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Proceedings of

The Seventh Annual Conference On

THE RESTORATION AND CREATION OF WETLANDS

Sponsored by

Hillsborough Community College
Environmental Studies Center
at Cockroach Bay
in cooperation with the
Tampa Port Authority

May 16 - 17, 1980

PROCEEDINGS OF
THE SEVENTH ANNUAL CONFERENCE ON
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Tampa Port Authority

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Editor's Note: AN UPDATE ON *Halodule wrightii* AND *Thalassia testudinum* RESTORATION (Anitra Thorhaug) and MANAGEMENT OF CYPRESS SWAMPS (Michael Duever) were not submitted for publication.

MARSHLAND REFLOODING IN THE KISSIMMEE RIVER VALLEY, FLORIDA

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ABSTRACT

A channelized tributary marsh adjacent to the Kissimmee River floodplain is being reflooded. This restoration is part of an experimental upland detention/retention demonstration project designed to evaluate water quality and develop pollution control practices for managing agricultural runoff in the watershed of Lake Okeechobee. The 75 ha site is located at the lower terminus of a 4800 ha watershed with land use dominated by improved pasture, citrus groves and limited native rangeland. Control structures were installed to restore historical water level fluctuation and duration disrupted by drainage of the wetland for grazing purposes. Pre-channelization flow conditions are also being simulated by blocking the excavated channel and causing sheet-flow through the adjacent marsh. Numerous state, federal and private agencies are conducting research programs to evaluate: 1) the impact of wetlands restoration on watershed hydrology and chemical loading, 2) the response of the biota to an extended hydroperiod, and 3) the continued but controlled use of the site as a grazing resource. Application of results from this study are discussed with respect to potential restoration of the Kissimmee River. Channelization of this riverine floodplain system for flood control purposes resulted in the loss of approximately 12,600 ha of wetlands. A restudy by the U.S. Army Corps of Engineers is presently evaluating restoration alternatives proposed by State entities ranging from de-channelization to creation of managed wetland impoundments.

INTRODUCTION

Several investigators have concluded that Lake Okeechobee is enriched with nutrients and should be classed as early eutrophic-eutrophic (Joyner 1974; Davis and Marshall 1975; Gayle 1975). Other studies proposed that land use and drainage practices in the lake's watershed are the source of nutrient enrichment (Gatewood and Bedient 1975; Black, Crow and Eidsness, Inc. 1975; Huber et al. 1976; Federico and Brezonik 1975) and contribute to an acceleration of the natural eutrophication process (Gleason and Stone 1975; McCaffrey et al. 1976; MacGill et al. 1976). The final report of the Special Project to Prevent the Eutrophication of Lake Okeechobee (MacGill et al. 1976) discussed the impacts of channelization of the Kissimmee River on the Kissimmee valley system and on Lake Okeechobee, but made no specific recommendations for corrective action directed at mitigating the environmental losses sustained as a result of the flood control works. Recommendations were made to deal with nutrient enrichment problems at their source - those upland areas where intensive agricultural land use generates non-point source pollution.

As an outgrowth of the Special Project and other issues concerning the region, the 1976 Florida Legislature created the Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin (Chapter 373.1965, Florida Statutes) with a charge to:

> "develop measures . . . to restore the water quality of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. Such measures shall be designed to minimize and ultimately remove the threats to the agricultural industry, the wildlife and the people of central and southern Florida posed by land use and water management practices which cause the degradation of water quality in such areas and shall be designed to alleviate excessive nutrient loads . . ."

In carrying out its charge, the Council was directed to conserve surface and groundwater supplies, restore seasonal water level fluctuations, recreate conditions favorable to wetlands functioning, maintain flood protection and utilize the natural or free energies of the system.

To fulfill this legislative mandate, the Council developed two programs incorporating wetlands restoration: 1) an Upland Detention/Retention Demonstration Project based on recommendations of the Special Project and 2) evaluation of a range of options for restoration of the Kissimmee River and associated floodplain system (McCaffrey et al. 1977a). Figure 1 locates the areas within Council programs to be discussed below.

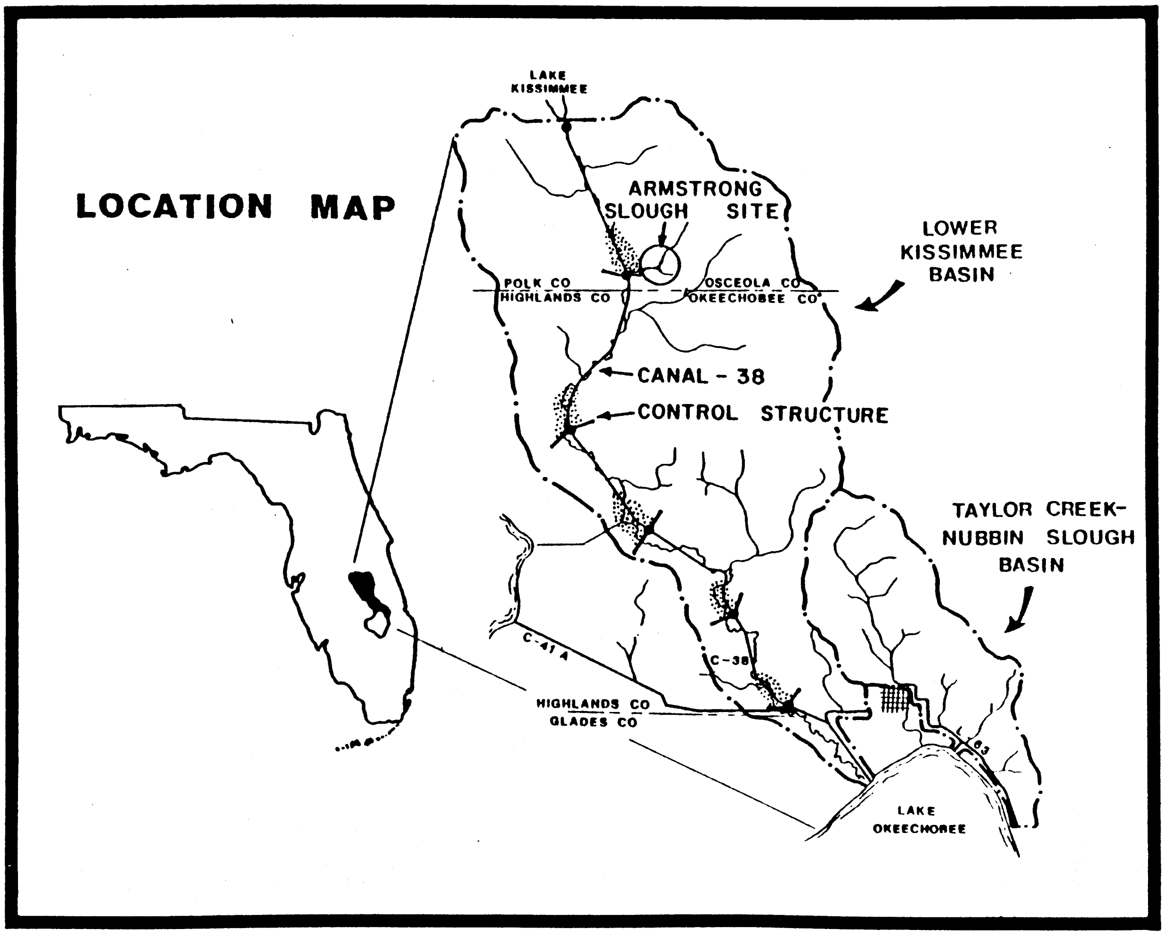

Figure 1. Location map for C-38 and Armstrong Slough site.

The Upland Detention/Retention Demonstration Project (McCaffrey et al. 1977b) is designed to detain runoff as near to where precipitation occurs as possible for as long as practicable and utilize natural or man-made wetlands to retain and/or transform nutrients and other pollutants. Within this project, the Armstrong Slough site involves reflooding of a former wetland site that was channelized and drained for agricultural purposes. The hydrologic, chemical and biological response of the system is being evaluated.

Analysis of restoration options for the Kissimmee River occurs at two levels. The Council is leading the efforts of various state agencies involved in the restoration issue and has made initial recommendations to the Legislature. It also coordinates the state's input to a Federally authorized Survey Review of the Kissimmee River being conducted by the Jacksonville District, Corps of Engineers (Corps of Engineers 1979). This review, initiated at the state's request, also is evaluating a wide range of alternatives and will result in a specific recommendation for corrective action.

METHODS AND MATERIALS

Armstrong Slough Detention/Retention Marsh

The purpose of this site is to evaluate the impact of wetlands restoration on such factors as water quality, hydrology, groundwater, vegetation dynamics, fish and wildlife populations, agricultural use and other aspects of wetlands function. Various contractors and cooperators are conducting specific research activities as identified in Table 1. Starting in the fall of 1978, preflooding data has been gathered by several investigators. Conditions necessary for actual reflooding were

Table 1. Contractors, cooperators and research topics for the Armstrong Slough detention/retention marsh.

CONTRACTORS

SOUTH FLORIDA WATER MANAGEMENT DISTRICT - Design, construction and maintenance of water control structures; water quantity monitoring; water quality monitoring; and operation of the Okeechobee Environmental Research Center.

U.S. GEOLOGICAL SURVEY - Rainfall and shallow (less than 10 feet) groundwater monitoring.

DEPARTMENT OF ENVIRONMENTAL REGULATION - 1) BIOLOGY SECTION: Investigate the dynamics of periphyton and phytoplankton communities; 2) CHEMISTRY SECTION: Analyze sediment and water samples for heavy metals and toxic organic compounds.

UNIVERSITY OF FLORIDA, INSTITUTE OF FOOD & AGRICULTURAL SCIENCES - 1) RANGE MANAGEMENT PROGRAM: Vegetation analysis and evaluation of the impacts of cattle; 2) SOIL SCIENCE DEPARTMENT: Evaluation of nutrient fluxing between bottom sediments and the water column; 3) AGRICULTURAL ENGINEERING DEPARTMENT: Evaluation of rainfall-groundwater-runoff relationships; 4) FLORIDA MEDICAL ENTOMOLOGY LAB: Investigate mosquito production potential from reflooding.

UNIVERSITY OF CENTRAL FLORIDA, DEPARTMENT OF BIOLOGICAL SCIENCES - Conduct microbial studies and evaluate the biochemical potential for nutrient assimilation and kinetics of decomposition.

CRAVEN THOMPSON & ASSOCIATES, INC. - Provide aerial photos and topographic maps.

COOPERATORS

FLORIDA GAME & FRESH WATER FISH COMMISSION - Conducts fish and wildlife investigations; co-located with South Florida Water Management District in the Okeechobee Environmental Research Center.

SOIL CONSERVATION SERVICE (in conjunction with local Soil and Water Conservation Districts) - Keeps track of agricultural management practices.

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completed in spring of 1980 and postflooding data is now being gathered.

The 75 ha detention/retention area (Figure 2) is located at the downstream end of a 4800 ha watershed dominated by improved pasture, citrus groves and limited native rangeland. It is adjacent to and was formerly part of the Kissimmee River floodplain, but is now separated by a dike used to impound watershed flow and permit water level manipulation through a discharge control structure installed as part of this project. Within the detention/retention area is a channel blockage and distribution swales designed to force water out of the channel and simulate sheet-flow through the adjacent vegetation to enhance pollutant assimilation. Prior to reflooding, vegetation consisted of heavily grazed unimproved pasture with only a small area (2 ha) of marsh. An area of approximately 125 ha has been fenced to control cattle access to the site. Extensive areas of organic muck soil exist at lower elevations.

Figure 3 illustrates the proposed annual water level control elevations at the discharge structure and a hypothetical plot of actual water levels in response to rainfall. This regulation schedule reflects certain functional constraints imposed on water levels by the physical layout of the site, including a minimum control elevation of 14.3 meters (47.0 ft.) msl and a maximum of 14.9 meters (49.0 ft.) msl. Actual water levels will probably fluctuate between 14.2 meters (46.5 ft.)msl and 16.5 meters (54.0 ft.) msl over the long term. It is anticipated that a stage of around 15.8 meters (52.0 ft.)msl will be reached on an annual basis.

<u>Kissimmee River Restoration Alternatives</u>

The Council's efforts addressing water quality in and restoration of the Kissimmee River focus on re-creation of floodplain wetlands as

