Resource Atlas of the Apalachicola Estuary

Written and Illustrated
by
Robert J. Livingston

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I enter a swamp as a sacred place—
a sanctum sanctorum. There is the
strength, the marrow of Nature.

— Thoreau

Out of the hills of Habersham,
Down the valleys of Hall,
I hurry amain to reach the plain;
Run the rapid and reach the fall.

— Sidney Lanier, *Song of the Chattahoochee*

All the rivers run into the sea;
yet the sea is not full.

— Ecclesiastes 1:7

Wherefore did Nature pour her bounties forth
With such a full and unwithdrawing hand,
Covering the earth with odours, fruits, and flocks,
Thronging the seas with spawn innumerable,
But all to please, and sate the curious taste?

— Milton, Commus

Swamp at dawn

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Acknowledgments

The research on which this atlas is based began as a field monitoring project in Apalachicola Bay during March 1972. Since that time, a continuous program has been developed and carried out within the Apalachicola drainage system. Over 1,000 people have participated in what is now an 11-year project. This effort has included students from Florida State University and the University of Florida, scientists from private industry and the state university system of Florida, and various technicians and professional staff people. The research has been multidisciplinary and interdisciplinary, covering such areas as hydrological engineering, chemistry, physical oceanography, biology, geography, resource planning and management, fisheries, computer programming, statistics, economics, and ecology. The results transcend any single approach to understanding natural phenomena and the application of such knowledge to progressive resource management has proven to be extremely rewarding for the research community as well as for those who depend on this unique ecosystem.

Technical reviews of all or part of this atlas were provided by Drs. Fred Prochaska and David Mulkey, University of Florida; Mrs. Pamela McVety, Florida Department of Environmental Regulation; Mr. Scott Andree, Franklin County Extension/Sea Grant; and Dr. Karen Steidinger and colleagues, Florida Department of Natural Resources Marine Research Laboratory.

Funding for this program has come from various sources although the major contributions in terms of allocation and consistency have been made by the Florida Sea Grant College (National Oceanic and Atmospheric Administration) and the Franklin County Board of Commissioners. Periodic supplementary funding has been provided by private industry as well as by state and federal agencies. The list includes local developers, forestry interests, the Florida Department of Environmental Regulation, the Florida Department of Community Affairs, the Coastal Plains Regional Commission, the U.S. Environmental Protection Agency, the National Science Foundation, the Florida Department of Natural Resources, the Northwest Florida Water Management District, the U.S. Geological Survey, the Florida Game and Fresh Water Fish Commission, the U.S. Fish and Wildlife Service, and the Man and the Biosphere Program of the U.S. Department of State. Special credit should be given to two divisions of Florida State University: the Department of Biological Science for its long-running support of the research on which this atlas is based and the Florida Resources and Environmental Analysis Center for its work in producing this atlas. The main impetus for the research has come from local concerns (i.e., the fishermen of Franklin County, Florida) and a federal agency (i.e., the Florida Sea Grant College, NOAA) that has consistently sought to apply basic scientific knowledge to practical problems. The people of Franklin County recognized at an early date that, as land development continues to proceed at an accelerated rate in Florida, a forward-looking management program would be necessary to protect a resource that has been at the center of their way of life for generations. The combination of basic and applied science, local, state, and federal involvement, and a multidisciplinary, long-term research program has led to a series of resource management/planning actions that are unprecedented in the nation.

Upper Apalachicola estuary

Foreword

This atlas represents a synthesis of the available knowledge about the Apalachicola Bay system as a natural ecosystem. This bay complex is, of course, only one part of a major drainage area that includes the Apalachicola, Chattahoochee, and Flint rivers to landward and the northeastern Gulf of Mexico to seaward. At an early stage of the studies, it became evident that a complete understanding of the bay system would depend on a broad overview of the related river and gulf areas. It was this realization that led to the present, long-term, multifaceted research effort.

A comprehensive approach, in which an entire system is studied as a whole, is extremely difficult to carry out. The boundaries that traditionally separate scientific disciplines from each other—biology from chemistry or meteorology from physics—and those between adjacent components of the system—the river, the bay, the wetlands—are arbitrary constructs of man; when the scientist forgets they are not real features of nature, he can be misled in his view of the system. On the other hand, without these arbitrary divisions, the scientist's task becomes almost hopelessly complicated. The amount of information to be handled is extensive. The scientist must compile and analyze millions of individual bits of information while maintaining some sort of central focus and direction. It is here that the advent of modern computers has made the difference. Data files that not long ago would have been impossible to handle can now be processed and analyzed electronically. There is at last the possibility of reversing the trend of modern science whereby ever more specialized researchers address ever smaller and more restricted problems, with the risk of losing sight of the ultimate complexity of the real world in which we live.

The comprehensive or systems approach can be likened to the growth of the concentric layers of a snowball as it rolls down a hill. As each problem is solved, it forms the foundation for a new question that, in turn, serves as the template for future work. Eventually, we can view the overall picture by cutting through the snowball of ideas, hypotheses, and results and, with the help of computerized analysis, form models of how the ecosystem works. These models are continually reevaluated and revised as new information becomes available, and eventually become detailed enough to offer actual predictions of the behavior of the system under differing circumstances. These predictions can, in turn, be tested through laboratory or field experiments, and the results of the experiments used to improve the models' predictive ability. The combination of comprehensive field studies and laboratory experiments provides the information on which models can be based, but it is the availability of sophisticated computerized analysis that makes compilation and use of so much information possible.

Some pieces of the information puzzle are necessary before even a preliminary model of process or function is possible. The broad habitat features, dominated by climatological conditions such as temperature and precipitation, are major forces that determine the behavior of any aquatic system. Mass movement of water, water quality features, and local variations in the habitat that determine the distribution of plants and animals are also important determinants of the system's features. Especially important are the amount and kind of plants that grow in the estuary. Green plants capture the energy of the sun and, through photosynthesis, turn it into a form useful to living things. This energy is passed through food webs as the plants—the primary producers—are eaten or die and are broken down by microbes. Thus the energy is continuously changing form, from plant matter to animal tissue or microbial colonies. The animal tissue may change form again as it passes further along the food chain from prey to predator. Thus knowledge of the distribution of this energy both in time and in space is critical to the analysis of any ecosystem. We must understand not only the plants and animals and their interactions, but also the microbes which are a very important factor in the redistribution of energy. Only if we understand the interactions of all these living things, not only among themselves but within the physical and chemical features of the system, will we be able to make even the crudest predictions about the effects of a change made anywhere in the system.

The Apalachicola estuary is considered by many people as a sanctuary for a variety of aquatic organisms. By definition, a sanctuary is a place of refuge and shelter, of protection as a privilege of a special place. In this case, the newly established Apalachicola River and Bay National Estuarine Sanctuary is a working refuge, a multiple-use system where natural resources are to be used as well as studied. It is hoped that the research carried out here will enable generations far into the future to enjoy these resources without destroying this goose that lays the golden eggs.

This atlas is designed to function as a plainly written compendium of knowledge and is part of a comprehensive base of scientific information to be used for future planning and management decisions in the region. It has been written for the general public, and the scientific data have been simplified as much as possible to present generalizations, observations, and overall trends. A bibliography of the technical basis for such information has also been provided.

Apalachicola flood plain

Apalachicola River

Contents

Introduction

The Apalachicola estuary is the gulfward extension of the Apalachicola-Chattahoochee-Flint (tri-river) system, which drains portions of Alabama, Georgia, and Florida. The Apalachicola is the largest river in Florida in terms of flow rate and is the only Florida drainage system with its origin in the Piedmont at the base of the Appalachian Mountains. This river system, or its forerunner, formed during the Miocene Epoch, more than 25 million years ago. Since that time, the estuary has moved up and down the valley with changes in sea level and topography. The general dimensions of the present Apalachicola drainage system were established by the Pleistocene Epoch, around 1 million years ago. During that time, sea level changed considerably; around 200,000 years ago, the sea level was over 410 feet (125 meters) lower than it is today, and the coastline was considerably seaward of its present position. It is thought that the barrier island chain that presently encloses the Apalachicola estuary was first formed around 5,000 years ago, when mean sea level attained its present position.

An estuary is a transitory buffer zone between the fresh water of a river and the saline water of the sea. Various classifications have been developed to describe the specific zones of an estuary. For example, an estuary may be separated into zones according to salinity. The head of an estuary is composed of a limnetic zone (salinity range: 0–0.5 parts per thousand), an oligohaline zone (0.5–5 parts per thousand), and a mesohaline zone (5–18 parts per thousand). A polyhaline zone (18–25 parts per thousand) exists around the middle reaches of the estuary, and a euhaline zone (25–35 parts per thousand) represents the outer portions of the estuary.

By definition, an estuary is physically unstable and is characterized by rapid, aperiodic changes and diel (daily), lunar (monthly), and seasonal cycles of temperature, salinity, current structure, and key water quality features. The biological system is physically and chemically stressed, and is strongly influenced by meteorological conditions and by the topography of the basin. Variability is the overriding ecological feature of such systems, along with relatively high productivity. The biotic components are often characterized by certain freshwater populations (not persisting in salinities greater than 0.1 parts per thousand), oligohaline populations (not tolerating salinities greater than 5.0 parts per thousand), and true estuarine populations that are broadly eurytopic, having marine affinities but adapted to a broad range of variations of key physico-chemical factors. The "true estuarine" organisms are joined by other forms that are either euryhaline marine or migratory, spending some part of their life history in the estuary. Such populations are often nurserying types that use the estuary as a sanctuary from predation or as a feeding ground.

Estuarine communities are often characterized by high productivity (phytoplankton, emergent and submergent vegetation), low species richness and diversity, and high dominance. There is considerable scientific debate concerning the biological stability of such communities. In the Apalachicola system, high rates of sedimentation, turbidity, and natural color are all part of the natural environment. Basin configuration, along with wind and tidal currents and salinity distribution, are key elements in the determination of the biological associations of the bay. Such populations are also influenced by selective predation and periodic, catastrophic natural occurrences such as storms and rapid temperature decreases. These features, together with latitude, watershed conditions including patterns of freshwater input, sediment interactions, estuarine circulation, nutrient distribution, and solar energy (light) factors all contribute to the shaping of the estuarine communities.

There are certain major driving forces that have been shown by Florida State University researchers to form the basis for the enormous productivity and rich food web structure of the Apalachicola estuary. The geographical features of the system, including the relatively shallow basin and the barrier island chain, form a natural sink into which nutrients, both dissolved and in the form of particles, are washed by the river and by local, overland runoff. The Apalachicola River is the single greatest factor controlling the seasonal changes of nutrient levels and salinity. The regular temperature changes, the cyclic inputs of organic matter controlled by the dominant physical forces, and the particularly favorable habitat characteristics of this system combine in such a way that the fisheries potential in the estuary has continued to be extremely high. The Apalachicola estuary provides between 80 and 90 percent of Florida's oysters. The famous Apalachicola oyster is, in fact, shipped all over the country. This bay system provides most of the shrimp in the Big Bend area of Florida and is adjacent to a major spawning ground for blue crabs. Finfish fisheries have been declining for several years although there is a lively, as yet scarcely tapped, sport fishery both inshore and offshore. In sum, the Apalachicola estuary represents a highly productive area at the terminus of what is currently one of the last major river systems in the country to remain in a relatively natural state.

In 1979, Franklin County, Florida, (which surrounds the main estuary) had a population of 8,403. The entire Apalachicola Valley is sparsely inhabited, with a relatively low rate of population increase in recent history. From 1969 to 1974, the regional population went from 101,782 to about 109,254—nearly a 7 percent increase over a five-year period. There is little industrial or commercial development (only 0.2 percent of the basin area is so used). The major industries include government service and renewable resource industries such as fisheries, forestry, and agriculture. The area is growing, however, and recent changes in the system along with projections of considerable new development in the near future have posed important new challenges to the region in terms of resource planning and management.

Perhaps the single most important factor in many aquatic systems is the growing human population. Over the years, evidence has accumulated that the effects of man's presence—municipalization, industrialization, habitat alteration or destruction, agricultural activities and the attendant release of pesticides and other toxic substances—have contributed to the alteration and/or reduction of the natural productivity of river and bay areas. It is this productivity—the ability to capture enough energy to produce a great deal of living tissue and to pass that energy along to organisms that man finds useful—that makes an estuary so economically valuable; only if productivity is high can the system support a significant fishery. Recently, there has been an increased need for a solid scientific understanding of natural drainage areas. It has been assumed that, with the help of such knowledge, planners can find strategies that will allow for badly needed economic development while protecting the natural productivity and aesthetic features of the natural system. The Apalachicola Valley has been part of a major experiment to determine whether scientific information can indeed be used to develop a resource management program to meet those needs. The central question remains how to broaden the existing, relatively narrow economic base while continuing to maintain one of the last naturally functional big river basins in the country. It is with these challenges in mind that this atlas has been written.

LANDSAT image of the lower Apalachicola system

The Apalachicola River and Bay System

The tri-river drainage system includes approximately 19,200 square miles in Georgia, Alabama, and Florida. The confluence of the Chatahoochee and Flint rivers forms the headwaters of the Apalachicola system, which drains about 1,030 square miles. The Chipola River system joins the Apalachicola near its southern terminus and has a drainage area or watershed approximately equal in area to that of the Apalachicola. The Apalachicola, which lies entirely within the coastal plain, is about 108 miles long, with a uniform slope of 0.5 feet per mile.

The tri-river basin is divided into an upper region, the Piedmont Plateau, and a lower region, the Gulf-Atlantic Coastal Plain. The Apalachicola River meanders in broad curves through the flood plain, which is relatively narrow along the upper river; the flood plain widens along mid portions of the river, while the lower river has the widest flood plain. Constant erosion and undercutting leads to the development of shoals, back-swamps, channels, sloughs, natural levees, and ox-bow lakes. The river is a dynamic system, constantly changing its form and structure as it ebbs and floods. Soil saturation is highly variable depending on river levels, topographic conditions, elevation, and other flood plain drainage characteristics. Periodic (seasonal) flooding, along with soil distribution and elevation, is largely responsible for the distribution of bottomland vegetation and the associated transport of dissolved and particulate organic substances, which eventually end up in the river and its associated estuary.

The Apalachicola River is underlain by limestone and sandy marine or clayey (shell) marl. These sands and clays add to the natural high turbidity of the river. The lower river valley is composed largely of Plio-Pleistocene sands, remnants of marine sediments from ancient seas that have periodically covered the area. Soils in the titi swamps and savannahs of the Apalachicola

Valley are strongly acidic, with relatively low total phosphorus concentrations. The cypress and gum swamps are also highly acidic. These soils are derived largely from erosion of the northern Piedmont-Appalachian area. The river bed is composed primarily of Pleistocene deposits, sand to coarse gravel, that are covered by fine clay particles. Such sediments are constantly being deposited in the bay system.

The Apalachicola Bay system is composed of six major subdivisions: the river delta, East Bay, Apalachicola Bay, St. Vincent Sound, St. George Sound, and Alligator Harbor. The total aquatic area approximates 155,324 acres (62,879 hectares). The southern boundary of the bay complex is formed by three barrier islands (St. Vincent Island, St. George Island, and Dog Island) and the peninsula of Alligator Point. These areas form four natural openings to the Gulf of Mexico: Indian Pass, West Pass, East Pass, and the expanse between Dog Island and Alligator Point known as Dog Island Reef. A man-made opening, Sikes Cut, is located on the western portion of St. George Island. Bulkhead Shoal is a natural, submerged boundary between Apalachicola Bay and St. George Sound. A 12-foot deep (maintained) portion of the Intracoastal Waterway extends through St. George Sound, Apalachicola Bay, and up the Apalachicola River to Lake Wimico and west along an artificial channel to St. Andrews Bay. Bridges link Apalachicola, East Point, and St. George Island.

The primary estuary, that area most affected by the Apalachicola River, includes the delta area, East Bay, Apalachicola Bay, St. Vincent Sound, and western portions of St. George Sound. The Apalachicola estuary is a lagoon and barrier island complex. Tidal currents originate from astronomical and wind tides. The average depth is between 6 and 9 feet at mean low tide. Because of the shallow depth, tides and winds are instrumental in driving the currents which act as a natural circulatory system for the bay. Apalachicola river flow influences various habitat features of the estuary such as salinity and sediment distribution. Average flow rates, measured at Blountstown, Florida, are 23,500 cubic feet per second (cfs) or 175,790 gallons per second (g/sec). Maximum and minimum flows in the past 15 years are 162,500 cfs (1,215,570 g/sec) and 6,280 cfs (46,980 g/sec). Such freshwater input, together with the physiographic characteristics of the basin (i.e., the barrier island string), are key ecological features of the system. The islands limit the release of fresh water (and nutrients) to the outer gulf, thus forming a low-salinity, nutrient-rich lagoon, which is physically dominated by Apalachicola river flow.

The Apalachicola Bay system is thus a composite of intergrading physical habitats that, in a strict sense, includes the entire upland drainage area, from the base of the Appalachians to the Gulf of Mexico. The functional attributes of the estuary include the seasonally fluctuating Apalachicola River, the physiographic structure of the receiving basin, the fresh- and brackish-water wetlands that line the river and bay, and the constantly pulsing ebbs and flows of the water in the estuary and the open Gulf of Mexico.

The Apalachicola River and Bay National Estuarine Sanctuary

In September 1979, the Apalachicola National Estuarine Sanctuary was created by the Office of Coastal Zone Management, a branch of the National Oceanic and Atmospheric Administration. The Apalachicola sanctuary is the largest of its kind in the country. According to Section 315 of the Coastal Zone Management Act (PL 92-583), certain coastal areas are "to be set aside as natural field laboratories," to be used mainly for "long-term scientific and educational purposes" in conjunction with the ongoing development and implementation of effective management for beneficial use of the natural resource. The principal aims of the act are to understand the ecological relationships of the estuary, to compile baseline data, to monitor changes associated with human impact on the ecosystem, and to provide a vehicle for public knowledge and awareness of estuarine processes and values. The act also encourages multiple use of the estuary insofar as such use is compatible with the primary sanctuary purposes (i.e., research and education).

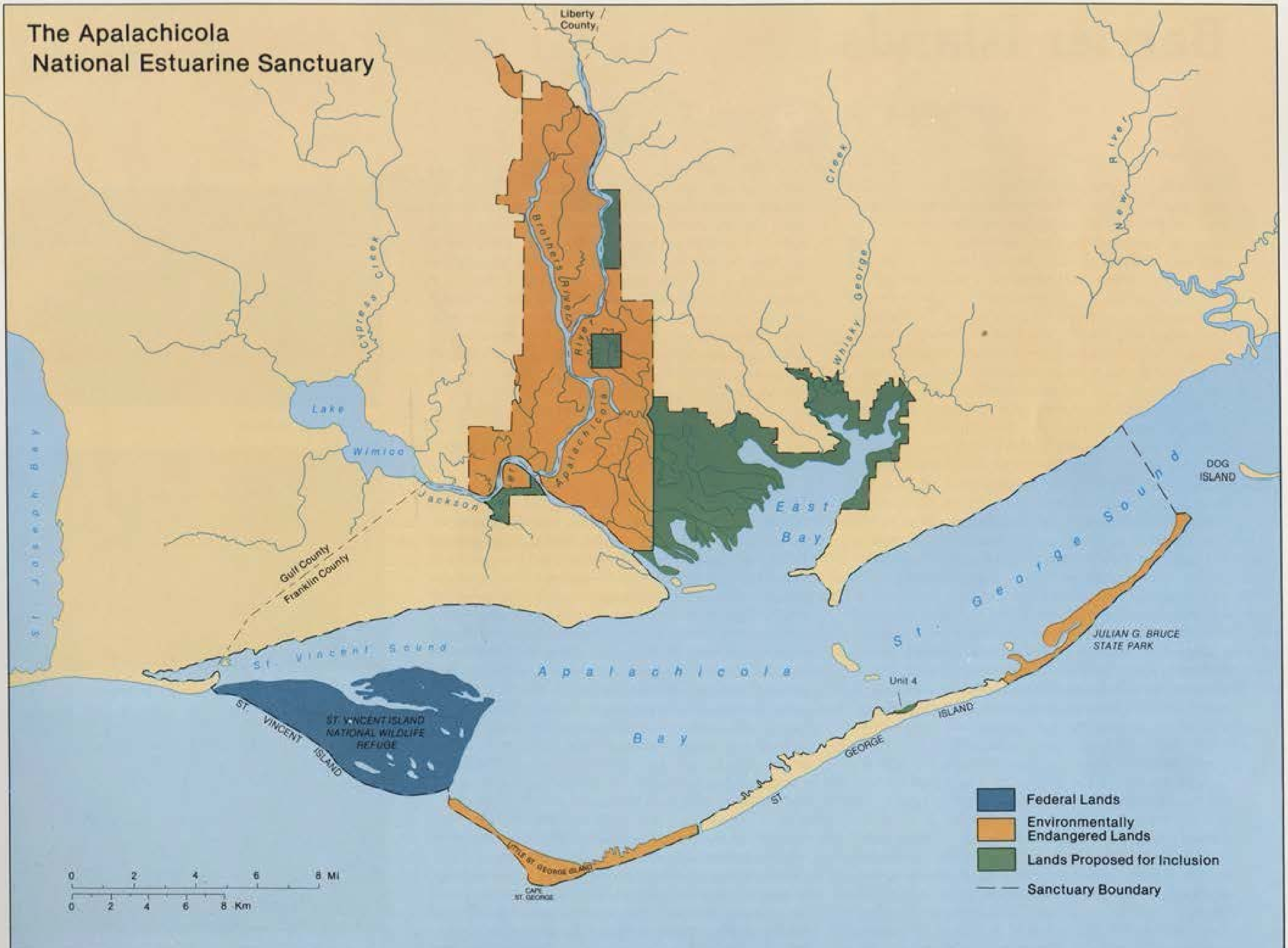
Sanctuary boundaries encompass the lower river flood plain (purchased by the state of Florida as part of an environmentally endangered lands program), Little St. George Island, Unit Four and the existing park on St. George Island, the St. Vincent Island National Wildlife Refuge, and (state owned) submerged lands and estuarine waters. With the proposed (ongoing) purchase of the fringing wetlands of East Bay (with a $1.8 million acquisition grant from the federal Office of Coastal Zone Management and matching funds from the state Environmentally Endangered Lands Program), the estuarine sanctuary will include over 190,000 acres of highly productive portions of the lower Apalachicola drainage system. As part of this program, negotiations are under way for public acquisition of major parts of the lower Apalachicola flood plain. The Nature Conservancy and the Northwest Florida Water Management District are currently engaged in discussions with private landowners which could lead to public ownership of the bulk of the Apalachicola wetlands from the gulf to Blountstown, Florida. Such purchases would be part of the "Save Our Rivers" program financed by the state of Florida. The ring of publicly owned lands that now surrounds the lower river and estuary, together with the proposed purchases, will form an important part of a comprehensive management program currently being implemented.

The Apalachicola National Estuarine Sanctuary will play a key role in the effort to use scientific understanding to manage an important natural resource. This effort includes the ongoing, long-term research programs of Florida State University and the Florida Sea Grant College, local comprehensive planning programs, and various educational initiatives at the local, regional, and state levels. With time, the sanctuary headquarters, which includes laboratory space, administrative offices, and educational facilities, should serve as a focal point for future research, education, and resource management in the region. The Apalachicola sanctuary represents an ambitious attempt to understand the interrelationships of a series of habitats—fresh- and brackish-water marshes and bayous, river flood plain, barrier islands, submerged vegetation, soft-bottom areas, and oyster bars—and to apply this knowledge to the maintenance of one of the most highly productive estuaries in the country. The combination of strong local support, a comprehensive scientific data base, and continuous assistance from state and federal agencies has contributed to a broad-based application of scientific principles to resource management in the Apalachicola basin. The key to the future success of the sanctuary will be the continuous cooperation of local, state, and federal interests.

Winter flooding of the Apalachicola River

Upland wetland system of the Apalachicola River

Upper East Bay marshes


The Apalachicola
National Estuarine Sanctuary
Liberty County
Cypress Creek
Brothers River
Apalachicola River
Lake Wimico
Jackson
Gulf County
Franklin County
St. Joseph Bay
St. Vincent Sound
Apalachicola Bay
East Bay
Whisky George Creek
New River
St. George Sound
DOG ISLAND
JULIAN G. BRUCE STATE PARK
Unit 4
ST. GEORGE ISLAND
ST. VINCENT ISLAND
ST. VINCENT ISLAND NATIONAL WILDLIFE REFUGE
LITTLE ST. GEORGE ISLAND
CAPE ST. GEORGE
0 2 4 6 8 Mi
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Federal Lands
Environmentally Endangered Lands
Lands Proposed for Inclusion
Sanctuary Boundary

Barrier Islands

The barrier island fringe of the Apalachicola Bay system is an environmentally sensitive portion of the estuarine complex. The response of various land protection agencies, public and private, attests to this sensitivity. St. Vincent Island, as a protected national wildlife refuge, is managed by the U.S. Department of the Interior. Considerable portions of Dog Island to the east have been acquired by the Nature Conservancy, a private, nonprofit land preservation organization. Both islands have no permanent connection with the mainland and are considered an integral part of the overall (regional) management program. Little St. George Island was recently purchased by the state of Florida under the Environmentally Endangered Lands Program (EEL) and is now administered by the Florida Department of Natural Resources. Northeastern portions of St. George Island (Unit Four) border one of the richest oyster bars of the bay, the so-called East Hole. Recently, the Trust for Public Land, Inc., also a private, nonprofit land preservation organization, preacquired and held Unit Four for state acquisition. Such acquisition was recently carried out, and Unit Four is now part of the National Estuarine Sanctuary. Together with Little St. George Island and the state park on the eastern end of St. George, such lands will now be managed by state agencies. This arrangement leaves the central portion of St. George open to private development.

St. George Island, the strategically placed ribbon of land that borders Apalachicola Bay and St. George Sound, is the key to an important part of the productivity of the Apalachicola estuary. This island, connected to East Point by a publicly owned bridge, is considered the most likely prospect for residential and commercial development in the region. Approximately 30 miles long and averaging less than one-third mile wide, St. George consists of about 7,340 acres of developable land and 1,200 acres of marshes. Of recent geological origin, St. George is completely surrounded by salt water. Freshwater input to the island comes solely from local rainfall. The surface soil is composed of medium to fine sand, which, together with a silty clay layer about 25 to 30 feet below the surface, forms the geological basis for a shallow lens of fresh water that is in contact, at the island borders, with the surrounding saline water of the lagoon, on the bay side, and the open gulf to the south. The main island drainages are determined largely by local rainfall, evapotranspiration, and physical features of the island. St. George is a critical component of the physiography of the bay system and a prime determinant of salinity distribution, current structure, productivity, and biological organization of the adjoining lagoon (or bay) complex.

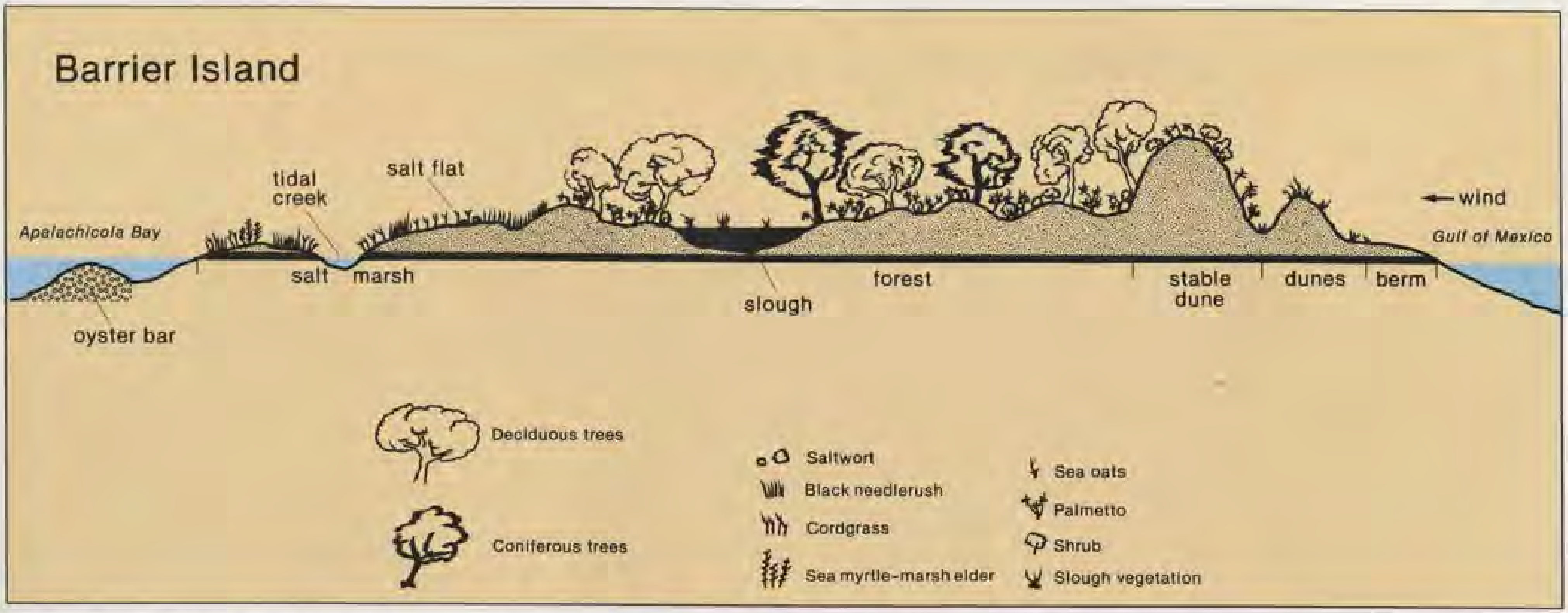
The physiography of St. George Island is constantly changing as a result of wind, waves, and storm action. Land and water resources are extremely limited on the island, and the indigenous biota reflects these limitations. The gulfward dune system is protected from wind erosion by various forms of vegetation with rhizomes (or roots) that bind the sand. Farther inland, various unique forms of trees and shrubs occur with successive groves of live oak trees and rosemary bushes, slash pine–scrub complexes, and pine flatlands. Sloughs, such as occur in the Nicks Hole area, are characterized by various forms such as laurel oak, live oak, wax myrtle, buttonwood, and saw grass. Such areas merge with the highly productive salt marshes that line the shallow, low-energy lagoon side of the island and are dominated by cord grasses, needlerush, marsh elder, and false willow. The composition and distribution of island vegetation are thus a product of what is essentially a marine environment.

