EFFECTS OF WATER DEPTHS ON GROWTH OF THREE-CORNERED GRASS

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ABSTRACT

Water depths were monitored over a 15-month period in three natural stands of three-cornered grass along the Louisiana coast using continuous water level recorders. Mean monthly water depths in the stands ranged from -11.9 cm to +45.4 cm. Water depths were generally lower and less variable from January through March, and monthly means ranged from -5.2 cm to +7.3 cm.

Three-cornered grass was grown in vitro and subjected to various water depths seasonally. Number of culms and length of culms were greater in plants grown at water depths of 15 and 30 cm than those grown at depths of 45 cm or less than 15 cm. Seasonal growth appeared to be influenced largely by temperature; it increased with time as summer approached and decreased with time as winter approached. Duration of flooding was tested at depths of 16 cm and less and did not affect growth.

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INTRODUCTION

Louisiana is the leading fur-producing area of North America and has maintained this lead as long as official records have been kept. In fact, the Louisiana fur harvest in some years is over one-half of the total catch of that in the remainder of the United States (Lowery 1974).

Throughout the first half of the 20th century, the muskrat (Ondatra zibethica) was the backbone of the Louisiana fur industry, and the catch reached an all time high of 8,337,411 animals during the 1945-46 season. Muskrat populations began declining after that time and during the 1964-65 season only 201,510 animals were taken. Since then, populations have fluctuated drastically and the annual harvest has mostly remained below one million animals (Lowery 1974). The market for Louisiana muskrat pelts remains strong, and in recent years the value of individual pelts has climbed to an all time high (O'Neil and Linscombe 1975).

In spite of the value of the muskrat to landowners and trappers in the Louisiana coastal marshes, specific procedures for producing annual crops on a sustained yield basis have not been developed. Without this information, landowners are reluctant to invest in costly marsh management operations. Greatest muskrat populations occur in marsh containing dense stands of three-cornered grass (Scirpus olneyi), and marsh management for muskrat should be designed to produce this plant in the greatest possible abundance (Arthur 1931, O'Neil 1949, St. Amant 1959).

The extremely high muskrat population along the Louisiana coast during the 1940s was associated with the abundance of three-cornered grass (O'Neil 1949). Three-cornered grass grew in a broad band across the coast and was a dominant species in the brackish vegetational type. The plant began declining by 1950 and dense stands have occurred only at isolated sites since that time. The decline of three-cornered grass was followed by a corresponding decline in the muskrat population.

O'Neil (1949) reported that weather conditions (extreme drought or flooding) were major factors affecting the growth of three-cornered grass prior to 1950. Much of the Louisiana coastal marshes was undisturbed by man, and natural systems produced a stabilizing effect on water levels and salinities. However, since that time, channelization projects for navigation, drainage, and pipelines have resulted in drastic fluctuations in water levels and salinities. Stands of plant species unable to tolerate the widely fluctuating conditions were greatly reduced. Three-cornered grass was in this group and dense stands are presently found on a recurring basis only in marshes adjacent to certain estuaries (Palmisano 1967). Plant species tolerant to a wide range of conditions became established and marshes formerly occupied by three-cornered grass became dominated by wiregrass (Spartina patens), a less desirable plant for muskrats (Chabreck 1970).

The environmental conditions necessary for the growth of three-cornered grass have been the subject of several investigations. Penfound and Hathaway (1938) reported a salinity tolerance ranging from 5.5 to 16.8 ppt, and O'Neil stated that all three-cornered grass on the Gulf Coast showed an annual range in salinity from 2.0 to 17.5 ppt. Palmisano (1967) found that soil and water salinities varied between 10 and 17 ppt in two dense stands of the species throughout an annual cycle. Chabreck (1972) made observations in 63 stands and found water salinities varying from 2.1 to 12.3 ppt.

Many previous field studies did not address the problem of water depth requirements of three-cornered grass and those that did only reported periodic observations. The best data are from Palmisano (1967) who recorded that best growth occurred when water levels were maintained at or slightly above the marsh surface and not allowed to drop more than two to three inches below the marsh surface.

