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PHYSICAL, HYDROLOGICAL, AND BIOLOGICAL CHARACTERISTICS OF THE LOXAHATCHEE RIVER ESTUARY, FLORIDA

By

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Base compiled from U.S. Geological Survey 7½ minute Quadrangle maps, Rood and Jupiter, Florida

Table 1.--*Physical characteristics of the Loxahatchee River estuary*

Divisions[1]	Area in acres (subtotal)	Area in acres (Total)	Depth in feet below NGVD of 1929 Mean	Depth in feet below NGVD of 1929 Maximum	Shoreline in miles	Average volume in acre-feet
Central embayment		380	3.5	15	6.3	1,400
North fork		200	[2]3.4	[2]6.6	10.0	620
Northwest fork[3]		850	-	-	26.9	2,600
Embayment	320		6.2	12.0	-	1,400
River	270		-	[2]24	-	1,200
Flood plain	260		-	-	-	-
Southwest fork		110	3	6	6.8	500
Embayment	70		[2]5.2	[2]10.0	-	310
C-18 to S-46	40		[2]3.6	[2]10.6	-	190
Subtotal to A1A		1,540	-	-	50.0	5,100
Jupiter Inlet to A1A		120	7.6	18	4.7	790
Total		1,650	-	-	54.7	5,900

[1]Divisions shown in figure 1B.
[2]Based upon U.S. Coast and Geodetic Survey, 1969, adjusted to NGVD of 1929.
[3]Extends from central embayment to Trapper Nelsons at river mile 10 (fig. 1B).

Table 2.--*Tidal and freshwater flow to the Loxahatchee River estuary, 1980*
[Values are in acre-feet, except for tide range which is in feet]

Date	Jupiter Inlet Incoming	Jupiter Inlet Outgoing	North arm of Intracoastal Waterway Incoming	North arm of Intracoastal Waterway Outgoing	Alternate A1A bridge Tide range, 12 hours	Alternate A1A bridge Incoming	Alternate A1A bridge Outgoing	Tides[1] prism	Major freshwater tributary inflow[2]
April 14	6,610	7,940	-	-	-	-	-	-	100
April 16	-	-	-	-	2.82	3,650	3,490	3,740	40
April 24	6,180	6,570	-	-	-	-	-	-	55
April 26	-	-	-	-	2.77	3,770	3,700	3,670	53
August 27	6,660	6,390	2,570	2,530	-	-	-	-	94
August 28	6,330	6,610	-	-	2.78	3,510	3,360	3,690	38
Average	6,450	6,380	-	-	2.79	3,640	3,580	3,700	-

[1]Computed from surface area and tide range.
[2]Inflow over 12 hours at tributaries listed in table 3.

Figure 1.--Loxahatchee River basin (A) and estuary (B).

Figure 3.--Progressive changes in a sand bar in the Loxahatchee River estuary, 1940-79, based on interpretation of aerial photographs.