According to a biological review of St. George Island (Livingston, Clewell, Iverson, Means, and Stevenson, 1975), the known terrestrial and freshwater vertebrate fauna (exclusive of fishes and birds) is composed of 31 known resident

Eastern St. George Island

Apalachicola Bay at dawn

St. George Island



species: 6 amphibians, 21 reptiles, and 4 mammals (plus 3 domestic or introduced species). These species form three major associations that occur in specific island habitats: 1) terrestrial communities inhabit the scrub zone, slash pine flatwoods, and slash pine-scrub zones; 2) aquatic communities inhabit freshwater bodies, including ponds, sloughs, and temporary wet sites; and 3) salt marsh organisms live within the marsh systems lining lagoonal portions of the island. Because of the limited range and extent of their habitats, such organisms are highly susceptible to eradication due to human activities. Animals living in freshwater bodies are especially vulnerable. Survival of many species will depend on the persistence of the native terrestrial vegetation in areas large enough to maintain an effective population size. Draining, ditching, and construction could lead to the almost total extirpation of organisms dependent on the limited freshwater habitats of the island. Increased habitat destruction could also endanger nesting sea turtles which periodically use the island for their reproductive functions. St. George Island also serves as part of an important flyway for a wide variety of birds. During spring flights, trans-gulf migrants often use the island as a first landfall or shelter during periods of adverse conditions such as cold fronts, strong head winds, and heavy rains. This rich and important fauna numbers thousands of individuals, representing over 250 species, during certain periods of the year.

Offshore there is a wide variety of marine fishes, signifying a substantial sport fishing potential for the island which also acts as protection for the lagoonal or inshore estuarine habitats. Such areas benefit from the marsh productivity and associated grassbeds which line the back side of the island. Drainages such as Nicks Hole are important nurseries for oysters, penaeid (edible) shrimp, and various finfishes. The island acts as a barrier to the direct release of the nutrient-laden fresh water entering the bay from the mainland. As such, the estuary becomes a nutrient trap and the dilute sea water discourages the entrance of various offshore predators, thus allowing the rapid growth and development of juveniles of many of the commercially important species. Such organisms are adapted to low or varying salinities. In this way, St. George Island is an important component of the estuarine area.

The barrier islands of the Apalachicola Bay system are thus of extraordinary value as habitat and food for amphibians, reptiles, birds, and mammals. The islands support various sport and commercial fisheries. St. George Island is a microcosm of the physical, environmental, legal, and economic problems currently found throughout Florida's coastal zone. Just how much development will occur and how such development will eventually affect the estuary will depend to a considerable degree on local support and implementation of environmentally feasible land management programs. Such programs, while protecting the abundant natural resources, should be compatible with the inevitable economic growth of the region.

Depths, Tides, and Currents

The Apalachicola estuary is relatively shallow, with depths averaging 6 to 9 feet. The distribution of depth in the bay is partly natural and partly the result of dredging. The Gulf Intracoastal Waterway (GICW) is the primary site of dredging and spoil disposal in the bay. This dredged channel extends south from the mouth of the river, then east through Apalachicola Bay to St. George Sound. Two-Mile Channel is maintained in the bay just south of Apalachicola and is connected with the GICW near the river mouth. Sikes Cut is maintained to a depth of 10 feet. Other less significant dredged areas include the East Point entrance and parallel channel, the Link Channel (just inside Little St. George Island), and the Apalachicola municipal boat basin. Naturally deep areas include portions of Indian Pass (14-16 feet), West Pass (40-50 feet), and East Pass (20-22 feet).

Tidal ranges vary from less than half a foot at Dog Island to nearly a foot at East Pass. Apalachicola Bay is thought to straddle a transitional region between the diurnal (one high tide each day) tides of west Florida and the semidiurnal (two high tides each day) tides of the Florida peninsula. The estuary has been characterized as unsymmetrical and semidiurnal except during periods of strong winds when tides appear to be diurnal. Such tides are also influenced by the main entrances and the smaller passes. Wind, however, is the primary modifying factor of water movement in the bay. The tidal and wind-driven currents of the bay system can be quite strong. Bay current velocities are normally 1.5 to 2 feet per second although velocities in the passes may reach up to 3 feet per second. Since the bay is relatively shallow, the tidal and wind-driven currents tend to keep the system well mixed and relatively active. Such tidal energy is an important part of the high level of biological productivity in the Apalachicola estuary.

While the hydrodynamics of current structure are little affected by river flow except in the im-

The net flow of water in the Apalachicola Bay system was averaged over a complete tidal cycle. This map was made from a computer generated model verified by field sampling.

Data courtesy of Dr. B.A. Christensen, University of Florida mediate receiving areas, the effects of wind on water level and movement are pronounced, with associated effects on the distribution of salinity in the estuary. Air circulation over the gulf is usually anticyclonic during the year although strong continental air masses often move through north Florida during winter. Storms tend to move across the gulf from west to northeast at this time. Tropical storms are most prevalent during summer and early fall, with a likelihood of a hurricane in the northeastern gulf of about once every 17 years. General wind direction is predominantly from the south from March through June and from the north or northeast during the fall and winter. Although there is wide variability in wind velocity and direction at any given time, such trends tend to hold up from year to year. Southerly winds augment astronomical tides to the point where high water is maintained without appreciable ebb flows for varying periods of time. Because of the shallowness of the estuary, the wind factor can cause rapid changes in the usual tidal pattern and the current distribution in the bay system. It is thought that this estuary is wind-dominated in terms of flushing and current generation. Wind is up to three times more effective than tides in the determination of current strength and direction.

The various passes are important in the determination of current structure and water mass flow in the Apalachicola Bay system. Such processes have been studied by B.A. Christensen of the University of Florida and his students. The major outlet for the low salinity water of the estuary is West Pass. Net flows tend to move to the west from St. George Sound into Apalachicola Bay, where they merge with water moving out of East Bay. When under the influence of high velocity winds from the east or west, most of the water moves through West Pass. There is also a net westward flow through St. Vincent Sound, although movement through Indian Pass may be retarded by the Picoline Bar. Salinities in this area are relatively stable, although currents and the associated salinity regime can be affected by excessive land runoff or river flow.

LANDSAT image of the Apalachicola estuary

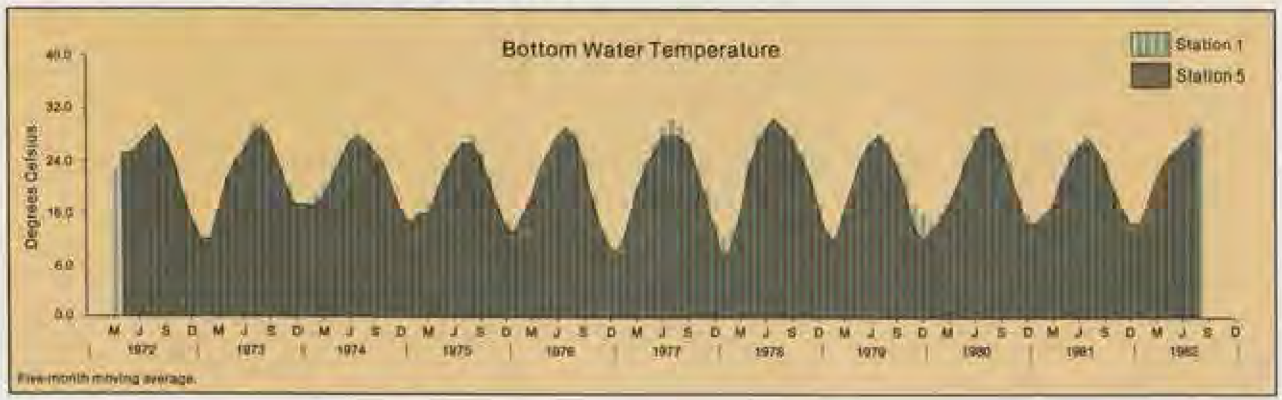
Temperature and Salinity

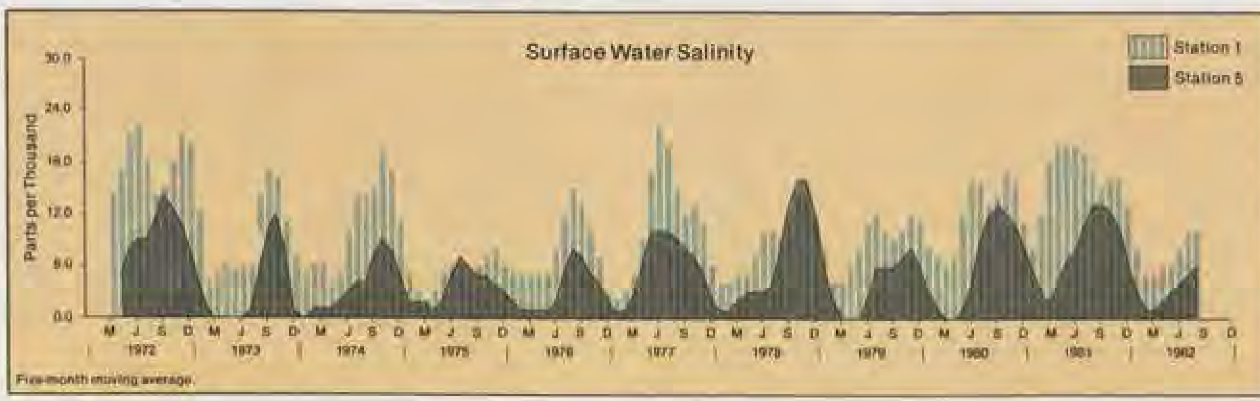
Temperature is an important ecological factor in most aquatic systems. Various organisms are adapted to specific temperature levels and ranges. Water temperature in the highly active estuarine waters usually follows closely the air temperature. Daily temperature variation approximates 1 °C to 3 °C and varies little from area to area in the estuary at any given instant. Vertical temperature stratification is minimal. Peak temperatures occur during July and August while temperature minima occur during January and February. (For locations of permanent sampling stations used by the Florida State University Aquatic Study Group, see map, p. 11.) Summer temperature peaks vary little from year to year although there is considerable annual variation in winter minimum monthly average temperatures. During the 1970s, the lowest winter temperatures occurred during the 1976–1977 season. The seasonal range during such periods was 28 °C (from 5 °C to 33 °C). Thus, the south temperate Apalachicola estuary undergoes regular periodic changes in temperature, which span a considerable range in any given seasonal cycle.

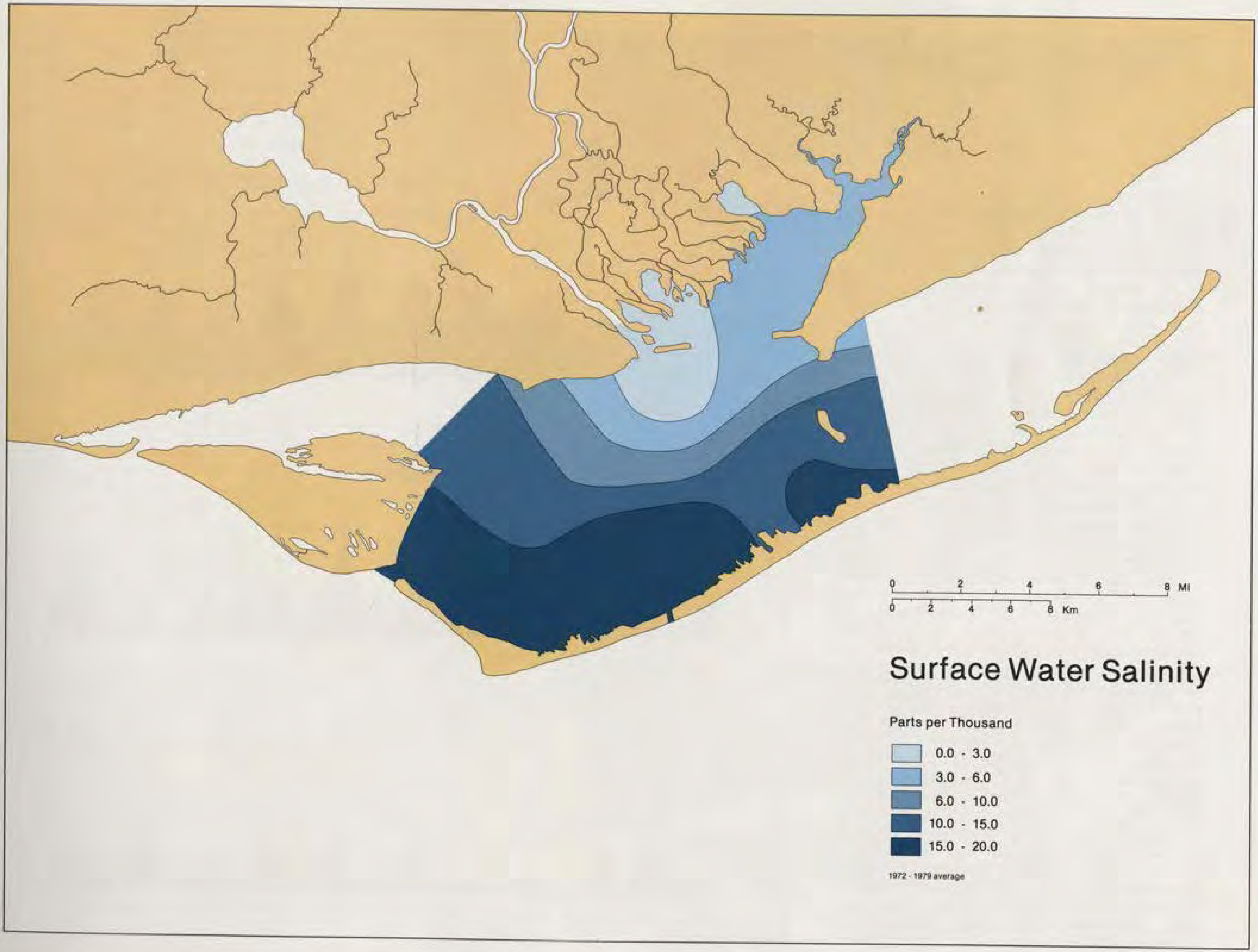
Salinity (the dissolved salt content of the water) is the single most important determinant of the distribution of organisms in the estuary. The open gulf salinity approximates 35 parts per thousand; however, land runoff dilutes such salinity in the estuary. This lowered salinity prevents most organisms that inhabit either the open gulf or freshwater areas from moving into the estuary. Relatively few species are able to maintain their normal body fluids (i.e., osmoregulate) in the extremely variable salinity of the estuary, and consequently the salinity gradient is a primary determinant of the estuary's biological organization. Euryhaline organisms (those adapted to the highly variable estuarine salinity levels) are often free of predation by gulf species, making the estuary a nursery or sanctuary for young or developing forms of salt-tolerant marine life.

Salinity in the Apalachicola estuary follows definite seasonal patterns, which are primarily determined by fluctuations of river flow. Peak salinities usually occur during summer-fall periods. Low salinities are noted in the estuary during winter and spring months of high river flow, with secondary reductions in East Bay salinities during periods of high local rainfall. Unlike temperature, salinity shows distinct latitudinal gradients, with the lowest salinities at the mouth of the Apalachicola River and upper East Bay. The Nicks Hole slough drainage also has an effect on the salinity distribution in the estuary. Seasonal vertical stratification of the salinity in the estuary is most pronounced in deep areas and those parts of the bay that are most affected by river flow. The highest salinities with the least temporal variation were found just inside Sikes Cut, the man-made pass that allows highly saline gulf water into the bay.

Salinity, through the osmoregulatory stress on indigenous species, is the master factor in the biological organization of the estuary and consequently is critical in determining the distribution of organisms in the Apalachicola estuary.



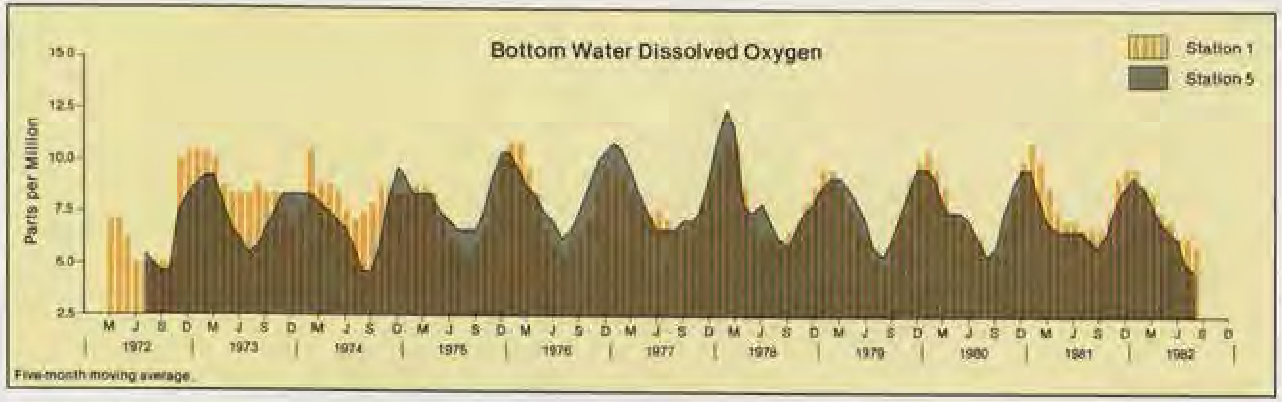


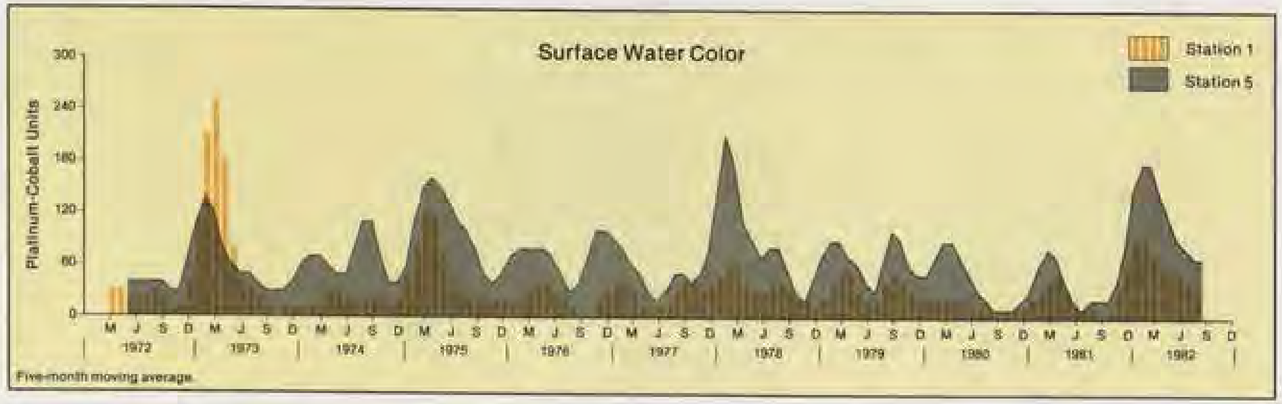

0 2 4 6 8 MI
0 2 4 6 8 Km
Surface Water Salinity
Parts per Thousand
0.0 - 3.0
3.0 - 6.0
6.0 - 10.0
10.0 - 15.0
15.0 - 20.0
1972 - 1979 average

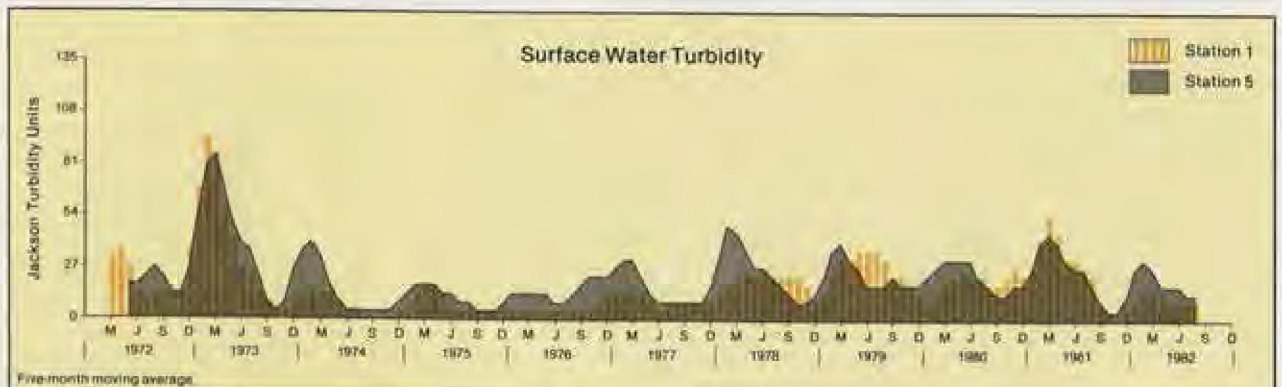
Water Quality Features

Water quality characteristics are an integral part of the habitat features of the Apalachicola system. Dissolved oxygen (DO), color, and turbidity are physical and chemical measures of water quality which determine key biological processes in the estuary such as primary productivity, predator-prey interactions, and food web functions. As such, the spatial and temporal distribution of water quality features is an important part of the characterization of the estuary.

Dissolved oxygen is an important habitat feature in freshwater and estuarine systems. Water holds far less oxygen than air; consequently, the DO levels in estuaries are often near threshold levels for some forms of life. Concentrations less than 4 parts per million over a prolonged period are usually too low for a balanced biological community. However, there is considerable natural daily and seasonal variation of dissolved oxygen levels. High plant productivity often leads to high DO concentrations. The lowest concentrations in the estuary usually occur during early morning hours (because of the combined nocturnal respiration of plants and animals, and the cessation of photosynthesis by oxygen producing plants). Temperature also controls the amount of oxygen in water; consequently, during summer-fall months when temperature reaches peak levels, dissolved oxygen usually is at its lowest levels. When water temperature goes down during the winter, dissolved oxygen often reaches peak levels. The long-term dissolved oxygen record reflects this temperature effect; the highest DO levels occurred during particularly cold winters. There was no indication of cultural eutrophication (nutrient enrichment due to pollution which leads to low DO levels) in the estuary over the 11-year period of observation. The spatial distribution of average dissolved oxygen in the estuary reflects drainage and circulation patterns. The highest DO levels were found in enclosed bodies of water in East Bay and in por-





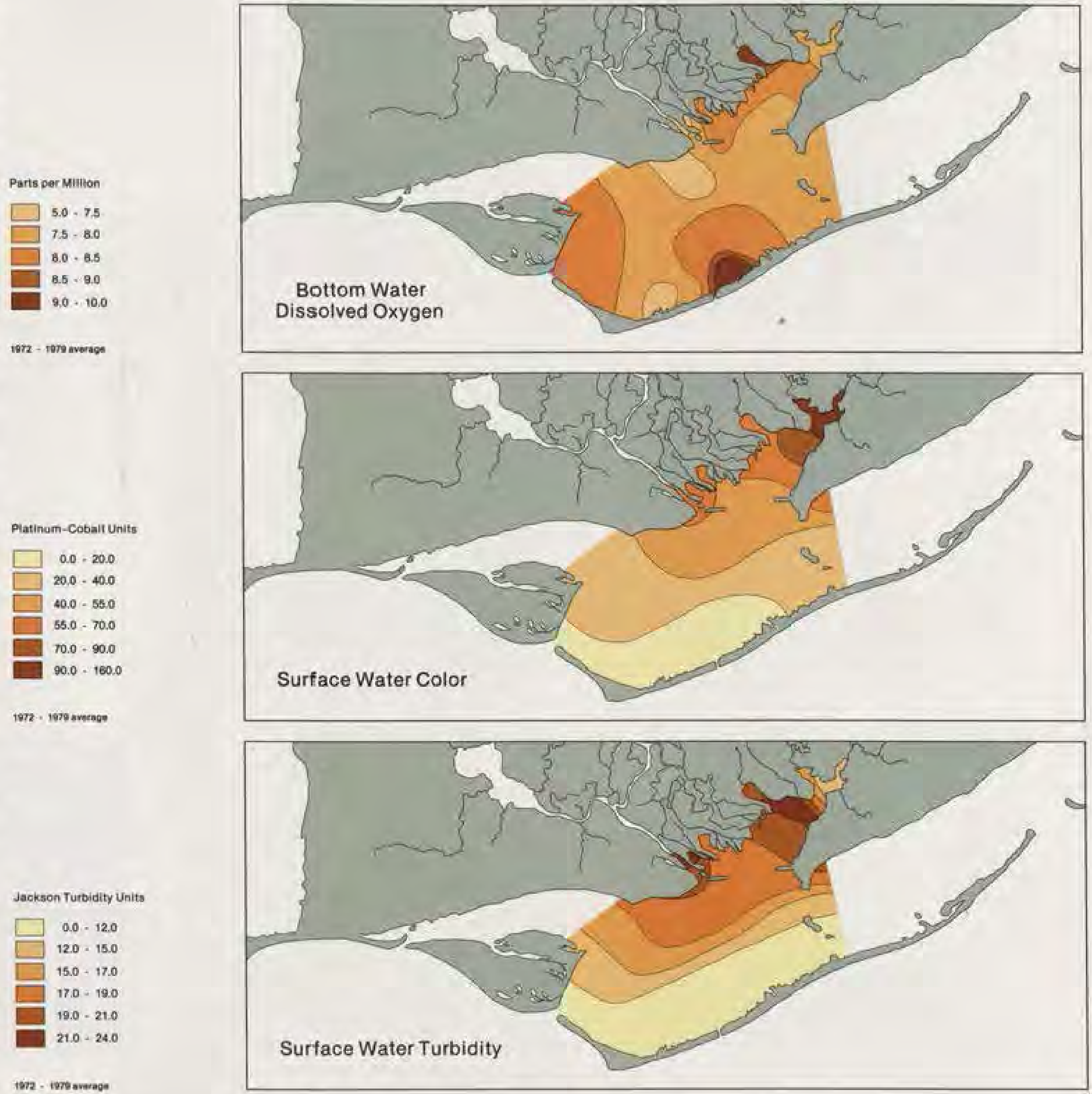


tions of the Nicks Hole drainage off St. George Island. These appear to be highly productive areas.

Color is a measure of dissolved substances in the water column, while turbidity indicates the level of suspended particulate matter. The spatial and temporal distribution of both factors reflects the pattern of freshwater runoff in the bay, and, in turn, determines the pattern of light penetration in the water. Both color and turbidity tended to peak during winter–early spring periods of high river flow and overland runoff. During the major flooding in the winter of 1973, color and turbidity reached their highest levels in Apalachicola Bay (station 1). The high levels of color in East Bay (station 5) could have been the result of forestry management practices in Tates Hell Swamp. East Bay was generally more highly colored than Apalachicola Bay because of its proximity to the swamp drainage. The upland swamps are often characterized by standing water of low pH and high color. Turbidity appeared to follow river flow fluctuations, while color was associated with runoff in areas draining specific upland areas around the estuary. Clear gradients of both color and turbidity were evident gulfward from the major overland drainages of the Apalachicola River and Tates Hell Swamp.

Various studies over the years indicate that the river water draining into the bay is relatively free of pesticides and heavy metal contamination. Such contaminants, if present, are known to accumulate in the sediments and animals of the estuary.

Overall, the general distribution of these water quality parameters during the 11-year monitoring program indicates that the Apalachicola estuary has not been adversely affected by man's activities in the region except in areas adjacent to population centers.



Rainfall and River Flow

In an estuary, various important habitat characteristics depend on the quantity and quality of freshwater runoff. The timing of runoff events is as important as the mass flow itself. Water movement represents an energy subsidy into the bay system. Dissolved nutrients and particulate organic materials are moved into the estuary from upland drainage areas. At the same time, excretory products are removed from various sedentary (stationary) organisms. Water is, in fact, the circulatory system for the river-estuary and performs the various functions that are usually associated with blood in an individual organism. The origin and movement of fresh water into the estuary through river flow and local rainfall are thus important features of the Apalachicola Bay system and are associated with functions such as nutrition, metabolism, circulation, and excretion at the organismal and community levels.

Mean annual rainfall in the Apalachicola basin is about 60 inches (150 cm), although distribution varies from one area to another. For instance, within the Apalachicola delta, the region west of the river receives almost one-third less rainfall than eastern areas such as Tates Hell Swamp. Local (Apalachicola) rainfall usually reaches peak levels during summer-fall periods with secondary increases during late winter and early spring. A seasonal drought usually occurs in October and November. While such seasonal rainfall cycles are relatively regular, there is considerable short-term and long-term variability in local precipitation. In addition to the usual day-to-day variation, there are also extreme annual changes in rainfall, although various statistical analyses have shown broad 5-7 year cycles of recurrent peak rainfall. Thus, within the natural variability of the spatial and temporal distribution of rainfall in the north Florida region, there are general seasonal and annual trends in precipitation that are an important part of the cycling of the estuary.

