Natural Systems

South Florida Regional Planning Council
March, 1978

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The preparation of this document was financed in part through a comprehensive planning grant from the U.S. Department of Housing and Urban Development.

INTRODUCTION

Natural environmental systems perform vital services in supporting human life and the economic activities upon which the people of the Region depend. These services include water supply, waste disposal, food production, hurricane and flood protection, air quality, climate, and the unique and beautiful environment that has attracted visitors and residents in unprecedented numbers. Like other complex systems, natural systems can operate efficiently only if they are maintained in a functional state. If vital components are destroyed, or if the system is overstressed, breakdown will occur and the system will fail. Technology can be used to increase the capacity of the natural system, but this requires expenditure of energy and capital to do work that was formerly performed free.

If appropriate technology and/or sufficient capital are not available to relieve stress on natural systems they deteriorate and the quality of life declines. Examples in the Region are: loss of beaches to erosion; degradation of water quality, both for water supply and for recreation; decline of fish and shellfish harvests; increasing travel distances to recreation and wilderness areas; and decrease of water available for both natural systems and human use.

Large areas of South Florida are naturally suitable for urban development. It is most cost efficient to manage other areas as natural support systems for supplying vital services and protection for the built environment. It makes economic sense to use each system for the function to which it is best suited, and to achieve optimum use of both the natural and built environments through intelligent management.

GOALS

1. Manage natural systems to insure that their valuable services to the people of the Region are not lost. These services include maintenance of water supply, water quality, hurricane and flood protection, recreation, food production, air quality, climate, and the environment that continues to attract tourists, commerce and industry.
2. Direct development to locations that are advantageous for development with the least undesirable impact on both the natural and the built environment.
3. Require sound development practices to preserve valuable natural system services and amenities, while providing a safe and beneficial human environment.

UPLANDS

The uplands of the Region are on the Atlantic coastal ridge, which has a maximum elevation of 20 feet. It extends from the northern boundary of the Region, paralleling the coast south to the Miami area, where it turns southwestward away from the shore. The ridge terminates at Homestead in south Dade County, with a few outcrops in Everglades National Park.

The underlying geological formation is limestone, covered by a thin layer of sand. In places the limestone is exposed at the surface, and rainfall either penetrates the ground rapidly, or runs off to lower elevations. The limestone contains numerous solution holes, both surficial and subterranean, which may create localized problems for construction, but has a sponge-like water bearing capacity.

Value of Uplands

Early settlements were located on the ridge because of its higher elevation and desirable coastal location. Geologic and soil conditions were also generally favorable for building, and these natural advantages attracted continuing development. Except for agricultural areas in south Dade County, most of the ridge has now been urbanized. As available high land became scarce, development spread westward into drained Everglades and eastward into the mangrove fringe. This was made possible by drainage and flood control projects, and by dredging and filling of former wetlands.

PINE-PALMETTO FOREST

Once the dominant plant community of the coastal ridge, the pine-palmetto community is largely replaced by urbanization and agriculture, and it may become the rarest of formerly common plant communities. This open forest community of slash pine, with under-story vegetation including saw palmetto and over 100 species of grasses, shrubs and herbaceous plants, prefers drier areas and/or shallow soils. It will not tolerate standing water, and where it is wet or very humid, hardwood hammocks or cypress are found among the pines.

Pineland is maintained by periodic fires that kill invading hardwoods, but spare the fire-resistant pines and saw palmettos. Fire has been curtailed, however, near development, and hardwoods – particularly the less desirable poisonwood and albizzia – are successfully invading pine forests near urbanized areas. Change from pine forest to hardwood hammock takes about 25 years.

Development practices in pineland must reflect the extreme susceptibility of pines to damage. If the roots or bark are injured by

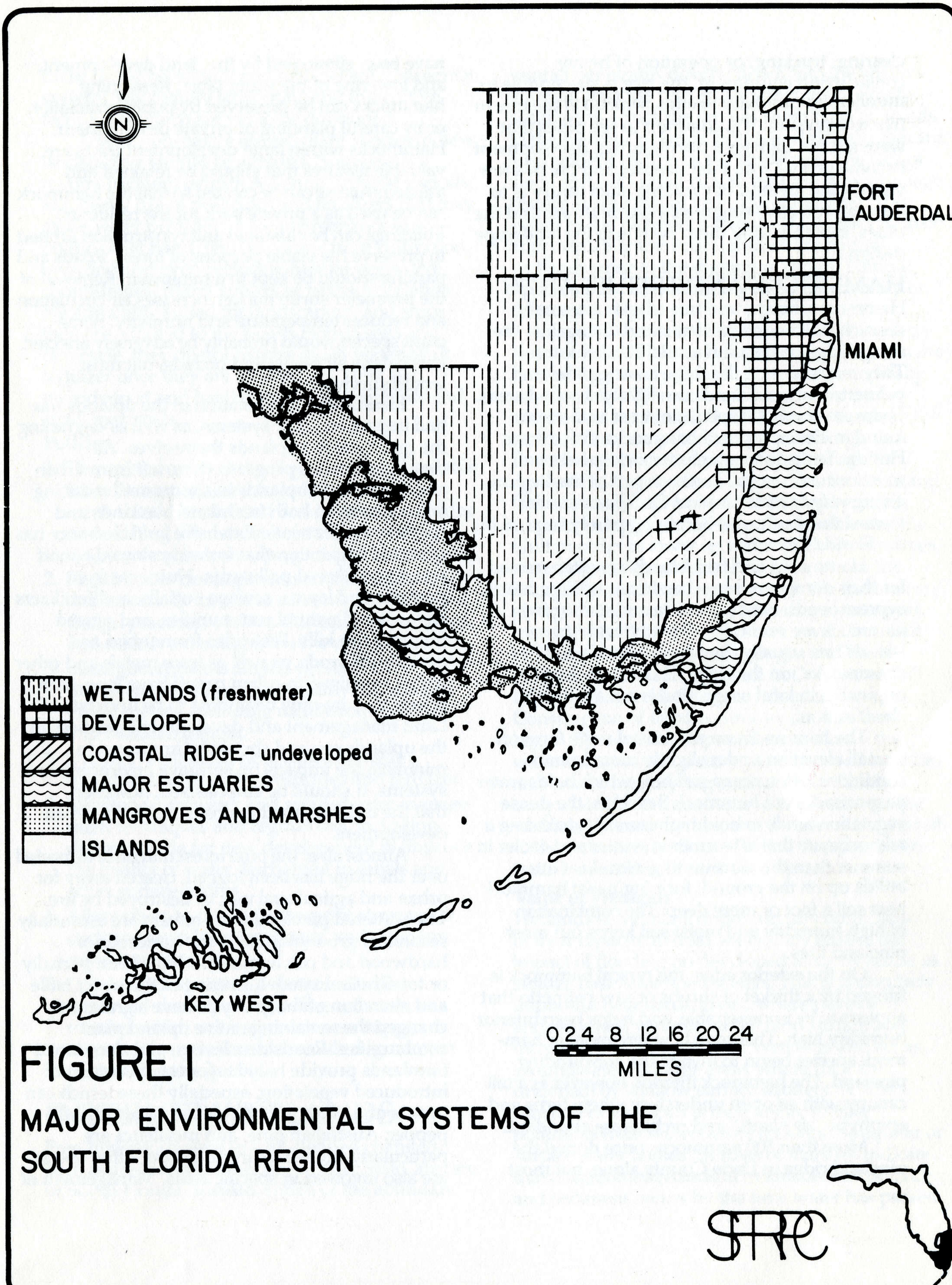

FIGURE I

MAJOR ENVIRONMENTAL SYSTEMS OF THE SOUTH FLORIDA REGION

clearing, trucking, or operation of heavy construction equipment, the tree is susceptible to invasion by pine bark beetles, which kill the tree in five to ten years. It is common to see pines that were left but damaged during urban development become yellow, lose their needles and die in a few years. One method of avoiding such injury is to leave a protective ring of saw palmetto around the pines, incorporating them both into the landscape design.

HAMMOCKS AND TREE ISLANDS

Hammocks, heads, and tree islands are small, dense hardwood areas that stand out against the surrounding vegetation as islands of trees. They may occur on the ridge among pines and palmettos, or in wetlands on slightly elevated areas. There are about 100 species of trees and shrubs found in eleven types of hammocks in southern Florida. Temperate zone hammock species are more common in the northern part of the Region, giving way to more tropical Caribbean species toward the south, and becoming purely tropical in the Florida Keys.

Hammocks and tree islands are often named for their dominant tree – bay heads, willow heads, cypress heads, oak hammock, and mahogany hammock are examples. "Heads" and "tree islands" are usually found in wetlands and "hammocks" on the ridge. The terminology originated in local usage, and is not a scientific classification.

The hammocks on the coastal ridge form on a small elevation under slightly more humid conditions, often near a sinkhole which holds water year-round. As a hammock develops, the dense vegetation tends to hold high humidity, creating a microclimate that is warmer in winter and cooler in summer than the surrounding area. Leaf litter builds up on the ground, forming moist hammock peat soil a foot or more deep. The combination of high humidity and moist soil keeps out most pineland fires.

On the exterior edge, the typical hammock is fringed by a thicket of shrubs or saw palmetto that appears to be impenetrable, and helps keep interior humidity high. This edge is where pioneer hammock species begin to invade the surrounding pineland. The hammock interior, however, is a tall canopy with an open understory where ferns and epiphytic "air plants" and orchids are abundant.

More than 500 hammocks once dotted the pineland ridge in Dade County alone, but most have been eliminated by fire, land development, and lowering of the water table. Remaining hammocks can be preserved by public acquisition or by careful planning of private development. Hammocks within large development tracts are valuable features that should be retained and utilized. Access can be created so that the hammock can be used as a private park for the residents. Buildings can be clustered and construction limited to preserve the viable portions of forest. Roads and parking should be kept to a minimum. Removal of the perimeter shrub thicket increases air circulation and reduces temperature and humidity. Some plant species would probably be adversely affected, particularly air plants and orchids, but most would survive.

Environmental alteration in the uplands has had impact on other systems, as well as degrading the quality of the uplands themselves. As development has progressed, runoff from urban and agricultural uplands has increased, reducing water quality in both freshwater wetlands and coastal environments. Extensive land clearance has removed vegetation that formerly slowed runoff water and filtered pollutants. Nutrients from pastures and lawns, sewage outfalls, and fertilizers have altered natural communities, and caused frequent fish kills. Pesticides from urban and agricultural lands, as well as trace metals and other toxins contained in urban runoff have long-term effects that are only beginning to be understood. Land management and development practices in the uplands can and should be improved to minimize the impacts on sensitive environmental systems. It should be emphasized, however, that the uplands are the most suitable for urban development.

Almost all of the pine forest that once extended over the ridge has been logged, cleared away for urban and agricultural use, or destroyed by fire. The scattered pinelands that remain are essentially secondary growth. Most of the hundreds of hardwood and oak hammocks have been partially or totally eliminated. Lowering of the water table and alteration of the fire cycle have significantly changed the remaining native upland plant communities. Roadsides, levees, and abandoned farmlands provide habitats for establishment of introduced vegetation, especially those which can invade and out-compete native species. Brazilian pepper, Australian pine, and melaleuca are particularly aggressive invaders, but other species are also involved in specific areas. Management of clearing, trucking, or operation of heavy construction equipment, the tree is susceptible to invasion by pine bark beetles, which kill the tree in five to ten years. It is common to see pines that were left but damaged during urban development become yellow, lose their needles and die in a few years. One method of avoiding such injury is to leave a protective ring of saw palmetto around the pines, incorporating them both into the landscape design.

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Use of non-native (exotic) plant species in new landscaping should be avoided. Some exotics require frequent irrigation during drought periods, and heavy use of pesticides and fertilizers that may cause water pollution. Low maintenance exotics, on the other hand, tend to escape from cultivation, invading and even replacing natural vegetative communities. Many species of native vegetation are admirably suited for landscaping, and since they are adapted to the South Florida soils and rain cycle, they do not require much watering or fertilizer once they are established. They also provide food and habitat for native songbirds and small mammals.

Policies

1. The upland areas of the Region are most suitable for urbanization; therefore, future development should be directed first to the coastal ridge and existing filled areas before more costly development in lower-lying areas is encouraged.
2. Require new developments in native pinelands and hammock forests to use ecologically sound design practices, such as clustering of buildings, and selective clearing of native vegetation.
3. Local governments should prohibit the deliberate planting of particularly undesirable exotic species, including melaleuca, casuarina, and Brazilian pepper.
4. Use native plants in new landscaping to minimize use of water, pesticides and fertilizer.
5. Develop stormwater and groundwater management techniques and regulations, including design criteria for new development to improve the quality of water discharged to canals and other surface waters.
6. Alternatives to direct discharge of stormwater, such as grassed swales, berms, and retention ponds, are preferred.
7. Conduct construction activity, including approved clearing and grading activities, in a manner which minimizes adverse impacts on natural vegetation and avoids degradation of air and water quality.

