BANK STABILIZATION AND SHORELINE WILDLIFE HABITAT IMPROVEMENT IN A LARGE NORTH LOUISIANA RESERVOIR (TOLEDO BEND)

Walter C. Holmes
Dick T. Stalling
Department of Biology and Microbiology
Northwestern State University
Natchitoches, Louisiana 71497

ABSTRACT

Four species of vascular plants were evaluated under field conditions to determine their effectiveness for erosion prevention and shoreline stabilization. The four plants were: (1) cutgrass (Zizaniopsis miliacea) also known as southern wildrice and water millet, (2) maidencane (Panicum hemitomon), (3) spikerush (Eleocharis macrostachya), and (4) soft rush (Juncus effusus). A total of 1920 plants (480 of each species) were planted in two 12 x 15 meters (m) test plots. The plants were spaced at 25 cm intervals on the shoreline at elevations ranging from 169.5 ft. mean sea level (msl) to 171.5 ft. msl. Each planting was fertilized with 4.12 grams of Osmocote 17-7-12 controlled-release fertilizer at the time of planting (January-February, 1986). A barrier was constructed to protect the plantings from the waves. Plants were evaluated on their ability to survive and prosper (includes vigor, spread, etc.) under inundation periods varying from 65 to 121 days.

At all periods of inundation, cutgrass thrived and evidenced superior performance in relation to the other species tested. Data analysis indicates that this plant is the most effective in qualities of vigor, survival, spread, and apparent wave protection value. This was particularly evident for longer periods of inundation.

Soft rush and maidencane appear to have acceptable survival and coalescence characteristics during shorter periods of inundation (less than 90-100 days). Additional study is needed to determine the erosion protection effectiveness of these species.

Spikerush had excellent survival and spread at most periods of inundation. While the plant may have excellent promise as an erosion control species, additional time is needed to determine if it can be grown as effectively on eroded shorelines as it grows in its native habitat.

INTRODUCTION

The state of Louisiana ranks fourth in the United States in surface water acres with about 1.9 million acres of inland waters. Maintaining and improving water quality of its inland waters is necessary in order to continue to produce wildlife, fur, and fisheries. In addition, a multi-million dollar industry of recreation and tourism is directly dependent upon water that is environmentally and aesthetically acceptable. The demand for high quality freshwater for home, industry, and agriculture has never been higher, and with increasing growth of urban areas, population, and agricultural irrigation will continue to rise (Long et al. 1974). The last several years has revealed a new menace, that of shoreline erosion, which threatens to severely diminish the employment of freshwater impoundments for the above mentioned purposes. Although the problem has just become apparent, it is evident that erosion of shorelines will continue to accelerate. This erosion process has been proceeding since the construction of these impoundments but is now reaching the critical stage, with some shoreline already lost. The problem is one that is typically not considered in the planning of freshwater impoundments (Frantz 1951). It is directly related to the inability of upland hilltop soils, totally unsuited in structure, resilience, and type of vegetational communities supported, to withstand the effects of water level fluctuations, saturation, and wave action for extended periods of time. It has become evident that specialized research is needed to develop technologies to assist land and water control agencies and users in applying the best management practices for prevention or reduction of soil erosion from shorelines, thereby substantially improving water quality and wildlife habitat and lessening reservoir siltation. Currently, little is known concerning the capabilities and limitations of control of shoreline erosion of moderate-to-large freshwater impoundments by vegetative means (Draft 1983-84; Holmes 1985). The major emphasis relative to this has centered on seacoasts and beach areas (Born & Stephenson 1973; Cutshall 1985; Sharp & Vaden 1970; Sharp et al. 1980.) which provides little information of value to freshwater shoreline management.

The present report is the result of the first year of field work of a five year project undertaken to address the above problem. The objective of the five year study is to determine the most ecologically sound, aesthetically pleasing, and economically feasible method of shoreline erosion control of impounded lakes by the use of indigenous species of plants. The aim of the first year of study was to identify those species of plants that offer the most promise to achieve this end. Initially, attention was focused on determining which plants offered the greatest success in establishing themselves and simultaneously controlling erosion under the varying environmental conditions. Primarily, the environmental conditions impacting the shoreline of major concern are the long periods of drought alternating with extended periods of inundation and waves. Promising plants will be the object of continued studies.