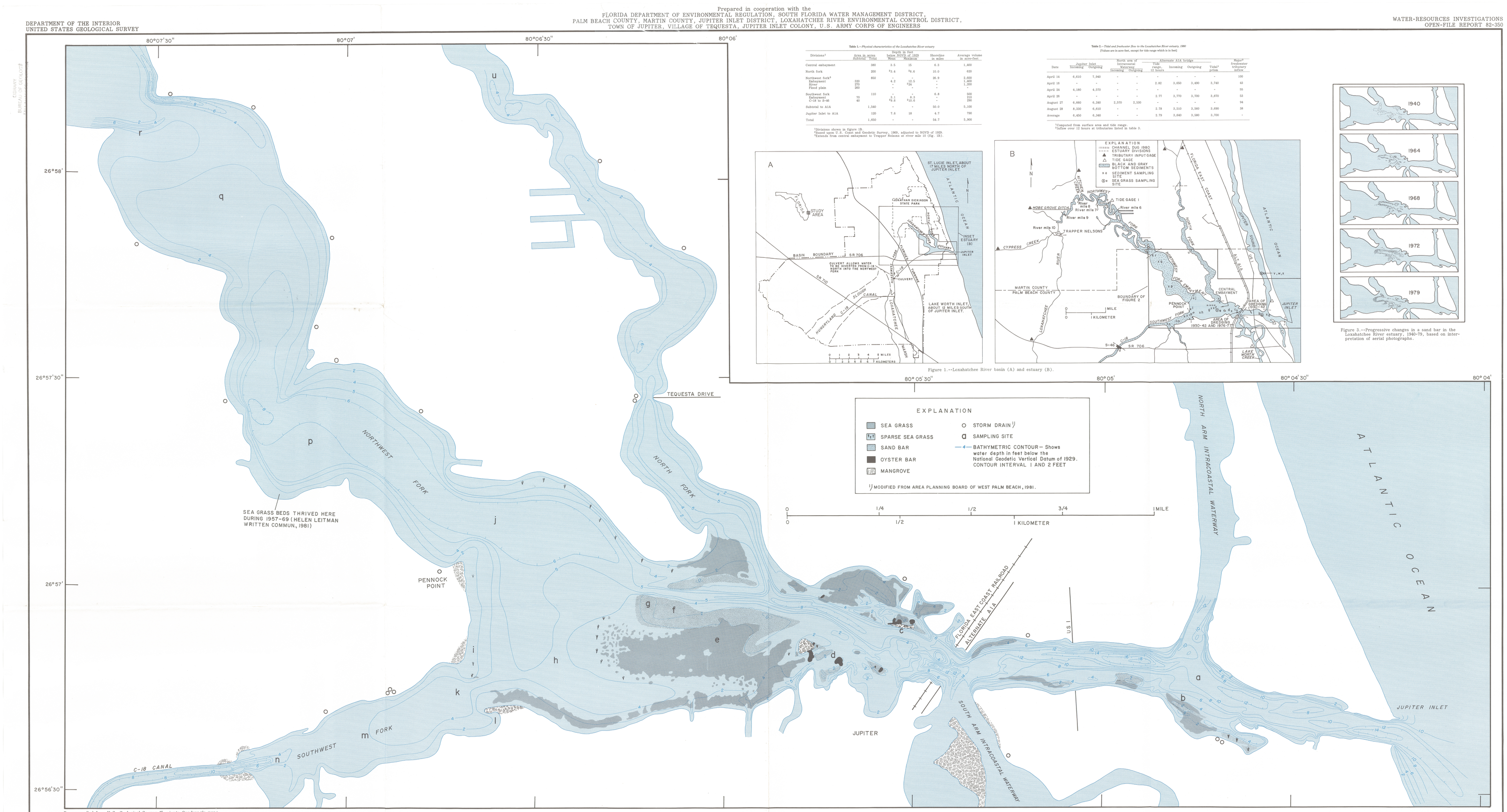

Figure 2.--Bathymetric and benthic features in the Loxahatchee River estuary, 1980-81.

INTRODUCTION

The Loxahatchee River estuary empties into the Atlantic Ocean at Jupiter Inlet in southeastern Florida (fig. 1A). Although relatively small, the estuary is important for its esthetic value and for its sport fishing, boating, recreation, tourism, and prime residential development. In recent years, the condition of the estuary has become of concern to many citizens and agencies of the State. In response to this concern, the U.S. Geological Survey planned and carried out an in-depth environmental investigation. The events that led to the investigation and the objectives of the investigation are outlined in a recent U.S. Geological Survey report by McPherson and Sabanskas (1980).

Purpose and Scope

One of the objectives of the ongoing U.S. Geological Survey investigation of the Loxahatchee River estuary is to provide baseline information on the estuary. This map report was prepared to fulfill part of this objective. It provides information on bathymetry, hydrology, and benthic sediment and biota. The map shows the distribution of sand bars, oyster bars, and sea-grass communities in the estuary. Information is provided on bottom-sediment characteristics and the biomass of sea grass. The map report shows conditions as they existed in the estuary in 1980-81. Additional information is given on the history of the estuary to provide a better perspective and understanding of physical and biological characteristics.

