

Seagrass Ecology Along the Coasts of Alabama, Louisiana, and Mississippi

Lionel N. Eleuterius
Botany Section
Gulf Coast Research Laboratory
Ocean Springs, Mississippi 39564

ABSTRACT

The seagrasses *Thalassia testudinum* Banks ex König (turtle grass), *Syringodium filiforme* Kützting (manatee grass), *Halodule wrightii* Ascherson (shoal grass), and *Halophila engelmannii* Ascherson occur in greatest abundance 30 to 50 miles offshore of Louisiana, east of Chandeleur Island, and 8 to 12 miles off the mainland shore of Mississippi, north of Horn and Petit Bois Islands. These species characteristically occupy sandy bottoms in estuarine and marine waters (20-35‰). Only *Halodule* is presently known to occur in Alabama waters. *Ruppia maritima* L. (widgeon grass) occurs on muddy bottoms, in waters of relatively low salinity (2-10‰), in bays, bayous, and river mouths along mainland Alabama, Louisiana, and Mississippi, and in tidal lagoons and certain ponds that are infrequently flooded on the barrier islands. It often grows associated with *Vallisneria*, *Najas*, *Zannichellia*, and other freshwater aquatics.

Hurricanes have eroded or buried in sand thousands of acres of seagrass beds near the offshore barrier islands. Freshwater discharges through the Bonnet Carré Spillway have also contributed to the loss of *Thalassia*, *Syringodium*, *Halodule*, and *Halophila*. However, because of its tolerance to brackish waters, *Ruppia* has spread over a greater portion of the local bay, bayou, and river bottoms.

During years when optimum conditions for growth occurred in Mississippi Sound, average short-shoot densities were 720 m⁻² for *Thalassia* (range: 80 to 1200 m⁻²), 400 m⁻² for *Syringodium* (range: 150 to 1600 m⁻²), and 2400 m⁻² for *Halodule* (range: 300 to 3200 m⁻²). Average leaf lengths were 24 cm for *Thalassia* (range: 8 to 41 cm), 43 cm for *Syringodium* (range: 18 to 65 cm), and 14 cm for *Halodule* (range: 6 to 21 cm). Biomass averaged 1100 g dwt m⁻² for *Thalassia* (range: 30 to 3200 g dwt m⁻²), with a shoot-to-rhizome-and-root ratio of 1:4. *Syringodium* biomass averaged 250 g dwt m⁻² (range: 20 to 650 g dwt m⁻²), with a shoot-to-rhizome-and-root ratio of 1:2. *Halodule* biomass averaged 138 g dwt m⁻² (range: 30 to 870 g dwt m⁻²), but in this species, biomass and leaf length increase with distance from shore and water depth, while shoot density decreases.

In each species, biomass varies seasonally, annually, and between beds, and continuous movement of sand bars affects leaf length, shoot density, and biomass. In 1968, a period of prolonged, extremely high salinity, epiphytic algae and bryozoans accounted for 70% of the total biomass of certain deepwater seagrass beds (*Thalassia*:epiphytes + bryozoans, 69:159 g dwt m⁻²). During this same period, about 100 species of marine invertebrates were found in seagrass beds in Mississippi Sound. *Thalassia* beds had the largest number of animal species (59), with 20 species found there exclusively. In contrast, during a period of prolonged low salinity in 1973, only 63 animal species were found among all beds.

Catastrophic death of marine invertebrates and vertebrates (seahorses) occurs when massive amounts of fresh water are discharged during periodic openings of the Bonnet Carré Spillway. Transplanting of seagrass, using coated metal anchors, has been very successful with *Halodule*. Some beds of *Thalassia* have been established, but no *Syringodium* transplants have survived. Information is seriously lacking concerning all aspects of seagrass biology and ecology for the Alabama, Louisiana, and Mississippi coastal region; less than two dozen reports or papers currently exist.

INTRODUCTION-HISTORICAL PERSPECTIVE

Thorne (1954) correctly stated that, in the early 1950's, no published information existed concerning seagrasses of the Alabama, Louisiana, and Mississippi coasts. The first report on the seagrasses of Mississippi was published shortly thereafter, and included identifications and descriptions by Humm (1956), who, at that time, was teaching and doing research at the Gulf Coast Research Laboratory in Ocean Springs, Mississippi. Humm (1956) suggested that *Halophila baillonis* Ascherson may occur in Mississippi, Louisiana, or Alabama waters, but the species has never been found there. Humm and Caylor (1957) also mentioned seagrasses in a description of the marine algae found in Mississippi Sound during summer, and Humm and Darnell (1960) described the seagrasses on the lee side of the Chandeleur Islands. Lemaire (1961) listed the seagrasses of Chandeleur and Breton Sounds.

Moore (1963) suggested that the virtual absence of *Thalassia testudinum* from the coast of Louisiana west of the Mississippi River was caused by westward drift of muddy water from the river mouth, and noted that *Thalassia* occurred most often on long, wave-damping shelves of the Gulf and Atlantic coasts. He also mentioned that *Thalassia* occurred in Mississippi Sound from Dauphin to Cat Islands, but that seagrasses did not occur in the inlets or island passes. Miller and Jones (1967) listed seagrasses that occurred north of Ship Island, and Richmond (1962) listed seagrasses from the shallow water north of Horn Island.

Eleuterius (1971, 1973) reported on an extensive survey conducted in 1968 and 1969, in which small dredges and scuba were used to locate and map seagrasses in the territorial waters of Mississippi. This survey revealed that the seagrasses *T. testudinum*, *Halodule wrightii*, *Syringodium filiforme*, and *Halophila engelmannii* were restricted to a relatively narrow strip north of Horn, Petit Bois, Ship, and Cat Islands. A shallow-water shoal area called the "Middle Ground," located north of Horn Island in Mississippi Sound, provided one of the most unique seagrass habitats in the area. At that time, seagrasses also grew on the sandy shoals located in Horn Island Pass, between Petit Bois and Horn Islands, and in Dog Keys Pass, between Horn and Ship Islands. *Ruppia maritima* was found in the low-salinity waters of the mainland.

Later, Eleuterius (1974) reported on trans-

planting of seagrasses in Mississippi Sound, and Jones (1974) listed the five species of seagrasses in his key of aquatic monocots of Mississippi. Descriptions of seagrass transplanting in Mississippi were prepared by Eleuterius (1975a) and by Eleuterius and McClellan (1976). Eleuterius (1975b) pointed out some salient biological features of seagrasses and their general ecology in Mississippi coastal waters. Destruction of seagrass beds by Hurricane Camille in 1969 and the effect on seagrasses of fresh water discharged through the Bonnet Carré Spillway, north of New Orleans, were reported by Eleuterius and Miller (1976). A review of some pertinent seagrass literature was presented by Eleuterius (1977).

Montz (1979) listed *Halophila*, *Thalassia*, *Halodule*, and *Syringodium* from St. Bernard Parish, which includes Chandeleur Sound. This work was based on herbarium collections held by several universities in Louisiana. Some of the specimens were obviously relatively old and could not be used to evaluate current conditions. Recently, Lanning and Eleuterius (1985) investigated certain chemical aspects of *Halodule* and *Ruppia*.

Perret et al. (1971) and Montz (1978) reported on the distribution of *R. maritima* in Lake Pontchartrain, Louisiana, and Turner et al. (1980) reported changes that had occurred in the lake's submerged vegetation from 1954 to 1973. Borom (1979) reported on *Ruppia* in Mobile Bay and stated that the species was in decline. Sullivan (1979) published a list of the encrusting diatoms obtained from three seagrass species in Mississippi Sound, and the general distribution of *Ruppia* in Mississippi tidal marshes was described by Eleuterius (1980). In a review of the botanical literature concerning Mississippi Sound, Eleuterius (1981) found only 14 papers that mentioned or concerned any detailed study of seagrasses in Mississippi Sound. Since that time, Eleuterius and Gill (1981) described the value of long-term observations of seagrass transplants.