DESCRIPTION OF THE STUDY AREA

The experimental sites were located in Sabine Parish, Louisiana, along the shoreline of Toledo Bend Reservoir (Figure 1), which covers 186,000 acres and is the fourth largest impounded lake in the United States (URS/Forrest & Colton 1979). It was created by the damming (late 1966) of the Sabine River, and now forms much of the border of Texas and Louisiana. The reservoir is 72 miles long north to south and varies from 1 to 5.5 miles wide. It has 1265 miles of shoreline on the Louisiana side which encompasses nearly every type of shoreline conditions typically found in freshwater impoundments within the state.

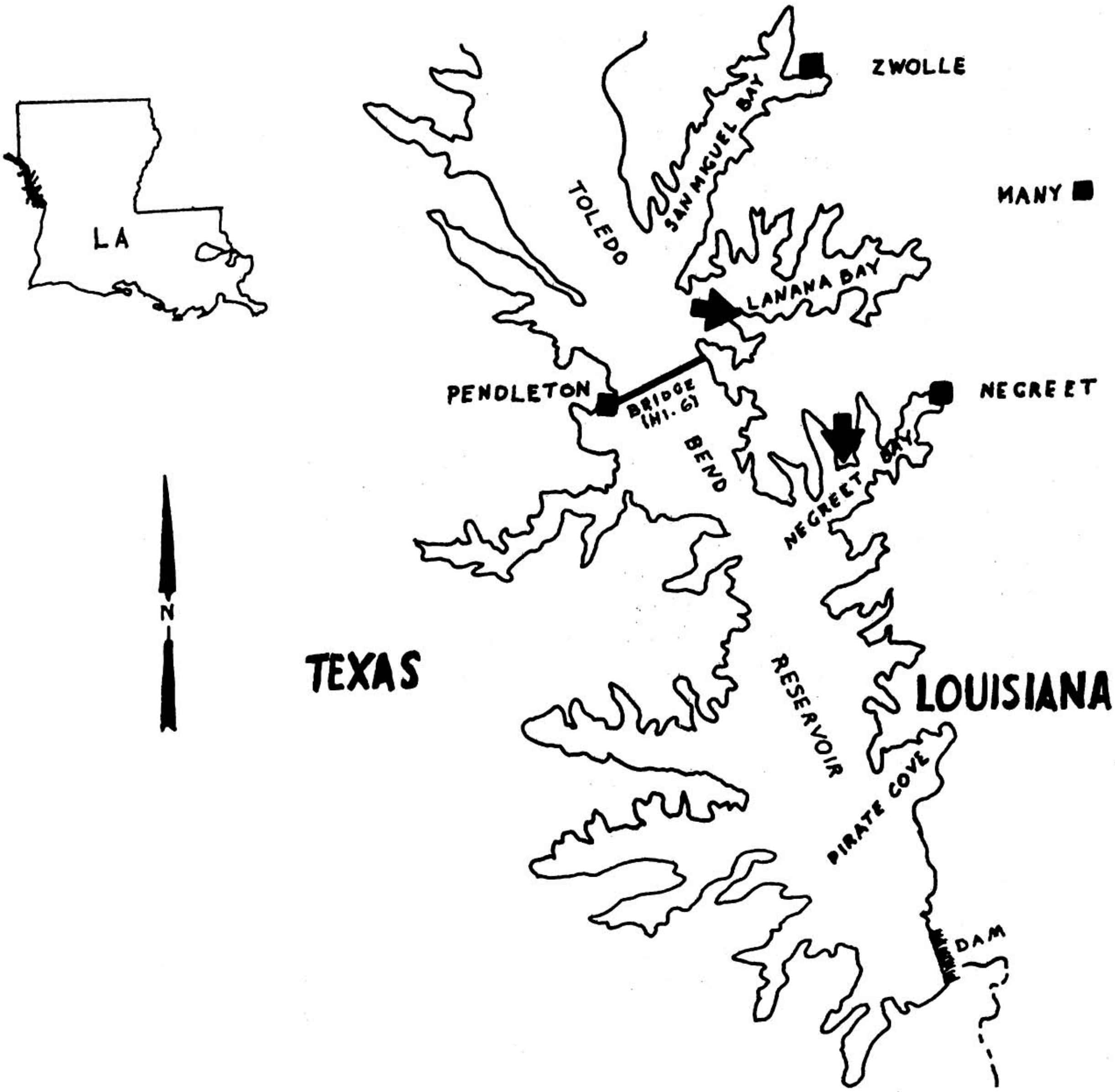


Figure 1. Location of the study site.

