodrilus hoffmeisteri	F
	Limnodrilus hoffmeisteri (var.)	F
	Psammoryctides convolutus	F
	Tubificoides brownae	E
	Tubificoides motei	E
	Tubificoides wasselli	E
Rhyacodrilinae	*Heterodrilus* spp.	M
	Heterodrilus bulbiporus	M
	Heterodrilus pentcheffi	M
	Monopylephorus parvus	E
	Monopylephorus rubroniveus	E
Limnodriloidinae		
	Limnodriloides spp.	E-M*
	Limnodriloides appendiculatus gp.	M
	Limnodriloides baculatus	M
	Limnodriloides barnardi	M
	Limnodriloides monothecus	M
	Limnodriloides rubicundus	M
	Marcusaedrilus luteolus	M
	Tectidrilus squalidus	M
	Thalassodrilides belli	E
Phallodrilinae	*Aktedrilus monospermathecus*	F
	Bathydrilus ingens	M
	Bathydrilus notabilus	M
	Inanidrilus bulbosus	M
	Inanidrilus leukodermatus	M
	Olavius imperfectus	M
	Olavius vacuus	M
	Phallodrilus spp.	M
	Phallodrilus sabulosus	E
Lumbriculidae	*Lumbriculidae* spp.	F
	Eclipidrilus spp.	F
Hirudinea		
	Dina microstoma	F
	Erpobdella spp.	F
	Helobdella spp.	F
	Helobdella elongata	F
	Helobdella lineata	F
	Helobdella stagnalis	F
	Myzobdella lugubris	E
	Piscicolidae spp.	F-E*
	Piscicola punctata	F

[a] F = freshwater and occasionally estuarine, E = estuarine, M = offshore estuarine/marine.
[b] * = instances where habitat preference differs from that found in the general literature.

Appendix Table AL. Common benthic macroinvertebrate infauna of the offshore estuarine Springs Coast (after Culter 1986).

Species	Type	Species	Type
Ampelisca holmesi	Amphipod	*Aricidea philbanae*	Polychaete worm
Cerapus benthophilus	Amphipod	*Axiothella mucosa*	Polychaete worm
Grandidierella bonnieroides	Amphipod	*Boguea enigmatica*	Polychaete worm
Maera cf. *williamsi*	Amphipod	*Caraziella hobsonae*	Polychaete worm
Brachidontes exustus	Bivalve	*Chone americana*	Polychaete worm
Mulinia lateralis	Bivalve	*Cirrophorus furcatus*	Polychaete worm
Nuculana acuta	Bivalve	*Fabricia sabella*	Polychaete worm
Transennella conradina	Bivalve	*Fabricia* sp.	Polychaete worm
Polyplacophora spp.	Chitons	*Fabriciola trilobata*	Polychaete worm
Calanoid copepoda spp.	Copepod	*Filograna implexa*	Polychaete worm
Harpacticoid copepoda spp.	Copepod	*Goniadides carolinae*	Polychaete worm
Cyclaspis sp.	Cumacean shrimp	*Mediomastus ambiseta*	Polychaete worm
Ogyrides alphaerostris	Decapod shrimp	*Mediomastus californiensis*	Polychaete worm
Amphiuridae sp.	Echinoderm	*Mediomastus* spp.	Polychaete worm
Micropholis gracillima	Echinoderm	*Myrochele oculata*	Polychaete worm
Caecum strigosum	Gastropod	*Paraprionospio pinnata*	Polychaete worm
Cerithium muscarum	Gastropod	*Pholoe* spp.	Polychaete worm
Crepidula plana	Gastropod	*Prionospio* sp.	Polychaete worm
Panathura formosa	Isopod	*Salmacina* sp.	Polychaete worm
Nematoda spp.	Nematode worm	*Spirorbis corrugatum*	Polychaete worm
Inanidrilus bulbosus	Oligochaete worm	*Spirorbis spirullum*	Polychaete worm
Inanidrilus nr. *mexicana*	Oligochaete worm	*Streblospio benedicti*	Polychaete worm
Tubificidae spp.	Oligochaete worm	*Tharyx* cf. *dorsobranchialis*	Polychaete worm
Tubificoides nr. *wasselli*	Oligochaete worm	*Calazodion wadei*	Tanaid shrimp
Parasterope pollex	Ostrocod	*Halmyrapseudes* cf. *cubanensis*	Tanaid shrimp
Podocopa spp.	Ostrocod	*Hargeria rapax*	Tanaid shrimp

Appendix Table AM. Common benthic macroinvertebrate infauna of the inshore fresh and occasionally estuarine Springs Coast (after Culter 1986).