In Alabama, Stout and Lelong (1981) pointed out that *H. wrightii* occurred in patchy beds north of the western tip of Dauphin Island. They mentioned that *R. maritima* is abundant in Mobile Bay and in tidal marshes and bayous around Bayou La Batre, Alabama. An extensive bed of *Halodule* was also reported in Old River, near Perdido Bay.

This brief review shows that most of the work in Alabama and Louisiana has concerned *R. mari-*

tima. Indeed, wildlife publications often list *Ruppia* as waterfowl food. What is known about the ecology of *T. testudinum*, *S. filiforme*, *H. wrightii*, and *H. engelmannii* in the north-central coastal region of the Gulf of Mexico comes from work carried out in Mississippi's coastal waters.

The specific subjects covered in the following pages are plant distribution, flowering phenology, flower and sexual distribution, shoot density, biomass and productivity, an analysis of anthropogenic (human) impacts, and a short review of transplanting in Mississippi.

SEAGRASS DISTRIBUTION

When the marine angiosperm assemblages in the coastal waters of Alabama, Louisiana, and Mississippi are compared, the greatest diversities of seagrasses are found in Mississippi and Chandeleur

Sounds (Figure 1). Here, the highly salt-tolerant *T. testudinum*, *S. filiforme*, and *H. wrightii* grow in abundance. *Halophila engelmannii*, once found frequently in Mississippi Sound, now occurs primarily in Chandeleur Sound. These four species of seagrasses are the only ones known to grow in waters of relatively high salinity (25‰+) in this region. They occur in the clear, shallow, protected waters north of Petit Bois, Horn, and Ship Islands in Mississippi Sound and also in the shallows immediately west of Chandeleur and Breton Islands. The most luxurious beds occur in protected waters west of Chandeleur Island. Relatively small beds occur nearshore, but extensive beds exist in the clear, deep water slightly westward of Chandeleur Island. Here, seagrasses grow at their greatest depths (8-9 m) in this entire region. Relatively homogeneous seagrass beds cover thousands of hectares. Although hurricanes often cause temporary disruptions and a discontinuous pattern in some of the seagrass beds of Chandeleur Sound, these lush meadows contrast

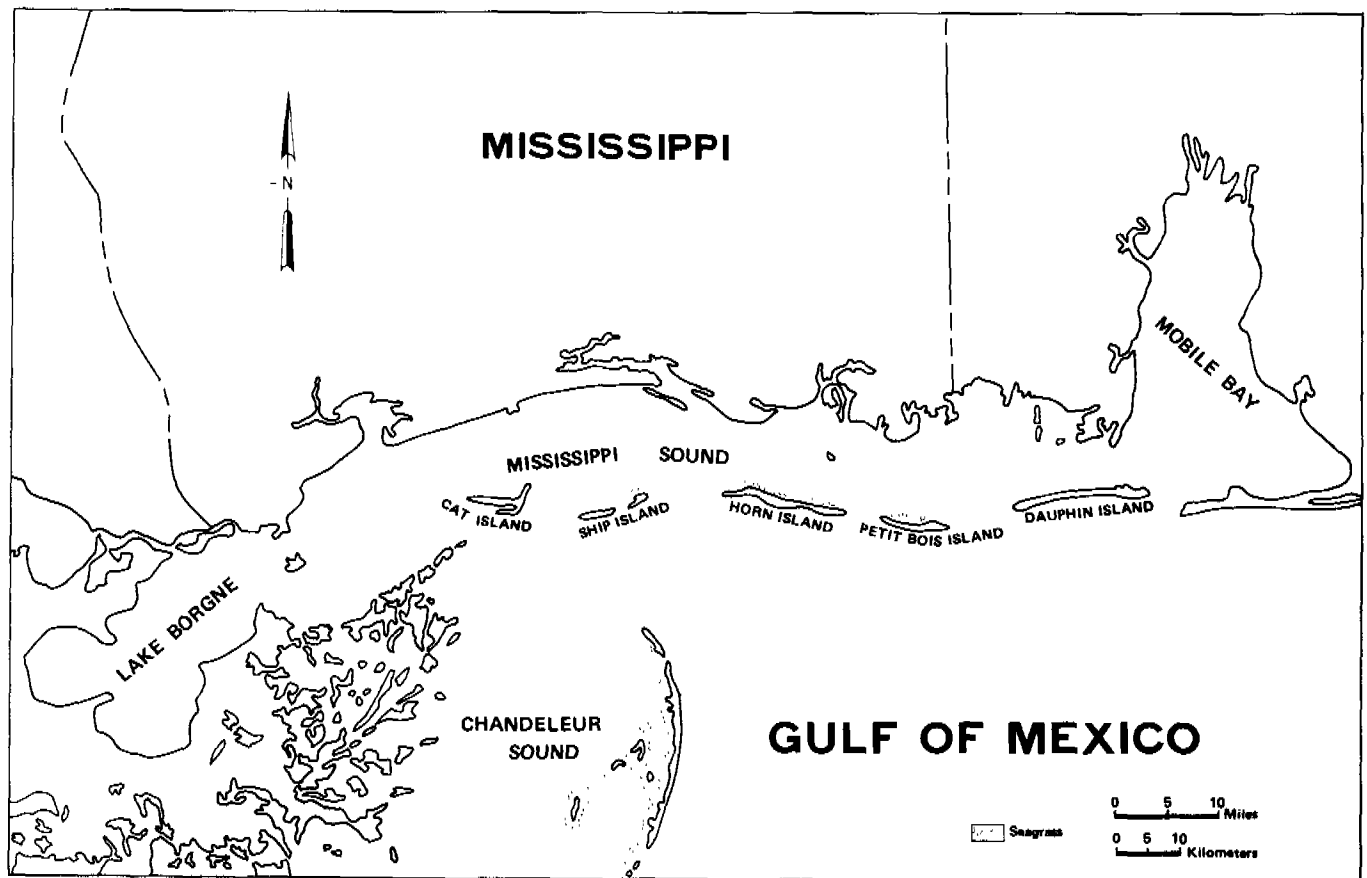


Figure 1. The most productive habitats for *Halodule wrightii*, *Thalassia testudinum*, *Syringodium filiforme*, and *Halophila engelmannii* are Mississippi and Chandeleur Sounds. These seagrasses occur near the barrier islands in Mississippi and near Chandeleur Island in Louisiana. *Ruppia maritima* occurs along the mainland in bayous, bays, and the estuaries of rivers. It also occurs in lagoons and ponds on the islands.

sharply with the patchy discontinuous beds found in Mississippi Sound.

Differences in latitude and, thus, temperature account, in part, for the lushness of beds in Chandeleur Sound, which lies 48 km south of Mississippi Sound. Chandeleur and Breton Islands, a chain of small islands spreading southward for another 48 km, are at the same latitudes as the area from St. Andrews and Apalachee Bays to Cedar Key, along the Florida coast. The mouth of the Mississippi River lies 64 km south of Breton Island.

In Mississippi Sound, seagrasses occur in patchy, discontinuous beds of irregular shapes, indicative of coasts exposed to high wave energy (Tutin, 1938). These beds are generally small, usually several square meters. Occasionally, larger beds, covering 100 or more square meters are found, but the size, shape, and number of beds often vary between years and from place to place. No large, ex-

tensive areas of coverage have been observed over the past 18 years, but accounts from old fishermen suggest that such areas may have existed in the recent past. The beds are often dome-shaped mounds, elevated from a few to 45 cm above the sea bottom. However, most seagrasses form meadows parallel to and between sand bars that run perpendicular to the island shoreline. The most diverse seagrass beds occur in the shallow waters north of Horn Island, but the most productive seagrass meadows occur on the "Middle Ground," a large shoal in Mississippi Sound (Figure 2).