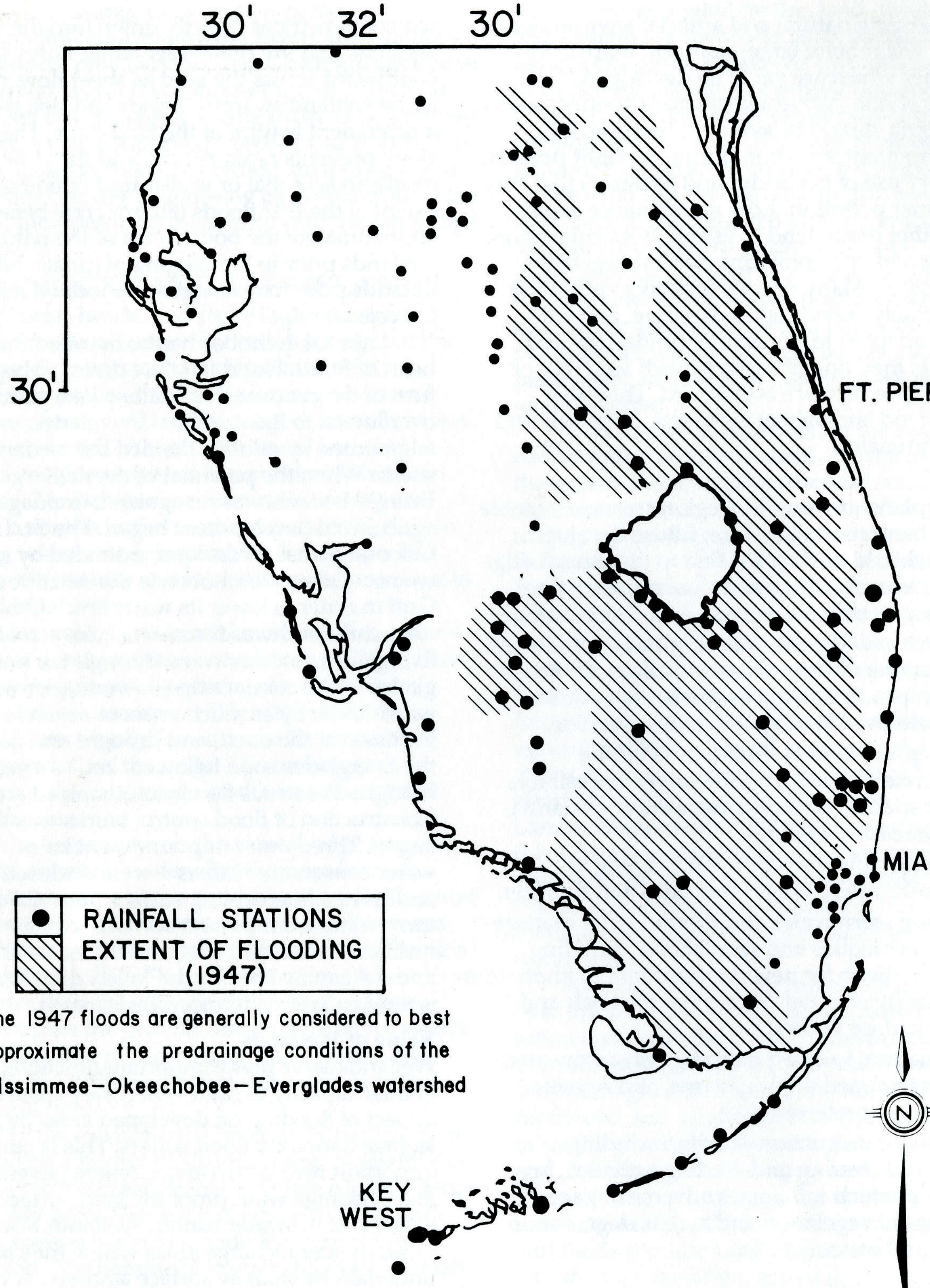
INTERIOR WETLANDS

Free-flowing streams in well-defined channels, such as are found in other parts of the State, are rare in South Florida. Instead, much of the abundant rainfall penetrates directly down into the shallow aquifers, and the remainder either flows slowly southward across the land as sheet flow, or stands in the wetland swamps, ponds and sloughs that are a prominent feature of the landscape. The lack of slope prevents rapid runoff, and the slow drainage results in seasonal or year-round flooding. The extent of the 1947 floods (Figure 2) are believed to be approximately the boundaries of the natural wetlands prior to the digging of canals. Natural uplands prior to drainage were located mainly on the coastal ridge.

Lake Okeechobee has been called the watery heart of South Florida. Before drainage began at the turn of the century, this shallow lake periodically overflowed to the northern Everglades, and, augmented by rainfall, flooded the wetlands to the south. When the potential of the rich organic Everglades soils was recognized, drainage for agricultural development began. The St. Lucie and Caloosahatchee rivers were extended by canals to connect Lake Okeechobee to the Atlantic and the Gulf in order to lower its water level. Other canals were dug southward from the Lake across the Everglades, and eastward through the transverse glades of the coastal ridge, lowering former peak water levels by as much as six or seven feet. Salt intrusion at the coast, and drought and fire in the Everglades soon followed. Yet, wet years still brought disastrous floods to urbanized areas. Construction of flood control works was then begun. Three water impoundment lakes – the water conservation areas – were enclosed by dikes and levees, intercepting surface flow. Canals carry water from these reservoirs to recharge the wellfields of coastal cities, and the excess is diverted to the Atlantic. The South Florida drainage basin is now an artificially controlled system.

Value of Wetlands

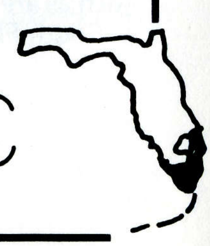
Wetlands serve many important functions. Because of their capacity to hold water, they reduce the impact of flooding on developed areas by acting as storage basins for flood waters. This is particularly important near urban areas, where pavement and buildings waterproof the land surface and increase stormwater runoff. Wetlands also act as groundwater recharge areas where they are underlain by shallow surface aquifers. A vital function of wetlands is their ability to filter pollutants from water before it enters the aquifer or surface water bodies. Studies of marshes indicate that a significant reduction in amounts of pollution and sediment occurs by the time water has passed



The 1947 floods are generally considered to best approximate the predrainage conditions of the Kissimmee–Okeechobee–Everglades watershed

FIGURE 2
EXTENT OF 1947 FLOODS

SOURCE: MARSHALL. 1971



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through the marsh.

Wetlands are one of the most productive natural systems; some having been found to equal or exceed the productivity of intensively farmed cropland. Fish and waterfowl production is particularly important economically, both for recreation value, and for harvest. Wetlands are also essential for wildlife, as many rare or endangered species are wetland dependent.

An additional substantial value of wetland systems is recreational. Fishing, hunting, and simple relaxation and enjoyment of the spectacular water birds and unparalleled diversity of life forms are wetland resources that are irreplaceable.

The plants and animals of the Everglades are dependent on a yearly rhythm of flooding and drying, and the timing of the cycle is important, as is the total water quantity. Too much water at nesting time can prevent reproduction of certain birds, for example. Plant communities also have critical requirements. In the cypress community, for example, the seeds sprout on moist soil in the winter, after the water recedes, and grow rapidly the first year to remain above the level of flooding the following year. Short periods of flooding can be tolerated, but long submergence will kill the seedling, as will prolonged dry periods.

Many other species have equally specific needs if they are to reproduce and survive. Ecologist Arthur Marshall has described these complex interrelationships:

> Heavy tropical rains come to south Florida in the summer and fall throughout the Everglades waterway. The water rises out of its shallow, scattered depressions – lakes, rivers, ponds, and sloughs. It sheets over the southern Everglades marshes in the form of a very broad river which historically was seven or eight feet deep at summer flood.
>
> Regenerative processes bloom with the rising spread of the water under the warm summer sun. Plant germination and growth flourish. Many aquatic organisms – insects, crayfishes, killifishes, reptiles – engage in an orgy of reproduction and in a few weeks their progeny can be seen in all reaches of the summer river.
>
> After the rains let up, the sheet water recedes into the deeper ponds and sloughs and concentrates the summer's production of small organisms, making them available in essential densities to the waiting large predators. This phenomenon of flood-bloom-recession-concentration is a marvel of synchronization – for the summer's organic products are thus served up to the flocks of colonial birds who are then fledging their young and to the young and adults of many marine fishes which invade the brackish and fresh waters of the lower Everglades to forage there.

The major freshwater wetland system of the South Florida Region, the Everglades, has been subdivided by flood control works and by urban, agricultural and park development, into four major subunits:

1. Water Conservation Areas. These are shallow artificial water storage lakes, managed by the South Florida Water Management District.
2. East Everglades. Semi-drained wet prairie and sawgrass marsh east of the Conservation Areas, between the levees and the urbanized coastal ridge.
3. Southern Everglades Coastal Marsh. A broad, low freshwater marl prairie lying between the coastal ridge and the saline mangrove fringe in southern Dade County.
4. Everglades National Park and Big Cypress Freshwater Preserve. Occupying much of western Dade and all of mainland Monroe counties, these federal preserves also include the southern fringe of the Big Cypress Swamp.

THE EAST EVERGLADES

The eastern Everglades, the area in Broward and Dade counties between the coastal ridge in the east and the flood control levees and Everglades National Park in the west, is an area of former wet prairie and sawgrass marsh that was flooded part of the year. Much of this area, now extensively drained, has been altered for urban development or agriculture. The area was formerly part of the Everglades watercourse but is now isolated by conservation area levees to the west, and peak water levels are 2 to 4 feet lower than they were prior to canal drainage.

The former wetland community is being invaded by non-native species, and the peat soils have been burned away in places by fires, or have partially oxidized by exposure to air. These changes result from lowering of the water table and shortening of the flood period. Where agricultural

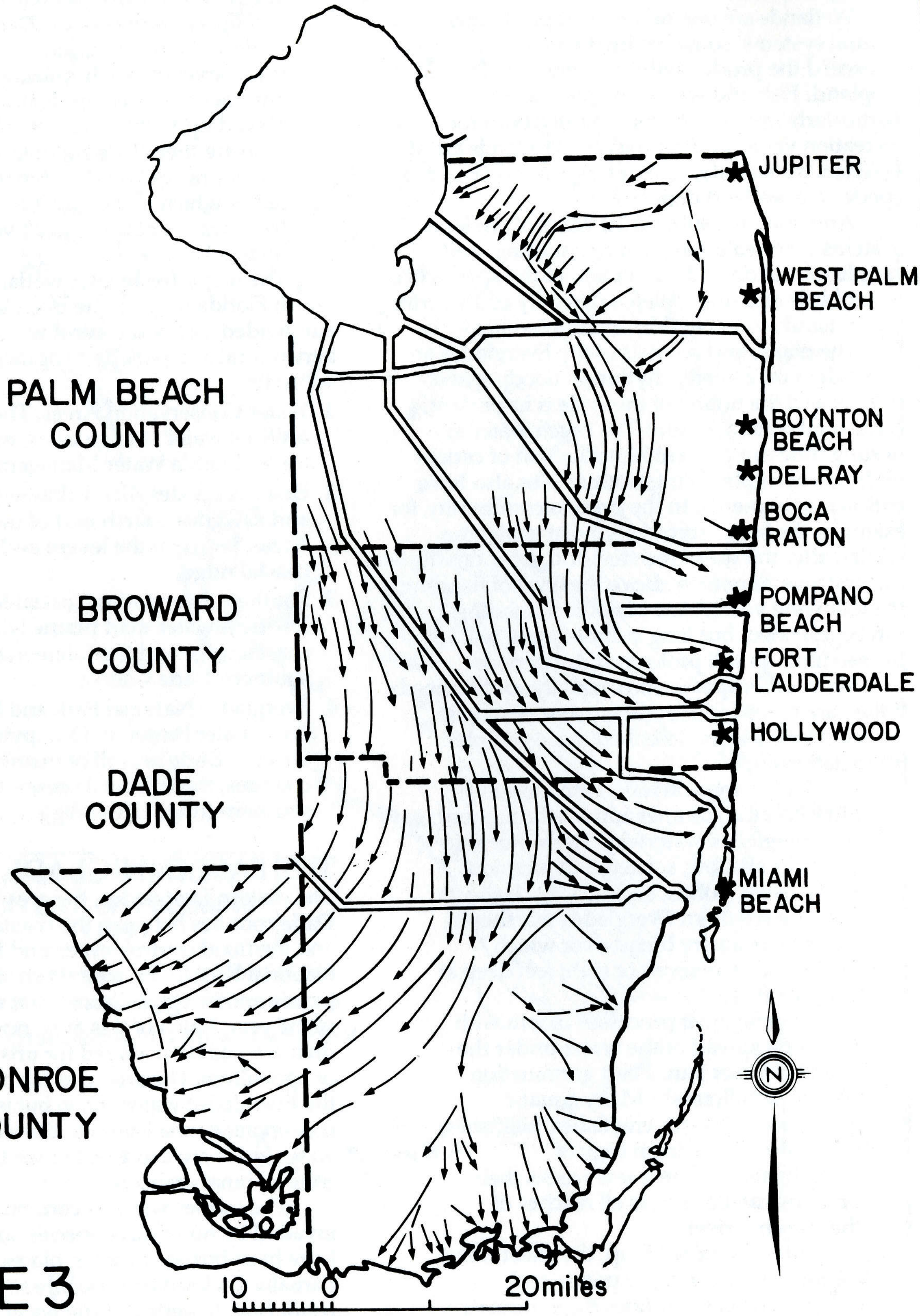

FIGURE 3

DIRECTIONS OF NATURAL SURFACE DRAINAGE

SOURCE: PARKER ET. AL 1955

or urban development has occurred, runoff has impacted water quality.

When development is absent, however, the area functions as an important aquifer recharge area due to the filtering capacity of organic muck soil and the permeability of the underlying geologic formations. Although the natural habitat value of the area has been lessened by alteration, it still acts as an important buffer zone between the urbanized coastal strip and the natural communities of the conservation areas, which have high environmental and recreational value.

There is increasing pressure for development in the east Everglades, and large tracts have already been committed for future residential projects. The proposal for a major jetport in north Dade is stimulating proposals for industrial development. If extensive development proceeds, the capacity of the area to retain flood waters would be reduced, as would its essential aquifer recharge capability, because additional filling and drainage would be necessary for flood protection of new development. If the remaining natural value of the area is to be retained, it is necessary to limit the amount of fill or topographic disturbance which takes place, and to minimize removal of existing organic soils. The cumulative effect of demucking and fill is a decrease in total aquifer recharge, and lower quality of both surface and ground water.

A particular concern is control of land use adjacent to the conveyance canals which supply water to municipal wellfields, and land uses near wellfields themselves. All major conveyance canals flow through portions of the east Everglades, and can influence ground water movement one-half mile or more from their banks. Similarly, the zone of influence of a major wellfield extends outward from the well, the distance depending on rate of pumping, adjacent rock formations, and seasonal fluctuation of the water table. Preliminary EPA studies have shown that urban runoff and industrial waste have already contaminated ground water in the vicinity of at least one major municipal wellfield. Local government land use regulations, water quality management programs, and requirements for sound development practices are essential to protect the water supply.

The upper drainage basin of Taylor Slough lies within the east Everglades, outside the boundaries of Everglades National Park. It is a seasonally important feeding area for birds which nest in the Park, but its chief importance is in the flow of water provided to the Slough itself, and to its downstream estuaries which support 90 percent of the United States populations of American crocodile and Cape Sable sparrow, 50 percent of the nesting egrets and roseate spoonbills in Florida, and significant populations of brown pelicans, bald eagles, and ospreys, as well as juvenile life stages of many sport and commercial fishes.

Land use in the Taylor Slough drainage basin must be carefully planned and regulated to avoid cutting off the vital flow of water to the Park and Florida Bay.

