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Proceedings of the Conference on the Apalachicola Drainage System, 23-24 April 1976 Gainesville, Florida

ROBERT J. LIVINGSTON AND EDWIN A. JOYCE, JR., EDITORS

Florida Department of Natural Resources
Marine Research Laboratory

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Edwin A. Joyce, Jr.
Editor

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Florida Department of Natural Resources
Marine Research Laboratory

100 Eighth Avenue SE St. Petersburg, Florida 33701

ABSTRACT

Livingston, Robert J. and Edwin A. Joyce, Jr., Editors. Proceedings of the Conference on the Apalachicola Drainage System, 23-24 April, 1976, Gainesville, Florida. Fla. Mar. Res. Publ. No. 26. 177 pp. The Proceedings provide a compendium of information concerning the intrinsic and extrinsic values of the Apalachicola Drainage System. Various topics are covered including the legal, economic, managerial, and environmental aspects of the Apalachicola basin with contributions from two state university systems, three departments of state government, the Florida Bar, one private Florida research facility, and one out-of-state university system. Papers are presented on the geobotany, terrestrial and aquatic fauna, and natural history of the Apalachicola River and Bay systems. The Apalachicola Valley is shown to be a center of endemism in the Southeastern United States and critical to the environmental and economic considerations of a three-state area (Florida, Georgia, Alabama). The principal aim of the conference was to present a multidisciplinary base of information that can be used in future planning and management decisions.

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PREFACE

THE BOUNTIFUL APALACHICOLA RIVER
LET'S KEEP IT THAT WAY!

Harmon W. Shields
Executive Director
Florida Department of Natural Resources

For thousands of years the beautiful Apalachicola River made its way unscathed from the upper areas of Georgia and Alabama to the great estuarine expanses of Apalachicola Bay. Formed by the confluence of the Chattahoochee and Flint Rivers, the Apalachicola River was first assaulted by man in 1947 with the initiation of the Jim Woodruff Dam. The inroads on the pristine qualities of the River have continued. Channel dredging and maintenance became a requirement and spoils from these operations were disposed of without environmental consideration. More people, more pollutants, more freshwater withdrawals, a barge port, clear cutting forestry in the water shed; all were either beginning or would soon exert their influences on the Apalachicola system. But we did not know! Except in a few biological research laboratories, the old tenet was still held that nature was man's antagonist, there only to be conquered and "improved" upon. The words "environmental consequences" were totally unfamiliar to the general public and virtually no one considered them.

Research, most of it completed in the last two decades, has greatly enlarged our understanding. In the late 50's and early 60's, studies at our Department's own Marine Laboratory, and other similar institutions were adding to the growing knowledge of the tremendous importance and value of marshes and estuaries. Approximately 75% of the economically important marine species were found to utilize these areas especially during the early juvenile stages and hence the "nursery ground" concept was born. Based on this information, the first laws controlling dredge and fill operations were finally passed.

Even with these advances, many people still thought of the "environment" as something "over there." Through the help of further, more detailed and multidisciplinary research, we are beginning to realize that we too are part of the environment and just as dependent upon it as the most delicate forest creature. Ecological systems are in a state of dynamic equilibrium. What happens in one part of the system affects all other parts of the system. Natural channels are there because natural forces keep them there. By the same token, man-made changes are affronts to these systems, and even before their construction is completed the natural forces are working to return to the former equilibrium. Thus, the man-made channel remains there only through man's efforts. A channel is not dredged once, it must be dredged continually. Certainly, we must have industry, transport capabilities and all of the other requirements for a healthy national economy, but this does not need to be, and must not be, accomplished through the loss of irreplaceable environmental assets. Any successful individual takes stock of his assets and uses each to its best advantage. Mankind must do this with his environmental assets as well. He must balance his needs. He must not destroy diamonds to build rocks.

The Apalachicola is a North Florida diamond. Even among the unique, it is incomparable. With all the previous inroads, the Apalachicola system still remains one of the most beautiful and biologically productive in the entire State.

We are stuck with the results of our past environmental ignorance. But we know better now. We have no more excuses. We recognize the irreplaceable value of the Apalachicola system and the key role the river itself plays in that system. It is up to us to prove these values to the less informed: present the data we have worked so diligently to obtain and by doing so, show beyond anyone's doubt that the greatest public value of the Apalachicola system rests in maintaining it in as close to its natural condition as is possible. That has been the purpose of this meeting and the reason that it is so important that the results of this multidisciplinary evaluation be published and made available. For the first time we will have, in one package, the most up-to-date information on the natural values of the Apalachicola system, and thus the very best arguments for its protection. I, and my staff are extremely pleased to be able to assist this effort, not only through the presentation of our almost 30 years of work in the Apalachicola system, but also through providing the funds and the vehicle for the publication. There are viable alternatives to making the Apalachicola a ship channel. The results of this meeting should convince everyone that they are also the least expensive.

As a further step, our Department is at this time investigating the possibility of designating Apalachicola Bay as a National Estuarine Sanctuary under Section 312 of the Federal Coastal Zone Management Act. If this is possible, the Office of the Coastal Zone Management of NOAA would provide matching funds equivalent to the purchase price of appropriate shorelands purchased under the Environmentally Endangered Lands Program. Moreover, it would also provide some 50-50 matching funds on an annual basis for the operation, management and development for research purposes of such a sanctuary. This designation, if successful, together with an adopted Florida CZM plan and program would give substantial leverage against any upstream uses or developments along the Apalachicola River that might endanger the viability of the estuary.

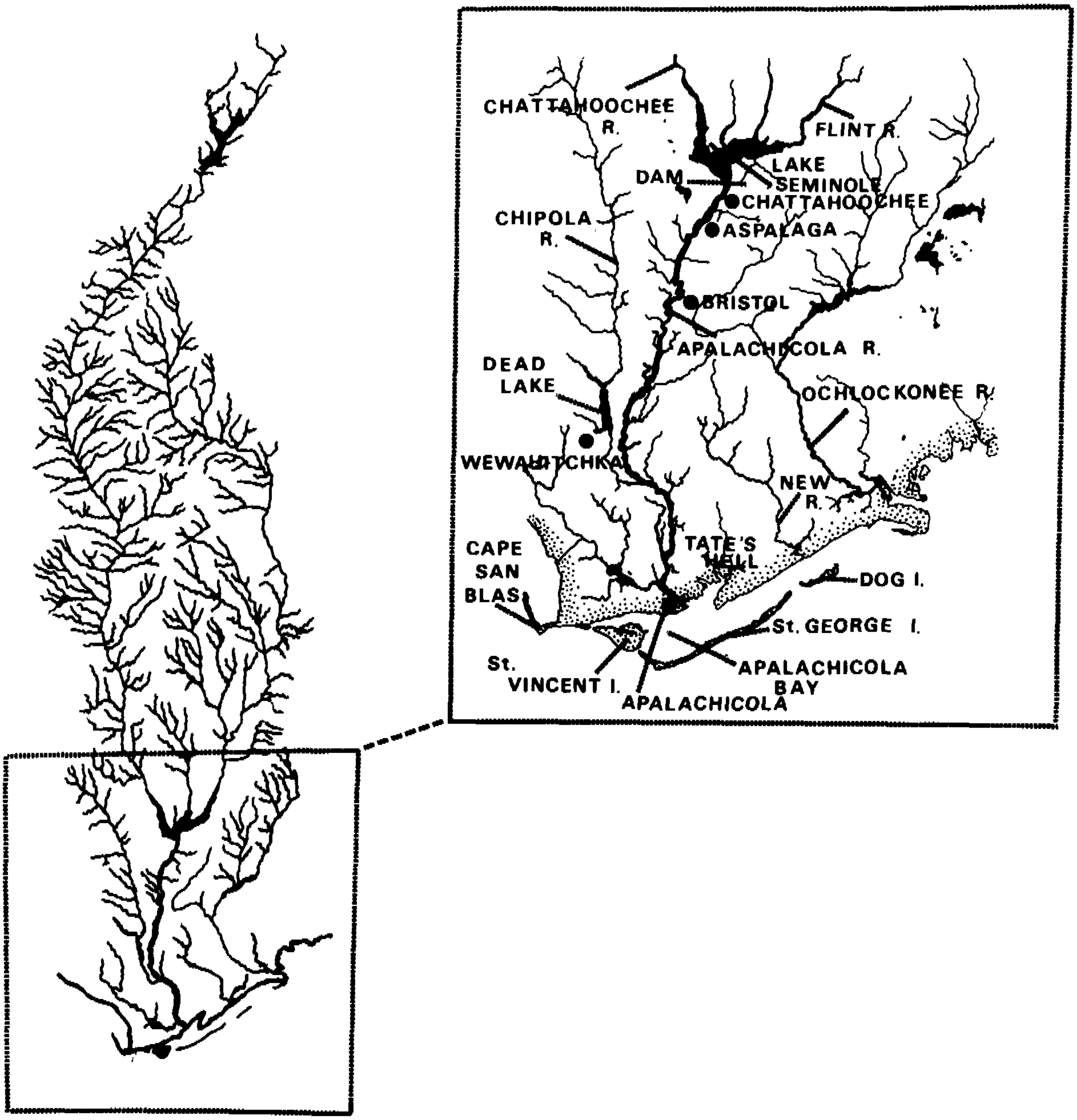

Fig. 1: The Apalachicola Drainage System

INTRODUCTION

Robert J. Livingston
Florida State University

The entire drainage area terminating with the Apalachicola River System is located in three states (Florida, Georgia, Alabama), and is formed by four major rivers (Flint, Chattahoochee, Chipola, and Apalachicola) (Figure 1). The Apalachicola Valley is dominated by the Apalachicola River System originating at the confluence of the Flint and Chattahoochee. The Flint and Chattahoochee drainage area has recently been impounded (Jim Woodruff Lock and Dam, 1957) to form Lake Seminole, a shallow impoundment of 37,500 acres and a mean depth of 9.8 ft. This impoundment now serves as the head waters for the Apalachicola River. The primary aim of the "improvement" of the Flint-Chattahoochee-Apalachicola system is to provide a channel with a depth of 9 ft and a minimum width of 100 ft from the Gulf Intercoastal Waterway (Apalachicola Bay) to Columbus, Georgia and Bainbridge, Georgia. The Apalachicola Drainage system is located entirely in Florida, and is thus the terminal portion of a relatively extensive drainage area; much of the region above the Jim Woodruff Dam has been severely altered by damming, dredging, urban runoff, and agricultural activities.

The freeflowing Apalachicola River drains a relatively undeveloped portion of north Florida. As of 1970, there was a total population of about 106,000 in the six counties comprising the immediate Apalachicola drainage basin; growth in the area is slow with relatively low economic output and development. Much of this area is periodically flooded due to the overflow of the Apalachicola River, with deep swamps, broad and narrow stream margins, pocosins, and bays comprising over 40% of the Apalachicola River system. Almost 1/3 of the wetland forest is owned by private forestry interests with little agricultural or industrial development outside of scattered areas around local population centers. Timber harvesting forms a major economic base in the area, although upland fish and game resources are abundant, and the sports and commercial fisheries of the associated Apalachicola Bay System are extensive. The Apalachicola Basin thus includes an interlocking system of rivers, streams, wooded and shrub swamps, freshwater and brackish marshes, and one of the most productive bay systems in the state of Florida. Both emergent and submerged vegetation contribute to abundant fish and wildlife assemblages in a largely undisturbed environment. Periodic (seasonal) flooding is an integral part of the ecological balance of the area with water, nutrient, and detritus exchanges believed to form the basis of the aquatic food webs of the upland and estuarine systems. The fresh-water overflows and tidal interactions provide extensive nursery areas and forage grounds for numerous species which comprise the sports and commercial fisheries of this area. In short, the largely undisturbed Apalachicola Basin remains an almost unique example of a broad, river-dominated wetlands area that has so far remained relatively intact in a functional sense.

A review of the available scientific literature on the Apalachicola Drainage System is available (Livingston et al., 1974), and will not be attempted here. Certain distinctive attributes of this area should be noted, however. The Apalachicola River (107 mi long) is the largest in Florida in terms of flow rate [annual mean flows approximating 23,000-24,000 cubic feet per second (cfs) with seasonal high flows occasionally exceeding 140,000 cfs] and extent of the drainage area (19,500 mi^2). In a hydrological survey of the northeastern Gulf of Mexico, Curl (1959) noted the influence of the Apalachicola River as far as 160 miles to the south. The system remains in a relatively unpolluted condition (Livingston, 1974) although there are various problems along the river associated with the Jim Woodruff Dam, such as, maintenance dredging (Cox, 1969; Cox, 1970; Cox and Auth, 1971, 1972, 1973), diking, and configurational changes in upland drainage patterns (Livingston et al., 1974). Significant seasonal fluctuations of river flow dominate the aquatic areas from an ecological point of view, with periodic flooding, swift currents, high turbidity, and resultant fluxes of nutrients and detritus throughout the system.

The Apalachicola Bay System is physically dominated by the river with salinity, nutrient and detritus distribution, primary and secondary productivity, and other factors dependent on seasonal changes in the drainage characteristics. As shown by Livingston et al. (1974), the Apalachicola Bay System is characterized by high levels of primary (phytoplankton) productivity and relatively little development of benthic macrophyte assemblages except in fringing areas. It is a shallow, barrier island system with periodic reductions in salinity due to river flow. This combination of factors makes the bay system an important oyster (*Crassostrea virginica*) habitat in addition to serving as a nursery area for such species as blue crabs (*Callinectes sapidus*), penaeid shrimp (*Penaeus setiferus*, *P. duorarum*, *P. aztecus*), and various finfishes (spot, croaker, redfish, seatrout, flounder, and mullet). Consequently, Franklin County, almost entirely economically dependent on Apalachicola Bay, ranks as high as third in the state for total marine landings and produces up to 90% of Florida's oysters. Thus, the Apalachicola Drainage Basin, with the Apalachicola Bay System at its southern terminus, is an excellent example of a highly productive river-dominated wetlands area that is still relatively undisturbed by human activity.

Equally important are the political and economic aspects of future development along the Apalachicola River. The projections of river development along the Apalachicola-Chattahoochee-Flint waterway and associated problems have been outlined and discussed by Vanderhill (1975). The Gulf Intracoastal Waterway is joined to the Apalachicola and serves as a conduit for navigation whose functional limits extend to Bainbridge, Georgia on the Flint (142 mi from the Gulf) and Columbus, Georgia and Phenix City, Alabama on the Chattahoochee (273 mi from the Gulf). Since the Rivers and Harbors Acts of 1945 and 1946 were passed by Congress, a system of dikes and dams has been developed for the A-C-F waterway to guarantee a 9 ft channel and a 100 ft bottom width. Various portions of this system have been completed although waterborne traffic has remained low with a relatively slow rate of growth (Vanderhill, 1975). Public docking facilities in Florida are largely limited to the Sneads Terminal of the Jackson County Port Authority near the Jim Woodruff Dam, while various small (private) facilities are available along the river. Due to widely varying flow rates of the Apalachicola River (both on a seasonal and annual basis), there are difficulties in maintaining standard channel depths for barge traffic. This is complicated by flooding, floating debris, silting, and the meanders of the river. According to Vanderhill (1975), this makes water-borne commerce "slow, risky, comparatively costly, and relatively inefficient."

Efforts to correct this situation have been variously attempted since the early 1950's. Out of a largely disorganized group of users, the Tri-Rivers Waterway Developmental Association was formed in 1972. This organization, backed by the states of Alabama and Georgia, various county governments (including 3 from Florida), upstream users, and shipping interests has pushed for action on the channelization of the Apalachicola River. The U.S. Army Corps of Engineers has carried out a program of dredging, snagging, and diking at the bends of the River to maintain the 9 ft channel. A feasibility study (1973) brought forth four alternative plans for further manipulation of the river with two to four dams and reservoirs, and associated canals and dikes to be placed along the river. Due to vociferous opposition by a broad coalition of interests located primarily in Florida in 1973, the Corps of Engineers backed away from these proposals. At the urging of the Chattahoochee River Basin Developmental Commission and the Tri-Rivers Association, the Corps came back with a proposal for a single, run-of-the-river dam near Blountstown with channel-diking upstream. This has stirred new protest from Florida which has much to lose and relatively little to gain from such a project. According to Vanderhill (1975), while there is some demand for more dependable river traffic, the limitations imposed by the natural waterway have brought into focus serious questions concerning the long-term feasibility of such a project. The question of who should pay for such a project remains unresolved. Since the Apalachicola River is the bottleneck (albeit a long one) to the navigational strategy for the system, and since there are associated questions such as industrial and municipal wastes, agricultural runoff, and configurational changes which could lead to serious environmental disruption, the overall solution to the problem remains unresolved.

In a draft environmental statement by the Mobile District Corps of Engineers (1975) concerning Lake Seminole and the Jim Woodruff Lock and Dam, several adverse effects were noted in the operation of the dam:

1. "As long as Lake Seminole exists, one may expect an aquatic plant problem to exist . . ."
2. "A temporary reduction in water quality results from the addition of herbicides to an area heavily infested with aquatic plants. As the plants die and decompose, large amounts of dissolved oxygen are taken from the water, temporarily resulting in a noxious condition in the vicinity."
3. "Lake Seminole provides an attractive and adequate habitat in which mosquitos may breed . . . Malathion insecticide is employed by the Corps in the mosquito control progam."
4. "Sedimentation and subsequent dredging in the upper reaches of the Chattahoochee arm of Lake Seminole in order to maintain an adequate navigation channel is definitely an important cause of decreased fish food organisms production in this area of the lake."
5. "The current disposal method used for dredged material is to obtain areas above the river bank and pump the sand and silt into these diked, firm, spoil sites."
6. "Snagging operations on the upper stretch of the Chattahoochee arm of Lake Seminole consist of picking up fallen trees, dislodged stumps, and logs and placing them on the bank. . . ."

In addition to considerable levels of sedimentation and some eutrophication, estimates for the total input and output of key nutrients indicate a 16% decrease of nitrogen and an almost 70% decrease in phosphate as water moves through Lake Seminole.

According to the Draft Environmental Statement (1976) concerning the operation and maintenance of the Apalachicola, Chattahoochee, and Flint Rivers by the corps, the following adverse impacts were noted:

1. "Hydraulic dredging and open water or unconfined disposal of the dredged material results in localized and short-term increases in turbidities and suspended solids concentrations."
2. "In an effort to provide the 9 x 100 foot navigation channel year-round, the natural reaeration rate of the river has been altered by modifications, such as dredging, contraction dikes, and cutoffs. . . . The result is a deeper channel with reduced velocity which in turn may reduce the reaeration rate. The magnitude of the effect of providing the deeper navigation channel is not known; however, it is considered to be insignificant."
3. "River traffic using the channel introduce pollutants to the water and although these are normally in small quantities, the potential is present for oil and chemical spills to occur. This potential will increase as commercial traffic on the rivers increases. The availability of barge transportation and water may stimulate the growth of industry in the area, thereby increasing the waste-load on the rivers."
4. "The dams on the Chattahoochee and Flint Rivers block the migration of striped bass, sturgeon, suckers, eels, shad, hog chokers, and other migratory species of fish. Flood control on the Chattahoochee River reduces flood heights downstream, thereby reducing

bank overflow. This detrimentally affects the fisheries because high water is an important factor in the life-cycle of many animals and the organic detritus picked up by the stream contributes to the productivity of not only the river but the bay."

5. "Disposal of dredged material . . . provides poor habitat for recolonization of organisms due to the shifting of sediments. . . . Also, during dredging, the dredge is non-selective . . . The maintenance dredging destroys those benthic organisms inhabiting the channel area. . . . Disposal of dredged material within the river banks further contributes to the impact. . . ."
6. "The impact of continued operation and maintenance of the project upon the aquatic ecosystem of Apalachicola Bay is uncertain . . . It is expected that no study will be conducted because of the obviously high costs."
7. "Snagging operations . . . deprive the river of valuable cover for fish, food, habitat for burrowing and sessile organisms and reduce the esthetic quality of portions of the river banks."
8. "Mosquito control measures for disease-carrying species consists of spraying areas with ultra-low volume application of Malathion, snagging, and the fluctuation of pool levels."
9. "Disposal of dredged material on the banks destroys wildlife habitat by raising ground elevation and destroying vegetation. . . . This method of disposal of dredged material is more detrimental than within the banks disposal."
10. "The primary adverse impacts of present operation and maintenance of the project upon (rare and endangered) species is generally detrimental. . . . The secondary long-term impacts of continued operation and maintenance of the project, such as increased urbanization, industrial development, and increased barge traffic, would be more detrimental to the threatened, and rare and endangered species."

Both statements were almost devoid of (scientific) baseline or impact data; indeed, the above environmental problems were simply listed and finally dismissed when alternative action was reviewed. Thus, the basic functions of the Apalachicola River have been largely ignored in these preliminary evaluations.

The Apalachicola wetlands are presently under pressure due to various forms of development. Agricultural and lumbering activities, physical alterations of the system through dredging, damming, diking, increased use of herbicides and pesticides, and potential disruption due to municipal and industrial wastes will necessitate the implementation of a broad upland management program if the natural functions of this system are to be maintained. This compendium of papers has been developed primarily as a source of integrated information that can serve various purposes. In addition to detailing the unique ecological relationships of the Apalachicola Drainage System, this knowledge will contribute to a broader evaluation of the environmental and economic aspects of various forms of proposed development. In addition, it is hoped that further research will be stimulated by this effort. The possibility exists that through informed development and long-range planning based on solid scientific information, the unique features of the Apalachicola Basin can be maintained and nurtured.

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GEOBOTANY OF THE APALACHICOLA RIVER REGION

Andre F. Clewell
Florida State University

INTRODUCTION

The Apalachicola River is unique because it is the only one in Florida with its headwaters in the southern Appalachians and the adjacent Piedmont. The rivers of Florida otherwise arise within the coastal plain. The present Apalachicola River Valley began its formation during the late Miocene or roughly 18 million years ago. Previously, sea level had been higher relative to the regional land forms, and the coastline was located in southern Georgia. The highlands along the upper portion of the Apalachicola River are believed to have been occupied continuously by plants since the late Miocene, whereas many other parts of Florida were inundated by seas then and subsequently. Much of the unusual floristic diversity of the Apalachicola River region is attributable to the continuity of region with the southern Appalachians both in space and time (Thorne, 1949; James, 1961).

The Apalachicola River begins at the Jim Woodruff Dam and Lake Seminole near the City of Chattahoochee (see Figure 1 of Introduction for location). From Chattahoochee south to Bristol, the Apalachicola River Valley passes through the Northern Highlands province of the Florida panhandle (Puri and Vernon, 1964). From Bristol to the city of Apalachicola, it flows through the Gulf Coastal Lowlands. Although its mouth is at Apalachicola, the river system extends into the estuaries, presently delimited by barrier islands and spits, including Cape San Blas, St. Vincent Island, St. George Island, and Dog Island. During the parts of the Pleistocene, when sea level was much lower than at present, the river valley extended even beyond these islands.

The eastern side of the river in the Northern Highlands province in Florida is characterized by steep bluffs and a narrow floodplain. These bluffs are the western limit of the Tallahassee Hills portion of the Northern Highlands and commonly overlook the river 150-200 ft above its surface. In a few places, notably Alum Bluff and Aspalaga, the bluffs drop precipitously to the river's edge, interrupting the floodplain. The uplands behind these bluffs are capped with dry sands (Ft. Preston Formation in Vernon and Puri, 1965) and dissected by steep ravine systems. Many ravines begin abruptly at springy steepheads (Means, 1977).

The upper portions of the bluffs consist of Miocene, slightly clayey and silty sands (Shoal River Formation). These are underlain by Miocene limestones which locally outcrop on the bluffs or near their springy bases.

The western side of the river opposite the bluffs is, in great contrast, a broad lowland, rising very gradually in elevation from the floodplain into the Grand Ridge region and then dropping slightly into the Marianna Lowlands. The Marianna Lowlands region of Jackson and adjacent counties is a karst plain that has been lowered in elevation by solution of the shallow limestones and by the dissection of streams. The Marianna Lowlands are drained to a large extent by the Chipola River, which enters the Apalachicola River about 9 mi southeast of Wewahitchka. Natural levees of the Apalachicola River dammed the Chipola River in historical times to form Dead Lake (Vernon, 1942).

The bluffs disappear just below Bristol with a minor exception 9 mi south at Estiffanulga. Throughout these lowlands the river meanders more and occupies a wider floodplain than it does farther north. The Gulf Coastal Lowlands are characterized by marine sands of Pliocene age to the north and Pleistocene age nearer the Gulf (Alt and Brooks, 1965). The floodplain consists of Holocene sediments which reach a depth of at least 80 ft near the river's mouth (Schnable and Goodell, 1968) and 45 ft at Bristol (Vernon, 1942). These recent sediments lie directly on Miocene strata, because sediments of the Pliocene and much of the Pleistocene were eroded at times when sea level was much lower and the flow of the river was stronger.

Mean sea level fluctuated greatly during the Pleistocene. At the height of the Wisconsin glaciation which occurred roughly 20,000 years ago, sea level was about 410 ft lower than it is today. The coastline was considerably seaward of its present position. The barrier islands and spits began to be formed about 5,000 years ago, when mean sea level had risen essentially to its present position. These islands began as beach ridges which formed on top of the eroded remains of previous islands and dunes that dated to earlier times of Pleistocene interglacial high sea levels. Present mean sea level was attained and has remained nearly static for about 3,000 years.

Dunes bordering the coast from Carrabelle to Cape San Blas are traversed by US 98. One of these dunes, known as Royal Bluff, lies over peats 6,000 years old and older. Royal Bluff, and presumably the other coastal dunes, either formed shortly thereafter or perhaps earlier and migrated over these peats about 6,000 years ago.

Relic barrier islands and spits are isolated inland as low ridges and owe their origin to pre-Sangamon interglacial periods roughly 300-500 thousand years ago, when the coast line was inland, perhaps at the latitude of Wewahitchka. Puri and Vernon (1964) mapped several of them in the Tate's Hell region of southeastern Franklin County.

Coastal geomorphology is more complicated than one would expect. Generally, coastal features in this area were thought to have developed from beach ridges, many of which have become modified by winds and currents to varying degrees. Many are now called dune ridges to designate both their origin as beach ridges and their dunal aspect caused by later wind decoration. The ages of the coastal features are not uniform. For example, Gap Point on eastern St. George Island is older than the rest of the Island. Shorelines are continually changing, and the region is presently experiencing an erosional cycle (Tanner, 1975).

Each of the regions associated with the Apalachicola River can be characterized in a general manner by the dominant forms of vegetation. Scientific names of plants designated by their common names below are given in the Appendix.

1. The dry, sandy uplands east of the bluffs (Ft. Preston formation) contains an open forest of longleaf pine and associated scrub oaks, mainly turkey oak, with a turf of wiregrass and various herbs and low woody plants. Under natural conditions this vegetation experiences frequent surface fires, which are necessary for the maintenance of this community.

2. The bluffs (Shoal River Formation) contain a rich, mesic forest with many tree species. Some of the more important trees are southern magnolia, beech, white oak, southern sugar maple, and American holly. This forest is protected from fire by the river to the west and by the steep slopes, down which fire can scarcely spread. The uppermost portions of the bluff contain a drier forest, which may experience infrequent fire. Important species are southern red oak, shortleaf pine, mockernut hickory, post oak, and dogwood.

3. The floodplain contains several vegetation types that are not always sharply differentiated from each other. Sand bars which are aggrading are characterized by black willow, cottonwood, and sycamore. Steeper river banks contain river birch, ogechee-tupelo and alder. Natural levees, formed along river banks when river waters drop their load of sand at flood stage, contain a mixture of species, including some characteristic of bluffs. Included may be southern magnolia, swamp-chestnut oak, spruce pine, silver bells, ironwood water oak, and sweetgum. Sloughs and oxbow ponds contain bald-cypress and water tupelo. The low terraces between sloughs and levees contain overcup oak, water hickory, diamond-leaf oak, sweetgum, and ash. Where floodplains gradually rise in elevation and grade into the adjacent upland (i.e., where bluffs are absent), loblolly pine shares dominance with some of the species of the lower terraces. From about the confluence of the Brothers River south towards the Gulf coast, a fresh water marsh occurs and becomes increasingly prominent between the river's edge and the river swamp. Cut-grass, saw-grass, cat-tail, bulrushes, and rushes are conspicuous.

4. The Marianna Lowlands and Grand Ridge regions contain both longleaf pine woods and mesic hammocks similar to those on the bluffs.

5. The Gulf Coastal Lowlands are typified by flatwoods of longleaf pine, saw palmetto, wiregrass, runneroak, and gallberry. These woods are interrupted frequently by poorly drained depressions and stringers of pond-cypress, blackgum, sweetbay, and titi. Seepage slopes and other locations with prolonged hydroperiods in the soil contain grass-sedge savannahs (bogs) with few or no trees, St. John's-wort and a few other scattered shrubs, and a spectacular array of orchids, pitcher-plants, and wild flowers. The pine flatwoods and savannahs are frequently burned.

6. Coastal dunes and beach ridges contain a scrub of myrtle oak, Chapman oak, dwarf live oak, and rosemary. Sand pine sometimes forms an overstory on dry sites as does slash pine in moist flats and interdunal swales. Fire is rare to infrequent and often damaging to the plants. Fire-killed pines tend to become reestablished by seedlings immediately after fire, and the other scrub species mostly resprout from their undamaged root crowns, thereby reestablishing the community without an interceding successional stage. Salt spray limits the distribution of some scrub species and alters the growth form of those that are salt-tolerant. Some scrubs are isolated inland, evidently since the Pleistocene, on ridges that were never completely colonized by the floristically and structurally different flora of the longleaf pine woods.

7. Salt marshes occur on flats protected from waves and along river banks in the intertidal zone. Cordgrass (*Spartina alterniflora*), needle rush, and salt grass dominate where tidal inundation is frequent. Sawgrass, cattail, and cordgrass (*Spartina patens*) are dominant where salt concentrations are lower.

Although preceded by a few naturalists, the first important botanical efforts are credited to H.B. Croom (1797-1837), who managed a plantation across the river from Aspalaga. He discovered the narrowly endemic Torreya tree and published other botanical observation (e.g., Croom, 1834). His work stimulated investigations by Gray (1875), Chapman (1885), Harper (1919), and Kurz (1927, 1933, 1938a). As a result, the Aspalaga area is known the world over as a classic locality in the field of phytogeography. Harper (1949) summarized the history of plant exploration in Florida with reference to the state's endemic species. James (1961) followed with a geobotanical account of Florida endemism. The Apalachicola River species were treated in both papers.

Ecological observations were noted on the marshes and river banks towards the mouth of the river by Harper (1910, 1911). Harper (1914) also characterized all of the plant communities in northern Florida. Kurz (1938b) further delineated the plant communities associated with the upper portion of the river. Later he described in detail the vegetation of the dunes and scrub along the Florida coastline at many sites, including Beacon Hill (Gulf County), Carrabelle, and Lanark (Franklin County), both near the mouth of the Apalachicola River (Kurz 1942). Wagner and Kurz (1954) studied the tolerance and responses of cypress to deep water at Dead Lake.

Godfrey and Kurz (1962) announced that the Torreya trees had suffered a fungus disease subsequent to 1954 that had killed nearly all Torreyas on the Apalachicola River bluffs. They held little hope of the recovery of the species. My personal observations at Torreya State Park in recent years revealed that widely scattered saplings of up to four inches in diameter were resprouting from the roots of infected trees. Like those of the chestnut tree of the Appalachians, these sprouts apparently are subject to fungus attack. The long-persisting logs of fallen Torreyas are common on the forest floor. Little (1975) appropriately listed both the Torreya tree and another endemic of the Aspalaga area, the Florida yew, among the rarest conifers in the United States.

Two floristic studies involve the northern Apalachicola River region. Thorne (1954) prepared a check list of the vascular plants in southwestern Georgia which includes the area north of Lake Seminole between the Flint and Chattahoochee rivers. Mitchell (1963) produced a comparable list for Florida Caverns State Park, the flora of which is representative of the Marianna Lowlands. Both authors correlated plant distribution with geological features. Mitchell mapped the distribution of several Appalachian species that extend southward into the Apalachicola River region.

Hubbell et al. (1956) described the plant communities within a 25-mi radius of the Jim Woodruff Dam at the time of its construction. They intended to resurvey their 28 study sites after the formation of Lake Seminole to assess environmental changes caused by the impoundment, but no follow-up studies have appeared. They summarized all of the physiographic information for the region and tried to correlate the distribution of plant communities largely or entirely on physiography but with only limited success. Other factors must also be operative.

In one of the finest ecological studies ever attempted in Florida, Kurz and Wagner (1957) correlated plant zonation in the intertidal salt marshes with chlorinity and other factors. Two of their study sites were in Gulf and Wakulla counties. Their results appear to be directly applicable to at least the salt marshes that are common on the leeward side of the barrier islands.

Clewell (1971) described the plant communities of the Gulf Coastal Lowlands that are represented in the Apalachicola National Forest. This federal land parallels the Apalachicola River from a few miles south of Bristol nearly to the coast and borders the river at Ft. Gadsden. The influence of fire in maintaining plant communities was stressed.

Broadfoot (1973) measured growth rings of many trees bordering Lake Seminole. He compared the growth rates before and after the creation of the lake. In general, he concluded that the increased soil moisture was beneficial to most trees. Growth was impaired where flood waters had deposited several inches of sand on the soil over tree roots.

Clewell (in Livingston et al., 1974) described most of the plant communities of St. George Island.

Wharton (in Wharton et al., 1976) surveyed the river swamps in Florida. He estimated the forested floodplain of the Apalachicola River comprised 112,284 acres, nearly 42,000 acres larger than Florida's next largest and only other major alluvial floodplain, that along the Choctawahatchee River. Wharton's many diagrams and photographs are valuable in understanding physiographic development and vegetational zonation in river swamps, even though the number of specific examples from the Apalachicola River were few. Basic food webs and energy and nutrient pathways were diagrammed. The consequences of channelizing and building fill-roads across floodplains were considered. Non-alluvial wetlands were characterized, diagrammed and photographed.

Hebb and Clewell (1976) described a slash pine-bay swamp in the Apalachicola National Forest.

Besides the above-mentioned studies, a few others have been made elsewhere that seem to be directly applicable to the environments of the Apalachicola River region. Penfound and Hathway (1938) and Eleuterius (1972) studied brackish marshes and contiguous swamps near the mouths of rivers in Louisiana and Mississippi. Penfound (1952) defined the floodplain communities in the South. Putnam et al. (1960) described the origin and development of land forms in southeastern floodplains and showed the relationship between land form and vegetation in considerable detail. They include an elaborate table which lists ecological tolerances, reproductive capacities, growth rates, and other parameters for many species of floodplain trees. Wharton (1970) argued the economic benefits of natural floodplains in Georgia in comparison to those that had been modified by man.

Important collections of Apalachicola River area plant specimens reside in the herbarium of Florida State University and in that of Mr. Angus Gholson of Chattahoochee.

NOTABLE SPECIES

The Herbarium at Florida State University maintains a card file on all species of vascular plants ocurring in the eastern portion of the Florida panhandle. The exact locations of species collections are mapped and habitats are noted. I was able to prepare several lists of notable species, using this card file, taxonomic monographs, and my own observations in the field, as well as those of R.K. Godfrey.

TABLE 1. PLANTS KNOWN IN FLORIDA ONLY FROM THE FLOODPLAIN OF THE APALACHICOLA RIVER.

Acer saccharinum L.
Carex cephalophora Muhl.
Carex frankii Kunth
Clematis viorna L.
Cornus amomum Mill.
Corydalis flavula (Raf.) DC.
Cryptotaenia canadensis (L.) DC. rare
Dentaria laciniata Muhl.
Helianthus strumosus L.
Hypericum frondosum Michx.
Impatiens capensis Meerb. rare
Lysimachia ciliata L. rare
Nemophila aphylla (L.) Brummitt
Scrophularia marilandica L.
Sicyos angulatus L.
Treptocarpus aethusae Nutt.

Table 1 lists 16 species of northern distribution that occur in Florida only on the floodplain of the Apalachicola River (a few weedy species could also have been added to this list). Three of these species are considered rare on the Department of the Interior (1975) list of rare, threatened, and endangered species. The only tree is silver maple.

TABLE 2. PLANTS KNOWN IN FLORIDA ONLY FROM THE BLUFFS OF THE APALACHICOLA RIVER, OR SOME OF THEM ALSO FROM THE FLOODPLAIN.

Actaea pachypoda Ell. rare
Arnoglossum atriplicifolium (L.) Pippen
Baptisia megacarpa Chapm.
Carex gracilescens Steud.
Cornus alternifolia L. f. rare
Croomia pauciflora (Nutt.) Torr. threatened
Cynoglossum virginianum L. rare
Dioclea multiflora (T. & G.) Mohr
Hepatica americana (DC.) Ker. rare
Hydrangea arborescens L.
Luzula acuminata Raf.
Luzula echinata (Small) F. J. Hermann
Matelea baldwyniana (Sweet) Woods.
Matelea flavidula (Chapm.) Woods.
Phlox carolina L.
Silene polypetala (Walt.) Fern. endangered
Smilacina racemosa (L.) Desf.
Trillium lancifolium Raf. rare
Uvularia sessilifolia L. rare
Veratrum woodii Robbins endangered
Verbesina alternifolia (L.) Britt.
Viola affinis LeConte
Woodsia obtusa (Spreng.) Torr.
Zizia aurea (L.) Koch

Table 2 lists 24 species known in Florida only on the bluffs between Chattahoochee and Bristol, although some of them also grow on the adjacent floodplain. Two are endangered, one threatened, and six rare. *Silene polypetala* is narrowly endemic to Gadsden County and adjacent southern Georgia. *Croomia pauciflora* is known from Gadsden and Liberty counties and several locations in Georgia and Alabama. The others are northern species with southern extensions into Florida.

TABLE 3. PLANTS KNOWN IN FLORIDA ONLY TO THE APALACHICOLA RIVER REGION, EXCLUDING THOSE KNOWN ONLY ON BLUFFS AND FLOODPLAINS.

Ampelopsis cordata Michx.
Arnica acaulis (Walt.) BSP.
Aster plumosus Small threatened
Cuphea aspera Chapm. endangered
Cyperus aristatus Rottb.
Dicliptera brachiata (Pursh) Spreng.
Eragrostis glomerata (Walt.) Dewey
Eragrostis pectinacea (Michx.) Nees
Euphorbia telephioides Chapm. threatened
Gentiana saponaria L.
Harperocallis flava McDaniel endangered
Heliopsis minor (Hook.) Mohr
Heteranthera dubia (Jacq.) MacM.
Iva annua L.
Justicia americana (L.) Vahl
Justicia crassifolia (Chapm.) Small
Linum sulcatum Ridd var. *harperi* (Small) Rogers threatened
Macbridea alba Chapm. endangered
Oxypolis greenmanii Math. & Const. endangered
Parnassia caroliniana Michx.
Parnassia grandifolia DC.
Phoebanthus tenuifolia (T. & G.) Blake
Rhexia parviflora Chapman. endangered
Scutellaria floridana Chapman. threatened
Sphenopholis nitida (Bieler) Scribn.
Taxus floridana Nutt. endangered
Thaspium trifoliatum (L.) Gray
Torreya taxifolia Arn. endangered
Verbesina chapmanii Coleman threatened
Viola hastata Michx.
Vuika hirsutula Braierd

Table 3 lists 31 species restricted to the Apalachicola River region, excluding those already listed in Tables 1 and 2 and excluding species known in Florida only in the Marianna Lowlands. Six are endangered, five are threatened, and 11 are endemic largely or entirely to the Apalachicola River region. *Torreya taxifolia* is known from Liberty, Gadsden, and Jackson counties, Florida, and Seminole County, Georgia. *Taxus floridana* has been seen only in Liberty and Gadsden counties.

Harperocallis flava, a monotypic genus of the Liliaceae discovered and described by McDaniel (1968), is known only from the type locality in Franklin County near Sumatra in wet pineland near titi bogs. *Macbridea alba, cuphea aspera, Euphorbia telephioides*, and *Scutellaria floridana* are endemic to pinelands near the mouth of the Apalachicola River. *Oxypolis greenmanii* is known only from Calhoun and Gulf counties in the west savannah lands near the Apalachicola River. *Verbesina chapmanii* grows only in savannahs with alluvial clay soils in the lower Apalachicola River region. *Rhexia parviflora* is known from Franklin County and one county in southwest Georgia. *Linum sulcatum* var. *harperi* occurs only in the mid-panhandle and in adjacent Alabama and Georgia.

TABLE 4. NOTEWORTHY PLANTS KNOWN IN FLORIDA FROM THE APALACHICOLA RIVER REGION AND OTHER AREAS.

Adiantum capillus-veneris L. rare
Anemonella thalictroides (L.) Spach rare
Arnoglossum diversifolium (T. & G.) Pippen threatened
Asclepias viridula Chapm. threatened
Aster spinulosus Chapm. threatened
Calamintha dentatum Chapm. threatened
Carex baltzellii Chapm. threatened
Conradina glabra Shinners endangered
Dirca palustris L. rare
Erythronium umbilicatum Parks & Hardin rare
Gentiana pennelliana Fern. endangered
Hedeoma graveolens Chapm. endangered
Heterotheca flexuosa (Nash) Harms threatened
Hexastylis arifolia (Michx.) Small rare
Hypericum lissophloes Adams rare
Isoetes flaccida Schuttlw. threatened
Isopyrum biternatum (Raf.) T. & G. rare
Laportea canadensis (L.) Weddell rare
Liatris provincialis Godfrey endangered
Linum westii Rogers endangered
Lithospermum tuberosum Rugel rare
Magnolia ashei Weatherby threatened
Malaxis unifolia Michx. rare
Manisuris tuberculosa Nash threatened
Mediola virginiana L. rare
Myriophyllum laxum Shuttlw. threatened
Nolina atopocarpa Bartlett endangered
Pinckneya bracteata (Bartr.) Raf. threatened
Pinguicula ionantha Godfrey endangered
Pinguicula planifolia Chapm. threatened
Polygonella macrophylla Small threatened
Pteris phillyreifolia (Hook.) DC. threatened
Rhapidophyllum hystrix (Pursh) Wendl. & Drude threatened
Rhexia salicifolia Kral & Bostick threatened
Rhododendron austrinum (Small) Rehder threatened
Sarracenia psittacina Michx. threatened
Senecio aureus L. rare
Smilax smallii Morong. threatened
Uvularia floridana Chapm. rare
Uvularia perfoliata L. rare
Warea sessilifolia Nash endangered
Xyris isoetifolia Kral threatened
Xyris longisepala Kral rare
Xyris scabrifolia Harper threatened
Zephyranthes treatiae S. Wats. threatened

Table 4 lists 49 species known from the Apalachicola River region as well as other parts of Florida. Eight are endangered, 22 are threatened, 15 are rare, and 14 are endemic largely or entirely to the panhandle. *Nolina atopocarpa* is known from silty pinelands associated with savannahs in the lower Apalachicola River region and from eastern peninsular Florida. *Liatris provincialis* occurs from Leon to Franklin counties, mostly near the Gulf coast. *Gentiana pennelliana* grows only from Wakulla to Walton Counties. *Conradina glabra* exists from the Apalachicola River to Santa Rosa County. *Hedeoma graveolens* is known only from Leon, Liberty, and Bay counties. *Linum westii* has been collected only in Franklin, Jackson, and Baker counties. *Pinguicula ionantha* occurs only in Franklin, Liberty, Gulf, and Bay counties. *Xyris isoetifolia* is known from Bay and Gulf counties. *Xyris scabrifolia* has been seen in the panhandle and in central Georgia. *Magnolia ashei* and *Rhexia salicifolia* are endemic to the panhandle. *Polygonella macrophylla* occurs from Franklin County into southern Alabama. *Xyris longisepala* is known from the panhandle in the general vicinity of the Apalachicola River. *Hexastylis arifolia* occurs near the Gulf coast from Leon County reportedly to Louisiana. *Rhododendron chapmanii* is endemic to Liberty, Gadsden, Gulf, and Clay counties.

Three additional species are noteworthy, because they occur in the panhandle only on St. Vincent Island but are widespread southward in the peninsula. These are a fern, *Phlebodium aureum;* a rush, *Juncus interstincta*, which is otherwise known no further north than Sarasota; and a tree, *Sapindus marginatus*, which is otherwise reported as far north as Dixie county. The *Sapindus* occurs in a rich hammock on top of an extensive kitchen-midden of Indian-deposited oyster shells on the oldest part of the island. The *Juncus* occurs in a swale immediately behind the hammock. Factors that may explain the occurrence of these species are the calcium of the shells, the ameliorating effects of the Gulf on winter temperatures, and the protection afforded by the hammock from winter winds.

In summary, 116 noteworthy species are known in the immediate vicinity of the Apalachicola River. Seventeen are endangered, 28 threatened, and 30 rare. Nine are narrowly endemic within the watershed of the Apalachicola River, and 27 others are endemic to a somewhat larger region which includes the Apalachicola River area. It should be emphasized that these plants do not live in a vacuum. To preserve them, the habitats in which they occur must be protected.

PRESENT STATUS OF THE VEGETATION

In general and in comparison to other rivers of this size, the natural environment and vegetation of the Apalachicola River bluffs are protected at Torreya State Park, and many other portions are essentially in their natural state in spite of timber harvest. The Marianna Lowlands and the Grand Ridge areas are becoming increasingly developed in terms of agriculture, forestry, and quarrying for limestone. Nonetheless, many acres are still relatively unaffected. Marianna Cavern State Park protects the unique flora of the Marianna Lowlands. The Gulf Coastal Lowlands to the west of the Apalachicola River are experiencing recent and substantial modification from intensive forestry, soyabean production, grazing, and drainage by ditching. The lowlands to the east of the River are better protected within the Apalachicola National Forest, although some intensive forestry is practiced there. The U.S. Forest Service is to be commended for preserving some of the best savannah areas near Sumatra and the type locality of *Harperocallis flava.* These areas deserve long-term protection and should be incorporated in the National Wilderness Preservation System. Since these are fire-maintained habitats, wilderness designation must carry with it a mandate for the Forest Service to manage these lands with frequent prescribed fires.

The floodplains are almost entirely in private ownership, with exceptions at Torreya State Park, Ft. Gadsden State Park, and in part of the Apalachicola National Forest. The forests have suffered extensive and repeated timber harvest for a century, but the second growth is rapid. The vastness and inaccessibility of this floodplain forest helps protect the natural systems. On the other hand, the Tate's Hell Swamp is rapidly and permanently being converted from its natural state by intensive forestry. St. Vincent Island is protected by its status as a National Wildlife Refuge and by its inaccessibility except by boat. Portions of Cape San Blas and St. George Island are protected in State Parks, although both are accessible by auto. Dune buggies have destroyed many acres of vegetation on St. George Island. Uncontrolled development, primarily by weekend cottages, threatens to destroy the large, privately-owned portion of the island. Dog Island, which is accessible only by boat or plane, is not threatened at present.

Additional portions of the bluffs near Aspalaga should be preserved, particularly the unique steepheads. Feral hogs must be eradicated or at least controlled at Torreya State Park, St. Vincent Island, and hopefully on other, privately owned lands. These animals destroy acres of hammock lands by rooting in the soil. There is no way of telling how many species of plants have been extirpated or greatly reduced in Florida from years of foraging by hogs.

THREATS TO FLOODPLAIN VEGETATION

Apalachicola was first settled about 1820, just before Florida became a territory of the United States. Before the Civil War, Apalachicola was a major cotton port, and shipments of timber from upriver were minor. Over 130 steamboats sailed on the Chattahoochee, Flint and Apalachicola rivers from 1828 to 1860 (Owens, 1969). Williams (1837) wrote: "The lands on the banks of this river (the Apalachicola), are generally rich, and the produce conveyed to market down its various channels is already very considerable, and is rapidly increasing."

The timber boom of approximately 1870 to 1925 has not been summarized in the historical literature, even though lumbering is the most obvious impact on the floodplain. Harper (1911) wrote, "The country along the lower Apalachicola is so thinly settled that the effects of civilization on the river-bank vegetation, except for the removal of a good deal of *Taxodium distichum* by lumberman, do not need to concern us at present." Paisley (1973), in reference to a source from 1914, said, "The Apalachicola was also used to float rafts of cottonwood, ash, or poplar logs to the Cypress Lumber Co. of Apalachicola." A mosiac of aerial photographs of the lower Apalachicola River, taken in the mid-1930's and placed on permanent display in the Carraway Building, Florida State University, shows numerous skid marks leading to many river landings, from which logs were rafted or, more recently, loaded and transported by barge down river. A recent canoe trip from Blountstown to Apalachicola revealed that these acre-sized landings are slow to become reforested. Tree roots, which once held the soil in place, no longer prevent the bank from eroding. Some landings are still in use and logs are removed by overhead cables. Evidence of recent clear-cutting was observed.

The preceding discussion verifies a long and continuous use of the floodplain, with timber removal being the most obvious impact on the vegetation. At present, sweetgums and water oaks of essentially mature height but of small caliper are the most conspicuous trees in the forest behind the river bank. Cypress are infrequent, and the forests of overcup oak, ash, and water-hickory, which are common along other alluvial rivers of the panhandle, are rarer along the Apalachicola. The possibility exists that the forests of sweetgum and water oak are secondary and have replaced an original forest which contained more cypress and other hardwoods. Spruce pine and some loblolly pine are also common in present stands, both of which could owe their presence to invasion and reduced competition following lumbering.

Even this long history of land use has not caused a severe threat to the vegetation of the floodplain, but damming and intensive forestry could do so in the near future. A dam would be a threat to the existence of at least some of the species listed in Table 1. Depending on the depth of the resulting reservoir, some of the lower bluffs could become inundated permanently, thereby reducing the scarce habitat for Torreya and the other, aforementioned disjunct and endemic species of that area. An impoundment would also kill the trees of many species (Broadfoot and Williston, 1973) and prevent the reproduction of others (Hosner 1958, 1959; Dickson et al., 1965).

Another threat is the tree farming of fast growing, bottomland hardwoods, such as cottonwood. There is talk of the establishment of such tree farms in the floodplain of the Apalachicola. Forestry, as presently practiced, may scar some of the soil and cause a shift in dominance of the trees that recolonize a site. On the other hand, tree farming reduces the natural plant diversity and modifies the physiognomy of the vegetation.

The effect of barges on the vegetation of the river banks is of immediate concern. These barges are often in excess of 200 ft in length and run day and night. They have difficulty negotiating the sharp curves, especially since they hug the outside curves where the channel is deepest. Virtually all of the curves have trees that were recently pushed over by barges running aground. Slabs of bark are removed from trunks where the barges made contact. A barge captain admitted that such accidents are common and, "really rattles the dishes." Many curves display a row of trees about a quarter-mile long that have been recently knocked over.

Theoretically, the removal of trees on the outside curves exposes the river banks to the most swiftly flowing currents of the channel and thus rapid erosion. Such erosion would make the meanders of the river sharper and even less easily navigated than before. The removal of dead trees and eroded soil from the river must add to maintenance costs.

Another threat to the vegetation of the floodplain is the encroachment of housing developments. Apiaries and an occasional fishing camp are acceptable, but real estate developments can cause serious problems. Red Bull Island, a high terrace on the common floodplain of the Chipola and Apalachicola rivers at Wewahitchka, was cleared of its vegetation, partially filled, canals dug, and lots sold to mobile home owners. Although such developments presently are exceptional, the clamor by property owners for flood protection could be used by proponents of dam construction to win approval of their projects.

THREATS TO THE ADJACENT GULF COASTAL LOWLANDS

Agriculture and intensive forestry are permanently changing the natural vegetation in the longleaf pine flatwoods and open savannahs near the Apalachicola River. These fire-maintained communities are extraordinarily permanent and contain a high species diversity. Unlike most vegetation types, some of the dominant species, especially wiregrass, are incapable of reproduction. Since wiregrass is the most abundant plant, and since it is the primary fuel for fire, its demise by the mechanical disturbance of the soil precludes the reestablishment of flatwoods and savannahs, even after disturbed lands have lain fallow (Clewell, 1971).

The deleterious effects of mechanical disturbance during site preparation for tree farms, such as chopping, disking and bedding, on wiregrass and its associates were documented by Clewell and Hilty (1976). Heavy fertilization of unburned slash pine plantations can cause shade and leaf litter sufficient to eliminate virtually all herbaceous and low shrubs. The high density of planted pines and the reduction in species diversity must invite pests and diseases of pine. Fusiform rust, pitch canker, and shoot-moth are already serious in the plantations near the Apalachicola River. The cost of mechanized site preparation and of fertilization which hopefully will slow the rapid conversion of natural pinelands is another damaging practice. The conversion of pinelands into improved pastures also causes a permanent alteration of the vegetation.

All of these practices are prevalent in the Gulf Coastal Lowlands on the west side of the Apalachicola River. Intensive forestry has claimed much or most of the natural vegetation of Tate's Hell Swamp. The only viable possibility for preserving a substantial portion of these pinelands and savannahs would be for the U.S. Forest Service to manage timber by the shelterwood method in the Apalachicola National Forest (Croker and Boyer, 1975).

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APPENDIX I. PLANTS NOTED IN THE TEXT

Alder	*Alnus serrulata* (Ait.) Willd.
Ash	*Fraxinus* spp.
Birch, River	*Betula nigra* L.
Blackgum	*Nyssa biflora* Walt.
Bulrush	*Scirpus* spp.
Cabbage palm	*Sabal palmetto* Lodd.
Cattail	*Typha domingensis* Pers.
Cordgrass	*Spartina* spp.
Cottonwood	*Populus deltoides* Marsh.
Cut-grass	*Zizaniopsis miliacea* (Michx.) Doell & Aschers.
Cypress, Bald-	*Taxodium distichum* (L.) Rich
Cypress, Pond-	*T. ascendens* Brongn.
Dogwood	*Cornus florida* L.
Gallberry	*Ilex glabra* (L.) Gray
Hickory, Mockernut	*Carya tomentosa* Nutt.
Water	*C. aquatica* (Michx. f.) Nutt.
Holly, American	*Ilex opaca* Ait.
Ironwood	*Carpinus caroliniana* Walt.
Magnolia, Southern	*Magnolia grandiflora* L.
Maple, Red	*Acer rubrum* L.
Southern Sugar	*A. barbatum* Michx.
Needlerush	*Juncus roemerianus* Scheele
Oak, Chapman's	*Quercus chapmanii* Sarg.
Diamond-leaf	*Q. laurifolia* Michx.
Dwarf-live	*Q. geminata* Small
Myrtle	*Q. myrtifolia* Willd.
Overcup	*Q. lyrata* Walt.
Post	*Q. stellata* Wang
Red	*Q. falcata* Michx.
Runner	*Q. pumila* Walt.
Swamp-chestnut	*Q. prinus* L.
Turkey	*Q. laevis* Walt.
Water	*Q. nigra* L.
Pine, Loblolly	*Pinus taeda* L.
Longleaf	*P. palustris* Mill.
Sand	*P. clausa* (Chapm.) Vasey
Shortleaf	*P. echinata* Mill.
Spruce	*P. glabra* Walt.
Planer-tree	*Planera aquatica* (Walt.) Gmel.
Reedgrass	*Phragmites australis* (Cab.) Trin.
Rice, Wild	*Zizania aquatica* L.
Rosemary	*Ceratiola ericoides* Michx.
Rush	*Juncus* spp.
St. Johns-wort	*Hypericum fasciculatum* Lam.
Saw palmetto	*Serenoa repens* (Bartr.) Small
Sawgrass	*Cladium jamaicense* Crantz.
Silverbells	*Halesia diptera* Ellis
Sweetbay	*Magnolia virginiana* L.
Sweetgum	*Liquidambar styraciflua* L.
Sycamore	*Platanus occidentalis* L.
Titi	*Cyrilla* spp., *Cliftonia monophylla* (Lam.) Sarg.
Torreya	*Torreya taxifolia* Arn.
Tupelo, Ogeeche	*Nyssa ogeche* Bartr.
Water	*N. aquatica* L.
Willow, Black	*Salix nigra* Marsh.
Wiregrass	*Aristida stricta* Michx.
Yew, Florida	*Taxus floridana* Nutt.

EFFECTS OF A FILL OPERATION ON TREE VITALITY IN THE APALACHICOLA RIVER FLOODPLAIN, FLORIDA

Andre F. Clewell
Florida State University

and

Helen McAninch
Florida Department of Environmental Regulation

INTRODUCTION

This paper describes the effects of a dredge and fill operation on tree vitality 3-4 years after the initial action. The study site is located on the common floodplain of the Chipola and Apalachicola rivers near the City of Wewahitchka.

The Chipola River enters the floodplain of the much larger Apalachicola River from the northwest a few miles north of Wewahitchka. The Chipola eventually enters the Apalachicola about 8 mi. south of the city. About a mile east of Wewahitchka near the western bank of the Chipola River is a high terrace on the floodplain called Red Bull Island. This island is accessible across a short fill-road that spans the bald-cypress and water tupelo swamp surrounding most of Red Bull Island. (Tree nomenclature follows Kurz and Godfrey, 1962.)

Real estate development began late in 1972. Lots have been sold and are occupied by mobile homes whose owners use them primarily as week-end fish camps. Several canals were dredged for access by boats to the Chipola River, and much of the fill was spread on low-lying, peripheral areas to increase the size of the development. Although many of the trees had been removed by the time that the fill was spread, almost all of those remaining in the filled-in areas have died or have suffered a partial loss of their crowns subsequent to treatment. Since the trees on adjacent unfilled areas *are* healthy, it is evident that the fill operation is responsible for the loss of vitality and death of the trees in the treated areas.

DESCRIPTION OF THE STUDY AREA

Red Bull Island lies in section 20, T4S, R9W, Gulf County. The USGS Quadrangle (7.5 min. series) for Wewahitchka shows the floodplain of the Chipola and Apalachicola rivers to be 10 to 20 ft in elevation above sea level, except for Red Bull Island and very few additional terraces which lie between 20 and 30 ft in elevation. Red Bull Island at its extreme is 0.6 mi long and 0.5 mi wide and comprises about 90 acres of natural and filled lands. Aerial photographs in October 1970 revealed no disturbance, except for a small slash pine plantation on the uppermost site. Other aerial photographs (March, 1974) showed that the canals were essentially completed and the fill already distributed. Dredging and filling began in late 1972 and continued through 1973. Tree death in the filled areas was abundantly evident on a site visit in September 1975.

The remaining natural vegetation on higher elevations includes *Magnolia grandiflora*, *Carya tomentosa*, *Quercus tellata*, and *Q. falcata*. The *Magnolia* is characteristic of river bluffs and is not uncommon on the higher natural levees of the Apalachicola River, where flooding is infrequent and brief. The other trees are characteristic of high bluffs. The presence of this hardwood community strongly suggests that the higher portions of Red Bull Island are flooded no more than once every few decades and for no more than a few days at a time.

At lower elevations the vegetation includes *Liquidambar styraciflua*, *Quercus nigra*, *Q. laurifolia*, *Nyssa biflora*, and *Pinus taeda*, all common on more frequently flooded terraces of floodplains. These species and others, such as *Betula nigra*, extend to the bank of the Chipola River along the southern edge of Red Bull Island. Swamps bordering the other sides of the island mostly contain *Taxodium distichum*, *Nyssa aquatica*, *N. ogeche*, and some *Fraxinus caroliniana*.

Fill materials ranged in texture from a loose, medium, sharp sand coated with brown silt (silty sand) to a pure, easily molded clay. Intermediate textures of clayey sand or sandy clay predominated. This fill was deposited at various depths of up to a meter, or deeper where shallow sloughs were filled. Although topographic relief is slight for much of the area, sheet erosion of the fill materials from heavy rains has been extensive. Shallow erosion channels are evident. Many trees retain a ring of sediments on their bark, denoting the level to which the fill stood before erosion. Several pairs of trees were positioned in such a way that surface erosion bypassed the fill between each pair, thereby leaving a narrow ridge of fill mostly 3-6 dm higher than the level of the surrounding soil surface. The extent of surface erosion varied from place to

TABLE 1. RELATIONSHIP BETWEEN DEPTH OF FILL (CM) AND TREE VITALITY.

	Number of Trees Sampled.	Minimum depth of fill over trees with reduced vitality.	Mean depth of fill C over trees with reduced vitality.	Maximum depth of fill over living trees.	Maximum depth of fill over sprouting trees.	Number of vigorous trees unaffected by fill.
Liquidambar styraciflua	19	5	30	73	44	0
Quercus nigra	26	8	35	73	40	0
Nyssa biflora	21	7	34	60	37	1
7 Upland Species A	15	4	21	60	29	1
8 Lowland Species B	15	12	49	120	120	1
Total	96					3

A—
Carya tomentosa (5), *Quercus falcata* (3), *Q. stellata* (2), *Q. prinus* (2), *Q. hemisphaerica* (1), *Ilex opaca* (1), *Magnolia grandiflora* (1).

B—
Quercus laurifolia (5), *Pinus taeda* (4) *Cyrilla racemiflora* (1), *Persea palustris* (1), *Magnolia virginiana* (1), *Betula nigra* (1), *Ulmus americana* (1), *Acer rubrum* (1).

C—
Mean depth of fill, weighted as if all vitality values belonged to class 3 (1/2 dead) by using the following formula:

$$\frac{ED}{N} \times \frac{EV}{3N}$$

where D=depth of fill, V=vitality index, and N=number of trees. The vitality index ranges from 1 (dead trees) to 5 (unaffected trees).

place. Some of the apparent loss of fill may have been partially attributable to compaction.

Most trees exhibited injuries where draglines or other equipment had scraped off patches of bark. One tree, around which the fill had completely eroded, showed that machinery had removed some of the original topsoil, exposing feeder roots. Injuries to the bark of living trees were healing. No appreciable deleterious effects were noted that were directly attributable to these injuries, except for a few trees which were nearly girdled. Dead trees also showed bark damage comparable to that of the living trees. We, therefore, assumed that the deposition of fill rather than mechanical injury was largely responsible for the loss of vitality and death of trees.

METHODS

Ninety-six trees belonging to 18 species were located which had fill materials spread beneath them. The depth of the fill was determined with a soil auger. The texture of the fill was estimated and assigned to one of four categories: silty sand, clayey sand, sandy clay, and clay. Tree vitality was determined according to the proportions of the crown that consisted of dead branches. Five categories of vitality were recognized: dead, 3/4 dead, 1/2 dead, 1/4 dead, and unaffected. The diameter at breast height was recorded for each tree.

Some trees with low vitality were sprouting short, adventitious shoots from their trunks and larger branches. The root systems of five of these trees were examined after removing the fill and some of the original top soil. These five included two trees of *Liquidambar styraciflua* and one each of *Quercus nigra*, *Q. stellata*, and *Betula nigra*.

Although many dead trees were seen, only 11 were included in the survey, because the identification of dead trees usually could not be ascertained with confidence. Those 11 were *Liquidambar styraciflua* (4), *Quercus nigra* (3), and one each of *Nyssa biflora*, *Pinus taeda*, *Carya tomentosa*, and *Quercus stellata*. The dead trees generally occurred in the areas containing the deepest fill.

RESULTS

Table 1 gives the extremes in data regarding the effect of depth of fill on vitality. Since only *Liquidambar styraciflua*, *Quercus nigra*, and *Nyssa biflora* were sampled in quantity, the other species were combined into two categories: those that normally grow on well-drained mesic sites and those that grow in wetter hatitats. As a group, the latter trees were more tolerant of fill than those from well-drained sites.

Only three of 96 trees were completely vigorous. These were *Nyssa biflora* growing beneath 13 cm of fill and *Magnolia grandiflora* and *Pinus taeda*, each growing beneath 19 cm of fill. Trees of all species or groups showed reduced vigor with only 4-13 cm of fill deposited beneath them. Only three trees survived under more than 80 cm of fill. These were *Acer rubrum* (120 cm), *Liquidambar styraciflua* (86 cm), and *Ulmus americana* (86 cm). Of the upland trees only two survived beneath more than 30 cm of fill (*Carya tomentosa* — 60 cm, *Ilex opaca* — 40 cm). Of the 22 trees that contained adventitious shoots on their trunks, all but two grew beneath no more than 44 cm of fill. These two were *Acer rubrum* (120 cm) and *Betula nigra* (53 cm).

Of the five trees with adventitious shoots whose roots were excavated, one, *Betula nigra*, contained adventitious roots up to 2 cm thick that had sprouted from the trunk directly into the fill. The other four (*Quercus nigra*, *Q. stellata*, and two of *Liquidambar styraciflua*) each contained new roots of 1-2 mm thickness. These roots originated from the undersides of the large, lateral roots that are responsible for the support of the tree. These new roots had grown upwards to within 1-few cm of the present soil surface, often following the fissures of the bark on the portion of the trunk buried by fill. When all soil was removed from around these new roots, they often stood erect without support.

The minimum depths at which trees were killed were *Liquidambar styraciflua* at 45 cm, *Quercus nigra* at 50 cm, *Nyssa biflora* at 67 cm, *Quercus stellata* at 49 cm, *Carya tomentosa* at 28 cm, and *Pinus taeda* at 15 cm.

There was a tendency for the deeper fill around surviving trees to consist of clay or sandy clay rather than the coarse textured clayey or silty sands. This relationship was particularly pronounced for *Liquidambar styraciflua* and *Quercus nigra*. In an attempt to quantify this tendency, the 81 trees of all species that had lost part of their crowns were assigned to three different ranges of depth of fill. Within each category the mean index value was determined. Table 2 shows that the deeper the fill, the more clayey it was, and the shallower the fill, the more sandy it was.

These results should not be interpreted as an indication of greater surface erosion of the more coarse textured soils. Areas where the fill had eroded more than a few centimeters were not included in the study except in a few instances in which the depth of fill was measured to the top of the sediment ring on the trunk, rather than to the present soil surface.

Tree diameters ranged from 10 to 66 cm, except for one tree each of *Ilex opaca* (5 cm) and *Cyrilla racemiflora* (3 cm). No relationships were noted between diameter and survival or vigor.

Regression lines showing the relationship between vitality and depth of fill were established for the three species and the two groups of species in Table 1. The confidence limits of the lines were too broad to merit the incorporation in this paper.

TABLE 2. AVERAGE SOIL TEXTURE OF 81 TREES WITH PARTIAL LOSS OF CROWN IN RELATION TO DEPTH OF FILL.

Depth of Fill (cm)	Number of Trees	Average Soil Texture Index*
40-120	22	3.3
20-40	37	2.7
4-19	22	2.3

*1 = silty sand; 2 = clayey sand; 3 = sandy clay; 4 = clay.

The broad limits were due to the inability to identify sufficient dead trees and to the variability of soil textures and mechanical injury of the trees.

DISCUSSION

The effects of fill on trees is scarcely treated in the literature, at least for the Southeast. Broadfoot (1973) made one study at Lake Seminole which flows directly into the Apalachicola River. He compared the growth rates of trees bordering this reservoir by comparing the widths of growth rings for five years before and five years after the construction of the Jim Woodruff Dam. The higher water tables associated with the formation of Lake Seminole caused increases in growth for most species. He said,

> "In general, tree radial growth around the Jim Woodruff Reservoir increased markedly only where no recent sediment was present around the trees. Growth of most trees along the reservoir near where the Chattahoochee River enters was retarded by sand deposits . . . The sand deposit, which averaged about 6 inches around the trees at location 5, was too irregular to measure around each separate tree. Generally, stand growth was decreasing, and the sand deposit appeared to be the cause."

Among the trees adversely affected were *Liquidambar styraciflua* and *Quercus nigra*.

Broadfoot and Williston (1973) said that three or more inches of silt or sand may be sufficient to seal the soil and smother tree roots. They suggested that clay soils dry and crack in summer, permitting the air to reach the roots. On the contrary, silts and sands do not crack and are more effective in smothering roots.

Our own results corroborate those of Broadfoot (1973) and of Broadfoot and Williston (1973). Table 2 lends credence to their observation that coarser textured soils are more effective in smothering roots than are clays.

In an apparent attempt to save trees from the detrimental effects of the fill, the developer arranged for no fill to be placed within a radius of several meters of certain trees. This attempt failed, in that surface drainage collected in the resultant basins and was unable to escape because of the impermeability of the fill materials. The impounded trees were nearly all dead, even though neighboring trees of the same species survived beneath a deposit of fill. Broadfoot and Williston (1971) also noted the lethal effects of the continuous impoundment of water on bottomland hardwoods.

Table 1 shows that trees of *Nyssa biflora* were comparable in their tolerance of fill to those of *Quercus nigra* and other lowland species. This result was unexpected. *Nyssa biflora* is dominant on floodplains where the soil is too wet for the occurrence or at least the dominance of the other lowland species. *Nyssa biflora*, therefore, would be expected to be tolerant of deeper fill.

CONCLUSIONS

Several factors contribute to the loss of vitality or death of trees subjected to a fill operation on a floodplain. These include the species of tree, the depth and texture of the fill, the rate of erosion of the fill, the ability of a tree to grow roots into the oxygenated strata of the fill, and the effects of mechanical injury suffered from machinery used in the fill operation. Collectively these variables detract from identifying the importance of each as a factor. Nonetheless, the present study circumscribes the limits at which an effect may be expected from a fill operation. These limits apply to *Liquidambar styraciflua*, *Quercus nigra*, *Nyssa biflora*, and some of the other important tree species of the well-drained and periodically flooded communities but not necessarily to the wetter cypress-tupelo and associated forest types that were not studied.

The limit of survival for those upland species listed in Table 1 is established at 30 cm of fill. Survival at greater depths is unlikely for the large majority of trees. The limit of survival of *Liquidambar styraciflua*, *Quercus nigra*, *Nyssa biflora*, and the other lowland species is established at 80 cm of fill. Survival at greater depths is likewise improbable.

The minimum depth at which mortality is expected for lowland species was not established. The sparsity of living trees and the numbers of dead trees that were observed suggests that mortality is much greater than shown by the results of this study. The vitality of nearly all trees is reduced as a result of fill, even if the depth of the fill is as little as 4-12 cm.

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FRESHWATER MOLLUSCA OF THE APALACHICOLA DRAINAGE

William H. Heard
Florida State University

Of the drainages of the Apalachicolan or West Floridian molluscan province (viz., from the Escambia to the Suwannee), that of the Apalachicola River contains the largest total number of species of freshwater gastropods and bivalves, the most species endemic in the province and the greatest proportion of endemics to the total fauna (Clench and Turner, 1956: 108).

Sixteen of the 20 gastropods are prosobranchs (Table 1), i.e. gill-breathers, and their adults are thus more susceptible to pollution and silting than are the air-breathing pulmonates. The apple snail, *Pomacea paludosa*, however, also employs the mantle cavity as a pulmonary chamber and lays "terrestrial" eggs. The eggs of the other 19 species, including the pulmonates, are subject to the vagaries of the aquatic medium in which they are deposited.

The pleurocerid snails (*Goniobasis* spp.) and the vast majority of amblemid and unionid clams are lotic organisms and only rarely occur in standing waters (e.g., natural lakes and impoundments of streams).

Sphaeriid bivalves are relatively uncommon in the southern U.S.A. (cf. Heard, 1963). The amblemids and unionids are more diverse in that area, but are conspicuously declining in range and abundance (Heard, 1970; Athearn, 1970). Athearn (1970) considered several Apalachicola mussels to be rare and endangered species (Table 1). To that list can be appended *Anodonta cataracta*, *A. couperiana*, *Anodontoides radiatus*, *Elliptio crassidens*, *E. negella*, *Glebula rotundata*, *Quincucina infucata*, *Strophitus subvexus* and *Villosa villosa*, as well as the gastropods *Goniobasis albanyensis*, *G. boykiniana*, *G. catenoides*, *Lioplax choctawhatchensis*, *Pomatiopsis lapidaria* and *Somatogyrus substriatus* (personal observation).