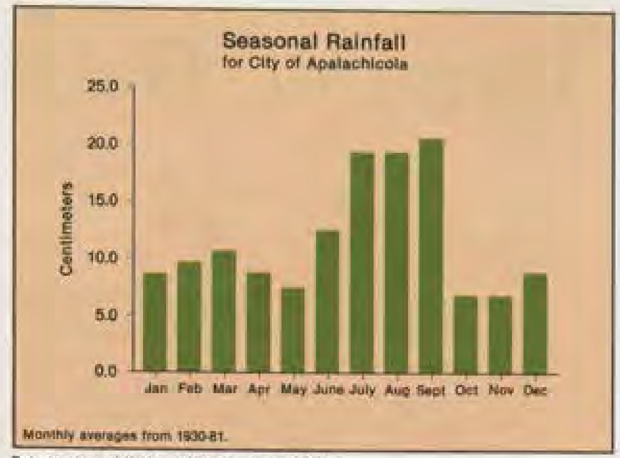
Only 11.6 percent of the tri-river drainage system lies within Florida. Consequently, Georgia rainfall is a more important determinant of Apalachicola river flow than Florida rainfall. In Georgia, precipitation peaks in March and July, with drought periods during the fall of the year. Such a seasonal pattern coincides with the flow characteristics of the Apalachicola River. This river is one of the 28 great rivers of the United States and is the largest river in Florida in terms of flow rate. River flow peaks from January through April probably as a result of reduced evapotranspiration in the tri-river flood plain during the winter and increased rainfall in Georgia. Such flooding is timed with the Georgia rainfall peaks and follows 6-7 year cycles. River stage fluctuations vary considerably from the upper to the lower river, with the narrowest ranges, from peak to low, occurring in downstream areas. Seasonal low flows usually occur from September through November. In this way, Apalachicola river flow originates largely in upstream flood plain areas of Georgia, and observed seasonal flow patterns are the result of a complex network of interacting factors, which include the trends in a range of local precipitation, evapotranspiration rates, flood plain characteristics, and relative flow inputs along the tri-river drainage system.

The hydrology of the Apalachicola watershed depends on certain features of the drainage basin. The upper drainage system contains various types of creeks and streams, some of which are clear (from the Marianna lowlands karst plain) while others are highly colored with organic acids (from the flatwoods associations). The Grand Ridge area, bounded by the Chipola and Apalachicola rivers, is associated with numerous springs. Between the city of Bristol and Torreya State Park, there are "steepheads" or amphitheater-shaped heads of valleys with very steep walls. The Marianna lowlands form a sponge-like karst plain with numerous cave systems. Swamps predominate in the Apalachicola lowlands, a flatwoods region that harbors various endemic species of plants and animals.

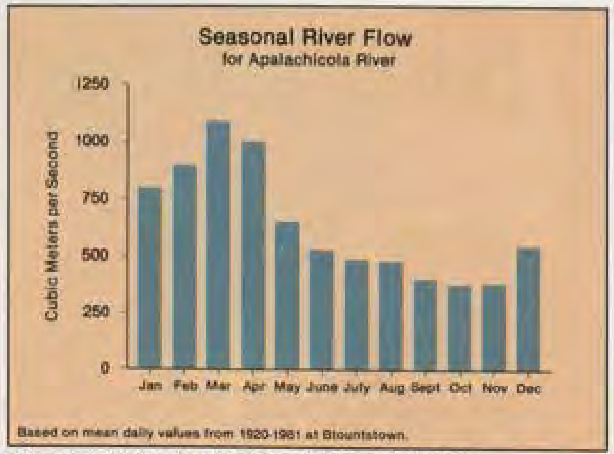
The high physical diversity of the habitats along the Apalachicola flood plain, together with the rather mild climate, has lead to an extremely rich terrestrial and aquatic biota. The river flood plain is a major center of primary productivity in the region. Scientists of the U.S. Geological Survey have carried out extensive studies in the Apalachicola flood plain (Elder and Cairns, 1982). Emergent plant life within the flood plain is an important modifying feature of the freshwater (riverine) runoff in terms of volume and water quality. The wetlands that line the river act like a sponge, which absorbs the excess or flooding water and subsequently releases it over a prolonged period. Thus, the wetlands modify and neutralize the flash flood potential of the basin. In addition, the vegetation acts like an enormous filter for various nutrients and impurities such as pesticides and other toxic agents. In this way, the flood plain vegetation is extremely important in terms of modifying both the quantity and quality of the freshwater input into the estuary. In addition, such plant life is enormously productive in terms of the manufacture of organic matter, which serves as a source of food for terrestrial and aquatic organisms throughout the drainage basin (Mattraw and Elder, 1980, 1982). These plants are also a major habitat for such organisms, another reason why the Apalachicola Valley is so rich in wildlife.

The rainfall patterns and river hydrology form the basis for the rich wetlands vegetation. They are, in turn, affected by such plant life through evapotranspiration, nutrient uptake, and transformation of available inorganic compounds into organic matter that serves as food for wildlife (terrestrial and aquatic) throughout the entire region. Bottomland hardwood species such as tupelo, gum, and cypress predominate in the upper delta. The lower delta is characterized by the shortleaf pine and titi of the coastal dunes, and the slash and longleaf pines of the coastal plain pinelands. The fresh-and brackish-water swamps and marshes of this region are characterized by the tupelo-ogeechee-tupelo association, the tupelo-bald cypress association, the water tupelo-swamp tupelo association, and various forms of marsh grasses. The exact distribution of such plant groups is determined by water depth, duration of inundation and saturation, water level fluctuations, flood plain topographic relief, and specific drainage characteristics (Leitman, Sohm, and Franklin, 1982). It all adds up to the largest forested flood plain in Florida and one of the last unbroken bottomland hardwood systems in the United States.

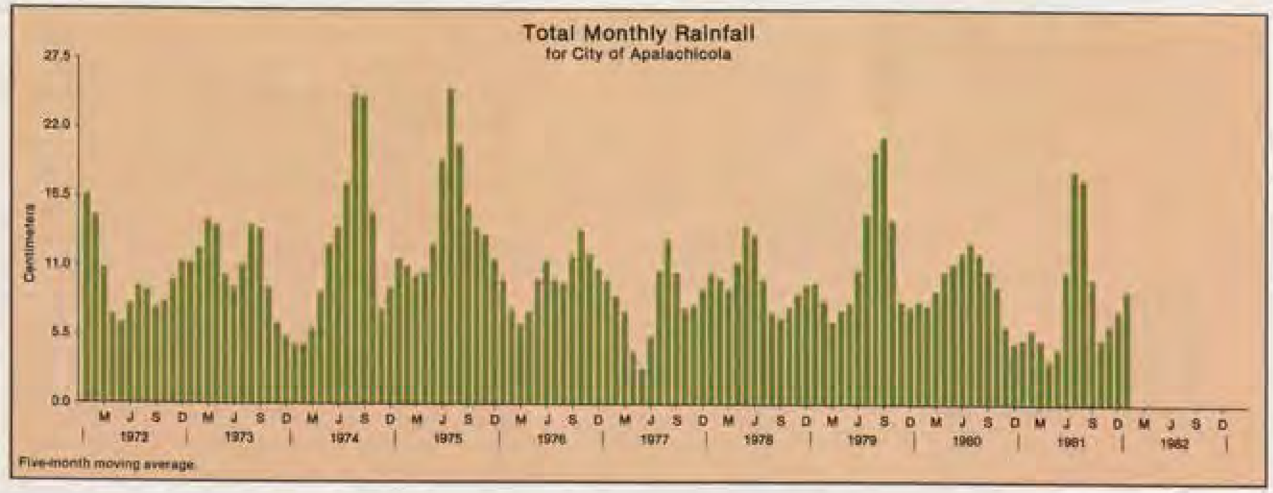
In sum, the river drainage acts like a vast, slow-motion circulatory system whose seasonal pulses of flooding account for countless interactions among the diverse and highly productive terrestrial and aquatic components. The final result of such interactions in space and time is the pulsed flow of clean, nutrient-rich fresh water to the Apalachicola estuary. As a result, the bay system is but one part of the vast flood plain of the tri-river drainage area. The wetlands vegetation along the river helps to nourish and support the Apalachicola estuary.



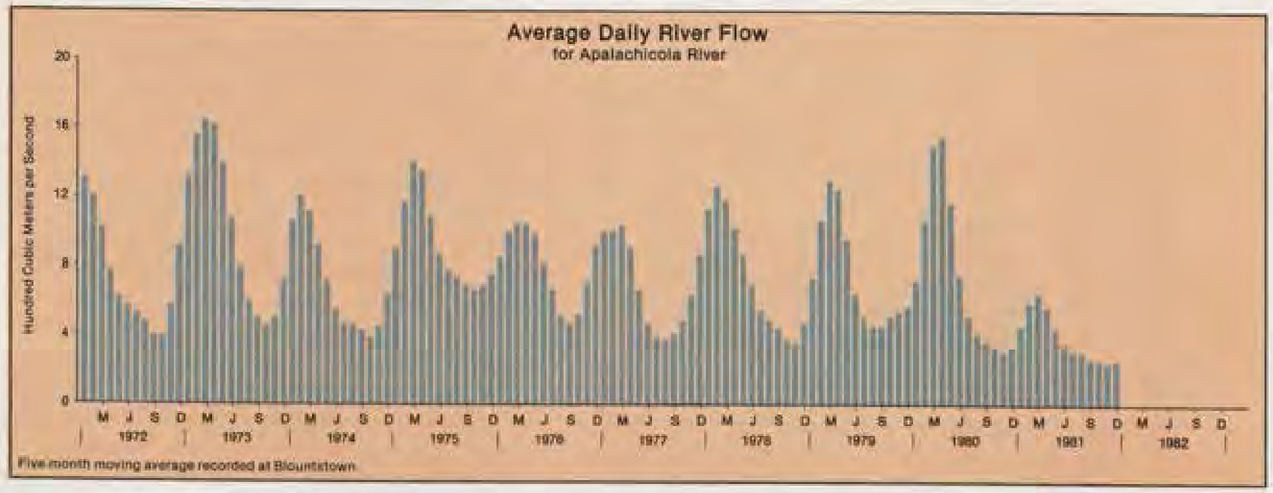
Data courtesy of National Climate Center, N.O.A.A.



Data courtesy of United States Army Corps of Engineers, Mobile District

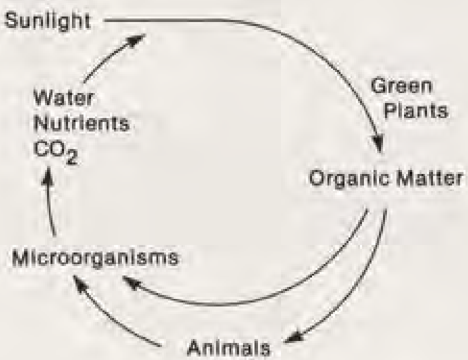


The Apalachicola River



Nutrients and Organic Detritus

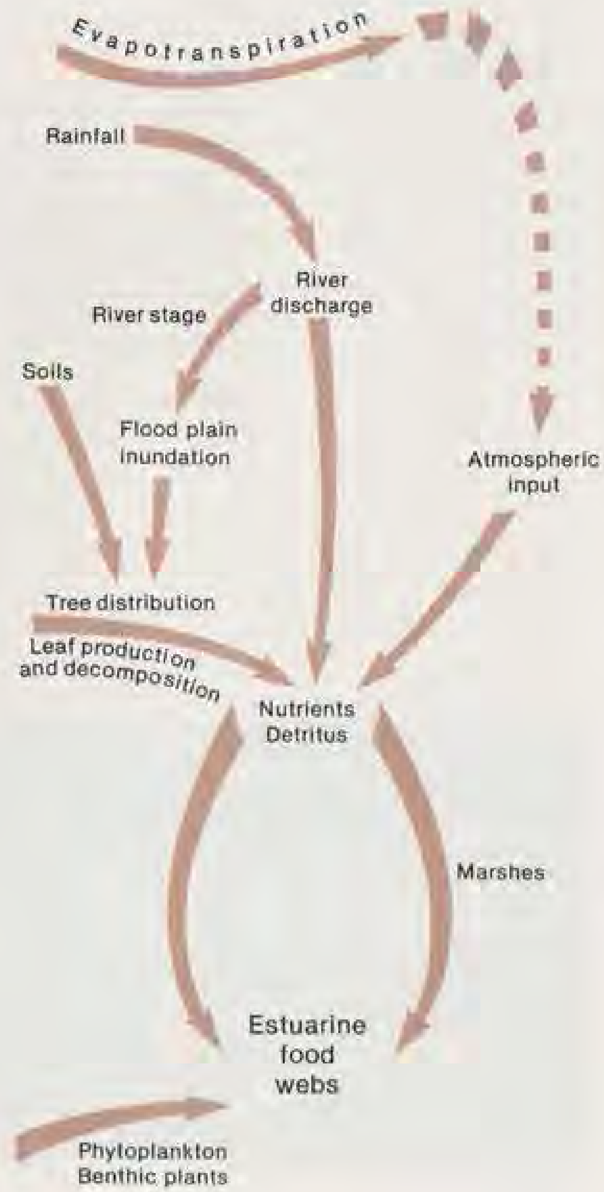
Green plants produce organic matter from the sun's energy (light) through the process of photosynthesis. Most biological systems on earth depend on this process for food. The organic matter is used by animals and, eventually, is broken down by microbes into its components. Such breakdown products include inorganic nutrients (nitrogen and phosphorus compounds) and are necessary for further production of organic matter by plants. Thus, the plant-animal-microbe association is in the form of a basic cycle.



Aquatic systems such as rivers and bays depend on production both outside the system (i.e., allochthonous: leaf matter, organic detritus) and within the system (i.e., autochthonous: phytoplankton and bottom plants). Organic matter and nutrients from land areas are washed into the aquatic system by runoff and are then utilized by aquatic organisms for their energy needs. Nutrients are used by the plants within the aquatic system for primary productivity, while organic matter is broken down by microorganisms. The microbes may then be consumed directly or indirectly by the indigenous organisms. Although such nutrient interactions are extremely complex, the fundamental cycle remains the basis for most ecosystems on earth.

The Apalachicola estuary is inextricably linked to the river and its flood plain for the input of dissolved nutrients and organic matter. Dead leaves, twigs, and other formed products are called particulate organic matter or debris. Water is usually the transport medium for such input. The Apalachicola is a large, alluvial river with substantial sediment loading which depends on seasonal discharge rates. Water movement keeps particles, such as sediment and organic detritus, in suspension. The winter-spring flooding of the river into surrounding wetlands is an important part of the nutrient and detritus cycling within the system. Particulate organic matter is moved out of the flood plain and into the river and estuary. In turn, the distribution of upland or wetlands vegetation in the flood plain depends on such overflow for its continued production of organic matter. Thus, the land-water interface in the wetlands depends on the river for continued production of particulate organic matter, which is then transported to downstream aquatic areas. In addition to the flood stage height, there are various factors that determine how nutrients and detritus are distributed in the river-bay system. The heights of surrounding land, soil types, existing flood plain water levels, and drainage characteristics are primary determinants of the dynamic river interactions. Such interactions thus control the distribution of the flood plain vegetation and the movement of dissolved and particulate substances into the receiving river and estuary.

One key to the nutrient-detritus cycling in the Apalachicola River and estuary lies in the production and decomposition of organic matter in the flood plain wetlands. There is a mean litter fall of 800 grams (1.8 lbs.) of organic matter per square meter in the Apalachicola wetlands, which amounts to over 360,000 metric tons per year. This relatively high production level is higher than that demonstrated in other temperate forests and is comparable to rates found in equatorial forests.

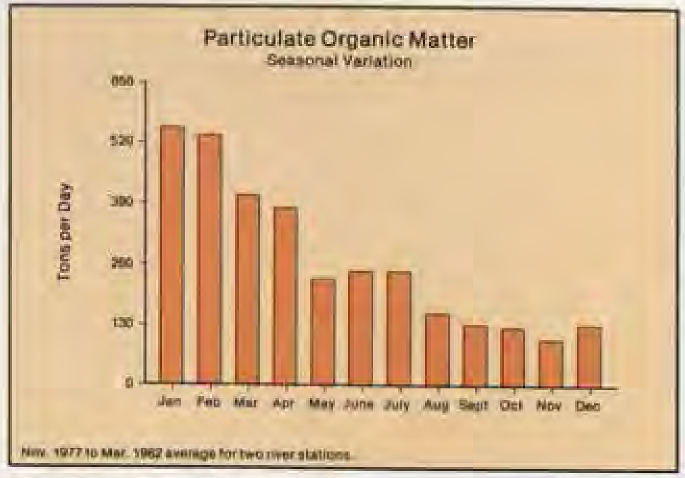


In general, levee vegetation produces more litter fall than swamp vegetation. Tupelo, cypress, and ash trees are particularly productive. Such production peaks during the late autumn. Subsequent seasonal flooding then mobilizes the produced substances out of the wetlands. At the same time, such flooding immerses litter fall and enhances decomposition rates. Thus, river flooding is important in the transfer of dissolved nutrients and detritus into the river and estuary.

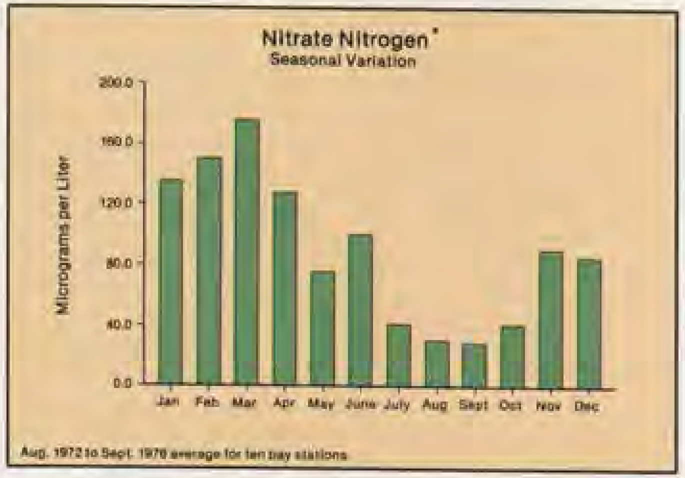
In addition to the wetlands, there are various other sources of nutrients and detritus for the system, including headwater inflow, tributary and groundwater inflow, upland productivity, atmospheric fallout, and productivity within the aquatic system itself. Studies by the U.S. Geological Survey have shown that on an annual basis, the Apalachicola flood plain contributes 214,000 metric tons of total organic carbon, 21,400 metric tons of nitrogen and 1,650 metric tons of phosphorus to the estuary. The timed pattern of seasonal flooding is important to the cycle of detritus flow. Although there is an annual net transport of nutrients into the estuary, the wetlands can, at certain times of the year, act as a nutrient sink (that is, nutrients are taken up by wetlands rather than released). The exact timing of the river flow peak, together with seasonal changes in the wetlands productivity, contributes to the long-term trends of input of nutrients and particulate organic matter into the estuary. Since the Jim Woodruff Dam removes practically all of the particulate matter transported down the Flint and Chattahoochee rivers, the Chipola-Apalachicola wetland area is the primary contributor of organic detritus to the estuary.

While geomorphology of the wetlands basin, upland freshwater cycles, and tidal range of the estuary are all important considerations in the net influx of particulate organic matter into the bay system, various other factors are important in the net transfer rates of nutrients and detritus and the ultimate utilization of such substances by aquatic organisms. Mechanical fragmentation of particles is a more or less continuous process as dissolved nutrients are leeched from the plant material. Chemical breakdown processes include autolysis, hydrolysis, and oxidation. Microbial processing and scavenging comprise an important part of the chemical breakdown of particulate organic matter and the repackaging of nutrients and detritus into forms that are more readily assimilated into the great detrital food webs of the estuary. Colonization of the detritus by bacteria, fungi, microalgae, and protozoans is an important part of the dynamics of nutrient-detritus transfer into the estuary.

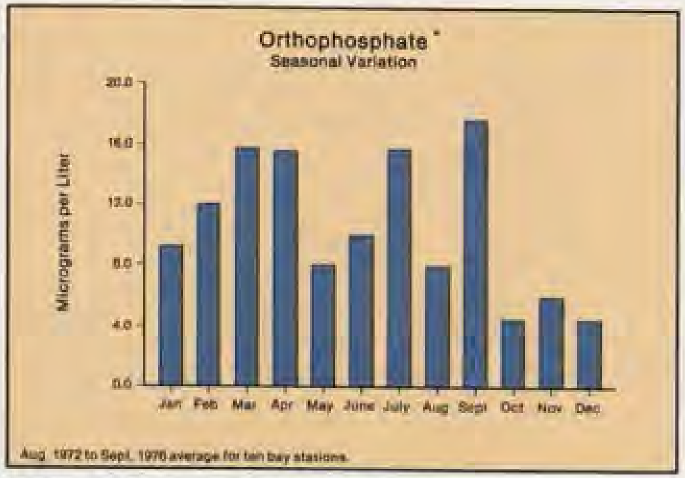
The availability of nutrients and detritus is a central feature of the productivity and biological organization of the Apalachicola estuary. Recent studies by the scientists of the U.S. Geological Survey have shown that the ultimate distribution of such substances is the result of complex interactions of basin physiography, wetlands processes, hydrological events, and physical habitat features. The importance of the river, both as a necessary component of wetlands productivity and as a transport medium for nutrient and detritus flux, should not be underestimated since the ultimate deposition of such formed products in the Apalachicola estuary is directly tied to the seasonal cycles of the upland river system. Wetlands productivity, together with factors such as phytoplankton productivity and the emergent (marsh) and submergent (benthic or bottom) plants or macrophytes, all contribute to the food webs of the Apalachicola Bay system.



Nov. 1977 to Mar. 1982 average for two river stations.



Aug. 1972 to Sept. 1976 average for ten bay stations.



Aug. 1972 to Sept. 1976 average for ten bay stations.

*Data courtesy of Dr. R. Iverson and his students, Florida State University

Phytoplankton

Phytoplankton are microscopic plants that are ubiquitous in estuaries and coastal systems. Because they remain relatively small and dispersed in the water column, these tiny plants are greatly affected by water currents. Phytoplankton transform light energy into organic matter which forms the basis for the planktonic (i.e., phytoplankton-zooplankton) food webs of the estuary. Phytoplankton standing crop (the biomass at a given instant in time) is usually quite low, while phytoplankton primary productivity (organic carbon produced per unit area per unit time) may be extremely high. Phytoplankton productivity in the Apalachicola estuary has been studied by R.L. Iverson and his students, R.H. Estabrook, H.F. Bittaker, and V.B. Myers, at Florida State University.

The concentrations of dissolved organics in the estuary do not vary seasonally, whereas particulate organic matter is transferred primarily during periods of winter-spring river flooding. For instance, during an 86-day flood in 1980, 60 percent of the annual detritus load of the Apalachicola River was transferred downstream. Also, 53 percent of the phosphorus was transported during this period. During summer and fall, there is no correlation between river flooding and detritus flow, while the strongest such associations are found during winter and, to a lesser degree, spring (Livingston, 1981). Thus, the degree and timing of seasonal river flooding are important determinants of detritus movement from flood plain wetlands into the river and estuary. Surface nitrogen and phosphorus concentrations in the estuary also peak during winter periods of increased river flow. However, such nutrient concentrations are also influenced by phytoplankton utilization in the spring and summer and mobilization of phosphorus from the sediments resulting from wind action. In this way, while nutrient concentrations are positively correlated with river discharge, various factors such as temperature, phytoplankton productivity, depth and width relationships, and flushing rates all contribute to the observed levels of nutrients such as nitrate and orthophosphate in the estuary. The nutrients thus are inextricably tied to cycles of phytoplankton productivity in the bay system.

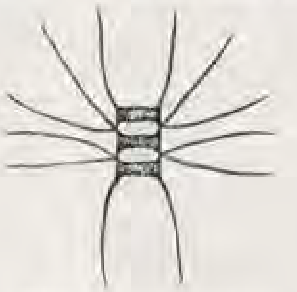
Despite extensive studies of nutrient distribution in the Apalachicola drainage system, our understanding of this extremely complex subject remains very incomplete. The connection between upland nutrient sources and nutrient recycling within the estuary remains virtually unknown. For instance, different kinds of leaf matter from wetlands vegetation are decomposed by microbes at different rates. Tupelo and sweetgum leaves break down completely in six months, whereas bald cypress and diamond-leaf oak are resistant to decomposition. Phosphorus and nitrogen are leached out of the leaf within a month after entering the aquatic habitat, while carbon and total biomass are broken down over the entire decomposition period. Thus, when the river floods, the litter-fall products undergo enhanced decomposition rates and are physically transported into the river and bay system. However, different species of trees contribute varying quantities of material to the associated aquatic areas. The headwater inflow provides substantial loads of dissolved nutrients from other (upland) areas while the Apalachicola/Chipola wetlands provide nearly all of the particulate matter. The exact mechanism of the translation of nutrients and organic matter into living tissue of the estuarine populations remains unclear although it is thought that microorganisms and phytoplankton may hold an important key to the nutrient cycling within the river-bay system.

Phytoplankton growth depends on temperature, light, and nutrients such as phosphorus (in fresh- and brackish-water areas) and nitrogen (in the open ocean). Phytoplankton in the Apalachicola estuary are dominated by diatoms, which have silicon skeletons. Thus, silicon may also play a role in nutrient limitation of phytoplankton productivity in the Apalachicola Bay system. Phytoplankton are consumed by various herbivorous or plant consuming organisms. For instance, filter-feeding copepods, a form of zooplankton, are major consumers of phytoplank-

Diatom (*Chaetoceros curvisetus*)

Diatom (*Nitzschia closterium*)

Dinoflagellate (*Ceratium massiliense*)



Diatom (*Chaetoceros lorenzianum*)

Diatom (*Ditylum brightwellii*)

ton. Such grazers may have a major effect on the phytoplankton populations. The relatively non-uniform distribution of phytoplankton, however, has led to various problems in the differentiation of causative features (i.e., physical, chemical, biological) that control phytoplankton productivity in coastal areas. Quite obviously, no single factor is responsible for the distribution and abundance of phytoplankton in the estuary.

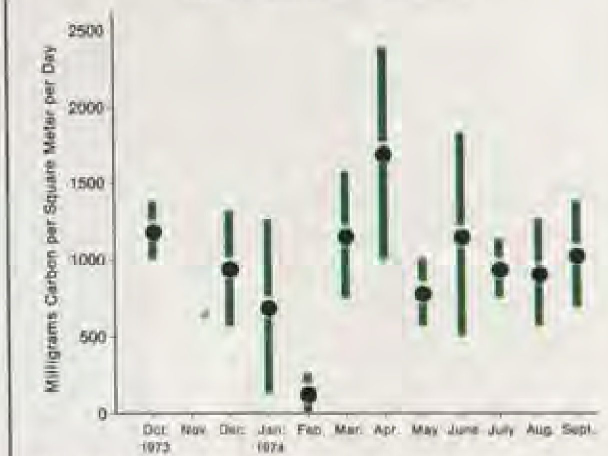
Studies indicate that compared with other estuaries in the Gulf of Mexico the Apalachicola Bay system has a moderately high level of phytoplankton productivity (Livingston, Iverson, and White, 1976). Although the river is the main source of the life-giving nutrients, wind and currents are also important to the distribution and utilization of such nutrients by the phytoplankton. Diatoms such as *Chaetoceros lorenzianum* are often prevalent in Apalachicola Bay although such dominance is highly seasonal. The overall phytoplankton productivity is cyclic with low levels during winter periods of low temperature and high river flow. Phytoplankton production peaks in the spring as temperature increases and river flow falls. Although surface nitrogen and phosphorus levels peak in the winter during periods of river flooding, the actual utilization of such nutrients by phytoplankton is regulated by temperature. Much of the nutrient flow into the estuary is entrained in the sediments. During summer and fall, wind mobilization of phosphorus from the sediments is followed by periods of increased phytoplankton growth as the nutrients are driven into the well-lighted upper waters. By the fall, there are secondary peaks of such productivity, which last until the low winter temperatures again become limiting. In this way, the interplay of climatic and biological factors determines the seasonal changes in the phytoplankton productivity of the estuary.

Average phytoplankton productivity levels range from 63 to 1,694 milligrams of carbon per square meter per day. The estimated annual production for the estuary (East Bay, St. Vincent Sound, and Apalachicola Bay) is 103,080 metric tons of carbon per year. Compared with other coastal areas of the northeast Gulf of Mexico, nutrient concentration and phytoplankton productivity are uniformly higher in the Apalachicola estuary. There are indications that, in a geographic sense, river flow volume is a major factor in the distribution of phytoplankton productivity along the coast. Mathematical models indicate that river discharge explains 20 to 50 percent of the variability of nutrient-related factors such as chlorophyll a and phytoplankton productivity. Temperature accounts for 26 to 49 percent of such variability. Wind speed is also correlated with nutrient availability and productivity.

Certain factors are extremely important in controlling phytoplankton productivity in the Apalachicola Bay system. Temperature is the primary limiting factor for productivity, especially during the winter months. River discharge is strongly associated with nutrient concentrations in the estuary. Nutrient concentrations, in turn, control phytoplankton production during the summer and fall when temperature is not a major influence. Phosphorus, in relatively low abundance throughout the Apalachicola Valley, is the major limiting factor during such periods in portions of the estuary characterized by low salinity. Although it is generally acknowledged that herbivores probably play an important role in cropping the phytoplankton standing biomass, the exact relationship between the phytoplankton and zooplankton has not been determined. However, it is clear that river flow and high nutrient levels, together with other natural modifying factors, combine to form the ecological conditions that lead to a relatively high level of phytoplankton productivity in the Apalachicola estuary.