Species	Type	Species	Type
Cerapus benthophilus	Amphipod	*Almyracuma* sp.	Cumacean shrimp
Gammarus mucronatus	Amphipod	*Assiminea succinea*	Gastropod
Gammarus tigrinus	Amphipod	Hydrobiidae spp.	Gastropod
Grandidierella bonnieroides	Amphipod	*Munna reynodsi*	Isopod
Hyalella azteca	Amphipod	Nematoda spp.	Nematode worm
Bivalvia spp.	Bivalve	*Limnodrilus hoffmeisteri*	Oligochaete worm
Corbicula manilensis	Bivalve	*Psammoryctides convolutus*	Oligochaete worm
Pisidium sp.	Bivalve	Tubificidae spp.	Oligochaete worm
Chironomidae spp.	Chironomid midge	*Tubificoides* sp. C	Oligochaete worm
Cladotanytarsus spp.	Chironomid midge	*Amphicteis gunneri*	Polychaete worm
Polypedilum spp.	Chironomid midge	*Laeonereis culveri*	Polychaete worm
Calanoid copepoda	Copepod	*Hargeria rapax*	Tanaid shrimp

Appendix Table AN. Common benthic macroinvertebrate infauna of the intermediate mesohaline (moderate, fluctuating-salinity) Springs Coast (after Culter 1986).

Species	Type	Species	Type
Ampelisca abdita	Amphipod	*Cassidinidea lunifrons*	Isopod
Cerapus benthophilus	Amphipod	*Erichsonella* cf. *attenuata*	Isopod
Corophium ellisi	Amphipod	*Xenanthura brevitelson*	Isopod
Corophium tuberculatum	Amphipod	*Limnodriloides rubicundis*	Oligochaete worm
Gammarus mucronatus	Amphipod	Tubificidae spp.	Oligochaete worm
Grandidierella bonnieroides	Amphipod	*Wapsa grandis*	Oligochaete worm
Melita "nitida" complex	Amphipod	*Haplocytherida setipunctata*	Ostrocod
Balanus improvisus	Barnacle	*Amphicteis gunneri*	Polychaete worm
Anomalocardia auberiana	Bivalve	*Aricidea philbinae*	Polychaete worm
Bivalvia spp.	Bivalve	*Haploscoloplos foliosus*	Polychaete worm
Tagelus plebeius	Bivalve	*Leitoscoloplos foliosus*	Polychaete worm
Tagelus spp.	Bivalve	*Mediomastus ambiseta*	Polychaete worm
Polypedilum spp.	Chironomid (larva)	*Paraprionospio pinnata*	Polychaete worm
Calanoid copepoda	Copepod	*Streblospio benedicti*	Polychaete worm
Cyclaspis sp.	Cumacean shrimp	*Halmyrapseudes* cf. *cubanensis*	Tanaid shrimp
Assiminea succinea	Gastropod	*Hargeria rapax*	Tanaid shrimp
Hydrobiidae spp.	Gastropod		

Appendix Table AO. Common marine fishes of the Springs Coast (after Grimes and Mountain 1971; Phillips 1986).

