ASSESSMENT OF FISHERIES HABITAT: CHARLOTTE HARBOR AND LAKE WORTH, FLORIDA

FINAL REPORT FOR CONTRACT PERIOD
18 NOVEMBER 1981 THROUGH 30 NOVEMBER 1983

Barbara A. Harris, Kenneth D. Haddad, Karen A. Steidinger, and James A. Huff

Florida Department of Natural Resources
Bureau of Marine Research
Marine Research Laboratories
St. Petersburg, Florida

November, 1983

ASSESSMENT OF FISHERIES HABITAT:
CHARLOTTE HARBOR AND LAKE WORTH, FLORIDA

Final Report

for contract period 18 November 1981 through 30 November 1983

Barbara A. Harris, Kenneth D. Haddad, Karen A. Steidinger,

and James A. Huff

Florida Department of Natural Resources

Bureau of Marine Research

Marine Research Laboratories

St. Petersburg, FL

November 1983

This project was supported by a grant from the Florida Office of Coastal Management, Department of Environmental Regulation, with funds provided by the United States Office of Ocean and Coastal Resource Management, NOAA, under the Coastal Zone Management Act of 1972, as amended.

CONTENTS

CONTENTS (Continued)

ACKNOWLEDGEMENTS

We express much gratitude to many people who provided assistance during this project, particularly to those who helped formulate ideas on a project to assess fisheries habitat loss during discussions as far back as 1980. We thank NASA Earth Resources Laboratory personnel for initial training in ELAS and for answering the many questions concerning the development of the Marine Resources Geobased Information System. We thank Fred Calder and Dave Worley (DER) for providing valuable advice and support in developing the successful grant application. Jim Stoutamire (DER) did much to facilitate the completion of this report by providing expeditious contract guidance. Thanks also to Roy Williams and Mark Leiby for their help with fisheries data; to Ann Marshall of Lee County's Marine Extension Office, Roger Clark and William Sheftal of DNR Bureau of Land Management, Steve Travis of DNR Bureau of Parks and Recreation, and Stewart Bradow of DER for their help in field sampling; to Mike Sprague for the use of SEAS' boats; to Robin Lewis of Mangrove Systems, Inc. for use of his data in our presentations; to Mark Moffler for his excellent drawings of seagrasses; to David Crewz for his drafting and drawings of mangroves; to Warren Clary of DOT for providing computer training; to Mary Krost and library staff for providing much assistance; to Winnie Sue Moravec and Jeff Brown for folding maps and binding the report, to DNR's Division of Recreation and Parks for the use of their white printer; to Alonzo Felder for drafting numerous graphs; and, finally, to Margie Myers for typing this report.

I. INTRODUCTION AND RATIONALE

Estuaries are coastal embayments or lagoons where saltwater and freshwater interact. They are among the most productive ecosystems on Earth because of this interaction and their relative shallowness compared to open seas. Estuaries provide food and shelter for a multitude of living resources such as fishes and crustaceans. Their fringing vegetation and wetlands can absorb flood waters, recharge ground water, assimilate wastes and excess nutrients and, therefore, they maintain water quality, recycle nutrients, and control erosion. Estuaries also have a direct aesthetic, recreational, and commercial value, exemplified by the location of urban centers and recreational and commercial enterprises. Protection and management of Florida estuaries to retain their natural functions and benefits to man is tied to efficient growth management.

Nearly 70% of Florida's recreational and commercial fisheries species are dependent on estuaries during at least part of their life span, usually in the juvenile stages prior to reaching harvest size. In Nakamura et al.'s (1980) listing of recreational finfish stages found in estuaries, he stated "In each estuarine area, the number of species was lowest for eggs, second lowest for larvae, third lowest for adults, and highest for juveniles....Thus, additional credence is provided to the importance of estuaries as nursery grounds for juvenile recreational fishes...." Shrimp and many species of juvenile fishes move out of the estuary to offshore areas to spawn or spend their adult life. They reenter the estuary as eggs, larvae or juveniles. Some species, such as spotted seatrout, spend their entire life within the estuary while others move out as juveniles and come back to spawn near barrier islands or at the lower reaches of the estuary.

Estuarine environments provide necessary food and protection from predators for these growing fishes. This dependency is one of inference based on known repeated frequencies and abundance of juveniles in bays and lagoons. Various experiments and field observations have also illustrated that shallow bay bottoms and intertidal vegetated areas provide cover and food items to a variety of animals. These estuarine and nearshore areas lend support and continuity to animal populations seeking refuge, but only if the estuary, as a system of structural components and interactive processes, maintains a healthy, dynamic state of diversity and productivity.

Florida has extensive estuarine and marine coastal areas with emergent vegetation such as marsh grasses and mangroves and submergent vegetation such as seagrasses. About 430,000 acres of mangroves and an estimated 502,000 acres of submerged vegetation exist in Florida. Sixty percent of saltwater wetlands in the United States occur in Gulf Coast states and the Gulf of Mexico supports two of the largest U.S. commercial fisheries: menhaden and shrimp. Amounts of emergent and submergent vegetation and freshwater flow have been associated statistically with shrimp and fish yield in some areas.

The estuary is a multi-dimensional and multi-structured habitat for living resources such as fishes and crustaceans. Habitat represents where an organism lives in time/space and includes bottom type (e.g. vegetated), water depth, water quality, salinity, and other parameters than can change daily, seasonally or geographically. Habitat has vertical and horizontal variability. A specific species' habitat typically changes with age whereby the animal moves from one area to another. The species is adapted to such change; it is part of its life history. If the habitat is removed or altered in a substantial way, populations of that species may not survive because of stress, lack of food, or increased competition or predation. Many people interpret estuarine habitat by structural component, e.g. mangrove stands, salt marshes, seagrass beds, oyster reefs, mud flats, sand bars, or even man-made structures such as jetties. These components represent shoreline and bottom type. Although certain species or assemblages may be more prevalent in these areas, "habitat" per se is temporally and spatially multi-dimensional. It varies from one species to another and is defined by a multitude of parameters. It is more than a person can perceive visually from any one vantage point.

A variety of potential variables exist to determine relationships between species and habitat. For example, the U.S. Fish and Wildlife Service (USFWS) and others have identified availability of food items at different ages, spawning season and area, age at spawning, transport of eggs and larvae, larval recruitment and its area and timing, salinity and temperature tolerances, substrate type, presence and abundance of predators, water quality, available cover, and other habitat and species variables. Resource partitioning among different species as juveniles or adults can involve different temporal and spatial distributions by age and feeding habits. Differences in feeding apparatuses, digestive systems, and feeding habits can lessen direct competition for available resources and allow species to co-exist. To develop Habitat Suitability Indices (models), USFWS has used ranges and means of salinity, turbidity, depth, dissolved oxygen, and temperature, water color, bottom type, sediments, and diversity or amount of cover. The index is thought to have a relationship to "habitat" carrying capacity, but values only suggest whether one area is more or less suitable than another.

Since the 1950's, Florida's population has soared. With people came development, agriculture, urbanization, and industrialization. Such development has destroyed or altered coastal habitats and wetlands. These events have led to loss of productive vegetation and cover, loss of open bay areas, alteration of freshwater flow patterns, pollution of rivers and estuaries, and other perturbations.

The direct loss of estuarine shoreline and bottom habitat components such as saltmarshes, mangroves, and seagrasses has been dramatic, particularly adjacent to urban areas. Such direct loss has resulted from dredging and filling, channelization, ditching, and mosquito impoundments. For example, Lewis (1979) documented a 44% loss of mangroves on the southern shore of Hillsborough County and estimated an 81% loss of seagrasses in Tampa Bay. Frayer et al. (1982) estimated that over one-third of the United States losses in coastal wetlands due to urbanization occurred in Florida. According to other projections, 215,000 additional acres will be lost due to development during 1980-2000. Direct loss of habitat components leads to loss of nursery habitat, increased suspended loads, increased erosion, and decreased water quality. One of the most dramatic examples of impact involves mosquito impoundments where salt tolerant vegetation dies, poor water quality causes physiological stress, and diverse fish assemblages are reduced to only a few tolerant species lower in the food chain (Harrington and Harrington, 1982). When one impoundment was opened, it became revegetated and fish diversity increased (Gilmore et al. 1982). This example points out that although habitat components may be lost through removal or die offs, the habitat itself merely changes; it has gone from a healthy environment with biotic diversity and richness to one that supports fewer, less desirable species. It then is the alteration of habitat that impedes the function and efficiency of the system through shifts in species composition and loss of certain populations.

Alteration of freshwater flow to coastal areas has severely impacted estuarine systems. Alterations have occurred in timing, amount, quality, and direction of freshwater discharge. Such alterations through water retention areas, canalization, irrigation, and programmed releases can increase or decrease estuarine salinity regimes and stress populations, affect available dissolved oxygen, and affect the delivery and type of nutrients and food particles. Modification of estuarine circulation patterns through altered freshwater flow, channelization, dredge and fill, bridges, and spoil banks can create poor flushing and exchange of water in shallow areas and lead to a condition of excess nutrients and monospecific algal blooms (eutrophication).

Other sources that can alter the quality and quantity of estuarine habitats are point and nonpoint source pollutants, e.g. sewage, land runoff, industrial wastes, pesticide spraying, mining, toxic chemical spills, etc. Often these impacts are accumulative. Pollutants in the water column may be barely detectable, yet they can be magnified in the sediments through settling, adsorbtion, flocculation, and high residency. They can, therefore, impact the system because the bottom and water are coupled through biological, physical and chemical interactions. Even though estuaries are dynamic systems adjusted to wide fluctuations, major acute or chronic stresses or impacts will alter the systems and the life it supports.

Amounts of emergent and submergent vegetation and freshwater flow have been associated statistically with fisheries yield in some areas, yet most perceived fisheries declines are based on user group observations and/or reduced commercial landings, not on documented catch-per-unit effort decreases. Sports fishermen and commercial fishermen have both complained of reduced resource availability and have attributed it to a variety of causes, but mainly to overfishing and/or habitat alteration. However, without adequate fisheries statistics to determine total fishing mortality and population dynamics, catch-per-unit effort and total population abundance cannot be determined for such multispecies fisheries (>100 species of interest in Florida marine waters). Correlation of fisheries decline with habitat component loss is also difficult because of problems with available fisheries statistics and lack of current quantification for carrying capacity of different habitat components or ecosystems. Carrying capacity itself is difficult to define and characterize, much less quantify, because it involves both benthic and pelagic environments, their structure, quantity and quality. It represents how much biomass of a specific species or multiple species can be supported in a specified time-space relationship. Carrying capacity can differ between saltmarshes, and vegetated bay bottoms; it could vary between two seagrass beds in two different parts of the same estuary.

Florida is currently the second fastest growing state in the nation with 17.4 million residents projected for the year 2000. Over 60% of the 1000 new residents per day will locate along the coast; today, over 78% of

Florida's residents already live in coastal counties. Decisions and implementation of actions in the next few years will determine how Florida's estuaries survive and in turn whether they will support living resources as we know them now, and whether they will retain any aesthetic and recreational appeal and value.

This is a critical period in Florida's history, one requiring farsighted management and legislation. First we must understand what an estuary is, how it functions, and why it is necessary to maintain it as a system. Only if we recognize and accept the values of individual estuaries can we manage them properly.

The Department of Natural Resources, as well as many others, recognizes that habitat alteration is a significant factor affecting fisheries yield. Therefore, the Department has made a long term commitment through various research projects and legislative requests to pursue documentation of such alterations, their effects on resource availability and yield, the development of a more comprehensive fisheries statistics program, restoration and enhancement techniques, and a program to purchase sensitive lands. Concurrently with development of mitigation, restoration and creation of estuarine habitat and the establishment of preserves and sanctuaries, we need to: 1) conduct long term multidisciplinary system studies, 2) conduct trend analyses by inventorying estuarine resources and changes therein over time, and 3) inform and educate the public on the function and importance of estuaries. This Coastal Management project entitled "Assessment of Fishery Habitat Loss, Use of a Coastal Geographic Digital Data Base and Establishment of a Geobased Information System" addressed trend analyses over time to correlate changes in habitat components, such as mangroves and seagrasses, with changes in fisheries yield using aerial photography and commercial landings by individual system, i.e. the Charlotte Harbor System and the Lake Worth System. The continuance of the program in 1983-85 addresses trend analyses for additional systems and public education.

II. ESTUARIES

II A. DESCRIPTION

Estuaries and lagoons constitute 80-90% of the Atlantic and Gulf coasts of the continental United States (Lauff 1967). Pritchard (1967) provided the most widely accepted defiinition of an estuary: "a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." This fresh water is introduced as river flow, stream flow, or overland sheet flow, with resulting estuarine waters known as "brackish." Lankford (1977) described a coastal lagoon as "a coastal zone depression below MHHW (mean high high waves) having permanent or ephemeral communications with the sea, but protected from the sea by some type of barrier."

Estuaries are characterized by constant and variable changes. Tides daily influence water depth, salinity regimes, and the presence or absence of water in very shallow zones. Heavy rainfall introduces for short time periods large amounts of fresh water. Dry spells cause estuarine waters to become more saline. Wind mixes the water. Estuaries are capable of withstanding these wide ranges in environmental parameters - conditions that normally would collapse other ecosystems. These variabilities are the driving forces of estuaries. Without them, the system would not be an estuary.

Day and Yanez-Arancibia (1982) describe the physical traits of estuaries:

1. They are semi-enclosed yet connected to the sea. This partial envelopment provides a buffer from oceanic effects.
2. They receive input from a freshwater source. The amount of freshwater varies from very low during periods of extreme drought to high after storms or seasons of heavy rainfall. Dissolved and suspended materials and nutrients also enter the system via freshwater inflow.
3. Tides influence the circulation pattern of estuaries and are important in physical, chemical, and biological interactions Tidal action allows the mixing of fresh and salt water and plays a major role in exporting and importing material from and into the estuary.
4. Estuaries are shallow. Surface turbulence, such as wind and waves, affects the bottom as well as the surface.
5. Estuaries have complex water circulation patterns, influenced by winds, tides, river currents, and the geomorphology of the basin.
6. Relatively rapid geomorphological changes occur in estuaries because powerful physical energies resuspend and move sediments. This characteristic is exemplified in Florida by the change in shape and location of some barrier islands and the natural construction of new islands or channels during severe storms.

Whittaker (1975) found that estuaries, in comparison to several other ecosystem types, are one of the most highly productive systems on Earth (Table 1). Estuaries are characterized by high rates of primary and secondary production because of their rich nutrient supplies, efficient

Table 1. NET PRIMARY PRODUCTION OF MAJOR ECOSYSTEMS (After Whittaker 1975)

Ecosystem	Net Primary Production ($g/m^2/yr$ dry weight)	
	Normal range	Mean
Lake and stream	100-1500	500
Swamp and marsh	800-4000	2000
Tropical forest	1000-5000	2000
Boreal forest	400-2000	800
Woodland and shrubland	200-1200	600
Savanna	200-2000	700
Temperate grassland	150-1500	500
Tundra and alpine	10-400	140
Desert scrub	10-250	70
Extreme desert, rock and ice	0-10	3
Agricultural land	100-4000	650
Open ocean	2-400	125
Continental shelf	200-600	350
Attached algae and estuaries	500-4000	2000

conservation, and the occurrence of several different types of primary producers (Day and Yanez-Arancibia 1982). Estuaries are also ecologically complex, not because of a high species diversity (species diversity is actually quite low in estuaries), but because of the variety of environmental factors, habitat types, and highly complex food webs.

Although estuaries are dynamic, transient, and variable, they are remarkably stable as an ecosystem. Margalef (1968) explains that ecological stability evolves in two different ways: (1) a system evolves under constant conditions and develops a steady state and thus stability, or (2) a system evolves under variable conditions and develops mechanisms to adapt to the variability. Estuaries undoubtedly developed via the second method. Estuarine biota have developed physiological and behavorial patterns to adapt to their fluctuating environment (Day and Yanez-Arancibia 1982). Organisms that successfully dwell within the dynamic estuarine system must be tolerant of change (Beal 1980).

Probably the single most renowned function of estuaries is their role as nursery grounds for growing fish, shrimp, and shellfish. Because of their high productivity, large food supply, diversity of cover, and shallow, calm waters, estuaries serve as prime nurseries for many species. This aspect will be discussed in detail in the next section.

High productivity of coastal offshore waters may result from the existence of estuaries. Odum (1980) explained that most fertile coastal zones receive nutrients either from deep water upwelling or from shallow water outwelling with areas such as reefs, banks, seagrass beds, algal mats, and salt marshes being the prime contributors. In Florida, mangroves would also contribute nutrients. Odum (1980) stated that outwelling is likely a periodic or seasonal occurrence, associated with high spring tides and storms. Turner et al. (1979) found that offshore productivity and densities of zooplankton, fish eggs, and fish larvae were strongly coupled with the extent and productivities of local estuaries. They concluded that the influence of estuaries on continental shelf ecology was extensive.

II B. IMPORTANCE OF ESTUARIES AS NURSERY GROUNDS

According to life history studies, very few marine species of recreational and commercial value utilize the shallow coastal waters of estuaries as spawning areas. However, estuaries are used extensively as nursery grounds. Most finfishes and crustaceans migrate offshore to spawn. The eggs are usually planktonic, developing into larvae that depend on currents and tides to transport them toward shore. As post larvae, they enter the estuary, and spend their juvenile existance in close association with the estuarine system (Odum and Smith 1981). Some species grow within the estuary for several years while others remain there for life. Numerous authors such as Nakamura et al. (1980) and Odum and Smith (1981) have noted the importance of estuaries as nursery grounds.

Joseph (1973) described nursery grounds as areas that (1) are physiologically suitable in terms of chemical and physical features, (2) provide an abundant food supply, and (3) provide some degree of protection from predators. Chemical and physical parameters include water depth, temperature, salinity, turbidity, and tidal and wave action. Climatic features such as rainfall, cold spells, and wind coupled with tidal action may be the most influencing factors on depth, temperature, and salinity, irrespective of human influence. Because juveniles are more tolerant of wide ranges in environmental variabilities than their adult counterparts, changes in depth, temperature, and salinity serve as protective mechanisms for the juveniles by forcing out adults during periods of (for them) intolerable conditions. Seagrasses as well as mangrove roots and salt marsh stalks mitigate predation by providing hiding places, as well as baffles for waves and currents (Orth 1977). Beal (1980) summarized the nursery aspect by stating that because the estuary is dynamic, species that dwell there must be tolerant of change. This is certainly true for juvenile fish and shrimp.

Margalef (1963) suggested that unpredictable environments characterized by high abiotic stress maintain both a high resource standing crop and low utilization by endemic species. Miller and Dunn (1980) applied this concept to estuaries: an outside population whose early life stages are spent in estuaries to exploit the food source will profit by this strategy.

Miller and Dunn (1980) summarized the general features of feeding relationships of estuarine juvenile fish assemblages:

1. Flexibility of feeding habits in time/space
2. Omnivory
3. Sharing a common pool of resources among species
4. Exploitation of food chains at different levels by the same species
5. Ontogenetic changes in diet with rapid growth
6. Short food chains based on detritus/algal feeders.

The most important feeding characteristic is likely the first: the ability to switch prey items in accordance with food availability, commonly termed the generalist strategy. Miller and Dunn (1980) point out that prey items undergo rapid and unpredictable changes in distribution and abundance in response to abiotic stresses. For example, after a heavy rain, the sudden presence of freshwater due to increased river flow, terrestrial run-off, and the rain itself would probably produce a period of hyposaline turbid conditions. This situation might present the juvenile population with a new supply of food items. The generalist feeding strategy then gives juvenile species a selective advantage over species that have restricted diets.

II C. <u>ESTUARINE HABITAT COMPONENTS</u>

Florida estuaries are composed of six structural components or habitat types: mangroves, seagrass beds, salt marshes, intertidal mudflats, unvegetated subtidal bottoms, and oyster bars. Overlying all six is the water column. In the intertidal zone, salt marshes and mangroves occur high with mudflats and oyster bars found low. Seagrass beds grow in the shallow subtidal zone. Unvegetated subtidal bottom occurs at depths below the seagrass zone and within seagrass beds. The water column overlies all the habitats during high tides and covers only the subtidal areas during low tides. Sections II C1 through II C7 describe these seven areas in greater detail.

II C 1. MANGROVES

Mangroves in Florida extend from the Keys to approximately 30°N latitude on both coasts. Three species of mangroves are found in Florida (Figure 1):

Red mangroves (Rhizophora mangle) are easily identified by their prop roots. Reds generally grow nearest to the shoreline.

Black mangroves (Avicennia germinans) have characteristic small verticle root offshoots, called pneumatophores, attached to the underground roots and arising from the substrate. Blacks commonly grow higher in the intertidal zone than reds.

White mangroves (Laguncularia racemosa) have a diffuse below-ground root system with verticle, bulbous knee-like projections arising from the roots. Whites generally occur much higher than reds or blacks, out of the intertidal zone, in areas affected only by extreme tides.

Odum et al. (1982) describe four factors that determine mangrove distribution and extent of development:

1. Climate - since mangroves are a tropical species, they do not tolerate temperatures below freezing for any length of time.
2. Saltwater - most mangroves are able to grow without difficulty in pure freshwater habitats. However, they are faculative halophytes; salinity acts as a competitive excluder to other vascular plants.
3. Tidal fluctuation - tides serve as subsidies to mangrove systems (a) The constant alternation of standing water and then no water

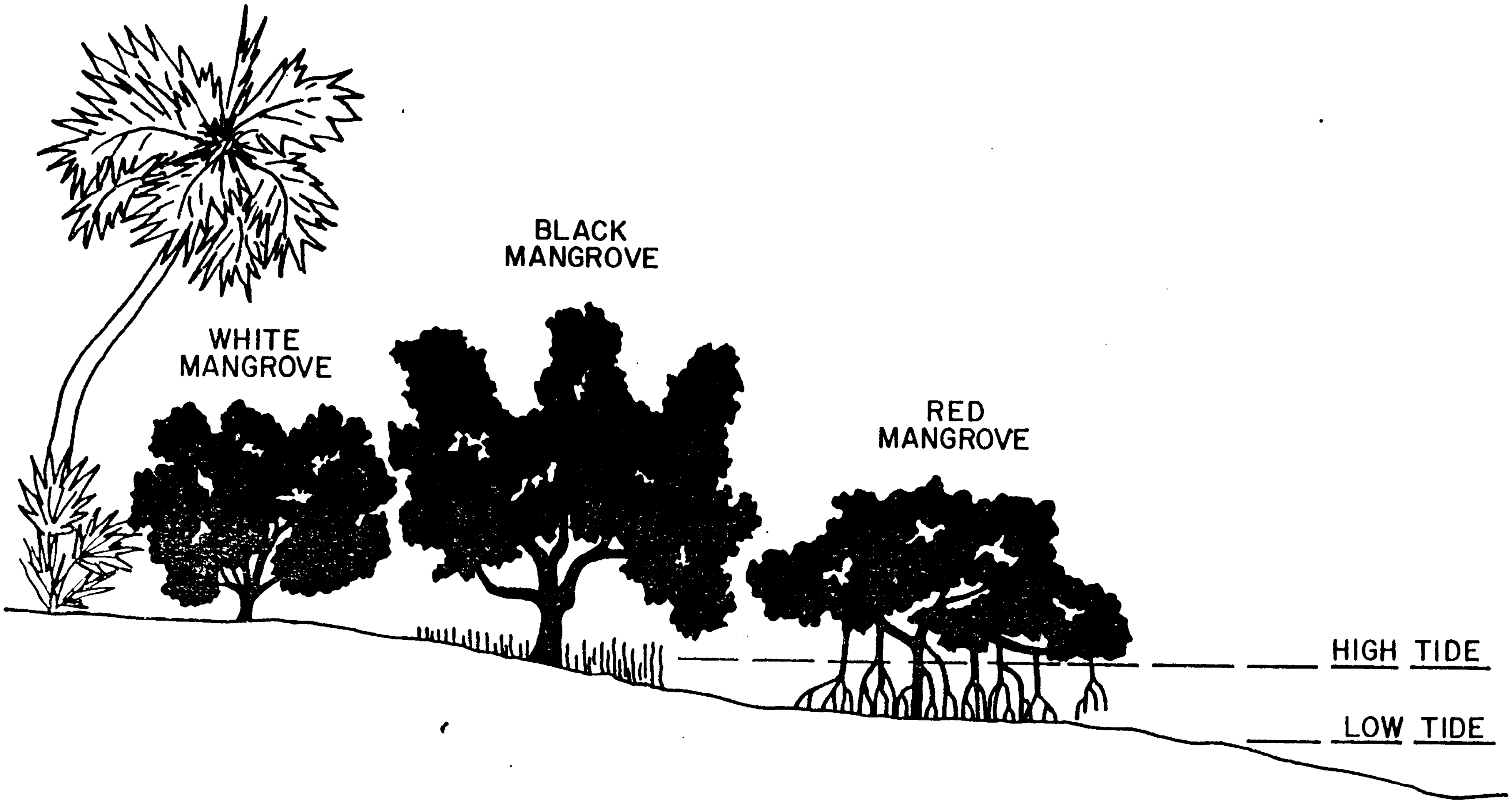


Figure 1. A stylized view of Florida mangroves.

and fluctuations in salinity reduces competition from other vascular plants. (b) In some areas, tides carry salt water high into the estuary against the outgoing flow of freshwater, allowing the establishment of mangroves well inland. Tides also transport nutrients into mangroves, and export organic carbon, reduced sulphur compounds, propagules (seeds), and detritus.

4. Substrate and wave energy - the most productive mangrove systems develop on substrates of anaerobic fine-grained muds composed of silt, clay, and a large percentage of organic matter, with very little wave energy.

Lugo and Snedeker (1974) described six major mangrove forest communities (Figure 2): the overwash mangrove forest, fringe mangrove forest, riverine mangrove forest, basin mangrove forest, hammock forest, and scrub or dwarf forest. Each type embodies its own characteristic variables, ranges, and differences such as soil type, soil depth, flushing rates, primary production, rate of litter decomposition, and nutrient recycling rates.

Mangroves are considered one of the Earth's most productive systems (Odum et al. 1982; see Table 2). Productivity of the three species vary (Odum et al. 1982); red mangrove has the highest net productivity, black has intermediate values, and white retains the lowest, assuming the plant inhabit the zones for which they are best adapted and that these areas ar devoid of strong limiting factors. Odum et al (1982) additionally noted that reds experience a decreasing gross productivity with increasing salinity while the productivity for blacks and whites increases to a certain extent with increasing salinity.

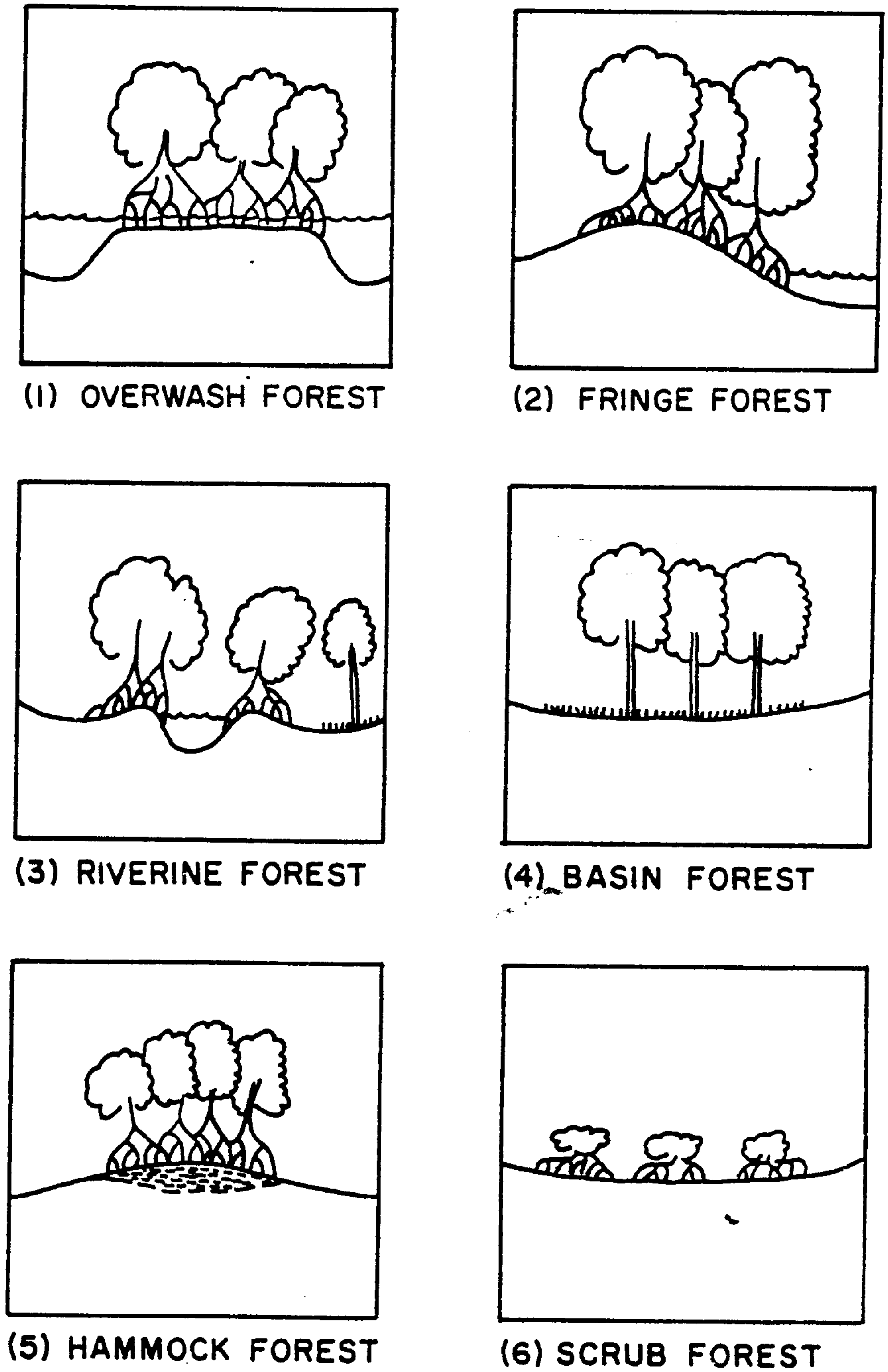


Figure 2. The six mangrove communities (redrawn from Odum et al. 1982, after Lugo and Snedaker 1974).

Table 2. NET PRIMARY PRODUCTION OF HABITAT COMPONENTS

Habitat	Average NPP ($gC/m^2/day$)	Range NPP ($gC/m^2/day$)	Source
Mangroves (all species)	5.3	1.0 - 12.6	Odum et al. 1982
Seagrasses (*Syringodium*, *Halodule*, and *Thalassia*)	1.0 - 4.0	0.5 - 16.0	Zieman 1982
Salt marsh	4.2	0.8 - 8.2	Durako et al. 1983
Mud flat	0.5	---	Pomeroy 1959
Water column (phytoplankton)	0.9	---	Thayer and Ustach 1981

The estuarine system can benefit by the presence of mangroves. The aerial root system, especially the red mangrove prop roots, provides a substrate for algae attachment and serves as a protected habitat for nursery-stage fish, crustaceans, and shellfish. These intricate root systems also play an important part in substrate stabilization; their presence retards erosion. Litter fall also can be important, forming the basis of a mangrove-detritus food web, providing a supply of food to many organisms.

Mangroves cleanse inflowing water and aid in nutrient cycling. Nitrogen, phosphorus, heavy metals, and more are removed from the water by the combined activities of prop roots, prop root algae, associated sediments, and the multitude of invertebrates and microorganisms present in the system (Odum et al. 1982). Nutrient import, originating mostly from upland and terrestrial sources, is either reduced by faunal species and exported, or it becomes mangrove or algal biomass. Low nutrient import results in low storage, low biomass, low productivity and small export, whereas the outcome of high nutrient import is high storage, high biomass, high productivity, and moderate export (Odum et al. 1982).

II C 2. SEAGRASS BEDS

Seven species of seagrasses inhabit Florida waters (Figure 3). Turtle grass (*Thalassia testudinum*) is the most abundant of the seagrasses with ribbon-like leaves from 2 to 35 cm in length and 2 to 12 mm in width. The tips of the leaves are rounded. *Thalassia* is capable of forming extensive beds. Shoal grass (*Halodule wrightii*) is generally accepted as the most tolerant of all the seagrasses to temperature and salinity changes (cf. Zieman, 1982). Leaves are flat and are from 10 to 20 cm long and 3 mm wide. Leaf tips have 2 to 3 points. Shoal grass, too, is capable of forming extensive beds. Manatee grass (*Syringodium filiforme*) is usually found amongst other species, or in small dense patches. Leaves are cylindrical from 1.0 to 1.5 mm in diameter; length is variable. Three species of *Halophila* are sparsely distributed (Zieman 1982). Leaves are ovate from 10 to 30 mm long. *Halophila engelmannii* has 4 to 8 leaves on the end of a stem 2 to 4 cm long. *Halophila decipens* and *H. johnsonii* have paired leaves arising from a single rhizome node. *Halophila decipens* differs from *H. johnsonii* in that the latter lacks root hairs, and veins emerge from the midrib at 45° angles rather than 60° angles of the former. Widgeon grass (*Ruppia maritima*) occurs in both fresh and salt water environments. In saline systems, *Ruppia* is found primarily in areas of reduced salinity (Zieman 1982), but it also inhabits and reproduces

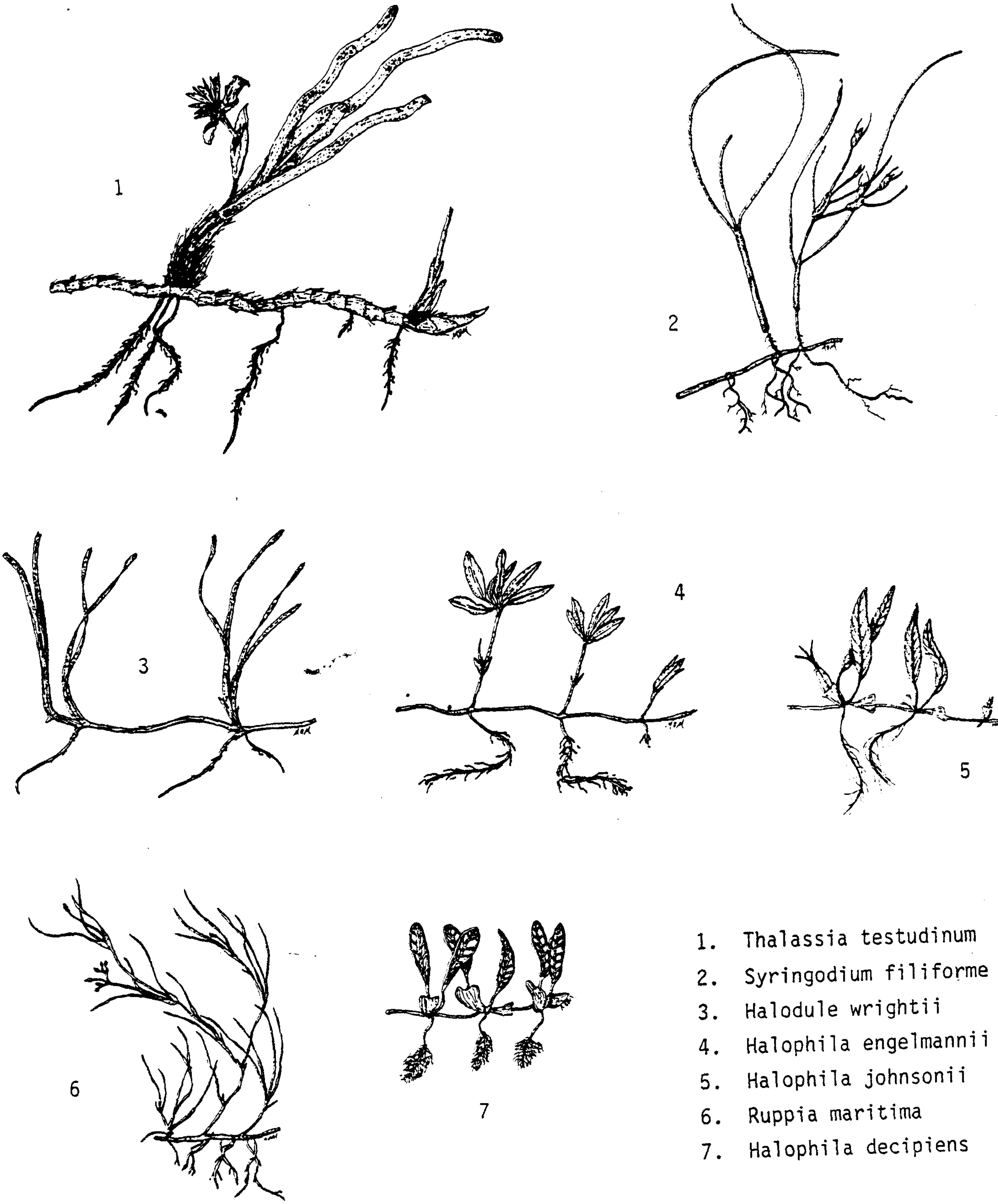


Figure 3. Seagrasses of Florida.

sexually in sites with salinities as high as $38^{o}/oo$ (M. Moffler, personal communication).

Seagrasses perform many significant functions in estuarine systems. (1) Since leaf growth is generally >5mm per day, and the typical lifetime of a single Thalassia leaf is 30-60 days, seagrasses provide a tremendous food source to herbivores, such as sea turtles and manatees, and detritivores (Zieman 1982). In addition, exportation of living and detrital material provides energy to areas quite remote from the source grass beds (Zieman 1981). (2) In addition to their abundant food supply, seagrass beds provide shelter, i.e. places to hide for young stages of numerous fish, crustaceans and shellfish. The presence of seagrasses is essential to the occurrence and growth of many species of marine life (Zieman 1982). Seagrasses also provide a surface for attachment for sessile epiphytes. (3) Seagrass systems stabilize sediments; the leaves provide a baffle for waves and currents and roots and rhizomes bind the sediments, thereby retarding erosion (Zieman 1982). (4) Seagrasses aid in the cycling of nitrogen by transporting it from the sediments into their leaf structure, then into the environment via herbivory or as detritus (Zieman 1982).

In viewing seagrass systems with a holistic approach, they may be classified as ecosystems of high diversity. Seagrass meadows provide a habitat for numerous organisms. Kikuchi and Peres (1977) described the biota that inhabit seagrass beds:

1. Species living on or near the leaves, including epiphytes, micro and meiofauna, sessile fauna, mobile creeping and walking fauna, and swimming epifauna.
2. Species attached to stems and rhizomes.

3. Mobile species living under the leaf canopy (permanent residents, seasonal residents, visitors, and occasional migrants).

4. Infaunal species (found in unvegetated parts as well).

Added to this list are nektonic species living within and above the blades. Brooke (1978) found 38 to 80 species were represented within five Thalassia meadows (blade density >3,000 blades/m^2) in south Florida; abundance varied from 292 to 10,644 individuals/m^2.

Seagrass blades create a surface on which epiphytes can attach. After a leaf emerges, it remains "clean" for a period of time (Zieman 1982). As they grow, they become heavily colonized, more so at the tips than at the bases. Harlin (1980) compiled a species list of the microalgae, macroalgae, and animals that have utilized seagrasses for attachment. Because the majority of seagrass consumers (turtles and manatees excluded) do not possess a gut flora to digest structural cellulose, their nutrition is derived from seagrass cell contents and attached epiphytes. Epiphytized blades thus provide a more valuable food source to most consumers than clean blades.

Seagrasses probably are more important to the food web as detritus than as a source for direct herbivory. Physical breakdown of detritus occurs through the activities of crabs, shrimp, and amphipods. During decomposition, particles become smaller and provide a larger surface area for colonizers such as bacteria, fungi, and other microorganisms. Detritus is an important food source for deposit feeders, providing polychaetes, amphipods, isopods, ophiuroids, some gastropods, and mullet with much of their nutrition (Zieman 1982). Detritivores assimilate plant compounds with <5% efficiency as opposed to 50-100% efficiency at assimilating associated microflora (Zieman 1982).

II C 3. SALT MARSHES

Salt marshes are herbaceous plant communities in northern Florida intertidal zones that are periodically tidally flooded by salt or brackish water. They predominate over mangroves (39% more acreage) as the most abundant plant community of Florida's intertidal zone (Coastal Coordinating Council 1973). They are replaced by mangroves as the dominate vegetation south of Cape Kennedy and Tarpon Springs (Odum et al. 1982); marshes in this southern region generally serve as a transitional zone between the mangroves and fresh water marshes (McNulty et al. 1972).

Smooth cordgrass (*Spartina alterniflora*) dominates Florida's east coast marsh vegetation (Durako et al. 1983). Along the southeast tip of Florida, black needle rush, (*Juncus roemarianus*) exists in large marsh areas in association with mangroves (Eleuterius 1976). *Juncus* also occurs in large stands from Tarpon Springs to Apalachicola Bay. The Florida panhandle has very little salt marsh.

Juncus produces plant biomass continuously whereas *Spartina* grows in the spring with a general dieback in the winter (Turner 1976). No two marshes are alike and variations in productivity (Table 2) reflect complex interactions between light energy, temperature, tidal subsidy, nutrient availability and other factors. Kruczynski et al. (1978) reported that net aerial primary production of *Juncus* was highest in the low marsh decreasing landward to about 30% of the low marsh value in the high marsh. They also found the same to be true for *Spartina*; production decreased landward to less than 20% in the high marsh of the original value in the low marsh.

Detrital material is the end result of 90% of the net production of salt marshes (de la Cruz 1973). The export of detritus has historically been believed to be the most important contribution of salt marshes to the estuarine system. Studies have provided evidence that energy was being exported because production values were consistently higher than the sum of the losses due to respiration, grazing, and the accumulation of organic sediments within the marsh (Durako et al. 1983). Studies that measure amounts of carbon or organic matter entering and departing salt marshes showed both a net export to the estuary and a net import. Other studies however, demonstrated that salt marshes may retain and utilize their own production (Durako et al. 1983).

Animal production is high in salt marsh systems. Subrahmanyam et al. (1976) found densities of marsh invertebrates to be 540 individuals/m^2 for a Juncus low marsh and 381 individuals/m^2 for the high marsh. Proximity of the marsh to tidal waters or frequency of tidal inundation may be the determining factor of organism density in salt marshes (Day et al. 1973). Day et al. (1973) also reported that animal diversity within the marsh is lower than values of adjacent open water areas, however, he found that animal biomass was higher. Zimmerman (in prep.) found shrimp densities of 11 shrimp/m^2 within a Spartina marsh as opposed to 1.5 shrimp/m^2 in non-vegetated sites.

Like seagrass and mangrove systems, salt marshes provide a concentration of high quality food for estuarine animals in addition to a conducive environment for early life stages. Park and Batie (1979) describe four additional functions for salt marshes: 1) tertiary sewage treatment, 2) fundamental part of nutrient cycles, 3) long-term accumulators of non-point source pollution, and 4) short term pollutant buffers.

Releasing primary treated sewage into marshes introduces large amounts of organic matter into a system already high in organic detritus and can reduce the oxygen content of the water to unfavorable levels. Eutrophication can easily result. On the other hand, marshes are capable of assimilating secondary-treated sewage into their biological systems without added stress. Secondary treatment of sewage wastes is a relatively inexpensive process when done by sewage treatment plants. Tertiary treatment, however, is quite costly. By introducing secondary-treated sewage into marshes, marshes can then become a site of free tertiary treatment (Gosselink et al. 1974).

Salt marshes share in the nitrogen and phosphorus cycle; salt marsh systems break down particulate organic nitrogen and phosphorus, exporting them in dissolved forms (Park and Batie 1979). This reaction increases estuarine productivity since estuarine biota are better able to assimilate dissolved organics.

As runoff, with its various types of associated non-point source pollution, moves through salt marshes, its velocity is reduced. This causes suspended particles to settle out and become part of the sediment. If these particles remain permanently deposited, the following may result (Park and Batie 1979):

1. reduction in turbidity.
2. reduction of sediment in main part of the estuary.
3. reduction of eutrophication due to adsorption of nutrients to sediments.
4. reduction of toxic materials due to adsorption of pesticides and heavy metals to sediments. In addition, the toxins may become

buried or decomposed.

Salt marshes are capable of acting as short-term pollution buffers by stretching out the time frame of pollutant loading during periods of heavy rainfall. Without wetlands, run-off would enter the estuary directly, however, by first flowing through the marsh, the length of time for estuaries to receive run-off increases (Figure 4). This may not decrease the total amount of pollution entering the estuary, but it would decrease the amount per unit of time.

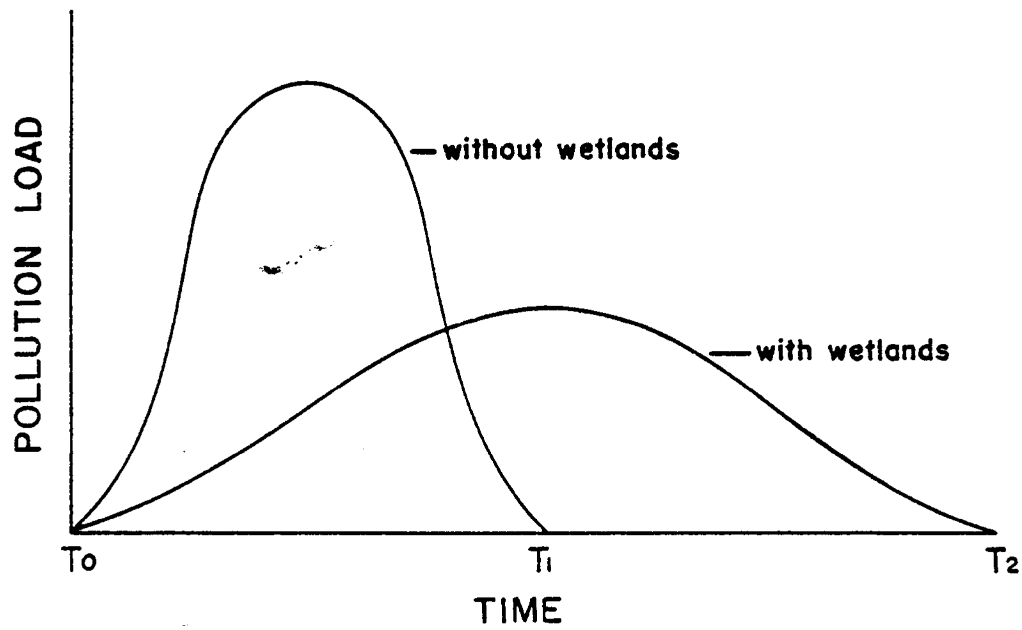


Figure 4. Rate of pollution loading to the receiving water body (after Park and Batie 1979).

II C 4. MUD FLATS

Petersen (1981) defines mud flats as "any unvegetated shoreline of a sound, lagoon, estuary, or river mouth that becomes exposed by lower tides." Because of their barren appearance, at least in contrast to seagrasses and salt marshes, they are perceived to be insignificant in their contribution to the gross primary production of the estuary. They function, however, to produce not macrophytes, but rather microscopic benthic algae.

Diatoms, dinoflagellates, filamentous green algae, and blue-green algae compose the primary producers of mud flats, and are observed as a discoloration of the sediment. Turnover is rapid, but productivity rates are less than half that of salt marsh and seagrass systems (Table 2), however, the crop is in a form readily useable by consumers. Many herbivores and deposit feeding invertebrates consume the benthic algae of mud flats.