Various studies of phytoplankton in the Apalachicola estuary have thus given us a rather comprehensive view of seasonal changes in phytoplankton occurrence and productivity. Such productivity follows seasonal cycles of temperature and nutrient limitation, with phosphorus as the most important factor in the estuary during summer periods while temperature is limiting during colder months. D.A. DiDomenico and R.L. Iverson (Florida State University; see Livingston, Iverson, and White, 1976) showed that mollusks such as clams were able to incorporate dissolved organic compounds into their tissues, which would indicate that phytoplankton, which produce such organic compounds, may nourish filter-feeding organisms such as clams and oysters both directly (through active consumption) and indirectly (through absorption and assimilation of dissolved organic byproducts). There is little doubt, in any case, that the seasonally high levels of phytoplankton productivity in the Apalachicola Bay system are an important reason for the bay's value as a regional center for sport and commercial fisheries. Although the precise interactions, physical and biological, which control such phytoplankton populations remain relatively unknown, it is clear that regular, seasonal cycles of such productivity are an integral part of the great food webs of the Apalachicola estuary.

Phytoplankton Productivity
Average Seasonal Variation



Data courtesy of Dr. R. Iverson and his students, Florida State University

Emergent Vegetation

The emergent vegetation along rivers and around estuaries is usually dominated by various forms of grasses. Marshes represent a transition zone between upland forms of vegetation and the open water of the bay system. Marsh grasses occur most often in delta areas and intertidally along coastal systems. Fresh- and brackish-water marshes are characterized by cattails (*Typha* spp.), bullrushes (*Scirpus* spp.), saw grass (*Cladium* spp.), cordgrass, and needlerush. Salt marshes in the gulf region are often dominated by black needlerush (*Juncus roemerianus*), cordgrass (*Spartina* spp.), *Distichlis spicata*, and *Salicornia* spp.

Marshes perform various ecological functions. The root systems of the plants bind the sediments and prevent erosion, thus stabilizing the land-water interface and buffering the upland areas from storm and tidal surges. Organic productivity of marshes is usually quite high, which provides considerable amounts of organic matter for various organisms. Marshes are often characterized by tidal channels and creeks, which afford access for diverse aquatic organisms. In this way, the emergent vegetation of marshes performs a variety of ecological functions for the estuary, including the provision of food and habitat for a number of commercially important species.

Marshes are significant nursery, feeding, and reproductive zones. However, few organisms spend their entire life histories there. Rather, the marsh habitat provides periodic protection for various migratory species. Marsh grasses are often used as a substrate for the attachment of different sessile forms. Because of the ready availability of detritus within the marsh, complex food webs are formed, which support associations of insects, mollusks, crustaceans, fishes, birds, and other vertebrates. The vertical and lateral stratification of the habitat often provides the conditions which ultimately house and feed some of the most well-known and important species in the river-bay system. Many species of sport and commercial importance, including blue crabs, penaeid shrimp, mullet, spotted seatrout, snapper, red drum, geese, and ducks, use marshes for food gathering.

Much of the intertidal area around the Apalachicola Bay system is dominated by freshwater, brackish, and saltwater marshes. The primary concentration of marshlands consists of the fresh-and brackish-water forms in the river delta just above East Bay. Such areas are dominated by bullrushes (*Scirpus* spp.), cattails (*Typha domingensis*), saw grass (*Cladium jamaicense*), and brackish-water forms of cordgrass and needlerush. Mainland areas, from Indian Lagoon to Alligator Point, are characterized by very limited marsh development. However, lagoon portions of St. George Island, Dog Island, and Alligator Point have light to moderate concentrations of fringing saltwater marshes. Such areas are dominated by needlerush (*Juncus roemerianus*), with secondary concentrations of the smooth cordgrass (*Spartina alterniflora*). The northeast section of St. Vincent Island has a well-developed brackish water marsh. Overall, these marshes account for approximately 14 percent of the total aquatic area of the Apalachicola Bay system.

The high productivity of marshes is now a generally accepted scientific fact. W.L. Kruczynski and his colleagues at Florida A&M University have studied tidal marshes around the northeast Gulf of Mexico. These marshes are dominated by the needlerush (*Juncus roemerianus*). Total above ground production of a north Florida *Juncus* marsh is 8.5 metric tons per hectare per year (low marsh), 5.7 metric tons per hectare per year (upper marsh), and 1.8 metric tons per hectare per year (high marsh). When such estimates for the above ground production of north Florida *Juncus* marshes are applied to the Apalachicola marsh areas, the annual estimated net production of organic matter is 47,000 metric tons. Usually, such organic matter is sloughed off and "conditioned" by microorganisms before it enters the detrital food webs. What happens to such material and how it is distributed from the marshes through the estuary are still not well understood.

Tidal marshes may function as net exporters of particulate organic matter (POM) to the estuary. This is the so-called detritus outwelling theory. However, recent studies by various scientists have cast doubt on this concept, since, under certain circumstances, no net annual export of POM from marshes can be demonstrated. It is probable that net detrital flux from wetlands depends on various factors such as geomorphology of the basin, magnitude of the tidal range, and upland freshwater runoff. Detrital matter from wetlands is subject to mechanical fragmentation, chemical leaching, hydrolysis, oxidation, and microbial processing. The tidal range in the Apalachicola estuary is small, although freshwater runoff in the delta area is considerable. Some studies indicate that little particulate organic matter moves directly from the marshes into the estuary except in areas receiving direct river flow. Other studies by B. Ribelin and A. Collier at Florida State University have shown, however, that regional marshes export tiny detrital aggregates, which are produced by microscopic plants. Tidal action lifts films of such material out of the marshes, especially during ebb flows in the late summer. It is quite possible that, while the particulate organic matter remains largely within the marsh where it undergoes microbial decomposition, small plants may utilize the nutrients released by such mineralization. The amorphous algal aggregates, which are composed of microalgae, may be transferred into the estuary by tidal currents, especially during late summer-fall periods of high productivity. In this way, some form of the net productivity of the marsh vegetation may enter the estuarine food webs via microbiological and tidal action.

Despite unanswered questions concerning the exact mode of energy interactions between the emergent vegetation of marshes and the associated bay system, the marshes of the Apalachicola Bay system undoubtedly perform important environmental functions. Direct and indirect detrital consumption within the marsh, together with some form of nutrient export to associated aquatic areas, is the most obvious marsh activity. The marshes are known to support major food webs, which include commercially important shellfish, blue crabs, shrimp, and finfishes. They also serve as a refuge from marine predators as well as breeding and staging areas for migratory shore birds and water fowl. The eventual export of energy in the form of larval and juvenile stages of migratory aquatic organisms is another form of marsh activity whereby energy is transferred to other parts of the system. The marshes thus are an integral part of the great cycle of life in the Apalachicola estuary and are an important source of productivity for the river-bay system.

Fringing marshes of the Apalachicola Bay
Photo by J. Michael Kuperberg

Submergent Vegetation

Benthic macrophytes are plants that grow on the bottom of the bay. Grassbeds are areas along the coast which are populated by seagrasses and algae, the so-called submergent vegetation. Such plants are usually highly productive and provide both food and habitat for various estuarine organisms. The distribution of bottom plants affects the currents and water quality in the estuary, usually providing a more stable environment by modifying rapid changes in pH and dissolved oxygen. Benthic macrophytes bind sediments and change sedimentation patterns, again resulting in a more stable habitat for various types of organisms. Of course, the functions submergent plant species perform within the food webs vary spatially and temporally in the estuary. However, the overall influence of the grassbeds is considerable in terms of providing basic productivity and habitat for a broad group of invertebrates and fishes.

The naturally high rates of sedimentation in the Apalachicola estuary, together with the light-limiting features of high color and turbidity, have sharply restricted the development of grassbeds. Wherever the river influence is strong, such plants are usually restricted to shallow areas less than 3 feet in depth. There is little grassbed development in St. Vincent Sound. Such distribution may also be affected by the establishment of marshes that are often associated with grassbeds. In Apalachicola Bay, the main grassbeds are located in shallow areas off St. George Island, often downstream of the salt marshes. The main concentrations of benthic macrophytes are in upland, shallow portions of East Bay and throughout eastern St. George Sound. Within the entire bay system, grassbeds account for little more than 10 percent of the aquatic area.

Temperature, light, salinity, depth, sediment type, and nutrient availability are among the chief limiting factors of benthic macrophyte distribution in the Apalachicola estuary. In East Bay, the grassbeds are composed largely of fresh- and brackish-water species such as tape grass (*Vallisneria americana*), sago pondweed (*Potamogeton* spp.), and widgeon grass (*Ruppia maritima*). These macrophytes are richly developed throughout the bayous and inlets of the upper estuary. In 1979, drifting plants of the introduced Eurasian watermilfoil (*Myriophyllum spicatum*) were sighted in this area. During 1980–1981, watermilfoil was observed to be rooted in Round (or Blounts) Bay, and by 1982 this species was rooted throughout the upper East Bay area. How the introduction of *Myriophyllum* will affect the distribution of the native plant species is difficult to predict; it is clear, however, that this species is in the initial stages of taking over the East Bay grassbeds.

Submerged vegetation off St. George Island, Dog Island, and western portions of Alligator Point is dominated by shoal (*Halodule wrightii*), manatee (*Syringodium filiforme*), and turtle (*Thalassia testudinum*) grasses. Such species are adapted to higher salinity than occurs in East Bay. These grasses are often found in association with algae such as *Gracilaria* spp., *Caulerpa*, and *Padina*. The *Halodule* beds of western parts of the estuary grade into the *Thalassia-Syringodium* beds of eastern St. George Sound. Such mixed grassbeds flourish in areas outside of those that are most affected by Apalachicola river flow. Studies indicate that bottom-living organisms (the so-called infauna) in *Halodule* beds off the Nicks Hole drainage of St. George Island occur in numerical

Turtle Grass (*Thalassia testudinum*)

Manatee Grass (*Syringodium filiforme*)

Shoal Grass (*Halodule wrightii*)

Widgeon Grass (*Ruppia maritima*)

Tape Grass (*Vallisneria americana*)

abundances that rival or exceed the highest densities recorded in scientific literature for coastal portions of the continental United States. It would appear, then, that the bottom plants represent an important habitat and source of energy for the animals that inhabit the grassbed areas the Apalachicola Bay system.

Detailed studies have been carried out in the *Vallisneria* beds of East Bay by B.H. Purcell and R.J. Livingston. The standing crop biomass of such grassbeds is lowest during winter months. Low winter temperature is the chief limiting factor during such periods. As temperature increases during early spring, there is usually a relatively rapid burst of growth by the bottom plants, which is followed by maximal leaf development from May through July. By August, there is considerable degeneration of the grassbeds and sloughing off of grass blades which is followed by some new growth during September and October. Similar seasonal cycles of grassbed growth occur in areas of high salinity. Mixed grassbeds of *Halodule, Syringodium,* and *Thalassia* usually undergo rapid growth during spring–early summer. The standing crop of such grassbeds usually peaks during summer months. The grassbeds then undergo rapid degeneration as temperatures fall during November and December.

Net annual production of the *Vallisneria* or tape grass beds varies from 320 to 350 grams of carbon per square meter. Studies in associated, high salinity (mixed) grassbeds indicate a net annual production of 500 grams of carbon per square meter. Based on previous estimates of sea grass distribution, this finding would mean that grassbed productivity in the Apalachicola Bay system approximates over 27,213 metric tons per year. Leaves are continuously sloughed off through the summer–fall months. Such leaf matter provides a substrate for microbes, thus forming a high-quality detritus that adds to the food base of the estuary. Peak levels of such macrophyte-derived detritus occur during the fall as river flow and rainfall reach their lowest levels.

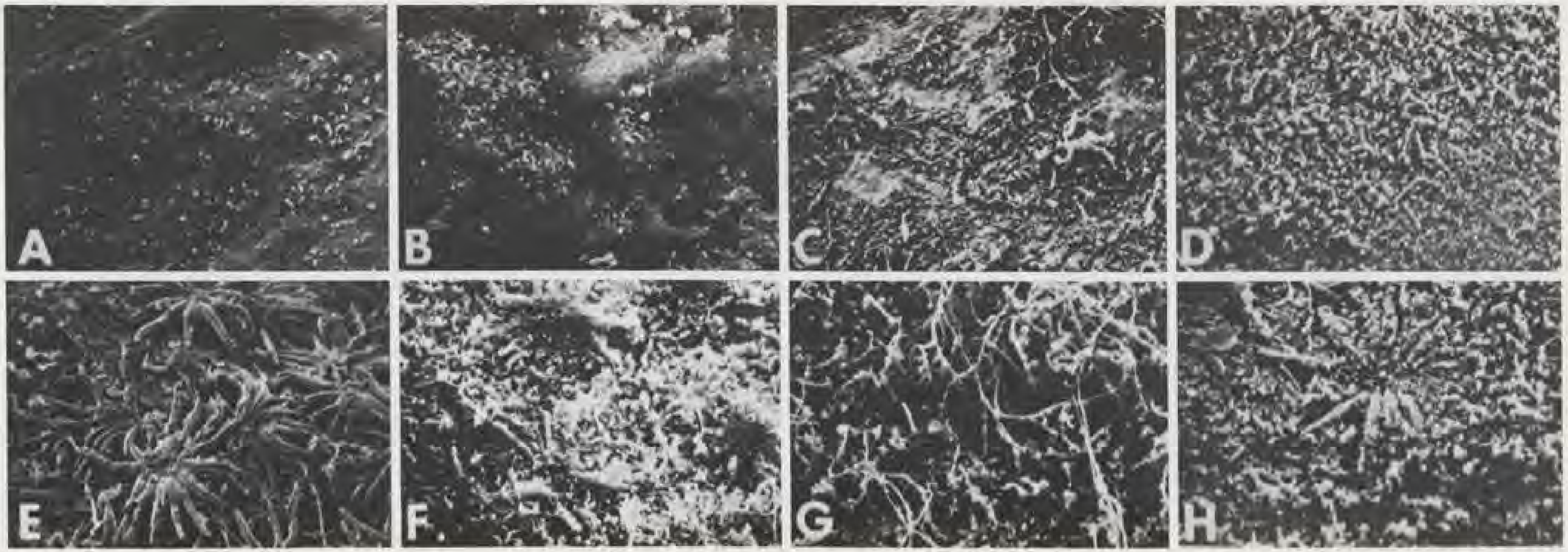
As a source of high productivity and relatively stable environmental conditions, the grassbeds serve as nursery areas for various species of mollusks (*Neritina reclivata*), polychaete worms, insect larvae, crustaceans (including amphipods and shrimp), and fishes. Such organisms feed on detritus, epiphytes (small plants), and the various invertebrates that live within the grassbeds. There are seasonal successions of grass shrimp, pink shrimp, blue crabs, silver perch, pigfish, pinfish, and spotted seatrout; all such organisms make use of the relatively high grassbed productivity. Most of these animals live in these areas as rapidly growing juveniles. In this way, the freshwater, brackish, and marine grassbeds of the Apalachicola Bay system are an important part of the overall productivity and detritus-based food webs that are so important to the commercial and sport fisheries of the region.

Microbial Ecology

Microbes are tiny organisms—invisible to the naked eye—and include bacteria, fungi, and algae of various types. Although they are small in size, microorganisms are extremely numerous and capable of rapid reproduction. Their activities are very important for processing organic matter and transforming dissolved nutrients into a high-quality form of particulate organic matter that is basic to the detrital food webs of the estuary. Some microorganisms are vectors of disease and thus pose a significant threat to the valuable Apalachicola oyster industry. In aquatic systems, the biomass of the microbes has been estimated to approach that of the entire fauna which includes all the fishes and invertebrates that inhabit a given area. There is little doubt that these seemingly insignificant creatures comprise an extremely vital though poorly understood part of the food web structure and commercial viability of the Apalachicola Bay system.

D.C. White and his students at Florida State University have studied such processes in the Apalachicola Bay system. The scanning electron micrographs below show colonization of oak (*Quercus virginiana*) leaves during incubation for various lengths of time in water taken from the Apalachicola estuary. After the leaves are washed into the bay, microorganisms colonize the surfaces in a timed succession. At first, colonization is slow and patchy. During the first few weeks, the microbes are primarily bacteria. Figures A (dorsal surface, week 0, 230X, 10Kv), E (ventral surface, week 0, 210X, 10 Kv), B (dorsal surface, week 2, 200X, 30Kv), and F (ventral surface, week 1, 160X, 30Kv) show these early stages. By the fourth week, however, the surface is more densely covered with filamentous organisms, the fungi. This situation can be seen in Figure C (dorsal surface, week 4, 140X, 5Kv). By the fifth and sixth weeks, such fungal mats predominate along with plants such as diatoms or algae and spirochaete-type organisms. Figures D (dorsal surface, week 6, 210X, 10Kv), G (ventral surface, week 5, 230X, 10Kv), and H (ventral surface, week 6, 290X, 10Kv) illustrate this stage. These organisms thus produce a biomass that is more protein rich (i.e., more nutritious for nitrogen-limited invertebrates) than the original plant matter. The microbial com-

Photos reprinted, by permission, from S.J. Morrison, J.D. King, R.J. Bobbie, R.E. Bechtold, and D.C. White, "Evidence for Microfloral Succession on Allochthonus Plant Litter," *Marine Biology* 41:229-40.

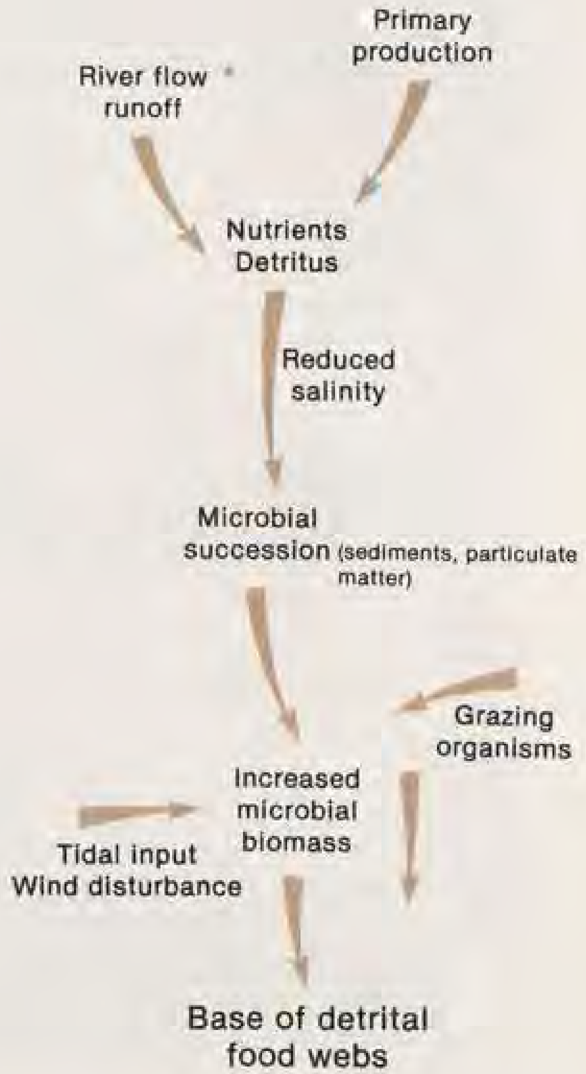


munities are more diverse biochemically and morphologically than the original, inert, organic matter. Thus, the decomposition phase adds nutrients to the detritus via microbial action, and such organic matter is now ready for incorporation in the detrital food webs of the estuary.

Various organisms consume detritus: shredders and grinders, which actively chew the particulate matter; filter feeders, which strain the water for food; deposit feeders, which swallow the sediment and digest the detrital matter; and grazers, which selectively skim the microbes off the organic substrate. Protozoans, sponges, oligochaete and polychaete worms, nematodes, small crustaceans (i.e., copepods, amphipods, isopods), bivalve and gastropod mollusks, and even fishes (i.e., mullet) depend on microorganisms for food. Grazing amphipods can remove the microbes without affecting the structure of the leaf substrate. The activities of the grazing organisms actually enhance and stimulate microbial production. In this way, grazing as a disturbance stimulates microbial growth and alters the microbial associations.

Through intensive studies of the movement, conditioning, and consumption of particulate and dissolved organic matter in the Apalachicola estuary, a pattern is becoming evident that represents one of the keys to the understanding of why this system is so productive. River flooding, together with input from estuarine marshes and autochthonous sources such as phytoplankton and benthic macrophytes, provides an almost continuous source of organic matter to the bay system. The organic matter is in both the dissolved and particulate states. Although the phytoplankton and benthic macrophytes produce organic matter, which is continuously recycled through the estuarine food webs, the microorganisms also play a role in the productivity of the estuary by transforming the organic detritus into a more nutritious food for the various detritivorous organisms. The microbial successions are continuously interrupted by grazing, which, in turn, induces increases in microbial activity (and biomass) and causes qualitative shifts in the microbial community structure from the mixed diatom-fungus-bacteria association to bacteria-dominated forms. Sediments and particulate organic matter are the substrate for microbes, whose growth is stimulated by dissolved nutrients and by disturbance from physical and biological forces. The shallowness of the Apalachicola estuary allows maximal disturbance of the substrate by wind-driven and tidal currents. Such action, together with almost constant movement and grazing of estuarine organisms, provides the appropriate habitat for a highly productive system. The periodic input of organic matter and short-term and seasonal trends in temperature and salinity produce a microbial community that forms a vital link between the raw organic materials from plant productivity and the complex estuarine food webs.

It is ironic that organisms invisible to the naked eye are, in fact, an important part of the bay productivity. Recent experiments by T. Federle, R.J. Livingston, D.C. White, and their colleagues indicate that, in high salinity areas, the microbes in the mud are indirectly affected by the larger invertebrate and fish predators. Such predators control the detritivorous invertebrates in the sediments, which in turn may affect, qualitatively and quantitatively, the microbial associations in the sediments. In this way, mutual interactions at various trophic levels within the food webs, together with energy subsidies from river flooding, wind- and tide-induced currents, and other disturbances of the shallow estuary, all combine to form the immense microbial biomass that represents the almost continuous translation of various compounds into biologically important materials.



Zooplankton and Larval Fishes

Some of the animals of the floating community that feed largely on planktonic plants (and each other) are called zooplankton. This group lives in the water column and is quite diverse. It includes types such as foraminiferans and radiolarians, which are tiny organisms living within complex skeletons made of calcium carbonate and silica. The predaceous arrow worms or chaetognaths are an important component of the zooplankton. These transparent creatures feed on copepods and small fishes. The planktonic crustaceans include copepods, shrimps, and other joint-legged creatures. Although related to the terrestrial insects, crustaceans (particularly copepods) function more like cattle. As plant grazers, they transform the phytoplankton into a form of food which is eventually consumed by the larger invertebrates and fishes. Many other interesting forms of zooplankton occur in the estuary, including ctenophores (the comb jellies) and numerous larval stages of organisms that inhabit the estuary.

When zooplankton eat phytoplankton, they perform important ecological functions. The organic matter produced by phytoplankton occurs in relatively small particles. However, when eaten by zooplankton, such particles are repackaged into particles larger in size by a factor of 100. This process concentrates the relatively diffuse energy stored by phytoplankton into more concentrated forms that can then be consumed by higher predators. At the same time, the zooplankton excrete inorganic nutrients into the water, such as ammonia and phosphorus, which can then be used by phytoplankton in the production of organic matter via photosynthesis. In this way zooplankton provide food for a broad range of organisms while contributing to the production of plant matter by reconstituting the nutrient pool.

The zooplankton community is dominated by a small number of species with relatively simple life histories. Copepods are by far the most numerous of all zooplankton. The zooplankton represent an important level of secondary production, which usually falls between 10 percent and 40 percent of the primary production by phytoplankton. Phytoplankton are usually patchy in their distribution, and it is thought that zooplankton find enough food only in the densest aggregations. Fish larvae also feed on phytoplankton although the exact relationship between these two basic feeding or trophic levels is still poorly understood. The zooplankton, particularly the calanoid copepods, are thus an important part of this process. They eat phytoplankton in a very efficient manner. Copepods have considerable ability in selecting floating particles. The grazing copepods are often quite effective in eliminating phytoplankton from an estuarine or coastal system. Although the exact nature of phytoplankton-zooplankton relationships is still not well understood, physical factors such as wind and temperature, chemicals such as nutrients, and biological factors (predator–prey relationships) all contribute.

Zooplankton in the Apalachicola estuary have been studied by H.L. Edmisten (1979). He found the calanoid copepod *Acartia tonsa* to be a major dominant throughout the estuary. Such dominance tends to increase with increasing salinity in the estuary proper. Apalachicola Bay had the highest number of species (species richness) and number of individuals of the three areas sampled. Seasonal peaks occur in May with lesser increases during the summer and fall. East Bay had the greatest seasonal variability while offshore areas in the gulf showed the least such month-to-month differences. Other zooplankton types such as cladocerans and chaetognaths were prevalent mainly in the coastal waters. Various larval forms of crabs, polychaete worms, ostracods, amphipods, isopods, mysids, echinoderms, ctenophores, and coelenterates (jellyfish) were part of the zooplankton found in the Apalachicola estuary.

It is well known that the zooplankton organization is influenced by changes in the temperature and salinity through time. Increased temperature was associated with *Acartia* numerical abundance, total numbers and biomass of zooplankton, and zooplankton diversity. Such diversity peaked during periods of increased salinity. Optimum salinity for *Acartia tonsa* ranged from 16 to 22 parts per thousand (35 parts per thousand represents the open gulf). Thus, seasonal cycles of temperature and freshwater runoff, along with the increased phytoplankton productivity during spring and summer, all tend to control the abundance and

Copepod *(Acartia tonsa)*

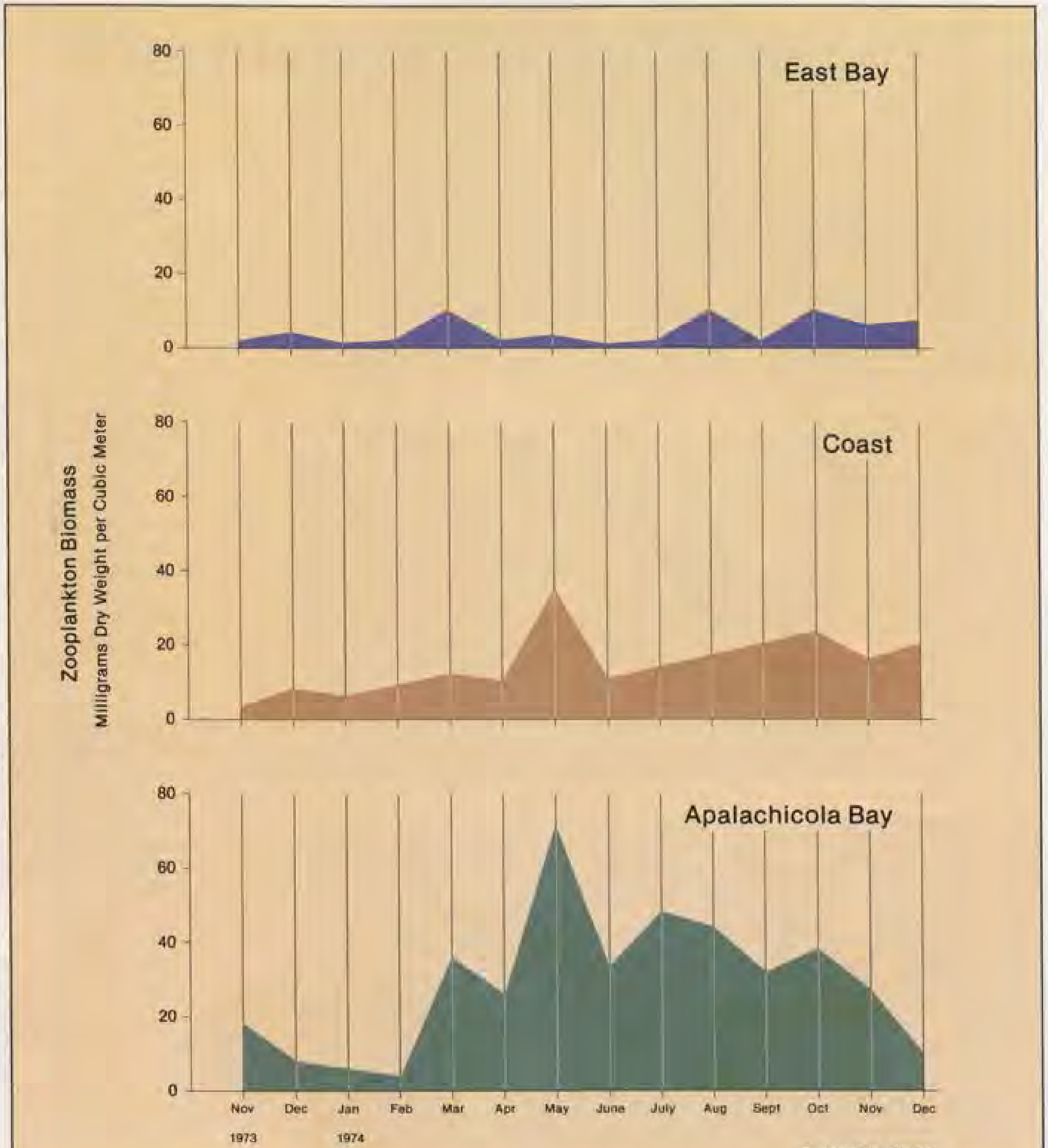
Copepod *(Paracalanus parvus)*

Copepod *(Oithona nano)*

distribution of zooplankton in the Apalachicola estuary. Zooplankton numbers tended to peak about one month after the spring phytoplankton peaks, while the fall phytoplankton and zooplankton concentration peaks tended to coincide. Thus, the zooplankton assemblages in the Apalachicola estuary are still not well understood in terms of distribution and controlling factors.