Local extinctions, particularly of mussels, have involved the concomitant appearance of the introduced Asiatic clam, *Corbicula manilensis*. The mechanism of this replacement is presently unknown.

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TABLE 1. FRESHWATER MOLLUSCA OF THE APALACHICOLA RIVER DRAINAGE. DERIVED FROM ATHEARN (1970), BURCH (1975), CLENCH AND TURNER (1956) AND HEARD (1963).

GASTROPODA: PROSOBRANCHIA		
	Hydrobiidae	
		Notogillia wetherbyi (Dall)
		Pomatiopsis lapidaria (Say)
		Somatogyrus substriatus Walker
	Pilidae	
		Pomacea paludosa (Say)
	Pleuroceridae	
		Goniobasis albanyensis Lea[1]
		G. athearnia Clench and Turner[1]
		G. boykiniana (Lea)[1]
		G. catenoides (Lea)[1]
		G. curvicostata (Reeve)
		G. dickinsoni Clench and Turner
		G. floridensis (Reeve)
		G. viennaensis Lea
	Viviparidae	
		Campeloma geniculum (Conrad)
		Lioplax choctawhatchensis Vanatta
		L. pilsbryi Walker[1]
		Viviparus georgianus (Lea)
GASTROPODA: PULMONATA		
	Ancylidae	
		Ferrissia (Laevipex) dalli Walker
	Lymnaeidae	
		Pseudosuccinea columella (Say)
	Physidae	
		Physa crocata Lea
		P. pumilia Conrad
PELECYPODA (BIVALVIA)		
	Amblemidae	
		Amblema neislerii (Lea)
		Elliptoideus sloatianus (Lea)[2]
		Megalonaias boykinianan (Lea)[2]
		Quincuncina infucata (Conrad)
	Corbiculidae	
		Corbicula manilensis (Philippi)
	Sphaeriidae	
		Byssanodonta cubensis (Prime)
		Musculium lacustre (O. F. Müller)
		M. partumeium (Say)
		M. transversum (Say)
		Pisidium casertanum (Poli)
		P. compressum Prime
		P. dubium (Say)
		Sphaerium occidentale Prime
		S. striatinum (Lamarck)
	Unionidae	
		Alasmidonta triangulata (Lea)[2]
		Anodonta cataracta Say
		A. couperiana Lea
		A. imbecilis Say
		A. peggyae Johnson
		Anodontoides radiatus (Conrad)

TABLE 1. FRESHWATER MOLLUSCA OF THE APALACHICOLA RIVER DRAINAGE. DERIVED FROM ATHEARN (1970), BURCH (1975), CLENCH AND TURNER (1956) AND HEARD (1963). (CONTINUED)

Unionidae (continued)
- *Carunculina parva* (Barnes)
- *Elliptio arctata* (Conrad)
- *E. chipolaensis* (Walker)[1]
- *E. complanata* (Lightfoot)
- *E. crassidens* (Lamarck)
- *E. icterina* (Conrad)
- *E. lanceolata* (Lea)
- *E. nigella* (Lea)[1]
- *Glebula rotundata* (Lamarck)
- *Lampsilis binominatus* (Simpson)[1,2]
- *L. claibornensis* (Lea)
- *L. teres* (Rafinesque)
- *Medionidus penicillatus* (Lea)[2]
- *Pleurobema pyriforme* (Lea)[2]
- *Strophitus subvexus* (Conrad)
- *Uniomerus tetralasmus* (Say)
- *Villosa lienosa* (Conrad)
- *V. subangulata* (Lea)
- *V. vibex* (Conrad)
- *V. villosa* (Wright)

[1]Endemic to the Apalachicola system.
[2]Cited by Athearn (1970) as rare and endangered.

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FISHES OF THE APALACHICOLA RIVER

Ralph W. Yerger
Florida State University

INTRODUCTION

The diversity and importance of the fishes of the Apalachicola River, the largest river emptying into the Gulf of Mexico in Florida, have never been fully investigated nor appreciated. The objectives of this paper are to compile a species list for the entire drainage system, including the major tributaries (the Flint and Chattahoochee rivers) in Georgia and Alabama, and to discuss briefly certain groups of fishes which are significant components of the fish fauna or which are economically important.

The large size of this drainage system and the complex fluctuating faunal composition in the lower river and estuary place certain limitations on the scope of this paper. The primary concern will be those fishes which occur in the Apalachicola River proper and its tributaries from the Jim Woodruff Dam on the Georgia-Florida state line (approximatley 107 mi upstream from the mouth) to a point in the lower Apalachicola just above the limit of tidal influence, below which the river and estuary are subject to frequent invasions by a great variety of marine species. The estuarine areas are discussed in a separate paper in this volume (Livingston et al., 1977). Thus, although the montane and piedmont species found in the Flint and Chattahoochee rivers are included in the checklist, these species together with the marine species in the Lower Apalachicola will be excluded from the discussion.

Myers (1951) provided a useful classification of the several categories of fishes found in freshwater based on their salt tolerance and migratory behavior. His definitions follow:

I. Primary — strictly intolerant of salt seawater. (Most of the fishes on the checklist belong here).
II. Secondary — rather strictly confined to freshwater but evidently capable of occasionally crossing narrow sea barriers; tolerance for sea water for short periods known for many (e.g., longnose gar).
III. Diadromous — fishes which regularly migrate between fresh and salt water at a definite period of the life cycle.
IV. Vicarious — presumably non-diadromous freshwater representatives of partly or primarily marine groups (brook silverside).
V. Complementary — freshwater fishes, often or usually diadromous and belonging to marine groups which become dominant in freshwater only in the paucity or absence of primary, secondary, and probably also vicarious freshwater faunas (mountain mullet).
VI. Sporadic — fishes which live and breed indifferently in salt or freshwater or which enter freshwater only sporadically and not as a part of a true migration (striped mullet).

A summary of Table 1 reveals that 86 species of fishes are found in the Apalachicola River proper (as restricted earlier in this introduction), belonging to 43 genera and 21 families. If we extend the tabulation to include the total Apalachicola system, including the Flint and Chattahoochee rivers, the numbers increase to 116 species, 52 genera, and 23 families, a large fauna exceeded by few drainage systems in the United States. Of the total 116 species, 83 are primary freshwater fishes, which compares with the number of primary freshwater fishes in the St. Johns (54), Savannah (86) and Mobile River systems (128+) (Numbers are approximate).

Zoogeographically the fauna has originated from multiple sources. The Mississippi basin has contributed the largest number of species, through dispersal along the Gulf Coastal Plain, and by stream piracy from the upper Tennessee Basin. From the Atlantic coast fauna, some species gained access to the Apalachicola system through the southeastern and Gulf Coastal Plain, while others entered the headwaters via stream capture from the Savannah River. A few euryhaline marine invaders have penetrated upstream from the Gulf of Mexico. The several endemic species have apparently evolved within the drainage system itself.

A unique physical feature of the Apalachicola System is the deep penetration of its headwaters far into the Southern Appalachian Mountains, while its north-south axis provides an accessible and convenient dispersal route for temperate aquatic and terrestrial plants and animals from the high elevations of the southeastern United States southward all the way to the Gulf of Mexico (for discussion, see Carr, 1940). The snail bullhead is a good example of a fish that utilized this dispersal and immigration route to the Panhandle of Florida.

ENDEMISM

Three species of fishes are restricted to the Apalachicola River and its major tributaries; a fourth unquestionably originated in the system,

TABLE 1. LIST OF FISHES RECORDED FROM THE APALACHICOLA, CHATTAHOOCHEE, AND FLINT RIVERS (EXCLUSIVE OF ESTUARINE WATERS). SPECIES OCCURRING IN THE APALACHICOLA RIVER PROPER ARE NUMBERED WITH ARABIC NUMERALS. ROMAN NUMERALS IN PARENTHESES REFER TO MYERS'S (1951) CLASSIFICATION BASED ON RELATION TO SALT TOLERANCE (SEE DEFINITIONS, TEXT PAGE 2). I = INTRODUCED SPECIES' DATA COMPILED PRIMARILY FROM DAHLBERG AND SCOTT (1971), GILBERT (1969), RAMSEY (1965), SMITH-VANIZ (1968), AND RECORDS FROM THE FLORIDA STATE UNIVERSITY FISH COLLECTION.

	Apalachicola	Chattahoochee	Flint
Petromyzontidae			
1. *Ichthyomyzon gagei* - Southern brook lamprey (IV)	X	X	X
Acipenseridae			
2. *Acipenser oxyrhynchus* - Atlantic sturgeon (III)	X	?	X[a]
Lepisosteidae			
3. *Lepisosteus oculatus* - spotted gar (II)	X	X	X
4. *Lepisosteus osseus* - Longnose gar (II)	X	X	X
Amiidae			
5. *Amia calva* - Bowfin (I)	X	X	X
Anguillidae			
6. *Anguilla rostrata* - American eel (III)	X	X	X
Clupeidae			
7. *Alosa alabamae* - Alabama shad (III)	X	X	?
8. *Alosa chrysochloris* - Skipjack herring (III)	X	X	
9. *Dorosoma cepedianum* - Gizzard shad (IV)	X	X	X
10. *Dorosoma petenense* - Threadfin shad (IV)	X	X	X
Salmonidae			
Salmo gairdneri - Rainbow trout *(IV)*		I	
Salmo trutta - Brown trout (IV)		I	
Salvelinus fontinalis - Brook trout (IV)		X	
Esocidae			
11. *Esox americanus* - Redfin pickerel (I)	X	X	X
12. *Esox niger* - Chain pickerel (I)	X	X	X
Cyprinidae			
Campostoma anomalum - Stoneroller (I)		X	X
Carassius auratus - Goldfish (I)		I	
13. *Cyprinus carpio* - Carp (I)	I	I	

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	Apalachicola	Chattahoochee	Flint
14. *Ericymba buccata* - Silverjaw minnow (I)	X	X	X
15. *Hybopsis winchelli* - chub (I)	X	X	X
16. *Notemigonus crysoleucas* - Golden shiner (I)		X	
Notropis atrapiculus - Blacktip shiner (I)		X	
Notropis baileyi - Rough shiner (I)		I	
17. *Notropis callitaenia* - Bluestripe shiner (I)	X	X	X
18. *Notropis chalybaeus* - Ironcolor shiner (I)	X	X	X
19. *Notropis cummingseae* - Dusky shiner (I)	X	X	
20. *Notropis emiliae* - Pugnose minnow (I)	X	X	X
Notropis euryzonus - Broadstripe shiner (I)		X	
21. *Notropis harperi* - Redeye chub (I)	X	X	X
Notropis hudsonius - Spottail shiner (I)		X	
22. *Notropis hypselopterus* - Sailfin shiner (I)	X	X	X
Notropis hysilepis - Highscale shiner (I)	X	X	X
24. *Notropis longirostris* - Longnose shiner (I)	X	X	X
Notropis lutipinnis - Yellowfin shiner (I)		X	
25. *Notropis maculatus* - Taillight shiner (I)	X	X	X
26. *Notropis petersoni* - Coastal shiner (I)	X	X	X
27. *Notropis signipinnis* - Flagfin shiner (I)	X		
28. *Notropis texanus* - Weed shiner (I)	X	X	X
29. *Notropis venustus* - Blacktail shiner (I)	X	X	X

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	Apalachicola	Chattahoochee	Flint
30. *Notropis welaka* - Bluenose shiner (I)	X	X	X
Notropis xaenocephalus - Coosa shiner (I)		X	
31. *Notropis zonistius* - Bandfin shiner (I)	X	X	X
32. *Semotilus atromaculatus* - Creek chub (I)	X	X	X
Catostomidae			
33. *Carpiodes cyprinus* - Quillback (I)	X	X	
Erimyzon oblongus - Creek chubsucker (I)		X	X
34. *Erimyzon sucetta* - Lake chubsucker (I)	X	X	X
Hypentelium etowanum - Alabama hog sucker (I)		X	
35. *Minytrema melanops* - Spotted sucker (I)	X	X	X
Moxostoma lachneri - Greater jumprock (I)		X	X
Moxostoma poecilurum - Blacktail redhorse (I)		X	
Moxostoma rupiscartes - Striped jumprock (I)		X	
36. *Moxostoma* sp. - Grayfin redhorse (I)	X	X	X
Ictaluridae			
37. *Ictalurus brunneus* - Snail bullhead (I)	X	X	X
38. *Ictalurus catus* - White catfish (I)	X	X[b]	
39. *Ictalurus natalis* - Yellow bullhead (I)	X	X	X
40. *Ictalurus nebulosus* - Brown bullhead (I)	X	X	X
41. *Ictalurus punctatus* - Channel catfish (I)	X	X	X
42. *Ictalurus serracanthus* - Spotted bullhead (I)	X	X	X

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	Apalachicola	Chattahoochee	Flint
43. *Noturus funebris* - Black madtom (I)	X[b]		
44. *Noturus gyrinus* - Tadpole madtom (I)	X	X	X
45. *Noturus leptacanthus* - Speckled madtom (I)	X	X	X
Pylodictis olivaris - Flathead catfish (I)			I
Aphredoderidae			
46. *Aphredoderus sayanus* - Pirate perch (I)	X	X	X
Belonidae			
47. *Strongylura marina* - Atlantic needlefish (III or VI)	X	X	
Cyprinodontidae			
48. *Fundulus chrysotus* - Golden topminnow (II)	X		X
49. *Fundulus cingulatus* - Banded topminnow (II)	X		
Fundulus lineolatus - Lined topminnow (II)			X
50. *Fundulus notti* - Starhead topminnow (II)	X	X	X
Fundulus olivaceus - Blackspotted topminnow (II)		X	
Fundulus stellifer - Southern studfish (II)		X	
51. *Leptolucania ommata* - Pygmy killifish (II)	X		
52. *Lucania goodei* - Bluefin killifish (II)	X		
Poeciliidae			
53. *Gambusia affinis* - Mosquitofish (II)	X	X	X
54. *Heterandria formosa* - Least killifish (II)	X	X	X
Atherinidae			
55. *Labidesthes sicculus* - Brook silverside (IV)	X	X	X

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	Apalachicola	Chattahoochee	Flint
Percichthyidae			
56. *Morone chrysops* - White bass (IV)	I	I	I
57. *Morone saxatilis* - Striped bass (III)	X[c]	X[b]	X[b]
Centrarchidae			
Ambloplites ariommus - Southern rock bass (I)		X	X
58. *Centrarchus macropterus* - Flier (I)	X	X	X
59. *Elassoma evergladei* - Everglades pygmy sunfish (I)	X		X
60. *Elassoma okefenokee* - Okefenokee pygmy sunfish (I)	X		
61. *Elassoma zonatum* - Banded pygmy sunfish (I)	X	X	X
62. *Enneacanthus gloriosus* - Bluespotted sunfish (I)	X		X
63. *Enneacanthus obesus* - Banded sunfish (I)	X		
64. *Lepomis auritus* - Redbreast sunfish (I)	X	X	X
65. *Lepomis cyanellus* - Green sunfish (I)	X[b]	X[b]	
66. *Lepomis gulosus* - Warmouth (I)	X	X	X
67. *Lepomis humilis* - Orangespotted sunfish (I)	I	I	
68. *Lepomis macrochirus* - Bluegill (I)	X	X	X
69. *Lepomis marginatus* - Dollar sunfish (I)	X	X	X
Lepomis megalotis - Longear sunfish (I)		X	
70. *Lepomis microlophus* - Redear sunfish (I)	X	X	X
71. *Lepomis punctatus* - Spotted sunfish (I)	X	X	X
72. *Micropterus* sp. - Shoal bass (I)	X	X	X
Micropterus coosae - Redeye bass (I)		X	X

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	Apalachicola	Chattahoochee	Flint
Micropterus dolomieu - Smallmouth bass (I)		I	
73. *Micropterus punctulatus* - Spotted bass (I)	I	I	
74. *Micropterus salmoides* - Largemouth bass (I)	X	X	X
Pomoxis annularis - White crappie (I)		I	I
75. *Pomoxis nigromaculatus* - Black crappie (I)	X	X	X
Percidae			
76. *Etheostoma edwini* - Brown darter (I)	X	X	X
77. *Etheostoma fusiforme* - Swamp darter (I)	X	X	X
78. *Etheostoma parvipinne* - Goldstripe darter (I)	X	X	X
79. *Etheostoma swaini* - Gulf darter (I)	X	X	X
80. *Perca flavescens* - Yellow perch (I)	I	I	
81. *Percina nigrofasciata* - Blackbanded darter (I)	X	X	X
82. *Stizostedion canadense* - Sauger (I)	I	I	
Stizostedion vitreum - Walleye (I)		I	
Mugilidae			
83. *Agonostomus monticola* - Mountain mullet (III or V)	X		
84. *Mugil cephalus* - Striped mullet (VI)	X		
Cottidae			
Cottus bairdi - Mottled sculpin (IV)		X	
Cottus carolinae - Banded sculpin (IV)		X	
Bothidae			
85. *Paralichthys lethostigma* - Southern flounder (VI)	X		

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	Apalachicola	Chattahoochee	Flint
Soleidae			
86. *Trinectes maculatus* - Hogchoker (III)	X	X[a]	

[a]Recent occurrence doubtful

[b]Probably introduction

[c]Native populations plus introduced stocks

but now occurs in the extreme headwaters of the Savannah River system. (Two other endemics occur in the Flint and Chattahoochee rivers.) A variety of the blue gill sunfish also appears to be endemic to this river.

The bluestripe shiner, *Notropis callitaenia* Bailey and Gibbs, bears a superficial resemblance to the more abundant blacktail shiner, *Notropis venustus*, with which it is commonly associated. In addition to morphological differences, the bluestripe shiner manifests ecological preferences for the sandy bottoms of large rivers, rarely if ever enters the smaller creeks (as does the blacktail), and avoids soft organic bottoms. Consequently, impoundment of river waters removes large areas of suitable habitat available to this species in undisturbed environments. The original description reported a single small specimen from the Escambia River (Baily and Gibbs, 1956). No additional specimens of this species have been collected from that drainage in twenty years. Consequently, this record was either a misidentification or bore erroneous locality data. The bluestripe shiner is thus considered an endemic in the Apalachicola system.

The bandfin shiner, *Notropis zonistius* (Jordan), for many years was thought to be restricted to tributaries of the Chattahoochee River in Alabama and Georgia. More recent collections revealed that it also occurred in tributaries of the Flint and Apalachicola rivers (Yerger and Suttkus, 1962). Very little information is available on this fish except that it inhabits clear water with a rather swift current, often occurring in pools below riffles rather than in the swiftest waters. While the bluestripe shiner is found chiefly in the main river, the bandfin apparently prefers small to medium-large tributaries. One record of this shiner in the upper Savannah system of Georgia indicates that this species has crossed a drainage divide, either by stream capture, or perhaps by introduction (Gilbert, 1964). If it is dispersed by natural events, then in a strict sense it is no longer endemic to the Apalachicola system.

The grayfin redhorse, *Moxostoma* sp., is an undescribed sucker which was misidentified or confused with other species of redhorse suckers for many years. In his monographic treatment of this group, Jenkins (1970) recognized it as a form endemic to the Apalachicola drainage, widespread in the main river and in all major tributaries. It occurs from small streams to large rivers, and has been collected from an impoundment, Lake Eufala, of the Chattahoochee River. It is usually found in white, clear to turbid waters, in slow to moderate current, over sand and gravel bottoms with scant vegetation, but occasionally over silt, rubble, and bedrock. Spawning apparently takes place in late March.

The shoal bass, *Micropterus* sp., is yet another species which only recently has been recognized as distinct from a closely related form, *Micropterus coosae* Hubbs and Bailey, the redeye bass. It is widely distibuted in the lower Chattahoochee and Flint, in the Chipola and upper Apalachicola rivers. In contrast to the largemouth bass, it occurs in moderate to swift currents and usually over a rock or bedrock bottom. Sportfishermen easily recognize its superior fighting qualities. This species will be described and named by John Ramsey of Auburn University.

The "handpaint" is a variety of the bluegill, *Lepomis macrochirus* Rafinesque, and apparently is restricted to the Apalachicola River in Florida. Most striking is the coloration of breeding males: blood red breast; below the lateral line, a broad black band from the opercle to the tail; upper body a bright copper. Both sexes have black patches on the sides of the body. These striking differences from other southeastern populations gave rise to the local name of "handpaint." A comparison of morphological and genetic characters with other bluegill populations is in progress (Felley, 1976).

DIADROMOUS FISHES

Like most large rivers, the Apalachicola provides spawning sites for a number of anadromous species, and habitats for the young and juvenile stages of a few catadromous forms. No other group of fishes is affected more profoundly by the construction of dams than these migratory species. Prior to the completion of the Jim Woodruff Dam in 1957, sturgeon, shad and striped bass were known to penetrate the Flint and Chattahoochee rivers of Georgia, in some cases for considerable distances. Since 1957, access to the waters behind the dam has at best been extremely limited; some fishes use the locks as a passage into Lake Seminole. No assessment of the success or failure of these species to disperse upstream from the dam and Lake Seminole has been made to my knowledge, but it appears that very few fishes are successful. The "piling up" of these species along with thousands of suckers in the tailrace of the dam every spring points to the formidable obstruction encountered by these migratory species.

The Atlantic sturgeon occurs in most of the large rivers along the northern Gulf coast, and is recognized as a subspecies of the Atlantic coast form by some ichthyologists (*Acipenser oxyrhynchus desotoi* Vladykov) The population in the Apalachicola River supported a commercial fishery since the end of the last century, but declining numbers have virtually ended this industry (see section on Commercial Fisheries, Miller et al., 1977). A sport fishery developed in the 1950's and 60's between the Woodruff Dam downstream to Bristol, but this, too, has dwindled in recent years. Specimens from 35 to 160 lb have been taken on hook and line, and even larger fishes to 266 lb in nets. A 420 lb specimen was reported many years ago from the Flint River in Georgia (J. Taranto, personal communication). Although spawning areas have not been identified, an area below Woodruff Dam and deep holes in the Brothers and Florida rivers and vicinity have been suggested by knowledgeable fishermen.

Recent studies of sturgeon in the Suwannee River have yielded important data on movements, reproduction, age and growth, food habits, and related aspects which are no doubt applicable to other Gulf coast populations (Huff, 1975). An investigative team from the University of Florida is currently studying the ecology, population levels, seasonality, and exploitation of Gulf of Mexico sturgeon both in the Suwannee and Apalachicola rivers. During the summer and fall of 1975 they failed to catch a single sturgeon in the Apalachicola (Anonymous, mimeographed interim report to the Phipps Florida Foundation, 1976). Whether this indicates that the sturgeon is on the way out, or whether unusually high water levels or other natural phenomena are to blame, cannot be determined at this time.

The Alabama shad, *Alosa alabamae* Jordan and Evermann, is the most abundant anadromous species in the river. Enormous numbers ascend the river as far as the Woodruff Dam and Dead Lakes (on the Chipola River), and some apparently enter the Flint and Chattahoochee rivers during their spring spawning run from February to April and May. Biological investigations by Laurence and Yerger (1967) and Mills (1972) have provided important knowledge on the life history and habits of the fish. Unlike the vast numbers of American shad that are harvested each year by commercial and sport fishermen on the Atlantic coast, the Alabama shad represents a non-utilized resource. A few are captured by sport fishermen with light tackle at the low-level dam on the Chipola River below the Dead Lakes, below the Woodruff Dam, and in the lower Chattahoochee River. Very few persons eat the roe or flesh, both of which are comparable to the high quality of the American shad. Laurence and Yerger (1967) and Mills (1972) indicated that the large populations of shad could probably support a small commercial fishery, but no local market exists at the present time.

The skipjack herring, *Alosa chrysochloris* (Rafinesque), is probably better known by fishermen than is the Alabama shad, for in the spring it provides extensive sport for the fly-rod enthusiast, especially below the Woodruff Dam. Wolfe (1969) studied the life history of this species in the Apalachicola River, and concluded that some doubt exists as to the anadromous nature of this fish. It may spend most of its life in fresh water and only occasionally invade Gulf waters even though a number of Gulf specimens have been recorded.

The Atlantic needlefish *Strongylura marina* (Walbaum), is of least importance among the anadromous fishes in the Apalachicola. It is commonly observed swimming at the surface, sometimes in considerable numbers during June, July, and August. The fresh water breeding of this marine fish is not widely known. Ripe adults have been collected from March to August, and young 15-25 mm in total length have been captured from Lake Seminole. Similar breeding data have been reported from the St. Johns River, Florida (McLane, 1955), and from Lake Pontchartrain, Louisiana (R.D. Suttkus, personal communication).

The striped bass, *Morone saxatilis* (Walbaum), commonly called striper or rockfish locally, is a favorite gamefish among sportfishermen. Barkuloo (1961, 1967) summarized the results of his extensive studies on this species. The Apalachicola River is the only river on the Florida Gulf Coast that supports a substantial fishery. Few persons fished for striped bass until the completion of the Jim Woodruff Dam in 1957. Since then there has been a highly successful seasonal fishery, March-May and September-December, expecially in the tailrace of the dam, and below the low level dam on the Chipola River. The spring of 1976 yielded a fine catch.

In contrast, reports from commercial fishermen at Apalachicola indicate that striped bass were formerly abundant in the lower river, but in recent years they have been non-existent, except for a few small fish caught in the spring of this year (probably a result of stocking). These fishermen also claim that although the stripers enter the estuary, they do not move into marine waters as do populations along the Atlantic Coast. If this is indeed true, the striped bass population in the Apalachicola is not truly anadromous.

Among the catadromous fishes inhabiting the Apalachicola River, the American eel, *Anguilla rostrata* (Lesueur), is the most abundant, and widely known for its long migrations to spawning grounds in the Sargasso Sea south of Bermuda. Leptocephalus larvae are occasionally taken along the Gulf coast, while the metamorphosed elvers and juveniles up to 6 in. in length are at times found in tremendous concentrations at the base of the Woodruff Dam which blocks their upstream migrations. Bait dealers collect these small eels, hold them alive in tanks and sell them as bait. Fishermen encounter all sizes of juveniles and subadults, but few people utilize them for food.

The hogchoker, *Trinectes maculatus* (Bloch and Schneider) a small flatfish belonging to the sole family, is another catadromous species. Young and juvenile specimens are abundant in the Apalachicola River over sand and muddy sand bottoms. Prior to the completion of the Woodruff Dam, they were known from the Flint and Chattahoochee rivers. Adults occur in coastal waters and spawn in the estuaries. Young hogchokers begin their upstream migration, and after a period of growth to approximately 70 mm, return to the estuary. No records of adults are known from fresh water and young are not known from coastal marine waters.

The mountain mullet, *Agonostomus monticola* (Bancroft), (listed also as a category V fish in the checklist) is another catadromous species, and although the young are occasionally found in streams along the Gulf coast from Florida to Texas, it does not complete its life cycle in waters of the United States. In Central America and the West Indies this fish lives in the freshwater streams and rivers, and upon reaching maturity, descends to the sea for breeding. The larvae are dispersed widely by currents, and occasional waifs reach the Gulf coast and ascend the Apalachicola River.

INTRODUCED SPECIES

For better or for worse nearly all of the river systems in the United States have been subject to the introduction of non-indigenous and exotic fishes, and hatchery-raised native species. The Apalachicola River is no exception. Nearly all of the introduced species were originally stocked in the Chattahoochee or Flint rivers in Georgia and have subsequently moved downstream into the Apalachicola. Except for the carp (and striped bass), all species are more or less restricted in the Apalachicola River to the area immediately below the Woodruff Dam.

The carp, *Cyprinus carpio* Linnaeus, is widespread throughout the river, attains weights at least to 16 lb, and at times is exceedingly abundant. Introduction into the Apalachicola undoubtedly dates back to the late 1800's, although this stocking has not been verified. In contrast to the severe, detrimental environmental alterations following the introduction of the carp in many parts of the United States, its presence in this riverine situation has not produced obvious adverse effects.

Introductions of white bass, *Morone chrysops* (Rafinesque), into many river systems with major reservoirs in Georgia has led to the passage of these fish from Lake Seminole into the Upper Apalachicola River. The white bass is well-known locally and has become a popular sport fish, attaining weights up to five pounds.

The striped bass is native to the Apalachicola drainage system, but over the past ten years numerous stockings have been made into the Flint and Chattahoochee rivers by the Georgia Game and Fish Commission, and into the Apalachicola by the Florida Game and Fresh Water Fish Commission. In 1975 hybrids between striped bass and white bass were stocked in Lake Seminole, and as might be expected, have made their way downstream into the Apalachicola River (F. G. Banks, personal communication).

Two species of sunfishes are uncommon in the river below the Woodruff Dam, and apparently are derived from stocks in Lake Seminole. The status of the green sunfish, *Lepomis cyanellus* Rafinesque, is not certain; it is probably native to the Chattahoochee River (Dahlberg and Scott, 1971) and dispersed southward to Florida. However, the probability of its introduction cannot be ruled out, and accordingly is mentioned as a possible introduction. The orange-spotted sunfish, *Lepomis humilis* (Girard), appears to be a rather clear-cut case of an introduction because of the distance separating this small population from the contiguous range of the species. The original introduction was undoubtedly in Georgia.

The yellow perch, *Perca flavescens* (Mitchill), is occasionally taken by fishermen. It may be native to the Apalachicola drainage, but is more likely the result of widespread introductions in Georgia, followed by dispersal southward to Florida.

The sauger, *Stizostedion canadense* (Smith), in Florida is known from a single specimen, but additional records have been reported form Lake Seminole. This species was stocked into reservoirs along the Chattachoochee River of Georgia in 1961, but the program has since been considered unsuccessful (Yerger and Beecher, 1975).

INVASION BY MARINE FISHES

As mentioned in the introduction, no attempt will be made here to discuss the diversity and complex aggregations of secondary marine and freshwater species which occur in the lower reaches of the Apalachicola River and its estuary. Excluding the diadromous species which spend part of their life history in salt water, only two species of secondary marine fishes (listed as category VI — Sporadic freshwater fishes in the checklist) regularly penetrate freshwater all the way to the Woodruff Dam and beyond: the striped mullet and Gulf flounder. Other marine fishes may rarely be encountered in the river, but data are inadequate for inclusion.

Floridians are familiar with the presence and behavior of the striped mullet, *Mugil cephalus* Linnaeus, in most of the rivers in the state where they are frequently caught in nets and even on hook and line. Reports of their alleged breeding in connecting arms of the river are not substantiated; spawning normally occurs offshore in the Gulf.

Large adult Gulf flounders *Paralichthys lethostigma* Jordan and Gilbert, have been collected from the tailrace of the Woodruff Dam by electroshocking devices, and by gigging on sandbars during low water levels. These flatfishes are primarily found in coastal areas, but occasionally ascend large rivers.

COMMERCIAL FISHERIES

The importance of the sturgeon fishery has steadily declined. During the first half of this century catches were large, and available markets like New York made the industry a profitable one. In the late 1950's, the combination of greatly reduced catches and competition from Russian imports resulted in a drastic reduction in this fishery for the seafood dealers in Apalachicola. In contrast to single catches of two to three thousand pounds in earlier periods, the fishery produced only a few hundred pounds per week even at the height of the season. By 1976 the scarcity of sturgeon and the termination of direct freight hauling to the major markets have virtually closed down the commercial operations.

An abundance of catfishes (both in numbers of species and individuals) in the Apalachicola River has supported a commercial fishery for many decades. Fishing methods include slat baskets, trotlines, and hook and line. Annual production fluctuates rather drastically, partially due to local demand, but mostly to the variable supply. In the mid-sixties, poor catches forced most commercial fishermen to quit fishing, and the industry was nearly wiped out. Fishermen placed much of the blame on dredging and removal of logs and stumps from the river. Since then the fishery has made a comeback.

In 1976 reports reveal that catfish are plentiful and that fishermen are having a good year. The channel catfish, *Ictalurus punctatus* (Rafinesque), is the most sought after species, but white catfish, *Ictalurus catus* (Linnaeus), and several species of bullheads also enter the commercial catch.

SPORT FISHERY

The diversity of food and game fishes inhabiting the river has attracted a profitable industry to the Apalachicola Valley. Because this topic is treated elsewhere in this volume (Miller et al., 1977), the sport fishery will only be mentioned briefly here.

The mainstay of the sport fishery has been the numerous species of centrarchids (basses and sunfishes) indigenous to these waters, the striped bass, the white bass (introduced), catfishes, and sturgeon. To a much lesser extent the Alabama shad, skipjack, mullet, yellow perch (introduced) and flounder are sought by relatively few fishermen. An account of the fishes of the Apalachicola River written for the sportsmen may be found in Byrd et al. (1959).

ACKNOWLEDGMENTS

Recent information on the status of commercial and sport species was obtained through dis-

cussions with Anthony Taranto of Apalachicola and D. Dodson of Chattahoochee, Florida. I am grateful for their willingness to share with me their years of experience in the fishes of the Apalachicola River.

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A COMPARISON OF THE APALACHICOLA RIVER AVIFAUNA ABOVE AND BELOW JIM WOODRUFF DAM

Henry M. Stevenson
Tall Timbers Research Station

INTRODUCTION

One of the greatest difficulties usually encountered in attempts to determine the effects on animal populations of major habitat changes is the fact that biologists are often not afforded the opportunity to census the affected area thoroughly before the habitat is changed. And even when this is not the case and preliminary studies are made, the effects that later occur are demonstrated "after the fact"—too late to be avoided. Such exceptions as the current attempt to restore portions of the Kissimmee River to their former condition are all too rare.

Thus, the almost certain effects on the avifauna of building one or more additional dams on the Apalachicola River could be demonstrated by a comparison of the bird life that formerly occurred just upstream from Chattahoochee with that now found around Lake Seminole. Although some preliminary work was done there by Fred Bartleson in 1954, his data were never published and his present whereabouts is unknown. The only evidence available from his work is a collection presently housed at the Florida State Museum in Gainesville.

In lieu of Bartleson's date, a before-and-after comparison can best be inferred by comparing the results of bird counts in the unmodified basin of the Apalachicola and Chattahoochee Rivers with those in the vicinity of present-day Lake Seminole. Assuming that the riparian habitat now covered by Lake Seminole was similar to that farther upstream and downstream (as evidenced by numerous stumps still standing in the lake), this comparison is believed valid.

The data available for this study consist of random bird counts I have made along and near these two rivers in Jackson, Liberty, and Calhoun counties from 1950 to the present, as against counts made in the vicinity of Lake Seminole beginning in 1969. It should be obvious that these counts were not made with the intent of providing such a comparison. If they had been, they would not have included any time away from the very edge of the lake and river, and the contrasts would have been even more striking. However, within the limitations discussed below, the two sets of data demonstrate real differences in the avifauna of the two areas.

Field trips along the two rivers were made chiefly in riparian habitat, but smaller portions of time were spent in surrounding fields. In contrast, the edges of Lake Seminole consist mainly of open fields, shrubs and vines, or marsh plants. The small patches of woods are of an upland character and, for the most part, do not provide suitable habitat for birds restricted to river and creek bottoms. An example of such woodlands (possibly the best developed along any part of the lake) is at the south end in Three Rivers State Park.

Fortunately, most of the available data in these two contrasting areas was taken at the height of the breeding season (May to July), as it is the breeding species with which we should be primarily concerned. The total time afield along the rivers (about 50 h) surely represents an adequate sample, but the total of only 10-1/2 h at Lake Seminole is less than might be desired. The use of such a small amount can be justified only because of the great degree of differences in bird abundances in the two sets of data. That is, if the amount of data at Lake Seminole were increased by five or ten times, the ratio of birds per hour afield for most of the species listed could hardly become comparable with that in the river bottoms. The following shows the breakdown of the data into the three months of study:

		Rivers	
Field Time	May	June	July
H:min	19:45	19:15	10:45
		Lake Seminole	
H:min	0:00	5:30	5:00

All field work was done during daylight hours. Most counts were made on foot (with some by canoe) in all areas of study.

The species selected for this comparison were, of course, those known to be either restricted to, or most abundant in, river bottoms. Whereas these species decrease when their habitat is greatly altered, species that prefer more open environments naturally increase. The point, however, is simply that riparian habitats (along with their avian inhabitants) are steadily diminishing in Florida and elsewhere.

Table 1 presents comparative data for 13 species of river-bottom habitat along the two rivers and Lake Seminole.

Evidence exists that at least some of these riparian species formerly existed in fair abundance along that part of the river now obliterated by Lake Seminole. During June 1954 Bartleson and J. C. Dickinson collected 7 Northern Parulas, 3 Red-eyed Vireos, 2 Acadian Flycatchers, and a Red-shouldered Hawk there. A comparison of the percentage representation of these species among

TABLE 1. COMPARATIVE DATA FOR 13 SPECIES OF RIVER-BOTTOM HABITAT ALONG THE APALACHICOLA AND CHATTAHOOCHEE RIVERS AND LAKE SEMINOLE

Species	River		Lake Seminole	
	Number	Per hour	Number	Per hour
Swallow-tailed Kite, *Elanoides forficatus*	6	.12	0	.00
Mississippi Kite, *Ictinia misisippiensis*	21	.42	3	.29
Red-shouldered Hawk, *Buteo lineatus*	14	.28	1	.10
Barred Owl, *Strix varia*	11	.22	0	.00
Pileated Woodpecker, *Dryocopus pileatus*	30	.60	3	.29
Hairy Woodpecker, *Dendrocopos villosus*	7	.14	0	.00
Acadian Flycatcher, *Empidonax virescens*	64	1.28	0	.00
Red-eyed Vireo, *Vireo olivaceus*	122	2.44	3	.29
Prothonotary Warbler, *Protonotaria citrea*	96	1.92	0	.00
Swainson's Warbler, *Limnothylypis swainsonii*	1	.02	0	.00
Northern Parula, *Parula americana*	193	3.86	1	.10
Yellow-throated Warbler, *Dendroica dominica*	26	.52	0	.00
Hooded Warbler, *Wilsonia citrina*	34	.68	1	.10

the total number of birds collected with their representation among the total individuals seen in the course of my field work is shown in Table 2. Although the procedure of comparing per cent of all birds collected with per cent of all birds seen is a questionable one, these data surely tend to corroborate the previously cited data in showing that certain species have decreased markedly following the construction of Jim Woodruff Dam.

TABLE 2. PERCENT OF TOTALS OF CERTAIN SPECIES SEEN ALONG RIVERS AND TO TOTAL NUMBER COLLECTED/SEEN IN VICINITY OF LAKE SEMINOLE

Species	Rivers	Lake Seminole Site	
		1954	*1969ff*
Northern Parula	4.5%	8.5%	0.3%
Red-eyed Vireo	2.8%	3.7%	1.0%
Acadian Flycatcher	1.5%	2.4%	0.0%
Red-shouldered Hawk	0.3%	1.2%	0.3%

RARE AND ENDANGERED SPECIES

Various state and federal agencies have designated a number of avian forms as rare and endangered species (Means, 1977). For Florida, such a list has been drawn up by the Florida Committee on Rare and Endangered Plants and Animals. Two species on their Endangered list have been recorded along the Chipola River since 1950. A pair of Ivory-billed Woodpeckers (*Campephilus principalis*) nested near Scott's Ferry until 1951 when a storm broke the nest tree at the site of the nest hole. A number of competent ornithologists saw these birds, and I saw one of the pair in April 1950. On 30 March 1951, Herbert Stoddard, Sr. and Leon Neel saw a male Bachman's Warbler (*Vermivora bachmanii*) in the same general area. Both of these species are now close to extinction if not truly extinct, but Bachman's Warbler did not nest in Florida. In view of the secretive behavior of the Ivory-bills mentioned above and the vast amount of habitat still remaining in the Apalachicola drainage, it is possible that a few individuals still remain there. If so, any substantial change in the habitat would surely doom them.

This same committee included the Short-tailed Hawk (*Buteo brachyurus*) in its list of Rare species. One example of this species was seen near the Ivory-bill location by Stoddard and Neel on 20 April 1951. Another species in this category, the Louisiana water thrush (*Seiurus motacilla*), is a regular transient along this river system, and may nest there near the Alabama State line.

Under Species of Special Concern, the committee listed one species in the above table — the Hairy Woodpecker. It is well represented in river bottoms, but less numerous or lacking in more open areas.

SUMMARY AND CONCLUSIONS

Evidence presented above indicates that significant changes occur in the representation of various avian species concomitant with the alteration of riparian habitats due to the damming of rivers. Such changes have already taken place along the Apalachicola River in the case of Lake Seminole. There is no reason to doubt the fact that additional dams would cause the same changes.

ACKNOWLEDGMENTS

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ASPECTS OF THE SIGNIFICANCE TO TERRESTRIAL VERTEBRATES OF THE APALACHICOLA RIVER DRAINAGE BASIN, FLORIDA

D. Bruce Means
Tall Timbers Research Station

INTRODUCTION

Within the State of Florida, the Apalachicola River basin is as biologically distinctive as the Everglades, but is much less well known. In this basin are encountered the greatest physical relief in the state: karst topography with caves having vadose and aquatic portions; deeply entrenched ravines containing relict and endemic animals and plants; geologically unique stream environments called steepheads; an extensive large-river floodplain; at least eight coastwise sloping marine terraces; extensive flatwoods developed on a large deltaic plain; and a well-developed estuarine environment containing barrier islands, lagoons, and flats. The river itself is the largest river in Florida and the only one having its headwaters outside the Coastal Plain. Indeed, its headwaters drain the Blue Ridge in the southernmost reaches of the Appalachians. All these environmental factors combine to make the Apalachicola River basin important to more vertebrates than any other drainage in the state.

This paper is mainly concerned with the terrestrial vertebrate species (birds, mammals, amphibians, and reptiles including aquatic species) inhabiting the Apalachicola River drainage (including Chipola River) in Florida, with emphasis on amphibians and reptiles. The fishes are treated elsewhere (Yerger, 1977).

Many terrestrial vertebrates inhabiting the Apalachicola drainage are unique to it (or nearly so), endemic, or otherwise considered by state, regional, or federal authority as endangered, threatened, rare, of special concern, or status undetermined. Several of these species are individually discussed in this paper and ecological data for some is presented for the first time. The geographic distribution of some in the drainage is precisely mapped as presently known.

A number of geologic, physiographic, and biogeographic reasons contribute to the vertebrate species richness of the Apalachicola drainage. In this paper, I discuss some of the geological processes which have led to the physical diversity of the landforms of the area. Two unique environments found mainly in the Apalachicola drainage, or best represented there, are defined and discussed (steepheads, underground troglobite ecosystems). I then divide the area into biotic units, defining some new areas of biotic distinctness.

Finally the biogeographic importance of the Apalachicola drainage and reasons for the high species richness of the area are given. The contributions of the Atlantic Coastal Plain, the Gulf Coastal Plain, the Appalachian highway of dispersal, and the possible peninsular effect are elucidated.

THE VERTEBRATE FAUNA

The Apalachicola basin supports at least 344 species of vertebrates including 85 freshwater fishes (Yerger, 1977), 44 amphibians (Conant, 1975; Kiester, 1971; Means, 1976a and Appendix I) 64 reptiles (Conant, 1975; Kiester, 1971; Means, 1976a and Appendix I), 99 breeding birds (not including marine or estuarine species, Wamer in Appendix I), and 52 mammals (Hall and Kelson, 1959; Appendix I).

In Florida, no other river system has so many species of freshwater fishes (Bailey et al., 1954; Swift et al., 1976). This is expected, however, because the Apalachicola is the largest river in the state. Birds and mammals are about as numerous as elsewhere in the Gulf Coastal Plain (Simpson 1964, Wamer, personal communication, 1976), but it is in the number of species of amphibians and reptiles that the Apalachicola drainage basin is most noteworthy. The highest species density of amphibians and reptiles in North America north of Mexico occurs in the upper Apalachicola River basin (Kiester, 1971; and as modified in Appendix I). This results from high numbers of turtles, frogs, salamanders, and especially snakes. Only the lizards are depauperate as a group, probably because of high humidity and rainfall. Because of the warm climate, high snake, frog, and turtle diversity is to be expected. Salamanders are unexpectedly diverse, however, probably because they are traditionally considered as colder climate, mountain forms; an overlooked diverse assemblage of swamp-dwelling and aquatic species helps increase the total species number.

THREATENED SPECIES, GEOGRAPHICAL RELICTS, AND ENDEMISM

During the last decade, the American public has become more aware of its vanishing natural resources. A greater concern for the protection of wildlife has been generated, resulting in state and federal recognition of threatened species. Because many threatened species are also strict local endemics or geographical relicts, I discuss in this section a number of Apalachicola drainage vertebrates whose survival status is either threatened or which are otherwise unique in some way in the drainage.

AUTHORITY

A number of governmental agencies and other organizations have compiled lists of vertebrates whose survival status was considered in some category ranging from "rare" or "special concern" to "endangered" or "recently extinct." For vertebrates of the Apalachicola drainage, 3 lists are important. First is the original "Redbook" list of *Threatened Wildlife of the United States*, as amended 27 July 1973 to include the category "endangered." This federal list was promulgated by the Endangered Species Conservation Act of 1969 and published in the Federal Register (Vol. 38, No. 106). The second list was drawn up by Florida biologists (Florida Committee on Rare and Endangered Plants and Animals) convened by Florida Audubon Society. The survival status of Florida vertebrates was carefully considered by the Committee and a special report for each vertebrate listed was written by an appropriate specialist. Regulations concerning the survival status of these animals have been adopted by the Florida Game and Freshwater Fish Commission. Legal considerations regarding Apalachicola vertebrates on this list are contained in the *Wildlife Code of Florida*, as amended July 1976.

A third list, entitled *Endangered and Threatened Vertebrates of the Southeastern United States*, was compiled by biologists from throughout the southeastern United States, meeting together in Tallahassee, Florida under the auspices of the Southeastern Wildlife Society, the Federal Office of Endangered Species, U. S. Fish and Wildlife Service, and hosted by Tall Timbers Research Station. A report was prepared in the format of the Redbook for each vertebrate considered. The resulting publication (Hillestad et al., 1977) will be strongly considered in the updating of the federal Redbook. Ultimately, vertebrates whose survival is potentially or imminently threatened in some way will be protected by law at both the state and federal levels. Those terrestrial vertebrates inhabiting the Apalachicola drainage which appear on any of the 3 lists are presented in Appendix II with their status and listing authority.

Amphiuma pholeter Neill — One-toed Amphiuma

The One-toed Amphiuma (Figure 1) was first described in 1964 from Florida on the basis of five preserved specimens (Neill, 1964). Prior to that time, the salamander family Amphiumidae had been considered by many people to be monotypic, containing only one species. The type description of *Amphiuma pholeter* was so vague that the validity of this species was not at first accepted by most zoologists. Four brief notes (Stevenson, 1967; Means, 1972b, 1976a, 1977a) are the only other published information available on this unique species. These papers and unpublished data gathered by the author during seven years of field work on *A. pholeter* form the basis of the following comments.

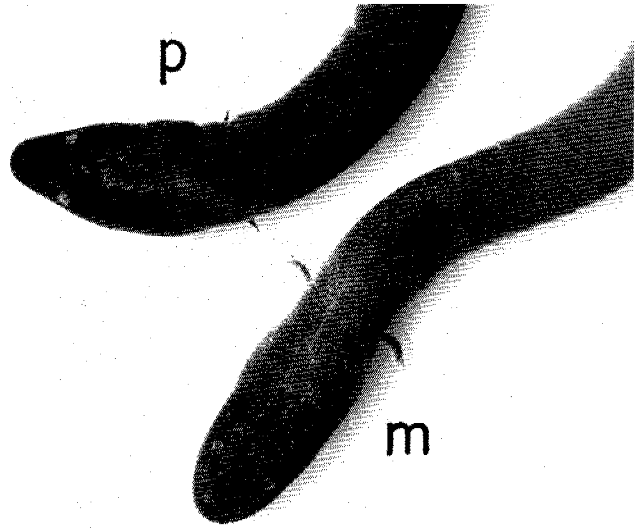

Figure 1. Apalachicola River drainage salamanders of the family Amphiumidae. P = the regional endemic, *Amphiuma pholeter*, characterized by one toe, sharp snout (adult); M = *A. means* (same size as P, but small juvenile).

Figure 2 illustrates the known geographic distribution of *A. pholeter*. The restricted range of this species and the apparent paucity of individuals in most habitats are probably due to the special nature of the environment in which *A. pholeter* lives. This species is found primarily in mucks of a particular quality. These are liquid, amorphous mucks derived from hardwood litter, often in association with cypress and cypress litter. Table 1 lists physical properties of 13 habitats from which *A. pholeter* has been collected.

The most important habitat variables associated with the occurrence of *A. pholeter* are 1) low to moderate stream gradient, 2) swampy and periodically inundated floodplains, 3) mixed hardwoods and cypress, 4) seepage, and 5) vulnerability to drought. All these factors except drought tend to promote well-developed muck habitats. By far the most extensive habitat from which *A. pholeter* has been taken is Sweetwater Creek, a tributary entering the Apalachicola River floodplain north of

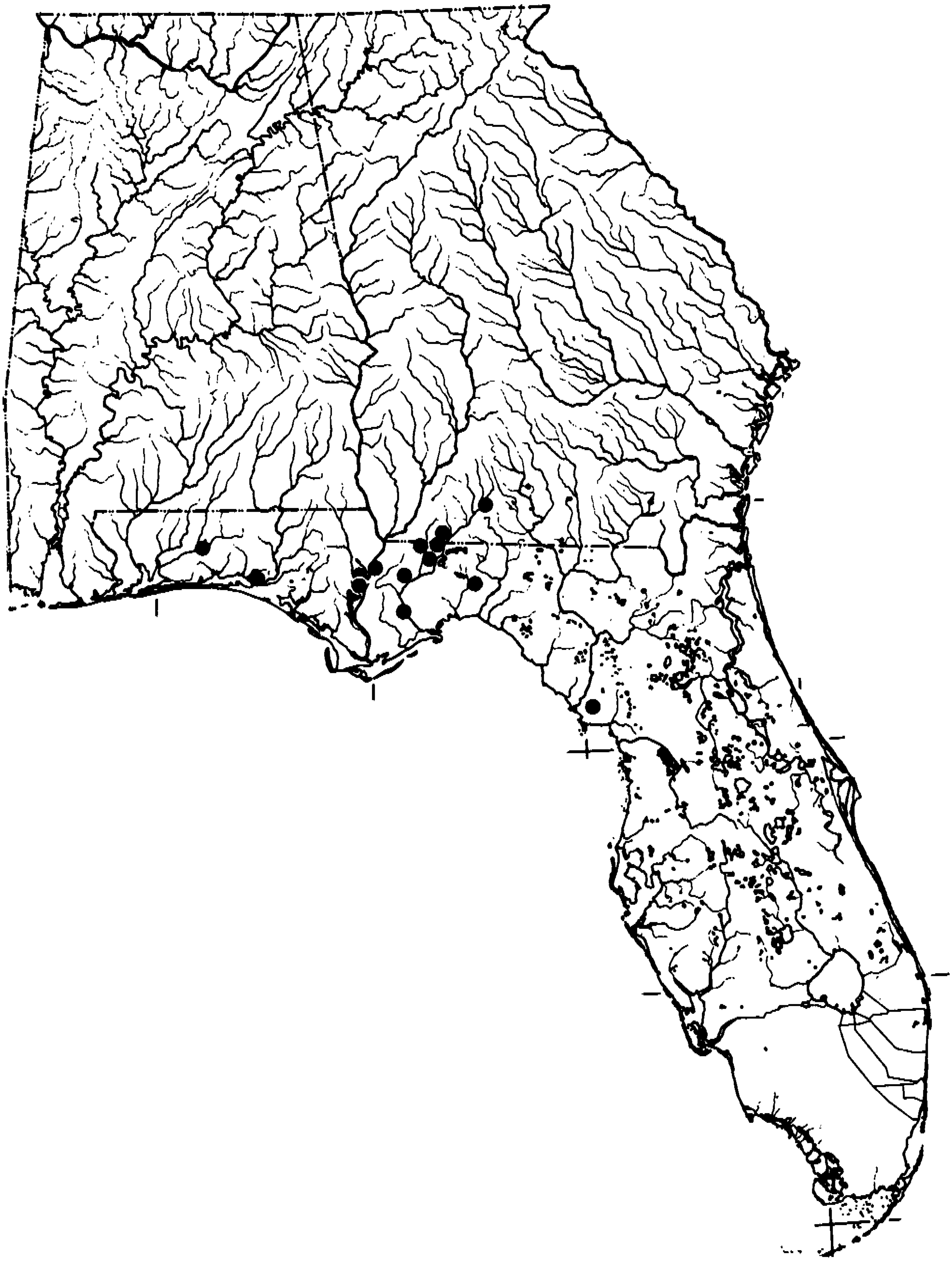

Figure 2. Geographic distribution of *Amiphiuma pholeter*.

TABLE 1. QUALITIES OF THE HABITAT OF *AMPHIUMA PHOLETER*. STREAM ORDER DESIGNATION FOLLOW STRAHLER 1964 AND MEANS 1975. SURROUNDING PHYSIOGRAPHY: A=DISSECTED MIOCENE UPLANDS; B=HIGH FLATWOODS; C=DISSECTED PLIO-PLEISTOCENE UPLANDS. VEGETATION: 1=*TAXODUIM* SP., 2=*NYSSA* SP., 3=*MAGNOLIA VIRGINIANA*, 4=*MAGNOLIA GRANDIFLORA*, 5=*LIRIODENDRON TULIPIFERA*, 6=*FAGUS GRANDIFOLIA*; 7=*QUERCUS NIGRA*, 8=*QUERCUS PRINUS*, 9=*QUERCUS* SP., 10=*CARPINUS CAROLINIANA*, 11=*OSTRYA VIRGINIANA*, 12=*ILEX OPACA*, 13=*LIQUIDAMBAR STYRACIFLUA*, 14=*ACER RUBRUM*, 15=*ILEX* SP., 16=*CARYA GLABRA*, 17=*CARYA* SP., 18=*ILLICIUM FLORIDANUM*, 19=*SPHAGNUM* SP., 20=*PINUS* SP. 21=*PINUS GLABRA*, 22=*CLIFTONIA* SP., OR *CYRILLA* SP., 23=*BETULA NIGRA*, 24=*SALIX* SP. HUMAN IMPACT: 1=SEDIMENTED, 2=LOGGED, 3=IMPOUNDED.

Locality	Stream Order	Surrounding Physiography	Streambed Habitat	Drought Known	Seepage Present	Vegetation	Human Impact
1 Sweetwater	5	A	braided floodplain	No	Yes	1, 2, 3, 4, 5, 10, 13, 18, 19	1, 2, 3
2. Cow Swamp	2-3	A	ravine		Yes	4, 6, 7, 9, 12, 14, 20	1, 2
3. Bullhead	2-3	B	flatwoods swamp			1, 3, 13	2
4. Scott Ferry	2-3	B	flatwoods swamp			3, 5, 14, 21	2
5. Shoal	7	C	large river floodplain swamp	Yes	Yes	1, 2, 3	2
6. Mill Branch	2-3	C	boggy ravine		Yes	3, 5, 15, 18, 19	1, 2
7. Smith Creek	7	B	large river floodplain swamp	Yes		1, 2, 3, 4, 18, 19, 23, 24	3
8. Ocklawaha	4	A	large creek floodplain		Yes	1, 2, 3, 9, 12, 13, 18, 19	
9. Double Br	3	A	creek floodplain	Yes	Yes	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 21	
10. Swamp Creek	1-2	A	mucky hillside		Yes	3, 4, 6, 9, 12, 19	1, 2
11. Pronto Springs	2-3	A	swampy creek	Yes	Yes	2, 3, 4, 5, 9, 15, 20	
12. Pine Hill	2-3	A	swampy creek	Yes	Yes	2, 3, 6, 7, 9, 12, 13, 14, 16, 19	1, 2
13. Coolidge	2	A	swampy creek			2, 3, 4, 7, 19, 20	2

Bristol. *Amphiuma pholeter* occurs here only in the 5th order (Strahler, 1964 classification) portion of this stream, to no more than about 20 ft above mean high water of the Apalachicola River. This is the most viable population known of the species. The life history and ecology of this species are the subject of a separate study (Means, unpublished).

Lampropeltis getulus — Apalachicola Lowlands Populations

In 1949, Neill and Allen described a new race of the Eastern Kingsnake as *Lampropeltis getulus goini*. The type locality of this new race, the Blotched Kingsnake, was Wewahitchka, Gulf County, Florida on the west side of the Apalachicola River. Neill defined the range of this subspecies to be "the Apalachicola and Chipola River Valleys," specifically referring to the deeply entrenched valleys of both rivers in the western highlands, where ravines are noted for containing a number of endemic plants and animals such as the Florida Yew (*Taxus floridana*) and Stinking Cedar (*Torreya taxifolia*). Research in progress (Means, 1976g) indicates that the types of *L. g. goini* are probably intergrades between an unrecognized subspecies (Figure 3) occurring mostly east of Apalachicola River and the nominate race. Furthermore, the distribution of the new race is not the "Apalachicola and Chipola River Valleys," but the Apalachicola Lowlands, described below as a distinctive biotic unit having a suite of endemics indigenous to it and different from the endemics of the Apalachicola Ravines.

The Round-tailed Muskrat

The Muskrat (*Ondatra zibethicus*) has not been known from Florida in recent times but it once was widespread judging from abundant Pleistocene to recent fossil material (Webb, 1974). However, a relative, the Roundtailed Muskrat (*Neofiber alleni*), is almost a strictly endemic species of the Florida peninsula (Hall and Kelson, 1959). Only a small portion of the distribution of the species occurs in the Okefenokee Swamp of Georgia. This is a bog- and pond-inhabiting herbivore that constructs nests and feeding platforms in shallow water, usually with two escape holes leading downward. Open runways or tunnels under grasses are maintained around the perimeter of aquatic habitats.

The westernmost known populations of the Round-tailed Muskrat are from the lower Apalachicola River (Schwartz, 1953). These populations and others extending eastward to about the Suwannee River have been recognized as racially distinct, *N. a. apalachicolae*. Since the species seems to be on the decline over the past decade, and probably because of habitat deterioration in general, *Neofiber alleni* is considered a species of special concern by the Florida Committee on Rare and Endangered Plants and Animals.

Aquatic Turtles

Four turtles living in the mainstream of the Apalachicola and Chipola Rivers are of special importance because they are considered as rare (*Graptemys barbouri*), threatened (*Chrysemys concinna suwanniensis*), status undetermined (*Macroclemys temmincki*), or geographically disjunct (*Chrysemys nelsoni*). *Graptemys barbouri* is the only one of the four which is also an endemic species strictly found only in the Apalachicola-Flint-Chattahoochee drainage in the Coastal Plain. This species has suffered from human impact by the impoundment of part of its natural range (Jim Woodruff Dam) and by local harvesting of the turtle for food. This species is considered a delicacy in the area. *Graptemys barbouri* is distinguished as being the only endemic vertebrate other than some fishes (Yerger, 1977) which is exclusively found in the mainstream waters of the Apalachicola drainage.

The Alligator Snapping Turtle (*Macroclemys temmincki*) has been threatened in the past decade by commercial exploitation of its meat. Also inhabting the mainstream of the river as well as oxbows, sloughs, and tributaries, this is the world's largest freshwater turtle. The large traps used to capture this species commercially also entrap the other turtles (Dobie, 1977).

The Suwannee Cooter (*Chrysemys concinna suwanniesis*) is a large river-inhabiting turtle occurring in Florida Gulf Coast drainages from the Apalachicola River to Tampa Bay. Contrasting with the carnivorous Alligator Snapping Turtle, the Suwannee Cooter is primarily an herbivore preferring dense growths of *Naias* and *Sagittaria*. This species is considered threatened because it has dramatically declined in numbers throughout its range. This has been attributed to at least two factors: (1) a general degradation of rivers it inhabits which may have an impact on abundance of food plants, and (2) harvest of turtles for their highly prized meat (McDiarmid, 1977).

The Florida Red-bellied Turtle (*Chrysemys nelsoni*) occurs in the Apalachicola and Chipola Rivers, from at least the Dead Lake to above the coastal estuary (personal observation). So far as is known, this species is disjunct across the Ochlockonee, St. Marks-Wakulla, Aucilla-Wacissa, Econfina and Fenholloway Rivers, occurring again in the Suwannee River and throughout peninsular Florida. The Apalachicola population is not well-studied but such a disjunction in riverine turtles might have

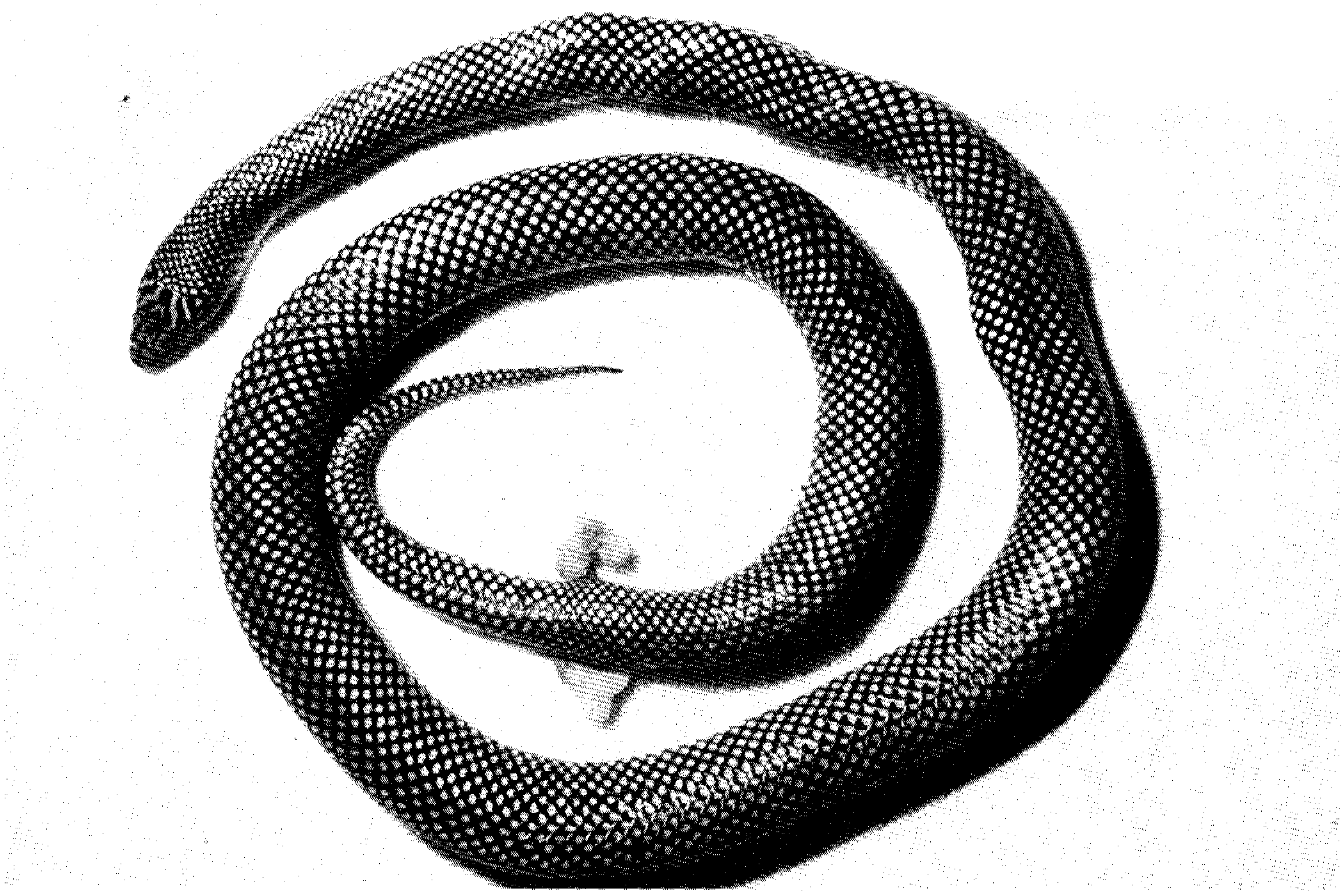

Figure 3. Undescribed pattern variant of the Eastern Kingsnake (*Lampropeltis getulus*) geographically restricted primarily to the eastern Apalachicola Lowlands (Means, unpubl.)

led to genetic divergence at the racial level. If such were the case, the Apalachicola drainage would contain another endemic form. The occurrence of red-bellied turtles in the Apalachicola drainage is complicated by taxonomic confusion (Carr and Crenshaw, 1957). In addition to *Chrysemys nelsoni* another red-bellied phenotype (*Chrysemys alabamensis*) is known from the coastal estuary of the Apalachicola drainage (Carr and Crenshaw, 1957). Whether both red-bellied types are distinct species or ecotypes of a single species is unknown. This problem requires further investigation.

GEOGRAPHICAL RELICTS AND RARE SPECIES

The Apalachicola drainage contains numerous isolated populations of plants and animals found elsewhere in the eastern United States (Harper, 1914; Neill, 1957; James, 1961). Because many of these geographical relicts are known only from one or a few populations in Florida they are considered as rare on threatened species lists (see Appendix II). Five such reptiles and amphibians in the Apalachicola drainage merit discussion.

The Four-toed Salamander (*Hemidactylium scutatum*) ranges widely throughout the northeastern United States. South of the southern Appalachians, its range is broken into isolated fragments. The first discovery of *Hemidactylium scutatum* in the eastern Gulf Coastal Plain was a population reported by Grobman (1954) from near the confluence of the Apalachicola-Chattahoochee-Flint Rivers. This locality was subsequently obliterated by the Lake Seminole impoundment. Other populations of this species are likely to occur in swampy floodplains of the Apalachicola and its tributaries in Florida (Stevenson, 1958; Fugler and Folkerts, 1967; Means, 1976c).

The Flatwoods Salamander, *Ambystoma cingulatum*, has a small geographic distribution in the Coastal Plain from panhandle Florida to South Carolina, not including peninsular Florida south of Ocala. It breeds in cypress ponds and depressions in flatwoods and appears not to be abundant anywhere (Means, 1977b). Adults are always difficult to find and known larval ponds seem to be skipped in some years. Very little is known about the life history of this species (Means 1972a; Anderson and Williamson, 1976) but indications are that it may be highly sensitive to the alteration of its habitat. In the Apalachicola drainage, *Ambystoma cingulatum* occurs in the Marianna Lowlands, on the Grand Ridge, and spottily in the Apalachicola Lowlands.

In addition to northern salamanders, the geographic range of some other northern vertebrates juts southward into western Florida (Stevenson, 1962; Foquette, 1976; Means and Longden, 1970, 1976). The steep slopes of the Apalachicola Ravines provide suitable habitat for the Southern Copperhead (*Agkistrodon contortrix*) which is uniformly distributed throughout the Piedmont and Appalachians to the north. This species maintains a population along the bluffs east of Apalachicola River from about 5 mi south of Bristol to north of Chattahoochee. Recently, specimens have turned up from near Kinard (D. Sebolt, personal communication) and south of Sneads (P. Moler, personal communication) on the west side of the Apalachicola Ravines biotic areas (see below). These three natural areas are those having the most relief in the drainage, and were once part of a continuous land mass before being bisected by the Apalachicola and Chipola river valleys (Puri and Vernon, 1964).

The Southern Coal Skink (*Eumeces anthracinus pluvialis*) ranges westward from Mobile Bay, Alabama to about the Ocholockonee River in Florida. Only a few localities are known for this species in this state and for this reason it appears on the list of the Florida Committee on Rare and Endangered Plants and Animals list as status undetermined (Means, 1976f). The Southern Coal Skink is peculiar among United States lizards for its sometimes aquatic habits. It lives along the margins of swampy streams and ponds in Florida, often diving into water and remaining submerged to escape detection or predation. In the Apalachicola drainage individuals have been collected from tree trunks and logs along the margin of the Dead Lake (H. W. Campbell, C. J. Longden, personal communication).

Another rare vertebrate in panhandle Florida that occurs in the Apalachicola drainage basin is in the Mole Snake, *Lampropeltis calligaster rhombomaculata*. This is a largely fossorial species rarely found at the surface of the ground, but possibly being more abundant locally than the frequency of encounter of individuals suggests. This species apparently ends its eastward Florida distribution in the Apalachicola Lowlands (Means 1976e). It seems to prefer drier habitats in the Flatwoods, often in ecotones or even edificarian sites in early old-field succession.

UNIQUE SPECIES ASSOCIATIONS

THE CHATTAHOOCHEE CAVE FAUNA

Beginning with Lönnberg (1894a, 1894b), studies of the animal life of caves and sinkholes in Florida and adjacent parts of the Coastal Plain of Georgia and Alabama have revealed that a large number of cave-adapted animals is present. Here I present evidence that the cave-adapted organisms found in the Apalachicola River drainage basin (containing the whole of the Marianna Lowlands, and the southern portion of the Dougherty Plain physiographic regions) are endemics there, occurring nowhere else. Not only are the animals unique to the upper Apalachicola-Flint-Chattahoochee drainage, but together they comprise an entire ecosystem that is itself unique because the animals define it.

The eastern Gulf Coastal Plain of the United States generally consists of alternating carbonate terranes and clastic deposits, the latter becoming thicker toward the Mississippi River. Limestone has been raised above depositional levels in the eastern Gulf area by upward movements of the crust during the Tertiary (Figure 4). It is exposed in southwestern Georgia, extending into the eastern panhandle of Florida and a small portion of southeastern Alabama (Veatch and Stephenson, 1911; Cooke, 1945; Puri and Vernon, 1964; Stringfield, 1966), forming a large karst plain named the "Marianna Lowlands" in Florida. After the overlying clastics had been removed by erosion, limestone was exposed to extensive solution, eventually allowing invasion of underground cavities by life forms.