Policies

8. Allow only those uses and intensities in the eastern Everglades that minimize adverse impacts on water quality, surface flow, hydroperiod, soil cover, aquifer recharge, and the natural, wildlife, and recreational values of the Conservation Areas, and Everglades National Park and Florida Bay.
9. When adequate public services are available or programmed, priority should be given to development within the generally urbanized area, followed by staged growth outward from the urbanized area.
10. Develop areas which have already been filled or otherwise significantly disturbed, before alteration is permitted in less disturbed areas. An exception would be areas in which alteration has caused damage to vital environmental systems; such areas and their functions should be restored if feasible.
11. Develop special land use and land development controls for areas which are within the zone of surface or groundwater influence of existing or proposed public wellfields and their conveyance canals.

SOUTHERN EVERGLADES COASTAL MARSH

This area of salt and freshwater marshes occupies southernmost Dade County as shown on Figure 1. Everglades National Park forms the western border, and Card Sound, Barnes Sound, and Biscayne Bay form the boundary on the south and east.

Elevations range from a maximum of five feet near the Park entrance, grading imperceptibly down to sea level at the coast. The majority of the area is less than three feet above mean sea level, making it extremely prone to hurricane flooding. Soils are primarily marl over bedrock or marl over peat. Mangrove peat underlies the estuarine areas along the coast, where the elevation is generally less than one foot above mean sea level.

In the past the area was characterized during high water periods by uninterrupted overland flow of freshwater from the ridge in the vicinity of Florida City, southward and eastward into the coastal mangrove estuaries. Most of the area is flooded yearly to a depth of at least one foot. Inundation in the southern portions is more frequent and longer lasting than in the north. Management of existing canals in the area provides a semblance of natural water flow to the coastal estuaries.

Predominant vegetation includes spikerush, beakrush, and sawgrass, typical of wet prairies. South of the C-111 canal, widely dispersed sloughs support the growth of shrubs and stunted trees. The algal mat or periphyton is a dominant feature, and forms the foundation of the biological community of the freshwater marshes. It also plays an important role as a water filtering agent and soil builder. The wildlife habitat value of this area is extremely high, and several endangered species inhabit the area. The overland flow of freshwater maintains the valuable brackish water habitat areas and carries nutrients to the important fish and shrimp nurseries of the mangrove estuaries.

Environmental changes within this area have been primarily caused by drainage canals and alteration of surface flow, and by the Florida Power and Light Company cooling system in the eastern portion. Canal 111, in addition to its drainage function, was intended to be used as a waterway for barge traffic. However, at the insistence of various agencies and organizations, both public and private, Canals 109 and 110 were left with earthen plugs, thus preventing the drainage of these valuable wetlands, and C-111 was equipped with gated control structures.

Although the area has been altered by a number of canals, levees and roads, it is still highly productive biologically. If no additional obstruction to sheetflow occurs, it can continue to function as a wet prairie from which nutrient-laden waters flow into the mangrove estuaries along the south and southeastern coast. This wetland is also vital as a feeding ground for animals inhabiting and protected by Everglades National Park, but which nest and feed in this area outside the Park.

The area is also important as a freshwater recharge area for prevention of further saltwater encroachment into the aquifer. This function is critical, since the intrusion line penetrates further inland in south Dade County than anywhere else in the Region.

The Turkey Point nuclear power plant, and the proposed South Dade nuclear facility site are located in the eastern portion of the area, and precautions should be taken to limit development in their vicinity and monitor their impact in this environment.

Much of the southern Everglades coastal marsh has been designated as an Environmental Sensitivity Zone, or Conservation Zone by the Dade County Comprehensive Development Master Plan, and implementation of resource management objectives now underway by Dade County should adequately protect this area. These guidelines address varied environmental concerns (drainage, flood control, water quality and quantity, vegetation) and reflect the area's unique and vulnerable hydrological, soil and vegetative conditions.

Policies

12. Future land use in the Southern Everglades should be consistent with the area's high biological value, recognizing the extreme vulnerability of the area to flooding and hurricane damage.
13. Precautions should be taken to prevent further disruption of the flow of surface water to the estuaries. Preservation of sheetflow is vital for maintenance of the area's endangered wildlife species and for the marine communities of the estuaries (fish and shrimp).
14. No new drainage canals should be permitted in the coastal marshes as further drainage or changed salinity will adversely affect important biological functions and ecosystems.
15. Limit inappropriate development in the vicinity of existing and proposed nuclear power facilities.
16. Implement the resource management guidelines (environmental guidelines) proposed in the Dade County Master Plan (Part 2) to protect "environmental sensitivity zones" (i.e. Southern Everglades Coastal Marshes). These guidelines address varied environmental concerns (drainage, flood control, water quality and quantity, vegetation) and reflect the area's unique hydrological, soil and vegetative conditions.
17. Restore, to the extent practical, the natural water flow disturbed by drainage structures which are unneeded where these obstructions are detrimental to the functioning of the natural system.

EVERGLADES NATIONAL PARK

Everglades National Park was officially designated in 1947. The original statute creating the Park directed that:

> The land area or areas shall be permanently preserved as a wilderness, and no development of the project or plan for the entertainment of visitors shall be undertaken which will interfere with the preservation intact of the unique flora and fauna and the essential primitive natural conditions now prevailing in this area (16 U.S.C. 410c).

Shark River Slough and the coastal mangrove estuaries comprise the major portion of Everglades Park. Part of the water flow to the Slough, the major drainageway of the Park, has been cut off by flood control levees and is regulated by control structures along the southern boundary of Conservation Area 3A. The timing and quantity of water allocated to the Park from the Conservation Area has long been a subject of controversy. The effects of drydown or flooding that is out of phase with the natural hydroperiod has caused habitat alteration, change in plant and animal community, composition, and disruption or failure of wildlife reproduction cycles. The Park is dependent for its survival upon high quality water of sufficient quantity flowing from the north, timed to correspond to the life cycles and processes of the plants and animals.

Only the southeastern fringe of the Big Cypress watershed lies in the Region, partly within the boundaries of Everglades National Park, and partly in the area which has been designated for purchase as the Big Cypress Freshwater Preserve. The eastern portion of the Big Cypress is relatively pristine – probably the most undisturbed portion of the South Florida peninsula – and is vital to the continuing viability of the western part of Everglades Park.

The entire southern Florida peninsula has been vastly altered by drainage and flood control operations during the past 50 years, which have changed the water flow patterns and drained away much of the surface water which would have otherwise flowed to and through Everglades Park. Since the Park contains only a *segment* of the Everglades system, and the subsystems of the Everglades are so interrelated and dependent upon the sheet flow of freshwater, the National Park does not include enough area to assure the preservation of even this small remnant of the total Everglades system. Conditions within the Park are profoundly affected by activities outside the Park and beyond the control of Park officials. Land and water management decisions around the National Park will determine the survival of this single "preserved" area of the Everglades ecosystem.

The major issue, then, is water supply to the Park, including quantity, quality, and timing. Its management is a challenge to decision-makers and institutions.

Policies

18. Quantity, quality, and timing of water flow to Everglades National Park should be as close to natural conditions as possible, as an integral part of the regional water management plan.
19. Land use in areas of the Shark Slough and Taylor Slough drainage basins which lie outside the Park boundaries should be consistent with sound management of the valuable biological and recreational resources of the Park and the Florida Bay estuaries.

ESTUARIES

High productivity, diversity of plants and animals, and unique environmental characteristics make estuaries one of the most valuable natural systems. These areas, where fresh water from the land mixes with sea water, provide a lower salinity nursery ground for many important species of sport and commercial fish and shellfish.

The estuaries in the Region are located behind long, narrow barrier islands. Biscayne Bay, including Card and Barnes sounds, is located in Dade and Monroe counties. Smaller estuarine areas in Broward County are connected by the Intracoastal Waterway. Many were freshwater lakes and wetlands until the Waterway was constructed and various inlets were dug to connect to the sea.

The estuaries of Florida Bay and the Gulf coast are different from those of the east coast. They are part of a complex swamp shoreline composed of many mangrove-covered islands. Numerous shallow rivers, sloughs, and tidal channels bring freshwater from the Everglades and Big Cypress Swamp to the many small estuarine water bodies. Unlike the highly urbanized east coast, this shoreline is relatively natural, and west of Barnes Sound it is part of Everglades National Park.

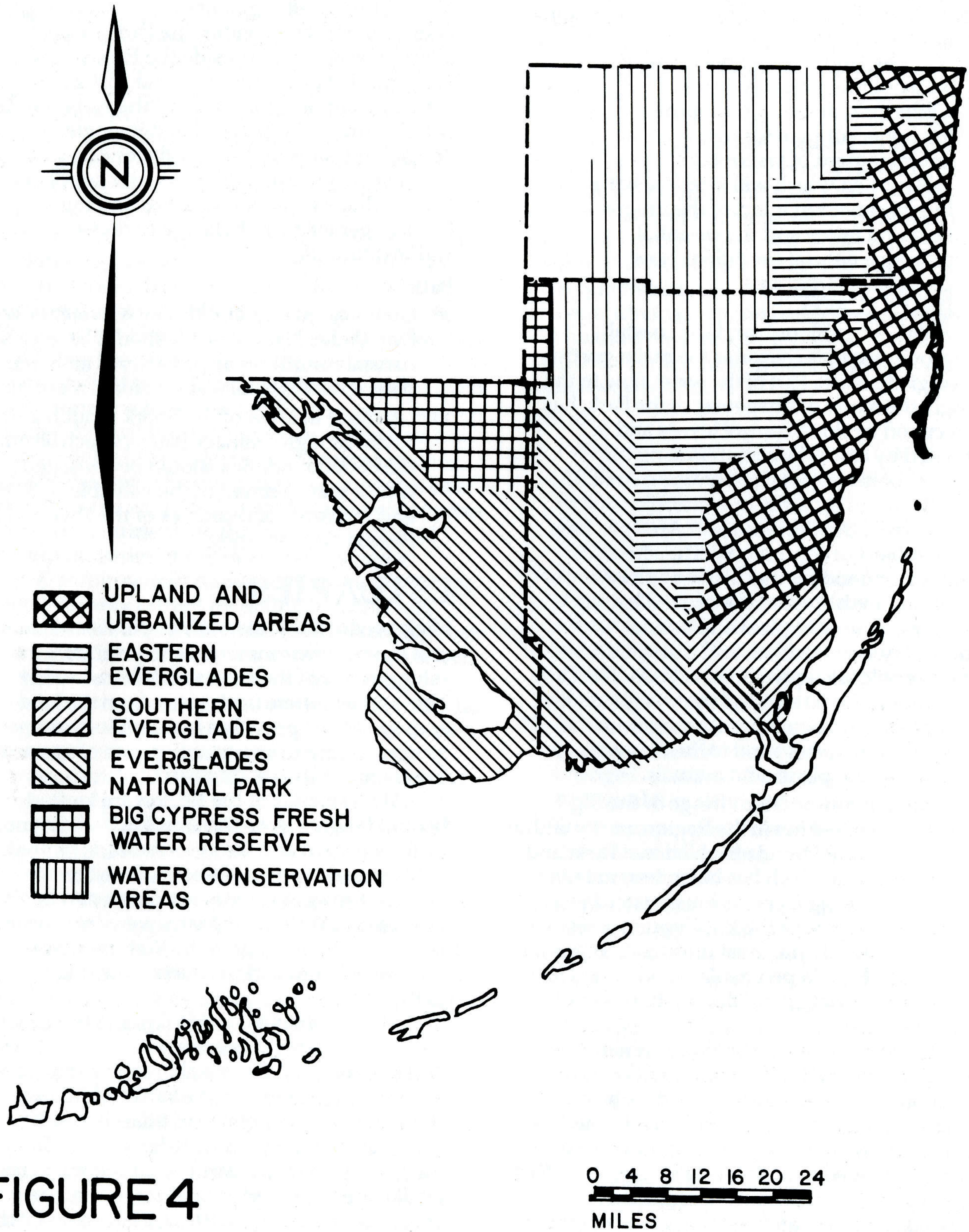

FIGURE 4

FRESHWATER WETLAND AREAS OF THE SOUTH FLORIDA REGION

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Value of Estuaries
Sub-tropical estuaries support a high degree of biological diversity and productivity, with complex life patterns and closely interdependent species. Estuaries rank with tropical rainforests and coral reefs as highly productive ecosystems. They are usually more productive than either the sea on one side or the freshwater drainage area on the other. This high natural productivity is due to a combination of characteristics.

Shelter: An estuary is protected from wave action, allowing bottom dwelling organisms to attach, seagrasses and algae to become established, and nutrients and floating organisms to remain. Lower salinity also deters marine predators. Large ocean predators are deterred by the shallow depth.

Sunlight: Shallow depth allows light to penetrate to the bottom, supporting photosynthesis by bottom vegetation. Turtle grass and other seagrasses are the major primary producers in the food chain of warm-water estuaries.

Salinity: The reduced salinity of the estuarine environment provides suitable habitat for young of the many marine species which cannot survive ocean salinity as juveniles.

Nutrient storage: Nutrients are trapped within the estuary in the stems and leaves of plants, and later slowly released as detritus (tiny particles produced as the plant parts are broken down by fungi, algae, protozoans, and small shellfish).

Tidal Zone Vegetation: Another important source of nutrients is the detritus originating in tidally flushed mangrove swamps and coastal marshes. The small organisms which break down the detritus are a vital link in the food chain. The most productive part of the estuarine nursery is the tidal zone and adjacent shallow water zone. This is also the first part of the estuary to be effected by land-based activity.

Tidal Action: Detritus, nutrients, small organisms, and waste are swept out of the intertidal zone by the tide, and transported to other parts of the estuarine system. Tides also eventually carry excess nutrients to the sea, where they are used in offshore systems.

The interaction of sea, land, tides, and sunlight in estuaries creates some of the richest food producing areas in the world. The system is based on the detritus mentioned above – nutrients from decaying vegetation. In the North River estuary of the Everglades, biologists found that detritus accounts for 80-90% of the food of crabs, worms, insect larvae, and small fishes. These small animals in turn are the food for over sixty juvenile fish species which depend on the estuarine environment for part of their life cycle. Among them are tarpon, snook, ladyfish, and gray snapper. Other game fish which use the mangrove estuaries are sea trout, crevalle jack, and jewfish. Shrimp are also detritus feeders, as are mullet and blue crab.