Larval fishes are small, developmental stages of various species. Although such larval stages live and feed with the zooplankton, they are not, in a strict sense, part of the zooplankton community. The distribution and abundance of larval fishes or ichthyoplankton of the Apalachicola estuary have been studied by R.H. Blanchet (1978). The most abundant form was the bay anchovy (*Anchoa mitchilli*), which accounted for 92 percent of the eggs and 75 percent of the larvae taken over a one-year survey. Other key fish larval types included the silversides (*Atherinidae*), skilletfish (*Gobiesox strumosus*), and gobies (*Gobiosoma* spp.) as summer forms, and winter species such as croaker (*Micropogonias undulatus*), menhaden (*Brevoortia patronus*), and spot (*Leiostomus xanthurus*). In addition to the spot and croaker, various sciaenid larvae were taken, including redfish (*Sciaenops ocellata*) and the sand seatrout (*Cynoscion arenarius*). Thus, the Apalachicola Bay system serves as a nursery for the larval and juvenile stages of various fishes. As such, the estuary forms the basis for the sport and commercial fisheries in the area.

The fish larvae were most abundant in western portions of Apalachicola Bay, in large part because of the major dominant, *Anchoa mitchilli* (Blanchet, 1978). Eggs of most of the fish populations (except the anchovies) were found offshore, which indicates that most fish populations spawn offshore. Certain species, such as the anchovies, atherinids, blennies, and gobies, do spawn in the bay, but most of the commercially important species move into the estuary as larvae or juveniles. Anchovies have an extended breeding season although they are largely warm-season spawners. Cold-season spawners include menhaden, pinfish (*Lagodon rhomboides*), silver perch (*Bairdiella chrysura*), and the spotted seatrout (*Cynoscion nebulosus*). The actual causal factors that determine the distribution of fish larvae in the Apalachicola estuary remain largely unknown.



Courtesy of H.L. Edmiston

Benthic Macroinvertebrates

The benthic, or bottom, macroinvertebrates are animals without backbones that live in (infauna) or on (epifauna) the sediments of the estuary. The epifauna include motile or swimming types such as crabs, shrimp, and squid. The infaunal invertebrates are characterized by burrowing or nonswimming types of organisms such as clams, snails, worms, insect larvae, and various forms of crustaceans.

Infaunal invertebrates usually fall into four general categories: crustaceans, polychaete worms, mollusks, and miscellaneous groups. The benthic infauna are usually quite small, with body lengths usually measured in fractions of inches or millimeters. Of all the infaunal species taken within the sediments of the Apalachicola estuary, the polychaete *Mediomastus ambiseta* is one of the most abundant. Another major dominant of the infaunal polychaetes is *Streblospio benedicti*. Such worms are found in various bay habitats and are adapted to live in broad ranges of temperature or salinity. Many polychaete worms are omnivorous and consume fine plant detritus, algae, and small organisms in the sediments. Many of the polychaete worms are cosmopolitan in their distributions; that is, they are found in coastal areas around the country. Breeding mechanisms vary considerably among polychaete forms, with some having planktonic larvae. Individual worms may have multiple broods in a single year. Populations often have substantial seasonal and annual fluctuations in numbers. A closely related group, known as oligochaete worms, are also abundant in the estuary. Oligochaete worms are often found in sediments of rivers, ponds, lakes, and estuaries. Many are tolerant of broad variation of the environmental features of a given system. Oligochaetes are often associated with high concentrations of organic matter and feed on organic detritus.

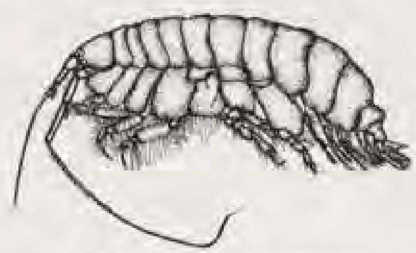
Various forms of crustaceans are found on or within the sediments. Amphipod crustaceans, with names like *Corophium*, *Ampelisca*, and *Grandidierella*, are common in the Apalachicola estuary. Many amphipods are detritus feeders. During winter and spring periods, when organic detritus is abundant in the bay system, the amphipods reach their numerical peaks. Some filter the organic matter out of the water, while others feed directly or indirectly on leaf matter and its associated microbiota. Some are predators, while others feed in different ways using specialized appendages of various kinds. Some crustaceans known as isopods are found in the estuary. Isopods are small organisms that are often omnivorous, eating fine organic detritus, inorganic particles, and tiny plants known as diatoms. Some isopods are parasites. One of the most abundant of the infaunal crustaceans is the tanaid known as *Hargeria rapax*. This species is often found in grassbeds off St. George Island. Like many of the infaunal groups, *Hargeria* feeds on fine detrital matter and diatoms from its tubes in the substrate.

Studies have been carried out over the past few years with leaf litter packs, which, when dropped into the bay, resemble detritus that is carried into the system by the Apalachicola River. Various types of organisms such as isopod, amphipod, and decapod crustaceans are associated with leaf litter. These organisms use the litter for shelter and food. Most litter-associated organisms are detri-

Stone Crab (*Menippe mercenaria*)

Polychaete Worm (*Mediomastus ambiseta*)

Amphipod (*Corophium lacustre*)



Amphipod (*Ampelisca vadorum*)

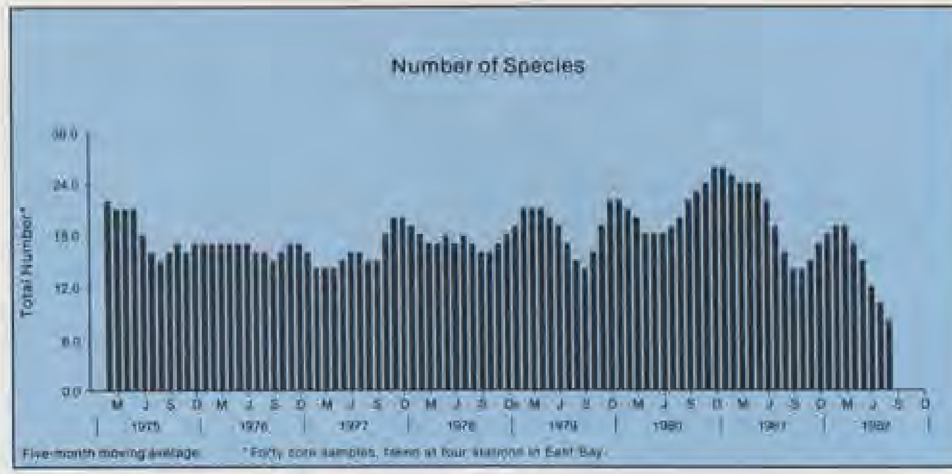
tivores or omnivores. Some of the dominant species are the amphipods (*Grandidierella bonnieroides* and *Gammarus mucronatus*) and an estuarine snail (*Neritina reclivata*).

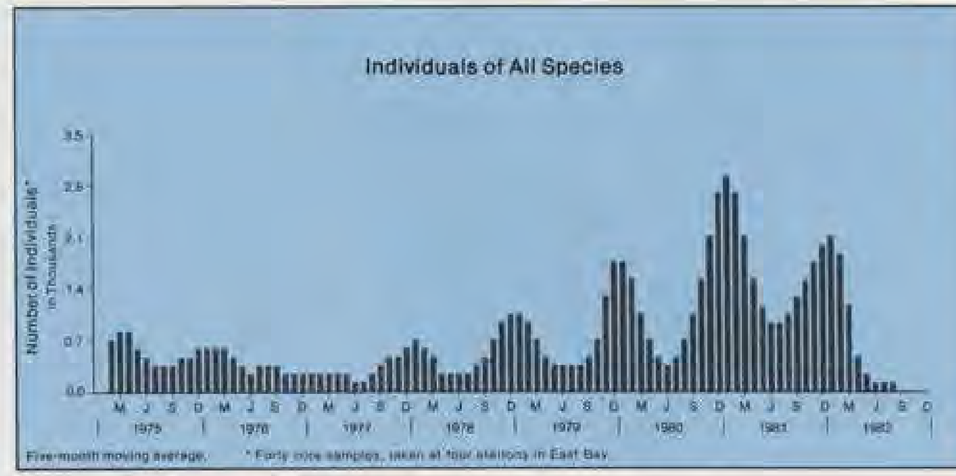
Studies by Sheridan and Livingston (in press) indicate that some of the highest densities of benthic macroinvertebrates in the northern hemisphere have been taken in the sea grass meadows off St. George Island. In most areas of the bay system, numerical abundance and dry weight biomass of the estuarine infaunal invertebrates usually peak during winter and early spring. The lowest numbers usually occur during the summer. However, there is considerable seasonal and year-to-year variation in the numbers of individuals as well as the numbers of species. The most prevalent polychaete worm (*Mediomastus ambiseta*), for example, usually is present in peak numbers during the winter. However, from 1975 to 1981, there were progressive annual increases in abundance of *Mediomastus*, which were also reflected in the year-to-year trends in overall invertebrate abundance.

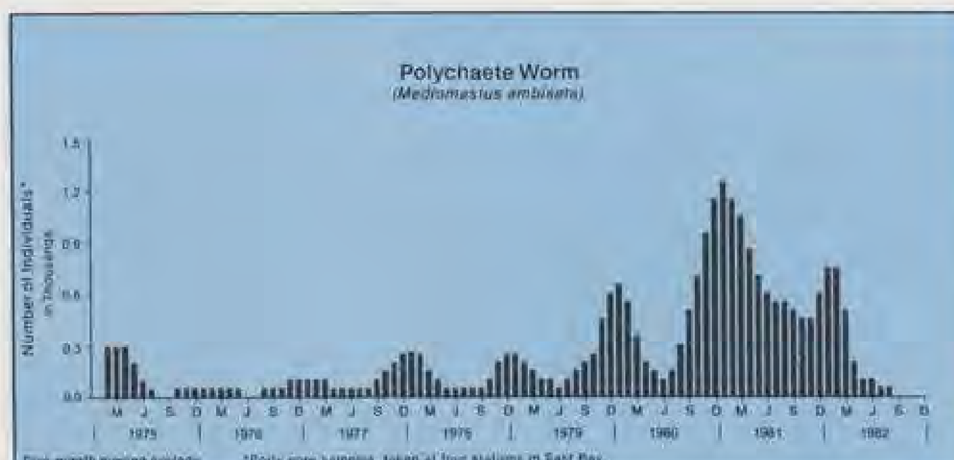
The infaunal macroinvertebrates are distributed in relatively clear-cut patterns within the estuary. Such distribution depends on gradients of salinity, seasonal changes in river flow and temperature, local habitat trends including substrate (sediment) characteristics, and trends of productivity. While such factors are important determinants of the infaunal distribution, other factors such as predator effects and mode of reproduction, recruitment, and larval settlement may also have an important effect on community structure. The importance of these infaunal assemblages to the bay system as a whole cannot be underestimated, as these organisms form the basis of the food for various commercially important organisms throughout the estuary. The benthic infauna thus form an important link between the organic detritus and nutrients washed into the estuary by the river and overland runoff and the vast numbers of epibenthic or swimming organisms in the system.

The epibenthic invertebrates within the Apalachicola Bay system are dominated by the penaeid shrimp, blue crabs, squid, and various other forms such as palaemonid shrimp, crabs (mud crabs, stone crabs), and mollusks. Many of these species have annual life cycles during which the adults spawn offshore and the larval or juvenile stages move into the estuarine and coastal areas to feed before they return to the open gulf.

The Apalachicola Bay system, with its diverse habitats such as mudflats, soft sediment areas, grassbeds, and oyster reefs, represents a highly productive feeding ground for important commercial species. The high concentrations of organic matter from the river, fringing marshes, phytoplankton, and grassbeds form the basis of complex food webs of the estuarine system. The invertebrate assemblages wax and wane with the seasons, as each species responds to the unique combinations of physical and biological stimuli which are critical to its continuing existence.







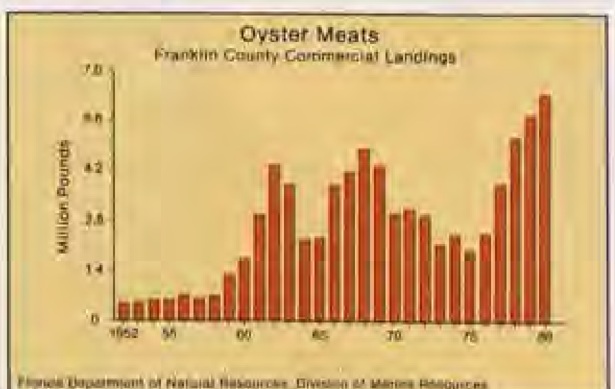
Oysters

The oyster, *Crassostrea virginica*, is one of the most intensely studied of estuarine organisms. An early bibliography (Ruge, 1897) listed 546 references, some dating back to 1665. Joyce (1972) has a partial list of 4,117 references. One of the dominant invertebrates in the Apalachicola estuary, the oyster has been taken as food for hundreds of years by residents of the region. The Apalachicola system is one of the most ideal environments in the country for the growth and culture of the oyster. Around 90 percent of Florida's oysters come from the Apalachicola Bay system, and revenue from the oyster industry accounts for almost 50 percent of the income of Franklin County (Whitfield and Beaumariage, 1977). If a single organism is symbolic of this estuary, past and present, it is the oyster.

Oyster distribution in the Apalachicola estuary is determined in large part by a combination of physical and biological factors. Such conditions include Apalachicola river flow, basin configuration and water currents, substrate type, primary productivity (inside and outside the drainage), and spatial/temporal patterns of temperature and salinity. Oyster bars account for about 7 percent of the overall aquatic area. The main concentrations of oysters reside in Apalachicola Bay (1,659 hectares), western St. George Sound (1,489 hectares), and St. Vincent Sound (1,097 hectares). Scattered oyster bars also occur in East Bay, eastern St. George Sound, and Alligator Harbor, although such areas represent a relatively insignificant part of the oyster productivity of the region (Livingston, 1980c). Existing maps of oyster distribution are based on relatively old data (1917). An updated version of the oyster map presented on the next page is needed.

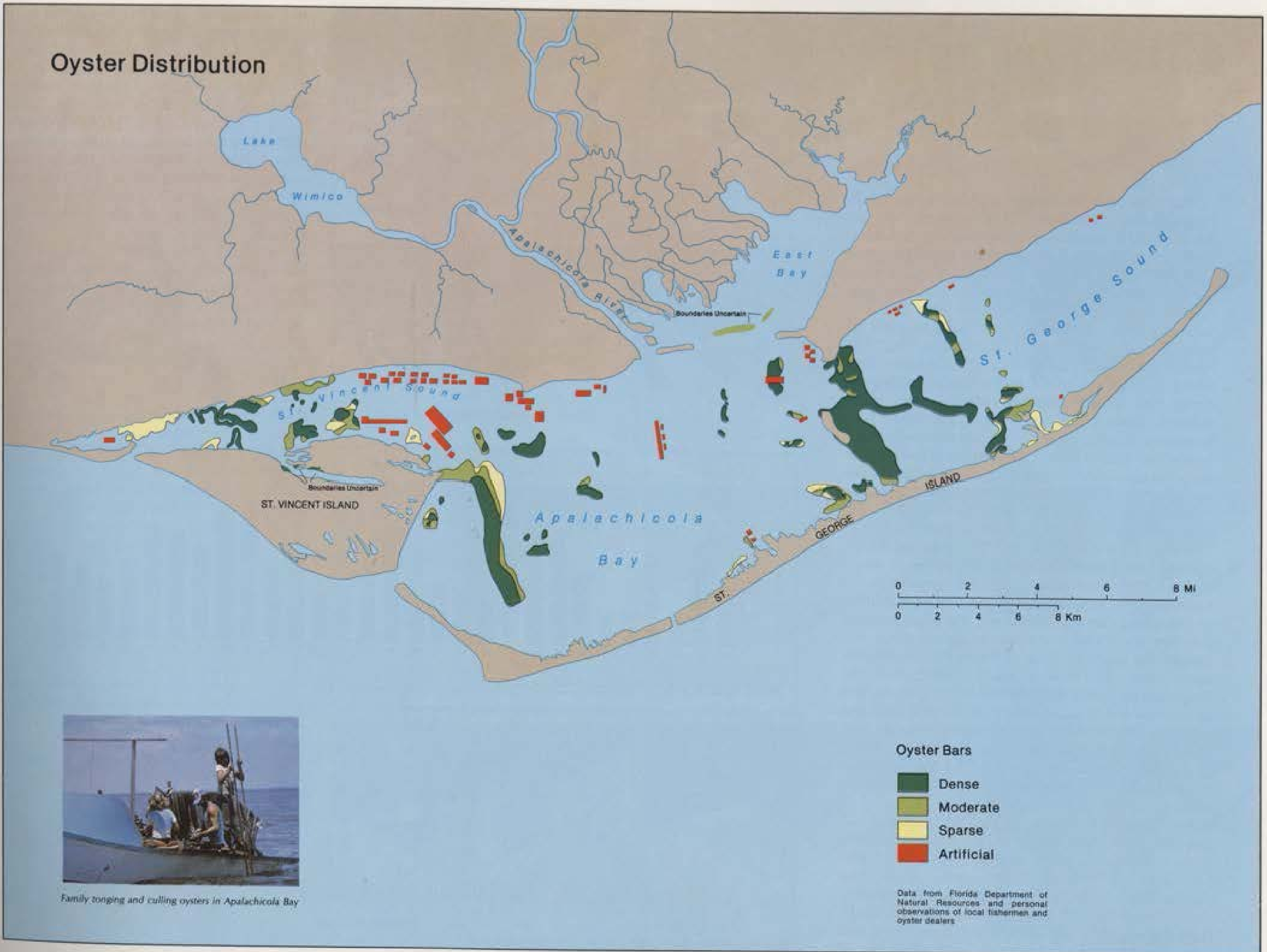
Oyster (*Crassostrea virginica*)

Oysters do not usually spawn below 22.5°C. Mass spawning usually occurs when temperatures reach 26.0°C. The spawning season in the Apalachicola estuary is one of the longest in the United States and extends from April through November. Free-swimming larvae exist for about two weeks. Once they have settled, the oysters grow throughout the year. Their growth is extremely rapid compared with that in other areas. In fact, Ingle and Dawson (1952) reported that oyster growth in the Apalachicola estuary is more rapid than that in any other area of the country. Ingle (1951) indicated that Florida oysters attain a length of 4 inches during a 31-week period. Although temperature and high productivity of the bay waters are key determinants of such growth, salinity is also an important limiting factor for oyster growth and distribution. Oyster bars contain various organisms that prey on oysters (Menzel, Hulings, and Hathaway, 1958, 1966); such predators include boring sponges, polychaete worms, gastropod mollusks, and crustaceans. The mollusks (*Thais haemastoma* and *Melongena corona*) and the stone crab (*Menippe mercenaria*) are particularly abundant during periods of high salinity. Experiments by Menzel, Hulings, and Hathaway (1966) showed that during periods of drought and high salinity such predators were the main cause of reef depletion. However, when salinities were low, these gulf organisms were eliminated, and the reefs retained their former productivity. Thus, salinity, as a control factor for predation pressure, has an important influence on oyster productivity.



Temperature, river flow, and rainfall (hence salinity), nutrient and detritus availability, productivity, bottom type, and predation pressure all tend to shape and define the distribution and growth of oysters in the estuary. River flow is a particularly important factor because it controls primary productivity and salinity distribution in the bay system. Meeter, Livingston, and Woodsum (1979) found that commercial oyster catches tended to follow, indirectly, the long-term (multiyear) cycles of the river system. Whitfield and Beaumariage (1977) indicated that shell planting (or "cultching"; i.e., piling oyster shells on the bottom to provide a suitable substrate for larval settlement and growth) is an important way to increase the oyster productivity of the bay. Fully 40 percent of the Apalachicola Bay area is suitable for growing oysters. More sanitary (safe) harvesting waters for oyster production exist in the Apalachicola estuary than in any other such water body in Florida.

It is clear that the future of the Apalachicola oyster industry depends on the sustained quantity and high quality of Apalachicola river flow along with progressive management of the resource within the estuary.



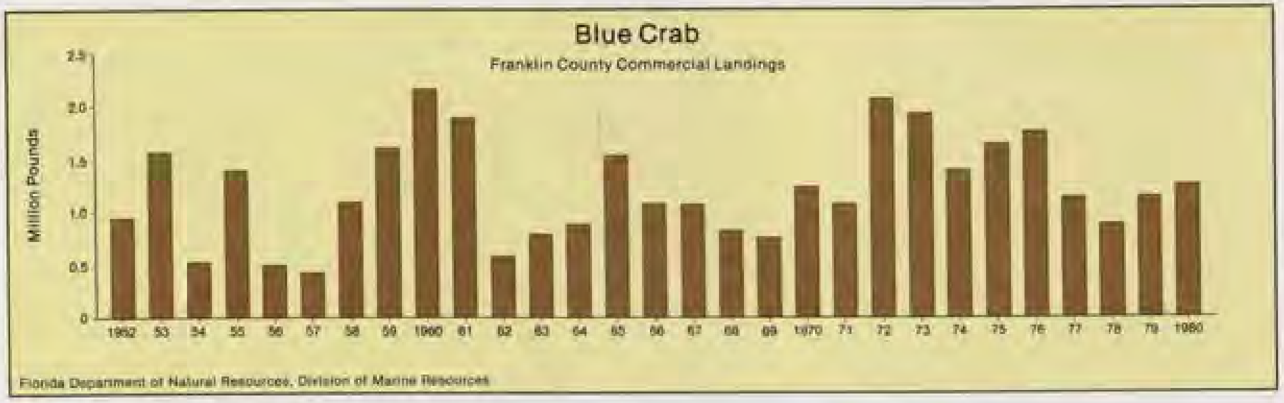
Family tonging and culling oysters in Apalachicola Bay

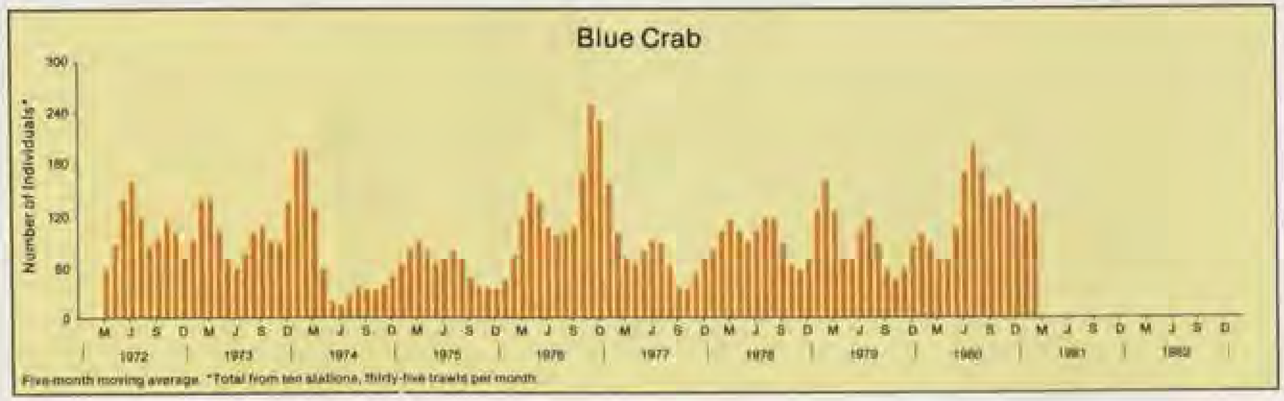
Blue Crabs

The blue crab, *Callinectes sapidus*, is one of the numerically dominant invertebrates in the Apalachicola estuary. Mating usually occurs in fresh or brackish water, while the females spawn in high-salinity, offshore gulf waters. After going through a series of larval (zoeal) stages, the megalops and juvenile crabs migrate into the low-salinity estuary, which serves as a nursery for the species. Studies by Oesterling and Evink (1977) have shown that egg-bearing female blue crabs along the Florida gulf coast migrate toward the north (the males usually remain in the home waters); some crabs swim over 300 miles to a spawning ground believed to be somewhere between the Apalachicola and Ochlockonee drainages. Concentrated spawning assemblages have been noted off Dog Island. The spawning migration appears to be timed with river flooding (and abundant food in the form of organic detritus). The young blue crabs move inshore during winter periods when peak numbers, estimated to be as high as 30 million individuals, are present in the Apalachicola estuary. Although the distribution of the larvae remains unknown, it is hypothesized that the zoeal or planktonic stages are dispersed toward the south by loop currents that eventually wash onto the Florida shelf. Eventually, the megalops or young crabs settle to the bottom and move into the coastal estuaries. In this way, the migration of the blue crab along the Florida gulf coast could be associated with the reproductive characteristics of the species and the physical organization of the Apalachicola drainage system.

Although the major peaks in numbers of juvenile blue crabs occur during the winter, secondary increases occur during the summer and fall. As the young blue crabs enter the Apalachicola estuary during the winter months, they concentrate in East Bay and off the Nicks Hole drainage (St. George Island). During May and June, there are renewed peaks in the number of

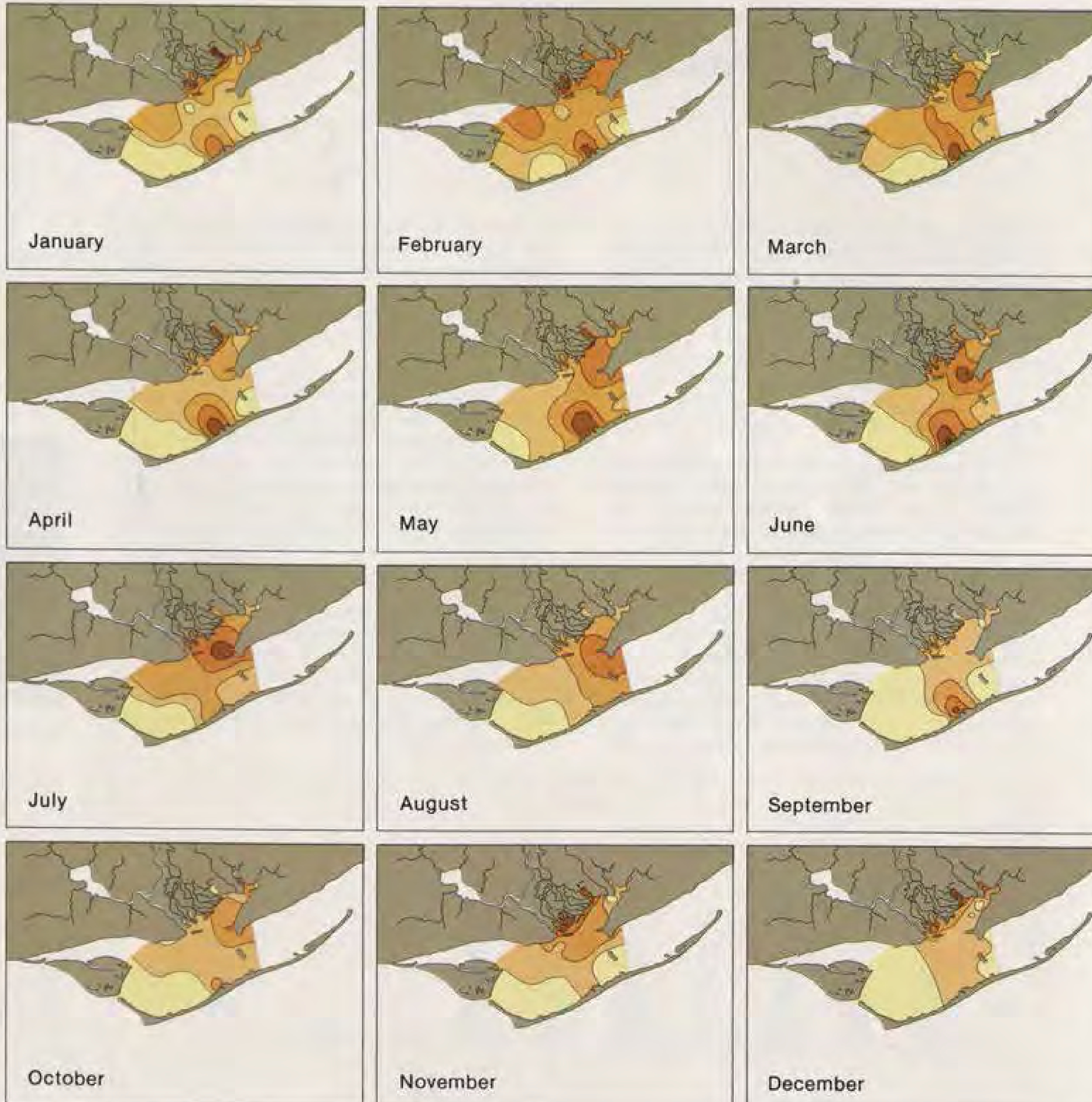
Developmental Stages of the Blue Crab *(Callinectes sapidus)*





blue crabs in these areas. By the summer and fall months, the blue crabs are concentrated in East Bay. This species appears to be attracted to areas that receive overland runoff although the blue crabs are not attracted by direct river flow.