In contrast to the larger faunas in vadose (air-filled passages) cave ecosystems of the Appalachian region to the north, not many species of troglobites (cave-adapted animals) inhabit air passages in the eastern Gulf Coastal Plain, but the number of phreatobite species (aquatic troglobites) is large. The reason seems to be simply that most of the solution cavities are presently filled with water. Much of what is known about phreatobites from karst areas in the eastern Gulf region came from specimens brought up from wells which penetrate cavities in the Floridan aquifer (Carr, 1939; Hobbs, 1941; Hobbs, 1971; Hobbs and Means, 1972). In many cases the nearest entrance to the aquifer is through sinkholes or springs several miles away. In the past, the aquifer was largely inaccessible to biological investigation because of inadequate diving technology. With the development of SCUBA, studies of life forms in sinkholes and springs have increased in peninsular Florida, but the biota of the extensive karst systems of the Gulf Coastal Lowlands and the Marianna Lowlands-

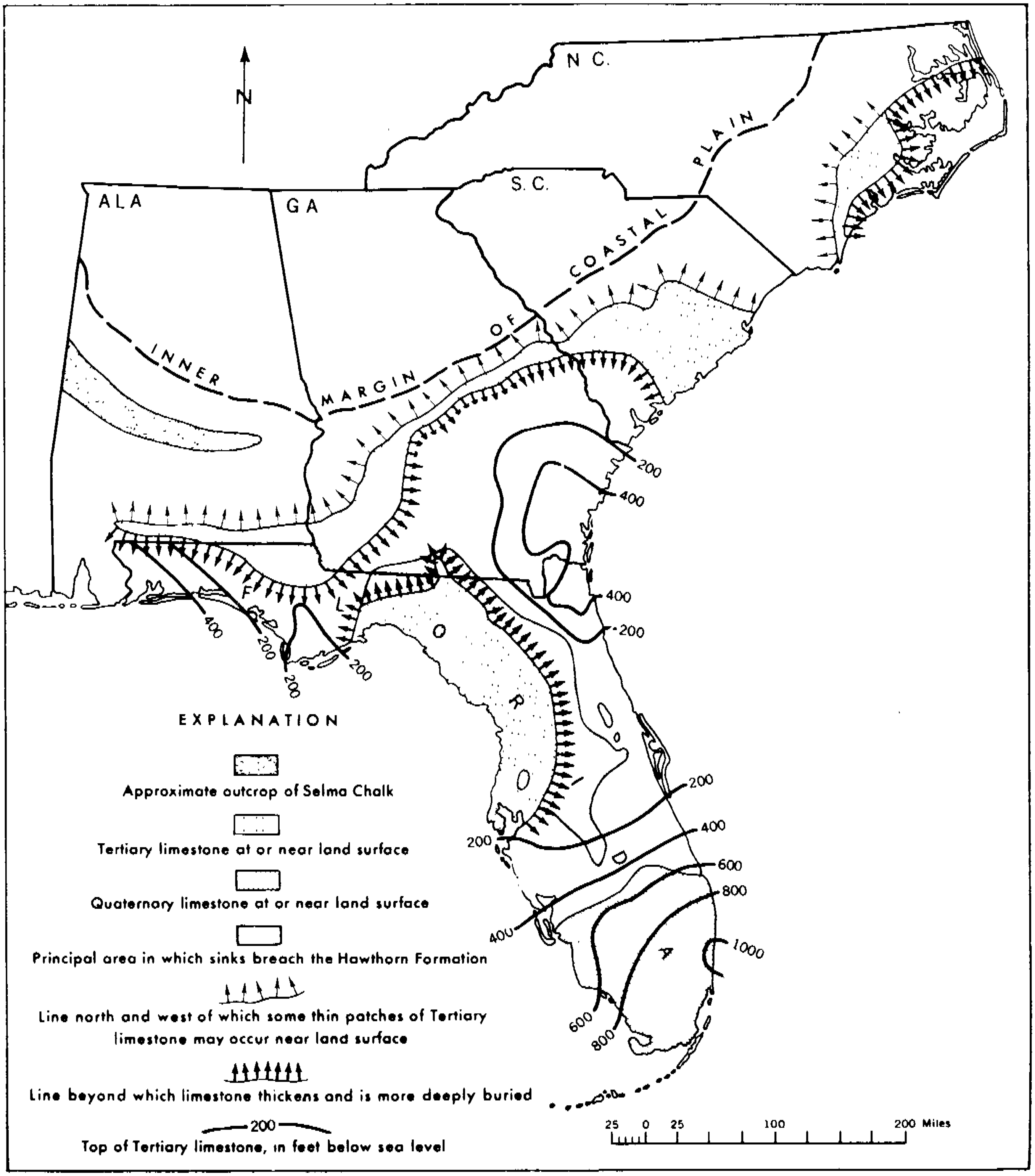

Figure 4. Limestone at or near the surface in Florida and adjacent states (reproduced from Stringfield and LeGrand, 1966).

Dougherty Plain physiographic regions (Puri and Vernon, 1964) has not been well studied. For instance, nineteen years after the description of *Haideotriton wallacei* Carr from a deep well in Albany, Dougherty Co., Georgia, specimens assignable to this genus were discovered in caves in Jackson County, Florida. The endemic crayfish, *Cambarus cryptodytes* (Hobbs), was also described from the specimens obtained from a well; they, too, are now known to be abundant in caves in Jackson County, Florida.

By 1961 it was apparent that those troglobitic species occurring in the Marianna Lowlands-Dougherty Plain karst area were not found in karst to the southeast. Warren (1961) mentioned the possibility that a distinct northern and a southern region existed and were separated by " . . . a break in the surface stratigraphy from limestones to clastics between the Ochlockonee and Apalachicola Rivers. . . . Confusion surrounding interpretation of the geology of the areas concerned and the paucity of information on troglobites of southern Georgia and Alabama preclude any further comments on this fascinating zoogeographic problem."

In this paper three groups of troglobites are recognized by the following names: The Chattahoochee fauna, named for the anticline which brought limestone terranes to the surface in the Marianna Lowlands-Dougherty Plain physiographic region (same as Warren's northern region); the Woodville fauna, named for the Woodville Karst Plain of the Gulf Coastal Lowlands physiographic region (Hendry and Sproul, 1966); and the Ocala fauna, named for the Ocala Uplift in peninsular Florida (these last two areas plus sinkholes breaching the Hawthorne along the Peninsular Arch, correspond to Warren's southern region).

At least eight caves in the Marianna Lowlands-Dougherty Plains region share the Chattahoochee fauna (Figure 5). Only juveniles of the genus *Haideotriton* have been reported from caves in Jackson County, Florida and from Climax Cave, Decatur County, Georgia (Pylka and Warren, 1958; Dundee, 1962; Valentine, 1964) and no comparison has previously been attempted with the type specimen, a gravid female. Vandel (1967) suggested that these may be a new species of *Haideotriton*. On 14 November 1970, I collected a gravid specimen on a dive in Gerard's Cave, at a depth of about 15 feet. Comparison with published descriptions (Carr, 1939; Valentine, 1964) reveal no taxonomically significant morphological differences between the holotype and the Florida specimen. Therefore, all troglobitic salamanders presently known from this karst region are here considered to be *H. wallacei* Carr.

The results of dives made into sinkholes and springs in the Woodville Karst Plain of the Gulf Coastal Lowlands were reported elsewhere (Hobbs and Means, 1972). The juveniles previously identified as *Procambarus pallidus* from this region are now assigned to the new species *P. orcinus* and *P. horsti* on the basis of substantial series of adult specimens (Figure 5). The nearest known population of *P. pallidus* is a spring in western Suwannee County (Hobbs, 1971).

GEOLOGIC BARRIERS

The distribution of the larger phreatobite species in Panhandle Florida indicates that two faunas are present, distinct from each other, and each endemic to a geographically separate subterranean ecosystem. Members of the Chattahoochee fauna were found together at almost all stations in the Marianna Lowlands-Dougherty Plain karst region. This fauna ranges throughout this karst system in Florida and Georgia wherever solution of limestone has provided underground cavities large enough for the species to disperse. The southern portion of this karst system including almost all the air caves lies entirely within the Apalachicola drainage basin. These connections have probably always been open to permit gene flow throughout the system since no taxonomically significant variation is known in any species. The Woodville Karst Plain contains two species of troglobitic crayfish in its ground waters. Neither species is known from other karst areas to the north or in peninsular Florida.

Besides distributional evidence for the distinctness of the Chattahoochee and Woodville faunas, it is significant that among the crayfishes, the epigean genera which gave rise to the troglobites are different. The only similarity between these two faunas is the reported presence of the troglobitic isopod, *Asellus hobbsi*, in both karst areas. However, its occurrence in crayfish burrows in Calhoun County south of Blountstown (Maloney, 1939) and the tendency for other subterranean isopods to occur in epigean waters (Minckly, 1961) indicates surface dispersal and would not require continuous limestone connection between the two regions in the study area.

The nature of the barrier isolating the Chattahoochee fauna from other troglobites now is better known because of geological and hydrological studies carried out in the past decade (Figure 6). A faulted syncline complementary to the Chattahoochee Anticline exists between the Apalachicola and Ochlockonee Rivers, and contains clastic sediments of low permeability (Veatch and Stephenson, 1911; Applin and Applin, 1944; Herrick and Vorhis, 1963; Sever, 1964; Kaufman et al. 1969). Also, limestone underlying the clastic sediments in the trough do not show evidence of significant solution or secondary permeability

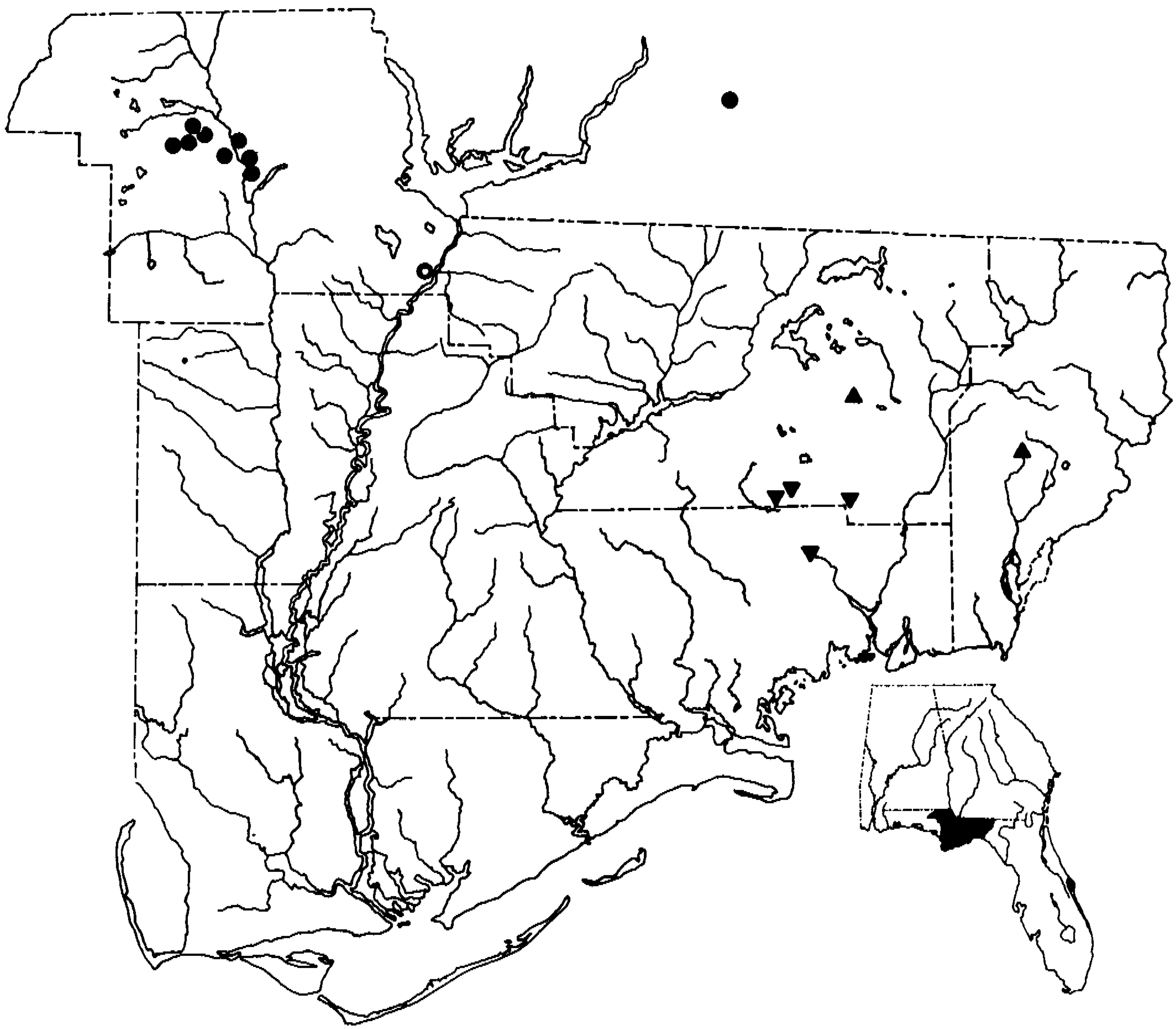

Figure 5. Distribution of caves and phreatobites in panhandle Florida. Filled circles are localities for the Chattahoochee Fauna (single open circle = unexplored cave likely to contain *Haideotriton wallacei* or *Cambarus cryptodytes*; Georgia circle = Climax Cave); triangles with apex down = Woodville Fauna; triangles with apex up - occurrence of *Procambarus horsti*.

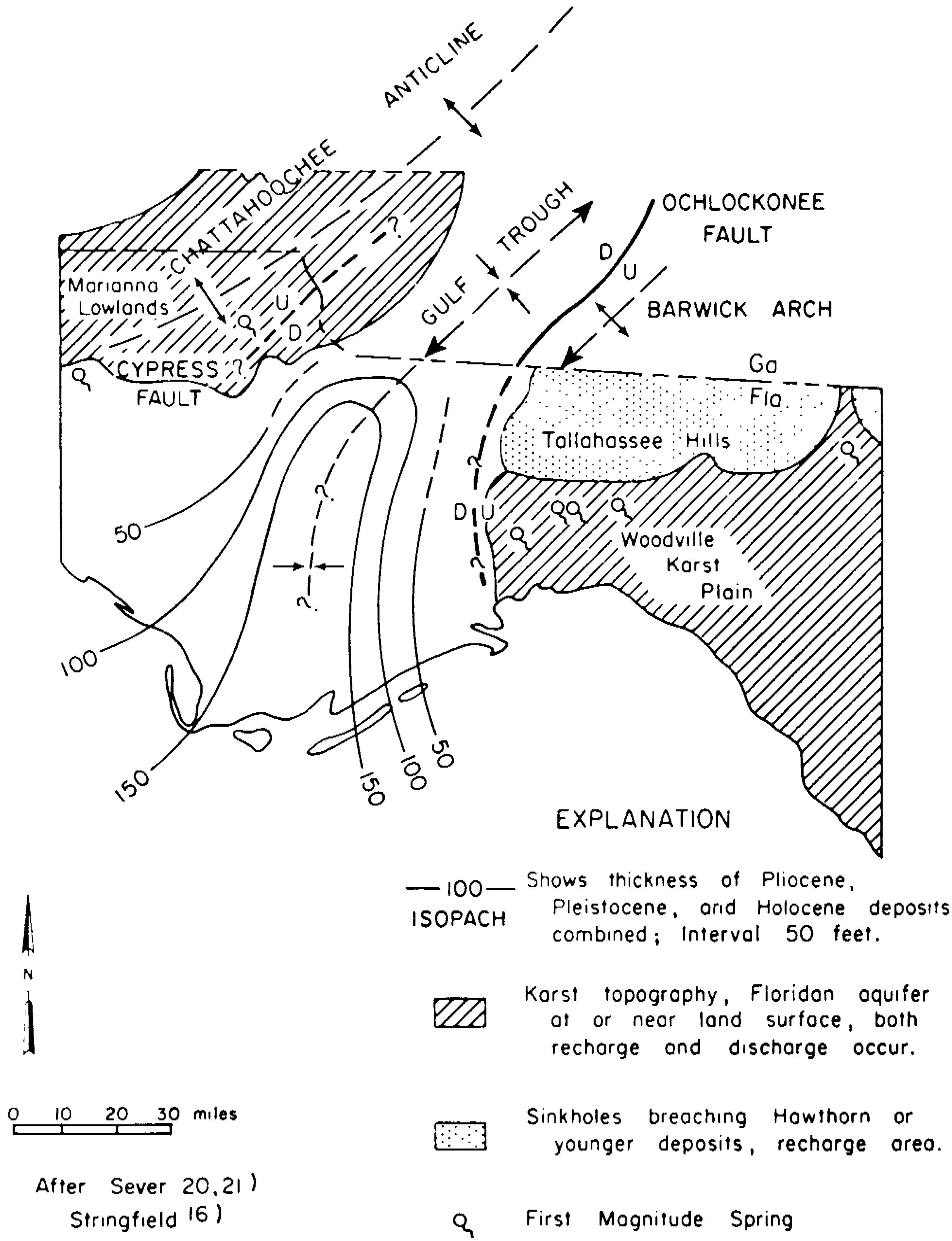

Figure 6. Regional structure of eastern panhandle Florida showing the Gulf Trough putative barrier to dispersal between the Chattahoochee and Woodville phreatobite faunas. (Reprinted from Kaufman, et al. 1969 with permission from North-Holland Publishing Company.)

(Hendry and Sproul, 1966). This geomorphic feature has been called the Gulf Trough (Hendry and Sproul, 1966). The eastern edge of the Gulf Trough contains another structure, the Ochlockonee Fault (Kaufman et al., 1969) which may also serve as an impediment to hydrologic flow to the southeast (Figure 6). Recent studies of disequilibrium patterns of naturally occurring uranium isotopes demonstrate that ". . . the Gulf Trough and Ochlockonee Fault act as a hydrologic barrier that prevents any significant southeastward flow of groundwater" (Kaufman et al., 1969).

Haideotriton wallacei is not closely related to any known troglobitic salamander. Several species of troglobitic salamanders occur in the Balcones Escarpment (Edwards Plateau) region of Texas whose epigean ancestry probably belongs to the genus *Eurycea*. *Haideotriton* probably evolved from this genus independently and is similar, morphologically, to *Typhlomolge rathbuni* by evolutionary convergence.

Two epigean species (*E. bislineata*, *E. longicauda*) are known troglophiles in caves of the Marianna Lowlands and in Climax Cave, Georgia. Larvae of both species have been found in and near the mouths of caves in pools and streams issuing from the underground water system (personal observation). Both of these species of *Eurycea* are typically northern animals. It is not known whether either gave rise to *Haideotriton wallacei*, but they or their ancestors are the most likely candidates. The species *H. wallacei* and *T. rathbuni* of Texas share the distinction of being the most highly cave-adapted salamanders in North America.

Thus the extensive system of subterranean waters and solution cavities drained by the upper Apalachicola basin contains an isolated and unique ecosystem of cave-adapted aquatic organisms. Major threats to this ecosystem are impacts from pollution (municipal waste effluents, siltation, and turbidity due to surface erosion in open recharge areas) and alteration of the water table (impounding local streams including the Apalachicola and Chipola Rivers or heavy drawsdown caused by wells). Serious consideration should be given to influences on the local water table. A number of springs and subterranean water-filled passages which probably contain the Chattahoochee fauna are located along the west bank of the Apalachicola River for several miles south of Sneads.

THE GOPHER TORTOISE ASSOCIATION

Because they occur in interactive associations (communities), all plants and animals are dependent upon or influenced by other species in one way or another for food or shelter. This is markedly demonstrated in the association of animals with the Gopher Tortoise, *Gopherus polyphemus*. The Gopher Tortoise excavates one or more extensive burrows (up to 30 ft long, 10 ft deep, and 18 in wide at the mouth — Hallinan, 1923; Hansen, 1963) in its lifetime (up to at least 25 yr — Ernst and Barbour, 1972) which provides a shelter used from occasionally to almost obligately by other vertebrates. Moreover, a number of arthropods are found either exclusively on the Gopher Tortoise (Wilson and Baker, 1972) or obligately in tortoise dung along the burrow floor (Young and Goff, 1939). Partly because the Gopher Tortoise is itself threatened, other vertebrates that depend on tortoise burrows for an overwintering shelter, or as an important microhabitat in their own ecology are themselves threatened.

The Gopher Tortoise is distributed in the Coastal Plain from southern South Carolina to eastern Louisiana including most of peninsular Florida. Everywhere throughout its range it has experienced reduction of its natural habitat, which is well-drained sandy soils originally supporting Longleaf Pine-Turkey Oak-Wiregrass, or sandhill scrub vegetation. The Gopher Tortoise also inhabits ecotonal or edificarian habitats having well-drained, friable, or sandy soils, and an open canopy. Normally those habitats occupied by the Gopher Tortoise are subject to frequent periodic fires which are essential to the long-term persistence of the habitats. The greatest threat to the survival of the Gopher Tortoise and its associates is the loss of habitat. With an increasing human population in Florida and elsewhere, the Gopher Tortoise has suffered loss of habitat to agriculture, silviculture (especially to site preparation and closely spaced replanted pines), and urban and suburban development including construction of roads, airports, towns and cities. In addition, the Gopher Tortoise is locally considered a delicacy, and commonly taken for food.

A third threat to the Gopher Tortoise association probably has a much more serious impact on the associated vertebrates and invertebrates than on the tortoise itself. This is the increasing use of gasoline and its fumes, both of which are forced into Gopher burrows for the purpose of evicting rattlesnakes that use the burrows as an overwintering refuge (Speake and Mount, 1973). The fumes have been shown to seriously debilitate or actually kill not only rattlesnakes but the threatened Indigo Snake (*Drymarchon corais*) and the Florida Pine Snake (*Pituophis melanoleucas mugitus*), considered Status Undetermined (Appendix II). The Florida Gopher Frog (*Rana areolata aesopus*) is another vertebrate that is commonly found in Gopher Tortoise burrows. Individuals also occur in other holes in the same habitat type including the burrows of the Oldfield mouse (*Peromyscus polionotus*) and Crayfish burrows. That the Gopher

Frog is declining in numbers may be at least partially attributed to the same impacts on Gopher Tortoise habitats and to diminution of the number of tortoise burrows.

Hence in the Apalachicola River drainage basin a suite of at least four vertebrates having some threatened status is locally distributed in suitable habitats. Extirpation of the threatened Gopher Tortoise almost assures the loss of or an impact on at least three other species having threatened status and definitely insures loss of the obligate invertebrates.

THE PHYSICAL ENVIRONMENT

The biota of the Apalachicola River drainage basin owes its high species richness at least partly to the diversity of the physical environment. The physiography of the basin is as diverse as any equivalent area in Florida. The northern portion of the basin lies entirely within a vast karst plain (the Marianna Lowlands-Dougherty Plain) with extensive subterranean solution cavities. The surface of the karst plain is relatively flat to gently rolling and surface waters are characteristically clear and hard in quality. Both the Apalachicola River and its major tributary, the Chipola, breach a high east-to-west band of highlands comprised of tightly-packed clays, sands, and gravels. The greatest relief in this system and in the state of Florida occurs along the bluffs of the river valleys here.

The southern portion of the Apalachicola drainage basin passes through a coastwise, gently inclined plain of Plio-Pleistocene sandy sediments. Away from the river floodplain both east and west are extensively developed pine flatwoods with blackwater streams and permanent swamps.

The whole drainage system contains streams of varying types ranging from first-order (Strahler classification, 1964) ravine streams dissecting the uplands, to low-gradient meandering streams containing high organic acid content in the flatwoods, to calcareous, clear streams of spring origin in the Marianna Lowlands of the upper Chipola River. Many sinkhole ponds and small lakes occur throughout the Marianna Lowlands karst plain and one large natural body of water, Ocheesee Pond, is found in an abandoned bed of the Apalachicola River. Two other large natural lakes (Lake Wimico, Dead Lake) occur in the drainage.

STEEPHEADS

In the Apalachicola drainage and a few other drainages to the west, Florida possesses a highly distinctive habitat type called "steephead" which has long been unrecognized by biologists. Originally described by geologists (Sellards and Gunter, 1918), steepheads occur throughout the panhandle of Florida in a narrow east-to-west alignment across drainage systems (Means, 1975). Steepheads are amphitheater-shaped heads of valleys with exceedingly steep walls, often approaching 100 ft in depth. These form in deep porous sands by the lateral sapping of the water table and headward migration of the streambed through undercutting (Sellards and Gunter, 1918; Sharp, 1938; Means, 1975). Aspects of the biology of Florida steepheads are discussed by Means (1975). In the Apalachicola drainage, some of the deepest and best developed steepheads in Florida occur in small drainages dissecting the eastern escarpment between Bristol and Torreya State Park (Big Sweetwater Creek, Little Sweetwater Creek, Beaverdam Creek).

Steepheads are very important habitats for a number of reasons. (1) They provide a sort of natural laboratory for ecological studies in that the physical and vegetational characteristics of these environments are relatively constant from one to the other both within drainages and between drainages. Means (1975) has already utilized the constancy between steepheads across drainages to examine the distribution of plethodontid salamanders in them. Much more needs to be done on the comparative similarities and differences between steepheads in Florida. (2) They are habitats in which the hardwood overstory has been left relatively intact because of inaccessibility to logging. (3) Because of their spring-origin nature and protection of steep valley walls, the water and seepage slopes at the valley heads are buffered from extremes in temperature and humidity. Steepheads are thus seasonally very constant environments.

NATURAL AREAS

APALACHICOLA RAVINES

Hardly any introduction is necessary to a discussion of the Apalachicola Ravines (Figure 7), a distinctive biotic region of Florida (Harper, 1914; Kurz, 1933; Neill, 1957; Hubbell et al., 1956; James, 1961). A small portion of this unique blend of remarkable endemics and disjunct northern biota has been set aside in public ownership as Torreya State Park. The eastern boundary of the Apalachicola Ravines is here defined as the drainage divide between ravines dissecting the high eastern escarpment of the river and low-gradient tributaries of Telogia Creek to the east. This biotic unit contains mostly small-order stream bottoms

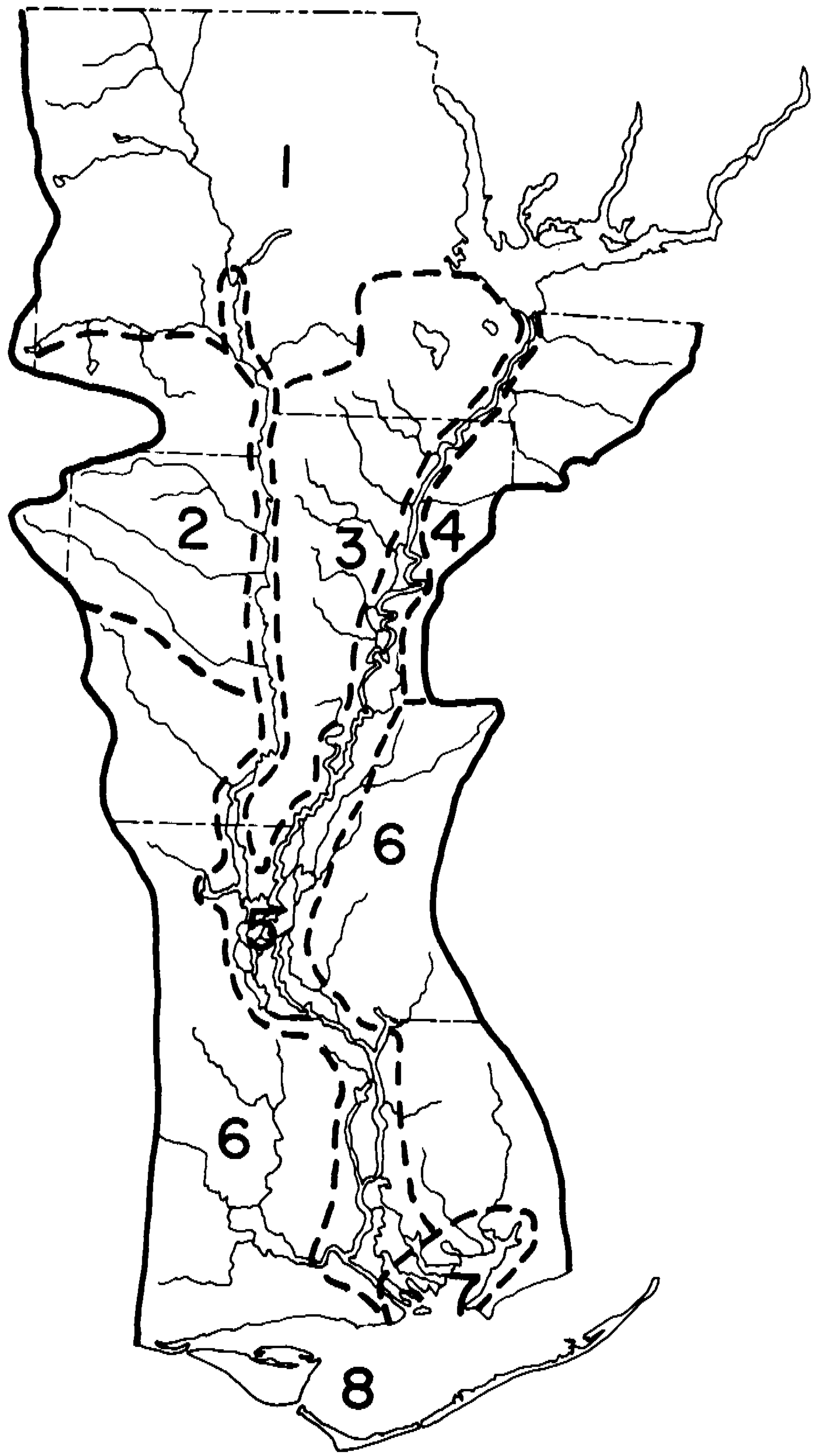

Figure 7. Natural areas of the Apalachicola River drainage basin based on geology, physiography, vegetation types, and the distribution of plants and animals. 1 = Marianna Lowlands, 2 = Western Red Hills, 3 = Grand Ridge, 4 = Apalachicola Ravines, 5 = River Bottomlands, 6 = Apalachicola Lowlands, 7 = Coastal Marshes, 8 = Offshore Spits, Bars, and Barrier Islands. Bold lines east and west mark crest of drainage divides.

having mesic to hydric plant communities, steep valley slopes grading from xeric vegetation near the top to mesic at bottom, and xeric vegetation inhabiting the tops of small divides between ravines.

The southern boundary of the Apalachicola Ravines biotic region is a scarp running east-west at about the 100 ft contour. This marks the boundary between Miocene clastics of the Sunderland-Okefenokee terrace and the Plio-Pleistocene sands of the Wisconsin terrace (Healy, 1976). The Apalachicola Ravines natural area can be subdivided into a narrow strip along the escarpment about 0.5 km wide that consists of the deepest ravines, steepest slopes, and bluffs overlooking the Apalachicola River and an easternmost portion that has been separately considered as the Tifton Uplands (Hubbell et al., 1956). The tops of the divides between tributaries represent the remnants of the surface of an ancient plain.

While the botanical distinctiveness of the Apalachicola Ravines has long been established (Harper, 1914; Kurz, 1933; James, 1961) no terrestrial vertebrates are strictly endemic in this natural area. However, the unique shaded ravine habitats contain Florida's greatest abundance of northern streamside salamanders (*Desmognathus fuscus, Eurycea bislineata, Pseudotriton ruber*); also the Copperhead and sometimes *Amphiuma pholeter* are found in the Apalachicola Ravines.

MARIANNA LOWLANDS

Long recognized as a distinctive physiographic unit of the Gulf Coastal Plain, the Marianna Lowlands (Figure 7) is a large karst plain formed on limestones of Oligocene and Eocene age that have been elevated by structural lift (Puri and Vernon, 1964). The original Miocene clastic sediments which capped the limestone were rapidly eroded, leaving occasional remnants still obvious today (Orange Hill, Falling Waters Hill, Rock Hill, Marianna Red Lands). Mitchell (1963) gives an account of the unique plants of the Marianna Redlands, an interesting subregion of the Marianna Lowlands. The Marianna Lowlands contains more vadose cave ecosystems than anywhere else in Florida or throughout the entire Coastal Plain of the United States.

The most distinctive faunal element of this biotic unit is the endemic cave-adapted fauna including the obligate cavernicoles, *Haideotriton wallacei* and *Cambarus cryptodytes*. The air passages of caves in this region also support a varied bat fauna including two endangered species (*Myotis griscescens, Myotis sodalis*) and one rare species (*Myotis keeni*). Another rare vertebrate found in the Marianna Lowlands is the Flatwoods Salamander, *Ambystoma cingulatum*. This species breeds in cypress ponds and lives in the soil surrounding them. Its survival status is considered Undetermined (Appendix II).

APALACHICOLA LOWLANDS

While many authors have recognized the biological distinctness of the Apalachicola Ravines, none have recognized that south of this natural region along both sides of the Apalachicola River lies another equally biologically distinctive natural area having its own endemics. This I call the Apalachicola Lowlands (Figure 7). This is a primarily flatwoods region on a low, slightly inclined coastwise plain with little relief and extensive swamplands. A list of endemic plants and animals is given in Table 2. Means (1976d, 1976g) argued that the Apalachicola Kingsnake (*Lampropeltis getulus*, new subspecies) is an autochthon of the Apalachicola Lowlands along with the Brown-chinned Racer (*Coluber constrictor helvigularis*) and that the apparent focus of distribution of either race is not the "Apalachicola and Chipola River Valleys" to the north as claimed by Neill and Allen (1949).

The Apalachicola Lowlands are bisected into a western and eastern portion by the Apalachicola River and river bottomland habitats (River Bottomlands). The eastern portion of the Apalachicola Lowlands contains part of the Apalachicola National Forest and Tates Hell Swamp. The latter onetime wilderness area has been drained and is undergoing extensive clearcutting. Much of the western portion is being developed into a large cattle ranch. Unfortunately, so much of the Apalachicola Lowlands is currently undergoing drastic habitat alteration that the many species and races of animals and plants found only or mainly there may be extirpated before their distinctness is fully recognized. This natural area is also noted for numerous small but botanically interesting savannahs (Clewell, 1971, 1977).

TABLE 2. PLANTS AND ANIMALS ENDEMIC TO THE APALACHICOLA LOWLANDS

Species
Hypericum exile Adams
Hypericum chapmanii Adams
Verbesina chapmanii Coleman
Justicia crassifolia Chapm.
Harperocallis flava McDaniel
Pinguicula planifolia Chapm.
Pinguicula ionantha Godfrey
Cuphea aspera Chapm.
Rhexia parviflora Chapm.
Macbridea alba Chapm.
Oxypolis greenmanii Math. & Const.
Euphorbia telephioides Chapm.
Rudbeckia graminifolia (T. & G.) Beadle & Boynton
Rudbeckia mohrii Gray
Lampropeltis getulus goini
Coluber constrictor helvigularis

WESTERN RED HILLS

The Western Red Hills (Figure 7) are the western portion of a once continuous band of clastic sediments oriented east to west including Grand Ridge and the Apalachicola Ravines. The Western Red Hills biotic unit is separated from the other two natural areas by the deep valley of the Chipola River. Although higher in elevation and more relieved than Grand Ridge, the Western Red Hills are not as extensive or as deeply dissected as the Apalachicola Ravines. Most of the unique endemics and northern relics in the latter area are absent from the western highlands probably because ravines are not as well developed there. But it must be stated that this particular biological unit has not been so well studied as others in the Apalachicola drainage. No endemic vertebrates are presently known from this region. The Western Red Hills biotic unit is bounded on the north by Dry Creek, on the east by the Chipola River Valley, on the south by Cody Scarp, and on the west by the drainage divide between Econfina Creek and tributaries of Chipola River which drain the Western Red Hills.

GRAND RIDGE

Grand Ridge (Figure 7) is a wedge-shaped area bounded by the Chipola and Apalachicola Rivers on the west and east, respectively, and the Marianna Lowlands to the north. Grand Ridge originally was part of the same upland land mass that extended from the Apalachicola Ravines westward to and including the Western Red Hills. Originally the same elevation, Grand Ridge has been eroded more rapidly than the other two biotic units. At one time an ancient channel of the Chattahoochee River bisected Grand Ridge (Hendry and Yon, 1958). The ancient stream bed is occupied today by Ocheesee Pond and the old river valley can be seen on topographic maps or aerial photographs. The erosion of Grand Ridge has been so extensive that in its southern portion it has well-developed flatwoods habitat (Hubbell et al., 1956). Grand Ridge has no endemics restricted to it, but because limestone is exposed or not far below the surface in places (especially along the Apalachicola River on its northeast side) it is possible that the Chattahoochee troglobite fauna occurs in subterranean cavities which have outlets in springs in the area. *Ambystoma cingulatum*, the gopher tortoise association, and the Copperhead are found on Grand Ridge. The only known occurrence of *Torreya taxifolia* outside the Apalachicola Ravines natural area is a stand west of the Apalachicola River at Dog Pond in Grand Ridge.

RIVER BOTTOMLANDS

The river bottomlands of the Chipola and Apalachicola Rivers form a distinct biological unit of its own (Figure 7). Most of this is floodplain habitat which is readily recognized on aerial photographs by the characteristic hardwood vegetation occupying it. This environment contains the river channel, sloughs, backwaters, swamps, and periodically inundated lowlands. Since the river bottomlands extend in a north-south direction from the Marianna Lowlands through the upland sediments of high relief and into the Apalachicola Lowlands, many of the unique and endemic vertebrates primarily occupying these other regions also occur in the River Bottomlands natural area. For instance, many springs and aquatic cave systems empty into the Chipola River in the floodplain of the river itself. Upstream and underground from their first surface contact these habitats contain the Chattahoochee troglobite fauna. The rivers themselves contain threatened or rare turtles including *Graptemys barbouri*, *Macroclemmys temmincki*, *Chrysemys concinna suwanniensis* and *Chrysemys nelsoni*. In addition, the unique *Amphiuma pholeter* occurs in mucky environments mostly at the edge of the river bottomlands. The last holdout in Florida of the endangered, if not extinct, Ivory-billed Woodpecker may have been in these very bottomlands. Where the river bottomlands pass through the Apalachicola Lowlands, both the Apalachicola Kingsnake and the Brown-chinned Racer are found occasionally in the bottomlands; both are endemics more strictly of the Apalachicola Lowlands.

COASTAL MARSHES

Where the Apalachicola River approaches salt water in the Apalachicola Bay an extensive estuarine environment is encountered, termed here the Coastal Marshes biotic unit (Figure 7). The value of this ecosystem has been thoroughly addressed (Livingston et al., 1974). Two distinctive reptiles are characteristic of this environment. The Salt Marsh Watersnake (*Natrix fasciata clarki*) occurs throughout the salt water marshes on the mainland as well as on the barrier islands (Dog, St. George, St. Vincent). This race of watersnake is characteristically an estuarine form. Also in the bay system itself occurs a succulent turtle (*Malaclemys terrapin*). Although confirmation is necessary, the estuary may support a population of red-bellied turtle (cf. *Chrysemys alabamensis*).

OFFSHORE SPITS, BARS, BARRIER ISLANDS

Off the mouth of the Apalachicola River is a well developed sound, barrier island, and offshore flat system (Figure 7). Three barrier islands (St. Vincent, St. George, Dog) parallel the coastline a few miles offshore. These islands basically are comprised of sets of dunes of differing ages clothed in distinctive dunes vegetation, pine flatwoods, and fresh and saltwater marshes. The vertebrate fauna of these islands has been treated moderately well (Blaney, 1971; Means, 1974b). The Carolina Wren on Dog Island has been recognized as racially distinct from its counterpart populations on the mainland (Stevenson, 1973). No other vertebrate populations have as yet been recognized as differing substantially from mainland forms. The Salt Marsh Watersnake and the Diamondback Terrapin are common inhabitants of the shore lines of these islands. Blaney reports the interesting occurrence on St. George Island of the Island Glass Lizard (*Ophisaurus compressus*) which is otherwise known only from peninsular Florida.

BIOGEOGRAPHY

Aside from its distinctive fish fauna the Apalachicola drainage basin is most noteworthy for its high species number of reptiles and amphibians. The reasons for this biogeographic phenomenon are briefly discussed. First, no geographic area can support high diversity in any organismal group without a correspondingly high diversity of the physical environment (already mentioned for the Apalachicola River basin in a previous section). Second, a large species pool must be available in adjacent geographic regions from which to recruit species. The Apalachicola basin is strategically located in the southeastern United States to receive faunal and floral elements from four major adjacent areas of endemism (from the north, the Atlantic Coastal Plain, the Gulf Coastal Plain, and peninsular Florida). Table 3 indicates the origin of reptiles and amphibians in the Apalachicola drainage by assigning each species to one of eight categories depending upon the bulk of the species' geographical distribution. For instance, a species is ranked as northern if most of its geographical range occurs north of the Apalachicola basin and predominantly in Piedmont and Appalachian physiographic regions; or a species is scored as widespread Coastal Plain if most of its geographical distribution is about equally in the Atlantic and Gulf Coastal Plain. It is obvious that most amphibians and reptiles have geographic affinities with predominantly two categories, widespread eastern United States and widespread Coastal Plain.

The number of species of amphibians and reptiles in the Apalachicola drainage whose origins are probably northern, Atlantic Coastal Plain, Gulf Coastal Plain, peninsular Florida, strict Apalachicola endemics, and regional endemics is quite small compared to the other two categories. Both vertebrate classes have about the same number of species distributed over these eight categories. If one assumes that most regions of the eastern United States contain about the same number of amphibians and reptiles which are widespread throughout the eastern Unted States, then clearly the Apalachicola drainage basin has a high species density because of the representation there of animals having widespread Coastal Plain distributions. This is relatively more important for amphibians than for reptiles, but the fact remains that the Coastal Plain has both a large endemic amphibian and reptile fauna.

The species inhabiting the Apalachicola drainage that are basically northern animals are three salamanders (*Desmognathus fuscus*, *Hemidactylium scutatum*, *Pseudotriton ruber*), one frog (*Pseudacris triseriata*), and two snakes (*Regina septemvittata*, *Agkistrodon contortrix*). Those species having predominantly Atlantic Coastal Plain distributions are one salamander (*Siren lacertina*), one frog (*Limnaeodus ocularis*), and two snakes (*Natrix taxispilota*, *Seminatrix pygaea*). The Gulf Coastal Plain contributes the same number of species as the Atlantic Coastal Plain; these are one salamander (*Necturus beyeri*), one frog (*Hyla avivoca*), one turtle (*Macroclemys temmincki*), and one lizard (*Eumeces anthracinus*). Peninsular Florida contributes one salamander (*Pseudobranchus striatus*), two turtles, *Trionyx ferox*, (*Chrysemys nelsoni*), one snake, (*Drymarchon corais*), and one lizard (*Eumeces egregius*).

Only two full species are strict Apalachicola endemics, a caverniculous salamander (*Haideotriton wallacei*) and one turtle (*Graptemys barbouri*). However, the Apalachicola drainage contains two other species whose geographical distributions are primarily focused on the Apalachicola basin, but which range somewhat beyond. These are classed as "regional endemics" and are the two salamanders, *Amphiuma pholeter* and *Ambystoma cingulatum*. The remaining 32 amphibians and 52 reptiles are categorized as either widespread Coastal Plain or widespread eastern United States (each is easily recognized from distributional maps in Conant, 1975).

Because the climate is mild and the phyiscal diversity relatively high, the Apalachicola drainage basin supports a moderately large complement of species that are wide-ranging both throughout the eastern United States and in the Coastal Plain. However, in addition to this, the species density is increased by the fact that from four different adjacent regions having faunal distinctiveness of their own, a moderate contribution is made from species whose ranges end in the Apalachicola drainage.

Thus, there is overlap in this drainage of Gulf Coastal Plain species whose easternmost distribution is in the Apalachicola drainage overlapping Atlantic Coastal Plain species whose southwestern distributional limits also terminate there. Further, several northern species find their southernmost distributional limits in the Apalachicola basin while a few peninsular Florida forms extend their northwestern limits into the basin. All these factors in combination result in the highest species density of amphibians and reptiles in North America north of Mexico. The Apalachicola drainage basin is truly a crossroads where physiographic changes take place and biotas meet.

Although only two full vertebrate terrestrial species are strict endemics (*Haideotriton wallacei*, *Graptemys barbouri*), the Apalachicola River drainage has a number of endemic fishes, (Yerger, 1977). Moreover, at least two other vertebrates are racially distinct (*Lampropeltis getulus* subspecies, *Coluber constrictor helvigularis*). Means (1974a) concluded that *Desmognathus "fuscus"* populations inhabiting Apalachicola ravines were probably not *D. fuscus;* but were more closely related to the Appalachian *D. ochrophaeus.* Considering the number of known racial and species-level endemic vertebrates, plants, and invertebrates (Neill, 1957) and the fact that few biologists have concentrated their field research in the Apalachicola drainage basin, it is highly likely that even more endemics will come to light in the future. However, past impacts and present habitat alteration schemes pose a serious threat to the overall uniqueness of the whole system.

TABLE 3. GEOGRAPHIC AFFINITIES OF APALACHICOLA DRAINAGE AMPHIBIANS AND REPTILES

Bulk of species range	Amphibians	Reptiles
Northern	4	2
Atlantic Coastal Plain	2	2
Gulf Coastal Plain	2	2
Widespread Coastal Plain	17	14
Peninsular Florida	1	2
Widespread Eastern U.S.	15	38
Strict Apalachicola endemics	1	1
Regional endemic	2	3
	44	64

SUMMARY

The Apalachicola River drainage in Florida supports at least 344 species of vertebrates (85 fishes, 44 amphibians, 64 reptiles, 99 breeding birds, and 52 mammals); species lists are produced in Appendix I. Among this diverse vertebrate fauna several species and races are considered to be endangered, threatened, rare, of special concern, or of status undetermined; these are listed giving status and authority in Appendix II. A number of vertebrates are discussed separately because they have some special relationship to the Apalachicola drainage as 1) endemics, 2) rare species having unusual geographic distributions, 3) especially vulnerable to ecological perturbation. Two different groups of vertebrates that contain ecologically associated species are discussed because each group characterizes a unique and vulnerable ecosystem (aquatic troglobites, gopher tortoise association) of individual species whose survival is closely linked. Three associations of cave-adapted animals are named for the karst areas where they occur (Chattahoochee Fauna, Woodville Fauna, Ocala Fauna). The unique Chattahoochee Fauna is isolated from any other cave ecosystem and is entirely contained in the Apalachicola-Flint-Chattahoochee drainage basin. The richness of terrestrial vertebrates in the Apalachicola drainage is dependent upon the diversity of the physical environment. A unique habitat type (steephead) is discussed because it is well-developed in the Apalachicola drainage and has not yet received the attention from biologists it deserves. The Apalachicola drainage is divided into eight biotic units (natural areas) that correspond to distributional patterns of terrestrial vertebrates and physiography. A natural area having its own endemic flora and fauna is recognized and named here for the first time as the Apalachicola Lowlands. Biogeographic reasons for the high species density of amphibians and reptiles are discussed.

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APPENDIX I

CHECKLIST OF AMPHIBIANS IN THE APALACHICOLA RIVER DRAINAGE BASIN

SALAMANDERS

SIRENIDAE	
Pseudobranchus striatus	Dwarf Siren
Siren intermedia	Lesser Siren
Siren lacertina	Greater Siren
NECTURIDAE	
Necturus beyeri	Gulf Coast Waterdog
AMPHIUMIDAE	
Amphiuma means	Two-toed Amphiuma
Amphiuma pholeter	One-toed Amphiuma
SALAMANDRIDAE	
Notophthalmus viridescens	Spotted Newt
AMBYSTOMATIDAE	
Ambystoma cingulatum	Flatwoods Salamander
Ambystoma opacum	Marbled Salamander
Ambystoma talpoideum	Mole Salamander
Ambystoma tigrinum	Tiger Salamander
PLETHODONTIDAE	
Desmognathus auriculatus	Southern Dusky Salamander
Desmognathus fuscus	Dusky Salamander
Eurycea bislineata	Two-lined Salamander
Eurycea longicauda	Long-tailed Salamander
Manculus quadridigitatus	Dwarf Salamander
Haideotriton wallacei	Georgia Blind Salamander
Hemidactylium scutatum	Four-toed Salamander
Plethodon glutinosus	Slimy Salamander
Pseudotriton montanus	Mud Salamander
Pseudotriton ruber	Red Salamander

FROGS

PELOBATIDAE	
Scaphiopus holbrooki	Eastern Spadefoot
BUFONIDAE	
Bufo quercicus	Oak Toad
Bufo terrestris	Southern Toad
HYLIDAE	
Acris crepitans	Northern Cricket Frog
Acris gryllus	Southern Cricket Frog
Hyla avivoca	Bird-voiced Tree Frog
Hyla cinerea	Green Tree Frog
Hyla crucifer	Spring Peeper
Hyla femoralis	Pine-woods Tree Frog
Hyla gratiosa	Barking Tree Frog
Hyla squirella	Squirrel Tree Frog
Hyla chrysoscrelis	Gray Tree Frog
Limnaeodus ocularis	Little Grass Frog

APPENDIX I

CHECKLIST OF AMPHIBIANS IN THE APALACHICOLA RIVER DRAINAGE BASIN (CONTINUED)

FROGS

Pseudacris nigrita	Southern Chorus Frog
Pseudacris ornata	Ornate Chorus Frog
Pseudacris triseriata	Upland Chorus Frog
RANIDAE	
Rana areolata	Gopher Frog
Rana catesbeiana	Bullfrog
Rana clamitans	Bronze Frog
Rana grylio	Pig Frog
Rana heckscheri	River Frog
Rana pipiens	Leopard Frog
MICROHYLIDAE	
Gastrophyrne carolinensis	Narrow-mouthed Toad

CHECKLIST OF REPTILES IN THE APALACHICOLA RIVER DRAINAGE BASIN

CROCODILIANS

CROCODYLIDAE	
Alligator mississippiensis	American Alligator

TURTLES

CHELYDRIDAE	
Chelydra serpentina	Snapping Turtle
Macroclemys temmincki	Alligator Snapping Turtle
KINOSTERNIDAE	
Kinosternon subrubrum	Eastern Mud Turtle
Sternotherus minor	Loggerhead Musk Turtle
Sternotherus odoratus	Stinkpot
EMYDIDAE	
Deirochelys reticularia	Chicken Turtle
Gopherus polyphemus	Gopher Tortoise
Graptemys barbouri	Barbour's Map Turtle
Chrysemys concinna	Cooter
Chrysemys floridana	Florida Cooter
Chrysemys nelsoni	Florida Red-bellied Turtle
Chrysemys scripta	Yellow-bellied Turtle
Terrapene carolina	Box Turtle
Malaclemys terrapin	Diamondback Terrapin
TRIONYCHIDAE	
Trionyx ferox	Florida Softshell
Trionyx spinifer	Gulf Coast Softshell

APPENDIX I

CHECKLIST OF REPTILES IN THE APALACHICOLA RIVER DRAINAGE BASIN (CONTINUED)

LIZARDS

IGUANIDAE	
Anolis carolinensis	Green Anole
Sceloporus undulatus	Fence Swift
TEIDAE	
Cnemidophrus sexlineatus	Six-lined Racerunner
SCINCIDAE	
Eumeces anthracinus	Coal Skink
Eumeces egregius	Red-tailed Skink
Eumeces fasciatus	Five-lined Skink
Eumeces inexpectatus	Southeastern Five-lined Skink
Eumeces laticeps	Broad-headed Skink
Scincella laterale	Ground Skink
ANGUIDAE	
Ophisaurus attenuatus	Slender Glass Lizard
Ophisaurus ventralis	Eastern Glass Lizard
Ophisaurus compressus	Island Glass Lizard

SNAKES

COLUBRIDAE	
Cemophora coccinea	Scarlet Snake
Coluber constrictor	Black Racer
Diadophis punctatus	Ringneck Snake
Drymarchon corais	Indigo Snake
Elaphe guttata	Corn Snake
Elaphe obsoleta	Rat Snake
Farancia abacura	Mud Snake
Farancia erytrogramma	Rainbow Snake
Heterodon platyrhinos	Eastern Hognose Snake
Heterodon simus	Southern Hognose Snake
Lampropeltis calligaster	Mole Snake
Lampropeltis getulus	Kingsnake
Lampropeltis triangulum	Scarlet Kingsnake
Masticophis flagellum	Coachwhip
Natrix cyclopion	Green Water Snake
Natrix erythrogaster	Red-bellied Water Snake
Natrix fasciatus	Banded Water Snake
Natrix taxispilota	Brown Water Snake
Opheodrys aestivus	Rough Green Snake
Pituophis melanoleucas	Pine Snake
Regina rigida	Glossy Water Snake
Regina septemvittata	Queen Snake
Rhadinea flavilata	Yellow-lipped Snake
Seminatrix pygaea	Black Swamp Snake
Storeria dekayi	Brown Snake
Storeria occipitomaculata	Red-bellied Snake
Tantilla coronata	Crowned Snake
Thamnophis sauritus	Ribbon Snake

APPENDIX I

CHECKLIST OF REPTILES IN THE APALACHICOLA RIVER DRAINAGE BASIN (CONTINUED)

SNAKES

Thamnophis sirtalis	Garter Snake
Virginia striatula	Rough Earth Snake
Virginia valeriae	Smooth Earth Snake
ELAPIDAE	
Micrurus fulvius	Coral Snake
CROTALIDAE	
Agkistrodon contortrix	Copperhead
Agkistrodon piscivorus	Cottonmouth
Crotalus adamanteus	Eastern Diamondback Rattlesnake
Sistrurus miliarius	Pygmy Rattlesnake

CHECKLIST OF MAMMALS OF THE APALACHICOLA RIVER DRAINAGE BASIN

DIDELPHIDAE	
Didelphis virginiana	Opposum
SORICIDAE	
Sorex longirostris	Southeastern Shrew
Blarina brevicauda	Short-tailed Shrew
Cryptotis parva	Least Shrew
TALPIDAE	
Scalopus aquaticus	Eastern Mole
VESPERTILIONIDAE	
Myotis austroriparius	Southeastern Myotis
Myotis grisescens	Gray Myotis
Myotis keenii	Keen's Myotis
Myotis sodalis	Indiana Myotis
Pipistrellus subflavus	Eastern Pipistrelle
Eptesicus fuscus	Big Brown Bat
Lasiurus cinereus	Hoary Bat
Lasiurus borealis	Red Bat
Lasiurus seminolus	Seminole Bat
Lasiurus intermedius	Northern Yellow Bat
Nycticeius humeralis	Evening Bat
Plecotus rafinesquii	Rafinesque's Big-eared Bat
MOLOSSIDAE	
Tadarida brasiliensis	Brazilian Free-tailed Bat
DASYPODIDAE	
Dasypus novemcinctus	Nine-banded Armadillo
LEPORIDAE	
Sylvilagus floridanus	Eastern Cottontail
Sylvilagus palustris	Marsh Rabbit

APPENDIX I

CHECKLIST OF MAMMALS IN THE APALACHICOLA RIVER DRAINAGE BASIN (CONTINUED)

SCIURIDAE	
Sciurus carolinensis	Gray Squirrel
Sciurus niger	Fox Squirrel
Glaucomys volans	Southern Flying Squirrel
GEOMYIDAE	
Geomys pinetus	Southeastern Pocket Gopher
CASTORIDAE	
Castor canadensis	American Beaver
CRICETIDAE	
Microtus pinetorum	Woodland Vole
Neofiber alleni	Round-tailed Muskrat
Neotoma floridana	Eastern Woodrat
Sigmodon hispidus	Hispid Cotton Rat
Reithrodontomys humulis	Eastern Harvest Mouse
Oryzomys palustris	Marsh Rice Rat
Peromyscus polionotus	Oldfield Mouse
Peromyscus gossypinus	Cotton Mouse
Ochrotomys nuttalli	Golden Mouse
MURIDAE	
Mus musculus	House Mouse
Rattus rattus	Black Rat
Rattus norvegicus	Norway Rat
CANIDAE	
Urocyon cinereoargenteus	Gray Fox
Vulpes vulpes	Red Fox
URSIDAE	
Ursus americanus	Black Bear
PROCYONIDAE	
Procyon lotor	Raccoon
MUSTELIDAE	
Lutra canadensis	River Otter
Mephitis mephitis	Striped Skunk
Spilogale putorius	Eastern Spotted Skunk
Mustela vison	Mink
Mustela frenata	Long-tailed Weasel
FELIDAE	
Lynx rufus	Bobcat
Felis concolor	Mountain Lion
SUIDAE	
Sus scrofa	Feral Pig
CERVIDAE	
Odocoileus virginianus	White-tailed Deer

APPENDIX I
BREEDING BIRDS OF THE APLACHICOLA RIVER DRAINAGE BASIN, EXCEPTING THOSE FOUND ONLY IN MARINE OR ESTUARINE CONDITIONS.

PODICIPEDIDAE
- Pied-billed Grebe *Podilymbus podiceps*

ANHINGIDAE
- Anhinga *Anhinga anhinga*

ARDEIDAE
- Great Blue Heron *Ardea herodias*
- Green Heron *Butorides virescens*
- Little Blue Heron *Florida caerulea*
- Cattle Egret *Bubulcus ibis*
- Common Egret *Casmerodius alba*
- Snowy Egret *Leucophoyx thula*
- Louisiana Heron *Hydranassa tricolor*
- Black-crowned Night Heron *Nycticorax nycticorax*
- Yellow-crowned Night Heron *Nyctanassa violacea*
- Least Bittern *Ixobrychus exilis*

ANATIDAE
- Wood Duck *Aix sponsa*

CATHARTIDAE
- Turkey Vulture *Carthartes aura*
- Black Vulture *Coragyps atratus*

ACCIPTRIDAE
- Swallow-tailed Kite *Elanoides forficatus*
- Mississippi Kite *Ictinia misisippiensis*
- Cooper's Hawk *Accipiter cooperii*
- Red-tailed Hawk *Buteo jamaicensis*
- Red-shouldered Hawk *Buteo lineatus*
- Broad-winged Hawk *Buteo platypterus*
- Bald Eagle *Haliaeetus leucocephalus*

PANDIONIDAE
- Osprey *Pandion haliaetus*

FALCONIDAE
- American Kestrel *Falco sparverius*

PHASIANIDAE
- Northern Bobwhite *Colinus virginianus*

MELEAGRIDAE
- Turkey *Meleagris gallopavo*

GRUIDAE
- Sandhill Crane *Grus canadensis*

RALLIDAE
- Purple Gallinule *Porphyrula martinica*
- Common Gallinule *Gallinula chloropus*

CHARADRIIDAE
- Killdeer *Charadrius vociferus*

SCOLOPACIDAE
- American Woodcock *Philohela minor*

COLUMBIDAE
- Mourning Dove *Zenaida macroura*
- Ground Dove *Columbina passerina*

PSITTACIDAE
- Carolina Parakeet *Conuropsis carolinensis+*

CUCULIDAE
- Yellow-billed Cuckoo *Coccyzus americanus*

TYTONIDAE
- Barn Owl *Tyto alba*

STRIGIDAE
- Screech Owl *Otus asio*
- Great Horned Owl *Bubo virginianus*
- Barred Owl *Strix varia*

CAPRIMULGIDAE
- Chuck-will's-widow *Caprimulgus carolinensis*
- Common Nighthawk *Chordeilus minor*

APODIDAE
- Chimney Swift *Chaetura pelagica*

TROCHILIDAE
- Ruby-throated Hummingbird *Archilochus colubris*

ALCEDINIDAE
- Belted Kingfisher *Megaceryle alcyon*

PICIDAE
- Common Flicker *Colaptes auratus*
- Pileated Woodpecker *Dryocopus pileatus*
- Red-bellied Woodpecker *Centurus carolinus*
- Red-headed Woodpecker *Melanerpes erythrocephalus*
- Hairy Woodpecker *Dendrocopos villosus*
- Downy Woodpecker *Dendrocopos pubescens*
- Red-cockaded Woodpecker *Dendrocopos borealis*
- Ivory-billed Woodpecker *Campephilus principalis+*

TYRANNIDAE
- Eastern Kingbird *Tyrannus tyrannus*
- Great Crested Flycatcher *Myiarchus crinitus*
- Acadian Flycatcher *Empidonax virescens*
- Eastern Wood Pewee *Contopus virens*

HIRUNDINIDAE
- Rough-winged Swallow *Stelgidopteryx ruficollis*
- Barn Swallow *Hirundo rustica*

CORVIDAE
- Blue Jay *Cyanocitta cristata*
- Common Crow *Corvus brachyrhynchos*
- Fish Crow *Corvus ossifragus*

PARIDAE
- Carolina Chickadee *Parus carolinensis*
- Tufted Titmouse *Parus bicolor*

SITTIDAE
- White-breasted Nuthatch *Sitta carolinensis*
- Brown-headed Nuthatch *Sitta pusilla*

TROGLODYTIDAE
- Carolina Wren *Thryothorus ludovicianus*

MIMIDAE
- Northern Mockingbird *Mimus polyglottos*
- Brown Thrasher *Toxostoma rufum*

APPENDIX I

BREEDING BIRDS OF THE APLACHICOLA RIVER DRAINAGE BASIN, EXCEPTING THOSE FOUND ONLY IN MARINE OR ESTUARINE CONDITIONS.

TURDIDAE
- Wood Thrush *Hylocichla mustelina*
- Eastern Bluebird *Sialia sialis*

SYLVIIDAE
- Blue-gray Gnatcatcher *Polioptila caerula*

LANIIDAE
- Loggerhead Shrike *Lanius ludovicianus*

STURNIDAE
- European Starling *Sturnus vulgaris*

VIREONIDAE
- White-eyed Vireo *Vireo griseus*
- Yellow-throated Vireo *Vireo flavifrons*
- Red-eyed Vireo *Vireo olivaceus*

PARULIDAE
- Prothonotary Warbler *Protonotaria citrea*
- Swainson's Warbler *Limnothlypis swainsonii*
- Northern Parula *Parula americana*
- Yellow-throated Warbler *Dendroica dominica*
- Pine Warbler *Dendroica pinus*
- Prairie Warbler *Dendroica discolor*
- Louisiana Waterthrush *Seiurus motacilla*
- Kentucky Warbler *Oporonis formosus*
- Common Yellowthroat *Geothlypis trichas*
- Yellow-breasted Chat *Icteria virens*
- Hooded Warbler *Wilsonia citrina*

PLOCEIDAE
- House Sparrow *Passer domesticus*

ICTERIDAE
- Eastern Meadowlark *Sturnella magna*
- Red-winged Blackbird *Agelaius phoeniceus*
- Orchard Oriole *Icterus spurius*
- Common Grackle *Quiscalus quiscula*
- Brown-headed Cowbird *Molothrus ater*

THRAUPIDAE
- Summer Tanager *Piranga rubra*

FRINGILLIDAE
- Cardinal *Cardinalis cardinalis*
- Blue Grosbeak *Guiraca caerulea*
- Indigo-Bunting *Passerina cyanea*
- Rufous-sided Towhee *Piplio erythrophthalmus*
- Bachman's Sparrow *Aimophila aestivalis*
- Chipping Sparrow *Spizella passerina*
- Field Sparrow *Spizella pusilla*

Total species: 101 (2 extinct)
Compiled by Noel A. Wamer

APPENDIX II

Endangered, Threatened, etc. Vertebrates of the Apalachicola River drainage. U.S. = United States Department of the Interior *Threatened Wildlife of the United States* (as revised 27 July 1973); S.E. = *Endangered and Threatened Vertebrates of the Southeastern United States* (H. Hillestad, D. B. Means, W. W. Baker, eds.; Misc. Publ. No. 6., Tall Timbers Res. Sta. In Press); FLA = *Florida Committee Report on Rare and Endangered Plants and Animals* (Fla. Game and Freshwater Fish Commission). Status abbreviations area E=endangered, T=threatened, R=rare, SC=special concern, U=status undetermined.

TAXON		STATUS		
	AMPHIBIANS	U.S.	S.E.	FLA.
Rana areolata aesopus (Florida Gopher Frog)		—	T	T
Amphiuma pholeter (One-toed Amphiuma)		—	SC	R
Haedeotriton wallacei (Georgia Blind Salamander)		—	—	R
Hemidactylium scutatum (Four-toed Salamander)		—	—	R
Ambystoma cingulatum (Flatwoods Salamander)		—	U	—

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TAXON	STATUS		
REPTILES	U.S.	S.E.	FLA.
Alligator mississippiensis (American Alligator)	E	SC	SC
Gopherus polyphemus (Gopher Tortoise)	—	T	T
Graptemys barbouri (Barbour's Map Turtle)	—	R	SC
Macroclemmys temmincki (Alligator Snapping Turtle)	—	U	SC
Chrysemys concinna suwanniensis (Suwannee Cooter)	—	T	T
Drymarchon corais couperi (Eastern Indigo Snake)	—	T	T
Pituophis melanoleucas mugitus (Florida Pine Snake)	—	SC	—
Lampropeltis calligaster rhombomaculata (Mole Snake)	—	—	R
Lampropeltis getulus Apalachicola Lowlands populations (Eastern Kingsnake)	—	—	R
Agkistrodon contortrix (Southern Copperhead)	—	—	R
Crotalus adamanteus (Eastern Diamondback Rattlesnake)	—	—	SC
Eumeces anthracinus pluvialis (Southern Coal Skink)	—	—	U
MAMMALS			
Myotis griscescens (Gray Myotis)	E	E	E
Myotis sodalis (Indiana Bat)	E	E	R
Myotis keeni (Keen's Myotis)	—	—	R
Myotis austroriparius (Southeastern Myotis)	—	—	T
Eptesicus fuscus (2 sbspp) (Big Brown Bat)	—	—	R
Lasiurus cinereus (Hoary Bat)	—	—	R

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TAXON	STATUS		
MAMMALS	U.S.	S.E.	FLA.
Plecotus rafinesquii (Eastern Big-eared Bat)	—	SC	R
Felis concolor (Mountain Lion)	E	E	E
Ursus americanus (Black Bear)	—	E	T
Neofiber alleni (Round-tailed Muskrat)	U	T	T
Sorex longirostris longirostris (Southeastern Shrew)	—	—	R
Mustela frenata olivacea (Southeastern Weasel)	—	—	R
Mustela vison mink (Southern Mink)	—	—	R
BREEDING BIRDS			
Dendrocopos borealis (Red-cockaded Woodpecker)	E	E	E
Campephilus principalis (Ivory-billed Woodpecker)	E	E	E
Haliaeetus leucocephalus (Bald Eagle)	E	E	E
Pandion haliaetus (Osprey)	U	—	T
Casmerodius albus (Common Egret)	—	—	SC
Egretta thula (Snowy Egret)	—	—	SC
Florida caerulea (Little Blue Heron)	—	—	SC
Nycticorax nycticorax (Black-crowned Night Heron)	—	—	SC
Nyctanassa violacea (Yellow-crowned Night Heron)	—	—	SC
Ixobrychus exilis (Least Bittern)	—	—	SC
Accipiter cooperii (Cooper's Hawk)	—	SC	U

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TAXON	STATUS		
BREEDING BIRDS	U.S.	S.E.	FLA.
Falco sparverius paulus (American Kestrel)	—	SC	U
Buteo lineatus (Red-shouldered Hawk)	—	SC	—
Cathartes aura (Turkey Vulture)	—	SC	—
Coragyps atratus (Black Vulture)	—	SC	—
Dendrocopos villosus (Hairy Woodpecker)	—	—	U
Sitta carolinensis (White-breasted Nuthatch)	—	—	U
Dendroica discolor (Florida Prairie Warbler)	—	—	U
Aimophila aestivalis (Bachman's Sparrow)	—	U	—

ASPECTS OF NUTRIENT LIMITATION OF THE PHYTOPLANKTON PRODUCTIVITY IN THE APALACHICOLA BAY SYSTEM

Vernon B. Myers and Richard L. Iverson
Florida State University

INTRODUCTION

The quantification of the extent of nutrient limitation in a marine ecosystem is critical for the prediction of the response of the system to various nutrient related stresses. To make sound environmental policy, the critical nutrients and the relationships between these nutrients and plant productivity must be known.

In estuarine systems, patterns of nutrient limited phytoplankton production are complex and variable. It has been suggested that while nutrients can limit phytoplankton growth in stratified estuaries, shallow, well-mixed estuaries usually have nutrients, and especially phosphorus, present in excess of phytoplankton demands (Pomeroy et al., 1972). However, spatial and temporal variability in nitrogen and phosphorus limitation have been identified in both types of estuaries (Putnam, 1967; Flemer, 1970; Carpenter, 1971; Ryther and Dunstan, 1971; Thayer, 1971; Kraswick and Caperon, 1973).

Nitrogen occurs in estuarine systems in various dissolved and particulate forms. Nitrite, nitrate, molecular nitrogen, ammonium, urea, dissolved organic nitrogen, particulate organic nitrogen, and amino acids are nitrogen forms that can be used directly or indirectly by plankton in marine ecosystems (Dugdale and Goering, 1967; Riley and Chester, 1971; Carpenter, 1971; Thayer, 1971). The distribution of the different nitrogen forms in marine environments is controlled by complex interactions between biological, physical, and chemical processes.

Phosphorus occurs in estuarine systems, in a variety of colloidal, dissolved, and particulate forms (Taft et al., 1975). The distribution of the forms of phosphorus in marine systems is controlled by physical, chemical, and biological processes. The residence time of phosphate in coastal systems is fairly short, between 5 and 100 h (Pomeroy, 1960). Phosphorus concentrations in estuarine systems may be controlled by reversible sorption reactions between sediments and the overlying water (Rochford, 1951; Carritt and Goodgal, 1954; Jitts, 1959). Biological activity within the sediments can also move significant amounts of phosphorus between the sediments and the water column (Pomeroy et al., 1965; Hale, 1975), and has been shown to control the seasonal cycle of phosphorus concentrations in several shallow turbid estuaries (Pomeroy et al., 1972). Phosphorus fluxes within estuaries can also be dominated by reactions occurring within the water column. Phosphorus uptake within the water column is usually due to phytoplankton and/or bacteria (Correll et al., 1975, Taft et al., 1975). Regeneration of phosphorus within the water column can take place by autolysis, zooplankton consumption and remineralization, or bacterial degradation (Pomeroy et al., 1963; Martin, 1968; Hargrave and Geen, 1968; Peters and Rigler, 1973; Barsdate et al., 1974).

Previous phytoplankton productivity studies in Apalachicola Bay indicated that nitrogen and phosphorus were potential limiting nutrients, while silicate and trace metal additions never stimulated phytoplankton productivity (Estabrook, 1973). This paper presents preliminary results of nutrient enrichment experiments and phosphate uptake experiments designed to quantify the extent of nutrient limited phytoplankton production and to determine the importance of phosphorus in the Apalachicola Bay System.

METHODS AND MATERIALS

Sampling trips to Apalachicola Bay and East Bay (Livingston et al., 1977: Figure 1) were taken seasonally during 1975 and 1976 to determine the extent of nutrient limitation in the Bay System. A detailed description of the physiography and biota of the Apalachicola Bay System can be found in Livingston et al. (1974).

Water temperature and salinity were determined with a Beckman RS 5-3 portable salinometer. Secchi disc measurements were taken to estimate light attenuation with depth. Turbidities were analyzed with a Hach model 2100 A Turbidometer. Suspended solids were determined gravimetrically. Inorganic suspended solids were also determined gravimetrically after ashing the samples at 550°C for 4 h.

Five hundred milliliter water samples were collected at stations 1A in East Bay and 7 in Apalachicola Bay, for nutrient analysis (Livingston, et al., 1977: Figure 1). Samples were immediately filtered through Whatman GF/A glass fiber filters upon collection. One milliliter of 2% $HgCl_2$ solution was added to eliminate microbial processes and the samples were then placed on ice. All nutrients were analyzed within 48 h. Soluble reactive phosphate was analyzed by the method of Murphy and Riley as outlined in Strickland and Parsons (1972). Total dissolved phosphate was analyzed by the persulfate oxidation method listed in Standard Methods (1971). Nitrite was determined by the method of Bendschneider and Robinson given in Strickland and Parsons (1972). Nitrate determinations were based on the method of Morris and Riley with modifications given in Strickland and Parsons (1972).

Chlorophyll *a* was determined by the method of Loftus and Carpenter (1971) or the spectrophotometric method given in Strickland and Parsons (1972). The total inorganic carbon (ΣCO_2) content of the water was either determined with a Total Carbon Analyzer (Oceanography International, Inc.) using an infrared detector or from a salinity vs ΣCO_2 standard curve determined from two years of data collected in the Bay System. Dissolved organic carbon was determined by the method of Menzel and Vaccaro (1964) using the Total Carbon Analyzer. Phytoplankton taxonomy was determined by the method of Holmes (1962). Cell carbon was estimated from cell volumes according to the method of Strathmann (1967).