Estuarine value can be partially measured in the economic yields of the tourist industry and commercial fisheries. In 1969, Florida tourists spent $5.5 billion on sport fishing – almost one quarter of personal income in the State. The National Marine Fisheries Service found that the value of commercial marine landings for 1972 was $57 million, and in 1973 statewide income from shrimp alone exceeded $26 million.

All components of the estuarine system, and their interactions, must be considered to protect estuarine function:

> Protection of estuarine resources depends not on the protection of a *point* (grassflat) but on the protection of a *process*. (Marshall)

Protection of estuarine systems can be facilitated by establishing a 50′ coastal construction setback in estuarine areas. This would allow for a natural vegetative buffer between the mean high water line and any structures. This vegetative buffer, 50′ landward of the mean high water level, will cleanse upland run-off before it enters estuarine waters, provide for shore stabilization, and protect life and property.

The main components of estuarine systems discussed below are:

1. The tidally flushed mangrove or coastal marshes
2. Marine grassbeds and other bottom vegetation
3. The water body itself.

ESTUARINE MANGROVE AND COASTAL MARSH

In southern Florida mangroves occur intermittently along the entire coast, primarily in quieter estuarine waters. Coastal marshes are found adjacent to the mangroves, but are more common in northern Florida, where frost limits the spread of mangroves.

In southern Florida, both mangroves and coastal marshes cover large areas because they are able to withstand contact with seawater.

The term "mangrove" refers to tree species not closely related but generally found in the mangrove forest. There are many species of mangrove, but the only three found in southern Florida are the red, the black, and the white mangrove.

Red mangroves usually occupy the outer or seaward zone. They are distinctive in appearance, with arching prop roots projecting from the trunk or branches down into the water. They produce cigar-shaped seedlings that sprout while attached to the parent tree, and after they drop into the water and float away, they become rooted if caught in debris or in a mudbank in shallow water. Red mangroves can grow in shallow offshore areas where the roots are always under water, or onshore where the soil surface is barely under water at the highest tide. The seedlings can also be carried far inland, where they may grow in dwarf form in isolated clumps, or up tidal rivers where they form tall forests in the floodplain.

The middle zone, at slightly higher elevations, is dominated by black mangrove in association with salt marsh plants. This zone is usually flooded during high tide. Black mangroves may sometimes be found at the edge of the water with no intervening band of red mangrove. Often these trees are old and large, remaining after the reds have been washed away by a storm.

The most landward zone is affected only by the highest spring and storm tides. The white mangrove is found here in association with the buttonwood (not a mangrove) and marsh vegetation.

Estuarine mangroves perform several valuable functions. Their leaves are a major source of nutrients for the many estuarine-dependent animal species, particularly sport and commercial fishes and shellfish.

They also act as soil-builders. Mangrove forests are associated with deposits of peat. The leaves that fall on the soil decompose and are reduced to detritus in about a year, or are washed away by tides. The roots, however, resist decay in saturated soil, forming peat that has been found to depths of 12 feet. These deposits have kept pace with the rising sea at a rate of 1 inch each hundred years.

The mangroves, in their role as buffers to storm winds and tides, prevent devastation of the coastline by absorbing the energy of storms. This protects the upland, but in the process the mangroves may be damaged or destroyed. In some cases natural recovery takes place, but in others a new shoreline replaces the old. Where upland development needs protection, careful management of the mangrove forest is necessary.

One form of management is the planting of mangroves in new areas, as was done to stabilize portions of the Florida Overseas Railway causeway. Numerous experimental plantings have been successfully started in South Florida and elsewhere.

Experimental work by the Florida Department of Natural Resources in Tampa Bay showed that the black mangrove is at least as important as the red in shoreline protection and land building. The black mangrove has the added advantage of being tolerant to lower temperature as well as to adverse soil conditions, such as may be found in man-made shorelines. It can also tolerate some covering by pumped materials by producing new sprouts, and it can survive heavy top damage by hurricanes or frost. It is also quicker to develop a root system to protect the soil from erosion. Both red and black mangroves respond well to pruning, which suggests that they could be used as waterfront hedges, even to protect seawalls or possibly replace them.

Where possible, mangroves and their associated upland should be left alone to perform their protective functions. Generation and regeneration of mangrove forests occurs on wilderness shorelines without the interference of man, but where impacted by human activity, problems arise. Florida mangroves, however, are well suited for careful management. The red mangrove is recognized as the most important species for fisheries productivity. It also serves as a soil producer and stabilizer as well as a storm buffer. The black mangrove is important for shoreline stabilization, both as a secondary defense behind the red mangrove, and because its root system develops more rapidly than that of the red.

Policies

20. To provide for shore stabilization, cleanse upland run-off, and protect life and property, the State should establish a construction setback line for estuarine shorelines, similar to the existing State program (Ch. 161, F.S.) for beach and dune setbacks. This setback line should be a minimum of 50′ upland of the most landward mean high water line (consistent with Ch. 161, F.S.) unless an analysis of topography, vegetation, and other environmental characteristics indicates a more appropriate setback.

21. Route surface runoff in the upland through green swales, ponds, mangroves and other vegetated buffer zones before release into an estuary.
22. Locate marinas in upland rather than wetland areas, preferably adjacent to existing water bodies. They should be designed to take full advantage of tidal exchange. Deposit spoil excavated for construction or maintenance upland, not in wetlands.
23. Slope perimeters of marinas, canals, and other artificial water bodies to minimize slumping and erosion. If stabilization is required, riprap of indigenous rock rubble should be used to provide a relatively natural surface on which marine organisms can grow.
24. Where development in upland mangrove areas is deemed acceptable, selective clearing can maintain water quality and natural productivity of the mangrove system, while allowing the upland area to be developed. Mangroves seaward of the mean high water line are protected by state law. Selective clearing in mangrove and marsh areas should follow these minimum guidelines until the State can develop performance standards.
    A. Leave tidally flushed mangrove forest intact, with a landward buffer strip at least 50′ wide.
    B. Riverine forest. Where there is some tidal flushing, leave tall red mangroves intact, with a landward buffer at least 50′ wide. Channels may be cut through to increase tidal flushing. Where there is no flushing, the tall red mangroves may be selectively cleared without affecting most marine systems.
    C. Fringe forest. Along the coast, and bordering canals and streams, leave fringing mangroves intact in a buffer zone at least 50 feet inland of the mean high-water line.
    D. Dwarf forest. Leave dense areas bordering the coast and canals intact, as in the fringe forest. Tidal channels may be cut through the forest and may actually increase productivity. Where growth is sparse and trees are so far apart that their branches do not touch, dwarf mangroves are not very productive and do not contribute significantly to the marine environment.
    E. Coastal marsh. Preserve buffer zones similar to those recommended for the mangroves in the coastal marsh. Leave 50 foot buffer of marshland inland of all water bodies and streams.
25. Avoid lake excavation, sewage disposal and refuse disposal in estuarine mangroves or coastal marshes. In all areas seaward of the 1000 isochlor line (groundwater), allow these activities only after careful consideration of effects upon saltwater intrusion and water quality.

MARINE GRASS BEDS

The major submerged plant and animal community in estuaries is associated with sea grasses. These include turtle grass, Cuban shoal grass and manatee grass, as well as interspersed clumps of marine algae. Their location depends on water depth, with denser zones found near the shore. A complex assortment of algae are found growing on the older sea grass blades, and together with the grasses, are a source of primary productivity that exceeds that of the mangroves.

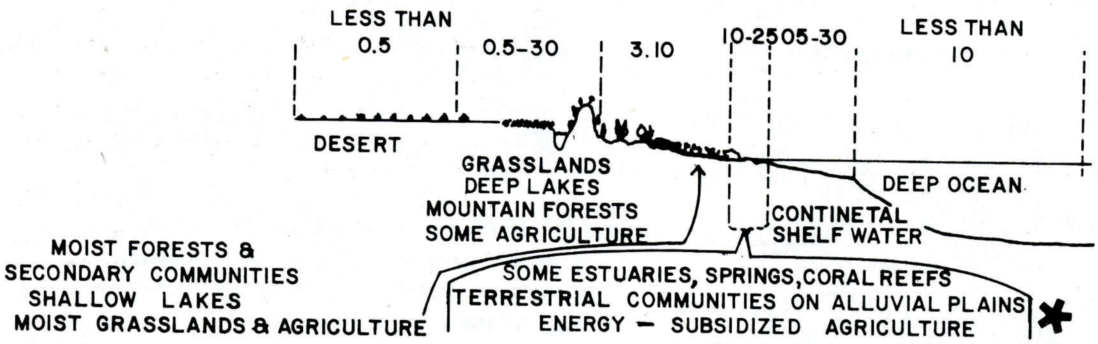
Many estuarine life forms are part of the marine grass community, or dependent on it, including shrimp, sea urchins, conch, sea cucumbers, molluscs, fishes, turtles, and manatee. The food web starts with photosynthesis by the grasses, followed by growth of algae and decomposition of old blades, their consumption by bottom-dwelling organisms, which are consumed in turn by larger fishes. Many of the bottom animals are filter feeders that keep the water clear, while processing the remains of decomposition.

Sea grasses are vulnerable to human activity, and management is necessary to prevent loss of the diverse and productive estuarine community associated with them. Their importance to marine fisheries is not as well studied as that of mangroves, but is thought to be similar or greater.

Dredge and fill activities have the greatest impact on sea grasses, but thermal effluents, sewage, oil, heavy metals, and pesticides also affect them adversely. Since seagrasses are densest close to shore, they are affected first by land based activities in estuaries. Binding and stabilization of bottom sediments is an important function of seagrasses. Where they have been destroyed or removed, re-establishment has been successful in experimental plantings in Biscayne Bay. Their use in stabilization of borrow areas and canals is also a possibility.

Dredging in estuarine waters is usually done to create or maintain canals, navigation channels, turning basins, harbors and marinas, for laying pipelines, as a source of material for fill, or to create construction sites. Since estuaries are much more productive than the open ocean, providing food and shelter for most species of commercial and

WORLD DISTRIBUTION OF PRIMARY PRODUCTION



The world distribution of primary production in terms of annual gross production (in thousands of -kilocalories per square meter) of major ecosystem type. Only a relatively small part of the biosphere is naturally fertile. (After E. P. Odum, 1963.)

ECOSYSTEM	AREA (10^6 KM^2)	GROSS PRIMARY PRODUCTIVITY (KCAL/M^2/Year)
MARINE		
Open ocean	326.0	1,000
Coastal zones	34.0	2,000
* Upwelling zones	0.4	6,000
Estuaries and reefs	2.0	20,000
SUBTOTAL	362.4	—
TERRESTRIAL		
Deserts and tundras	40.0	200
Grasslands and pastures	42.0	2,500
Dry forests	9.4	2,500
Boreal coniferous forests	10.0	3,000
Cultivated land with little or no energy subsidy	10.0	3,000
Moist temperate forests	4.9	8,000
Fuel subsidized (mechanized) agriculture	4.0	12,000
Wet tropical and subtropical (broadleaved evergreen) forests	14.7	20,000
SUBTOTAL	135.0	—
TOTAL for biosphere (not including ice caps) (round figures)	500.0	2,000

ESTIMATED GROSS PRIMARY PRODUCTION (ANNUAL BASIS) OF THE BIOSPHERE AND ITS DISTRIBUTION AMONG MAJOR ECOSYSTEM

FIGURE 5

COMPARISON OF ESTUARINE PRODUCTIVITY WITH OTHER ECOSYSTEMS

SOURCE: E.P. ODUM, 1971

sport fish, the effects of estuarine dredging are similar to but more serious than those of offshore dredging:

- Removal of the bottom sediments removes plant and animal habitat.
- Sedimentation reduces the productivity of biological communities by lowering oxygen levels.
- Turbidity inhibits photosynthesis by reducing water clarity.
- Water pollution is increased when dredging activity stirs up bottom sediments that have absorbed many kinds of pollutants, including heavy metals and pesticides from canals and both urban and agricultural runoff.
- Creation of basins or channels by dredging also changes water circulation, eventually causing changes in water temperature, salinity, dissolved oxygen, sediment accumulation and ultimately productivity.

Channel and basin dredging necessarily produces spoil that has to be disposed of somewhere. Spoil disposal through sidecasting in estuarine waters or through direct disposal in offshore ocean waters can smother bottom organisms and lower oxygen levels, which reduces the productivity or even kills bottom communities. Extensive disposal in a given area, particularly in estuarine waters, can cause shoaling and adversely affect water circulation. Open water disposal can also increase turbidity and sedimentation. If the spoil is polluted, its release in open water will cause oxygen depletion. Polluted spoil may also be toxic because of the presence of heavy metals, pesticides, and other chemicals.

While the creation of spoil banks or islands may reduce subsequent sedimentation, this method of spoil disposal is directly destructive of wetlands or bottom communities. Spoil banks or islands adjacent to navigation channels may also adversely affect water circulation. In addition, these disposal areas may be aesthetically unpleasing and produce obnoxious odors.

Policies

26. Align navigation and access channels to avoid shellfish beds, seagrass flats, or other productive areas whenever feasible and with preference for degraded areas.
27. New canals and channels should be dredged only when in the public interest and to provide access to common marina facilities with public access and should be designed to maximize flushing action.
28. Prohibit new finger-fill canals, or other canal designs which result in stagnant water.
29. When repairing existing bulkheads, place rock riprap seaward of the repaired bulkhead, to a height appropriate for local tides in order to provide a more durable shoreline. This provides a surface suitable for estuarine plants and animals to become established. It also reduces the force of waves, thereby reducing erosion and allowing marine grasses to become established.
30. Plant mangroves in rip-rap, where practical.
31. When favorable conditions are re-established replant marine grasses in areas where they have been destroyed by dredging or by pollution.
32. The cumulative impacts of numerous small projects should not be overlooked. The dredging and bulkheading of a thousand feet of shore and bottom in one large development is no more harmful than a dozen small projects covering a similar length. Small projects should be reviewed in the context of a management plan which addresses the problem of cumulative effects, and considers existing conditions on a large-scale basis, and not project-by-project as applications are filed.
33. In order to minimize the necessity or pressure to alter viable natural shoreline areas, require boat dockage facilities as shoreline redevelopment occurs, and where conditions are already suitable.

ESTUARINE WATER QUALITY

The alteration of drainage patterns by canals has had important effects on coastal estuaries. Prior to drainage, freshwater reached the coast by overland flow, through the wetlands of the Everglades or through the transverse glades of the lower coastal ridge. Other wetlands, drained by the natural rivers of the Region, slowed the flow and cleansed the water before it reached the estuary. Freshwater flow was more evenly distributed, both spatially and over time.