Methods

The map (fig. 2) of the seaward part of the estuary was prepared using low-altitude (2,000 feet) color aerial photographs taken August 4, 1980, and ground-truth surveys. Bathymetric field surveys were made in December 1980 and January to April 1981. Bathymetric data were collected from a boat using a sonic sounder. Transects were made across the estuary from shore location identified on a U.S. Geological Survey quadrangle map. The location (and time) of the boat at points on each transect was determined by a shore observer using a plane table and alidade. Water depth was recorded in feet below National Geodetic Vertical Datum of 1929 (NGVD of 1929). Relatively small areas not covered by the field surveys, mainly in the north fork, were supplemented by earlier bathymetric data (U.S. Coast and Geodetic Survey, 1969). A U.S. Geological Survey 7½ minute topographic map enlarged to a map scale of 1:6,000 was used for horizontal control and as a reference base map.

The distribution of sea-grass beds, sand bars, and oyster bars was delineated on overlays of aerial photographs, field checked, and transferred to the base map. The use of aerial photographs to delineate sea-grass beds can be misleading unless field surveys are carried out because (1) sea grass may not be evident on photographs because of sparse growth; and (2) marine algae may be misinterpreted as sea grass beds on the photographs.

The inflow of surface water from the major tributaries into the estuary was measured at gaging stations equipped with continuous recording instruments (fig. 1B). Also, tidal inflow and outflow at alternate A1A bridge, Jupiter Inlet, and in the north arm of the Intracoastal Waterway were measured on several days in 1980.

The texture and color of surficial bottom sediments in different parts of the estuary were observed and recorded. Samples were collected at 24 sites (fig. 1B) to represent different areas or habitats. The surficial bottom sediments were collected by hand, Ekman[1], dredge, or coring device and were analyzed for the size and organic content.

Sea grasses were sampled at three locations (sites b, e, and v, fig. 1B) for biomass. At each location, three samples were collected in an area visually judged to represent maximum density of sea grass. A post hole sampler that removes a 6dSx8 inch plug of sea grass and sediment was used for sampling. Each sample was sieved through an 0.5 millimeter mesh to remove sediments, sorted, and preserved. The sea grasses were identified taxonomically, separated into photosynthetic and nonphotosynthetic portions, dried at 105°F for 24 hours, and weighed.

HISTORY OF THE ESTUARY

The Loxahatchee River estuary owes its existence to a rise in sea level and an increase in rainfall. About 15,000 years ago, the shore of the Atlantic Ocean was several miles east and more than 300 feet lower than its present location and altitude at Jupiter Inlet. The climate was windy, cool, and dry (Watts and Stuiver, 1980). From about 15,000 to 6,000 years ago, sea level rose relatively rapidly at a rate of more than 3 feet per century (Schubel and Hirschberg, 1978). Near the end of this period, modern vegetation and climate became established (Watts and Stuiver, 1980), and the rise in sea level slowed. Sometime near the end of the rapid rise in sea level and several thousand years ago, tidal waters began to flood the estuary embayment. Prior to this time, the embayment was probably a flood plain or a freshwater marsh. From the time of first tidal flooding to about 1900, the shape and bathymetry of the estuary were modified solely by natural processes of sedimentation and erosion.

Historical evidence indicates the estuary periodically closed and opened to the sea as a result of natural causes. Originally, the inlet was kept open not only by flow from the Loxahatchee River, but also by flow from Lake Worth Creek and Jupiter Sound (fig. 1B). Near the turn of the century, some of this flow was diverted by creation of the Intracoastal Waterway and the Lake Worth Inlet, and by modification of the St. Lucie Inlet (Vines, 1970). Subsequently, Jupiter Inlet remained closed much of the time until 1947, except when periodically dredged. After 1947 it was dredged open 100,000 cubic yards of sediment from the inlet and constructed jetties. The JID dredged the inlet again in 1951 and 1956 and every few years after 1947. About 10,000 to 100,000 cubic yards were removed at each dredging episode and was enlarged to a map scale of 1:6,000 was used for horizontal control and as a reference base map.