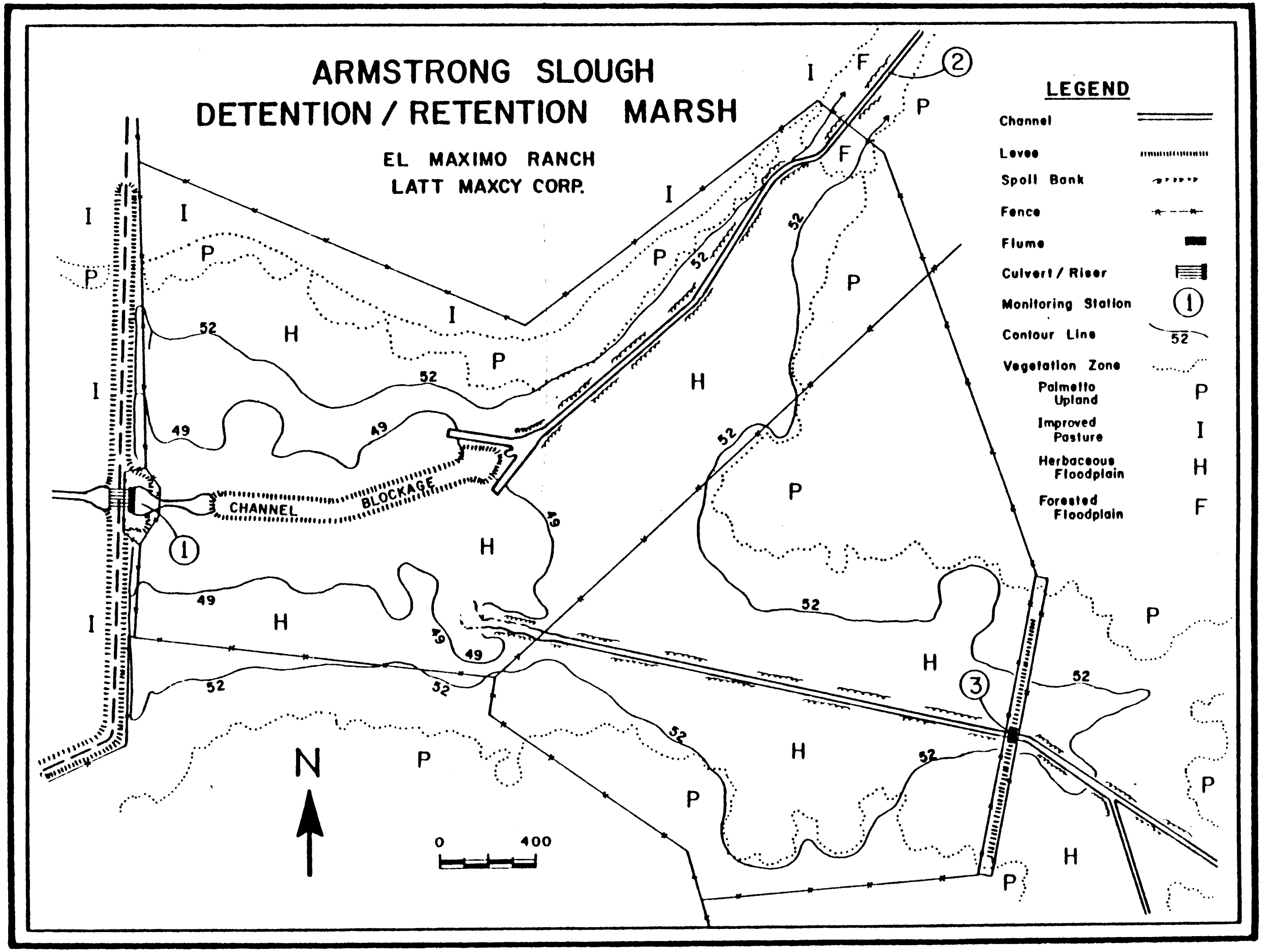
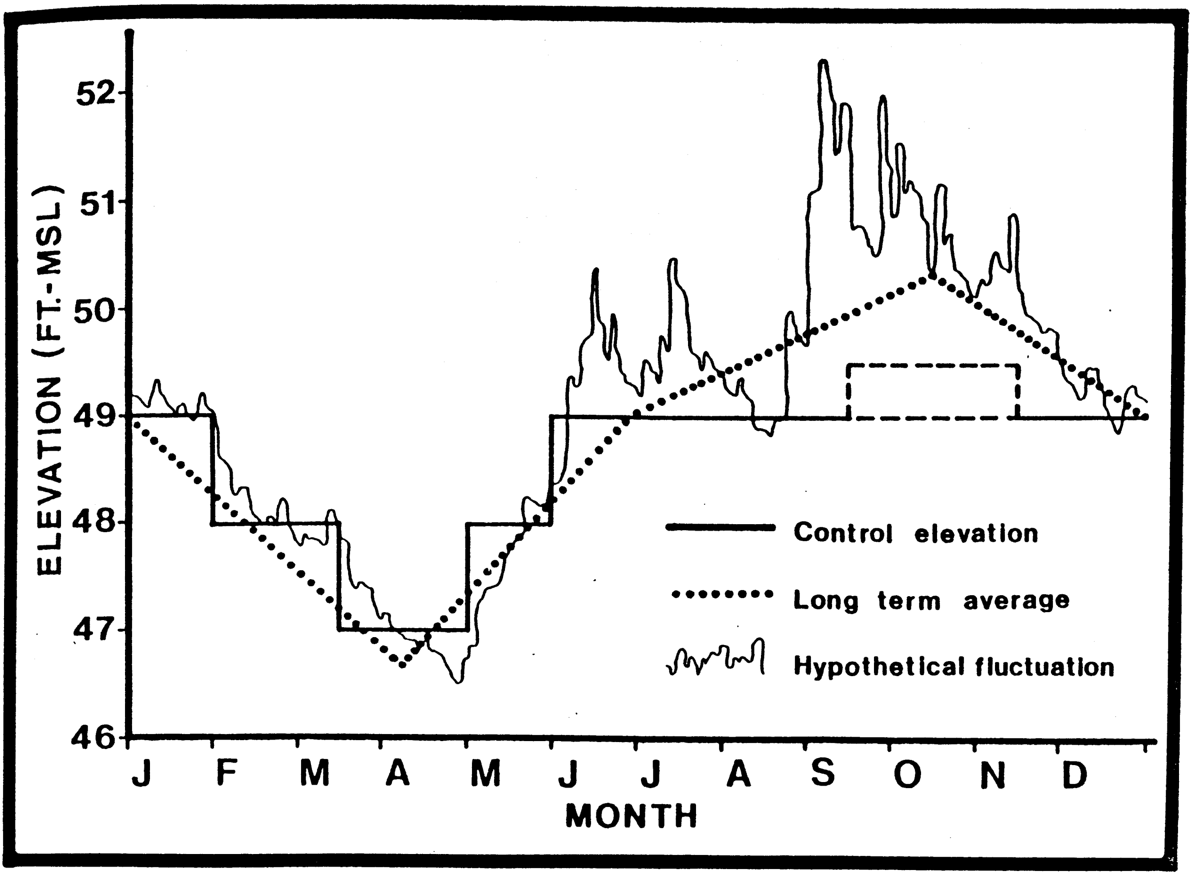


Figure 2. Site map for Armstrong Slough detention/retention marsh.

Figure 3. Annual water level control elevations, hypothetical fluctuation and anticipated long term average for the Armstrong Slough detention/retention marsh.



the primary objective and reestablishment of a meandering river system as a potential objective, depending on feasibility. The original channelization, completed in 1971 by the Corps of Engineers as part of a public works flood control project, reduced floodplain marsh acreage from 16,200 ha in 1954 to 3600 ha in 1974 (Pruitt and Gatewood 1976). Approximately 3100 ha of the current marsh exist under stabilized water level conditions immediately above each of five control structures along Canal-38 (Figure 1). These control structures create essentially flat pools that step water levels down in six foot increments along the naturally sloping floodplain. In contrast to the permanently flooded area just above each structure, the area below each structure is permanently drained. This has permitted the amount of improved pasture in the floodplain to be increased from 2400 ha in 1954 to 11,400 ha by 1974. In addition, spoil from canal excavation covers 3500 ha (Pruitt and Gatewood 1976). Thus the loss of wetland habitat was significant and the quality of remaining habitat has been reduced (Goodrick and Milleson 1974).

Prior to channelization, the Kissimmee River meandered approximately 56 km through a floodplain that averaged 2/3 km wide. Water levels fluctuated considerably on an annual basis and even more drastically over the long term (Figure 4). Channelization reduced channel

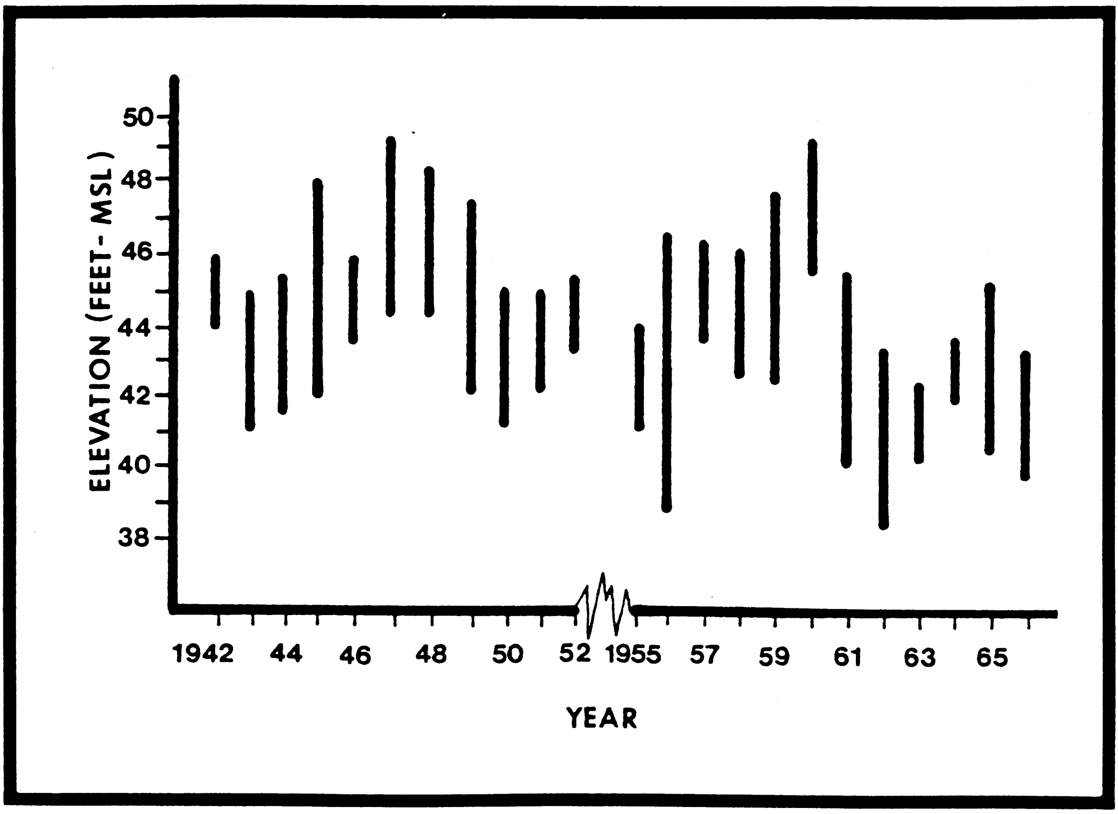


Figure 4. Annual range of water level fluctuation in the Kissimmee River floodplain at Fort Kissimmee gauge: 1942-1966.

length to about 31 km and confined the majority of water flow to a canal that is 9.1 meters deep and averages 90 meters wide. Even during intense and prolonged rainfall events, water levels remain relatively stable and confined to the canal prism.

The Council interpreted its enabling legislation as not requiring the physical restoration of a meandering Kissimmee River, but also not ruling that out of consideration. As a result, a wide variety of alternatives were initially evaluated, ranging from complete de-channelization of the C-38 system to actions as basic as manipulating water levels in the existing pools above each structure (Table 2). Based on preliminary analysis during the first year, the Council recommended a partial backfilling alternative if C-38 was to be negated and an impounded wetlands alternative if C-38 was to be retained (Figure 5). The ultimate decision was left in the hands of the Legislature.

Table 2. Restoration alternatives for the Kissimmee River.

1. COMPLETE BACKFILLING	6. SHEET-PILE PLUGS
2. PARTIAL BACKFILLING	7. STRUCTURAL PLUGS
3. FLOW-THROUGH MARSHES	8. PARALLEL WATERCOURSES
4. TRIBUTARY MARSHES	9. DEFLECTION DAMS AND GROINS
5. EARTHEN PLUGS	10. POOL-STAGE MANIPULATIONS
11. COMBINATIONS AND PERTURBATIONS	

However, the Council also recognized Federal authority over the system of works and recommended that the Corps of Engineers be authorized by Congress to thoroughly restudy the existing system and recommend modifications if necessary. A "Survey Review" was authorized and funded

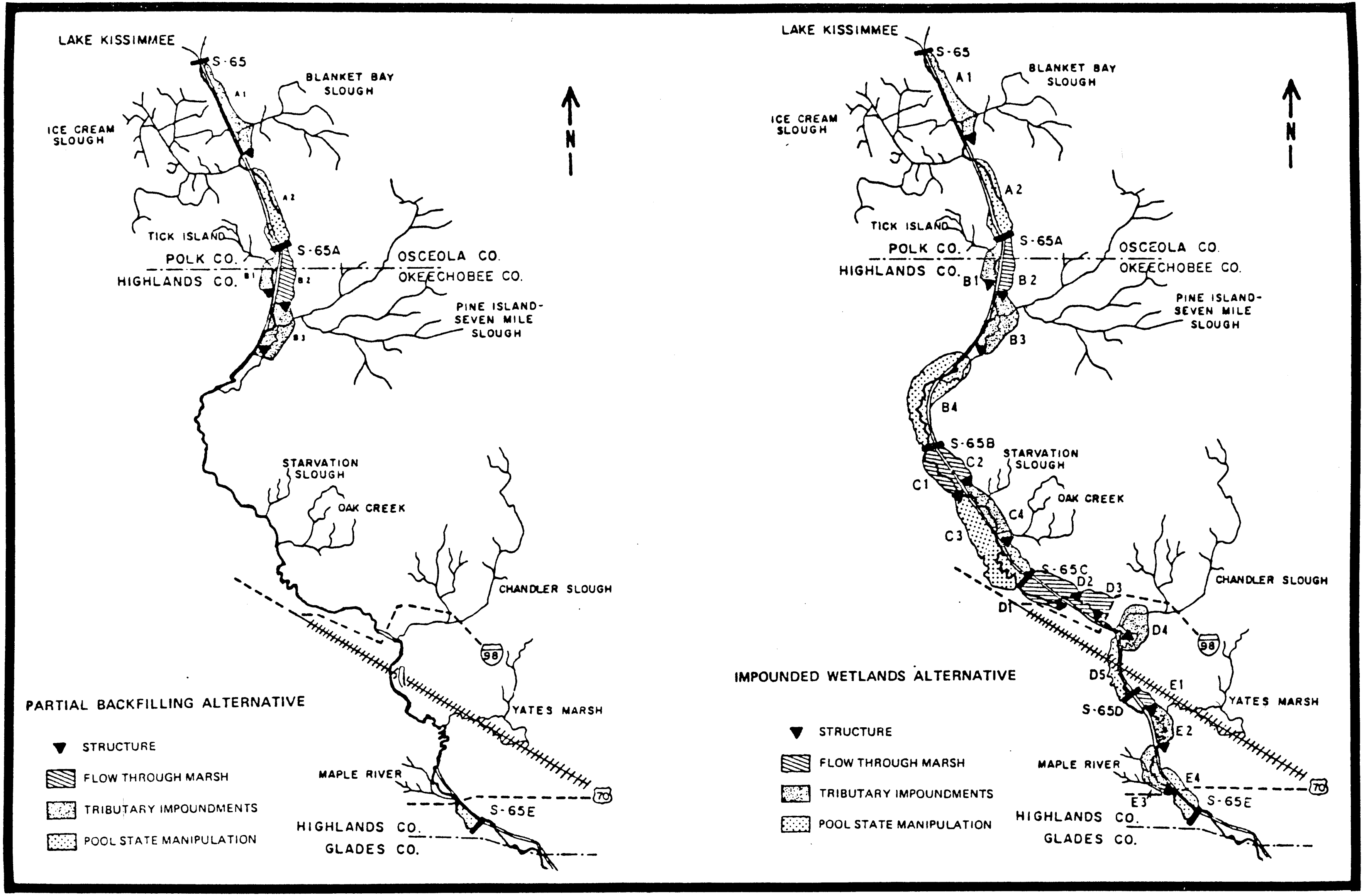


Figure 5. Partial backfilling and impounded wetlands restoration alternatives.

in 1978 and is scheduled for completion in 1982. The Corps is looking at a similar range of options, however in much greater detail and with the ultimate goal of developing a specifically designed plan or plans for implementation. The state must then decide which alternative plan should be implemented and seek further authorization and funding from the Congress to proceed.