The survival and growth of three-cornered grass plantings under greenhouse and field conditions provided some insight into the problems associated with natural stands. Ross (1972) tested growth and survival of the plant in tanks at 5 water salinity levels (0, 5, 10, 15, and 20 ppt) and five water depths (-10, -5, 0, +5, +10 cm). He found significantly greater growth at the +5 and +10 cm depths. He concluded that management of three-cornered grass depended primarily on the maintenance of proper water depths with water salinity of secondary importance.

The importance of water depth on the survival and growth of three-cornered grass was also reported by Hess (1975). He established stands in impounded marshes by planting, but accidental flooding to a depth of 60 to 90 cm for two weeks during the growing season (May) killed 80 to 90 percent of the plants. He found that best survival of planted materials was obtained when water levels were maintained slightly below the soil surface for approximately six weeks after planting. Then, shallow flooding to a depth of +5 to +10 cm at a salinity of 5 ppt promoted normal culm development and reduced competition from annual plants. Ross (1972) had excellent survival of planted three-cornered grass when water depths were only slightly above the soil surface. Attempts to establish plantings with water levels 10 to 20 cm below the soil surface resulted in complete failure.

Hess (1975) noted that periodically lowering water levels and permitting soil aeration stimulated sprout growth of three-cornered grass and caused stands to spread. This observation verifies the findings by O'Neil (1949) that temporarily draining a three-cornered grass marsh following a muskrat eat-out will promote seed germination, rhizome growth, and revegetation of the marsh. Neither author, however, indicated the time of year, desired water depth, or duration of the water drawdown period. In order to properly manage stands of three-cornered grass using this technique, precise information must be available.

The objectives of this study were to:

1. determine water level regimes within natural stands of three-cornered grass.

2. determine the seasonal growth response of three-cornered grass subjected to different water depths.

DESCRIPTION OF STUDY AREAS

Three-cornered grass was grown under controlled conditions at the forestry greenhouse located at Louisiana State University, Baton Rouge. The study that envolved the recording of water levels in natural stands of Scirpus olneyi was conducted at three sites in the Louisiana coastal marsh.

Water level recorders were installed north of Lake Pontchartrain in southeastern Louisiana, north of Vermilion Bay in south-central Louisiana, and in Cameron Parish in southwestern Louisiana west of the Mermentau River (Fig. 1).

Climate

The southern portion of Louisiana is located in a semi-tropical latitude, and its climate is greatly influenced by the Gulf of Mexico. During the summer months, humid winds from the Gulf of Mexico prevail. The moisture-laden air from southerly winds is conducive to the formation of afternoon thundershowers (Ross 1972). Whenever westerly or northerly winds interrupt the prevailing moist conditions during the summer, hotter and dryer weather results (Chabreck 1970). Cold northern winds alternate with warm southerly winds during the winter. This causes a wide variation in temperatures in the southern portion of the state.

Annual rainfall along the Louisiana coast averages approximately 150 cm per year, but during the study period the annual rainfall was over 180 cm (Table 1). Rainfall rates were above normal at the three study sites selected in natural stands of three-cornered grass.

Tropical storms and hurricanes may occur at any time along the coast of Louisiana between June and November (Nichols 1959). Strong hurricanes (100 miles per hour) hit the coast every ten years. During the time of this study, hurricanes Claudette (24 July) and Frederic (11 September) affected water levels in study areas, but neither was rated locally as a major hurricane.

Soils

The soils of the Louisiana marsh are classified as peats, mucks, and clays, with all occurring in various proportions (Chabreck 1970).

The organic soils are classified on a basis of the stage of decomposition. Peat is soil that is brown or black and contains plant parts only partially decomposed and generally with over 50 percent organic matter (Dachnawski-Stokes 1940). Mucks are usually black or dark gray and contain organic matter that is finely divided and well decomposed with none of the plant parts identifiable (Chabreck 1972). The organic content of muck usually ranges from 15 to 50 percent. Soils with less than 15 percent organic matter are classified as clay.

METHODS AND MATERIALS

Field Studies

Water Depth Variation in Natural Stands

Water level recorders were installed in natural stands of three-cornered grass at three sites in south Louisiana (Fig. 1). Stands were selected north of Lake Pontchartrain in southeastern Louisiana (Bayou Lacombe marsh), near Vermilion Bay in south central Louisiana (Cypremort Point), and in Cameron Parish in southwestern Louisiana (Mermentau River marsh). Recorders were checked on a monthly basis and were operated continuously for 15 months (January 1979 through March 1980).