Two-factorial nutrient enrichment experiments with nitrogen and phosphorus were conducted with phytoplankton in water samples from stations in East Bay and Apalachicola Bay. General methods of nutrient enrichment experiments can be found in Scheleske et al. (1974) and Gerhart and Likens (1975). Water was collected in 20 l polyethylene carboys and aliquots were placed in 500 ml glass incubation bottles. Samples from each station were treated with either 0, 5, or 50 μg-atm l^{-1} nitrate-nitrogen and 0.0, 0.2, 0.5, or 50 μg-atm l^{-1} phosphate-phosphorus. Nutrients were added as 1 ml volumes. Duplicates were prepared for each concentration. A 4 h acclimation period was begun about 10 AM and was followed by an incubation with either 2 or 4 μCi ^{14}C labeled bicarbonate for approximately 4 h. Incubation and acclimation were performed in situ. Two 100 ml aliquots from each bottle were filtered through Whatman GF/C glass fiber filters. The filters were placed in 5 ml of Aquasol^R and the activity was determined by liquid scintillation counting (LSC). Primary productivity was calculated by the method of Strickland and Parsons (1972).

Phosphorus uptake was measured in the Apalachicola Bay System to determine phosphate dynamics and uptake rates of natural plankton communities. General methods of planktonic phosphorus uptake as a function of concentration can be found in Halmann and Stiller (1974) and Taft et al. (1975). Water was collected in 20 l polyethylene carboys and aliquots were placed in 500 ml glass incubation bottles. Samples were treated with 0.0, 0.2, 0.5, or 2.0 μg-atm l^{-1} phosphate-phosphorus. Half of the samples were poisoned with 1 ml of 2% $HgCl_2$ solution. Between 500,000, and 1,000,000 dpm/ml of carrier free ^{32}P phosphoric acid was added to the samples. Samples were incubated in situ. Fifteen milliliter subsamples were periodically removed from all bottles and filtered through Whatman GF/A glass fiber filters. Ten milliliters of filtrate was then pipetted into an LSC vial for counting. The ^{32}P was counted by measuring Cerenkov radiation of the filtrate (Curtis and Toms, 1972; Fric and Palovickova, 1975) with a liquid scintillation spectrometer. Planktonic phosphate uptake rates were estimated from linear regression slopes of total minus $HgCl_2$ treated phosphate uptake vs time.

RESULTS AND DISCUSSION

The results of nutrient enrichment experiments can be found in Table 1. At station 1A, phosphate enhanced phytoplankton carbon fixation more than nitrate. Phosphate enhanced carbon fixation during July and September 1975 and June and July 1976. No significant enhancement occurred during January and March 1976. Nitrate additions did not affect carbon fixation by phytoplankton at this station and no significant phosphate-nitrate interactions were observed.

Enrichment experiments at station 7 indicated both nitrate and phosphate enhanced fixation of carbon during certain times of the year. Significant nitrate enhancement occurred during September 1976, while significant phosphate-nitrate interactions were found during July 1975 and July 1976.

Nutrient enhanced phytoplankton carbon fixation occurred only when water temperatures were above 21.5°C and nitrate and phosphate concentrations were low (Table 2). Nitrate levels less than 0.47 μg-atm NO_3-N l^{-1} limited phytoplankton production in Apalachicola Bay; however, significant nitrate-phosphate interactions were observed at nitrate concentrations up to 3.49 μg-atm NO_3-N l^{-1} and phosphate concentrations as high as 0.43 μg-atm PO_4-P l^{-1}. Phosphate enhanced phytoplankton carbon fixation in East Bay when concentrations were less than 0.35 μg-atm PO_4-P l^{-1}.

The nutrient enrichment experiments suggest that at phosphate concentrations less than 0.35 μg-atm PO_4-P l^{-1} the internal functional phosphorus pools (Fuhs, 1969; Rhee, 1973) of the Bay phytoplankton were unsaturated. Phosphorus uptake data tends to support this hypothesis (Table 3). Planktonic phosphate uptake rates did not maximize until external phosphate concentrations were between 0.57 and 0.93 μg-atm PO_4-P l^{-1} under

TABLE 1. NUTRIENT ENRICHMENT RESPONSE: PHYTOPLANKTON PHOTOSYNTHETIC ENCHANCEMENT IN RESPONSE TO NUTRIENT ADDITIONS.

1A 7/11/75

		NO_3 0.0	5.0	50.0
	0.0	29.8	30.1	32.3
PO_4	0.5	40.0	41.8	42.2
	2.0	41.0	39.9	41.1

7 7/13/75

		NO_3 0.0	5.0	50.0
	0.0	28.7	30.2	32.3
PO_4	0.5	30.4	31.6	33.4
	2.0	33.0	32.6	34.1

1A 9/26/75

		NO_3 0.0	5.0
	0.0	46.8	47.0
PO_4	0.5	57.4	56.4
	2.0	60.8	59.5

7 9/26/75

		NO_3 0.0	5.0
	0.0	29.8	35.6
PO_4	0.5	30.3	36.5
	2.0	30.8	38.2

1A 1/13/76

		NO_3 0.0	5.0
	0.0	35.6	38.3
PO_4	0.5	34.4	32.4
	2.0	35.7	32.1

7 1/13/76

		NO_3 0.0	5.0
	0.0	26.9	27.1
PO_4	0.5	28.6	27.2
	2.0	28.5	27.0

1A 3/29/76

		NO_3 0.0	5.0
	0.0	21.4	22.7
PO_4	0.5	23.7	20.5

7 3/29/76

		NO_3 0.0	5.0
	0.0	18.9	18.0
PO_4	0.5	18.4	18.1

TABLE 1. NUTRIENT ENRICHMENT RESPONSE: PHYTOPLANKTON PHOTOSYNTHETIC ENCHANCEMENT IN RESPONSE TO NUTRIENT ADDITIONS. (CONTINUED)

1A 6/10/76

		NO_3 0.0	NO_3 5.0
PO_4	0.0	56.7	55.1
	0.25	64.2	-------
	0.5	72.3	74.7
	2.0	70.9	71.3

7 6/10/76

		NO_3 0.0	NO_3 5.0
PO_4	0.0	36.8	37.0
	0.25	37.6	------
	0.5	40.1	39.5
	2.0	39.5	38.0

1A 7/5/76

		NO_3 0.0	NO_3 5.0
PO_4	0.0	50.2	50.7
	0.25	58.7	-------
	0.5	59.2	56.2
	2.0	56.2	57.2

7 7/5/76

		NO_3 0.0	NO_3 5.0
PO_4	0.0	40.4	46.7
	0.25	48.7	------
	0.5	49.2	50.2
	2.0	47.4	52.3

*Photosynthetic enchancement in μg C $hr^{-1} l^{-1}$. Nitrate concentrations in μg-atm NO_3-N l^{-1} and phosphate concentrations in μg-atm PO_4-P l^{-1}.

TABLE 2. ENVIRONMENTAL AND NUTRIENT DATA*

Station	Date	Temp	Sal	NO_2	NO_3	PO_4	Turb	Chl-*a*	Carbon
1A	7/11/75	27.2	0.0	0.09	0.86	0.32	12.4	5.82	--------
7	7/13/75	26.3	4.2	0.08	0.57	0.27	6.8	3.46	--------
1A	9/26/75	21.7	3.2	-------	1.67	0.28	12.4	5.32	231.7
7	9/26/75	22.1	11.3	-------	0.45	0.34	7.4	3.10	130.3
1A	1/13/76	11.2	0.0	-------	4.05	0.38	18.7	4.64	219.3
7	1/13/76	10.3	1.8	0.27	4.52	0.40	7.3	3.86	196.3
1A	3/29/76	20.9	2.3	-------	11.24	0.64	21.0	2.72	129.9
7	3/29/76	21.1	2.1	0.31	12.41	0.47	12.4	2.36	108.6
1A	6/10/76	25.0	4.9	0.04	9.62	0.35	10.8	5.76	282.1
7	6/10/76	25.1	6.9	0.17	12.71	0.41	12.0	3.84	133.6
1A	7/5/76	28.7	0.3	0.07	2.81	0.32	14.0	8.07	258.7
7	7/5/76	28.4	2.4	0.17	3.49	0.43	7.8	4.09	150.7

*Temp is temperature in °C; Sal is Salinity in $^0/oo$; NO_2 in μg-atm NO_2-N l^{-1}; NO_3 in μg-atm NO_c-N l^{-1}; PO_4 is soluble reactive phosphate in μg-atm PO_4 P l^{-1}; Turb is turbidity in FTU; Chl-*a* is chlorophyll-*a* in μg l^{-1}; Carbon is phytyoplankton carbon in μg l^{-1}.

TABLE 3. PHOSPHATE UPTAKE RATES: ng-atm l^{-1} hr^{-1}*

Station	Date	Phosphate additions: μg-atm PO_4-P l^{-1} 0.00	0.25	0.50	2.00
1A	9/26/76	40.51	----------	79.40	79.40
7	9/26/76	43.48	----------	51.38	44.49
1A	1/13/76	53.17	----------	43.83	54.07
7	1/13/76	26.51	----------	32,20	27.69
1A	3/29/76	61.01	----------	67.43	69.79
7	3/29/76	25.60	----------	30.56	29.81
1A	6/10/76	86.11	101.87	118.34	125.63
7	6/10/76	44.47	42.52	41.09	43.17
1A	7/5/76	53.56	65.46	75.55	72.19
7	7/5/76	52.76	67.83	67.23	64.07

*Phosphate uptake rates were estimated from the slope of linear regressions of plankton phosphate uptake vs time. All R^2 were greater than 0.90.

TABLE 4. PHYTOPLANKTON SPECIES DATA*

	9/76	1/76	3/76	6/76	7/76
Amphiprora spp.	-- --	+- --	-- --	+- --	-- --
Bacillaria paxillifer	-- --	++ --	-- --	-- --	-- --
Bacteriastrum spp.	-- --	-- --	-- --	-- +-	-- --
Ceratium furca	-- --	-- --	-- --	-- +-	-- --
Chaetoceros lorenzianum	++ --	-- +-	-- --	-- --	-- --
Chaetoceros spp. 1	-- --	-- --	-- --	-- +-	-- ++
Chaetoceros spp. 2	-- --	-- --	-- --	-- ++	-- +-
Cocconeis disculodes	+- +-	+- --	-- +-	+- +-	+- +-
Coscinodiscus radiatus	+- +-	-- --	+- --	+- --	-- +-
Coscinodiscus spp.	-- --	-- --	-- --	-- +-	+- --
Cyclotella spp. 1	++ ++	-- --	-- --	++ ++	++ ++
Cyclotella spp. 2	++ ++	+- ++	++ ++	++ ++	++ ++
Gyrosigma spp. 1	+- --	+- --	+- +-	++ +-	++ +-
Gyrosigma spp. 2	-- --	-- --	-- --	+- --	+- --
Melosira granulata	-- --	-- ++	++ ++	-- --	-- --
Navicula spp. 1	+- +-	+- +-	+- +-	+- +-	+- +-
Navicula spp. 2	-- --	-- --	-- +-	-- --	-- --
Nitzschia closterium	+- --	+- +-	+- +-	+- +-	+- +-
Nitzschia paradoxa	-- --	-- --	-- --	-- +-	-- --
Rhizosolenia spp.	-- --	-- --	-- --	-- +-	-- --
Striatella spp.	-- --	-- --	-- --	-- +-	-- --
Surirella smithii	-- --	-- --	-- --	-- +-	-- --
Synedra fulgens	-- --	-- ++	+- +-	-- --	-- --
Thalasionema nitzschioides	+- +-	-- --	-- --	-- +-	+- --
Thalasionema spp.	-- --	-- --	-- --	+- --	+- +-

*Under each date the left column represents station 1A and the right column represents station 7. Species absent --; species present greater than 100,000/l +-; species present greater than 100,000/l ++.

phosphate limited conditions. However, when phosphate was not limiting, maximum uptake rates were obtained at lower phosphate concentrations. Similar observations have been cited in the literature (Perry, 1976).

The differences in the spatial responses of phytoplankton of the Apalachicola Bay-East Bay system to nutrient additions cannot be satisfactorily explained by species composition differences (Table 4). Phytoplankton species differences do occur between the two stations; however, the majority of the species are common to both areas. Spatial differences in nitrate enrichment responses may be due to the presence of other assimilitive forms of nitrogen, such as ammonium, nitrite, or urea. Differences in phosphate limitation between the two stations cannot be explained by concentration differences alone and may be due to suspended sediment and water column interactions.

Temporal differences in the response of phytoplankton to nutrient additions suggests that temperature limits phytoplankton productivity during colder months (Estabrook, 1973) and that nutrients limit productivity during the warmer seasons. The nutrient enrichment and phosphorus uptake experiments presented in this paper suggest that phosphorus is the most critical limiting nutrient in this estuarine system and that a reduction in phosphate level during summer months could reduce phytoplankton productivity.

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THE BIOTA OF THE APALACHICOLA BAY SYSTEM: FUNCTIONAL RELATIONSHIPS

Robert J. Livingston, Peter S. Sheridan, Bradford G. McLane,
F. Graham Lewis, III and Gerard G. Kobylinski
Florida State University

INTRODUCTION

Initiated in March 1972, this study is one of a series of publications concerning long-term fluctuations of biota in the Apalachicola Bay System. It has been used to apply biological information to management concepts and decisions. A literature survey of the system and basic overview of some of the upland development in the Apalachicola Drainage Area is available (Livingston et al., 1974b). The problems associated with the application of scientific data to administrative decisions of resource utilization has also been reviewed (Livingston, 1976a). More technical reports and papers have been concerned with methods of biomonitoring estuarine systems (Livingston, 1974; Livingston, 1977), fluctuations of populations (Livingston et al., 1976a) and communities (Livingston, 1976b) in Apalachicola Bay and behavioral responses of individuals and populations under laboratory and field conditions (Livingston et al., 1974a; Livingston et al., 1976b). Past studies have confirmed that the Apalachicola Bay System has a relatively high level of primary and secondary production, and that such production depends to a large degree on the Apalachicola River system, the largest of its kind in Florida. This unpolluted shallow coastal estuary is a river-forced, barrier island system that serves as a major source of sports and commercial fisheries in Florida. The purpose of this paper is to describe the Apalachicola Bay System as a natural resource, and to outline its basic biological components.

METHODS AND MATERIALS

Methods of data collection are described in detail (Livingston 1974, 1976b; Livingston et al., 1974b; Livingston et al., 1976a).

PHYSICOCHEMICAL PARAMETERS

Water samples (surface and bottom) were taken at fixed stations (Figure 1) with a 1-1 Kemmerer bottle. Temperature was measured with a stick thermometer and a YSI dissolved oxygen meter. Salinity was determined with a temperature-compensated refractometer calibrated periodically with standard sea water. Turbidity was analyzed with a Hach model 2100 A turbidimeter and water color was measured with an American Public Health Association Platinum-Cobalt standard test. River flow data were supplied by the U.S. Army Corps of Engineers (Mobile, Alabama) while local rainfall data were provided by the Environmental Data Service (NOAA, U.S. Department of Commerce). All information was examined and presented on a monthly basis.

BIOLOGICAL DATA

Various methods of collection have been used in this study. Repetitive (multiple) trawl-tows were taken on each station with 5 m (16 ft) otter trawls (3/4 in. mesh wing and body; 1/4 in. mesh liner) as described by Livingston (1976b). Beach seines were used in marsh areas (Little St. Marks River, Round Bay, East Bayou, West Bayou, St. George Island at Nick's Hole and at the Causeway). Larger fishes were taken in these areas with trammel nets (100 m; 1-1/2 in. mesh, 64 in. inside wall) at night. Small invertebrates were collected in detritus baskets (15 cm x 15 cm x 15 cm) constructed with plastic-coated wire mesh (25 mm^2) lined on the bottom and sides by fiber glass screening (1 mm^2). Measured quantities of leaves taken from upland areas were placed in these baskets and dropped at stations 1X, 3, and 5A (5 baskets at each station). Samples were taken at weekly intervals during the spring, summer, and fall of 1974. Organisms trapped in the screening were saved for analysis (Livingston, 1974). This program has been continued for a period of two years to determine spatial and temporal distribution of detritus-associated species. Benthic infauna was sampled using a hand operated corer (diam 7.7 cm) with 10 sub-samples taken monthly for two years at each fixed station in the bay. Samples were run (wet) through 500 μm sieves, and were stained with Rose Bengal for ease in rough sorting. Organisms were identified to species, counted, and weighed (ash-free dry weight). Collections in shallow grassbed areas of East Bay were also carried out (night and day) on a monthly basis from January, 1975 to December 1976. Multiple (6) subsamples were taken using a 20 in dredge net with a nylon bag (500 μm mesh) for bottom samples and a plankton net (500 μm mesh) for surface samples. All organisms taken from the various sampling ef-

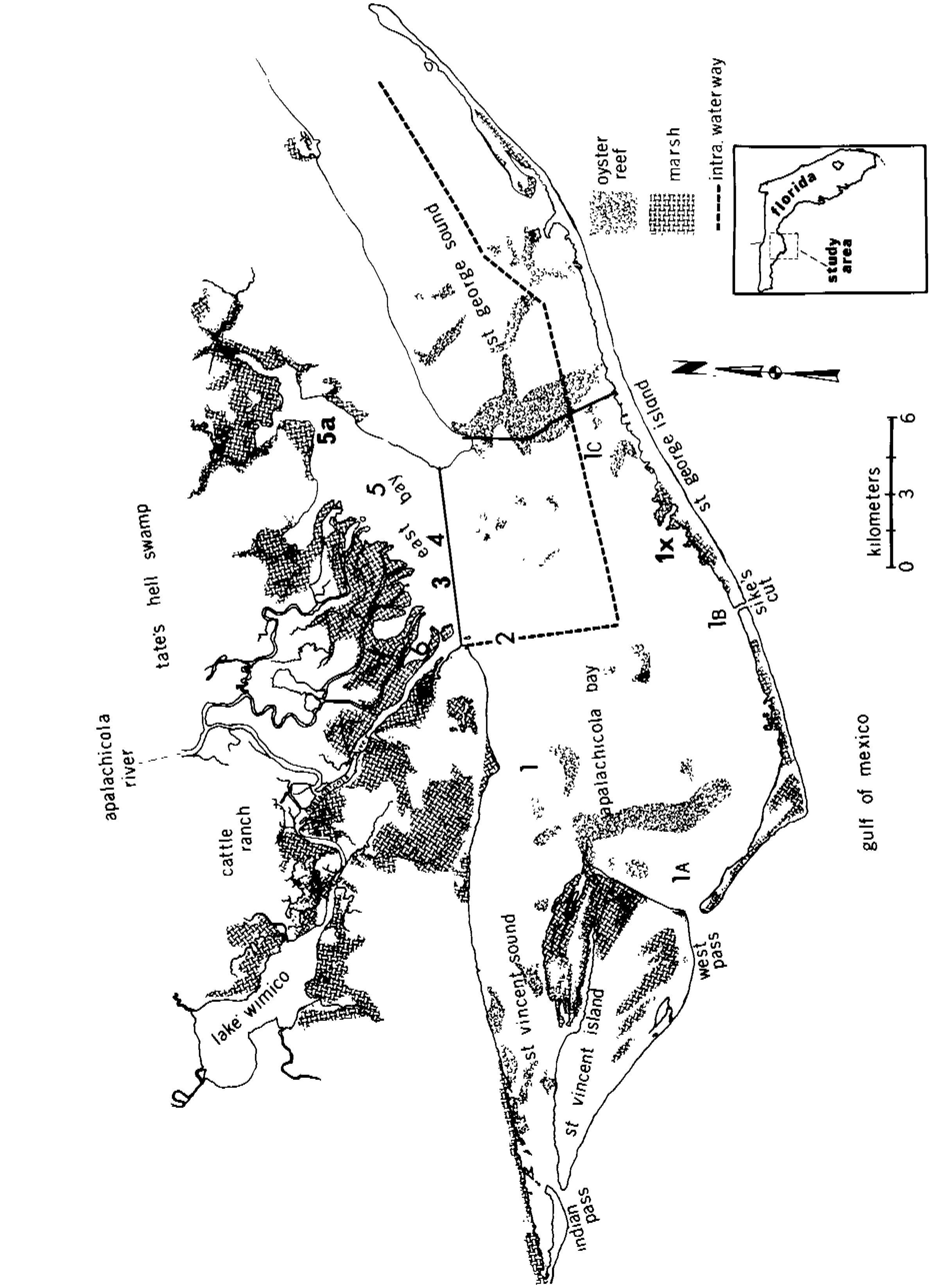

Figure 1. The Apalachicola Bay System showing distribution of oyster bars, marshes, and sampling stations for studies of R. J. Livingston and R. L. Iverson*.

forts were preserved in 10% formalin in the field. Invertebrates were then washed and transferred to 40% isopropyl alcohol prior to sorting, measuring, counting, and weighing. All data (physical, chemical, biological) were eventually compiled into a permanent file for analysis using an interactivè computer processing system (Livingston, and Woodsum, 1976). This project is a continuing one, and is designed to determine the basic functions of the Apalachicola Bay System.

RESULTS AND DISCUSSION

PHYSICOCHEMICAL RELATIONSHIPS

River flow and local precipitation patterns in the Apalachicola drainage area from February 1972 to March 1975 are shown in Figure 2. The dates indicate that there are regular seasonal and annual changes with high river flows usually occurring from December or January to April of each year. Annual variations occur also; there was major river flooding during the late winter and spring of 1973. The local rainfall patterns are almost completely out of phase with the river flow; major peaks of rainfall usually occur during the summer and early fall months (July - October) with minor peaks in the late winter (January - March). The salinity of the Bay was dependent on river flow (Figure 3) with upland stations (East Bay) having generally lower salinity than the outer stations. (Apalachicola Bay). The highest salinities were found at Sike's Cut although, even here, the influence of the Apalachicola River was evident. Color and turbidity levels generally followed the seasonal fluctuations of river flow (Figure 3). A principle-component analysis (run with 12 variables including tidal patterns, wind, river flow, rainfall, chlorophyll *a*, Secchi, turbidity, and temperature) indicated that river flow was inversely related to salinity and Secchi disk readings and directly related to color and turbidity thus showing that the Apalachicola River is a dominant factor in the determination of physical forcing functions in the Bay.

Water temperature showed regular seasonal changes with peaks in July and August and lowest levels during January and February. There was little vertical or station-to-station variability in water temperature at a given time (Figure 4); however, seasonally directed salinity stratification did occur at various stations. Dissolved oxygen was relatively uniform on a seasonal basis with lower levels usually found at depth during late summer periods. A survey of 24 h variations in dissolved oxygen at two stations in the bay over a 9 mo period (Livingston, 1974) indicated that there was no significant cultural eutrophication in the Apalachicola Bay System.

Overall, the data are consistent with a relatively unpolluted, river-forced estuary with considerable short and long-term variation in key physicochemical parameters which are related to regular (seasonal) fluctuations in river flow and local meteorological phenomena.

ACCUMULATION AND DISTRIBUTION OF MACRO-DETRITUS

Detritus accumulations at 11 stations in the Apalachicola estuary during an annual cycle (January - December, 1975) are shown in Figure 5. Several conclusions can be drawn from these data although it should be emphasized that due to the method of collection, such numbers are quite conservative and do *not*, in all probability, reflect the total amount of detritus in the Bay at any given time. The three major forms of macro-detritus (leaf litter, wood debris, and benthic macrophytes) are roughly comparable in terms of relative abundance. Peak levels of leaf detritus occurred during April and May while wood debris reached maximum levels during May. These accumulations were roughly correlated with increased river flow, although there was a secondary increase in the woody detritus during the subsequent fall period. After a slight increase in the spring, benthic macrophyte detritus peaked during the fall period. After extrapolation to the entire bay area, it was estimated that there was an annual total of thousands of tons (wet weight) of macro-detritus through river flow alone. This was matched by comparable levels of micro-detritus (47 μm - 2 mm) as shown by monthly sieve samples of the river. It is of interest that there was nearly twice as much allochthonous macro-detritus as authochthonous debris. This study will be continued through the spring of 1977. Upon completion, a detailed analysis will be performed to estimate the relative importance of such detritus to the overall productivity of the bay.

The qualitative and quantitative aspects of the spatial distribution of detritus in the bay are related to placement and proximity of river flow. Detritus in upland (oligohaline) portions of the bay (5A, 6) was characterized by benthic macrophytes such as *Ruppia* and *Vallisneria* with lesser amounts of wood and leaf litter. River dominated stations (2, 3, 4, 5) were largely characterized by wood debris and leaf detritus with lesser amounts of *Ruppia* and *Vallisneria* (benthic macrophytes showed an increase during the fall). Leaf matter was contributed by numerous species of terrestrial plants which are commonly found in upland river

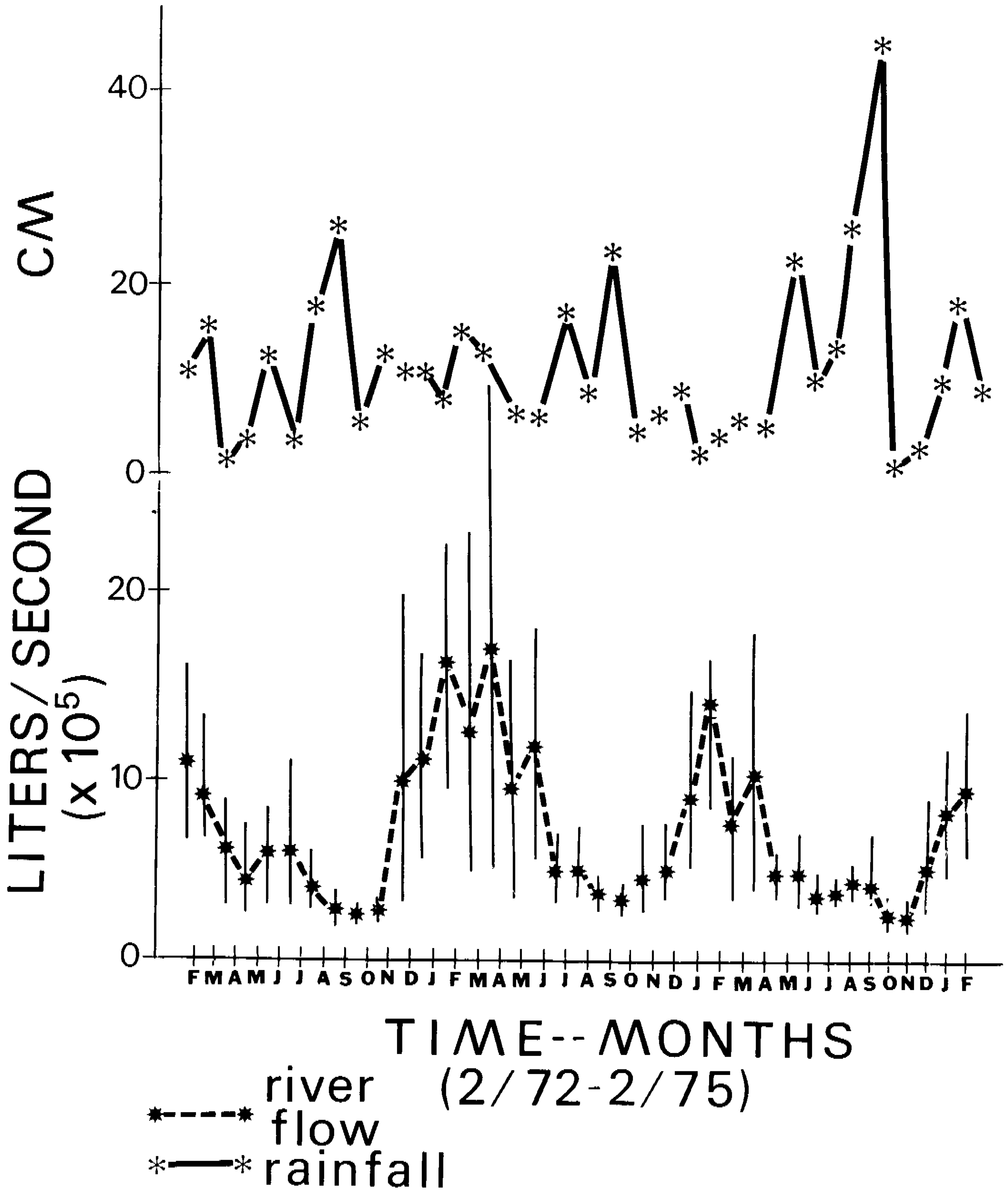

Figure 2. Long-term changes in local (Apalachicola) rainfall (totals by month) and river flow (Blountstown mean and range by month) from February 1972 through February 1975.

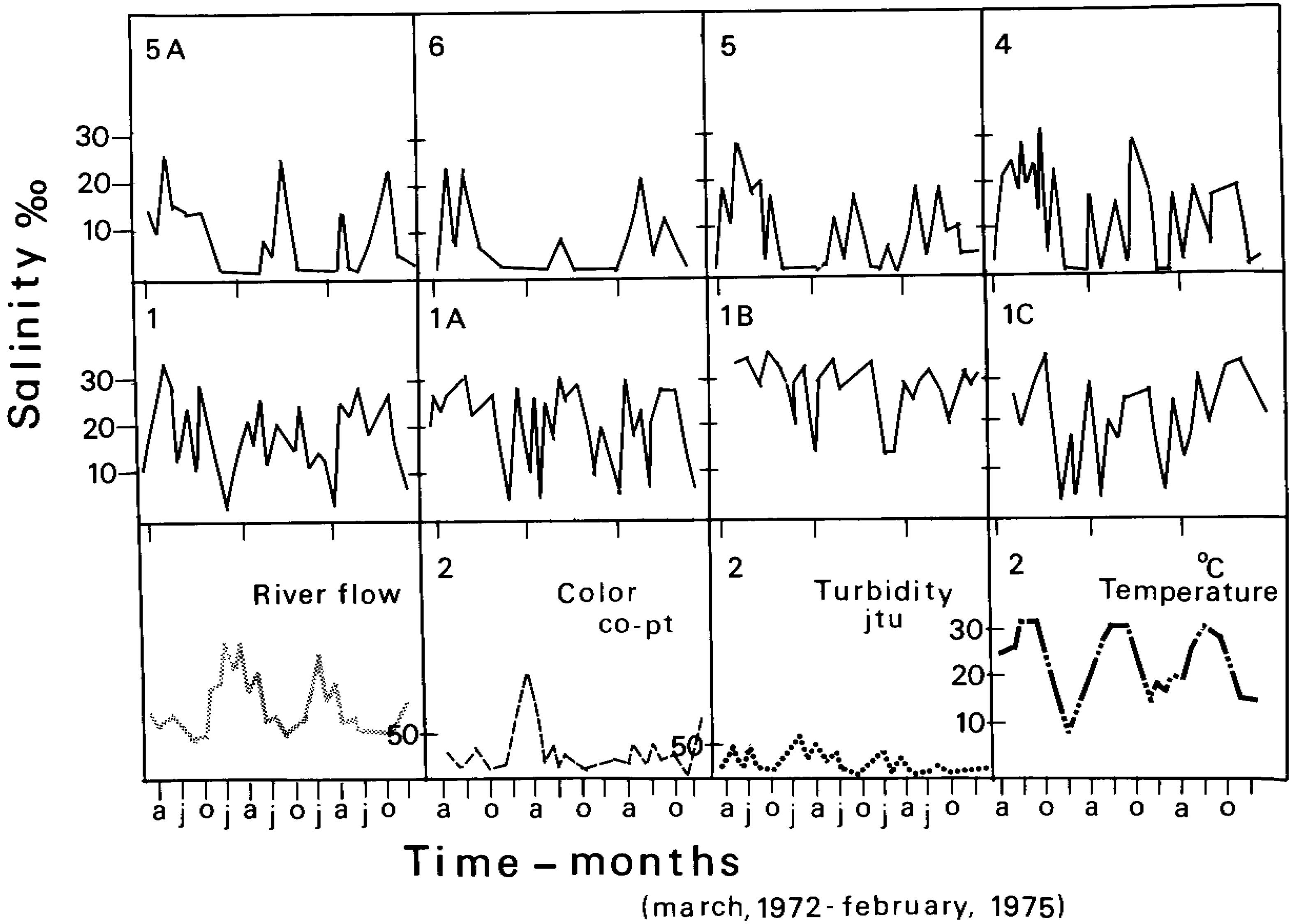

Figure 3. Changes in salinity, water temperature, color, and turbidity, at selected stations (bottom) in the Apalachicola Bay System from March 1972 through February 1975. A comparison can be made with fluctuations in Apalachicola River flow.

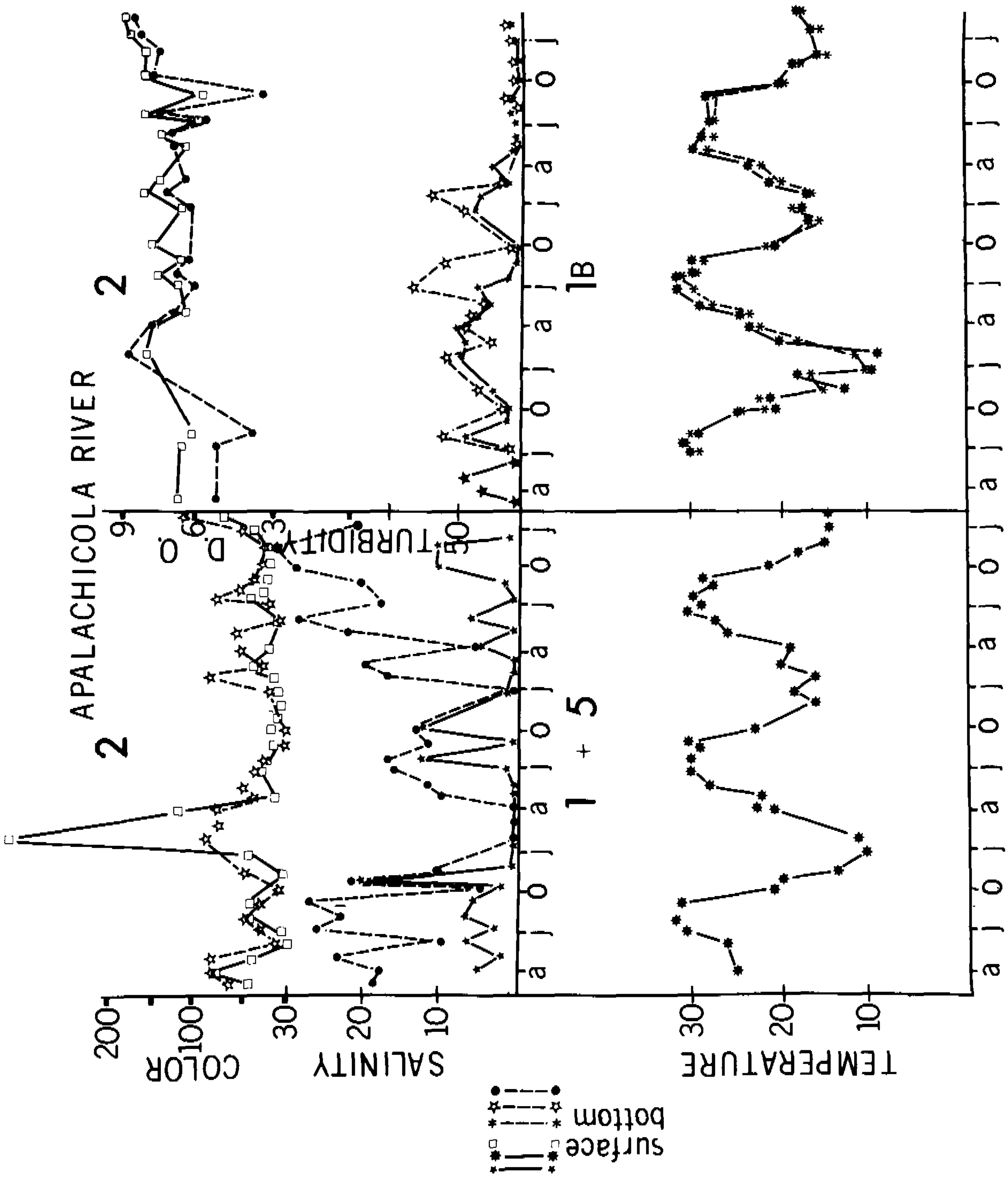

Figure 4. Variations (surface and bottom) of water temperature, salinity, color, and turbidity at stations in the Apalachicola Bay System from March 1972 through February 1975.

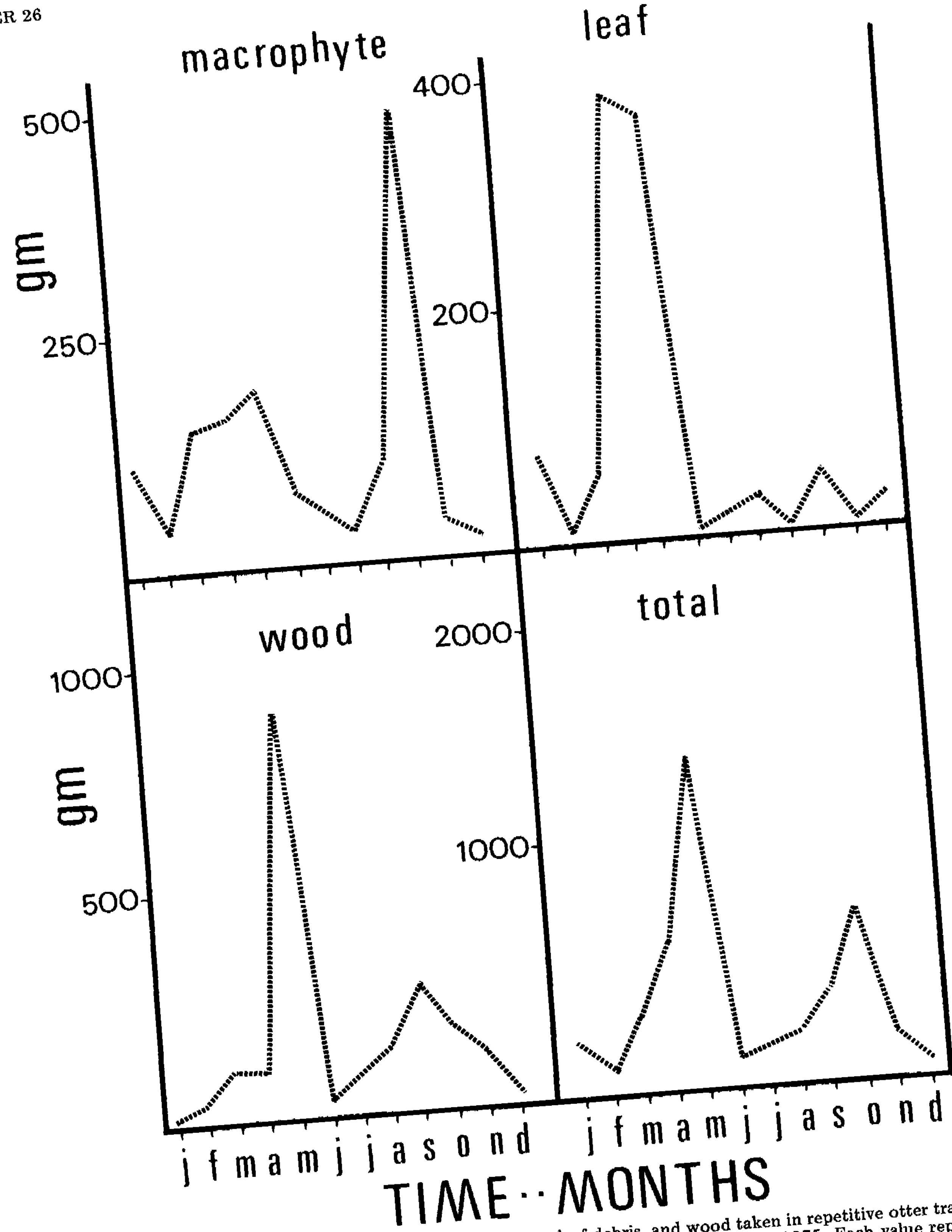

Figure 5. Changes (dry weight) in levels of benthic macrophytes, leaf debris, and wood taken in repetitive otter trawl samples at various stations in the Apalachicola Bay System from January 1975 through December 1975. Each value represents the total of mean levels per trawl tow for stations 1, 1A, 1B, 1C, 2, 3, 4, 5, 5A, and 6 (the equivalent of ten, 2-min trawl samples). Monthly changes in total debris are also shown, and are considered conservative (semi-quantitative) estimates due to the inexact method of data collection.

and swamp areas. Dominant forms included *Quercus nigra*, *Quercus lyrata*, *Liquidambar styraciflua*, and *Acer rubrum*. Benthic macrophyte debris was derived largely from *Ruppia maritima*, *Vallisneria americana*, and *Gracilaria* spp. Outer bay areas receiving river drainage (Stations 1, 1A, 1B) were characterized by wood debris, leaf litter, and benthic macrophytes in equal proportions. Outer bay stations not receiving direct river runoff (Stations 1C, 1E, 1X) were dominated by detritus of benthic macrophyte origin, notably *Gracilaria foliifera*, *Halodule wrightii*, and *Ulva lactuca*. Thus, the data indicate that various forms of detritus of terrestrial origin represent an important component of energy transfer into the Apalachicola Bay System, and areas directly associated with river runoff are typified by seasonally adjusted deposits of allochthonous leaf litter and wood debris which could serve as an important source of food for micro-organisms and detritovores. The timing of blue crab migrations could be directly related to this phenomenon (Oesterling and Evink, 1977).

BENTHIC INFAUNA AND DETRITUS ASSOCIATED ORGANISMS

The invertebrate fauna taken by coring, recovery of detritus baskets, and repetitive sampling with dredge nets in grass beds of East Bay is listed in Table 1. Many of these species serve as food for animals at higher trophic levels in the bay. The collection of such animals has been designed to determine seasonal variation of such assemblages at the population and community level to test the use of such elements for impact analysis. This will eventually allow an evaluation of trophodynamic interactions in the Apalachicola Bay System. Detailed reports and papers on this subject are presently in preparation.

LEAF LITTER ASSOCIATIONS

For the past three years, studies have been carried out with detritus associated organisms in the Apalachicola estuary. The importance of detritus to estuarine systems has been well established by Darnell (1958). Representative assemblages of organisms associated with mixtures of leaf litter (water oak, *Quercus nigra;* over-cup, *Q. lyrata;* red maple, *Acer rubrum;* and sweet gum, *Liquidambar styraciflua)* at different seasons of the year are shown in Table 2. In every case, there was a significant difference in terms of numbers of species and individuals between the empty baskets and those containing leaf litter. The litter fauna is primarily composed of isopods, amphipods and decapods. Dominant species, which appeared to vary on a seasonal basis, included *Melita* sp., *Gammarus mucronatus*, *Grandidierella bonnieroides*, *Gitanopsis* sp., *Neritina reclivata*, *Munna reynoldsi*, and *Corophium louisianium*. There were general increases in the numbers of individuals and species with increased salinity. These organisms appear to utilize such detritus as a substrate for shelter and/or food. Various studies have indicated that such species often depend on microbial components of detritus for food (Adams and Angelovic, 1970; Fenchel, 1970; Kaushik and Hynes, 1971; Odum and Heald, 1972). However, the actual details of the trophodynamic relationships of detritus-based systems are little known. The leaf litter associations are composed of omnivores and detritovores which ultimately become directly or indirectly available to higher trophic levels. The relative significance of autochthonous and allochthonous detritus in the overall energy budget of the Apalachicola Bay System is still in question. The ultimate importance of detritus in this estuary is indicated by the major associations of detritus-associated organisms found here. It would follow that any alteration, natural or unnatural, which would affect the availability of detritus in this bay would affect the productivity of this system.

INFAUNA AND EPIFAUNA TAKEN BY CORES

Leptochelia rapax (Crustacea, Tanaidacea)

This crustacean was the most abundant invertebrate taken from infaunal samples in Apalachicola Bay. It was almost entirely restricted to the *Halodule wrightii* beds on the inner side of St. George Island where it builds tubes on the substrate or attached to seagrass blades. In this area, the salinity ranged from 6.3 - 26.8 $^{0}/_{00}$ and the water temperature ranged from 11.5 - 32.5° C. Peak abundances were noted in the spring (February - April) with lowest numbers found in September. Tanaidaceans in general are hermaphroditic (Barnes, 1968); ovigerous females were noted throughout the year, being most abundant in the spring, as were individuals showing male characteristics. *Leptochelia* apparently feeds on fine detrital matter, sand, and benthic diatoms, and is preyed upon by small carnivorous fishes (Odum and Heald, 1972).

Grandidierella bonnieroides (Crustacea, Amphipoda)

This species was the second most abundant organism taken in the core samples. It ranged from the *Halodule* beds on the inner side of St. George Island up into the freshwater areas of East Bay, where it was most abundant. It was found in salinities of 0-26.8 $^{0}/_{00}$ and water temperatures of 6.0 -

TABLE 1. INVERTEBRATES TAKEN IN CORES, LEAFBASKET SAMPLES, AND DREDGE-NETS IN THE APALACHICOLA BAY SYSTEM (1975-1976).

Pelecypoda	
Tagelus plebeius	*Crassostrea virginica*
Amygdalum papyria	*Pseudocyrena floridana*
Ensis minor	*Mactra fragilis*
Tellina texana	*Macoma mitchelli*
Dosinia elegans	*Spisula solidissima*
Mulinia lateralis	*Congeria leucophaeta*
Rangia cuneata	*Abra aedualis*
Gastropoda	
Odostomia laevigata	*Prunum apicinum*
Odostomia bisuturalis	*Mitrella lunata*
Mangelia sp.	*Bittium varium*
Retusa canaliculata	*Neritina reclivata*
Anachis avara	*Epitonium rupicola*
Littoridina sphinctostoma	*Credpidula plana*
Polychaeta	
Sedentaria	
Amphicteis gunneri floridus	*Arenicola cristata*
Polydora ligni	*Melinna maculata*
Streblospio benedicti	*Aricidea fragilis*
Paraprionospio pinnata	*Magelona polydentata*
Mediomastus californiensis	*Diopatra cuprea*
Capitella capitata	*Fabricia* sp.
Heteromastus filiformis	*Spiophanes bombyx*
Capitellides jonesi	*Onuphis* sp.
Prionospio heterobranchia	
Errantia	
Glycinde solitaria	*Haploscoloplos fragilis*
Loandalia americana	*Eteone heteropoda*
Laeonereis culveri	*Scoloplos rubra*
Sigambra bassi	*Amphinome rostrata*
Neanthes succinea	*Marphysa sanguinea*
Phyllodoce fragilis	*Podarke* sp.
Polyodontes lupina	
Ancistrosyllis sp.	
Oligochaeta	
sp. 1 sp. 2	
Arthropoda	
Branchiura	
Argulus sp.	
Mysidacea	
Taphromysis bowmani	*Mysidopsis bigelowi*
Bowmaniella dissimilis	*Mysidopsis almyra*
Mysidopsis bahia	*Mysidopsis* sp. 4 & sp. 5
Taphromysis louisianae	
Cumacea	
sp. 1 sp. 2 sp. 3	

Tanaidacea	
Leptochelia rapax	
Tanaid No. 2	
Isopoda	
Sphaeroma quadridentatum	*Edotea montosa*
Sphaeroma terebrans	*Xenanthura brevitelson*
Cyathura polita	*Munna reynoldsi*
Erichsonella filiformis	*Cassidinidea ovalis*
Amphipoda	
Gammarus mucronatus	*Grandidierella bonnieroides*
Gammarus n. sp. 1 (*G.* "*macromucronatus*")	*Ampelisca vadorum*
	Ampelisca verrilli
Gammarus n. sp. 2	*Carinobatea* sp.
Melita appendiculata	*Cymadusa compta*
Melita nitida	*Gitanopsis* n. sp.
Melita n. sp. 1 (M. "*elongata*")	*Paracaprella tenuis*
Melita n. sp. 2 (M. "*intermedia*")	*Microprotopus* n. sp.
Melita n. sp. 3 (M. "*longisetosa*")	*Parametopella cypris*
Cerapus n. sp.	*Orchestia uhleri*
Corophium louisianum	
Batea catharinensis	
Turbellaria	
sp. 1 (?)	
Rhynchocoela	
sp. 1 (?)	
Aschelminthes	
Nematode No. 1	
Phoronida	
Phoronis architecta	
Insecta (italics if genus known)	
Anisopteran No. 1	
Anisopteran No. 2	
Caenis sp.	
Callibaetis sp.	
Ceratopogonid No. 1	
Chironomid No. 2	
Corixid No. 1	
Dicrontendipes sp.	
Dipteran No. 1 (non-aquatic)	
Nymphula sp.	
Zygopteran No. 1	

32.5° C. Abundance peaks were noted in early spring (March) and late summer (August), with lowest numbers during early summer (May) and intermediate abundances in winter months. Ovigerous females were collected from November through April. *Grandidierella* feeds upon very fine detrital matter and is in turn consumed by small carnivorous fishes (Odum and Heald, 1972).

Heteromastus filiformis (Polychaeta, Sedentaria)

This polychaete ranked third in the bay in terms of overall abundance of numbers even though it was largely restricted to grass beds (dominated by *Halodule wrightii)* just inside St. George Island (IX). Peak abundance was noted in April with low numbers taken during October and November,

TABLE 2. TOTAL NUMBERS OF LEAF-LITTER ASSOCIATED ORGANISMS TAKEN AT 3 STATIONS IN APALACHICOLA BAY DURING THE SPRING, SUMMER, AND FALL OF 1974.

Station 5A	with leaves	without leaves
SPRING		
Invertebrates		
Neritina reclivata	882	152
Palaemonetes pugio	263	73
Corophium louisianum	242	5
Gammarus sp. (2)	218	10
Gammarus mucronatus	130	
Grandiderella bonnieroides	107	
Rhithropanopeus harrisii	98	8
Callinectes sapidus	54	11
Melita sp.	37	
Cerapus sp.	15	3
Munna reynoldsi	7	
Cassidinidea ovalis	3	
Leptochelia rapax	3	
Fishes		
Bairdiella chrysura	21	6
Brevoortia patronus	1	
Syngnathus scovelli		1
SUMMER		
Invertebrates		
Corophium louisianum	601	45
Taphromysis bowmani	339	2
Grandiderella bonnieroides	246	2
Neritina reclivata	186	30
Melita sp.	71	
Gammarus mucronatus	29	1
Callinectes sapidus	22	2
Munna reynoldsi	20	3
Penaeus setiferus	18	3
Gammarus sp. (2)	16	
Palaemonetes pugio	15	1
Rhithropanopeus harrisii	7	
Cerapus sp.	7	1
Gitanopsis sp.	7	
Edotea montosa	5	
Cassidindea ovalis	4	
Sphaeroma terebrans	1	
Fishes		
Gobiosoma bosci	42	9
Bairdiella chrysura	17	2
Syngnathus floridae	2	
FALL		
Invertebrates		
Grandiderella bonnieroides	14	
Gammarus mucronatus	1,379	67
Munna reynoldsi	1,281	46
Gitanopsis sp.	1,128	59
Polydora ligni	948	263
Melita sp.	919	25
Corophium louisianum	308	11
Cassidinidea ovalis	100	8
Neanthes succinea	78	5
Callinectes sapidus	39	4
Neritina reclivata	39	8

TABLE 2. TOTAL NUMBERS OF LEAF-LITTER ASSOCIATED ORGANISMS TAKEN AT 3 STATIONS IN APALACHICOLA BAY DURING THE SPRING, SUMMER, AND FALL OF 1974. (CONTINUED)

Station 5A	FALL with leaves	FALL without leaves
Palaemonetes vulgaris	24	8
Edotea montosa	13	
Cerapus sp.	12	
Rhithropanopeus harrisii	11	1
Melita appendiculata	5	
Cymodusa compta	2	
Ampelisca vadorum	2	1
Nemerteans	2	
Sphaeroma quadridentatum	1	
Penaeus duorarum	1	
Parametopella cypris	1	
Paranaites speciosa	1	
Mysidopsis bigelowi	1	3
Fishes		
Gobiosoma bosci	12	5

Station 3 — Invertebrates	SPRING with leaves	SPRING without leaves
Melita sp.	2,068	82
Munna reynoldsi	1,400	126
Gammarus sp. (2)	788	89
Cerapus sp.	382	118
Grandiderella bonnieroides	335	81
Palaemonetes pugio	306	91
Rhithropanopeus harrisii	295	14
Corophium louisianum	292	90
Cassidinidea ovalis	99	11
Xanthid juveniles	70	
Neritina reclivata	56	6
Palaemonid juveniles	33	6
Gammarus mucronatus	23	
Edotea montosa	10	1
Callinectes sapidus	10	
Sphaeroma terebrans	2	
Fishes		
Gobiosoma bosci	45	10
Ictalurus catus	4	
Lagodon rhomboides	1	
Bathygobius soporator	1	

Invertebrates	SUMMER with leaves	SUMMER without leaves
Munna reynoldsi	3,137	23
Grandiderella bonnieroides	1,725	26
Melita sp.	1,471	15
Gitanopsis sp.	1,460	4
Corophium louisianum	632	10
Cassidinidea ovalis	380	7
Gammarus mucronatus	290	18
Palaemonetes pugio	130	
Palaemonetes vulgaris	90	49
Gammarus sp. (2)	84	2
Callinectes sapidus	40	6
Edotea montosa	24	
Neritina reclivata	18	3

TABLE 2. TOTAL NUMBERS OF LEAF-LITTER ASSOCIATED ORGANISMS TAKEN AT 3 STATIONS IN APALACHICOLA BAY DURING THE SPRING, SUMMER, AND FALL OF 1974. (CONTINUED)

Station 3	SUMMER with leaves	without leaves
Penaeus setiferus	8	
Cerapus sp.	7	
Rhithropanopeus harrisii	4	
Sphaeroma terebrans	2	
Xanthid juveniles	2	6
Penaeus aztecus	1	
Argulus sp.	1	
Fishes		
Bairdiella chrysura	56	
Gobiosoma bosci	29	4
Gobiosoma robustum	4	
Orthopristis chrysoptera	1	

FALL — Invertebrates	with leaves	without leaves
Gammarus mucronatus	1,897	160
Gitanopsis sp.	1,346	51
Corophium louisianum	812	11
Grandiderella bonnieroides	529	23
Munna reynoldsi	375	18
Cassidinidea ovalis	253	11
Melita sp.	173	2
Bittium varium	112	5
Neanthes succinea	34	2
Palaemonetes vulgaris	23	1
Callinectes sapidus	18	2
Cerapus sp.	18	
Neritina reclivata	14	
Leptochelia rapax	6	
Polydora ligni	2	
Edotea montosa	2	
Rhithropanopeus harrisii	1	
Amphicteis gunneri	1	
Nemerteans	1	
Palaemonetes pugio		1
Fishes		
Gobiosoma bosci	3	
Lutjanus griseus	1	

Station IX — SPRING — Invertebrates	with leaves	without leaves
Gammarus mucronatus	9,982	82
Melita sp.	2,504	24
Grandiderella bonnieroides	1,961	79
Corophium louisianum	608	82
Cassidinidea ovalus	308	5
Xanthid juveniles	224	3
Leptochelia rapax	148	
Palaemonetes vulgaris	125	
Gitanopsis sp.	104	2
Nemerteans	41	
Edotea montosa	38	4
Erichsonella filiformis	37	
Ampelisca vadorum	37	5
Neanthes succinea	35	4

TABLE 2. TOTAL NUMBERS OF LEAF-LITTER ASSOCIATED ORGANISMS TAKEN AT 3 STATIONS IN APALACHICOLA BAY DURING THE SPRING, SUMMER, AND FALL OF 1974. (CONTINUED)

Station IX

SPRING

	with leaves	without leaves
Cymodusa compta	15	3
Neopanope texana	10	
Sphaeroma quadridentatum	8	
Callinectes sapidus	5	
Hoploscoloplos fragilis	3	2
Penaeus duorarum	1	
Alpheus heterochaelis	1	
Rhithropanopeus harrisii	1	
Cerapus sp.	1	
Taphromysis bowmani		1
Leptochelia rapax		105
Fishes		
Opsanus beta	1	
Lagodon rhomboides	1	
Strongylura marina	1	1

SUMMER

Invertebrates	with leaves	without leaves
Melita sp.	6,017	27
Grandiderella bonnieroides	2,569	149
Gitanopsis sp.	424	1
Cassidinidea ovalis	314	7
Cymadusa compta	219	17
Nemerteans	101	12
Xanthid juveniles	93	
Gammarus mucronatus	92	19
Palaemonetes vulgaris	82	7
Edotea montosa	22	3
Callinectes sapidus	17	4
Palaemonid juveniles	16	1
Leptochelia rapax	14	4
Taphromysis bowmani	13	3
Neopanope texana	12	1
Corophium louisianum	5	1
Erichsonella filiformis	3	
Penaeus duorarum	3	
Palaemonetes pugio	2	1
Clibanarius vittatus	1	2
Neritina reclivata	1	1
Nudibranch species	1	
Fishes		
Gobiosoma bosci	7	
Fundulus grandis	3	
Opsanus beta	2	
Lutjanus griseus		1

FALL

Invertebrates	with leaves	without leaves
Melita sp.	1,662	32
Gammarus mucronatus	904	16
Cymodusa sp.	605	40
Grandiderella bonnieroides	417	26
Cassidinidea ovalis	255	14
Neanthes succinea	198	35
Gitanopsis sp.	152	

TABLE 2. TOTAL NUMBERS OF LEAF-LITTER ASSOCIATED ORGANISMS TAKEN AT 3 STATIONS IN APALACHICOLA BAY DURING THE SPRING, SUMMER, AND FALL OF 1974. (CONTINUED)

Station IX	FALL with leaves	FALL without leaves
Podarke sp.	151	
Palaemonetes vulgaris	114	15
Nemerteans	59	
Crepidula plana	43	
Leptochelia rapax	38	
Bittium varium	27	5
Corophium louisianum	19	1
Hoploscoloplos fragilis	18	2
Erichsonella filiformis	13	
Fabricia sp.	8	
Anachis avara	7	2
Neopanope texana	7	
Edotea montosa	6	
Neritina reclivata	5	
Polydora ligni	5	7
Taphromysis bowmani	5	5
Clymenella sp.	4	
Paranoites speciosa	2	
Penaeus duorarum	2	
Callinectes sapidus	2	1
Paracaprella tenuis	1	
Penaeus aztecus	1	
Streblospio benedicti		1

corroborating the findings of Santos and Simon (1974). This species was collected over a range of salinities from 6.3 - 26.8 $^0/_{00}$ and temperatures from 11.5 - 32.5°C.

Mediomastus californiensis (Polychaeta, Sedentaria)

As the fourth most prevalent species of infauna, this polychaete was found in fine mud bottoms throughout the bay, ranging in length from 20 to 40 mm. It occurred in salinities from 0 - 18.8 $^0/_{00}$ and temperatures from 6 - 31° C. Peak abundance occurred in March with lows in the summer (July - August).

Ampelisca vadorum (Crustacea, Amphipoda)

Ampelisca vadorum was the fifth most abundant organism collected. It was almost entirely restricted to the St. George grass flats, where it builds weak tubes on (or slightly within) the substrate. This crustacean was found to be nocturnally active. It was found at salinities of 6.3 - 26.8 $^0/_{00}$ and water temperatures of 11.5 - 32.5° C. Peak abundance was noted in the spring (February) with a minor peak in early fall (October). Ovigerous females were noted in all months of the year (except August), with a peak in February. This organism is probably omnivorous, feeding mainly on detrital particles: it is preyed upon by small carnivorous and (at night) planktivorous fishes.

Streblospio benedicti (Polychaeta, Sedentaria)

This species of polychate was the sixth most abundant form of benthic infauna in the bay. This worm was found in a variety of habitats in the Apalachicola Bay System including *Halodule* beds on the bay side of St. George Island and fine mud flats in East Bay. Ranging from 10 to 20 mm in length, this species secretes a thin membranous tube in salinities from 0 - 26.5 $^0/_{00}$ and temperatures from 6 - 32° C.

Amphicteis gunneri floridus (Polychaeta, Sedentaria)

As the seventh most abundant form of benthic invertebrate in the Apalachicola estuary, this polychaete was found throughout the bay from the grassbeds of St. George Island to oligohaline mud flats in East Bay. It was found in salinities ranging from 0 - 26.8 $^0/_{00}$ and temperatures from 6 - 32.5° C. Peak abundance was noted in September with low numbers observed in the summer (May - August).

Oligochaete *sp.* 2

This unidentified oligochaete was found to be the eighth most abundant form of infauna in the Bay, and was restricted to a *Halodule* bed on the inside of St. George Island. It ranges from 20 to 40 mm in length. Salinity in this area varies from 6.3 to 26.8 $^{0}/_{oo}$ and temperatures range from 11.5 - 32.5^{O} C. Peak numbers occurred in winter and early spring with low numbers in August and September.

Aricidea fragilis (Polychaeta, Sedentaria)

This polychaete species was the ninth most prevalent form of benthic infauna and was largely restricted to the St. George Island *Halodule* grass beds. It ranges from 10 to 20 mm in length and was found in salinities from 6.3-26.8 $^{0}/_{oo}$ and temperatures from 11.5 - 32.5^{O} C. Peak numbers occurred in April with low numbers taken during the fall (September - October).

Dicrontendipes sp. (Insecta, Diptera)

Dicrontendipes was the tenth most abundant species collected. It was mainly found in oligohaline marsh embayments in East Bay in salinities of 0 - 10 $^{0}/_{oo}$ and temperatures of 6 - 31^{O} C. Peak abundance was noted in late fall and winter (November - February). Chironomid larvae are generally herbivorous, feeding upon submerged plants, algae, and detritus, and being consumed by predatory invertebrates and fishes (Odum and Heald, 1972).

Cerapus sp. (Crustacea, Amphipoda)

Cerapus sp., apparently an undescribed species (E. L. Bousfield, personal communication), was the eleventh most abundant organism collected. *Cerapus* builds tubes attached to the substrate and often forms large colonies. It is also known to detach a small portion of the tube and enter the plankton of Apalachicola Bay (H. Lee Edmiston, personal communication). It was mainly found in riverine and oligohaline marsh embayments in East Bay at salinities of 0 - 10 $^{0}/_{oo}$ and temperatures of 10 - 30^{O} C. Peak abundances were noted in late spring and summer months. Ovigerous females were noted in May through July. Although its food habits are unknown, *Cerapus* sp. may utilize its long antennae, which are abundantly covered by setae, either to filter the water column or scrape the surface of the substrate. Both small carnivorous fishes (*Gobiosoma bosci*) and planktivorous fishes (*Anchoa mitchilli*) are known to feed upon *Cerapus* in Apalachicola Bay.

In general the polychaetes mentioned above were largely eurythermal and euryhaline species, and were composed primarily of selective and non-selective deposit feeders. These species are usually preyed upon by predacious polychaetes, crustaceans, and benthic fishes.

EPIBENTHIC FISHES AND INVERTEBRATES

Fishes and invertebrates taken with otter trawls in the Apalachicola Bay System are shown in Table 3. Both groups were represented by high dominance, with relatively few species accounting for a considerable proportion of the numbers of organisms in the bay. The top three species of each group accounted for over 80% of the total. As shown above, the Apalachicola River causes regular seasonal variations in key environmental parameters such as salinity, turbidity, color, and detritus levels. The estuarine biota is generally synchronized with these and other functions in such a way that there is a progression of dominants occurring in an orderly way through a given annual cycle. Species-specific phase relationships are regular even though no single set of physical parameters can account for the succession. Among fishes, *Anchoa mitchilli* becomes dominant in the fall while *Micropogon undulatus* and *Leiostomus xanthurus* prevail during late winter and spring months. During the late spring and summer months *Cynoscion arenarius* predominates. Among invertebrates, blue crabs (*Callinectes sapidus*) are dominant during winter months, grass shrimp (*Palaemonetes pugio*) are in abundance during the spring, and penaeid shrimp (largely the white shrimp, *Penaeus setiferus*) are dominant during the summer and fall. When viewed in terms of community composition, Livingston (1976b) found regular seasonal fluctuations of various richness and diversity indices with peaks for fishes and invertebrates usually occurring during summer and fall periods. The community changes were comparable to those found in other areas (Dahlberg and Odum, 1970; Copeland and Bechtel, 1971). Such biological functions were viewed as part of a relatively well timed biological system which was synchronized with Apalachicola River flow, patterns of productivity and microhabitat variability, and other less predictable phenomena such as predation, inter- and intra-specific competition, reproduction, and trophic relationships.

Fishes taken by seines and trammel nets at various locations in the Apalachicola Bay System are given in Tables 4 and 5. The species lists are largely indicative of habitat characteristics with an obvious relationship to salinity levels in the various sub-systems. These data, together with the trawl information, have been compared with (published) background information concerning the dominant species in other portions of the Gulf of Mexico (Table 6). Although minor variations were evident (notably among the fishes), the appearance of dominants in the Apalachicola Estuary was consistent with previously recorded data from other coastal systems in the northern Gulf of Mexico.

TABLE 3. FISHES AND INVERTEBRATES TAKEN IN THE APALACHICOLA BAY SYSTEM FROM MARCH 1972 TO MARCH 1975. SPECIES ARE RANKED BY ABUNDANCE (NUMBERS OF INDIVIDUALS).

FISHES

1	*Anchoa mitchilli*				
2	*Micropogon undulatus*	28	*Chaetodipterus faber*	54	*Astroscopus y-graecum*
3	*Cynoscion arenarius*	29	*Orthopristis chrysoptera*	55	*Hippocampus erectus*
4	*Polydactylus octonemus*	30	*Brevoortia patronus*	56	*Lepisosteus osseus*
5	*Arius felis*	31	*Dorosoma petenense*	57	*Lucania parva*
6	*Leiostomus xanthurus*	32	*Peprilus burti*	58	*Lutjanus griseus*
7	*Chloroscombrus chrysurus*	33	*Peprilus paru*	59	*Opsanus beta*
8	*Menticirrhus americanus*	34	*Monacanthus hispidus*	60	*Paralichthys albigutta*
9	*Symphurus plagiusa*	35	*Sphoeroides nephelus*	61	*Ophidion beani*
10	*Bairdiella chrysura*	36	*Ophichthus gomesi*	62	*Aluterus schoepfi*
11	*Etropus crossotus*	37	*Syngnathus louisianae*	63	*Diplodus holbrooki*
12	*Trinectes maculatus*	38	*Syngnathus scovelli*	64	*Gobionellus hastatus*
13	*Prionotus tribulus*	39	*Gobionellus boleosoma*	65	*Hypsoblennius hentzi*
14	*Stellifer lanceolatus*	40	*Harengula pensacolae*	66	*Menticirrhus saxatilis*
15	*Anchoa hepsetus*	41	*Archosargus probatocephalus*	67	*Myrophis punctatus*
16	*Porichthys porosissimus*	42	*Microgobius gulosus*	68	*Ogilbia cayorum*
17	*Prionotus scitulus*	43	*Bagre marinus*	69	*Oligoplites saurus*
18	*Eucinostomus gula*	44	*Menidia beryllina*	70	*Pomatomus saltatrix*
19	*Paralichthys lethostigma*	45	*Monacanthus ciliatus*	71	*Rhinoptera bonasus*
20	*Synodus foetens*	46	*Caranx hippos*	72	*Scomberomorus maculatus*
21	*Eucinostomus argenteus*	47	*Centropristis melana*	73	*Selene vomer*
22	*Dasyatis sabina*	48	*Syngnathus floridae*	74	*Sphyraena borealis*
23	*Cynoscion nebulosus*	49	*Ancyclopsetta quadrocellata*	75	*Sphyrna tiburo*
24	*Microgobius thalassinus*	50	*Chilomycterus schoepfi*	76	*Sardinella anchovia*
25	*Urophycis floridanus*	51	*Diplectrum formosum*	77	*Caranx bartholomaei*
26	*Lagodon rhomboides*	52	*Ictalurus catus*	78	*Mugil* sp.
27	*Gobiosoma bosci*	53	*Sciaenops ocellata*	79	*Gymnura micrura*

INVERTEBRATES

1	*Penaeus setiferus*				
2	*Callinectes sapidus*	23	*Menippe mercenaria*	44	*Busycon spiratum*
3	*Palaemonetes pugio*	24	*Xiphopeneus kroyeri*	45	*Procabarus paeninsulanus*
4	*Penaeus duorarum*	25	*Alpheus heterochaelis*	46	*Eupleura sulcidentata*
5	*Trachypenaeus constrictus*	26	*Latreutes parvulus*	47	*Hemipholus elongata*
6	*Chrysaora quinquecirrha*	27	*Palaemonetes intermedius*	48	*Alpheus normanni*
7	*Lolliguncula brevis*	28	*Metoporhaphis calcarata*	49	*Eurypanopeus depressus*
8	*Penaeus aztecus*	29	*Crassostrea virginica*	50	*Lysmata wurdemanni*
9	*Palaemonetes vulgaris*	30	*Palaemon floridanus*	51	*Pentacta* sp.
10	*Portunus gibbesii*	31	*Periclimenes longicaudatus*	52	*Petrolisthes armatus*
11	*Stomlophus meleagris*	32	*Ogyrides limicola*	53	*Podochela riisei*
12	*Neritina reclivata*	33	*Trachypenaeus similis*	54	*Tozeuma carolinense*
13	*Squilla empusa*	34	*Busycon contrarium*	55	Nudibranch sp.
14	*Callinectes similis*	35	*Branchiosychis americana*	56	*Alpheus armillatus*
15	*Rhithropanopeus harrisii*	36	*Brachiodontes exustus*	57	*Sesarma cinereum*
16	*Neopanope texana*	37	*Hexapanopeus angustifrons*	58	*Sicyonia dorsalis*
17	*Pollinices duplicatus*	38	*Luidia clathrata*	59	*Anadara brasiliana*
18	*Neopanope packardii*	39	*Persephona mediterranea*	60	*Dinocardium robustum*
19	*Mulinia lateralis*	40	*Clibanarius vittatus*	61	*Cantharus cancellaria*
20	*Acetes americanus*	41	*Libinia dubia*	62	*Urosalpinx perrugata*
21	*Pagurus pollicaris*	42	*Periclimenes americanus*	63	*Ovalipes guadulpensis*
22	*Rangia cuneata*	43	*Ambidexter symmetricus*	64	*Pagurus longicarpus*

While the timing of individual populations was essentially stable from year to year, there was considerable within-species variability in terms of annual abundance. The bay anchovy (*Anchoa mitchilli*) was particularly abundant during the first year of sampling; this is presently under investigation with respect to causal relationships. The Atlantic bumper (*Chloroscombrus chrysurus*), although not considered a common gulf species (Perret and Caillouet, 1974), was relatively abundant in the Apalachicola estuary, especially during the first year of sampling. Habitat preferences were evident with *Palaemonetes pugio* located primarily in East Bay grass bed areas during periods of low salinity while *Lolliguncula brevis* usually inhabited the outer bay during summer-fall periods of increased salinity. Although generalized temperature and salinity preferences have been shown for various estuarine species (Copeland and Bechtel, 1974), most of the dominants are tolerant of short-term fluctuations of these parameters. In a comparison of the temporal relationships among the 10 dominant fish species in the Apalachicola estuary, the peaks of abundance were fairly evenly distributed over any 12 mo period whereas dominant invertebrate species usually peaked during early summer (May-June) and fall (September-November) periods. In both groups, however, top dominants showed time-based (sequential) patterns of distribution with temporal partitioning through an annual cycle.