DISCUSSION

The Armstrong Slough site and the demonstration project in general were designed to follow through with proposals and recommendations made prior to creation of the Council. Addressing nutrient problems at the source is recognized as a major part of the overall plan to protect Lake Okeechobee from further cultural eutrophication. Restoration and creation of wetlands in upland areas as biological treatment units and as viable habitats in and of themselves may prove to be a simple, inexpensive and low energy means of dealing with problem areas.

Data from research investigations of baseline conditions at Armstrong Slough has been compiled and will provide a point from which to measure changes and impacts as long-term reflooding proceeds and marsh restoration is completed. It is anticipated that about 14 ha of permanent marsh wetland will be created at this site. This is not much when considering the total loss of wetland habitat sustained in this watershed as a result of development for intensified use, but the demonstration aspect of this project could show the way for landowners throughout the region to implement similar practices on their respective holdings.

In the Kissimmee River floodplain, most people agree that some type of wetlands restoration activities are required for water quality enhancement and mitigation of habitat losses. They also agree that reestablishment of a more natural hydroperiod, considering both fluctuation level and duration, is the best way to achieve this end. The point of divergence is how to re-create this hydroperiod and to what extent.

Partial backfilling would restore about 2/3 of the meandering river and result in re-creation of approximately 9200 ha of wetlands controlled by naturally fluctuating water levels within the restored reaches. It would also create 2100 ha of artificially managed wetland detention areas, similar to the Armstrong Slough site, in sections of the floodplain where C-38 is retained for flood control purposes. The impounded wetlands alternative would create a whole series of these managed wetlands totalling about 8700 ha along the length of C-38. The canal would be maintained in its entirety; however, water management in the system would be altered to accommodate the new conditions. The pool stage manipulation alternative would require minor modifications to the existing structures to permit fluctuation of water levels and should increase pool marsh area from 3100 ha to 6800 ha. Most other aspects of the system would remain unchanged. Even though the Federal survey review is only half completed, the Jacksonville District of the Corps has already indicated that the "no action" alternative, i.e. no modifications, is not a viable alternative. Some form of wetlands restoration will occur, depending on the final analysis of costs and benefits, hydrologic impacts, water quality impacts and a host of other parameters, not the least of which will be the political realities that exist at the time the decisions are made.

In summary, the Kissimmee River basin is at a point in time where the potential for substantial restoration and protection of wetland systems now exists, following the previous era of rampant wetlands destruction and mismanagement. Through demonstration projects in upland area wetlands, landowners can see the value of marshes for grazing, pollutant reduction, water management and habitat preservation. Through the Kissimmee River Survey Review and related state efforts, some level of restoration of floodplain wetlands will be undertaken, including the potential re-creation of a meandering riverine system. These efforts to revitalize damaged wetlands throughout the watershed should serve to demonstrate a growing commitment to protection, enhancement and enlightened utilization of wetland systems on a massive scale.

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EFFECTS OF WATER LEVEL INCREASES ON KISSIMMEE RIVER VEGETATION

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ABSTRACT

The Kissimmee River system has been modified by the construction of a drainage and navigational channel and a series of water control structures. These changes have effectively drained major portions of the former marshlands. In the present study, effects of marsh reflooding were observed on vegetation in ten study plots in the Kissimmee River floodplain.

Study plots were established in Pool B in areas that were 12.1 to 12.9 m above mean sea level (msl) and represented a variety of vegetation communities. Pool B had been maintained at or below 12.3 m msl since 1971. Water levels in Pool B were increased to 12.5 m msl from October through April during the years 1974 through 1978. Changes in vegetation in each plot were documented monthly from October 1974 through September 1976 and annually in 1977 and 1978.

Areas that were near 12.2 m, especially near the river, showed an increase in floating species such as water hyacinths (Eichhornia crassipes). Emergent species such as pickerelweed (Pontederia lanceolata) and maidencane (Panicum hemitomon) increased in coverage in study plots just above the 12.2 m contour. Softrush (Juncus effusus), which had been dominant in many areas above 12.2 m, generally was reduced in number and size of plants. Areas above 12.5 m showed stimulated growth of wax myrtle (Myrica cerifera) and a loss of understory vegetation.

Regulation of water levels is an essential feature of floodplain management. Further studies of the effects of water level manipulation, in conjunction with controlled burning and other plant control measures, are recommended as tools for management of the existing Kissimmee River floodplain.

INTRODUCTION

The Kissimmee River floodplain has been severely altered in recent years by man's activities. Major changes have included the construction of the C-38 canal from 1962 to 1970 and the conversion of much of the upland marshes to improved and unimproved pastures (Dineen 1974). Various management techniques have been suggested for this floodplain to reestablish some of the drained marshes. Alteration of these marshes may be desirable to improve fish and wildlife habitats, remove nutrients from the river system, and preserve water quality in Lake Okeechobee (Florida DOA 1976). Methods that are used in other parts of the country and that have been used successfully in other parts of Florida include seasonal reflooding, drying, and burning (Lynde 1969).

Previous studies in the Kissimmee River valley have shown that seasonal fluctuations in water levels increase plant species diversity, especially among those species that reproduce annually, and result in a high rate of seed production of these plants (Goodrick and Milleson 1974; Dineen 1972; Dineen et al. 1974; Dineen 1974; Federico et al. 1978). These fluctuations also stimulate the growth of willows and myrtles that provide nesting habitat for wading birds and provide for the seasonal abundance of food organisms for these birds.

In the early 1970's, experiments were conducted to assess the effects of water level drawdowns on river marshes (Goodrick and Milleson 1974). During this period, Pool B was maintained at 12.2m (40 ft) above mean sea level (msl), or below, from 1971 until 1975. Seasonal reductions in water levels were shown to increase secondary productivity by favoring the production of small aquatic animals during high water periods and by increasing the food supply of larger predators during dry periods (Milleson

1976). Fire also results in a significant increase in numbers and diversity of aquatic macrofauna (VanArman and Goodrick 1979).

In the present study, seasonal increases in water levels were used to reflood portions of the Kissimmee River floodplain that had been drained for about four years. The effects of this reflooding were observed and documented from 1974 to 1978.

AREA DESCRIPTION

Alterations of the Kissimmee River by the Corps of Engineers have created five water control impoundments within the floodplain (Dineen et al. 1974). The current studies were conducted in the second impoundment, Pool B (Figure 1A). This impoundment has several remaining areas of marshlands near the southern end, an extensive oxbow system, and plant species that are generally representative of marshes throughout the Kissimmee floodplain.

Sample site locations (Figure 1B) were selected on the basis of: 1) representation of plant communities that are marginal or transitional between terrestrial and wetland areas; 2) proximity to the river; and 3) accessibility.

MATERIALS AND METHODS

Reference plots were established at 10 stations in Pool B. Each plot was defined as 3.05 x 3.05m square. Each corner of the plot was permanently marked by placement of a metal pipe. A photo reference pipe was mounted 4.5m south of each plot. Photographs were taken from the reference pipe monthly from October 1974 to October 1976; in April 1977; and April 1978. Each plot was examined in detail at the time that it was photographed to document the growth and distribution of plants. Subjective observations were made to note which species were

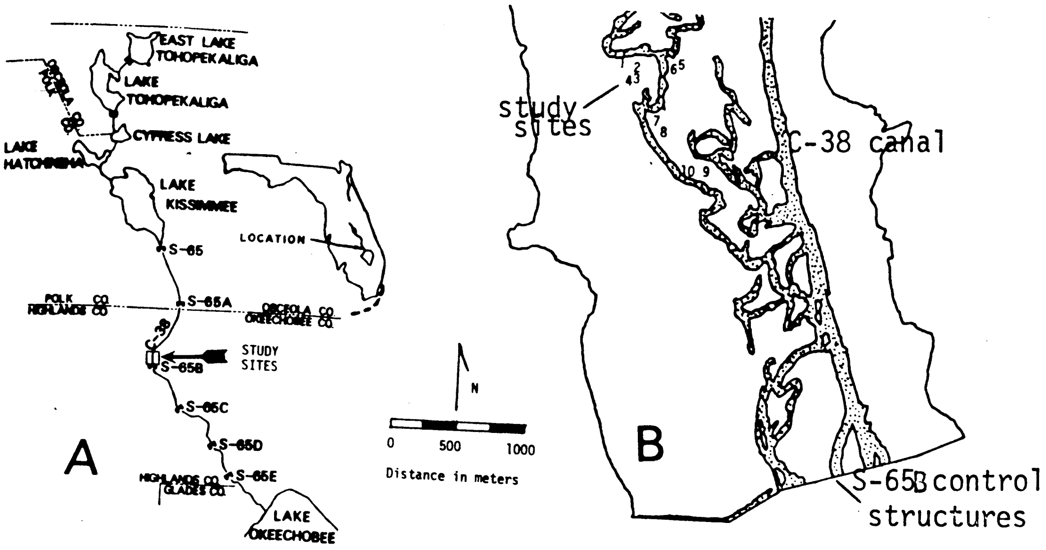

Figure 1. The Kissimmee River valley in Florida (A) and the location of ten selected study sites in the river floodplain (B).

simply present in small numbers, were common, or were dominant in the plot.

Two metal pipes were used to mark the front of each study site. Numbered tags were placed on the left-hand pipe to record the plot number and date of the photograph. Surveyor's range poles, graduated at 30.5cm increments, were placed at the back corner of each site to provide a vertical reference scale. Pool water levels for the period of record, 1969 to 1978, were monitored by a permanent recorder at control structure S-65B (see Figure 2A). At the time that each plot was established, surveyors' instruments were used to establish the ground elevation at the center of the plot, at each corner of the plot, and to reference these elevations to the surface elevation of the pool, which was 12.51m (41.03 ft.) msl. Figure 2B shows the average elevation and range of elevation in each plot.

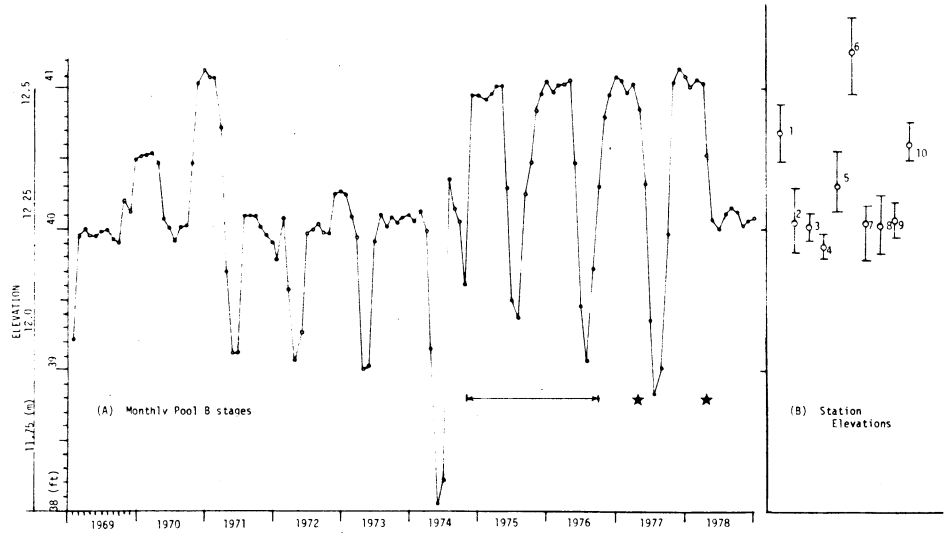

Figure 2. Pool stage levels and experimental plot elevations in Pool B. Historic stage records from 1969 thru 1978 (A). Monthly observations were made in 1974, 1975, and 1976 (—), followed by observations (*) in April 1977 and April 1978. Elevations of study plots (B).

RESULTS

The plant species that occurred in the ten study plots are listed in Table 1 according to the frequency of occurrence in the plots. The first four species occurred in all ten plots. The next species occurred in nine plots, the next three species occurred in eight of the plots, etc. An analysis of the monthly observations and a description of the vegetation changes that were recorded by photography are presented below.

Plot 1. Plot 1 was located approximately 3.7m from a river oxbow on a slight ridge. When the pool was flooded to 12.51m (41.03 ft.) msl, land surface elevation of this plot averaged 10.1cm above the water table (see Fig. 2B).

Ground cover vegetation at the start of the experiment consisted of various species of grasses, *Panicum repens*, and *Centella asiatica*. Emergent vegetation consisted of 3 clumps of *Juncus effusus* and three

Table 1. Plant species observed in ten study plots in the Kissimmee River floodplain, 1974 to 1978.