Benthic infauna are the primary inhabitants of mud flats during low tide when the flats are exposed. Numerous species of birds extensively utilize this habitat as feeding grounds during daylight hours. However, during high tides and especially at night, crabs, shrimp, and fish become the major consumers. Summerson (1980; cited by Petersen 1981) found that crabs and bottom-feeding fishes are more evenly distributed over vegetated and unvegetated bottoms during the night. During daylight, however, seagrass beds contain far higher numbers of fishes, crabs, and shrimp (Petersen 1981).

In addition to their value as a food producer, mud flats also serve as a site for detrital breakdown. Currents and tides carry plant debris from the source habitat to the mud flat. During low tide, much debris is available to fiddler crabs, amphipods, and other detritivores that physically break it down. Through these processes, a substantial amount of production of other habitats is made available to mud flat consumers (Petersen 1981).

II C 5. OYSTER REEFS[1]

Oyster reefs are defined as "the natural structures found between the tide lines that are composed of oyster shell, live oysters, and other organisms that are discreet, contiguous, and clearly distinguishable (during ebb tide) from scattered oysters in marshes and mud flats, and from wave-formed shell windrows." (Bahr and Lanier 1981).

Oyster reefs in Florida are composed of the American oyster (Crassostrea virginica) that range from 20°N to 54°N latitude. The oyster is a typical estuarine inhabitant, tolerating broad limits of salinity, temperature, turbidity, and oxygen content. Because oysters are gregarious, they tend to form mounds ranging in size from scattered clumps to huge solid masses. The middle section of the intertidal zone affords the best habitat for oyster reef development; the lower zone subjects oysters to increased predation.

A typical reef is composed of three horizons. The upper layer (5-10cm) dries out during low tide, hosts a film of algae, and is colored a

[1]Summarized from Bahr and Lanier (1981).

pale greenish grey. The mid layer remains moist and lacks an algal film. A thin layer of detritus covers each shell and is colored reddish-brown. The lower layer is composed of non-living shells that are buried in anerobic sediments. Of the upper and mid layers together, approximately 61% by volume consists of living oysters, 21% consists of dead shells, and 18% consists of silt, clay, and non-oyster macro-fauna.

In theory, oyster reefs benefit estuaries by influencing physical and hydrological regimes. Oyster reefs dampen current velocities, undoubtedly for small areas, perhaps influencing the entire estuary. A slower current allows for settlement of particulate matter, thereby, decreasing turbidity. Within natural systems, where hard substrate is rather limited, oysters provide a much needed habitat for algae and animals that require hard surfaces for attachment. In fact, every square meter of oyster reef provides at least 50 square meters of available hard surface. The irregular surface, filled with nooks and crannies, serves as shelter for motile invertebrates and, during high tides, for small fish.

Oyster reef communities are composed primarily of suspension and deposit-feeding macrofaunal species. The community consists of various mud crabs, polychaetes, barnacles, other macrofauna, protozoa, metazoa, and bacteria. Oysters themselves serve as food for various boring sponges and the American oystercatcher, one of their major predators. Overall, this macro-faunal community more importantly serves to assimilate carbon derived from phytoplankton and detritus than it contributes to the food web.

Because many oyster reefs are intertidal or shallow subtidal, they exist constantly at or near their stress tolerance threshold. Further disturbance may destroy an entire reef community (Table 3).

Table 3. GENERAL EFFECTS OF MAN-INDUCED STRESS ON OYSTERS (from Bahr and Lanier 1981)

	Stress	Detectable Effects
1)	Sedimentation	Burial and anoxia of adult oysters
2)	Salinity increase over ambient concentrations	Increased predation and/or fouling
3)	Oxygen depletion in bottom water (Eutrophication)	Toxic effects of blue green algae and other algae; excess particulate organic carbon
4)	Chemical Pollutants	Sublethal effects, increased mortality, reduced resistance to natural stress, subtle changes in entire community, reduced gametogenesis
5)	Physical effects of oil-type pollutants	Impairment of feeding mechanism
6)	Thermal loading	Decreased community diversity, increased respiratory cost
7)	Overharvesting	Depletion of breeding stock and culch and decrease in bottom stability
8)	Loss of wetlands	Loss of wetland-water interface prime reef habitat, decline of primary production

II C 6. UNVEGETATED SUBTIDAL BOTTOM AREAS

Located below the photic zone or scattered throughout the estuary are areas of unvegetated subtidal bottom. Large patches (>3m) of bare bottom occur naturally in the photic zone due probably to high energy circulation patterns. Large bar-type bare sites may serve to lessen wave surges and current velocities, providing calmer areas behind the bar. Natural defoliation may result from herbivore feeding behaviors such as those described by Bjorndal (1980) for green turtles (Chelonia mydas) and by Packard (1981) concerning West Indian manatees (Trichechus manatus). Reasons for the natural existence of small patches of bare sand within expansive grass flats remain questionable. Blowouts, or bare sites within beds that consistently reject seagrass growth, may result because of high energy patterns such as eddies that occur continuously at that particular location (Durako, M., personal communication). Cryptic behavior of cownose rays have caused total removal of Zostera communities (Orth 1977). Many areas where underlying rock layers protrude through the bottom surface are unsupportive of seagrasses and macro algal beds (personal observation).

Though reasons for their presence must exist, small sites of unvegetated subtidal bottom probably are not very productive. Orth (1977) described sediment stability within these bare sites: storm activities produced sand ripples and erosion of <20cm in the bare areas whereas the adjacent Zostera community indicated no evidence of instability. Orth concludes that this instability accounts for the lack of species and individuals in this habitat. Human-induced defoliations are numerous and include activities such as motor boat propeller cuts, disposal of heated effluent, turbidity, physical removal, and high energy circulation patterns; these are discussed in greater detail in section IVB.

II C 7. WATER COLUMN

Overlying parts or all of the six other estuarine habitats is the water column. Several variables and, especially, the interactions between the variables, cause the estuarine water column to exhibit differing physiochemical characteristics. Depending on the time of year, time of day, weather, tide and circulation patterns, the water column may be extremely saline or fresh, clear or turbid, warm or cold, deep or shallow, and calm or turbulent. Further, it is capable of existing in any combination of these features. The water column is the medium through which most marine fauna travel and feed. It is dynamic and organisms living within it must be tolerant of change.

As the tide comes in, meroplanktonic stages entering the estuary can rise to the top of the water column and profit by the free ride to safer territory. High tide also creates a feeding habitat for larger predators by deepening those areas that physically excluded them during low tide. Receding tides, in a sense, "cleanse" the estuary by removing nutrients that may eventually serve as a food source for offshore systems.

Phytoplankters are the primary producers of the water column. Compared with seagrasses, mangroves, and salt marshes, productivity values for phytoplankton are minimal (Table 2), however, phytoplankton productivity is not limited to shallow areas (as are seagrasses) or shorelines (as are marshes and mangroves). Instead, these organisms are capable of reproducing in the photic zone over the total area of the system. Further, phytoplankton exist in a state readily available to consumers. In other words, phytoplankton need not pass through the many steps of the vascular plant detrital food web before consumption by "higher" organisms. Although the vascular plant detrital food chain may be most important in estuaries, phytoplankters are essential components in the food chain supporting zooplankton and larval fishes. Larval fish consume zooplankton, and zooplankton can consume detritus, however, almost all detrital consumers include at least 10 to 20% fresh algal cells in their diet (Odum 1970).

II D. ESTUARINE FOOD WEB

The trophic structure of estuaries features different sources of primary production, numerous generalist feeders, and an intricate food web (Day and Yanez-Arancibia 1982). Zieman (1982) listed the main sources of primary production:

1. Macrophytes - seagrasses, mangroves, macroalgae, and marsh grasses
2. Benthic microalgae - benthic and epiphytic diatoms, dinoflagellates, filamentous green and blue green algae
3. Phytoplankton

A diverse set of consumers contribute to the food web. An organism rarely fits exclusively into one category or level due to changing food habits resulting from age, time of year, and food availability (Odum and Heald 1972; Day and Yanez-Arancibia 1982). Juvenile fish, for example, switch prey items as they grow. Following is a list of estuarine consumers (Day and Yanez-Arancibia 1982):

1. First order consumers - pure herbivores, detritivores, and omnivores; includes most zooplankton, filter feeders, fishes such as mullets and menhaden, benthic deposit feeders, shrimps, crabs, and most other fauna of wetlands.
2. Second order consumers - organisms that consume mostly first order consumers and also small amounts of plant material and detritus; fishes consuming zooplankton (anchovies and sardines, for ex-

ample), demersal fishes (such as croaker and catfish), other crabs, and starfish.

3. Third order consumers - exclusively carnivorous organisms that prey on first and second order consumers; many larger fishes and birds.

Two basic food chains exist within the estuary: the grazing food chain and the detrital food chain. Interactions between these two create the complex food web of the estuary. The grazing food chain is basically:

primary producers → herbivores → carnivores → bacteria.

The detrital food chain is basically:

detritus → bacteria → detritus feeders → carnivores → bacteria.

The detrital chain is considered by many researchers to be the most important of the two food chains (see Day and Yanez-Arancibia 1982). The process is based, obviously, not on living primary production, but on dead material. After a mangrove leaf, Juncus shoot, Spartina shoot, or seagrass blade breaks off from its host plant, physical breakdown occurs immediately. The material is shredded into smaller fragments by crabs and amphipods and quickly becomes colonized by bacteria, fungi, and microalgae. These decomposers are considered rich sources of vitamins and proteins, greatly increasing the food value of the material. Heald and Odum (1970) found that broken-down particles after 12 months contained 22% more protein as compared to a protein content of 6% when they were still intact. Net nutrient value is much higher for detritus materials than for the plant material alone. In addition, this rich source of food decomposes slowly, insuring a continuous production of food. Mann (1972; cited by Day and

Yanez-Arancibia 1982) states that the detrital colonizers are the actual food source; the plant material passes through the gut systems of detrital feeders almost unaltered.

Eighty to ninety percent of the nutrition of several species of crustaceans, polychaetes, insect larvae, and small fishes is derived from detritus (Robas 1970). Detritus feeders are consumed by over 60 species of juvenile fishes that live in the estuary during at least parts of their lives (Robas 1970). However, no estuarine food web is completely dependent upon vascular plant detritus, in fact, according to Odum (1970), detritus consumers appear unable to grow and successfully reproduce when consuming solely detritus. He adds that at least 10 to 20% algal cells in the form of diatoms or filamentous and blue-green algae are included in the diets of almost all detrital consumers.

III. ADJACENT LAND USE AND HABITAT ALTERATION

III A. ESTUARINE LIMITATIONS

As discussed in Section II A, estuaries are extremely interactive, highly dynamic ecosystems. However, even though estuarine biota are quite capable of withstanding frequent environmental changes, they do have limitations. In this section these boundaries will be described as well as how they are exceeded and the resulting effects on estuarine habitats.

Odum and Copeland (1969) described three main energy types that dominate estuarine systems:

1. Light energy activates the process of photosynthesis and is the primary source of the estuarine food web.
2. Organic fuels constitute a second energy source. Incoming nutrients flowing through the estuarine habitats "fertilize" the system resulting in an increase in vascular plants and algae.
3. Mechanical energy, such as waves, wind, river and stream flow, and tides serve as energy subsidies and are responsible for many interactions that occur in the estuary.

A reduction in light energy, as might occur if estuarine waters became turbid, would greatly affect the seagrass system. Copeland (1965) tested the effect of light reductions by lowering the input of sunlight from 1500 to 200 foot candles on a simulated seagrass community. The community, previously dominated by *Thalassia*, soon became a blue-green algae community. After stabilization, however, the productivity of the two community types became equivalent. But, considering that blue-green algae is consumed successfully by only a few species (Copeland 1965), as opposed to *Thalassia* leaves and detritus that are consumed by numerous species, Thalassia communities are much more useful, both as a food source and as a hiding habitat.

Lessening the amounts of incoming organic fuels (commonly derived from freshwater sources such as rivers and terrestrial run-off) would decrease the biomass of all the systems - mangroves, salt marshes, seagrasses, and phytoplankton. However, an overabundance of nutrients precedes eutrophication. In response to increased nutrients, productivity increases resulting in an increase in detrital material, but the amount of energy required to breakdown this material has not changed. The system becomes eutrophicated and consists of sediments and a water column devoid of oxygen. Vascular plants die and the system begins to cease functioning.

Mechanical energies within the estuary are numerous, and their importance cannot be overemphasized. For example, tides and freshwater inflows are responsible for the chemical properties of the water. If tides were restricted from the estuary, freshwater would predominate and the system would drastically change from a euryhaline system to a fresh system. Decrease in freshwater flows would cause an increase in salinity. The numbers of molluscs, crustaceans, and fishes would rise, but the subtle qualities of the estuary would be lost, especially its value as a protective nursery ground.

Consistent high levels of dissolved oxygen do not occur in estuaries, due mostly to the large volume of organic matter in the surface sediments and water column (Odum 1970). In fact, many estuaries possess a value well below the standard of 4.0 mg O_2 per liter water established for polluted estuaries by the National Technical Advisory Committee in their 1968 report on water quality criteria to the Secretary of the Interior (Odum 1970). Odum (1970) theorized that since estuaries already exist in a borderline condition, a decrease in dissolved oxygen content is capable of causing mass mortalities. He further states that any process that suspends oxidizable sediments also reduces the oxygen concentration of estuarine water to a level unfit for normal biota. An example of this occurs frequently in an unpolluted Everglades estuary during rainy season: large volumes of cold rainwater sink to the bottom causing resuspension of detrital materials. Oxygen is depleted and marine animal mortalities follow.

Although estuarine biota are capable of withstanding drastic temperature fluctuations, they cannot deal with continuous heat or cold. Severe cold spells cause adult fish to migrate to offshore warmer waters, and freezes destroy mangroves. Many resident species of tropical areas are surviving within a few degrees of their upper lethal limit (Lindall 1973). Fishes rarely survive temperatures of 38°C, and waters typically exceeding 35°C would probably not support a large or diverse fish population (Carr and Giesel 1975). Effects of excessive heat from natural sources have not been reported, but effects of heated effluent from power plants have been well documented. Roessler and Zieman (1969) found adverse effects from effluent emerging from Turkey Point Power Plant in southern Biscayne Bay; nearly all biota within 125 acres nearest the outfall were destroyed or greatly reduced. By comparing two thermally-influenced creeks to an ambient temperature creek, Carr and Giesel (1975) found a higher fish density during summer months in the ambient creek. In addition, juveniles of species of commercial and recreational importance were 3 to 10 times greater in biomass and numbers in the ambient creek than in the thermally affected creeks.

Two extremely important, but not easily defined, parameters that greatly influence the effects of various perturbations, are time and multiple interactions. The estuary apparently can cope with literally almost any major alterations, but for only relatively short periods of time. For example, seagrasses will not be detrimentally affected by turbidity if the condition exists for merely a week. But further periods of inundation may result in reduction of photosynthesis and decreased production.

Synergistic or multiple interactions are those perturbations that occur coincidentally with others. It is often difficult to separate the effects of single disturbances when another, or others, are present as well. Using the seagrass community again as a hypothetical example, turbidity, excessive freshwater, and above normal nutrient levels are simultaneously introduced into the seagrasses due to heavy rains and river flooding. Two months later, after the system returned to normal conditions, the seagrasses are thinner and less dense with fewer faunal inhabitants. It would be difficult to pinpoint any single variable for the results.

In summary, a reduction of light energy or a reduction or over-abundance of organic fuels and mechanical energy, excessive changes in chemical properties (oxygen and salinity) and temperature, or a combination of any or all, since all variables are interrelated, may result in decreased production. Lowered productivity is realized through the food chain and the outcome is lower yields in fish stocks.

III B. PERTURBATIONS

Probably the greatest single disturbance that causes irreversible damage in the shortest period of time is physical removal of parts or all of the estuarine habitats. Destruction of this type often occurs on a large-scale and includes activities such as channel dredging, dredge and fill, shell-mining, and various sorts of shoreline modifications. Small scale perturbations that directly and physically destroy habitat are produced from activities such as motorboat cuts and clam digging. Anything that exceeds estuarine limitations, as discussed in the previous section, either destroys habitat or reduces productivity; these disturbances may include the introduction into the estuary of power plant effluent, storm water run-off, industrial discharges, mosquito impoundments and vessel discharges (gas and oil).

Channel Dredging

Because estuarine habitats are relatively shallow and typically link the oceanic waters to the mainland, they pose transportation difficulties to large vessels and even small boats. To alleviate this problem, channels are cut into the sediment, providing deep areas for easy access through the shallow zone. Odum (1970) explains that the dredging process would cause minimal damage if properly engineered; only the actual area containing the navigation channel should be altered. However, Odum describes the continual adverse effects resulting from the "hydraulic dredge cycle". Material dredged from channels is typically dumped as nearby spoil banks. As the spoil banks erode, dredged material is transported back into the channel, necessitating re-dredging. Turbidity and destruction of circulation patterns are often unavoidable by-products. Lindall and Saloman (1977) reported outcomes of channel dredging that are significant to fishery resources. Physical loss of aquatic habitat by creation of spoil islands, segmentation and isolation of parts of the estuary, alteration of tidal exchange and circulation patterns, increased turbidity, and destruction of submergent and emergent vegetation are some of these significant problems.

Mosquito Impoundments and Ditches

Mosquitoes, as adults, pose a threat to the health and sanity of people and yet, as larvae, serve as food for juvenile fishes. Unfortunately, both mosquitoes and humans wish to occupy the same coastal areas -- humans, because of the aesthetic qualities, and mosquitoes because of their need for moist, exposed soil on which to lay eggs. Higher intertidal salt marsh and mangrove areas provide exceptional habitat on which mosquitoes lay eggs. To help eradicate mosquitoes, a dike is built around the system or channels are dug through it. Dikes serve to retain water within the system while canals dry it out. They change an occasionally-flooded area to one continuously flooded or to one persistently dry. Diking and channelization remove the influence of tides and the inflow of terrestrial freshwater and, therefore, a part of the nutrient import. Estuarine fauna are no longer capable of moving into and out of the site, and its importance as habitat for growing fishes and shellfish is destroyed. Harrington and Harrington (1982) reported that during a few months following impoundment of a salt marsh community in Indian River County, nearly all the vegetation died and juvenile fish that originally used the site previous to impoundment disappeared as well. Of 16 species found before impoundment, only five remained after impoundment (Harrington and Harrington 1982, 1961.) Gilmore et al. (1982) found a total of 12 species within the

Harrington's impounded site as compared to 41 species in an impounded site that was reopened to tidal influence via a single 80 cm culvert.

Power Plants

To cool the operating system of electrical generating power plants, water is essential. Placement of a power plant adjacent to an estuary provides easy access to a direct source of required cooling water. After the water is used, it is deposited back into the estuary. The foremost perturbation the power plant provides to the estuary is the direct destruction of shoreline habitat, usually mangroves and marsh, to build the plant. Three additional problems are as follows:

1. Impingement - organisms can get trapped on screens that filter the intake water.
2. Entrainment - organisms of the intake water that pass through the filter system can be killed or damaged by the turbulent and pressurized process of the cooling system.
3. Thermal effects - the impact of thermal pollution depends on several variables - discharge volume, average and maximum temperature elevations, characteristics of plume dispersion, and hydrography of receiving waters. In addition to the reports discussed in Part I of this section, another investigation found that thermal effects from a coal-fired power plant destroyed 200 acres of seagrasses and lowered the diversity of invertebrates to 40% of their original value (Blake et al. 1976).

Sewage Disposal

"The greatest direct threat to the clear productive waters of the Charlotte Harbor area is inadequately treated and improperly disposed domestic wastes" (U.S. Department of the Interior, Bureau of Land Management, 1978). As described in Section III, estuaries provide an ideal site for the disposal of secondary-treated sewage. However, the addition of primary-treated sewage contains more nutrients than the system can properly handle. A study of Hillsborough Bay found progressive eutrophication after years of receiving primary treatment (Federal Water Pollution Control Administration, 1969). Water quality was lower as compared to all other parts of Tampa Bay; measurements of dissolved oxygen were low, coliform bacteria surpassed safe levels, sediments became anoxic, and frequent noxious algal fish kills and blooms occurred. In addition, diversity and abundance of macroinvertebrates were lowered (Taylor et al. 1970).

Canals and Canal Developments

During the 1950's and 1960's, demand for waterfront property in the southern half of Florida was immense. Developers met this need by extensively exploiting the coastline. Available shoreline was limited, so developers planned communities around networks of branching canals, maximizing the amount of waterfront property to land configuration. Some of these canal systems extend inland over thousands of acres. Morris (1981) distinguishes three basic designs of waterfront canals:

1. Bay-fill or finger-fill canals: those constructed below mean low tide by dredging and filling shallow bay bottoms.
2. Intertidal developments: those constructed by dredge-and-fill between mean low and mean high water, typically in mangroves, salt marshes, bays, estuaries, lakes, or other wetlands.
3. Inland or upland canals: those developed by excavating land above mean high tide and connecting the canals to natural channels,

lakes, rivers, bays, or other natural or artificial waterways.

In the past, canal developments were usually constructed by dredging out the channels, first, and depositing the dredged material behind bulkheads, or seawalls, elevating the land surface to meet State criteria for hurricane tide and flood protection (Morris 1981). During construction, mangroves, seagrasses, and trees were removed from the dredge location, and the fill material covered vegetation located in the landfill sites, often destroying estuaring nursery sites over vast areas. Lindall and Saloman (1977) determined that 23,521 acres of Florida estuaries have been filled, the majority for housing developments and industrial real estate.

Three major deleterious effects of canal developments are apparent, irrespective of less obvious concurrent impacts:

1. The immediate destruction of habitat at the construction site.
2. The presence of seawalls at the land/water interface, eliminating critical habitat for the development of estuarine shoreline vegetation. This, in turn, eradicates nursery habitat, as well as a cleansing site for incoming water.
3. The inability of circulation patterns to adequately flush the waters and carry undesirable pollutants to the receiving water body, and/or maintain a sufficient concentration of dissolved oxygen throughout the water column of the entire canal network.

Fortunately, the direct causes of water degradation within canal systems were clear. The documentation of canal problems resulted in restrictive legislation, causing a significant decrease in canal construction. However, canal developments continue to be permitted.

Perhaps these developers can follow the less negative approach to canal design as devised by Morris (1981) and discussed in Section IV D. Of course, the best approach is to completely ban the construction of canals.

Stormwater Run-off

When rainfall occurs, much of the water perculates through the ground. It is cleansed by the soil and lower rock layers and enters the groundwater system. When rainwater falls on land it can enter the estuary via rivers and streams as terrestrial run-off, relatively clean but full of nutrients. The remainder enters the estuary via storm pipes as run-off from roads, lawns, parking lots, and agricultural cropland. This run-off may contain pollutants such as pesticides, gasoline, oil, heavy metals, and fine particles of rubber and asbestos. Odum (1970) termed the influence of these pollutants "sub-lethal effects", and described it as a poorly understood occurrence. Butler (1966) has shown that widespread pesticide pollution significantly decreases the production of estuarine fish and shellfish. Anderson and Peterson (1969) discovered that sublethal concentrations of DDT prevented the establishment of a visual conditioned avoidance response in some fish and also affected the thermal acclimation mechanism.

Industrial Discharge

In Florida, phosphate is the prevalent mineral extracted from the ground. Phosphate plants, like power plants, require a cooling system that utilizes water, therefore, Florida phosphate plants typically are found on rivers or on estuarine shorelines. Upchurch et al. (1976) found that effluent from a phosphate processing plant in Hillsborough Bay was heated to 18°C above ambient water temperatures, contained much fluoride, and was acidic. The discharge caused the disappearance of all animals within 61 hectares, and diversity and abundance were low where organisms did occur. Phosphate strip mining and processing plants established far upstream affect the estuary. Though outflow water temperatures have probably cooled by the time they reach the estuary, the chemical contaminants would no doubt be sustained within the outflow.

Miscellaneous Activities

Numerous additional activities that affect estuarine production continuously occur. Vessels, whether they are large, small, commercial, or recreational, release gas and oil into the water. Larger vessels are capable of producing wakes that may disturb quiet areas and cause detrimental affects such as stripping newly established vegetation from the sediments. Motorboat scars within seagrass meadows persist for years (Zieman 1976). The construction and placement of causeways and bridges destroys habitat of the immediate site. After stabilization, however, estuarine vegetation may sometimes return depending on boat activity, wave action, turbidity, and other factors influencing reestablishment. Causeways additionally alter circulation patterns that can severely affect some areas. Oil spills can cause extensive damage. Oyster shell dredging creates temporary turbid conditions within approximately 30 meters of the site, in addition to a reduced organic content within the sediment, a 40% loss in species, a 66% loss in abundance, and an 87% loss in biomass. Within six to 12 months, however, these parameters can become naturally restored to pre-dredge conditions (Conner and Simon 1979).

Cumulative Effects

The health and well being of estuaries is based not on an impact of a solitary activity, but rather on the accumulated effects of all activities, since the whole estuarine system is interrelated and interactive. Estevas (1981) states:

> "In Coastal Ecosystem Management, Clark (1977) names or discusses nearly 100 activities with adverse estuarine impact. The permutations of just those activities possibly relevant to southwest Florida estuaries all profoundly numerous, and of inestimable impact due to the many variables involved. This does not mean, however, that cumulative impacts cannot be anticipated, identified, or managed. For all purposes, recent efforts to protect Charlotte Harbor by its designation as a complex of aquatic preserves, and possibly as an area of critical state concern, represents the emergence of public concern for cumulative (additive and interactive) effects (CHPRMC, 1980)."

IV. RESTORATION

Estuarine shorelines and nearby shallow waters provide the perfect ecological environment for salt marshes, mangroves, and seagrasses, however, this same shoreline aesthetically appeals to many humans as well. Unfortunately, in many areas of Florida, humans who dwell along shorelines do not want to coexist with native habitats. Instead, they live on shoreline habitat restructured by developers. An anonymous author once wrote:

> No thought has been given to the fact that the highly-touted offshore fishing in this area of retirement homes is directly related to the very mangrove swamps being destroyed to make homes for the fishermen.

Present knowledge linking the estuarine system to such important entities as growth and survival of juvenile fish and shellfish, shoreline stabilization, water quality, and food production has led scientists into the complex realm of habitat restoration. Of course, the simplest and most inexpensive "method" is preservation, in other words, absolutely no adverse effects due to development shall occur. For areas already destroyed, preservation is of course, impossible; only future development can employ this procedure. Next to preservation is conservation -- if a project must be constructed at a specific location resulting in damage to natural systems, then the construction process should cause the least possible deleterious effects. Mitigation is also a choice, but still results in destruction of habitat in trade for preservation or re-establishment of another site. This section addresses (1) post-development sites devoid of native vegetation, where vegetative restoration is indeed a possibility, and (2) miscellaneous restorative and pre-development concerns such as spoil island configuration, bulkhead alternatives, and rational canal design. Various techniques of restoration are discussed, and those with best results will be delineated. The reader should always keep in mind that each restoration site is unique with different flow patterns and water regimes, varying sediment compositions, and other parameters. Restorative capacity is, therefore, peculiar to each site where restoration has or will occur.

IV A. SEAGRASS RESTORATION

The major methods of reestablishing a seagrass population are seed cultivation or transplantation of plugs, turfs, or sprigs, possibly applying hormone treatments executed at different times of the year. The discussion is limited to reports of seagrasses that occur in Florida waters.

Plugs: A plug of seagrass is composed of seagrass blades, roots, and rhizomes with attached sediment. A plug is removed from the transplant site with a shovel or post hole digger and transported intact to the recipient site. A hole is dug into which the plug is placed; an anchor or sediment cover holds it in place. Plugs are typically spaced one meter apart. Disadvantages to this system are the damages it induces to the donor site, the substantial time and labor requirements, and the slowness of regrowth, especially of *Thalassia* (Godcharles 1971). Kelly et al. (1971) was unsuccessful in applying this technique to *Thalassia* in Boca Ciega Bay. Van Breedveld (1976), however, had 100% survival of *Syringodium* in Tampa Bay by using a post hole digger and planting in rows in early spring. Lewis and Phillips (1980) planted plugs in a small borrow area of the Florida Keys that had silted in with fine calcareous sand and silt.

They had 35% survival for *Syringodium* and 37% for *Thalassia*; *Halodule* plugs, however, failed.

Turfs: A turf is a large clump of sediment with seagrasses. A turf is removed from the donor site and placed into a shallow trench at the recipient site. Disadvantages are the same as described for plugs. Phillips (1974) had no success with *Thalassia* in Tampa Bay, probably because of erosion by currents, but *Halodule* exhibited some success. Van Breedveld (1975) concluded that turf transplants are most preferable. He suggested that the clumps be planted in rows, spaced 30 cm apart in favorable substrates, and closer in unfavorable substrates with donor sediment in between.

Sprigs: Sprigs are single "plants" composed of the blades, short shoot, roots, and maybe the rhizomes, but no sediment. The donor site is affected less deleteriously, but stress on the plant itself might be much greater. Kelly et al. (1971) planted sprigs of *Thalassia* without rhizomes in Boca Ciega Bay; 11 of 60 plants survived. Lewis and Phillips (1980) reported a failure of nearly 100% of *Thalassia*, *Halodule*, and *Syringodium* using springs in a borrow area of the Florida Keys.

Seeds: Thorhaug (1974) gathered *Thalassia* fruits from Caribbean beds and immediately separated the seeds. The seeds were transported under recirculating sea water and planted in the denuded Turkey Point Power Plant discharge canal in Biscayne Bay. After 2.5 years, the transplant site was moderately dense. After 4 years, blade density was 2000/m^2 as compared with 2295/m^2 at a control site. Lewis and Phillips (1980) reported nearly 100% failure of planting *Thalassia* seeds and seedlings in a silted-in borrow area created by dredging.

Durako and Moffler (1981) reported 100% success in planting laboratory seedlings in peat pellets (compressed dehydrated peat containing low grade fertilizer); plants exhibited healthy leaf growth after 3 months, and maintained good health in situ for over 6 months. The transplant site however, presented unsuitable growth parameters of high sedimentation and turbidity, therefore, field results were inconclusive.

Durako and Moffler (1981) described several physiological variables that must be considered when choosing seed stock for restoration projects:

> When considering seed stock for mitigation projects, the possibility of genetic fixing in local strains may be important (Odum, 1971). Geographically separated T. testudinum populations exhibit ecoplastic limits that are adaptive to local conditions (McMillan, 1978, 1979; McMillan and Phillips, 1979). Response to the influence of habitat include variation in leaf length and width (Phillips, 1960; Zieman, 1974) and variable reproductive patterns (Grey and Moffler, 1978; Moffler and Durako, unpublished data). In this regard, transplanting seeds or seedlings from remote locations may result in failure or poor success since they lack this factor compensation. The possibility of pathogen introduction utilizing nonlocal seeds also suggests that indigenous seed stock would be preferable for revegetation projects.

An important consideration for seagrass restoration projects is the feasibility for growth at the recipient site. Thorhaug (1980) planted seedlings in 4 types of high stress environments in Biscayne Bay: areas of submerged dredge spoil, bottoms damaged by sewage pollution, areas of high tidal currents, and areas of shifting sand. Low survival occurred in areas of strong tidal currents, those with wave action from boats, and the dredge spoil site that was experiencing erosion and sediment shifting. Suitable sites for seedling growth included areas of low energy with peaty bottoms consisting of sandy, consolidated sediments.

Miscellaneous Techniques: Fonseca et al. (1979) removed *Halodule* (and *Zostera*) from donor beds and rapidly transported them to a processing area. Terminal shoots were separated and woven into pre-cut biodegradable 20 x 20 cm mesh paper, with 15 shoots per 0.04m^2 mesh. The squares were placed 1 m apart in a 6 x 6 m plot and attached to the substrate with sharp pins. The logic behind this complex technique is a compromise between recovery time and cost: revegetating only a small portion of the damaged area to an advanced stage of succession. Though apparently successful, it is time consuming, costly, and labor intensive.

Hormone treatments (mostly the use of Naphthalene Acetic Acid -NAA) appear to exhibit no consistent results. In his work with plug and sprig transplants, Van Breedveld (1975, 1976) reported no advantages from using hormone treatments. Thorhaug (1974), however, found that seeds soaked in NAA solution appeared to increase root propagation. Kelly et al. (1971) reported 100% success in transplanting sprigs without rhizomes that were first dipped into NAA solution previous to planting. Whether the successful attempts were due to hormone treatment or to other parameters such as viability of the recipient site and the restoration technique itself remains questionable.

The season in which restoration is attempted may play an important role in successful projects. Saurs (1981) and Van Breedveld (1975) suggest early spring as optimal for planting since seagrasses exist in a semi-dormant state during this time. Saurs (1981) also emphasized that historical changes must also be considered, i.e., if seagrasses are disappearing within an area, restoration may prove useless. Disturbance to the system is causing their demise and any restorative attempts may fail.

In summary, investigators must choose between several alternatives before attempting restoration of a seagrass bed. Selection concerning which restoration techniques to use, when to plant, the use or disuse of a hormone treatment, cost considerations, and, most important, the receptivity of the recipient site must all be considered. A final option regards which species to place into the new site. Often, the system has changed extensively and new growth of the original species may not be feasible. Thorhaug (1980) noted that some investigators plant *Halodule* because it grows faster, however, she argues against this reasoning because *Halodule* might not support a faunal system as large or diverse as those maintained by *Thalassia* beds, nor does it apparently function to stabilize sediments as well. Lewis and Phillips (1980) suggest that *Thalassia* exists as the climax species in an ecological succession with *Halodule* and *Syringodium*; *Halodule* roots are shallow and it grows quickly, *Syringodium* has deeper roots and grows slower than *Halodule*, and *Thalassia* has the deepest roots and grows the slowest of all three. Reasons describing why one site is better suited than another for a particular species are multitudinous, and basically unknown (M. Durako, personal communication). The reader is referred to Coastal Engineering Technical Aid No. 80-2 (Phillips, 1980) and a bibliography on seagrass planting and propagation techniques (Knight et al. 1980) prepared for the U.S. Army, Corps of Engineers, Coastal Engineering Research Center, for more information regarding seagrass restoration.

IV B. MANGROVE RESTORATION

Lewis (1981) described some of the major reasons for the recent increased interest in mangrove restoration: (1) the value of mangrove forests has been realized and documented; (2) large-scale losses of mangroves have occurred; and (3) legal authority has been granted to regulatory agencies to control destruction of mangroves through development and to establish fines, replanting requirements, and other mitigation procedures.

Teas (1980) describes one goal for mangrove restoration: to develop a functional, diverse ecosystem as rapidly as possible. He suggests (1981) several short cuts that rapidly establish a mature system. Dense planting and planting larger trees help accelerate development. Faster growth is achieved with fertilizer treatments. Large block plantings as opposed to scattered plantings are favored since larger forests harbor a more diverse fauna. If the site is distant from other mangroves, introducing invertebrates, algae, and other fauna could accelerate development (Teas 1980).

Substrate stabilization appears to be one of the most important functions of mangroves. Since black mangroves form dense root mats, they may serve as better stabilizers than red mangroves (Savage 1972; Carlton 1974). White mangroves also grow dense root mats; they, too, can stabilize substrate (Teas 1981). Lewis and Dunstan (1975) suggested achievement of rapid stabilization by first planting *Spartina alterniflora* and then planting mangroves within the *Spartina*. Pulver (1975) suggested planting mangroves in greater densities, then allowing natural overcrowding and competition or artificial thinning to occur.

Four basic methods of mangrove reestablishment have been applied: planting of propagules, planting nursery-grown seedlings, transplanting from field stocks, and air layering. These methods are herein described as well as some common decisions and problems encountered in the field.

Planting propagules: This method simply involves collecting propagules and placing them into the substrate at the restoration site.

Most restoration failures of planting seeds or seedlings appear to occur due to high wave energy. This form of stress physically undermines and removes plant material before it becomes established (Hoffman et al., in prep.). Natural high wave energy is caused by strong winds, but boat wakes constitute an induced stress, especially in well-used recreation areas. Teas et al. (1975) planted 178 young *Rhizophora* seedlings on a St. Lucie River site that was subjected to waves from boat traffic; after 7 months, there were no survivors. However, a nearby low energy site had a dense growth of mangroves after 5 years (Teas et al. 1975). After planting 60,000 *Rhizophora* propagules on a low energy site in Charlotte Harbor, the same authors reported 85 to 90% survival after one year. Teas (1977) reported 100% survival after 5 months of small pot-grown mangroves of all species planted along a low energy canal. The establishment of a "rocky" berm in areas prone to high wave energy in order to absorb destructive water movements are sometimes used; this berm should be high enough to inhibit waves, but porous enough to allow tidal infiltration.

If planted or growing too low in the tidal zone, mangroves are subject "*Sphaeroma* disease." *Sphaeroma terebrans* is an isopod parasite that bores into mangrove roots and stems, weakening them and making them more vulnerable to adverse effects of wave stress. Hannan (1975) reported that all mangroves planted 10 cm too low in the tidal zone were killed by Sphaeroma, but trees planted above this level were not attacked.

Nursery-grown mangroves: This method involves the growth of mangroves in an artificial environment and transplanting them to restorative sites. Evans et al. (1978) described how several methods of treatment affected growth and survival of mangrove seeds. Mulched soils (50% grass clippings/50% soil) enhanced growth rates of red and black mangroves, but had no effect on survival of reds and an undetermined effect on survival of blacks. Salt additions increased survival for both reds and blacks but was ineffective on growth rate. Fertilizers showed no effect for red mangroves, but were detrimental to blacks. Various watering schedules did not affect red mangroves, but blacks exhibited greater survival after one watering per week. These authors suggested that black mangrove seeds, prior to planting, be soaked until their seed coats fall off and roots start growing.

Transplanting mangroves: This method involves the removal of plants from a donor site and replanting them at a recipient site. Pulver (1976) developed guidelines for transplanting mangroves:

(1) The top and side branches should be pruned to approximately 2/3 of the original length.

(2) A root ball diameter about 1/2 the original tree height should be retained.

(3) At the recipient site, when replacing soil in the hole, the root ball should be watered and pushed down to insure a seal between it and the sides of the hole.

(4) The plant should be placed at about the same substrate

depth and the same tidal elevation as the original source site.

(5) Plants should not be placed into unstable substrates.

Hoffman and Rogers (1980) successfully applied these methods but without initial pruning. They reported 73.3% success after 13 months for transplanting red and black mangroves on a dredge spoil island in Tampa Bay on an area of low wave energy and proper elevation. Hannan (1975) transplanted 4-year old root balled red mangroves at or above mid-tide range in the Jensen Beach area; after 13 months, 85 to 100% survived. Teas (1977) transplanted 14 black mangroves and white mangroves that were previously root-pruned and top-pruned at the time of translocation; after 6 months, all were dead. Teas attributes these losses not to pruning, but to improper handling.

Mangrove Air Layering: Air layering serves as an untried method of restoration. Short sections of bark and phloem are stripped to the cambiam and wrapped with *Sphagnum* moss and aluminum foil to retain moisture. Roots soon emerge from the "layers". To form new trees, stems may be cut underneath the layers and planted at a new location. Carlton and Moffler (1978) observed root growth 5 to 6 months following layering with 39% success for red mangroves, 35% for white mangroves, and 6% for black mangroves. Further investigations by the Department of Natural Resources (DNR) Bureau of Marine Research indicate that root growth requires 4-6 months with success rates of 87.5% for whites, 60.4% for reds, and 12.5% for black mangroves (D. Crewz, personal communication). Investigators at DNR suggest that air layering be performed just before the rainy season to take advantage of higher humidities and temperatures, however, they warn that too much water may lead to fungal/bacterial infection. Air layering provides larger planting material without the labor-intensive costs of growing nursery plants or the loss of plants from source sites associated with transplanting. Additionally, air layering allows for phenotypic selection for specific traits (D. Crewz, personal communication).

In summary, restoration of mangrove stands and even the introduction of mangroves into new sites is highly feasible. Planting in recipient sites of low wave energy and fairly stable substrate appears to enhance survival. Berms or another method of lowering wave stress can be placed at sites of high wave energy. All four methods of restoration exhibit successful results when guidelines are properly followed. Fehring et al. (1979) stress the importance of community acceptance and assistance with projects at or near developed areas. They further point out that most of the habitat restoration projects are run by government agencies - these projects are assured of long-term commitments in most cases. Developers, too should be responsible for long-term commitments; i.e., successful re-establishment and not just initial plantings.

IV C. SALT MARSH RESTORATION

As with seagrasses and mangroves, the importance of marsh vegetation is well-known and documented. Present salt marshes occupy calm waters subject to tidal influences; restored marshes prefer the same habitat. In planning for a restored site with the ultimate vegetative composition in mind, Hunt (1979) suggested that investigators first observe the species composition of nearby marshes (if any) occurring at the same elevations as the site to be restored. Local species may be more likely to invade and colonize the area. Like mangroves, salt marsh revegetation has incorporated three methods: planting seeds and transplanting field and nursery stock.

Seeds: If water levels maintain relatively shallow depths during the time of seed germination and establishment or the site is located in the upper portion of the tidal zone, revegetation by seeds may have positive results; tidal action may otherwise dislodge seeds (Hunt 1979). Darovec et al. (1975) recommended collecting cord grass seeds at least 3.0m from the seaward edge of the marsh. Woodhouse et al. (1972) describe the proper techniques of handling seeds and Darovec et al. (1975) summarized these procedures: seeds should be stored in seawater between 1.7-3.3°C for two to four months. Seeds planted in vivo require 6 to 25mm substrate over them to prevent being washed away.

Transplants: Depending on the species, various harvest methods have been suggested for different types of marsh vegetation. 15cm plugs of Spartina alterniflora and S. patens should be removed from a mature marsh in random locations, however, Juncus stock should be removed from one site since the plant is easily destroyed by human traffic (Hoffman et al, in prep.). Plugs of Spartina can be planted intact, or separated into individual stalks, which reduces collection labor since one plug supplies many stalks (Hoffman et al., in press). Removing the top 1/3 of Juncus shoots reduces aerial transpiration and allows greater ease in handling (Hoffman et al., in press). If high tide covers the cut top, survival is reduced (Coultas, 1980). Some important techniques for transplanting are described by Darovec et al. (1975):

1. "Transplants should be removed beyond 15 ft. from the

seaward edge of the marsh, taken in alternating square yards in checkerboard array. Three to five plants should remain in the center of each thinned square yard."

2. "Cordgrass and needlerush should be removed by shovel. To minimize erosion, holes should be refilled with soil rinsed from plant roots. Bare root plantings will work satisfactorily if plants are kept moist and are not exposed to direct sunlight. When transportation is involved, roots can be kept in buckets of seawater or in wet burlap sacks."

3. "Marsh transplanting should be done in winter and early spring, preferably after the coastal storm season."

4. "Salt marsh plants should be planted in rows paralleling the shoreline, cordgrass nearest the shoreline, plants 18-24 inches apart."

Coultas (1980) recommended that transplants with one or more buds be used since these will produce more leaves and a greater height. He also noted that "Rootone" (a commercial growth regulator) produces deleterious effects.

Hoffman and Rogers (1980) performed an S. alterniflora restoration project on dredge material in Hillsborough Bay. Plugs of S. alterniflora were planted on a 1.64 ha. site of low wave energy and a favorable tide regime. The 12cm plugs were placed one meter apart (center to center) in rows two meters apart. After 14 months, 93.4% survived. Hunt (1979) reported that sprigs of Spartina alterniflora grew well when planted 0.3, 0.6, and 0.9m apart, but 1.8 and 2.7m spacings resulted in poor survival. *Spartina patens*, however, grew best at spacings of 1.8 and 2.7m (Hunt 1979). Hunt additionally found that seeds grew with greater success than sprigs.

IV D. MISCELLANEOUS RESTORATION TECHNIQUES

Spoil Island Configuration: The initial formation and subsequent maintenance of ship and boat channels requires huge amounts of sediments to be dredged up. The sediments are typically dumped as random piles or spoil islands, adjacent to the channel sites, sometimes without regard to island configuration in relation to current flow and ensuing erosion. Many times, these islands quickly erode back into the channel necessitating further dredging. In Tampa Bay, for example, three spoil islands were created in 1931. By 1957, two islands had completely eroded away. However, the remaining island shifted continuously, and finally stabilized forming a horseshoe shape with distinct arms. By 1966, one arm was shortened and curved around forming a lagoon. A mixed mangrove habitat became established and by 1979 the island served as a nesting site for 13 species of birds.

Lewis and Dunstan (1974) suggested several methods to correctly configure inevitable spoil islands. These suggestions were recommended for a proposed Tampa Bay harbor deepening project, but can also be applied to other proposed channel sites as well. The overall shape of the new spoil island should describe a three-to-one ratio of length to width. Stabilization can be achieved more quickly through the establishment of oyster reefs and vegetation such as mangroves. An artificial reef composed of surplus construction materials can be built to minimize wave action and protect the shoreline.

Bulkhead Alternatives: Seawalls not only deprive the estuary of the important shallow intertidal gradient between dry land and water, but they also provide residents with an impersonal and false view of the natural world. There are less obtrusive methods of changing or creating shoreline to allow man to live adjacent to water. One method is to leave the natural vegetation and allow the mangroves and salt marsh to control erosion, a task for which they were so well designed. Houses built on stilts elevate their residents and provide not only a scenic view over the natural shoreline vegetation, but also assurance against storm and hurricane tides. The natural shoreline additionally provides habitat for numerous birds, fish, and invertebrates. Depending on the shoreline width, it may also help cleanse water flowing through it.

A second method is to build a low wall of rip-rap. Rip-rap, with its wealth of crevices, holes, and surface area, provides a habitat for algae and invertebrates. It may also provide protection for ingrowing mangove seedlings and other shoreline vegetation. It is relatively inexpensive and extremely strong and stable. Depending on the material used to create the rip-rap wall, it can also be aesthetically appealing.

Rational Canal Design:

The early approach to canal designing was to maximize waterfront property in relation to shoreline space. Traditional designs provided little potential for effective flushing. This most always leads to water quality and biological degradation. However, Morris (1981) states that on a day to day basis, small amplitude tides, supplemented by periodic winds, in most cases provides enough energy for flushing, if the canal was designed properly. Obtaining the required energy, as Morris continues, can be accomplished by (1) eliminating unnecessary energy losses due to mechanical reasons such as right-angle bends, deep holes, and culverts and biological inbalances such as the absence of natural filtering action and nutrient uptake provided by vegetation and aquatic organisms, and (2) utilizing open channels to optimize mixing.

A good example of rational canal designing is demonstrated by a canal network currently under construction along the intracoastal waterway south of Jupiter, Florida. The site includes (Morris 1981):

> meandering channels
> large areas of intertidal channels
> sloping, vegetated banks
> elimination of dead ends
> increased tidal prism
> freshwater flow over salinity structures
> more uniform change in section through tidal entrances
> natural preserves set aside along the water
>
> The rational approach to canal design includes common sense planning, in-depth data collection, the correct application of physical chemical biological and ecological principles, and the use of judgement. The method cannot guarantee that a given design will function as planned, but it will provide the kind of guidance needed for environmentally compatible development.