Additionally, large segments of the shoreline are nearly devoid of vegetation and are presently in various stages of erosion. The reservoir has a yearly fluctuation of water level that usually varies from a low pool stage of 168.0 ft. msl from September to January, to a high pool stage of 172.0 ft. msl in May and June. In exceptional years the pool stage may vary from a high of 173.0 or more to a low of 167.0 ft. msl (Figure 2). Prevailing winds are generally from the west, with winds of the greatest velocity occurring during the late winter through spring months. The shoreline is subjected to moderate to severe wave action, the principal erosion force, during these times. This erosion process appears to be accelerating because of the loss of standing timber, which, inundated at the time the reservoir was filled, served to moderate the wave action.

The area is also subjected to high humidity as rainfall averages 132cm per year. The maximum rainfall is attained during the month of May, while the minimum occurs during the autumn months. The average annual temperature is 19° C., summer average is 27° C., and winter average is 10.5° C. The average frost free period is 230 days and generally lasts from late March to Early November (Anderson 1960).

The soils of the study area are on moderately steep wooded hill-sides. The topsoil is a brown to light yellow fine sandy loam that is medium to strongly acidic. These overlay a strong brown to light brownish gray clay that is very acidic (Soil Conservation Service 1973). On the shorelines of the reservoir, the topsoil is nearly to totally eroded away, exposing the clay subsoil.

STUDY METHODS

Plant Components

The general lack of specific information concerning plants suitable for shoreline erosion control of freshwater reservoirs required screening of indigenous vegetation for use in the plantings. The following criteria were used in selecting species for testing (Gray & Leiser 1982).

1. Ability of the plant to withstand extended periods of drought followed by long periods of inundation and waves.

2. Perennial, allowing propagation by cuttings, rhizomes, etc.

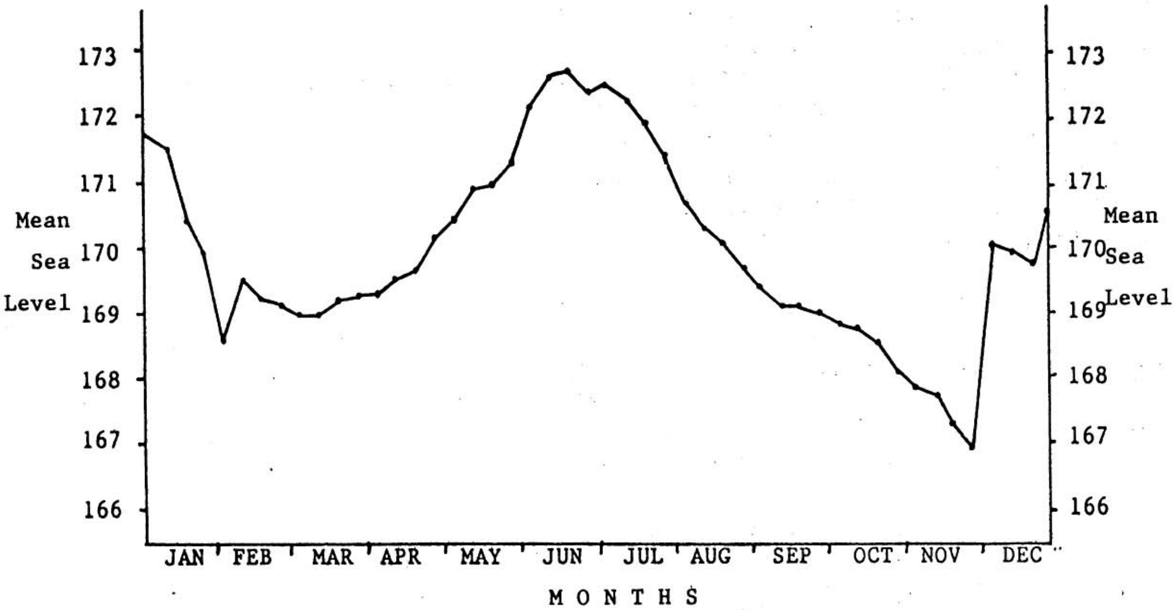
3. Growth potential, clumped growth form with soil binding ability.