	PLOT 1 4-75 4-76 4-77 4-78	PLOT 2 4-75 4-76 4-77 4-78	PLOT 3 4-75 4-76 4-77 4-78	PLOT 4 4-75 4-76 4-77 4-78	PLOT 5 4-75 4-76 4-77 4-78	PLOT 6 4-75 4-76 4-77 4-78	PLOT 7 4-75 4-76 4-77 4-78	PLOT 8 4-75 4-76 4-77 4-78	PLOT 9 4-75 4-76 4-77 4-78	PLOT 10 4-75 4-76 4-77 4-78
Centella asiatica	C P P P	P P P -	C P P P	* P P P	C P P P	C C C P	P P P P	P P P P	P P P -	C P P P
Diodia virginiana	P - P -	- - * -	P * P P	P P P P	P P P P	* * P -	P * P P	P * P -	* * P P	P P P C
Hydrocotyle umbellata	P - P C	P P P P	C P P P	* P P P	P P P P	* P P P	P P P P	- P P P	* P P P	P P P P
Panicum repens	C D P P	D C C P	D D D D	P * * P	D D C P	C C C -	C C C C	D D C C	D P P -	D D D D
Ludwigia repens		P P P P	P - - -	P * * P	P P P -	- P * -	* P P P	P P P P	P P P P	P P P C
Alternanthera philoxeroides	P D P D	P P P P			P P P D	P P P -	P C C D	C C C C	P P P P	P P P P
Hydrochloa caroliniensis	- - - D	D D C P	- P P -	- * - -	- P P P	- P P P	D D C D		D C C -	
Juncus effusus	P P P P	P P P P			P P P P	P P P P	D C P P	P P P P	P P P C	P P P P
Unknown grasses	C P P P	P - - -	P P P P		P P P P	P P P P		P P P -		P P P P
Bacopa caroliniana		- - - P	C P P C	C C C C	P P P D		- P P P	C C C D	* P P P	
Leersia hexandra	P - P -	C P P P	C P - -	C P P -	* P P -			P P P P		
Pontederia lanceolata		- * * D	P P P -	P P P C			P P P P	P P P P	P C C D	
Eleocharis acicularis		P P P -	P * * -			* P P -	- P P -	P P P -	- - P P	
Fuirena pumila		* - - -			* * - -			- - * -	- P P -	P * P -
Panicum hemitomon	- P P -	P P P -	- P P -	P C P P			P P P P			
Rhynchospora harveyi			* - - -		P * - -	- * - -		P * - -		P * - -
Urena lobata	* P P -					P P P P	P * - -		P - - -	- * * -
Ambrosia elatior	* - - -				- - * -	P * * P		* * - -		
Cephalanthus occidentalis				P P P P		P * * P	* P P P	P P P P		
Eleocharis sp.				P P P -	- P P -					- P P -
Lippia nodiflora				P * * P	P P P P	P P P -				* * P P
Sagittaria lancifolia			P * - -	P P P C			P P P P	P P P P		
Cyperus haspan					P * * -	P * P -				
Eclipta alba		- * * -							- * P P	- * - -
Eichhornia crassipes		P D D D			- - - P					- * - -
Eupatorium capillifolium	P * P -					P P - -		P P * -		
Sacciolepis striata		- * - -		- * * -			- - P -			
Unknown Leguminosae					- - - P	* P P P		- * - -		
Unknown sp.	- P - -					- * - -				* - - -
Aster sp.						* - - -	* - - -			
Commelina communis						* * - -			P * - -	
Cyperus articulatus		- - P -		P P P P						
Cyperus sp.		- * P -				P * * -				- * P P
Glottidium vesicaria						- * - -				* - P P
Hibiscus grandifloris							P P P P	P P P P		
Juncus bifloris					* - - -	- * * -				
Jussiaea sp.			- P P -			- - * -				
Mikania sp.							- P P P	P P P P		
Myrica cerifera					P P P D	P P D D				
Panicum paludivagum				- * - -					- P - -	
Polygonum sp.				* * - P				P P P P		
Proserpinaca palustris		P * - -		P P P P						
Sagittaria latifolia		P P P P					- P P P			
Unknown mint/composite							* P P -			- * - -
Andropogon sp.							* - - -			
Azolla caroliniana		- * * -								
Cicuta sp.									- - - P	
Cirsium horridulum						* - - -				
Echinochloa walteri		- - P -								
Habenaria repens								- * - -		
Hypericum mutilum										- P P -
Juncus megacephalus										- * - -
Juncus sp.										P * - -
Jussiaea peruviana								- P P P		
Lindernia anagallidea										- * P P
Oxalis sp.						P P - P				
Paspalum dissectum		- - * -								
Paspalum sp.	- * P -									
Pistia stratiotes	- P * -									
Polygonum hydropiperoides									C C P P	
Psidium guajava										* - - -
Rhynchospora inundata				C C C C						
Sarcostemma clausa								P P P P		
Unknown Malvaceae							- - P -			
Unknown Verbinaceae								* * P -		
Unknown Orchidaceae						* - * -				
Utricularia sp.		- * * -								
Xyris sp.										- - P -

Key: C = Common
P = Present
D = Dominant
- = Not Observed

* = Observed during previous year, but not in month indicated

terrestrial species, Urena lobata, Eupatorium capillifolium, and Ambrosia elatior.

During the first season of flooding, C. asiatica and Hydrocotyle umbellata declined in abundance and P. repens became dominant along with Alternanthera philoxeroides. By the end of the second year, P. repens had declined; unidentified grasses, Hydrocotyle umbellata and A. philoxeroides were the most common species. After four years, A. philoxeroides and Hydrochloa caroliniensis were the dominant species and H. umbellata was common.

All three terrestrial species disappeared during the first year. U. lobata was reestablished during the subsequent dry period from May 1975 to October 1975 and seedlings persisted for the next two years. J. effusus plants in Plot 1 declined noticeably in total size and number of shoots within two years. Only vestiges of these plants remained after four years.

Plot 2. This plot was approximately 21.4m from the river oxbow and had an average depth of 30.2cm when Pool B was at 12.5m msl. Vegetation in Plot 2 initially consisted of an understory of P. repens, H. caroliniensis and Leersia hexandra. Several clumps of J. effusus were present in the plot. Eichhornia crassipes and Sagittaria latifolia were also present in small numbers. Flooding of the plot covered much of the understory vegetation. At the end of the first wet season, E. crassipes and A. philoxeroides had increased in abundance. There was less open water in the plot during the second year of reflooding than had been present during the first year. When water levels were lowered in May 1976, E. crassipes was the dominant ground cover species and P. repens and H. caroliniensis were common. E. crassipes was the dominant ground cover species after four years. Very little change in emergent vegetation occurred during the first year. During the second year, Pontederia lanceolata invaded the plot. By the end of the second year, J. effusus had noticeably declined in size and number of shoots. After four years, P. lanceolata was the dominant emergent species and J. effusus plants were in very poor condition.

Plot 3. Plot 3 was located about 150m from a river oxbow. This plot had an average depth of 31.1cm when Pool B was at 12.51m msl.

Vegetation in Plot 3 consisted entirely of ground cover plants and grasses. P. repens was the dominant grass but was mixed with several other unidentified grasses. Bacopa caroliniana, L. hexandra, H. umbellata, and C. asiatica were common. During the first year after reflooding, the plot was invaded by species such as P. lanceolata, Eleocharis acicularis, Sagittaria lancifolia, Jussiaea sp., Panicum hemitomon, and H. caroliniensis, but these species did not become common. At the end of the first year, the abundance of B. caroliniana, H. umbellata, C. asiatica, and L. hexandra had declined. There were no signigicant changes in species composition in this plot during the second, third, and fourth years.

Plot 4. Plot 4 is located about 160m from the oxbow. Water depth in this plot averaged 35.7cm when Pool B water stage was 12.51m msl. This plot contained a diverse mixture of wetland plant species. L. hexandra and B. caroliniana were the dominant understory plants. Taller vegetation included S. lancifolia, P. lanceolata, Rhynchospora inundata, Cyperus articulatus, and P. hemitomon.

By the end of the first year, L. hexandra had declined in abundance, and P. lanceolata, S. lancifolia, and P. hemitomon had increased in abundance. Within two years, P. lanceolata was the dominant species. After three years, P. lanceolata, and S. lancifolia appeared to be equal in abundance. By the end of four years, growth of S. lancifolia was greater than that of P. lanceolata. P. repens and B. caroliniana were the dominant components of the understory.

Plot 5. This plot is located approximately 66m from a river oxbow. Elevations ranged from a water depth of 14.6cm to an elevation of 27.7cm above the water table when the stage in Pool B was 12.51m msl.

Ground cover vegetation in Plot 5 at the beginning of the experiment was dominated by P. repens and C. asiatica. Taller plants included J. effusus and one specimen of Myrica cerifera.

Ground cover vegetation showed an influx of wetland species such as L. hexandra, L. repens, H. caroliniensis, and E. acicularis during the first and second years. P. repens and C. asiatica decreased in abundance after two years. After four years, P. repens and C. asiatica were less abundant. L. hexandra, L. repens, H. caroliniensis, and E. acicularis were not observed. B. caroliniana and A. philoxeroides were the dominant species of ground cover vegetation.

Within one month after the pool was raised, M. cerifera was stressed, as evidenced by chlorosis. This plant remained chlorotic throughout the wet season, but flowered in March. M. cerifera recovered when the pool was lowered, but by the end of the first year, this myrtle had grown much less than myrtles on a nearby ridge that were not flooded (see Plot 6). The myrtle in Plot 5 grew rapidly during the second year and was the dominant plant in the plot after four years. The size and number of shoots of J. effusus in Plot 5 declined noticeably within two years and were greatly reduced after four years.

Plot 6. Plot 6 was located above the 12.5m contour and was 40m from the nearest oxbow. When Pool B was raised to 12.51m msl, this plot averaged about 30.5cm above the 12.51m water level.

Overstory vegetation in this plot at the beginning of the experiment consisted mainly of M. cerifera, J. effusus, E. capillifolium, and U. lobata. During the study period, M. cerifera grew rapidly and eventually covered the entire plot. J. effusus declined in size, probably due to effects of crowding or shading. E. capillifolium disappeared from the plot during the second year. The terrestrial shrub U. lobata did not show signs of stress throughout the four-year test period.

Understory vegetation in Plot 6 at the beginning of the experiment consisted primarily of P. repens and C. asiatica, Aster sp., Cirsium horridulum, Oxalis sp., an unknown species of Orchidaceae, Commelina communis, and mixed grasses. During the first year, E. acicularis, L. repens and H. caroliniensis were observed in the plot. Aster sp. and C. horridulum disappeared. During the second year, ground cover remained dominated by P. repens, C. asiatica and mixed grasses. After four years, P. repens was no longer observed in the plot. The understory consisted of a low-growing carpet of mixed grasses, H. caroliniensis, and C. asiatica.

Plot 7. This plot is located approximately 44m from a river oxbow and had an average depth of 30.2cm when the water level in Pool B was at 12.51m msl.

The taller vegetation in Plot 7 consisted of clumps of J. effusus and several plants of P. lanceolata, S. lancifolia, U. lobata, Hibiscus grandifloris, Cephalanthus occidentalis, and Andropogon sp. After one year, Andropogon sp. and U. lobata were no longer present and P. lanceolata and S. lancifolia had increased in size. After two years, S.

lancifolia was the dominant overstory plant. Several plants of S. latifolia were present after four years, H. grandifloris was more abundant, and J. effusus was reduced in size.

Ground cover vegetation at the beginning of the experiment was dominated by H. caroliniensis and P. repens. After one year, the A. philoxeroides had increased in abundance. During the second year, the plot was invaded by aquatic ground cover species, B. caroliniana and E. acicularis. After four years, H. caroliniensis was the dominant ground cover species and P. repens and A. philoxeroides were common.

Plot 8. Plot 8 is located on a narrow ridge about 11m from an oxbow and had an average depth of 30.8cm after reflooding. Major species in the overstory included J. effusus, H. grandifloris, P. lanceolata, Polygonum sp., S. lancifolia, and C. occidentalis. There was little change in species composition or distribution in this plot in the first two years. S. lancifolia spread along the east side of the plot and Polygonum sp. declined in abundance. During the second year, Juncus peruviana became established. After four years, species composition was similar to the composition of the original plot, with the exception that H. grandifloris had formed a dense growth on the east side of the plot.

Ground cover in Plot 8 was dominated by P. repens. A. philoxeroides and B. caroliniana were common, and C. asiatica, L. repens, L. hexandra, and E. acicularis were present in smaller amounts. H. umbellata invaded the plot during the first year. At the end of two years, the ground cover contained these same species, but P. repens was common rather than dominant, and B. caroliniana had increased in abundance. After four years, B. caroliniana was dominant and P. repens was common. L. repens, L. hexandra, and E. acicularis were not observed in Plot 8 after four years.

Plot 9. Plot 9 was located about 55m from the river oxbow and had an average depth of 29.6cm when the stage of Pool B was 12.51m msl.

Overstory vegetation of Plot 9 included J. effusus, Polygonum hydropiperoides, and U. lobata. One plant of P. lanceolata was above the water table when Pool B was at 12.2m msl. Within the first year after flooding, U. lobata disappeared from the plot and P. hydropiperoides increased in abundance. During the second year, the amount of P. hydropiperoides declined and the amount of P. lanceolata increased dramatically. After four years, P. lanceolata was dominant over most of the Plot and J. effusus dominated the remainder of the Plot. P. hydropiperoides was still present.

Ground cover in Plot 9 was dominated by H. caroliniensis and P. repens at the beginning of the study. During the first year, B. caroliniana, L. repens, and E. acicularis invaded this plot and P. repens was no longer dominant. After two years, H. caroliniensis was dominant. Within four years, most of the understory had been lost and H. caroliniensis, P. repens, C. asiatica, L. repens, and E. acicularis were no longer observed in this plot.

Plot 10. Plot 10 was located on a ridge, 8m from an oxbow, and contained a mixture of pasture grasses, seedlings of terrestrial plants and small clumps of J. effusus. Water depth in Plot 10 averaged 14.0cm when the Pool B water stage was at 12.51m.

Virtually all plants in Plot 10 were less than 30cm in height. P. repens was the dominant species in Plot 10 throughout the course of the study. C. asiatica was common in this plot at the start of the study, but the abundance of this species declined during the first year. Two wetland plants, H. umbellata and D. virginiana, were also present along with seedlings of two terrestrial species, Psidium guajava and

Glottidium vesicaria.

Plot 10 showed a continual influx of new species, especially during the first year. By October 1976, the species composition of this plot was almost the same as at the beginning of the experiment. After four years, there was a noticeable increase in *L. repens* and *D. virginiana*.

SUMMARY AND CONCLUSIONS

This study was designed to document the effects of flooding the 30.5 cm (one ft.) contour interval, which lies above the previously stabilized maximum stage of Pool B in the Kissimmee River floodplain.

Ten experimental plots were established and ranged in elevation from 12.11 to 12.97m above mean sea level (msl). Water levels were fluctuated between elevations of 11.83 and 12.53m during the period from 1974 to 1978. Water levels in Pool B had been previously stabilized below elevation 12.34m from 1970 through September 1974.

Vegetation in the contour interval between 12.11 and 12.97m, prior to the experiment, consisted of three types: 1) a diverse mixture of understory species, especially *Centella asiatica*, *Hydrocotyle umbellata*, *Panicum repens*, *Alternanthera philoxeroides*, and *Hydrochloa caroliniensis*; 2) taller, emergent marsh plants and shrubs such as *Juncus effusus*, *Panicum hemitomon*, *Sagittaria lancifolia*, *Pontederia lanceolata*, *Cephalanthus occidentalis*, and *Polygonum* sp.; and 3) several terrestrial species such as *Myrica cerifera*, *Urena lobata*, *Ambrosia elatior*, and *Eupatorium capillifolium*.

Among the understory species, *C. asiatica* declined in plots 1,3,5, and 10, and *H. umbellata* increased in abundance in plots 1,6,8, and 9. *P. repens* and *H. caroliniensis* had variable responses. *P. repens* showed an initial increase in abundance followed by a decline in plots 1,2,5,6, 8, and 9. In plots 3,4,7, and 10, P. repens showed no significant change. A. philoxeroides increased in plots 1,4, and 7 but showed no significant change in other plots. H. caroliniensis increased in plots 1,3,5, and 6 and decreased in plots 2 and 9.

J. effusus declined in plots 2,5, and 7 and increased in Plot 9. Panicum hemitomon increased in plots 1,3, and 4 and declined in Plot 2. S. lancifolia declined in plot 3 and increased in plot 4. P. lanceolata increased in plots 2, 4 and 9 but decreased in plot 3. C. occidentalis was generally unaffected.

The terrestrial species generally responded adversely to increased water levels except in Plot 6 where the plot was not flooded. U. lobata declined in plots 1,7,9, and 10, but was not affected in plot 6. A. elatior declined in plots 1 and 8, but not in Plot 6. E. capillifolium declined in plots 2, 6, and 8. M. cerifera was adversely affected during the first year in Plot 5, but showed stimulated growth during the three following years. Growth of M. cerifera was stimulated throughout the four year period in Plot 6.