Water Quality Improvements:

Indirect problems, in many cases, causes the disappearance of estuarine vegetation, especially seagrasses. Poor water quality such as high levels of organics and/or pollutants, high turbidity, and poor circulation oftentimes is the cause. Restoring vegetative habitats, especially seagrasses, in an area of poor water quality, would probably result in a failed attempt. Several methods exist to improve water quality; these, of course, depend on the type of water quality perturbation pasting at the site.

Improving sewage treatment and wastes released into the estuary would lessen the amount of introduced nutrients, this reducing the process of eutrophication. To induce better circulation in areas where circulation has been moderated or terminated, one-way tidegates, cuts, and/or culverts can be installed. Treatment of point and non-point sources of pollution, especially stormwater run-off, would decrease the amount of chemicals and toxins that are released into the estuary. These ideas represent only a few options that exist to improve water quality of damaged estuaries.

V. LINKING JUVENILE FISHERIES SPECIES TO ESTUARIES

V A. SPECIES FOUND IN ESTUARIES

Many investigators have produced rather extensive juvenile species lists for estuarine environments in Florida alone. Among them are Reid (1954) and Kilby (1955) who listed species from Cedar Key; Harrington and Harrington (1961) who recorded species from Indian River; Tabb and Manning (1961) who listed species of Florida Bay; Springer and Woodburn (1960) and Sykes and Finucane (1966) who listed fishes of Tampa Bay; and Odum and Heald (1972) who recorded species from North River estuary.

While species lists represent single point-in-time presence of juvenile fish in estuaries, studies of age and growth can document longer-term presence. An example of this concept is a two year age and growth project currently underway by DNR Bureau of Marine Research. The project involves bimonthly collections of juvenile trout, drum, and related species from various sites in the Tampa Bay estuary. Sites include seagrass beds, sandy bottoms, and back water sites with generally turbid water and muddy bottoms. Collections at these sites have yielded progressively larger juvenile fish of the same species, indicating that these fish live and grow within the estuarine system. In addition, this study will document growth rates, site preference, and arrival time of new post-larvae that indirectly indicates spawning times of adults.

Table 4 lists the recreational and commercial fishes of Florida. Robins et al. (1980) provided the scientific and common names. Commercial species are defined as those recorded in Florida Landings (Florida

Table 4. FLORIDA RECREATIONAL AND COMMERCIAL SPECIES

FAMILY/SPECIES	ESTUARINE-DEPENDENT	RECREATIONAL EAST	RECREATIONAL WEST	COMMERCIAL EAST	COMMERCIAL WEST
Carcharhinidae - requiem sharks					
(Carcharhinus spp.)	+	X	X	X	X
Sphyrnidae - hammerhead sharks					
Hammerheads, bonnethead (Sphyrna spp.)	+	X	X	X	X
Acipenseridae - sturgeons					
Atlantic sturgeon (Acipenser o. oxyrhynchus)	-	X		X	
Gulf sturgeon (Acipenser oxyrhynchus desotoi)	-		X		X
Shortnose sturgeon (Acipenser brevirostrum)	-	X		X	
Albulidae - bonefishes					
Bonefish (Albula vulpes)	+	X	X		
Elopidae - tarpons					
Ladyfish, Tenpounder (Elops saurus)	+	X	X		
Tarpon (Megalops atlantica)	+	X	X		
Clupeidae - herrings					
Alabama shad (Alosa alabamae)	+				X
Alewife (Alosa pseudoharengus)	+			X	X
American shad (Alosa sapidissima)	+			X	X
Atlantic thread herring (Opisthonema oglinum)	-		X		
Atlantic menhaden (Brevoortia tyrannus)	+			X	
Gulf menhaden (Brevoortia patronus)	+				X
Spanish sardines (Sardinella aurita)	-			X	X
Ariidea - sea catfishes					
Gafftopsail catfish (Bagre marinus)	+	X	X	X	X
Sea catfish (Arius felis)	+	X	X	X	X
Exocoetidae - flying fishes					
Ballyhoo (Hemiramphus brasiliensis)	-			X	X
Carangidae - jacks and pompanos					
Blue runner (Caranx crysos)	+	X	X	X	X
Cigarfish, scad (Decapterus spp.)	-			X	X
Crevalle jack (Caranx hippos)	+	X	X	X	X
Florida pompano (Trachinotus carolinus)	+	X	X	X	X
Greater amberjack (Seriola dumerili)	-	X	X	X	X
Permit (Trachinotus falcatus)	+	X	X	X	X
Centropomidae - snooks					
Snook (Centropomus pectinatus)	+	X	X		
Coryphaenidae - dolphins					
Dolphin (Coryphaena hippurus)	-	X	X	X	X

Table 4. FLORIDA RECREATIONAL AND COMMERCIAL SPECIES (Continued)

FAMILY/SPECIES	ESTUARINE-DEPENDENT	RECREATIONAL EAST	RECREATIONAL WEST	COMMERCIAL EAST	COMMERCIAL WEST
Ephippidae - spadefishes					
Atlantic spadefish (*Chaetodipterus faber*)	+	X	X		
Gerreidae - mojarras					
Spotfin mojarra (*Eucinostomus argentus*)	+	X	X	X	X
Striped mojarra (*Diapterus plumieri*)	+	X	X		
Yellowfin mojarra, sand perch, goatfish (*Gerres cinereus*)				X	X
Silver jenny (*Eucinostomus gula*)	+	X	X	X	X
Haemulidae - grunts					
Pigfish (*Orthopristis chrysoptera*)	+	X	X	X	X
Tomtate (*Haemulon aurolineatum*)	+	X	X		
White grunt (*Haemulon plumieri*)	+	X	X	X	X
Istiophoridae - billfishes					
Blue marlin (*Makaira nigricans*)	-	X	X	X	X
Sailfish (*Istiophorus platypterus*)	-	X	X		
White marlin (*Tetrapturus albidus*)	-	X	X	X	X
Labridae - wrasses					
Hogfish (*Lachnolaimus maximus*)	-			X	X
Lobotidae - tripletails					
Tripletail (*Lobotes surinamensis*)	+	X	X	X	X
Lutjanidae - Snappers					
Cubera snapper (*Lutjanus cyanopterus*)	+	X	X	X	X
Lane snapper (*Lutjanus synagris*)	+	X	X	X	X
Mangrove (Gray) snapper (*Lutjanus griseus*)	+	X	X	X	X
Mutton snapper (*Lutjanus analis*)	+	X	X	X	X
Red snapper (*Lutjanus campechanus*)	+	X	X	X	X
Vermillion snapper (*Rhomboplites aurorubens*)	-	X	X	X	X
Yellowtail snapper (*Ocyurus chrysurus*)	-	X	X	X	X
Malacanthidae - tilefishes					
Tilefish (*Lopholatilus chamaeleonticeps*)	-			X	X
Mugilidae - mullets					
Black mullet (*Mugil cephalus*)	+	X	X	X	X
Fantail mullet (*Mugil trichodon*)	+			X	X
Silver, white mullet (*Mugil curema*)	+			X	X
Percichthyidae - temperate basses					
Striped bass (*Morone saxatilis*)	+	X	X		
Pomacanthidae - angelfishes					
Angelfish (*Holacanthus* or *Pomacanthus* spp.)	-			X	X

Table 4. FLORIDA RECREATIONAL AND COMMERCIAL SPECIES (Continued)

FAMILY/SPECIES	ESTUARINE-DEPENDENT	RECREATIONAL		COMMERCIAL	
		EAST	WEST	EAST	WEST
Pomatomidae - bluefishes					
Bluefish (*Pomatomus saltatrix*)	+	X	X	X	X
Rachycentridae - cobias					
Cobia (*Rachycentron canadum*)	+	X	X	X	X
Sciaenidae - drums					
Atlantic croaker (*Micropogon undulatus*)	+	X	X	X	X
Black drum (*Pogonias cromis*)	+	X	X	X	X
Grey seatrout (*Cynoscion regalis*)	+	X		X	
King whiting, southern kingfish (*Menticirrhus americanus*)	+	X	X	X	X
Red drum (*Sciaenops ocellatus*)	+	X	X	X	X
Sand seatrout (*Cynoscion arenarius*)	+	X	X	X	X
Silver perch (*Bairdiella chrysura*)	+	X	X		
Spot (*Leiostomus xanthurus*)	+	X	X	X	X
Spotted seatrout (*Cynoscion nebulosus*)	+	X	X	X	X
White, silver seatrout (*Cynoscion nothus*)	-	X	X	X	X
Scombridae - mackerels and tunas					
Bigeye tuna (*Thunnus obesus*)	-	X	X		
Blackfin tuna (*Thunnus atlanticus*)	-	X	X		
Bluefin tuna (*Thunnus thynnus*)	-	X	X		
Little tunny (*Euthynnus alletteratus*)	-	X	X	X	X
Skipjack tuna (*Euthynnus pelarnis*)	-	X	X	X	X
Frigate mackerel (*Auxis thazard*)	-	X	X	X	X
King mackerel (*Scomberomorus cavalla*)	+	X	X	X	X
Spanish mackerel (*Scomberomorus maculatus*)	+	X	X	X	X
Serranidae - sea basses					
Bank sea bass (*Centropristis ocyurus*)	-		X		X
Black sea bass (*Centropristis striata*)	-	X	X	X	
Gag grouper (*Mycteroperca microlepis*)	+	X	X	X	X
Jewfish (*Epinephelus itajara*)	+	X	X	X	X
Red grouper (*Epinephelus morio*)	+	X	X	X	X
Rock sea bass (*Centropristis philadelphica*)	+	X	X		
Southern sea bass (*Centropristis melana*)	+	X	X		
Warsaw (*Epinephelus nigritus*)	-	X	X	X	X
Sparidae - porgies					
Pinfish (*Lagodon rhomboides*)	+	X	X		
Scup (*Stenotomus chrysops*)	?			X	X
Sheepshead (*Archosargus probatocephalus*)	+	X	X	X	X
White snapper, porgy (*Calamus* spp.)	?	X	X	X	X

Table 4. FLORIDA RECREATIONAL AND COMMERCIAL SPECIES (Continued)

FAMILY/SPECIES	ESTUARINE-DEPENDENT	RECREATIONAL EAST	RECREATIONAL WEST	COMMERCIAL EAST	COMMERCIAL WEST
Sphyraenidae - barracudas					
Great barracuda (*Sphyraena barracuda*)	+	X	X	X	X
Guaguanche (*Sphyraena guaguancho*)	+	X	X	X	X
Xiphiidae - swordfishes					
Swordfish (*Xiphias gladius*)	-	X	X	X	X
Bothidae - lefteye flounders					
Gulf flounder (*Paralichthys albigutta*)	+		X		X
Southern flounder (*Paralichthys lethostigma*)	+	X	X	X	X
Summer flounder (*Paralichthys dentatus*)	+	X		X	
Balistidae - leatherjackets					
Triggerfish (*Balistes capriscus*)	+	X	X	X	X
Tetraodontidae - puffers					
Southern puffer (*Sphoeroides nephelus*)	+	X	X		
CRUSTACEANS, SPONGES, AND MOLLUSKS					
Spongiidae - sponges					
Glove sponge (*Spongia* spp.)	+			X	X
Grass sponge (*Spongia graminea*)	+			X	X
Sheepswool sponge (*Hippiospongia lachne*)	+			X	X
Yellow sponge (*Spongia zimocca*)	+			X	X
Loliginidae: Squid (*Loligo plei*)	-			X	X
Strombidae: Conch (*Strombus gigas*)	+	X	X	X	X
Ostreidae: Oyster (*Crassostrea virginica*)	+	X	X	X	X
Pectinidae: Scallops (*Argopectin irradians*)	+	X	X	X	X
Veneridae: Clam (*Mercenaria mercenaria*)	+	X	X	X	X
Penaeidae: Brown shrimp (*Penaeus aztecus*)	+	X	X	X	X
Pink shrimp (*Penaeus duorarum*)	+	X	X	X	X
White shrimp (*Penaeus setiferus*)	+	X	X	X	X
Sicyoniidae: Rock shrimp (*Sicyonia brevirostris*)	+	X	X	X	X
Palinuridae: Spiny lobster (*Panulirus argus*)	+	X	X	X	X
Portunidae: Blue crab (*Callinectes sapidus*)	+	X	X	X	X
Xanthidae: Stone crab (*Menippe mercenaria*)	+	X	X	X	X

Department of Natural Resources, 1978). Considering that certain species may or may not be regarded as recreational, depending on the fisherman, recreational species are here defined as any fish caught and kept by saltwater anglers, all fish currently listed as a Florida record catch (a co-sponsored DNR/IGFA project in developmental stages), and all species pursued by sports fishermen. Species designated as non-food fishes (typically bait fish) are included only as commercial species. Of 108 total species, 89 are caught commercially (85 on the east coast, 83 on the west coast), and 88 represent the recreational catch (84 on the east coast, 83 on the west coast).

Table 4 also indicates which species reside in estuaries during some time in their lives. This information is based on literature citations that indicate the presence within an estuary of any sub-adult stage of the species listed. 71.9% (n=64) of the commercial species and 73.9% (n=65) of the recreational species dwell in estuaries at least as pre-adults. Of the total commercial and recreational species, 68.5% (n=74) use estuaries as nursery grounds. These amounts are significant, especially considering the importance of fishing industries in Florida. Adding to this information is the report by McHugh (1976) who estimated, using 1970 statistics, that 98% by weight of all Gulf of Mexico landings are estuarine-dependent.

Unfortunately, the simple presence of young stages within an estuary is not enough proof of the use of estuaries as nursery grounds. A link must be established. Several methods exist to define this link. Direct evidence can be attained by diet analyses and feeding studies. Indirect evidence is provided by stable isotope analyses, correlations between fisheries yield and habitat type, and correlations between declines in fisheries yield and wetlands destruction.

V B. DIET ANALYSES

Many researchers have examined gut contents to determine diet. Table 5 lists some recreational and commercial juvenile estuarine fishes along with items found in their digestive tracts. An attempt was made to include only fishes reported as less than or equal to 100mm in length, regardless of species, to insure juvenile age class. Food items found most commonly (composing over 50% of the gut content) are underlined.

Three obvious conclusions can be drawn from the table: (1) juvenile fish utilize several food sources, (2) differing species share common food sources, and (3) diets change as fish grow. These conclusions emphasize four (#1, #3, #4 and #5) of Miller and Dunn's (1980) features of juvenile fish feeding relationships as discussed in the previous section.

The most common food items found in digestive tracts of the majority of species are copepods, shrimp, mysids, amphipods, fish, and polychaetes. A subsequent food chain study would require a diet analysis of each of these animal groups. However, within each group, no single feeding strategy exists, especially for those groups occupying the sub-tropical shoreline waters of Florida. Within the polychaete group, for example, omnivores, herbivores, deposit feeders, carnivores, and detritivores are found, each consuming a wide variety of food items. Diet studies of these groups are feasible and certainly important, but must be very specific.

Table 5. DIET ANALYSES OF SOME PRE-ADULT RECREATIONAL AND COMMERCIAL ESTUARINE FISH

Species	Size (mm)	Code for Food[1]	Reference[2]
Ladyfish	19-38	120,132	106
Atlantic thread herring	21-40	230	14
	Juvenile	300	6
	>40	120,140,131,230	14
Sea catfish	small	620,160,100	90
Crevalle jack	79	600	61
Permit	15-20	140,135	14
	15-44	160,420,221	38
	26-35	610	14
	>35	900	14
	50-100	180,200	38
Silver jenny	11-15	120	14
	16-39	120,911	14
	19-70	160,120,400	102
	>35	911	14
Striped mojarra	35-172	140,160,410	106
Pigfish	12-15	120,110,210	60
	16-20	120	14
	21-30	120,135 and/or 140,630	14
	31-40	135 and/or 140,911,120	14
	40-100	160,135,133,200,911	60
	41-55	911,135 and/or 140,160,120,630	14
	56-80	135,911,134,630,210,120	14
White grunt	21-35	120,140 or 135,500	14
	36-40	140 or 135,120	14
Black mullet	Juvenile	500,510	61
Atlantic croaker	10-39	911,400,160,120	130
	10-49	300,700,500,510	61
	17-42	200,110,120,911,600	156
	<39	120,100	133
	40-49	121,120,141,100	133
	40-89	911,400,160,120,500,140,135	130
	50-59	100,141,120	133
	50-124	510,500,300,700,600	61
	60-79	121,141,120,100	133
	80-99	120,100,911,141	133

[1]Code list located on page .
[2]Numbers refer to references listed in Section X.

Table 5. DIET ANALYSES OF SOME PRE-ADULT RECREATIONAL AND COMMERCIAL ESTUARINE FISH (continued)

Species	Size (mm)	Code for Food	Reference
Grey seatrout	30-49	121,100,141	133
	50-99	141,911,100	133
Red drum	0-19	120,140	4
	20-39	140,120,160	4
	40-49	160,140,600	4
	50-69	600,160,911	4
	70-99	160,911,133,600,511,512	
Sand seatrout	10-39	140,120,135,600	130
	40-99	600,140,135,300	61,130
Silver perch	6-30	120,630,600,135 or 140,160, 110,170,140,911	14,60,90, 106
	23-63	130,140,410,160,610	90
	25-50	140,135,133	60
	25-99	135,120,160,200,911,600,100	122
	30-39	121	133
	31-35	120,135 and/or 140	14
	36-70	135,120,160,100	14
	40-69	911,121,100	133
	50-80	140,135,161,911	60
	60-82	140	156
	70-99	141,100	133
	Larval	120,630	102
Spot	<25	120,110	60
	Post-larval	120	70
	15-100	500,200,910,100	60
	20-69	911,500,120,920,140,220,400	130
	40-99	700,500,510	61
	50-99	120,121	133
Spotted seatrout	20-100	120,140,138	97
	20-130	600,135 and/or 140,120,160	14
	25-150	140,137	138
	40-99	600,300,700,800,500,510	61
	68-122	140,160,410,138,610	102
Pinfish	10-30	120,160,135 and/or 140,1100, 911,100	14
	15-50	135,160,120	122
	31-65	160,1100,911,135 and/or 140	14
	39-61	222,140,160,223	106
	40-99	700,500,800,600	61
	51-100	120,135,510,160,200,133,600, 1400	122
	66-90	135 and/or 140,1100,600,500	14
	<76	1200,100,911,2000	53
	Post-larval	120	70

Table 5. DIET ANALYSES OF SOME PRE-ADULT RECREATIONAL AND COMMERCIAL ESTUARINE FISH (continued)

Species	Size (mm)	Code for Food	Reference
Sheepshead	<40	120,160,410,140,1300,200	106
Southern puffer	6-25	500,300,911,210,133,135	14

DIET CODE LIST

100 Crustaceans
- 110 Ostracods
- 120 Copepods
  - 121 *Pseudodiaptomus coronatus*
- 130 Decapods
  - 131 Megalops larvae
  - 132 Crab zooae
  - 133 Crabs
  - 134 Xanthid crabs
  - 135 Shrimp
  - 136 Post larval shrimp
  - 137 Penaeid shrimp
  - 138 Cariddean shrimp
- 140 Mysids
  - 141 *Neomysis americana*
- 150 Isopods
- 160 Amphipods
  - 161 Gammarid amphipods
- 170 Cladocereans
- 180 Larger crustaceans

200 Mollusks
- 210 Gastropods
- 220 Bivalves
  - 221 *Donax variabilis*
  - 222 *Brachidontes exustus*
  - 223 *Congeria leucophaeta* (now called *Mytilopsis leucophaeta*)
  - 230 *Veliger larvae*

300 Zooplankton

400 Insect larvae
- 410 Chironomids
- 420 Larval and adult Dipteran insects

500 Detritus
- 510 Organic matter
  - 511 Animal remains
  - 512 Fecal pellets

600 Fish
- 610 Small fish
- 620 Fish eggs
- 630 Fish larvae

700 Micro-invertebrates

800 Larger invertebrates

900 Benthic invertebrates
- 910 Annelids
  - 911 Polychaetes
- 920 Nematodes

1000 Vegetation
- 1100 Epiphytes
- 1200 Diatoms
- 1300 Algae
- 1400 Plant debris

2000 Chordates

300 Zooplankton: mostly copepods, mysids, larval penaeid shrimp

700 Micro-invertebrates: small bivalves, isopods, amphipods, small crabs, chironomid larvae

800 Larger invertebrates: mud crabs, blue crabs, shrimp spp.

500 Detritus: decaying marsh grasses, phytoplankton, zooplankton, micro-benthic animals

Since most sources of Table 5 reported food items as groups, i.e. copepods and polychaetes, without knowing the exact species serving as food items, no conclusions can be drawn. However, using gut analyses to link seagrasses and mangroves to juvenile fishes has potential, although available knowledge about different trophic levels and their food items does not provide enough information to concretely link juvenile species to primary producers.

V C. STABLE ISOTOPE ANALYSES

Carbon, the element upon which all life is based, occurs on Earth in three isotopic forms (^{12}C, ^{13}C, and ^{14}C), and all prove useful in scientific investigations. Radioactive ^{14}C, due to its inherent instability and, therefore, its rate of decay, provides an extremely valuable tool for dating fossils.

^{12}C and ^{13}C occur as stable isotopes. Because the two isotopes react at different rates during photosynthesis, every primary producer embodies a certain ratio of the two isotopes, specific to the plant or plant group. The ratio, known as the relative ^{13}C content ($\delta^{13}C$), is determined by the equation

$$\left(\frac{^{13}C/^{12}C \text{ sample}}{^{13}C/^{12}C \text{ standard}} - 1 \right) 10^3$$

in which the standard refers to the PDB marine carbonate standard (Craig, 1953). $\delta^{13}C$ is typically measured in parts per million ($^o/oo$).
Because the standard has a higher ratio than almost all other carbon-based materials, most materials have negative values. C_3 plants (those that

convert carbon dioxide to a 3-carbon molecule) possess $\delta^{13}C$ values between about -21 and $-34^{o}/oo$ (Wong and Sacket 1978; Sacket, in press). C_4 plants (those that convert carbon dioxide to a 4-carbon compound) maintain values of approximately -6 to $-19^{o}/oo$ (Smith and Epstein 1971).

An interesting fact about $\delta^{13}C$ is that the ratio is maintained through the food chain. In other words, whereas primary producers fix $^{13}C/^{12}C$ into their biomass through photosynthesis, secondary consumers maintain the ratios of plants they eat. Subsequently, tertiary consumers maintain the ratio of their prey. The theory for the estuarine system follows that pre-adult fishes, existing as top carnivores (irrespective of larger fish and birds), should maintain $\delta^{13}C$ values identical to seagrasses and mangroves, if these two primary producers do indeed serve as important food sources for the estuarine system. Although the first measurements of ^{13}C were made in 1939 (Nier and Gulbransen 1939), the concept of ratio maintenance through the food chain is relatively new, and very little work has been done to date in this realm of research. A significant point is that $\delta^{13}C$ is a function of an animal's history - it provides data of feeding behaviors over time, averaging out seasonality and food availability. In comparison, gut analyses provides data for only a single point in time.

Haines and Montague (1979) recognized two significant criteria for using $^{13}C/^{12}C$ ratios to analyze food chains: (1) definite ratios must exist for food sources alternate to those under investigation, and (2) the ratio must be maintained through the food chain. Fry and Parker (1979) noted that previous studies have indicated that animals possess a ^{13}C value very near the value of their diets, however, metabolism may affect the value $\pm$ 2% between individuals or species (Minson et al. 1975; DeNiro and Epstein 1978).

No $\delta^{13}C$ studies for Lake Worth or Charlotte Harbor have been reported; however, Fry and Parker (1979) and Fry et al. (1977) investigated the Upper Laguna Madre seagrass ecosystem in Texas. The dominant seagrass at the site was Halodule wrightii with smaller areas of Thalassia testudinum and Halophila engelmanni. By comparing $\delta^{13}C$ values of fish, shrimp, and invertebrates of the seagrass system to the same species offshore, they found that benthic plants heavily influenced the carbon flow. Results from another study by Fry et al. (1982) of a Caribbean seagrass bed and coral reef suggested that benthic plants contribute 48-76% of the carbon in fish generally greater than 40mm in length. Thayer et al. (unpublished) found that deposit feeders and herbivorous invertebrates living on eelgrass blades near Beaufort, N.C. obtained about 60% of their carbon from seagrasses. In the same study, seagrasses provided omnivorous invertebrates and fishes 45% of their carbon.

Nitrogen and sulfur also are used as tracers in food web studies. Both elements have two major stable isotopes: ^{15}N and ^{14}N, and ^{32}S and ^{34}S. Joseph Zieman (Department of Environmental Science, University of Virginia, Charlottesville, VA) is currently analyzing juvenile shrimp of south Florida estuaries using carbon, nitrogen, and sulphur. Other than this study, little work has been done using tracer methods in Florida estuaries, however, the papers reported here certainly support the use of these methods as an effective tool in tracing estuarine food webs. Such tracer studies could determine the significance of different vegetation components within major estuarine systems, e.g. Charlotte Harbor and Tampa Bay. These studies could partition out the contributions of mangrove detritus, seagrasses, and phytoplankton in disturbed versus relatively undisturbed systems.

V D. CORRELATIONS BETWEEN FISHERIES YIELD AND HABITAT TYPE

Amounts of emergent and submergent vegetation and freshwater flow have been associated statistically with fisheries yield in some areas. For example, Turner (1977) related shrimp yield to acreage of marsh and submerged grassbeds as did Barrett and Gillespie (1973) who demonstrated a positive correlation between brown shrimp landings in Louisiana and marsh acreage with salinities above $10^{o}/oo$. More recently, Zimmerman et al. (1984) showed that juvenile brown shrimp in Texas were more abundant in salt marsh areas than in nonvegetated areas.

The association between faunal abundance and marine vegetation is not limited to shrimp. Macalaster (1982) showed that fish were more diverse and abundant at vegetated sites than nonvegetated sites in the Chesapeake Bay and that a decline in submerged grasses affected fisheries yield. Weinstein and Brooks (1983) determined fish species and abundance differences between a tidal creek and an adjacent seagrass bed and although both areas harbored wide ranging species, the seagrass area had higher diversity. As Weinstein and Brooks pointed out, the specifics of habitat selection and utilization are not well documented, yet we accept the theory of estuaries as nursery ground habitat based on occurrence, distribution, abundance, and gut contents of those fisheries species studied.

Yokel (1975) reported that crustacean abundance was 3.9 times larger within seagrass beds and algal mats than on nearby unvegetated bottoms.

Densities of fishes in south Florida estuaries and lagoons were found generally higher within grass beds as opposed to adjacent non-vegetated habitats (cf. Zieman 1982; Figure 5).

In addition to these reports, other studies have shown that in Thalassia beds, areas of greater plant biomass contained both a higher diversity and a greater abundance of epibenthic invertebrates than areas of lesser biomass (Heck and Orth 1980). An extremely important point is that the presence of seagrasses is critical to the presence of many other plant and animal species living within the system. In other words, if all seagrass blades were removed, much of the epibenthic faunal community would probably vanish as well. Zieman (1982) notes that "there are few other systems which are so dominated and controlled by a single species...". In summary, areas containing seagrasses are inhabited by a greater abundance

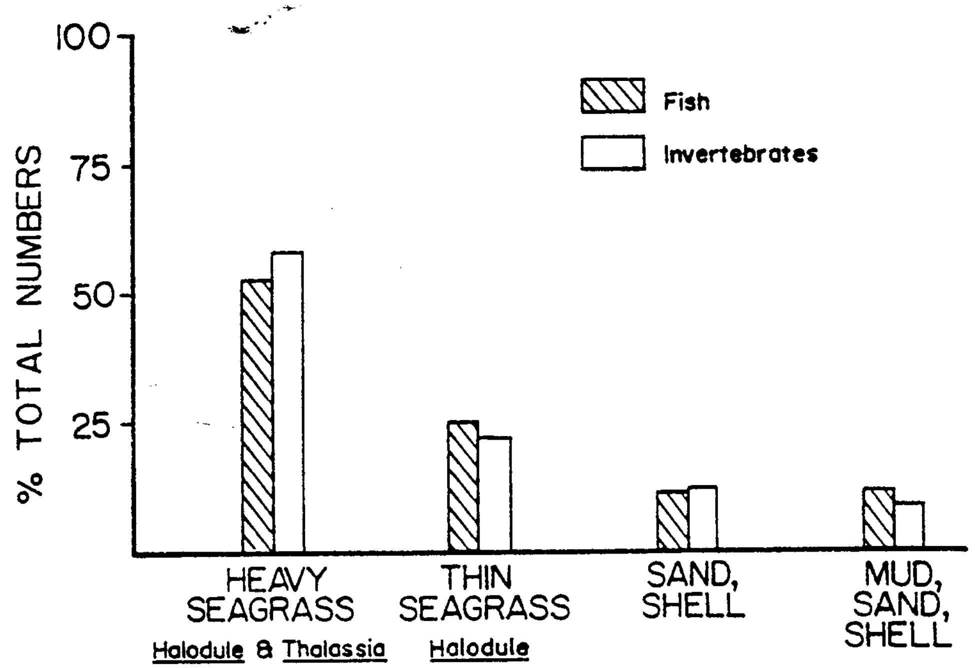


Figure 5. Relative abundance of some faunal communities within seagrass beds and within adjacent non-vegetated sites. (Redrawn from Zieman 1982, after Yokel 1975).

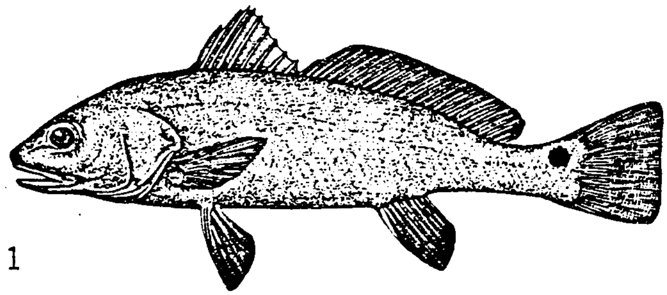
of organisms than unvegetated sites, and abundance appears to be directly related to seagrass density.

V E. CORRELATIONS BETWEEN DECLINES IN FISHERIES YIELD AND WETLANDS DESTRUCTION

Since the literature well documents the importance of estuaries as nursery grounds, it is obvious that as estuarine habitat disappears, a decline in associated fisheries also should occur. Lindall and Saloman (1977) warned that "man's physical and chemical alterations of gulf estuaries are threatening the continued production of its fisheries resources." However, they could not quantify the impact.

Two methods exist to quantify the relationship between fisheries habitat alteration and associated fisheries decline. One method is to determine carry capacities of the various habitats. In theory, carrying capacity would describe the amount of fisheries species and individuals that an area of habitat can support. As fisheries habitat is altered or destroyed, the quantity of fisheries it supports can be predicted to be destroyed as well. In practice, however, ways to determine carrying capacity are basically unknown and are under investigation.

A second method is to relate catch statistics of estuarine-dependent species to declines in estuarine habitat over a period of time. Assuming that catch effort has remained stable, that catch efforts occur at habitat carrying capacity, and that all life history stages of a species is known, this method should reflect a change in fisheries relative to changes and alterations in habitat. To test this theory, five estuarine-dependent species were chosen as target groups: red drum (Sciaenops ocellatus), spotted seatrout (Cynoscion nebulosus), black mullet (Mugil cephalus), blue crab (Callinectes sapidus), and pink shrimp (Penaeus duorarum). Fisheries statistics, though improper and inadequate as will be described in Section V E 2, of these five species were obtained for the two study sites, Charlotte Harbor and Lake Worth.



V E 1. LIFE HISTORY STUDIES

RED DRUM (Sciaenops ocellatus)[1]

Red drum spends its juvenile and early subadult stages within estuaries. Some adult populations live exclusively in the Gulf while others live in estuaries. Red drum's range extends from Buzzards Bay, Massachusetts to Key West, Florida on the Atlantic Coast and throughout the Gulf of Mexico to at least as far south as Taxpan, Mexico on the Gulf Coast.

Shrimp, crab and fish primarily comprise the diet of the adult red drum. The literature also reports annelids, echinoderms, and bryozoans as food items; these probably are ingested only incidentally. Florida red drum spawn offshore in fall, reportedly near passes and channels. Fecundity estimates for artificially conditioned and spawned red drum are 2 x 10^4 to 2 x 10^6 eggs per spawn. Fecundity of wild fish from Texas ranges from 0.5 x 10^6 to 3.5 x 10^6 eggs per fish. Tidal currents carry larvae through inlets and passes into estuarine areas where they settle out among

[1]Summarized from Perret et al. (1980)

the aquatic vegetation until they are strong enough to swim. In Florida, the smallest larval fishes (5-7mm) were always found in shallow areas in or near the Gulf. In Mississippi abundant juvenile red drum are found at the perimeter of marshes. In Florida, young fish are found in protected waters with grassy or slightly muddy bottoms that are not affected by tides. Following spawning, red drum appear to spend more time in offshore waters and less time in estuaries.

Growth of the small fishes is rapid, and continues to be rapid during the first year. A study of 106 juveniles collected from Everglades National Park found growth rates of about 20mm per month. Results from tagging studies in Florida indicated that growth is not constant throughout the year; fish exhibit a growth lag in spring, a rapid growth in summer and a slight lag at the end of summer. Food density and larval stock density influence growth as demonstrated in studies in mariculture systems.

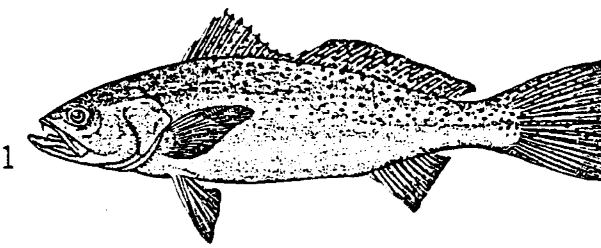
For their first winter, many red drum ranging from 50 to 150mm move to the deeper areas of estuaries. A gradual movement of fishes into the Gulf during colder weather and a definite movement back into the estuary in early spring occurs after the first year. No apparent seasonal movement of juveniles into the Gulf is known. As sub-adults, they move offshore prior to maturation and spawning.

Red drum are euryhaline and eurythermal. Although they are found in salinities from 0 to $50^{o}/oo$, they appear to prefer an optimum range of $30\text{-}35^{o}/oo$. A direct relationship between size and salinity generally occurs with smaller fish prefering low salinities and larger fish favoring higher salinities. Red drum also have the ability to tolerate a wide range of temperature. Although they are found in temperatures ranging from 2-

31.8°C, red drum are sensitive to rapid and sustained lows in water temperature.

In Florida, winter produces the greatest availability of red drum, whereas in Texas, Louisiana, and Mississippi, the greatest numbers occur in fall.

SPOTTED SEATROUT (*Cynoscion nebulosus*)[1]



The spotted seatrout is a species that spends all of its life within the estuary. Primarily found in large areas of quiet brackish water with extensive submerged vegetation, the species ranges from Cape Cod to Mexico. Reflecting the mottled appearance of seagrasses, the spotted seatrout's body is silvery with numerous dark spots on the sides and on the dorsal and caudal fins. The world-record catch was a 7.3kg fish taken in Virginia; Florida's state record is a 7kg fish.

Feeding habits of the spotted seatrout change as the fish grows. Postlarval seatrout feed on larval shrimp, copepods, small fish, and crabs. They also prey on their own species. Copepods, mysids, penaeid shrimp, and carridean shrimp comprise the diet of juveniles. Fish become an increasingly important food item during the adult stage. Adult diets most often consist of black mullet (*Mugil cephalus*), anchovies (*Anchoa* spp), pinfish (*Lagoden rhomboides*), mojarras (*Eucinostomus* sp.), sheepshead minnows (*Cyprinodon variegatos*), and penaeid shrimp (*Penaeus* sp.). It appears that any preference for food items is more a function of food availability than

[1]Summarized from Lorio and Perret (1980)

of selectivity. This theory is exemplified by studies that found that shrimp and fish were equally present in gut contents during May, June, and July, when shrimp are most abundant in the area.

The spawning season of spotted seatrout in the Gulf is generally from February through October. In Florida, spawning occurs from April through September, peaking in late May/early June. Ripe fish occur all year in Florida Bay, the southern limit of the species range, with a major peak occurring in May and a lesser peak in September. Spawning takes place at night and is believed to occur in the deeper channels and holes adjacent to grassy bays and flats. Some spawning may also take place in the tidal portions of estuaries and also outside the estuary. Fecundity estimates range from 15,000 to 150,000 eggs per spawn.

Larval spotted seatrout grow from 1.5mm at hatching to about 4.5mm in 15 days. Rapid growth continues to about 13cm by the first winter and about 24cm by the second winter. Growth lessens or ceases during winter due probably to decreased metabolism and cessation of feeding activities at lower temperatures. The most rapid growth occurs in July and August. Longevity for spotted seatrout appears to be about 8 or 9 years.

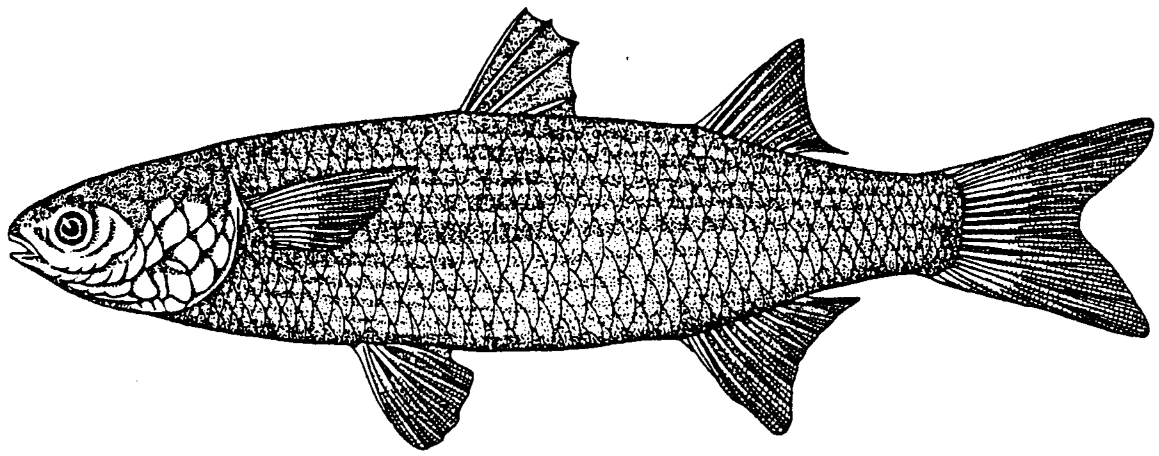
Growth rates are density dependent, and may vary from one population to another. Growth of spotted seatrout in five different estuaries along the Florida coast occurred at different rates. Because seatrout populations from given estuaries exhibit differing growth characteristics, each estuary and its population of spotted seatrout should be considered as a separate stock.

Spotted seatrout are not considered a migratory species since they seldom move more than 48.3km from their tagging site and very few leaving their natal estuary. Movement patterns appear to be associated with temperature, avoidance of fresh water, spawning, feeding, and protection.

Winter habitat throughout the species' range extends farther offshore and at greater depths. Optimum temperatures in Florida are 15 to 27°C. Temperatures below 7 to 9°C force spotted seatrout to enter ocean inlets or live offshore along the beach area for brief periods of time. However, just as they move to deeper water to escape cold water, seatrout also travel to deeper water to escape intolerable warm water.

Spotted seatrout is a euryhaline species sometimes found in freshwater and in hypersaline water of 75^{0}/oo. Normal salinity fluctuation of 5 to 30^{0}/oo is important to all productive seatrout populations, however, sudden changes in salinity may cause mass migration or mortalities. Peak spawning occurs at 30 to 35^{0}/oo, but no spawning has been reported to take place when salinity exceeded 45^{0}/oo.

Spotted seatrout are found along their range within clear to very turbid waters. The only documented negative effect of turbidity occurred in Florida Bay following Hurricane Donna when turbulent water stirred up the sandy bottom causing packing of the fishes' gill chambers and mortality. Within the food web of the estuary, the spotted seatrout represents a top carnivore, in fact in many estuaries the only carnivore present in numbers. All other aquatic organisms, either directly or indirectly, can serve as food. Because of this, the general health of the estuary must be maintained to insure healthy populations of spotted seatrout.



BLACK MULLET (*Mugil cephalus*)[1]

Black mullet represents a species that spends most of its life within the estuary except during times of seasonal migration, annual spawning, and during very young stages. Also known as striped mullet, black mullet are found throughout in coastal waters and estuaries the tropics and subtropics.

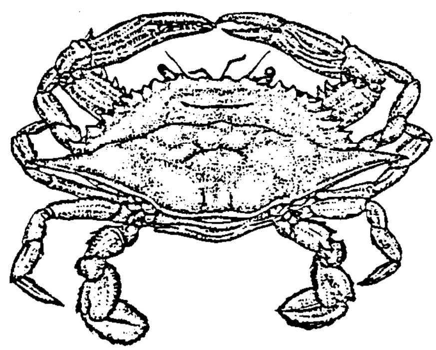
Adult and juvenile black mullet feed diurnally in bays and estuaries during high tide. Mullet feed by sucking up surface layers of muddy bottoms or by grazing on seagrasses, rocks, or other surfaces. Diatoms, dinoflagellates, copepods, plant detritus (especially attached microflora), and inorganic sediments commonly comprise their diet. When present, non-toxic plankton provides the exclusive diet. Larvae and small juveniles (2-35mm) feed on zooplankton.

[1]Summarized from Saltwater Fisheries Study and Advisory Council (1981) and Futch (1976).

Spawning takes place in Florida from October through February, peaking from November through January. Prior to spawning, mullet form large schools and migrate from the estuary to offshore waters. Along the east coast of Florida, spawning migrations move southward. The only distinct migration pattern reported for the west coast occurs from Cedar Key to Homosassa. Spawning usually occurs from 8 to 32km offshore in the Gulf of Mexico.

Females produce from 1.2 - 2.7 million eggs in a single spawn, releasing them directly into the water. Accompanying males fertilize the floating, planktonic eggs. Depending on water temperature, hatching occurs 30 - 50 hours after fertilization. Hatched larvae measure 2 - 4mm, maintaining an oceanic, planktonic existence for approximately 7 days. During this time, they grow to 20-30mm and migrate inshore, passing through inlets into the grassy parts of estuaries.

Growth rates directly correlate with water temperature and mullet from Florida mature in 1-2 years, growing to a length of 230-350mm. Black mullet live to 6-7 years and grow to about 750mm. Females typically live longer and grow larger than males.



BLUE CRAB (Callinectes sapidus)[1]

The blue crab inhabits coasts from Nova Scotia to Argentina. It is

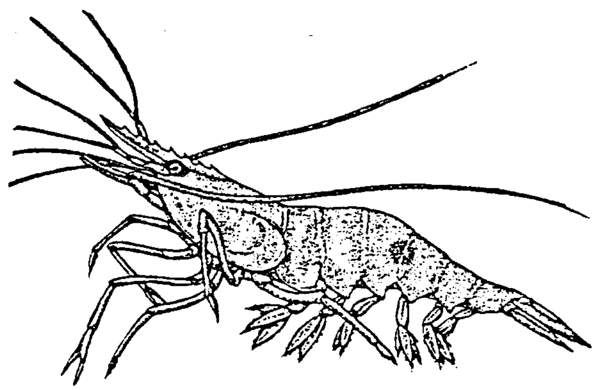
[1]Summarized from Saltwater Fisheries Study and Advisory Council (1981) and Oesterling (1976).

found from shore to approximately 90 meters in depth, but principally up to 35 meters.

The adult blue crab is characteristically omnivorous. Live and dead fish, aquatic vegetation, clams, mussels, snails, amphipods, isopods, insects and annelid worms comprise the diet of the adult blue crab. Food selection of larval crabs remains relatively unknown, however, laboratory larvae have been raised successfully on dinoflagellates, brine shrimp, and sea urchin eggs. Crabs at the megalops stage feed on fish, shellfish, and aquatic plants. Mating and spawning in Florida occur year-round, except in northern Florida waters when the water temperatures drop below 15.6°C. Female blue crabs mate only once per lifetime, during the molt from juvenile to adult. Prior to this transition, the female will move to less saline brackish waters, of 8-18^{o}/oo salinity. She will then pair with a male and will be carried, or cradled, underneath the male. While in this cradled position, the female completes her final molt into the adult. At this time, while in the soft inter-molt stage, copulation (lasting several hours) takes place. The male transfers his sperm to the female, of which she stores in seminal receptacles within her body. The sperm are able to live in this condition for about one year. After copulation, the male still cradles the female beneath him until her new shell hardens, then he releases her.

After mating, females migrate to nearshore high salinity waters (>25^{o}/oo) at the mouths of estuaries to spawn. Spawning typically occurs 1 - 9 months subsequent to mating, with peak spawning in April and June. Females spawn at least twice, each time laying 700,000 - 2 million eggs. Classically, females follow a general latitudinal onshore/offshore migration pattern. On Florida's Gulf coast, however, a tagging study conducted by DNR Bureau of Marine Research found that females migrate longitudinally, sometimes travelling over 640 km.

Females carry their eggs for 7-14 days in the offshore waters until they hatch into a zoea larvae stage. Dependent upon temperature and salinity, the seven zoea stages develop for 31-49 days, leading a planktonic existence. The following megalops stage has both planktonic and benthic features. By utilizing tidal currents, the megalops enter the estuary and molt into the first crab stage. Grass beds and a variety of shallow water areas provide habitats for growing crabs. Adult size (>120mm) is achieved within 12-14 months and 18-20 molts. Movement to deeper water occurs with increasing size. After reaching adult size, crabs live about one more year.



PINK SHRIMP (<u>Penaeus duorarum</u>)[1]

Pink shrimp range from lower Chesapeake Bay to south Florida on the Atlantic coast, throughout the Gulf of Mexico, and on the Bermuda coast. The greatest abundance of pink shrimp occurs along coastlines characterized by shallow bays and estuaries and where the continental shelf is broad and shallow. Optimum habitat varies with age; shallow, quiet, clear water with seagrass growth is preferred by young shrimp while adults live in the

[1]Summarized from Costello and Allen (1970) unless otherwise noted.

deeper offshore bottom areas with no seagrasses.

Pink shrimp spawn offshore and year round. Females release fertilized microscopic eggs into the water; the eggs then sink to the bottom. After hatching, the larvae are planktonic and are transported landward, apparently floating with currents. Three to five weeks are believed to pass before the 8mm postlarvae enter the estuaries. Mortality rates for shrimp larvae are estimated as 17% per day; extremely few make it to the estuaries. Postlarvae enter the south Florida estuaries throughout the year but are least abundant during the winter. When shrimp reach approximately 10mm, they become benthic, concentrating within shallow seagrasses, and developing into juveniles. Densities may exceed 32 individuals per m^2 within the subsequent two to four months. Shrimp grow rapidly, reaching commercially acceptable size within a few months. As they grow and mature, most shrimp gradually emigrate offshore into deeper, higher salinity water. Size at emigration averages 90-100mm. A few, however, remain in the estuaries after becoming adults. Eighty-three weeks is the estimated average maximum age.

Most shrimp that develop within the estuarine waters of southwestern Florida are captured either in the Dry Tortugas or Sanibel shrimping grounds. However, <u>most</u> offshore waters adjacent to south Florida contain maturing and adult pink shrimp, sometimes in depths to 110 meters. But much of the bottom is too rough for conventional trawling gear; a relatively smooth sandy bottom underlies the Sanbibel, Tortugas, and Hawk Channel grounds where most large pink shrimp are taken commercially (Costello and Allen 1966).