The shifting of sandy sediments is a primary factor influencing the size, shape, and distribution of seagrass beds in Mississippi Sound. Sand is pushed rapidly along the nearshore bottoms, faster than the plants can vertically adjust, and seagrass beds sometimes become entirely covered. Generally, *H. wrightii* can adjust to changes in bottom topography because of its unique and rapid growth

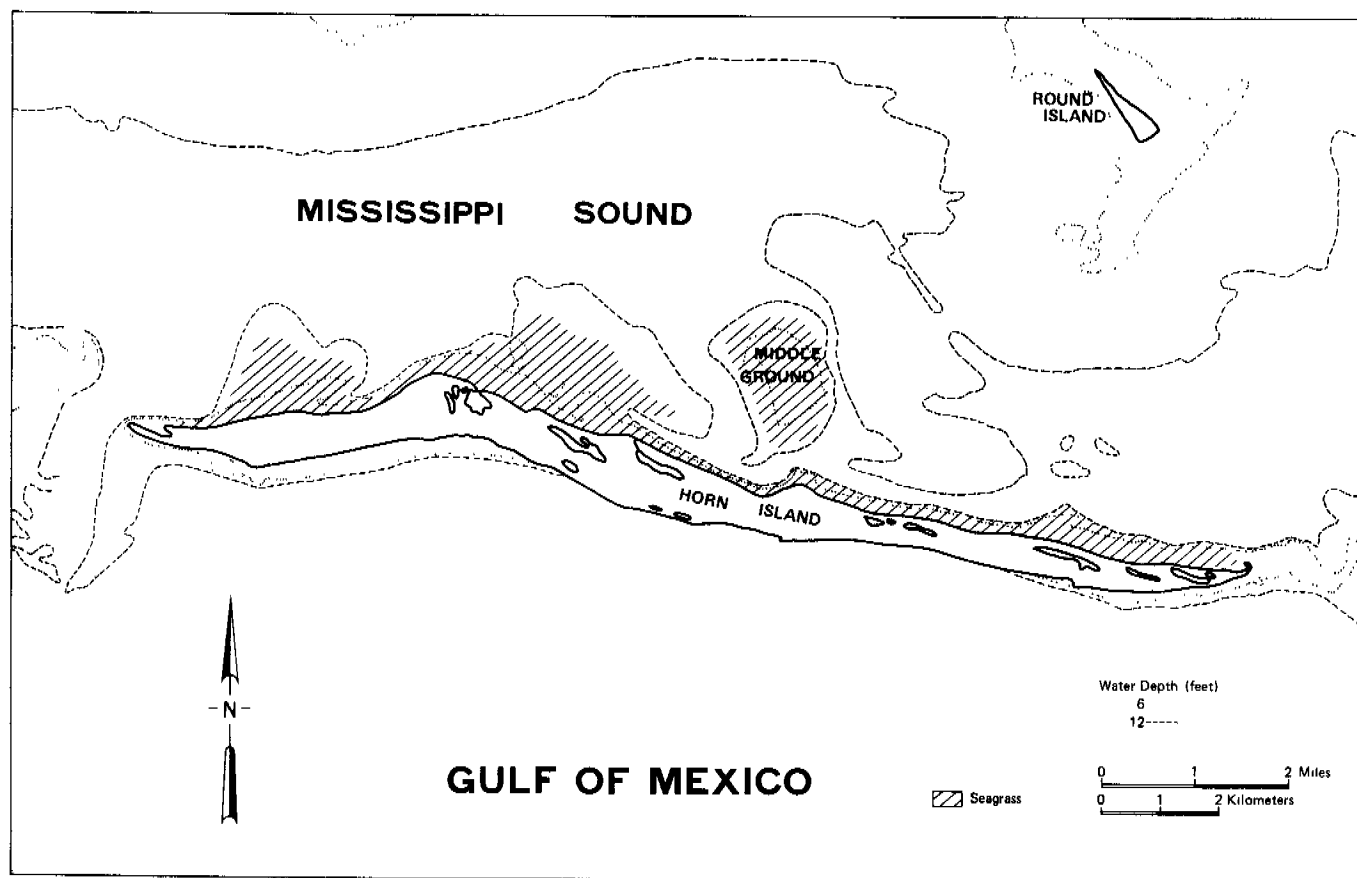


Figure 2. The shallow waters north of Horn Island and at the great shoal area called the "Middle Ground" are among the best habitats for the seagrasses *Halodule wrightii*, *Thalassia testudinum*, *Syringodium filiforme*, and *Halophila engelmannii*. The area out to the 6-foot depth contour is a prime area for seagrasses. However, the grassy meadows, which occur in discontinuous beds, often extend outward into depths of 9 feet or more.

(Eleuterius, 1974). *Thalassia testudinum* also has the ability to adjust to shifting bars by elongation of the vertical shoots, but its capacity for vertical adjustment is not as great as that of *Halodule*.

Seagrass beds are often cut in half by sand movement caused by along-shore currents and storm waves, forming two independent beds. Other beds coalesce, forming one bed from two or more. Some hurricanes have caused considerable damage to seagrass beds, the extent of damage varying with the magnitude of wind velocities and wave energy. In 1969, 1400 hectares (17%) of the seagrasses in Mississippi Sound were destroyed by the erosive action of waves generated by Hurricane Camille. Seagrass beds were either scoured away or covered by sand that was washed from across the barrier islands; island passes (inlets) were severely eroded (Eleuterius and Miller, 1976). Seagrass beds in Chandeleur Sound were also severely damaged by Hurricane Camille, but over the past 16 years, these beds seem to have recovered more completely than those in Mississippi Sound. However, the Chandeleur seagrass meadows are not as extensive now as those noted in 1968 and early 1969. Presently, about 1800 hectares of seagrass remain in Mississippi Sound, indicating a loss of about 50% from the amounts reported in the 1968-1969 surveys.

The Chandeleur Island beds remain low profile, heavily dissected masses, which do not offer the same amount of protection from the open sea that they did prior to 1969. When Hurricane Frederick struck the Alabama coast in 1979, the few remaining *H. wrightii* beds north of Dauphin Island were destroyed. Winds, primarily from the north, caused much erosion and destruction of seagrasses north of Petit Bois and Horn Islands. All of which confirms that hurricanes and violent winter storms severely affect the distribution of seagrasses in this north-central region of the Gulf of Mexico.

Thalassia testudinum, *S. filiforme*, *H. wrightii*, and *H. engelmannii* are not found elsewhere in this north-central region of the Gulf of Mexico. Primary factors probably accounting for this are mud bottoms, turbid waters, very deep waters, and shallows exposed to very rough seas. No seagrasses are found in the open sea, south of Horn, Petit Bois, and Ship Islands or east of Chandeleur and Breton Islands. They also are not found close to the mainland, because of unstable mud bottoms and turbid waters of low salinity. These seagrasses occur on sandy bottoms, in relatively clear waters of high salinity. *R. maritima* occurs in brackish waters of mainland bays, bayous, and in riverine estuaries.

FLOWERING PHENOLOGY AND SEXUAL DISTRIBUTION

Seagrasses have been observed to flower in Mississippi Sound. *Syringodium filiforme* generally begins flower production in April; *T. testudinum* and *H. wrightii* produce initial flowers in late May or June. *Halophila engelmannii* flowers have not been observed. Flower morphology indicates that most beds in Mississippi Sound are composed of a single plant type. About 65% of the *Halodule* beds are composed of plants bearing only staminate flowers, as opposed to plants bearing only pistillate flowers. This distributional pattern of sexual types indicates that each relatively small, patchy bed in Mississippi Sound may represent a single genotype. In addition, flowers occur primarily around the edges or fringes of the seagrass beds. Flowers are produced over a relatively short period of time; however, during some years, flowering fails to occur. Suppressed flowering is often associated with prolonged exposure to fresh water.