The combination of various management techniques such as drawdowns, reflooding, fires, etc., which simulate the pattern that has evolved through natural wet and dry cycles, may optimize the transfer of nutrients up through the food chain and the removal of these nutrients from the river system. Reflooding stimulated growth of some species of marsh plants in the newly flooded areas and caused significant shifts in the distribution of species. Both water drawdowns and reflooding stimulate growth of some major plant species and alter existing vegetation patterns. The significance and desirability of these changes needs further evaluation.

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AN EVALUATION OF WETLAND HABITAT ESTABLISHMENT AND WILDLIFE UTILIZATION IN PHOSPHATE CLAY SETTLING AREAS

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ABSTRACT

The Florida Game and Fresh Water Commission is cooperating with International Minerals and Chemical Corporation and the U.S. Fish & Wildlife Service in conducting a three year project to determine techniques for establishing wooded and herbaceous wetland habitat on phosphate mined land in Central Florida. Diked ponds used for waste clay storage are an integral part of present central Florida phosphate mining operations. The combination of rich phosphatic clays, surface water storage and natural plant succession has created elevated wetlands which support impressive populations of waterfowl, wading birds, mammals, amphibians and reptiles. Clay settling areas typically progress successionally from open water to herbaceous and shrub stages as the surface layer consolidates and dries. Results from field studies of 12 phosphate clay settling areas of varying ages totalling over 1,214 hectares (3,000 acres) are presented in terms of wetland habitat succession and wildlife utilization. Management implications and options for reclamation are also discussed.

INTRODUCTION

Clay settling areas are diked retention basins used to store and consolidate the unusable clay fraction generated in the processing of phosphate ore. Above ground storage is necessary since the clay volume expands due to water absorption during ore processing. Dikes are usually constructed on mined land using overburden spoil material excavated from the interior of the basin. Clays, which average about three percent solids by weight, are pumped into a retention area where the particles settle as water flows across the basin toward active spillways. The clarified water is decanted and routed back to the plant for re-use. Pumping rates and locations and drawdowns are frequently varied to more effectively utilize available storage volume, speed consolidation and accommodate a variety of water management uses.

When the upper clay crust has consolidated to about 35 to 40 percent solids and is strong enough to support equipment, the basin is capped with tailings sand or overburden and converted to crop or pasture land (Farmer and Blue 1978). The period between the end of active use and final reclamation can be 15 to 20 years in some cases, prompting both governmental concern and considerable research within the industry on methods to speed consolidation. Current practices result in the development of settling area on about 50 to 75 percent of all mined lands in Central Florida. The construction, maintenance and location of settling areas with respect to local drainages is regulated by the Florida Department of Environmental Regulation.

During the period of active use, clay settling areas are rapidly colonized by wetland vegetation and support large populations of aquatic and wetland wildlife species. This project was initiated to assess the habitat quality of these artificial wetlands pursuant to an agreement between the Florida Game and Fresh Water Fish Commission and the U.S. Fish and Wildlife Service in cooperation with International Minerals and Chemical Corporation (IMC). The specific objectives were: (1) to identify and characterize the habitats of clay settling areas in terms of their dominant plant composition and wildlife use, and (2) to identify the physical factors which control plant succession and community composit

This paper presents our preliminary findings based on data collected from October 1979 through March 1980. A final report will be submitted to the U. S. Fish and Wildlife Service in December 1980.

AREA DESCRIPTION

Twelve clay settling areas were selected for study from more than 30 areas initially surveyed during the summer of 1979. Final selection was made to insure access and to represent the full range of vegetation types. To minimize possible bias from surrounding habitats, 5 contiguous areas were selected to support a more intensive data gathering effort (Fig. 1). All study areas are located in Polk County and are part of either IMC's Kingsford Mine near Bradley Junction or their Noralyn Mine south of Bartow.

MATERIALS AND METHODS

The vegetation patterns in each study area were mapped from recent aerial photographs. Plant associations were identified on the basis of dominants or distinct physiognomy indicated by field inspections. The maps were also used to determine the total area of each study site and their relative habitat type composition.

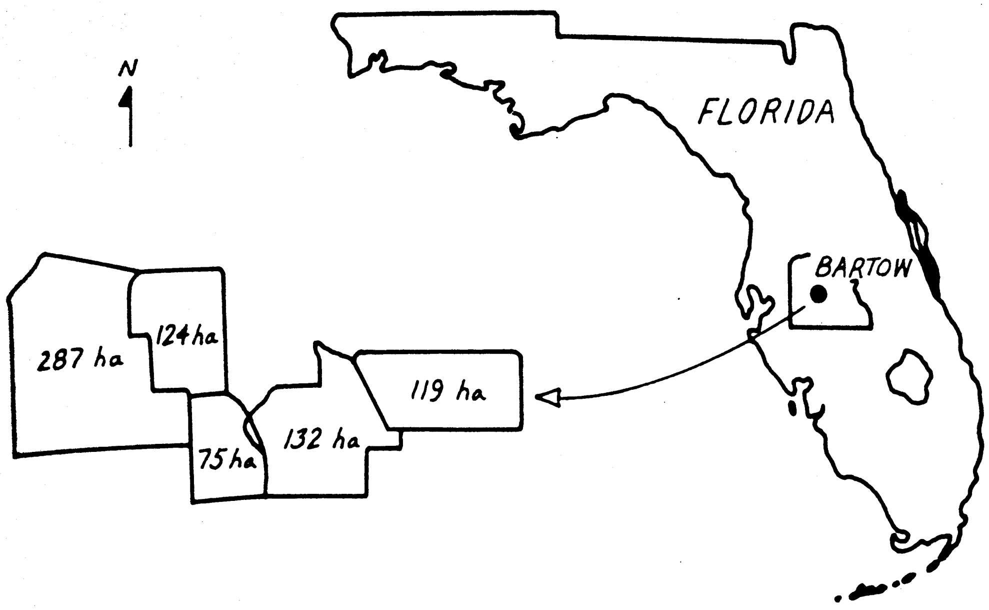

Figure 1. Configuration and location of the five intensively studied clay settling area sites.

Wildlife use of the 12 study areas was determined by recording observations from perimeter dike roads. Surveys included both total area wildlife counts and sampling within various habitats. Sixteen permanent observation points were established along the dikes of the five intensive study areas to sample the range of available habitat types. Viewing areas, which range from 0.8 to 32 hectares (2 to 80 acres) in size depending on the area which could be effectively observed from the dike, were then delineated using compass headings and local landmarks. The date, survey starting and ending times, weather conditions and use of habitat types by observed species were recorded on standard forms for each area and point sampled. Total area wildlife counts were conducted twice per month on the five intensive study areas, while the observation points were surveyed three times per month. Whole area surveys were performed monthly on the seven remaining areas.

Background information on the construction and management of the intensively studied areas was assembled to determine possible relationships and impacts on habitat development. Construction methods and materials, construction dates, dike configuration, size and potential storage volume, type and location of spillways, and the periods of active use were determined from IMC's records.

A water quality sampling program was also initiated in late January 1980 to provide information on four of the areas which have a sustained water flow. Samples are collected twice monthly at active inflow and outflow points and are analyzed by IMC for fluoride, phosphorus, pH, nitrates, total nitrogen, suspended solids and turbidity. This physical and chemical analysis and possible relationships to clay settling area biota will be included in our final report.

RESULTS

The contrasting vegetation patterns among our study areas (Fig. 2), illustrates that a typical wetland succession pattern occurs on clay substrates. Succession is apparently controlled by water level fluctuation and/or the degree of consolidation in the upper clay crust. The sequence of community types is: (1) open water or clay, occasionally dominated by rafts of water hyacinth (Eichhornia crassipes); (2) a rooted herbaceous stage, typified by cattail (Typha sp.) though occasionally represented by isolated stands of other early-colonizing emergents, particularly primrose willow (Ludwigia leptocarpa, and L.peruviana) and bulrush (Scirpus sp.); and (3) a woody shrub stage, dominated by Carolina willow (Salix caroliniana) usually in association with salt bush (Baccharis halimifolia) and wax myrtle (Myrica cerifera) in older stands. As the shrub community matures, the willow and wax myrtle may reach tree proportions. However, whether this community would ever be replaced by other forest species is conjectural since the areas are sufficiently consolidated to accommodate reclamation once they reach the late shrub stage.

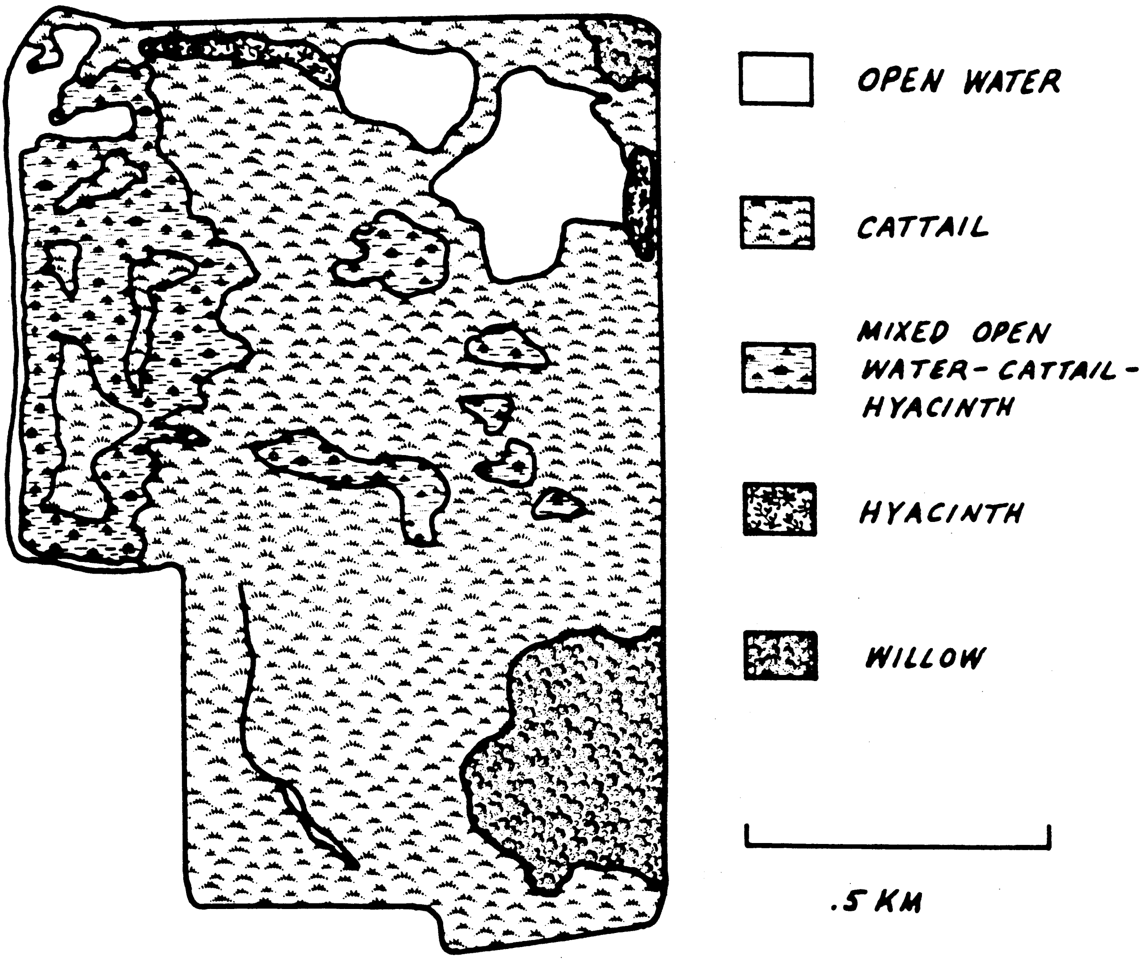

Figure 2. Typical clay settling area study site showing habitat configuration.

The transition from open water to the herbaceous stage is initiated by substrate exposure during dewatering. Typically, a delta forms near the point of inflow and becomes the first area colonized. Emergent vegetation then spreads over the area as the delta expands. Once establish the emergent community tends to persist until further drying and/or consolidation (usually associated with area dewatering at the end of active use) favors its replacement by willow.

Because of rapid colonization by species having prolific seed production and efficient dispersal mechanisms, the overall plant species di of the various community types is low. However, inter-community diversity is apparent in those areas where variations in substrate elevation have resulted from drainage channelization or irregular clay deposition patterns.

Our quantitative wildlife surveys and other field observations have identified 124 species using clay settling area habitats on our study sites (Table 1). Included are 8 species of mammals, 97 birds, and 19 reptiles and amphibians. Our quantitative survey findings are summarized in Table 2.

The most significant function of settling areas observed to date is the provision of wintering habitat for migratory birds, especially waterfowl. It should be noted however that endemic wading birds and other wetland and aquatic species have shown a sustained high usage and the significance of clay settling areas to these species should not be minimized.

The wildlife observation point survey data from the intensively studied settling areas indicates trends in terms of habitat preference.

Table 1. Wildlife species recorded on clay settling area study sites from October 1979 to March 1980.