Water Salinity Variation in Natural Stands

A water sample was collected monthly at the site of each water level recorder to determine water salinity variation. Each sample was taken after agitating the surface and ground water at the sample point. Salinity determinations were made with a conductivity bridge as described by Richards (1954). Sampling began in February 1979 and continued through March 1980.

Plant Species Composition of Study Sites

The plant species composition and plant cover were determined for the three sites selected for water level studies. The sites were selected in areas that have produced annual stands of three-cornered grass for at least 30 years. This segment of the investigation was conducted to determine the abundance of three-cornered grass at the site and the plants growing in association with three-cornered grass.

Plants were sampled at each site using the line intercept method described by Canfield (1941). Sample points were located by using the water level recorder as a beginning point. Transect measurements were made 3 m, 9 m, and 15 m from the recorder to the north, east, south, and west. A 1-m rule was used for sampling and plant species and openings were tabulated to the nearest 1 cm as they occurred along the rule.

In Vitro Studies

Collection and Establishment of Plants

Three-cornered grass was collected from a brackish marsh on the north shore of Lake Pontchartrain, west of Bayou Lacombe in St. Tammany Parish, Louisiana.

Plants with attached root systems were excavated with a shovel and by hand and placed in a large metal container. Plants were kept in the container in about 10 cm of water until they were potted.

On 16 March 1978, three-cornered grass was planted in 144 three liter clay pots. Seventy-two pots contained mineral soil and 72 pots contained organic soil. Two three-cornered grass plants with one to three green culms each were planted to a depth of two inches below the soil surface in each pot.

Potted plants were placed in eight metal tanks (244 x 61 x 31 cm deep). The water level in each tank was kept at the soil surface of the pots and the water salinity was maintained at 5 ppt.

Water Depth Studies

Plants were housed at the Louisiana State University forestry greenhouse in Baton Rouge to facilitate evaluation of treatments under controlled environmental conditions. Experimental treatments began in December 1978.

Shallow flooding. Potted plants were subjected to flooding and drying conditions, and treatments were initiated in December (winter treatment), March (spring treatment), June (summer treatment), and September (fall treatment). Four water depths were tested each season (-8, 0, +8, and +16 cm). Thirty-six plants potted in mineral soil (<10% organic matter), and 36 plants potted in organic soil (>70% organic matter) were evaluated at the four water levels in each season. Plants were maintained at specific depths for one, two, and four months. Twelve plants were put at zero water level after one month of treatment, twelve more after two months, and twelve more after four months. This procedure was followed for winter, spring, summer, and fall treatments.

Immediately prior to each treatment the plants in each pot were clipped to five stems. Stem counts and measurements were made monthly for five months after initiation of individual tank treatments.

Deep flooding. A second series of tests was made to test three-cornered grass growth response to deeper flooding. Potted plants were placed in metal tanks (241 x 81 x 60 cm deep) with water containing 5 ppt of salt. Four water levels were tested--0, +15, +30, and +45 cm--and treatments were initiated in June (summer), September (fall), and December (winter) 1979. Treatments were terminated in April 1980. Plants in one tank containing organic soil and one containing mineral soil were tested at different water levels seasonally. All plants were clipped to five stems prior to initiation of each treatment.

Pots that were below the surface of the water were elevated to within 3.8 cm of the water surface to facilitate data collection during stem counts. Water salinity in all tanks was checked periodically with a Beckman Electrodeless Salinometer.

RESULTS AND DISCUSSION

Studies of Natural Stands of Three-Cornered Grass

Water Depths

Water depths in natural stands of three-cornered grass varied from -11.9 cm to +45.4 cm (Table 2). Both extremes occurred at the Mermentau River site and within a four-month period. The greatest monthly average (+45.4 cm) was associated with hurricane Frederick in July 1979. The greatest depth reached during the hurricane was 108.2 cm, but flood waters remained in the area for several weeks following the storm. Culms of three-cornered grass were killed by the wind and water action but promptly sprouted back after the flood waters receded.

Water depths at the site along the northern shore of Lake Pontchartrain ranged from -0.3 cm to +28.4 cm. Along the northern shore of Vermilion Bay, water depths ranged from -11.0 cm to +7.3 cm. In fact, the extreme water levels at the Vermilion Bay site occurred in consecutive months (September and October 1979).