VEGETATIVE GROWTH

Halodule wrightii grows much faster than *T. testudinum* and *S. filiforme* in Mississippi Sound. Growth rates, determined from the lateral spread of seagrasses from transplants and in delineated (marked) beds, indicate that the maximum growth of *Halodule* was 355.6 cm over one year, or an average of 29.7 cm per month. *Syringodium* showed a maximum growth of 134.6 cm over one year, or about 11.2 cm per month. *Thalassia* had maximum growth of 203.2 cm over the observation period, for a monthly average of 17 cm. These data, taken from Eleuterius (1974), clearly show that seagrasses can and do grow rapidly in certain situations. Lateral spread of the grassy meadows is normally reduced during winter, so monthly averages for the peak growth periods are probably much greater than those shown for a full year.

SHOOT DENSITY AND LEAF LENGTH

Shoot counts within a 100-cm-square frame were used to obtain some idea of production in Mississippi Sound from 1968 through 1971. The number of seagrass shoots per unit of sea bottom area is difficult to obtain, partly because it varies

considerably within and between seagrass beds. Therefore, the data presented herein are relatively crude estimates for the region. Numerical data obtained from the best developed and most luxurious beds often reflect the maximum growth response possible for a particular area. In seagrass beds with large numbers of shoots per unit of sea bottom area, the shoots generally have shorter leaves than those in beds with more widely spaced shoots. Seagrass beds nearest the shore generally have the shortest leaves and a correspondingly greater number of shoots. *Thalassia testudinum* shoot density in the best developed beds ranged from approximately 80 to 1200 m⁻², with a mean of 720 m⁻²; *S. filiforme* shoots ranged from 150 to 1600 m⁻², with a mean of 400 m⁻²; *H. wrightii* shoots ranged from about 300 to 3200 m⁻², with a mean of 2400 m⁻². However, *Halodule*, in areas of high energy caused by strong waves, produced a very sparse cover of shoots with very short leaves.

Eleuterius (1974) presented a considerable amount of morphological data, gathered in 1972, concerning the seagrasses of Mississippi Sound. In that report, mature *T. testudinum* was shown to range in length from 8 to 41 cm, with a mean of 24 cm; *S. filiforme* leaf length ranged from 18 to 65 cm, with a mean of 43 cm; *H. wrightii* leaf length ranged from 6 to 21 cm, with a mean of 14 cm. These data

reflect the lengths of mature leaves in the best developed seagrass beds, during 1972, a period following four years of consistently high salinities (25-35‰).

Although shoot density and leaf length are important factors in understanding growth and production of seagrasses, year-to-year fluctuations over the past decade have made all such data almost meaningless, except as a record in time.

A summary of morphological data across a *T. testudinum* bed that was located adjacent to a sand bar is shown in Table 1. These measurements confirm that *Thalassia* has considerable phenotypic plasticity. The magnitude of the morphological adjustment that *Thalassia* made to accommodate sand deposition along the sand bar can be determined by comparing those data with measurements of plants along the spreading edge and in the middle of the bed.

BIOMASS

Thalassia testudinum has a standing crop (biomass per unit of area) about three times greater than *S. filiforme*'s and about eight times greater than *H. wrightii*'s (Table 2). Leaf, rhizome, and root masses of *Thalassia* are all much greater than those of *Syringodium* and *Halodule*. These estimates of biomass are conservative, but they provide an index for comparison with data obtained elsewhere. These data also reflect biomass under the best conditions for seagrass growth observed during the past 18 years; during many years, biomass was very much lower, due to sparse, poorly developed meadows. Moreover, *Halodule* grows faster than *Thalassia* or *Syringodium* and, consequently, has a greater leaf turn-over rate. *Halodule* production increases with depth off the north shore of Horn Island (Table 3). However, the seagrasses seem to abruptly reach a limit of growth in waters deeper than 3 m.

Dead leaf material is quickly washed away or deposited elsewhere in the seagrass beds, but, because few dead rhizomes or roots were found in the samples, rhizomes would appear to be long lived, perhaps existing several years. The oldest areas of *T. testudinum* beds generally have the greatest biomass. These old areas also have the greatest assortment and accumulation of epiphytic algae and attached animals. Sometimes epiphytes and epifauna completely cover older leaves. The biomass of algal epiphytes can account for more than 50% of the total leaf-plus-epiphyte dry weight. Encrusting bryozoans and numerous large, red algae account for about 70% of the total leaf biomass for

TABLE 1. A SUMMARY OF MORPHOLOGICAL DATA OBTAINED FROM THREE SAMPLES OF *Thalassia testudinum* COLLECTED 27 JULY 1972. These data show general morphological differences across a representative seagrass bed. [Reproduced from Eleuterius (1974)]

Location	Morphological Component	Range	Average
Edge of bed	Leaf length	7.9 to 30.7 cm	20.0 cm
	Leaf width	0.3 to 0.6 cm	0.4 cm
	Sheath length	3.0 to 10.4 cm	7.0 cm
	Internode length	1.0 to 10.5 cm	5.5 cm
	Internode width	0.2 to 0.6 cm	0.3 cm
	Internode roots	0.0 to 8.0 cm	3.0 cm
	Nodal roots	1.0 to 9.0 cm	4.0 cm
Middle of bed	Leaf length	7.3 to 25.7 cm	14.4 cm
	Leaf width	0.2 to 0.7 cm	0.4 cm
	Sheath length	2.8 to 8.9 cm	5.7 cm
	Internode length	0.8 to 11.1 cm	4.4 cm
	Internode width	0.3 to 0.4 cm	0.3 cm
	Internode roots	0.0 to 5.0 cm	2.0 cm
	Nodal roots	0.0 to 12.0 cm	4.0 cm
Along sandbar	Leaf length	14.8 to 41.2 cm	29.8 cm
	Leaf width	0.2 to 0.6 cm	0.4 cm
	Sheath length	7.1 to 23.7 cm	15.1 cm
	Internode length	0.8 to 8.3 cm	4.3 cm
	Internode width	0.2 to 0.5 cm	0.3 cm
	Internode roots	0.0 to 4.0 cm	2.0 cm
	Nodal roots	2.0 to 12.0 cm	6.0 cm

TABLE 2. SEAGRASS BIOMASS (G DRY WT/M²) BASED ON APPROXIMATE VALUES AND ESTIMATES, AND RATIOS BETWEEN SHOOTS (LEAVES AND STEMS), RHIZOMES, AND ROOTS.
All data was obtained during the summer of 1971, when seagrass growth was extremely vigorous, producing lush meadows characteristic of those found in 1968 and 1969. Similar lush growth and high standing crops were also observed in 1972.
These data represent the best seagrass growth observed by the author over the past 18 years.