REPTILES & AMPHIBIANS

Alligator
(Alligator mississippiensis)

Eastern mud turtle
(Kinosternon subrubum subrubum)

Peninsular cooter
(Chrysemys floridana peninsularis)

Florida red-bellied turtle
(C. nelsoni)

Florida softshell
(Trionyz ferox)

Florida green water snake
(Natrix cyclopion floridana)

Banded water snake
(Natrix fascista fasciata)

Florida watersnake
(N. fasciata pictiventris)

Eastern garter snake
(Thamrophis sirtalis sirtalis)

Peninsula ribbon snake
(Thamnophis sauritus sackeni)

Southern ringneck snake
(Diadophis punctatus punctatus)

Southern black racer
(Coluber constrictor priapus)

Rough green snake
(Opheodrys aestivus)

Yellow rat snake
(Elaphe obsoleta quadrivittata)

Florida cottonmouth
(Agkistrodon piscivorus conanti)

Southern toad
(Bufo terrestris)

Bullforg
(Rana catesbeiana)

Pigfrog
(R. grylio)

Southern leopard frog
(Rana utricularia)

MAMMALS

Opossum
(Didelphis marsupialis)

Raccoon
(Procyon lotor)

River otter
(Lutra canadensis)

Striped skunk
(Mephitis mephitis)

Bobcat
(Lynx rufus)

House Mouse
(Mus musculus)

Eastern cottontail
(Sylvilagus floridanus)

Marsh rabbit
(S. palustris)

BIRDS

Eared grebe
(Podiceps caspicus)

Pied-billed grebe
(Podilymbus podiceps)

White pelican
(Pelecanus erythrorhynchos)

Double-crested cormorant
(Phalacrocorax auritus)

Anhinga
(Anhinga anhinga)

Mallard
(Anas platyrhynchos)

Black duck
(A. rubripes)

Florida duck
(A. fulvigula)

Pintail
(A. acuta)

Gadwall
(A. strepera)

American widgeon
(Mareca americana)

Shoveler
(Spatula clypeata)

Blue-winged teal
(A. discors)

Green-winged teal
(A. carolinensis)

Wood duck
(Aix sponsa)

Redhead
(Aythya americana)

Canvasback
(A. valisineria)

Ring-necked duck
(A. collaris)

Lesser scaup
(A. affinis)

Ruddy duck
(Oxyura jamaicensis)

Hooded merganser
(Lophodyles cucullatus)

Turkey Vulture
(Cathartes aura)

Table 1. continued

Black vulture
(*Caragyps atratus*)

Sharp-shinned hawk
(*Accipiter striatus*)

Marsh hawk
(*Circus cyaneus*)

Red-tailed hawk
(*Buteo jamaicensis*)

Red-shouldered hawk
(*B. lineatus*)

Bald eagle
(*Haliaeetus leucocephalus*)

Osprey
(*Pandion haliaetus*)

Sparrow hawk
(*Falco sparverius*)

Bobwhite quail
(*Colinus virginianus*)

Great egret
(*Casmerodius albus*)

Snowy egret
(*Leucopnoyx thula*)

Cattle egret
(*Bubulcus ibis*)

Great blue heron
(*Ardea herodias*)

Louisiana heron
(*Hydranassa tricolor*)

Little blue heron
(*Florida caerulea*)

Green heron
(*Butorides virescens*)

Black-crowned night heron
(*Nycticorax nycticorax*)

American bittern
(*Botaurus lentiginosus*)

Least bittern
(*Ixobrychus exilis*)

Wood stork
(*Mycteria americana*)

Glossy ibis
(*Plegadis falcinellus*)

White ibis
(*Eudocimus albus*)

Sora rail
(*Porzana carolina*)

King rail
(*Rallus elegans*)

Common gallinule
(*Gallinula chloropus*)

American coot
(*Fulica americana*)

American avocet
(*Recurvirostra americana*)

Black-necked stilt
(*Himantopus mexicanus*)

Killdeer
(*Charadrius vociferus*)

Greater yellowlegs
(*Totanus melanoleucus*)

Lesser yellowlegs
(*T. flavipes*)

Short-billed dowitcher
(*Limnodromus griseus*)

Long-billed dowitcher
(*L. scolopaceus*)

Common snipe
(*Capella gallinago*)

Ring-billed gull
(*Larus delawarensis*)

Laughing gull
(*L. atricilla*)

Bonaparte's gull
(*L. philadelphia*)

Least tern
(*Sterna albifrons*)

Common tern
(*S. hirundo*)

Forster's tern
(*S. forsteri*)

Gull-billed tern
(*Gelochelidon nilotica*)

Royal tern
(*Thalasseus maximus*)

Caspian tern
(*Hydroprogne caspia*)

Black tern
(*Chilidonias niger*)

Black skimmer
(*Rynchops nigra*)

Mourning dove
(*Zenaidura macroura*)

Ground dove
(*Columbigallina passerina*)

Smooth-billed ani
(*Crotophaga ani*)

Common nighthawk
(*Chordeiles minor*)

Belted kingfisher
(*Megaceryle alcyon*)

Eastern kingbird
(*Tyrannus tryrannus*)

Eastern phoebe
(*Sayornis phoebe*)

Barn swallow
(*Hirundo rustica*)

Tree swallow
(*Iridoprocne bicolor*)

Table 1. continued

Common crow
(*Corvus brachyrhynchos*)

Fish crow
(*C. ossifragus*)

House wren
(*Troglodytes aedon*)

Carolina wren
(*Thryothorus ludovicianus*)

Long-billed marsh wren
(*Telmatodytes palustris*)

Short-billed marsh wren
(*Cistothorus platensis*)

Mockingbird
(*Mimus Polyglottos*)

Catbird
(*Dumetella carolinensis*)

Robin
(*Turdus migratorius*)

Blue-gray gnatcatcher
(*Polioptila caerulea*)

Loggerhead shrike
(*Lanius ludovicianus*)

Myrtle warbler
(*Dendroica coronata*)

Palm warbler
(*D. palmarum*)

Yellowthroat
(*Geothlypis trichas*)

Bobolink
(*Dolichonyz oryzivorus*)

Eastern meadowlark
(*Sturnella magna*)

Red-winged blackbird
(*Agelaius phoeniceus*0

Boat-tailed grackle
(*Cassidix mexicanus*)

Cardinal
(*Richmondena cardinalis*)

Rufous-sided towhee
(*Pipilo erythrophthalmus*)

Savannah sparrow
(*Passerculus sandwichensis*)

Swamp sparrow
(*Melospiza georgiana*)

Song sparrow
(*M. melodia*)

Table 2. Total and percentage[1] of the total wildlife numbers observed by morphological group which were at least partially using each habitat during clay settling area surveys.

	Total Observed	Open Water	Hyacinth	Exposed Sediment	Herbaceous	Shrub	Tree	Spoil Island	Stick-up[3]
Duck-like Birds[2]	96,546	90	21	<1	13	<1	0	3	3
Perching Birds	7,818	9	29	1	71	16	7	11	20
Swallow-like Birds	7,657	67	19	1	33	3	<1	18	18
Upright-perching Waterbirds	7,215	74	1	0	2	0	0	44	63
Long-legged Waders	3,591	31	39	1	79	1	<1	13	20
Gull-like Birds	2,800	97	1	1	<1	0	0	40	1
Sandpiper-like Birds	2,609	45	<1	99	1	0	0	1	0
Chicken-like Marsh Birds	1,127	26	70	0	40	2	0	1	18
Hawk-like Birds	123	28	5	5	76	6	0	0	2
Mammals	12	100	0	0	8	0	0	17	0
Pigeon-like Birds	11	18	0	0	73	9	0	0	0
Upland Ground Birds	5	0	20	40	40	0	0	0	0

1 Observed animals were frequently utilizing more than one habitat; therefore, total percentages for each group often exceeds 100.

2 Morphological groups named according to those listed in "The Audubon Society Field Guide to North American Birds" (Bull and Farrand 1977).

3 Dead or stressed willow over open water.

The average animal density, number of species, and diversity (H') (Shannon and Weaver 1963, as in Guillory et al. 1979) per survey tend to peak in areas with about 50 percent vegetation cover. Of greatest significance (Fig. 3) was the correlation between the average number of species and the percent vegetation cover of the observation point viewing areas ($R^2 = 0.60$, probability >F value = 0.002). Similarly, lower correlations in

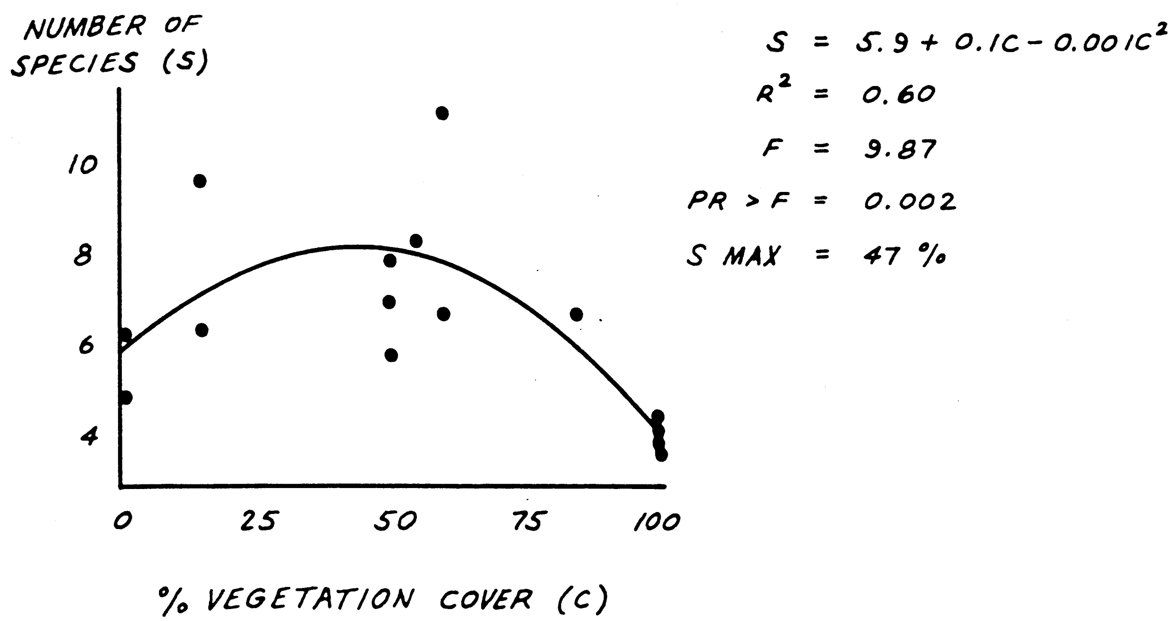

Figure 3. Average numbers of species per observation point survey relative to percent vegetative cover - observed values and model results.

the data were derived from the relationship between percent vegetative cover and average animal density ($R^2 = 0.31$, probability >F value = 0.09) and diversity (H') ($R^2 = 0.35$, probability >F value = 0.06), respectively.

DISCUSSION AND CONCLUSIONS

These findings indicate that active clay settling areas are providing valuable habitat for migratory and endemic wetland and aquatic wildlife. Although this value represents a considerable shift from the ecological role of mined areas which may have been formerly uplands or forested wetlands, they are serving to mitigate short-term, overall wildlife losses. However, their full benefit seems tied to the water management practices which produce successional stages characteristic of early periods of active use. Whether this habitat value can be enhanced and maintained over time will depend on the development of design criteria which produce the desired hydrological regime while minimizing subsidy costs and the liability associated with possible dike failure.

Our observations show that settling areas not only serve as feeding and roosting habitat, but sometimes support rookeries for wading birds and their associates. The wildlife management potential of clay settling areas has been discussed by Montalbano et al. (1978), Montalbano (1980) and Wenner (1979). Interim management of inactive, unreclaimed clay setting areas would not provide only valuable wildlife habitat or recreation areas, but could support additional research necessary for the development of a wetland reclamation technology. Research areas which need to be addressed include a epidemiological and toxicological assessment, a fisheries assessment, vegetation management alternatives and methods of modifying within-settling area drainage and topographic features. We hope to encourage industry participartion in cooperative research-demonstration projects at the conclusion of this study.

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FRESHWATER MARSH RECLAMATION IN WEST CENTRAL FLORIDA

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ABSTRACT

Three methods for establishing marsh vegetation on reclaimed phosphate mines are evaluated. The first method relies on natural colonization. After two years, seventy (70) species of plants were present, although most of the site was without vegetation. The second method requires individual plants to be transplanted from natural marshes. Three species were planted: maidencane, softrush, and pickerel weed. After two years, seventy-six (76) species were present. The third method utilizes the spreading of a mulch derived from the surficial layer of soil from a natural marsh. This method resulted in the rapid development of a dense cover of vegetation. After two years, ninety-five (95) species of plants were present.

INTRODUCTION

W. R. Grace & Company is proposing an open pit phosphate mine in northeastern Manatee County and southeastern Hillsborough County, Florida. The site, termed the Four Corners Mine, encompasses 7688 hectares. W. R. Grace & Co. has proposed a reclamation effort to establish both forested and nonforested wetlands as an element of the Master Mining and Reclamation Plan for the Four Corners Mine. During the first years of mining, approximately 182 hectares of wetlands are scehduled to be restored in the vicinity of Alderman Creek in Hillsborough County, Florida. These man-made wetlands must be designed and constructed in a manner which minimizes potential adverse impacts caused by the loss of natural wetlands due to mining.

Since January 1978, Conservation Consultants, Inc. has conducted a research program to develop data to assist in the design and construction of wetlands. The study includes the construction and monitoring of three pilot-scale marshes to evaluate methods of establishing wetlands vegetation. Two natural marshes have been monitored to provide comparative data for assessing the success of the artificial marshes.

AREA DESCRIPTION

The approximately 3.2 ha area where the artificial wetlands were constructed was orginially covered by pine-palmetto flatwoods. Most of the pines had been removed prior to this project and the area was being used as rangeland. The ground sloped gradually to the east towards Alderman Creek, an intermittent stream with a dense hardwood canopy. The western side of the site had an elevation of about 38 m above mean sea level, dropping to an elevation of approximately 34 m at Alderman Creek. Soil borings to a depth of 10 m revealed sands and clayey sands. No hardpan was encountered.

Two nearby natural marshes were studied to provide a comparison with the artificial marshes. They were selected to represent the extremes of types available on-site: one, a 0.4 ha marsh termed "Shallow", is normally dry during winter and spring; the other, a 1.6 ha marsh termed "Deep", normally retains some water all year. Both are surrounded by severely logged, pine-palmetto flatwoods which are heavily grazed by cattle.

METHODS

Three depressions, approximately 1.2 m deep, were constructed by first grading the site to approximately 0.6 m below design elevation and then backfilling to reach the final elevation. This procedure was employed to thoroughly disturb the substrate, simulating conditions of an actual mining/reclamation operation.

Following the contouring of the site in June 1978, the area was seeded to prevent erosion. Bahia and millet seed each were applied in June 1978, at a rate of 45 kg of seed per hectare. At the same time, 898 kg of 10-10-10 fertilizer was applied per hectare. Another 225 kg of seed was applied in July 1978, to cover areas where germination had been poor. In September 1978, dolomite and fertilizer were applied at rates of 2245 kg/ha and 450 kg/ha, respectively.

The three circular depressions (each approximately 0.16 ha in area) were used to determine the best method for establishing marsh plants. The northernmost depression was designated the control and no further manipulations were performed on it. The middle depression was selectively planted in July 1978, with maidencane (Panicum hemitomon), pickerel weed (Pontederia lanceolata), and softrush (Juncus effusus) removed from nearby natural marshes. The southernmost depression received a 30 cm thick layer of organic material from the upper 15 cm of soil, including all plants, from a nearby natural marsh. The mulching was completed in July 1978.

A permanent transect was established in each of the natural and artificial marshes to provide permanent reference points for the collection of data. Each transect originated near the center of the marsh and extended to its perimeter. Wooden stakes were placed at 2 meter intervals along the transects.

Within each of the marshes, species composition was determined by annually censusing the species present in contiguous, 1 m^2 quadrats located along each transect.

RESULTS

Two zones were present in each natural marsh. The outer zone of the shallow marsh was dominated by Centella asiatica, Andropogon sp., Solidago microcephala, Eleocharis baldwinii, and Ludwigia suffruticosa. The central zone was dominated by Eleocharis baldwinii, Ludwigia arcuata, Hydrochloa caroliniensis, Solidago microcephala, and Lindernia grandiflora. In all, seventy-six (76) species of plants have been recorded in the shallow marsh.