Spawning and distribution of shrimp populations may be determined by temperature and salinity. On the Tortugas grounds, shrimp spawn in waters of 19.6°-30.6°C, with highest activity coinciding with highest bottom temperatures. A rising temperature may trigger spawning activity.

Preference for various salinity regimes vary with shrimp size and geographic area. Young shrimp can survive for a short time at low salinities. In the Florida Bay area, postlarvae were caught at salinities from 12-43^{0}/oo, juveniles at 0-47^{0}/oo, and adults at 25-45^{0}/oo. The Tortugas grounds, have salinities of 36-38^{0}/oo.

Water that is mostly turbid generally harbors the largest concentrations of young shrimp per unit area. Kutkuhn (1966) suggested that since more detrital material is suspended, a greater food source and protective cover is created.

Juvenile and estuarine-dwelling adult pink shrimp are omnivorous bottom feeders, feeding primarily in shallow waters within seagrass beds. Crustaceans and polychaetes comprise the main food source of juveniles in south Florida, with no difference seasonally or with shrimp size. Stomach contents from juvenile and adult shrimp from Tampa Bay, Florida indicated indiscriminate feeding behaviors; diets consisted of sand, debris, algae, diatoms, seagrass particles, dinoflagellates, foraminiferans, nematodes, polychates, ostracods, copepods, mysids, isopods, amphipods, caridean shrimp, caridean eggs, mollusks, and fish scales. Most feeding occurs at night, though some takes place during daytime under turbid conditions.

V E 2. FISHERIES STATISTICS

Catch data for the five selected species were obtained from the annual summaries of Florida Landings (Florida Department of Natural Resources, 1950-1978). National Marine Fisheries Service (Southeast Center, Miami) provided information for 1979-1981 from their computer data base. All data include only commercial catch information. Florida Landings lists commercial catch by county of landing (processing); study sites are, therefore, defined by the counties surrounding them:

Charlotte Harbor = Charlotte and Lee Counties
Lake Worth = Palm Beach County

Catch data are graphically depicted in Figure 6 through Figure 14 for Charlotte Harbor and Figure 15 through Figure 22 for Lake Worth. Each figure with "LBS CATCH" on the y-axis shows a straight horizontal line drawn through it; this line represents the 31-year average for that species for that study site. Note, too, that the y-axis scale differs for each figure. Since data for bait shrimp catch in Lake Worth are non-existent, Lake Worth has no figure for bait shrimp.

There are five major problems associated with commercial catch data. One of the most significant difficulties concerns the location where the catch was made as opposed to the location where it was landed. Lake Worth exemplifies this problem. The use of commercial nets except cast nets in Lake Worth was banned in 1931 (Special Acts, 1931, Chapter 8796) and banned in 1955 from any inlets and in waters surrounding the inlets of Palm Beach County (Special Acts, 1955, Chapter 31137). However, Palm Beach County continuously contributes catch data, albeit low amounts, for estuary-dwelling species to the landings' data base. Illegal commercial netting supposedly occurs at night in Lake Worth; this may account for some of the reported landings, since landing the catch in Palm Beach County is not illegal. Theoretically, however, unless caught legally by hook or cast net or illegally by commercial nets, landed catch in Palm Beach was harvested outside the county. This problem of where the harvest was made is typical throughout Florida's landing statistics.

The second significant problem, most critical for this study, is the absence of effort data. Catch per unit of effort would best reveal a rise or fall in catch rate for specific sites and species. For example, Figure 8, depicting the spotted seatrout catch of Charlotte Harbor, indicates a general upward slope in landed poundage. This increase may be due to the presence of more seatrout or because of a rise in the number of fishermen. Without effort data, increases and decreases in landed amounts remain unassessable.

A third consideration is that landings data exclude recreational fisheries which, for certain species, exceed commercial efforts. Red drum and spotted seatrout, for example, are caught extensively by recreational fishermen. This concern is compounded by the fact that effort in recreational fishing has significantly increased in conjunction with the rise in Florida's population and tourist industry.

Fourth, since landings data are obtained from reports made by the commercial dealers themselves, values are only as accurate as the dealers' record; values are perhaps much higher. In addition, some commercial catch is not reported at all (e.g. live catch of blue crabs sold to restaurants.

Finally, landings data do not account for open and closed seasons or local laws. For example, bait shrimp has the potential to serve as an excellent indicator species of estuarine health, since juvenile bait shrimp grow and are captured within an estuary. However, in 1976, Charlotte County, for example, banned the use of more than 1 trawl net at a time and the trawl net must be under 25' in length (Special Acts, 1976 Chapter 76-343 as amended by Chapter 77-525). In addition, Lee County banned the practice of sweeping, dragging or hauling any nets except hand cast nets or bait nets; bait nets must not exceed 100' in length, a depth greater than 6', nor a mesh size greater than 1 3/8" (Special Acts 1947, Chapter 23951, as amended by Chapters 63-1560, 69-1236 and 69-1237). These laws must certainly affect the distribution of landing statistics. Another example concerns the local laws of Palm Beach County as described in the second paragraph of this section - commercial netting, except cast netting, is banned altogether in Lake Worth.

Existing problems in fisheries statistics can be resolved through establishing a State program. A memorandum of understanding with National Marine Fisheries (NMFS) has been signed by DNR to access aggregate commercial landings. A cooperataive agreement between NMFS and DNR is under consideration that will allow individual data access and eventually the acquisition of the commercial statistics program. Additionally, DNR has formulated a State marine fisheries statistics program that includes both commercial and recreational fisheries statistics. The program was designed to collect effort, area of catch, species composition and weight, gear type used, and biological data. The acquisition of such data augments historical data and will provide a more comprehensive data base necessary for future management strategies and decisions. Until an improved fisheries statistics program is established, the use of present Landings' data for comparing between site catch values and even trends over time may prove erroneous. However, because no other data exists, Landing's values remain as the only available information.

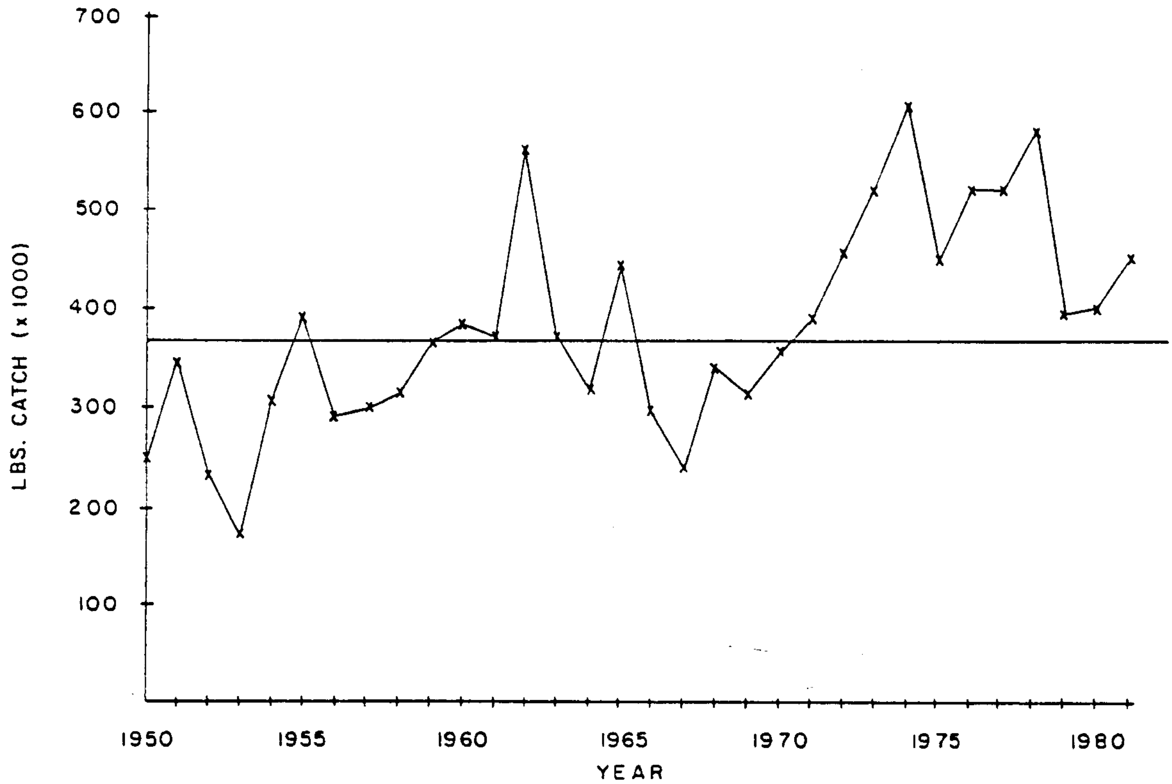


Figure 6. Annual summaries of Florida Landings for red drum landed in the Charlotte Harbor area. Horizontal line indicates the 31 year average.

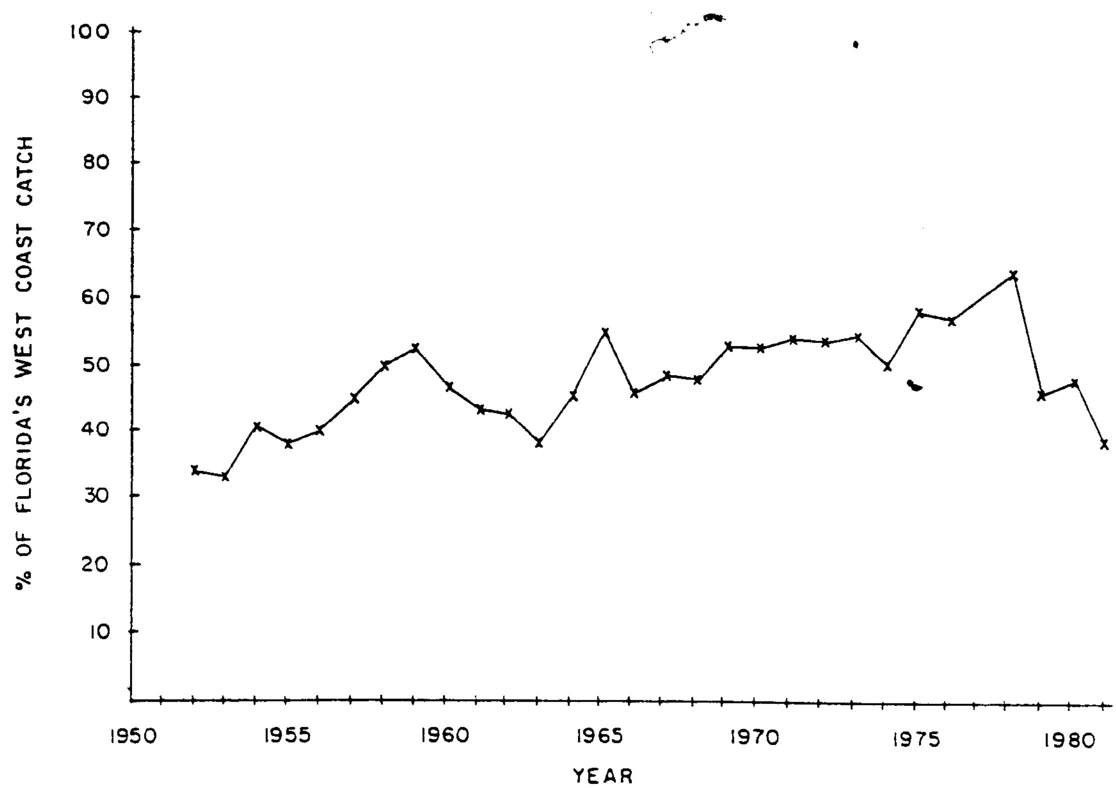


Figure 7. Annual summaries of Florida Landings for red drum landed in the Charlotte Harbor area over the amount landed for the west coast of Florida.

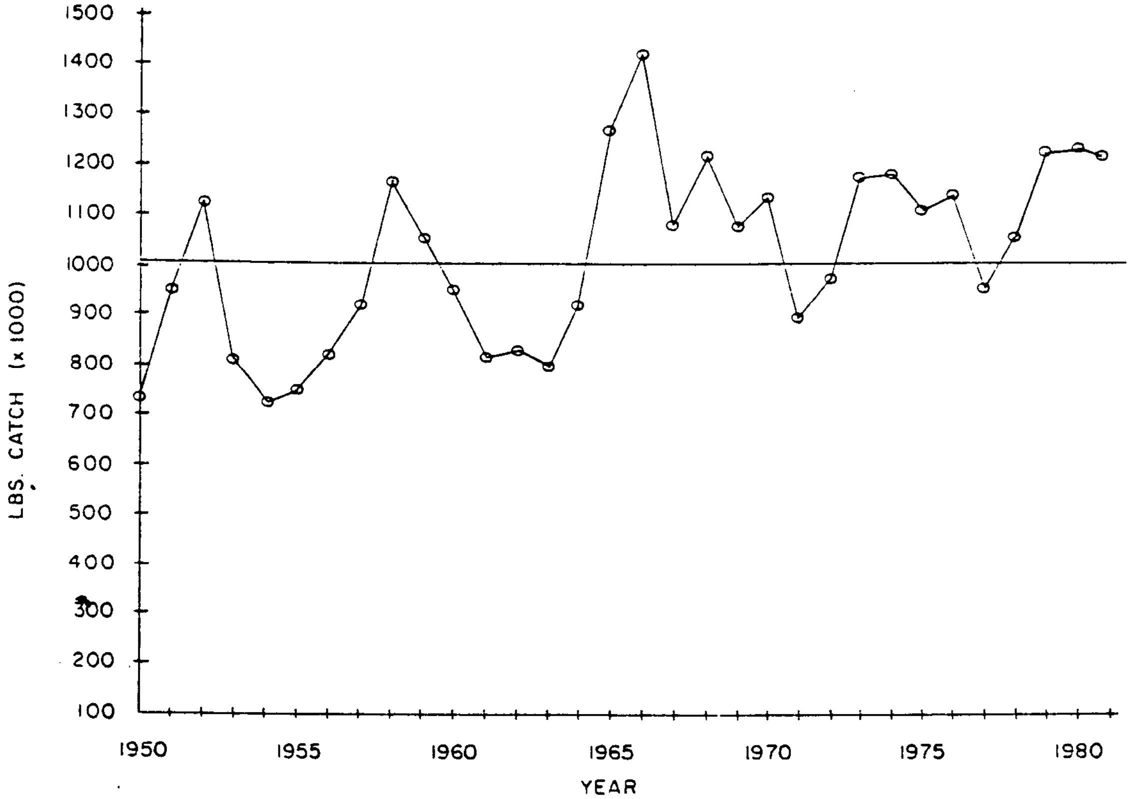


Figure 8. Annual summaries of Florida Landings for spotted seatrout landed in the Charlotte Harbor area. Horizontal line indicates the 31 year average.

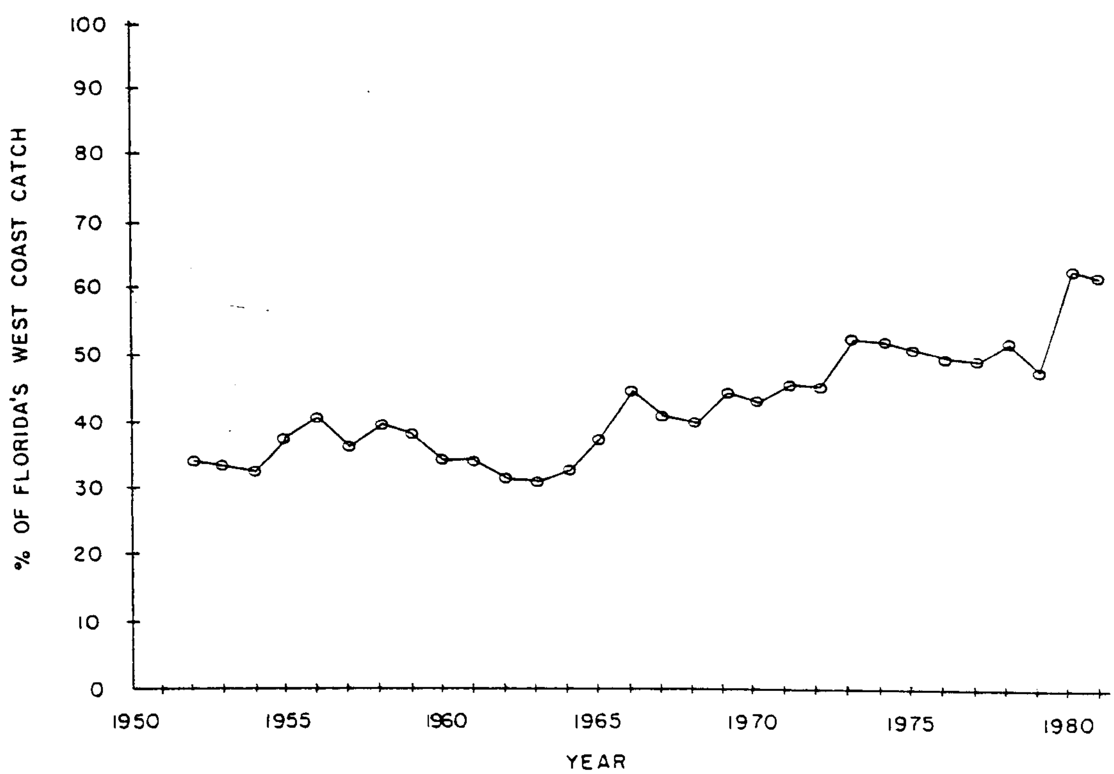


Figure 9. Annual summaries of Florida Landings for spotted seatrout landed in the Charlotte Harbor area over the amount landed for the west coast of Florida.

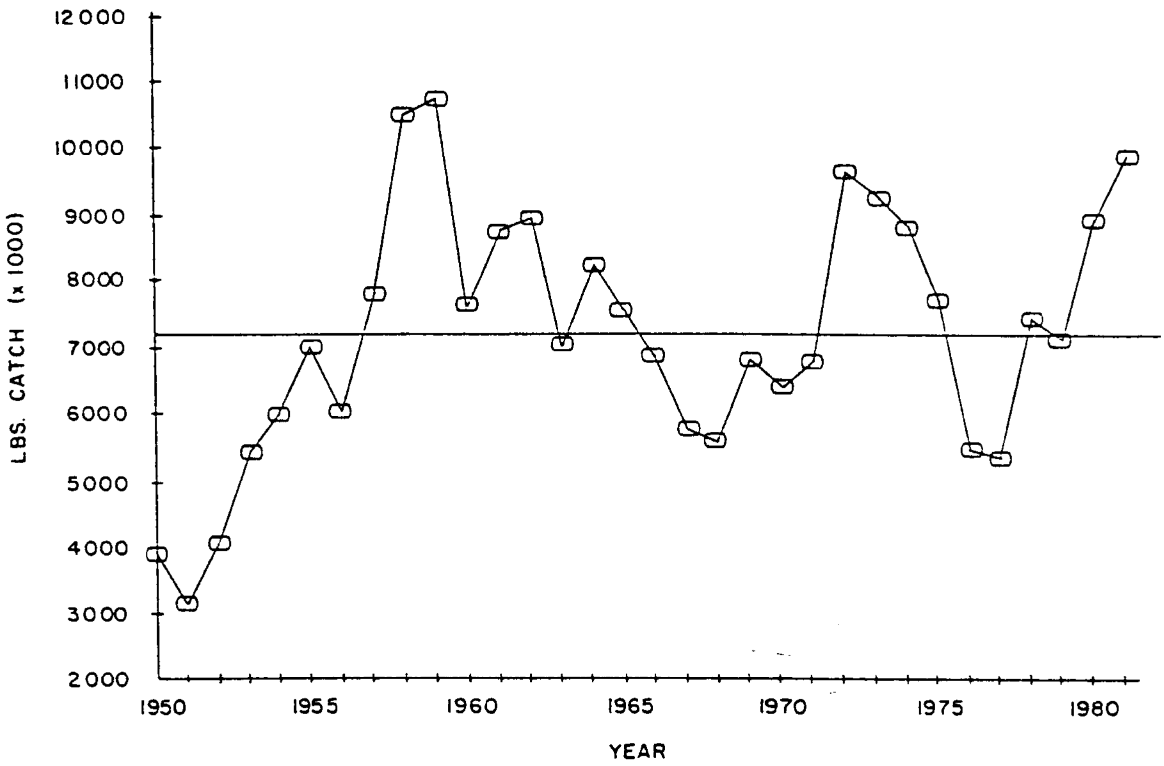


Figure 10. Annual summaries of Florida Landings for black mullet landed in the Charlotte Harbor area. Horizontal line indicates the 31 year average.

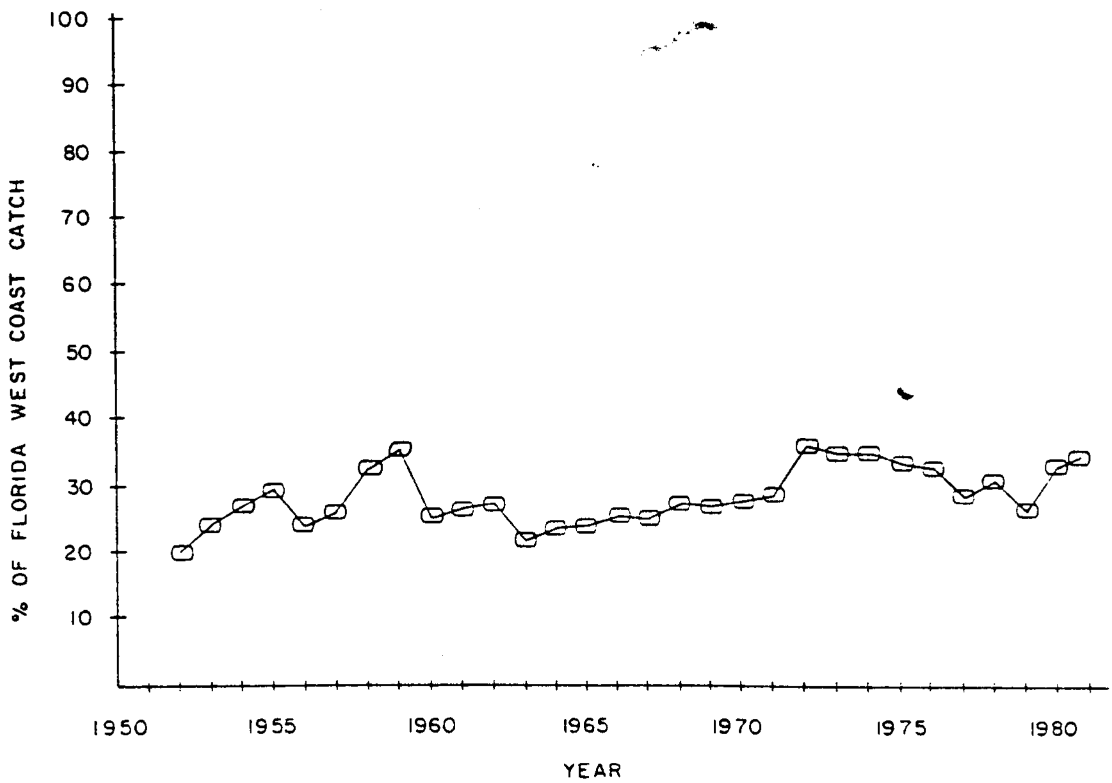


Figure 11. Annual summaries of Florida Landings for black mullet landed in the Charlotte Harbor area over the amount landed for the west coast of Florida.

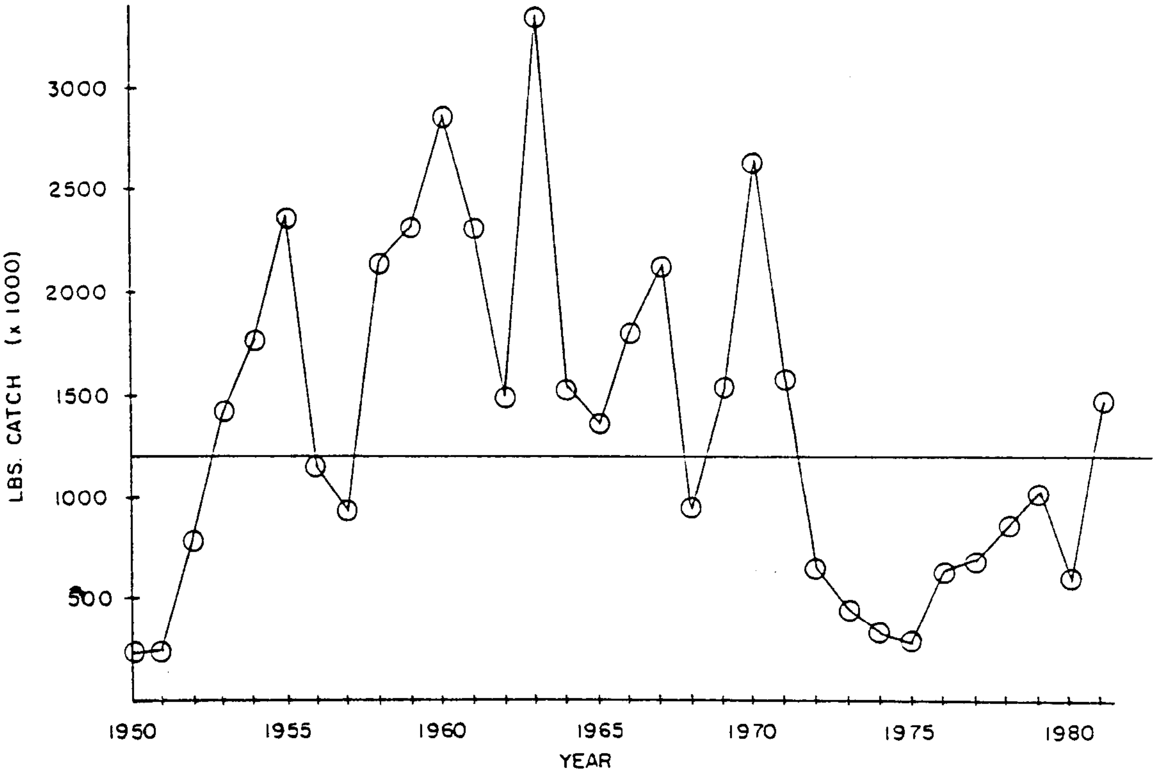


Figure 12. Annual summaries of Florida Landings for blue crab landed in the Charlotte Harbor area. Horizontal line indicates the 30 year average.

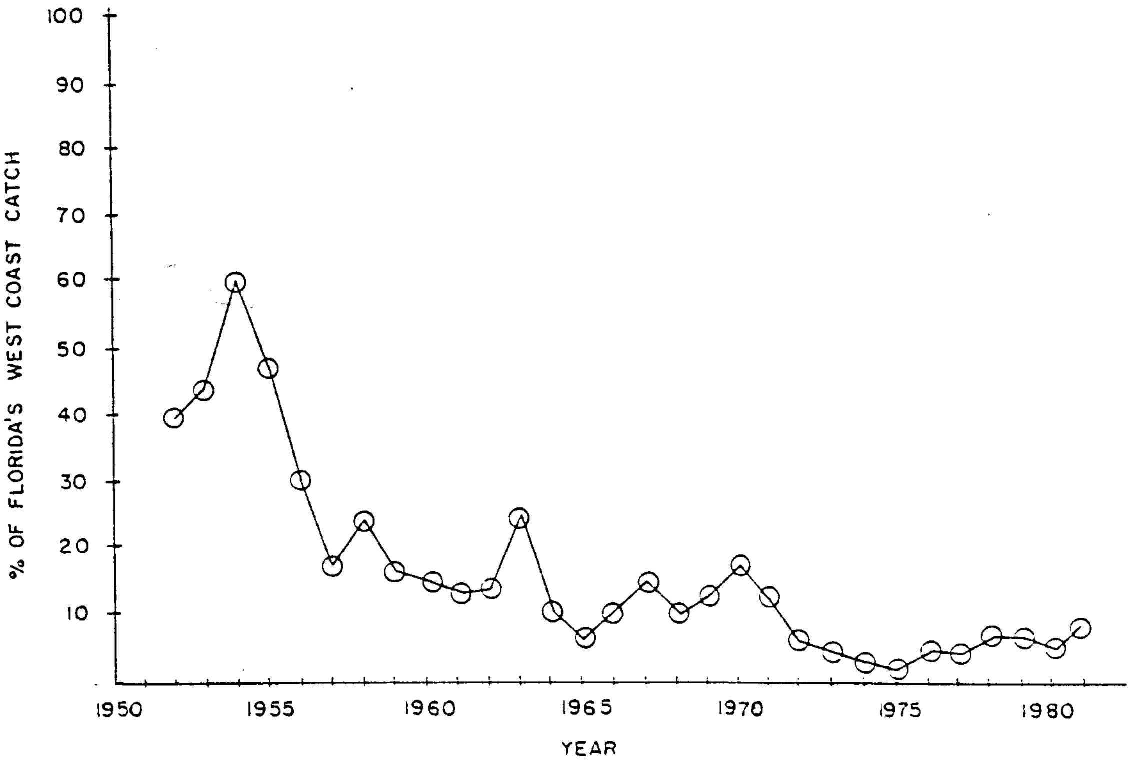


Figure 13. Annual summaries of Florida Landings for blue crab landed in the Charlotte Harbor area over the amount landed for the west coast of Florida.

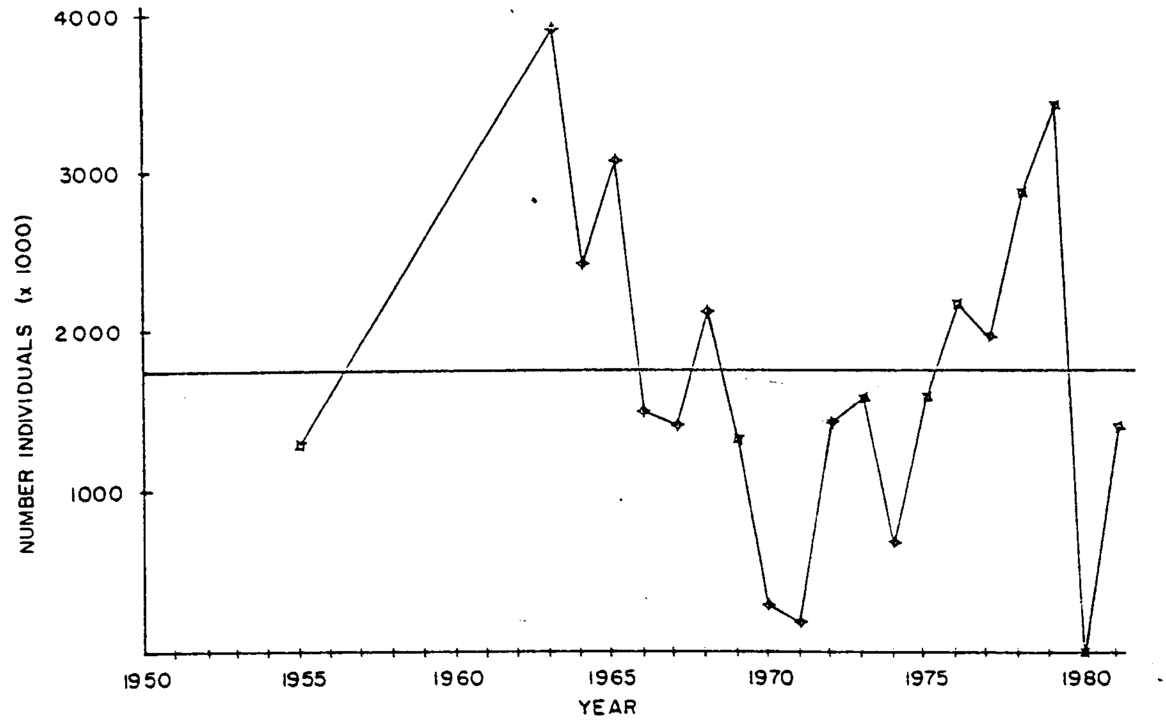


Figure 14. Annual summaries of Florida Landings for bait shrimp landed in the Charlotte Harbor area. Horizontal line indicates the 30 year average.

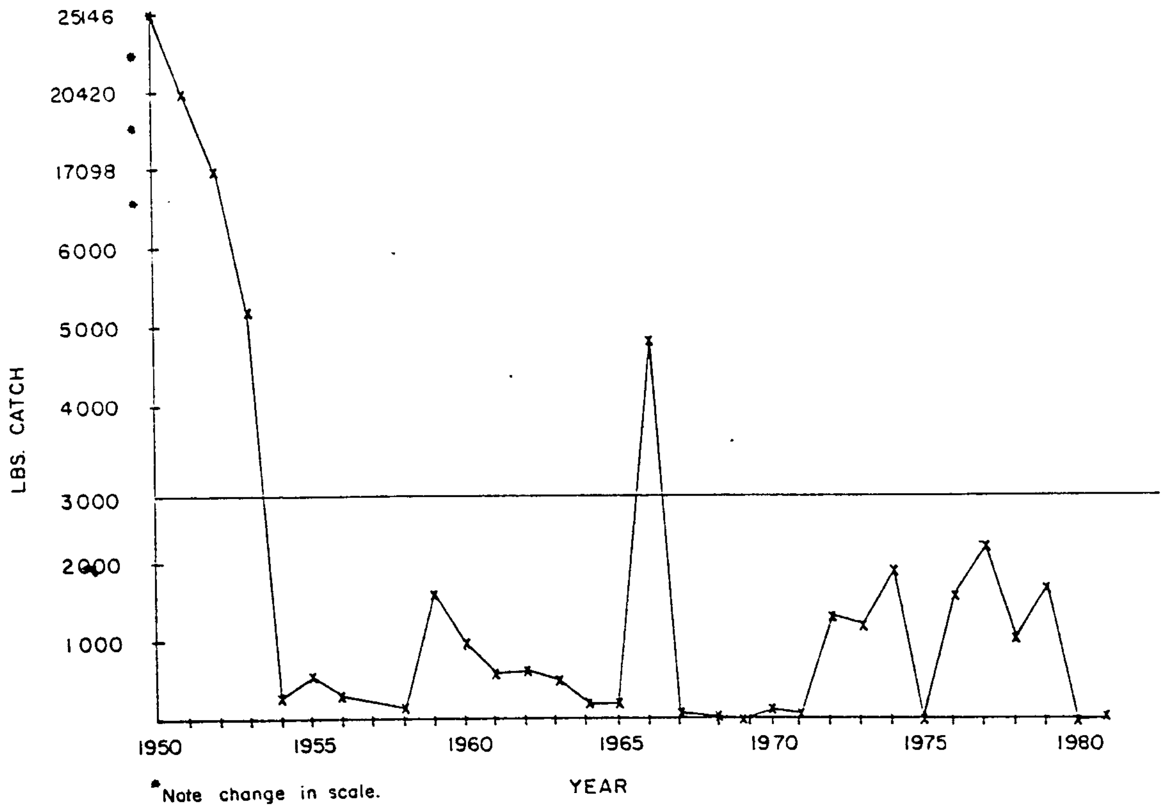


Figure 15. Annual summaries of Florida Landings for red drum landed in the Lake Worth area. Horizontal line indicates the 31 year average.

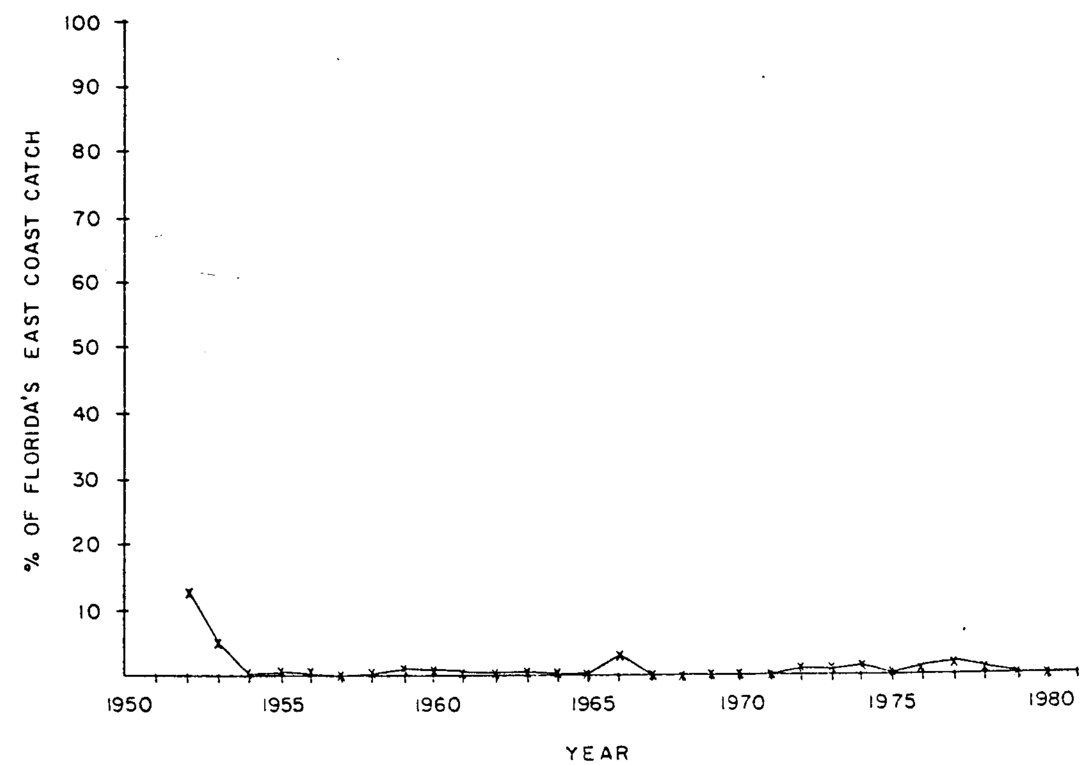


Figure 16. Annual summaries of Florida Landings for red drum landed in the Lake Worth area over the amount landed for the east coast of Florida.

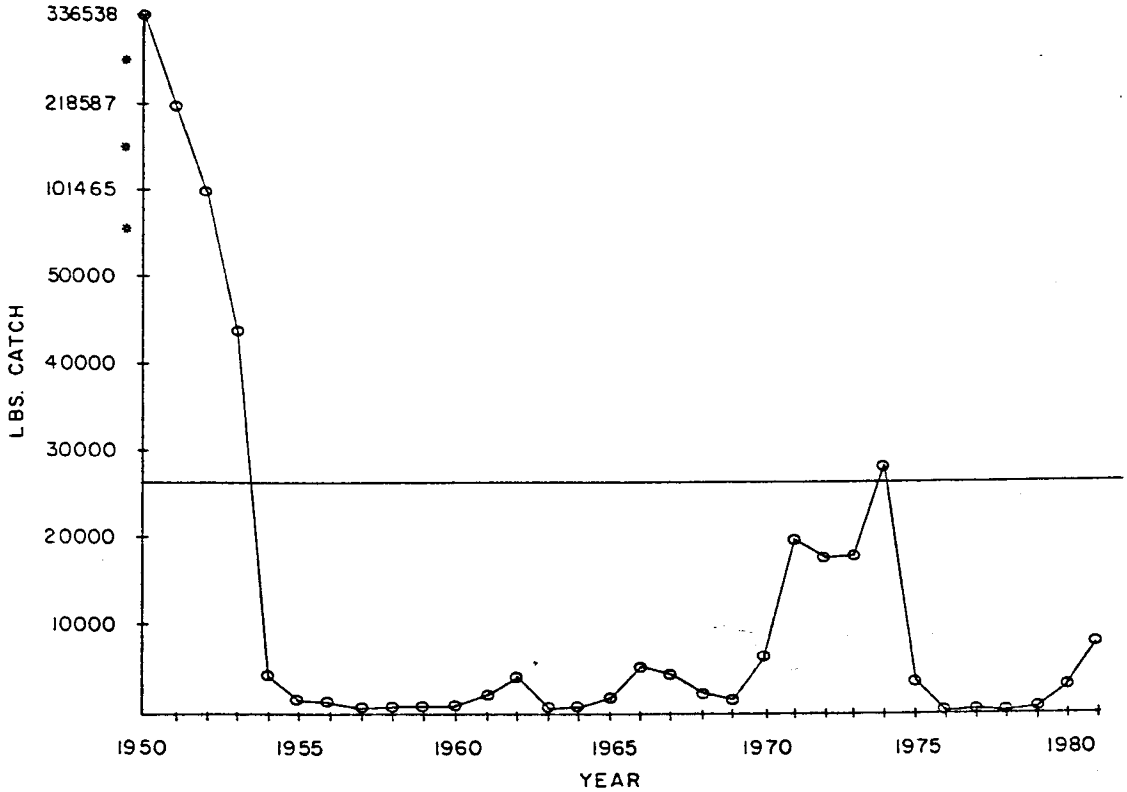


Figure 17. Annual summaries of Florida Landings for spotted seatrout landed in the Lake Worth area. Horizontal line indicates the 31 year average.

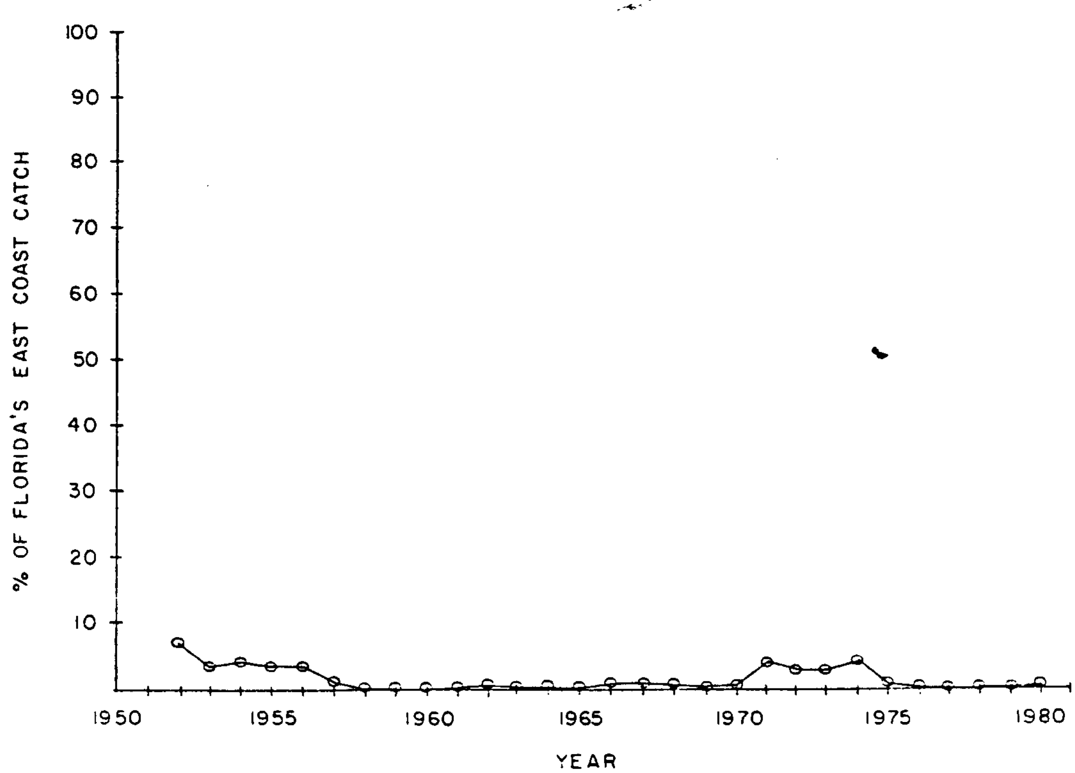


Figure 18. Annual summaries of Florida Landings for spotted seatrout landed in the Lake Worth area over the amount landed for the east coast of Florida.

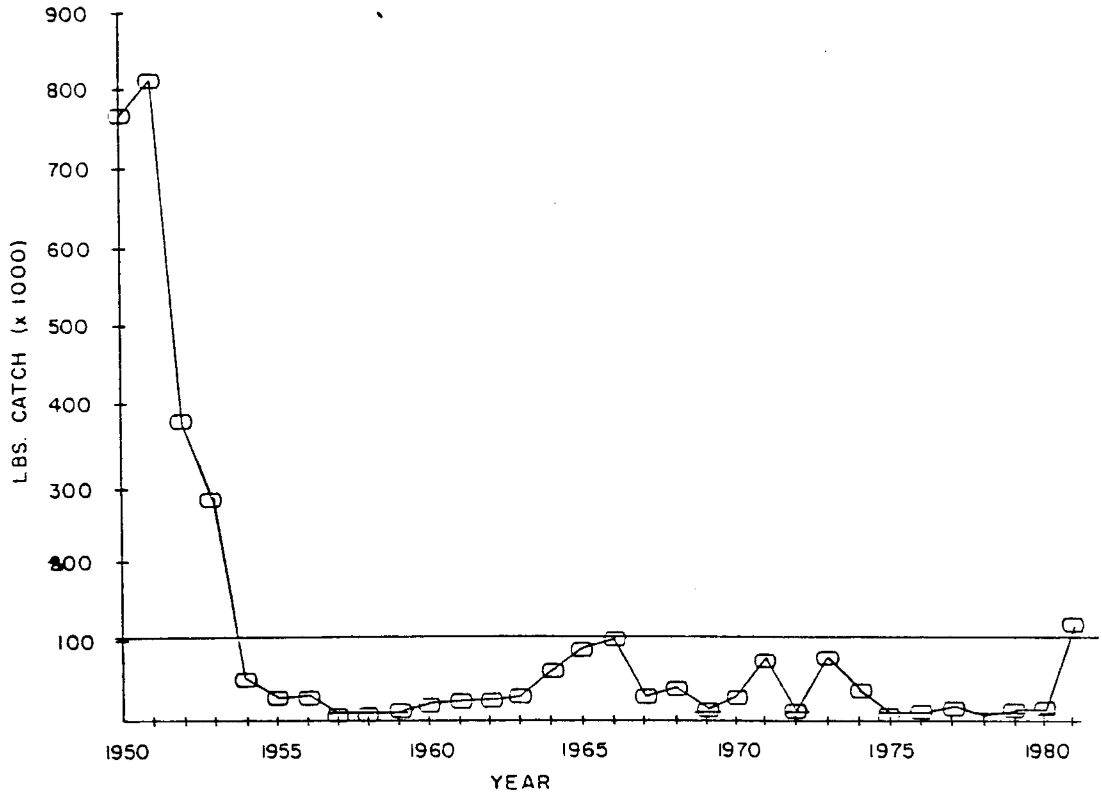


Figure 19. Annual summaries of Florida Landings for black mullet landed in the Lake Worth area. Horizontal line indicates the 31-year average.