4. Availability in the local area.

5. Value to wildlife.

6. Lack of undesirable (problem) characteristics.

Toledo Bend Reservoir Water Levels
(feet above mean sea level (MSL)) on
Days 1, 8, 15 & 22 for Each Month, 1986



Toledo Bend Reservoir Water Levels
(feet above mean sea level (MSL)) on
Days 1, 8, 15 & 22 for Each Month, 1987 (Inc.)

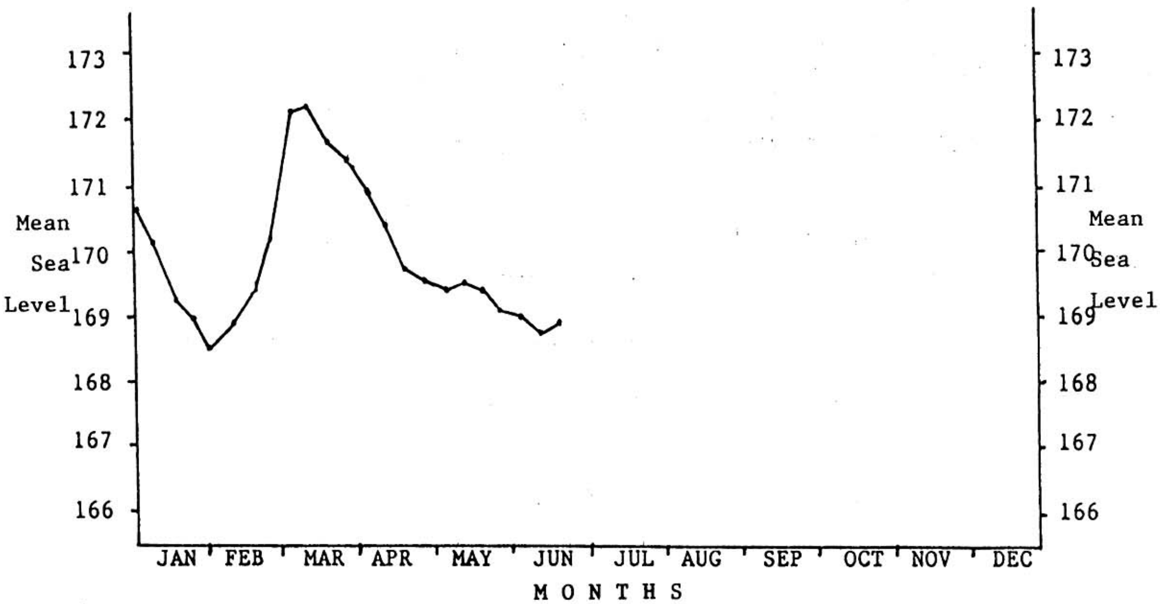


Figure 2.

Four species of vascular plants were selected for the first year's plantings. These included:

1. Cutgrass (Zizaniopsis miliacea (Michx.) Doell. & Asch. This plant is also called southern wildrice and water millet.

2. Maidencane (Panicum hemitomon Schult.).

3. Soft rush (Juncus effusus L.).

4. Spikerush (Eleocharis macrostachya Britt.).

Planting materials were collected in December 1985 and January 1986. Soft rush and spikerush were collected by using a bulb planter which removed a three inch diameter by five inch long plug. Cutgrass and maidencane were collected by digging the rhizomes which were later cut to planting size. All plants were placed in containers, covered to prevent drying, then stored at 3.3° C. until planting time.