The outer zone of the deep marsh was dominated by Centella asiatica, Eleocharis baldwinii, Panicum hemitomon, Andropogon sp., Axonopus furcatus, and Rhynchospora sp. The central zone was dom by Panicum hemitomon, Pontederia lanceolata, Hydrocotyle umbellata, Polygonum hydropiperoides, and Utricularia sp. The deep marsh con a total of eighty-eight (88) species of plants.

The seventy (70) species of plants present in the control mar November 1979, were confined to a narrow band near the edge of the (Figure 1). Cattails (Typha latifolia) were the dominant invading

Figure 1. Control marsh - August 1980.

The planted marsh contained 76 species of plants by Novembe The dominant species were pickerel weed, maidencane, and softrush plants which were selectively planted. The additional plants were in the shallow water near the edge of the marsh (Figure 2).

The mulched marsh had a dense cover of vegetation except in center of the marsh where there has been continuous standing water (Figure 3). There were 95 species of plants in the mulched marsh

November 1979.

Seventeen species of plants were found in both of the natural marshes and all three artificial marshes. They were *Andropogon virginicus*, *Axonopus furcatus*, *Cyperus haspans*, *Cyperus polystachyos texensis*, *Cyperus retrorsus*, *Eleocharis baldwinii*, *Eragrostis refracta*, *Hedyotis uniflora*, *Juncus scirpoides*, *Ludwigia arcuata*, *Nymphoides aquatica*, *Panicum hemitomon*, *Polygala rugellii*, *Pterocaulon virgatum*, *Rhynchospora fascicularis*, *Solidago microcephala*, and *Xyris jupicai*.

Sixteen species were found in both natural marshes, but not in any of the artificial marshes. Most of these are typical of flatwoods and occurred at the margins of the natural marshes: *Amphicarpum muhlenbergianum*, *Andropogon longiberbis*, *Aristida spiciformis*, *Drosera capillaris*, *Elephantopus elatus*, *Erigeron vernus*, *Hypericum myrtifolium*, *Hypoxis juncea*, *Panicum angustifolium*, *Panicum tenerum*, *Paspalum setaceum*, and *Xyris brevifolia*. Those that were typical marsh inhabitants were *Gratiola ramosa*, *Utricularia inflata*, *Viola lanceolata*, and *Xyris fimbriata*.

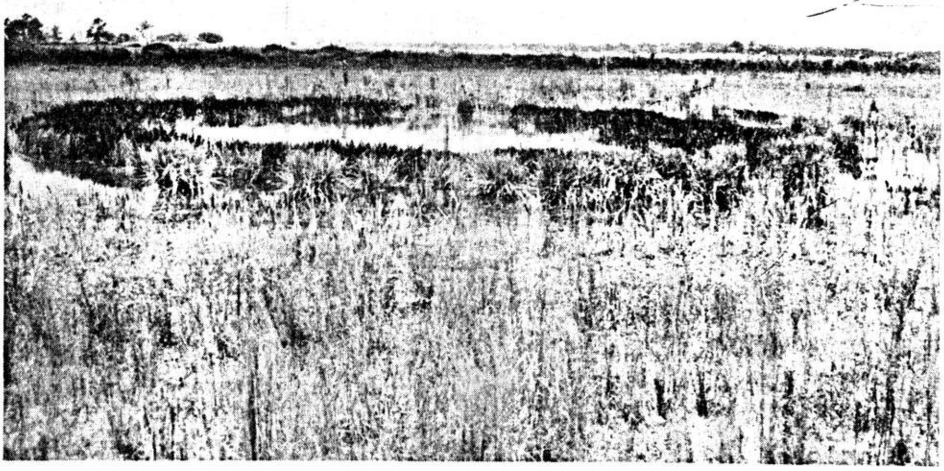

Figure 2. Planted marsh - August 1980.

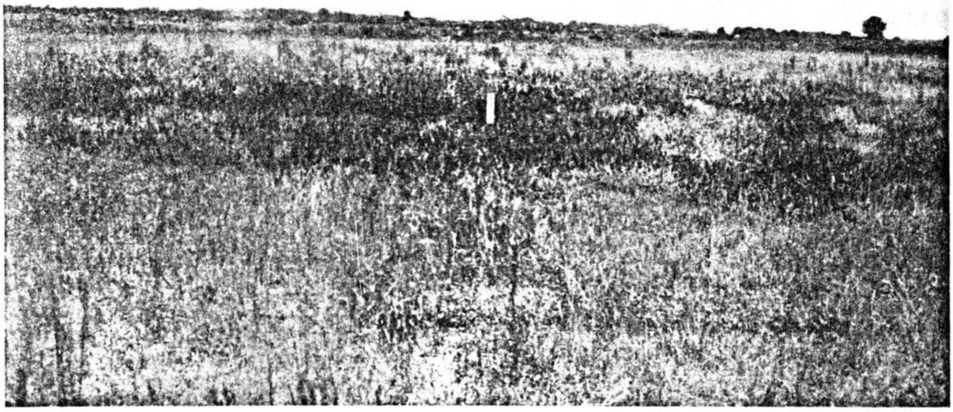

Figure 3. Mulched marsh - August 1980.

There were 17 species which were present in the mulched marsh and at least one of the natural marshes, but were absent from the other artificial marshes. They were Agalinis linifolia, Cephalanthus occidentalis, Digitaria serotina, Eragrostis elliottii, Hypericum mutilum, Juncus dichotomus, Lachnocaulon anceps, Ludwigia pilosa, Ludwigia suffruticosa, Panicum rigidulum, Paspalum laeve, Pluchea rosea, Rhexia mariana, Rhynchospora cephalantha, Sabatia grandiflora, Utricularia biflora, and Xyris smalliana.

Although there have been no specific studies of the fauna of the artificial wetlands, many animals have been observed during the other studies. Fishes were present in all of the artificial wetlands. Mosquitofish (Gambusia affinis) were the most abundant species. Other fishes which have been observed include the lease killifish (Heterandria formosa), flagfish (Jordanella floridae), golden topminnow (Fundulus chrysotus), pygmy sunfish (Elassoma evergladei), warmouth (Lepomis gulosus), bluegill (Lepomis macrochirus), and walking catfish (Clarias batrachus). Other animals observed at the artificial wetlands site include the southern toad (Bufo terrestris), southern leopard frog (Rana sphenocephala), bullfrog (Rana catesbeiana), alligator (Alligator mississippiensis), black racer (Coluber constrictor), great blue heron (Ardea herodias), cattle egret (Bubulcus ibis), common snipe (Capella gallinago), American egret (Casmerodius albus), little blue heron (Florida caerulea), sandhill crane (Grus canadensis), armadillo (Dasypus novemcinctus), white-tailed deer (Odocoileus virginiana), and raccoon (Procyon lotor).

DISCUSSION

Preliminary indications, as a result of this study, are that selective establishment of freshwater wetlands is technologically feasible as an element of mined land reclamation in west-central Florida.

It is our observation that water depth is a critical factor in determining the species composition and vegetational abundance in wetlands reclamation. Although definitive data are not yet available, we believe that the maximum water depth should not exceed two feet for ready establishment of emergent vegetation. Greater depths within a wetlands reclamation project are not prohibitive, but they will probably support submerged aquatic plants rather than emergent plants, at least for several years. Hand planted specimens of pickerel weed and maidencane have survived in water to one meter deep. We have not observed any significant spreading of vegetation in deep water, however. Maidencane occurs naturally at depths exceeding 1.8 m in ponds (Godfrey and Wooton 1979). It is possible that seedling establishment may occur only during years of extremely low water levels.

In conjunction with the maximum depth of the water, it should be noted that success is greatest on areas which dry out at some time during the year. To date, the only areas of the mulched marsh which have not established a cover of vegetation are areas which have had continuous standing water.

The mulching technique has demonstrated itself to be superior to the other methods in terms of accelerated development of a dense and diverse cover of vegetation. Unassisted natural recolonization (the control marsh) has shown little progress to date. The vegetation in the control marsh is very sparse, except for some scattered stands of cattails. A construction error resulted in the depressions being deeper than desired. This is probably responsible in part for the minimal colonization which has been observed so far. The planted marsh shows promise of eventual success, but its rate of establishment is appreciably slower when compared to the mulching technique.

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VEGETATION ESTABLISHMENT

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ABSTRACT

The Water Resources Development Act of 1974, designated as Public Law 93-251, authorized the US Army Corps of Engineers to establish a nationwide, 5-year, 8-million-dollar program to develop and demonstrate low cost means of preventing shoreline erosion. The New Orleans District's demonstration site is located at Fontainbleau State Park on the north shore of Lake Pontchartrain.

In addition to engineered structures, the range of experimental devices in the demonstration project included plantings, consisting of several nursery grown, native grass species and a spreading native shrub. Spartina alterniflora constituted the intertidal plantings; Spartina patens, Phragmites australis, and Rosa bracteata were planted in the upper beach zone. Planting stock included peat-pot seedlings, plugs, sprigs, rhizomes, and cuttings.

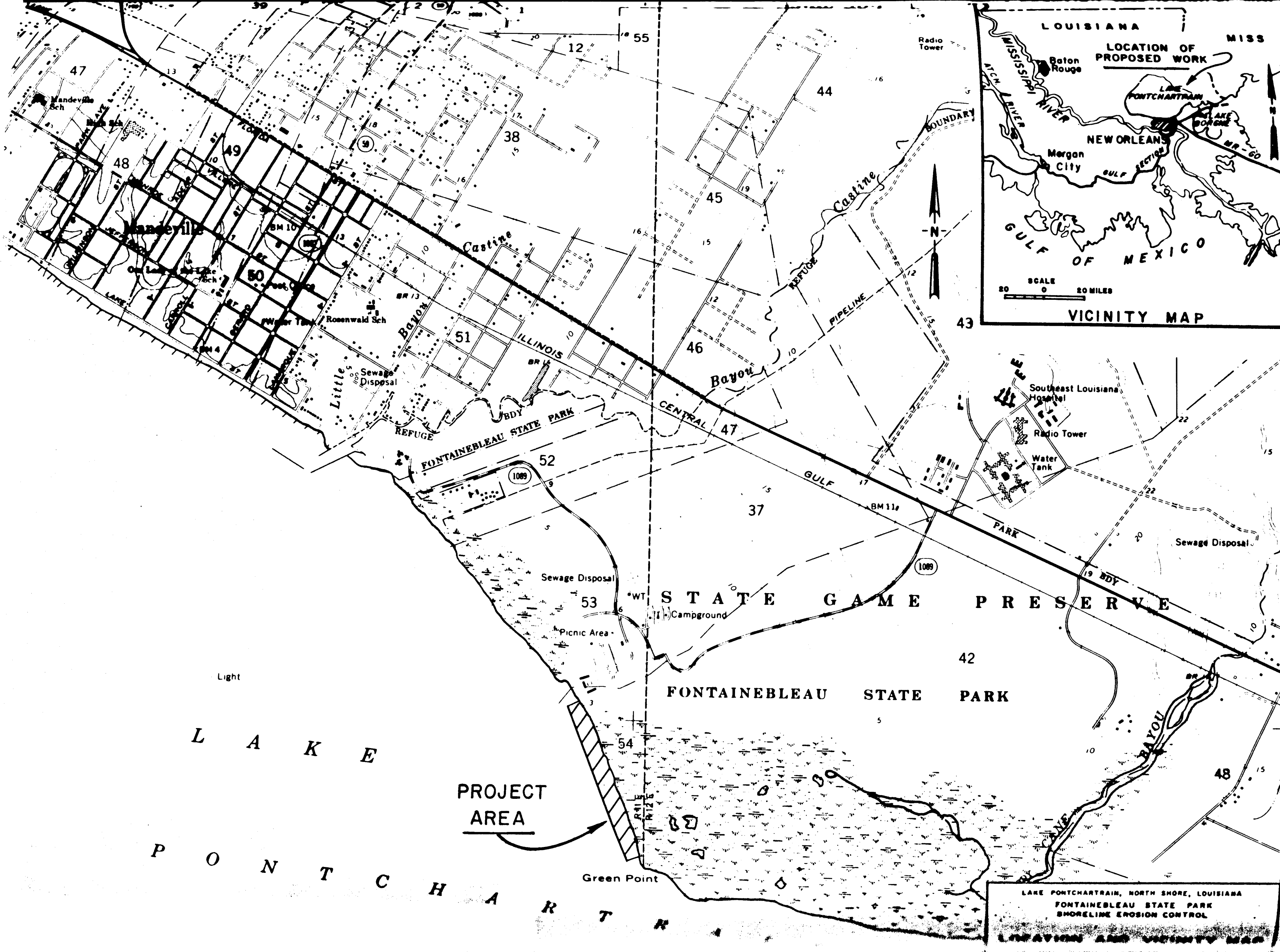
Planting success was moderately successful at the site. Although several plantings were lost during the year, intertidal S. alterniflora surviving at the end of 1979 produced seed and looked healthy and robust; no upper beach plantings remained except for a row of transplanted S. patens. Frequent storms on Lake Pontchartrain elevated lake levels causing washouts. Planned protective breakwaters were not in place at the time of the initial planting. The thin layer of quartz sand quickly washed away; only S. alterniflora planted in marsh peat substrates remained through the end of the first year. These same storms damaged fences of adjacent landowners, allowing cattle to graze plant tops and roots. Replanting efforts are being undertaken in 1980 to restore the intertidal zone plots.

INTRODUCTION

Section 54 of the Water Resources Development Act of 1974, also known as Public Law 93-251 or the Shoreline Erosion Control Demonstration Act, authorized the US Army Corps of Engineers to establish a nationwide program to develop and demonstrate a variety of low-cost means for preventing shoreline erosion. The program was to be evaluated over a 5-year period and was funded for 8 million dollars. Thirty sites were initially selected for evaluation and/or monitoring based on various substrate, wave,climate, and engineering criteria, as well as the need for erosion control. The New Orleans District's demonstration site is located on the north shore of Lake Pontchartrain at Fontainbleau State Park.