Species	Shoots	Rhizomes	Roots	Total	Approximate Ratio
<i>Halodule</i>	30	90	20	140	1:3:1
	15	50	15	80	1:3:1
	320	680	200	1200	1:2:1
	150	360	180	690	1:2:1
	70	210	140	420	1:3:2
	260	640	320	1220	1:2:1
				$\bar{x} = 625$	
<i>Thalassia</i>	190	830	215	1235	1:4:1
	340	825	205	1370	1:2:1
	1210	3750	925	5885	1:3:1
	730	1680	620	3030	1:2:1
	1460	4200	1100	6760	1:4:1
	970	2040	910	3920	1:2:1
	3100	1120	890	5110	3:1:1
	4200	990	750	5940	4:1:1
	2650	1220	1050	4920	2:1:1
	3180	1155	1135	5470	3:1:1
	2235	2214	2160	6610	1:1:1
	1980	3650	1780	7410	1:1:1
				$\bar{x} = 4805$	
<i>Syringodium</i>	910	280	105	1295	9:3:1
	1215	575	235	2025	6:3:1
	1165	395	195	1755	6:2:1
	1105	345	200	1650	5:2:1
	1005	450	180	1635	5:2:1
				$\bar{x} = 1672$	

these seagrass beds. Encrustation by bryozoans and increases in number and size of algal species account, in part, for the high ratio of epifauna and epiphytes to seagrass biomass. Leaf, rhizome, and root growth is also suppressed by dense animal and algal accumulation on the leaves of seagrasses, thereby further reducing the ratio of seagrass to attached biota. Paradoxically, some seagrass beds remain free of epifauna and epiphytes. This is especially true of those seagrasses nearest the shore. *Halodule wrightii* and *S. filiforme* have fewer attached epiphytes than *T. testudinum*. The reason for this is not entirely clear, but *Halodule* often grows on near-surface shoals that are subject to high energy waves, which may keep the leaves free of attached algae. Seagrasses on the "Middle Ground" support very rich epiphytic and epifaunal communities, compared to those near the shore at Horn Island. The fringes of most seagrass beds are free of epiphytic and epifaunal growth because these areas generally are populated by new growth and young shoots. Sieburth and Thomas (1973) found few algae or bacteria on the surface of young *Zostera marina* L. leaves, and they suggested the necessity

for one species of a pinnate diatom to form a crust on the leaf surface before other epiphytes and epifauna become attached.

Direct observation and numerous random samples indicate the seagrasses of Chandeleur Sound are far more vigorous than those in Mississippi Sound, and the Chandeleur seagrass beds have a greater variety and abundance of associated marine algae and animals.

TABLE 3. PRODUCTION OF *Halodule wrightii* IN RELATION TO DEPTH.*

Two transects, each composed of three large beds, were sampled at different locations off the north shore of Horn Island.
[Modified from Eleuterius (1974)]

Distance from Shore		Water Depth**		Dry Weight g/m ²
(meters)	(feet)	(meters)	(feet)	
91.4	300	.76	2.5	293.76
167.6	550	1.07	3.5	359.04
259.1	850	1.37	4.5	587.52
91.4	300	.61	2.0	212.16
228.6	750	.91	3.0	342.72
335.3	1,100	1.37	4.5	554.88

*Data obtained in 1972.

**Water depth is below mean low water (MLW).

SHOOT AGE

A recent local study suggests that the short-shoots of *T. testudinum*, *S. filiforme*, and *H. wrightii* can live for several years (Eleuterius, unpublished data). Evidence of this was obtained by examining shoots for leaf scars and tagging newly produced rhizomes with monofilament fishing line. The rate of leaf production was estimated to be two leaves per year. *Thalassia* shoots appear to be capable of living seven years and longer, although the average life span appears to be about three years. *Halodule* shoots can live more than four years, but the average life span is difficult to determine. Recent morphological examination of *Halodule* indicates short-shoots remain alive long after they have stopped leaf production and that they are capable of producing long internodes and new shoots from old ones, resulting in the enormous ability of the plant to spread rapidly. Living *Halodule* rhizomes longer than 2 m have been washed out of the sandy sediment by using a small hydraulic pump. Diagrams drawn of these rhizome segments show an unusual branching pattern (unpublished data). The life span of *Syringodium* shoots is undetermined, but appears short, with an upper limit of perhaps three years. In contrast to *Thalassia* and *Halodule*, *Syringodium* seems to maintain beds by reinvasion of the same terrain. Furthermore, *Syringodium* does not appear to spread as rapidly as *Halodule* or *Thalassia*. Although short-shoots appear to be capable of long life in Mississippi Sound, generally they are killed prematurely by the shifting sands of the sea bottom.

ANIMALS AMONG THE SEAGRASSES

The greatest variety and abundance of animals in seagrass beds of Mississippi were observed during 1968 through 1972, prior to the great freshwater flood that occurred during the spring of 1973. During this period, probably more than 100 species were associated with seagrasses in Mississippi Sound. Many seahorses, pipefish, and several octopi were found. Lot (1977) pointed out that fishermen on the coast of Mexico "look for *Octopus* spp. and white clams among the roots and rhizomes of *Thalassia testudinum* and *Syringodium filiforme* that grow on sandy sediments."

Animal abundance increases during years with relatively low amounts of freshwater inflow. However, animal diversity and abundance have never

returned to pre-1973 levels.

However, quantitative data, gathered during the summer of 1973, showed that more animals were associated with *T. testudinum* beds than with any other seagrass beds. *Thalassia* had 59 associated animal species; *H. wrightii* and *S. filiforme* had 41 and 40, respectively. Sandy, unvegetated areas were lowest in species diversity and abundance. Only a few animal species were taken from adjacent barren areas. Among these were *Pagurus longicarpus*, *P. pollicaris*, and *P. annulipes*, in various gastropod shells, and the polychaete worm *Diopatra cuprea*.

Eleuterius' (1974) general comparison of invertebrates from Mississippi beds of *H. wrightii*, *S. filiforme*, and *T. testudinum* can be applied here. About 100 animal species are known to have occurred in grass beds in 1972 and previous years. Comparison of the numbers of species in various groups shows about 22 species of infauna, 50 species on the surface of the sandy substratum, and 20 "cryptic" species. The epifauna was composed of 8 species.

Of the 63 animal species collected during June 1973, 29 were common to *T. testudinum*, *H. wrightii*, and *S. filiforme* beds, 35 were common to *Thalassia* and *Halodule* beds, and 33 were common to *Thalassia* and *Syringodium* beds. No organisms were common to *Syringodium* and *Halodule* beds. Nineteen species were found exclusively in *Thalassia* beds, 6 in *Halodule*, and 1 in *Syringodium*. The animals were grouped into four categories: "infauna" or species generally found within the substratum; "surface" or species generally found on top of substratum; "cryptic" or species generally found among the leaves of plants; and "epifauna" or those species permanently attached to the leaves of plants. Twenty-two species comprised the infauna; 18 populated substratum surface; 18 were "cryptic"; and 4 composed the epifauna.

The numbers of infauna and "cryptic" species were about the same in 1973 as in previous years. In contrast, the number of "surface" species declined: only 18 species were collected in June 1973, compared to 51 species in 1972 and previous years. Although low in number in both cases, twice as many epifaunal species were collected in 1972 (8 species) as in 1973 (4 species). Only 27 of the species collected in 1972 were found in 1973, indicating a faunal decline of almost 66%. Although small and large fish were abundant in and around the seagrass beds, no detailed quantitative sampling of fish populations has been carried out locally.

HUMAN IMPACTS ON SEAGRASSES

The greatest anthropogenic impact on seagrasses in Mississippi Sound is the release of fresh water from the Mississippi River during periodic openings of the Bonnet Carré Spillway. This great outflow of fresh water enters Lake Pontchartrain north of New Orleans, travels across Lake Borgne, and enters Mississippi Sound. In 1973, water salinity along the north shores of Petit Bois and Horn Islands was reduced to zero and sustained at a freshwater concentration for more than three months. The Bonnet Carré Spillway was opened several times in the 1970's and early 1980's to relieve pressure on levees near New Orleans, which is below sea level. Table 4 shows the years in which the Bonnet Carré Spillway was opened and the corresponding amounts of freshwater discharge. River water levels characteristically rise in the spring, following snow melt and heavy rainfall in the Mississippi River drainage basin. These massive diversions of fresh water have altered the otherwise marine environment near the barrier islands of Mississippi Sound and, probably, the northern part of Chandeleur Sound. Darnell (1961), Gunter (1953), and Viosca (1938) noted that operation of the Bonnet Carré Spillway introduces organic material into Lake Pontchartrain and beyond Mississippi Sound. Long-term enhancement of biological production by this addition and redistribution of nutrients was suggested by these authors.