Test Site Establishment

In October and November, 1985, two moderately eroding shorelines were selected for establishment of test plots. Each plot was 12 x 5 m, the greater dimension being parallel to the water. Plot elevations (in feet msl) varied from 169.49 to 171.51 for the North site and 169.85 to 171.20 for the South site. Each plot was divided into three equal subunits of 4 m x 5 m. The subunits were further subdivided into strips 1 m wide and 5 m long (replicates) with the greater dimension being perpendicular to the water. Each of the 4 strips of each subunit was planted with one of the plant species being tested. Locations of replicates in a subunit were determined randomly. Individual plantings were spaced at 25 cm, thus each square meter was planted with 16 plants, and each 1 x 5 m strip with 80 plants. This planting arrangement was repeated in the other two subunits, with the location of each replicate also being determined randomly. Each 12 x 5 m plot thus contained 960 individual plantings equally divided between the four test species. Each plant was fertilized with 4.12 grams (equivalent to 100 lbs. of Nitrogen per acre) of Osmocote controlled-release fertilizer at the time of planting. The elevation of each plant was determined so that the number of days of inundation could be computed by comparing its elevation with reservoir stage levels (obtained from the reservoir engineer's office). A plant was considered inundated if the reservoir pool stage (in feet msl) equaled or exceeded the elevation of the plant. The South site was established 31 January through 1 February, 1986. The North site was planted 9-10 February, 1986. Each plot was surrounded, on the lake side, by snow fencing to protect the plantings from waves (Webb & Dodd 1983) and from being covered by washed-in aquatic vegetation. Plots were watered weekly as required during periods of non-inundation.

Preinundation survivability for both plots was evaluated on 4

April 1986. Known non-survivors of soft rush, maidencane, and spikerush were replanted at that time assuring 100% survival prior to inundation. Very retarded springtime growth of cutgrass, apparently the normal situation, prevented similar determination of survivability and replanting in April. Heavy rains in the reservoir watershed followed, causing the reservoir pool stage to increase continuously until early June, when it attained a pool stage of over 173 feet (Rumsey 1984-1987). This prevented accurate determination of preinundation survivability and replanting of non-survivors. Inundation times of the plantings varied from 65 to 121 days. Post inundation survival and vigor were evaluated in September and October. The spreading growth habit and numerous new stems produced by spikerush prohibited evaluation of post inundation survival and vigor. Instead, five 25 x 25 cm (0.16 m^2) stratified-random quadrats were taken in each replication and used to compute density. Vigor ratings were based on the number of stems present, number of leaves, and height of the plant. Vigor was used to compare the condition and success of plants subjected to the various inundation periods. The different growth forms for the species being tested mandated that each have its own vigor criteria (cutgrass vigor = no. stems x no. leaves x plant height; soft rush vigor = no. stems x plant height; maidencane vigor = no. rooted plants x plant height; spikerush vigor = no. stems per quadrat). This prevented interspecific comparison of vigor. Regression coefficients were calculated for each species on each replicate (days of inundation vs. vigor for each propagule).

RESULTS

Preinundation Survival

Preinundation survival was evaluated two months after test plot establishment. All species tested exhibited excellent survival (Table 1), irregardless of position on the shoreline.

Table 1. Inundation survival in percent.
(Pre-April 1986; Post-Sept. 1986)

SPECIES	NORTH PLOT		SOUTH PLOT		MEANS	
	Pre	Post	Pre	Post	Pre	Post
SPIKERUSH	99.2	*	99.2	*	99.2	*
SOFT RUSH	95.2	39.6	95.8	47.1	95.5	43.4
MAIDENCANE	93.3	58.8	87.1	46.3	90.2	52.6
CUTGRASS	87.1	70.9	85.0	54.2	86.0	62.6

*Information not available due to plant coalescence.

Spikerush demonstrated the highest percentage survival at nearly 100%, with the failure of the very few survivors attributable to incorrect planting. Most of the plants developed flower clusters, but indications of spreading were not evident. Soft rush had a survival rate averaging slightly over 95% on both plots. Numerous plants developed flower clusters, but lateral spread appeared inhibited. Maidencane had an acceptable survival rate of 93.3% and 87.1%. Although easily detectable as survivors, the species showed a very slow growth rate during this period. Production of flowers was not expected since the plant rarely flowers even under optimum conditions and if flowering does occur, it is in the autumn. Preinundation survival for cutgrass was difficult to evaluate. The plant apparently is slow to initiate growth in the spring, often taking months to show positive growth signs. At this stage, numerous plantings were brown and dried and showed signs of decay. Removal of several planters showed positive growth was occurring below ground. The survival figures are adjusted to include as preinundation survivors those plants suspected of not surviving but later found to have survived the period of inundation. The actual preinundation survival should be slightly higher than the figures presented, but it could not be accurately determined if the plants were dead prior to inundation or if they failed to survive the inundation period. Both plots has survival percentages of 85% or more, which is exceptionally good. Growth consisted mainly of culm elongation and production of leaves. Flowering did not occur because of the small size of the plants.