Blue crabs represent an important commercial fishery in the Apalachicola Bay system. A direct correlation appears to exist between crab size and salinity; the smaller crabs are usually more abundant in less saline waters. Laughlin (1979) has shown that blue crabs undergo developmental changes in food preference. Juveniles, abundant during winter months, feed to a considerable degree on plant matter, organic detritus, and bivalve mollusks such as clams and oysters. As they grow, blue crabs tend to feed more on fishes and crustaceans, such as mud crabs and xanthid crabs. Cannibalism is relatively common and is a significant characteristic of the older blue crabs. The blue crab is an opportunistic organism whose diet reflects seasonal trends of bay productivity and prey availability. It is well adapted to rapid environmental changes and to broad ranges of temperature and salinity. As a result, the Apalachicola estuary is a food-rich, optimal form of environment for this species.



Individuals per Two-Minute Trawl Tow
by Month

0.0 - 1.0
1.0 - 2.0
2.0 - 4.0
4.0 - 6.0
6.0 - 9.0
9.0 - 13.0

1972 - 1979 average

Penaeid Shrimp

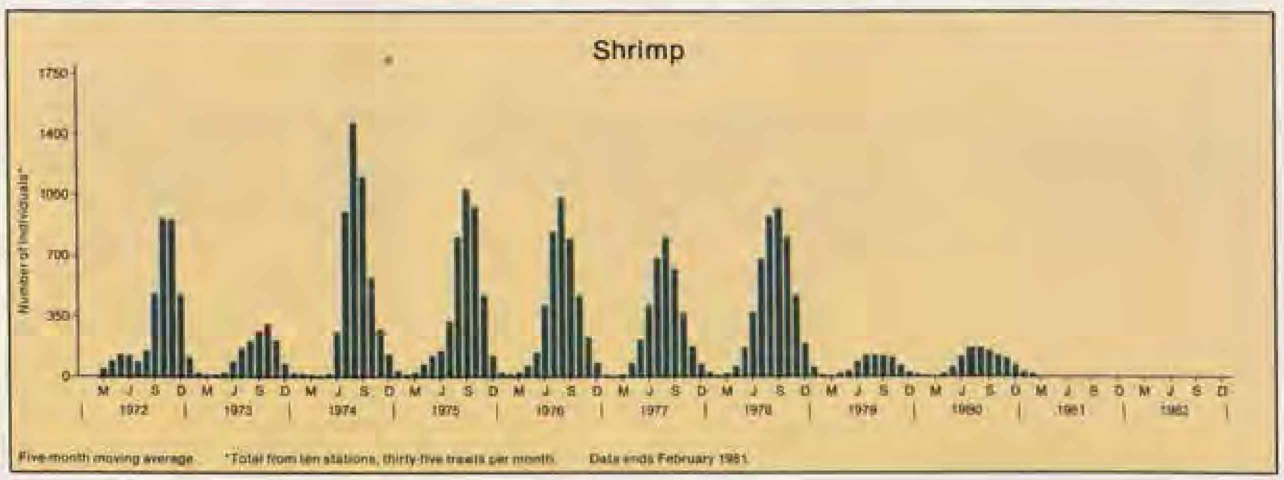
The penaeid shrimp have an annual life cycle. Spawning occurs in offshore gulf waters, and the larvae and postlarvae migrate into the shallow, low-salinity estuaries, which serve as nurseries for the developing animals. As they mature, the juveniles and adults migrate offshore into the saline waters of the Gulf of Mexico, to return, eventually, to their spawning grounds. Thanks to their commercial importance, the life history characteristics of penaeid shrimps are relatively well understood.

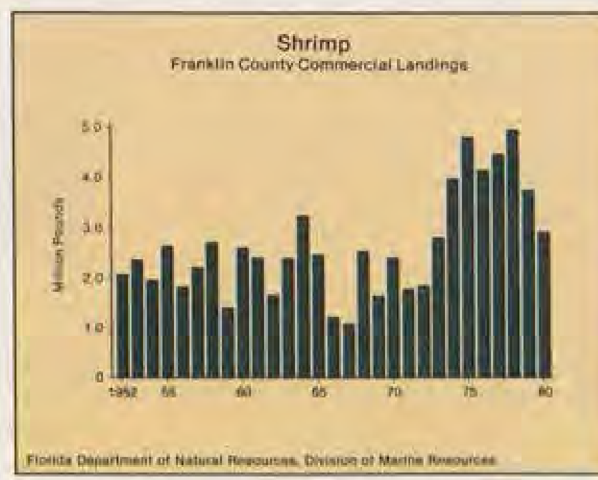
There are three species of penaeid shrimp in the Apalachicola Bay system: white shrimp (*Penaeus setiferus*), brown shrimp (*Penaeus aztecus*), and pink shrimp (*Penaeus duorarum*). White shrimp are the most abundant epibenthic or swimming invertebrates in the Apalachicola estuary, comprising over 40 percent of the trawl catch. They prefer low salinities; salinity and size are often correlated, although habitat (and perhaps food preference) determines local distribution. Spring-summer spawning and recruitment are common. The larval and postlarval forms then move into northern portions of East Bay, where they reach peak numbers in the bay during summer and fall. At this time, the white shrimp grow rapidly. As the fall water temperatures go down, the white shrimp move offshore although there is evidence that some overwinter in the deeper channels of the bay system. Spawning is thought to be initiated in this species by abrupt changes in temperature.

The pink shrimp, comprising around 5 percent of the annual trawl catch, spawns during spring and summer. The young shrimp migrate into the estuary during summer and fall. Some adults overwinter in the bay. While pink shrimp are observed at various temperatures and salinities, they prefer high salinity waters and often become dominant at salinities approximating 18 parts per thousand. Abundance peaks vary from year to year, occurring during spring, summer, and fall. Brown shrimp are the least abundant of the penaeid species in the Apalachicola area, usually making up between 2 and 3 percent of the annual invertebrate trawl catch. It is thought that brown shrimp spawn during winter and early spring with juvenile peaks usually in the spring and summer. Brown shrimp are taken over a wide range of temperature and salinity.

White Shrimp *(Penaeus setiferus)*

Apalachicola shrimp boat





There is limited evidence that all three penaeid shrimp are omnivores, consuming a varied diet of plant matter, organic detritus, inorganic particles, polychaete worms, mollusks, and crustaceans. There is considerable year-to-year variation in shrimp abundance, with low numbers taken during periods of high river flow. The long-term trends of penaeid abundance are still being worked out (Livingston, unpublished data), although commercial landings were higher during the last half of the 1970s than at any other time since 1952. Shrimp constitute over 50 percent of the commercial value of fisheries in Franklin County.

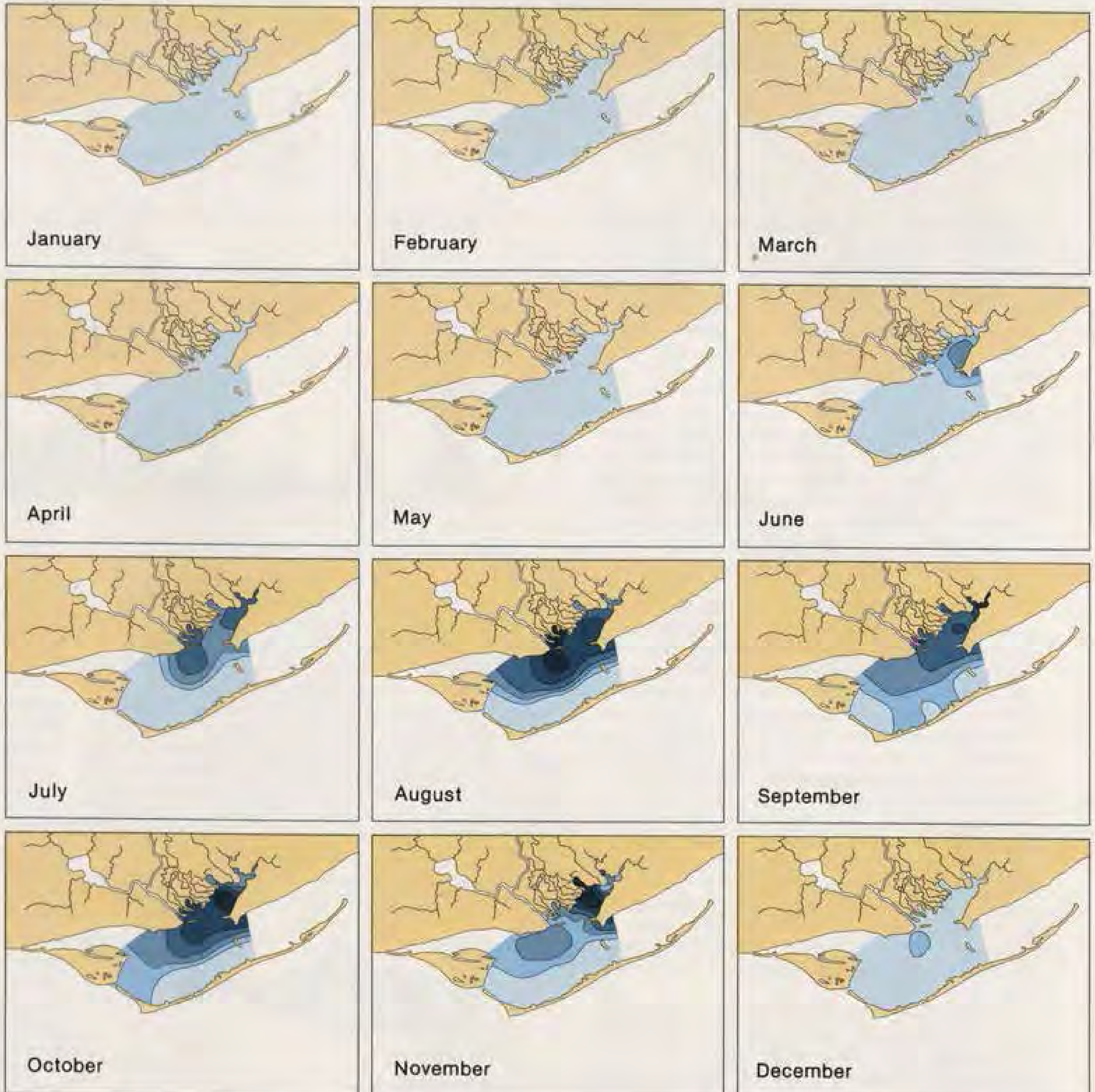
Postlarval penaeid shrimp in the Apalachicola estuary are dominant in the summer and fall. During early summer, they are concentrated in East Bay. By July and August, high numbers are noted at the mouth of the Apalachicola River. By fall, although still concentrated in East Bay, they tend to spread throughout the estuary as they move into the open gulf to spawn. Few shrimp are taken during the winter months. Like other dominant species in the bay, the penaeids appear to be attracted to the freshwater drainages in the northern fringes of the system.

The estuarine environment is crucial to the life history of shrimp, which appear to benefit from the various forms of primary productivity in the bay. The Apalachicola estuary is a major regional center for penaeid shrimp as well as for blue crabs and other commercially valuable species.

Individuals per Two-Minute Trawl Tow
by Month

0.0 - 2.0
2.0 - 5.0
5.0 - 10.0
10.0 - 20.0
20.0 - 35.0
35.0 - 70.0

1972 - 1979 average

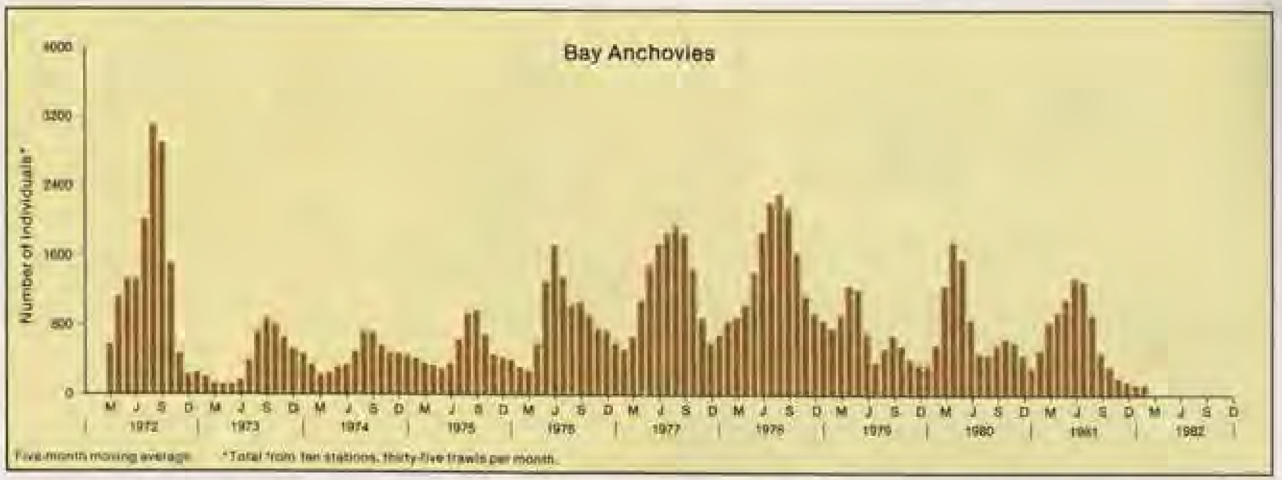


Anchovies

The anchovy is the basis of the world's most productive fishery. In surface waters along the coast of Peru more than 10 million metric tons of anchovies are caught each year. Anchovies are, in general, part of the phytoplankton food webs that are prominent in nutrient rich areas. Phytoplankton, the primary converters of the sun's light energy into living biomass, are eaten by the herbivorous zooplankton. These organisms, in turn, are eaten by the primary carnivores which include anchovies, the herring and sardine groups, squid, and small fishes. In the northern Gulf of Mexico, the bay anchovy (*Anchoa mitchilli*) occupies this same niche or position in the food webs of major estuaries. It is thus no coincidence that anchovies are one of the dominant populations in the shallow bays along northern gulf areas.

The bay anchovy is the most numerous fish in the Apalachicola estuary and represents over 40 percent of the trawl catch in the bay system. It is well known that anchovies have the greatest biomass of any species that inhabits the estuaries along the northern Gulf of Mexico. Anchovies tolerate a wide range of temperature and salinity. Peak numbers usually occur in the Apalachicola system during late summer and fall. The anchovy is one of the few species in the estuary that does not have seasonal patterns of growth, a result, in large part, of the fact that *Anchoa* has a long spawning season (from spring to late fall). Anchovies spawn largely in inshore areas. Juveniles are taken in almost every month of the year. The anchovy eggs and larvae are the most abundant of all those taken in the Apalachicola estuary. They are especially numerous in western sections of the bay and are not commonly found in offshore gulf areas.

In the 1970s, the distribution of anchovies varied considerably in space and time. The highest numbers were taken in 1972, during a period of relatively high winter temperatures and high salinity. The major flooding during the winter of



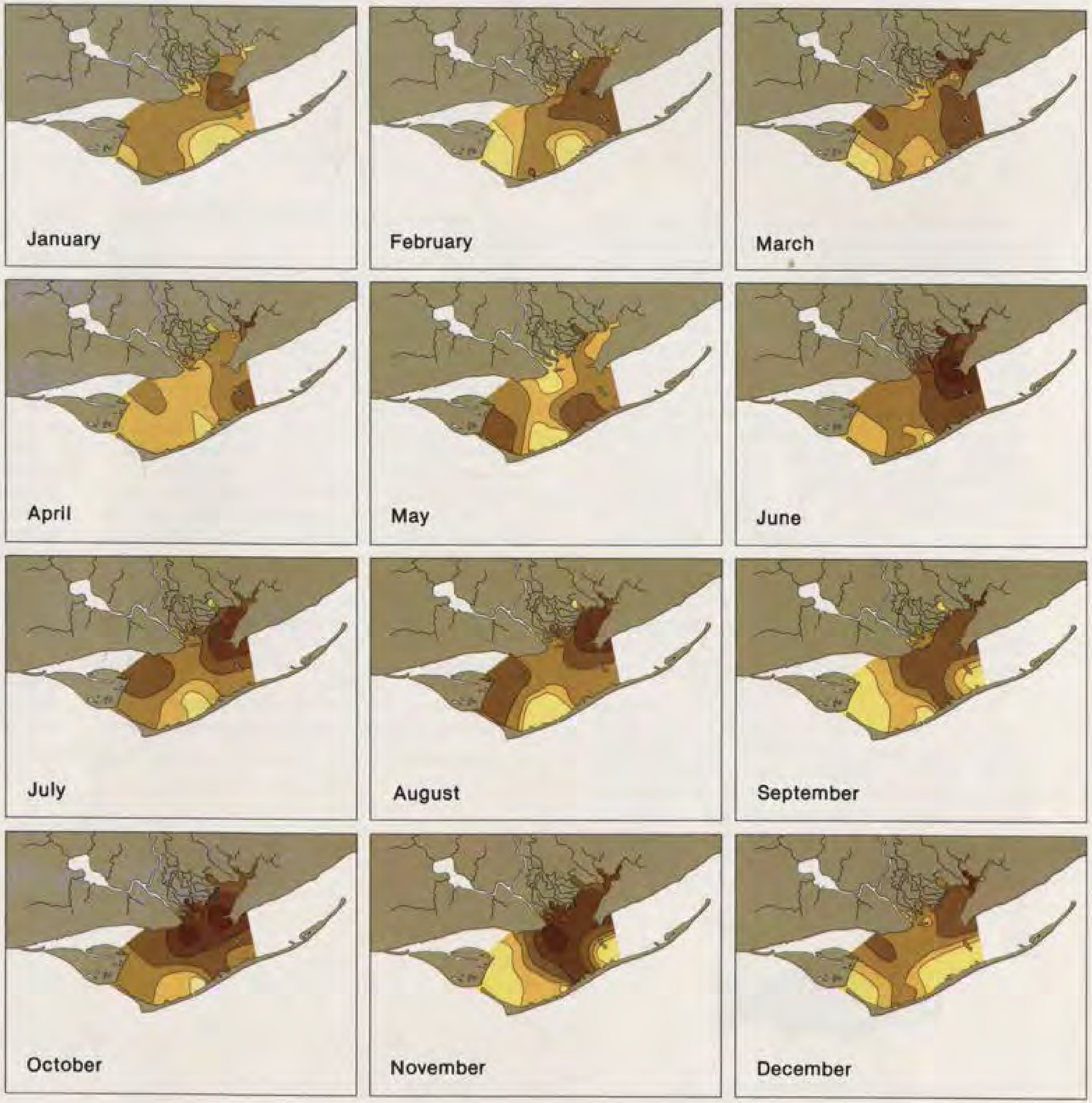
1972–73 appeared to be associated (either indirectly or directly) with reduced numbers of anchovies. Populations tended to increase from 1973 to 1978, after which time there were successive declines in numbers until the beginning of 1982. In spatial terms, anchovies are concentrated in upper portions of East Bay. During the early summer, there are minor population peaks with primary concentrations in eastern portions of East Bay. By the fall, the anchovies concentrate around the mouth of the Apalachicola River as well as in portions of East Bay. By early winter, the anchovies are uniformly distributed throughout East Bay and Apalachicola Bay. During periods of abundance, the anchovies appear to concentrate within the major freshwater

Bay Anchovy (*Anchoa mitchilli*)

drainages of the estuary: East Bay and the mouth of the Apalachicola River. This pattern is in keeping with the nursery function of the bay system and the patterns of productivity in the area.

One of the key determinants of fish distribution is food availability. Comprehensive studies of the feeding habits of anchovies have been carried out and reported by Sheridan (1978) and Sheridan and Livingston (1979). Although the pelagic or free-swimming anchovies feed primarily on calanoid copepods (zooplankton) throughout their life history, there appears to be some change in diet as the fish matures. The young anchovy is primarily a zooplankton feeder (over 70 percent of their diet is copepods). Older fish feed on insect larvae, mysid shrimp, and fishes in addition to the calanoid copepods. The spring phytoplankton and zooplankton peaks co-occur with peaks of the planktivorous anchovies, and it has been suggested that such population increases are blunted by sand seatrout (*Cynoscion arenarius*), which feed predominantly on the anchovies. The fall increases in anchovy numbers could be due to the combination of secondary plankton peaks and movement of major fish-eating predators out of the estuary. Anchovy abundance and distribution depend on a complex combination of physical habitat changes, seasonal productivity cycles, and availability of suitable prey as well as predation pressure, reproductive habits, and recruitment of young anchovies throughout the year. Such recruitment or joining of the main populations by juvenile fish is a continuous process.

The Apalachicola estuary presents a relatively ideal area for the propagation and well being of *Anchoa mitchilli*. The anchovy patterns of summer-fall population peaks, long spawning seasons with year-round recruitment of juveniles, and feeding habits found in the Apalachicola estuary are consistent with the results of other studies around the northern Gulf of Mexico.



Individuals per Two-Minute Trawl Tow by Month

- 0.0 - 5.0
- 5.0 - 10.0
- 10.0 - 20.0
- 20.0 - 50.0
- 50.0 - 100.0
- 100.0 - 202.0

1972 - 1979 average

Spot

Particulate organic matter (POM) enters the estuary via freshwater runoff and is also produced *in situ* (within-system). As these processes occur, the Apalachicola Bay becomes a repository, or sink, for this form of energy. Microbes condition the POM, making it a high quality (high in nitrogen and phosphorus) form of food for detritivores and omnivores. Such animals include the masses of benthic macroinvertebrates that live within or on the soft bottom sediment habitats of the bay system. These organisms usually peak in numbers during winter-spring periods of major river flow and abundance of detritus. It is not surprising, then, that with this seasonal increase of benthic macroinvertebrates, there is a response by organisms that feed on them. Numerically dominant animals such as the spot (*Leiostomus xanthurus*), together with croaker (*Micropogonias undulatus*), and blue crabs (*Callinectes sapidus*) make good use of this abundant food source. These organisms, as omnivores and carnivores, are an important part of the established food webs of the Apalachicola Bay system.

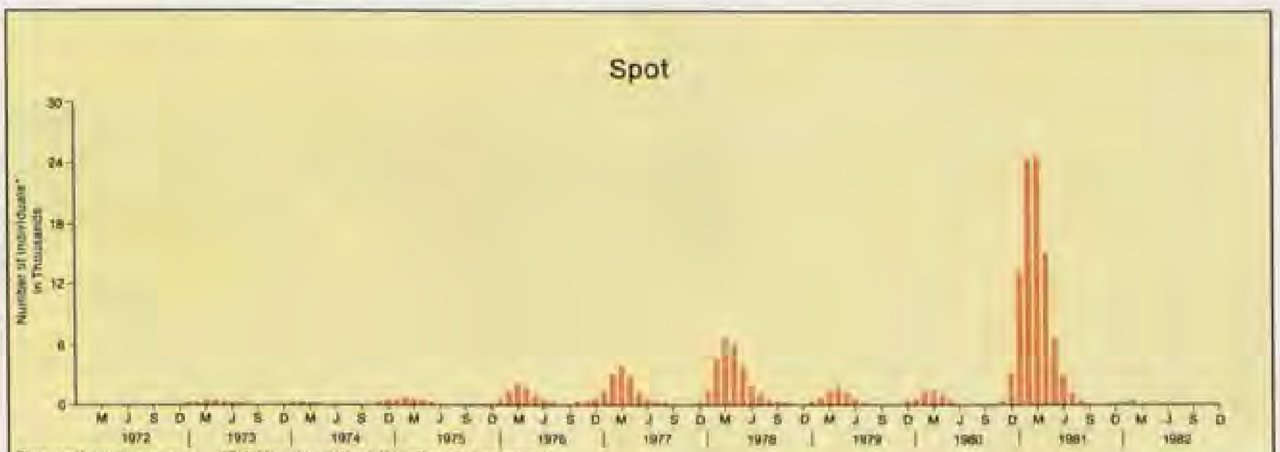
The spot (*Leiostomus xanthurus*) is another estuarine species with a tolerance for a wide range of temperature and salinity. The spot is one of the more abundant fish species in the Gulf of Mexico and is the fourth most abundant of the trawled fishes in the Apalachicola estuary. It represents just over 5 percent of the total fishes captured in any given year. It is the most common fish in Alligator Harbor; highest catches are usually taken at salinities between 10 and 15 parts per thousand.

Spot are thought to spawn in the open Gulf of Mexico or near passes to inshore areas during winter and spring. Juvenile spot appear in the Apalachicola estuary during the winter. Peak numbers usually occur during late winter and spring months. By the summer and fall, spot are relatively uncommon in the bay system. Adults are usually collected in more saline waters. There is considerable year-to-year variation in the abundance of this species. During the early 1970s, there were relatively few spot overall; from 1975 to 1978, spot increased in numbers. After two years of relatively low numbers, there was a population explosion of this species during the winter of 1981. There is some evidence that such trends are in some way related to population changes in the croaker, another form of sciaenid fish, which occupies the estuary during the same periods as the spot. However, the exact combination of factors that determine the trends of this species remains unknown.

As spot move into the estuary in January, they tend to congregate in upper East Bay and around the Nicks Hole drainage off St. George Island. This distribution broadens throughout eastern portions of East Bay and Apalachicola Bay during February and March. Concentrations of spot appear in areas of the bay that receive freshwater runoff from upland areas. East Bay appears to be a particularly important nursery area for this species. By summer, remnants of the population are found off St. George Island. This pattern of seasonal change is consistent with other studies of spot in the northern Gulf of Mexico.

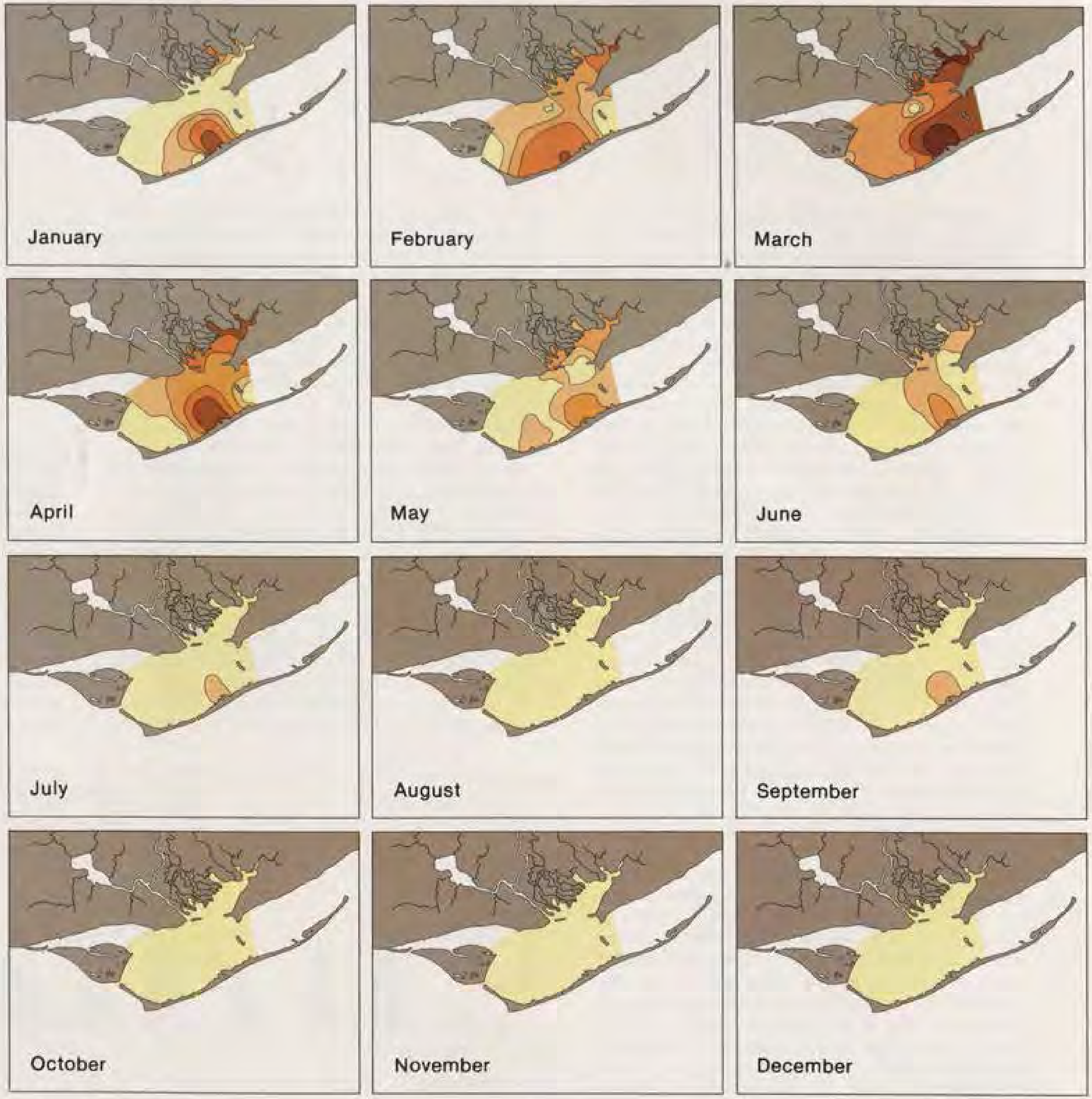
The spot is part of a relatively orderly seasonal progression of organisms in the estuary, which is synchronized in a general way with environmental variables such as temperature, river flow, and salinity. An important factor in this progression is the feeding behavior of individual species. Spot are benthic omnivores that feed on plant matter and organisms found on or within the soft sediment habitats of the Apalachicola estuary. Spot do not concentrate on a single prey but eat a variety of polychaete worms, nematodes, bivalve mollusks, and harpacticoid copepods. Dietary differences between age classes are not as distinctive as those of other fish species. For example,

Spot (*Leiostomus xanthurus*)



Five-month moving average. *Total from ten stations, thirty-five trawls per month the croaker has larger feeding apparatus than the spot and is thus able to feed on larger prey, which live deeper in the sediments. Spot thus occupy a portion of the food web that is directly tied to detritus cycles in the system although the exact form of its diet reflects complex adaptive responses to various other organisms including prey and potential competitors.