DOMINANT FISH SPECIES

Anchoa mitchilli (Valenciennes)

The bay anchovy has been reported as the top dominant in various studies (Norden, 1966; Fox and Mock, 1968; Perret, 1971; Swingle, 1971) with claims that this fish has the greatest biomass of any species in estuaries along the northern Gulf of Mexico. During the first 3 yrs of sampling in Apalachicola Bay, *A. mitchilli* composed 42.3% of the total numbers of individuals. Highest numbers were collected during fall periods. Bechtel and Copeland (1970) found that the bay anchovy was dominant in areas receiving the greatest stress. Accordingly, the possibility exists that the Apalachicola system was highly stressed during the first year of sampling when *A. mitchilli* was particularly abundant. This species tolerates a wide range of temperature and salinity, and showed no particular seasonal pattern of growth during the period of study.

Micropogon undulatus (Linné)

The Atlantic croaker, the second most abundant fish in the Apalachicola Bay System, composed 26.0% of the trawl catch during the first 3 yrs This species was the major dominant during the 1973 period which was characterized by inordinately high levels of river flow and relatively low salinities in the bay. The croaker has been reported scarce or absent in collections south of Alligator Harbor (Reid, 1954; Kilby, 1955; Joseph and Yerger, 1956; Springer and Woodburn, 1960). Joseph and Yerger (1956) postulate that Apalachee Bay may be the southern (or eastern) boundary for this species. Juveniles have been reported in estuaries from October and April (Gunter, 1945; Suttkus, 1956; Perret, 1971; Swingle and Bland, 1974) with peak abundance in spring and summer (Fox and Mock, 1968; Perret and Caillouet, 1974); juveniles were initially taken in the Apalachicola esturary in October or November with peaks occurring from January to April each year. Highest numbers are found generally at salinities below 10 - 15 $^{0}/_{00}$ (Fontenot and Rogillo, 1970) which is consistent with our data.

Cynoscion arenarius Ginsburg

The sand seatrout was the third most abundant fish in the Apalachicola Bay System in terms of numbers of individuals, comprising 8.7% of the catch during the study period. Sand seatrout are usually abundant during late spring and summer months (Fox and Mock, 1968; Copeland and Bechtel, 1974). In Apalachicola Bay, juveniles were found during April and May, with peak catches usually occurring during the summer.

Leiostomus xanthurus Lacépède

The spot is a relatively abundant fish in the Gulf, being dominant in areas such as Alligator Harbor (Joseph and Yerger, 1956), Tampa Bay (Springer and Woodburn, 1960), and in Alabama's coastal systems (Swingle, 1971). In Apalachicola Bay, the spot accounted for 5.4% of the total number of fishes taken. Peaks of abundance usually occurred from January or February to late spring, coinciding with peak numbers of *Micropogon undulatus.* Spot were almost absent in the Bay from early summer to early winter. This species has been collected over a wide range of salinity (Gunter, 1945; Perret, 1971; Swingle and Bland, 1974).

Bairdiella chrysura (Lacépède)

The silver perch, not particularly abundant in the northern Gulf, was the sixth most abundant fish in the Apalachicola estuary comprising about 1.6% of the total catch. Usually, peak numbers of this species occur during the summer and early fall in the Gulf (Gunter, 1945). In the Apalachicola estuary, peaks were usually observed during the fall. Generally, the smallest specimens of this species were found during the summer. Few silver perch were taken during the spring.

Chloroscombrus chrysurus (Linné)

The Atlantic bumper is not an abundant fish in the northeastern Gulf of Mexico (Kilby, 1955; Gunter and Hall, 1965; Norden, 1966; Swingle, 1971; Perret and Caillouet, 1974). In the Apalachicola Bay System, this species ranked seventh in abundance, comprising 1.5% of the total catch. This is a higher percentage than any other previously studied area. The Atlantic bumper was taken

TABLE 4. FISHES TAKEN BY SEINE IN FRESHWATER MARSHES (LITTLE ST. MARKS RIVER, 1972) OLIGOHALINE MARSHES (EAST BAY, 1975-6) AND MESOHALINE MARSHES (ST. GEORGE ISLAND, 1974) WHICH BORDER THE APALACHICOLA BAY SYSTEM.

Little St. Marks River Species	East Bay Species	St. George Island Species
Ictalurus natalis (Yellow bullhead)	*Lepomis microlophus* (Redear sunfish)	*Anchoa hepsetus* (Striped anchovy)
Micropterus salmoides (Largemouth bass)	*Micropterus salmoides* (Largemouth bass)	*Menidia beryllina* (Tidewater silverside)
Lepomis microlophus (Redear sunfish)	*Notemigonus crysoleucas* (Golden shiner)	*Eucinostomus gula*(Silver jenny)
Lepomis punctatus (Spotted sunfish)	*Lepisosteus osseus* (Longnose gar)	*Synodus foetens* (Inshore lizardfish)
Poecilia latipinna (Sailfin molly)	*Dorosoma petenense* (Threadfin shad)	*Strongylura marina* (Atlantic needlefish)
Adinia xenica (Diamond killifish)	*Fundulus grandis* (Gulf killifish)	*Lucania parva* (Rainwater killifish)
Cyprinodon variegatus (Sheepshead minnow)	*Fundulus similis* (Longnose killifish)	*Fundulus similis* (Longnose killifish)
Fundulus grandis (Gulf killifish)	*Fundulus confluentis* (Marsh killifish)	*Syngnathus floridae* (Dusky pipefish)
Fundulus confluentis (Marsh killifish)	*Lucania parva* (Rainwater killifish)	*Lagodon rhomboides* (Pinfish)
Fundulus similis (Longnose killifish)	*Poecilia latipinna* (Sailfin molly)	*Leiostomus xanthurus* (Spot)
Notemigonus crysoleucas (Golden shiner)	*Brevoortia patronus* (Gulf menhaden)	*Bairdiella chrysura* (Silver perch)
Lucania parva (Rainwater killifish)	*Anchoa mitchilli* (Bay anchovy)	*Cynoscion nebulosus* (Spotted sea trout)
Lucania goodei (Bluefin killifish)	*Menidia beryllina* (Tidewater silverside)	*Mugil cephalus* (Striped mullet)
Notropis sp. (Minnow)	*Leiostomus xanthurus* (Spot)	*Orthopristis chrysoptera* (Pigfish)
Lepisosteus osseus (Longnose gar)	*Sciaenops ocellata* (Red drum)	*Opsanus beta* (Gulf toadfish)
Cyprinus carpio (Carp)	*Cynoscion arenarius* (Sand seatrout)	
Anguilla rostrata (American eel)	*Eucinostomus argenteus* (Spotfin mojarra)	
Poxomis nigromaculatus (Black crappie)	*Strongylura marina* (Atlantic needlefish)	
Menidia beryllina (Tidewater silverside)	*Mugil cephalus* (Striped mullet)	
Anchoa mitchilli (Bay anchovy)	*Syngnathus scovelli* (Gulf pipefish)	
Brevoortia patronus (Gulf menhaden)	*Gobionellus boleosoma* (Darter goby)	
Mugil curema (White mullet)	*Gobiosoma bosci* (Naked goby)	
Mugil cephalus (Striped mullet)	*Microgobius gulosus* (Clown goby)	
Micropogon undulatus (Atlantic croaker)	*Lagodon rhomboides* (Pinfish)	
Bairdiella chrysura (Silver perch)	*Trinectes maculatus* (Hogchoker)	
Cynoscion arenarius (Sand seatrout)		
Paralichthys lethostigma (Southern flounder)		
Trinectes maculatus (Hogchoker)		
Eucinostomus gula (Silver jenny)		
Lutjanus griseus (Gray snapper)		
Gobiosoma bosci (Naked goby)		
Microgobius gulosus (Clown goby)		
Archosargus probatocephalus (Sheepshead)		

TABLE 5. FISHES TAKEN IN TRAMMEL NETS IN OLIGOHALINE (EAST BAY, 1975-76) AND MESOHALINE (ST. GEORGE ISLAND, 1974-75) PORTIONS OF THE APALACHICOLA BAY SYSTEM.

East Bay Species	St. George Island Species
Amia calva (Bowfin)	*Carcharhinus limbatus* (Blacktip shark)
Lepisosteus osseus (Longnose gar)	*Sphyrna tiburo* (Bonnethead)
Carcharhinus leucas (Bull shark)	*Gymnura micrura* (Butterfly ray)
Dasyatis sabina (Atlantic stingray)	*Dasyatis sabina* (Atlantic stingray)
Brevoortia patronus (Gulf menhaden)	*Brevoortia patronus* (Gulf menhaden)
Elops saurus (Ladyfish)	*Arius felis* (Sea catfish)
Ictalurus catus (White catfish)	*Bagre marinus* (Gafftopsail catfish)
Arius felis (Sea catfish)	*Lagodon rhomboides* (Pinfish)
Bagre marinus (Gafftopsail catfish)	*Micropogon undulatus* (Atlantic croaker)
Leiostomus xanthurus (Spot)	*Leiostomus xanthurus* (Spot)
Micropogon undulatus (Atlantic croaker)	*Cynoscion nebulosus* (Spotted seatrout)
Cynoscion nebulosus (Spotted seatrout)	*Sciaenops ocellata* (Red drum)
Sciaenops ocellata (Red drum)	*Mugil cephalus* (Striped mullet)
Mugil cephalus (Striped mullet)	*Orthopristis chrysoptera* (Pigfish)
Paralichthys lethostigma (Southern flounder)	*Paralichthys lethostigma* (Southern flounder)
Trinectes maculatus (Hogchoker)	*Paralichthys albigutta* (Gulf flounder)
	Scomberomorus maculatus (Spanish mackerel)
	Caranx hippos (Crevalle jack)
	Opsanus beta (Gulf toadfish)
	Chilomycterus schoepfi (Striped burrfish)
	Pomatomus saltatrix (Bluefish)

during periods of high temperature and salinity in the summer and fall, which is consistent with other distributional studies (Gunter, 1945).

DOMINANT INVERTEBRATE SPECIES

The commercially valuable penaeid shrimps, composed of three sympatric species throughout most of the northern Gulf of Mexico, utilize the same inshore areas as nurseries at different times of the year. Due to their commercial importance, there are various extensive studies and reviews concerning life histories of these organisms (Lindner and Anderson, 1956; Eldred et al., 1961; Williams, 1965; Joyce and Eldred, 1966; Perez Farfante, 1969).

Penaeus setiferus (Linné)

The white shrimp was the dominant macrobenthic invertebrate in the Apalachicola System, comprising 40.1% of the total catch. Catches of this organism followed seasonal trends established in other studies along the Gulf coast (Lindner and Anderson, 1956; Ingle, 1957; Loesch,1965; Perret, 1971; Swingle, 1971; Gaidry and White, 1973). Major peaks of abundance usually occur in late summer and fall in the Gulf of Mexico; in Apalachicola Bay, increased numbers were noted from August to November. White shrimp were rarely found from April to June at which time gravid females have been reported in the Gulf-side vicinity of West Pass and Indian Pass. Spawning is followed by immigration into the bay system by the post-larval and juvenile shrimp. Small shrimp appear to prefer low salinity portions of the system (East Bay). While there is a general migration out of the bay during periods of falling temperatures in the autumn, some shrimp appear to overwinter in the deeper channels observed in other estuaries (Ingle, 1957; Stokes, 1974).

Penaeus duorarum Burkenroad

The pink shrimp, comprising 5.3% of the total invertebrate catch in the Apalachicola estuary, is usually taken from spring to fall, with abundance peaks noted in March - April and October (1972) and from July to November (1973, 1974). No pink shrimp were found in June. This seasonal pattern of abundance has also been observed in other areas of the Gulf (Eldred et al., 1961; Joyce and Eldred, 1966; Perret., 1971; Swingle, 1971; Stokes, 1974). It is postulated that in the Apalachicola area, pink shrimp spawn during late spring to early summer with movement into the bay of the developing young during summer and early fall. Some overwintering in the deeper areas exists, although most of the pink shrimp move out of the bay during the fall. Although this species showed some minor dominance in the bay during summer and fall months, this never exceeded 40% of the total invertebrate catch.

Penaeus aztecus Ives

The least abundant of the penaeid shrimp in the Apalachicola area is the brown shrimp which

TABLE 6. COMPARISON OF NATURAL HISTORY INFORMATION CONCERNING THE DOMINANT SPECIES OF FISHES AND INVERTEBRATES TAKEN IN THE GULF OF MEXICO AND THE APALACHICOLA SYSTEM (MARCH 1972 - FEBRUARY 1975).

Species	Peak Abundance in Gulf Estuaries	Peak Abundance Apalachicola System	Salinity and Temperature Tolerance	Reproductive Patterns in Gulf Estuaries	Reproductive Patterns in Apalachicola Systems	References
Anchoa mitchilli (Bay anchovy)	Summer and Fall	Summer, Fall and Early Winter	High; direct relationship of size with salinty	Long spawning season with juvenile recruitment throughout year.	Compatible with previous studies	Gunter, 1945; Reid, 1954; Springer and Woodburn, 1960; Gunter and Hall, 1965; Fox and Mock, 1968; Perret, 1971; Swingle, 1971.
Micropogon undulatus (Atlantic croaker)	Spring and Summer	January - April	High	Spawning in passes during late fall and early winter; Juveniles in estuaries October-April	Juveniles in bay around October-November. Adult migration, June to October.	Gunter, 1945; Suttkus, 1956; Fox and Mock, 1968; Fontenot and Robillio, 1970; Perret, 1971; Swingle, 1971; Perret and Caillouet, 1974.
Cynoscion arenarius (Sand seatrout)	May - July	March - August	Even distribution over salinty; caught between 20 - 35°C.	Spring spawning with juveniles in estuaries April - September.	Juveniles in bay April - May	Gunter, 1945; Reid, 1954; Kilby, 1955; Springer and Woodburn, 1960; Hoese, 1965; Bechtel and Copeland 1970; Perret, 1971; Copeland and Bechtel, 1974; Swingle and Bland, 1974.
Leiostomus xanthurus (Spot)	April - July	January - April	High; highest catches. 10 - 15 ‰	Spawn near passes late winter, early spring; juveniles in bays December - May	Juveniles in bay January - February	Pearson, 1929; Gunter, 1945; Joseph and Yerger, 1956; Norden, 1966; Sykes and Finucane, 1966; Nelson, 1969; Perret, 1971; Swingle, 1971; Swingle and Bland, 1974.
Bairdiella chrysura (Silver perch)	Summer - Early Fall	Fall - Early Winter	High; direct relationship of size with salinity	Spawn in estuaries April - June with juveniles appearing from May to September	Juveniles in bay summer months	Gunter, 1945; Kilby, 1955 Springer and Woodburn, 1960; Gunter and Hall, 1965; Norden, 1966; Fox and Mock, 1968; Perret, 1971; Swingle, 1971
Chloroscombrus chrysurus (Atlantic bumper)	Summer and Fall	July - October	Abundant in high salinity with direct relationship of size with salinity			Gunter, 1945; Reid, 1954; Kilby, 1955; Joseph and Yerger, 1956; Springer and Woodburn, 1960; Gunter and Hall, 1965; Norden, 1966; Swingle, 1971; Perret and Caillouet, 1974.

TABLE 6. COMPARISON OF NATURAL HISTORY INFORMATION CONCERNING THE DOMINANT SPECIES OF FISHES AND INVERTEBRATES TAKEN IN THE GULF OF MEXICO AND THE APALACHICOLA SYSTEM (MARCH 1972 - FEBRUARY 1975). (CONTINUED)

Species	Peak Abundance in Gulf Estuaries	Peak Abundance Apalachicola System	Salinity and Temperature Tolerance	Reproductive Patterns in Gulf Estuaries	Reproductive Patterns in Apalachicola Systems	References
Penaeus setiferus (White shrimp)	Spring and Fall	Summer and Fall	High; prefer low salinity. Direct relationship of size with salinity	Spawn in Gulf in early spring and fall. Postlarvae and juveniles enter bays in spring	Juveniles enter bay in spring, summer	Gunter, 1950; Lindner and Anderson, 1956; Ingle, 1957; Eldred, et al., 1961; Loesch, 1965; Williams, 1956; Copeland and Truitt, 1966; Christmas, et al., 1966; Perez Farfante, 1969; Perret, 1971; Swingle, 1971; Gaidry and White, 1973; Calder, et al., 1974; Copeland and Bechtel, 1974; Stokes, 1974; Swingle and Bland, 1974.
Penaeus duorarum (Pink shrimp)	Late Summer, Fall	July - November	High; prefer high salinity, usually dominant at salinities 18 $^0/_{00}$	Spring and summer spawning; post larval peaks, August - September	Juveniles stages enter bay during summer	
Penaeus aztecus (Brown shrimp)	Late Spring, Summer	Late Spring, Early Summer	High; prefer low salinities 10 - 20 $^0/_{00}$	Postlarvae enter bays late winter-spring; juveniles early summer	Juveniles in bay during early summer	
Palaemonetes pugio (Grass shrimp)	February, March	February - April	High; prefers low salinities 10 - 20 $^0/_{00}$	Spawn in summer and fall		Hoese and Jones, 1963; Wood, 1967; Rouse, 1969; Perret, 1971; Swingle, 1971; Swingle and Bland, 1974.
Callinectes sapidus (Blue crab)	Large crabs numerous in summer; small crabs, numerous winter and summer	Winter - Spring - Summer	High; direct relationship of size with salinity	Spring, summer and fall spawning	Young enter bay in summer and winter	Gunter, 1950; Hedgepeth, 1950; Daugherty, 1952; Van Engel, 1958; Darnell, 1959; Tagatz, 1968; More, 1969; King, 1971; Lyons, et al., 1971; Swingle, 1971; Adkins, 1972; Copeland and Bechtel, 1974.
Lolliguncula brevis (Brief squid)	Varied, early spring to late fall	Summer, Fall	Prefers high salinity, 15 $^0/_{00}$	Suggested estuarine spawning throughout the year		Reid, 1955; Tabb and Manning, 1961; Dragovich and Kelly, 1967; Perret, 1971; Swingle, 1971; Swingle and Bland, 1974.

comprised 2.6% of the total macrobenthic invertebrate catch. During the first two years of the study, brown shrimp peaked in May, with a July peak the following year. This pattern is consistent with other reports for Gulf estuaries (Reid, 1955; Loesch, 1965; Perret., 1971; Swingle and Bland, 1974). It is thought that brown shrimp in the Apalachicola system spawn during winter and early spring at which time few adults are observed in the study area. Entry into the bay was generally noted to begin in early spring with brown shrimp appearing throughout the spring and summer.

Palaemonetes pugio Holthuis

The grass shrimp, along with its two congeners, *P. intermedius* and *P. vulgaris*, are commonly found in shallow vegetated marshes and bays along the Gulf coast. *Palaemonetes pugio* has been collected over a wide range of temperatures and salinities with abundance often noted below 20 ‰ (Gunter and Hall, 1965; Wood 1967; Swingle and Bland, 1974). In the Apalachicola estuary, grass shrimp peaked during the winter and early spring months sharing dominance with the blue crab, *Callinectes sapidus.* This is similar to grass shrimp patterns in other areas of the Gulf (Hoese and Jones, 1963; Swingle, 1971). Grass shrimp are located primarily in low salinity water of the grass beds in East Bay (Station 6, for example). Gravid females have been observed during the late winter and spring months.

Callinectes sapidus Rathbun

The blue crab is one of the most abundant organisms in shallow coastal portions of the Gulf of Mexico, ranging from fresh water to shallow offshore waters up to 50 fm in depth (Franks et al., 1972) with concentrations in secondary bays having adjacent creeks and tidal marshes (More, 1969). During the study period, *Callinectes sapidus* was the third most abundant macrobenthic invertebrate comprising 20.2% of the total catch in the Apalachicola estuary. Peaks of abundance were observed during summer, fall, and winter periods, with smaller crabs usually occurring during late fall and winter periods. Maximum numbers of blue crabs occurred during the winter with a conservative (baywide) estimate (based on only daytime trawling) placed at 30,000,000 individuals. The trends of abundance and size-frequency correspond well with established life history data (Van Engel, 1958; Darnell, 1959; Williams, 1965; Tagatz, 1968; Oesterling and Evink, 1977). According to the literature (Daugherty, 1952; Darnell, 1959; Copeland, 1965; More, 1969; King, 1971), spawning of blue crabs usually occurs during spring and summer months. In the Apalachicola Bay System, gravid females have been observed near the outer passes during the summer months with subsequent fall spawning thus giving rise to winter abundance of juveniles. During the winter abundance peaks, small crabs tended to predominate in areas of reduced salinity such as East Bay.

Our studies indicate that the Apalachicola estuary is an unpolluted, highly productive system which is dependent to a large degree on the seasonal fluctuations of the Apalachicola River. Studies currently underway will attempt to determine the energy relationships and consequent trophodynamic interactions which are responsible for the incredible productivity of this system. Any upland development should address the problem of alteration of detritus input to the bay system in addition to the usual forms of contamination. The reduction of detritus flow due to dams, dikes, or other forms of physical changes along the river should be carefully considered in view of its obvious value to the Bay system.

SUMMARY AND CONCLUSIONS

1. Results of a long-term study of the Apalachicola Bay System were discussed with respect to the functional relationships of the biological assemblages of estuarine organisms with the physico-chemical environment.
2. The relatively unpolluted Apalachicola estuary is a shallow, barrier island system which is physically dominated by the Apalachicola River. There is a regular seasonal variation in parameters directly related to river flow, including salinity, turbidity, color, and detritus deposition.
3. Thousands of tons (wet weight) of detritus of terrestrial origin such as leaf litter and wood debris are swept into the bay each year by the Apalachicola River. Qualitative and quantitative aspects of macro-detritus distribution are seasonally variable. Such detritus is associated with various species assemblages dominated by amphipods, isopods, and decapod crustaceans. These organisms are thought to utilize the detritus as a source of shelter or food and, in turn, serve as food for higher trophic levels in the bay. However, the exact importance of the detritus input to the overall energy relationships in the bay is still under study.
4. The benthic infauna and epifauna of the Apalachicola Bay System were described with special attention to the dominant species. Organisms such as blue crabs, penaeid shrimp, sea trout, and other commercially important

groups utilize this system as a major nursery area. The system is dependent to a considerable degree on river based parameters and influxes of inorganic and organic substances from upland areas.

5. The Apalachicola estuarine biota can be characterized by regular, species-specific phase relationships on a seasonal basis which are temporally stable and broadly adapted to the physico-chemical functions of the bay. The biological functions are thus synchronized with physical changes, river flow, patterns of phytoplankton productivity, microhabitat variation, and interspecific functions. Annual variations in population changes and community indices are also evident.

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RELATIONSHIP BETWEEN FLORIDA'S BLUE CRAB POPULATION AND APALACHICOLA BAY

Michael L. Oesterling and Gary L. Evink*
University of Florida

*Current address: Department of Transportation, P. O. Box 47, Deland, Florida 32720

INTRODUCTION

The blue crab, *Callinectes sapidus* Rathbun, is a common coastal inhabitant of Florida. The relative ease of capture and the delicacy of the meat makes it a highly prized sport and commercial fisheries species. According to Perry (1975), the blue crab represents the third largest food fishery in the entire Gulf of Mexico. During 1974, more than 10 million lb of blue crabs were landed commercially along Florida's Gulf coast alone (Florida Department of Natural Resources, 1976). Of the 413 statewide commercial blue crab permits issued, 70% (292) were issued for Florida's Gulf coast. Those dependent on blue crabs for a livelihood include more than commercial fishermen. To process the live crabs into marketable crabmeat, seafood processing establishments along the Florida Gulf coast employ 300 to 350 (or more) crabmeat pickers, cooks, or packagers (1976 telephone survey of licensed blue crab processors).

Although the Florida blue crab fishery is a multimillion dollar industry, relatively few studies have been conducted on the blue crab's life history in Florida waters (Futch, 1965; Tagatz, 1965, 1968a, 1968b). With the present concern over declining yields (Tagatz, 1965; Mahood et al., 1970), the need for studies dealing with the biology of the blue crab is evident. In particular, the spawning, migration, and distribution of blue crabs along Florida's Gulf coast were investigated in this study.

BIOLOGICAL BACKGROUND

For the blue crab, life begins as a planktonic zoea larva (Costlow and Bookhout, 1959). Due to their planktonic nature, zoea are carried along with the prevailing currents. It is not inconceivable that the larvae could be transported to an area not even associated with the spawning area. As with other organisms that have a planktonic stage, only a very small number of these zoae will survive to become adults. Van Engel (1958) estimated that only about one ten thousandth of one percent (0.000001) of the zoea become mature crabs. Following development (31-49 days), zoea metamorphose into a single megalops stage which has both planktonic and benthic features (Williams, 1971; Sulkin, 1974). The megalops stage persists for 6-20 days after which it molts into the first crab stage (Costlow and Bookhout, 1959). Evidence indicates that hatching and molting of blue crab larval stages might proceed most efficiently in waters of salinities found outside river outfalls (Sandoz and Rogers, 1944).

Classically, blue crab larval development has been considered to take place "offshore" in more saline waters than the confines of the estuary. The young crabs, however, spend the majority of their growing life within estuarine nursery grounds. To reach these areas, there must be some mechanism to return larvae/young crabs to the estuaries. This appears to be accomplished during the megalops and first few crab stages by way of a "directed migration" shoreward (Van Engel, 1958; Darnell, 1959; Tagatz, 1968a; Sulkin, 1974; Williams, 1974). It has been suggested that the megalops takes advantage of incoming tidal currents by rising into the water column during flood tide, settling and holding to the bottom during ebb tide, and thus eventually reaching the estuary (Williams, 1971; Sulkin, 1974).

Following the first crab stage, growth is rapid. The adult crab stage will be reached 12 to 18 mo after egg hatching. After reaching adulthood, blue crabs live about one year longer.

Movements in blue crab populations have been well documented by previous studies (Cargo, 1958; Van Engel, 1958; Darnell, 1959; Fischler and Walburg, 1962; Tagatz, 1968a; Judy and Dudley, 1970). These are not full population migrations, but consist of the female component of the population only. Female blue crabs have been found to have a definite migrational pattern related to their life cycle stage. Prior to their last juvenile molt into the adult, female blue crabs move into lower salinity waters (shoreward, and into creeks and marshes). At this time they pair with a male for mating. While the female is in the soft stage after her final molt, copulation occurs. Following the hardening of her new shell, the male releases the female. When released, females begin to move to higher salinity waters "offshore" for spawning. The net result is a movement onshore/offshore with little mixing of populations from adjacent estuaries.

Although this migration pattern may hold true for the regions in which it was described, this appears not to be the case for populations of blue crabs along Florida's Gulf coast. The basic pattern of mating in lower salinities and spawning in higher salinities still applies, but the classic onshore/offshore movement does not. Instead, there is an onshore/along-shore movement where, following mating, females move along shore to specific spawning areas.

METHODS

A tag-recapture study was conducted to: 1) map the migrational patterns of market-size Florida Gulf coast blue crabs; 2) determine the source area(s) for the fisheries; and 3) provide basic population data for future management programs should they become necessary to assure a sustained yield.

Basically, the tag-recapture program entailed tagging a crab and releasing it in the hopes it would be recaptured at some future date. Sites chosen along the Gulf coast as release points corresponded to major blue crab fisheries. These sites were, from south to north along the coast: Chokoloskee Bay; Fort Myers; Punta Gorda; New Port Richey; Crystal River; Horseshore Beach; Steinhatchee; Keaton Beach; Panacea; and Apalachicola (Figure 1). Arrangements were made at each site to purchase 500-600 live blue crabs from either a local processing house or individual crabber with the stipulations that the crabs were caught in the immediate vicinity and immediately preceding the scheduled tagging. On the day of the tagging, crabs were obtained as soon after their initial capture as possible, thus assuring healthy, lively crabs. Crabs were then tagged with a dorsal carapace tag. Each tag included a sequence number, the address and telephone number to contact upon recapture, and data requested concerning the recapture (date, site). Data recorded for each crab included the tag number, sex, carapace width (mm) measured dorsally from lateral spine to lateral spine, and general condition (for example, missing limbs). Crabs were then released in the same general area of capture, but at a distance from existing trap-lines to assure adequate mixing with the untagged population and to avoid excessive immediate recaptures.

All taggings were conducted from September through March. It appears that the greatest portion of the female migration takes place during this time. In a preliminary study (Oesterling, unpublished data), taggings were conducted throughout all months of the year. During the warmest months (May through August) there were no long distance movements observed. Therefore, to focus our efforts on the most productive periods, taggings were only conducted in the fall/winter/early spring period.

Besides the actual field work, an extensive public notification program was conducted. Notices of the project, its purpose, and what to do with a tagged crab, were sent to licensed commercial crabbers, processing houses, Marine Patrol agents, local newspapers, and the scientific community along the Gulf coast. Although there was no reward offered for the return of a tagged crab, there was excellent cooperation from the commercial interests along the Gulf coast, with 87% of all returns coming from the commercial community. Persons or agencies submitting return data were individually acknowledged with a letter describing the program and the tagging history of the captured crab.

RESULTS

During the period from November 1974 through December 1975, sixteen blue crab taggings were conducted at ten different sites along Florida's Gulf coast (Table 1). There were 6287 crabs tagged and released — 3231 (51.4%) males and 3056 (48.6%) females. Of the 709 crabs recaptured, only six could not be used because of incomplete information. The 366 (51.6%) females and 343 (48.4%) males recaptured resulted in a return rate of 11.3%.

Female crabs traveled the greatest distances (Table 2). Approximately 25% of recaptured females moved distances greater than 30 mi. Mean distance traveled by females was 30.54 mi with a standard error of 2.81. The extensive range of female movement is evidenced by the 18 crabs which traveled over 200 mi and the two individuals which went as far as 310 mi.

In contrast, 95% (324) of males recaptured were returned from within 15 mi of the release site. Mean distance traveled by males was 4.38 mi with a standard error of 0.53. The limited movement of male crabs was further substantiated by two males which were recaptured 205 and 245 days after release but within several miles of their release site. Statistical treatment of return data indicated a highly significant (1% level of confidence) difference in distance traveled by males and females.

In addition to traveling great distances, female blue crabs exhibited a directional movement. With few exceptions, all non-local movement was in a northerly direction along the peninsular portion of

TABLE 1. TAGGINGS SITES, DATES OF TAGGINGS, AND NUMBER OF CRABS TAGGED AT EACH TAGGING (BY SEX AND TOTAL).

Tag Site	Tagging Date	Males Tagged	Females Tagged	Total Tagged
Chokoloskee Bay	6 December 1974	124	115	239
Fort Myers	14 October 1975	472	85	557
Punta Gorda	7 February 1975	435	105	540
	13 October 1975	416	97	513
New Port Richey	6 November 1974	230	90	320
	28 January 1975	155	15	170
	23 September 1975	248	19	267
Crystal River	21 January 1975	126	358	484
Horseshoe Beach	30 January 1975	4	303	307
Steinhatchee	25 November 1974	231	291	522
	3 October 1975	135	63	198
	29 October 1975	251	74	325
Keaton Beach	29 January 1975	10	336	346
Panacea	16 January 1975	33	669	702
Apalachicola	11 March 1975	114	224	338
	28 October 1975	247	212	459
	TOTALS	3,231	3,056	6,287

the State and westerly along the panhandle (Figure 2-11).

DISCUSSION

MIGRATION AND REPRODUCTION

In this study, male crabs exhibited no real trend in their movements, remaining in their "home estuary." When they did travel, it was not as dramatic as the females. Although one male traveled 132 mi to the south of the release site, there was a general tendency to disperse back into the surrounding creeks and marshes. This is in keeping with Cargo's (1958) Virginia findings that males exhibit a nondirectional and random movement within their home estuary. Further substantiation of this were the two male crabs caught 205 and 245 days after tagging, only a short distance from the initial release point.

In North Carolina, Judy and Dudley (1970) found that crabs may "scatter widely within their respective habitats [estuaries], but show only limited movement to other inland and coastal waters." Florida's Gulf coast blue crab population does not migrate in this fashion; the inshore/offshore movement noted by Judy and Dudley (1970) was not evident. Rather, along-shore migrations were documented. Figures 2-11 clearly indicate that female blue crabs moved out of the estuaries in which they were tagged and were subject to mixing with adjacent stocks. The distances traveled by females (Table 2) indicate that these migrants were more than "scattered widely." We must assume that these crabs have indeed moved along-shore into (or through) a neighboring estuarine area. In the cases of the three crabs that moved from Punta Gorda (Figure 4) to the Panacea area, at least seven estuarine areas were traversed.

It has previously been pointed out that migrations of females are directly linked to reproduction. The migrations observed in this study correspond to movement towards the spawning area after mating. In the classic description, this movement would be to "offshore", higher salinity waters. Migrations observed along the Gulf coast demonstrate movement would be to a site, or sites, to the north of the mating estuary. The Apalachicola Bay region (defined as being from Panacea to St. Vincent Island) appears to be a primary spawning ground for the blue crab along the Florida coast. In returns from the Gulf coast, only seven crabs (of 709 or about 1%) moved to the west of Apalachicola Bay (Figures 2-11). The majority of returns seem either to head towards or to terminate in the Apalachicola Bay region.

Personal communications with local crabbers and shrimpers in the Apalachicola area and results from a questionnaire survey of commercial crab-

TABLE 2. MILES TRAVELED BY REPORTED RECAPTURES. THE COLUMNS LABELLED MALES AND FEMALES ARE THE NUMBER CAPTURED OF THAT SEX AT SOME MILES FROM THE RELEASE SITE.

Miles Traveled	Males	Cumulative % Male Return	Female	Cumulative % Female Return
0	33	9.7	32	8.8
1	69	29.9	23	15.2
2	88	55.7	18	20.2
3	52	71.0	35	29.8
4	42	83.3	40	40.9
5	9	85.9	14	44.8
6	2	86.5	10	47.5
7	7	88.6	—	
8	3	89.4	15	51.7
9	7	91.5	1	51.9
10	8	93.8	7	53.9
11	2	94.4	6	55.5
13	1	94.7	1	55.8
14	—		1	56.1
15	1	95.0	3	56.9
16	4	96.2	14	60.8
17	—		1	61.0
18	1	96.5	—	
20	—		15	65.2
23	1	96.8	1	65.5
24	2	97.4	21	71.3
25	3	98.2	2	71.8
26	—		2	72.4
29	—		3	73.2
30	—		5	74.6
31	1	98.5	—	
32	—		3	75.4
33	—		3	76.2
34	—		3	77.1
35	1	98.8	7	79.0
37	—		2	79.6
38	—		8	81.8
40	—		2	82.3
43	—		1	82.6
45	—		2	83.1
47	—		4	84.3
48	—		1	84.5
50	1	99.1	5	85.9
53	—		1	86.2
55	—		1	86.5
60	—		8	88.7
61	1	99.4	—	
63	1	99.7	4	89.8
64	—		2	90.3
65	—		3	91.2
66	—		1	91.4
67	—		1	91.7
68	—		1	92.0
72	—		1	92.3
80	—		3	93.1
94	—		1	93.4
112	—		1	93.6
115	—		1	93.9
120	—		1	94.2
126	—		1	94.5
132	1	100.0	—	
134	—		1	94.8
157	—		1	95.0
200	—		7	97.0
208	—		1	97.2
225	—		1	97.5
230	—		1	97.8
243	—		1	98.1
250	—		2	98.6
264	—		1	98.9
276	—		1	99.2

TABLE 2. MILES TRAVELED BY REPORTED RECAPTURES. THE COLUMNS LABELLED MALES AND FEMALES ARE THE NUMBER CAPTURED OF THAT SEX AT SOME MILES FROM THE RELEASE SITE. (CONTINUED)

Miles Traveled	Males	Cumulative % Male Returns	Females	Cumulative % Female Returns
297	—		1	99.4
310	—		2	100.0

bers support the hypothesis that this is a major spawning area for Gulf coast blue crabs. Fishermen have reported great concentrations of egg-bearing crabs. Further corroboration of this area's importance occurs in the return of tagged ovigerous crabs from the Apalachicola Bay region. Tagged crabs were caught bearing egg masses which were not present at the time of tagging. These egg masses were all orange, indicating that they had only recently been laid (Van Engel, 1958; Darnell, 1959). No other tagged ovigerous crabs were returned from any other location along the Gulf coast. This is not to say that blue crab spawning does not occur along the entire length of Florida's west coast; for indeed it does. However, the concentrations of spawning (egg-bearing) blue crabs along the Gulf coast apparently do not approach the large numbers of ovigerous blue crabs found in the Apalachicola Bay area.

LARVAL DISPERSAL

We have presented strong evidence suggesting that ovigerous crabs concentrate in the Apalachicola Bay region. Such a trend without continued recruitment in southwest Florida would result in declining stocks there. Landing statistics indicate no significant decline. Thus, recruitment along the southwest coast can be assumed.

Larval dispersal from the Apalachicola Bay region could be presumed, based on knowledge of surface circulation patterns in the eastern Gulf of Mexico. Current patterns in the Gulf of Mexico are generally known (Leipper, 1954; Curl, 1959; Gaul and Boykin, 1964; Leipper, 1970; Austin, 1971; Nowlin, 1971; Ichiye et al., 1973; Jones et al., 1973; Maul, 1974; Murphy et al., 1975). These studies have described general patterns of surface circulation in the Gulf of Mexico. The Caribbean Current flows northward through the Yucatan Straits into the eastern Gulf of Mexico basin, where it forms a clockwise loop (the Loop Current) and flows southward into the Florida Straits to join the Florida Current. During spring, the Gulf Loop Current encroaches increasingly northward, reaches maximum penetration by fall, and recedes during winter (Leipper, 1970; Maul, 1974). Gyres from the main current body sometimes detach as eddies and wash onto The Florida Shelf (Jones et al., 1973). Gaul and Boykin (1964), Nowlin (1971) and Ichiye et al. (1973) have illustrated Loop Current related circulation patterns in the northeastern Gulf of Mexico.

Drift bottle recovery data reported by Gaul and Boykin (1964) and Ichiye et al. (1973) indicate that waters near the Florida panhandle, once integrated with the Gulf Loop Current and the Gulf Stream, may be transported to both the Gulf and Atlantic coasts of Florida (Figure 12). Gaul and Boykin (1964) releases during April-May 1973, at the approximate time of blue crab spawning in Apalachicola Bay, resulted in recoveries within 35-47 days.

If Apalachicola River waters are flushed offshore, they could eventually become integrated with the current system of the eastern Gulf of Mexico. Planktonic organisms would be similarily entrained. Previous studies indicate that blue crab spawning occurs most often near mouths (Sandoz and Rogers, 1944; Tagatz, 1968a). Blue crab zoea spawned in the Bay would become entrained in the discharge of the Apalachicola River and carried offshore. Once in the current pattern of the eastern Gulf of Mexico, they would be carried southward. Larvae would be separated out by generated eddy currents and transported nearer to shore, as demonstrated by the drift bottle recoveries of Ichiye et al. (1973) (Figure 12). Moreover, the drift bottle recoveries of Gaul and Boykin (1964) were generally within the period of blue crab larval development to the megalops stage (31-49 days; Costlow and Bookhout, 1959). One could therefore assume that zoea would be spread along the entire coast before the megalops settle and proceed to the estuaries. This is a possible mechanism for the redistribution of blue crabs via the current systems of the Apalachicola Bay and Gulf of Mexico (Figure 13).

If blue crab larvae are being carried away from Apalachicola Bay, how does one account for the large numbers of juvenile blue crabs reported by Livingston et al. (1975a) to be inhabiting the Bay? Possibly the current system described above will not remove all the larvae spawned within the Bay system. A good portion of these larvae may never be flushed far enough offshore to encounter the eastern Gulf currents. This would tend to keep a large population of zoea "offshore" from Apalachicola Bay. Favorable developmental condi-

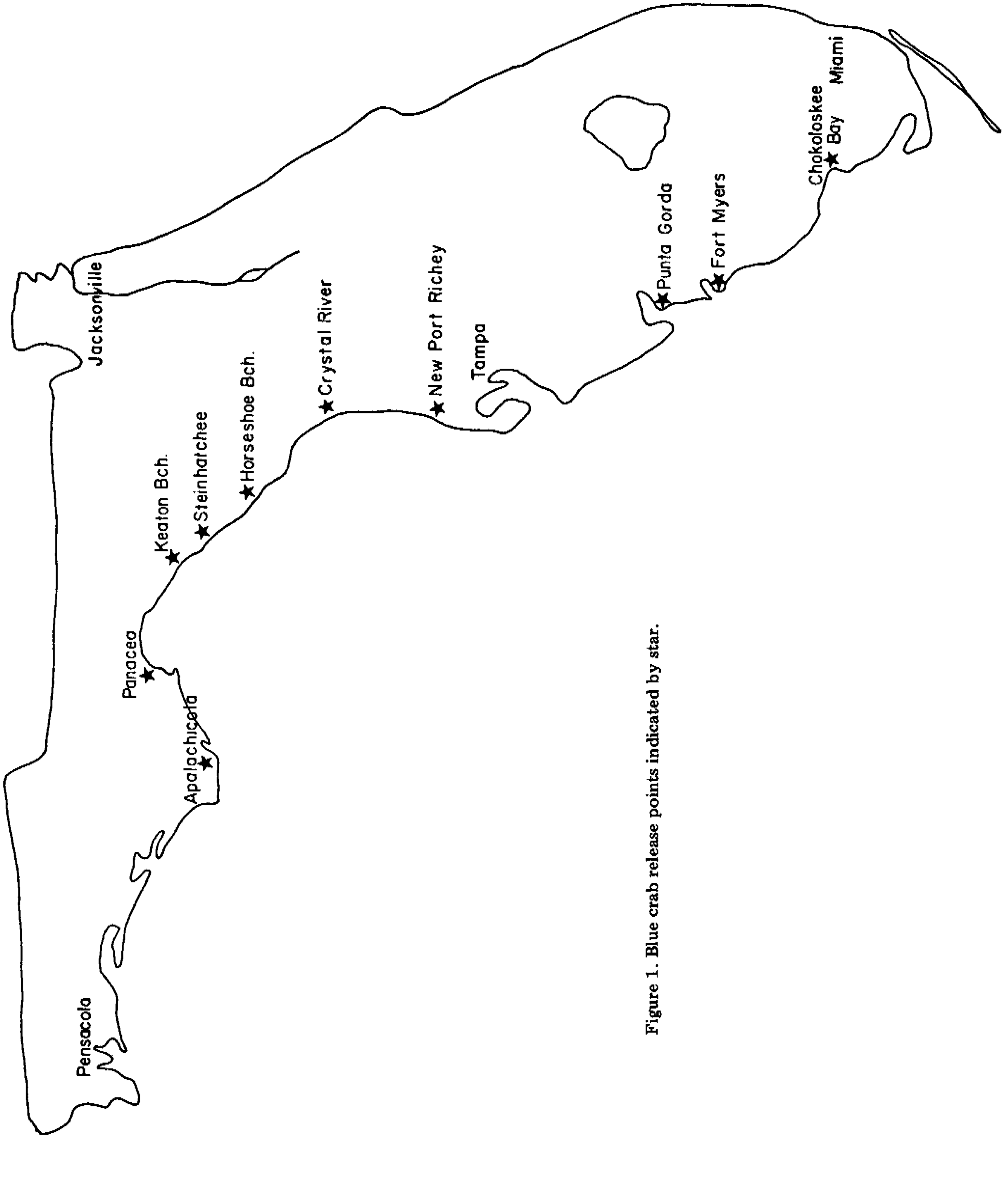

Figure 1. Blue crab release points indicated by star.

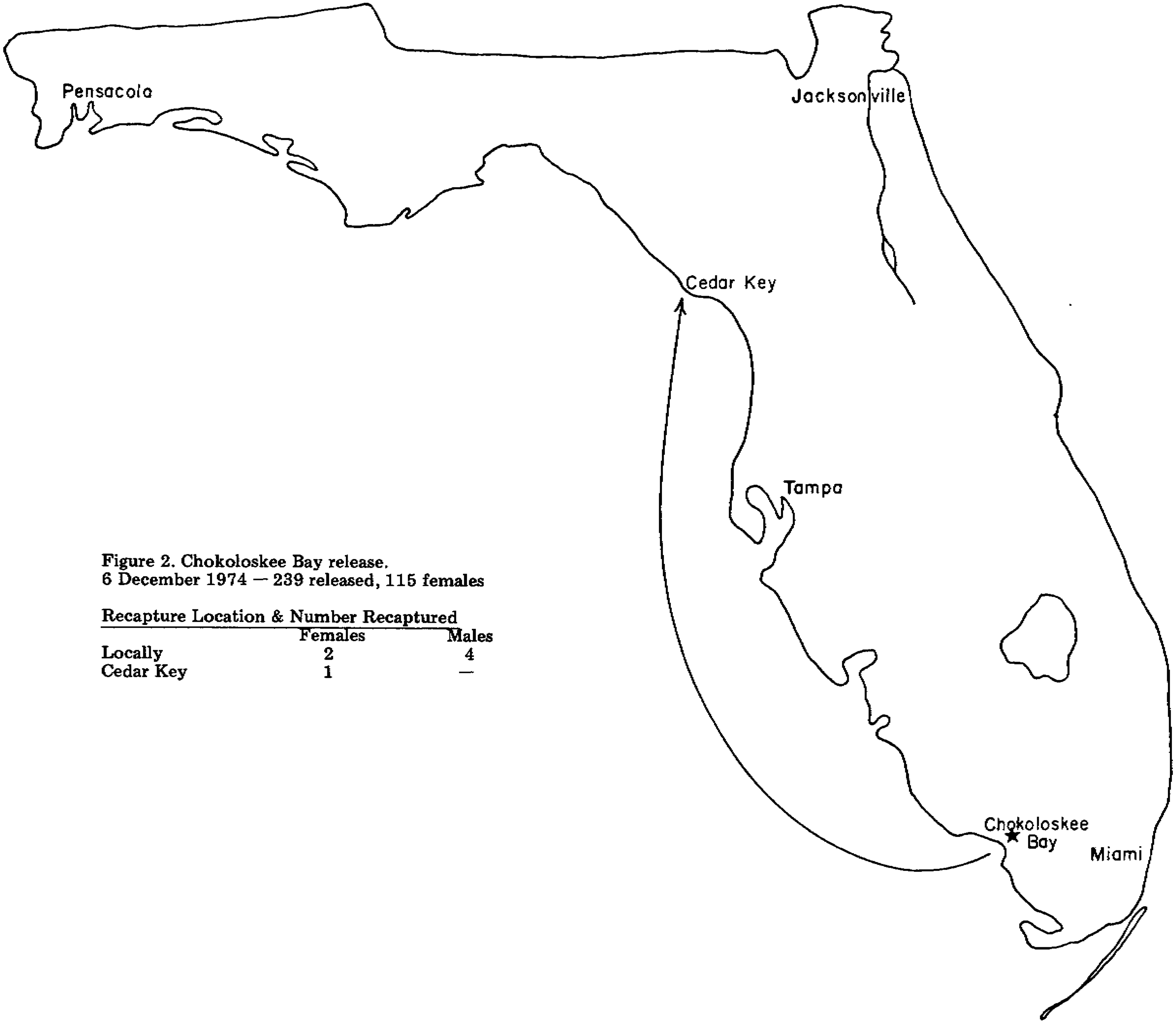

Figure 2. Chokoloskee Bay release.
6 December 1974 — 239 released, 115 females

Recapture Location & Number Recaptured

	Females	Males
Locally	2	4
Cedar Key	1	—

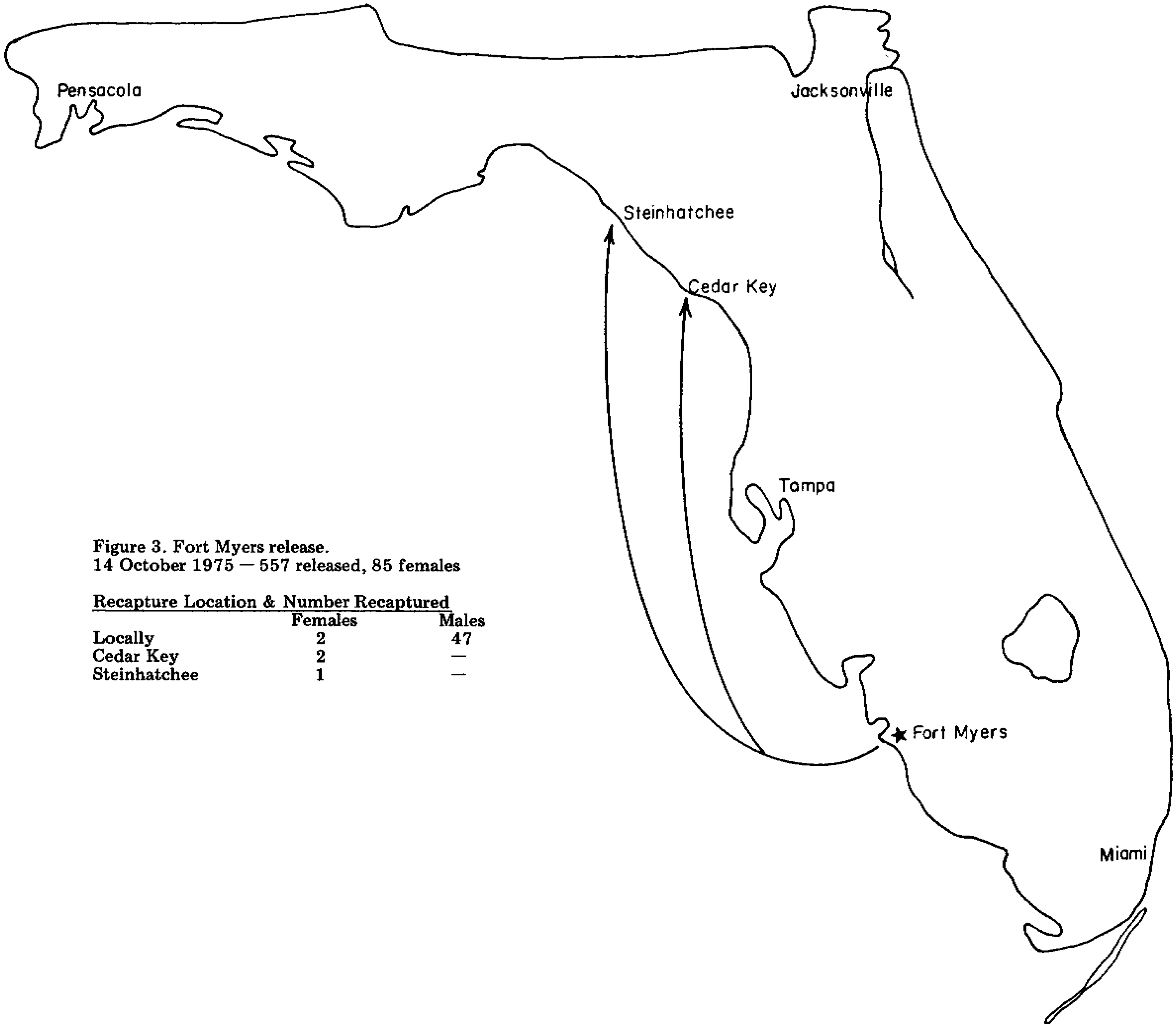

Figure 3. Fort Myers release.
14 October 1975 — 557 released, 85 females

Recapture Location & Number Recaptured	Females	Males
Locally	2	47
Cedar Key	2	—
Steinhatchee	1	—

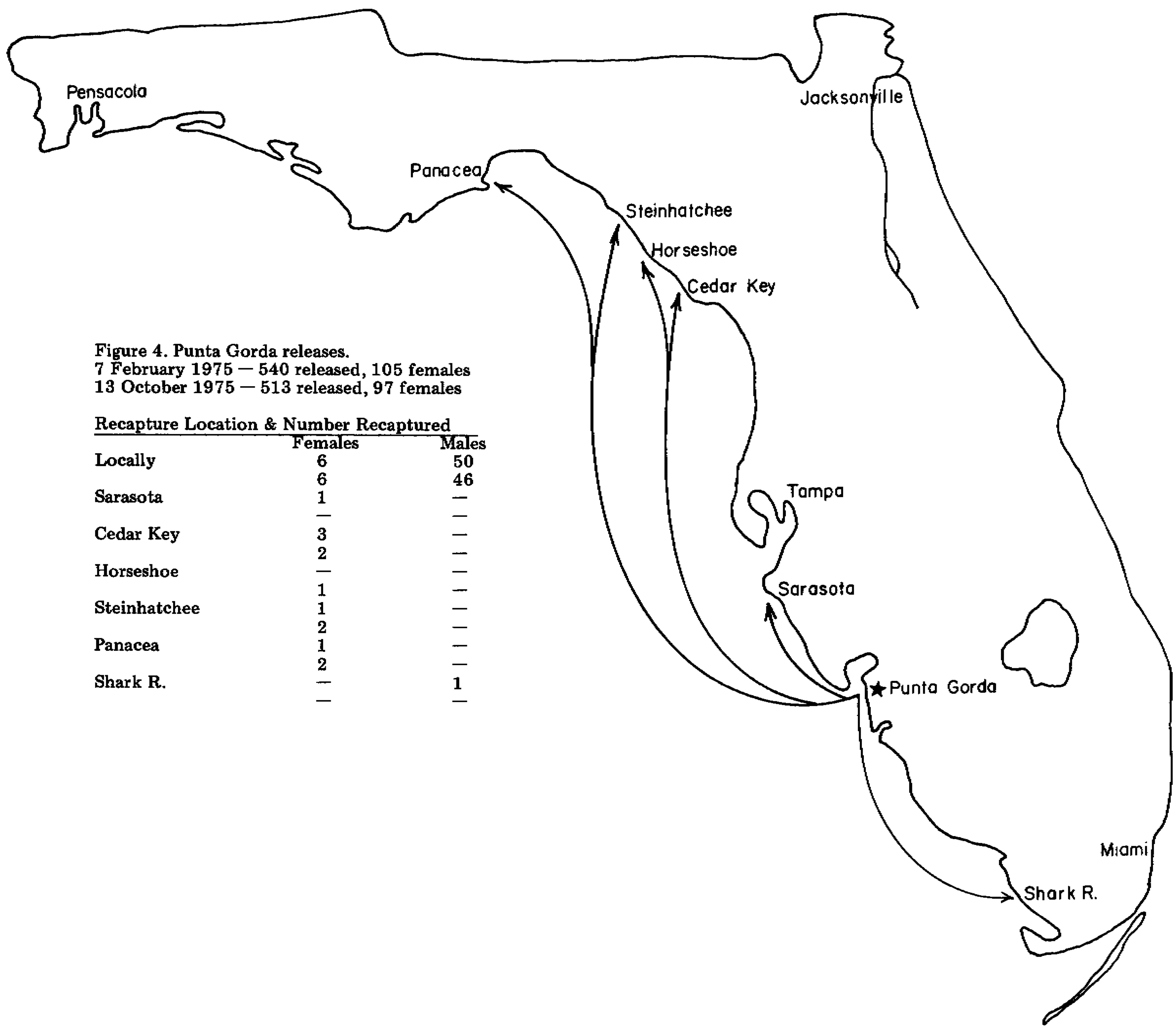

Figure 4. Punta Gorda releases.
7 February 1975 — 540 released, 105 females
13 October 1975 — 513 released, 97 females

Recapture Location & Number Recaptured	Females	Males
Locally	6	50
	6	46
Sarasota	1	—
	—	—
Cedar Key	3	—
	2	—
Horseshoe	—	—
	1	—
Steinhatchee	1	—
	2	—
Panacea	1	—
	2	—
Shark R.	—	1
	—	—

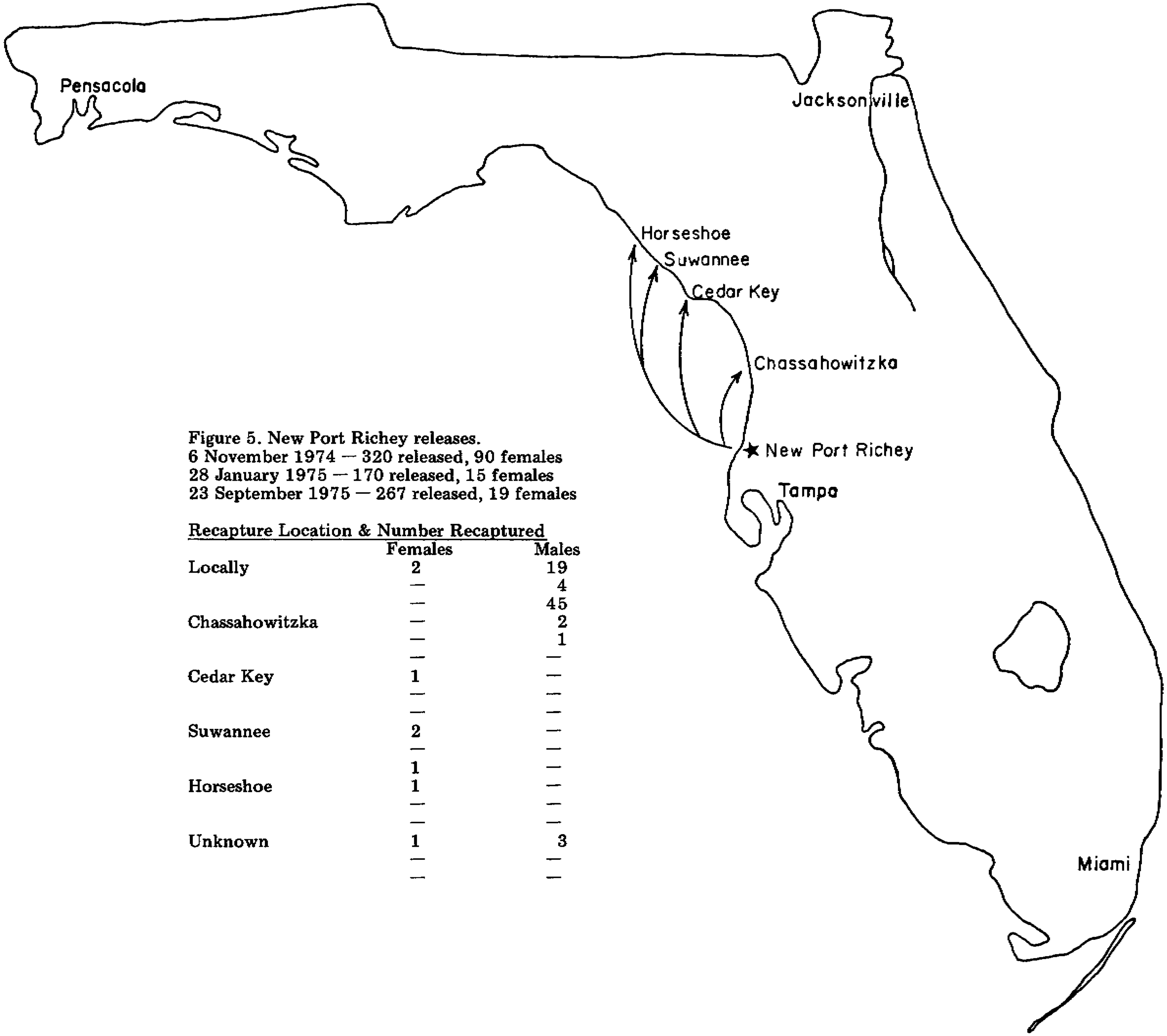

Figure 5. New Port Richey releases.
6 November 1974 — 320 released, 90 females
28 January 1975 — 170 released, 15 females
23 September 1975 — 267 released, 19 females

Recapture Location & Number Recaptured	Females	Males
Locally	2	19
	—	4
	—	45
Chassahowitzka	—	2
	—	1
	—	—
Cedar Key	1	—
	—	—
	—	—
Suwannee	2	—
	—	—
	1	—
Horseshoe	1	—
	—	—
	—	—
Unknown	1	3
	—	—
	—	—

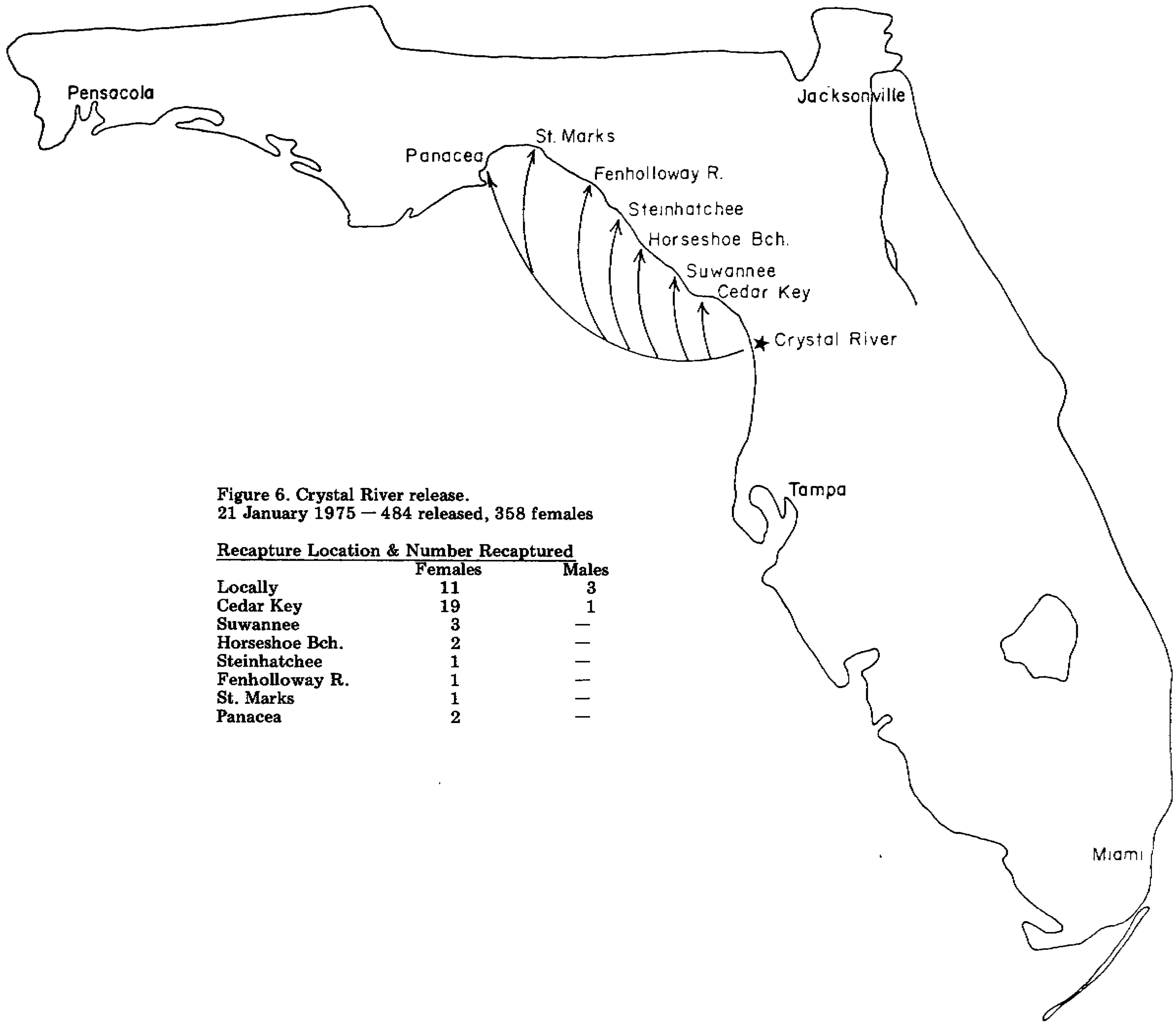

Figure 6. Crystal River release.
21 January 1975 — 484 released, 358 females

Recapture Location & Number Recaptured	Females	Males
Locally	11	3
Cedar Key	19	1
Suwannee	3	—
Horseshoe Bch.	2	—
Steinhatchee	1	—
Fenholloway R.	1	—
St. Marks	1	—
Panacea	2	—

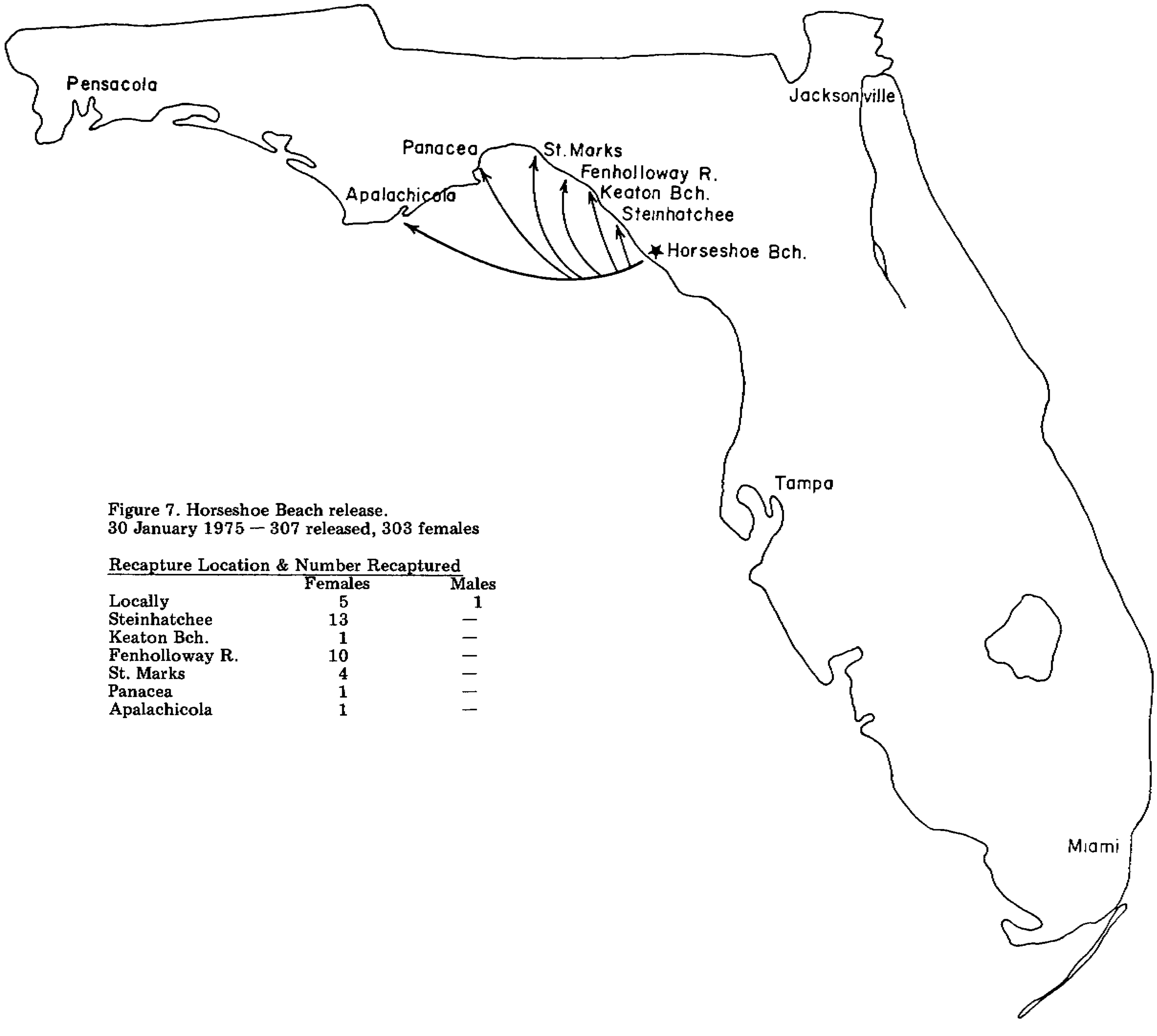

Figure 7. Horseshoe Beach release.
30 January 1975 — 307 released, 303 females

Recapture Location & Number Recaptured	Females	Males
Locally	5	1
Steinhatchee	13	—
Keaton Bch.	1	—
Fenholloway R.	10	—
St. Marks	4	—
Panacea	1	—
Apalachicola	1	—

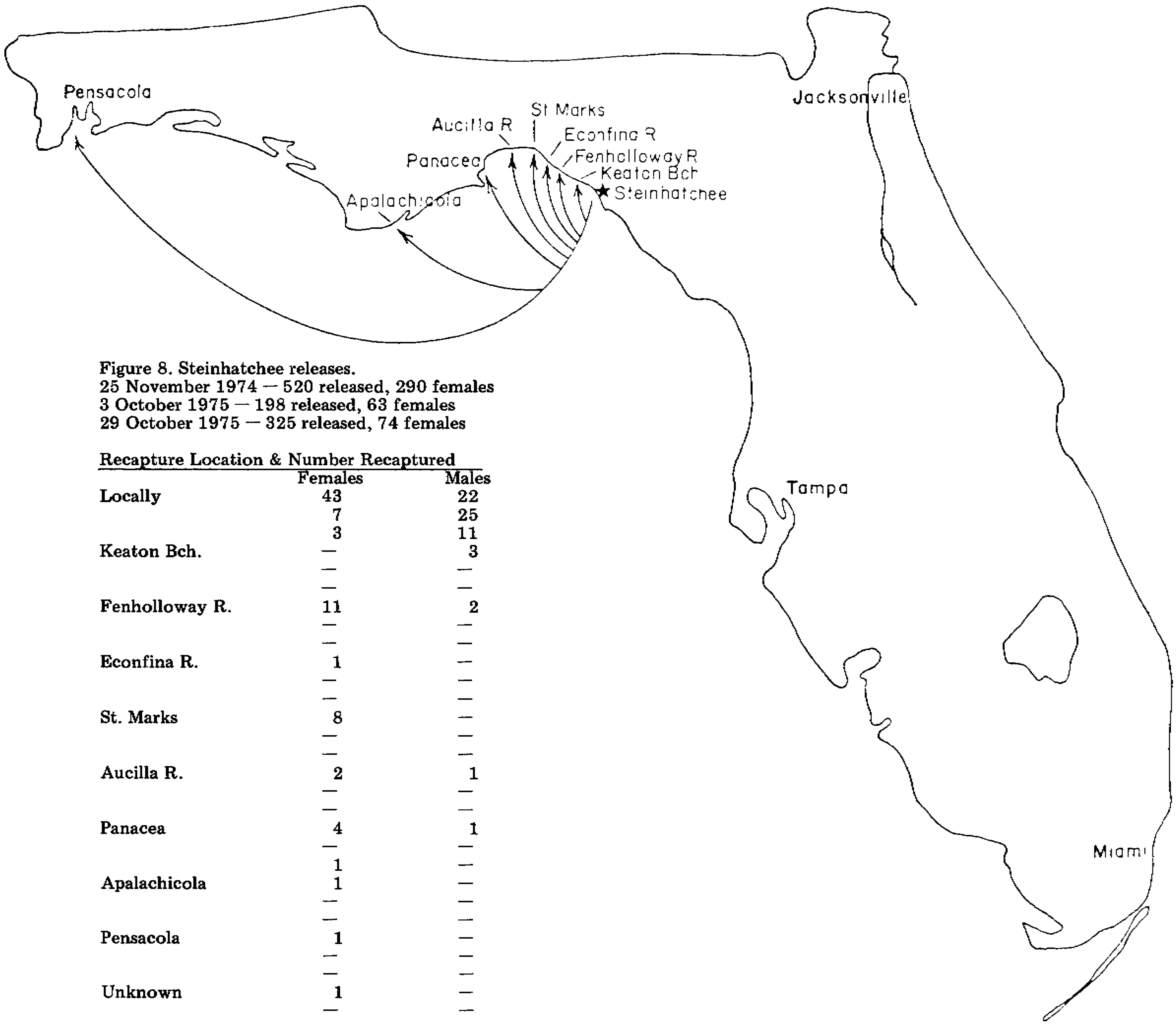

Figure 8. Steinhatchee releases.
25 November 1974 — 520 released, 290 females
3 October 1975 — 198 released, 63 females
29 October 1975 — 325 released, 74 females