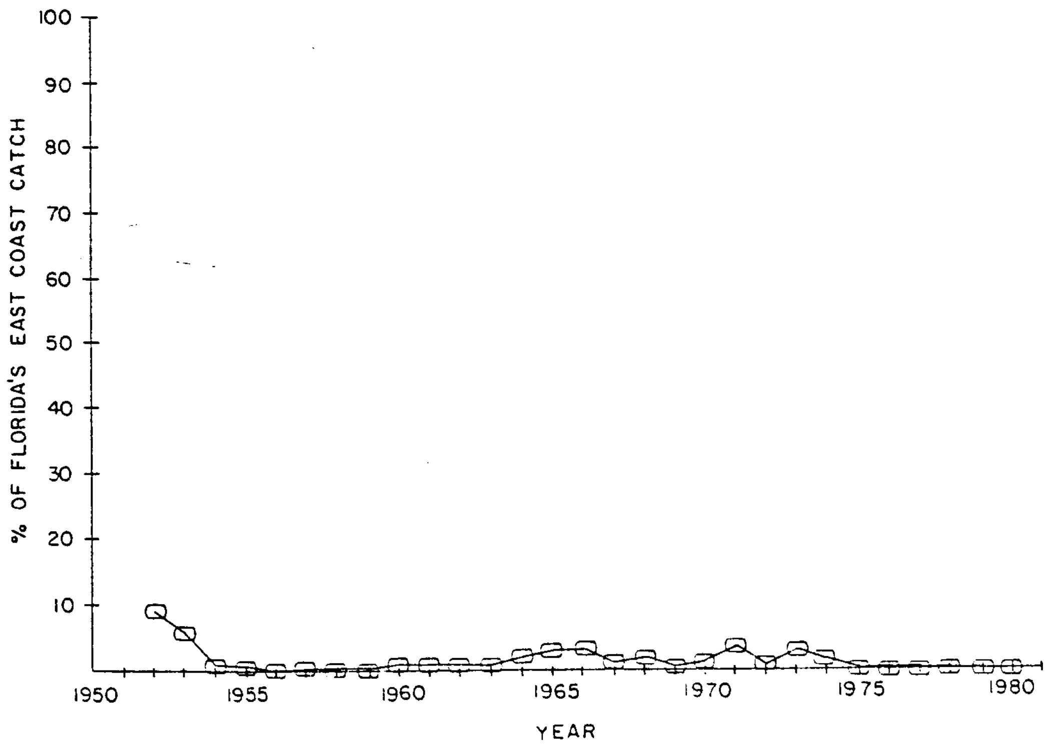


Figure 20. Annual summaries of Florida Landings for black mullet landed in the Lake Worth area over the amount landed for the east coast of Florida.

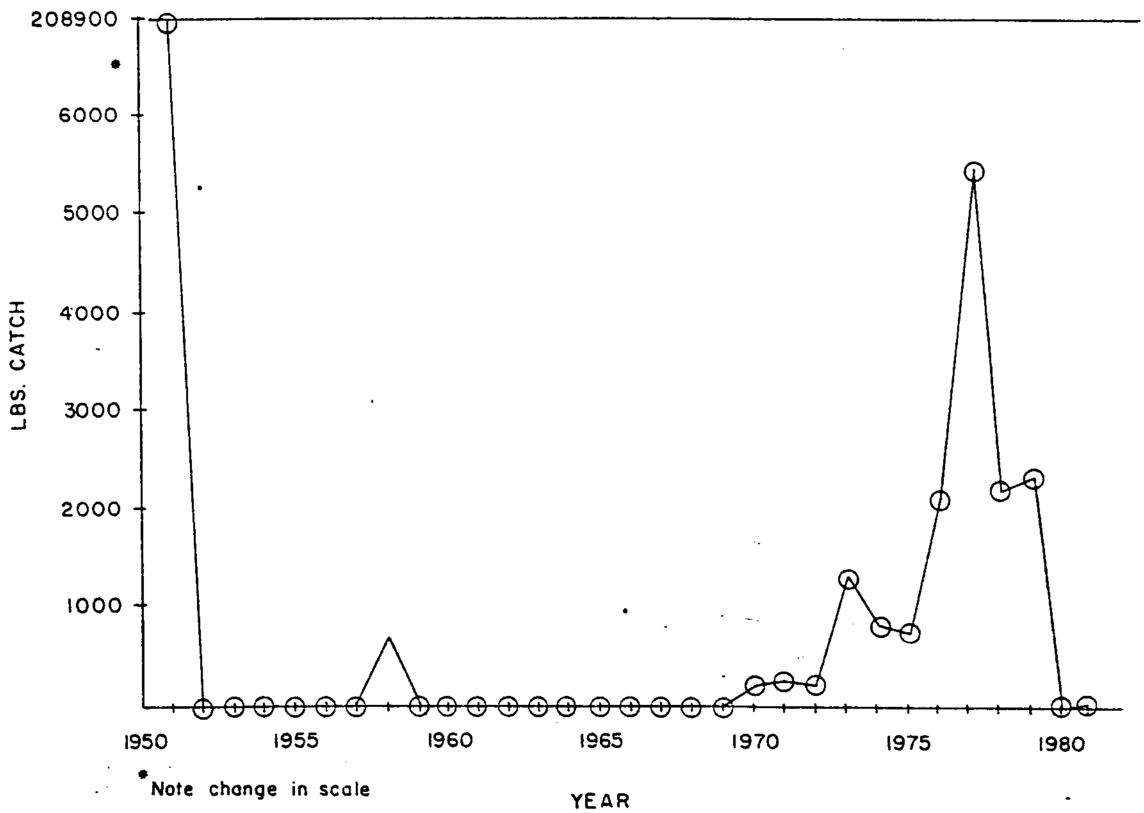


Figure 21. Annual summaries of Florida Landings for blue crab landed in the Lake Worth area. Horizontal line indicates the 30 year average.

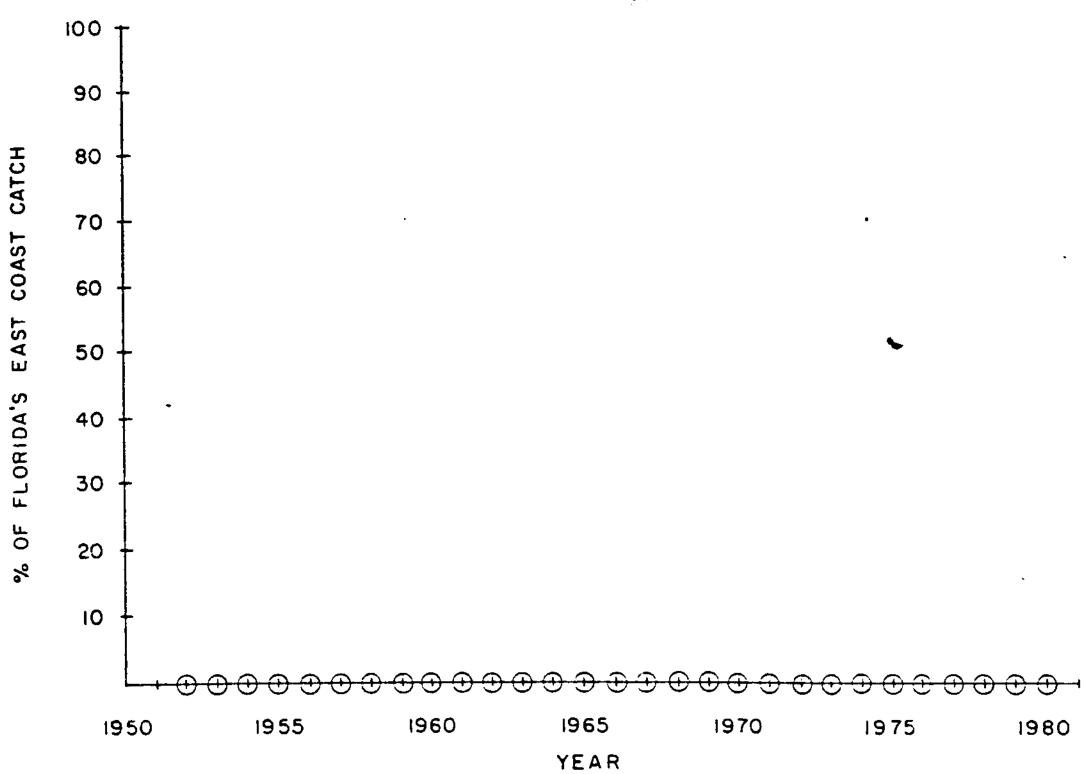


Figure 22. Annual summaries of Florida Landings for blue crab landed in the Lake Worth area over the amount landed for the east coast of Florida.

VI. LAND USE AND VEGETATION MAPS OF CHARLOTTE HARBOR AND LAKE WORTH: HISTORICAL AND RECENT

A primary objective of this project was to develop a digital data base of coastal/estuarine habitat components and changes from 1940-50 to the present in a quantitative and geographically specific manner.

VI A. BACKGROUND

The Florida Department of Transportation (DOT) Topographic Bureau was sub-contracted to provide the interpretation and mapping of historical and current land use, vegetation, and drainage patterns of the Charlotte Harbor and Lake Worth study sites. For the current interpretation of Charlotte Harbor, controlled aerial photographs (flight altitude 12,000 ft, 2658 m) were acquired in April, 1982 at a scale of 1:24,000 (1 in = 2,000 ft; 1cm= 0.24 km) utilizing a specially outfitted Rockwell Aerocommander. Positive false color infrared transparencies were produced for standard photo-interpretation utilizing stereoscopic vision equipment. Current interpretation for Lake Worth involved color aerials flown in 1975. Historical interpretation involved using black and white aerial photographs taken in 1940 for Lake Worth and 1946 and 1951 for Charlotte Harbor. Interpretation and subsequent classification of surface features followed the scheme of Kuyper et al. (1981).

Land use, vegetation, and drainage categories were then digitized into the DOT computer graphics system. Digitized geographic data were placed in a point-vector data format in this proprietary system (Friedly and Unger

1981). Output mapping products include ballpoint pen plots on drawing paper and ink plats on mylar overlays for USGS 7.5 minute quadrangles (quads) (1:24,000). Because the maps are digitized, adjacent 7.5 minute quads may be merged to produce smaller scale maps typically at 1:48,000 scale (1"=4,000', 1.0 cm=0.48km). Other products that will be available to users are maps depicting only selected land use or vegetation categories, such as seagrass and mangroves, without other features and graphics displayed. A combination of merging maps to any scale, and the selection of one class to be displayed would result, for example, in a seagrass or mangrove map of Charlotte Harbor.

VI B. PROBLEMS AND RECOMMENDATIONS

DOT encountered several major difficulties in the interpretation and digitization of the aerial photographs. These problems resulted in a delay in final map production.

The principal problem with interpretation of aerial photographs dealt with seagrass delineations. The historical black and white photographs presented an inherent lower quality for identifying seagrasses. In addition, the historical aerials were interpreted before the 1982 photographs. Because historical interpretations could not be ground truthed, a problem in the interpretation of seagrasses was not noticed until the 1982 photointerpretations were completed and comparative acreages computed. Several historical photographs were reexamined and it became apparent that general misinterpretations had occurred because of the unfamiliarity of the photointerpreter with the photographic signatures of seagrasses. The recent color infrared aerials presented no such problem as the quality was exceptional for seagrass delineation. As a result of this finding, a time consuming reanalysis and digitization of the historical seagrasses was necessary.

A similar problem occurred in the analysis of mangroves versus tropical hammocks. The interpreters classified much of the exceptionally large mangrove fringe as tropical hammock. This problem was again due to the interpreter encountering new land cover signatures. Until the study site was visited, this problem was not realized. Several valuable interpretive methodologies were learned in this process:

1. Interpret the most recent aerials first. These are generally of better quality and provide the photointerpreter with a feel of the study site. This method may bias the historical interpretation, however, the bias is far outweighed by the increase in accuracy.
2. Visit the study site in the early stages of interpretation. This will eliminate obvious classification errors because of unfamiliarity with vegetation cover characteristics.
3. Complete all ground truthing effort prior to digitization.

Since most photointerpreters are unfamiliar with interpreting seagrasses, some general comments on seagrass interpretation and quantification follow:

1. Color infrared photography provides excellent seagrass mapping media in addition to the best delineation of all other emerged habitats.
2. Low tide with clear waters (<u>generally</u> late October through early June) provide the best imagery.

3. The relationship between the time of year the aerials were flown to the seasonal densities of seagrasses is under investigation (Section VIII D). It may have some impact on total acreages or perhaps on density descriptions.

4. The 1982 aerials for Charlotte Harbor were of sufficient quality to develop a density classification system:

   901 (sparse underwater vegetation) - This class was characterized by approximately >70% exposed sand in the actual meadow regardless of the patchiness observed within the meadow and was considered minimal as habitat cover. This category will most likely be the subject to misinterpretation particularly if seasonal differences exist.

   903 (moderate to dense underwater vegetation) - This class encompassed all contiguous meadows with approximately <30% uniformally exposed sand. No attempt was made to develop a separate class for moderate densities because of the subjectiveness in interpretation at that level.

   904 (Patchy underwater vegetation) - This category was characterized by large unvegetated patches within areas of >1m^2 moderate to dense grass.

The historical aerials were simply classified as seagrass in one category:

645(submerged aquatic vegetation)

Only one classification could be interpreted due to the quality of the historical aerials and the absence of a method for ground truthing.

The major factor delaying map production was the digitization process. This is a time-consuming job requiring an understanding of both the subject matter and the complex digitization system. The bottleneck in the digitization process occurred for two related reasons. A system software upgrade was implemented with the intent to streamline the digitization process and provide the ability to compute acreages, to merge quads and to do other needed data manipulations. The new software introduced a series of deficiencies that required extensive time for correction. This was compounded by a series of hardware failures. These delays created a severe backlog in the digitization process. Considering that this project was only one of many priorities for production, the order by which jobs were completed was weighed by the contractor.

VI C. DESCRIPTION OF MAP PRODUCTS

The photointerpretation and ditgitizations were based on the U.S. Geological Survey 7.5 minute by 7.5 minute quadrangle (quad) grids depicted in Figure 23 for Charlotte Harbor and Figure 24 for Lake Worth. The quads are individually named both numerically and with a common descriptor. The common descriptor names have been used throughout this discussion.

Included in the map pockets of this report are several maps to provide examples and references of the map products available and used in the report. They are as follows:

Map 1. Drainage Map - Historical (El Jobean)

Map 2. Drainage Map - Recent (El Jobean)

Map 3. Land Use and Vegetation Map - Historical (Matlacha)

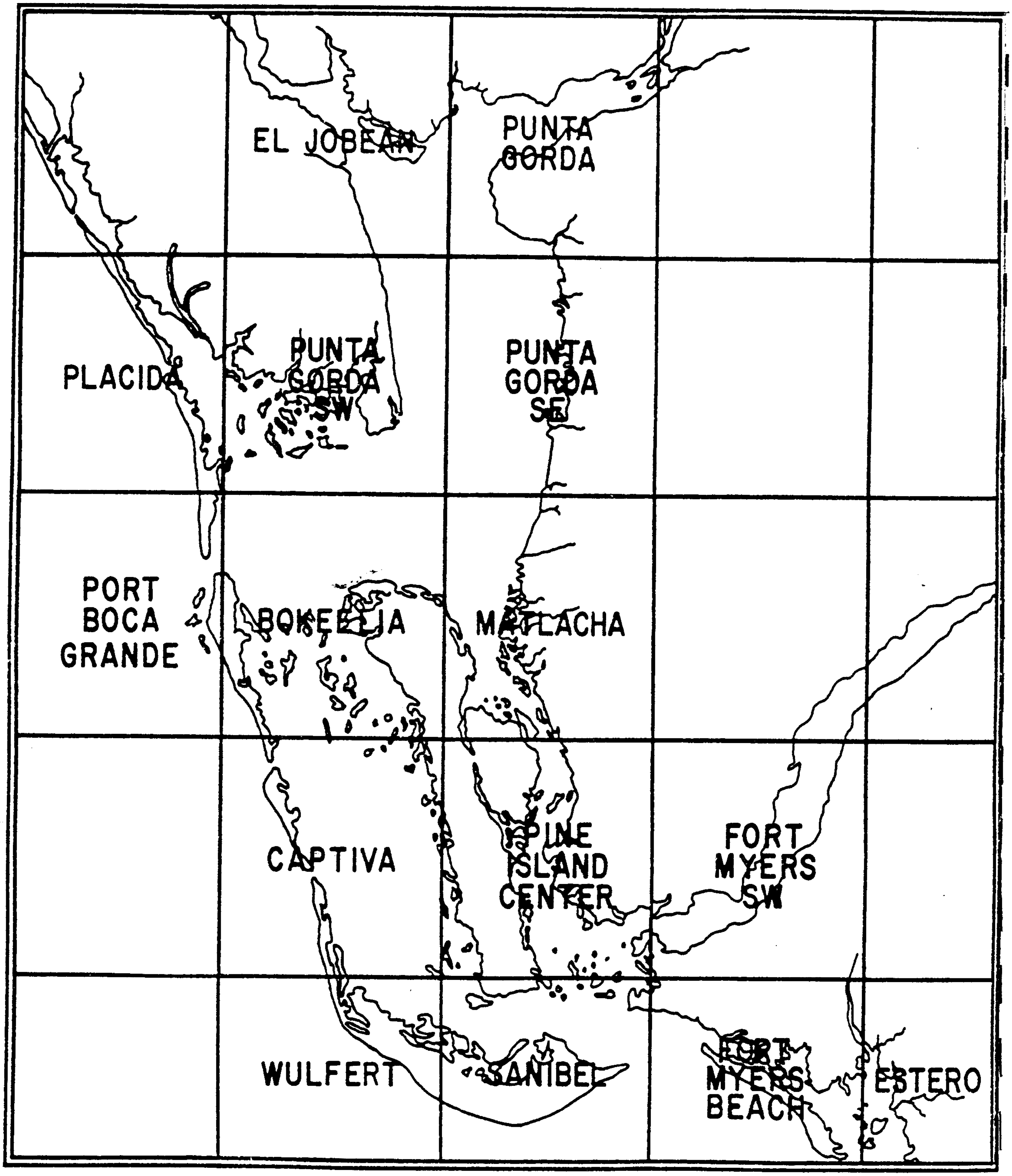


Figure 23. Charlotte Harbor quadrangle names and locations.

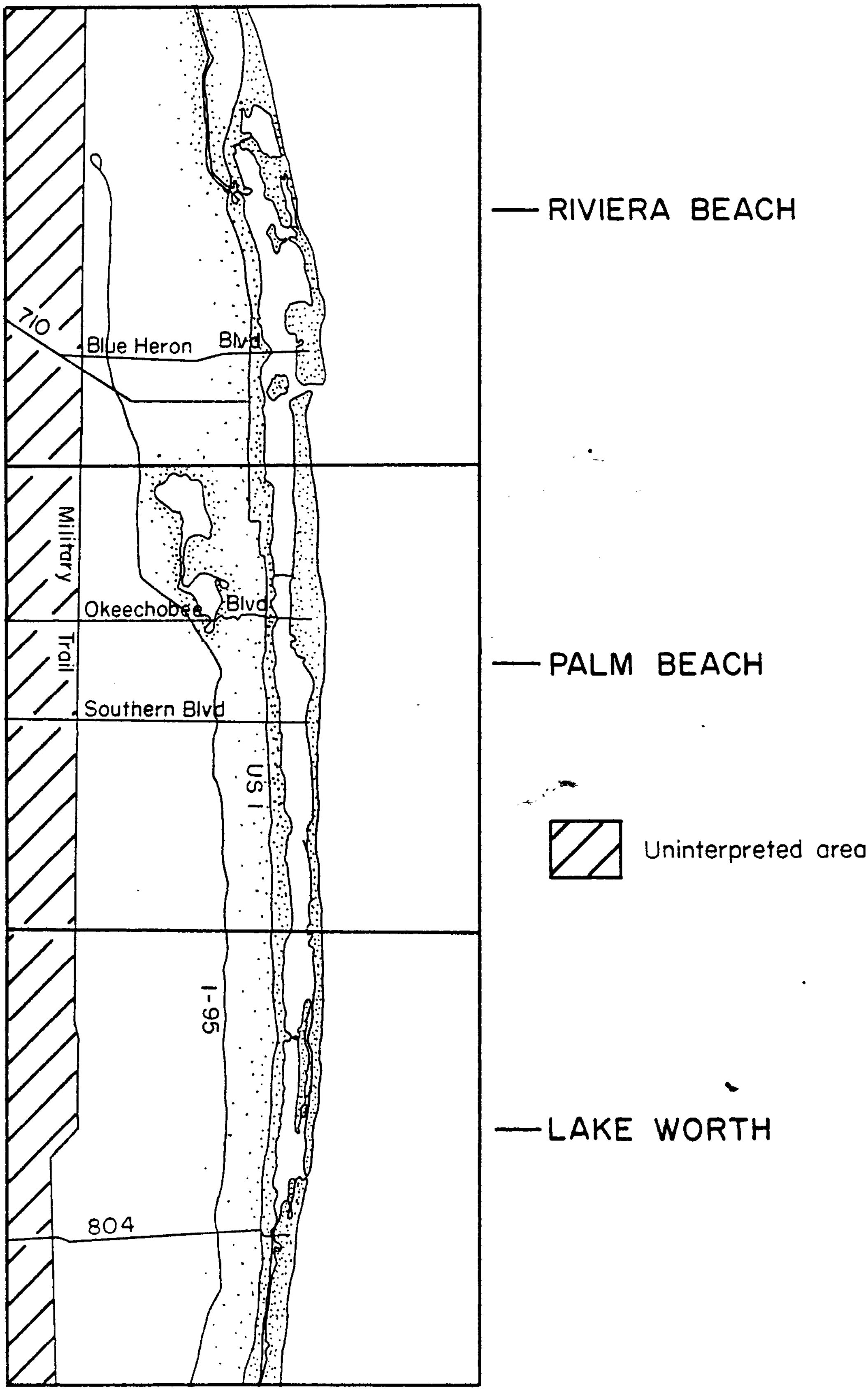


Figure 24. Lake Worth quadrangle names and locations.

Map 4. Land Use and Vegetation Map - Recent (Matlacha)

Map 5. Merged Land Use and Vegetation - Recent (El Jobean, Punta Gorda)

Map 6. Merged Land Use and Vegetation - Recent (Placida, Port Boca Grande)

Map 7. Merged Land Use and Vegetation - Recent (Punta Gorda SW, Punta Gorda SE, Bokeelia, Matlacha)

Map 8. Merged Land Use and Vegetation - Recent (Captiva, Pine Island Center, Wulfert, Sanibel)

Map 9. Merged Land Use and Vegetation - Recent (Fort Myers SW, Fort Myers Beach, Estero)

Map 10. Land Use and Vegetation Map - Historical (Riviera Beach)

Map 11. Land Use and Vegetation Map - Recent (Riviera Beach)

The reader/user should note that the historical and recent maps often are not directly comparable. Due to subjectivity in photo interpretation, boundary lines are somewhat incongruous. The maps, therefore, should not be overlayed to determine temporal changes in classification boundaries except when making purely widescale, synoptic observations.

Drainage Maps: Historical and recent drainage maps have been produced and are available for the Charlotte Harbor study area in quad or in merged form. Examples of these are Maps 1 and 2, depicting the historical and recent El Jobean quad. These maps provide a visual inventory for non-point source drainage pattern changes that have occurred. Acreage of a drainage system, linear miles of canals, and other drainage schematics potentially can be quantified to assess the non-point source runoff into the estuary.

Land Use and Vegetation Inventory Maps: Maps 3, 4, 10, and 11 represent the style of Land Use and Vegetation Inventory products produced for the Charlotte Harbor and Lake Worth study areas. Appendix A provides users of these products with the D.O.T. classification description associated with the numerical classification codes. Maps 3 and 4 represent historical and recent interpretations of the Matlacha quad with corresponding acreage values. Maps 10 and 11 provide the same format for the Riviera Beach (Lake Worth) quad. Because of the large number of individual quads (15 recent and 15 historical for Charlotte Harbor and 3 recent and 3 historical for Lake Worth), the entire set of individual interpreted quad maps could not be included in this report.

Merged Maps: Maps 4-9 are examples of the map product created by merging adjacent individual quad maps into a scale addressing a larger area. Unfortunately, neither a classification key nor acreage values could be incorporated into the merged maps. The user should refer to Appendix A where numerical classifications can be identified.

VI D. CHARLOTTE HARBOR

VI D 1. GENERAL SITE DESCRIPTION

The Charlotte Harbor estuarine complex began to form approximately 5,000 years ago when a rise in sea level flooded the mouths of the Myakka and Peace Rivers. Flooding caused sediments to be deposited in a series of deltaic formations which began the in-filling of the present estuary.

This process also formed the present barrier island chain which began as a spit of land north of the present Gasparilla Island. River sediments and those of the littoral drift helped create the chain of barrier islands. The resulting five major barrier islands of today (Gasparilla, Cayo Costa, North Captiva, Captiva, and Sanibel) have joined, separated into additional islands, and changed shapes continuously since their development (Herwitz 1977).

"Pine Island is believed to be a remnant of the original mainland, that was isolated by a southerly shift in the river flow. Then, as sediments built up at the present location of Little Pine Island and the evolving shape of Sanibel Island restricted water flow, the estuary broke through the Gulf, creating a deep channel near the present Boca Grande Pass. This pass eventually shifted to its present position (Herwitz 1977). Other passes have been opened and closed by storm events and other natural forces that are still acting on the system today. Both Cayo Costa and North Captiva Island have had new cuts through them in the last year." (Department of Natural Resources Bureau of Environmental Land Management 1983).

Charlotte Harbor today (Figure 25) is approximately 56km long encompassing at least 71,680 ha of water area. Total shoreline includes 320km excluding the numerous mangrove islands. Shallow water up to 1.8m predominates the estuary with natural depressions and channel margins of 1.8 to 3.7m and 3.7m or greater within channels and anchorages (Taylor 1976).

Three major rivers flow into Charlotte Harbor. The Mayakka and Peace Rivers, together draining a land area of approximately 76,800ha, flow into

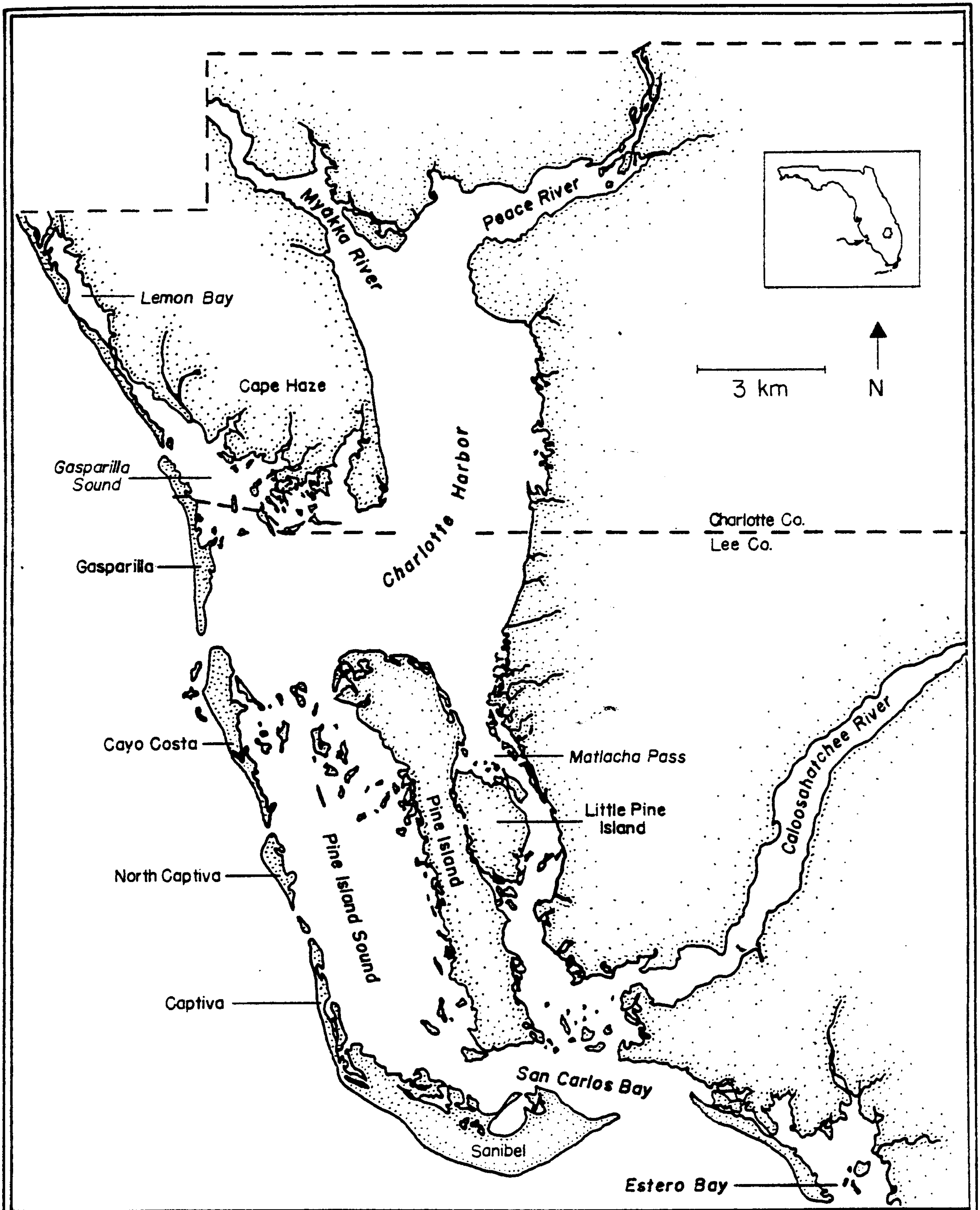


Figure 25. Charlotte Harbor.

the northwest and northeast ends of Charlotte Harbor proper (Taylor 1976). The Caloosahatchee River enters San Carlos Bay, south of Charlotte Harbor proper, draining about 307,200ha of land (Taylor 1976).

The watershed of all three rivers contain areas of pasture land, citrus groves, and cultivated ground. In addition, the Peace River flows through expansive sites of phosphate mines, while the Caloosahatchee receives industrial and domestic wastes from the urban areas surrounding Fort Myers.

During periods of low tide and heavy rainfall, high river flow reduces surface salinity throughout the estuary and also offshore to a distance of several kilometers. During high tide and low river flow, a saline wedge of bottom water has been documented to 38 miles upstream in the Caloosahatchee and well upstream in the Myakka and Peace Rivers (Taylor 1976).

Aside from nutrient and waste inputs from the three river systems, Charlotte Harbor has suffered very few detrimental impacts and remains a relatively natural ecosystem. Beginning in 1977, the State of Florida has purchased most of the land along Charlotte Harbor's shoreline, attempting to maintain a natural mangrove/marsh and, thereby, hopefully, a healthy estuary. In addition, approximately 90% of the harbor itself exists as four aquatic preserves. However, behind some of this natural buffer area encroaches vast areas of development.

"The Charlotte Harbor area has been the site of enormous subdivision development during the past thirty years. The General Development Corporation's Port Charlotte project covers almost 200 square miles inland from Charlotte Harbor, between the Myakka and Peace Rivers. The projected population of Charlotte County, if this and the other subdivisions presently platted in the county were occupied, would be nearly 1,000,000 people. The 1980 U.S. census population for Charlotte County was 58,460.

"Cape Coral, Gulf American Corporation's subdivision north of the Caloosahatchee River and east of Matlacha Pass, covers approximately 96 square miles. An estimated 400,000 people may one day inhabit that presently incorporated city. The 1980 U.S. census population for Lee County was 205,266. The Ft. Myers-(Cape Coral)-Lee County area has been identified in a number of reports as the fastest growing area in the United States." (Department of Natural Resources Bureau of Environmental Land Management 1983).

Obviously, if wide-scale development continues with no consideration for environmental impact, Charlotte Harbor could change radically. Wang and Raney (1971) described Charlotte Harbor as one of the largest and least contaminated estuarine complexes in all of Florida. Today, Charlotte Harbor retains that image. Its unspoiled habitat houses over 40 endangered and threatened species, including at least 15 active eagle nests.

In addition, the harbor's importance as a productive fisheries environment, both in the past and today, is emphasized by Figures 6 through 14. Hopefully, the future will find Charlotte Harbor unchanged.

VI D 2. GENERAL ACREAGE VALUES

Much change has occurred in Charlotte Harbor. Table 6 provides acreage values for eight general categories. The eight categories are herein described. The number in parentheses following the category name is the DOT numerical classification code. Appendix A provides a complete description.

Table 6. CHARLOTTE HARBOR ACREAGE VALUES

Level 1 Land Use name	Urban		Agriculture		Rangeland		Forestland	
Level 1 Land Use code	100		200		300		400	
Year	1945	1982	1945	1982	1945	1982	1945	1982
USGS Quadrangle Name								
El Jobean	90	16657	1872	870	15222	2380	3586	1896
Punta Gorda SW	0	1093	0	0	6459	5128	737	2247
Placida	283	1915	0	249	3688	1464	647	1783
Bokeelia	162	1593	541	444	1477	1181	2655	1864
Port Boca Grande	299	300	0	0	360	458	229	292
Captiva	60	546	87	0	490	203	348	297
Wulfert	10	658	92	40	1045	329	461	875
Sanibel	113	3100	50	0	4456	668	494	1864
Punta Gorda	1270	16412	2336	1534	12319	1810	4106	1937
Punta Gorda SE	9	4249	454	1460	8237	1543	4341	6701
Matlacha	7	13561	1051	783	16155	866	4641	6348
Pine Island Center	1	9120	490	954	10064	1482	4159	3786
Fort Myers Beach	320	2734	855	504	4321	982	908	2221
Fort Myers SW	1006	22556	5091	3288	16086	583	5341	3472
Estero	80	1611	218	157	5840	1627	1930	4908
TOTAL ACRES	3710	96105	13137	10283	106219	20704	34583	40491
% TOTAL ACRES	1%	16%	2%	2%	17%	3%	6%	7%
Acreage Change	+92395		-2854		-85515		+5908	
Percent (%) Change	+ 2490%		- 22		- 81%		+ 17%	

Table 6. CHARLOTTE HARBOR ACREAGE VALUES
(Continued)

Level 1 Land Use name	Water		Wetlands		Barrenland		Transportatio and Utilities	
Level 1 Land Use code	500		600		700		800	
Year	1945	1982	1945	1982	1945	1982	1945	1982
USGS Quadrangle Name								
El Jobean	11231	12400	8772	6899	819	1176	178	287
Punta Gorda S.W.	17406	18191	18065	15762	2	148	21	34
Placida	33038	33711	4321	2979	447	319	170	207
Bokeelia	21126	21886	15861	15213	704	405	62	66
Port Boca Grande	41150	41354	421	98	131	77	58	49
Captiva	20426	30159	21008	11292	233	192	45	13
Wulfert	36428	37581	4311	3100	354	143	37	16
Sanibel	28795	29960	8548	6896	195	172	89	75
Punta Gorda	13876	14037	7197	3906	911	1564	531	1357
Punta Gorda S.E.	19347	19850	9456	7772	749	870	14	164
Matlacha	8462	9090	12230	10900	43	942	71	175
Pine Island Center	3598	5214	24122	21843	107	80	146	207
Fort Myers Beach	24786	25572	11371	9755	143	615	28	366
Fort Myers SW	7643	9847	6253	1844	1147	840	126	263
Estero	1487	3853	8290	5644	217	283	225	154
TOTAL ACRES	288799	312705	160226	123903	6202	7826	1801	3433
Acreage Change	+23906		-36323		+1624		+1632	
Percent (%) Change	+ 8%		- 23%		+ 26%		+ 91%	

Urban and Built Up (100)

In 1944-45, the Charlotte Harbor area had 3,710 acres classified as urban. The Punta Gorda and Fort Myers SW quads comprised 61% of this total. The 1982 inventory showed 96,105 acres (a 2490% increase). Fort Myers SW experienced the greatest increase from 1,006 acres to 22,556 acres (23% of the total).

Striking urban features in the Charlotte Harbor area are the massive 1960-1970's land boom development tracts where huge areas were cleared and roads were built. Few, if any, have dwellings. Most of the tracts also have canals for land drainage and harbor access. These urban tracts (classification 192) comprise 47,298 acres (49%) of the total urban area. If these tracts alone are developed, assuming 4 dwellings/acre and 3 persons/dwelling, 567,576 new residents can impact the area with no additional land development. This would cause a significant impact on the Charlotte Harbor area if not properly planned.

Agriculture (200)

As evidenced by the acreage values, agriculture is not a major industry in the Charlotte Harbor study area. The historical acreages (13,137 acres) decreased 22% to 10,283 acres at present. The bulk of this acreage is pasture land or citrus crops.

Rangeland (300)

Rangeland decreased 81% from 106,219 acres to 20,704 acres. The primary acreages in this category were shrub and brushland characterized by scattered pines, palmetto and grasses. These vegetation types often support cattle grazing, however, this is not quantified. It may be assumed that most of the acreage loss (85,515 acres) transferred to urban gains (92,395 acres). The shrub/brushland type areas supported the greatest upland loss in the study area.

Forestland (400)

Forestland was the only Level I vegetation category to increase in acreage (17%) from 34,583 to 40,491 acres. The majority of forestland acreage is pine flatwoods. A large increase in exotic forestland (i.e. Brazilian pepper, Melaluca, and Australian pine) was observed during this time period. These species compete with natural rangelands, forestlands, and wetland mangroves, accounting for the greatest forest habitat alteration.

Water (500)

This category increased 8% from 288,799 acres to 312,705 acres. Most of the increase may be attributed to canals and vegetated (seagrass) bottom loss. Water comprised the major acreage of the study area.

Wetlands (600)

Wetlands experienced a 23% decrease in acreage from 162,226 acres to 123,903 acres. The major decrease in this category was seagrass (submerged aquatic vegetation). Wetlands (fishery habitats) will be discussed in detail in the following section.

Barrenland (700)

Barrenland increased 26% from 6,202 acres to 7,826 acres. Some barrenland beach categories are important nesting habitat for terns, skimmers, and other open-ground nesting birds.

Transporation (800)

A 91% increase from 1,801 acres to 3,433 acres was observed in the study area. This directly reflects the increased development.

Special Category (900)

This category was used to record the 1982 seagrass densities and will be discussed later in the following section. The historical seagrass inventory was included under Wetlands (600) as code 645. For comparable total wetlands acreages, the 1982 900 category has been added to the 1982 600 category in Table 6.

VI D 3. FISHERIES HABITAT COMPONENT ACREAGES

Fisheries habitat is considered the geographical, physical, chemical and biological environment in which a species can find food, cover, and reproduce during the various stages of its life cycle. A fisheries habitat component for this report is defined as a specific remotely-sensed and interpretable submerged or emerged vegetated or non-vegetated class. Different species at different ages can utilize many different habitat components or can be monospecific as to habitat component. Although different habitat components can be readily defined, a specific fish habitat may only be determined through extensive sampling and research. This report delineates some of the habitat components currently considered important to fisheries production in general, but neglects many of the more transient components such as salinity, temperature, turbidity, etc. Some of these interpretable components include mangroves, seagrass beds, salt marshes, non-vegetated tidal flats (mud flats), and oyster reefs. They provide cover and an indirect food source for over 70% of Florida's recreational and commercial fisheries species. Table 7 provides historical and recent acreage values for these fisheries habitat components.

Mangroves (612)

Section II C 1 provides a complete discussion of mangroves and can be reviewed to familiarize the reader with the role of mangroves in estuaries. Species delineation was not attempted within the mangrove category. A 10% increase, 51,524 acres to 56,631 acres, was recorded for the study area.

These results are surprising because they do not follow the general trend for wetland loss. State and local regulations protecting the mangrove fringe surrounding Charlotte Harbor were enacted prior to any large-scale destruction. Consequently, very few mangrove areas have been dredged or filled and, in fact, areal coverage has increased by 5,107 acres. Increases can be explained by natural growth. It appears that much of the mangrove increase could be related to the 8,158 acre loss of non-vegetated tidal flat. Tidal flats provide suitable locations for mangrove seedlings to take hold. If conditions are suitable for growth, new mangrove stands can be propagated. Other factors such as rising sea level, spoil island creation, marsh succession, and restoration can explain increases, but they

Table 7. CHARLOTTE HARBOR FISHERIES HABITAT COMPONENT ACREAGES

Habitat Component	Mangrove		Non-Vegetated Tidal Flat		Oyster Reef		Saltmarsh		Seagrass	
Year	1945	1982	1945	1982	1945	1982	1945	1982	1945	1982
USGS Quadrangle Name										
El Jobean	3433	4321	757	126	0	4	1762	1528	1632	894
Punta Gorda SW	6885	8251	2930	1079	173	28	436	169	6881	5760
Placida	1083	968	267	142	55	56	157	0	2610	1566
Bokeelia	3544	3731	52	31	0	38	29	24	12154	11367
Port Boca Grande	39	32	0	0	0	0	0	0	382	66
Captiva	1033	1121	57	0	0	2	0	7	19907	10162
Wulfert	1392	1426	0	0	0	0	0	0	2749	1674
Sanibel	3067	2943	148	3	8	10	22	0	5296	3940
Punta Gorda	4310	2799	858	95	4	5	550	140	892	772
Punta Gorda SE	2821	3502	1081	255	0	0	424	0	4246	3562
Matlacha	4243	5821	1268	51	0	8	462	0	5780	4940
Pine Island Center	8937	11291	2324	358	515	303	709	197	11462	9684
Fort Myers Beach	6032	5955	775	362	2	3	767	747	3586	2626
Fort Myers SW	1936	1190	378	53	0	0	1384	341	1465	189
Estero	2769	3280	311	168	49	31	549	394	3917	1293
TOTAL	51524	56631	11206	2723	806	488	7251	3547	82959	58495
Acreage Change	+5107		-8483		-318		-3704		-24464	
Percent (%) Change	+ 10%		- 76%		- 39%		- 51%		- 29%	

are most likely minor in this case.

The only quads showing mangrove losses were Placida, Port Boca Grande, Sanibel, Punta Gorda, Ft. Myers Beach, and Ft. Myers SW. These areas lost a total of 2,581 acres of which Punta Gorda comprised 1,511 acres or 59% of the loss. Punta Gorda is one of the oldest developed areas within the Charlotte Harbor study site and the mangrove loss can be attributed to the early waterfront development that eliminated fringing mangroves.

The quads with the greatest increase in mangrove acreage were Punta Gorda SW, Matlacha, and Pine Island Center (+5,298 acres). Pine Island Center had the largest increase at 2,354 acres or 46% of the total increase. These same quads had the largest decrease in non-vegetated tidal flats (5,034 acres or 59% of the decrease). This further substantiates the hypothesis that the conversion of tidal flats was a major portion of the mangrove increase.

It is apparent that the protection and preservation of mangroves in the Charlotte Harbor area has helped to stabilize the existence of this habitat component for fisheries utilization.

Non-Vegetated Tidal Flat (651)

Section II C 4 provides a discussion of tidal flats, i.e., mud flats. A 76% decrease in non-vegetated tidal flats (from 11,206 acres to 2,723 acres) was observed. As discussed in the preceding category, mangrove increases appear to account for loss of tidal flat. Pine Island Center experienced the largest decrease in tidal flats and the largest increase in mangroves. This is a natural loss of tidal flats and the total acreages involved account for only a small fraction of the entire area of fisheries habitat components considered.

Oyster Reefs (654)

Section II C 5 discusses oyster reefs as a habitat component. The acreages observed for oyster reefs are most likely low for two reasons: (1) The reefs are often too small for photointerpretation, and (2) turbid waters often associated with these areas render the reefs difficult to remotely sense. Larger reef areas have been delineated and show a 38% decline from 806 to 488 acres. Punta Gorda SW (Turtle Bay) and Pine Island Center (Matlacha Pass) supported the historical highest acreages with 173 and 515 acres respectively. The recent interpretations indicate that Pine Island Center and Placida have the highest acreages, with 303 and 56 acres respectively. Reasons for loss are purely speculative but could involve overharvesting, circulation changes, and particularly salinity changes.

Salt Marshes (642)

Section II C 3 contains a detailed discussion on salt marshes. A 51% decrease in salt marsh acreage, from 7,521 to 3,547 acres, was observed in the study area. El Jobean comprised a historical high of 1,762 acres (24% of the total) and also contains the highest recent acreage of 1,528 acres or 43% of the total. Punta Gorda, Punta Gorda SE, Matlacha, and Pine Island Center, and Fort Myers SW incurred the greatest losses (as much as 100%) accounting for 77% of the salt marsh loss.

The loss of salt marshes can be directly attributed to the major land developments. Although these developments did not always directly destroy the marshes, they apparently indirectly destroyed them by canalization. The digging and networking of canals (see Drainage Maps 1 and 2 for visual impact) in order to drain the low-lying uplands has apparently served to divert the natural flow of freshwater away from the salt marshes. This would cause saltwater intrusion allowing mangroves to outcompete and succeed the marsh habitat. This succession is well documented in four quads: Punta Gorda, Punta Gorda SE, Matlacha, and Pine Island Center.

The direct loss (removal) of salt marshes could be catastrophic to many organisms, but the impact caused by succession from saltmarsh to mangroves is unknown. The major losses occurred where there was relatively low marsh acreage originally. The greatest acreage of salt marshes occurred up the Myakka and Peace Rivers, out of the study area. Succession from marsh to mangrove may be immaterial at least to fisheries species, however, it is certainly significant to the above water community, such as birds, and also to the benthic infauna.

Seagrasses (645 historical; 901, 903, 904 recent)

A complete discussion on seagrasses is found in Section II B. Also Section II C 2 should be consulted in reference to problems encountered in mapping seagrasses (specifically the historical photointerpretation). The level of accuracy in delineating historical extent of seagrasses cannot be assessed by groundtruthing. The fact that they are submerged introduces an optical variation not found in emergent vegetation and can affect the interpretation. The 1982 photointerpretations, however, were of exceptional quality and extensively groundtruthed; we are quite confident in their accuracy.

A 29% decrease in seagrass, from 82,959 acres to 58,495 acres, was observed between 1944 and 1982. This is substantial and surprising since the Charlotte Harbor estuary is perceived as an area of little detrimental impact. Virtually every quad experienced decreases in seagrass acreages. The largest loss occurred in the Captiva quad with a 9,745 acre loss or 40% of the total Charlotte Harbor seagrass decline. The adjacent Wulfert, Sanibel, and Pine Island Center quads also accrued substantial losses; these four quads comprise Pine Island Sound and account for 57% of the total loss in seagrasses.

Several factors that most likely account for the loss of seagrasses in this specific area. When reviewing nautical charts of Pine Island Sound, a subjective analysis of tidal circulation can be made by observing topographic patterns. A shallow bar extending entirely across Pine Island Sound (<5 ft depth) is a prominent feature and was apparently the location of the first channel dredging operation (sometime before 1948) in the area. Deeper tidal channels (8-15 ft) existed on both sides of the bar. It was likely that this bar area represented a tidal node. During an ebb tide, flow occurred to the north above the bar and to the south below the bar. Coastal Engineering Laboratory (1958, c.f. Esteves 1981) determined the tidal node to be just to the north and south of Redfish Pass, substantiating the implication that the shallow bar historically delineated the tidal node.

In the early 1960's, several major alterations to the Pine Island Sound area occurred that appear to have dramatically affected the ecosystem. (1) The Intracoastal Waterway was dredged through Pine Island Sound and up the Caloosahatchee River, (2) The Sanibel Causeway was constructed across San Carlo Bay. Even before 1960, the Caloosahatchee River was channelized to Lake Okeechobee and lock systems were installed.