Tarver (1974) discussed the 1973 opening of the Bonnet Carré Spillway as "an ecological necessity, which was historically considered a natural phenomenon that occurred each time the Mississippi River topped its natural level." However, I believe that, historically, flood waters from the Mississippi River were spread out and dispersed over a very

large area of marsh, in marked contrast to the spillway conduit, which results in a concentrated point of discharge for the fresh water. Consequently, the ecosystem has been changed significantly over the past 16 years. These periodic large-scale environmental perturbations have favored the estuarine components of the coastal ecosystem, to the detriment of the more marine elements in Mississippi Sound. Eleuterius and Miller (1976) showed that localized rainfall along the Mississippi coast compounds the effects of Bonnet Carré Spillway discharges on seagrasses, but drought years favor growth of seagrasses and seaweeds.

Opening of the Bonnet Carré Spillway in 1973 caused a corresponding catastrophic decline of *S. filiforme*, and, I believe, caused the complete disappearance of *H. engelmannii*. *Thalassia testudinum* was also affected detrimentally, but not as severely as *S. filiforme*. *Halodule wrightii*, the seagrass with the greatest distribution in Mississippi Sound, was destroyed in many areas, but seems to have been the least affected of the four species. Recovery of *Halodule* appears to be significant in some areas, but the species still does not occupy the large amount of sea bottom documented in 1968 and 1969.

The general shift in seagrass growth in the latter part of the "growing season," resulting from the opening of the Bonnet Carré Spillway during the 1970's, is shown in Figure 3. McMillan and Moseley (1967) and McMahan (1968) studied the salinity tolerance of seagrass species native to the Texas coast. *Halodule wrightii* exhibited the widest tolerance range and *Halophila engelmannii* the least, with *S. filiforme* and *T. testudinum* intermediate. *Ruppia maritima* apparently was able to survive in fresh water.

Long periods of freshwater discharge kill the leaves of seagrasses first, then rhizomes near the

TABLE 4. BONNET CARRÉ SPILLWAY OPERATIONS.

Note the 23 years between 1950 and 1973 when the Spillway was not opened and the frequent openings during the 1970's and early 1980's. The Spillway was opened completely in 1973 for the longest period on record (75 days).

As shown, an enormous amount of water was discharged during that period.

[Modified from Eleuterius (In review)]

Year	Date		Days Open	Maximum Number Of Bays Used	Average Flow 1,000 cfs	Total Discharge 1,000 Acre-ft
	Opened	Closed				
1937	28 JAN	16 MAR	48	285	155	14,880
1945	23 MAR	18 MAY	57	All 350	224	25,536
1950	10 FEB	19 MAR	38	All 350	156	11,856
1973	8 APR	21 JUN	75	All 350	141	21,150
1975	14 APR	26 APR	13	225	69	1,794
1979	17 APR	31 MAY	45	All 350	134	12,060
1983	20 MAY	23 JUN	35	All 350	196	12,450

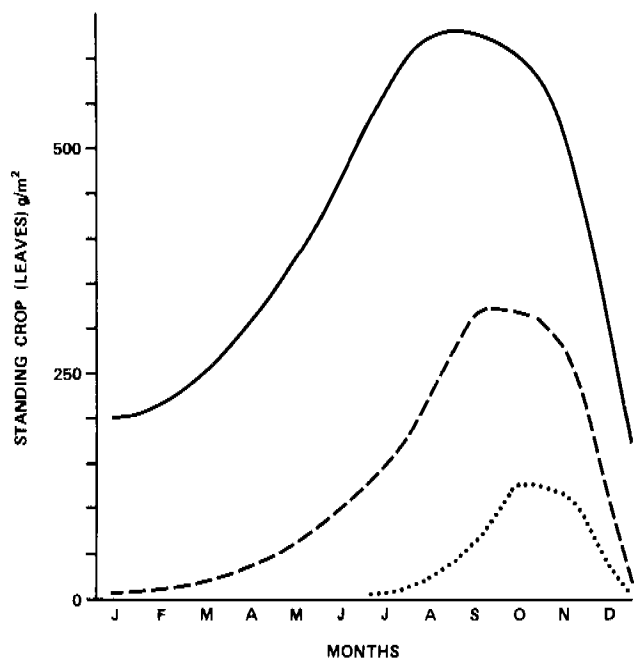


Figure 3. Approximate growth curve for seagrasses (based on random samples) near Horn Island, Mississippi, and the effect of fresh water discharged through the Bonnet Carré Spillway on their growth. The solid line shows the general growth curve for a year free of hurricanes or freshwater discharge from the Spillway. The dashed line shows the effect of moderate freshwater discharge on seagrass growth. The dotted line shows the severe effect of prolonged exposure to fresh water. Note that the growth phase is delayed in a manner corresponding to the amount of freshwater discharge and that the amount of plant material (leaves) produced is reduced.

sediment surface, a process that affects deeper rhizomes and leaves until the plants are killed. Marine invertebrates, such as the large *Busycon* snail (some as long as 30 cm), scallops, and an array of other snails, clams, crustaceans, and marine algae are also killed, indicating that most invertebrates of seagrass beds near the barrier islands are typically marine, rather than estuarine. Burrowing animals generally survive better than those on the surface. The effect of low salinity on the fish populations of seagrass beds in this region is unknown. In many cases, rhizomes and roots of the seagrasses remain alive, indicating that interstitial water of the substratum may mediate low salinity conditions.

Numerous shells of *Busycon contrarium*, *Busycon spiratum*, *Bittium varium*, *Mitrella lunata*, *Oliva sayana*, *Aequipecten irradians*, *Dinocardium robustum*, *Macrocallista nimbosa*, *Spisula solidissima*, and particularly *Atrina serrata* were collected in the grass beds during June 1973, but no living specimens were found. These snails and clams were very

abundant in 1972 and in previous years. Clams such as *Mercenaria mercenaria* and *Ensis minor* were very abundant in 1973, as well as in 1972 and previous years, indicating that these animal species can tolerate long periods of exposure to fresh water. However, the numbers of *Nassarius vibex*, *Cantharus* sp., *Terebra dislocata*, *Thais haemastoma*, and *Anachis avara* were drastically reduced from collections and observations made in 1972. A reduction in the number of individuals of each surviving species was also observed. Invertebrates that burrow deep into the sediments seemed to survive better than those that live on or near the sediment surface. All epiphytes and animals attached to the seagrass leaves were killed.

Other anthropogenic impacts include propeller ruts, shrimp trawls, dredging, and various types of pollution. Outboard motor ruts criss-cross and dissect seagrass beds in the shallow waters north of Ship, Horn, and Petit Bois Islands. The ruts do not fill in rapidly; in fact, currents and turbulence caused by waves cause erosion of these ruts, and ruts more than 20 cm wide and 28 cm deep suggest they are actually scoured out and deepened.

Deeper and wider tracks are dug by large boats that go aground, most noticeably in deeper seagrass meadows. Shrimp trawls also scrape the leaves off seagrasses in waters deep enough (2-3 m) for large trawlers. The edges of the seagrass beds are often completely torn up or dug out by intense, repeated dragging of shrimp trawls. Shallow seagrass beds are safe from shrimp trawlers, except during high tides in late spring and early summer. Great masses of seagrass have often been observed floating on the sea surface soon after the shrimp season opens each year in Mississippi.

Domestic sewage and toxic waste continue to increase along the mainland shores, despite the presence of pollution control agencies. Much domestic sewage, treated and untreated, enters Mississippi Sound, and the volume is increasing because of a corresponding increase in population. Toxic substances are manufactured locally and other materials are brought into the area for processing. Inadequate controls result in periodic accidental toxic waste discharge into coastal waters. During hurricanes, treatment facilities at many toxic waste storage and processing sites are not operational because of a lack of electricity, etc., resulting in the release of untreated toxic material. Heavy rains often flood earthworks that enclose toxic waste storage and work areas. These flood waters may breach dikes, flow over the dikes, or be released through the dikes

by workers. The effects of domestic sewage and toxic waste on seagrasses have not been studied in Alabama, Louisiana, or Mississippi.