Over the 15-month period that water depths were monitored, the Lake Pontchartrain site produced consistently greater water depths. This area was greatly influenced by runoff water carried by Bayou Lacombe and inundation was frequent. The greatest variation in water depth was noted at the Mermentau River site, and the least variation at the Vermilion Bay site. Nevertheless, all sites produced conditions apparently favorable to the growth of three-cornered grass.

Water Salinity

Water salinities were determined monthly at the three sites in natural stands of three-cornered grass from March 1979 through March 1980 (Table 3). Lowest salinities were at the Lake Pontchartrain site and ranged from 0.51 to 3.40 ppt. Highest salinities were at the Mermentau River site and ranged from 1.60 to 9.47 ppt. Water salinity at the Vermilion Bay site ranged from 1.01 to 5.45 ppt.

The highest salinity noted (9.47 ppm) was at the Mermentau River site in September 1979, approximately six weeks following hurricane Claudette. The area was flooded during the hurricane and salinities showed an immediate increase from 1.60 (July) to 4.45 ppt (August), but some storm waters remained, and through evaporation the salinity gradually increased to the level noted in September. Rainfall after that month caused water salinities to gradually decline through January 1980.

Water salinities at the three sites remained below 10 ppt during the study and were within optimum growth range of the plant as determined by Ross (1972).

Plant Associations

Three-cornered grass was the dominant plant species at each of the three study sites (Table 4). At the Lake Pontchartrain and Vermilion

Bay sites, however, wiregrass occurred at a frequency very similar to that of three-cornered grass. At the Mermentau River site, however, three-cornered grass completely dominated wiregrass and composed 74.8% of the species composition.

The number of species at the study sites was related to water salinity and decreased as water salinity increased. Seven species occurred at the Lake Pontchartrain site (salinity $\bar{x}$ = 1.30 ppt), three species were present at the Vermilion Bay site (salinity $\bar{x}$ = 2.79 ppt), and only two species were present at the Mermentau River site (salinity $\bar{x}$ = 3.68 ppt). A decrease in the number of species as water salinity increased was previously reported by Chabreck (1970) during studies of vegetation types along the Louisiana coast.

In Vitro Studies of Water Depths

Effects of Shallow Flooding

Three-cornered grass was grown in pots containing organic and mineral soil and subjected to seasonal treatments with varying water depths and flooding duration. During the treatments, four water depths (-8, 0, +8, and +16 cm) and three flooding durations (one, two, and four months) were used to evaluate growth response. The number of culms and length of culms were used to indicate growth response, and measurements were made monthly in each test pot for five consecutive months after the treatment was initiated.

Number of Culms

Season by Soil Types. The number of culms of three-cornered grass varied seasonally within both organic and mineral soils ($P < 0.01$) (Table 5). Treatments were conducted with varying water depths, flooding durations, and sample dates. The greatest number of culms were produced during the spring, and pots containing organic soil produced a greater number (17.8) than pots containing mineral soil (14.2) ($P < 0.01$). The least number of culms was produced during the fall but no difference was noted between soil types. Winter and summer growth rates were similar, but only during summer was a difference between soil types noted (organic: 9.8 and mineral: 10.9; $P < 0.05$).

Season by Water Depth. The number of culms of three-cornered grass varied seasonally within the four water depths tested ($P < 0.05$) (Table 6). The greatest number of culms was produced in treatments begun during the spring and the least number was produced during the fall. The increase in number of culms during the winter and summer was similar with winter producing a slightly greater number. Differences among water depths were significant ($P < 0.01$) only during summer and fall. The number of culms increased with increasing water depths during both seasons.

Season by Flooding Duration. No difference was noted in the number of culms of three-cornered grass produced during the three flooding periods. Even when compared on a seasonal basis (Table 7) and a season by water depth basis (Table 8), the difference in flooding duration, which seemed apparent, were not significant ($P > 0.05$).

Culm Length

Season by Soil Type. The length of three-cornered grass culms varied seasonally within both organic and mineral soils ($P < 0.01$) (Table 9). Culm lengths were longest during the summer and shortest during the winter in both soil types. Treatments included varying water depths, flooding durations, and sampling dates, and organic soil produced greater culm lengths during all seasons ($P < 0.01$) except winter. No difference was noted between soil types in tests initiated during winter.