The spot responds to complex combinations of physical and biological stimuli, and is an important winter-spring resident of the Apalachicola estuary. It is a major dominant organism adapted to the varying physical conditions and the rich productivity which is part of the estuarine ecosystem.



Individuals per Two-Minute Trawl Tow
by Month

0.0 - 10.0
10.0 - 20.0
20.0 - 50.0
50.0 - 100.0
100.0 - 250.0
250.0 - 505.0

1972 - 1979 average

Croaker

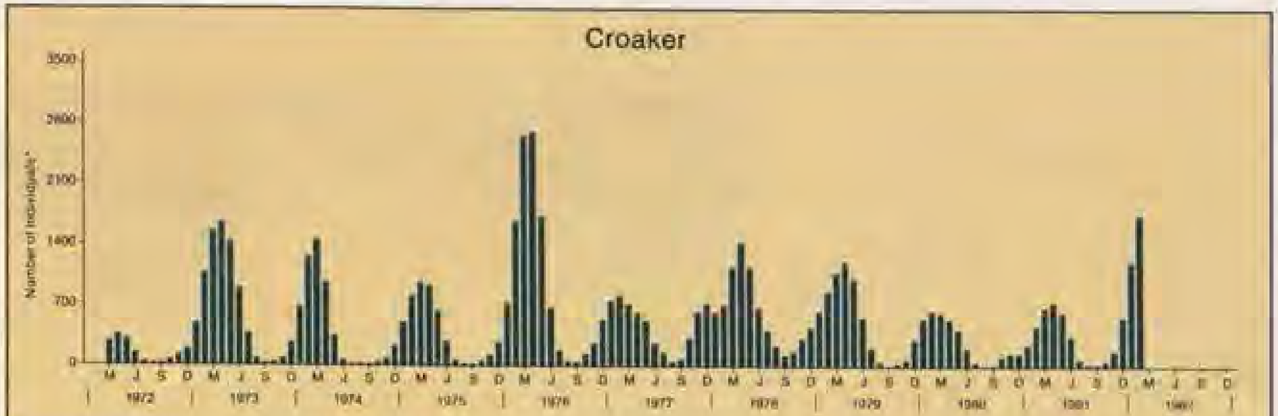
In a relatively shallow system such as the Apalachicola estuary, the benthic or bottom consumers are relatively more important in terms of energy processing than they are in deeper areas of the gulf. High turbidity and sedimentation prevent the development of extensive seagrass beds. At the same time, the wind action on the bay causes active sediment-water interactions or disturbances that stimulate microbial production. Such activity provides the food for benthic macroinvertebrates. When combined with the phytoplankton food webs, this situation allows for extensive development of filter-feeding clams and oysters. Such conditions are responsible for the extensive distribution of soft-sediment subsystems which comprise a major part of the Apalachicola Bay area. These unvegetated areas represent the principal feeding ground for benthic detritivores and omnivores that eat the filter-feeding and deposit-feeding macroinvertebrates. The croaker (*Micropogonias undulatus*) is well designed as such an omnivore. Temperature, salinity, turbidity, nutrients, and productivity change with the season and determine the spatial distribution of the benthic organisms and their predators. Because of the regular cycles of such variables, the spatial and temporal abundance and distribution of croaker in the Apalachicola estuary is relatively predictable as part of a regular annual succession of dominant fishes in the system.

The croaker is the second most numerous fish species in the Apalachicola estuary according to the long-term trawl survey. Croaker spawn in passes along the northern Gulf of Mexico, and juveniles are found in associated estuaries from October to April. Although some juvenile croaker are taken in the Apalachicola estuary during fall and early winter, peak numbers usually occur between January and April each year. Movement back into the gulf from the estuary occurs during the summer and early fall, at which time *Micropogonias undulatus* is relatively uncommon within the Apalachicola Bay system. Like most estuarine organisms, the croaker occurs over a wide range of temperature and salinity. The highest numbers occur at salinities below 10 to 15 parts per thousand. Once again, the estuary serves as a nursery ground for the young croaker where it can feed on the abundant food while remaining relatively protected from offshore predators in the low-salinity waters of the estuary. The usual life cycle of *Micropogonias* takes two years, although older fish may live offshore for a number of years.

While the seasonal cycle of croaker abundance in the estuary is relatively constant, there is considerable variation from year to year. The flooding of 1973 was accompanied by relatively high numbers. Subsequently, croaker numbers decreased until the peak abundance noted during the winter-spring of 1976. There were subsequent decreases in numbers from 1978 to 1982. These long-term population trends are currently under analysis by the Florida State University Ecology Team (Livingston, unpublished data).

Croaker are not abundant in eastern portions of the Apalachicola Bay system, and it is thought that Apalachee Bay is the eastern boundary for this species in the northern Gulf. Within the Apalachicola estuary, croaker start to congregate at the mouth of the Apalachicola River and upper portions of East Bay during January. By February, this distribution is more uniform throughout East Bay and northern Apalachicola Bay. This general distribution appears to hold during ensuing winter and spring months until, by May or June, the croaker move out of the bay. East Bay and the mouth of the Apalachicola River appear to be important areas for this species. Peak numbers occur during periods of high river flow.

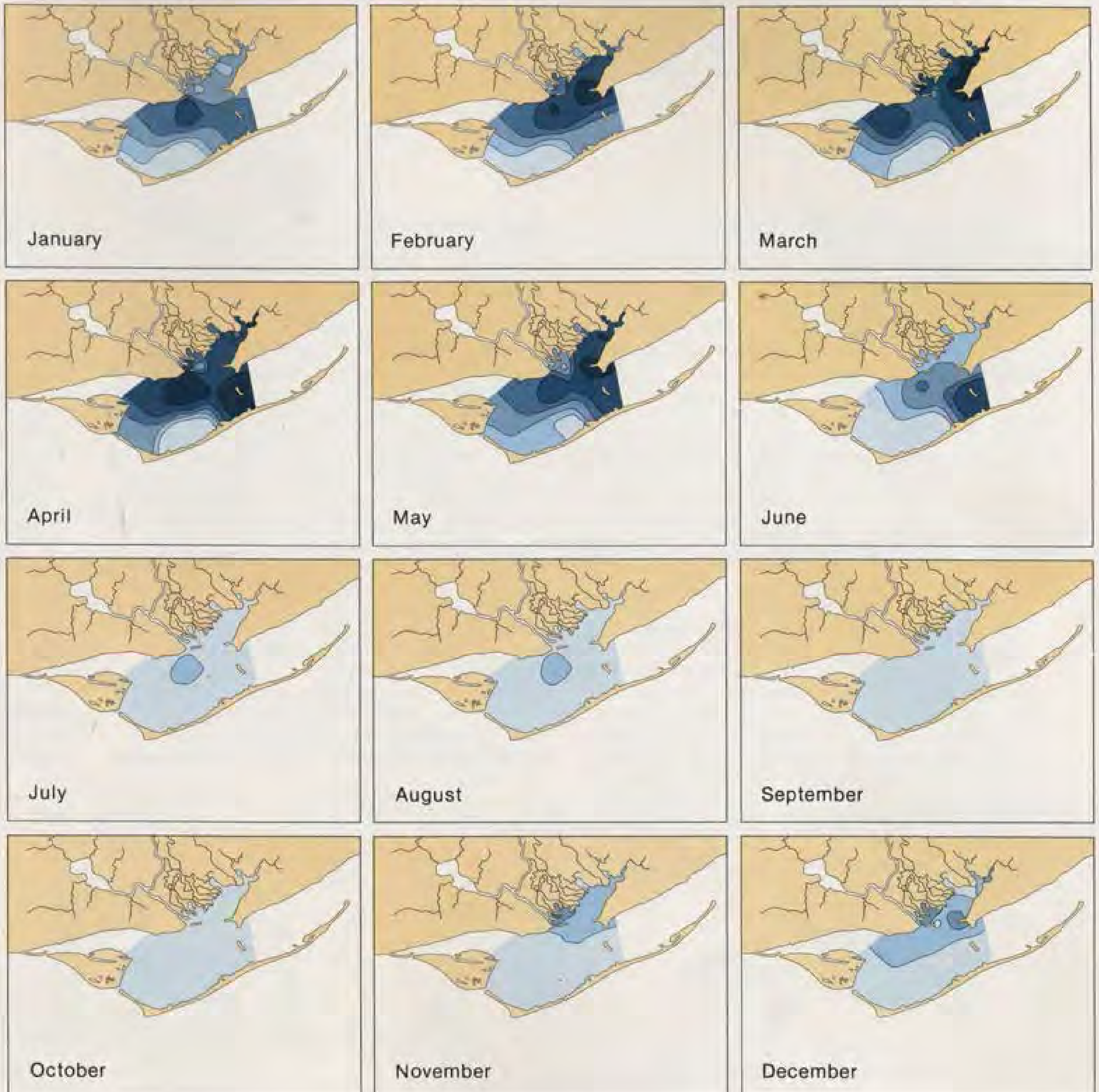
Atlantic Croaker (*Micropogonias undulatus*)



Five-month moving average. *Total from ten stations, thirty-five trawls per month.

Croaker are bottom feeders and are considered omnivores because they feed on a wide variety of plant and animal matter. At all stages of growth, croaker eat polychaete worms. However, croaker go through a series of feeding stages where the diet changes as the fish grows. The young fish eat insect larvae, calanoid copepods, and harpacticoid copepods (crustaceans). With further growth the croaker eats organic detritus, mysid shrimp, and isopods (crustaceans). Larger fish eat crabs, shrimp, and other fishes. In general, the inshore migration of this species is timed with river flooding, availability of detritus, and presence of detritivorous organisms in the sediments of the bay. The Apalachicola estuary is thus an ideal place for a bottom-feeding omnivore such as the croaker.

The croaker is a relatively typical form of offshore spawner. The young of the year move inshore into the rich estuarine waters during periods of high abundance of detritus-based food. The juvenile fish grow rapidly during this time. While the individual details of the life history of such fish vary from estuary to estuary, the general pattern remains more or less the same. In various parts of the Gulf of Mexico, this species is important commercially.



Individuals per Two-Minute Trawl Tow by Month

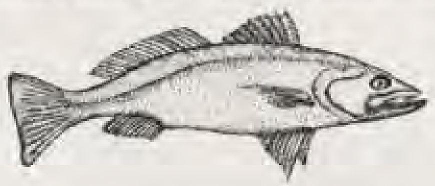
0.0 - 5.0
5.0 - 10.0
10.0 - 20.0
20.0 - 30.0
30.0 - 50.0
50.0 - 100.0

1972 - 1979 average

Sand Seatrout

The primary productivity of plant associations is translated into animal tissue by the herbivores. The herbivores are then consumed by the carnivores and omnivores such as anchovies and spot. At the next feeding or trophic level are the carnivores which feed on fishes, shrimp, and other motile, intermediate-sized organisms. Included in this group are the shark and seatrout. The sand seatrout (*Cynoscion arenarius*) is a member of the sciaenid family of fishes; this family includes many of the most familiar fishes of inshore areas along the northern gulf (i.e., spot, croaker, spotted seatrout, black drum, red drum). The sand seatrout is an important sport fish. It becomes almost entirely piscivorous (fish eating) at an earlier age than does its cousin, the spotted seatrout (*Cynoscion nebulosus*). The sand seatrout is a muddy bottom predator and is the gulf version of the Atlantic weakfish (*Cynoscion regalis*).

The sand seatrout is one of the numerically dominant fishes of the Apalachicola estuary and is a relatively common fish species along the northern Gulf of Mexico. Spawning is thought to occur somewhere just offshore of the estuaries during the spring. The youngest sand seatrout are found during April and May each year. Peak abundance in the gulf estuaries for the juveniles is usually from May to July. In the Apalachicola estuary, sand seatrout are usually found from March to December. Peak numbers usually occur during summer and early fall. The gulfward migration occurs during the fall. This species is almost completely absent from the Apalachicola Bay system during winter and spring months.

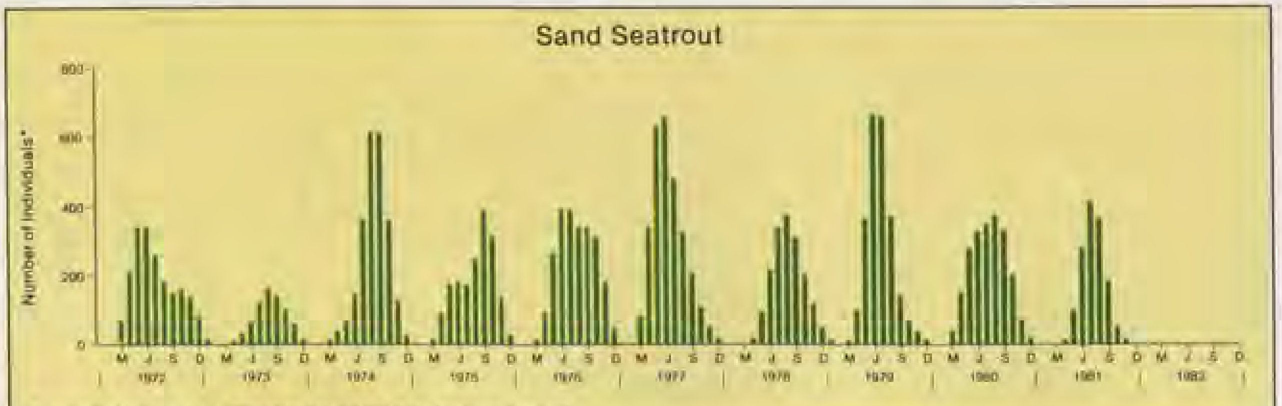


Sand Seatrout (*Cynoscion arenarius*)

The sand seatrout has a relatively uniform distribution over a range of salinities. Temperature is considered to be an important limiting factor for this species; catch ratios are usually highest between 20 and 35°C. Catches from 1972 to 1982 reflected some year-to-year variation. The year after the major river flooding of the winter of 1973, there was a relatively low number of sand seatrout. Studies are currently under way to model mathematically these long-term trends (Livingston, unpublished data).

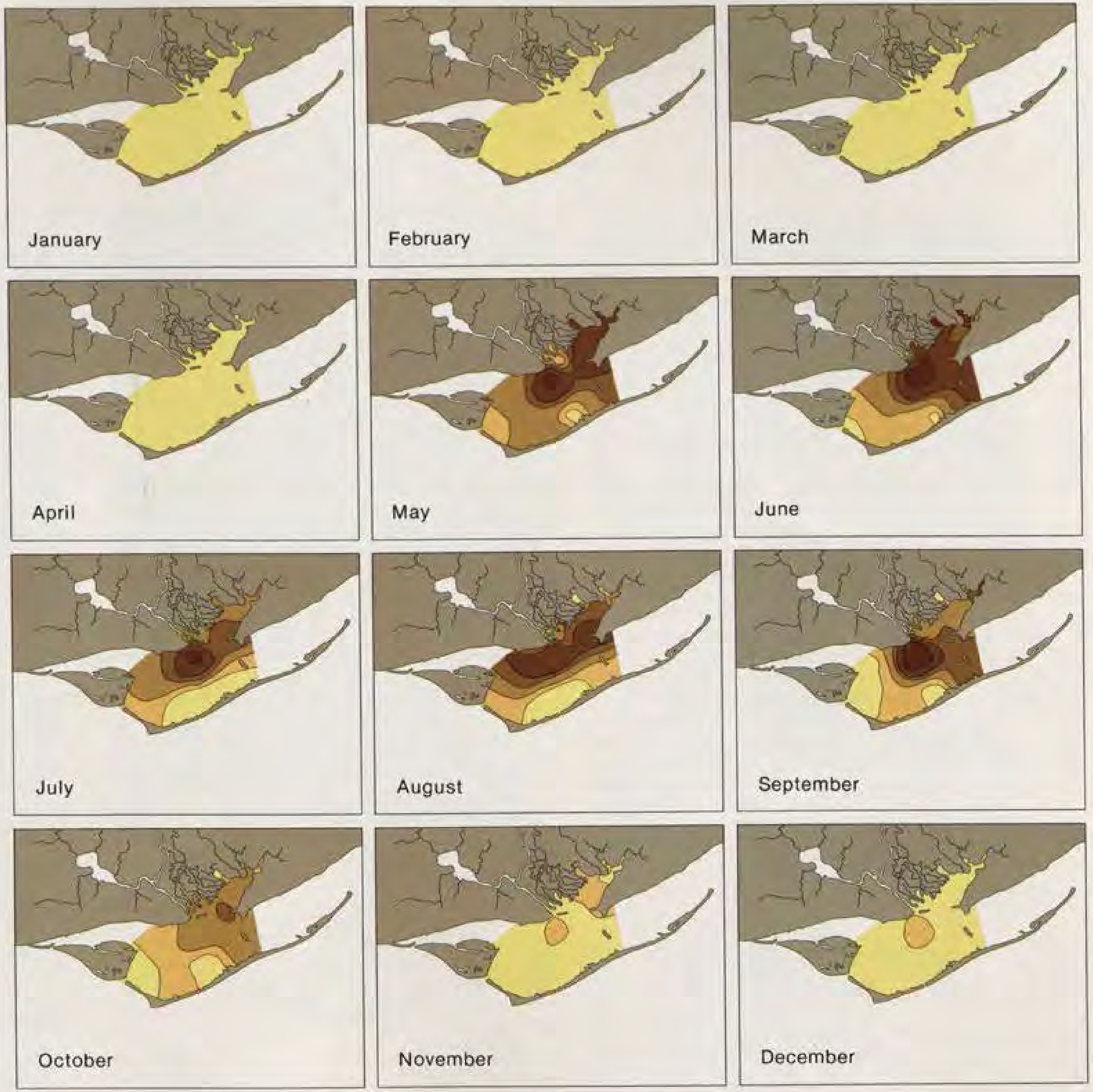
The spatial distribution of sand seatrout through a given seasonal cycle is quite regular. As the young seatrout move into the bay system in May, they concentrate in upper portions of East Bay and just off the mouth of the Apalachicola River. Secondary concentrations are found throughout East Bay and northern portions of Apalachicola Bay. Such distribution changes little in June, but by July, the highest concentrations of the sand seatrout are found at the mouth of the Apalachicola River. This distribution remains relatively unchanged during August and September. Remaining fish, dwindling in numbers, spread throughout East Bay and northern Apalachicola Bay. By winter and early spring, as noted, no sand seatrout are taken. It should be remembered that such distributions represent averages over the period from 1972 through 1979. Therefore, there may be considerable variation in such a pattern in any given month or year. However, these general patterns (based on long-term averages determined by computer analyses at the Florida State University Computing Center) are representative of general trends. Such analyses allow the most accurate formation of a probable location of this species in space and time.

The distribution of a given fish population at a certain stage of its development is, in part, determined by its food. During the early growth stages, sand seatrout eat zooplankton and small fishes. As it grows, the sand seatrout becomes predominantly piscivorous; that is, it eats fishes such as anchovies. No single set of environmental stimuli can be identified with such food habits or with population distribution. However, the relatively well-timed migrations of fishes such as the sand seatrout are generally associated with seasonal and annual trends of temperature, river flow (and salinity), productivity, predator-prey relation-



Five-month moving average. *Total from ten stations, thirty-five trawls per month.

ships, and species-specific cycles of reproduction. The seasonal distribution of sand seatrout in the Apalachicola estuary is somewhat stable from year to year. As an estuarine species, the sand seatrout shows generalized temperature and salinity preferences. It fits into the usual pattern of those organisms that use the estuary during periods of rapid growth and maturation. The highly productive Apalachicola Bay system, although physically unstable in time, is actually the habitat for a highly evolved and temporally stable biological organization. The sand seatrout is an important part of this ebb and flow of life in the estuary.



Sport and Commercial Fisheries

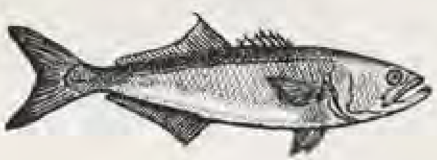
Any assessment of the fisheries of this region should address the Apalachicola drainage system as a whole, since various so-called anadromous species live in the gulf as adults but spawn in the Apalachicola River. Miller, Hartman, and Dunford (1977) and Yerger (1977) have reviewed the freshwater fisheries of the Apalachicola River system. The striped bass (*Morone saxatilis*) was, at one time, the object of an important sport fishery. While the migratory habits of this species remain unclear, striped bass populations have declined drastically according to recent studies by the U.S. Fish and Wildlife Service (Barkuloo, 1967; Crateau, Moon, and Wooley, 1981). Dams along the tri-river system, together with habitat destruction from dredging and pollution, are thought to have contributed to this situation. Such habitat loss has also been associated with the recent decline of the sturgeon fishery along the Apalachicola River. The sturgeon (*Acipenser oxyrhynchus*) is considered an anadromous fish that once was important commercially. The Alabama shad (*Alosa alabamae*) is still the most abundant anadromous species along the river.

The commercial catfish fishery is still important along the river, although Miller, Hartman, and Dunford (1977) have cited studies that show snagging (stump removal from the river bed for navigation) could be associated with further habitat loss and decline of the fishery. The white bass (*Morone chrysops*) is a popular sport fish. Hybrids of striped bass and white bass are an important part of the freshwater fishery. Largemouth bass and various forms of bream and shellcrackers are also important sport fishes. The yellow perch (*Perca flavescens*) is taken occasionally by freshwater fishermen. As pointed out by Miller, Hartman, and Dunford (1977), the general decline of the freshwater fisheries is inevitable if habitat destruction along the river continues. Habitats are destroyed by dredging and channelization, damming, urban and agricultural runoff, toxic substances, and other forms of river modification. There is a need for a comprehensive assessment of the current status of the Apalachicola River fisheries and the current and future effects of river modifications and habitat loss on such productivity.

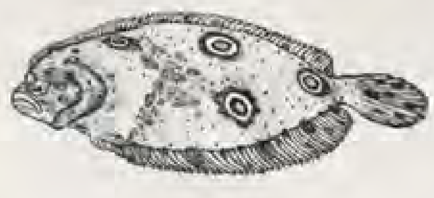
The combination of periodic low salinity, high productivity, and limited predation pressure makes the Apalachicola estuary an ideal environment for various stages of commercially important species. Organisms with a variety of life history patterns are evident in the estuary. Some species, such as oysters (*Crassostrea virginica*) and the spotted seatrout (*Cynoscion nebulosus*) spend their entire lives in the estuary. Other organisms, such as penaeid shrimp (*Penaeus* spp.), blue crabs (*Callinectes sapidus*), and the sciaenid fishes (spot, croaker, silver perch, red drum) spawn offshore and move into the estuary as larvae, postlarvae, or juveniles. Compared with other estuaries along the Florida gulf coast, the Apalachicola Bay system is a most productive area for sciaenid fishes (Livingston, 1981). The nursery function of the estuary is thus an important feature of the fisheries potential of the Apalachicola system.

The Apalachicola oyster fishery, the backbone of the gulf-based industry, is of historic, cultural, and economic importance. Up to 90 percent of Florida's oysters come from the Apalachicola estuary. However, commercially valuable oyster bars currently cover about half the area of 80 years ago. Shell planting with "cultch" or shucked shells is a proven management technique with potential for the Apalachicola Bay where it is estimated that up to 40 percent of the area is suitable for growing oysters. Such productivity, along with the fastest growing oysters in the country, is the result of the unique geographical and ecological features of the Apalachicola Bay system. Since more sanitary (safe) harvesting waters for oysters exist in the Apalachicola estuary than than any other Florida estuary (Whitfield and Beaumariage, 1977), there is considerable support throughout the region for the industry as an important source of future economic growth.

The problem of fecal coliform contamination of oysters from urban runoff, sewage and septic wastes is of central concern to local and regional planning offices. The capacity of oysters to filter food out of the water leads to concentration of pathogenic microbes if they are present. Because concentrations of microbes may result in public health problems, oysters are constantly monitored by regulatory agencies. Of over 2 million acres of available shellfish areas in Florida, only 22 percent are approved for harvesting, while 13 percent are prohibited, 5 percent are conditionally approved, and about 60 percent are unclassified. The Apalachicola system is closed periodically during periods of heavy rainfall and high river flow when bacteria are washed into the system from various sources.



Bluefish (*Pomatomus saltatrix*)



Ocellated Flounder (*Ancylopsetta quadrocellata*)

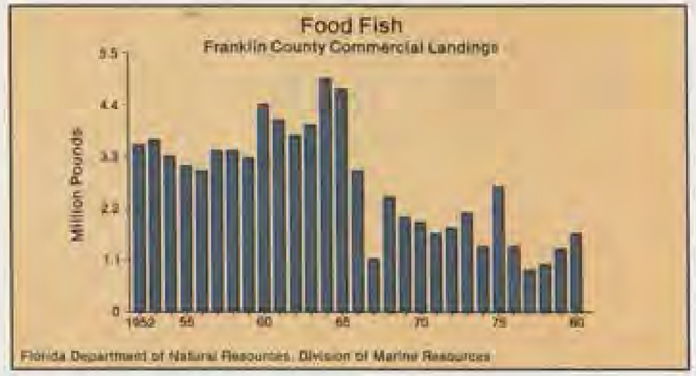
Studies are under way to determine the influence of processing and storage on the microbial load of oyster meats. Transplantation of oysters from contaminated areas to uncontaminated ones, where they then become suitable for harvesting, has been successfully introduced in the Apalachicola system. Such oyster relaying can be used to buffer the adverse economic effects on the region during periods when the bay is closed to harvesting because of high rainfall and river flow. All of these issues constitute the relatively complex process of managing the valuable and renewable oyster resource.

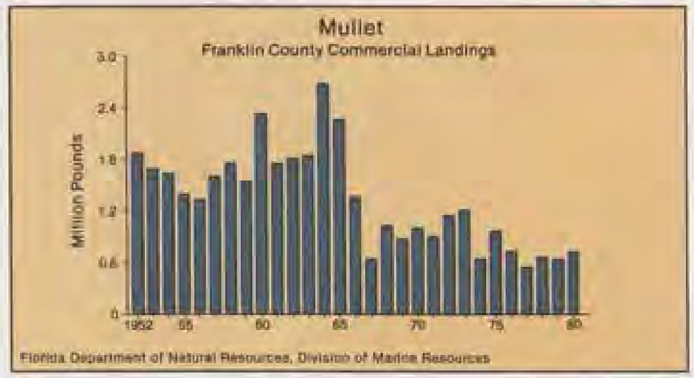
Penaeid shrimp (mainly white shrimp) represent an extremely valuable fisheries resource in the Apalachicola estuary, with dockside landings between 5 and 6 million dollars annually. The shrimp are taken within the bay system as well as in the Gulf of Mexico. Thus, the landings reported by the 300 to 350 shrimp boats that work the bay system each year represent only a fraction of the total catch of shrimp that are nurtured by the Apalachicola estuary.

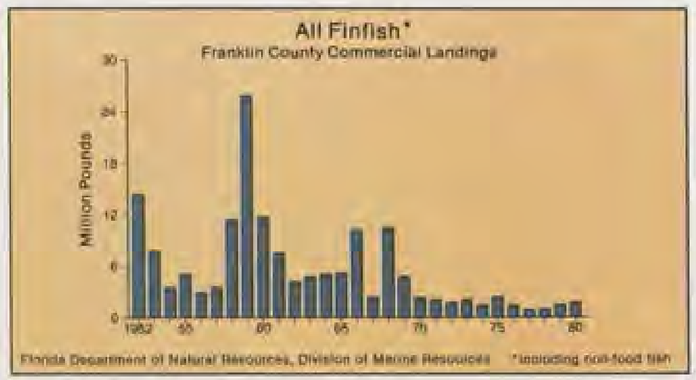
Blue crabs represent another important fisheries resource in the region. A primary spawning ground for blue crabs is located in the offshore region between the Apalachicola and Ochlockonee river drainages (thought to be centered just offshore of Dog Island). The blue crab harvest along Florida's gulf coast is worth from 2 to 3 million dollars annually. In Franklin County, blue crabs constitute about 5 percent of the total commercial fishery value. Of the commercial finfish catch, black mullet (*Mugil cephalus*) is the most important crop economically. Grouper, whiting, and menhaden are also taken.

The sport fisheries associated with the Apalachicola Bay system could be an economic sleeping giant. Spotted seatrout (*Cynoscion nebulosus*) and red drum (*Sciaenops ocellatus*) are important species taken during summer, fall, and winter months. Tarpon (*Megalops atlanticus*) are also taken at the mouth of the Apalachicola River and portions of the bay during the summer. Sheepshead (*Archosargus probatocephalus*), black drum (*Pogonias cromis*), and flounder (*Paralichthys* spp.) are also taken in season. Fishes taken off the barrier islands and Alligator Point include various species of sharks, cobia (*Rachycentron canadum*), bluefish (*Pomatomus saltatrix*), red snapper (*Lutjanus campechanus*), and different species of grouper. The continued development of artificial offshore reefs in the region could play an important part in the continued development of the sport fisheries.