Post Inundation Survival

Table 1 shows there was a definite trend for soft rush and maidencane to have dramatically decreased survivability as inundation time increased. This was particularly obvious in the South plot. Cutgrass on the South plot showed this same general trend, but its survivability on the North plot seemed to be little affected by the length of inundation. Due to the rapidly spreading nature of spikerush in favorable areas, determination of survival in individual plantings was impossible.

Table 2 lists by plots and replications the mean and standard error for days of inundation and for vigor in the surviving plants. Due to previously mentioned problems with spikerush, data collection was done by a previously explained quadrat sampling procedure. Mean inundation times were longer on the North plot and vigor values for cutgrass and maidencane were obviously higher here. However, more vigor was seen in the soft rush and spikerush survivors in the South plot.

Mean inundation, mean vigor, and regression coefficients were calculated for each replicate, using the plant vigor (0 if it died) and length of inundation for each replicate's planting (Table 3). As in Table 2, obvious differences occur in replicate vigor values for all four species. Positive regression coefficients indicate a positive

Table 2. Sample size, days of inundation, and vigor of surviving plants.

SPECIES, & AREA	SAMPLE SIZE	DAYS OF INUNDATION MEAN	DAYS OF INUNDATION S.E.	VIGOR MEAN	VIGOR S.E.
CUT GRASS					
*NP,N	64 plantings	98.9	1.40	42.0	5.18
NP,M	59	92.8	1.93	52.3	8.78
NP,S	47	94.3	2.53	55.0	8.23
SP,N	57	88.2	0.83	26.9	2.48
SP,M	38	88.2	1.49	24.1	3.94
SP,S	35	91.3	1.70	39.1	6.29
MAIDENCANE					
NP,N	47 plantings	96.4	1.36	14.7	1.11
NP,M	54	91.0	1.88	12.6	0.88
NP,S	40	85.8	2.40	7.7	0.68
SP,N	41	85.4	1.24	6.6	0.72
SP,M	35	84.4	1.02	5.7	0.65
SP,S	35	84.3	1.11	5.7	0.65
SOFT RUSH					
NP,N	29 plantings	86.2	1.39	11.5	1.66
NP,M	42	86.8	1.92	19.4	2.14
NP,S	24	84.6	2.83	12.1	1.97
SP,N	48	84.4	0.74	19.5	1.66
SP,M	33	83.9	0.61	18.7	1.79
SP,S	32	81.5	1.11	12.0	1.26
SPIKERUSH					
NP	14 quadrats	92.0	4.09	27.0	5.47
SP	14	88.4	2.58	39.0	7.86

*NP = North Plot
SP = South Plot
N = North Replicate
M = Middle Replicate
S = South Replicate

Table 3. Replicate's mean inundation days, mean vigor, and regression coefficients.

SPECIES, & AREA	SAMPLE SIZE	MEAN INUNDATION	MEAN VIGOR	REGRESSION COEFFICIENT
CUTGRASS				
*NP,N	80 plantings	98.70 days	33.58	1.50
NP,M	80	92.95	38.57	1.46
NP,S	80	93.70	32.32	1.10
SP,N	80	88.35	19.17	0.97
SP,M	80	89.40	11.44	0.15
SP,S	80	91.40	17.11	0.96
	N = 480	$\overline{X}$ = 92.42		$\overline{X}$ = +1.02
MAIDENCANE				
NP,N	80 plantings	101.00 days	8.65	-0.41
NP,M	80	94.15	8.48	-0.09
NP,S	80	93.55	3.84	-0.16
SP,N	80	87.35	3.39	-0.07
SP,M	80	88.00	2.50	-0.12
SP,S	80	90.60	2.49	-0.11
	N = 480	$\overline{X}$ = 92.44		$\overline{X}$ = -0.16
SOFT RUSH				
NP,N	80 plantings	95.55 days	4.17	-0.33
NP,M	80	92.45	10.17	-0.49
NP,S	80	94.15	3.63	-0.24
SP,N	80	88.75	11.55	-1.09
SP,M	80	91.25	7.72	-0.59
SP,S	80	87.95	4.72	-0.34
	N = 480	$\overline{X}$ = 91.68		$\overline{X}$ = -0.51
SPIKERUSH				
NP	15 quadrats	93.33 days	25.20	-0.46
SP	15	89.47	36.40	-1.35
	N = 30	$\overline{X}$ = 91.40		$\overline{X}$ = -0.91