Season by Water Depth. The length of three-cornered grass culms varied seasonally within the four water depths tested ($P < 0.05$) (Table 10). Culm lengths were greatest during summer and smallest in winter. During the spring, culm lengths were only slightly less than those of summer, and those of fall were similar to those of winter. Difference among water depths were significant ($P < 0.01$) during all seasons except winter, and culm length increased with increasing water depth. No difference was found among water depths in tests initiated during winter.

Season by Flooding Duration. Differences in culm length of three-cornered grass were found by season ($P < 0.01$) and flooding duration ($P < 0.05$); however, the interaction of season by flooding duration was not significant (Table 11). Also, the interaction of season by water depth by flooding duration was not significant, but the water depth by flooding duration interaction was significant ($P < 0.01$) during spring and summer. During both seasons, culm length increased with flooding duration at the +16 cm depth and decreased with flooding duration at the -8 cm depth (Table 12).

Effects of Deep Flooding

Potted three-cornered grass was grown in two soil types and subjected to four depths of flooding (0, 15, 30, and 45 cm) for four months. Treatments were made in summer, fall, and winter. The number of culms and culm length were determined monthly in each treatment. No tests were conducted during the spring.

Number of Culms

Season by Sample Date. Seasonal comparisons within sample dates disclosed that the number of stems was fewer during the fall than during the summer ($P < 0.01$) (Table 13). Little variation was noted within summer and fall sample dates, but during winter the number of stems increased considerably from Sample Date 1 (one month after initiation of treatments) to Sample Date 4 (four months after initiation of treatments). In fact, the number of culms produced in winter by Date 4 was the greatest number recorded in all season by date combinations tested. It is also of interest to note that Sample Date 4 (winter) was actually in early spring and spring also produced the greatest number of culms in the test of shallow flooding (Table 6).

Season by Soil Type. The number of culms of three-cornered grass varied seasonally within both organic and mineral soils ($P < 0.01$) (Table 14). The greatest number of culms were produced during treatments initiated in winter and no difference was found between soil types. The least number of culms was produced during the fall.

Season by Water Depth. The number of culms of three-cornered grass varied seasonally within the four water depths ($P < 0.01$) (Table 15). The least number of culms was produced during the fall. Summer and winter growths were similar at depths of 0 and 15 cm, but at 30 and 45 cm, winter produced 36.1 and 41.8% more stems than summer, respectively. Comparisons among water depths disclosed that the number of culms was generally greater at depths of 15 and 30 cm than at 0 and 45 cm; however, several exceptions were noted.

Culm Length

Season by Sample Date. The length of culms varied seasonally within the four sample dates ($P < 0.01$) (Table 16), and plants produced greater culm lengths in summer than in winter. Differences among sample dates showed only small variation in summer; nevertheless, significant differences occurred ($P < 0.01$). The greatest variation among sample dates was recorded during fall and winter. Culm lengths during fall decreased with time (sample dates), whereas winter culm lengths increased with time. This comparison suggests that culms begin "dying back" as fall advances toward winter; and in treatments initiated during early winter, culms grow progressively longer as spring is approached.

Season by Soil Type. Greatest culm length of three-cornered grass was recorded within both organic and mineral soils during summer ($P < 0.01$), and organic soil produced slightly greater growth that season ($P < 0.01$) (Table 17). Lowest culm length growth occurred during winter in mineral soil. The differences between soil types in fall were not significant.

Season by Water Depth. The length of culms varied seasonally within the four water depths tested ($P < 0.01$) (Table 18). Culm lengths were greatest in summer and least in fall. Differences among depths were significant ($P < 0.01$) during all seasons, and culm lengths were greater at depths of 15 and 30 cm than at 0 and 45 cm.

SUMMARY AND CONCLUSIONS

Water depths were determined in natural stands of three-cornered grass at three locations along the Louisiana coast. Water level recorders were used to monitor water depths and were operated over a 15-month period. Mean monthly water depths varied from -11.9 cm to +45.4 cm. The greatest depth recorded (108.2 cm) was during hurricane Claudette in July 1979 at the Mermentau River site.