Prior to these alterations, Pine Island Sound was under oceanic influence, with sponges, some corals, Thalassia and other higher salinity species growing within the Sound (Art Marshal, personal communication). Esteves et al. (1981) presented excerpts from a U.S.F.W.S. report to the U.S. Army Corp. of Engineers on the construction of the Sanibel Causeway:

> The U.S. Fish and Wildlife Service has reviewed the application of the Board of Lee County Commissioners, Fort Myers, Florida, for a Department of the Army permit (Bridges 1057) to construct a causeway with three bridges across San Carlos Bay so as to connect Sanibel Island with the mainland at Punta Rassa in Lee County, Florida.
>
> The project as proposed would adversely affect the fish and wildlife resources of the area in two different ways. One of these would be the effect of dredging and filling. The bottom plant and animal communities in the areas to be filled would be permanently destroyed. The communities in the areas to be dredged would be destroyed at least temporarily and permanently if frequent maintenance dredging were required Such reduction in bottom communities would have the effect of reducing important fish populations to some degree.
>
> A second effect of the project, and a much more damaging one, would result from reduced salinities in lower Pine Island Sound, San Carlos Bay, Matlacha Pass, and the lower estuary of the Caloosahatchee River. With lowering of the salinity, changes in the biota would result. As a particular example, the scallop beds of lower Pine Island Sound might very well be eliminated, inasmuch as these mollusks reqiuire salinities of better than 20 parts per thousand. In more complex fashion, the abundance of some of the brackish and marine fishes in the area would be reduced.

The above report was very prophetic. After causeway construction in 1962, the area went from a major scallop producer in Florida (as great as 180,000 lbs/yr) to no scallop population by 1964. Circulation alterations caused by the causeway diverting flow into Pine Island Sound from the Caloosahatchee River were probably the primary reasons for the scallop loss.

The effects on seagrass communities are as apparent as that on the scallops, perhaps compounded by dredging for the Intercoastal Waterway. The 13,936 acre seagrass loss in the four mid and lower Pine Island Sound quads primarily occurred in the deeper portions of the water (>3 ft). With the described construction projects the location of the tidal node has most likely been artificially destroyed or dramatically shifted. This may be explained if the causeway is considered a dam impeding the outflow of freshwater from the Caloosahatchee. This would create a high pressure at the low end of the sound inducing a net flow of freshwater up Matlacha Pass and Pine Island Sound. The tannins and particulates associated with the freshwater would increase turbidity and consequently reduce water clarity. Compounded by direct destruction and reintroduction of fine sediments into the environment by dredging, a decrease in seagrasses would be expected and has certainly occurred.

Although exact explanations cannot account for seagrass losses in other portions of the study area, some analogies may be implied. Primary seagrass loss has been in the deeper portions of the Harbor, at the fringing bars, and in lagoonal-type areas. Very little direct destruction has occurred. It is likely that overall changes in drainage patterns and introduction of sewage pollutants and storm water runoff has served to increase the suspended load in the Harbor. The loss of natural filtration of nutrients also has probably increased the phytoplankton production. All of these factors would synergistically act to increase turbidity in the Harbor and eliminate seagrass meadows in the deeper waters.

Whether the loss is continuing is unknown and can only be assessed through periodic monitoring and mapping. The predominant grass beds are located in the very shallow waters behind protective sandbars. If circulation patterns change and bars are altered, additional losses may be expected. If turbidities increase, the seagrass meadows will exist only in the shallowest waters.

The long term alteration of this fisheries habitat component may one day have a pronounced effect on fisheries of the area. With every new canal, lawn, road, storm pipe, sewage treatment facility, septic tank, etc., additional nutrients and particulates are introduced into the system. This can potentially increase turbidity and alter water quality to an extent that further losses may occur. In addition, as the human population increases, boating pressure and propeller damage to the shallower seagrass beds will occur. On-site management of this habitat component, which the Department of Natural Resources Aquatic Preserve Program provides in Charlotte Harbor, is important. However, concurrent upland management must occur also. Unlike for mangroves and other emergent vegetation types, seagrasses are not readily observable and, unfortunately, management considerations typically have not applied to seagrasses. This trend is changing, but further research must be conducted on declining seagrass populations to determine exact causative factors of loss and determine the best possible approaches for management. This should not preclude effective management today.

VI D 4. COMPARISON BETWEEN FISHERIES STATISTICS AND HABITAT ALTERATION

At the onset of this project it was realized that the available commercial fisheries statistics as landings data were inadequate for a confident comparison to habitat alterations and loss (see Section VI B). At this point, in the total scope of the project, a comparative analysis will not be attempted. Certain subjective comparisons can be made such as the total loss of the scallop industry discussed in Section VI D 3, but quantitative analysis is not possible. We have documented the areal extent and location of many of the fisheries habitat components and have documented their alterations over a 35-40 year period. Florida is attempting to develop a State fisheries statistics program in cooperation with NMFS which will provide the proper data needed for area-specific commercial catch and effort data, as well as recreational data.

Section V E 2 presents existing fisheries statistics for the Charlotte Harbor area. The general trend for the target species is for increases in landings. But we do not know how much effort (man hours, number of trips, length of trips, etc.) was required per pound landed to assess if this reflects an increase, decrease, or stability in the total population. However, the trends are evident and may prove beneficial for comparative purposes.

With this in consideration, a future report (CM-69) will compare habitat component alterations and fisheries statistics of Charlotte Harbor and Tampa Bay. This comparative analysis will provide a basis for management decisions even though the results may be subjective in their presentation. We can logically deduce that loss of fisheries habitat will eventually result in changes in fisheries yield. Loss in habitat components may be a direct or indirect cause and, thus, a direct or indirect measure of fisheries population changes. Only continued research on the entire life histories of the species in different areas will provide the direct or synergistic relationships to the habitats in which they live.

VI E. LAKE WORTH

VI E 1. GENERAL SITE DESCRIPTION

As sea levels declined following the Ice Age, Lake Worth, then a saltwater lagoon, became elevated above sea level and became a predominately freshwater system. Extreme high tides and waves, high freshwater, and storms occasionally breached the thin eastern rock and sand ridge (now the island of Palm Beach) that separated Lake Worth from the Atlantic Ocean, forming natural inlets. These inlets were unstable and closed spontaneously within a short period of time, returning the system to freshwater. A sand ridge immediately west of Lake Worth separated the lake from the mainland. This ridge ran continuously from the Hillsborough River north to the Loxahatchee River where it then turned east, connecting to the eastern sand-rock ridge. The ridge was bordered on the north and west by a system of lakes and sawgrass sloughs. By 1845, two islands in Lake Worth existed naturally: Big Munyon Island and Hypoluxo Island. Vast freshwater marshes surrounded the lake and freshwater grassbeds grew within.

In the 1860's, the first manmade inlet to the Atlantic Ocean was excavated north of the present site of the North Palm Beach inlet, but it soon closed naturally. In 1877, a relatively stable inlet was cut through a section of the eastern ridge that stood 25 feet above sea level. A rapid conversion took place changing the freshwater system to a saltwater environment. Beach sand swept in through tidal action smothering the bottom vegetation and benthic organisms, replacing them with organic muds. By the late 1800's, mangroves replaced the freshwater marshes.

The area's resident population was approximately 1,000 persons in 1894. During the 1890's, resort developers began filling the wetland edges of Lake Worth. At the same time, the East Coast Canal Company finished dredging a navigational canal, now part of the Intracoastal Waterway, that extended from the north end of Lake Worth through the northern sand ridge and sawgrass sloughs to the Jupiter Inlet. Water that had previously flowed from portions of the mainland inland to the Jupiter Inlet was now directed south into Lake Worth, thus increasing the organic load of the lake. In the early 1900's, the Intracoastal Waterway was completed from the south end of Lake Worth to Biscayne Bay.

By 1915, the Port of Palm Beach created an inlet 4' deep at the north end of Lake Worth. Dredge and fill activities replaced more and more acres of mangroves in the 1920's. By 1925, 4 additional alterations were completed. (1) The North Lake Worth inlet was deepened to 16' and bulkheaded. Peanut Island was created by the dumping of dredge spoil during creation of North Lake Worth Inlet. (2) The South Lake Worth inlet was constructed to help flush Lake Worth, however, tidal action increased sand deposition into Lake Worth. (3) The West Palm Beach Canal was completed by the Everglades Drainage District (EDD), connecting Lake Okeechobee to the Atlantic Ocean. This canal functioned for drainage and transportation and was provided with two water control structures, one at Lake Okeechobee and the other on the coast at the fresh and salt water interface. (4) Part of the natural sawgrass slough system of the mainland was impounded and inflow was diverted into Clear Lake and Lake Mangonia to serve as a water supply for the cities of West Palm Beach and Palm Beach. Resident population at this time was approximately 30,000.

The West Palm Beach Canal and alteration of the mainland drainage pattern greatly affected urbanization. Prior to these changes, settlement occurred primarily on the island of Palm Beach and along the high and dry sand ridge bordering Lake Worth. Now, however, drainage made available much more land for development. Urbanization and agriculture quickly spread west, placing additional pressures on surface waters of the area, including Lake Worth.

By 1950, resident population of West Palm Beach increased to over 43,000. The entire urban development at that time was discharging 10 million gallons of raw sewage daily directly into Lake Worth or through septic tanks into ground waters. Already, much of Lake Worth shoreline had been dredged, filled, and bulkheaded. The cumulative effect of interior drainage, agricultural and urban runoff, sewage disposal, and shoreline development peaked in the early 1950's. Concurrently the cost of waterfront property skyrocketed. In 1959, Munyon Island was significantly enlarged by deposition of dredge spoil. In 1967 North Palm Beach Inlet was further dredged to 35'. By 1972, almost the entire Lake Worth shoreline was urbanized with half the shoreline bulkheaded. Figure 26 describes Lake Worth.

Between 1950 and the present, several steps to improve the lake have been taken. Dredge and fill and bulkhead operations have been prohibited. By mid-1960, 70% of the urban population was served by sewage treatment facilities. A massive cleanup occurred through the 1970's resulting in all sewage receiving secondary treatment prior to disposal.

Today, Lake Worth receives saltwater input from the intracoastal waterways and from the two inlets directly opening Lake Worth to the

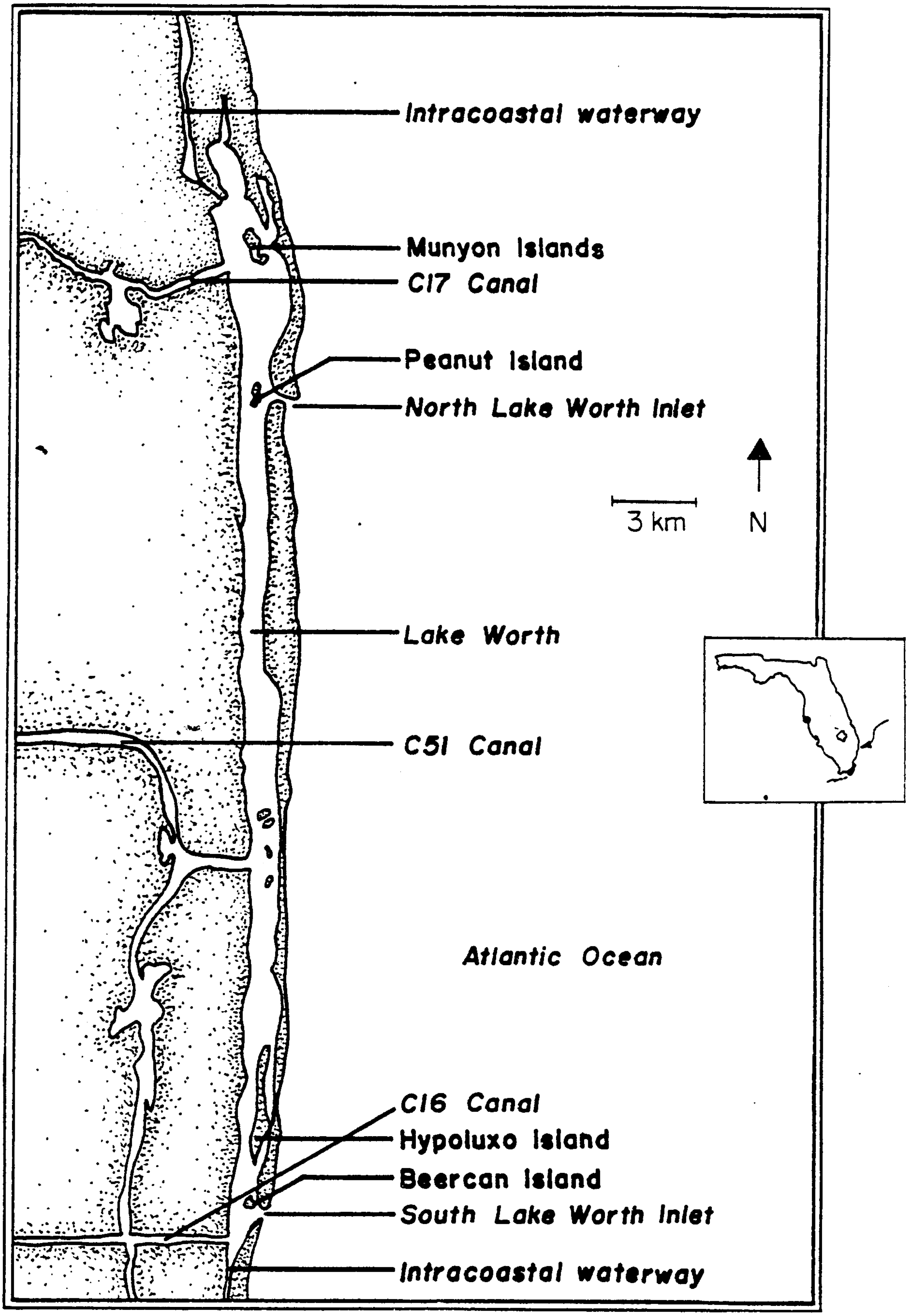


Figure 26. Lake Worth.

Atlantic. Freshwater input arrives from 7 sources with the C-51 canal being the major source of freshwater and a major source of nutrients and pollutants (Table 8).

Table 8. SOURCES OF FRESHWATER FLOWING INTO LAKE WORTH

SOURCE	% OF TOTAL FRESHWATER INPUT
C-17 canal	12.1%
C-51 canal	49.7% (75% flows north, 25% flows south)
C-16 canal	10.7%
WPB Sewage Treatment Plant	1.3%
Boynton Sewage Treatment Plant	0.3%
Surface runoff	4.1%
Groundwater discharge	22.3%

In summary, Lake Worth naturally evolved from a saltwater lagoon to a fresh-water lake. Man-made changes modified the lake into an estuarine lagoon. Though it is not feasible to return Lake Worth to its original freshwater condition, it is desirable to maintain the lake as a productive estuary.

VI E 2. GENERAL ACREAGE VALUES

Several inconsistencies exist with the interpretation of the three Lake Worth quads that did not occur with any of the Charlotte Harbor quads. The Lake Worth study site did not extend entirely to the western boundaries of the three quads; it stopped approximately 1.5 km east of the western edge (See Figure 24). However, the contractor continued interpretation to the western boundary on the 1975 Riviera Beach quad. Since the extended interpretation also included acreage values, only those categories that are not included within the 1.5 km interpretation extension are accurate for comparing the historical and recent Riviera Beach quads. These include only marine waters and marine wetlands. However, all categories were compared between historical and recent interpretation of the other two Lake Worth quads. Also the Atlantic Ocean was classified as "Bays and Estuaries" on both the historical and recent Lake Worth quad maps. Another interpretation error is the delineation of reefs for all 1940 quads but not for the 1975 quads. Reviewing the 1975 aerial photographs and ground truthing revealed that these reefs still exist.

Table 9 lists the eight general categories and their associated historical and recent acreage values. Since seagrasses were classified as a special category (900) for the recent interpretation, these values were added to the recent wetlands' values (600). Historically, seagrasses were classified under the wetlands category.

The following paragraphs describe the Level I acreage changes. The numbers in parentheses following the category name relate to the interpretation index numbers as found on the maps.

Table 9. LAKE WORTH ACREAGE VALUES

Level 1 Land Use name	Urban		Agriculture		Rangeland		Forestland	
Level 1 Land Use code	100		200		300		400	
Year	1940	1975	1940	1975	1940	1975	1940	1975
USGS Quadrangle Name								
Riviera Beach	5274	15499	1217	1440	15408	2015	3493	4204
Palm Beach	8788	16910	525	427	6599	427	809	1326
Lake Worth	3490	14500	4340	1633	4663	1324	5566	2201
TOTAL ACRES	17552	46909	6082	3500	26670	3766	9868	7731
Acreage Change[1]	+19132		-2805		-9511		-2848	
Percent (%) Change[1]	+ 159%		- 58%		- 84%		- 45%	

Level 1 Land Use name	Water		Wetlands		Barrenland		Transportation and Utilities	
Level 1 Land Use code	500		600		700		800	
Year	1940	1975	1940	1975	1940	1975	1940	1975
USGS Quadrangle Name								
Riviera Beach	31255	16168	13863	1226	896	1060	732	1001
Palm Beach	13740	15962	5691	212	461	111	658	2676
Lake Worth	15307	16911	4733	373	420	838	211	1147
TOTAL ACRES	60302	49041	24287	1811	1777	2009	1601	4824
Acreage Change[1]	+3826		-22476		+ 68		+2956	
Percent (%) Change[1]	+ 13%		- 93%		+ 08%		+ 341%	

[1]The Riviera Beach quad acreage values are not included in these totals since different size areas were photointerpreted for that quad.

Urban (100)[1]

Urban area increased 159%, from 12,278 acres to 31,410 acres. The Palm Beach quad nearly doubled in urban area while the Lake Worth quad quadrupled. The majority of the urban category is residential housing. Since much of the area immediately surrounding Lake Worth was already urbanized by 1940, much of this increase occurred farther inland.

Agriculture (200)[1]

Agriculture land decreased by 3,805 acres, a 58% decrease. The Lake Worth quad experienced 97% of this loss accounting for 2,707 acres. Most of the lost agricultural land was replaced by urban area and occurred inland from Lake Worth.

Rangeland (300)[1]

Rangeland decreased by 84%, a loss of 9,511 acres. This rangeland was converted into urban area and, like the agriculture class above, occurred inland of Lake Worth.

Forestland (400)[1]

Forestland lost 2,848 acres, a decrease of 45%. This value does not reflect a true loss of natural forestland because it includes acreage increases of exotic species. These increases include 1,514 acres of Brazilian Pepper, 331 acres of *Melaleuca*, and 215 acres of Australian Pine.

[1]Does not include acreage data from the Riviera Beach quad.

Conversely, natural pine flatwoods lost 3,680 acres, a decline of 76%. In addition, sandpine scrub, one of Florida's most unique natural upland habitats, lost 511 acres, an 85% decline.

Water (500)[1]

Water area increased 13%, a gain of 3,826 acres. Most, if not all, of this increase can be explained by the loss of acreage from the seagrass category.

Wetlands (600)[1]

Wetlands experienced an overall decrease of 22,476 acres, a decline of 93%. Wet prairies and freshwater marsh lost 7,017 acres, a 97% decline. Marine wetlands will be discussed in detail in the following section.

Barrenland (700)[1]

Barrenland increased by 8%, a gain of 68 acres. These lands were generally the result of land clearing and other construction activities.

Transportation and Utilities (800)[1]

This category increased 341%, from 867 acres to 3,823 acres. Much of the increase can be explained by the addition of Interstate 95 and expansion of West Palm Beach International Airport. In addition, several other factors, such as bus terminals and sewage treatment plants, have increased the acreage value for this category.

[1]Does not include acreage data from the Riviera Beach quad.

VI E 3. FISHERIES HABITAT COMPONENT ACREAGES

Section VI D 3 defines fisheries habitat components. Table 10 provides historical and recent acreage values for fisheries habitat in Lake Worth. Acreage values for the Riviera Beach quad can be included within this section since the interpretation error does not include marine wetlands.

Mangroves (612)

Mangroves lost 1,881 acres, a decrease of 87%. Mangroves appear to be replaced by Australian Pines and urbanization in the form of seawalls and residential and commercial housing. The remaining 276 acres of mangroves occur in very small scattered areas and are now protected by strict regulations.

Non-Vegetated Tidal Flat (651)

Mudflats apparently did not exist either historically or presently within the Lake Worth study site.

Oyster Reefs (654)

Oyster reefs did not exist either historically or presently within the Lake Worth study site.

Saltmarshes (642)

Only one site of saltmarsh occurred historically within the study site, which was located in the Riviera Beach quad. All 130 acres of this marsh was replaced by residential area and a small lake. Some tropical

Table 10. LAKE WORTH FISHERIES HABITAT COMPONENT ACREAGES

Habitat Component / Year	Mangrove 1940	Mangrove 1975	Non-Vegetated Tidal Flat 1940	Non-Vegetated Tidal Flat 1975	Oyster Reef 1940	Oyster Reef 1975	Saltmarsh 1940	Saltmarsh 1975	Seagrass 1940	Seagrass 1975
USGS Quadrangle Name										
Riviera Beach	1667	112	0	0	0	0	130	0	1995	152
Palm Beach	66	46	0	0	0	0	0	0	1014	0
Lake Worth	424	118	0	0	0	0	130	0	1262	9
TOTAL ACRES	17552	46909	0	0	0	0	130	0	4271	161
Acreage Change	- 1881						- 130		-4110	
Percent (%) Change	- 87%						- 100%		- 96%	

hammock also occurred there possibly as a result of natural succession but more likely a result of residential trees planting.

<u>Seagrasses (645 historical; 901, 903, 904 recent)</u>

Due to the poor quality of photography (for seagrass interpretation) in the Lake Worth study area, it has been determined that a historical comparison is of unacceptable accuracy. Because of the long term turbidity patterns in Lake Worth, even the recent photography was difficult to interpret and much of the seagrass delineation was provided to the contractor through ground truth efforts and personal communication. The only substantial seagrass bed found in Lake Worth was north of Palm Beach Inlet adjacent to John MacArther State Recreation Area. This seagrass bed consisted of primarily <u>Halodule</u> and <u>Thalassia</u>. During the ground truth efforts, the <u>Thalassia</u> was found to be highly reproductive with large accumulations of viable seeds. This is of important consequence for future restoration work in the Lake Worth area.

Some recollective communication with early researchers in the Lake Worth area has provided some understanding of seagrass populations. Dr. Gilbert Voss (personal communication) stated that seagrasses within Lake Worth historically existed only near the inlets and were never very abundant. In addition, Dr. Voss stated that no seagrasses ever existed within mid Lake Worth; he described this area as a "big mud hole." Seasonal and short term variations most likely occur, however, it is probable that seagrass populations have remained relatively unchanged over the past 40 years.

VI E 4. COMPARISON BETWEEN FISHERIES STATISTICS AND HABITAT ALTERATION

Since commercial fisheries statistics were inadequate in general and grossly inaccurate for the Lake Worth Study site (see Section V E 2), and because the acreage values for the seagrass category are questionable, no attempt was made to compare wetland loss to fisheries decline. Observing the commercial catch values in 1951 (Fig. 15 through 22), however, shows that before regulations were enacted that banned all net fishing other than cast nets in Lake Worth, a large commercial fishing industry existed in the area. As discussed in Section V E 2, the catch may not have come from Lake Worth. The data presents only the county in which the catch was landed. Much of the catch may well have come from the Loxahatchee estuary. Unfortunately, no data are available to clarify this discrepancy.

Until fisheries statistics are improved to include effort data and knowledge of where the catch was made, no conclusions can be drawn to associate habitat alteration to fisheries decline.

VII. MARINE RESOURCES GEOBASED INFORMATION SYSTEM

VII A. DESCRIPTION

A Marine Resources Geobased Information System (MRGIS) has been installed at the Florida Department of Natural Resources Bureau of Marine Research (BMR) in St. Petersburg, Florida. The MRGIS is designed for processing, analyzing, and integrating satellite data and other digital data from a grid system with a variety of environmental and socioeconomic data for resource analyses and applications modeling. The MRGIS will be used primarily as a research tool for coastal zone resource management and for integrating coastal zone data bases. The system is a research prototype for the State of Florida and is being used to demonstrate regional and state-wide applications.

The MRGIS was developed at the BMR with the following reasoning:

1. BMR has actively pursued research with satellite imagery since the early 1970's and has participated in field experiments with NASA, testing prototype sensors and applications of these sensors.
2. Scientists from BMR represented DNR on the LANDSAT Evaluation Committee and, thus, the integration of the MRGIS as a prototype for a statewide research system was consistent with the intent of the committee.
3. BMR had the capability of assessing hardware and software required to develop the MRGIS and was current with the latest technology in the field by close association with NASA.
4. BMR Scientists had been trained on Earth Resources Laboratory Applications System (ELAS) software and were computer-oriented.

This permitted the purchase, installation, and use of the system without additional staffing.

5. Habitat loss is of critical concern to the State of Florida and the MRGIS provides an exemplary tool to establish a digital data base for coastal habitats.

Since the MRGIS was the prototype for a State of Florida research system, extreme caution was required in hardware configuration. With the assistance of NASA Earth Resource Laboratory personnel, specific hardware configurations to meet general budgetary constraints were developed. At that time bid specifications were developed. Since the intent was to establish a turnkey system that would use ELAS as the operating software, a major requirement to the vendor was the installation of ELAS on the model they bid. In addition, specific hardware requirements to ensure expandability and state of the art technology were included to maintain the potential for future systems development.

The image processor and display was purchased as a sole source item because the software driver and interface to the mainframe were available and ELAS was designed with I/O commands specific to the processor. Software and hardware development would have been necessary if any other approach had been taken.

The mainframe hardware (Fig. 27) consists of a 512 kilobyte core memory and peripheral storage and retrieval devices. The image processing system (Fig. 28) is interfaced to the mainframe and is capable of image and graphics display. The system configuration was designed by NASA Earth Resources Laboratory (ERL) to satisfy requirements of the Earth Resources Laboratory Applications Software (ELAS).

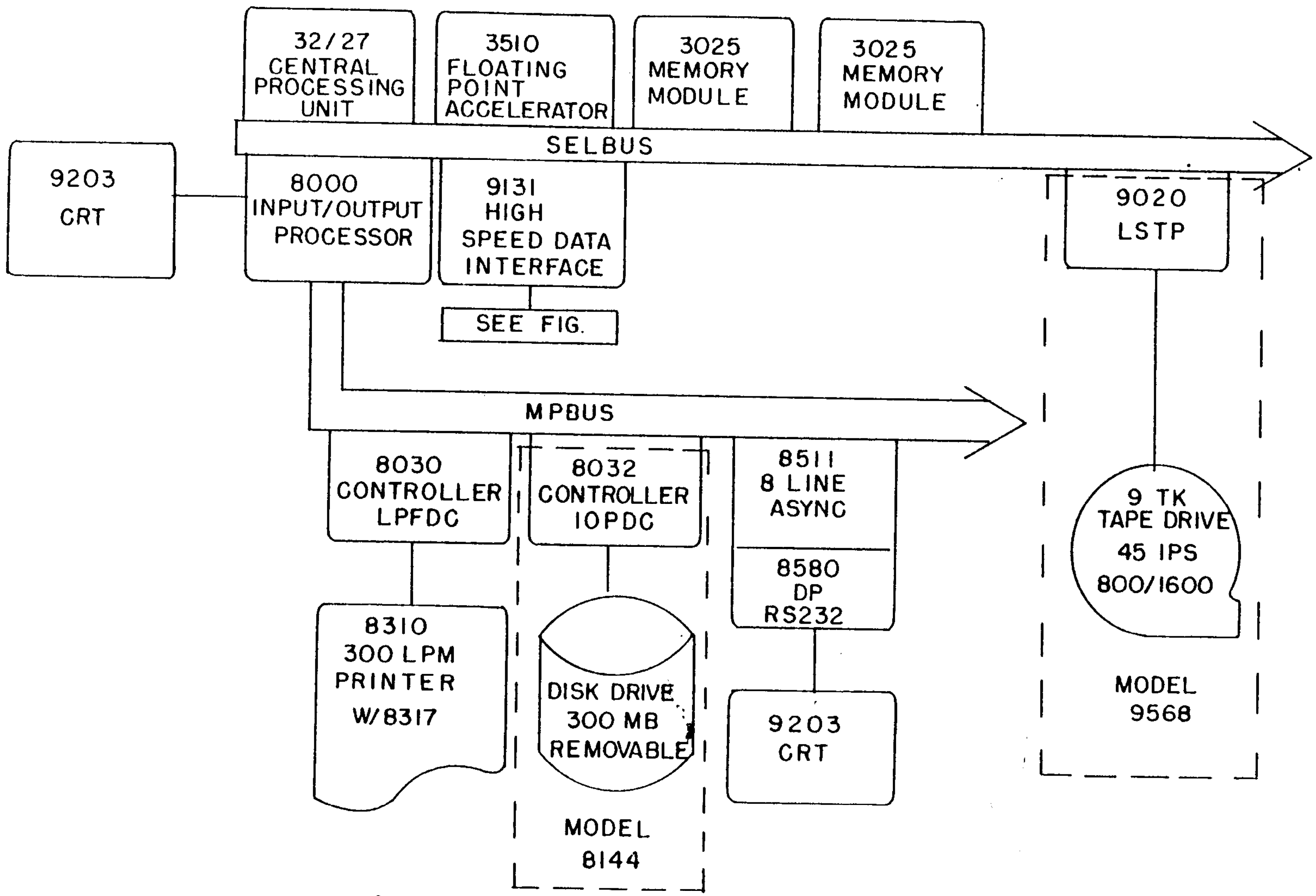


Figure 27. MRGIS mainframe and peripheral hardware.

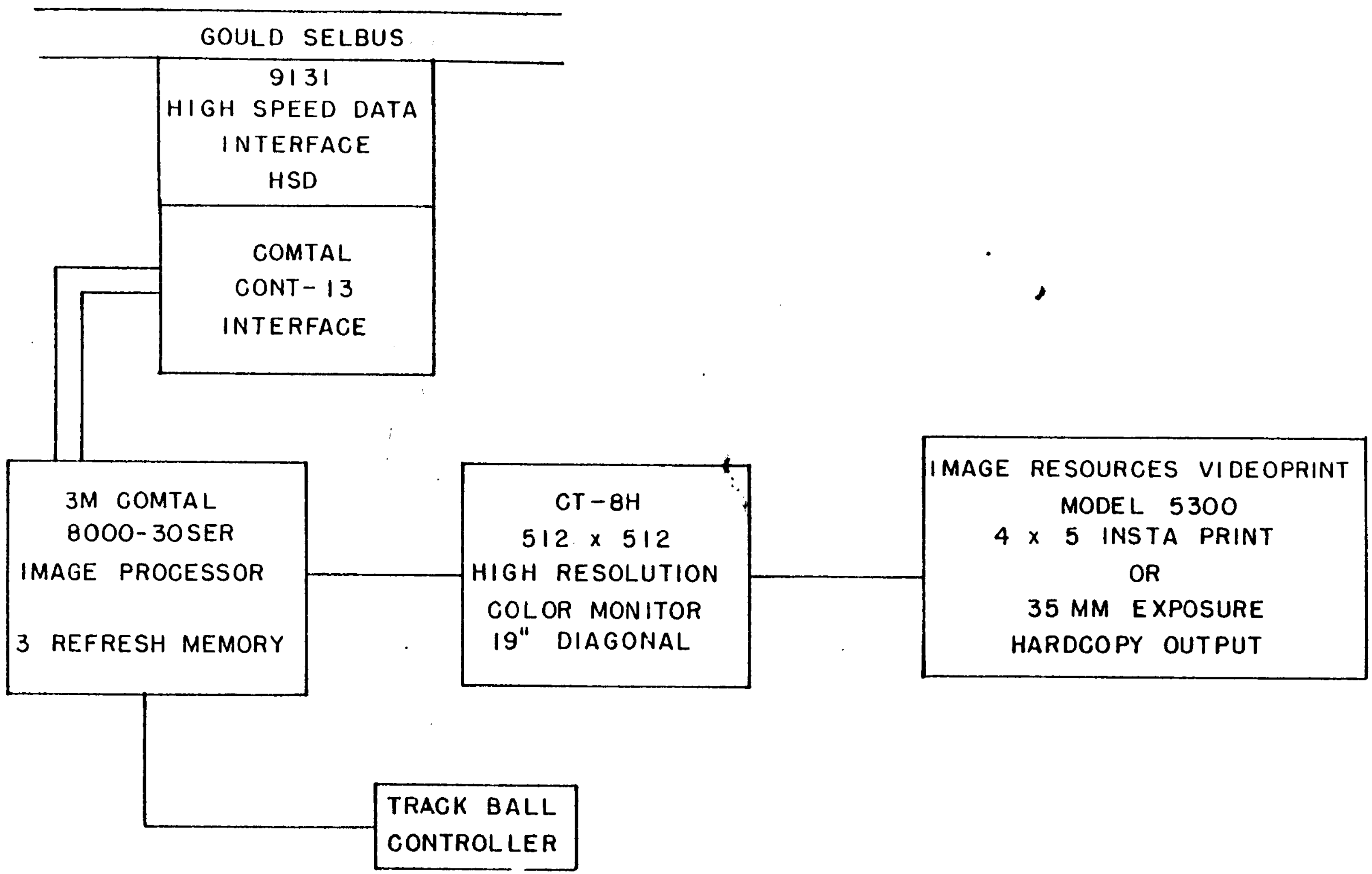


Figure 28. MRGIS graphics hardware.

The software (Fig. 29) installed on the MRGIS consists of three levels:

1. System Software - machine-specific operating software for primary level communication.
2. FORTRAN, Symbolic Debugger, Scientific Run Time Library - Programing language and programing aids.
3. Application Software - ELAS, Coastal Zone Color Scanner, and any other level two programs.

The principal applications software installed on the system is ELAS. This software was sponsored and developed by the Earth Resources Laboratory (ERL) of the National Space Technology Laboratories (NSTL) of the National Aeronautics and Space Administration (NASA). ELAS software development began in the early 1970's. The initial work was directed towards supervised classification of LANDSAT and aircraft data. Development progressed with the addition of the capability to geographically reference the data to the Universal Transverse Mercator (UTM) grid. Also, the data processing approach was changed from batch to interactive processing. A data base program was added to allow the storage of numerous parameters, (i.e.) LANDSAT classifications, soil types, rainfall, elevation, per-cent slope, slope length, aspect, ownership, oceanographic variables, etc., by a selectable cell size. This permits manipulation of these parameters through selectable application algorithms to produce resource management information.

The ELAS software is divided into two components, the operating subsystem and the applications modules. The operating subsystem is FORTRAN-based and uses some machine-dependent routines for INPUT/OUTPUT and control functions.

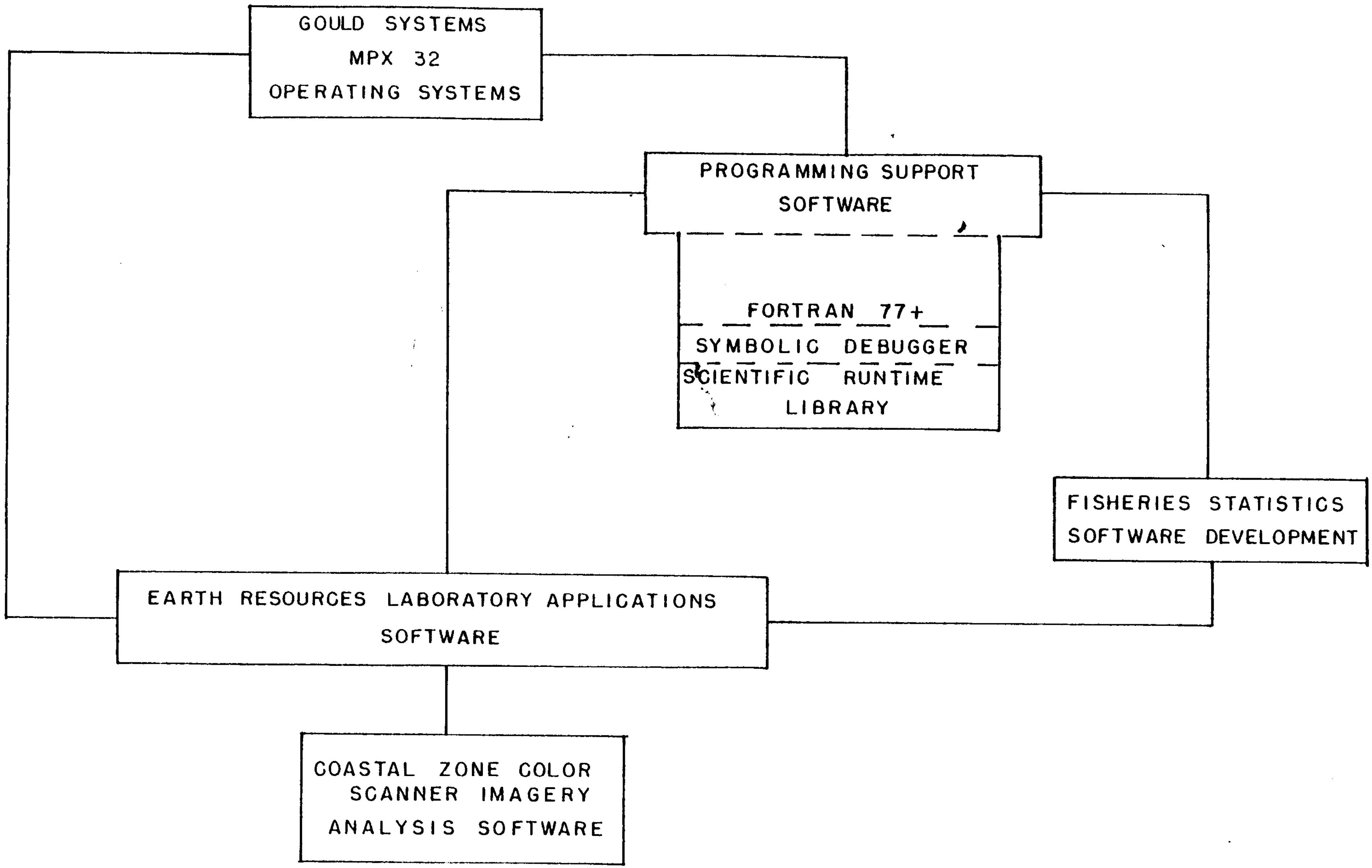


Figure 29. MRGIS software configuration.

The applications modules are written in FORTRAN, utilizing the operating subsystem for the machine dependent functions. The application modules exist generally as FORTRAN overlays or subroutines. Depending on the application, needed modules are called or released by the operating subsystem. Approximately 133 processing modules now exist within the ELAS package. A complete description of ELAS is documented by Junkin et al. (1980).

The usefulness of information derived from LANDSAT multispectral scanner data has been recognized by state agencies primarily as a result of the Florida LANDSAT Demonstration Project (Brannan et al. 1981). That project was developed in conjunction with the NASA Earth Resources Laboratory Regional Applications Program and the Florida LANDSAT Evaluation Committee.

VII B. LANDSAT IMAGERY ANALYSIS OF CHARLOTTE HARBOR

General LANDSAT vegetation cover classifications have been developed for the Charlotte Harbor area. Development of these classifications represents the initial phase of the MRGIS operational development. These initial classifications are at Level I/Level II resolutions and statistical accuracies of the classifications have not yet been developed. As we gain better familiarity with ELAS, it is certain that classifications will be greatly enhanced and specific analysis techniques relative to the information desired will be refined. A stepwise progression to provide a general understanding of the process in developing these classifications, including observations and comments for this report, follows:

1. LANDSAT: When utilizing LANDSAT data it is important to understand physical processes of data acquisition. The LANDSAT program was initiated in 1972 and data are available from 1972 to the present. This report utilizes data collected by the multispectral scanner (MSS) located on board all four LANDSAT satellites launched since 1972. The satellites were launched into a polar sun-synchronous orbit at an altitude of 920km and pass over a given area every 18 days. The MSS has a ground resolution of one pixel (equal to $80m^2$ or 1.1 acres) and measures average reflectence of the pixel in four wavelength bands (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 nanometers). Each LANDSAT scene (fixed image) covers an area approximately 183 x 183km (115 x 115 statute miles). These data are relayed to earth stations and radiometric and geometric corrections are made by computer. The raw data, in several forms, are then available for purchase (currently through NOAA) as computer compatible tapes. LANDSAT 4 contains the MSS and a new Thematic Mapper (TM) sensor with coverage every 16 days and a lower orbit. The TM measures seven wavelength bands and has a ground resolution of 1/4 acre. These data are not yet available. One TM scene has been installed on the MRGIS and initial review suggests a tremendous increase in the ability to resolve fisheries habitat. TM data will be compared to MSS and aerial photography in detail in subsequent reports.

2. Acquiring data: Data are ordered on computer compatible tapes from data centers located in several cities across the U.S. Prior to ordering a scene it is important to know the percent cloud cover over the area of interest. Usually, the best imagery has less than 20% cloud cover. In addition, the type of information to be extracted from the data should

be considered before ordering data. If, for example, the prime interest is seagrasses, late fall to early spring (when the water is clearer) at low tides provides the best data. If the interest is in deciduous forests then a multitemporal analysis from summer (when leaves are present) and winter (when leaves are absent) would provide the best data sources. It is advised that the scene be personally scrutenized through microfiche or hardcopy prior to purchase.

3. Processing: Raw computer compatible tape (CCT) imagery consists of four data channels for each scene. The data consist of a numerical value between 0 and 255 representing an average relative reflectance value for each of the four spectral bands of each pixel. The raw data, therefore, can potentially contain four of $(256)^4$ possible values for each pixel. ELAS contains numerous statistical packages which can be used to transform the raw data into a managable data set, a necessary step in developing a vegetative and land use classification. By using one or two of the statistical classifiers, less than 62 classes will be developed based upon the statistical boundaries set by the investigator. At this point, the investigator evaluates the classes broken out by the processing techniques and assigns them a land cover type such as mangroves, pines or hardwoods. During this interactive process, some classes may be lumped and others may be further statistically evaluated.

4. Charlotte Harbor: The Charlotte Harbor study area required two scenes of data, Upper and Lower Charlotte Harbor (Fig. 30 and 31).

Upper Charlotte Harbor (Fig. 30) was developed from an August 22, 1980 scene. Originally, 54 classes were developed for this image, however, they have been combined to present nine final classes and are defined as follows:

Impacted/Cleared refers primarily to areas undergoing development. The land has been cleared and has very little vegetation. The primary component of the soil is sand and the reflectence values are high. Some naturally occurring saltbarrens may be found within this category.

Impacted/Urban are areas which are composed primarily of buildings such as downtown areas or dense suburban areas, or any recent housing developments with little vegetation.

Impacted/Vegetated are areas comprised primarily of cleared land which has revegetated and exists in various stages of succession. The majority of lands in this class were cleared, platted and installed with roads during the 1960's - 1970's land boom period. This class also includes crop and pasture land and housing developments that are typically older and lushly vegetated.

The Palmetto Scrub/Pine Scrub/Tropicals refers to the predominant natural vegetation types in a particular scene. Palmetto and pine scrub contain from 0-30% pine with palmetto the predominant vegetation. These areas are typically on high ground that is rarely flooded. Tropical vegetation (generally non-native introduced species) were lumped into this class and consists of very small areas. The type of tropicals included are primarily woody tree species such as eucalyptus and members of the fig family.

Palmetto/Marsh/Mangrove classes were combined to present a subarborial vegetation which is either seasonally or tidally wet. This refers to vegetation types less than 3m in height. The palmetto areas in this class have <30% pine and are seasonally wet with a high water table.

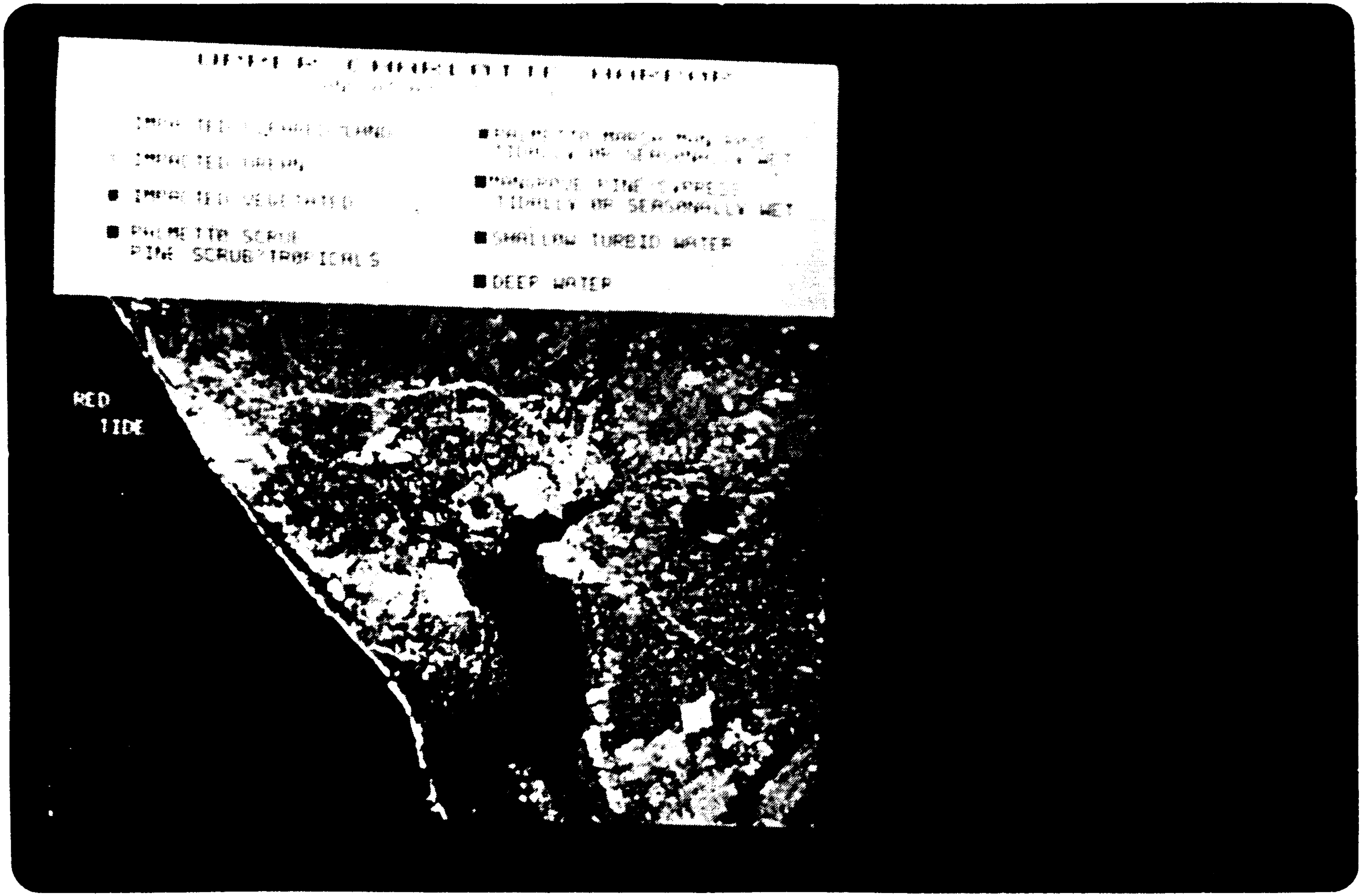


Figure 30. General LANDSAT classification of Upper Charlotte Harbor.