Common name	Scientific name	Common name	Scientific name
Lined sole	*Achirus lineatus*	Halfbeak	*Hyporhamphus unifasciatus*
Orange filefish	*Aluterus schoepfi*	Feather blenny	*Hypsoblennius hentzi*
Striped anchovy	*Anchoa hepsetus*	Hogfish	*Lachnolaimus maximus*
Bay anchovy	*Anchoa mitchilli*	Scrawled cowfish	*Acanthostracion quadricornis*
Anchovy	*Anchoa* sp.	Pinfish	*Lagodon rhomboides*
Ocellated flounder	*Ancylopsetta quadrocellata*	Spot	*Leiostomus xanthurus*
Hardhead catfish	*Arius felis*	Gray snapper	*Lutjanus griseus*
Bronze cardinalfish	*Astrapogon alutus*	Southern kingfish	*Menticirrhus americanus*
Gafftopsail catfish	*Bagre marinus*	Fringed filefish	*Monacanthus ciliatus*
Silver perch	*Bairdiella chrysoura*	Planehead filefish	*Monacanthus hispidus*
Gulf menhaden	*Brevoortia patronus*	Leatherjacket	*Oligoplites saurus*
Grass porgy	*Calamus arctifrons*	Redbellied batfish	*Ogcocephalus nasutus*
Gulf black sea bass	*Centropristis striata*	Atlantic thread herring	*Opisthonema oglinum*
Atlantic spadefish	*Chaetodipterus faber*	Gulf toadfish	*Opsanus beta*
Florida blenny	*Chasmodes saburrae*	Pigfish	*Orthopristis chrysoptera*
Striped burrfish	*Chilomycterus schoepfi*	Gulf flounder	*Paralichthys albigutta*
Sand seatrout	*Cynoscion arenarius*	Gulf butterfish	*Peprilus burti*
Spotted seatrout	*Cynoscion nebulosus*	Leopard sea robin	*Prionotus scitulus*
Atlantic stingray	*Dasyatis sabina*	Bighead sea robin	*Prionotus tribulus*
Sand perch	*Diplectrum formosum*	Red drum	*Sciaenops ocellatus*
Spottail pinfish	*Diplodus holbrooki*	Lookdown	*Selene vomer*
Sharksucker	*Echeneis naucrates*	Southern puffer	*Sphoeroides nephelus*
Fringed flounder	*Etropus crossotus*	Dusky pipefish	*Syngnathus floridae*
Spotfin mojarra	*Eucinostomus argenteus*	Pipefish	*Syngnathus* sp.
Silver jenny	*Eucinostomus gula*	Inshore lizardfish	*Synodus foetens*
Mojarra	*Eucinostomus* sp.	Florida pompano	*Trachinotus carolinus*
Code goby	*Gobiosoma robustum*	Permit	*Trachinotus falcatus*
White grunt	*Haemulon plumieri*	Southern hake	*Urophycis floridana*
Seahorse	*Hippocampus* sp.		

Appendix AP. Federal, State, and local environmental control agencies and their responsibilities

Federal Agencies

1. **Army Corps of Engineers**
   This agency is concerned with all activities that affect or modify navigable waters of the United States, and is primarily concerned with construction in navigable waters and with dredge and fill permits. Its staff 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 the authority to respond to emergency hazardous waste releases and to force responsible parties to clean up.

3. **Department of Commerce—National Oceanic and Atmospheric Administration**
   NOAA is currently involved in 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 permit activities of the Corps of Engineers and sets guidelines for State environmental programs.

5. **Department of Interior**
   Functions performed by this agency include reviewing proposed activities that affect threatened or endangered species, reviewing Corps of Engineers' permits for effects on fish and wildlife, and managing all Federal public lands. In 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 is charged with managing timbering of many Federal lands, including watershed management, wildlife habitat management, and reforestation programs. Through many programs, the Agricultural Stabilization and Conservation Service helps protect wetlands and solves 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's). These are studies of developments that could have a substantial effect upon the health, safety, or welfare of citizens of more than one county.

Appendix AP. Concluded.

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 oversees the Florida Water Management Districts and interacts closely with other Federal and State agencies on water-related matters.

4. **Florida Game and Fresh Water Fish Commission**
The purpose of this Commission is to manage, protect, and conserve wild terrestrial and fresh-water animal 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 permitting septic tank systems through county health departments, coordinating mosquito control, and investigating threats to public health.

6. **Department of Natural Resources**
The DNR is heavily 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 the 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 that 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.

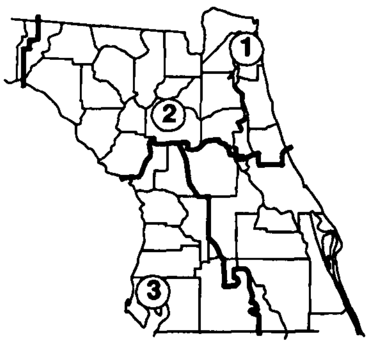
3. **Soil and Water Conservation Districts**
These districts are supervised to a limited degree by the Department of Agriculture and Consumer Services and carry out preventive measures for flooding and soil erosion.

4. **Miscellaneous**
Many local counties and municipalities have environmental and planning agencies that can be involved in environmental management. Local governments can also pass pollution control laws, zoning and land use laws, and many other ordinances that can be effective in preventing environmental problems.

Many of these agencies perform functions that overlap on the State, Federal, and local level. There are also many Memoranda of Understanding between agencies that allow sharing of overlapping functions. Local, State, and Federal agencies interact extensively on programs because of mutual benefits and cost sharing agreements.

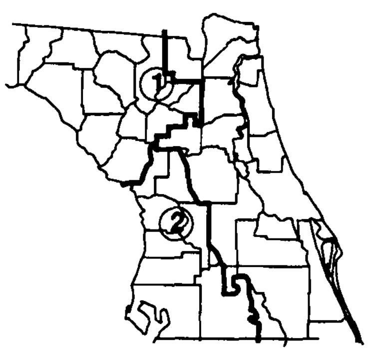
Appendix AQ. Springs Coast regulatory agency locations, addresses, and phone numbers.