Three-cornered grass was planted in clay pots, permitted to become well established, then submitted to various in vitro treatments with varying water depths to evaluate growth response. Growth indicators tested were number of culms and length of culms, and measurements were made monthly. Two separate tests were conducted using shallow flooding (-8, 0, +8, and +16 cm water depths) and deep flooding (0, +15, +30, and -45 cm water depths). Variables included in the test of shallow flooding, in addition to water depth, were season, soil type, flooding duration, and sample date. Variables tested with deep flooding were water depth, season, soil type, and sample date.

In tests of shallow flooding, the number of culms of three-cornered grass was greatest during the spring and lowest in the fall, but culm length was longest in summer and shortest in winter. Organic soils generally produce a greater number of culms and culm lengths than mineral soil. The effects of water depths were significant during summer and fall and the number of culms and culm lengths increased with increasing water depths. The duration of flooding did not affect the number or length of culms of three-cornered grass in tests using shallow flooding.

The tests of growth response with deep flooding were conducted only during summer, fall, and winter. The number of culms was greatest during winter and length of culms was greatest during summer. Least growth was produced during the fall. Differences among sample dates indicated that growth decreased with time during tests initiated during the fall and increased with time during winter tests. Temperature thus appeared to be a critical factor affecting growth. In general, the number and length of culms were greater at water depths of 15 and 30 cm than at depths of 0 and 45 cm.

As indicated by the results of this study, the management of stands of three-cornered grass should include maintenance of proper water depths during summer and fall seasons. During that time, maximum growth can be achieved if water depths do not fall below +8 cm or exceed +30 cm for periods greater than one month. Also, data from natural stands indicate that water salinity should be maintained at levels of less than 10 ppt.

APPENDIX I

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LITERATURE CITED

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APPENDIX II

TABLES

Table 1. Monthly rainfall[a] (cm) at selected sites along the Louisiana coast with natural stands of three-cornered grass.

	N. Lake[b] Pontchartrain	Vermilion Bay[c] Shore	Mermentau[d] River Area
1979			
January	15.67	15.95	33.43
February	27.25	25.73	19.46
March	9.98	5.97	11.56
April	16.87	39.09	10.03
May	10.90	19.96	20.96
June	4.60	3.28	.91
July	34.67	24.69	39.14
August	7.24	13.48	18.39
September	12.07	16.69	9.80
October	2.84	4.45	9.91
November	13.69	9.22	9.30
December	10.11	8.56	8.46
1980			
January	18.14	14.91	18.87
February	5.77	1.85	1.65
March	29.62	23.85	13.36

[a]Source: National Weather Service (1979, 1980).

[b]Rainfall data from Slidell Station.

[c]Rainfall data from Jeanerette Station.

[d]Rainfall data from Rockefeller Refuge Station.

Table 2. Mean monthly water depth[a] in stands of three-cornered grass at three locations along the Louisiana coast.

Month	N. Lake Pontchartrain	Vermilion Bay Shore	Mermentau River Area
	---------- centimeters ----------		
1979			
January	+2.74(4.57)	-3.05(1.22)	+0.91(0.91)
February	+6.10(10.06)	--	+0.30(5.17)
March	+7.32(10.92)	-0.91(7.62)	--
April	+28.35(27.43)	+6.40(11.28)	--
May	+19.51(24.38)	+3.96(8.53)	-11.89(6.71)
June	+0.91(7.92)	+0.31(5.18)	+10.06(10.06)
July	+12.80(18.59)	-6.40(6.71)	-3.66(22.56)
August	+1.52(3.66)	+3.35(8.53)	+45.42(19.20)
September	+25.91(11.28)	+7.32(14.33)	+28.35(3.05)
October	+9.14(9.75)	-10.97(8.53)	+8.84(1.83)
November	+6.40(5.79)	-0.91(6.40)	+7.01(3.66)
December	+2.13(4.27)	-3.35(2.44)	+8.53(4.57)
1980			
January	+5.18(7.92)	+0.61(3.05)	+7.01(3.96)
February	-0.30(3.66)	-1.22(3.96)	+6.10(4.57)
March	--	-5.18(2.44)	-0.30(1.52)

[a]Based on readings taken at eight-hour intervals throughout the month with water level recorders. The standard deviation is shown in parenthesis.

Table 3. Monthly water salinity (ppt) in stands of three-cornered grass at three locations along the Louisiana coast.