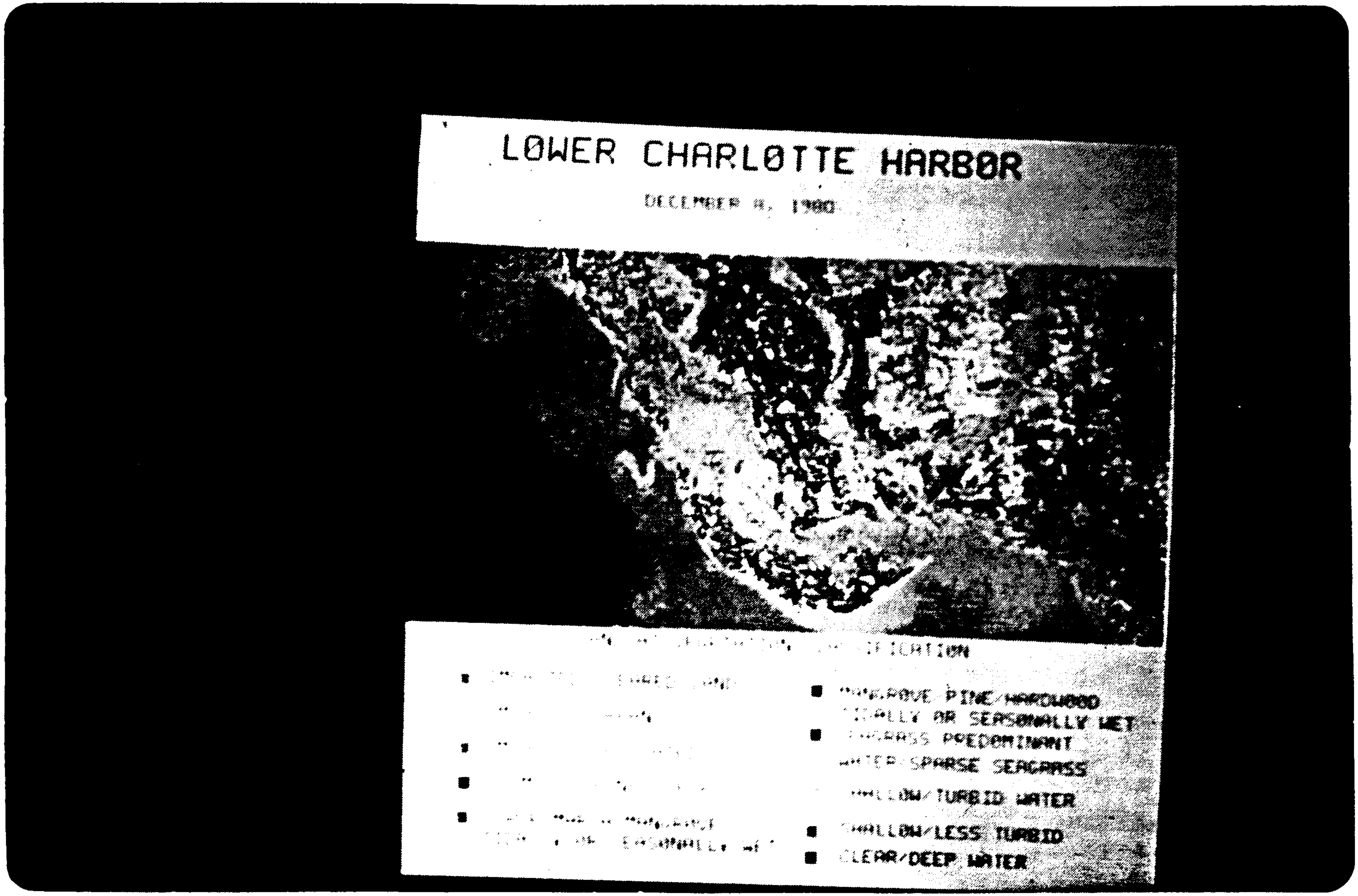


Figure 31. General LANDSAT classification of Lower Charlotte Harbor.

The marsh areas consist of Juncus, Spartina and other fresh and brackish water species. The mangroves included in this class are generally stunted and sparse. Batis, Salicornia and other salt-tolerant species coinhabit these areas.

The Mangrove/Pine/Hardwood class is also characterized by seasonal or tidal inundation. This vegetation class typically has a dense canopy and is >3 m in height. The mangroves are typically so dense that little water is reflected through the canopy. The pine areas have a 30-60% canopy cover and usually have an understory of palmetto. These pine flatwoods are seasonally wet although the pines individually inhabit the higher ground. The deciduous hardwoods inhabit primarily bottom lands associated with the rivers and their tributaries that comprise the Charlotte Harbor watershed. These hardwoods are generally composed of cypress, sweetgum, oaks, bays, and others.

The Shallow/Turbid Water class represents those waters usually <3m in depth and either have a bottom reflectance or are turbid.

Deep Water refers to those waters >3m and are less influenced by bottom reflectance.

Figure 32, entitled Punta Gorda SW, is a section of the Upper Charlotte Harbor satellite image. This image has been corrected from spacecraft coordinates to Universal Transverse Meridian (UTM) grid coordinates. The conversion results in a north-south orientation of the image, comparable to available aerial photography and map products. Figure 30 covers the same area as a quad map (7.5 x 7.5 minutes) and is, therefore, compatible to the photointerpretation of the Punta Gorda SW quad. A seperate set of statistics was developed for this image with 50 original land cover classes. Again, many of the classes were combined, but in this case the final classification is more specific in vegetation type. In addition to land cover classes, several Indian mounds and bald eagle nesting sites have been integrated into this image.

The first two classes are identical to the Upper Charlotte Harbor classification description. There are no urban areas in this image.

Palmetto Scrub refers to those areas with <30% pine and a palmetto understory. These areas range from 90% palmetto to a mixture of palmetto, xeric grasses, wax myrtle, and other subarboreal vegetation.

Pine scrub consists of >30% pine and generally has a palmetto understory.

Fresh/Brackish Marsh consists primarily of *Juncus*, *Spartina* and *Typha* in areas of low salinity. Also included in this class are large sites of *Batis* and *Salicornia*. These areas were typically found in the center of mangrove islands or in supratidal areas with dead or stunted and sparse mangroves.

Mangrove Predominant contains red, black and white mangroves. Quite often man-impacted mangroves were interspersed with Brazilian pepper.

Vegetated Saltern or Tidal Flats primarily refers to the fringe areas separating mangroves from palmetto and pine scrub habitats. Vegetation on these flats is patchy in nature and consists of grasses, palmetto, mangroves and succulents tolerant to extreme wet and dry periods. The barren areas are both organic and inorganic in nature.

Lower Charlotte Harbor (Fig. 31) represents a December 8, 1980 scene. Originally, 43 classes were developed for the image but have been combined to a final 10 classes.

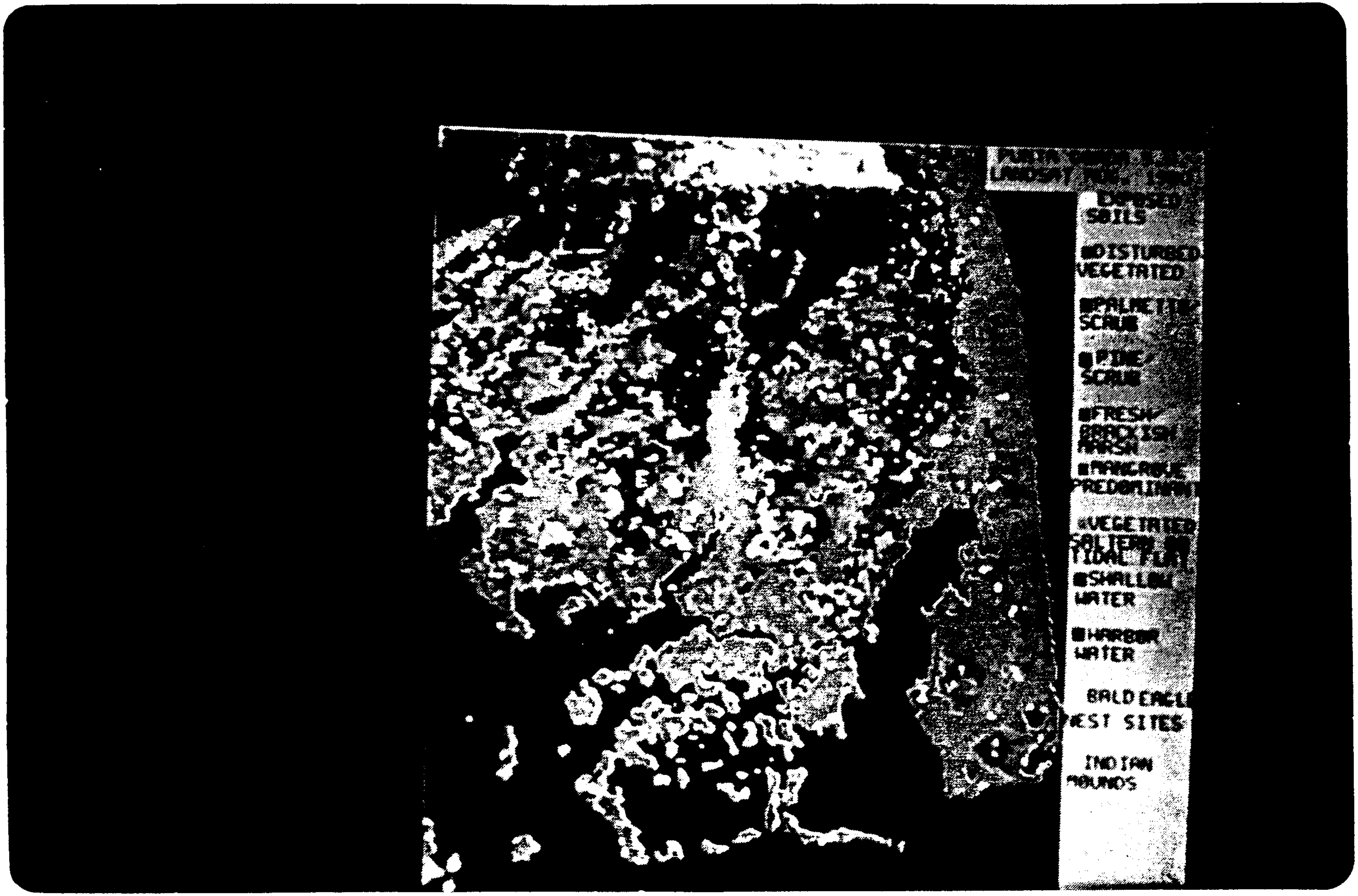


Figure 32. Detailed LANDSAT classification of the Punta Gorda SW quad.

The classification scheme for this image is comparable to the Upper Charlotte Harbor image with one exception. Since this was a winter scene, the water was clear and submerged seagrasses were statistically separable The two seagrass classes represent moderate or dense meadows versus sparse or patchy meadows.

The above classifications (Fig. 30-32) are initial work products and represent a stage in the development of the MRGIS. The Charlotte Harbor area is being used as a training exercise to demonstrate the potential of the MRGIS. Aerial photographs and associated digitized photointerpretations are being used to develop an accuracy assessment and comparison of the aerials and LANDSAT images. The Punta Gorda SW image (Fig. 32) has been analyzed and ground truthed for comparison to the Punta Gorda SW digitized quad map (Map 7). Although the statistics for the image may not yet be the best for all the classes, a comparison of mangrove acreages has been made. The image contains 8,486 acres of mangroves while the photointerpreted quad contains 8,251 acres. This demonstrates a very close agreement but can be misleading. For example, while the geographical locations of the mangroves are very similar, some areas on the image that depict mangrove are not found on the photointerpreted quad and vice-versa.

These differences are being addressed in a detailed, and eventually a statistical, manner which will allow us to proceed to other areas of the state with a developed level of accuracy.

VII C. ADDITIONAL USES OF THE MRGIS

The MRGIS is now being utilized in several other areas of research.

1. Coastal Zone Color Scanner (CZCS): In conjunction with the Gulf

States Marine Fisheries Commission SEAMAP program, we have installed additional software into ELAS capable of analyzing imagery from the CZCS on board the Nimbus 7 satellite. The software was provided by the National Marine Fisheries Service and is used to measure chlorophyll concentrations and turbidity in coastal and ocean waters. CZCS data will be analyzed in conjunction with ichthyoplankton surveys being made on the west Florida Shelf. This will aid in determining larval fish distribution and recruitment. We will be developing a CZCS analysis program to research migration patterns of pelagic/coastal species such as mackerel. We will be cooperating with University of Miami personnel in using CZCS imagery in conjunction with swordfish research.

The BMR has been using CZCS imagery in Red Tide research and this will continue. With the CZCS capability now operating on the MRGIS, numerous other requests and discussion from state, university and federal organizations have been enacted and it is assured the CZCS will greatly enhance our understanding of the coastal environment.

2. LANDSAT: The DNR Bureau of Aquatic Plants is currently working with the MRGIS to assess its use in monitoring the spread of aquatic weeds in Florida.

We are working with the DNR Bureau of Environmental Land Management to inventory Florida's aquatic preserves.

We will also be working with Rookery Bay National Estuarine Sanctuary to provide an inventory of the sanctuary and the surrounding areas.

LANDSAT can also be applied to red tide research. The dinoflagellate Ptychodiscus brevis is responsible for massive fish kills and neurotoxic shellfish poisoning. Figure 30 is the first LANDSAT image to document a

Florida west coast toxic dinoflagellate bloom and possibly the first LANDSAT image, world wide, to ever document a toxic dinoflagellate bloom. This type of imagery can provide the scientific investigator and resource manager with information pertinent to the development and dynamics of a bloom simply unattainable by conventional shipboard measurements.

As visiting scientists and resource managers are introduced to the technology of the MRGIS, immediate applications are conceived. This is a relatively new technology that has not been adequately transferred to scientists and/or resource managers. The MRGIS is bridging the gap.

VIID. GROUND TRUTHING

Ground truthing started in August 1982 and will continue for this phase of the project through early 1984. Initial ground truthing served two major purposes and currently serves two additional intentions.

Initial ground truthing efforts:

1. DNR personnel assisted DOT in verifying their photointerpretation of Charlotte Harbor aerial photography. This involved visiting specific sites in question by the interpretors and identifying the vegetation. Representative areas of numerous vegetation types were visited, including coastal habitats such as seagrasses and mangroves.
2. DNR personnel, assisted by a DER staff member and the Lee County Marine Extension Agent, ground truthed several seagrass areas to verify DOT's system of classifying seagrasses. The original classification delineated four categories: sparse, moderate,

dense, and patchy. Ten transects were assessed for spatial distribution of seagrasses. These initial observations suggested that the classification system be altered to three designates: sparse, moderate-dense, and patchy.

<u>Current ground truthing efforts:</u>

1. When using remotely-sensed imagery it is important to understand seasonal density changes in vegetation resulting from leaf drop and leaf growth to allow multitemporal analysis. Five of ten original preliminary transect sites were chosen for quarterly investigations of seagrass density over one year.

   Each sampling period and station requires measurements of several parameters. Currently, measurements are taken only for the dominant seagrass, <u>Thalassia testudinum</u>. (1) Seagrass density is determined by counting the number of short shoots per 1/16 meter quadrats. An average value is calculated and extrapolated resulting with an average value per square meter. (2) Random seagrass short shoots are measured to determine number of blades and blade length and width. (3) Water temperature and salinity are recorded. (4) If drift algae is present, random samples using the 1/16m quadrat are taken. The algae is dried and an average dry weight per square meter is determined.

   A similar study will proceed for the Tampa Bay study (CM 69). Data from Charlotte Harbor and Tampa Bay will be analyzed to determine a method to seasonally assess seagrasses using remote sensing techniques.

2. Statistical analyses of Landsat images sometimes delineate certain

areas as being different from sites that are actually of the same classification. Conversely, analyses also classify very different areas as being the same. Ground truthing may clarify these questionable sites. These preliminary observations will greatly facilitate future analyses involving Landsat images of other sites of coastal Florida.

VIII. APPENDICES

VIII A. Appendix A

The following is a general description of the classification scheme used on the map products. It is reproduced from Kuyper et al. (1981).

SECTION I

General Description

This land use, vegetation cover and land form classification system is arranged in hierarchical levels with each level containing land information of increasing specificity.

LEVEL I

This class of data is very general in nature. It can be obtained from remote sensing satellite imagery with supplemental information. Level I would normally be used for very large areas, statewide or larger, mapped typically at a scale of 1:1,000,000 or 1:500,000. At these scales, one inch equals 16 miles or one inch equals eight miles, (1 centimeter per 5 kilometer), respectively.

LEVEL II

This class of data is more specific than Level I. Level II data is normally obtained from high altitude imagery (40,000 to 60,000 feet), supplemented by satellite imagery and other materials such as topographic maps. Mapping typically might be at a scale of 1:100,000 or one inch equals 8,333 feet (1 centimeter per 1 kilometer).

LEVEL III

This class of data usually is obtained from medium altitude photography flown between 10,000 and 40,000 feet. The mapping scale typically is 1:24,000, or one inch equals 2,000 feet (1 centimeter per 0.24 kilometer).

LEVEL IV

This more specific class of data is obtained from low altitude photography flown below 10,000 feet. In comparison with the above mentioned levels, Level IV typically might be mapped at a scale of 1:6000, or one inch equals 500 feet (1 centimeter per 0.06 kilometer).

Scope and Use

The Florida Land Use, Cover and Land Form Classification System is an important step toward the development of a geographic data based information system. It serves to reduce a large amount of primary data (such as remote sensing imagery or field survey records) to a more understandable, smaller amount of secondary data (such as a land use map). The system also provides a useful structure of land concepts of properties. Yet, it does not collect or analyze information or offer conclusions.

The definitions which follow will provide understanding of what is included in each category at Levels I, II and III. The definitions are largely based on U.S.G.S publications referenced in this report.

100 URBAN OR BUILT-UP

Urban or Built-up land consists of areas of intensive use, with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, and such areas as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.

As development progresses, small blocks of land of less intensive or nonconforming use may be isolated in the midst of built-up areas and will generally be included in this category. Agricultural, forest, or water areas on the fringe of urban and built-up areas will not be included except where they are part of low-density urban development.

The Urban or Built-up category takes precedence over others when the criteria for more than one category are met. For example, residential areas that have sufficient tree cover to meet Forestland Upland criteria will still be classified as Residential in the Urban or Built-up category.

110 Residential

Residential land uses range from high-density urban housing to low-density areas with relatively few dwelling units per gross acre. The variation extends from the multi-family apartments generally found in larger urban centers to those single-family houses sometimes having lot sizes of more than one acre.

Areas of sparse residential land use (generally less than one dwelling unit per five acres), such as farmsteads, will be included in other categories to which they relate. However, rural residential and recreational type subdivisions will be included in the Residential category since the land is almost totally committed to residential use, even though it may have forest or range types.

In most instances the boundary will be clear when new housing developments abut clearly defined agricultural areas. Conversly, the residential boundary may be vague and difficult to discern when residential development is sporadic and occurs in smaller isolated units, developed over an extended period of time in areas with mixed or less intensive uses. A careful evaluation of density and the overall relationship of the area to the total urban complex must be made.

Other land use categories may embrace areas that meet the Residential category requirement. Often such residential sections are an integral component of the category with which they are associated and should be included within that category. For example, in the Institutional category, residential units may be found on military bases in the form of barracks, apartments, dormitories or homes; and on college and university campuses, in the form of apartments and dormitories in close proximity to instructional buildings. Agricultural field operations and resort facilities commonly provide temporary lodging for their employees and these areas would be classified under Agriculture, and Commercial and Services respectively.

110 Residential, Low Density [less than two dwelling units per acre]

111 Single Family Units

112 Mobile Home Units

113 Mixed Units

119 Low Density, Under Construction

120 Residential, Medium Density [two-five dwelling units per acre]

121 Single Family Unit

122 Mobile Home Units

123 Mixed Units [fixed and mobile home units] *Note 1

129 Medium Density, Under Construction

130 Residential, High Density

131 Single Unit [six and over dwelling units per acre]

132 Mobile Home Units [more than six dwelling units per acre]

133 Multiple Dwelling Units, Low Rise [two stories or less]

134 Multiple Dwelling Units, High Rise [three stories or more]

135 Mixed Units [fixed and mobile home units] *Note 1

139 High Density, Under Construction

140 Commercial and Services

Commercial areas are predominantly connected with the sale of products and services. This category is composed of a large number of individual types of commercial land use, often occurring as a complex mixture of uses.

The Commercial and Services category includes the main building plus secondary structures and integral areas assigned to support the base unit. Included are sheds, warehouses, office buildings, driveways, parking lots, and landscaped areas.

Other types of commercial areas include shopping centers and commercial strip developments. These areas have distinctive patterns and are easily identifiable. Frequently, individual houses and other urban uses may be found in commercial areas. These uses are not delineated, unless they cannot be plotted into categorized cell size of at least one acre at Level III, in which case the Mixed category should be used.

Another commercial use that is not easily identifiable is the commercial resort. These businesses cater to vacationing patrons and contain associated recreational facilities such as swimming pools and ball courts.

141 Retail Sales and Services

The area of Retail Sales and Service is primarily devoted to sale of products and the services. This category will be comprised of elements of central business districts, shopping centers, and office buildings, with associated buildings, driveways and parking lots, etc.

142 Wholesale Sales and Service [except warehousing associated with industrial use]

This element represents primarily structures identified by size, shape, and adjacent features. Normally, structures are large and of boxlike shape, designed to hold large quantities of products. Included in this category are open storage areas that can be identified as being in use or the result of supplemental data to support this classification.

143 Professional Services

This category is unique: associated elements with the prime structure, along with supplemental data, are the major keys to category identification and location. The typical use would be lawyers, doctors, consulting firms, etc.

144 Cultural and Entertainment

This category includes theatres, museums, open air theatres (such as motion pictures and those for theatrical performances). Recreational facilities such as skating rinks and tennis courts are not included in this category.

145 Tourist Services

This category includes all those facilities that can be identified in support of a motel and hotel facility.

146 Oil and Gas Storage [except those areas associated with industrial use or manufacturing]

This category identifies storage facilities used in the retail and wholesale sales of these specific products. The Port Everglades facility in Fort Lauderdale would be a typical example.

147 Mixed Commercial and Service *Note 1

148 Cemeteries

149 Commercial or Service Under Construction

150 Industrial

The Industrial category embraces those land uses where manufacturing, assembly, or processing of products is accomplished. Industrial areas include a wide array of industrial types ranging from light manufacturing and industrial parks to heavy manufacturing plants. Included are facilities for administration and research, assembly, storage and warehousing, shipping, and associated parking lots and grounds.

Typical examples of industrial types found in Florida are pulp, or lumber mills, oil refineries with tank farms, chemical plants and brickmaking plants. Stockpiles of raw materials, larger power sources, and solid waste products disposal areas are visible industrial categories and are easily identified on conventional aerial photography.

151 Food Processing

Citrus processing plants, sugar refineries, and seafood packaging plants are typical of this category.

152 Timber Processing

Plywood manufacturing, woodchip plants, and saw mills are the prime components in this category.

153 Mineral Processing

Refining of basic earth materials such as Koalin, phosphates, heavy metals (Titanium, Zircon concentrates) is accomplished in Florida and the facilities for processing these materials are located near the mining operations.

154 Oil and Gas Processing

This category includes production of jet fuel, processing and recycling used petroleum products, also other products such as asphalt and liquid gases, as well as the classic petroleum product, gasoline.

155 Other Light Industrial

Steel fabrication, small boat manufacturing, electronic manufacturing and assembly plants are typical light industry facilities.

156 Other Heavy Industrial

Major ship repair, ship building, and large lumber mills can be placed in this category. In some instances mineral extraction can also be assigned here if the facility is processing a final and finished product.

159 Industrial Under Construction

160 Extractive

Extractive lands encompass both surface and subsurface mining operations. Included are sand, gravel and clay pits, phosphate mines, limestone quarries, plus oil and gas wells. The recognition of these activities on the landscape varies from the unmistakable giant pit mines covering vast areas, to oil wells which cover only a few square feet. Obviously, uniform identification of all these diverse extractive uses with their varied degrees of photographic expression is extremely difficult from remote sensing data alone. Industrial complexes, where the extracted material is refined, packaged, or further processed, are included in this category.

Abandoned or inactive mining operations are a part of the Extractive category until revegetation occurs. Flooded pits and quarries, which may be part of a mining operation, will be included in this category.

The presence of water bodies does not necessarily mean inactive or unused extractive areas. Ponds or lakes are often an integral part of an extractive operation. Areas of tailings and abandoned pits and quarries may remain recognizable for a long time. These areas may be barren for decades after deposition. During the interval from discontinued use until revegetation occurs, the parcel will be retained in the Extractive category.

161 Strip Mines

The mining method used in this category is easily identified by its land scarring, either in pit form or in long trenches, with tailings along the trenching operation.

162 Sand and Gravel Pits

The category of Sand and Gravel Pits will be relatively small in area size when compared to the category of strip mining operations. These pits are used primarily to support construction activities.

163 Rock Quarries

This category identifies the excavation of building materials that can be found in part in the St. Augustine, Brooksville and Ft. Myers areas. Equipment used in this category is the major identifying feature.

164 Oil and Gas Fields

These are petroleum products sources and are found in the Sunnyland and Jay areas. No processing facilities are found near these fields. The primary distinguishing feature will be the well head sites, some pumping facilities, and small storage tank facilities.

165 Abandoned Mine and Fields

166 Reclaimed Land

This category primarily identifies phosphate mining areas that are being restored.

167 Holding Ponds

170 Institutional

Educational, religious, health and military facilities are typical components of this category. Included within a particular institutional unit are all buildings, grounds and parking lots that compose the facility. Those areas not specifically related to the purposes of the institution should be excluded. For example, agricultural areas not specifically associated with correctional, educational or religious institutions are placed in the appropriate agricultural categories.

Educational institutions encompass all levels of public and private schools, colleges, universities, training centers, etc. The entire areas of buildings, campus open space, dormitories, recreational facilities and parking are included when identifiable.

Military facilities have a wide variety of conditions including training camps, missile sites, etc. Administration, storage, repair, security and other functional military buildings, plus the practice ranges, storage areas, equipment storage lots and buffer zones compose the institutional military facilities. Auxiliary land uses, particularly residential, commercial, and other supporting uses located on a military base, are included in the Institutional category.

171 Educational Facilities

This category includes all facilities, such as parking lots, stadiums, all buildings and any other features that can be related to the facility.

172 Religious

All buildings that can be related to this category are included. Many religious facilities have schools and day care centers within their property.

173 Military

All buildings and grounds that compose the facility are included, along with auxiliary land uses, particularly residential services and other supporting land uses.

174 Medical and Health Care

All buildings and grounds that compose the facility are included.

175 Governmental

Identifiable buildings and facilities are included, and supplemental data is used to identify this category.

176 Correctional

This facility normally is confined, with multiple fence structure. All structures and grounds are included that are known to be associated with this category, either by the interpretation process or as the result of supplemental data support.

177 Social and Services

This category is to list facilities which are unique in structure and location. Supplemental data is required for identification; e.g., Elks Club, Masonic Lodge, V.F.W., etc.

179 Institutional Under Construction

180 Recreational

Recreational areas are those areas whose physical structure indicates that active user-oriented recreation is or could be occurring within the given physical area. This category would include golf courses, parks, swimming beaches and shores, marinas, fairgrounds, etc. (Note: Swimming beaches are identifiable by such features as bath houses, picnic areas, service stands and large parking lots adjacent to the beach areas). In order to make this recreational determination, supplemental information may be required.

181 Swimming Beach

182 Golf Courses

183 Race Tracks [horse, dog, car, motorcycle]

184 Marinas and Fish Camps

185 Parks, Zoos

186 Community Recreational Facilities

187 Stadiums [Those facilities not associated with high schools, colleges or universities.]

188 Historical Sites [Prehistoric or historic]

189 Other Recreational [riding stables, go-cart tracks, skeet ranges, etc.]

190 Open Land

This includes undeveloped land within urban areas, and inactive land with street patterns but without structures. Open Land normally does not exhibit any structures or any indication of intended use. Often, urban inactive land may be in a transitional state and ultimately will be developed into one of the typical urban land uses, although at the time of the inventory, the intended use is impossible to determine.

191 Undeveloped Land within urban areas

192 Inactive Land with street pattern but without structures

193 Urban Land in transition without positive indicators of intended activity

194 Other Open Land

*Note Mixed

1. This category is used where no single use predominates. When more than one-third intermixture of another use or uses occurs, the specific classification is changed to Mixed. But, where the sum of the intermixture is less than one-third, it is mapped as the dominant land use.

The Mixed category includes developments along transportation routes and in cities, towns, and built-up areas where separate land uses cannot be individually mapped. Residential, commercial, industrial and occasionally other land uses will be included.

2. Abandoned or not in use

Any land use classification that is confirmed as abandoned or not in use will be preceded, in the numerical identifier, by a zero "Ø"; i.e., 0175.

200 AGRICULTURE

In a broad sense, agricultural land may be defined as those lands which are cultivated to produce crops and livestock. The sub-categories of Agriculture are: Cropland, Pastureland, Orchards, Groves (except Citrus), Vineyards, Nurseries, Ornamental Horticulture Areas, Citrus Groves, Confined Feeding Operations, Specialty Farms, and Other Agriculture.

210 Cropland and Pastureland

This includes agricultural land which is managed for the production of row or field crops, and improved, unimproved and woodland pasture.

Cropland and Pastureland include:

1. Cropland harvested or land from which crops are harvested, other than tree and bush crops, and horticultural crops.

2. Cropland used only for pasture or pasture in rotation with crops.

3. Pastureland used more or less permanently for that purpose.

Numerous variables must be recognized in identifying crop and pasture uses of land in different parts of Florida. Field size and shape are highly variable depending upon topographic conditions, as well as soil types, sizes of farms, kinds of crops and pastures, capital investment, labor availability, and other conditions.

In Florida, supplemental irrigation of cropland and pastureland by use of overhead sprinklers can be detected from photography where distinctive circular patterns are created. Drainage or water control on land used for cropland and pastureland at times creates a recognizable pattern that may be helpful in identifying this type of land use from photography.

The duration of crop growth in the field may be rather limited. A false impression of non-agricultural use in a field may result if the conditions of temporary inactivity are not recognized. However, this can be substantiated by field checking.

Pastures may be drained and/or irrigated lands. Where the management objective is to establish or maintain stands of grasses, such as bahia, pangola or bermuda grass, either alone or in mixtures with white clover or other legumes, land can be categorized as pastures regardless of treatment. Much of the "permanent" pastures occur on land which usually is not tilled or used as cropland. Topographically rough land, stream floodplains, wooded areas, and wetlands often may be used for pasture more or less permanently.

211 Improved Pasture

This category in most cases is composed of land which has been cleared, tilled, reseeded with specific grass types and periodically improved with brush control and fertilizer application. Water ponds, troughs, feed bunkers, and in some cases, cow trails are evident.

212 Unimproved Pasture

This category includes cleared land with major stands of trees and brush where native grasses have been allowed to develop. Normally, this land will not be managed with brush control and fertilizer application.

213 Woodland Pasture

This is an area where forestlands are used as pasture. Strong evidence of cattle activity, such as trails to feed bunkers, salt licks and watering areas, is required. In some cases, detection of cattle in the area will be the clue used to identify this category. When supplemental data is available, this will be used along with verification during field checks.

214 Row Crops

Corn, tomatoes, potatoes, and beans are typical row crops found in Florida. Rows remain well defined even after crops have been harvested.

215 Field Crops

Wheat, oats, hay and grasses are the primary types identified as field crops. Some problems may occur in identification of field crops, and field checks are necessary in many cases, especially when crop growth is in the early stages.

220 Tree Crops

Orchards and groves generally occur in areas possessing a specific combination of soil qualities and climatological factors. Water bodies, which moderate the effects of short duration temperature fluctuations, often are in close proximity to these types of farming. Site selection for air drainage on sloping land also may be important.

221 Citrus Groves [Orange, grapefruit, tangerine, etc.]

222 Fruit Orchards [Peaches are an example of a crop type which is typical for this category]

223 Other Groves [Pecan, avocado, coconut, mango, etc.]

If specific crop type can be determined from aerial photography, Level IV classification will be used; e.g., 2231 - Pecan Grove.

230 Feeding Operations

Feeding operations are specialized, livestock production enterprises which include beef cattle feedlots, dairy operations with confined feeding, large poultry farms and hog feedlots. These operations have large animal populations restricted to relatively small areas. This restriction results in a concentration of waste material that is an environmental concern. The attendant waste disposal problems justify a separate category for these relatively small areas. Some operations are located near urban areas to take advantage of proximity to transportation facilities and processing plants.

231 Cattle

232 Poultry

233 Hogs

240 Nurseries and Vineyards

This category is composed of nurseries, floricultural areas, and seed-and-sod areas used perennially and generally not rotated with other uses.

241 Tree Nursery

Areas in this category are not associated with the timber industry; trees primarily are ornamentals.

242 Sod Farms

This category is unique, requiring the crop to be in harvest stages for detection. Supplemental data can be used for the identification of this specific category.

243 Ornamentals [perennial]

This category is defined as plants or shrubs grown for decorative effects.

244 Vineyards

This category is defined as land devoted to cultivating grape vines.

245 Floriculture [annual]

This category is defined as the cultivation of flowers (decorative flowering plants.)

246 Timber Nursery

Areas in this category are associated with the timber industry. Tree seedlings (primarily pine) are grown for forestation of timber sites.

250 Specialty Farms

Specialty farms include a variety of special or unique farming activities such as thoroughbred horse farms, dog kennels and aquaculture.

251 Horse Farms

This category defines farms which breed and train horses for sport uses in racing, riding and harness racing.

252 Dairy

This is a commercial establishment which processes and distributes milk and milk products.

253 Kennels

In this category, specific uses of dogs are not defined. In most cases it will require ground "truthing" on an extensive basis by visiting each site.

254 Aquaculture [Fish farms]

The definition of this category is the culture of marine or aquatic species under either natural or artificial conditions.

259 Other

260 Other Open Lands [Rural]

This category includes those lands whose intended usage cannot be determined.

300 RANGELAND

Historically, Rangeland has been defined as land where the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs, and is capable of being grazed. Management practices may include brush control, regulation of grazing intensity, and season of use. If revegetated to improve the forage cover, it is managed like native vegetation. Generally, this land is not fertilized, cultivated, or irrigated.

The definition of Rangeland used in the CONSERVATION NEEDS INVENTORY by the U.S. Departments of Agriculture and Interior is used in this classification scheme and describes the natural potential (climax) plant cover as being composed of principally native grasses, forbs, and shrubs valuable for forage. This category includes Grassland, Shrub and Brushland, and Mixed Rangeland.

310 Herbaceous

This category includes prairie grasses which occur on the upland margins of the wetland zone and may be periodically inundated by water. Generally, it is the marginal area between marsh and upland forested areas. These grasslands are generally treeless, but in wet areas would have many types of soils resulting in a variety of vegetation types dominated by grasses sedges, rushes and other herbs, while dryer grass areas would be dominated by wire grasses with some saw palmetto present.

320 Shrub and Brushland

This category includes saw palmettos, gallberry, wax myrtle, coastal scrub, and other shrubs and brush. Generally, saw palmetto is the most prevalent plant cover intermixed with a wide variety of other scrub forest plants such as scrub oaks, sand pines, as well as various types of short grasses. Coastal scrub vegetation would include pioneer herbs and shrubs composed of such typical plants as sea purslane, sea grapes, sea oats, without any one of these types being dominant.

321 Palmetto Prairies

These are areas in which saw palmetto (Serenoa repens) is the most dominant vegetation. Common associates of saw palmetto in this cover type are: fetterbush, tar flower, gallberry, wire grass and brown grasses. This cover type is usually found on seldom flooded dry sand areas. These treeless areas are often similar to the pine flatwoods, but without the pines.

322 Coastal Scrub

This scrub category represents a conglomeration of species found in the coastal zone. A few of the more common components are saw palmetto, sand live oak, myrtle oak, yaupon, railroad vine, bay bean, sea oats, sea purslane, sea grape, spanish bayonet and prickly pear. This cover type is generally found in dune and white sand areas.

329 Other Shrubs and Brush

This category includes other shrubs and brush cover types not previously mentioned.

330 Mixed Rangeland

When more than one-third intermixture of either grassland or shrub-brushland range species occurs, the specific classification is changed to Mixed Rangeland. Where the intermixture is less than one-third, it is classified as the dominant type of Rangeland, whether Grassland, of Shrub and Brushland categories.

400 FORESTLAND

Forestland includes uplands, basically the drier areas, which have a tree crown density (crown closure of 10 percent or more), and are dominated by trees and other woody vegetation.

Lands from which trees have been removed to less than 10 percent crown closure, but which have not been developed for other use, are also included in this category. For example, lands on which there are rotation cycles, involving clear-cutting and block planting, are part of the forestland classification.

Since most naturally seeded forestlands are composed of a mixture of species, for purposes of classification a minimum of 66 2/3 percent stand dominance (by crown area measurement) of one species or species groups is necessary for inclusion into separate categories. Less than 66 2/3 percent stand dominance of one species or species groups is considered to be a mixed category. It should be noted that classification is based on overstory species composition, as interpreted from aerial photography. Forestlands are classified as follows:

410 Coniferous Forest

A Coniferous Forest is a forested area having a dominant tree crown that is of coniferous species and is a result of natural seeding.

411 Pine Flatwoods [undifferentiated]

This is a forested area dominated by longleaf pine on the drier sites, and slash and/or longleaf pine on the wetter areas. Common understory associates are saw palmetto, wiregrass, wax myrtle, fetterbush, and gallberry.

412 Longleaf-Xeric Oak

This forest type is dominated by longleaf pine. Common understory associates are bluejack oak, turkey oak, and sand post oak.

413 Sand Pine Scrub

This forested area occurs on excessively drained sands, often associated with former dune areas. The dominant overstory tree is sand pine. Common understory trees are myrtle oak, sand live oak, and chapman oak.

414 Australian Pine

This is not a true pine; the species is commonly found in almost pure stands with little or no understory vegetation.

415 Longleaf-Upland Oak

This forest type is dominated by an overstory of longleaf pine and upland oak, commonly live oak or laurel oak.

419 Other Pine

This category is composed of other coniferous cover types not previously mentioned.

420 Hardwood Forest

A Hardwood Forest is a forested area having a dominant tree crown that is of hardwood species and is a result of natural seeding.

421 Xeric Oak

This forest area is dominated by xeric oak generally located on well-drained upland sands. Typical species include bluejack oak, turkey oak, and sand post oak.

422 Brazilian Pepper

This cover type frequently occurs in dense pure stands often excluding understory vegetation. It is generally an indicator of a disturbed site.

423 Oak-Pine-Hickory

This is a mixed forest type in which no one species is consistently dominant. Major components of this cover type are southern red oak, post oak, black oak, shortleaf pine, loblolly pine, mockernut hickory and dogwood.

424 Melaleuca

This species occurs in almost pure stands. It is an extremely aggressive competitor, often taking over a site, forming a dense impenetrable stand. Melaleuca generally is an indicator of a disturbed site.

425 Temperate Hammock

This is a cover type also referred to as a low hammock. Common components of this cover type include cabbage palm, oaks (generally live oak), redbay, sweetbay, yaupon and cedar.

426 Tropical Hammock

This is a cover type also referred to as a coastal hammock. Common components of this cover type include gumbo limbo, mastic, stoppers, wild lime, strangler fig, lancewood, poison wood, sea grape, marl berry, and wild tamarind.

427 Upland Temperate Hammock

This is a cover type in which live oak is pure or predominant. Common associates are sweetgum, southern magnolia, holly and laurel oak.

428 Cabbage Palm

This is a cover type in which cabbage palm is pure or predominant. Associates are southern red cedar, southern magnolia, live oak, sand live oak with smaller quantities of laurel oak, red maple, redbay and holly.

429 Wax Myrtle-Willow

This is a cover type in which wax myrtle and/or willow is pure or predominant. It is often an indicator of a disturbed site and is commonly found on moist ground.

430 Hardwoods Forest Continued

431 Beech-Magnolia

Beech is the indicator species of this forest type, although it may not be the most abundant. Southern magnolia and a great variety of other moist site hardwoods occur in this forest with common associates including sweetgum, blackgum, yellow poplar, southern red oak, white oak, white ash and hickories.

432 Sand Live Oak

Sand live oak predominates in this cover type. Associates are cabbage palm, southern red cedar and southern magnolia with smaller quantities of chapman oak, myrtle oak, red maple, redbay, and holly. This cover type is generally found on old coastal dune and white sand areas.

438 Mixed Hardwood

This is a mixed hardwood forest type in which no one species achieves 66 2/3 percent composition by crown area measurement.

439 Other Hardwood

This category includes other hardwood cover types not previously mentioned.

440 Tree Plantations

441 Coniferous

These areas are forests created as a result of planting coniferous seedling stock or by direct seeding methods.

442 Hardwood

These areas are forests created as a result of planting hardwood seedling stock or by direct seeding methods.

443 Regeneration Area

Regeneration areas are forestlands where clearcutting and block plant timber management practices are in evidence and where it is evident that the intended future use will not be in another land use category. This category also includes areas of site preparation and planting.

444 Experimental Tree Farms

These areas are devoted to testing the growth response of different forest tree species to various experimental silvicultural treatments.

500 WATER

The delineation of water areas depends on the scale and resolution characteristics of the remote-sensor photography user for interpretation. One definition of water bodies, provided by the Bureau of Census, includes all areas within the land mass of the United States that are predominately or persistently water covered, provided that, if linear, they are at least 1/8 mile (660 feet or 200 meters) wide, and if extended, cover at least 40 acres (16 hectares).

Defining water boundaries at Level III, minimum size has been established to less than 10 acres. In some instances, water bodies of one acre will be plotted and identified. Water bodies or those portions of the water body having emergent vegetation are placed in the Wetland category.

510 Streams and Waterways

This category includes rivers, creeks, canals, and other linear water bodies. Where the water course is interrupted by a control structure, the impounded area will be placed in the Reservoirs category.

The boundary between streams and lakes, reservoirs, or the ocean is the straight line across the mouth of the stream, unless the mouth is more than one mile (1.85 kilometers) wide. In that case, the rule given under Bays and Estuaries is followed.

520 Lakes

The Lakes category includes inland water bodies, but excludes reservoirs. Islands within lakes that are too small to delineate will be included in the water area. The delineation of a lake will be based on the size of the water body at the time the remote-sensor data is acquired.

521 Lakes larger than 500 acres (202 hectares)

522 Lakes larger than 100 acres (400 hectares) but less than 500 acres

523 Lakes less than 100 acres but greater than 10 acres (4 hectares)

524 Lakes less than 10 acres which are dominant features

530 Reservoirs

Reservoirs are artificial impoundments of water. They are used for irrigation, flood control, municipal water supplies, recreation, or hydro-electric power generation. Dams, levees, other water control structures, or the excavation itself, usually will be evident to aid the identification.

531 Reservoirs larger than 500 acres

532 Reservoirs larger than 100 acres but less than 500 acres

533 Reservoirs larger than 10 acres but less than 100 acres

540 Bays and Estuaries

Bays and estuaries are inlets or arms of the sea that extend into the land and, as such, are properly classified in this system only when they are included within the land mass of Florida.

In order that this land mass area be commensurate with the area of the United States used in compiling census statistics, the convention used by the Bureau of the Census in setting the outer limits of the United States has been followed. Where bays and estuaries are between 1 and 10 nautical miles (1.85 and 18.5 kilometers) in width, the outer limit of the United States will be a straight line connecting the headlands, except where the indentation of the embayment is so shallow that the water area would be less than the area of a semicircle drawn with this straight line as the diameter. In that event, the coastline itself would form the outer limit of the United States.

Embayments less than one nautical mile in width are classed as Streams and Canals. Embayments or portions of embayments more than 10 nautical miles (18.5 kilometers) in width are not considered included within the land mass.

541 Opening directly into the Gulf or Atlantic Ocean

542 Not opening directly into the Gulf or Atlantic Ocean

550 Major Springs

The natural phenomena known as springs can easily be identified as points of origin of a water source. In many instances, major springs such as Silver Springs and Homosassa Springs can readily be identified by the associated recreational-commercial enterprises in the adjacent area.

560 Slough Waters

Sloughs are channels of slow moving water in the coastal marshland. The term also refers to "backwater sloughs", those narrow, often stagnant bodies of water found near inland rivers.

600 WETLANDS

Wetlands are those areas where the water table is at, near, or above the land surface for a significant part of most years. The hydrologic regime is such that aquatic or hydrophytic vegetation usually is established, although alluvial and tidal flats may be nonvegetated. Wetlands are frequently associated with topographic lows. Examples of wetlands include marshes, mudflats, emergent vegetation areas, and swamps. Shallow water areas with submerged aquatic vegetation are classed as Water and are not included in the Wetlands category.

Extensive parts of some river floodplains qualify as Wetlands. These do not include agriculture land where seasonal wetness or short-term flooding may provide an important component of the total annual soil moisture necessary for crop production. But, uncultivated wetlands yielding products such as wood, or grazed by livestock, are retained in the Wetlands category.

Wetlands areas drained for any purpose belong to other land use categories, whether they be Agriculture, Rangeland, Forested Uplands, or Urban or Built-up. When the drainage is discontinued and such use ceases, classification reverts to Wetlands after characteristic vegetation is reestablished. Wetlands managed for wildlife purposes may show short-term changes in vegetation type and wetness condition as different management practices are used, but are properly classified Wetlands.

610 Hardwood Forest

Wetland-Hardwood Forest areas are those wetlands which meet the crown closure requirements for the Hardwood Forest and are a result of natural seeding. These wetland trees are found both in salt and freshwater areas.

611 Bay Swamp

This category is composed of dominant trees such as loblolly bay, sweetbay, redbay and slash pine. Large gallberry, fetterbush, wax myrtle and titi are the understory vegetation.

612 Mangrove Swamp

This category is composed of red or black mangrove which is pure or predominant. The chief associates are white mangrove, buttonwood, cabbage palm and sea grape.

613 Gum Swamp

This category is composed of swamp tupelo or water tupelo which is pure or predominant. Associated species are bald cypress and a great number of wet site hardwoods, with wide variation in composition.

614 Titi Swamp

This category is composed of black titi and cyrilla which are predominant. Associated species are bays, cypress, swamp tupelo, and a great number of wet site hardwoods.

615 Stream and Lake Swamp

This category is also referred to as bottomland or stream hardwoods, and cover type is found on river, creek and lake overflow areas. It is a conglomeration of species, of which some of the more common components are: pond cypress, bald cypress, red maple, river birch, water oak, sweetgum, willow, swamp tupelo, okeechee tupelo, water hickory, water ash, and buttonbush.

616 Inland Ponds and Sloughs

This category is found in depressions or drainage areas not associated with streams or lakes. One of the following species will generally predominate in these communities: pond cypress, swamp tupelo, water tupelo, titi or willow.

620 <u>Coniferous Forest</u>

Wetland-Coniferous Forest areas are wetlands which meet the crown closure requirements for the Coniferous forest and are a result of natural seeding. These species are commonly found in the interior wetlands in such places as river flood plains, bogs, bayheads, and sloughs.

621 Cypress

This category is composed of pond cypress or bald cypress which is pure or predominant. In the case of pond cypress, common associates are swamp tupelo, slash pine, and black titi. In the case of bald cypress, common associates are water tupelo, swamp cottonwood, red maple, american elm, pumpkin ash, carolina ash, overcup oak, and water hickory. Bald cypress may be associated with laurel oak, sweetgum and sweetbay on less moist sites.

622 Pond Pine

This category is composed of pond pine which is pure or predominant. The major associate is titi. Minor associates are sweetbay, loblolly bay, redbay and swamp tupelo.