The accurate, scientific prediction of the future of the important commercial and sport species is difficult not only because of the natural, year-to-year variability of such populations, but also because of the impact of socioeconomic factors. The abolition of the Florida severance tax was associated with a considerable increase in oyster production throughout Florida from 1955 to 1959. Much of this increase has been attributed to the "conservative" reporting of oyster yields prior to the suspension of the tax. Meeter, Livingston, and Woodsum (1979) studied the relationship of the commercial catches of oysters, shrimp, and blue crabs with climatological factors such as river flow and rainfall. There are long-term (6–7 year) cycles of river flow, which are generally associated with oyster catches (negatively correlated) and blue crab catches (positively correlated). The Florida State University research group headed by R.J. Livingston is currently working with a long-term, multidisciplinary data base to develop models of population response to complex combinations of physical, biological, and socioeconomic factors.





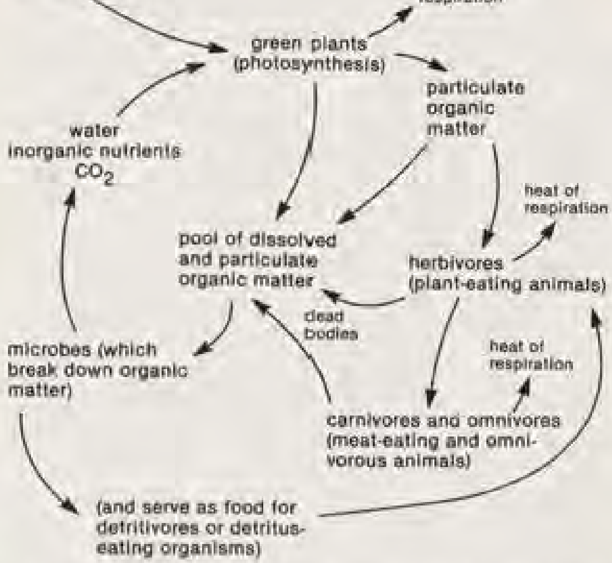


Food Webs

Of central importance to our concept of how ecosystems work is the idea of the food web. The early construction of distinct trophic levels (organisms that feed at a specific distance, so to speak, from the sun's energy) is an oversimplification of the real world. For instance, research has shown that the pinfish (*Lagodon rhomboides*), a common inhabitant of gulf grassbeds, goes through a series of basic trophic levels as it grows. As a young fish, moving inshore from its spawning grounds, it is a zooplanktivore, feeding on zooplankton in the water column. With time and growth, the young pinfish drops to the bottom and becomes a benthic carnivore feeding on small invertebrates. As it grows, the pinfish adds tiny plants to its diet and becomes an omnivore. Gradually, it takes more and larger forms of plant matter until, at the last stage of its grassbed existence, it becomes an herbivore feeding almost exclusively on seagrasses such as *Thalassia testudinum* and *Syringodium filiforme*. The aquatic food web is composed of the countless feeding interactions of hundreds of species living together in aquatic communities. The food web is thus the summation of complex feeding relationships among plants and animals that live together in a given place at a given time. Each lake, river, or estuary is characterized by a particular pattern or web of predator-prey interactions. These interactions ultimately determine the distribution of energy as it is passed through the ecosystem.

Plants and animals in the Apalachicola estuary are joined together into highly evolved feeding patterns. Light energy from the sun is transformed by green plants into organic matter, a process known as primary productivity, which has been intensively studied in the Apalachicola Valley. The organic matter from the plants is either consumed directly by animals or serves as a substrate for microorganisms which break it down into its inorganic constituents, including nutrients such as nitrogen and phosphorus compounds. Such compounds then serve as the necessary ingredients (or fertilizer) for continued plant productivity. The microbes themselves serve as food for various organisms, which means that the organic matter, together with dissolved nutrients, also moves into the food webs via the microbial components. Thus, the green plants, microbes, and animals are all joined together as the sun's energy, in the form of plant-derived organic matter, moves through the great food webs of the estuary.

The plant-microbe-animal combination forms a basic ecological cycle:

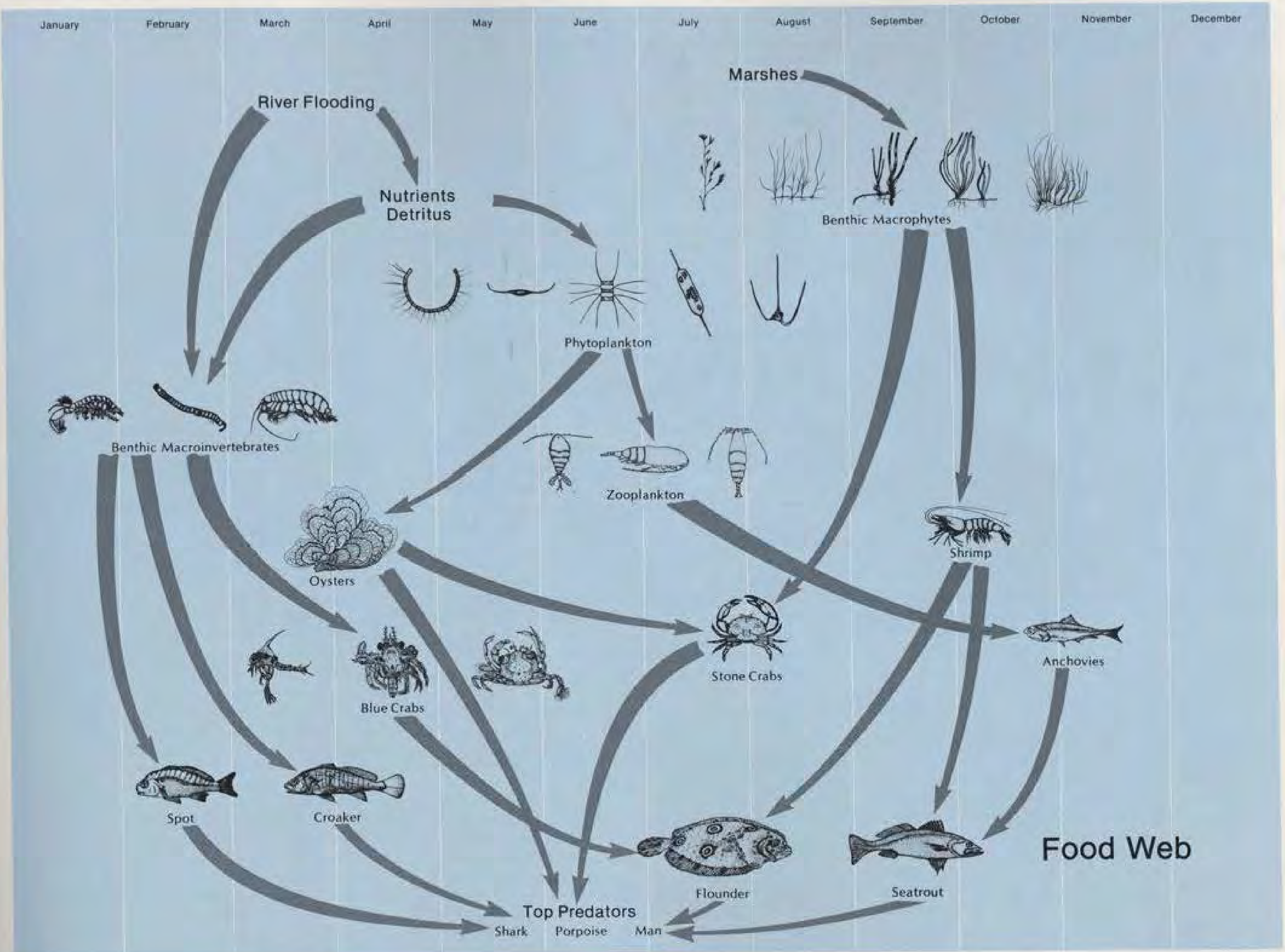


Each organism has a role to play in this cycle of life. Herbivores and small carnivores are eaten by the larger carnivores and omnivores. Eventually, the dead bodies of such organisms are broken down by microbes into their inorganic constituents and the cycle is complete as the nutrients are used for renewed plant productivity.

The estuary is between the river and the open gulf and, because of its structure and the complex chemical interactions that occur as the fresh water meets the salt water, energy is trapped in what amounts to an energy sink. Some of the combined particulate organic matter and microbial biomass is consumed by organisms that live in (or on) the sediments. The food webs of the estuary reflect seasonal changes in various productivity cycles and habitat features. Of the ten dominant infaunal invertebrates, five are detritus feeders, four are deposit feeders (swallowing sediment and extracting food from the processed muds), and one is a filter feeder (filtering or straining the water for food). There are also carnivore types but most of the bottom-dwelling invertebrates are detritus feeders or omnivores. These invertebrates include the amphipods, isopods, copepods, and polychaete worms, which, in turn, serve as food for the blue crabs, penaeid shrimp, spot, croaker and other predators.

Most of the free-swimming animals or nekton are omnivores at some stage of their life in the estuary. Detritus is found in the stomachs of many of the intermediate-sized fishes (croaker, spot) and invertebrates (crabs, shrimp). In addition to the detritus-based food web, there is a well-developed plankton-based energy transfer system whereby the phytoplankton are eaten by the zooplankton, which, in turn, are fed upon by the anchovies, silversides, menhaden, and the young of various fish species.

At the top of the food web are the major carnivores. The seatrout, redfish, flounders, silver perch, and sea robins feed on the shrimp, crabs, and intermediate-sized fishes. These predators are, in turn, fed upon by the so-called top predators—the sharks, porpoises, and man. Man, in fact, is a very diverse predator who feeds at various trophic levels and who is an integral part of the estuarine food webs.


January
February
March
April
May
June
July
August
September
October
November
December
Marshes
River Flooding
Nutrients
Detritus
Benthic Macrophytes
Phytoplankton
Benthic Macroinvertebrates
Zooplankton
Oysters
Shrimp
Stone Crabs
Anchovies
Blue Crabs
Spot
Croaker
Flounder
Seatrout
Top Predators
Shark
Porpoise
Man

Food Web

Community Organization

A population is a group of organisms, usually interbreeding and of the same species. Such organisms live together in the same place (or habitat) at the same time. There are various concepts of how plant and animal populations live together in associations. It is thought that groups of organisms, as they evolve through time, react in such a way that they eliminate direct competition by occupying separate niches or roles in the ecosystem. There is considerable controversy concerning the nature of such competition and how it works to achieve the diverse assemblages of organisms that are observed in nature. It is known that these assemblages reproduce, feed, and die in interrelated units of the ecosystem. When a group of populations lives together and interacts (usually eating each other or competing for space and food), such an assemblage is called a community. It is very difficult to draw distinct lines around communities of interacting organisms because the component populations vary considerably in their distribution in space and time. The dimensions of a community are determined by many factors, including the type of habitat, the nature of the sources of productivity, and the extent, in space and time, of the feeding interactions among the various populations. The keys to understanding a given ecosystem are definition of population interactions (with the environment and other populations) and description of the ways such interactions reflect the fabric of a community response.

The estuary contains communities of interrelated assemblages of plants and animals. Such associations include the marshes, grassbeds, soft-sediment areas, oyster bars, and open water areas. The overall estuarine habitat is determined by features such as river flow, temperature, salinity, sediment type, and water quality. Very distinctive habitat types are associated with emergent vegetation, sea grasses and algae, benthic macroinvertebrates or infauna, oysters, and the floating and free-swimming organisms that live in the water column.

Various kinds of grassbeds are found in the estuary. In upper portions of East Bay, the oligohaline (low salinity) grassbeds are dominated by tape weed, *Ruppia*, and *Potamogeton*. Such grasses act as the habitat and source of food for various animals, such as snails *(Neritina)*, different forms of crustaceans (amphipods, shrimp), insect larvae, and polychaete worms. Fishes such as silversides, gobies, pipefish, and killifish live and feed in the oligohaline grassbeds. Many of the free-swimming types such as the shrimp and fishes are seasonally abundant as they eat organic detritus, small plants, and various invertebrates. Farther out in the bay, along the lagoonal portions of St. George Island, lie the *Halodule* beds. In these highly productive nursery areas live large numbers of infaunal invertebrates, grass shrimp, pink shrimp, blue crabs, and finfishes such as pinfish, pigfish, silver perch, and spotted seatrout. The area off the Nicks Hole drainage is particularly productive in terms of numbers of such organisms. This production is probably due to the freshwater runoff from the island and the fringing marsh areas, which provide a flow of nutrients into the lagoons and associated offshore areas of Apalachicola Bay.

Oyster bars are the result of complex combinations of substrate, productivity trends, temperature, and salinity. Oysters, in turn, form the habitat for a wide variety of organisms such as bryozoans, flatworms, polychaetes, mollusks, crabs, and fishes. These animals use the oyster reefs for shelter and food. Salinity is an important factor in the distribution and number of such organisms. As salinity increases, species numbers and diversity increase. Various species of worms and mollusks move onto the reef during periods of high salinity. Likewise, crustaceans such as stone crabs move into reef areas and feed on the oysters. Various experimental studies indicate that under conditions of high salinity, such predation results in a significant loss of oysters. During summer months of high temperature, oysters may also be killed by the pathogenic fungus *Perkinsus marinus*. Optimal temperatures (15–30°C) and salinities (15–25 ppt), together with high rates of primary productivity, result in rapid oyster growth whereby commercial sizes can be reached within 12 to 18 months. It is thought that such growth is most favorable during periods of fluctuating salinity. The overall organization of the oyster reefs is thus a product of interacting physical, chemical, and biological features of the estuary.

The predominant habitat in the Apalachicola estuary is the unvegetated, soft sediment bottom. The invertebrates that live in the sediments are dominated by polychaete worms (such as *Mediomastus ambiseta* and *Streblospio benedicti*) and amphipod crustaceans (such as *Grandidierella bonnieroides*). Such organisms are very adaptable to wide ranges of temperature and salinity. These invertebrates serve as food for various estuarine species such as blue crabs, spot, and croaker. Many of the infaunal invertebrates are deposit and suspension feeders and detritivores, which eat the particulate organic matter and its microbial constituents. The infaunal winter peaks occur when detritus is abundant in the estuary as the river floods and organic matter from the adjoining wetlands is washed into the estuary. In this way, the timing of the river flooding is closely associated with food web response in the estuary.

All of the various populations in the estuary, from phytoplankton to fishes, are responsive to salinity gradients. In fact, salinity is a primary regulator of species numbers, which usually increase as salinity increases. The composition of species in the estuarine community is directly related to salinity. In areas of low salinity, those species that are adapted to low or fluctuating salinity, such as oysters, penaeid shrimp, blue crabs, and various finfishes, do very well as they are relatively free from the gulf predators. Thus, low salinity is a major reason why the estuary is an important and productive nursery. The estuary functions as a sanctuary for those species that form the basis of the important sport and commercial fisheries of the area. Although species diversity is relatively low in the Apalachicola estuary, the productivity is high as the estuary is a nursery for various gulf species. Thus, spatial and temporal gradients of salinity and productivity, along with seasonal changes of temperature and other habitat variables, control the distribution and relative abundance of the dominant estuarine populations.

The Apalachicola estuary, as an ecological system, reflects the response of various organisms to the combination of physical, chemical, and biological factors. Over aeons, these organisms have adapted to the distinctive estuarine conditions. There is a regular succession of dominant species that utilize the various subhabitats of the estuary. Without any portion of the system — the river and its wetlands, the marshes, the basin itself, and all the associated conditions, such as salinity and productivity — there would be changes in the biological response and inevitable shifts in the food web structure and relative abundance of the dominant species. The offshore Gulf of Mexico, as a center of spawning and recruitment for the bay system, remains virtually unknown in terms of its biological connection with the inshore area. This aspect of bay productivity deserves more study. However, as long as the major driving functions remain as they are, the pulsing river will support the natural seasonal successions of organisms that regularly thrive in the estuary.

Regional Economics

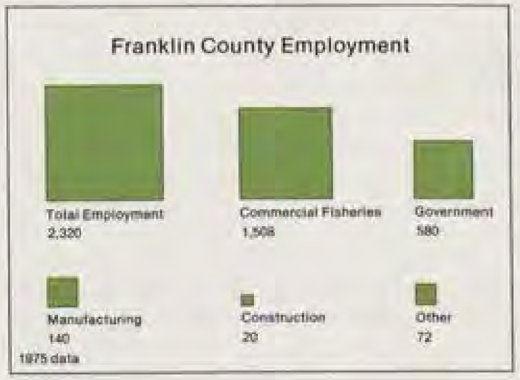
The Apalachicola Valley is economically dependent on forestry, agriculture, sport and commercial fisheries, recreation, and light manufacturing. Nearly 80 percent of the land in the basin is used for forestry or agriculture. Within the river basin, the total population was 109,254 in 1974, and only modest increases are projected over the next 20 years. Population density is relatively low; according to Mulkey and Maturo (1983), none of the seven counties in the region approaches the average density of 180.1 persons per square mile for the state as a whole. Per capita income is low, ranging from 46.6 percent (Franklin County) to 79.4 percent (Gulf County) of per capita income for Florida. Overall, the socioeconomic profile of the region reflects a strong dependence on a range of renewable resources, not the least important of which is the Apalachicola estuary.

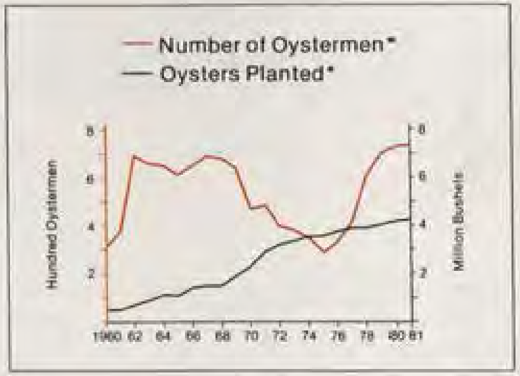
The Apalachicola Bay system is within Franklin County. The growth of this county reflects the economic trends of the rest of the valley. From 1960 to 1980, the population has increased by just under 28 percent, with much of the increase occurring in unincorporated areas, notably St. George Island, East Point, Alligator Point, and other parts of the coastal fringe. There is currently little urbanization or agriculture in the county and no heavy industry. Land use statistics indicate Franklin County's dependence on forestry and aquatic resources, both fresh and salt water. Prochaska and Mulkey (1983) have pointed out that Franklin County is economically dependent to a considerable degree on commercial fisheries. The dock value of commercial fisheries has increased from $1.5 million in 1960 to about $12 million in 1980. Over this period, shellfish (notably oysters and shrimp) values have increased from 70 to 90 percent of the total value of landings, while the county's share of total marine landings in Florida has increased from 7 to 10 percent. Economists have pointed out that export sales such as fisheries products stimulate a chain reaction known as the "multiplier" effect. Prochaska and Mulkey (1983) estimate that $1.00 in external sales generates an additional $0.41 in local sales. With a multiplier of 1.41 for Franklin County and 1.92 for the six-county region, the 1980 sales for all fishes and shellfish amounted to $16,964,237 and $23,100,238, respectively. In other words, when all transactions related to the commercial landings in Franklin County are considered, the local and regional value of such productivity is considerable. Colberg, Dietrich, and Windham (1968) projected a value of $34.2 million for commercial fishing and tourism by the year 2000 if water quality and natural productivity are maintained. With appropriate multipliers, this estimate increases from $34 million to almost $67 million, according to recent figures determined by Mulkey and Maturo (1983). When it is taken into consideration that such productivity requires a relatively slight investment for maintenance of what is essentially a naturally subsidized, renewable resource, the economic value of the as yet undiminished Apalachicola estuary for the local area and the region should not be underestimated.

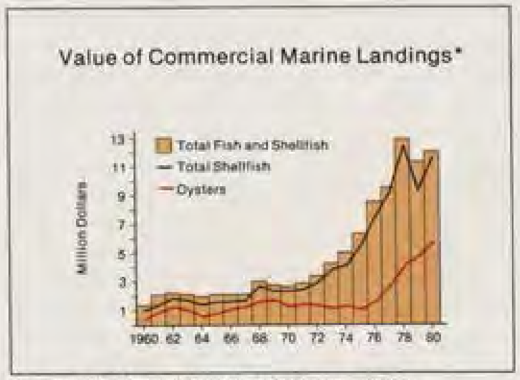
Overall, the most probable new means of future regional economic growth will be industrialization along the river valley and municipal development of areas such as St. George Island. Considering the potential for future growth in Florida, such expansion is inevitable. Already, there has been direct and indirect confrontation between the existing socioeconomic infrastructure and outside economic interests. The real question is whether such development can occur without destroying the natural (renewable) resource base. It is here that the main answer rests in progressive land use planning and enlightened resource management.

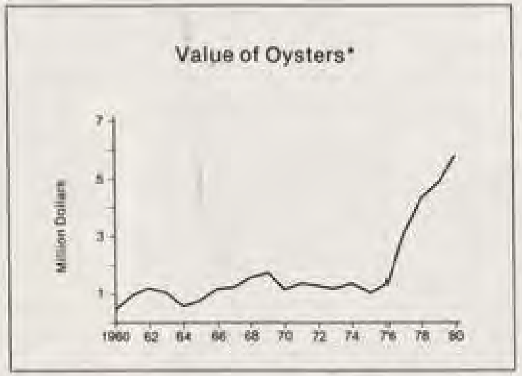
Oyster boats on Apalachicola Bay

Barge traffic on the Apalachicola River









*Courtesy of Dr. Fred J. Prochaska, personal communication

Population

Year	Franklin County	Apalachicola	Carrabelle	Unincorporated
1960	6,576	3,099	1,146	2,331
1965	7,300			
1970	7,065	3,102	1,044	2,919
1972	7,269	3,127	1,059	3,083
1973	7,497	3,130	1,086	3,281
1974	7,752	3,158	1,149	3,445
1975	7,855	3,117	1,177	3,561
1976	7,943	2,985	1,180	3,778
1977	8,128	2,999	1,244	3,885
1978	8,388	2,976	1,267	4,145
1979	8,403	2,955	1,263	4,185

Data from U.S. Census and Bureau of Economic and Business Research, University of Florida.

Land Use
in Franklin County

Each bar increment equals 10,000 acres.

Category	Total Acreage	Percentage of Total
Residential	6,082	1.3
Commercial, services	439	.1
Transportation, utilities	538	.1
Mixed urban or built-up areas	66	.0
Other urban or built-up areas	95	.0
All urban or built-up areas	7,220	1.5
Cropland and pasture	192	.0
Other agricultural	10	.0
All agricultural land	202	.0
Herbaceous rangeland	32	.0
Rangeland	32	.0
Evergreen forest land	169,510	35.7
Mixed forest land	89,936	18.9
All forest land	259,446	54.6
Streams and canals	3,631	.8
Lakes	1,118	.2
Reservoirs	24	.0
Bays and estuaries	115,761	24.3
All water	120,534	25.4
Forested wetland	63,164	13.3
Nonforested wetland	20,918	4.4
All wetlands	84,082	17.7
Beaches	3,560	.7
Quarries and pits	61	.0
Transitional areas	272	.1
All barren land	3,893	.8

Total for Franklin County 475,409 acres

Planning and Resource Management

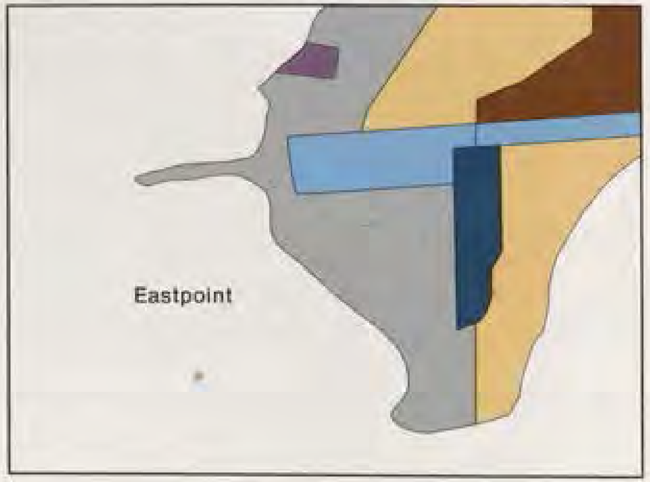
The Apalachicola Valley represents a unique opportunity for land planning and resource management. The natural systems, land and water, remain largely intact, with a rich supply of unpolluted surface water and a broad, unbroken freshwater wetland. Coastal areas, and the major estuarine habitats, remain almost completely intact. The population density remains low, and the people of the region have retained intimate cultural and economic connections with the natural resources of land and water. Moderate regional population growth, however, is inevitable, and with such growth will come problems associated with municipal and industrial wastes, stormwater runoff, sewage disposal, agricultural effluents, and structural changes in the basin (i.e., damming, diking, dredging). As more people move into the valley, the availability of clean, fresh water will be lessened. It has been projected that the growth of the metropolitan Atlanta area will seriously reduce the flow of the Chattahoochee River over the next 20 to 30 years. Since most of the Apalachicola river flow comes from Georgia, this reduction could have a serious impact on the Apalachicola ecosystem. Such projected changes in river flow could be associated with saltwater encroachment and reduction of the estuarine productivity. Land planning, which is now a relatively well-understood process, should be based on objective scientific and economic facts. There is a real opportunity for applied resource management since the Apalachicola Valley has been well studied by various researchers, and the base of information concerning the functional properties of the natural environment is relatively extensive.

There are different approaches available to planners. When certain areas are shown to be ecologically sensitive, they can be purchased by state and federal agencies. With such control, specific management programs can then be applied to protect the environmental attributes of the area. The river flood plain, freshwater and marine wetlands, and barrier islands all fall into this category. Other lands, less sensitive yet still ecologically important, can be managed in various ways by both private and public agencies. Because forestry is important in the Apalachicola valley, advanced forestry practices are a necessary part of any regional approach to planning. Forestry management has been advanced in various regions of the Apalachicola Valley. Various state and federal agencies have jurisdiction over the freshwater and coastal portions of the Apalachicola system. Florida state law has given considerable power to county government with respect to comprehensive planning and land zoning. In this way, local, state, and federal agencies, together with private corporations and individuals, have the opportunity to develop a network of planning designed to protect the existing resource base while supporting needed economic growth in the region. At present, all these approaches, together with an active program of environmental education, are being tried in what has come to be known as the Apalachicola Experiment.

Based on studies showing the important ecological functions of the river, associated wetlands, and the barrier islands, various land areas have been purchased by state and federal agencies for preservation and conservation of existing environmental resources. Over 28,000 acres of the lower Apalachicola flood plain have been purchased by the state of Florida under the Environmentally Endangered Lands program (EEL). Currently, the Nature Conservancy, a private, nonprofit land conservation group, is negotiating for the purchase of more Apalachicola River wetlands for eventual transfer to state or federal jurisdiction. Such negotiations have been encouraged by the Northwest Florida Water Management District. Such wetlands could be purchased by the state of Florida under the "Save Our Rivers" program with the result that most of the freshwater wetlands along the Apalachicola River would be in public hands. The wetlands surrounding East Bay are currently being negotiated for purchase by the Estuarine Sanctuary (through the Florida Department of Natural Resources) with money from the EEL program and the National Office of Coastal Zone Management (National Oceanographic and Atmospheric Administration). St. Vincent Island is a National Wildlife Refuge administered by the U.S. Department of the Interior. The eastern portion of St. George Island is a state park and Unit 4 was purchased by the Trust for Public Land and sold to the state through EEL. Little St. George Island was also purchased by the state through EEL. Most of Dog Island was sold to the Nature Conservancy for eventual use as a major conservation area. By any standard, the Apalachicola River and Bay system has been the subject of an active land preservation program with its roots deep into the extensive scientific data base of the region.

The Apalachicola National Estuarine Sanctuary serves as a major focal point for resource management and environmental education in the region. The various land purchases are managed by the Florida Game and Fresh Water Fish Commission and the Florida Department of Natural Resources. The combined efforts of the Franklin County Board of Commissioners, the Apalachee Regional Planning Council, the Coastal Plains Council, the Washington-based Conservation Foundation, Florida State University, and the Florida Sea Grant College were integrated into the Franklin County Comprehensive Plan. This plan was passed unanimously by the Franklin County Commission in 1981 and is based on the economic dependence of the county on the natural environment. Low-density (single-family) housing was designated in many of the environmentally sensitive land areas. Such low-density areas, together with areas zoned for forestry management and preservation areas, constitute the bulk of the land use designations in Franklin County. To conserve existing communities and minimize energy use, future high-density development is to be clustered around existing population centers (especially incorporated areas). This approach allows such future development to be located near existing sources of water and sewage disposal sites along with the usual services already in place in the existing population centers. If this plan is properly implemented, the usual urban sprawl, so common along sensitive coastal lands, will not occur and orderly growth will be encouraged without endangering the sensitive estuarine ecosystem.

While the implementation of this plan is still to be realized, the intent of the plan is clear: controlled growth with an eye to preserving the productivity of the natural systems and conservation of the economic base of the region. The strength of the current planning and management activities lies in the diversity of approaches by local, state, and federal interests. Such a program, grounded in scientific data and kept current through the educational process, is the basis of the Apalachicola Experiment.



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To him who in the love of Nature holds
Communion with her visible forms, she speaks
A various language.

— **William C. Bryant**, *Tanatopsis*

All are but parts of one stupendous Whole,
Whose body Nature is, and God the soul.

— **Pope**, *Essay on Man*

Speak to the earth, and it shall teach thee

— **Job 12:8**

Accuse not Nature, she hath
done her part:
Do thou but thine!

— **Milton**, *Paradise Lost*

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