Canals now channel freshwater rapidly to the coast and into the estuaries according to flood conditions in the interior and capacity for back pumping into the Conservation Area and Lake Okeechobee. The canals thus become concentrated sources of freshwater which enters the estuaries in "pulses," depending on artificial regulation, rather than in rhythm with the seasonal rains.

The first spring rains wash over the land surface, carrying the dry season accumulation of pesticides, oil and grease, coliform bacteria, and other substances to the canals, some of which still serve as receiving waters for sewage outfalls. These artificial waterways, in turn, carry the water rapidly to the coastal control structures, and into estuarine waters. As spring rains continue, it becomes necessary to open the control structures to regulate water levels inland. This releases a "pulse" of water and sediments which may contain heavy concentrations of nutrients, trace metals and pesticides.

Estuarine water quality depends on a complicated balance between the rate of pollutant inputs and the rate of their removal. Rate of input is a function of polluted runoff from the land, and water quality management. Removal rate depends on the capacity of the estuary to assimilate pollutants, and on its flushing rate.

Studies in Biscayne Bay by Lee and Rooth, show that shallow bays are very poorly flushed by tides. The result of limited flushing is that pollutants discharged into the estuary will accumulate there, and pollutant removal depends primarily on the assimilative capacity of the estuarine system itself. A healthy system with adequate populations of shoreline and bottom plants and animals can assimilate limited amounts of pollutants. When the number of plants and animals is reduced or when there are more pollutants than they can assimilate the waters may become turbid and nutrient laden, with the serious degradation indicated by algal blooms, odors, fish kills and low species diversity.

Alterations which decrease the ability of an estuary to assimilate pollutants include:

- Removal of mangrove or coastal marsh vegetation.
- Destruction of bottom vegetation, such as sea grasses, by dredging, filling, changes in salinity, temperature, or bottom scouring by currents (such effects may result from new inlets or channels).
- Changes in circulation and/or salinity, resulting from construction of causeway fills or spoil islands, or changes in inlets or in the amount or rate of runoff from the land.
- Destruction of plants and animals by introduction of toxic substances or smothering by dredge spoil.
- Reduction of plant photosynthesis due to increasing turbidity of the water, through dredging or boat traffic.

Canals are a major source of estuarine pollution. A study of the Environmental Protection Agency made a comparison of the nutrient load of Broward County sewage outfalls with that of its primary canals, which discharge to the estuarine waters of the Intercoastal Waterway. The total nutrient load carried by the canals is about 10,000 pounds per day, while that of the Pompano and Hollywood outfalls is only about 3,000 pounds per day. These findings emphasize the importance of ending the pollution of inland canals if the estuarine environment is to be protected.

Policies

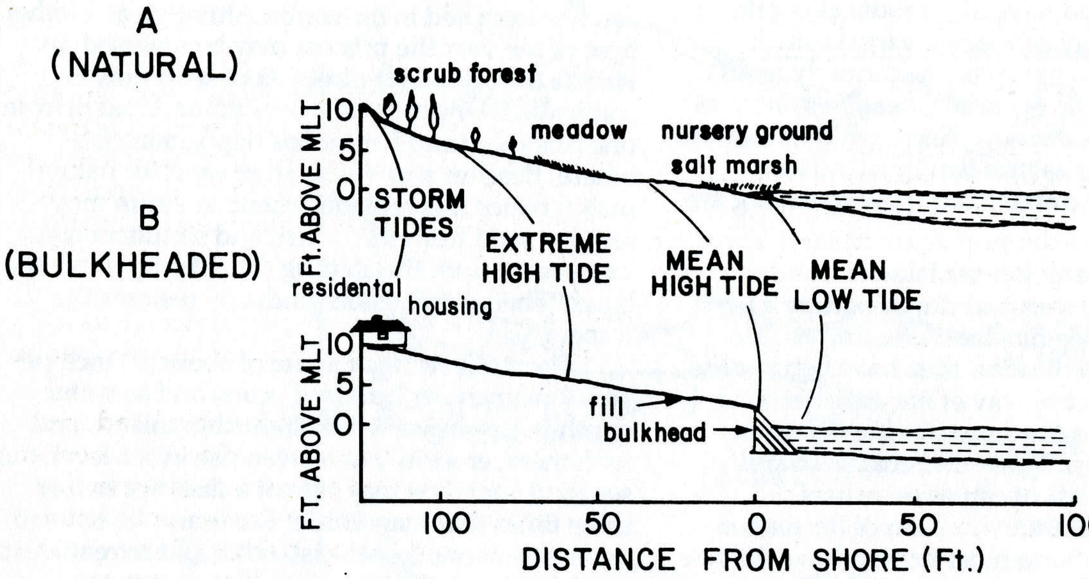
34. Design and implement a county level sampling program for estuarine waters to monitor trends in water quality, to measure the effectiveness of pollution abatement programs – nonpoint as well as point sources – and to serve as early warnings in areas where pollution may not be suspected.
35. Manage the canal system to minimize the adverse effects of canal discharge on estuarine waters.
36. Water management agencies should address the issue of timing and quantity of freshwater flow. Concentrated pulses of freshwater have an adverse impact on an estuary, acting as a pollutant, particularly in those which have limited circulation or which are naturally somewhat saline. If the productivity of the Region's estuaries is to be protected or enhanced, a more natural freshwater regime must be re-established.

BEACHES AND BARRIER ISLANDS

The southern tip of the Florida peninsula is surrounded by hundreds of islands. They can be grouped into three categories:

1. The sedimentary barrier islands of the east coast, extending from Key Biscayne north.
2. The Florida Keys, a chain of coral and oolitic rock islands extending from Soldier Key south to Key West.
3. The Ten Thousand Islands and the islands of Florida Bay, along the southern and western tip of the peninsula.

In geological terms, a barrier island is a long, narrow, offshore sandbar or bank. The ocean side is generally a beach area with adjoining sand dunes, and the landward side is an estuary or tidal lagoon. These highly mobile sand banks shelter the mainland from the severest impact of ocean waves and storms, and are maintained by vegetation acting against the forces of wind, storms, currents, and wave action.



"Bulkheading" destroys the most important part of the estuarine "nursery ground" and encourages the building of housing developments that are vulnerable to hurricanes and other storms. Diagram redrawn from Mock (1966), who reports that 10 months of intensive sampling yielded 2.5 times more brown shrimp and 14 times more white shrimp (the two chief commercial species) from a natural area in the Texas estuary (*A* in the diagram) than could be harvested from a bulkheaded area in the same estuary (*B* in the diagram).

FIGURE 6

EFFECTS OF THE DESTRUCTION OF ESTUARINE NURSERY GROUNDS

SOURCE: E.P. ODUM, 1971

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The islands of Key Biscayne, Virginia Key, and Miami Beach were formed by deposition of sand over a rock base which is a submerged extension of the Florida Keys formation. North of Miami Beach the "islands" are separated from the mainland by the Intracoastal Waterway, a canal which was dug to provide an inland navigation route along the coast. The Waterway connected various small inland lakes and wetlands (some formerly fresh water), producing an artificial estuarine system as well as navigable waterway. Although classification of the latter islands as true barrier islands is questionable, the natural forces now operating are similar.

Value of Beaches and Barrier Islands

Barrier islands, beaches and dunes occupy a very small part of the Region's land area, but are so attractive and desirable that they have become the symbol of the regional way of life. Beaches form a narrow band along the seaward side of barrier islands; behind them are found coastal strand forests, and wetlands of estuarine waters.

A study by the State Division of Recreation and Parks reported that most tourists have definite expectations of the vacation experience that a visit to Florida will provide. Outdoor recreation experiences are the type most desired, and beaches are mentioned most often – by 76 percent of those arriving by auto and 56 percent of those arriving by plane. It is essential to the Region's economy to continue to provide this type of experience and environment, and to protect barrier islands and beaches from further damage and erosion.

In addition to their traditional role as recreation sites, beaches and dunes also serve to protect upland development. They are built and rebuilt by the forces of ocean currents, storms and tides. They are essentially temporary, since the forces that built them can also alter them beyond recognition – sometimes during a single storm.

Needs for public beach facilities are increasing faster than the population, as increased leisure time and mobility allow a greater amount of use per person. The problems which must be addressed, therefore, are twofold: first, both public and private beaches should be protected from erosion and pollution; second, public access and/or acquisition of beachfront land should be increased to meet increasing demand for resident and tourist recreation.

Barrier islands are dynamic systems maintained or altered by the interaction of:

- vegetation
- wind, storm, and wave action
- currents
- sea level rise
- availability of sand
- biological activity, including man's

A barrier island system is ever-changing. During the season when the longshore current transports sand grains toward the south, the northern end of the island tends to erode, while sand is deposited to the south. Although at another time of the year the process may be reversed, in Florida the dominant direction of sand flow is southward. Under natural conditions, erosion from one island or sand bar means deposition elsewhere. Beaches and dunes store sand for natural maintenance and replenishment. A storm may remove sand from the beach, and simultaneously move sand from the shifting dune to replenish the beach. Then wind action gradually restores the dune.

The sea is rising at a rate of about .01 inch per year (one inch per hundred years) and as water depth increases waves reach further inland, and with them, erosion. For a given rise in sea level, the seaward shoreline may retreat a distance two or three times that magnitude. For example, with an ocean rise of one foot the island would retreat 100 to 1,000 feet per century – a significant distance. Erosion of barrier islands is accelerated by storm winds and tides.

A major source of sand for Florida barrier islands is quartz sand washed down from the mountains of Appalachia and transported to the coast by the rivers of Georgia and South Carolina. From the river mouths it is swept southward along Florida beaches by the longshore current. Reservoirs and dams constructed on these rivers have restricted the flow of quartz sand and, with the source reduced, Florida beaches are experiencing a net loss of sand. The quantity of sand moving past given points is shown below. Note that the further south the lower the amount.

ESTIMATED NET LITTORAL DRIFT RATE: FLORIDA-GEORGIA LINE TO KEY WEST

Location	Net average annual drift rate (cubic yards)
St. Johns River, Duval County	500,000
Ponce de Leon Inlet	500,000
Canaveral Harbor	350,000
Fort Pierce Inlet	200,000-250,000
St. Lucie Inlet	230,000
Lake Worth Inlet	230,000
Hillsboro Inlet	120,000
Port Everglades	50,000
Ocean entrance, Miami Harbor	10,000
Key West	Negligible

(U.S. Army Corps of Engineers)

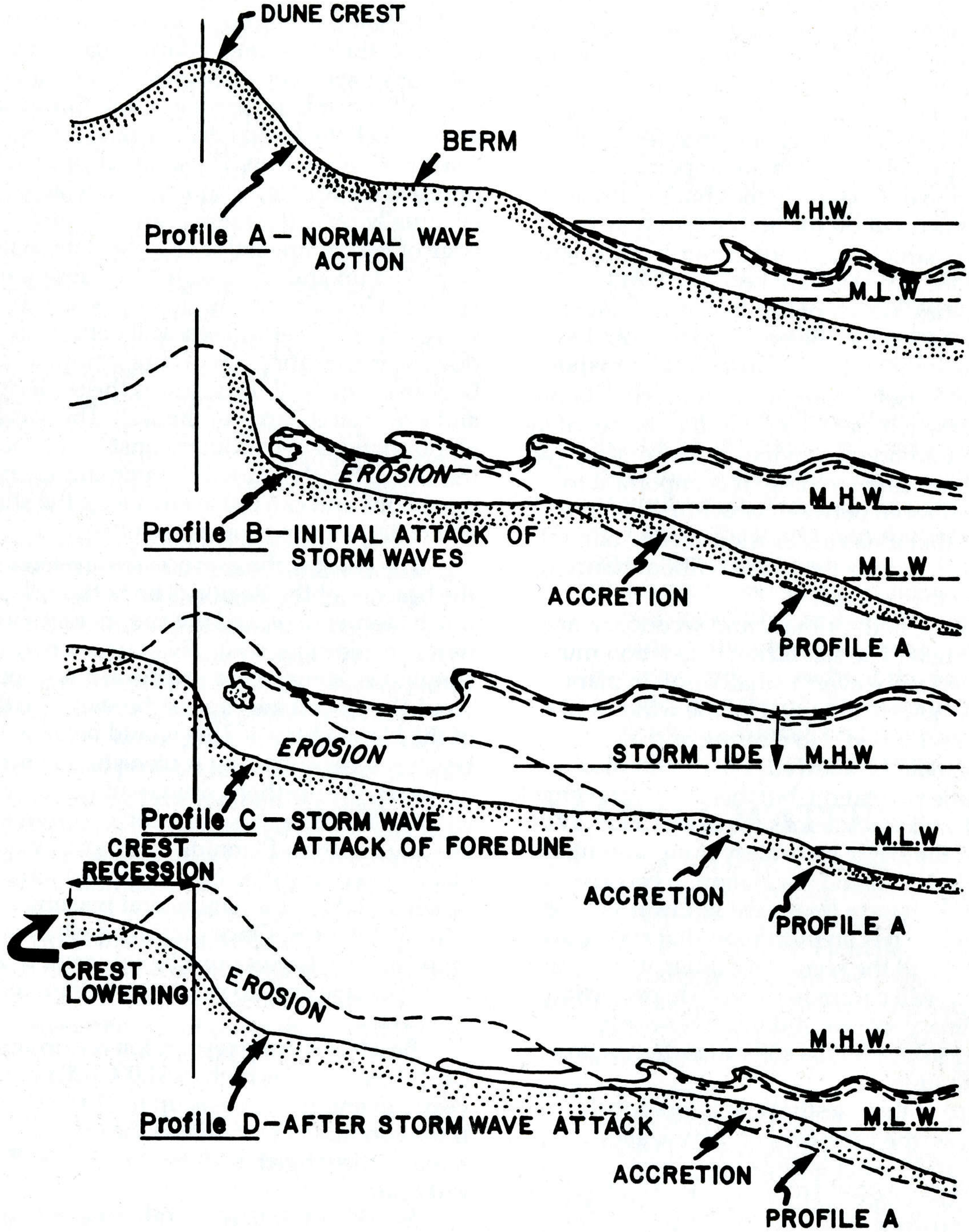


FIGURE 7

DIAGRAM OF STORMWAVE ATTACK ON BEACH AND DUNE

SOURCE: U.S. ARMY CORPS OF ENGINEERS

1971

SFRPC

Inlets play an important part in barrier island dynamics. The area around an inlet is unstable, and rapid large scale changes can occur, causing existing inlets to migrate or close entirely, and new ones to open. Dredging and stabilization projects, necessary to maintain navigation, interfere with natural inlet processes which are important to barrier island maintenance. Jetties built to prevent shoaling of inlets cut off the southward flow of sand, causing sand to accumulate north of the jetty, but eroding the downstream beaches. Sand transfer facilities, which pump the accumulated sand across the inlet to the eroding side, can help restore some semblance of natural sand transport.