In the early 1900's, the inlet was opened by man on several occasions. In 1921 the Jupiter Inlet District (JID) was established, and in 1922 the inlet was dredged open 100,000 cubic yards of sediment from the inlet and constructed jetties. The JID dredged the inlet again in 1931 and 1936 and every few years after 1947. About 10,000 to 100,000 cubic yards were removed at each dredging episode and was enlarged to a map scale of 1:6,000 was used for horizontal control and as a reference base map.

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The inflow of surface water from the major tributaries into the estuary was measured at gaging stations equipped with continuous recording instruments (fig. 1B). Also, tidal inflow and outflow at alternate A1A bridge, Jupiter Inlet, and in the north arm of the Intracoastal Waterway were measured on several days in 1980.

The texture and color of surficial bottom sediments in different parts of the estuary were observed and recorded. Samples were collected at 24 sites (fig. 1B) to represent different areas or habitats. The surficial bottom sediments were collected by hand, Ekman[1], dredge, or coring device and were analyzed for the size and organic content.

Processes of sedimentation and erosion undoubtedly still have a profound influence in the estuary. However, these processes are now closely related to, and not separated from, activities of man in the basin and estuary. The formation of the large horseshoe-shaped sand bar in the embayment over the last 20 years (fig. 3) is an example of recent sediment transport and deposition that has altered bathymetry.

After 1900, man began to influence the estuary, not only by dredging activities, but also by altering drainage in the basin. Generally, ground-water levels have been lowered, and freshwater inflow reduced or altered in direction or period of flow (McPherson and Sabanskas, 1980). The major surface flow to the estuary historically was into the northwest fork from the Loxahatchee Marsh and the Hungryland Slough (fig. 1A). Both of these drained north from low divides near State Road 710 (Parker and others, 1955). A small agricultural canal was dug before 1928 to divert a small amount of water from the Loxahatchee Marsh to the southwest fork. In 1957-58 Canal 18 was constructed in the natural drainage features to divert flow from the northwest to the southwest fork of the estuary. A culvert was installed in 1974 to allow water to be redirected from C-18 to the northwest fork (fig. 1A).

The biological characteristics of the Loxahatchee River estuary are also affected by freshwater and tidal flow and by the activities of man. In undisturbed estuaries in south Florida, mangrove forest, oyster bars, and sea-grass beds constitute major biological communities in brackish and saline environments, and wetland forest and marshes become dominant in freshwater environments. In the Loxahatchee River estuary, mangrove forest is most extensive in the northwest fork. Small stands of mangrove occur in the upper reach of the north fork, in Lake Worth Creek and other small tributaries, and on several islands. Sea-grass beds and oyster bars grow in the estuary where there is suitable, undisturbed substrata and adequate tidal flow and salinity. Wetland forest dominates the upper reach of the northwest fork and merges gradually with mangrove forest over several miles downstream from the wet season (May to September 1980) equaled about 5 percent of the total tidal discharge at A1A (based upon the mean tidal prism) over the same period. Of this total freshwater inflow (52,870 acre-feet), 77 percent was discharged into the northwest fork, 21 percent into the southwest fork from the C-18 Canal, and 2 percent into the north fork (table 3).

BOTTOM-SEDIMENT CHARACTERISTICS

The types of bottom sediment in the Loxahatchee River estuary vary with water depth, location in the estuary, and biological community (fig. 4). Fine sand is predominant throughout much of the estuary, but medium and coarse sand may predominate in the deeper channels of the Intracoastal Waterway-inlet area (for example, site a, figs. 2 and 4). Shell debris, larger than sand size, contributes less than 1 percent of the sediment except on oyster bars where it is abundant. Silt, clay, and organic matter are least abundant in the channels and on sand bars, somewhat more abundant in adjacent sea-grass beds, and in greatest abundance in the black and gray sediments in the forks of the estuary (figs. 4 and 5). Soft, black sediments common in the deeper waters of the forks, contain the largest percentage of clay, silt, and organic matter. Black and gray sediments range in thickness from a few inches to several feet.