Month	N. Lake Pontchartrain	Vermilion Bay Shore	Mermentau River Area
1979			
February	0.64	-	-
March	1.20	3.08	1.60
April	0.62	1.88	-
May	0.79	1.10	2.23
June	0.60	1.01	1.70
July	0.73	2.37	1.60
August	1.99	1.13	4.45
September	-	1.44	9.47
October	1.73	5.45	7.40
November	2.13	4.00	4.58
December	3.40	5.15	2.44
1980			
January	0.51	3.42	2.07
February	0.67	2.19	2.79
March	1.91	4.10	3.77
Mean	1.30	2.79	3.68

Table 4. Plant species composition and cover of study sites in dense three-cornered grass stands.

Plant species	N. Lake Pontchartrain	Vermilion Bay Shore	Mermentau River Area
	Percent		
Three-cornered grass (*Scirpus olneyi*)	49.0	48.9	74.8
Wiregrass (*Spartina patens*)	48.6	47.0	25.2
Marsh loosestrife (*Lythrum lineare*)	1.4	4.1	-
Square stem spikerush (*Eleocharis equisetoides*)	0.1	-	-
Fragrant flatsedge (*Cyperus odoratus*)	0.3	-	-
Marsh primrose (*Ludwigia* sp.)	0.5	-	-
Smartweed (*Polygonum* sp.)	0.1	-	-
Vegetation cover	65.2	44.5	71.6

Table 5. Mean number of culms of three-cornered grass by season and soil type during tests of shallow flooding. The data presented are means of all sample dates within each season (N = 180).

Season[a]	Soil type	
	Organic	Mineral
Winter[c]	8.6	8.6
Spring[a]	17.8	14.2
Summer[b]	9.8	10.9
Fall[c]	5.4	6.4

[a] $P < 0.01$

[b] $P < 0.05$

[c] $P > 0.05$

Table 6. Mean number of culms of three-cornered grass by season and water depth during tests of shallow flooding. The data presented are means of all sample dates within each season (N = 90).

Season[b]	Water depth (cm)			
	-8	0	+8	+16
Winter[c]	8.8	8.3	8.5	8.6
Spring[c]	14.2	15.7	18.1	15.9
Summer[a]	8.1	9.2	11.6	12.5
Fall[a]	3.9	5.6	6.9	7.1

[a] $P < 0.01$

[b] $P < 0.05$

[c] $P > 0.05$

Table 7. Mean number of culms of three-cornered grass by season and flooding duration during tests of shallow flooding. Data for each season were taken five months after the test was initiated (N = 24).

	Flood duration (months)		
Season[a]	1	2	4
Winter[a]	14.5	14.3	13.9
Spring[a]	20.7	21.2	21.5
Summer[a]	11.6	12.3	11.9
Fall[a]	4.2	3.4	5.4

[a] $P > 0.05$

Table 8. Mean number of culms of three-cornered grass by season, flooding duration, and water depth during tests of shallow flooding. Data for each flooding duration within a season were taken five months after the test was initiated (N = 6).

Flood duration by seasons[a]	Water depth (cm)			
	-8	0	+8	+16
Winter[a]				
1 month	18.2	12.8	14.3	12.7
2 months	16.3	14.3	11.5	15.0
4 months	11.2	13.0	15.5	15.8
Spring[a]				
1 month	19.8	20.0	23.2	19.7
2 months	17.8	22.8	24.8	19.2
4 months	17.5	20.5	23.3	24.8
Summer[a]				
1 month	9.2	11.2	12.7	13.5
2 months	9.3	9.2	14.0	16.7
4 months	7.7	10.8	14.5	14.5
Fall[a]				
1 month	2.0	5.5	4.7	4.7
2 months	1.3	2.2	4.2	5.8
4 months	1.8	4.0	7.0	8.8

[a] $P > 0.05$

Table 9. Mean length of culms of three-cornered grass by season and soil type during tests of shallow flooding. Data are means of all sample dates within each season (N = 180).

Season[a]	Soil Type	
	Organic	Mineral
Winter[b]	53.7	54.0
Spring[a]	113.4	104.9
Summer[a]	128.0	112.7
Fall[a]	71.6	59.6

[a] $P < 0.01$

[b] $P > 0.05$

Table 10. Mean length of culms of three-cornered grass by season and water depth during tests of shallow flooding. The data presented are means of all sample dates within each season (N = 90).