Recapture Location & Number Recaptured	Females	Males
Locally	43	22
	7	25
	3	11
Keaton Bch.	—	3
	—	—
	—	—
Fenholloway R.	11	2
	—	—
	—	—
Econfina R.	1	—
	—	—
	—	—
St. Marks	8	—
	—	—
	—	—
Aucilla R.	2	1
	—	—
	—	—
Panacea	4	1
	—	—
	1	—
Apalachicola	1	—
	—	—
	—	—
Pensacola	1	—
	—	—
	—	—
Unknown	1	—
	—	—
	—	—

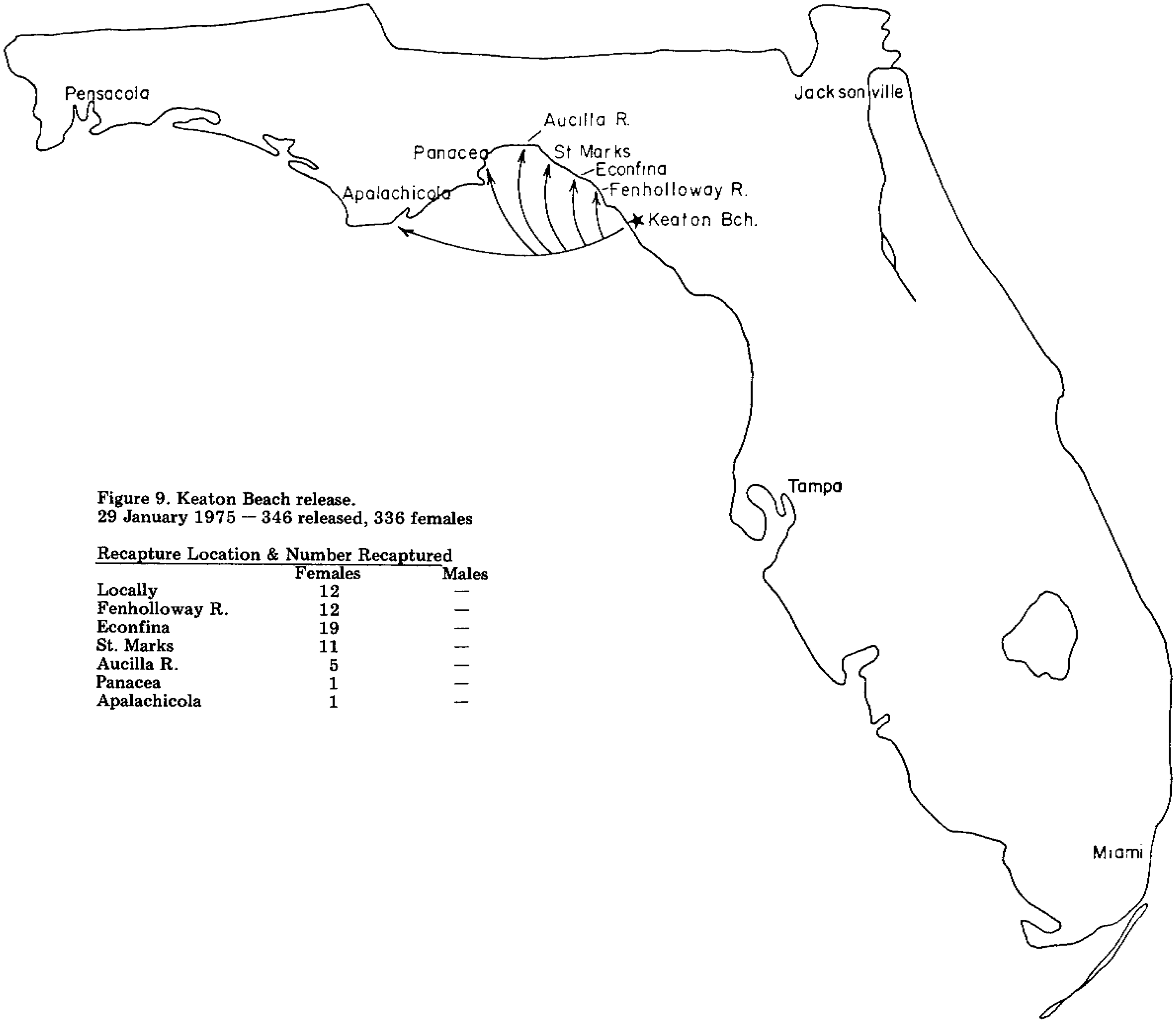

Figure 9. Keaton Beach release.
29 January 1975 — 346 released, 336 females

Recapture Location & Number Recaptured	Females	Males
Locally	12	—
Fenholloway R.	12	—
Econfina	19	—
St. Marks	11	—
Aucilla R.	5	—
Panacea	1	—
Apalachicola	1	—

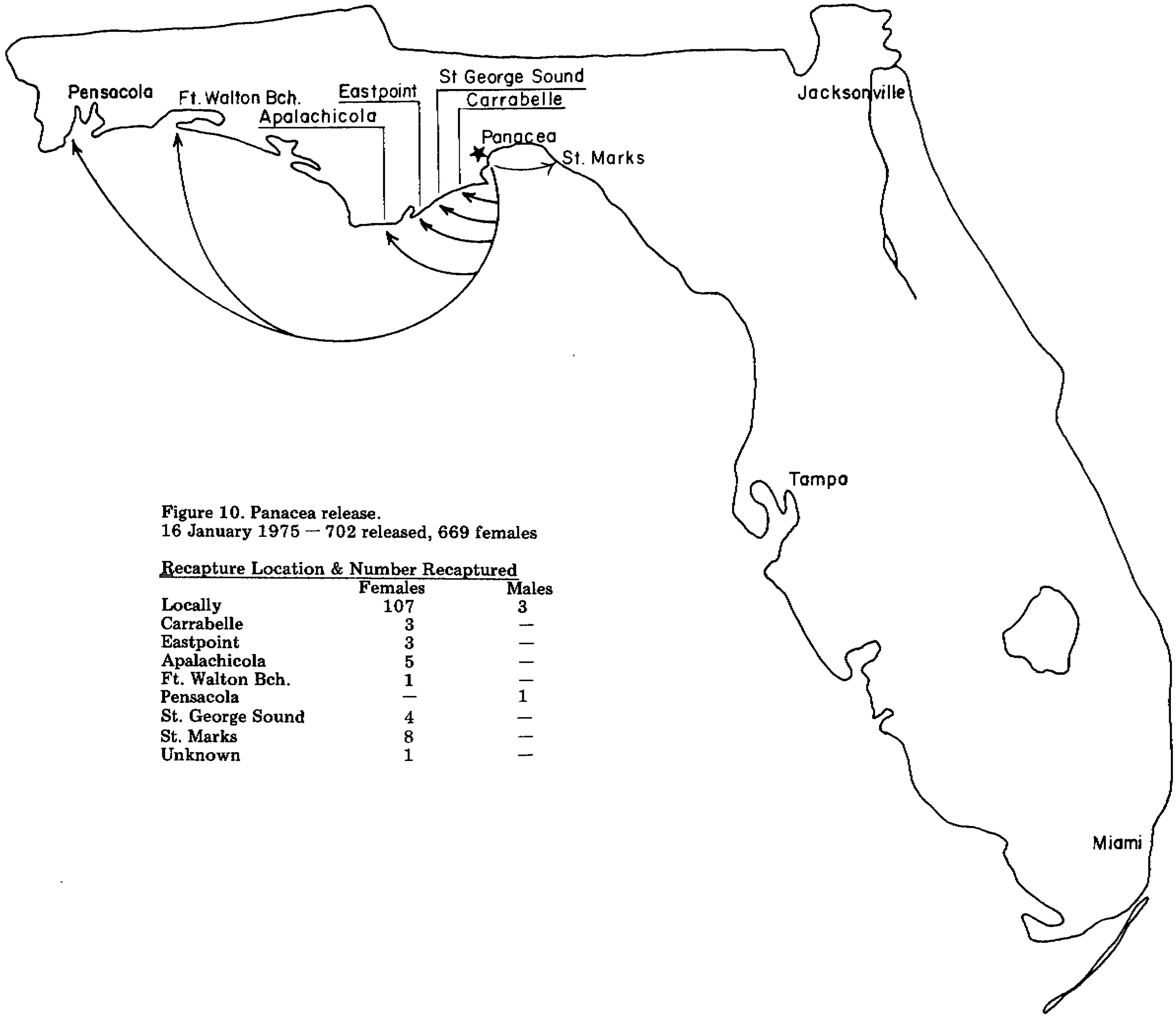

Figure 10. Panacea release.
16 January 1975 — 702 released, 669 females

Recapture Location & Number Recaptured	Females	Males
Locally	107	3
Carrabelle	3	—
Eastpoint	3	—
Apalachicola	5	—
Ft. Walton Bch.	1	—
Pensacola	—	1
St. George Sound	4	—
St. Marks	8	—
Unknown	1	—

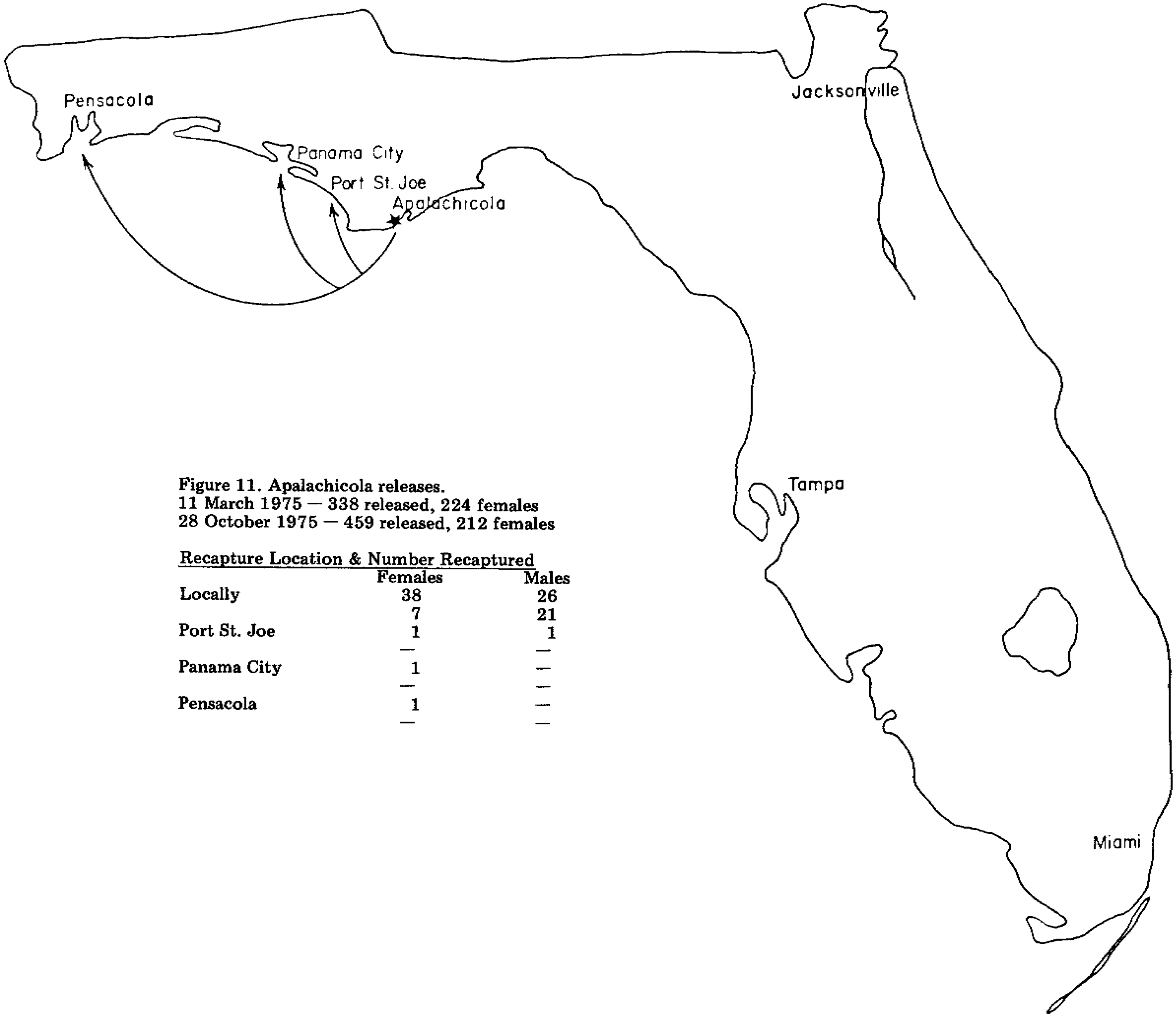

Figure 11. Apalachicola releases.
11 March 1975 — 338 released, 224 females
28 October 1975 — 459 released, 212 females

Recapture Location & Number Recaptured	Females	Males
Locally	38	26
	7	21
Port St. Joe	1	1
	—	—
Panama City	1	—
	—	—
Pensacola	1	—
	—	—

KEY

- 65 - 95 %
- 40 - 65 %
- 25 - 40 %
- 15 - 25 %
- 5 - 15 %
- 0 - 5 %

Note: Returns are noted as the % of the total returns.

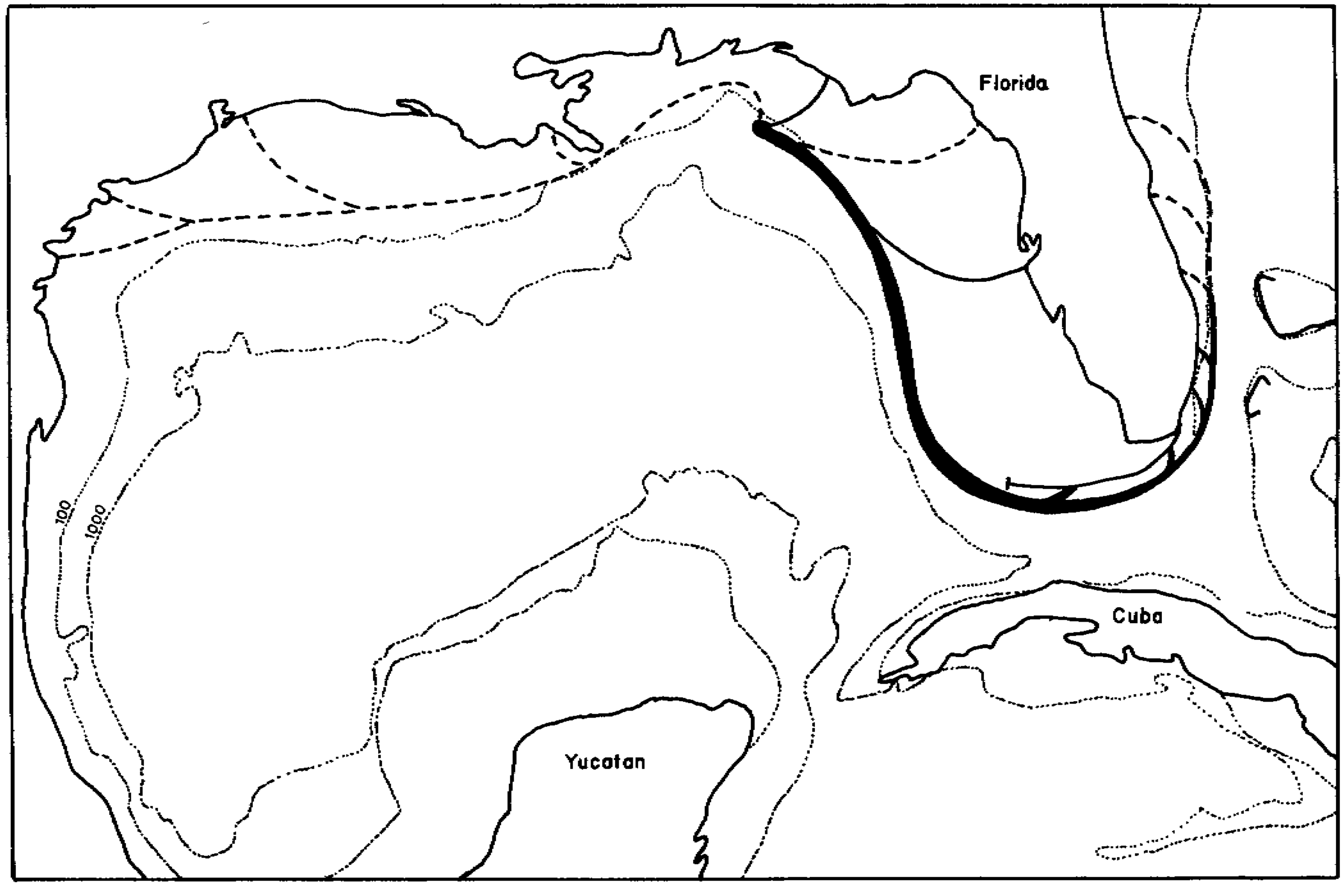

Figure 12. Drift bottle returns from releases made by Ichiye, et al. (1973) on 9 and 16 April 1963. There were 119 (24.8%) returns from 480 released. (figure drawn after Ichiye, et al., 1973).

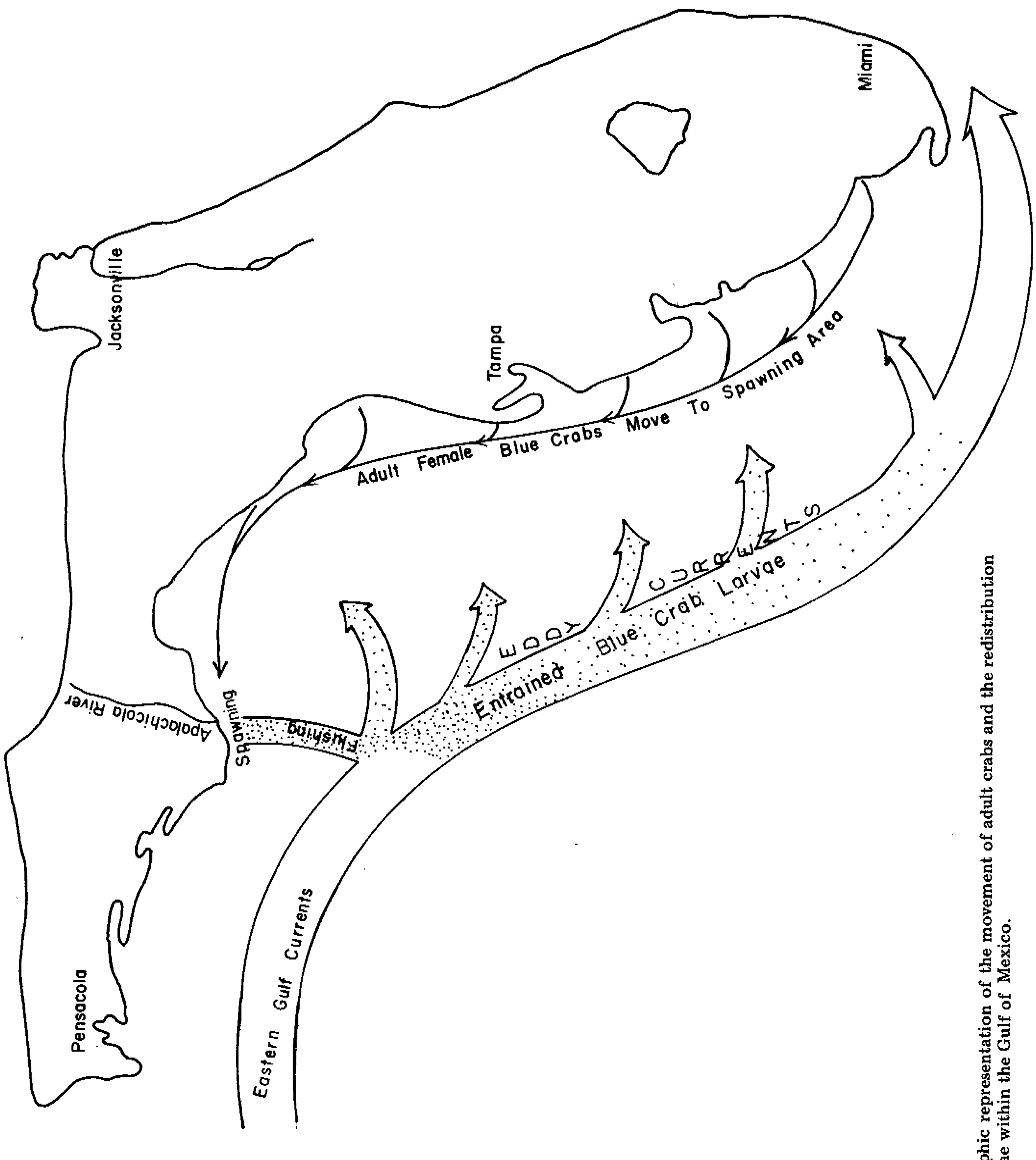

Figure 13. Graphic representation of the movement of adult crabs and the redistribution system for larvae within the Gulf of Mexico.

tions would permit these zoea to proceed through to the megalops and first crab stages, at which time the "directed migration shoreward" of megalops/post-larval crabs would carry these juveniles back into Apalachicola Bay. Livingston (1975) has pointed out that the Bay receives a large detrital import that is highest following the flooding of the Apalachicola River after the spring rainy season (January-April). The introduction of this potential food source to the system would be occurring about the same time as the influx of juvenile crabs from offshore. This would provide the juvenile crabs (detritivores while young; Darnell, 1959; Tagatz, 1968b) with a large food supply and could, therefore, support a large population of crabs.

CONCLUSIONS

The blue crab population along Florida's Gulf coast appears to behave contrary to previous studies in regards to their migratory habits. Instead of the classic description of an onshore/offshore pattern, an onshore/along-shore type movement was described where, following mating, female blue crabs leave the mating estuary and move towards specific spawning areas. For the Florida Gulf coast, there appears to be a primary spawning ground located in the Apalachicola Bay region. A hypothesis for redistribution of larvae to southwestern Florida includes transport through surface circulation patterns associated with the Loop Current.

Presently, the Army Corps of Engineers have plans for the construction of four additional dams along the Apalachicola River, together with the associated dredging and damage that accompany such activities. An important question to be asked then is: "What impact will this have on Apalachicola Bay and the entire Florida west coast blue crab industry?" It has been presented in this study that female blue crabs move along-shore for great distances, and that these movements are directed towards the Apalachicola Bay region for spawning purposes. Therefore any damage to Apalachicola Bay (via reduced flow of waters and nutrients) could impair the subsequent year's production of blue crabs. Any perturbations to the water quality in Apalachicola Bay could reduce its vital life support role at a delicate point in the blue crab's life history. Specifically, the number of eggs hatched and the chance of larval survival would be reduced, as would the ultimate number of market-sized crabs available for the entire Gulf coast blue crab industry.

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FISH AND WILDLIFE VALUES OF THE APALACHICOLA RIVER AND FLOODPLAIN

Mike Miller, Brad Hartman, and Dan Dunford
Florida Game and Freshwater Fish Commission

INTRODUCTION

This paper was prepared in response to public desire for information concerning the fish and wildlife values of the Apalachicola River and floodplain. In many areas information was scanty or absent. In these cases, literature from similar or adjacent systems was utilized to draw basic conclusions.

The report follows in two sections, the first dealing with the river itself and the second with the vast floodplain, periodically inundated, extending along both sides of the river. The conclusion contains monetary considerations which are added to amplify the needs for complete information on the real values of this complex system.

THE RIVER

The Apalachicola River is a large, moderately swift river, with a bottom generally characterized by sand and gravel substrate. In some locations, current-swept limestone provides hard, rocky bottom; in others, the current is sufficiently slow to allow deep sediment deposits to occur. Very little vegetation is found growing within the river due to heavy bedload transport with attendant siltation and high turbidity.

The aquatic fauna is, with few exceptions, characteristic of "red water" rivers of the southeastern United States as defined by Wharton (1976). A complete list of fishes occurring in the Apalachicola River has not been compiled. Yerger (1974) listed more than 70 species occurring within the Apalachicola National Forest, which is bounded on the west by the Apalachicola River. This list has been updated in this volume (Yerger, 1977). Cox (1975) and others have sufficient collections to indicate Yerger's list to be nearly complete. Invertebrate data for the river have been gathered for many years by a variety of researchers. With the possible exception of mollusks, however, most invertebrate lists for the river are probably incomplete.

The Apalachicola River system is notable among Florida rivers for its relatively large number of endemic species. Of fish and invertebrates, these include new species of shoal bass (*Micropterus* sp.) currently being described (J. S. Ramsey, personal communication), two cyprinid fishes, numerous mollusks and undoubtedly some lower macroinvertebrates (Clench, 1956; Heard, 1970; Yerger, 1977).

The southern sea sturgeon has been listed as "rare" by the U.S. Fish and Wildlife Service and the general mollusk populations of the region have recently declined such that several of these species might qualify for "rare" or "endangered" status.

Due to the similiarity throughout its 107 mi length, the Apalachicola River has been described by at least one researcher as "monotonous" in terms of physical, biological, and chemical characteristics. Although there has always been considerable basis for this description, it would seem that continued channel modification activities performed by the U.S. Army Corps of Engineers enhances this monotony by altering or removing certain characteristics of the stream which, under natural conditions, contribute to the physical and biological diversity of the river. These same activities have undoubtedly contributed to the general decline of several populations of riverine biota within the Apalachicola River.

In the past 20 years, the Apalachicola River has felt the massive impact of navigation enhancement projects such as the construction of Jim Woodruff Lock and Dam, the excavation and maintenance of a commercial traffic channel the length of the river, and a de-snagging program removing approximately 10,000 snags for the river annually. The Corps' activities have resulted in the loss of some of the most productive habitats associated with the river and a general decline in commercially and recreationally important species such as channel catfish, sturgeon, and striped bass.

Beck (1965), Cox (1969, 1970, 1975), Yerger (1974), and others attribute the general decline in the fishery to the removal of physical structures such as snags and rock shoals which are considered to represent the most productive habitat within the river channel. This feeling is further substantiated (Funk and Robinson, 1974; Arner, et al., 1975), with the losses of riverine biota attributed to channel modification practices.

Under natural conditions, the upper Apalachicola River was characterized by hard substrate which presented a shallow, irregular bottom profile ideal for the attachment and growth of benthic algae and macroinvertebrates. These conditions provided an excellent food resource for game and forage fish as well as breeding habitat for several species including the endemic shoal bass.

Much of this habitat has been lost due to navigation improvement activities. In order to maintain the authorized navigation channel, the Corps of Engineers has continually removed large areas of rock substrate occurring in shallow water while covering other areas with up to several feet of spoil removed from within the main channel.

During the work periods in shoal area, benthic populations occurring within the work area are almost certainly lost while those for some distance downstream are adversely affected by silt deposition and increased turbidity within the water column. While some invertebrate recolonization occurs within the affected areas, the degree and character of recolonizing benthos is determined by condition of the remaining substrate. If the river bottom has not been greatly altered, and irregular substrate persists with no significant increase in depth, then it is reasonable to assume that drifting invertebrates will recolonize much like the preexisting population. On the other hand, if any one of the shoal characteristics has been greatly modified (i.e., the depth has been significantly increased or the hard substrate has been covered with a layer of silt), then recolonization will be incomplete.

The Game and Fresh Water Fish Commission conducted a seven-year study of the upper Apalachicola River to determine some of the effects of the navigation improvement activities. During 1968 and 1969, a large rock shoal was removed from within our sampling location at Ocheesee Landing. Although data collections at this site were discontinued after 1969 and must be considered incomplete, they are indicative of the situation which must occur when shallow productive habitat is excavated or otherwise lost.

Prior to the removal of the shoal, a number of may-fly and caddis-fly nymphs were collected at the site. Habitat requirements of the several collected species indicate a general preference for conditions similar to those of the site prior to modification. After the shoal was removed, reduced numbers of aquatic nymphs were collected at this station while the number of a species tolerant of deep water and soft substrate, such as the Asian clam (*Corbicula manilensis*) greatly increased.

The adverse effects of continual resuspension of small particles upon invertebrate populations must also be considered. These effects would include the clogging of respiratory mechanisms due to inordinately high silt loads as a result of dredging, the silting over of immobile benthic communities, and the loss of large particle substrate necessary for clinging and attachment. Cox et al. (1975) found that particle sizes, numbers, and diversity of invertebrates and fishes on the upper Apalachicola River decrease with distance downstream.

Snags occurring within the river appear to be of similar biological importance as rocky shoals. Like shoals, snags play an important role in maintaining habitat diversity, dissolved oxygen levels, and water column mixing. Behind the snag small eddys are created; this allows attachment by invertebrates and algae along the trunk and limbs of the tree. The changed current patterns, food, and cover offered by the snag provide excellent nursery zones for juvenile fish. Beck (1965) considers snags to be the most productive habitat of the Apalachicola River.

In contrast, the Corps of Engineers considers snags to be hazards to navigation and removes an estimated 10,000 snags from the Apalachicola River annually. This activity has been cited by Yerger (1974) as the chief cause for the recent decline of the commercial channel catfish harvest from the river. This view is substantiated by others (Funk and Robinson, 1974; Hickman, 1975) in work on rivers in Missouri. Funk and Robinson's study cited the removal of snags for the greatly reduced number and size of blue catfish within the Missouri River. Similarly, Hickman found that within desnagged areas of the Fabius River, general fish populations have declined by as much as 25% and "catchable" sized fish have decreased by 51% relative to portions of the river which have not been subjected to desnagging operations.

The zones of productivity previously mentioned are to be considered in the context of low water levels. There is no question that the available food resource is greatly expanded during high water periods when fish are able to move out of the channel onto the floodplain. During these times, the full productivity of the floodplain is available to the fishery both as a direct forage source—the invertebrates found in leaf litter and backwater sloughs—and as an indirect source in terms of the detritus transported by flood water into the main river channel to be later utilized by channel organisms. The real value of shoals and snags is felt during low water conditions when they become the mainstay of most main channel organism stocks.

Although the consensus of most researchers is that the riverine biota of the Apalachicola River continues to be nearly as diverse as ever in terms of numbers of species, the populations of those species intolerant of disruption are declining. This general decline has been accelerated by urban wastes, increased river traffic, and reduced habitat and range due to dams and impoundments throughout the upper system. It is probably that the continuing trend of river modification and impoundment construction will result not only in the reduction of existing populations within the river, but also the complete loss of some of these species from within the Apalachicola River.

THE FLOODPLAIN

The Apalachicola River floodplain forests rate as some of the highest wildlife values in north Florida. Wildlife values are high because of the richness of the alluvial clay soils, the high moisture of the area, the tremendous diversity of microhabitats available, and the high value of the tree species for wildlife food production, wildlife cover, and nest sites. In fact, bottomland hardwoods in general are considered by some to be the most productive wildlife habitat in North America (Glasgow and Noble, 1971). While sharing many of these attributes with other panhandle rivers, the Apalachicola's importance is magnified by its size, in excess of 200,000 acres (U.S. Army Corps of Engineers, 1975a). This may seem to be relatively paltry when compared to the 2,500,000 acres of bottomland hardwoods of the Mississippi drainage in Louisiana alone and the more than 5,000,000 acres of the entire delta area originally in floodplain forests. However, compared with the rest of the rivers in Florida, the Apalachicola is still the "Big River." Other panhandle rivers have bottomland acreages varying from a few thousand acres up to the 70,000 acres of the Choctawhatchee River.

Another attribute of the Apalachicola which enhances its total wildlife value is the large number of endemic, disjunct, or rare species of plants and animals found in its watershed. In wildlife, this is primarily true for amphibians and reptiles. One explanation for this is the connection of the Apalachicola-Chattahoochee-Flint system to the southern mountains (Loftin, 1962). The region is fairly old geologically, and may have acted to preserve certain earlier life forms in isolation.

AMPHIBIANS AND REPTILES

Amphibians of special interest in the Apalachicola Basin include the one-toed amphiuma of alluvial swamps, the four-toed salamander of floodplains, the southern coal skink of titi swamps, the flatwoods salamander of acidic, flatwoods cypress ponds, and the Gulf Coast waterdog of streams and river.

A number of threatened or interesting reptiles are also found in this watershed. The Barbour's Map Turtle, considered rare by the Florida committee on Rare and Endangered Plants and Animals, occurs in this watershed and utilizes the rocky shoals of the upper portions of the Chipola and Apalachicola Rivers. The alligator snapping turtle, the world's largest freshwater turtle (weighing over 200 lb) is in a status-undetermined category but is thought to be declining in numbers due to overharvesting throughout its range and loss of habitat through channelization and drainage (Dobie, 1975).

Another turtle of the Apalachicola, the Suwanee Cooter, *Chrysemys concinnia suwanniensis*, is considered threatened by the Florida Committee and is also in that category in the Game and Fresh Water Fish Commission classification. Overharvesting is thought to be a dominant factor in its decline but habitat preservation is also a vital part of its future management. Florida's wildlife code prohibits the possession, selling, or buying of threatened species; however, enforcement is difficult because of the problems of species identification.

The threatened American alligator is another reptile of special interest found in the floodplain and along the banks of the river, tributaries, sloughs and backwaters.

BIRDS

Although the Apalachicola floodplain has its share of rare and endangered species, probably its greatest value results from the total number and diversity of species supported. The bird life of the Apalachicola, for instance, is abundant and diverse. Birds are not restricted to the same microhabitats or well-defined niches as are many other animals, but general preferences can be discussed. No detailed study of the bird life of these bottomland hardwoods and swamps has been done; however, studies in the bottomland hardwoods of other states and in other parts of Florida have quantified bird values by species for different subhabitats within the floodplain.

Dickson (1974), in surveying Louisiana, found bottomlands to be among the best bird habitat in the country, especially as wintering habitat. In a comparison with 34 other forest types, bottomland hardwoods had the greatest overall density (3.1 breeding birds per acre, 5.7 wintering birds) and were exceeded by only five habitats in numbers of species.

Floodplain forests such as those of the Apalacicola provide an abundance of niches that enable heavy utilization by birds with minimum interspecific competition. Such forests are also one of the most mesic habitats of the region, and are typical of the northern portion of the Apalachicola. With its relatively low environmental stresses this contributes to the diversity and abundance of seed and fruit producing plants as well as insects heavily utilized by birds.

In a study of warbler migrations through a river floodplain area in North Carolina, Parnell (1969) found that this habitat contained the largest group of regularly occurring warbler species. The yellow warbler, prothonotary warbler, Canada warbler, and northern waterthrush were most selective for floodplains although the yellow warbler was also selective for wet thickets. Other species heavily utilizing the floodplain or associated wet thickets were the blackthroated blue warbler, Louisiana waterthrush, hooded warbler, yellowthroat, yellow-breasted chat, and prairie warbler.

The Game and Fresh Water Fish Commission (1976), in a census of the mixed swamp habitat of the Oklawaha, found that this habitat supported the highest populations of red-eyed vireos, prothontary warblers, and acadian flycatchers of all habitats studied. Wintering birds most commonly observed were the yellow-rumped warbler, American goldfinch, American robin, rubycrowned kinglet, and yellow-bellied sapsucker.

The microhabitats of birds for floodplain forests can be broken into height classes and serve to differentiate ground, midstory, and canopy birds. While birds are extremely mobile and difficult to strictly confine to the habitat classification schemes we invent, these attempts at identifying niches do aid in comprehending the overall value of the floodplain habitat.

Canopy users include most of the woodpeckers, blue jay, Carolina chickadee, and tufted titmouse. Representative midstory species include the Carolina wren, ruby-crowned kinglet, white-eyed vireo, and hooded warbler, while heavy ground (0-2 ft) users include the rufous-sided towhee and white-throated sparrow (Dickson, 1974).

Another low level bird of fairly restricted habitats within the bottomland hardwoods in the Swainson's warbler, considered to be the least abundant southern warbler except for the Bachman's warbler (Meanley, 1971). The canebrakes along the Apalachicola River can be expected to harbor this inconspicuous and uncommon warbler and support such leaf litter insects as crickets, ground beetles, ants, and spiders which form a major portion of this warbler's food. In addition to canebrakes, their classic habitat, this warbler is found in areas of scrub palmetto and sweet pepperbush.

The Apalachicola River floodplain also provides habitat for the wild turkey. Our regional biologist estimates a density of one turkey per 32 acres in the more mesic portions of the floodplain. Other estimates for hardwood bottomlands range from one turkey/15 acres (Glasgow and Noble, 1971) to 1/75 acres (Yancey, 1970).

The wood duck, a hole nesting resident as well as a migratory waterfowl, is also found extensively in the bottomlands at nesting densities of 1/100 acres and is dependent on the availability of sloughs, ponds, and trees with suitable nest cavities.

Endangered or threatened species of birds occurring or expected to occur in the floodplain forests include the southern bald eagle, osprey, peregrine falcon, and southeastern American kestrel. Additional birds from the lists of the Florida Committee on Rare and Engandered plants and animals include the American redstart and the Louisiana waterthrush. The northern part of the Apalachicola may be one of the southernmost extensions of breeding territory for the latter bird.

Two extremely endangered birds could be still living in the vast swamps and floodplain forests of the Apalachicola. The ivory-billed woodpecker was suspected to be in the lower Apalachicola area around the Brothers River by Tanner (1942) although most of that area has been intensively logged since that time. One of the last sightings of this large woodpecker, however, was in this area in 1950 (Sprunt, 1954). Of potential habitats remaining in Florida, the Apalachicola floodplain may still be one of the best.

The Bachman's warbler, the rarest of all warblers, is the other possible survivor in the forests of this area. In fact, one of the few sightings of this bird in this century was near the Chipola River, the major tributary stream of the Apalachicola (Sprunt, 1954).

The floodplain forest is one of the most important bird habitats in the southeast, both for residents, breeding birds, and wintering birds. In additions to its value for forest species, the sloughs, ponds, and terrace streams provide feeding areas for a number of wading birds such as the great egret, great blue heron, and little blue heron. These rivers also serve as "highways" for migration for many species and their overall importance increases as alternative upland habitats are eliminated by agriculture, pine plantations, and urban development.

MAMMALS

The mammal populations of the Apalachicola are perhaps even less well understood than the birds. The white-tailed deer is a common and sometimes abundant resident with densities in floodplain hardwoods ranging from one deer per 10-12 acres (Glasgow and Noble, 1971), to one per 80 acres (Turner, personal communication). River swamps not only provide high quality food sources but also serve as excellent escape cover from hunters and free-ranging dogs (Glasgow and Noble 1971). The grey squirrel reaches its maximum density in the swamps and hammocks of riverbottoms with densities often approaching one per acre. This is a highly sought game animal in lower Apalachicola and an estimated 1,500 hunters invade this area each year, primarily by boat, on the opening day of the hunting season (Frank Smith, personal communication).

Other fairly common mammals recorded in the floodplain of the Apalachicola (Pearson, 1960) include opossom, marsh rabbit, beaver, cotton mouse (most abundant in Pearson's survey), southern golden mouse, cotton rat, woodrat, house mouse, raccoon, grey fox, and striped skunk.

Endangered or threatened species include black bear and possibly panther. The extent of the floodplain and its function as a contiguous corridor for large mammal movements (Wharton, 1976) make this an area of potential habitat for either of these wide ranging animals. Other endangered mammals that potentially may occur are the southeastern shrew and hoary bat.

Bats heavily utilize the floodplain and the corridor over the channel as feeding areas. Several species also roost in tree cavities. Typical species are the red bat, evening bat, seminole bat, and eastern pipistrelle.

MANAGEMENT PRACTICES

The Florida Game and Fresh Water Fish Commission is indirectly involved with major portions of the Apalachicola floodplain and adjacent uplands through wildlife management areas. The Apalachicola National Forest is under the supervision of the National Forest Service with wildlife jointly managed by the Service and the Game and Fresh Water Fish Commission. Forest Service timber management plans call for eventual harvest of hardwoods in 25 acre clearcuts on a 100 year rotation (U.S. Forest Service, 1975). Although we have expressed some concerns over this management plan, it should retain much of the area's wildlife values. Only a small portion of the floodplain is in the national forest, however.

The G. U. Parker Wildlife Management Area is located between the river and Dead Lake. Consisting of pine flatwoods as well as swamp and floodplain hardwoods, this area currently has moderate to high wildlife values. It is owned by a private timber company, however, and future management plans are unknown.

International Paper Company owns 52,000 acres comprising most of the river corridor from the Calhoun-Gulf County line south to Jackson River, a distance of 28 mi. Most of this is known as a "Class II Wildlife Management Area." International Paper Company has their own permitting system. The only involvement of the Game and Fresh Water Fish Commission is to provide an extra degree of law enforcement patrols and limiting game animal restocking in exchange for public use of the area.

International Paper Company has the goal of clearcutting as much of the area as possible. Current management guides limit clearcuts to 80 acres and restrict cutting from the margins of the rivers. Approximately 8,000 acres have been clearcut on Cutoff Island and northward (Dave Warren, personal communication).

The Game and Fresh Water Fish Commission will probably acquire management responsibility for lands purchased in the vicinity of the Brothers River and Forbes Island under the state's Environmentally Endangered Lands Program. Management will, more than likely, consist of people management more than habitat management but some wildlife enhancement activities might be appropriate within the goals of the Environmentally Endangered Lands Program.

Threats to the wildlife values come from a number of sources. The maintenance of a high intensity navigation channel poses some direct problems and perhaps more important, some long-range indirect ones.

The Missouri River was once a meandering river of exceptionally high fish and wildlife values. Navigation enhancement techniques such as training dikes, cutting across meanders and ox bows, dredging and spoiling, riprap revetments, shoal removal, and desnagging operations were used on the Missouri. The end result was a narrowing of the river (and associated loss of surface area from the public domain), loss of highly productive islands, a shortening of the river channel, the overall loss of 50% of the original river surface area, and the loss of large areas of sloughs and other valuable backwaters (Funk and Robinson, 1974). In analyzing the results of this work, Funk and Robinson concluded that wildlife values had been significantly reduced largely as a result of these changes. The situation is not so severe on the Apalachicola-yet. However, most of the techniques used on the Missouri are in use now on the Apalachicola and future navigation ambitions are vague at best.

A proposed low level dam with seven miles of dikes separating the river from its floodplain may obviate the need for a portion of current navigation maintenance projects but may cause its own problems. Although its potential effects are not well understood, it could affect hydroperiods above and below the dike and dam with subsequent alterations of the forest species composition. There will be: the immediate loss of 175 acres of bottomland hardwoods for construction of the tie back levees or dikes, a 260 acre loss due to clearing in the lower reaches of the impoundment; and 600 acres of forest within the impoundment that would be affected to some degree depending on locations and elevation (U. S. Army Corps of Engineers, 1975b).

Although the direct effects of making this river completely reliable for navigation may be important to wildlife values, it is the indirect effects which may be of greater long range importance. A guaranteed nine foot channel could be the catalyst for a number of detrimental land use changes. One of the most severe changes in other bottomland hardwood areas, particularly the delta of the Mississippi, is the loss of habitat to agriculture. From 1962 to 1968, the 2,500,000 acres of bottomlands hardwood were being converted to farmland, predominately for soybeans, at a rate of 111,000 acres per year (Yancey, 1970). Our floodplain forest may not be as suitable for agriculture as the delta's, but the potential for major losses remains. It should be remembered, for instance, that one of the most frequently heard justifications for a guaranteed nine foot channel is that it will assure soybean farmers of a ready and profitable outlet.

Agriculture has already had a major impact on the Apalachicola along the Brothers River. The M-K Ranch purchased an immense tract of land extending from the Jackson River north to Willis Landing, a distance of approximately 15 mi. After several somewhat abortive efforts in the marshes of the Jackson River, they constructed a six mile dike roughly paralleling the Brothers River which isolated approximately 5,000 acres of floodplain from the Apalachicola system. The interior was ditched, pumped out, bulldozed, and converted to improved pasture leaving soybean production as a future option.

Forestry, which is probably one of the better long-range uses of the floodplain, can also be a major degrading factor, depending on the management plan used. Selective cutting, small shelterwood or seedtree cuts, and small clearcuts on a long rotation are all considered generally acceptable for maintaining wildlife populations (Glasgow and Nobles, 1971). Massive clearcuts change the entire nature of the forest, however, with a major loss in values, particularly among the more specialized forest animals such as the woodpeckers, wood ducks, and other hole dwelling wildlife.

Far worse than even a massive clearcut, however, is the large scale hardwood plantation. This type of management uses monocultures of cottonwood, sycamore, or sweetgum and requires intensive site preparation and even annual cultivation for the first few years of the cottonwood plantation. Although small plantations have some of the same interspersion values as clearings, the large scale usually required is devastating to long term wildlife production.

Hardwood plantations are not on the immediate horizon for Florida, primarily because of a lack of convenient market outlets and the current emphasis on pine production (George Reinert, personal communication). With changing land use patterns, however, this may be a future problem of major proportions.

In summary, we have many of the wildlife values in the Apalachicola River floodplain as the massive bottomland hardwoods of the Mississippi River system plus a few of our own unique values. We are also faced with problems, that, in the Mississippi system, are rapidly destroying these values. Any development activity on the Apalachicola should be closely reviewed for both its immediate impact and the long range, indirect effects it will have.

CONCLUSION

Although the technical information on wildlife and fisheries in the Apalachicola basin is limited, the data on one aspect that generally receives little attention in determining the overall utilization of a river system like the Apalachicola are even more limited. That is, the actual dollar values which can be placed on the utilization of the system by uses other than transportation development. It is necessary to know *all* the dollar values that can be determined for all uses of the system. To put arguments for fish and wildlife habitat in dollars is unappealing to many (including the authors) but unfortunately, dollars are still the leading influence in decision making.

A few studies have been accomplished in order to help determine the monetary values of fish and wildlife related recreation. This general category includes: fishing, hiking, hunting, canoeing, photography, etc. One recent study (Horvath, 1974) based dollar values on four basic parameters tested through surveys:

1. The average money spent per day by participants.
2. Average value assigned by non-participants that wished they did participate.
3. Average daily values required to give up participation.
4. Average pay lost.

The results showed big game hunting worth $61 per day, waterfowl hunting $49 per day, and small game hunting to be valued at $39 per day. It was also found that wildlife enjoyment activities were found valued at even higher rates than hunting. Animal enjoyment was found to be worth $80 per day, bird enjoyment $65 per day and fish $66 per day.

Another recent report samples activities on two river systems in Kentucky. Usage on one river was 20,561 man days per mile per year, valued at $38,782 miles per year; usage on the other was 9,700 user days per mile valued at $20,914 per mile per year (Willis, 1974).

An additional study completed in the Atchafalaya Basin in Mississippi showed, in a sample of 590,000 acres of river swamp, an annual expenditure of $6,730,000 for equipment expenses, licenses, etc. In addition, $35,897,000 was foregone for the opportunity to engage in recreational activities (Soileau et al., 1975).

Lastly, in 1974, the estimated annual value of recreation and tourism on the Suwannee was $16,000,000 (DRI Evaluation, Upper Suwannee River).

It is not known what a "greenback plan" for the Apalachicola River basin may show. We know, however, that the Apalachicola is a corridor for water transportation, presently terminating in Georgia and Alabama. With development of the proposed year-round reliable river channel of 9 ft depth, one could expect more development in the Florida portions of the river. Apparently, commercial barge transportation in the system is here to stay! What we wish to achieve in management will allow transportation, but not at the expense of intrinsic values which most Floridians do not want to give up. It may be that if all values are uncovered we would find that money may be lost in the long run trying to maintain an artificial system primarily for commercial transportation.

From a limited review of the fish and wildlife values elsewhere, it is suggested that if real dollar values are calculated for the Apalachicola basin, it would show a worth greater than that which we presently surmise. We are suggesting that these values are high enough to consider a plan which would investigate and develop uses which would be economically advantageous but not physically destructive to the system.

We know that the values of commercial harvests of invertebrates and fish are large — we suspect that recreational values are also large — in combination there may be an economic advantage to the existing system not yet fully realized.

The technical reports on the fish and wildlife present in the Apalachicola River sytem contain many biological justifications to protect the vitality and integrity of this system. There are, in fact, many reasons, in addition to fish and wildlife, which point towards a hold-the-line philosophy on industialization of the Apalachicola Valley.

The hold-the-line philosophy is necessary because we are nearing a point of decision which, unfortunately, has passed in much of our state. We have, however, the ability to take actions now which will determine the future of this river for all subsequent generations. Must we go the route south Florida has, with their artificial systems requiring millions of dollars of maintenance per year? Or, can we stop the rolling power of industrial expansion for awhile and totally examine the system which we may be on the brink of destroying? The Corps of Engineers required the gathering of much information in the Oklawaha Valley, in relation to the Cross Florida Barge Canal, yet are we to wait until it is *too late* before such data are developed for the Apalachicola?

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SHELLFISH MANAGEMENT IN APALACHICOLA BAY PAST—PRESENT—FUTURE

William K. Whitfield, Jr. and Dale S. Beaumariage
Florida Department of Natural Resources

INTRODUCTION

Until the 1960's, specious coastal development schemes in Florida were encouraged with little understanding of, or regard for, the concomitant reduction in value of existing estuarine resources. Such activities as dredge and fill, untreated sewage dumping and marsh drainage have occurred along our coastline with little public awareness of the riches being removed from the natural environment. As a result, many prime estuaries were either simply destroyed or so degraded by desultory urban growth that many shellfish producing areas were closed because of extant or potential health hazards. However, the shellfish industry of Apalachicola Bay is still alive and well. There are several reasons for this continued productivity.

Apalachicola Bay is truly a unique part of Florida. Environmental and geographic features provide salubrious conditions for the Bay's primary resource, the American oyster, *Crassostrea virginica* (Gmelin). This estuary has a dependable source of comparatively pollution-free, nutrient-rich fresh water in an area of minimal urban and industrial development. It is surrounded by an ecologically valuable marsh coastline. The Apalachicola Bay oyster bars have thrived for centuries during periods of river floods and low water. Those reefs near the Bay's seaward edge flourish when the river is high and those near the river mouth thrive during low water. The river brings a prodigious amount of nutrients into the Bay as river water ebbs and flows across the floodplain. Nowhere else in the State of Florida are all these factors combined.

Others papers in this symposium address these points in greater detail. It is our purpose to present a perspective of shellfish management in Apalachicola Bay to illustrate the investment Florida citizens have there, and to describe the potential value of Florida's oyster industry center.

Almost 90% of Florida's 1974 oyster crop was produced in Franklin County. The retail sales value was estimated to be between 7 and 8 million dollars. In 1969, this revenue constituted more than 48% of Franklin County's income.

HISTORICAL MANAGEMENT

The need for oyster resource management in Franklin County was not apparent until the close of the 19th century. Oysters were harvested in any manner that oystermen desired without regard for resource conservation. Many natural reefs were destroyed by indiscriminate dredging. It was reported by a U.S. Fish Commission survey of the area that by 1895-96 many oyster reefs were depleted from overfishing (Swift, 1897; 1898).

Laws permitting oyster grants were passed by the Florida Legislature in 1881. Individuals were permitted to obtain grants of unproductive oyster waterbottoms from local county commissions (Figure 1). Contractual stipulations required the grantee to cultivate his grant by placement of shell or live oysters thereon, enabling him to exclusively harvest and hold title indefinitely. It was felt that cultivation and harvest from private beds would stop the wasteful harvest practices on public reefs.

At least 15 such grants were issued in Franklin County between 1895 and 1905. Approximately 30% of the total area of Apalachicola Bay, St. Vincent Sound, and St. George Sound was under grant including many viable public oyster reefs. Lack of county law enforcement to limit poaching and to ensure adherence to the cultivation requirements prevented this management program from being effective. Most grants were abandoned before 1913 when State laws were established prohibiting grants.

In 1913, the value of the state oyster resource and its need for state management was recognized. The Florida Shellfish Commission was organized and shellfish laws were revised. Three important features of these 1913 revisions were the requirement of permits for oyster dredges, the establishment of a statewide oyster lease program, and the adoption of an oyster severence tax to fund the management program.

Permits to use dredges to harvest oysters from Franklin County public reefs were easily obtained from the Commission. Ineffective law enforcement could not prevent their illegal use and it was apparent more reefs were again threatened by destruction. This was due to the undesirable sediment load raised when a dredge would cut under the relatively thin layer of cultch and oysters comprising many Apalachicola oyster reefs lying upon muddy bottoms. In addition, oyster shells thin and brittle from new growth or from intrusion of boring sponge, tend to break, resulting in a greater waste than harvest by hand tonging. Further legal revisions over the years prohibited the use of dredges on public reefs. Eventually their use on pri-

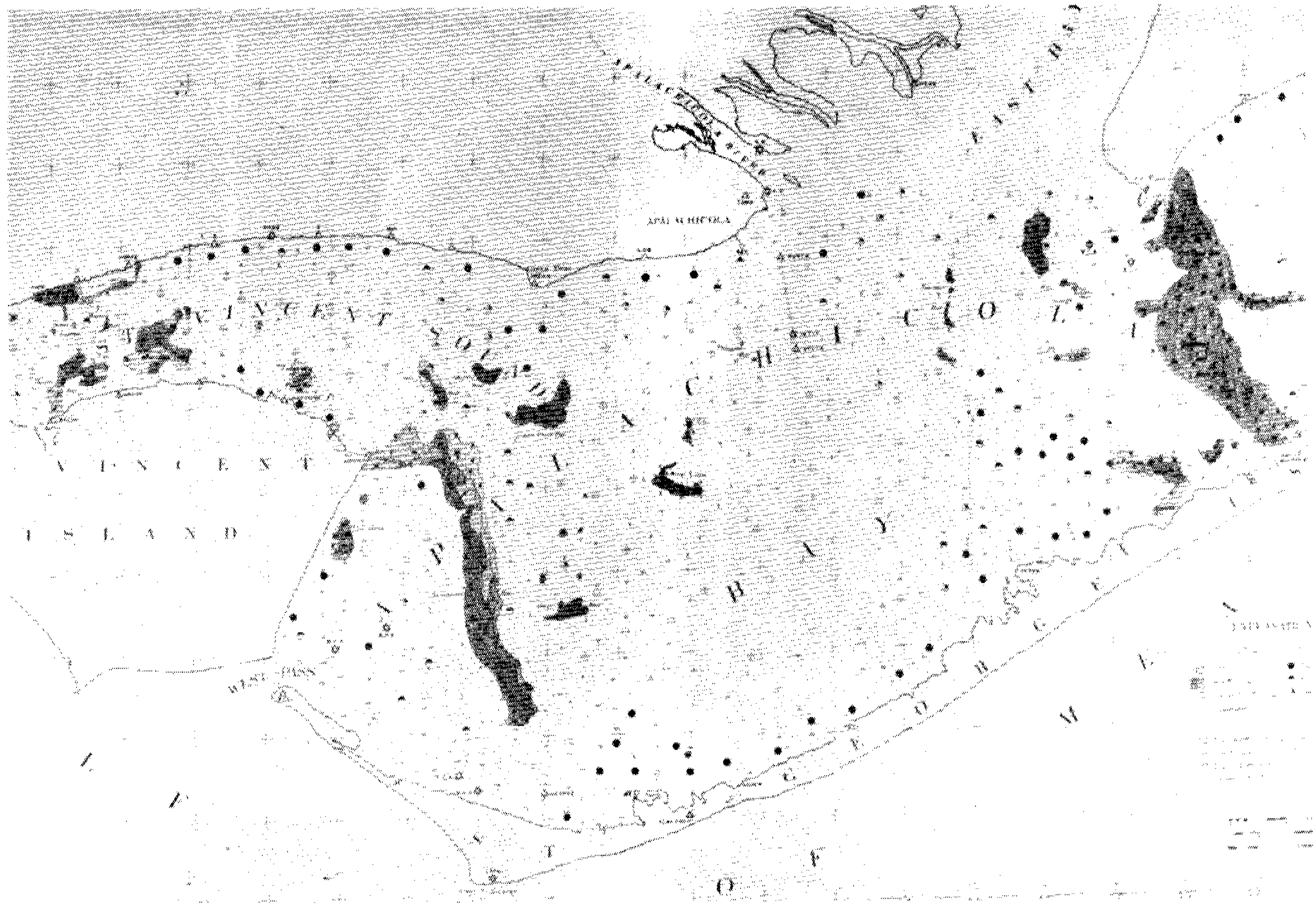

Figure 1. Natural oyster bars of Apalachicola Bay in 1917.

vate leases was discouraged by social pressure in Franklin County.

Oyster leasing replaced the grant management program to again encourage private enterprise to conserve and properly manage oyster resources throughout the State. Many leases were issued soon after 1913, but again ineffective law enforcement plagued the program. Several grandiose schemes arose. Among the most notable was William Lee Popham's 1920 enterprise of leasing to a number of investors approximately 90% of the total natural oyster reef acreage in Apalachicola Bay (Figure 2). This notorious enterprise ended in bankruptcy but the impact still haunts the leasing program.

Many leases were issued by the State in Franklin County during the 1930's and are surviving today where oysters are successfully cultivated. Most of these belong to owners of oyster shucking plants where a steady supply of shell to cultivate the leases is readily available. These activities are regularly monitored by the Department of Natural Resources to review cultivation progress.

After several attempts by eastern oyster interests to obtain control of the Apalachicola oyster industry in the late 1950's, the leasing of future sites for private cultivation in Franklin County was prohibited in 1963 by Florida Statutes Section 370.16(9). Nine existing oyster leases in Apalachicola Bay encompass a total of 623 acres. The 1913 oyster severence tax, hampered by ineffective tax collecting and accounting, was abolished in June 1959. Funds for marine research and salt water fisheries management in general were derived from a severence tax established in 1947 on dead oyster shells dredged from extinct reefs beneath other Florida estuaries.

It is believed by some that one of the benefits of the Jim Woodruff Dam completed in 1957 was an increase in oyster production through stabilizing river water flow. A dramatic increase in oyster production in Franklin County from 1955 to 1959 is recorded (Table 1), but that increase was more probably due to the abolition of the severence tax since similar increases in oyster production were recorded throughout the entire State during this same period. Before the repeal of the severence tax, oyster production landings figures for Franklin County as well as the entire State were undoubtedly conservatively reported. A similar comparison cannot be made for the County oyster production

TABLE 1. OYSTER LANDINGS, STATE OF FLORIDA, FRANKLIN COUNTY, AND FRANKLIN COUNTY LANDINGS AS A PERCENTAGE OF STATE TOTAL, CALENDAR YEARS 1950-1974

	State of Florida		Franklin County		Franklin County as Percentage of State	
Year	lbs.	Value in dollars	lbs.	Value in dollars	Total Production	Total Value
1950	895,248	unknown	695,957	unknown	77.7	-----
1951	735,304	unknown	546,560	unknown	74.3	-----
1952	562,987	unknown	451,145	unknown	80.1	-----
1953	585,356	117,071	459,225	unknown	78.5	-----
1954	685,496	137,099	553,946	unknown	80.8	-----
1955	649,581	142,908	542,874	unknown	83.6	-----
1956	888,735	213,296	722,046	unknown	81.2	-----
1957	734,878	205,477	624,222	unknown	84.9	-----
1958	824,729	232,395	713,230	unknown	86.5	-----
1959	1,454,998	416,931	1,268,757	unknown	87.2	-----
1960	1,975,400	496,082	1,744,760	436,190	88.3	88
1961	3,326,601	1,052,864	2,947,137	934,242	88.6	89
1962	5,019,771	1,435,762	4,366,700	1,244,510	87.0	87
1963	4,362,848	1,248,906	3,810,500	1,089,804	87.3	87
1964	2,885,123	808,844	2,252,377	629,990	78.1	78
1965	2,954,745	987,392	2,377,530	784,475	80.4	79
1966	4,291,925	1,343,034	3,809,941	1,171,194	88.8	87
1967	4,761,130	1,501,187	4,195,805	1,274,716	88.1	85
1968	5,568,773	1,853,634	4,825,668	1,542,801	86.7	83
1969	5,152,742	1,963,531	4,350,370	1,613,102	84.4	82
1970	3,786,519	1,593,873	3,044,401	1,299,025	80.4	82
1971	3,710,542	1,641,076	3,180,085	1,392,241	85.7	85
1972	3,357,371	1,581,530	2,980,543	1,360,021	88.7	86
1973	2,531,325	1,592,967	2,193,492	1,334,959	86.6	84
1974	2,751,385	1,609,239	2,453,995	unknown	89.1	-----
Average	2,578,140	--------------	2,204,455	--------------	84.3	-----

Source: Summary of FLORIDA COMMERCIAL MARINE LANDINGS. 1950-1974. Florida Department of Natural Resources Division of Marine Resources, Bureau of Marine Science and Technology.

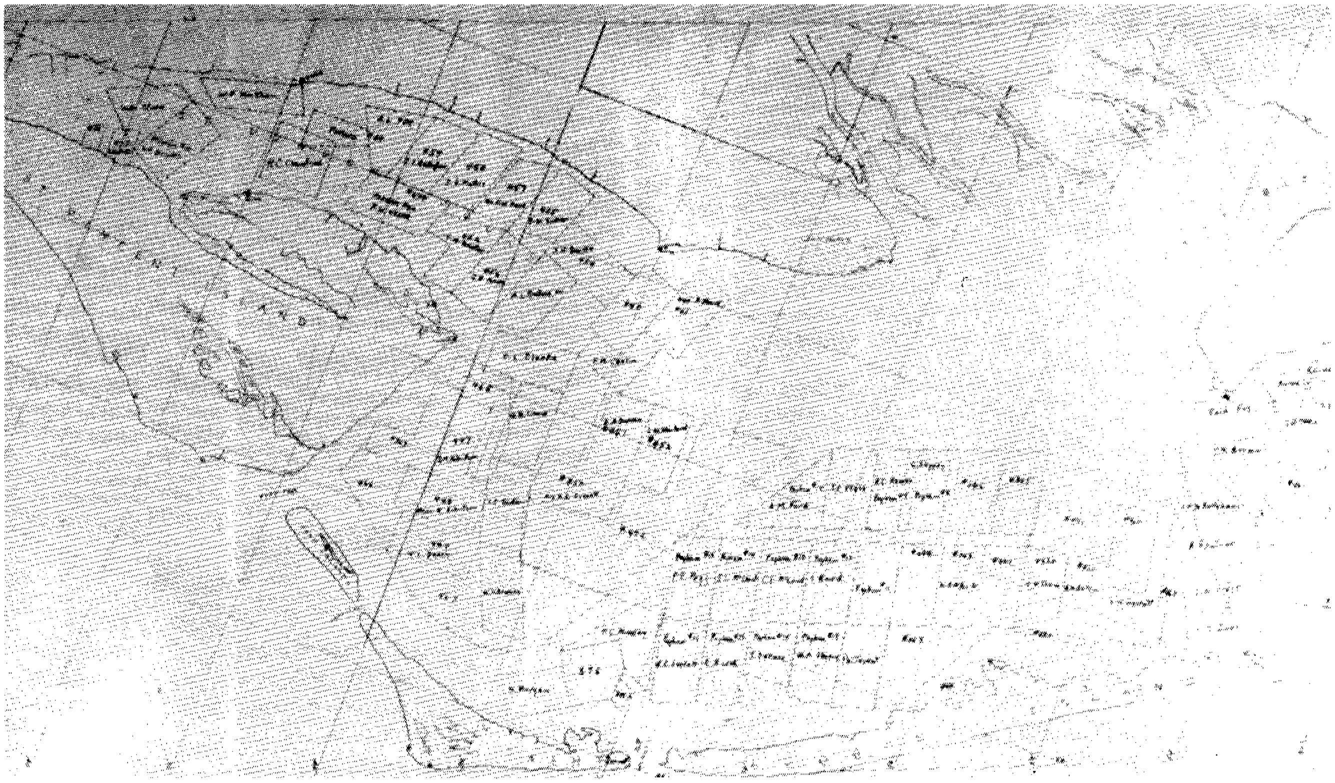

Figure 2. Oyster leases of Apalachicola Bay promoted in the early 1920's by William Lee Popham. (The leases were illustrated on a map drawn in the 1890's. Note that St. George Island was in 3 parts at that time.)

before and after the enactment of the severence tax in 1913 because early landings figures are incomplete (Table 2).

The benefits derived from recycling shucked oyster shell on oyster reefs to provide a fresh substrate for newly spawned oyster spat has been long accepted by titleholders to oyster grants and leases. However, this practice was not adopted as a public management program until 1949. Robert M. Ingle, hired in that year as Florida's principal marine research biologist, recognized that many public oyster reefs in Franklin County were steadily being stripped of oysters and cultch due to intensive tonging effort. Oyster shell was not being replaced on these non-leased reefs while the majority of the oystermen were harvesting oysters from them in prodigious numbers. Most of the shucked shell was being sold for road construction or land fill material.

Ingle's initial management plan establishing a program to replace shell on overfished public reefs resulted in more than four million bushels of shucked shell or aggregate limestock rock being used to rehabilitate natural reefs or construct new ones covering nearly 1,000 acres of suitable public bay bottom in Franklin County. This has been accomplished over the years at a cost of about $1,000,000, but has yielded $8,000,000 to $10,000,000 in benefits to Florida's oyster industry.

PRESENT MANAGEMENT

General areas throughout the State are chosen for oyster reef cultivation and construction by the potential for oyster production and local economic need. Specific sites are selected on the basis of water quality, hydrography, physiography and biological consideration. Florida law permits the Department of Natural Resources (DNR) to collect and stockpile shucked shell from shellfish houses (Figure 3) for oyster reef construction projects. This material is gathered when and where it is economically feasible to conduct such work. Approximately 250,000 bushels are collected from Franklin County shellfish houses annually (Figure 4).

Shell planting begins in Apalachicola Bay in spring when oyster spawning first occurs, to avoid fouling of the shell by oyster space competitors such as barnacles. Cultch is planted by "blowing" shell off stationary barges using high pressure water stream (Figure 5) thereby forming parallel ridges resembling natural oyster reefs (the Ingle method). Cultch is piled up two feet thick on hard bottoms and thicker on soft bottoms. Ingle's studies have shown greatest oyster growth and least sedimenta-

TABLE 2. ANNUAL OYSTER LANDINGS
FRANKLIN COUNTY, FLORIDA
1880-1971

Year	Quantity (1,000 pounds)	Value ($1,000's)
1880[a]	410	------
1888[a]	823	57
1889	1,062	26
1890	1,528	37
1895	423	14
1897	743	25
1902	2,750	75
1908[a]	3,764	------
1911[a]	1,312	------
1918[a]	2,616	------
1923[a]	1,642	69
1927[a]	1,736	167
1928	2,315	166
1929	1,999	143
1930	1,039	81
1931	912	58
1932[a]	1,109	59
1933[a]	1,402	77
1934	1,024	51
1935[b]	2,036	102
1936	613	36
1937	598	25
1938	678	45
1939[a]	742	62
1940[a]	668	49
1945	1,141	536
1948[c]	756	------
1949	658	------
1950	696	------
1951	547	------
1952	451	------
1953	459	------
1954	554	---------
1955	543	---------
1956	722	---------
1957	624	---------
1958	713	---------
1959	1,269	---------
1960	1,745	436
1961	2,947	934
1962	4,367	1,245
1963	3,811	1,090
1964	2,252	630
1965	2,338	784
1966	3,810	1,171
1967	4,196	1,275
1968	4,826	1,543
1969	4,350	1,613
1970	3,044	1,229
1971	3,180	1,392

[a]Statistics are for the West Coast of Florida.

[b]Statistics are for the State of Florida.

[c]Subsequently from gallons to pounds using a conversion factor of 8.75 pounds to the gallon.

Source: Florida Department of Natural Resources (1948-1974).
Rockwood (1973).
U. S. Department of the Interior (1969).

tion on new reefs planted in this manner with oyster production continuing indefinitely without further investment. Gaps between ridges are cultivated by oystermen culling shell and undersized oysters.

Natural oyster reefs are also replenished by scattering clean cultch across the sides and tops of old bars covered by barnacle-encrusted or sediment-covered shell. Many reefs planted in Franklin County in the early 1950's are still producing.

It has been estimated that some 40% of the 115,200 acre Apalachicola Bay area, (about 46,000 acres) is suitable for growing oysters (Figure 6). Commercially valuable oyster bars are estimated to currently cover only 5000 to 6000 acres (Rockwood, 1973). This is approximately half the amount (12,214 acres) estimated to have been available at the turn of the century (Swift, 1898).

Ingle and Whitfield (1968) and Whitfield (1973) estimated that about 400 bushels/acre are regularly harvested each year from artificially constructed reefs within two years after planting cultch. The annual value/acre to tongers is $1,400, if all 400 bushels were harvested at current landing prices of $3.50/bushel. The reef construction fixed cost is estimated to be $1,000 to $1,200/acre. Colberg and Windham (1965) estimated oystermen receive an average of 25% of the final retail sales value for oysters. If true, this would result in a theoretical annual value/acre for planted reefs of $5,600. Thus, a very favorable benefit-cost ratio exists even if only a portion of the theoretical number of available oysters/acre are actually harvested. It is estimated that over half of the oysters harvested in Franklin County are harvested from state constructed or rehabilitated reefs (Figure 7).

A serious oyster resource management problem in Franklin County today is the difficulties experienced by DNR Marine Patrol in enforcing the oyster legal size limit (3 in) and culling regulations. Section 370.16 (16), Florida Statutes, stipulates that all oysters must be culled during harvest by removing and replacing on the reef all undersized oysters. Not more than 15% of a cargo of oysters may be undersized and the possessor, not harvestor, is responsible for complying with the regulation.

Preventing the harvest of undersized oysters

Figure 3. Oyster grants with leases superimposed thereon.

Figure 4. Oyster shell pile adjacent to a shucking house. These shells are collected and stockpiled by the Department of Natural Resources for relaying as oyster cultch.