The beach itself is very tolerant to recreational use. Foot traffic will not harm it, and it can be safely used for the traditional activities of swimming, sun bathing, fishing, and strolling. It is important to allow enough room between structures and the shoreline so that if natural erosion occurs, natural deposition can restore the beach without harming structures in the process.

The dunes, both primary and secondary, are extremely fragile. The stabilizing vegetation must be maintained since even a small break in plant cover can be quickly enlarged by the wind until a major break is formed. No clearing or major structures should be allowed. Foot traffic also destroys dune vegetation, but this can be prevented with raised walkways across the dunes.

Behind the stable secondary dune, conditions are favorable for upland vegetation to become established. If mature trees exist landward of the secondary dune it is an indication that stabilization has occurred and the secondary dune, if undisturbed, will continue to provide protection against ordinary storms and tides; however, unusual storm conditions still cause destruction from time to time.

Because of their aesthetic and locational attractiveness, the pressures of urbanization are enormous, and barrier islands have been intensively developed. High density development as close as possible to the ocean is a continuing threat. Efforts to place permanent and stable buildings on the shifting, moving barrier beach place man in direct conflict with these natural forces.

The National Shoreline Study (U.S. Army Corps of Engineers, 1971) designated all of the beaches of the Region as areas of significant or critical erosion. The barrier island system survives by its flexibility. Unfortunately, when property lines are drawn and buildings built, property owners wish to halt the natural processes which may diminish their holdings. Many engineering solutions have been attempted, but their effect has generally been to increase erosion. Groins and jetties block the littoral drift of sand, starving the beaches downstream. These structures temporarily improve the upstream situation, but storm tides eventually carry the excess sand out and over the edge of the continental shelf, where it can no longer be picked up and redeposited by subsequent wave swells. While a naturally sloping beach dissipates wave energy, a vertical sea wall deflects the energy downward, creating a scouring action near the bottom of the wall. This causes the undermining and eventual collapse of the wall. The same is true of foundations of buildings constructed too close to the shore. Poorly located channel cuts create similar conditions and can cause erosion of the shoreline and collapse of onshore structures.

The effect of these processes are accelerated on the beaches of the Region. The bottom slope is much steeper here, and the continental shelf is only two or three miles wide. Even under natural conditions, some of the southward flow of sand would be lost off the edge of the shelf into the depth of the Florida Straits. This would be tolerable if the beaches were still being replenished naturally; however, the northern sources of sand are being cut off. Therefore, it is imperative to conserve existing beaches. Planning strategy in the coastal environment must recognize the dynamics of beach and dune formation, and maximize these natural defenses. Once they are destroyed, man-made defenses must be substituted, and these are expensive and do not provide long-term solutions.

Beach and dune restoration is extremely costly. Costs have been as high as $1,000,000 per mile, with yearly maintenance costs up to $100,000 per mile. If the conditions that caused the original erosion remain unchanged, restored beaches will be lost again.

Beach restoration operations can also destroy sea bottom contours near shore which would have trapped eroded sand until the next storm carried it back to the shore. Dredging and resultant siltation, associated with both urban development and beach restoration projects may destroy shell beds, which are a prime source of new sand, and bottom vegetation, which stabilizes sediment contours and reduces sand loss. The Crandon Park-Virginia Key restoration project in Dade County was followed by loss of 50 percent of the near shore sea grass beds since 1969.

Despite these adverse impacts, beach restoration and nourishment is probably the most acceptable shore protection method in areas which are already developed.

On the landward side of barrier islands there is generally an enclosed shallow estuary which separates the mainland from the island. These sensitive estuarine waters afford food sources for marine life, as well as nesting and feeding area for marine birds. In South Florida, particularly, these areas are ecologically valuable as well as vital to the economic viability of commercial and sport fishing. Threatened by intense development, these estuaries and mangroves are frequently destroyed by dredging and filling, and other associated building activities.

In addition to problems associated with natural systems, the man-made infrastructure is an issue of concern on the barrier islands. The major problems include obtaining adequate drinking water, sewage treatment facilities, and transportation access to the islands. The hazard of storm destruction of life and property where development has taken place is another problem in management and protection of the barrier islands.

The necessity of comprehensive management strategies is emphasized by the fact that public funds and programs have inadvertently contributed to stimulate development on barrier islands. Examples are three major Federal programs: flood insurance, which has made building in high-risk coastal areas more attractive; Environmental Protection Agency funding of sewage treatment plants; and the granting of bridge permits by the Coast Guard.

Policies

37. Manage barrier islands, beaches, and dunes to protect them from damage and erosion, to preserve their value to tourism and recreation, and to maintain their ability to protect upland development.
38. Locate development sufficiently back from and above mean high water to insure optimum protection from flood damage, and the least possible harm to natural beaches, dunes, and vegetation which can help protect against such damage.
39. Development on islands should not be encouraged unless sufficient public facilities and flood hazard protection (including hurricane shelter or evacuation routes) are available.
40. Public access and acquisition of beachfront land should be investigated as a major strategy for enhancing tourism and thus the viability of the regional economy as well as meeting the needs of residents.
41. Coastal erosion management and control should give preference to strategies which are imitative of natural processes. Beach nourishment, restoration and dune stabilization projects should be given preference over jetties, groins, seawalls, and other structural approaches.
42. Proposed beach restoration projects should be carefully evaluated to avoid damage to viable reef areas. Project design should include as minimum objectives:
    a) adequate pre-dredging surveys of the biological value and amount of available sand in the proposed dredging site; and
    b) monitoring throughout the project, to determine the quality and suitability of the dredged material, and to prevent damage to biologically valuable areas.

MARINE WATERS

The continental shelf is narrow off the coast of southeast Florida, ranging from a maximum of about 65 km (40 mi.) off Cape Canaveral, narrowing to about 3 km (2 mi.) off Palm Beach. South of Palm Beach it roughly parallels the coastline, gradually widening again east of Miami and south of the Florida Keys. Throughout the Region, the shelf is characterized by reef communities of great diversity and productivity.

It was formerly thought that the Florida reefs terminated in the northern Keys because of the lower temperatures and sand drift found north of Miami. More recent investigations, however, have revealed reef-like structures parallel to the full length of the southeast Florida coastline. The exact nature of these structures is not known. They may be true coral reefs, or they may consist of a recently formed coral veneer over rock formations. Investigation of the geologic structure of these ridges is not yet complete, but biologic investigations reveal a well developed coral community extending beyond the northern boundary of the Region.

The typical zonation of the south Florida reefs is shown in Figure 7. The back reef zone includes the reefs closest to shore, and is not as well developed as the outer reefs. In many places the first reef is composed of beach stone or coral rubble, with few living components. It has not been determined whether these were once healthy reefs that have deteriorated, or if natural conditions have always prevented full coral development in the back reef zone. There are well developed back reefs 300 feet off the highly urbanized coast of the Fort Lauderdale-Pompano Beach area, but the ones off Boca Raton consist mostly of beach rock.

The patch reef is usually separated from the first or back reef by a wide intervening zone of mostly barren sand. The shifting of this sand bed by storms may cover considerable portions of patch reef. The stress of this environment may be the reason that the corals of the patch reefs are smaller and not as well developed as those on the outer reef. The patch reefs are also greatly affected by beach restoration projects, since the usual sources of dredge sand are the sand pockets and beds surrounding the patch reefs.

The outer reef, usually separate from the patch reef by another zone of sand beds, is at the edge of the continental shelf, where reef growth is best. Here currents and wave action create ample circulation to oxygenate the water and bring essential nutrients.

Value of Marine Systems

Living coral reefs are an extremely important part of the marine system of the continental shelf of southeast Florida. They are among the most productive of all ecosystems, and many sport and commercial species of fish and shellfish depend on the reefs for food or shelter.

The reef is built by colonies of small, flower-like animals – coral polyps – that secrete calcium carbonate (limestone) to create a protective shelter for themselves, and thus form the solid structure of the reef. They need clear, relatively shallow water to allow penetration of sunlight, and a fairly stable water temperature. They survive best where current and wave action is high. The edge of the continental shelf in the western Atlantic satisfies these requirements and corals are found from Bermuda to Brazil.

Worm rock reefs (vermitid reefs) also occur in the Region. Often pieces of these reefs are broken off and washed ashore, and the fragments have the appearance of fossilized "spaghetti." They are prevalent locally in the inshore zone in Broward and Palm Beach counties, and in Florida Bay. They act as barriers to beach erosion, and, like coral reefs, provide a habitat and food source (in the larval stage) for numerous marine organisms.

Coral reefs create a habitat suitable for many other life forms. Reef communities together with estuarine systems produce many of the fishery species of southeast Florida. Species which spend their juvenile stages in the estuarine mangroves or sea grass beds may also depend on the reef in later stages of their life cycle.

The economic value of the reefs can be measured in commercial fishery productivity, income from sport fishing activities, and in the income from tourists who come to view and enjoy the spectacle of reef life. In Monroe County alone, the market value of commercial fishery products in 1973 was estimated by the Division of State Planning to be between $70 and $90 million. In addition, the value of sport fishing to the Keys economy was about $25 million annually. The reef also attracts tourists, and in 1973 John Pennekamp Coral Reef State Park alone recorded 376,000 visitors.

The reef also functions as a natural breakwater and sand trap. Both normal currents and tropical storms create wave forces that can erode the upland. The wave energy is considerably reduced as the surge passes over the reef. The coral heads and reef structure may be broken and damaged, but a living reef can repair itself over time. A dead reef, on the other hand, erodes and disintegrates. Wave and storm damage will then increase on the shore.

Another function of the reef is the trapping of sand in the depressions landward of the outer reef. These sand beds serve as reservoirs for natural beach renourishment, and sands in waters less than 30 feet deep are carried back inshore as part of the beach cycle. Where the continental shelf is narrow, as it is in southeast Florida, sand eroded from the beach is often lost to the deep ocean trenches if not trapped by the various reef structures. Captured and retained by the living reef, the sand can be recycled naturally to the beach by ocean currents or storms, or will remain available for artificial renourishment. Most artificially restored beaches erode significantly after renourishment and some of the lost sand can be redredged from the sand beds near shore, if reefs are there to trap it.

The reefs of South Florida may be at the natural limits for reef growth. Temperature is known to be a limiting factor for coral reefs in general. This natural stress, when increased by stress from human activity, may be beyond the limits of reef survival. If the coral animals die, so does the reef community. The other reef inhabitants leave if they are mobile, or die if they are attached to the bottom. Much localized reef damage has been done by collectors of coral or tropical fish. Pry bars and blasting, although prohibited, have been used, and boat anchors can tear away large pieces of reef at a time. Sewage outfalls located in reef areas destroy the reef community, which is smothered by the effluent and replaced by a brown hairlike algal growth and a few sewage-tolerant marine worms.

Aside from this significant but localized damage, there are extensive areas where the reefs are dying from unknown causes. A study by the Florida Coastal Coordinating Council described areas in the Keys where over 80 percent of reef corals and 77 percent of other life forms were dead. Since the northern reef tract has not yet been as well-studied as the Keys tract, it is not known whether similar damage is occurring.

Some authorities point to siltation from near-shore dredging and silt-laden runoff from upland clearing and development as a cause of reef decline. Sediment released by such activities can physically smother the coral, interfering with photosynthesis by substantially decreasing the penetration of sunlight. Turbidity also occurs naturally, when winter storms stir up bottom sediments and turn the water milky for days. The water does clear between storms, however, and the corals can secrete a mucous coating that entraps and removes limited amounts of sediment. Prolonged or continuous sedimentation, on the other hand, does not allow such recovery.

There are other clues to the reasons for coral reef mortality. The outer reefs are in better condition than the inner, or patch reefs. This may be a result of natural limits, as mentioned above, or may be the result of poorer quality waters near shore. The reefs in the northern Keys are in worse condition than those in the lower Keys. Again, these are closer to the land-based impacts of land clearing, septic tank effluent, and within southward flowing currents which may carry sewage effluent and urban and agricultural runoff from the mainland.

The cause of reef mortality, aside from local areas, is unknown at present. It may be that it is a combination of the natural stresses to which the reefs have adapted, made lethal by the additional impacts of reduced water quality and physical damage.

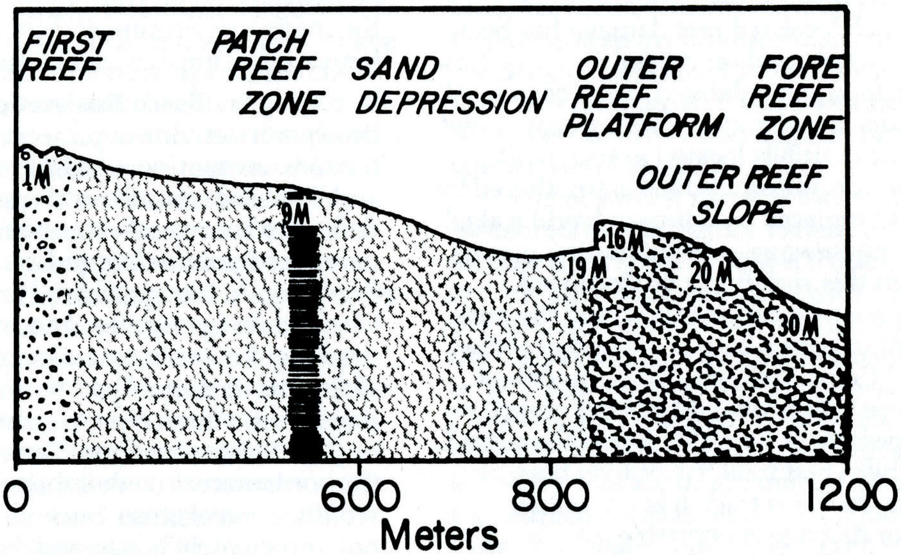
Major management problems of the southeast Florida continental shelf environment include dredging for beach restoration, and marine dumping of sewage effluents. Both activities can be managed to produce minimal impacts on the marine environment, but if precautions are ignored, the impacts can be serious.