Freshwater inflow to the Loxahatchee River estuary is small compared with tidal flow. Total inflow from the major tributaries equaled about 5 percent of total tidal discharge during the 1980 wet season. Seventy-seven percent of the tributary inflow was to the northwest fork, 22 percent to the southwest fork from C-18, and 1 percent to the north fork.

The environment of the estuary is largely determined by tidal and freshwater flow. These flows determine bottom-sediment characteristics and sustain several distinct biological communities. Sea-grass beds and oyster bars grow where suitable undisturbed bottom sediment occurs and where tides maintain adequate salinity and flow conditions. Wetland forest of cypress and other trees grow where freshwater soil inundation and flow dominate over saline tides. Wetland forest is restricted mainly to the upper reach of the northwest fork and is diminishing downstream where it merges with mangrove forest. Mangrove forest is most extensive in the northwest fork.

SEA-GRASS COMMUNITIES

Shoal grass, *Halodule wrightii*, the dominant sea grass in the Loxahatchee River estuary, extends from slightly above to several feet below the low tide line. It grows in discontinuous bands that parallel the shoreline from near Jupiter Inlet into the forks of the estuary. The largest area of shoal grass, about 70 acres, grows in the eastern part of the central embayment (fig. 2). The biomass in this area (site e, fig. 1B) was consistently smaller than at a more seaward site (b; fig. 1B) near the inlet (table 4). The biomass diminished in the western part of the central embayment and in the forks of the estuary. Only sparse growth was observed in 1980 in the vicinity of Pennock Point and in arms of the estuary forks. Sea grass (probably shoal grass) formed lush growth around Pennock Point some years ago (R. F. Gladwin, *Jr.*, oral commun., 1981) and thrived in parts of the northwest fork (see fig. 2) during 1957-69 (Helen Leitman, written commun., 1981).

Most of the biomass of shoal grass is in its roots and other nonphotosynthetic tissue (table 4). The photosynthetic (green) biomass accounted for only 4 to 24 percent of the total biomass at sites e and b. Photosynthetic biomass was larger from May to September than during other seasons.

Shoal grass is by far the most abundant sea grass in the Loxahatchee River estuary. However, other sea grasses are present. *Halophila* sp., sometimes grows with shoal grass, but its biomass is relatively insignificant. Manatee grass, *Syringodium filiformis*, and turtle grass, *Thalassia testudinum*, are rare in the estuary but do occur at several sites. Dense stands of manatee grass and turtlegrass grow just north of the estuary in the north arm of the Intracoastal Waterway. At site v (fig. 1B) in the Intracoastal Waterway, the biomass of manatee grass was about 2 to 25 times greater than the biomass of shoal grass at sites b or e in the estuary (table 4). In the Loxahatchee River estuary, shoal grass is often associated with marine algae. At times, algae become predominant and cover the sea-grass beds.

Shoal grass has a relatively wide range of tolerance for temperature, salinity, and tidal exposure (Phillips, 1960). It is widespread throughout the tropical Atlantic and has been reported as far north as Beaufort, N.C. Simmons (1957) found it present at salinities that ranged from 1 to 60 parts per thousand. It tends to grow farther up the beach in the intertidal zone than other species (Humm, 1956; Phillips, 1960), but also ranges to considerable depth (Phillips, 1960). This greater range of tolerance probably explains why shoal grass is the dominant sea grass in the Loxahatchee River estuary. Salinity, temperature, and water clarity are quite variable in the estuary compared with the north arm of the Intracoastal Waterway. In this arm of the waterway, inflow of ocean water maintains relatively high salinity, moderate temperature, and relative high water clarity. Manateegrass and turtlegrass are dominant under these conditions.

SUMMARY AND CONCLUDING REMARKS

The Loxahatchee River estuary has been shaped and modified by natural processes of sedimentation and erosion driven by tidal and freshwater flow. The estuary periodically closed and opened to the sea in response to changes in flow. Man began to modify flow near the turn of the century, and except when periodically dredged, the estuary remained closed much of the time until 1947. During the last 30 years, the estuary has been maintained open by dredging.