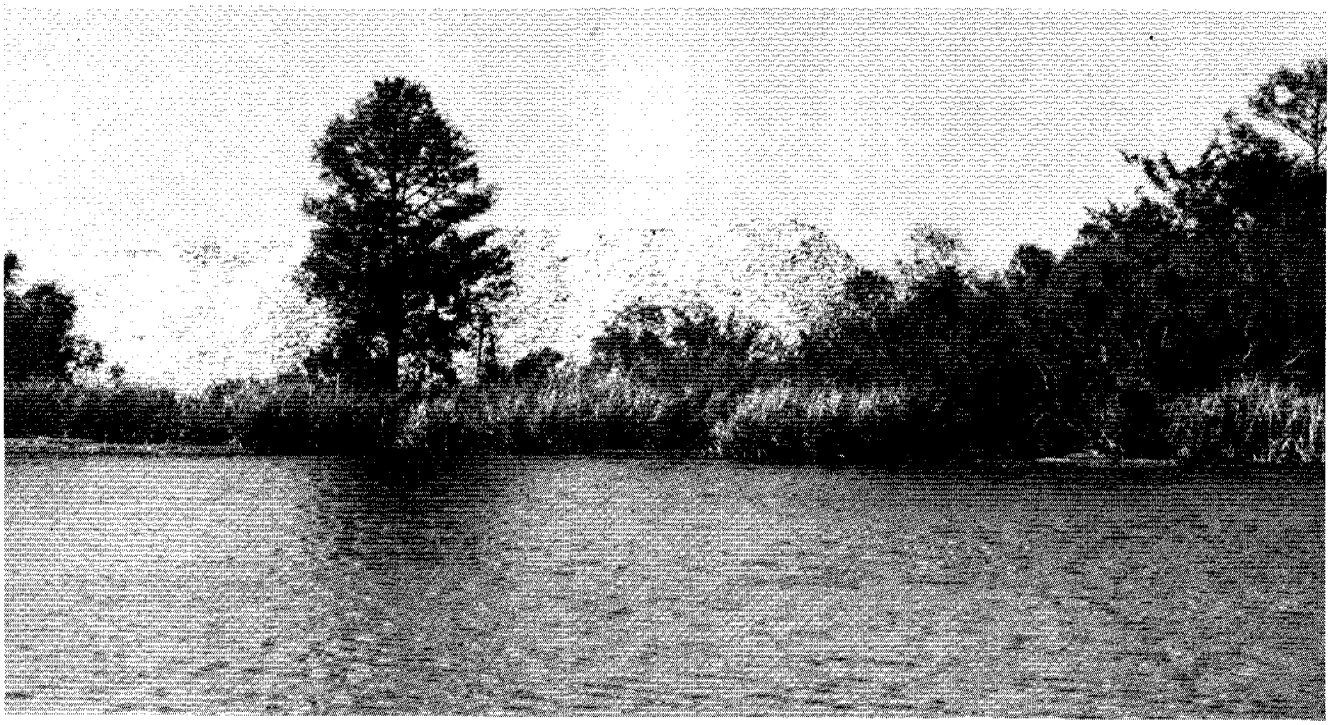

Figure 5. Stockpiled oyster shell to be used as oyster reef construction material.

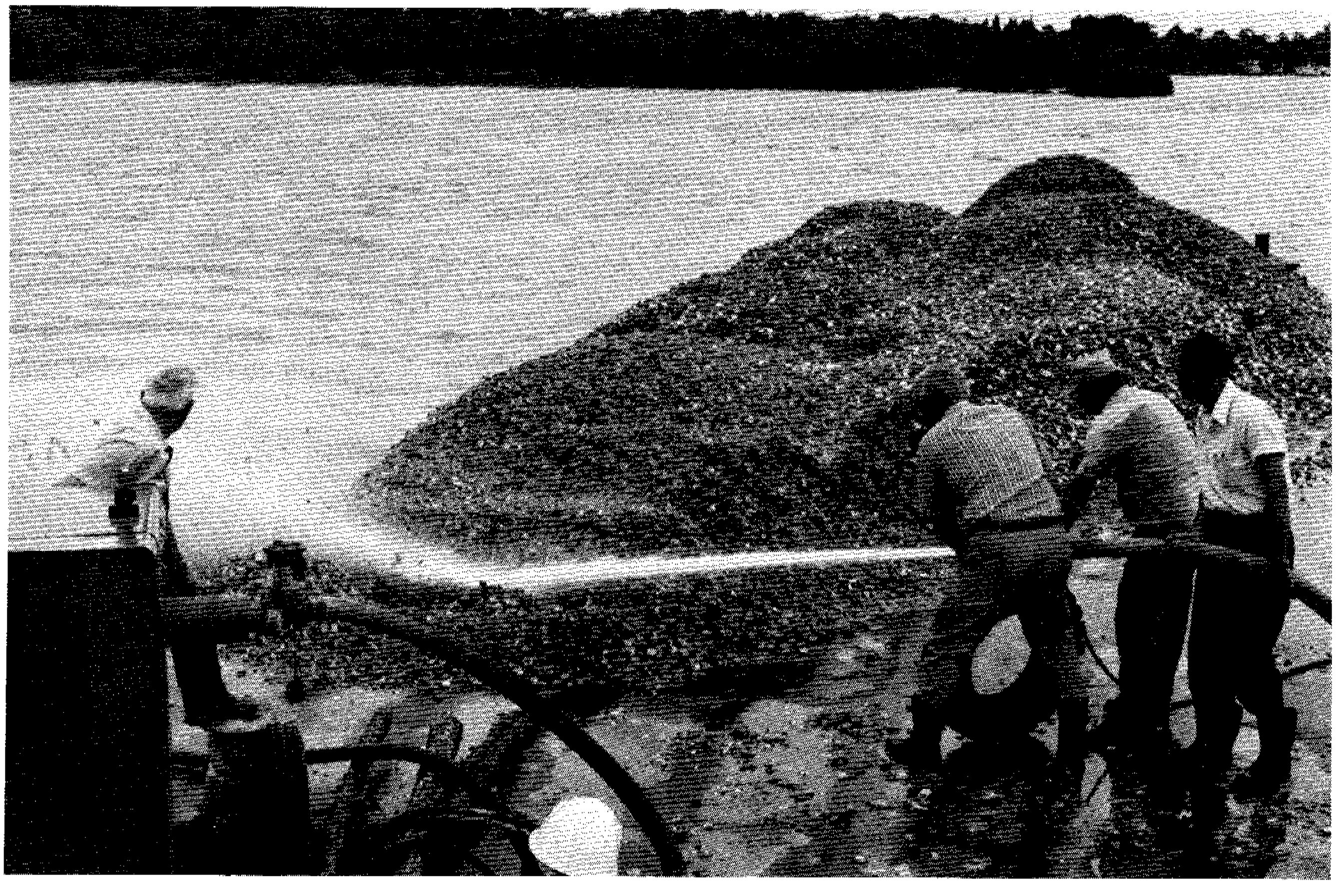

Figure 6. Cultch being unloaded with a high pressure water stream from an anchored barge.

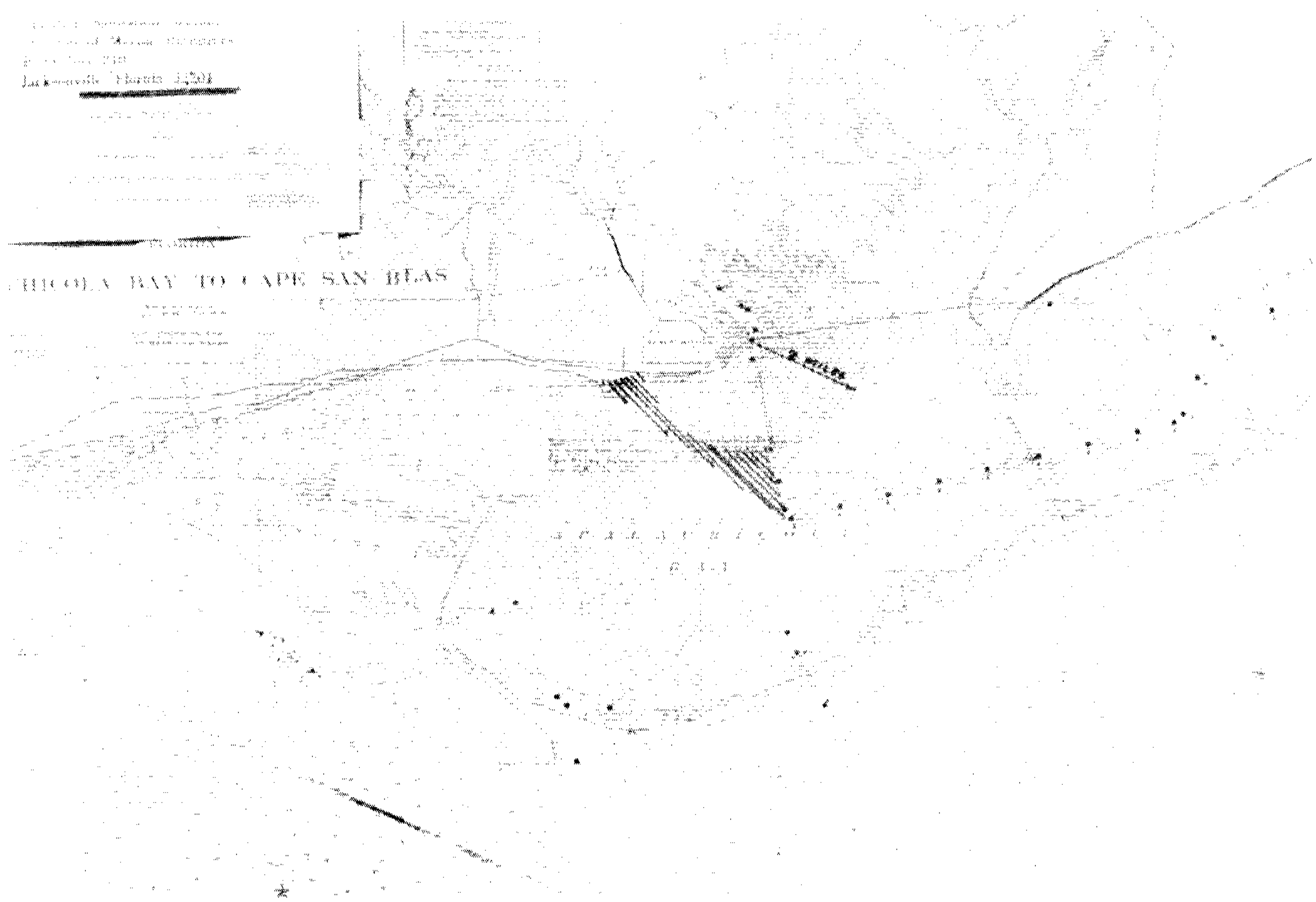

Figure 7. The classified shellfish harvesting waters of the Apalachicola Bay area as of 1976.

is designed to allow the oyster to attain spawning size before being removed from the reef. Failure to comply with this regulation also has economic consequences. Prevalence of undersized and muddy oysters taint the reputation of Apalachicola shell stock cargoes. Consequently they are sold at prices among the lowest nationally.

The Department of Natural Resources is well aware of this problem and is endeavoring to solve it by stricter law enforcement in the harvesting areas to make harvesters of undersize oysters more responsible. Laws to prohibit bagging of oysters in the boat by harvestors have been passed by the 1976 Florida Legislature. In addition, the Department has strong marketing and fishery advisory programs striving to influence dealers and harvesters in Franklin County to raise the quality of their oyster products.

Since the quality of local harvesting techniques on other than private oyster leases has been marginal, many Apalachicola oyster processors have sought oysters harvested in Texas and Louisiana. These imported oysters have posed some serious sanitation problems since they have a greater contamination potential during transit to the shucking house. Total coliform counts for this shellstock have generally remained within the acceptable 500,000/ml plate count, but are usually much higher than levels from locally harvested oysters.

Each shipment of imported shellstock is carefully monitored by DNR's shellfish sanitation personnel stationed in Apalachicola. During the summer of 1974, an embargo was imposed in Franklin County against out-of-state shellstock due to consistently unacceptable bacteriological tests.

Another Apalachicola Bay oyster management problem is the annual proposal by some local oystermen to open the bay to year-round harvesting from public reefs. We have opposed this due to the difficulties forseen in increasing the probability of more undersized oysters being illegally harvested and, more importantly, the risk of poor shellstock being introduced into commerce from both a marketing and sanitation point of view.

Instead, we have recommended reducing the length of the open oyster season on public reefs by three months so it would coincide with the open season in Texas and Louisiana (November 1 to May 1). The increased quality of oysters taken

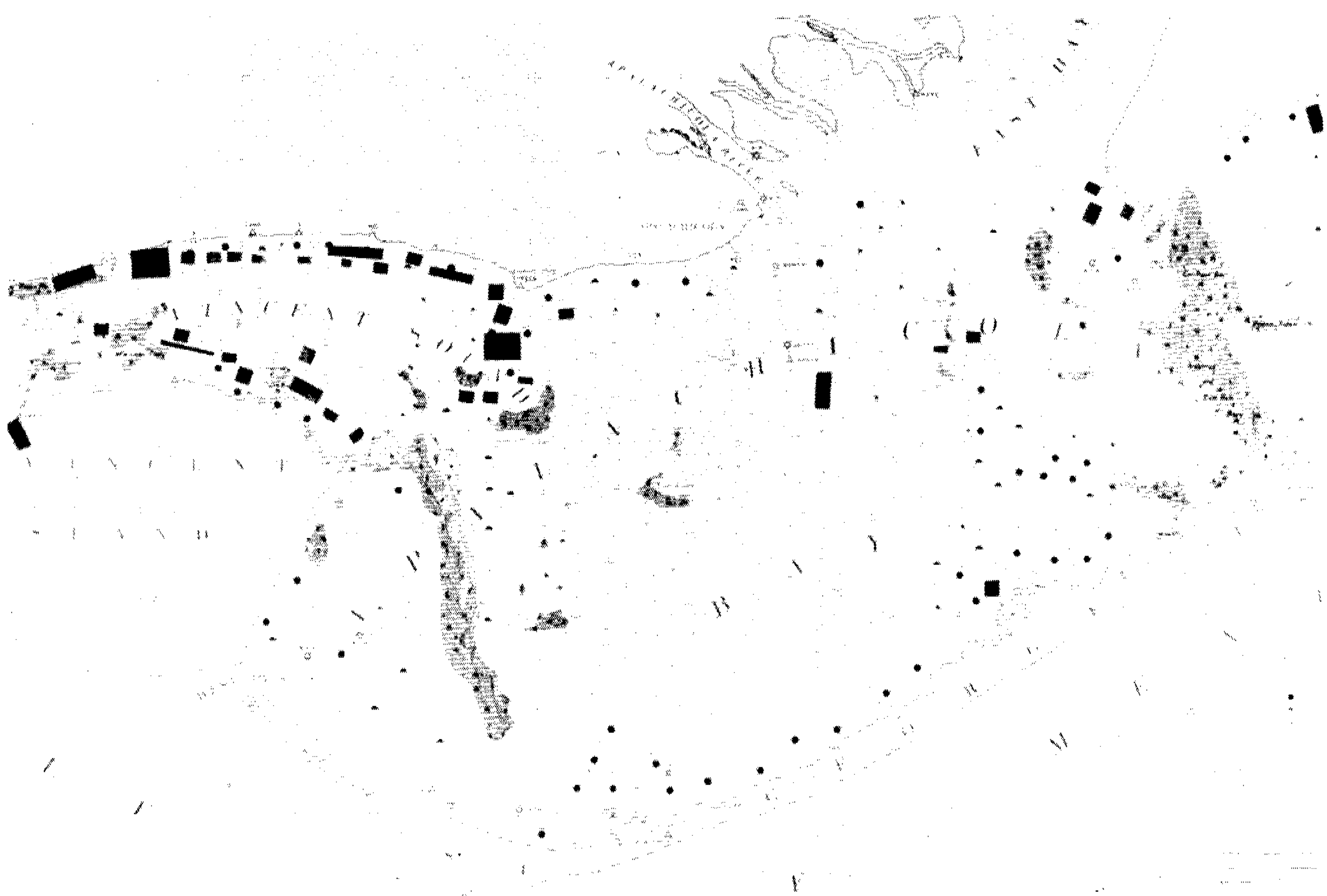

Figure 8. Natural oyster bars of Apalachicola Bay in 1976 with state and private artificial reefs illustrated.

only during peak harvesting periods should more than compensate any loss of income during the three months added to the closed season by increasing the net return from the marketable product.

Sanitary inspection or certification of shellfish processors is not the only responsibility of DNR's Shellfish Sanitation Section. Classification of harvesting waters throughout Florida is also accomplished by both our own personnel and cooperating County Health Department people. Depending upon the results of shoreline surveys and regular water sampling, harvesting clams and oysters may be approved, conditionally approved, or prohibited in Florida's coastal waters. Approximately 110,000 acres (95% of Apalachicola Bay) can support sanitary shellfish production at various times throughout the year. This is a higher percentage than is found in any other Florida estuary and represents about 15% of the total acreage approved or conditionally approved for shellfish harvesting throughout the entire State.

Those portions of Apalachicola Bay closed to shellfish harvesting include the area immediately adjacent to the two-mile docking space, the entire area within a two mile radius from the west end of the John Gorrie Memorial Bridge, and the vicinity of the East Point docks (Figure 8); analyses indicate pollution from local and upriver sources.

FUTURE MANAGEMENT

Management of Florida's oyster resources has involved both shellfish propagation and sanitary surveillance. Both activities, centered in Apalachicola, are serving as models for future programs elsewhere in our State. Improving the oyster producing potential of all coastal areas should contain a balance of protecting the existing resources and enhancing product marketability through technological innovations designed to expand production and modernize the shellfish industry. Individual recommendations in each area, while perhaps scientifically or legally sound, must be accepted locally or the management objectives will not be attained. Thus, it will be imperative that the resource managers work closely with resource users to implement management plans.

Both groups must make greater efforts to inform the general public about the economic benefits of the potential food production values of coastal estuarine systems and what effects shoreline or watershed development has on these systems. It is important that all of us recognize that the health and value of the marine resources are directly proportional to the health and vitality of the surrounding uplands that sustain them.

Shellfish harvesting regulations also must be vigorously adhered to, perhaps by placing more responsibility directly upon resource users. The open harvest season for oysters on public reefs should be reduced by three months to encompass November 1 to May 1 each year. Legislation allowing year-round harvest of oysters should not be adopted.

Greater emphasis should be placed on a marketing program for oysters, perhaps by contracting with the Food and Drug Administration to initiate a sponsored marketing and sanitation inspection program for participating Apalachicola oyster dealers. This program would enhance product quality, and participating dealers would receive positive marketing assistance by adopting the FDA seal of approval on inspected products.

Construction of new oyster reefs and the rehabilitation of old ones should be continued by the State, not only in Apalachicola, but elsewhere in Florida. Laws prohibiting private leasing of nonproductive areas of Apalachicola Bay for oyster cultivation should be amended to encourage private management and development of oyster reefs.

Sanitary surveillance of marginally approved shellfish harvesting waters should be expanded to incorporate all possible coastal waters into shellfish production. This will best illustrate to the general public the economic advantages of pollution abatement and allow better demonstration of the true value of Florida's threatened coastal regions.

Mechanical harvesting which will not destroy oyster reefs should be developed for use on leases and selected public bottoms. A State-sponsored oyster fattening pilot plant should be constructed (perhaps in Apalachicola). We have experimentally fattened oysters in the Department's St. Petersburg Marine Research Laboratory. Developed on a commercial scale, this process might allow year-round culture of prime quality oysters.

All these suggestions are predicated on the continued availability of the Apalachicola River both as a mainstay of Florida Oyster production and a light transportation pathway for barge traffic. Should the river be developed into a major transportation corridor, Florida's shellfish industry will surely be sacrificed.

Recent factional interest in construction of yet another dam across the Apalachicola River and concomitant channelization would seriously disrupt the marine resources of the Apalachicola Bay estuary. As mentioned, a variable but dependable source of fresh water is required for oyster production. It has been suggested that once the reservoir behind the dam is filled, the same total volume of water will reach Apalachicola Bay. The time required to fill the reservoir could deprive the Bay of enough fresh water to allow destruction of existing oyster reefs. The effect of increased evaporation from the reservoir on the supply of fresh water to the river has not been adequately addressed. Stabilization of river flow would limit oyster productivity to a narrow band of reefs, and deprive the Bay of nutrients that could not be washed from the flood plain.

Evidence that the Jim Woodruff Dam increased oyster production is spurious; abolition of the oyster severence tax in 1959 surely was the principal cause of increased landing reports.

Some proponents of a dam across the lower Apalachicola River point to the correlation between time and distance of transport and bacterial virulence, stating that construction of a dam would slow the river flow thereby reducing contamination by allowing bacterial die-off. Other contaminants could settle behind the dam structure. However, previous studies by the Shellfish Sanitation Section failed to find any significant difference in background river bacterial levels correlated with the completion of the Jim Woodruff Dam in 1957.

Discounting biological degradation resulting from the construction of the dam, there are other conditions that could reduce the sanitary quality of the river water flowing into Apalachicola Bay. Increased commercial boat traffic and effluent volume into the river from increased urbanization or industrialization along its banks would surely result from dam construction or river channelization.

SUMMARY

1. Since the turn of the century, oysters have comprised the principal industry in Franklin County. Apalachicola Bay oyster reefs, managed with varying degrees of success over the years, constitute almost 90 percent of Florida's oyster resources valued at over 7 million dollars.
2. Such productivity is dependent on the unique physical and geographical characteristics of Apalachicola Bay, sustained by minimal urban and industrial growth pressures.
3. Oyster resources in Apalachicola Bay are managed through construction or replenishment of reefs with shucked oyster shell to provide a substrate for new oyster growth. This cultch

is planted by the State on suitable public bay bottoms and by private leaseholders on leases obtained in the 1930's.

4. More sanitarily safe harvesting waters exist in Apalachicola Bay than in any other Florida estuary thus enhancing its suitability to support this major industry.
5. Although local resistance has often prevented rapid adoption of the most advanced harvesting and processing customs, Apalachicola Bay is gradually being realized as a model for shellfish resource management throughout Florida.
6. Florida's shellfish industry relies upon the preservation of the ecological integrity of the Apalachicola River drainage system emptying into Apalachicola Bay. Construction of a dam at Blountstown or further river channelization would seriously impair that integrity.

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FLORIDA'S ENVIRONMENTALLY ENDANGERED LAND ACQUISITION PROGRAM AND THE APALACHICOLA RIVER SYSTEM

James W. Pearce
Florida Department of Natural Resources

INTRODUCTION

In 1972, the Florida Legislature enacted the "Land Conservation Act" (Chapter 259, Florida Statutes). The Act has as its purpose the conservation and protection of environmentally unique and irreplaceable lands. It is implemented through a program of acquisition supported by a $200 million bond issue.

In the three years in which the Environmentally Endangered Lands (EEL) program has been operational, some 600 proposals for purchase have been submitted to the Florida Department of Natural Resources (DNR), the agency responsible for administration of the program. Of these 600, only ten projects have thus far been authorized for purchase by the Governor and Cabinet. One of these ten is the Lower Apalachicola River EEL project.

Faced by a flood of proposals to purchase land, the DNR recognized very early that stringent criteria and guidelines to govern selection of endangered lands would be an essential requirement in administering the program. Such criteria and guidelines were subsequently developed and incorporated within Florida's Environmentally Endangered Lands plan.

The EEL plan provides a broad definition of endangered lands and sets forth general and specific criteria governing their acquisition. The remainder of this paper concerns itself with those criteria as they relate to the Lower Apalachicola River project.

DEFINITION OF AN ENVIRONMENTALLY ENDANGERED LAND

An environmentally endangered land is any land area and related water resources that may be determined to contain naturally occurring and relatively unaltered flora, fauna, or geologic conditions and whose interdependent biophysical components, including historical and archaeological resources, might be essentially preserved intact by acquistition. In addition:

1. The area must be of sufficient size to materially contribute in some substantial measure to the overall natural environmental wellbeing of a large area or region; or
2. The area must contain flora, fauna, or geologic resources characteristic of the original domain of Florida and that these be unique to, or otherwise scarce within, the region or larger geographical area; or
3. The area, whatever its size or the condition of its resources, must be capable, if preserved by acquisition, of providing significant protection to natural resources of recognized regional or statewide importance.

There must also be some reasonable likelihood that the area's related natural and cultural resources will be subjected to some activity of man that might result in their substantial and irretrievable loss.

DEVELOPING AN APALACHICOLA RIVER PURCHASE PROPOSAL

Long before the advent of the Land Conservation Act of 1972, Florida governmental agencies, elected officials, environmentalists, and concerned citizens recognized the environmental significance of the Apalachicola River system in Florida. These same interests also recognized that the river system was being subjected to various activities which threatened to stress it severely. Pollutants, land speculation, agricultural practices, and proposals for major public works projects in the river constitute the most significant threats to the continued viability of the Apalachicola river and estuarine systems. The Land Conservation Act of 1972 seemed to offer considerable potential for reducing the adverse impact of these major threats.

PROJECT LAND SELECTION

The first step in defining a suitable endangered lands purchase area for the Apalachicola River involved the specification of critical parameters. The key question was, of course, what was to be achieved by buying lands in the area? This question was answered, in part, by the fact that ongoing studies (Livingston, 1974; Livingston et al., 1974) under the Florida Sea Grant Program showed that Apalachicola Bay, a highly productive marine fishery, was inextricably linked to the river which flows into it. More specifically, evidence was found to support the theory that the river and its floodplain produced and/or carried the nutrients and detritus which are essential to the functioning of the marine food webs in the bay. This matter contains a significant volume of hardwood leaf litter which originates in the river bottom hardwood swamps and is periodically swept up by floodwaters and transported to the bay (Livingston et al., 1974). This vital function of the river floodplain swamps was recognized as one of the critical parameters which should be considered. It would therefore be necessary to incorporate, within the purchase boundary, as much of the hardwood river bottom lands as could feasibly be acquired in order to insure the continuance of the basic material contribution to the bay. The logical sequence for acquisition was to purchase lands in the lower river beginning as close to the bay as possible and proceeding upstream.

Since it was not known at the time (nor is it yet known with any degree of certainty) exactly how much (volume) detrital material was necessary to fuel the marine biota in the bay, nor how much river bottom hardwood area was needed to provide that volume, other parameters had to be relied on in defining the final purchase boundary.

DISTRIBUTION OF RIVER BOTTOM HARDWOODS

The hardwoods in the lower Apalachicola River Basin are largely confined to soils which are very poorly drained and subject to seasonal flooding — alluvial soils. The approximate boundary of such soils associations is shown in Figure 1 (dashed line). Within this soils area the hardwood species are generally comprised of: blackgum and tupelo (24%), cypress (27%), bay and magnolia (10%), oaks (10%), sweetgum (5%), and miscellaneous species (24%).

Land ownership patterns — After delineating the alluvial soils boundary, land ownership patterns were determined (Figure 1). These patterns were essential to configuring the proposal since the endangered lands program is constrained severely in its ability to purchase desired lands by its lack of the power of eminent domain. Thus, the willingness of land owners to consider the voluntary sale of their lands is critical to the success (or failure) of the program.

It became evident, from the ownership patterns displayed, that a substantial portion of the lower river alluvial soils floodplain was comprised of several large land holdings. The largest of these were held by timber companies, which clearly presented a problem for the state since timber companies are not in business to divest themselves of land; rather to acquire and hold lands.

The lands in and around Lake Wimico are owned by St. Joe Paper Company and are not for sale; thus this important area of the floodplain has to be excluded from consideration. Lands to the east of the lower river, in the vicinity of Tate's Hell Swamp, were largely owned by the Buckeye Cellulose Corporation and were significantly altered by that corporation's timber practices which necessarily eliminated them from consideration. Along the river's main stem and extending upstream, the largest holdings are those of International Paper Company (IPC). IPC indicated a willingness to consider selling or trading its holdings up to the juncture of the Brothers River and the Brickyard Cutoff. Above this point, IPC is, again, the major landowner of the floodplain for a considerable distance but its current plans for timber harvesting required the use of these lands. Thus, the project boundary was, for all practical purposes fixed by these land ownership constraints shown in Figure 1. All owners within the project boundary have been willing to negotiate with the State for sale of their properties.

The final project boundary generally conforms to the alluvial soils boundary and contains some 30,000 acres. The areas shown in grey pattern on Figure 1 comprise some 14,000 acres which have thus far been successfully acquired by the State at a cost of just under four million dollars. A like amount of land is yet to be acquired to complete the project.

PROJECT LAND EVALUATION

As set forth in the definition of an endangered land presented earlier in the paper, there are two general tests and three specific (alternative) conditions which must be met for an area to be considered for purchase in the EEL program. Field investigations of the proposed purchase area revealed that the Lower Apalachicola project (as configured) was particularly well suited to the definition of an endangered land.

The first general test requires that an EEL contain naturally occurring and relatively unaltered biophysical components which could be preserved intact by acquisition. The project area was found to be admirably qualified to meet this test since it is comprised, substantially, of undisturbed hardwood swamp forest. The test for endangerment to the project was also met by virtue of the fact that clear cutting, draining, diking, and other similar activities having a deleterious effect upon wetlands areas adjacent to the project were already going on. These activities, particularly timbering, would very likely take place on project lands within the foreseeable future if the lands were not protected by public acquisition and management.

The first (alternate) condition provides for

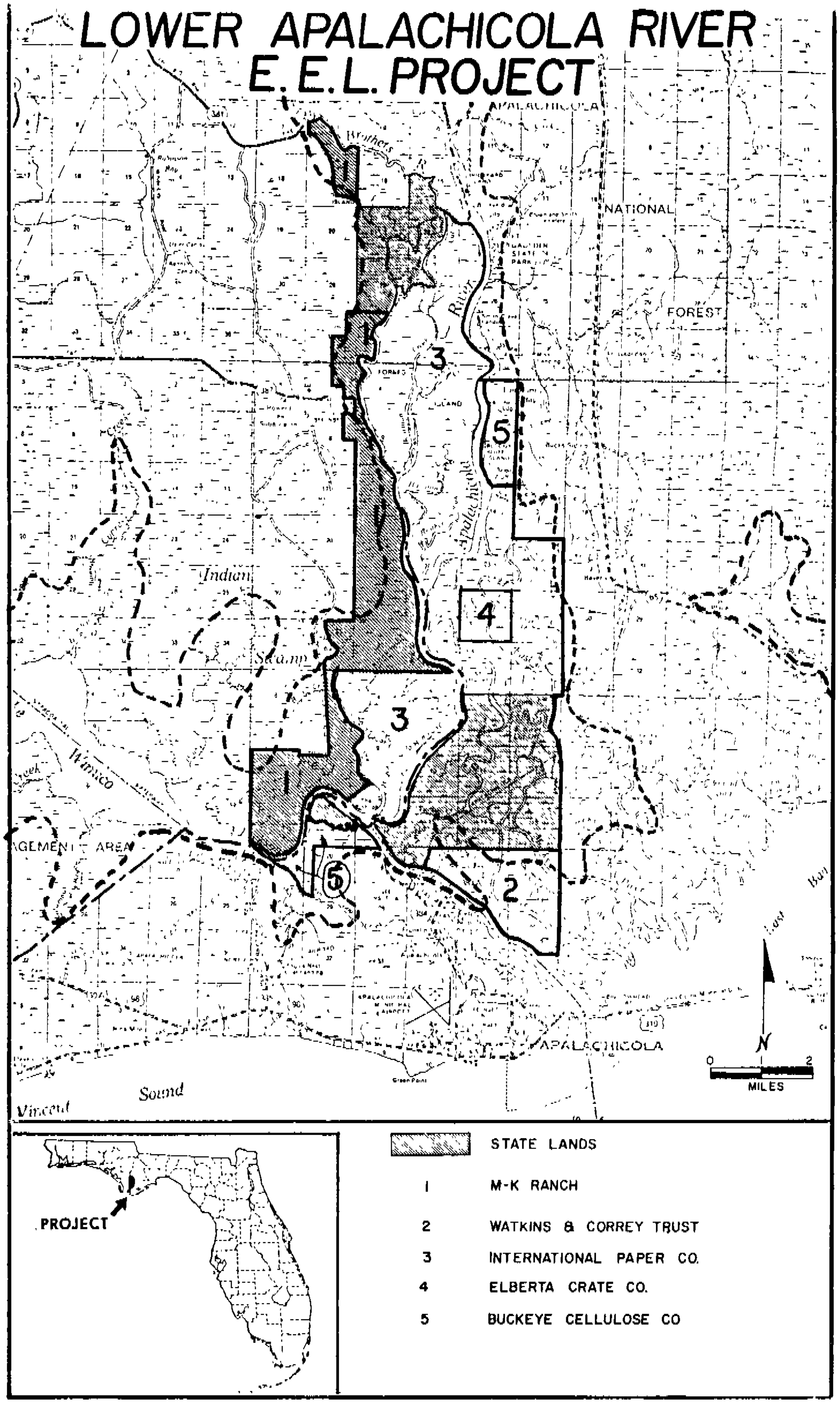

Figure 1. Lower Apalachicola River Environmentally Endangered Lands Project.

TABLE 1. FLORIDA HABITAT SURVEY, FLORIDA PANHANDLE

	Ecological Value							
Major Habitat Type	Wildlife Abundance	Endemic/ Rare Wild-life Value	Plant Diversity	Vulner-ability	Endanger-ment	Scarcity in Watershed	Scarcity in State	G&FC Priority for this watershed
1. Coastal strand	3	3	4	2	1	3	1	3
2. Pine flatwoods	3	2	3	5	4	4	5	5
4. Mixed hardwood/pine	2	3	1	4	2	3	1	1
5. Sandpine scrub	3	2	3	5	3	3	2	3
6. Longleaf pine/ Xeric oak sandhill	3	2	3	3	2	3	2	3
7. Cypress swamp	3	2	5	2	3	3	3	3
8. Hardwood swamp	2	2	3	1	2	4	3	1
9.2 Coastal marsh	2	3	5	4	2	2	4	3
13.1 Wet prairie	3	4	2	1	1	2	1	4
12.2 Live oak hammock	2	4	3	4	2	2	2	3
16. Freshwater marsh	3	3	3	1	2	2	3	2

1. Very High
2. High
3. Moderate
4. Low
5. Very Low

projects that contribute in some substantial measure to the environmental well being of a large area or region. The 30,000 acre project clearly meets the requirement of this condition on sheer size alone. In addition, the outstanding wildlife habitat values it possesses, as well as the fact that it is comprised of substantially undisturbed swamp forest and fresh and saltwater marshes, enhances its importance to the overall environmental integrity of the northwest Florida (Panhandle region). Table 1 displays various critical environmental factors within the Panhandle region. The major wildlife habitat types within the Apalachicola project boundary are "blocked" in on Table 1 and the relative importance of these types to the region, under each of the critical environmental factors, is evident from the numerical values assigned.

The third listed (alternate) condition provides for EEL projects which can be shown to have some significant beneficial impact upon natural resources of recognized regional or statewide importance. This all-important aspect of the Lower Apalachicola EEL project has already been mentioned with regard to the importance of the river bottom hardwoods and the function of the river in transporting hardwood leaf litter and nutrients to the estuary where such elements ultimately fuel vital marine food webs.

The estuary formed by Apalachicola Bay and St. George Sound is one of the most biologically productive in Florida. The leaf litter and nutrients produced by the 30,000 acre project area will have an assured long-term beneficial impact on productivity of the Bay. Whether this area alone could support all the necessary requirements of the bay is not known; however, the project lands will clearly contribute to the required elements if maintained in their existing natural condition. In addition, the protection of such a large wetlands area through which a vast quantity of fresh water entering the bay is filtered and cleansed, will have a beneficial impact upon maintenance of the quality of the water entering Apalachicola Bay.

FUTURE USE AND MANAGEMENT

Once the full project has been successfully acquired, the area will be managed by the State of Florida, Game and Fresh Water Fish Commission. The management program, which will be finalized once the purchase is complete, will capitalize on the outstanding recreational potential of the area for hunting, fishing, nature appreciation, etc. The overriding consideration in its future management, however, will be that of preserving the existing natural conditions. Some restoration of the area, particularly along the western boundary of the project, will be necessary in order to restore, as much as possible, the natural hydrologic regime which has been disrupted by diking, draining, and clearing activities. It should be emphasized that this purchase does not represent the final action in the protection of the Apalachicola Valley, and, by itself, will not assume the integrity of this system. It does represent the interest of the state of Florida in this important resource.

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THE LEGAL ASPECTS OF DAMMING THE APALACHICOLA RIVER

Jerry W. Gerde
Environmental Law Committee of the Florida Bar

INTRODUCTION

The Congress of the United States has adopted several pieces of legislation that are potentially useful tools for citizens desiring to protect the Apalachicola River. This body of Federal legislation includes the now famous National Environmental Policy Act of 1969 (National Environmental Policy Act, 42 U.S.C., Section 4321, et seq.), and the two lesser-known laws—The Protection of Wildlife Act (Protection of Wildlife Act, 16 U.S.C., Section 661, et seq.), and the Wild and Scenic Rivers Act (16 U.S.C., Section 1271, et seq.).

An analysis of the thrust and impact of each of these pieces of Federal legislation reveals that certain standards of conduct, and certain requirements and prohibitions, are established to guide the conduct of Federal agencies. A close analysis will also reveal the interdependence of these laws with the operation of our political process.

In the years ahead, if any campaign to preserve the Apalachicola is to be successful, it will be the result of the skillful and determined meshing of the existing Federal legislation with accomplishments in the political arena by private citizens who understand the interplay between these two disciplines.

THE NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act, passed in 1969 by the U. S. Congress, may be characterized as perhaps the most important piece of environmental legislation.

N.E.P.A. has been the basis for numerous battles, through the past seven years, to protect our natural resources. Perhaps most notably for Floridians, N.E.P.A. was a basis for the suit filed in 1970 by the Environmental Defense Fund and the Florida Defenders of the Environment against the United States Army Corps of Engineers, which led to the injunctive order entered by Judge Parker, enjoining for the first time the ill-planned construction by the Corps of the Cross Florida Barge Canal [Environmental Defense Fund, et al. -vs- Corps of Engineers, et al., 324 F.2d 878 (D.C.D.C. 1971)].

By way of background, N.E.P.A. reflects, in broad language, the Congressional recognition of the need for environmental awareness and, particularly, of the need for awareness of the accumulating impact of Federal activities on our limited natural resources. Congress chose the following language to reflect its new concern:

> "The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource, exploitation, and new and expanding technological advantages and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations, to use all practicable means and measure, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans." (42 U.S.C., Section 4331(a)).

Moving from the recognition of the need to protect our limited natural resources, Congress wrote some "teeth" into the Act by directing *all* Federal agencies to:

> "include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—
> (i) the environmental impact of the proposed action,
> (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
> (iii) alternatives to the proposed action,
> (iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and
> (v) any irreversible and irretrievable commitments of resources which would be involved if the proposed action should be implemented."
>
> (42 U.S.C., Section 4332).

At this point, the language from N.E.P.A. does *not* prohibit any Federal action.

N.E.P.A. itself does not prohibit Federal proposals; rather, according to Congress, men who supported the passage of N.E.P.A., it was the intent that publicity generated by an accurate E.I.S. would enable a concerned citizenry to direct political decision makers towards the proper decision.

Thus, in summary, the use of N.E.P.A. and its protections are absolutely dependent upon the existence and activity of a concerned citizenry. Without such a citizenry to require a Federal agency to prepare an accurate E.I.S., Federal agencies may obviously proceed without restriction. On the other hand, where a concerned citizenry insists that a Federal agency comply with the N.E.P.A. requirement of a detailed Environmental Impact Statement, the opportunity is presented for shaping a wise decision through the full public disclosure of the facts, and resultant public opinion and pressure.

STANDING UNDER N.E.P.A.

It may be useful to determine just who has "standing" to assert the provisions of N.E.P.A. That is, just who are the persons or organizations or governmental bodies who are, under N.E.P.A., entitled to insist that a Federal agency prepare the detailed Environmental Impact Statement?

This inquiry may be of particular importance in the case of the Apalachicola River, because there is potentially a very broad spectrum of persons and organizations who presently appear committed to protecting the River from further damage. For example, three of the County Commissions whose territory borders the Big River have, by public vote, recorded their opposition to the damming proposals offered by the Corps of Engineers (Resolution: Board of County Commissioners, Franklin County, Florida, dated June 15, 1973). In addition to the County Commissions, the City Commissions of Blountstown and Apalachicola have publicly recorded their opposition to Corps proposals. These units of local government have been joined by individuals, conservation organizations, commercial fishing groups, as well as numerous public officials.

Thus, there is a potentially broad variety of institutions and individuals who are entitled to rely on the N.E.P.A. requirements, and to insist that a Federal agency wishing to alter the Big River first prepare the detailed E.I.S.

A review of the pertinent Court decisions reveals that *all* of these local conservation organizations, businessmen, and individuals have legal standing to insist on the N.E.P.A. requirements. Initially, individual citizens who use a river for recreational purposes had been found to have standing, as well as conservation organizations ". . . which, through their research and other activities have actively sought to preserve and enhance the natural environment for the benefit of posterity" [Environmental Defense Fund, et al. -vs- Corps of Engineers, et al., 324 F.2d 878 (D.C.D.C. 1971)].

In addition, a municipality apparently has such standing. In a Federal case that arose in Connecticut, the Town of Groton alleged that the quality of the environment within the City was being threatened by a proposed navy construction project, and that the Navy had failed to submit an accurate E.I.S. The U.S. District Court ruled that the Town of Groton had standing to insist upon an accurate Environmental Impact Statement [Town of Groton -vs- Laird, 353 F. Supp. 344 (D.C. Conn. 1972)].

Unincorporated associations have been held to have standing to require the N.E.P.A. Environmental Impact Statement (F.C.R.A.T. -vs- United States, 346 F.Supp. 189 (D.C.D.C.1972). Sportsmen's Associations and individuals operating businesses connected with activities on a river also have standing, according to the U.S. Court of Appeals in a case that arose in the State of Washington [Association of Northwest Steelheaders -vs- U.S. Army Corps of Engineers, 485 F2d 67 (C.A.Wash.1973)]. Also, a state has standing to insist that the N.E.P.A. provisions be complied with by a Federal agency proposing action. A U.S. District Court stated this in authorizing Pennsylvania to maintain a suit alleging that the U.S. Department of Interior had failed to prepare an adequate Environmental Impact Statement [Commonwealth of Pennsylvania -vs- Morton, 381 F. Supp. 293 (D.C.D.C. 1974)].

A combination of local governments is entitled to jointly insist that the N.E.P.A. provisions be met. In an Illinois case, the U.S. District Court held that a group of governments consisting of the State of Illinois, the Cities of Parkridge and Des Plaines, and the Villages of Nile and Schiller Park were entitled to jointly insist that the Federal Aviation Administration comply with the N.E.P.A. requirements [State of Illinois, et al. -vs- Butterfield, 396 F. Supp. 632 (Northern District of Illinois, 1975)].

These precedents, then, may be of particular value in the protection of the Apalachicola River, since citizens and institutions reflecting a wide diversity apparently share the common goal of its protection. Specifically, we can envision the appropriate County Commissions being joined by the Apalachicola Chapter of the Organized Fisherman of Florida, and Congressman Don Fuqua and other office holders. They could issue a joint demand to the Corps that an accurate E.I.S. be prepared prior to any Corps activity.

In short, the opportunity is present now for cooperative action among individuals, cities, counties, businessmen, property owners, and conservation organizations, to insist that a new and higher level of impact assessment and disclosure to the public occur before *any* Corps alteration of the Apalachicola River is undertaken.

CONTENTS OF AN E.I.S.

Interested citizens, as well as businesses and conservation groups, should be aware that some rather specific standards for an "adequate" E.I.S. have been adopted by the Council on Environmental Quality.

Under this regulation, an E.I.S. must cover the following points:

"(i) The *probable impact* of the proposed action on the environment, including impact on ecological systems such as wildlife, fish and marine life. Both primary and secondary significant consequences for the environment should be included in the analysis. For example, the implications, if any, of the action for population distribution or concentration should be estimated and an assessment made of the effect of any possible change in population patterns upon the resource base, including land use, water, and public services, of the area in question.

(ii) Any *probable adverse* environmental effects which cannot be avoided (such as water or air pollution, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in section 101(b) of Public Law 91-190).

(iii) Alternatives to the proposed action (section 102 (2)(D) of the Act requires the responsible agency to 'study, develop and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources'). A rigorous exploration and objective evaluation of alternative actions that might avoid some or all of the adverse environmental effects is essential. Sufficient analysis of such alternatives and their costs and impact on the environment should accompany the proposed action through the agency review process in order not to foreclose prematurely options which might have less detrimental effects.

(iv) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This in essence requires the agency to assess the action for cumulative and long-term effects from the perspective that each generation is trustee of the environment for succeeding generations.

(v) Any irreversible and irretrievable committments of resources which would be involved in the proposed action should it be implemented. This requires the agency to identify the extent to which the action curtails the range of beneficial uses of the environment.

(vi) Where appropriate, a discussion of problems and objections raised by other Federal agencies and State and local entities in the review process and the dispostion of the issues." (35 Fed.Reg. 7390 (April 1970)).

Knowledge of the detailed requirements of this Federal regulation may be of significant value to citizens who are analyzing a draft E.I.S., in order to assess the accuracy and adequacy of the E.I.S. Again, note the inevitable nexus between the legal tool and the political process — that is, between the minimum data required of an E.I.S. by the Federal regulation, and the need for an interested citizen or citizens who would be prepared to object if those minimum standards are not met by the particular Federal agency. Without the vigilance and activity of one or more citizens, the protections of N.E.P.A. offer no obstacle to an aggressive Federal Agency.

PROTECTION OF WILDLIFE ACT

Another piece of Federal legislation is the Federal Protection of Wildlife Act (16 U.S.C., Section 661, et seq.). This unpretentious Act provides a variety of tools for a citizenry who oppose the ill conceived damming or altering of the Apalachicola River.

For example, in Section 662, the Act requires that any Federal agency desiring to impound or deepen any river:

> " . . . first shall consult . . . with the head of the agency exercising administration over the wildlife resources of the particular state where the impoundment, diversion or other control facility is to be constructed, with a view to the conservaation of wildlife resources by preventing loss of and damage to such resources . . . " (16 U.S.C., Section 662 (a)).

Thus, as a practical matter, any plan by the Corps to dam or deepen the Apalachicola River, must be preceded by consultation with the head of the Florida Department of Natural Resources. While the Act does not authorize the FDNR head to stop a damming or deepening project by a Federal agency, the Act does require notice to our own Department of Natural Resources, and does provide for recommendations from FDNR to be included in the final report regarding the impact of the project on wildlife conservation.

Speaking practically, the damage to the sturgeon and other endemic fish and wildlife populations that would be caused by damming the River, by maintenance dredging, or by blasting to deepen the River, is a factor that Mr. Shields has conscientiously raised, both in his recommendations to the Federal Government, and in reports to the people of Florida. Thus, the Florida Department of Natural Resources has become an important ally in the effort to inform the public of threats to the Apalachicola River and Bay by and from destructive Federal projects.

In a stronger provision of the Act, there is a requirement that " . . . adequate provision . . . shall be made . . . for the conservation, maintenance and management of wildlife resources thereof, and its habitat thereon." (16 U.S.C., Section 663(a). There can, of course, be disagreement as to what would constitute " . . . adequate provision . . . " to protect the sturgeon and other wildlife species in the River itself, and to protect the vast shellfish populations of the Bay. Nevertheless, this requirement could become an enormously effective tool, if used with skill and determination by the staff of the Florida Department of Natural Resources, and/or by concerned citizens, conservation groups, and businessmen. It is entirely conceivable that the Florida Cabinet could designate a particular office or individual within the Department of Natural Resources who would be responsible for a current review of Federal activities, to determine if such activities meet the plain requirements of the Federal Protection of Wildlife Act.

A proposed activity that deserves immediate inspection is the Army Corps proposal to dynamite portions of the bottom of the Apalachicola River. According to Public Notice No. 76-904, dated March 1, 1976, the Corps proposes to remove by dynamite and dragline 77,000 cubic yards from the bottom of the Apalachicola River. The Public Notice concerning this project advises that " . . . an environmental assessment is being prepared . . . [for the purpose of determining] . . . if an Environmental Impact Statement is required. If no E.I.S. is required . . . , the activity will commence without further notice." (Public Notice No. 76-904, Department of the Army, Mobile District). There is no mention in the Public Notice of the Federal Protection of Wildlife Act, much less even the hint of a request for recommendations from the FDNR regarding the impact of the project on the wildlife population; nor is there any attempt to make " . . . adequate provision . . . for the conservation . . . of wildlife resources . . . " as provided in Section 663(a) of the Act.

Again, this is a current example of an aggressive Federal agency which apparently feels no constraints of public opinion, and is apparently prepared to simply ignore the provisions of Title 16, U.S.C., Sections 662 and 663.

The Attorney General of Florida, should demand in writing that the Corps desist immediately from implementation of maintenance dredging and blasting activities, pending full compliance with the requirements of the Federal Protection of Wildlife Act. The head of the FDNR should make the same demands upon the Corps. The Florida Cabinet should support a resolution authorizing the Attorney General of Florida to seek an injunction against maintenance dredging or blasting of the Apalachicola River, under full compliance with the Federal Protection of Wildlife Act.

FEDERAL WILD AND SCENIC RIVERS ACT

Any discussion of the legal provisions that might be employed to protect the Apalachicola River would be incomplete without some mention of the Act that provides perhaps the most exciting opportunity for Floridians desiring to protect our Big River.

I refer, of course, to the Federal Wild and Scenic Rivers Act of 1968 [16 U.S.C., Section 1271, et seq.]. The declaration of policy by Congress in the preamble to the Act is so encouraging that I should like to share it with you:

> "It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstanding, remarkable, scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." (16 U.S.C., Section 1271, et seq.).

The body of the Act reflects the forceful imprint of numerous Representatives and Senators — though, unfortunately, none from Florida. I refer to the sections of the Act that specifically designate certain rivers that are now included in the System, such as the Allagash in Maine, the Wolf in Wisconsin, the Clearwater in Idaho, the Chattooga in Georgia. Happily, in addition to designating specific rivers that are Congressionally mandated into the Wild and Scenic Rivers System, the Act provides that other wild and scenic rivers may be included in the System if any particular river is:

> "designated as wild, scenic or recreational rivers by or pursuant to an act of the legislature of the State or States through which they flow . . . [and] . . . are found by the Secretary of the Interior . . . to meet the criteria established in this chapter." (16 U.S.C., 1273(a)(ii).

In summary, the U.S. Congress has provided a mechanism by which the citizens of a state are empowered to obtain the designation of a river as a part of the Wild and Scenic River System.

At this point, a brief review of the consequences of inclusion of a river in the Wild and Scenic River System may be useful. The principal protective provision triggered by the inclusion of a river in the System is found in Section 1278(a):

> " . . . no department or agency of the United States shall assist, by loan, grant, license, *or otherwise* in the construction of any water resources project that would have a direct and adverse effect on the values for which such river was established . . .
>
> No department or agency of the United States shall recommend authorization of any water resources project that would have a direct and adverse effect on the values for which such river was established . . . or request appropriations to begin construction of any such project . . . without specifically reporting to the Congress in writing at the time it makes its recommendation or request in what respect construction of such project would be in conflict with the purposes of this chapter." (Emphasis added) (16 U.S.C., Section 1278(a).

This language constitutes, for all practical purposes, a Congressional ban on any damming or altering of a river, once the river is designated for inclusion in the Wild and Scenic Rivers System.

A second protective provision in the Act, which is triggered by the designation of a river for inclusion in the System, is an authorization to the U.S. Secretaries of the Interior and of Agriculture to acquire lands adjacent to the river for inclusion in the System, up to 100 miles from the bank of the river [16 U.S.C., Section 1277(a)].

The potential of this Act to change even existing Federal projects is apparent. A dam has been authorized for some years by the Federal Government on the New River in North Carolina, with the usual justifications of hydroelectric power and recreational boating. The Legislature of North Carolina has recently designated the New River for inclusion in the National Wild and Scenic River System. This effort was deliberately launched in order to stop the Federal dam proposal.

The potential protection that this Act offers to the Apalachicola System is obvious. Once designated for inclusion in the Federal Wild and Scenic Rivers System, the Apalachicola would, as a practical matter, be forever free from the mechanical onslaughts of the Army Corps. The banks and watershed, if purchased as authorized under the Act, would receive a permanent reprieve from recurrent clear cutting practiced by International Paper and the other timber companies who presently own much of the watershed. And perhaps the most important feature of this Act is that the power to accomplish this designation lies here in Florida, with the Florida Legislature and our Governor. Such an issue, in the form of a bill presented to this Legislature, should receive overwhelming sponsorships, and should pass the House and Senate without a dissenting vote.

ECONOMIC PLANNING FOR THE APALACHICOLA DRAINAGE SYSTEM

Charles E. Rockwood and Steve Leitman
Florida State University

INTRODUCTION

The economic wisdom of developing further the water transportation potential of the Apalachicola-Chattahoochee-Flint river system is obviously a matter for careful consideration. Surprisingly, in view of the many changes contemplated for this river system, this has not yet been done. No study currently available to the public even pretends a complete economic evaluation of currently contemplated or proposed river development.

Many seem to think that a proper and favorable economic study must already have been completed. For some time, certain special interest groups have been arguing for further development of the transportation potential of the river system. It might be presumed that their positions were based on independent economic analysis. It is now well known that the Army Corps of Engineers, based on preliminary analysis, has argued that the benefits of more than one development plan outweigh the costs.

In a 1972-1973 study and presentation, the Corps concluded that a system of four locks and dams below the Jim Woodruff Dam at Chattahoochee, Florida would be economically viable. More recently the Corps has concluded that, at an interest rate of 6-7/8%, construction of a dam below Blountstown forming a lake (to be called Sutton's Lake) and maintenance dredging in the reaches below the Jim Woodruff dam would have a benefit-cost ratio of 1.61 to 1. At 5-5/8% this ratio would inflate to 1.95 to 1. Another plan calling for two dams, one at Sutton's Lake and another at Muscogee Lake, and maintenance dredging in the reaches below the Muscogee Dam would have a benefit-cost ratio of 1.00 to 1 at 5-5/8%, according to Corps analysis.

Since it is our conclusion that an adequate economic evaluation has not yet been done, this paper begins with a brief review of how economists compute the worth of projects such as those contemplated for the Apalachicola-Chattahoochee-Flint river system. Our second task will be to review existing (Corps of Engineers) cost-benefit analyses of some possible river development projects. Finally, we shall say something about the range, relative magnitude, and difficulty of calculation of the costs and benefits of river system development.

ECONOMIC COST-BENEFIT CALCULATIONS

Economists use the same basic analytical approach to decisions regarding development or use of any natural or material asset. The rules are no different for choices involving different resource use, material capital investment, or even human capital (i.e., the education and training of human beings) investment projects. The rules for government projects also are essentially the same as those used by the private market, and suffer from similar failings. The only significant difference between the public and the private market cost-benefit method is that economists, in assisting public decision-making, typically consider secondary (i.e., social) costs and benefits rather than solely primary benefits and costs.

The cardinal rule underlying any public or private market, investment or resource use decision is that assets should be employed so as to produce the highest net economic return. Calculation of highest economic return requires first that future net benefits be projected year by year. These futue net benefits then must be reduced (discounted) to present value terms through a process which is essentially the opposite of compound interest. In effect, we must ask the question, what sum of money would have to be invested, at compound interest, so that principal plus interest would equal the stream of expected future benefits. This net amount and these discounted future returns are then compared to the cost of the project and a ratio of costs to benefits is constructed. Projects whose ratios are slightly above 1:1 are narrowly favorable. Projects whose ratios are solidly above 1:1 are strongly favorable.

Currently, in evaluating public projects, the Corps of Engineers is by law held to at least a 1:1 ratio. The only exception is where a lower ratio is justified by the expected cost of any environmental improvement thought to result from the project (Water and Related Land Resources: Establishment of Principles and Standards for Planning, 1973).

However, the Corps' past record of consideration of and attention to environmental values has not been good. Ample evidence testifies to this point. For example, in 1968 the President's Council on Recreation and Natural Beauty reported that for the most part environmental values had been ignored by the Corps or relegated to low priority in assessing project feasibility (President's Council on Recreation and Natural Beauty, 1968).

When environmental values are considered it frequently has been to inflate project benefits, not to further evaluation objectivity. For example, in the Corps proposal for the Oakley reservoir on the Sangamon River in central Illinois, the Corps claimed average annual recreational benefits of $225,000 for flood control in a greenbelt area adjacent to the river. This value represented the average annual flood damage which occurred under pre-project conditions on land which was to be acquired for the greenbelt. However, the conversion of farmed bottomland to unfarmed greenbelt cannot properly be said to produce positive benefits in the form of reduced flood losses, since society will have lost the net value of crops produced on the land (Findley, 1973:64).

In this same Sangamon River project, the Corps estimated 30% of all economic benefits from the Oakley reservoir would arise from recreational uses. Two factors, however, appear inconsistent with these claimed benefits. First, vast shoreline mud flats were to result from periodic storage of silt-laden waters in the flood control pool and joint use for low flow augmentation. Second, pollution and eutrophication of reservoir waters was anticipated. These conditions would be likely to be unattractive to swimming or boating, yet the Corps expected recreational benefits for swimming alone to account for 40% of the projected recreational benefits and twelve per cent of the total project benefits (Findley, 1973: 81-82.)

The critical elements in any cost-benefit calculation are:

1. Determination of full project costs.
2. Determination of net benefits.
3. Prediction of the duration and year-by-year growth or diminuition of net benefits.
4. Selection of an interest rate for use in converting projected future benefits to present value terms.

An obvious advantage of applying the same cost-benefit analysis to a wide variety of economic problems is that, at least on a superficial level, this allows for comparison on a like basis of projects which are not at all alike. The difficulty of this approach, as will be made clear later in the paper, is that defects in existing cost-benefit techniques are particularly severe for some types of economic problems, for example those dealing with environmental use. Public choice decisions involving the environment should not be made solely on the basis of unamended application of standard cost-benefit analysis.

ECONOMIC REVIEW OF PRESENT CORPS OF ENGINEERS COST-BENEFIT ANALYSES OF APALACHICOLA DRAINAGE SYSTEM DEVELOPMENT

The Mobile District Corps of Engineers, in evaluating the worth of selected A-C-F river transportation development projects, has used a truncated version of the economists' standard cost-benfit model. This has sharply limited the value of existing Corps analysis.

Current Corps of Engineers analyses of possible Apalachicola-Chattahoochee-Flint river transportation development projects are based on a very modest reworking of a 1972-1973 justification report developed to support the case for construction of a multiple system of dams, all to be located below the Jim Woodruff dam. These same data with only minor changes were used to support the case for construction of the Sutton Lake project, a single dam and lock below the Jim Woodruff dam, together with some dredging below Sutton Lake and the Jim Woodruff dam. The Corps is in the process of revising their study, which is now substantially out-of-date, not only from an economic standpoint, but also from that of Corps guidelines for cost-benefit calculations. Nonetheless, the 1972-1973 study is essentially the same as the one used to support the more recent Sutton Lake lock and dam project (Personal interview, Mr. Walter Burdin, Project Leader, Apalachicola River Project, U.S. Army Corps of Engineers, Mobil, Alabama, 1976).

A first objection to the Sutton Lake proposal is, then, the Corps notion that the same benefits which were once thought likely to accrue from a system of locks and dams are now believed likely to accrue almost entirely from a single, not overly large lock and dam. A detailed public explanation for why one smaller dam is expected to accomplish almost all of what was once expected of a much larger system is lacking. This raises the possibility that primarily only the benefits that would accrue from a fairly complete river channel development are being measured. In view of that possibility, it seems wise to point out that, while the A-C-F system can make a useful contribution to the region's transportation needs, it is not presently a highly utilized system and is unlikely to change in this respect. We need to be suspicious of data supplied by user groups that give an exaggerated estimate of the benefits of federally subsidized river development projects.

In this connection, it should be kept in mind that the Corps has consistently overestimated the economic benefit of A-C-F development. For example, when the system was first opened the Corps projected a much higher use than actually materialized. One reason for the forecast error was failure

TABLE 1. PERCENTAGE OF TIME APALACHICOLA RIVER CHANNEL REACHED PROJECT DEPTH OF NINE FEET

Year	% at 9 ft	Year	% at 9 ft
1962	44.4	1969	39.1
1963	41.1	1970	50.7
1964	89.0	1971	78.9
1965	66.3	1972	71.5
1966	73.1	1973	89.7
1967	66.3	1974	67.7
1968	27.1	1975	100.0

Source: U. S. Army Corps of Engineers (1975a: 4)

to anticipate fully the development of pipelines as a transportation alternative, yet the Corps decision remained constant (Vanderhill, 1975: 1-16).

Also, the Corps seems to have been overly optimistic in the past about the extent to which construction projects would improve the navigability of this river system. For example, in 1967 Lt. General William F. Cassidy, Chief of the Army Corps of Engineers, assured industrialists and shippers using the Apalachicola-Chattahoochee-Flint river system that a nine foot channel could be expected 95% of the time by 1970 (The Albany [Ga.] Herald, 1967). As shown in Table 1, the nine foot channel actually has been attained 95% of the time only one year since 1970.

In view of these earlier forecast errors it is important to note that no system of locks and dams presently contemplated for the river system will deal with the rapid current or the extremes of high and low water often encountered on the river system. The drought and resulting low water that halted all barge traffic from July to November 1968 is not the sort of thing that could be overcome by any of the current river development proposals. A much larger system of reservoirs would be needed to deal with both low and high water problems. High water also makes navigation difficult, primarily because it increases the river current.

Another problem not dealt with by the Sutton Lake proposal is the narrow river channel (particularly at the river bends) often crowded by rock ledges. A 100 ft channel is not adequate for passing when barges are 35-50 ft wide, or for negotiating sharp turns where 50 ft wide tows approach 500 ft in length (including the tugboat), and 35 ft wide tows reach lengths longer than that. The Corps, however, contends that the channel width is adequate at the bends, based on simulation studies done in the Corps hydraulics laboratory in Vicksburg, Mississippi, and other information (personal interview, Mr. William Odum, Hydraulics Section, U.S. Army Corps of Engineers, Mobile District, May 1976). Shippers contest this point. Existing and continuing on-shore damage to trees and river banks at the sharp turn areas stands as a mute testimony to the validity of the shippers' contention.

A second critical objection is to the calculation of only direct benefits to development, rather than consideration of direct and indirect benefits combined. Also unacceptable is the failure to consider any negative effects of river development. In the existing Corps analysis, benefits were thought to be entirely positive and confined to savings in river transportation costs for present river traffic, plus savings over rail and truck transportation costs for traffic expected to divert to river transportation once the Corps development projects are completed. Even in the consideration of transportation cost savings, however, the possible effects of river system development on existing truck and rail transport costs and rates was not attempted.

Not giving due consideration to the effects on rail and transport rates can lead to gross overexaggeration of project benefits. For example, the dam and lock system on the West Pearl River in Louisiana was projected by Corps analysis to yield sizable transportation benefits mainly to the pulp and paper industry. After project construction was completed, a single barge load of pulp was ceremoniously taken downstream. This was the last barge load of pulp and paper to be shipped down the West Pearl River. The rail companies revised their rates downward, and the expected economic benefits from the waterway development were lost. Presently, the system is inoperative.

In making a proper calculation of net benefits, allowance needs to be made for changes in environmental quality, the value of recreation experiences and commercial fishing opportunities in the river system, Lake Seminole, Apalachicola Bay, and affected areas of the Gulf of Mexico. Effects to consider are problems which result from an increase in water pollution associated with intensified river development, the reduction in nutrients and detritus material flowing into Apalachicola Bay, and other environmental quality changes. Also, allowance needs to be made for the multiplicative on-shore costs and benefits accruing to projected increases in industrialization of the river basin.

A third major objection to the existing Corps of Engineers analysis is that the geographic and occupational distribution of benefits is not considered. It is clear that river development is largely beneficial to Georgia and Alabama, with the costs, or losses, borne largely by Florida — principally in Franklin County. The geographic distribution of these benefits and costs needs to be understood better. Even more important may be the consequences of river development in terms of the pattern and level of employment changes in the different regions.

As a fourth major criticism, the Corps projects future benefits will rise substantially. The calculated future benefits vary somewhat from project to project, but basically we are talking about an initial gain in river transportation benefits of about $2.5 million annually, when the project first opens. Benefits are then projected to rise, at a decreasing rate, until they reach a level of about $10 million annually 50 years hence. In view of the optimism of these projections, it should be noted that for many years after the Jim Woodruff dam was opened, water transportation uses of the river remained virtually constant. In recent years use has increased significantly. But, the waterway is still very lightly used in comparison with other systems; for instance the Black Warrior-Tombigbee. And, past Corps projections of transport tonnage for the A-C-F system have been much too optimistic. In 1974, the peak year in tonnage of commerce moved in the system, less than four trips per day were made up and down the Apalachicola-Chattahoochee-Flint river system (U.S. Army Corps of Engineers, 1975a). Obviously, this is not a heavily used transportation network.

As a final major criticism of the Corps analysis of Apalachicola-Chattahoochee-Flint development, interest rates used are really a little too low. Private businesses use discount rates approaching 10%, while the highest rate used in the Corps calculations is 6-7/8%. Their official rate, which is established by Congress, is now 6-1/8%. This will soon rise to 6-3/8%. The effect of this interest rate selection policy within the Corps calculations is to magnify substantially the estimated value of projected future benefits. Additionally, the use of a too low interest rate somewhat lowers the estimated projected costs. [A 1964 Resources for the Future study examined Army Corps of Engineer projects authorized in 1962 at the then prevailing discount rate of 2-5/8%. It was found that 9% of these projects would have a benefit cost ratio of less than unity at an interest rate of 4%; 64% would have had a ratio of less than unity at an interest rate of 6%; 80% less than unity at an interest rate of 8% (Fox and Herfindahl, 1964: 198-206)]. If consideration of environmental damage factors had been included in the project analysis, the low interest rate would have been less harmful. But this was not done.

In addition to criticism of benefit projections, the existing Corps of Engineers analysis contains some unwisely optimistic assumptions on the cost side. We have good reason to fear cost overruns. Although the Corps claims to strive for a liberal estimation of the costs of land acquisition, utilities relocation, and reservoir construction, studies have shown a consistent pattern in which actual costs far exceed estimates (Findley, 1973: 49). Without greater detail on construction and engineering costs than is now publically available, it is not possible to review all phases of the Apalachicola-Chattahoochee-Flint development cost estimates. But, several general points seem appropriate.

First, land acquisition costs are a significant element in total project costs for several of the proposals reviewed, and land acquisition costs currently are projected not to exceed $360 per acre. This figure needs to be revised upward. Depending on the project, land requirements varied from less than 1,000 acres to more than 10,000 acres.

Second, Corps estimates of the useful life of the proposed river development projects considered was 50 years in each case. This is the maximum time period the Corps is allowed by law to employ in projects of this type. In this particular context, problems of siltation and obsolescence suggest that a 50 year life span may be unrealistically optimistic. As one benchmark, the Jim Woodruff dam has now been in operation for 22 years, and some siltation problems have already developed.

As a final point about Corps cost projections, the Sutton's Lake project will improve navigation marginally, but it will not move this river system into the category of a highly efficient water transportation network. Perhaps this qualification helps to explain why earlier Corps project cost estimates for river system development have been too low, and why past river system maintenance expenses have been larger than expected. To date, the Corps has spent over one third of a billion dollars on this river system (U.S. Army Corps of Engineers, 1975b). There is in excess of another quarter billion to come. When the Corps has completed its development work, the river system will still contain substantial imperfections from the standpoint of the river transporters.

CONCLUSION

The defects cited in existing cost-benefit studies of A-C-F waterway development projects are surely sufficient to require a complete reexamination of the entire issue. Until that task is completed, further development obviously ought to be deferred. A public choice decision to foster industrialization of the Apalachicola drainage basin by development of the A-C-F waterway involves the nurturing of economic forces which once underway will not be easily reversed. We are talking about environmental use choices that are likely to be highly incompatible. If industrial users become a dominant group, water quality and land use changes are likely to occur that will drive out environmentally-based economic and recreational activity, such as fishing. Should this happen, future economic development will be forced along the path of further industrialization, even if it develops that the original choice to go this way was a poor one. We need to be sure of our policy before we begin.

To make the issue even tougher, when dealing with questions involving potential environmental collapse it is not sufficient to be right fifty-one percent of the time, as might be true for some business decision-making situations. It is necessary to be right beyond all reasonable doubt. Probability calculations of this nature do not adapt well to cost-benefit calculations. The fact that long range business and government choice decisions are notoriously inaccurate, together with substantial gaps in our storehouse of biological information concerning exact breaking points and trade-offs in the river system additionally complicates the problem.

In making a final determination about whether or not to develop the A-C-F as a water transportation network, the proper place to begin is with an analysis of the economy and of the region, and from this to formulate a regional economic plan. It is not possible to fully examine the advantages and disadvantages of water transportation development without this beginning. For example, one cannot really examine the question of the costs of locating business away from the river, unless we have some idea of what types of business we are talking about and how much transportation activity and of what type is likely to be generated. We suspect that the answer is not very many and not very much. This is because this rural region is not well suited to industrial development. It is remote from industrial supply sources. Its labor force is not trained in skills that most manufacturing concerns would need. Air, rail, and to some extent, truck transportation services are limited. For these reasons, the notion that improvement of water transportation facilities would bring great industrial growth is not well founded. Improved water transportation is but one link in the possible industrialization chain. Without other changes to make the area more attractive to industry, the thing to fear the most is that there would be enough industrialization to harm the regional environment, and not enough to provide the promised rise in employment and income.

Even if the hoped for industrial development were to occur, it might not be welcome after it arrived. Industrialization of a region causes substantial changes in a community's way of life that some find impossible to accept. This problem is intensified when regional development plans, zoning and the like are as inadequate, non-existent, and haphazard as they are at present for this area. A 1975 law passed in Florida now mandates such plans for Florida counties. But the completion of soundly based plans is still in the future, and Florida counties are only a portion of the area affected.

Since a major complaint against the Corps evaluation is their failure to consider the economic consequences of potential environmental damage, a critical issue is the dollar value of decreases in environmental quality. Unfortunately the tools of economics are not well adapted to handling this problem. The difficulty is that pure air and water, being abundant, are non-market goods. They have no price, and paradoxically are likely to have one only if they become desperately scarce. Natural and marine life also have no price, beyond perhaps that of a very modest license fee. The reason that natural and marine life have no price is that they belong to all. They are common property and as such are exploited to the point where access to them represents no special privilege. So they, too, are non-market goods. Sport and commercial fishing rights become market goods only if management of the resources is transferred to private owners, for example through a system of leases, or if a government manages the resources in a manner more closely akin to the management design that private owners would follow.

Unfortunately, economics has no satisfactory way of estimating the worth of non-market goods. A widely used and most unsatisfactory device for commercial fishing losses is to measure them in terms of market value of landed catch. Another widely used unsatisfactory device for recreational losses is to measure them in terms of daily recreational expenditures. But in the case of commercial fishing, the catching of fish requires an investment of capital in boats, equipment and operating costs, and of labor in fishing effort. The question then becomes, what if this capital and labor were used elsewhere? If economic markets are clearing properly, and if there have been no sudden and unanticipated shifts in relative economic values, the answer is that fishing capital and fishing labor ought to produce about as much value somewhere else as in fishing. This would say that commercial fishing is not really worth much.

By the same token, evaluation of recreational experiences by the expenditure approach says that money spent in a day by a drunk on the town is far superior to a day spent casting the same dollar seventy-five cent lure around, and then at sunset putting it back into the tackle box for another time. Moreover, the expenditure approach often considers general living expenses such as meals and lodging not properly attributable to the recreational experience. As perhaps an even more serious limitation, the expenditure approach fails to measure the value of one recreational site or experience over another.

A recent study by Robert Nathan and Associates, the latest in a long line of efforts to place a value on the oceans, estimates the value of commercial ocean fishing catches at 20% of production costs (U.S. Congress, Committee on Commerce, 1974) This estimate is based on the assumption that American fisheries are 20% less efficient than they would be if they were harvesting privately owned resources. This 20% inefficiency measure is then taken to be the value of our fisheries, which could be captured if we were to manage them differently. But if we are not going to manage them differently the 20% value coefficient has no economic meaning.

Another recent study determined recreational values by questionnaire survey: asking participants in recreational experiences to place a monetary value on their experience (Southeastern Association of Game and Fish Commission, 1975:26). The value of such outings was then taken to be equal to the average figure given times the number who participated. The results of the study indicated the recreational values shown in Table 2.