*NP = North Plot
SP = South Plot
N = North Replicate
M = Middle Replicate
S = South Replicate

relationship between length of inundation and vigor with an inverse relationship noted by negative regression values. Only cutgrass showed a positive effect with increased inundation and spikerush showed the most negative response to inundation.

DISCUSSION

Preinundation Survival

The results of the study showed that the four species tested can be successfully transplanted to and established on the eroded shoreline of Toledo Bend reservoir. All species tested exhibited very good to excellent survival (Table 1). Watering during dry periods appears to have negated differences which could be caused by differential moisture retention at the various plot levels or positions relative to the reservoir. The size and growth form of the species apparently has an affect on the survival percentages. Spikerush, with densely tufted culms averaging 25 cm in height (Correll & Correll 1972) displayed the highest survival rate. Soft rush, with an overall survival of 95.5%, and maidencane, with a survival of 90.2%, both have culms about one meter in height, but the former has a densely clumped growth form and the latter a creeping growth form. Cutgrass, the largest of the plants with a culm height of 3 m and a densely clustered growth, showed the lowest overall survival percentage of 86%. The apparent trend is that smaller sized and denser culmed species exhibit a greater survival because more of the plant (or plants) were transplanted into the same sized planting hole. These relatively larger plantings (as compared with the size of the plant) also had more rhizomes, roots, buds, and culms thus increasing transplanting success. This is especially noticeable when a plug of the plant is used as a planter, as was done with spikerush and soft rush. The plantings of maidencane consisted of hand-cut portions of the rhizomes which relatively reduced the amount of planting material per planting hole. The planting material of cutgrass consisted of a portion of a coarse and thick (about 1 cm) rhizome with at least one bud present. No culms or roots were noticeable, thus lowering transplanting success. This may also, in part, be responsible for the slow initial growth rate exhibited by the species. Consideration should be given to another method of propagation or possibly a later planting date (March).

Evidence of lateral spread was not apparent during the preinundation period. It may have been impeded by the tight clayey nature of the soils, which although watered regularly, were not as pliable as they would have been during inundation. Additional observations are needed on this subject.

Post Inundation Survival and Vigor

The decreased survivability of maidencane and soft rush (see Table 1) with longer inundation times was probably due to several factors, but certainly plant height played an important role. Cutgrass survivability was only slightly diminished by prolonged inundation and never in actively growing plants was the entire plant totally inundated. Total submersion of the other three species undoubtedly created oxygen deficiency problems and greatly slowed photosynthesis due to decreased light intensities and limited availability of gaseous carbon dioxide. The very spongy nature of the cutgrass leaf sheaths and its long, thin leaves probably aid in the uptake of oxygen and carbon dioxide from the air and its transport to the submerged plant base. The sturdy nature of well established cutgrass plants also helps to decrease planter loss due to wave action.

The longer mean inundation days on cutgrass, maidencane, and soft rush survivors (Table 2) typically results in greater vigor, but as previously noted, did reduce survivability. This would appear to indicate that soil saturation with water is desirable for maximum growth stimulation of these species. Spikerush would appear to be more vigorous under less saturated or inundated conditions.

The regression coefficients (Table 3) indicate that cutgrass responds positively to increased lengths of inundation, but does so weakly. Spikerush, with the smallest coefficient, is most adversely affected by inundation on the South plot. Maidencane's regression coefficient approaches zero suggesting that barring wave damage, would do equally well at all levels. Soft rush's coefficient fell between these last two species and thus probably planting at upper levels would be best.