Dredging for Beach Restoration

Beach erosion control projects were monitored by the U.S. Army Corps of Engineers in Palm Beach and Broward counties and results showed that damage to coral reefs was directly related to the nature of the area dredged and the methods of dredging. In the area from Pompano to Lauderdale-by-the-Sea, and in Deerfield Beach, dredging for beach restoration did no observable ecological damage. The investigators suggested that three major factors were responsible for the negligible damage. First, there was enough sand in the borrow areas so that there was only slight scouring of reef areas. Second, the borrow areas did not immediately border viable reefs, so sediment transport by currents from the dredging sites to the reefs was light. Third, the reef is far enough offshore and is washed by north-south, nearshore currents so that settling of sediments on the reef was slight.

Observations at the Hallandale restoration site revealed that the reef was substantially damaged in and adjacent to the borrow areas. The reasons appeared to be a lack of sufficient sand in the bottom areas, location of borrow areas near the reefs, scouring of reef edges, and careless handling of dredging equipment. Interestingly, Hallandale Beach was originally to have been nourished with sand imported by barge from Sandy Cay in the Bahamas. Apparently the discovery of sand nearby led to abandonment of the original proposal. In the light of the damage done by overdredging of marginal sand beds, the original proposal had significant merit, despite the greater initial cost.

Every effort should be made to protect viable reefs, both before and during beach restoration and nourishment projects. Ecological monitoring should be included as part of such projects, and adequate analysis of the proposed borrow site should be undertaken before any final decision is made to proceed with dredging. If the proposed borrow area is found to be suitable, the monitoring should continue through the project to ensure



General zonation and morphology of the reefs off the southeast Florida coast.

FIGURE 8

TYPICAL ZONATION OF SOUTH FLORIDA REEFS

SOURCE: GOLDBERG, 1973

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that the dredging contractor takes adequate precautions to avoid reef areas and protect them from sedimentation and physical damage. If damage occurs, appropriate measures should be taken immediately to correct the procedure and protect reef resources.

It should be emphasized that beach restoration and nourishment is less environmentally damaging in the long run than any other method of shore protection now available. If adequate planning is done beforehand, and sufficient care is taken during the operation, damage will probably be slight and will repair itself over time. The operation can be devastating, however, unless there is adequate consideration of the total system of beach, dune, nearshore bottom, and reef, and the damage caused may be permanent and irreversible.

Ocean Outfalls

The issues to be considered in the question of ocean disposal of sewage are well summarized by Bascom:

> There is good reason to restrict the amount of nutrient material that is discharged into lakes and rivers, where oxygen is limited and a reducing environment can be created. The ocean is another matter. It is an essentially unlimited reservoir of dissolved oxygen, which is kept in motion by currents and is constantly being replenished by natural mechanisms.
>
> It is nonetheless possible to overwhelm a local area of the ocean with a huge discharge of nutrient material that may form a deposit on the sea floor if the local conditions are not carefully considered. The materials must be presented to the ocean in the right places and at reasonable rates. Among the ways of achieving that objective are the use of discharge pipes that lead well offshore and have many small diffuser ports and, if the volume of discharge is exceptionally large, the distribution of the effluent through several widely dispersed pipes.
>
> Problems caused by the addition of nitrogen and phosphate to inland waters, which they overfertilize, do not apply to the ocean. There they could be helpful by producing the equivalent of upwelling, the natural process that brings nutrients from deep water to the surface waters where most marine organisms are found.
>
> As Issacs has pointed out, "the sea is starved for the basic plant nutrients, and it is a mystery to me why we should be concerned with their thoughtful introduction into coastal seas in any quantity that man can generate in the foreseeable future." (Bascom, 1974)

Carefully planned disposal of nutrients in the sea may not be harmful, but heavy metals and pesticides pose a different problem:

> Some industries discharge substantial quantities of heavy metals and complex organic compounds into municipal wastewater systems whose effluent reaches the ocean. Certain of the metals (mercury, chromium, lead, zinc, cadmium, copper, nickel and silver) are notably toxic and so are subject to stringent regulation. The most dangerous substances, however, are synthetic organic compounds such as DDT and polychlorinated byphenyls. The discharge of these substances as well as the heavy metals must be prevented. (Bascom, 1974)

Studies by the Environmental Protection Agency in the South Florida Region have shown that sewage outfalls, when properly designed and operated, are probably not harmful to the marine environment. The most significant considerations are: 1) sufficient length and depth to prevent onshore winds and currents from carrying the effluent plume back to shore, and 2) avoidance of such sensitive marine communities as estuaries, marine grass beds, or coral reefs.

Existing outfalls in the Region presently discharge in shallow waters, too close to shore. Studies have shown that effluent is sometimes carried back to bathing beaches by onshore winds and currents. Capital improvement programs are underway, however, to improve treatment of effluent, and to extend the outfalls to safer depths.

Policies

43. Research should be undertaken to identify the causes of coral reef decline in areas where no reasons are apparent.
44. Enforcement of existing State and Federal regulations for protection of coral in Florida waters should be funded.
45. Phase out ocean outfalls adversely affecting coral reef areas.

46. Implement appropriate engineering options when needed to improve existing ocean outfalls. Examples are:
    a) extension of existing outfalls to lower depths
    b) installation of diffusers to help mixing
    c) dilution of effluent with saltwater prior to discharge
    d) improved treatment prior to ocean discharge
47. Evaluate long-range sewage disposal alternatives, including recycling of wastes to insure protection of quality of coastal and estuarine water resources.
48. Consider importation of sand from environmentally acceptable areas as alternatives to dredging in local areas where the sand supply is marginal or insufficient, or where local sand is unsuitable for beach fill.

OTHER ENVIRONMENTAL ISSUES

ENDANGERED AND THREATENED SPECIES

Only a remnant of South Florida wildlife remains, since half of the original wetlands have been drained, and the other half substantially altered. Wildlife depends on suitable habitat for survival, and the key to preservation of wildlife species is protection of sufficient habitat. The complete domestication of wilderness areas makes them fit only for man, and those animals which can adapt to urbanization – lizards, opossum, squirrels, and rats. Some animals can survive in urbanized areas that are carefully managed by man. Moderate sized areas left in a natural state will provide habitat for songbirds, turtles, rabbits, foxes, and waterfowl. Other animals, such as the Florida panther and black bear, need true wilderness, and must retreat to the remotest parts of the Big Cypress swamp. Estuarine habitat is essential for at least 65 percent of all marine organisms during some portion of their life cycle. Marine turtles require relatively undeveloped, dark beaches for nesting, and the manatee must have access to warm inland waters.

The Florida Committee on Rare and Endangered Plants and Animals (FCREPA), a group of Florida biologists, has prepared an exhaustive inventory of the habitats of rare and endangered species. Figures 8 through 12 show the composite habitats of threatened and endangered plants and animals, compiled from maps for individual species included in the FCREPA inventory. The inventory is valuable as a reference, and should be consulted in the early stage of any planned development, so that sensitive habitats harboring endangered species may be totally avoided. In other, less sensitive areas, human use and survival of rare or endangered species can be achieved.

Decisions to permit development in an area of rare or endangered species habitat should be based on the sensitivity of the species to human proximity. Some habitats can be managed for both human use and wildlife. Ospreys, for example, can live near development if sufficient productive ponds or sloughs are left undisturbed for their feeding, if sufficient natural cover is allowed to remain, and if tall trees or nesting boxes on poles are provided. Other species may need greater protection through strict regulation or outright purchase of habitat. Planners need the expertise and assistance of biologists and ecologists to determine whether a proposed development or activity has adequately provided for such protective measures, and to evaluate the sufficiency of the measures proposed.

Policy

46. The appropriate State agencies and universities shall compile management techniques for insuring survival of rare, threatened, and endangered species, and establish criteria for evaluating proposed activities which might adversely impact those species. These techniques and criteria, which can be based on existing knowledge, can then be used by local planning agencies and elected officials in evaluating proposed development activities in their jurisdictions.

HURRICANE HAZARD

South Florida's coastal zone varies in elevation from near sea level in the southern coastal marsh, to almost 20 feet in areas along the coastal ridge. Much of this low-lying area is prone to flooding, both from rainfall accompanying hurricanes, and from storm-generated tidal surges. The National Weather Service estimates that a hurricane can be expected to pass through the Region every six to eight years.

Hurricane storm surge impact on a coastal area depends on several factors: the size of the hurricane, the direction from which it approaches, wind speed, shoreline configuration, continental shelf slope, and the height of the prevailing (normal) tide at the time. A NOAA study calculated that a hurricane of the intensity of Camille, with winds of 200 mph, would cause a maximum storm tide of 20 feet above mean sea level in Biscayne Bay. The highest land elevation around Biscayne Bay is 20 feet in Coconut Grove.

Several hurricane-related factors should be considered in planning for the location of coastal development.

1. Shoreline configuration: On a convex shoreline, tidal surge tends to be dissipated. Concave shorelines, especially bays which are partially enclosed by barrier islands or causeways, sustain a much greater impact because the flood water is trapped and prevented from flowing quickly back to sea. Water entering the bay through an inlet may be forced back out to sea across the back of the barrier island, depending on local circumstances.
2. Coastal elevation: The rate of fall-off of storm tide is about one foot per mile inland. A twenty foot storm tide could theoretically penetrate 20 miles inland in the absence of mitigating factors. The coastal ridge or stable dunes paralleling the shore can effectively protect inland areas. It is estimated that a ridge ten feet high or more, and five miles wide would probably prevent most storm tides from washing over to the interior. Channels through the ridge, either natural formations or man-made canals, however, allow storm elevated waters to penetrate inland.
3. Coastal vegetation: Dense coastal vegetation, such as mangroves, or coastal hammock forest, can moderate storm surge by increasing surface friction and absorbing wave energy. In the process, much of the forest may be destroyed, but impacts on the upland are lessened. The forest will probably repair itself over time, or it can be replanted or otherwise managed to recover more quickly.
4. Evacuation of coastal residents: Total evacuation of a threatened urban area is generally not possible, particularly from islands where only one road provides access to the mainland. The Keys are the most vulnerable example. Other measures, such as designated refuges in safe high rise buildings, should be incorporated into a regional emergency preparedness plan. The population of south Florida has increased greatly since the last severe hurricane, and the great majority of residents have never experienced a severe hurricane. Many of them live in new developments in low-lying coastal areas that are at risk in a major storm.

Policies

50. Natural systems which protect against hurricane storm surge must be protected. The coastal ridge, mangrove fringe, and the dunes and their stabilizing vegetation cover are examples.
51. Locate future development where the potential for hurricane damage is as low as possible.
52. Design projects to mitigate storm damage. For example: elevating buildings on stilts instead of fill to permit passage of storm water; reducing to a minimum any canals or other breaks in natural storm barriers; construction of necessary bridges on pilings instead of causeway fill to avoid trapping flood waters.

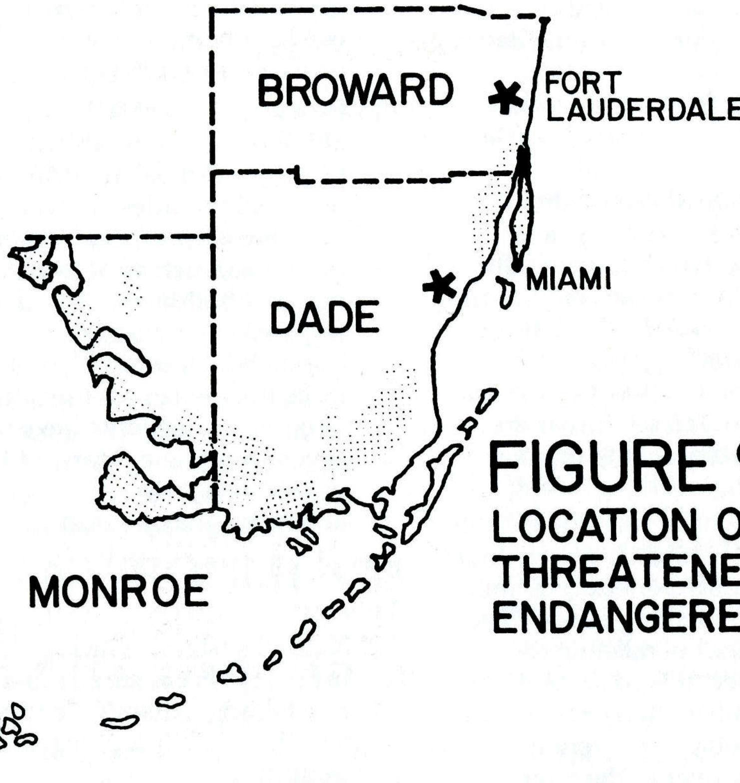
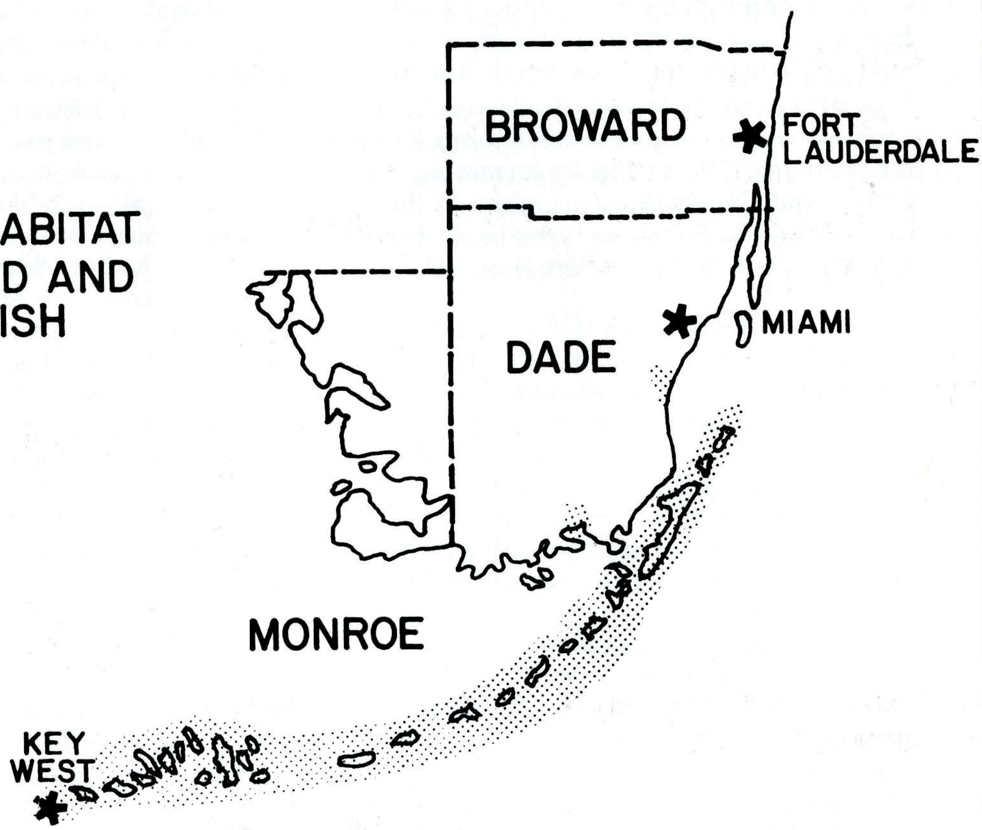