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) OF UNITS

Multiply	By	To obtain
inch (in)	25.4	millimeter (mm)
	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft³/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	3.785	liter per day (L/d)
	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter (m^3)
degree Fahrenheit (°F)	0.555 (°F-32)	degree Celsius (°C)

* * * * * * * * * * * * * * * * * * * *

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level."

Table 4.--*Biomass of the shoal grass, Halodule wrightii, at sites e and b in the Loxahatchee River estuary, and manateegrass, Syringodium filiformis, at site v in the north arm of the Intracoastal Waterway*

Date	Site	Dry weight, in grams per square meter	Percentage of dry weight Photosynthetic	Percentage of dry weight Nonphotosynthetic
1980				
Jan. 17	e	27	4	96
	b	111	6	94
Mar. 5	e	12	13	87
	b	27	11	89
Mar. 12	e	36	21	79
	b	119	22	78
July 8	e	44	20	80
	b	124	18	78
	v	373	20	80
Sept. 5	e	51	24	76
	b	183	12	88
	v	330	17	83
Nov. 5	e	17	16	84
	b	138	10	90
	v	414	16	84
1981				
Jan. 15	e	59	19	81
	b	192	9	91
	v	498	7	93

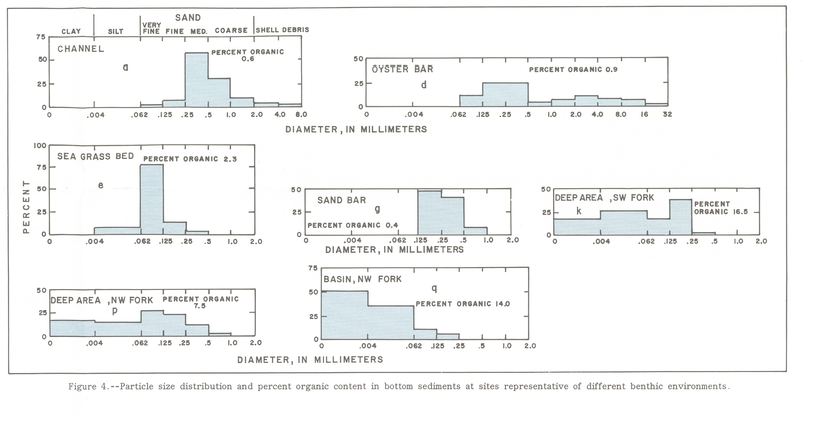

Figure 4.--Particle size distribution and percent organic content in bottom sediments at sites representative of different benthic environments.

Table 3.--*Freshwater inflow into the three forks of the Loxahatchee River estuary, 1980 wet season, May through September*
[Values are in acre-feet]

Divisions	Date	Maximum daily discharge	Wet season discharge
Northwest fork			
Kitchen Creek	May 26	123	2,340
Cypress Creek	May 27	503	14,720
Hobe Grove ditch	May 27	446	3,810
Loxahatchee River at SR 706	July 25	285	19,890
Subtotal for Northwest fork			40,760
North fork			
Unnamed	May 29	37	980
Southwest fork			
Canal 18 at S-46	Sept. 4	519	11,130
Total			52,870

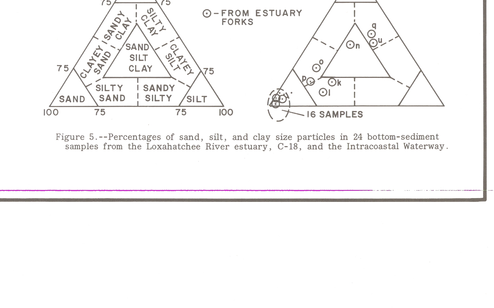

Figure 5.--Percentages of sand, silt, and clay size particles in 24 bottom-sediment samples from the Loxahatchee River estuary, C-18, and the Intracoastal Waterway.