The differences noted in the vigor versus inundation regression coefficients for the four species replicates are felt to be due to several factors, but two are of primary importance. First, the exposure of the plants to wave action. Although a wave barrier fence was built across the front of the plot, winds blowing at 60° or more angle to either side of a line from the plot center to the fence center could cause considerable damage especially during the exceedingly high pool stage of the reservoir in June. Damage would be caused by direct wave damage and by washing in of Hydrilla and the scouring action of its wave tossed strands. Secondly, soil types varied from one end of the plot to the other and no doubt greatly affected plant growth due to nutrient availability, leaching of fertilizer, porosity, stability to roots, and other similar factors. The low vigor values seen in the cutgrass and maidencane replicates of the South plot are felt to be caused by poor soil characteristics; whereas more desirable soil characteristics resulted in the high correlations seen in all three species on the middle replicates of the North plot.

CONCLUSIONS

The four species of plants tested can be successfully transplanted to and survive the environmental conditions of the eroded shoreline of Toledo Bend Reservoir. It should be realized that the time period of investigation was unusual in water heights and wind severity compared with past records of the area. It is expected that more moderate environmental constraints will allow higher survival rates in the plantings and more vigorous growth in most species. Relationships between growth success and soil saturation conditions indicate that a regular watering scheme to keep the soil saturated during non-inundation periods would increase planting success. Results of the study showed that cutgrass, because of its large size and sturdy growth characteristics, demonstrated the greatest potential for wave protection and erosion control at all inundation times tested. Soft rush, spikerush, and maidencane, while probably suitable for erosion control in areas subject to short periods of inundation, need further study.

In addition to protection from waves during the establishment phase, the use of a wave-stilling device appears essential to avert damage to the plantings that can be caused by the scouring and wrenching action of masses of aquatic vegetation that are periodically washed ashore.

LITERATURE CITED

Anderson, H. V. 1960. Geology of Sabine Parish. Department of Conservation, Louisiana Geological Survey, Baton Rouge, 164 pp.

Born, S. M., and D. A. Stephenson. 1973. Water management for shoreline erosion control on the Chippewa flowage. Journ. Soil & Water Conserv. 27:57-61.

Correll, D. S., and H. B. Correll. 1972. Aquatic and wetland plants of southwestern United States. U.S. Government Printing Office, Washington, D.C., 1777 pp.

Craft, B. 1983-84. Test plot for shoreline erosion control on Toledo Bend Reservoir. Unpub. Report, SCS, Alexandria, Louisiana, 6 pp.

Cutshall, J. R. 1985. Vegetative establishment of smooth cordgrass (*Spartina alterniflora*) for shoreline erosion control. Unpub. Report, SCS, Alexandria, Louisiana, 6 pp.

Frantz, C. F. 1951. Field notes and comments: Non-farm erosion problem often neglected by engineers. Journ. Soil & Water Conserv. 6:218.

Gray, D. H., and A. T. Leiser. 1982. Biotechnical slope protection and erosion control. Van Nostrand Reinhold, New York, 271 pp.

Holmes, W. C. 1985. Report on the state of the preliminary investigation of the Toledo Bend Reservoir Shoreline Erosion Control Project. Report submitted to Sabine Soil Conserv. Dist., 10 pp.

Long, W., et al. 1974. Development plan for Toledo Bend. Report submitted to the Sabine River Authority, Planning and Research Associates, Natchitoches, Louisiana, 38 pp.

Rumsey, B. 1984-87. Plottings of daily lake levels of Toledo Bend Reservoir. La. St. Dept. Trans. & Development, Toledo Bend Dam.

Sharp, W. C., and J. Vaden. 1970. Ten year report of sloping techniques used to stabilize tidal river banks. Shore & Beach 38:31-35.

Sharp, W. C., C. R. Belcher, and J. Oyler. 1980. Vegetation for tidal shoreline stabilization in the mid-Atlantic states. USDA-Soil Conserv. Service pamphlet, 19 pp.

Soil Conservation Service. 1973. Soil survey of the Toledo Bend area. SCS, U.S. Dept. Agriculture, Alexandria, Louisiana.

URS/Forrest and Colton. 1979. State of Louisiana Water Quality Management Plan. Basin 11, Sabine River. Final draft report prepared for Louisiana Department of Wildlife and Fisheries, Baton Rouge.

Webb, J. W., and J. D. Dodd. 1983. Wave-protected versus unprotected transplantings on a Texas bay shoreline. Journ. Soil & Water Conserv. 38:363-366.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 718 pp.