SEAGRASS RESTORATION BY TRANSPLANTING

Although flowers have been observed frequently on all seagrass species except *Halophila engelmannii*, few seeds have been found in 17 years of observation. The reason for this lack of seed production is not clear. *Halodule wrightii* recurrence through vegetative means has been aided by the polychaete worm *Diopatra cuprea*. The details of how this marine worm incorporates bits and pieces of *Halodule* into its tube are illustrated and explained in Eleuterius and Caldwell (in press). Living shoots are often anchored into the worm tubes, giving rise to "new" *Halodule* beds. The large size of shoots from other seagrass species apparently prevents selection by *Diopatra*.

A large-scale seagrass transplanting study was initiated in 1971 and carried out over three years by the Botany Section of Gulf Coast Research Laboratory, Ocean Springs, Mississippi. The work was funded by the Mobile District of the U.S. Army Corps of Engineers. Objectives of the work were to develop technology for transplanting seagrass in this region of the north-central Gulf of Mexico, increase the number of seagrass beds in the shallows north of the barrier islands in Mississippi Sound, establish or create new seagrass beds on barren, sandy spoil (i.e., dredged material) islands along channels, and restore seagrass beds destroyed by Hurricane Camille.

Follow-up studies and monitoring of the original 1971, 1972, and 1973 transplants have been ongoing (Eleuterius and Gill, 1981). The opening of the Bonnet Carré Spillway detrimentally affected the seagrass transplants and the evaluation of results from transplanting trials, although the impact on the transplanting effort was not fully realized at the time. Resurveys and evaluations, beyond the three-year period of the contracted studies, showed that many of the transplants were highly successful and led to substantial marine meadows (Eleuterius, unpublished data).

Transplanting was carried out year-round with spring, summer, autumn, and winter trials. Transplanting of sods was attempted first, but the sandy substratum made this difficult. The loosely arranged,

sandy substratum simply oozed out of the transplanting sod. No "plugs" could be taken with a posthole digger or coring device because of the unconsolidated nature of the sand.

Several types of anchors, made of iron construction rod and/or different types of wire mesh, were tried. The best anchors were constructed of #6 reinforcing construction mesh (a type used with concrete), which was coated with a thick vinyl paint used in sealing concrete swimming pools. Short pieces of iron, bent and coated with the same type of paint, also made excellent anchors. All uncoated metal anchors rusted and were detrimental to seagrass transplants.

Phillips (1980a) pointed out that transplanting studies had great potential for investigating such basic biological problems of seagrasses as intraspecific variation, phenotypic plasticity, and populational adaptations and phenology. Furthermore, he stated that transplanting studies may also lead to refined techniques that could be used in the creation of new seagrass meadows and, thereby, provide habitat for animal communities. Transplanting studies should be continued locally, especially in years free of massive freshwater discharge through the Bonnet Carré Spillway.

RUPPIA MARITIMA

Presently, *Ruppia maritima* occurs in great abundance in the estuarine waters along the Alabama, Louisiana, and Mississippi coasts. The species also occurs in the lagoons and certain infrequently flooded ponds on the barrier islands. It is absent from waters where the salinity is characteristically near full sea strength. Because salinity was relatively high (25‰) in bays and bayous along the Mississippi coast, throughout most of the summers of 1968 and 1969, little *Ruppia* was found. Scattered, poorly developed beds of *Ruppia* occurred in the extreme upper reaches of tidal bayous, where water salinity is generally low. The same general pattern prevailed in rivers where *Ruppia* was found: growth was poor and the beds were patchy in shallow water along the slopes and banks. Several small beds were found in St. Louis and Biloxi Bays. The absence of *Ruppia* was attributed to the prolonged period during which highly saline water, which apparently inhibits the growth of *Ruppia*, penetrated far up the tidal bayous and rivers.

In 1969, Hurricane Camille struck the Mississippi coast. The initial tidal surge pushed sea

water far up into the bays, bayous, and rivers, further reducing *Ruppia*. Immediately following Hurricane Camille, heavy discharges of fresh water from the rivers eroded many of the established beds in the rivers and bayous.

The long periods of low salinity across Mississippi Sound, caused by the Bonnet Carré Spillway, apparently have favored the growth of *Ruppia* in the adjacent bays, bayous, and rivers. This has been corroborated to some extent by Montz (1978) in a survey of *Ruppia* in Lake Pontchartrain, Louisiana, before and after the 1973 opening of the Bonnet Carré Spillway. He reported that *Ruppia* was not harmed by the great discharge of fresh water in 1973. The area covered by *Ruppia* in local bays, bayous, and rivers has increased dramatically over the past 17 years, corresponding with a decrease in *T. testudinum*, *S. filiforme*, *H. wrightii*, and *H. engelmannii* near the barrier islands. This correlation may be related to a general shift in salinity or a modification of the salinity regime in Mississippi Sound. Currently, *Ruppia* grows profusely in distinct zones in shallow waters along the banks of bayous and rivers along the Louisiana, Mississippi, and Alabama coasts. These beds of *Ruppia* represent the most luxurious growth of the species that the author has observed in 18 years. *Ruppia* is also now more widely distributed than the other seagrasses. In St. Bernard and St. Tammany Parishes, *Ruppia* completely covers the bottom of the shallow, open water areas in most of the marshlands. The environmental conditions under which *Ruppia* grows in this region clearly indicate that this species is adapted to low salinities. A phenological and taxonomic investigation, using the methods reviewed and suggested by Phillips (1980b), should be carried out on *Ruppia maritima*.

DISCUSSION

Location and logistics are important factors affecting research on seagrass species along the coasts of Louisiana and Mississippi, where all populations of *T. testudinum*, *S. filiforme*, and *H. engelmannii* are remotely located. Relatively large boats are required to reach the seagrass beds for study because researchers cannot drive to the sea by vehicle and collect, observe, or study seagrasses, as they can in Texas and Florida. As Moore (1963) pointed out, seagrasses "grow in situations rarely visited by most land botanists." *Halodule* beds in

Alabama, however, can be reached by truck, via a causeway that runs to Dauphin Island. The need for a boat to study seagrasses has hindered research on these plants in this region of the Gulf.

Observations and study clearly indicate that seagrasses in Mississippi Sound are capable of producing marine meadows as productive as some tropical meadows (Zieman and Wetzel, 1980). However, over the past 12 years, the seagrasses in Mississippi Sound have existed in a rather depauperate condition, with an overall decline in distribution. The exception is the enigmatic *Ruppia*, which has exhibited vigorous growth and spatial expansion near the mainland.

The entire seagrass ecosystem in Mississippi Sound is affected by the opening of the Bonnet Carré Spillway, and four of the seagrass species, which are obviously obligate halophytes, are seriously affected. This represents a large anthropogenic impact and is a major problem that can inhibit future recurrence and survival of *Halophila*, *Thalassia*, *Halodule*, and *Syringodium* in Mississippi and, probably, Louisiana. However, the large outflow of fresh water from the spillway favors growth of *Ruppia*. The spillway problem should eventually be directly addressed and resolved.

The seagrasses in the north-central region of the Gulf of Mexico appear to be physiologically different from the same species found elsewhere. Phenotypic and taxonomic research may reveal locally distinct ecotypes and clarify other systematic and ecological relationships.

Little is known of sexual reproduction and establishment of seedlings, and this information is needed to understand the natural maintenance of seagrasses in Mississippi. Although flowers are produced abundantly, few, if any, seeds seem to be produced.

Transplanting and culture studies should also be continued because, as this review indicates, many biological and ecological aspects of seagrasses in the Alabama, Louisiana, and Mississippi coastal areas are poorly known. A considerable amount of study is needed to truly understand this assemblage of important marine plants and the associated animals.