Department of Environmental Regulation



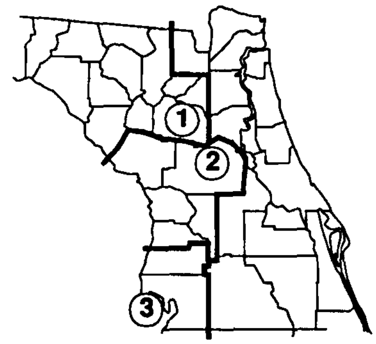
1. Northeast District Office
   7825 Baymeadows Way, Suite B200
   Jacksonville, FL 32256-7577
   (904) 448-4300
2. Northeast District Branch Office
   5700 S.W. 34th St., Suite 1204
   Gainesville, FL 32608
   (904) 336-2095
3. Southwest District Office
   4520 Oak Fair Blvd.
   Tampa, FL 33610-7347
   (813) 623-5561

Department of Natural Resources - Regional Biologists



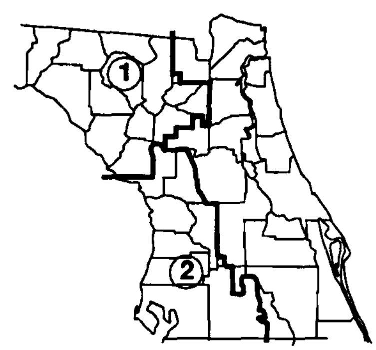
1. Suwannee River Region
   227 Hernando St.
   Lake City, FL 32055
   (904) 885-0464
2. Southwest Region
   6355 S. Florida Ave.
   Floral City, FL 32636
   (904) 726-8622

Regional Planning Councils



1. North Central Florida RPC
   2002 N.W. 13th St.
   Gainesville, FL 32601
   (904) 376-3344
2. Withlacoochee RPC
   1241 S.W. 10th St.
   Ocala, FL 32670
   (904) 732-3307
3. Tampa Bay RPC
   9455 Koger Blvd.
   St. Petersburg, FL 33702
   (813) 577-5151

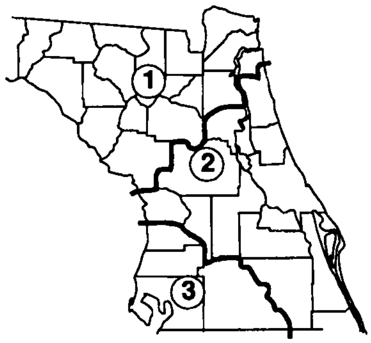
Water Management Districts



1. Suwannee River WMD
   Rt. 3, Box 64
   Live Oak, FL 32060
   (904) 821-3220
2. Southwest Florida WMD
   5060 U.S. Hwy. 41, South
   Brooksville, FL 33512
   (813) 628-4150

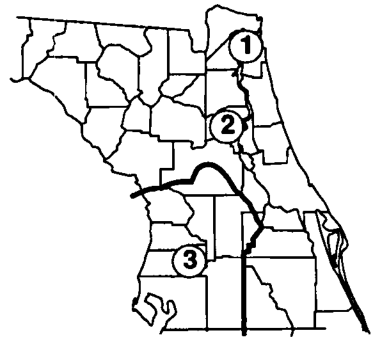
Appendix AQ. Concluded.

Florida Game & Fresh Water Fish Commission



1. Northeast Regional Office
   Rt. 7, Box 102
   Lake City, FL 32055
   (904) 885-0525
2. Central Regional Office
   1239 S.W. 10th St.
   Ocala, FL 32674
   (904) 667-1225
3. South Regional Office
   2202 Lakeland Hills Blvd.
   Lakeland, FL 33805
   (813) 552-7434

U.S. Army Corps of Engineers



1. Jacksonville District Office
   P.O. Box 4970
   Jacksonville, FL 32201
   (904) 791-2211
2. Palatka Area Office
   P.O. Box 1317
   Palatka, FL 32077
   (904) 328-2737
3. Tampa Area Office
   P.O. Box 19247
   Tampa, FL 33686
   (813) 228-2576

U.S. Environmental Protection Agency

Region IV
345 Courtland St. NE
Atlanta, GA 30365
(404) 347-4793

U.S. Fish and Wildlife Service

Southeast Region
Richard B. Russell Federal Bldg.
75 Spring St. SW
Atlanta, GA 30303-3376
(404) 242-3588

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TAKE PRIDE
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U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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. This 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 interests 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.