Season[b]	Water depth (cm)			
	-8	0	+8	+16
Winter[c]	51.8	52.1	55.3	56.2
Spring[a]	101.3	106.7	113.8	114.8
Summer[a]	114.4	116.7	120.8	129.4
Fall[a]	51.6	64.3	69.8	76.7

[a] $P < 0.01$

[b] $P < 0.05$

[c] $P > 0.05$

Table 11. Mean length of culms of three-cornered grass by season and flooding duration during tests of shallow flooding. Data for each season were taken five months after the test was initiated (N = 24).

Season[b]	Flooding duration (months)		
	1	2	4
Winter[a]	99.3	106.0	107.0
Spring[b]	118.7	119.6	123.0
Summer[b]	111.0	114.8	119.0
Fall[b]	29.3	28.9	33.5

[a] $P < 0.05$

[b] $P > 0.05$

Table 12. Mean length of culms of three-cornered grass by season, flooding duration, and water depth during tests of shallow flooding. Data for each flooding duration within a season were taken five months after the test was initiated (N = 6).

Flooding duration by season[b]	Water depth (cm)			
	-8	0	+8	+16
Winter[b]				
1 month	102.3	104.7	98.5	91.5
2 months	111.3	104.5	101.8	106.3
4 months	97.8	106.0	108.0	116.2
Spring[a]				
1 month	118.7	116.8	123.2	116.0
2 months	106.8	120.0	129.7	121.8
4 months	106.2	116.0	123.7	146.3
Summer[a]				
1 month	121.5	115.3	123.2	116.5
2 months	100.0	111.0	118.8	129.5
4 months	89.5	116.7	126.8	143.0
Fall[b]				
1 month	14.5	24.7	37.8	40.3
2 months	9.5	23.8	32.2	50.0
4 months	22.0	34.8	32.7	44.5

[a] $P < 0.01$

[b] $P > 0.05$

Table 13. Mean number of culms of three-cornered grass by season and sample date during tests of deep flooding (N = 72).

Season[a]	Sample date (months) 1	2	3	4
Summer[a]	10.6	12.6	13.2	13.0
Fall[a]	8.1	9.2	8.1	8.3
Winter[a]	7.0	9.4	13.6	16.4

[a] $P < 0.01$

Table 14. Mean number of culms of three-cornered grass by season and soil type during tests of deep flooding. Data for each season were taken four months after test was initiated (N = 36).

Season[a]	Soil type: Organic	Soil type: Mineral
Summer[a]	11.7	14.6
Fall[a]	8.8	7.8
Winter[b]	16.6	16.1

[a] $P < 0.01$

[b] $P > 0.05$

Table 15. Mean number of culms of three-cornered grass by season and water depth during tests of deep flooding. Data for each season were taken four months after the test was initiated (N = 18).

Season[a]	Water depth (cm) 0	15	30	45
Summer[a]	13.2	17.8	11.7	9.2
Fall[b]	5.3	8.7	9.9	9.2
Winter[a]	12.4	18.9	18.3	15.8

[a] $P < 0.01$

[b] $P < 0.05$

Table 16. Mean length of culms of three-cornered grass by season and sample date during tests of deep flooding (N = 72).

Season[a]	Sample date (months)			
	1	2	3	4
Summer[a]	106.2	110.9	116.2	112.7
Fall[a]	111.2	102.6	79.5	58.4
Winter[a]	48.4	46.2	62.0	88.1

[a] $P < 0.01$

Table 17. Mean length of culms of three-cornered grass by season and soil type during tests of deep flooding. Data for each season were taken four months after the test was initiated (N = 36).

Season[a]	Soil type	
	Organic	Mineral
Summer[a]	107.4	104.4
Fall[b]	66.6	68.6
Winter[a]	79.1	47.0

[a] $P < 0.01$

[b] $P > 0.05$

Table 18. Mean length of culms of three-cornered grass by season and water depth during tests of deep flooding. Data for each season were taken four months after the test was initiated (N = 18).

Season[a]	Water depth (cm)			
	0	+15	+30	+45
Summer[a]	107.2	114.0	120.0	110.0
Fall[a]	58.4	73.4	59.2	42.4
Winter[a]	76.0	94.7	91.2	90.7

[a] $P < 0.01$