FIGURE 9
LOCATION OF HABITAT FOR THREATENED AND ENDANGERED PLANTS

FIGURE 10
LOCATION OF HABITAT FOR THREATENED AND ENDANGERED FISH



SOURCE: FLA. COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS
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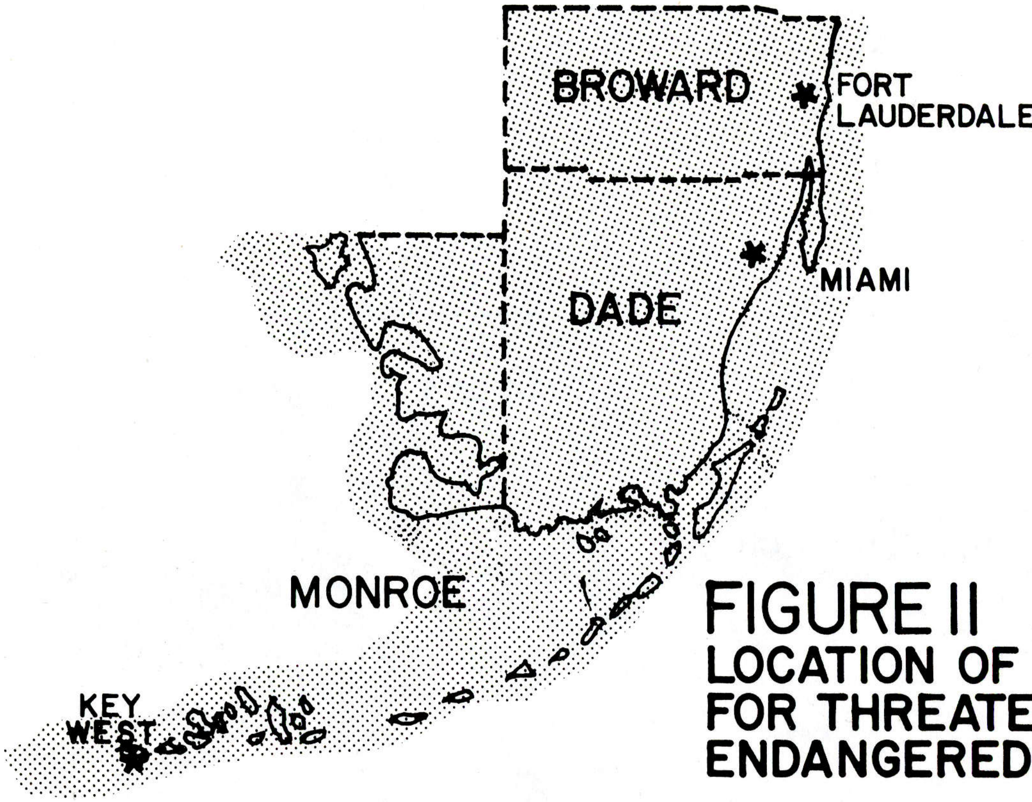
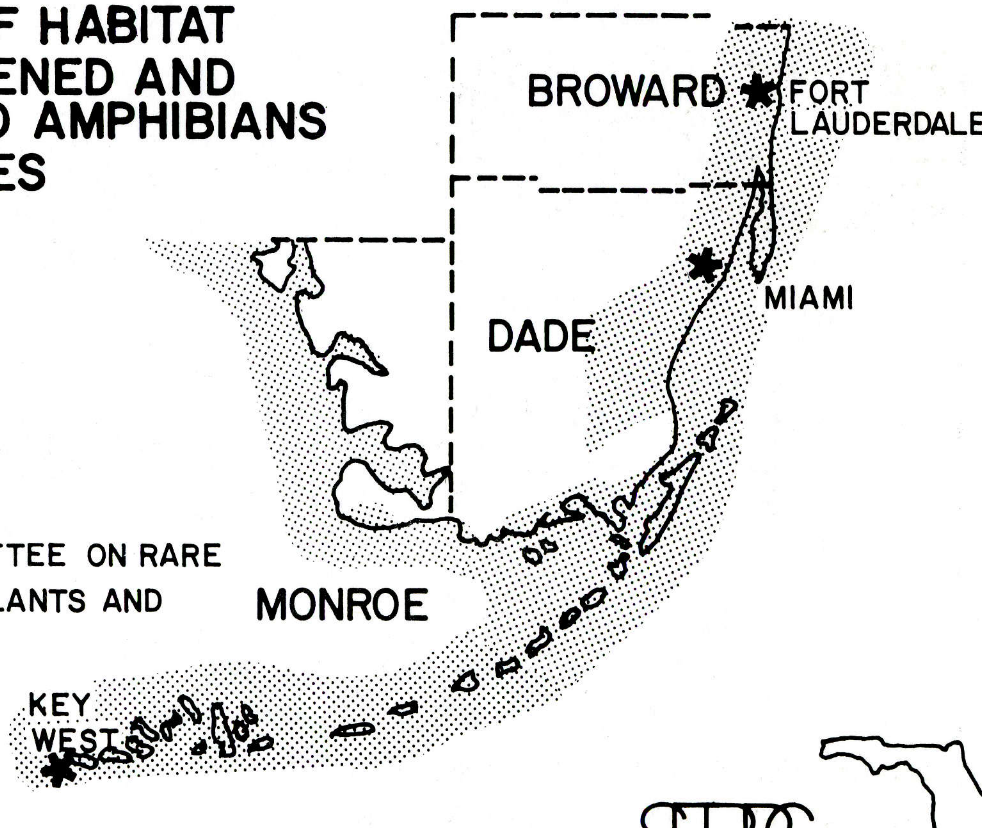


FIGURE 11
LOCATION OF HABITAT FOR THREATENED AND ENDANGERED BIRDS

FIGURE 12
LOCATION OF HABITAT FOR THREATENED AND ENDANGERED AMPHIBIANS AND REPTILES



SOURCE: FLA. COMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS, 1976

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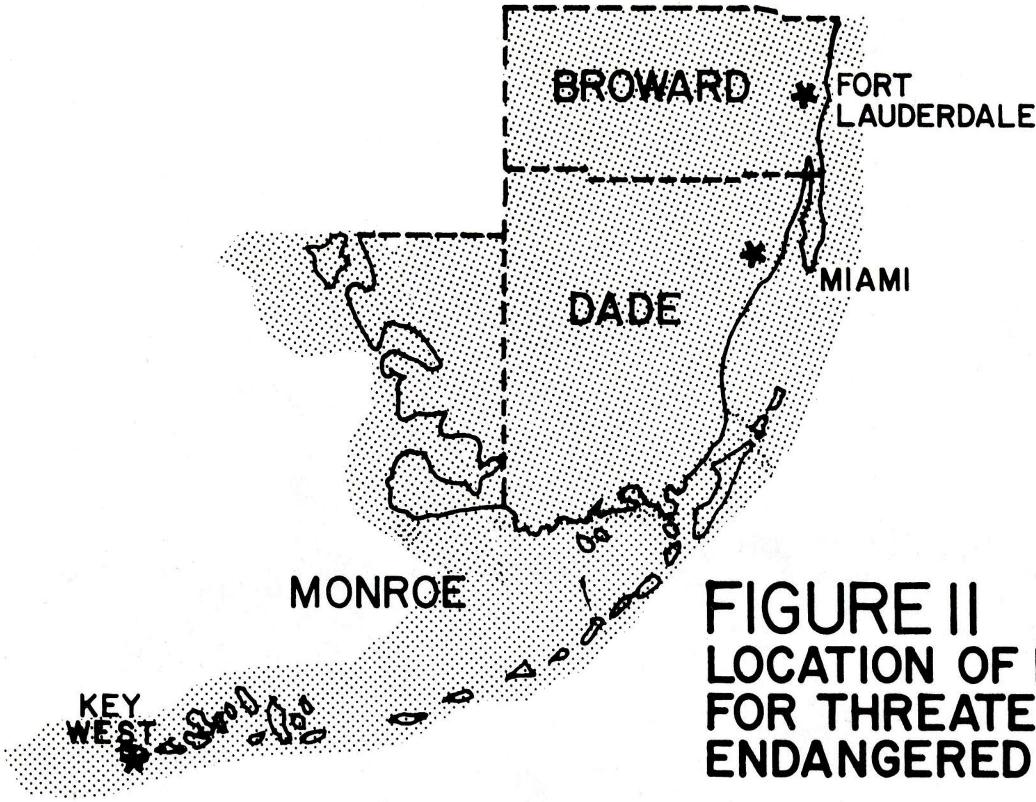

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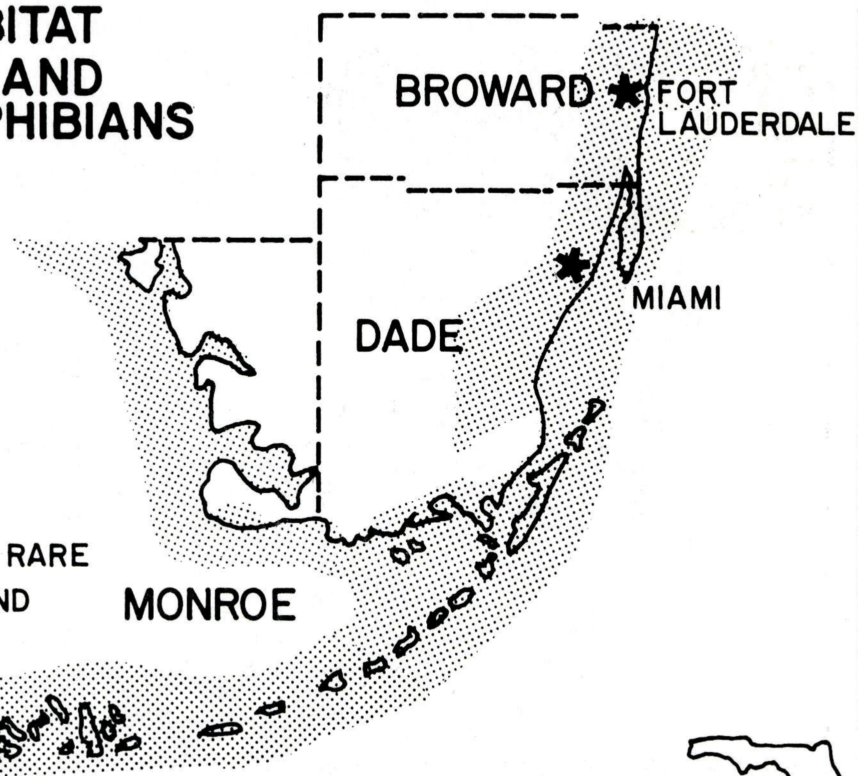

SOURCE: FLA. COMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS, 1976

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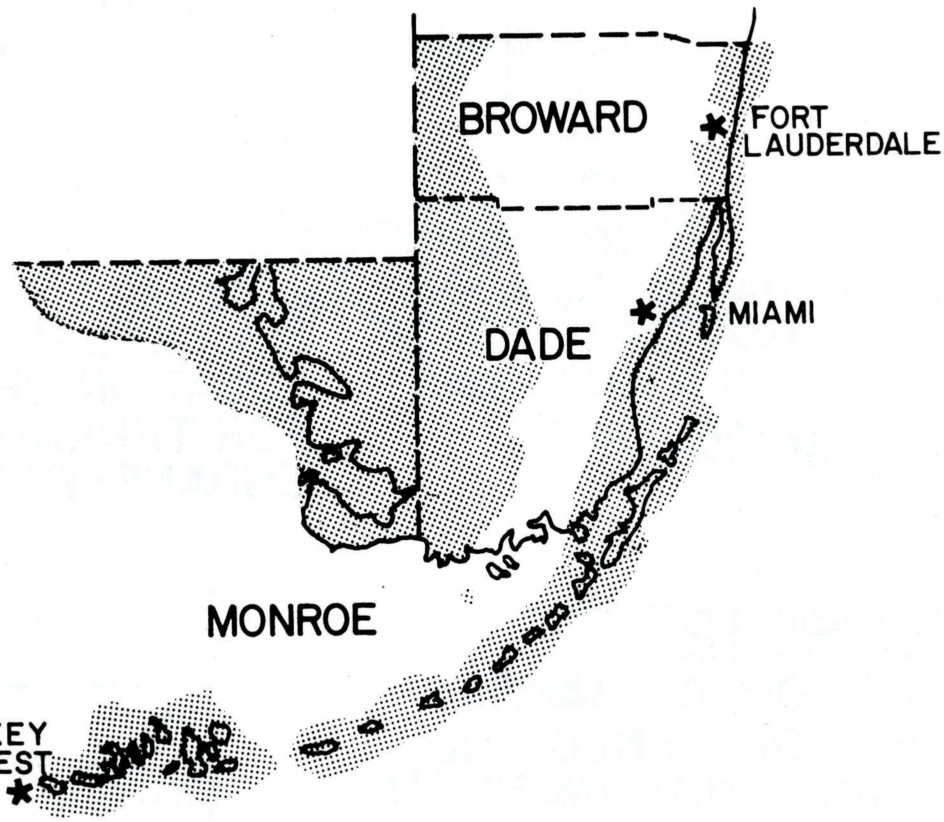

FIGURE 13
LOCATION OF HABITAT FOR THREATENED AND ENDANGERED MAMMALS

SOURCE: FLA. COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS, 1976

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