623 Atlantic White Cedar

In this category, atlantic white cedar is the indicator species although it may not always be the most abundant. Common associates are slash pine, cypress, swamp tupelo, sweetbay, redbay, loblolly bay, black titi and red maple.

630 <u>Forested-Mixed</u>

This is a mixed wetland, hardwood coniferous forest type in which neither hardwood nor coniferous species achieves 66 2/3 percent stand composition, by crown area measurement.

640 <u>Vegetated Non-Forested</u>

Wetland-vegetated, non-forested lands are found in seasonably flooded basins, meadows, and marshes. Wetlands are usually confined to relatively level areas. This category does not include areas whose tree cover meets the crown cover threshold for the forested categories. When the forested crown cover is less than the threshold for Wetland Forest or is non-woody, it will be included in this category. Sawgrass and cattail are predominant communities in freshwater marshes, while spartina and needlerush are the predominant saltwater marsh communities.

641 Freshwater Marsh

In this category, these communities will have predominantly one or more of the following species:

<u>Sawgrass and Cattail, Bulrush and Maidencane Marshes</u>

Sawgrass - (Cladium jamaicensis)
Arrowhead - (Sagittaria sp.)
Maidencane - (Panicum hemitomon)
Cattail - (Typha domingensis, T. latifolia, T. angustifolia)
Pickerel Weed - (Pontederia lanceolata, P. cordata)
Buttonbush - (Cephalanthus occidentalis)
Spartina - (Spartina bakeri)
Switchgrass - (Panicum virgatum)
Bulrush - (Scirpus americanus, S. validus, S. robustus)
Water lily - (Nymphea sp.)
Bladderwort - (Utricularia sp.)
Needlerush - (Juncus effusus)
Common Reed - (Phragmites communis [australis])

6411 Sawgrass (Cladium jamaicensis)

6412 Cattail (Typha sp.)

642 Saltwater Marsh

In this category, these communities will have predominantly one or more of the following species:

Spartina and Needlerush Marshes

Cordgrasses
Cordgrasses - (Spartina alterniflora, S. cynosuroides, S. patens, S. spartinae)
Needlerush - (Juncus roemerianus)
Seashore Saltgrass - (Distichlis spicata)
Saltwort - (Batis maritima)
Glassworts - (Salicornia sp.)
Fringerush - (Finbristylis castanea)
Salt Dropseed - (Sporobolus virginicus)
Seaside Daisy - (Borrichia frutescens)
Salt Jointgrass - (Paspalum vaginatum)

6421 Cordgrass (Spartina)

Vegetation association is the same as listed in 642 (Saltwater Marsh) classification. However, dominant vegetation is one of the following: (Spartina alterniflora, S. cynosuroides, S. patens or S. spartinae).

6422 Needlerush (Juncus)

Vegetation association is the same as listed in 642 (Saltwater Marsh) classification. However, dominant vegetation is (Juncus roemerianus).

643 Wet Prairies

This category is composed of dominantly grassy vegetation of wet soils, usually distinguished from marshes by having less water and shorter herbage. These communities will have predominantly one or more of the following species:

Maidencane - (Panicum hemitomon)
Cordgrasses - (Spartina bakeri, S. patens)
Spikerushes - (Eleocharis sp.)
Beach Rushes - (Rhynchospora sp.)
St. Johns Wort - (Hypericum sp.)
Spiderlily - (Hymenocallis palmeri)
Swamplily - (Crinum americanum)
Yellow-eyed Grass - (Xeric ambigua)
Whitetop Sedge - (Dichromena colorata)

644 Emergent Aquatic Vegetation

This category includes floating vegetation and/or aquatic vegetation that is found partially or completely above the surface of the water.

6441 Water Lettuce - (Pistia stratiotes)

6442 Spatterdock - (Nuphar sp.)

6443 Water Hyacinth - (Eichhornia sp.)

6444 Duckweed - (Lemna sp.)

645 Submergent Aquatic Vegetation

This category is composed of those aquatic species found growing completely below the surface of the water.

650 Non-Vegetated

Wetland non-vegetated areas are those areas where vegetation may be lacking due to the erosional effects of wind and water transporting the surface material so rapidly that plant establishment is curtailed. Also, submerged or saturated materials often develop toxic conditions of extreme acidity from sulfur generation. Tidal flats, shorelines and intermittent ponds are a main component of this category.

651 Tidal Flats

This category is composed of that portion of the shore environment protected from wave action, as in estuaries, comprised primarily of muds drained by tidal channels. An important characteristic of the tidal flat environment is its alternate submergence and subaerial exposure during the tidal cycle.

652 Shoreline

This category is usually defined as the line where land and water meet. Shorelines are formed mainly by marine or biological agents like coral reefs, barrier beaches, and marshes. (The shore is defined as the zone from low tide to the farthest point on land where waves transport sands.)

653 Intermittent Pond

This category is defined as a waterbody which exists usually only during a portion of the year. Its existence relies on water received from direct precipitation, runoff or spring flow.

700 BARREN LAND

Barren land has very little or no vegetation and limited ability to support life. In general, it is an area with only soil, sand or rocks. Vegetation, if present, is very widely spaced and scrubby. However, land also may be temporarily barren due to man's activities. Generally, this land is included in another land use category. Vast areas of agricultural land are temporarily without vegetation cover due to tillage practices, and areas of extractive and industrial land use have dumps for wastes and tailings. Barren Land categories are Beaches (areas exhibiting little or no evidence of human encroachment), Sand Other Than Beach, Exposed Rock, Disturbed Lands.

710 Beaches Other Than Swimming Beaches

Beaches are constantly affected by wave and tidal action. The fine clays and silts are washed away leaving sand. However, in protected bay and marsh areas, fine soil particles from surface drainage waters may settle out. The beach areas also are subject to water and wind erosion. Differing beach dimensions are due to factors such as tides, soil material size, water level and wave energy, all of which vary. When a stable surface is observed inland, as another land use occurs and erosion effects of water and wind decrease, the beach category is then terminated.

720 Sand Other Than Beaches

Sand other than beaches is composed primarily of dunes. These are of aeolian origin composed of sand grains downwind from a natural source of sand. Dune sizes vary greatly, with diameters ranging from a few feet to more than several hundred. Their heights also vary and their shapes display considerable variety. When the dunes are the major feature, shore and strand lines, coastal plains, river flood plains, and deltas are secondary.

730 Exposed Rock

Exposed rock areas consist of exposed bedrock and other accumulation of rocks lacking vegetative cover. Exposed bedrock, when weathered, may be unvegetated due to fine soil removal by water or wind erosion.

740 Disturbed Lands

Disturbed lands are the areas that have been changed due to man's activities, other than mining activities. In Florida, these areas may be rather extensive and often appear outside of urban areas.

741 Rural land in transition without positive indicators of intended activity

742 Borrow Areas

743 Spoil Areas

744 Fill Areas [highways-railways]

810 Transportation

Transportation facilities are used for the movement of people and goods; therefore, they are major influences on land and many land use boundaries are outlined by them.

Highways are easily identifiable on medium altitude photography. Highways include areas used for interchanges, limited access rights-of-way, and service facilities. The center median, pavement and sizable buffer zone should be included even if exact boundaries cannot be detected.

The Transportation category encompasses rail-oriented facilities including stations, round-houses, repair and switching yards, and related areas. Airport facilities include runways, intervening land, terminals, service buildings, navigation aids, fuel storage, parking lots and a limited buffer zone, and fall within the Transportation category.

Transportation areas also embrace ports, docks, shipyards, dry docks, locks and watercourse control structures designed for transportation purposes. The docks and ports include buildings, piers, parking lots and adjacent water utilized by ships in the loading or unloading of cargo or passengers. Locks, in addition to the actual structure, include the control buildings, power supply buildings, docks and surrounding supporting land use, i.e. parking lots and green areas.

811 Airports

812 Railroads

813 Bus and Truck Terminals

814 Major Highways

815 Port Facilities

816 Canal and Locks

817 Oil, Water, or Gas Long Distance Transmission Lines

818 Auto Parking Facilities (when not directly related to other land use)

819 Transportation Facilities Under Construction

820 Communications

Airwave communications, radar and television antennas with associated structures are typical major types that will be identified. When stations are associated with a commercial or governmental facility, they will be included in that specific category when located within the bounds of the specific facility and will not be listed as a separate element.

821 Transmission Towers [microwave are typical in this category]

822 Communication Facilities [includes transmitter stations, telephone exchanges, antenna farms, etc.]

829 Communication Facilities Under Construction

830 Utilities

Utilities usually include power generating facilities, water treatment plants and their related functions, such as transmission lines for the electric power facilities, and aeration fields for the sewer treatment sites. Small facilities or those associated with an industrial, commercial or extractive land use, are included within the larger category.

831 Electrical Power Facilities

This category includes hydropower, thermal, nuclear, gas turbine plants, transformer yards, sub-stations.

832 Electrical Power Transmission Lines

833 Water Supply Plants [including pumping stations]

This category includes treatment plants, settling basins, water storage towers and well fields.

834 Sewage Treatment

This category is composed of all related facilities such as aeration fields, digesters, etc.

835 Solid Waste Disposal

This category is composed of controlled and managed solid waste fields, non-permitted solid waste disposal sites, etc.

839 Utilities Under Construction

900 This section is reserved for special classification

This category is used primarily for specific topics to be addressed for a specific user requirement of those land uses and land cover which require identification at Level III or IV.

e.g. Marine grasses - dense
- medium
- sparse

IX. GLOSSARY

abiotic - any inorganic part of the environment.

amphipod - small macroscopic crustacean; body is laterally compressed.

anaerobic - a condition associated with absence of free oxygen in the environment.

benthic - living on the bottom.

brackish water - water that has a salt content intermediate between fresh water the sea.

coastal wetland - land where the water table is at or near the surface or the land is covered by shallow water or tidally influenced.

community - all the plants and animals of an area (or volume) which form a interactive assemblage.

crustacean - a class of animals that have a hard outer shell; includes shrimp, crabs, lobsters.

detritus - particles of non-living organic matter, usually in various stages of decomposition.

dike - a dam or embankment erected to prevent flooding of a lowland area.

dredge spoil - sediment material removed from a wetland bottom during dredging operations.

ecosystem - the community and its non-living environment, considered collectively.

epibenthic - living on the surface of bottom.

epiphyte - plant or animal attached to a plant, typically not a parasitic relationship.

euryhaline - able to tolerate wide variation of salinity regimes.

IX. GLOSSARY

abiotic - any inorganic part of the environment.

amphipod - small macroscopic crustacean; body is laterally compressed.

anaerobic - a condition associated with absence of free oxygen in the environment.

benthic - living on the bottom.

brackish water - water that has a salt content intermediate between fresh water the sea.

coastal wetland - land where the water table is at or near the surface or the land is covered by shallow water or tidally influenced.

community - all the plants and animals of an area (or volume) which form a interactive assemblage.

crustacean - a class of animals that have a hard outer shell; includes shrimp, crabs, lobsters.

detritus - particles of non-living organic matter, usually in various stages of decomposition.

dike - a dam or embankment erected to prevent flooding of a lowland area.

dredge spoil - sediment material removed from a wetland bottom during dredging operations.

ecosystem - the community and its non-living environment, considered collectively.

epibenthic - living on the surface of bottom.

epiphyte - plant or animal attached to a plant, typically not a parasitic relationship.

euryhaline - able to tolerate wide variation of salinity regimes.

facultative halophyte - able to live under freshwater and saltwater influences but living mostly under saltwater influence due to exclusion of other species.

finfish - sharks, rays, and bony fishes.

fishery - the complex of interactions within and between the population(s) of fish being harvested, the population(s) of fishermen, and the environments of each.

food chain - the series of nutritional steps through which food passes from plants to herbivores to carnivores; also the nutritional steps involved in parasite and microbial (decomposer) chains.

food web - the interlocking pattern formed by parallel and cross connecting food chains.

habitat - the natural environment in which an organism lives.

habitat component - a specific part, be it organic, inorganic, chemical, or environmental, of an organism's environment.

hectare - a measure of area equal to 2.47 acres.

infauna - animals living within the sediment.

isopod - small macroscopic crustacean; body is flattened.

life history - the series of stages through which an organism passes during its entire lifetime.

macrophytes - plants larger than microscopic size.

meiofauna - microscopic and small macroscopic animals living on the bottom.

meroplankton - larval plankton 15-20 mm in size.

nekton - macroscopic swimming animals that can freely regulate their distribution against movements of water masses.

non-point source pollution - pollution originating from non-localized sources such as storm drains.

nutrient - an organic or inorganic chemical substance required for the growth and reproduction of organisms.

omnivorous - eating a diet of both plants and animals.

pelagic - living offshore.

photic zone - surface zone of sea or lake sufficiently illuminated for photosynthesis.

photosynthesis - the chemical processes through which green plants manufacture organic molecules from inorganic using sunlight as an energy source.

plankton - aquatic organisms that cannot freely regulate their distribution against movements of water masses; includes microscopic plants (phytoplankton) and microscopic animals (zooplankton).

point source pollution - pollution originating from known, localized sources.

polychaete - a marine worm.

productivity - the rate of production of organic matter by living organisms (i.e., the amount per unit time).

recruitment - the process of addition of animals to a population. Typically, the term is used to describe when, or how large fishes are when they first enter a fishery.

rhizome - a horizontal underground stem.

riprap - rock, stone, or other rough material placed on stream banks, dam faces, and other structures to protect against erosion by the water.

sediment load - all particulate material (inorganic or organic) suspended in or transported downstream by water (may include clay, silt, sand, organic detritus, etc.).

sedimentation - the settling out of suspended matter from the water to the bottom.

sessile - attached to a substrate; non-motile.

shellfish - oysters, clams, scallops, and conch.

species - a group of populations in which the organisms reproduce and maintain separateness, genetically.

species diversity - the variety of types of organisms present in an area.

stress - a strain or pressure applied to an organism (or group of organisms) by an unfavorable or stress-producing factor.

tidal node - the area of no current velocity where an incoming tide meets from opposite directions or from which an outgoing tide recedes in opposite directions.

trophic level - one of the several levels of a food chain; plants constitute the primary level, herbivores the second level, and carnivores the third and remaining levels.

turbidity - the condition of water resulting from the presence of suspended material, often expressed as interference with light transmission.

X. LITERATURE CITED

1. Anderson, J. M. and M. R. Peterson. 1969. DDT: sublethal effects on brook trout nervous system. Science 164: 440-441.

2. Bahr, L. M. and W. P. Lanier. 1981. The ecology of intertidal oyster reefs of the South Atlantic coast: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS - 81/15. 105 pp.

3. Barrett, B. B. and M. C. Gillespie. 1973. Primary factors which influence commercial shrimp production in coastal Louisiana. La. Wildl. Fish. Comm. Tech. Bull. 9. 28 pp.

4. Bass, R. J. and J. W. Avault, Jr. 1975. Food habits, length-weight relationship, condition factor, and growth of juvenile red drum, Sciaenops ocellata, in Louisiana. Trans. Am. Fish. Soc. 104(1): 35-45.

5. Beal, K. L. 1980. Territorial sea fisheries management and estuarine dependence. Pp. 67-77 in V. S. Kennedy (ed.), Estuarine Perspectives. Academic Press, Inc., New York. 533 pp.

6. Beebe, W. and J. Tee-Van. 1928. The fishes of Port-au-Prince Bay, Haiti. Zoologica 10(1): 1-26, 60-62, 124, 127-128.

7. Bjorndal, K. A. 1980. Nutrition and grazing behavior of the green turtle Chelonia mydas. Mar. Biol. 56: 147-154.

8. Blake, N. J., L. J. Doyle, and T. E. Pyle. 1976. The benthic ecology of a thermally altered area of Tampa Bay, Florida. Pp. 296-301 in G. W. Esch and R. W. McFarlane (eds.), Thermal Ecology II. Atomic Energy Commission Symposium Series (Conf. 750425), Augusta, Georgia.

9. Brannon, D. P., W. H. Kuyper, L. Clay, and K. Haddad. 1981. Florida LANDSAT demonstration project report. NASA/NSTL Earth Resources Laboratory DR-002. 35 pp.

10. Brook, I. M. 1978. Comparative macrofaunal abundance in turtlegrass (Thalassia testudinum) communities in south Florida characterized by high blade density. Bull. Mar. Sci. 28(1): 213-217.

11. Butler, P.A. 1966. The problem of pesticides in estuaries. Amer. Fish. Soc. Spec. Publ. No. 3: 110-115.

12. Carlton, J. 1974. Land building and stabilization by mangroves. Environ. Conserv. 1(4): 285-294.

13. Carlton, J. M. and M. D. Moffler. 1978. Propagation of mangroves by air-layering. Environ. Conserv. 5(2): 147-150.

14. Carr, W. E. S. and C. A. Adams. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. Trans. Am. Fish. Soc. 102(3): 511-540.

15. Carr, W. E. S. and J. T. Giesel. 1975. Impact of thermal effluent from a steam-electric station on a marshland nursery area during the hot season. Fish. Bull. 73(1): 67-80.

16. Clark, J. R. 1977. Coastal ecosystem management. Conservation Foundation, Washington, D. C. 921 pp.

17. Coastal Coordinating Council, State of Florida. 1973. Statistical inventory of key biophysical elements in Florida's coastal zone. Tallahassee, Fla. 43 pp.

18. Conner, W. G. and J. L. Simon. 1979. The effects of oyster shell dredging on an estuarine benthic community. Est. Coast. Mar. Sci. 9: 749-758.

19. Copeland, B. J. 1970. Estuarine classification and response to disturbances. Trans. Am. Fish. Soc. 4: 826-835.

20. Copeland, B. J. 1965. Evidence for regulation of community metabolism in a marine ecosystem. Ecology 46(4): 563-564.

21. Copi, I. M. 1972. Introduction to logic. Macmillan Publishing Co., Inc., New York. 540 pp.

22. Costello, T. J. and D. M. Allen. 1970. Synopsis of biological data on the pink shrimp Penaeus duorarum duorarum Burkenroad, 1939. FAO Fish. Rep. 57(4): 1499-1537.

23. Costello, T. J. and D. M. Allen. 1966. Migrations and geographic distribution of pink shrimp, Penaeus duorarum, of the Tortugas and Sanibel grounds, Florida. Fish. Bull. 65(2): 449-459.

24. Coultas, C. L. 1980. Transplanting needlerush (Juncus roemerianus). Pp. 117-121 in D. P. Cole (ed.), Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 294 pp.

25. Craig, H. 1953. The geochemistry of stable carbon isotopes. Geochim. Cosmochim. Acta 3: 53-92.

26. de la Cruz, A. A. 1973. The role of tidal marshes in productivity of coastal waters. Assoc. Southeastern Biol. Bull. 20: 147-156.

27. Darovec, J. E., Jr., J. M. Carlton, T. R. Pulver, M. D. Moffler, G. B. Smith, W. K. Whitfield, Jr., S. A. Willis, K. A. Steidinger, and E. A. Joyce, Jr. 1975. Techniques for coastal restoration and fishery enhancement in Florida. Fla. Dept. Nat. Res. Marine Res. Publ. No. 15. 27 pp.

28. Day, J. W., Jr. and A. Yanez-Arancibia. 1982. Coastal lagoons and estuaries, ecosystem approach. Ciencia Interamericana OAS Wash., D.C. 22: 11-26.

29. Day, J. W., Jr., W. G. Smith, P. R. Wagner, and W. C. Stone. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuary system in Louisiana. Center for Wetland Resources. La. State Univ.,Baton Rouge, LA. LSU-SG-72-04. 80 pp.

30. DeNiro, M. J. and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochim. Cosmochim. Acta 42: 495-506. Department of Natural Resources, Bureau of Environmental Land Management. 1983. Charlotte Harbor aquatic preservesmanagement plan. 120 pp.

31. Durako, M. J., J. A. Browder, W. L. Kruczynski, C. B. Subrahmanyam and R. E. Turner. 1983. Florida aquatic habitat and fishery resources: salt marshes. Proc. Fla. Chapt. Am. Fish. Soc. 3rd Ann. Mtg., Feb. 7-9, 1983, Brooksville, FL. In review.

32. Durako, M. J. and M. D. Moffler. 1981. Variation in Thalassia testudinum seedling growth related to geographic origin. Pp. 99-117 in R. H. Stovall (ed.), Proceedings of the Eighth Annual Conference Wetlands Restoration and Creation. Hillsborough Community College, Tampa, Florida. 200 pp.

33. Eleuterius, L. N. 1976. The distribution of Juncus roemerianus in the salt marshes of North America. Chesapeake Sci. 17: 289-292.

34. Estevez, E. D., J. M. Miller, and J. Morris. 1981. A review of scientific information Charlotte Harbor estuarine ecosystem complex and the Peace River. Report to South West Florida Regional Planning Council. Mote Marine Laboratory, Sarasota, Florida.

35. Evans, M., T. Brungardt, and R. Evans. 1978. Shoreline analysis of Sarasota County bay systems with regard to revegetation activities. Sponsored by Environmental Studies Program of New College of U.S.F., Sarasota County C.E.T.A. program, and Sarsota Board of County Commissioners. 71 pp.

36. Federal Water Pollution Control Administration, Department of the Interior. 1969. Problems and management of water quality in Hillsborough Bay, Florida. Hillsborough Bay Technical Assistance Project. 88 pp.

37. Fehring, W. K., C. Giovenco, and W. Hoffman. 1979. An analysis of three marsh-creation projects in Tampa Bay resulting from regulatory requirements for mitigation. Pp. 191-206 in D. P. Cole (ed.), Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 357 pp.

38. Finucane, J. H. 1969. Ecology of the pompano (Trachinotus carolinus) and the permit (T. falcatus) in Florida. Trans. Am. Fish. Soc. 98(3): 478-486.

39. Florida Department of Natural Resources, Bureau of Marine Science and Technology. 1950-1978. Summary of Florida commercial marine landings. Tallahassee, Florida.

40. Fonseca, M. S., W. J. Kenworthy, J. Homziaki and G. W. Thayer. 1979. Transplanting of eelgrass and shoalgrass as a potential means of mitigating a recent loss of habitat. Pp. 279-326 in D. P. Cole (ed.), Proceeding of the Sixth Annual Conference on the Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 357 pp.

41. Frayer, W. E., T. J. Monahan, D. C. Bowden, and F. A. Graybill. 1982. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. Mimei. Tech. Rep. Fish and Wildlife Service, U.S. Department of the Interior. 18 pp.

42. Friedly, D. L. and F. A. Unger. 1981. Florida spatial data inventory, 1980-81. Florida Resources and Environmental Analysis Center, Tallahassee, Florida. 226 pp.

43. Fry, B., R. Lutes, M. Northam, P. L. Parker, and J. Ogden. 1982. A $^{13}C/^{12}C$ comparison of food webs in Caribbean seagrass meadows and coral reefs. Aquat. Bot. 14: 389-398.

44. Fry, B. and P. L. Parker. 1979. Animal diet in Texas seagrass meadows; ^{13}C evidence for the importance of benthic plants. Estuarine Coastal Mar. Sci. 8: 499-509.

45. Fry, B., R. S. Scalan, and P. L. Parker. 1977. Stable carbon isotope evidence for two sources of organic matter in coastal sediments: seagrasses and plankton. Geochim. Cosmochim. Acta 41: 1875-1877.

46. Futch, C. R. 1976. Biology of striped mullet. Pp. 63-69 in J. C. Cato and W. E. McCullough (eds.), Economics, Biology, and Food Technology of Mullet. State Univ. System of Florida Sea Grant Report No. 15.

47. Gilmore, R. G., D. W. Cooke, and C. J. Donohoe. 1982. A comparison of the fish populations and habitat in open and closed salt marsh impoundments in East-Central Florida. Northeast Gulf Sci. 5(2): 25-38.

48. Godcharles, M. F. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. Fla. Dept. Nat. Res. Tech. Ser. No. 64. 51 pp.

49. Gosselink, J. G., E. P. Odum, and R. M. Pope. 1974. The value of the tidal marsh. Center for Wetland Resources, Louisiana State University, Baton Rouge, LA. LSU-SG-74-03. 30 pp.

50. Grey, W. F. and M. D. Moffler. 1978. Flowering of the seagrass *Thalassia testudinum*, (Hydrocharitaceae) in the Tampa Bay, Florida area. Aquat. Bot. 5:251-259.

51. Haines, E. B. and C. L. Montague. 1979. Food sources of estuarine invertebrates analyzed using $^{13}C/^{12}C$ ratios. Ecology 60: 48-56.

52. Hannan, J. 1975. Aspects of red mangrove reforestation in Florida. Pp. 112-121 in R. R. Lewis (ed.)., Proceedings for Second Annual Conference on the Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida. 203 pp.

53. Hansen, D. J. 1969. Food, growth, migration, reproduction, and abundance of pinfish, Lagodon rhomboides, and Atlantic croaker, Micropogon undulatus, near Pensacola, Florida, 1963-65. U.S. Fish Wildl. Serv. Fish. Bull. 68(1): 135-146.

54. Harlin, M. M. 1980. Seagrass epiphytes. Pp. 117-151 in R. C. Phillips and C. P. McRoy (eds.), Handbook of seagrass biology - an ecosystem perspective. Garland STPM Press, New York.

55. Harrington, R. W., Jr. and E. S. Harrington. 1982. Effects on fishes and their forage organisms of impounding a Florida salt marsh to prevent breeding by salt marsh mosquitoes. Bull. Mar. Sci. 32(2): 523-531.

56. Harrington, R. W., Jr. and E. S. Harrington. 1961. Food selection among fishes invading a high subtropical salt marsh: from onset of flooding through the progress of a mosquito brood. Ecology 42: 646-666.

57. Heald, E. J. and W. E. Odum. 1970. The contribution of mangrove swamps to Florida fisheries. Proc. Gulf Caribb. Fish. Inst. 22: 130-135.

58. Heck, K. L. and R. J. Orth. 1980. Seagrass habitats: the roles of habitat complexity, competition and predation in structuring associated fish and motile macroinvertebrate assemblages. Pp. 449-464 in V. S. Kennedy (ed.). Estuarine Perspectives. Academic Press, Inc., New York. 533 pp.

59. Herwitz, S. 1977. The natural history of Cayo-Costa Island. New College Environmental Studies Program Pub. No. 14, Sarasota, Florida.

60. Hildebrand, S. F. and L. E. Cable. 1930. Development and life history of fourteen Teleostan fishes at Beaufort, N.C. Bull. U.S. Bur. Fish. 46: 383-488.

61. Hildebrand, S. F. and W. C. Schroeder. 1927. Fishes of Chesapeake Bay. Bull. U.S. Fish. Comm. 43(1): 1-366.

62. Hoffman, W. E., M. J. Durako and R. R. Lewis, III. 1983. Habitat restoration in Tampa Bay, Florida. (in press). Proceedings Bay Area Scientific Information Symposium (BASIS), May 3-6 1982, Tampa, FL.

63. Hoffman, W. E. and J. A. Rodgers, Jr. 1980. A cost/benefit analysis of two large coastal plantings in Tampa Bay, Florida. Pp. 265-278 in D. P. Cole (ed.), Proceedings of the Seventh Annual Conference Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 294 pp.

64. Hunt, L. J. 1979. Principles of marsh establishment. Pp. 127-142 in D. P. Cole (ed.), Proceedings of the Sixth Annual Conference on the Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 357 pp.

65. Joseph, E. G. 1973. Analyses of a nursery ground. Pp. 118-121 in A. L. Pacheco (ed.). Proceedings of a Workshop on Egg, Larval, and Juvenile Stages of Fish in Atlantic Coast Estuaries. Tech. Publ. No. 1, Mid-Atlantic Coastal Fish Center, Highlands, N. J.

66. Junkin, B., R. Pearson, B. Seyforth, M. Kalcic, M. Graham. 1981. ELAS Earth Resources Laboratory Applications Software. NASA/NSTL Earth Resources Laboratory Rep. No. 183. NSTL Station, Mississippi.

67. Kelly, J. A., Jr., C. M. Fuss, Jr., and J. R. Hall. 1971. The transplanting and survival of turtle grass, Thalassia testudinum, in Boca Ciega Bay, Florida. Fish. Bull. 69(2): 273-280.

68. Kikuchi, T. and J. M. Peres. 1977. Consumer ecology of seagrass beds. Pp. 147-193 in C. P. McRoy and C. Helfferich (eds.), Seagrass Ecosystems. Marcel Dekker, Inc., New York.

69. Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas of Florida. Tul. Stud. Zoo. 2(8): 175-247.

70. Kjelson, M. A., D. S. Peters, G. W. Thayer, and G. N. Johnson. 1975. The general feeding ecology of postlarval fishes in the Newport River estuary. U.S. Fish. Wildl. Serv. Fish. Bull. 73(1): 137-144.

71. Knight, D. B., P. L. Knutson, and E. J. Pullen. 1980. An annotated bibliography of seagrasses with emphasis on planting and propagation techniques. U.S. Army Corps of Eng. CERC Misc. Rep. 80-7. 46 pp.

72. Kruczynski, W. L., C. B. Subrahmanyam, and S. H. Drake. 1978. Studies on the plant community of a North Florida salt marsh, part 1, primary production. Bull. Mar. Sci. 28: 316-334.

73. Kutkuhn, J. H. 1966. The role of estuaries in the development and perpetuation of commercial shrimp resources. Pp. 16-36 in R. F. Smith, A. H. Swartz, and W. H. Massmann (eds.), A Symposium on Estuarine Fishes. Am. Fish. Soc. Spec. Publ. 3. 154 pp.

74. Kuyper, W. H., J. E. Becker, and A. Shopmyer. 1981. Land use, cover and forms classification system. A technical manual. Department of Transportation, State Topographic Office, Remote Sensing Center. 67 pp.

75. Lankford, R. R. 1977. Coastal lagoons of Mexico: their origin and classification. Pp. 182-215 in M. L. Wiley (ed.), Estuarine Processes. Academic Press, Inc. New York. 533 pp.

76. Lauff, G. H. (ed.). 1967. Estuaries. Am. Assoc. Adv. Sci. Spec. Publ. 83: 1-785.

77. Lewis, R. R., III. 1981. Economics and feasibility of mangrove restoration. Pp. 88-93 in R. C. Carey, P. S. Markovits, and J. B. Kirkwood (eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, FWS/OBS-80/59. 257 pp.

78. Lewis, R. R. and F. M. Dunstan. 1975. The possible role of Spartina alterniflora Loisel in establishment of mangroves in Florida. Pp. 82-100 in R. R. Lewis (ed.), Proceedings for Second Annual Conference on the Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida. 203 pp.

79. Lewis, R. R., III and F. M. Dunstan. 1974. Use of spoil islands in re-establishing mangrove communities in Tampa Bay, Florida, USA. Pp. 766-775 in G. Walsh, S. Snedaker, and H. Teas (eds.), Proceedings of International Symposium on Biology and Management of Mangroves. Honolulu, Hawaii, October 8-11, 1974.

80. Lewis, R. R., III, and R. C. Phillips. 1980. Experimental seagrass mitigation in the Florida Keys. Pp. 155-172 in D. P. Cole (ed.), Proceedings of the Seventh Annual Conference on the Restoration and Creation of Wetlands. Hillsborough Community College, Tampa, Florida. 294 pp.

81. Lindall, W. N., Jr., 1973. Alterations of estuaries of South Florida: a threat to its fish resources. Mar. Fish. Rev. 35(10): 26-33.

82. Lindall, W. N., Jr., and C. H. Saloman. 1977. Alteration and destruction of estuaries affecting fishery resources of the Gulf of Mexico. Mar. Fish. Rev. 39(9): 1-7.

83. Lorio, W. J. and W. S. Perret. 1980. Biology and ecology of the spotted seatrout (Cynoscion nebulosus Cuvier). Pp. 7-14 in R. O. Williams, J. E. Weaver, and F. A. Kalber (eds.) Proceedings of the Colloquium on the Biology and Management of Red Drum and Spotted Seatrout, Oct. 19-20, 1978. Gulf States Marine Fisheries Commission. 117 pp.

84. Lugo, A. E. and S. C. Snedaker. 1974. The ecology of mangroves. Annu. Rev. Ecol. Syst. 5: 39-64.

85. Macalaster, E. 1982. Probable causes for decline of submerged aquatic vegetation disclosed in EPA's Chesapeake Bay Program Report. Tidewater Fisheries News 15(6):1.

86. Mann, K. H. 1972. Macrophyte production and detritus food chains in coastal waters. Mem. 1st Ital. Hydrobiol., Suppl. 29: 383. Proc. IBP-UNESCO Symp. Detritus and its Ecological Role in Aquatic Ecosystems.

87. Margalef, R. 1968. Perspectives in ecological theory. Univ. of Chicago Press, Chicago, IL. 111 pp.

88. Margalef, R. 1963. On certain unifying principles in ecology. Am. Nat. 97: 357-374.

89. McHugh, J. L. 1976. Estuarine fisheries: are they doomed? Pp. 15-27 in M. Wiley (ed.), Estuarine Processes, Volume I. Academic Press, New York. 533 pp.

90. McLane, W. M. 1955. Fishes of the St. Johns River system. MS Thesis, Univ. Fla. 370 pp.

91. McMillan, C. 1979. Differentiation in response to chilling temperatures among populations of three marine spermatophytes, Thalassia testudinum, Syringodium filiforme, and Halodule wrightii. Amer. J. Bot. 66: 810-819.

92. McMillan, C. 1978. Morphogeographic variation under controlled conditions in five seagrasses. Thalassia testudinum, Halodule wrightii, Syringodinium filiforme, Halophila engelmanii, and Zostera marina. Aquat. Bot. 4:169-189.

93. McMillan, C. and R. C. Phillips. 1979. Differentiation in habitat response among populations of new world seagrasses. Aquat. Bot. 7:185-196.

94. McNulty, J. K., W. N. Lindall, Jr., and J. E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida. phase 1: area description. NOAA Tech. Rep. NMFS Circ. 368. 126 pp.

95. Miller, J. M. and M. L. Dunn. 1980. Feeding strategies and patterns of movement in juvenile estuarine fishes. Pp. 437-448 in V. S. Kennedy (ed.), Estuarine Perspectives. Academic Press, Inc., New York. 533 pp.

96. Minson, D. J., M. M. Ludlow, and J. H. Troughton. 1975. Differences in natural carbon isotope ratios of milk and hair from cattle grazing tropical and temperate pastures. Nature 245: 602.

97. Moody, W. D. 1950. A study of the natural history of the spotted trout, Cynoscion nebulosus, in the Cedar Key, Florida area. Q. J. Fla. Acad. Sci. 12(3): 147-171.

98. Nakamura, E. L., J. R. Taylor, and I. K. Workman. 1980. The occurrence of life stages of some recreational marine fishes in estuaries of the Gulf of Mexico. NOAA Tech. Memo NMFS-SEFC-45: 53 pp.

99. National Park Service. 1982. Wild and scenic river study. Loxahatchee Draft Environmental Impact Statement. U.S. Dept. Interior, National Park Service, Atlanta, GA.

100. Nier, A. O. and E. A. Gulbransen. 1939. Variations in the relative abundance of the carbon isotopes. J. Am. Chem. Soc. 61: 697-698.

101. Odum, E. P. 1980. The status of three ecosystem-level hypotheses regarding salt marsh estuaries: tidal subsidy, outwelling, and detritus based food chains. Pp. 485-495 in V. S. Kennedy (ed.), Estuarine Perspectives. Academic Press, New York. 533 pp.

102. Odum, E. P. 1971. Fundamentals of ecology. W. B. Saunders Co., Philadelphia. 574 pp.

103. Odum, H. T. and B. J. Copeland. 1969. A functional classification of the coastal ecological systems. Pp. 9-86 in H. T. Odum, B. J. Copeland, and E. A. McMahan (eds.), Coastal Ecological Systems of the United States. Rep. Fed. Water Pollut. Contr. Admin., Washington, D. C.

104. Odum, W. E. 1971. Pathways of energy flow in a south Florida estuary. Miami Sea Grant Tech. Bull. No. 7. 162 pp.

105. Odum, W. E. 1970. Insidious alteration of the estuarine environment. Trans. Am. Fish. Soc. 99: 836-847.

106. Odum, W. E. and E. J. Heald. 1972. Trophic analysis of an estuarine mangrove community. Bull. Mar. Sci. 22(3): 671-738.

107. Odum, W. E., C. C. McIvor, and T. J. Smith, III. 1982. The ecology of the mangroves of south Florida: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C. FWS/OBS-81/24. 144 pp.

108. Odum, W. E. and T. J. Smith. 1981. Habitat value of coastal wetlands. Pp. 30-35 in R. C. Carey, P. S. Markovits, and J. B. Kirkwood (eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D. C. FWS/OBS-80/59. 257 pp.

109. Oesterling, M. J. 1976. Reproduction, growth and migration of blue crabs along Florida's Gulf coast. State Univ. Syst. Florida Sea Grant. Rept. SUSF-SG-76-003. 19 pp.

110. Orth, R. J. 1977. The importance of sediment stability in seagrass communities. Pp. 281-300 in B. C. Coull (ed.), Ecology of Marine Benthos. Univ. of South Carolina Press, Columbia.

111. Packard, J. M. 1981. Abundance, distribution, and feeding habits of manatees, (Trichechus manatus) wintering between St. Lucie and Palm Beach Inlets, Florida. Report prepared for the U.S. Fish and Wildlife Service, 142 pp.

112. Park, W. M. and S. S. Batie. 1979. Methodological issues associated with estimating the economic value of coastal wetlands in improving water quality. International Estuarine Research Conference, Jekyll Island, Georgia, Oct. 7-12.

113. Perret, W. S., J. E. Weaver, R. O. Williams, P. L. Johansen, T. D. McIlwain, R. C. Raulerson, and W. M. Tatum. 1980. Fishery profiles of red drum and spotted seatrout. Gulf States Marine Fisheries Commission, Ocean Springs, Mississippi. 60 pp.

114. Peterson, C. H. 1981. The ecological role of mud flats in estuarine systems. Pp. 184-192 in R. C. Carey, P. S. Markovits, and J. B. Kirkwood (eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/59. 257 pp.

115. Phillips, R. C. 1980. Planting guidelines for seagrasses. U.S. Army Corps of Engineers CERC Coastal Eng. Tech. Aid 80-2. 28 pp.

116. Phillips, R. C. 1974. Transplantation of seagrasses with special emphasis on Zostera marina. L. Aquaculture 4(3): 161-176.

117. Phillips, R. C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Fla. St. Bd. Conser. Mar. Lab., Prof. Pap. Ser. No. 2. 72 pp.

118. Pomeroy, L. R. 1959. Algal productivity in salt marshes of Georgia. Limnol. Oceanogr. 4: 386-397.

119. Pritchard, D. W. 1967. What is an estuary: physical viewpoint. In G. H. Lauff (ed.), Estuaries. Am. Assoc. Adv. Sci. Spec. Publ. 83:3-5.

120. Pulver, T. R. 1976. Transplant techniques for sapling mangrove trees, Rhizophora mangle, Laguncularia racemosa, and Avicennia germinans, in Florida. Fla. Mar. Res. Publ. No. 22. 14 pp.

121. Pulver, T. R. 1975. Suggested mangrove transplanting techniques. Pp. 122-131 in R. R. Lewis (ed.), Proceedings of the Second Annual Conference on Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida. 203 pp.

122. Reid, G. K., Jr. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf Caribb. 4(1): 1-94.

123. Robas, A. K. 1970. South Florida's mangrove-boarded estuaries: their role in sport and commercial fish production. Univ. Miami Sea Grant Information Bull. No. 4. 28 pp.

124. Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. (4th Edition). Am. Fish. Soc. Spec. Publ. No. 12. 174 pp.

125. Roessler, M. A. and J. C. Zieman. 1969. The effects of thermal additions on the biota in southern Biscayne Bay, Florida. Gulf Caribb. Fish. Inst. Proc. 22nd. 135-145.

126. Sacket, W. M. (in press). Stable carbon isotope studies on organic matter in the marine environment. In P. Fritz and J. C. Fontes (eds.), Handbook of Environmental Geochemistry, Vol. III. Elsevier Publishing Co., New York.

127. Saltwater Fisheries Study and Advisory Council. 1981. Progress report. August 1980-January 1981. 38 pp.

128. Saurs, S. C. 1981. Seasonal growth of seagrasses in Sarasota Bay, Florida, with notes on historical changes and considerations for restoration. Pp. 118-139 in R. H. Stovall (ed.), Proceedings of the Eighth Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, Florida. 200 pp.

129. Savage, T. 1972. Florida mangroves as shoreline stabilizers. Florida Dept. Nat. Resour. Prof. Pap. Ser. 19. 46 pp.

130. Sheridan, P. F. 1979. Trophic resource utilization by three species of Sciaenid fishes in a northwest Florida estuary. Northwest Gulf Sci. 3(1): 1-15.

131. Smith, B. N. and S. Epstein. 1971. Two categories of $^{13}C/^{12}C$ ratios in dissolved and particulate organic matter in the sea. Deep Sea Res. 17: 19-27.

132. Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fl. State Board Cons. Prof. Pap. Ser. No. 1. 104 pp.

133. Stickney, R. R., G. L. Taylor, and D. B. White. Food habits of five species of young southeastern United States estuarine Sciaenidae. Chesapeake Sci. 16(2): 104-114.

134. Subrahmanyam, C. B., W. L. Kruczynski, and S. H. Drake. 1976. Studies on the animal communities in two North Florida salt marshes. Part II. Macroinvertebrate communities. Bull. Mar. Sci. 26: 172-195.

135. Summerson, H. C. 1980. The effects of predation on the marine benthic community in and around a shallow subtidal seagrass bed. M.S. Thesis, Univ. North Carolina, Chapel Hill. 118 pp.

136. Sykes, J. E. and J. H. Finucane. 1966. Occurrence in Tampa Bay, Florida, of immature species dominant in Gulf of Mexico commercial fisheries. Fish. Bull. 65(2): 369-379.

137. Tabb, D. C. 1961. A contribution to the biology of the spotted seatrout, Cynoscion nebulosus (Cuvier) of east-central Florida. Board of Conservation: Technical Series No. 35. 24 pp.

138. Tabb, D. C. and R. B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. Bull. Mar. Sci. Gulf Caribb. 11(4): 552-649.

139. Taylor, J. L. 1974. The Charlotte Harbor estuarine system. Fla. Sci. 37(4): 205-216.

140. Taylor, J. L., J. R. Hall, and C. H. Saloman. 1970. Mollusks and benthic environments in Hillsborough Bay, Florida. U.S. Fish Wildl. Serv. Fish. Bull. 68(2): 191-202.

141. Taylor, J. L. and C. H. Saloman. 1968. Some effects of hydraulic dredging and coastal development in Boca Ciega Bay, Florida. U.S. Fish Wildlife Serv. Fish. Bull. 67(2): 213-241.

142. Teas, H. J. 1981. Restoration of mangrove ecosystems. Pp. 95-103 in R. C. Carey, P. S. Markovits and J. B. Kirkwood (eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/59. 257 pp.

143. Teas, H. J. 1980. Mangrove swamp creation. Pp. 63-90 in J. C. Lewis and E. W. Bunce (eds.), Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a Workshop. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-80/27. 162 pp.

144. Teas, H. J. 1977. Ecology and restoration of mangrove shorelines in Florida. Environ. Conserv. 4: 51-58.

145. Teas, H. J., W. Jurgens, and M. C. Kimball. 1975. Plantings of red mangrove (Rhizophora mangle L.) in Charlotte and St. Lucie Counties, Florida. Pp. 132-161 in R. R. Lewis (ed.), Proceedings of the Second Annual Conference on Restoration of Coastal Vegetation in Florida. Hillsborough Community College, Tampa, Florida.

146. Thayer, G. W. and J. F. Ustach. 1981. Gulf of Mexico wetlands: value, state of knowledge and research needs. Proc. Gulf Coast Workshop. NOAA/Office of Marine Pollution Assessment, Miami, Fla. Oct. 1979.

147. Thorhaug, A. 1980. Techniques for creating seagrass meadows in damaged areas along the east coast of the U.S.A. Pp. 105-116 in J. C. Lewis and E. W. Bunce (eds.), Rehabilitation and Creation of Selected Coastal Habitats: Proceedings of a Workshop. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-80/27. 162 pp.

148. Thorhaug, A. 1974. Transplantation of the seagrass Thalassia testudinum Konig. Aquaculture 4:177-183.

149. Turner, R. E., S. W. Woo, and H. R. Jitts. 1979. Estuarine influences on a continental shelf plankton community. Science 206: 218-220.

150. Turner, R. E. 1977. Intertidal vegetation and commerecial yields of penaeid shrimp. Trans. Am. Fish. Soc. 106:411-416.

151. Turner, R. E. 1976. Geographic variations in salt marsh macrophyte production: a review. Contrib. Mar. Sci. 20: 48-68.

152. U.S. Department of the Interior, Bureau of Land Management. 1978.

153. Upchurch, S. B., E. D. Esteves, and R. Rea. 1976. Distribution and possible effects of removal and sedimentary contamination offshore of Gardinier, Inc. in Tampa Bay, Florida. Univ. Fla., Tampa, Fla. 110pp.

154. vanBreedveld, J. 1976. Transplanting of seagrasses with emphasis on the importance of substrate. Fla. Mar. Res. Publ. No. 126, St. Petersburg, Florida. 25 pp.

155. vanBreedveld, J. F. 1975. The transplanting of seagrasses with emphasis on the importance of the substrate. Fla. Dept. Nat. Res. Mar. Res. Publ. No. 17. 26 pp.

156. Welsh, W. W. and C. M. Breder, Jr. 1923. Contributions to the life histories of Sciaenidae of the eastern United States coast. Bull. U.S. Bur. Fish. 39: 141-201.

157. Weinstein, M. P. and H. A. Brooks. 1983. Comparative ecology of nekton residing in a tidal creek and adjacent seagrass meadows: community composition and structure. Mar. Ecol. Prog. Ser. 12:15-27.

158. Whittaker, R. H. 1975. Communities and Ecosystems. 2nd Edition. McMillan Publishing Co., Inc., New York.

159. Wong, W. W. and W. M. Sacket, 1978. Fractionation of stable carbon isotopes by marine phytoplankton. Geochim. Cosmochim. Acta. 42: 1809-1815.

160. Woodhouse, W. W., Jr., E. D. Seneca, and S. W. Broome. 1972. Marsh building with dredge spoil in North Carolina. N.C. Agric. Expt. Stn. Bull. 445. 28 pp.

161. Yokel, B. J. 1975. Rookery Bay land use studies: environmental planning strategies for the development of a mangrove shoreline, No. 5. Estuarine Biology. Conservation Foundation, Washington, D. C.

162. Zieman, J. C. 1982. The ecology of seagrasses of south Florida: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-82/25. 158 pp.

163. Zieman, J. C. 1981 The food within seagrass beds and their relationship to adjacent systems. Pp. 115-121 in R. C. Carey, P. S. Markovits, and J. B. Kirkwood (eds.), Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U. S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/59. 257 pp.

164. Zieman, J. C. 1976. The ecological effects of physical damage from motorboats on turtle grass beds in southern Florida. Aquat. Bot. 2: 127-139.

165. Zieman, J. C. 1974. Methods for the study of the growth and production of turtlegrass, *Thalassia testudinum* Konig. Aquaculture 4:139-142.

166. Zimmerman, R. J., T. J. Minello, and G. Zamora, Jr. (1984). Selection of vegetated habitat by brown shrimp, *Penaeus aztecus*, in a Galveston Bay salt marsh. Fish. Bull. 82(2):(in press).