LITERATURE CITED

- BOROM, J. L.
1979. Submerged grassbed communities in Mobile Bay, Alabama. Proc. Symp. on the Mobile Bay Estuary, May 1979.

DARNELL, R.

1961. Trophic spectrum of an estuarine community, based on studies of Lake Pontchartrain, Louisiana. *Ecology* 42: 553-568.

ELEUTERIUS, L. N.

1971. Submerged plant distribution in Mississippi Sound and adjacent waters. *Journal of Mississippi Academy of Sciences*, Vol. 17: 9-14.
1973. The distribution of certain submerged plants in Mississippi Sound and adjacent waters. Pp. 191-197 in *Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi. Phase IV, Biology*. Gulf Coast Research Laboratory.
1974. A study of plant establishment on spoil areas in Mississippi Sound and adjacent waters. Final Report. Corps of Engineers, U.S. Army. 327 pp.
- 1975a. Transplanting marine vegetation for habitat creation, sediment stabilization and rehabilitation in the coastal area of Mississippi. Pp. 84-87 in *Guide to the Marine Resources of Mississippi*. Mississippi Sea Grant Publications.
- 1975b. Submergent vegetation for bottom stabilization. *Estuarine Research* 2: 439-456.
1977. The seagrasses of Mississippi. *Journal of Mississippi Academy of Sciences*, Vol. 22: 57-59.
1980. Tidal marsh plants (an illustrated guide to tidal marsh plants of Mississippi). Mississippi-Alabama Sea Grant Consortium.
1981. The marine flora of Mississippi Sound: A review. Pp. 21-28 in J. R. Kelly, ed. *Symposium on Mississippi Sound*. Mississippi-Alabama Sea Grant Consortium.
- In review. The effect of fresh water discharged from the Bonnet Carré Spillway on seagrasses in Mississippi Sound.

ELEUTERIUS, L. N., and J. D. CALDWELL

- In press. Establishment of the seagrass *Halodule wrightii* by the polychaete worm *Diopatra cuprea*.

ELEUTERIUS, L. N., and J. I. GILL, JR.

1981. Long-term observations on seagrass beds and salt marsh established from transplants. Pp. 75-86 in *Proceedings of the Eighth Annual Conference on Wetlands Restoration and Creation*. Hillsborough Community College. Tampa, Florida.

ELEUTERIUS, L. N., and H. A. MCCLELLAN

1976. Transplanting maritime plants to dredged material in Mississippi waters. Pp. 900-918 in *Proceedings of the Symposium on Dredging and Its Environmental Effects*. Mobile, Alabama.

ELEUTERIUS, L. N., and G. J. MILLER

1976. Observations on seagrasses and seaweeds in Mississippi Sound since Hurricane Camille. *Journal of Mississippi Academy of Sciences*, Vol. 21: 58-63.

GUNTER, G.

1953. The relationship of the Bonnet Carré Spillway to oyster beds in Mississippi Sound and the "Louisiana marsh" with a report on the 1950 opening. *Publ. Inst. Mar. Sci.* 3: 17-71.

HUMM, H. J.

1956. Seagrasses of the northern gulf coast. *Bull. Mar. Sci. Gulf & Carib.*, 6: 305-308.

HUMM, H. J., and R. L. CAYLOR

1957. The summer marine flora of Mississippi Sound. *Publ. Inst. Mar. Sci.* 4: 228-264.

HUMM, H., and R. M. DARNELL

1960. A collection of marine algae from the Chandeleur Islands. *Publ. Inst. Mar. Sci.* 6: 265-276.

JONES, S. B., JR.

1974. Mississippi flora. I. Monocotyledon families with aquatic or wetland species. *Gulf Res. Rep.* 4: 357-379.

LANNING, F. C., and L. N. ELEUTERIUS

1985. Silica and ash in tissues of some plants growing in the coastal area of Mississippi, USA. *Ann. Bot.* 56: 157-172.

LEMAIRE, R. J.

1961. A preliminary annotated checklist of the vascular plants of the Chandeleur and adjacent islands, St. Bernard and Plaquemines Parishes, Louisiana. *Proc. La. Acad. Sci.* 24: 116-122.

LOT, A.

1977. General status of research on seagrass ecosystem in Mexico. Pp. 233-246 in C. P. McRoy and C. Helfferich, eds. *Seagrass Ecosystems*. Marcel Dekker, New York.

MCMAHAN, C. A.

1968. Biomass and salinity tolerance of shoal-grass and manatee grass in Lower Laguna Madre. *J. Wildlife Manag.* 32: 501-506.

- MCMILLAN, C., and F. N. MOSELEY
1967. Salinity tolerance of five marine spermatophytes of Redfish Bay, Texas. *Ecology* 48: 503-506.
- MILLER, G. J., and S. B. JONES, JR.
1967. The vascular flora of Ship Island, Mississippi. *Castanea* 32: 84-99.
- MONTZ, G. N.
1978. The submerged vegetation of Lake Pontchartrain, Louisiana. *Castanea* 43: 115-128.
1979. Distribution of selected aquatic species in Louisiana. U.S. Army Corps of Engineers, New Orleans, Louisiana. 33 pp.
- MOORE, D. R.
1963. Distribution of the seagrass *Thalassia* in the U.S. *Bull. Mar. Sci. Gulf and Carib.* 13: 329-342.
- PERRET, W. B., B. BARRET, W. LATAPIE, J. POLLARD, W. MOCK, G. ADKINS, W. GAIDRY, and C. WHITE
1971. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana, Phase I. Area Description. Louisiana Wildlife and Fisheries Commission. New Orleans, Louisiana.
- PHILLIPS, R. C.
1980a. Transplanting methods. Pp. 41-56 in R. C. Phillips and C. P. McRoy, eds. *Handbook of Seagrass Biology*. Garland STPM Press, New York.
1980b. Phenology and taxonomy of seagrass. Pp. 29-40 in R. C. Phillips and C. P. McRoy, eds. *Handbook of Seagrass Biology*. Garland STPM Press, New York.
- RICHMOND, E. A.
1962. The fauna and flora of Horn Island, Mississippi. *Gulf Res. Rep.* 1: 59-106.
- SIEBURTH, J., and C. D. THOMAS
1973. Fouling on eelgrass (*Zostera marina* L.) *J. Phycol.* 9: 46-50.
- STOUT, J., and M. LELONG
1981. Wetland habitats of the Alabama Coastal Zone. Marine Environmental Consortium. 60 pp.
- SULLIVAN, M. J.
1979. Epiphytic diatoms of three seagrass species in Mississippi Sound. *Bull. Mar. Sci.* 29: 459-464.
- TARVER, J.
1974. Bonnet Carré 73... Catastrophe or natural phenomenon? *Louisiana Conservationist Magazine*. January-February issue. Louisiana Wildlife and Fisheries Commission.
- THORNE, R. F.
1954. Flowering plants of the waters and shores of the Gulf of Mexico. *Fish Bull. U.S.* 89: 193-202.
- TURNER, R. E., D. M. REZNEAT, and J. BOND
1980. Changes in the submerged macrophytes of Lake Pontchartrain (Louisiana): 1954-1973. *Northeast Gulf Sci.* 4: 44-49.
- TUTIN, T. G.
1938. The autecology of *Zostera marina* in relation to its wasting disease. *New Phytol.* 37: 50-71.
- VIOSCA, P., JR.
1938. Effects of Bonnet Carré Spillway on fisheries. *Louisiana Conservationist Review*. Winter issue: 51-53.
- ZIEMAN, J. C., and R. G. WETZEL
1980. Productivity in Seagrass: Methods and Rates. Pp. 87-116 in R. C. Phillips and C. P. McRoy, eds. *Handbook of Seagrass Biology*, Garland STPM Press, New York. 353 pp.