The difficulty with the questionnaire evaluation approach is that first, since there was no charge for the recreational experience, questionnaire respondents could easily exaggerate or speak to the value of recreation rather than to the value of one recreational experience as opposed to another. Second, what is relevant is not the average value, but the value to the borderline participant. For example, if one-half of the duck hunters felt the expense to be worth $78 or more a day out of 100 respondents, then the value of the experience would be $78 times the 50 who would have paid that much or more for it.

These observations on how to value quality of recreational experiences, the value of harvest of common property resources, and the intrinsic worth of clean air and water are not made with the suggestion that we give up trying to evaluate public projects. Rather the point is that many of the losses suffered through Apalachicola drainage basin development are likely to be especially difficult to quantify, and perhaps slighted for that reason.

As still another problem, available census data and fishery landings statistics do not indicate the probable volume of that activity for the northwest Florida region. The 1970 census statistics on percent of the labor force engaged in fishing, farming, and forestry indicates 6% for Gulf County, 7% for Wakulla County, and 26% for Franklin County. Yet we know from other work that some 60% of Franklin County owes its employment either directly or indirectly to oystering. So available statistics appear to substantially understate the true direct and indirect employment attributable to fishing. Partly, this is because indirect employment is, of course, not calculated in census statistics. Part of the problem lies in the way part-time workers are counted, and the way persons in the fishing process are listed. Even when these adjustments are made, a cost-benefit analysis would be biased toward river development. This is because standard cost-benefit analysis assumes a perfect offset to a job lost in, say Franklin County, is a job gained in, say Bainbridge. More sensible analysis would conclude that job creation in Georgia and Alabama inducing immigration to these areas is not an equal offset to the social dislocations that a permanent decline in Franklin County fishing employment would cause. Losses in Gulf coast crab landings, as another illustration, suffer from the same problem. The dockside value of crab landings from St. Petersburg to Pensacola run about three quarters of a million dollars per year. Twenty percent of that amount, to use Nathan's technique, is not a large factor in light of the overall costs and projected revenues for river transportation development. A similar problem exists with the valuation of recreational activity in the area, which at present is not terribly extensive in light of the size of the Lower Apalachicola region.

TABLE 2. POPULATION ESTIMATES OF AVERAGE MONETARY VALUES ASSOCIATED WITH WILDLIFE-ORIENTED RECREATION IN THE SOUTHEASTERN UNITED STATES

	Dollars Demanded to Give Up a Day of Activity
Fishing	
Saltwater	$ 84.38
Fresh-Warmwater	47.86
Fresh-Coldwater	36.70
Hunting	
Small Game	51.78
Big Game	95.17
Waterfowl	77.91
Enjoyment of Wildlife	
Birds	93.72
Animals	108.22
Fish	88.57

Source: Southeastern Association of Game and Fish Commissioners (1975: 26)

It is clear that people should and do value the environment, but the tools of economics are awkward at best when placing a dollar assessment on such factors. Not only do we have the common property and non-market goods evaluation problem, but discount formulas, under the rules of economics, lead us to notoriously short-sighted conclusions. Simple rules of present value calculation discount nearly to zero costs, or benefits, that are of a very long-run nature. An environmental cost of $1, fifty years hence, even at the low discount rate of 5% would be worth only 9¢. An environmental cost of $1, one hundred years from now, again using a 5% discount rate, represents a present value of less than 1¢. If a more realistic rate of 8% is used, these figures are 2.1¢ and .05¢ respectively.

A curiosity of these calculations, on the other side of the issue, occurs when the expected rise in annual return on the resource is larger than the discount rate. Under these circumstances, for a renewable resource such as a fishery or a recreational experience which can be harvested or enjoyed indefinitely, the present value of the future returns cannot be calculated; i.e., it is always infinity. Benefit-cost studies presumptuous enough to present such a calculation cannot be located. But the principle is valid enough.

What the use of present discount formulas tells us is that unbridled private enterprise is not likely to be overly concerned with posterity, particularly if the Federal government is paying the bill. The intercession of conservation-minded citizen and government groups is necessary to provide long-term environmental protection. But that protection is not going to be provided if public choices are made solely on the basis of unamended reliance on standard cost-benefit calculations.

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AN ENERGY-BASED EVALUATION OF A PROPOSED NAVIGATION DAM ON THE APALACHICOLA RIVER, FLORIDA

W. R. Boynton
University of Maryland

INTRODUCTION

Flowing generally southward through the Florida panhandle, the Apalachicola River passes through a mosaic of ecosystem types. With a seasonal cycle the river rises and falls, overflowing into floodplain forests of cypress, ash, and palmettos in the wetter seasons and receeding in periods of lesser rainfall. Along with the seasonal pulse of rain, herring, striped bass, and other species migrate upriver to spawn below Jim Woodruff dam. In a less obvious fashion, organic matter and basic nutrients of phosphorus, nitrogen, and others are released from the river forests and flow southward with the receeding waters eventually entering Apalachicola Bay. The large volume and seasonal nature of the river flow plays a significant role in maintaining the ecological characteristics of the Bay and its fishery resources (Rockwood, 1973; Livingston, et al., 1974; Boynton, 1975). Along with other natural characteristics of this basin there are towns, logging operations, fish camps, river commerce, agriculture, and other features of man and his activities. From a satellite view it becomes clear that the activities of man and nature in this basin are tightly woven together into a regional landscape.

In the last few years the U.S. Army Corps of Engineers has proposed the addition of a new component to the regional landscape in the form of a dam or series of dams to aid in maintaining river depths needed for commercial river traffic. There is considerable concern as to the eventual effects, both positive and negative, of adding this facility.

It is the purpose of this paper to quantify the energetic basis of the six Florida counties along the Florida portion of the Apalachicola River. From this type of analysis, suggestions can be made as to the advisability of adding more development, such as a navigation dam, to this area. A second analysis concerns itself with an evaluation of the costs and benefits associated with the proposed navigation dam.

REGIONAL VIEW

The proposal to build a dam for navigation purposes on the Apalachicola River involves six counties in Florida, including fishery-dominated Franklin County. The energy-flow analysis used in this paper requires that the proposed dam be viewed both in the context of the region with which it is in exchange (i.e., State of Florida and undefined portions of the United States) and as a new alternative component within the six county region.

The first portion of the regional view is required because some new construction schemes can appear beneficial if evaluated only on a local scale. For instance, the decision to build a power plant at a particular site may appear appealing because of limited environmental impact. This is a local view. However, the region to which this plant would provide power may be heavily developed and have economic and environmental problems. The addition of more growth based on a new power source would do little to solve the economic or environmental problems that may have had their origins in rapid growth in the first place. In short, the regional analysis is needed to insure that new additions to a region do not place that area far ahead of neighboring areas in its dependence on purchased goods, fuels, and services.

The proposed dam is also evaluated at a local level. The reason for this scale of analysis is based on the concept that all components in either an ecosystem, city, or a regional mosaic must return to the system of which they are a part at least as much value as is required for construction and long-term maintenance of that component. In the case of the proposed dam, this concept requires an evaluation of both the economic and the ecological gains and losses within the study area.

FACTORS CONTROLLING APALACHICOLA BAY

The Apalachicola River is important in maintaining many characteristics of the basin, among them the present characteristics of Apalachicola Bay and its associated fisheries (Boynton, 1975; Livingston, et al., 1974; Copeland, et al., 1974). Since the proposed dam may have some important modifying influences on the river and because potential fishery impacts are considered in this analysis, a summary of some known or suggested river-bay relationships are considered here.

From a simulation model developed by Boynton (1975) it was estimated that in the summer period about 30% of the Bay metabolism was supported by imported organics; the remaining 70% by phytoplankton production. The recycle of nuturients originally combined with the imported organic matter was the main nutrient source. Thus, preliminary calculations suggest that the river is a major source of organic matter and nutrients which are later used in supporting biological activity in the bay. Bay sediments may also be a major nutrient source.

If river modifications have the effect of decreasing the silt, organic matter, and nutrient load of the river, the Bay could become less turbid, especially during low flow periods. Benthic grasses and macrophytic algae may become generally more dominant as they already are in the clearer portions of the Bay. If this were the case, overall metabolism may not change greatly but rather shift from a phytoplankton-detritus system to a benthic grass system of higher diversity. High yields of oysters may not be a dominant part of such a system. Simulation modeling suggested similar results for a general reduction in freshwater flow and organic matter input (Boynton, et al., 1976).

The seasonal rise and fall in river flow and the associated changes in salinity appear to play an important role in maintaining high stocks of oysters. Simulation model results suggested that under decreased and steady river input conditions, approximately twice the harvest effort was required as was needed to produce an equivalent harvest under pulsing conditions (Hawkins, 1974). Oyster bar data from Menzel and Cake (1969) in addition to the general opinion of local oystermen substantiate this suggestion (Apalachicola Times, 1975).

STUDY AREA

The Florida portion of the Apalachicola Basin is located in the center of the Florida panhandle, and is bordered by six counties. These are, from north to south, Jackson, Gadsden, Calhoun, Liberty, Gulf, and Franklin. The total area includes some 4026 sq mi of which 78 are inland bodies of water. The climate is mild with a mean average annual temperature of 20°C (68°F) and rainfall of about 135 cm (55 in) per year. Descriptions of the vegetation are given by Clewell (1971), Livingston, et al. (1974), and Boynton (1975) for the lower counties. Total population in the study area was slightly over 100,000 (approximately 26 people/ mi^2) in 1973 and slow population growth was projected (Florida Statistical Abstract, 1973). Total personal income was estimated to be about $278 million per year in 1973. Most of the population (72%), personal income (74%), and land in agricultural use was in Jackson and Gadsden Counties. More than 50% of the population in the study area lived in unincorporated areas. The proposed Sutton's Lake navigation dam would be located about 30 mi above the river mouth.

METHODS

The general methodologies used here are those developed by Odum and his colleagues at the University of Florida. General discussions of the technique are given in Odum (1971) and Odum and Brown (1975). Applications of the techniques to a variety of problems have been completed by Zucchetto (1975), McKellar (1975), Gilliland (1975), and others. Those portions of the energy methodology used in this paper are described below and include energy-value calculations, investment ratios, cost-benefit calculations, and the concept of energy quality.

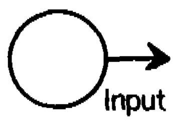
ENERGY-VALUE CALCULATIONS

Energy-value calculations were made to quantify total work contributions from all major components of the urban and natural ecosystems in the six county area. Energy flows (or flows of dollars or materials converted to energy equivalents) are believed to be a basic factor in the organization of all types of systems. Hence, if the energy basis of a system is estimated quantitatively, alternatives can be selected that tend to enhance the full value of that system as well as allow comparisons to be made with other systems of interest.

In developing an energy-value calculation, the first step is to construct a model diagram for purposes of organizing data. Included in the diagram are all major pathways entering and interactive in the system of interest. The diagramming seeks to summarize all the work processes that contribute to the overall functioning of a region including both those of man and nature. In this paper, energy circuit language symbols were used in constructing the diagrams given in Figures 2 and 3. Symbol definitions are given in Table 1.

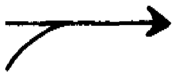
All major pathways on the diagram are then evaluated in units of work/time (Kcal/area/time). Natural ecosystem work was evaluated using gross metabolism as an estimate of total work. Work done by physical activities such as tidal and wind action were evaluated using standard formulas. Work done in urban activities was often most easily available in dollars and was later converted to energy units using the method given in Odum and Brown (1975). When the energy diagram was fully evaluated a table was constructed with each pathway in the diagram becoming an entry in the table. Next, each entry was converted to a com-

TABLE 1. SYMBOLS OF THE ENERGY CIRCUIT LANGUAGE USED IN THIS PAPER.



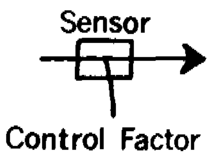
Forcing Function. An outside source of energy or materials entering the system of interest.

Pathway of energy or materials. The arrow indicates the direction of travel.

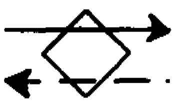


Adding Junction. Intersection of two similar flows capable of adding.

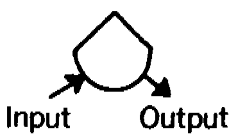
Pathway of money flow.



Rate Sensor monitors flow rate of carrier and controls the input of a quantity in proportion to the flow of the carrier. Sensor can also be used for similar purposes with a storage.

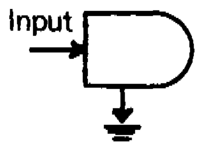


Economic Transaction. Flow of money is opposite to the flow of energy as in sales at a grocery store.

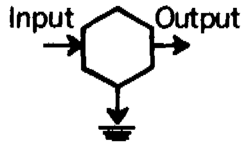


Passive Storage. A storage of energy or materials within the system of interest.

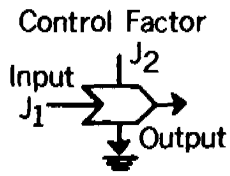
Heat Sink. Indicates a loss of potential energy as a consequence of the Second Law of Thermodynamics.



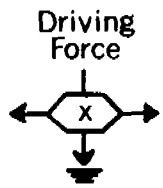
Green Plant. Normally used to illustrate photosynthesis, but utilized in regional diagrams to represent an entire ecosystem.



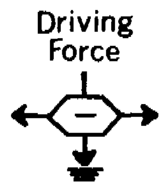
Self-Maintaining Consumer. Combination of storage and workgate symbols whose response is autocatalytic, e.g., an animal, city, industry.



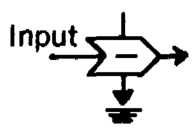
Workgate. Intersection at which one flow (J_2) makes possible a second, (J_1).



Two-Way Workgate. The direction of flow is determined by a gradient, hydrostatic head, etc. and the rate is in proportion to the gradient times the driving force.



Two-Way Workgate. As in above except driving force inhibits the flow.



Workgate. Special case of the above in which the intersection has a retarding effect on the process.

Adapted from Young et al., 1974.

mon type of energy flow using an energy quality ratio. Energy quality is discussed later in this section. Once all entries are converted they may be summed giving a quantitative index of value generated in the region per year.

ENERGY INVESTMENT RATIO

The information generated in the energy-value calculation can be used to calculate an energy investment ratio. The energy investment ratio is the ratio of energies purchased from outside the system to the natural energies operating in the study area. The purchased energies are generally goods, fuels, and services and are generally of higher quality than resident natural energies. In 1973 this ratio (Figure 1) was estimated to be 2.5 to 1 for the United States (Odum and Brown, 1974). Systems that have a relatively low investment ratio can match high quality external energies with more low quality natural energies and thus compete well with those products offered for exchange. This concept suggests that as the local investment ratio exceeds the ratio of surrounding systems, the local system generates less value per unit of high-quality energy used. This decline in value per unit could be reflected in higher prices required for exports and thus a disadvantage in competing with other, less developed systems, for high quality energies. The ultimate contribution of energy flows depends both on high quality purchased flows of fossil fuels and resident natural energies with which the high quality flows interact.

In this analysis, the energy-value calculation of the present regional pattern (without the dam) was done to characterize the balance of purchased and natural energies in the study area. These data were used to generate the investment ratio which serves as an indication of the desirability of adding more development to the region.

ENERGY COST-BENEFIT CALCULATION

This calculation is similar to the energy-value calculation in that a diagramatic model is constructed and evaluated, and pathways on the model are entered into a table for energy quality adjustment and tabulation. This main difference is that this calculation is focused on changes in energy flow pathways that may result if a proposed alternative is developed. The criteria for selection of an alternative requires that the alternative generates as much value as is required for its own development and maintenance. This calculation is somewhat similar to traditional cost-benefit calculations in that changes are considered. However, it differs in that environmental changes as well as financial changes are explicitly evaluated. It also differs in that all changes are first adjusted to the same energy quality level before comparisons are made.

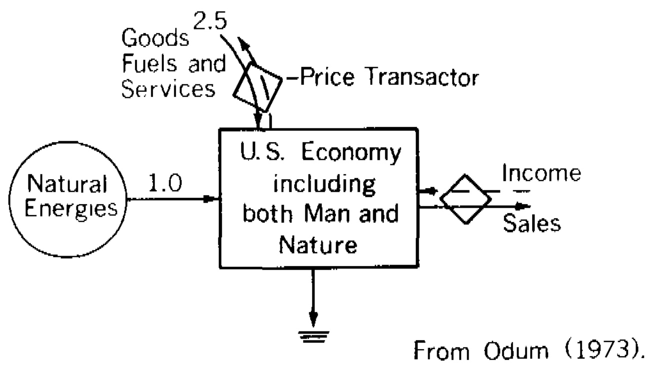


Figure 1. Simplified energy model showing estimated balance of input energies to the U.S. economy. The investment ratio (1973) from the figure is 2.5 (2.5/1).

ENERGY QUALITY

The value of a system process was defined as the contribution of the process to the useful work of the system. However, raw energy flows, as measured in kilocalories of heat, do not represent the ability to do work, but rather show only the heat content of that particular flow. Whereas any energy flow can be degraded to heat with 100% efficiency, the ability of an energy flow to do useful work depends on the packaging or concentration of the energy flow. For instance, the kilocalories associated with wood production in photosynthesis represent the concentration to wood kilocalories of the dilute kilocalories of unprocessed sunlight. In the same way, electrical energy is at higher concentration than the energy contained in coal; its generation requires approximately four kilocalories of coal type energy to obtain one unit of electrical type energy. Three kilocalories of coal energy are contributed from the coal to operate steam engines and one kilocalorie is expended to perform the work of constructing and maintaining the power plant structure. Several other examples of conversion calculations were given by Odum et al. (1974) for relating kilocalories of wind, wood, and electricity. Energy quality factors relating producers and many consumers in a shallow marine ecosystem were given by McKellar (1975). Thus, the above considerations suggest ways to compare varying types of energy flows in macroscopic systems of man and nature. Before comparisons are made, each flow must be converted to a common baseline energy quality. In this paper, all energy flows have been converted to the fossil fuel quality level (expressed as $Dcal_{FFE}$). A list of conversion factors was given by Boynton (1975).

DATA REQUIREMENTS

The models developed for this analysis were based on previous modeling experience, literature reviews, ecological and energetic concepts, and discussions with people familiar with processes characteristic of the study area. In this study, data were assembled, using the models as guides, from state and local agencies, the Florida Statistical Abstract, and from ongoing studies in the basin. Livingston et al. (1974) have summarized some of these studies. In those cases where local data were not available, state average per capita data were used. In the case of missing ecological data, estimates were used from areas having similar characteristics.

RESULTS

This section presents two sets of calculations for purposes of (1) characterizing the current state of development in the six county region and (2) estimating costs and benefits associated with adding a navigation dam to the current regional pattern. System components, interactions, numerical values of flows, and important issues were organized using two conceptual models.

The first model (Figure 2) attempts to characterize major inputs, components, pathways, and interactions of the present regional pattern. Figure 3 is identical except that expected or suggested new features and interactions associated with the proposed dam were overlaid on the original diagram. The data base used in the calculations comes mainly from 1973-74. In those cases when data for these years was not available, the next most recent data were used. Lastly, the cost-benefit calculation done here is aimed at evaluating the engineering plan which calls for one dam at Sutton's Lake and continued maintenance dredging below the proposed dam. This alternative had the highest benefit/cost relationship according to a Corps of Engineers fact sheet.

REGIONAL ANALYSIS

Data for the regional analysis were organized in the energy circuit language diagram in Figure 2. The model was drawn over a generalized map of the region including the tributary rivers forming the Apalachicola River (at top of diagram), Lake Seminole, and Jim Woodruff dam. Several towns are cross-hatched. Shown within the rectangle are the ongoing dredging activities. At the top of the diagram, sediments (S) and nutrients (N) flow in with river water (R). Shipping enters and leaves the river system at the top and bottom of the diagram with exchanges of cargo and shipping costs. Anadromous fish migrations enter the estuary and go up the river.

Natural energy inputs are shown interacting with the river ecosystem, terrestrial and lake ecosystems, and the estuarine ecosystem. The estuarine system has additional inputs of ocean water, tide, mixing energies, and seasonal fish migrations. The urban systems which were aggregated and shown in the lower left at the diagram, have imputs of fuels and goods and services and sales with external markets. Money runs counter to energy in these exchanges, the exchanges being regulated by prices. Natural ecosystems also add to urban work flows providing micro-climate control, water control, and other services. Additionally, the urban area is shown exporting products from all the natural ecosystems (commercial and recreational fishing, relaxation, retirement) as well as manufactured and agricultural products. Lastly, the dredging operations have money inputs from funds of the Corps of Engineers with which fuels, goods, and services are purchased for operations. Pathways in Figure 2 are numbered with the numbers referring to entries in Table 2.

Table 2 should be referred to for the relative magnitude of various inputs and activities. The final entries in Table 2 are all in $Kcal_{FFE}$ and thus, as suggested in theory, are generally comparable. Calculations from which the entries in Table 2 were obtained are given as footnotes following the table.

The energy inputs characterizing the present regional pattern amounted to 19.05×10^{12} $Kcal_{FFE}$/yr. This was calculated by summing all entries in Table 2 except sunlight. The sunlight was excluded because the work associated with sunlight was roughly accounted for by the inclusion of the remaining natural and metabolic energy flows. Notice that the total flow would have been about the same if only sunlight energy had been used. Of the total energy flow about 50% was associated with activities dependent on purchased goods, fuels and services. The remaining 50% was associated with non-purchased natural inputs. The energy investment ratio (purchased goods, fuels, and services divided by natural inputs) was 1.02. Current dredging activities were a very small feature of the present energy flow in the region, amounting to about 0.1% of the total.

EVALUATION OF PROPOSED DAM

To focus attention on the impact of the pro-

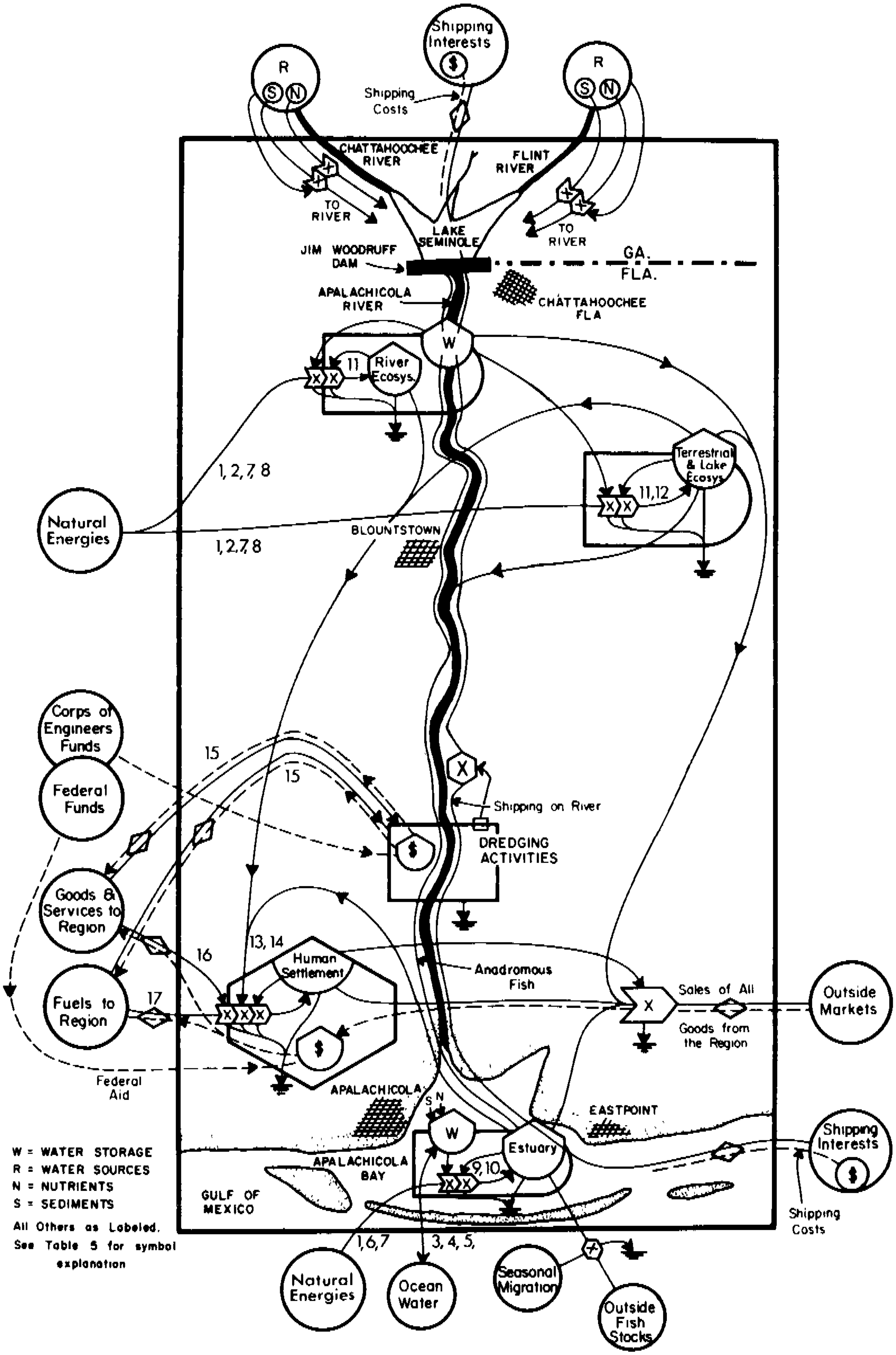


Figure 2. Simplified energy model of the Florida portion of the Apalachicola River Basin. Description of the model is given in the text.

TABLE 2. ENERGY VALUE CALCULATION FOR SIX COUNTY REGION

Pathway Figure 2	Name of Energy Flow	Area of System (Acres)	Annual Work Per Acre (10^7Kcal/acre/yr)	Total Annual Work (10^{12}Kcal/yr)	Energy Quality Factor (Boynton, 1975)	Annual Work in Fossil Fuel Equivalents (10^{12}Kcal$_{FFE}$/yr)
Contributing Natural Energy Flows						
1	Total Sunlight	3,256,742	591.0[a]	19,300.0	2,000	9.63
2	Heat Gradient	3,256,742	4.10[b]	134.0	10,000	0.01
3	Tides in Estuary	127,020	0.15[e]	0.19	2.5	0.08
4	Waves on Shoreline	---------------	0.06[c]	0.068	5.0	0.01
5	Mixing Energy (ΔF)	---------------	------------	0.256[c]	0.3	0.85
6	Hydrostatic Head	---------------	------------	0.23[c]	0.63	0.37
7	Wind	3,256,742	------------	8.21[d]	7.7	1.06
8	Rain					
	Mixing Energy (ΔF)	2,643,000		0[e]	0.3	0.0
Metabolic Energy Flows in Natural Systems						
9	Coastal Plankton System	406,400	1.33[f]	5.41	20	0.27
10	Estuarine Systems	149,853	4.90[f]	7.34	20	0.37
11	Freshwater Systems	56,600	11.20[g]	6.34	20	0.32
12	Terrestrial Systems	1,873,000	4.83[h]	90.5	20	4.53
						5.49
Metabolic Energy Flows in Managed Ecosystems						
13	Agriculture	630,000	4.9[i]	30.9	20	1.55
14	Urban Vegetation	33,600	1.2[j]	30.9	20	0.02
						1.57
Energy Flows in Urban Systems						
15	Expenditures for Dredging		---------	0.02[k]	10	0.02
16	Goods and Services		---------	5.16[k]	1.0	5.16
17	Fuels					
	Gasoline		---------	1.74[m]	1.0	1.74
	Kerosene			0.03	1.0	0.03
	Bottled Gas			0.07	1.0	0.07
	Electricity			0.73	0.28	2.61
						9.63

Total Energy Flow = 19.05×10^{12} Kcal$_{FFE}$/yr

Investment Ratio = *Purchased Goods, Fuels, and Services* / Natural Energy Flows = 9.63×10^{12} Kcal$_{FFE}$/yr / 9.42×10^{12} Kcal$_{FFE}$/yr

FOOTNOTES FOR TABLE 2

a. Total sunlight was estimated by multiplying average yearly sunlight by total area. Average sunlight input was estimated to 4×10^3 Kcal/m^2/day (Odum, 1971). Total area included all land and water areas in the six county region plus estuarine and coastal areas. (4.0×10^3 Kcal/m^2/day) (3.26×10^6 acres) (4.047×10^3 m^2/acre) x (365 days/yr.) = 1.93×10^{16} Kcal/yr.

b. Local heat gradient work was estimated by multiplying average sunlight input per area per year times a Carnot ratio ($\Delta T = 2^oC$) times the total study area (Odum et al., 1974).

$$(4000\ \text{Kcal/m}^2\text{/day}) \left(\frac{2}{288.5}\right) (365\ \text{days/yr}) (4047\ \text{m}^2\text{/acre}) (3.26 \times 10^6\ \text{acres}) = 1.34 \times 10^{14}\ \text{Kcal/yr}$$

c. Estimates of the work done by tides in the estuary, waves on the shoreline, mixing energy, and hydrostatic head, were defined and calculated as given in Boynton (1975). The hydrostatic head calculation was adjusted to reflect the elevation change between Apalachicola Bay and Jim Woodruff dam (Δ 44 ft).

d. The yearly work done by winds was based on the kinetic energy of the wind. An eddy diffusion coefficient of 1×10^4 cm^2/sec was used. Average wind velocity was estimated to be 8.7 mph (Florida Statistical Abstract, 1973). This wind speed was assumed to occur 10 meters above the ground. Total area for the six county region was 3.26×10^6 acres (1.32 x 1014 cm^2).

$$\frac{(1.2 \times 10^{-3}\ \text{g/cm}) (371\ \text{cm/sec})^2 (1 \times 10^4\ \text{cm}^2\text{/sec}) (2.39 \times 10^{-11}\ \text{Kcal/erg}) \times (3.15 \times 10^7\ \text{sec/yr}) (1.32 \times 10^{14}\ \text{cm}^2)}{(2)(1 \times 10^4\ \text{cm})}$$

8.21×10^{12} Kcal/yr

e. Annual work done by rain was divided into three categories. The work done in photosynthesis was accounted for in terrestrial and freshwater system metabolism measurements and was not recounted here. The potential energy of water (from rain) due to its position relative to sea level was included in the calculation of hydrostatic head of river water and was not recounted here although there is some head loss as local land areas drain into the river. The potential energy of rain water relative to river water due to the concentration differences (mixing energy) was calculated using runoff. Concentration changes were from 1.2 ppm (rain) to 120 ppm (river water). Mixing energy per gram of solute was calculated to be 78 calories. The total runoff flow was estimated to be 43 cm/yr.

Total flow/yr = (43 cm/yr) (1.04×10^{14} cm^2)
= 4.6×10^9 m^3/area/yr
(78 cal/g solute) (1.29 g/m^3) (4.6×10^9 m^3/area/yr) (10^{-3} Kcal/cal) =
= 4.31×10^8 Kcal/yr

f. Metabolism of the coastal plankton system and estuarine systems was estimated as given in Boynton (1975).

g. The area of freshwater systems included all lakes and rivers in six county study area (Florida Statistical Abstract, 1973). Metabolism was estimated to be about 11×10^7 Kcal/acre/yr (Odum, 1971).
(11×10^7 Kcal/acre/yr) (5.66×10^4 acres) = 6.34×10^{12} Kcal/yr

h. Metabolism of terrestrial systems was estimated as given in Boynton (1975). The area of terrestrial systems was adjusted to cover the six county area (Florida Statistical Abstract, 1973).
(5.68×10^7 Kcal/acre/yr) (2.64×10^6 acres) = 150.0×10^{17} Kcal/vr

i. Work done by metabolism of agricultural crops. Agricultural area was 2.55×10^9 m^2 (Florida Statistical Abstract, 1973). Agricultural crop metabolism was estimated to be 4.9×10^7 Kcal/acre/yr (Odum and Brown, 1975).
(6.3×10^5 acres) (4.9×10^7 Kcal/acre/yr) = 30.9×10^{12} Kcal/yr

j. Work done by urban vegetation was estimated using a metabolism of 1.2×10^7 Kcal/acre/yr (Bayley and Odum, 1973) and an area of 33,600 acres (Florida Statistical Abstract, 1973).
(1.2×10^7 Kcal/acre/yr) (33,600 acres) = 4.0×10^{11} Kcal/yr

k. Current dredging expenditures were estimated to be \$800,000/yr (U.S. Army Corps of Engineers, 1974). (\$800,000/yr) (25,000 Kcal/dollar) = 20 billion Kcal/yr

l. Energy equivalent of goods and services was estimated by converting total income to Kilocalories using a ratio of 25,000 Kcal_{FFE}/\$. Total income was from the Florida Statistical Abstract (1973).
(206.5×10^6/yr) (25,000 Kcal/\$) = 5.16×10^{12} Kcal/yr.

m. Total fuel use was obtained from the Energy Data Center, Florida Department of Administration (1974).
Gasoline (5.4×10^6 gal/yr) (1.27×10^5 BTU/gal) (0.253 Kcal/BTU) = 17.41×10^{11} Kcal/yr
Kerosene (0.93×10^5 gal/yr) (1.42×10^5 BTU/gal) (0.25 Kcal/BTU) = 3.21×10^{10} Kcal/yr
Bottled Gas (2.81×10^6 gal/yr) (4.24 lb/gal) (2.17×10^4 BTU/lb) x (0.253 Kcal/BTU) = 6.54×10^{10} Kcal/yr
Electricity (8.24×10^3 KWH/capita/yr) (860.5 Kcal/KWH) (1.03×10^5 people) = 7.30×10^{11} Kcal/yr

posed dam, a model (Figure 3) was constructed showing new components and interactions expected. This model is the same as that given in Figure 2 except that the proposed dam has been added (box symbol in center of diagram). Possible impacts of the proposed dam which were considered in this analysis included the following:

1. Interruption of the migration of anadromous fish. This was shown by the drag action multiplier.
2. Replacement of the terrestrial system by a plankton lake ecosystem in the creation of the small reservoir behind the dam. A pathway leads from the terrestrial systems to the reservoir ecosystem.
3. Retardation of normal seasonal flooding of river forests due to levies needed in construction of the project. A drag-action multiplier was used to indicate reduction in the flooding of terrestrial systems. With less water exchange between river forests and the river there may also be less detritus exported into the river. This is indicated by a drag action multiplier associated with the pathway leaving the terrestrial system and entering the river.
4. Possible loss of sediments and nutrients behind the dam. This is shown by short pathways labeled N and S leaving the water and affecting estuarine activities and fisheries.
5. Augmentation of shipping due to deeper channels behind the dam. This is shown as a two-way multiplier above the dam. This includes damage savings.
6. Introduction of Federal funds which would be used in the development of the project (dashed line going to dam) to purchase fuels, goods, and services.

The cost-benefit tabulation is given in Table 3 with explanatory footnotes following the table. Numbered pathways in Figure 3 are crossed-referenced in the table. Notice that Table 3 includes only new or modified pathways. These were listed as costs (those pathways or modifications required for the project to be built and maintained) and benefits (those new or augmented energy flows that come available because of the project).

Lastly, there was some uncertaintly about the regional pattern that would result if the project was completed. These uncertainties included the life span of the project, size of transportation savings, and the possibility of impacts on the estuarine fisheries. Several outcomes were suggested and calculated. These appear as Cases I-VI in Table 3 with a description of each outcome given in the footnotes.

In the six cases, costs ranged from 5.8 to 21.7 x 10^{10} $Kcal_{FFE}$/yr. Except for cases V and VI, natural system costs were about the same as urban system costs. Benefits ranged from 2.4 to 5.0 x 10^{10} $Kcal_{FFE}$/yr with most of the benefits associated with urban systems. Costs in all cases exceeded benefits.

DISCUSSION

Energy flow analysis has been used here to provide quantitative indices of the current pattern of man and nature in a rural area of Florida and to suggest costs and benefits associated with a proposed modification.

In the six county region, the energy investment ratio was calculated to be about 1.0. This ratio can be compared to others for several purposes. Odum and Brown (1975) calculated the ratio to be 2.5 for the United States, indicating that the six county region is less developed (using fewer goods, fuels, and services per unit of natural energy) than the country as a whole. DeBellevue (1976) calculated a ratio of 1.0 for Hendry County, Florida, an agricultural area. For rural Franklin County, Boynton (1975) found the ratio to be 0.2 while Zucchetto (1975) found a ratio of 3.9 for the Miami-Dade County area. In situations where the investment ratio is less than usual. theory suggests that these areas are economic and, if net energy is available, they should grow. When there are abundant natural energies (non-purchased) available and contributing to the production of output, and to the general maintenance of activities in a region, the sale price of products can be less and the region will be able to outcompete those with a higher ratio.

An additional calculation of interest is the ratio of total direct energy use (natural and fossil fuels) to the gross regional product. For the six county region, this ratio was 53,682 $Kcal_{FFE}$/dollar. This ratio for the U.S. was 25,000 $Kcal_{FFE}$/dollar in 1973 and only 13,580 $Kcal_{FFE}$/dollar for the Dade County area of Florida (Zucchetto, 1975). The very high ratio for the six county area indicates that fewer dollars are generated per unit of energy flow than in more developed areas. In general, rural areas with abundant natural energies and industrial areas may be characterized by high ratios. Areas characterized by lower ratios may be service oriented as suggested for Miami by Zucchetto (1975). Thus, energetic analysis suggests that the six county region is less developed than other areas of the country and some areas of Florida. The energy basis of the region was similar to an agricultural county in South Florida but more developed than Franklin County. The investment ratio theory suggests that the region could support more growth and still remain

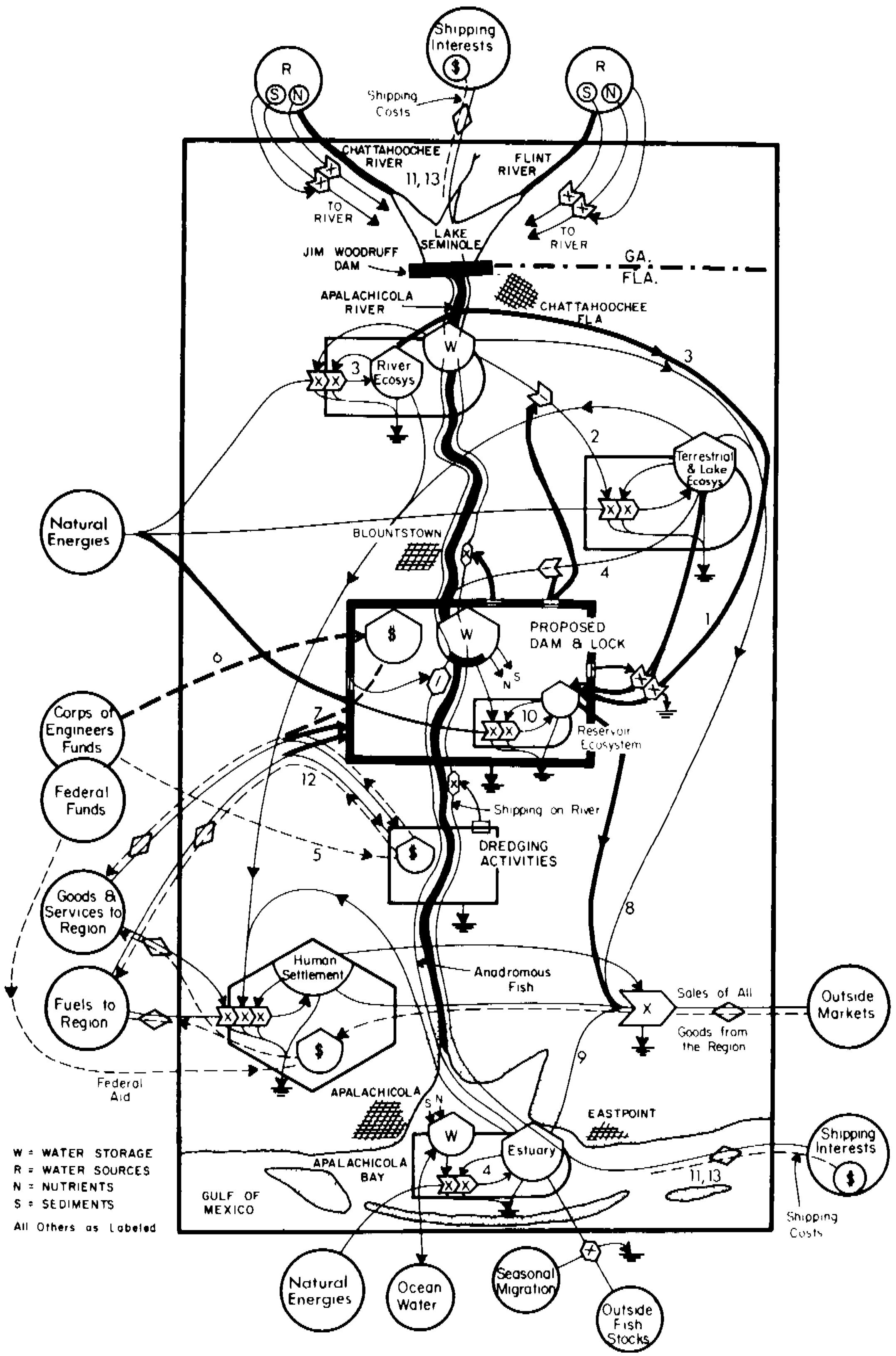


Figure 3. Simplified energy model of the Florida portion of the Apalachicola River Basin. Proposed navigation dam and new pathways are shown in bold lines. Explanations are given in the text.

TABLE 3. ENERGY COST-BENEFIT TABLE FOR PROPOSED NAVIGATION DAM ON THE APALACHICOLA RIVER

Pathway on Figure 3	Energy Flow[a]	CASES I[b]	II[c]	III[d]	IV[e]	V[f]	VI[g]
	COSTS						
	Natural Systems						
1.	Loss of forest production[h]	0.67	0.67	0.67	0.67	0.67	0.67
2.	Modification of forest production[i]	1.50	1.50	1.50	1.50	1.50	1.50
3.	Loss of river production[j]	0.43	0.43	0.43	0.43	0.43	0.43
4.	Modification of estuarine production[k]	?	?	?	?	?	?
	Urban Systems						
5.	Dredging costs[l]	1.25	1.25	1.25	1.25	1.25	1.25
6.	Cost of dam[m]	2.50	1.60	1.60	2.50	1.60	2.50
7.	Maintenance of dam[n]	0.36	0.36	0.36	0.36	0.36	0.36
8.	River fishery losses[o]	?	?	?	?	?	?
9.	Estuarine fishery losses[p]	?	?	?	?	?	?
	BENEFITS						
	Natural Systems						
10.	Creation of reservoir[q]	0.28	0.28	0.28	0.28	0.28	0.28
	Urban Systems						
11.	Transportation savings[r]	2.65	2.65	1.33	1.33	1.33	1.33
12.	Dredging savings[s]	0.75	0.75	0.75	0.75	0.75	0.75
13.	Barge damage savings[t]	?	1.32	?	?	?	?

FOOTNOTES FOR TABLE 3

This table has energy costs and benefits extracted from the regional energy cost-benefit calculations for purposes of showing the magnitude of local changes associated with the proposed dam. Each modification listed in Table 3 is shown diagramatically in Figure 3 (pathway numbers on diagram correspond to pathway numbers in Table 3).

a. All numbers shown in Table 3 are in $Kcal_{FFE}$/yr. Areas were taken from the U.S. Corps of Engineers Tentative Fact Sheet for Proposed Suttons Lake Lock and Dam, Apalalchicola River, Florida, and from McNulty et al. (1972).

b. Case I assumes payment of dam over 30 years; no fishery losses; dredging costs reduced to $500,000/year; and average travel distance of 1000 miles for all cargo moving on the river.

c. Case II assumes payment of dam over 50 years; no fishery losses; dredging costs reduced to $500,000/year; average travel distance of 1000 miles for all cargo moving on the river; and damage savings of $500,000/year (report issued by Corps of Engineers at Apalachicola meeting, 1973).

d. Case III assumes payment of dam prorated over 50 years; no fishery losses; dredging costs reduced to $500,000/year; and average travel distance of 500 miles for all cargo.

e. Case IV assumes payment of dam prorated over 30 years; no fishery losses; dredging costs reduced to $500,000/year; and average travel distance of 500 miles for all cargo.

f. Case V assumes payment of dam prorated over 50 years; one half of estuarine oyster fishery lost; dredging costs reduced to $500,000/year; and average travel distance of 500 miles for all cargo.

g. Case VI assumes payment of dam prorated over 30 years; estuarine oyster fishery lost; dredging costs reduced to $500,000/year; and average travel distance of 500 miles for all cargo.

FOOTNOTES FOR TABLE 3 (CONTINUED)

h. Gross production of Flood-Plain Forests was estimated to be 15.5×10^7 Kcal/acre/yr (Young et al., 1974). Area of forest lost estimated to be 864 acres (U.S. Army Corps of Engineers, 1974).
864 acres x $4046\ m^2$/acre x $38{,}300\ Kcal/m^2/yr = 13.4 \times 10^{10}$ Kcal/yr

i. Metabolic losses due to conversion of Flood Plain Forest to Bottom Land Hardwoods. Estimated to be the difference between total metabolisms of the two types over the 4000 affected areas adjacent to the west levy. Bottom Land Hardwood metabolism estimated to be 8.0×10^7 Kcal/acre/yr (Odum).
4000 acres x $4046\ m^2$/acre x 15.5×10^7 Kcal/acre/yr = 62×10^{10} Kcal/yr
4000 acres x $4046\ m^2$/acre x 8.0×10^7 Kcal/acre/yr = 32×10^{10} Kcal/yr
Metabolic change = 30×10^{10} Kcal/yr

j. Gross metabolism of river ecosystem estimated as $10{,}000\ Kcal/m^2/yr$ (Hall, 1972; Bayley and Odum, 1973). River area modified to reservoir estimated to be 2136 acres (U. S. Army Corps of Engineers, 1974). 2136 acres x $4046\ m^2$/acre x $10{,}000\ Kcal/m^2/yr = 3.6 \times 10^{10}$ Kcal/yr

k. Overall gross metabolism of the estuary may not increase or decrease but may change characteristics. No gains or losses are suggested here. Average metabolism of Apalachicola Bay estimated to be $15{,}000\ Kcal/m^2/yr$ (Boynton, 1975).

l. Dredging costs before and after dam construction estimated to be $800,000/yr and $500,000/yr, respectively (Jackson, 1974).
$\$0.8 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/yr = 2\ 0 \times 10^{10}$ Kcal/yr before project
$\$0.5 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/yr = 1.25 \times 10^{10}\ Kcal_{FFE}/yr$ after project
(entered in Table 3).

m. Total cost of dam and locks was estimated to be about $\$30 \times 10^6$. Prorated costs over 30 and 50 years is $\$1 \times 10^6$ and $\$0.6 \times 10^6/yr$, respectively (U.S. Army Corps of Engineers, 1974),
$\$1 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/\$ = 2.5 \times 10^{10}\ Kcal_{FFE}/yr$
$\$0.6 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/\$ = 1.6 \times 10^{10}\ Kcal_{FFE}/yr$

n. Maintenance of dam and locks was estimated to be $142,000/yr (U.S. Army Corps of Engineers, 1974).
$\$.142 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/\$ = 0.36 \times 10^{10}\ Kcal_{FFE}/yr$

o. National Marine Fishery Service biologists suggest that anadromous fish populations (Striped Bass, Sturgeon, Alabama Shad) would decline following dam construction. No estimates of before and after fish stocks were available (Nelson, 1974) and no estimates of losses are included here.

p. The dollar value of the estuarine fishery was estimated to be $\$6 \times 10^6/yr$ (Boynton, 1975; Rockwood, 1973). The fossil fuel equivalent work value of the fishery was calculated by converting dollar income to $Kcal_{FFE}$ using a factor of 25,000 $Kcal_{FFE}/\$$.
$(\$6 \times 10^6/yr) \times (2.5 \times 10^4\ Kcal_{FFE}/\$) = 15 \times 10^{10}\ Kcal_{FFE}/yr$

q. Gross metabolism of reservoir estimated to be $4{,}600\ Kcal/m^2/yr$ (Bayley and Odum, 1973). Total reservoir area was estimated to be 3000 acres (U.S. Army Corps of Engineers, 1974).

r. Transportation savings estimated to be $0.002/ton-mile due to deeper channel (Burdin, 1974). Barge traffic in 1971 estimated to be 0.53×10^6 tons/yr (Waterborne Commerce of the U.S., 1971). Assuming a 1000 and 500 mile barge trip, savings amount to:
$\$1.06 \times 10^6/yr$ and $\$0.53 \times 10^6/yr$
For 1000 mile trip-
$\$1.06 \times 10^6/yr \times 2.5 \times 10^4 Kcal_{FFE}/\$ = 2.65 \times 10^{10}\ Kcal_{FFE}/yr$
For 500 mile trip:
$\$0.53 \times 10^6/yr \times 3.0 \times 10^4\ Kcal_{FFE}/\$ = 1.33 \times 10^{10}\ Kcal_{FFE}/yr$

s. Dredging savings were estimated from the difference in dredging costs before and after construction of the project. See 1 in this footnote.

t. No firm estimates of damage savings due to deeper channels were available. For the best case calculation (Case II) we assumed that damage savings would be equal to transportation savings on a 500 mile trip (Report issued by Corps of Engineers at Apalachicola Meeting, 1973).
$\$0.53 \times 10^6/yr \times 2.5 \times 10^4\ Kcal_{FFE}/\$ = 1.32 \times 10^{10}\ Kcal_{FFE}/yr$

competitive in exchanges with other areas of Florida and the country in general.

If, as suggested by this analysis, the region could support more development, the question remains as to which of many alternatives will produce a good yield relative to costs. In the cost-benefit analysis of the proposed navigation dam, the "best case" results (Case II) indicated a net loss of about 0.8×10^{10} $Kcal_{FFE}$/yr. The "worst case" calculation, in which the estuarine oyster fishery was assumed to be disrupted, indicated a net loss some 25 times as great. The remaining four cases yielded estimates ranging between these extremes. If all major costs and benefits have been included, the return on the proposed dam does not appear to justify its construction and perhaps other alternatives should be considered.

There may be several activities that could be classed as benefits that were not considered here. These include increased business activity in towns along the river based, in part, on a dependable and inexpensive transportation system. Perhaps recreational use of the river might also develop near the dam. If these do not develop after the dam is built, the "best case" cost-benefit ratio presented here may be overly optimistic (although negative) because many of the benefits included in the present calculation may accrue to activities outside the river basin. In a sense, if this were to occur, the Florida portion of the basin would essentially export natural resources (river ecosystems) to other areas without a return feedback. This, in the long run, may not be competitive.

As additional information comes available, second generation calculations, including both natural and urban gains and losses associated with the proposed dam should be completed.

ACKNOWLEDGMENTS

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SUMMARY OF RESULTS

Robert J. Livingston
Florida State University

The proceedings of this compendium represent the efforts of 28 investigators in various fields such as environmental science, resource management, economics, and environmental law. This multidisciplinary effort includes a review of much that is known about the Apalachicola River and Bay System. Original papers deal with various aspects of the natural resources of the Apalachicola Valley. The entire Apalachicola Drainage System actually includes a area of over 19,500 sq mi in three states (Florida, Georgia, Alabama) and is composed of four major rivers (Flint, Chattahoochee, Chipola, Apalachicola). This effort is concerned with the Apalachicola River Valley (107 mi long) stretching from the Jim Woodruff Dam to the Gulf of Mexico. This is the largest river in Florida with an average flow rate in excess of 23,000 cubic feet/second. As yet, the drainage area is sparsely populated and little developed in terms of agricultural and industrial activity. It includes a wetlands area, and annual flooding of the river is considered to be a key ecological feature of the system.

TERRESTRIAL SYSTEMS

PLANTS

The Apalachicola Valley includes various ecological regions characterized by dominant forms of terrestrial vegetation. These include dry, sandy uplands (pines, oaks, herbs, and low woody plants), bluffs or shoal river formations (magnolia, beech, oak, maple, and holly), floodplain areas (Black willow, cottonwood, sycamore, river birch, ogeechee-tupelo, sweetgum, ash, and oaks), Marianna lowlands (longleaf pine and mesic hammocks), gulf coastal lowlands (pine, palmetto, blackgum, sweetbay, shrubs and flowers), coastal plains (oak, pine, and shrub species), and salt marshes (cordgrass, needle rush, sawgrass and cattails).

The important Tupelo honey industry is dependent on the unique Tupelo associations along the river. There are 116 noteworthy species of plants in the immediate vicinity of the Apalachicola River of which 17 are endangered, 28 threatened, and 30 are rare. Nine species are narrowly endemic (restricted to a given locality) within the Apalachicola River watershed while 27 species are endemic to the general Apalachicola area. There has been a relatively long and continuous use of the area for timber removal although, so far, this has not had a major impact on the natural vegetation. However, more intensive lumbering in the future could eventually have deleterious effects. Notable rare species in the Apalachicola Valley include Torreya (*Torreya taxifolia*) and the yew (*Taxus floridana*). The Apalachicola drainage system thus represents a speciose and unique botanical area which has remained in a relatively natural state for a considerable period. This has contributed to the high number of rare and endangered species still present in this region.

ANIMALS

There is a rich fauna of terrestrial vertebrates in the Apalachicola Valley with amphibians, reptiles, breeding birds, and mammals totaling 250 species. The richness of this biota depends on the diversity of the physical environment, with various types of unique habitats such as steepheads, ravines, the Apalachicola lowlands, and cave systems. These account for a great number of species unique to the system, endemic, rare, endangered, threatened, or of special concern. In this regard, the Apalachicola River Basin is as biologically distinctive as the Florida Everglades, but is less well known.

The highest species density of amphibians and reptiles in North America (north of Mexico) occurs in the upper Apalachicola River Basin. Rare species include various salamanders and the mole snake. Bird life of the Apalachicola Valley is abundant and diverse with bottomland hardwoods having the greatest density. The floodplain forest is one of the most important bird habitats in the southeast. Two species, (the ivory-billed woodpecker and Bachman's warbler), close to extinction, were last sighted (and might still be living) in the vast floodplain forests of the Apalachicola Valley. Other rare and endangered species include the southern bald eagle, osprey, peregrine falcon, and American Kestrel. Important mammals include the white-tailed deer, grey squirrel, and others including rare forms such as the round-tailed muskrat and the black bear. Thus, the Apalachicola drainage system contains numerous, isolated forms of organisms that are increasingly threatened due to habitat destruction along major rivers of the United States. The strategic position of the Apalachicola Basin, receiving floral and faunal elements from four major areas (the north, the Atlantic coastal plain, the Gulf coastal plain, and peninsular Florida), accounts for the high numbers of species and the uniqueness of the terrestrial associations. The Apalachicola system can therefore be viewed as the crossroads of physiographic versatility where various groups of species meet.

AQUATIC SYSTEMS

FRESHWATER

The Apalachicola River represents one of the last undammed, unpolluted systems of its kind in the United States. Of the drainages of the Apalachicolan or West Floridian molluscan province (from the Escambia River to the Suwannee River), the Apalachicola River contains the largest total number of species of freshwater gastropod and bivalve mollusks. This river also contains the most endemic species in the province and the greatest proportion of endemics to the total fauna. A number of these species are considered rare and endangered. As might be expected in a river of this size, no other such area in Florida has so many species of freshwater fishes. The physical location of the Apalachicola River is unique, with deep penetration of its headwaters into the Southern Appalachian Mountains. The broad north-south axis provides an accessible and convenient dispersal route for temperate aquatic and terrestrial plants and animals from the high elevations of the southeastern United States to the Gulf of Mexico.

Of the 116 species of fishes in the drainage, three are restricted to the Apalachicola River while a fourth originated in this system. In addition, a variety of bluegill sunfish (the "handpaint") is endemic to the Apalachicola River. Like most big rivers, the Apalachicola provides spawning sites and habitats for various andromous species (those breeding in fresh water but living in salt water) and catadromous forms (those living in fresh water and migrating to sea to breed). Prior to the construction of the Jim Woodruff Dam, anadromous fishes such as Atlantic sturgeon, Alabama shad, and striped bass penetrated considerable distances into the Flint and Chattahoochee Rivers of Georgia via the Apalachicola River. These, along with the skipjack herring and the Atlantic needlefish, are now restricted to the Apalachicola River which is the only river on the Florida Gulf coast to support a substantial striped bass fishery. The sports and commercial fisheries associated with some of these species have recently declined for as yet unknown reasons although habitat destruction along the river and the construction of the Woodruff Dam are widely believed to be associated with this phenomenon. Catadromous fishes inhabiting the Apalachicola River include the American eel, hogchoker, and mountain mullet. Marine species penetrating the river as far as the dam are caught commercially (channel catfish, white catfish, bullheads) while a highly profitable sports fishery is based on basses, sunfish, striped bass, white bass, catfishes, and sturgeon.

Thus, because of its unique physical characteristics and geographic position in a little developed portion of Florida, the Apalachicola River Valley presently houses a large number of racial and species level endemic plants, invertebrates, and vertebrates. Since few biologists have concentrated their research in this area, it is highly likely that there will be further discoveries to add to the already proven uniqueness of this system.

THE APALACHICOLA BAY SYSTEM

The shallow coastal estuary at the end of the Apalachicola River is a barrier island system physically dominated by the fluctuations of the River. Various studies have shown that the high level of productivity of the bay is associated with river functions. Reduced salinity, influx of dissolved nutrients such as nitrates and phosphates, and deposition of various forms of particulate organic matter (detritus) such as leaves, branches, and macrophytes from upland areas create a prolific estuarine environment nurturing extensive sports and commercial fisheries. Small (microscopic) plants called phytoplankton form an important part of the food webs of the bay system; such phytoplankton have a high level of productivity in this estuary and are dependent on the levels of nutrients. Nutrient enrichment experiments carried out over a period of years in the Apalachicola Bay System indicate that while temperature limits phytoplankton productivity during winter months, nutrients are limiting during the warmer (more productive) periods. Overall, phosphorous is the most critical limiting nutrient in this estuary, and a reduction in phosphate levels of the bay during summer months could reduce phytoplankton productivity and thus could affect the overall productivity of the Bay. Since the U.S. Army Corps of Engineers studies indicate a 70% reduction of phosphates behind Jim Woodruff Dam, this aspect of damming operations could reduce bay productivity.

Many of the bay species are detritivores, feeding directly or indirectly on various forms of particulate organic matter. Studies in the Apalachicola Bay System indicate that thousands of tons (wet weight) of such matter are brought into the bay by the river each year. During peak periods of river flow, macroparticulates in the form of wood and leaf matter are introduced in high levels from upland river and swamp areas. Dominant leaf types come from oak, maple, and sweetgum trees growing in the floodplain. These forms of organic detritus, originating from exchanges which occur during the flooding of the Apalachicola River, are considered as one source of energy for various food webs in the bay. Such forms of detritus have been associated with a number of estuarine species such as isopods, amphipods, and decapods; these organisms serve as food for larger species in the Bay. Any decrease in the amount of detritus reaching the Bay from the River could adversely affect the productivity of the Apalachicola Bay System. Thus, once again, forms of damming and diking which tend to reduce detritus flow along the River should be carefully evaluated before implementation.

The Apalachicola Bay System provides almost 90% of Florida's oysters. The oysters depend on the low salinity, nutrient-rich water, and phytoplankton productivity provided by the Apalachicola River. The Apalachicola estuary serves as a major nursery for penaeid shrimp, blue crabs, and various finfishes such as spot, croaker, redfish, seatrout, flounder, mullet, and sheepshead. A conservative estimate of 30 million blue crabs are known to use the Bay at certain times of the year during peak river flow; and these enormous numbers of animals are apparently related to the life history of crab populations along the Florida Gulf coast. Tagging experiments with blue crabs found in the Gulf of Mexico from Chokoloskee Bay (south Florida) to Apalachicola Bay indicate that while males do not usually make extensive or directed migrations from their home area, female blue crabs usually move to a site north of the "mating" or home estuary. In some cases, such movements are extensive (in excess of 300 mi) traversing as much as seven estuarine areas. Westward movement by female blue crabs past the Apalachicola Bay region appears to be much reduced indicating the Apalachicola as a major source area (spawning ground) for the blue crab fisheries along the Florida gulf coast. Concentrations of spawning (egg-bearing) blue crabs in other areas of the gulf do not approach the large numbers of ovigerous blue crabs found in the Apalachicola Bay region. This coincides with data concerning the timing of increased river flow, detritus influxes (young blue crabs are detritivores), and the high number of blue crabs in the Apalachicola estuary during or just after periods of migration and spawning. Since the effects of the Apalachicola River have been traced as far as 160 mi into the Gulf of Mexico, it is hypothesized that such migration and spawning patterns together with the flushing action of the Apalachicola River, could aid in the dissemination of the young crab larvae along the gulf coast of Florida. Thus, any adverse changes of river flow, detritus input, or water quality could disrupt the intricate pattern of the blue crab migration and life cycle thus having an impact on the number of market-sized blue crabs along the entire gulf coast fishery.

Based on the data, the as yet unpolluted Apalachicola Bay System is regionally important in terms of various key sports and commercial species. Such organisms are dependent on the natural cycles of the Apalachicola River which include movements of clean water, nutrients, and detritus into the estuary on a seasonal basis. The species associations in the bay system are timed with the seasonal patterns of the Apalachicola River so that various forms of upland development which would alter river flow or water quality could adversely affect the bay-associated industries.

MANAGEMENT AND RESOURCE PLANNING

Up to now, the Apalachicola River has not been subjected to a comprehensive management program. Navigation enhancement projects such as the construction of the Jim Woodruff Lock and Dam, the dredging and maintenance of a channel, spoil deposition, a desnagging program (the removal of 10,000 snags annually), and removal of rock substrate have been identified as causative factors in the general (recent) decline in recreationally and commercially important fishes such as channel catfish, sturgeon, and striped bass. These practices tend to eradicate snags and rock shoals which are considered the most productive habitats within the river channel during periods of low water. In addition, spoil deposition tends to cover other productive areas. Shoal removal results in the loss of mayfly and caddisfly nymphs while deep water species tolerant of soft substrates increase. Snagging tends to remove food and shelter needed for young fishes. As has been shown in other rivers, this can lead to a 51% increase in "catchable" sized fishes and a 25% decrease in the general fish populations. Continued reduction of habitat and range due to dams and impoundments, together with contamination from urban waste and river traffic resulting from such development, will contribute to further reduction of the river biota and the complete loss of sensitive species.

The Apalachicola floodplain rates some of the highest wildlife values in north Florida due to the richness of substrate, high moisture, microhabitat diversity, and the various forms of vegetation which serve as shelter, food sources, and nest site areas. The 200,000 acre Apalachicola floodplain represents the largest of its kind in Florida and supports the large numbers of species of amphibians, reptiles and birds, with bottomland hardwood forests and swamps especially important for the high density populations. The river serves as a highway for migratory birds. Game animals include wild turkey, white-tailed deer, and grey squirrel. Management practices for this fauna should include protection of river and floodplain forests and marshes with avoidance of such forestry practices as large scale clearcutting or the development of extensive hardwood plantations. Any economic evaluation of the area should include analysis of the value of wildlife enjoyment activities, hunting, fishing, tourism, and other recreational functions. In terms of wildlife values, the Apalachicola system is one of the most valuable areas in the southeast and must be saved.

Shellfish management in the Apalachicola Bay System presents a set of different though related problems. Industrial and municipal wastes represent serious threat to continued oyster harvesting; however, there has been no significant increase in levels of coliform bacteria in Apalachicola oysters since the 1940's showing that, as yet, the Apalachicola drainage is still relatively unpolluted. The creation of the Jim Woodruff Dam did not reduce the coliform counts in the bay, and thus it cannot be assumed that it acts as a trap for upriver pollutants. A dependable supply of fresh, unpolluted river water is essential to the oyster industry in Franklin County. Stabilization of the river flow will limit the bay productivity to a narrow band of reefs. Dams placed along the river could cause changes in the amount of river flow due to increased evaporation and the filling of holding arms (especially during periods of low flow). Contrary to published information, the completion of the Jim Woodruff Dam did not result in increased oyster production due to stabilization of river flow; rather, the apparent increase in oysters taken was general throughout the state, and was probably due to the abolition of the severence tax previously contributing to conservative estimates of oyster production. The past and present methods of oyster management are well developed and there is ample room for increased utilization of the Apalachicola oyster reefs through such practices. The potential for further exploitation of this resource is broad-based since approximately 110,000 acres (95% of Apalachicola Bay) can support sanitary shellfish production at various times of the year. This is a higher percentage than any other Florida estuary. The fate of this renewable resource depends on the continued maintenance of the natural flow and water quality of the Apalachicola River.

As part of a general management approach to the Apalachicola Drainage System, 30,000 acres of the lower Apalachicola floodplain were purchased under the Environmentally Endangered Lands Program of the state of Florida. This purchase, one of only ten authorized to date, was based on biological data produced in conjunction with the Florida Sea Grant Program, and was carried out in accordance with the general and specific criteria as set forth under the Land Conservation Act of 1972. This was an attempt to protect portions of the river and floodplain producing nutrients and detritus essential to the functions of the river and bay system. This purchase included river bottom hardwoods, undisturbed swamp forests, and fresh and saltwater marshes which can now be managed by the state agencies. While it is still uncertain whether this purchase will eventually support all the necessary requirements of the bay system, this action is considered as a progressive first step in the management of the Apalachicola Valley. This purchase, by itself, will not assure the integrity of the system, but it represents a basic commitment of the state of Florida for the protection of this aquatic system.

PROBLEMS ASSOCIATED WITH RIVER DEVELOPMENT

According to a draft environmental statement by the Mobile District Corps of Engineers (1975), the following real and potential adverse effects were noted in the operation of the dam:

1. Aquatic weed problem.
2. Water quality degradation due to use of herbicides on aquatic weeds.
3. Increased mosquito production with use of malathion for control.
4. Continued sedimentation and dredging.
5. Disposal of dredged material on river banks.
6. Snagging operations.
7. Decrease of 16% of nitrogen and 70% of phosphate behind the dam.

According to a draft environmental statement by the Mobile District Corps of Engineers (1976), the following real and potential impacts due to operation and maintenance of the Apalachicola, Chattahoochee, and Flint Rivers were noted:

1. Dredging and open water or unconfined soil disposal.
2. Alteration of reaeration rate in the river due to dredging, diking, etc.
3. Increased water pollution due to increased spills (oil and chemical) and waste-load from industry.
4. The dams block migration of striped bass, sturgeon, suckers, eels, shad, hog chokers, and other migratory fishes.
5. Reduced bank overflow due to flood control (reduced detritus in river and bay; altered life cycles of water shed species).
6. Dredging causes non-selective destruction of benthic organisms.
7. Snagging reduces cover, food, and habitat

for fishes and sessile organisms while reducing aesthetic quality of river.

8. Mosquito control with malathion.
9. Spoil disposal on banks destroys vegetation and wildlife habitat.
10. Generally deterimental effects of project operation and maintenance on rare and endangered species with secondary, long-term impacts on such species due to increased urbanization, industrial development, and increased barge traffic.

There is evidence that deposition of fill has an adverse impact on various forms of terrestrial vegetation. Three or more inches of silt or sand are sufficient to smother tree roots, with coarser textured soils more detrimental than clays. Factors in mortality include species of tree, depth and texture of fill, and ability of roots to grow in oxygenated strata of the fill. Vitality of nearly all affected trees is reduced even when inundated by shallow fill.

A comparison was made of the (breeding) riverine bird fauna before and after the completion of the Jim Woodruff Dam. This showed that some of the riparian species, abundant before the dam, were no longer present after its construction. Thus, dam construction along the river could cause significant changes in the bird fauna due to altered river habitats.

ECONOMIC AND LEGAL ASPECTS

An economic study was performed concerning the cost-benefit analyses of proposed Apalachicola River development including the construction of dams for navigation purposes. Although the proposal has been reduced from four dams to only one (the Sutton Lake proposal), the benefits thought to accure to a system of dams were ascribed almost entirely to the single lock and dam. The Corps has consistently overestimated the economic benefit of the Apalachicola-Chattahoochee-Flint system, in addition to being overly optimistic about the extent of improvement of this system. The rapid current together with extremes of high and low water of the Apalachicola River cannot be overcome to make this an effective navigation system. A much large system of reservoirs would be needed to fulfill the promised results. The river is very narrow in places, and a 100 ft channel would not be adequate for barges 35 - 50 ft wide. Only direct benefits (rather than direct and indirect benefits) were considered in the Corps' economic analysis, and no negative effects of river development were brought into the estimates. Alternatives to river "improvement" such as rail and track transportation were not adequately reviewed and evaluated. Allowances were not made for changes in environmental quality, the value of recreation experiences, and the commercial fishing opportunities (present and future) along the entire system. This includes evaluation of the effects of pollution, reduced nutrients and detritus flowing into the bay, and other environmental quality changes. The geographic and occupational distribution of benefits was not considered although most of these would occur in Georgia and Alabama while the costs or losses would be borne largely by Florida. The substantial future benefits projected by the Corps are overly optimistic, especially when it is noted that the Woodruff Dam did not stimulate increased traffic for many years after its construction. Compared to other waterways, traffic along the Apalachicola is still light. In addition, the interest rates used were a little too low, and there is good reason to believe that there will be cost overruns should the project be started. Although the Corps could spend well over ½ billion dollars for such a system, (with considerable, additional maintenance costs), it is highly likely that even after such an effort, the river will still contain substantial imperfections from the standpoint of river transportation. These defects are sufficient to require a complete reexamination of the entire issue. This should include a full-scale regional study of the economic possibilities and regional potential for industrial development. Since it is difficult to place an exact dollar value on the environment, other factors, such as the long-term benefits of a natural system, should be considered.

Energy flow analysis suggests that the six county region in the Apalachicola Valley can support further growth; however, the proposed dam, even in a "best case" situation, would result in a net loss of about 0.8×10^{10} kilocalories/year with "worst case" calculations showing a net loss of 25 times as great. Further analysis would be necessary for justification of this project since the energy based calculations and economic conclusions tend to coincide.

From a legal point of view, various alternatives are available for a minimization of adverse impact on the Apalachicola System due to damming and industrialization. This would include the Environmental Policy Act of 1969, the Protection of Wildlife Act, and the Wild and Scenic Rivers Act.

Historically, the Apalachicola Valley has remained largely intact from an environmental point of view. However, current attempts to use the Apalachicola River as an industrial corridor would cause significant changes in the natural functions of the system. The environmental and economic facts presented in this compendium clearly demonstrate that the proposed damming and current channelization practices are not necessary and should be abandoned unless a far more convincing case can be made for such operations. This position is strengthened by an almost total lack of objective data on the environmental impact of the channel projects and the economic costs and benefits involved. The argument that this involves only one dam is an oversimplification of the ultimate goals of the channelization program, and its construction could set a damaging precedent for the future. This issue should be broadened into an objective, multidisiplinary effort to determine an overall management program for the entire drainage system whereby positive steps would be taken to encourage progressive forms of land use and development compatible with the enormous natural resources of the area. For this purpose, an integrated resource inventory and evaluation, together with appropriate scientific studies, should be carried out to provide the necessary base of information for a management program. The Apalachicola Valley is a priceless national resource which demands such action. This is especially true since there is still ample time for comprehensive planning, and an entire way of life for a number of people is at stake. This compendium of information amply qualifies this region as a potential model for planning and management on a national scale.