AREA DESCRIPTION

Fontainbleau State Park (Figure 1), formerly the site of a large sugar cane plantation, is located approximately 3.2 km east of Mandeville, LA, and 48 km north of New Orleans. The park contains nearly 1,130 hectares of pine-oak-sweetgum dominated forests and *Spartina patens*-dominated marshes. Climate at this section of south-central Louisiana is subtropical, with mild winters and hot, humid summers. Average annual temperature is 20^{o}C. The demonstration site, about 915m in length, is under wave attack from waves approaching from southerly to westerly directions. Predominate waves are 0.3-0.7m in height; although, with increased lake levels in Lake Pontchartrain, waves can approach 1.2-1.5m in height. Predominant wind directions are southeast from January to July and northeast to east-northeast from September to November. Erosion rates for some localized sections of shoreline are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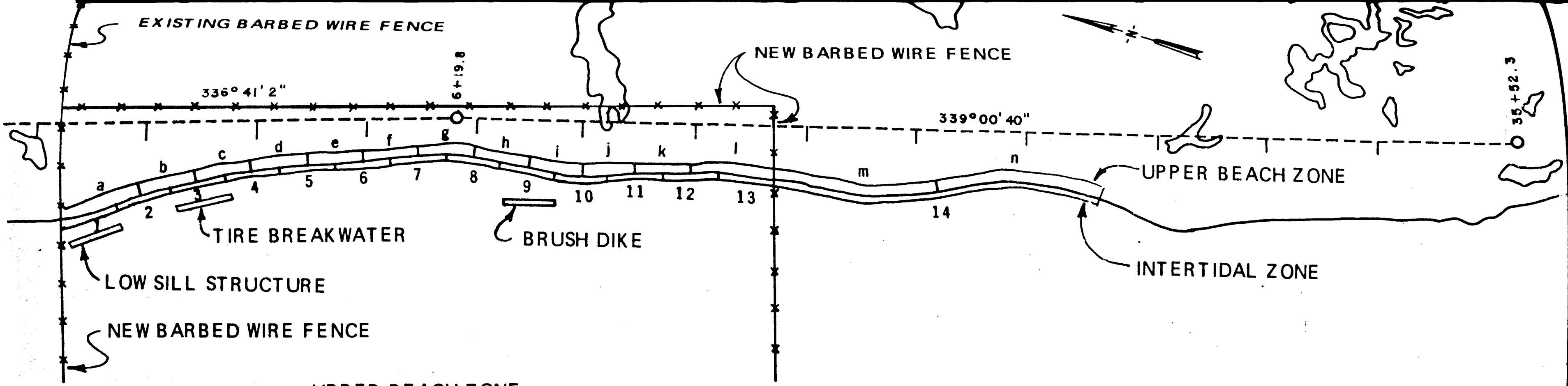
LOCATION OF PROPOSED WORK
Baton Rouge
LAKE PONTCHARTRAIN
MISSISSIPPI RIVER
ATCH. RIVER
LAKE BORGNE
NEW ORLEANS
Morgan City
GULF SECTION
MR-GO
GULF OF MEXICO
SCALE
20 0 20 MILES
VICINITY MAP
Mandeville
Mandeville Sch
High Sch
Post Office
Water Tank
Rosenwald Sch
Sewage Disposal
Little Bayou Castine
Bayou Castine
ILLINOIS CENTRAL GULF
FONTAINEBLEAU STATE PARK
BDY
REFUGE
REFUGE BOUNDARY
PIPELINE
PARK BDY
Radio Tower
Southeast Louisiana Hospital
Radio Tower
Water Tank
Sewage Disposal
Sewage Disposal
Campground
Picnic Area
STATE GAME PRESERVE
FONTAINEBLEAU STATE PARK
BAYOU CANE
Light
LAKE PONTCHARTRAIN
PROJECT AREA
Green Point
LAKE PONTCHARTRAIN, NORTH SHORE, LOUISIANA
FONTAINEBLEAU STATE PARK
SHORELINE EROSION CONTROL

estimated to be up to 2.8m per year, although the overall rate is closer to 1.0-1.5m per year. Natural in situ soils consist of clays, organic silts, and marsh peat deposits overlain by shallow, quartz sand beaches. Maximum elevation of the beach is 1.0-1.5m with immediate offshore depths of 0.3m below mean sea level (msl) decreasing to 1.8m below msl 300m offshore. Tides in Lake Pontchartrain are diurnal, with a mean range of 0.2m; highest observed storm tide in the vicinity of the site was 2.4m at Mandeville during a hurricane in 1915.

MATERIALS AND METHODS

Two basic methods of shoreline protection were proposed for Fontainbleau State Park. The first method -structural- included revetments and breakwaters constructed of tires, concrete filled bags, various concrete structures, and a brush dike. The second method consisted of the use of plant material, both with and without fertilization, to protect the shore. Figure 2 illustrates the proposed planting scheme for the demonstration project. The vegetated beach, approximately 580m in length, was divided into an upper beach and a lower, or intertidal beach, then subdivided into sub-plots designated by letter and number, respectively. Plots A and L are 45.75m long by 6.1m wide. Plots B-K are 30.5m long and 6.1m wide, and plots M and N are 91.5m long by 6.1m wide. Intertidal plots 1-13 are 30.5m long by 3.05m wide and plot 14 is 183m long by 3.05m wide. The intertidal plots extended from the low water level at elevation +0.3m msl to the mean high tide line at elevation +0.6m msl. The upper beach plots extended from the mean high tide level (+0.6m) to the spring tide or annual storm tide level, an elevation varying between



UPPER BEACH ZONE

SELECTED VEGETATIVE SPECIES

MEAN HIGH WATER TO HIGH SPRING OR STORM TIDE

SECTION NO.	TREATMENT	SECTION LENGTH
a	COMMON REED	45.75 m
b	NO PLANTINGS	30.5 m
c	TORPEDO GRASS	30.5 m
d	SALTMEADOW CORDGRASS-SELECTION 1	30.5 m
e	SALTMEADOW CORDGRASS-SELECTION 1	30.5 m
f	SALTMEADOW CORDGRASS SELECTION 2	30.5 m
g	SALTMEADOW CORDGRASS-SELECTION 3	30.5 m
h	TORPEDO GRASS - NO FERTILIZER	30.5 m
i	COMMON REED - NO FERTILIZER	30.5 m
j	SALTMEADOW CORDGRASS-SELECTION 1 NO FERTILIZER	30.5 m
k	NO PLANTINGS	30.5 m
l	TORPEDO GRASS	45.75 m
m	NO PLANTINGS	91.5 m
n	TORPEDO + McCARTNEY ROSE + SALTMEADOW CORDGRASS	91.5 m

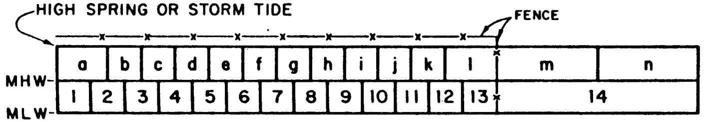
INTERTIDAL ZONE

SMOOTH CORDGRASS (SPARTINA ALTERNIFLORA)

MEAN LOW WATER TO MEAN HIGH WATER

1	STANDARD PLANTING + PROTECTION	30.5 m
2	STANDARD PLANTING (CONTROL)	30.5 m
3	STANDARD PLANTING + PROTECTION	30.5 m
4	SPACED 18 INCHES ON CENTERS	30.5 m
5	SPACED 36 INCHES ON CENTERS	30.5 m
6	NO PLANTING (UNTREATED CONTROL)	30.5 m
7	PLUGS	30.5 m
8	SPRIGS	30.5 m
9	SPRIGS	30.5 m
10	SPRIGS	30.5 m
11	SPRIGS	30.5 m
12	SPRIGS	30.5 m
13	PEAT POTS	30.5 m
14	SPRIGS	183 m

SECTION LABELS SHOW DEVIATION FROM STANDARD PLANTING. EVERYTHING ELSE IS STANDARD.



SCALE 1" = 200'

LAKE PONTCHARTRAIN, NORTH SHORE, LOUISIANA
FONTAINEBLEAU STATE PARK
SHORELINE EROSION CONTROL

VEGETATION PLAN

+1.0-1.3m msl. Two offshore plots were planned for establishment at depths of approximately -0.6m msl.

Plant species initially planned for the site were Spartina alterniflora (oystergrass, smooth cordgrass) in the intertidal zone, and Spartina patens (wiregrass, saltmeadow cordgrass), Panicum repens (torpedo grass), Phragmites australis (Roseau cane, common reed grass), Rosa bracteata (McCartney rose), and Tamarix gallica (salt cedar) in the upper beach zone. Offshore plantings were to consist of transplants from local beds of Vallisneria americana (eel grass) and Ruppia maritima (widgeon grass) into two 6.1m wide by 30.5m long plots.

Plant materials consisted of peat-pot seedlings, single stemmed sprigs, multi-stemmed plugs, rhizomes, and cuttings. Seeds of S. alterniflora were collected in the fall of 1978 along the banks of the Mississippi River - Gulf Outlet channel east of New Orleans and stored in plastic bags under moist (i.e., high humidity) refrigeration at the US Department of Agriculture's (USDA) Southern Regional Research Center in New Orleans, following methods, with modifications, of Woodhouse et al. (1974). Seeds were shipped in early 1979 to the USDA's Plant Materials Center, Coffeeville, Mississippi, where they were raised in 7.6 cm tall peat-pot cups. Sprigs and plugs of S. alterniflora were dug on the day of transplanting from a natural marsh approximately 2.4 km west of the planting site. Cuttings of R. bracteata were taken from plants occurring a short distance west of the planting site and rooted at the Coffeeville Center. Three selections (MS-4278, AM-2954, AM-2922) of bare-rooted S. patens were obtained from the USDA Plant Materials Center, Knox City, Texas, as were several hundred rhizomes of P. australis. The P. australis rhizomes were of adequate length so that by cutting each in half, double the number of planned rhizomes were obtained.

Fertilizers selected for inclusion in the planting were 13-13-13, ammonium nitrate, and slow release "Osmocote" (18-6-12). Fertilizers were to be applied either to the soil surface or into the planting hole during the project.

A contract was entered into between the New Orleans District, US A- Corps of Engineers, and the Bogue Chitto - Pearl River Soil & Water Co- servation District, Franklinton, LA, in 1979 to provide all equipment, transportation, fertilizer, and all labor to plant the demonstration s- for a total contract price of $20,000. Plantings began in May 1979 an- continued through August 1979. Size of the planting crew averaged thr- with part-time help increasing the number to five.

RESULTS

A summary of intertidal zone plantings is shown in Table 1. A "standard planting" in this zone was used predominantly, with spacings between plants and rows of 60.9 cm, planting five rows for a total of 250 plants per plot. Variations in spacing ranged between 45.7 cm and 91.4 cm, respectively. Multiple dates (shown in plots 2-5) indicate replantings; multiple dates in plot 14 indicate dates plants were ini- tially planted. Column 5 of Table 1 indicates numbers of plants util- at each planting. Fertilization of intertidal zone plantings was by b- casting "Osmocote" at the rate of 272.15 kg/acre on plots having veg- on 10 August. All plantings after 10 August received "Osmocote" in th- planting hole (approx. one-half cup per hole) at the time of planting.

Survival data of intertidal zone plants as recorded in December - are shown in Table 2. A significant loss of plants occurred in the i- tidal zone during the year, although surviving plants looked healthy.

Table 1. Intertidal plantings - 1979.

PLOT NUMBER	DATE(S) PLANTED	SPACINGS	ROWS	TOTAL # OF PLANTS	PLANT MATERIALS
1	21 June	60.9 cm	5	250	sprigs
2	17 April	60.9 cm	5	250	sprigs
	17 May	60.9 cm	6	300	peat-pots
3	17 April	60.9 cm	5	250	sprigs
	8 June	60.9 cm	5	250	sprigs
	10 August	60.9 cm	5	250	sprigs
4	17 April	45.7 cm	6	396	sprigs
	8 June	45.7 cm	6	396	sprigs
	16 August	45.7 cm	-	120*	plugs
5	17 April	91.4 cm	5	200	sprigs
	8 June	91.4 cm	-	120*	plugs
	28 June	91.4 cm	-	120*	plugs
	16 August	91.4 cm	-	75*	plugs
6		CONTROL	PLOT		
7	21 June	60.9 cm	5	250	plugs
8	21 June	60.9 cm	5	250	sprigs
9	28 June	60.9 cm	5	250	sprigs
10	28 June	60.9 cm	5	250	sprigs
11	28 June	60.9 cm	5	250	sprigs
12	28 June	60.9 cm	5	250	sprigs
13	17 May	60.9 cm	6	300	peat-pots
14	28 June	60.9 cm	2	600	sprigs
	14 July	60.9 cm	-	-	"
	6 August	60.9 cm	-	-	"

(*) Replants. (-) Plants added to fill in gaps in the plots or different dates of planting as for plot 14.

Table 2. Survival counts - intertidal zone, December 1979.

PLOT NUMBER	SPECIES PLANTED	TOTAL PLANTINGS*	SURVIVAL COUNT	PERCENT SURVIVAL
1	*Spartina alterniflora*	250	0	0
2	" "	550	0	0
3	" "	750	138	18
4	" "	516	120	23
5	" "	515	105	20
6	NOT PLANTED			
7	" "	250	175	70
8	" "	250	80	32
9	" "	250	50	20
10	" "	250	9	4
11	" "	250	70	28
12	" "	250	50	20
13	" "	300	300	78
14	" "	600	25	4

(*) Indicates replanting efforts as shown in Table 1.

had flowered during the fall and had produced seed. Plot 7 (plugs) and plot 13 (peat-pot seedlings) demonstrated highest survival rates, at 70% and 78%, respectively; while plots 1 and 2, planted with sprigs and peat-pot seedlings, had no visible survivors at the end of the year. Average intertidal planting zone survival for the 14 plots was 22.6%. Of the estimated number of survivors, highest counts occurred in plots planted in marsh peat substrates. Nearly all plants put into sandy substrates were lost within a short time after planting. Plant shoots resulting from rhizomal growth were not widely evident in the plots during the December count.

Upper beach plantings are shown in Table 3. Planting materials were not sufficient for more than one planting; thus, no replanting was attempted in 1979. As in the intertidal zone, plant spacings were 60.9 cm between plants, except for a 91.4 cm spacing in plot N for the McCartney rose cuttings. Upper beach zone fertilization was broadcast application of 13-13-13 and ammonium nitrate on 10 August on all plots except H and I. Application rates were 156.48 kg/acre of 13-13-13 and 52.16 kg/acre ammonium nitrate. Broadcast application of 78 kg/acre of 13-13-13 on plots A-L, excluding H and I, was made on 30 August.

Survival counts of upper beach plots, as recorded in December 1979, are shown in Table 4. During field inspection and additional discussion at the District Office, torpedo grass and salt cedar were eliminated from further consideration for planting due to the prevalence of torpedo grass at the site and ecological problems reportedly resulting from the introduction of salt cedar into several western states. The only plot having planted material remaining at the end of 1979 was plot N with 22 trans- planted S. patens counted, yielding a survival rate of 92%. Total survi- percentage was 6.4% for the upper beach planting zone. It should be no- that plots C, H, L, and part of plot N were not planted since P. repens already occurred at the site. Individual stems of P. repens were not counted but vegetative growth was noted and is further discussed in the Discussions and Conclusions section of this paper.

Transplant Costs (1979)

Through the end of 1979, total expenditures by the Bogue Chitto - Pearl River Soil & Water Conservation District have been $13,687, cover labor, materials, transportation, and administrative costs associated the project. Five hundred ninety-two man-hours have been reported by contractors at a cost of $6,633. This cost plus fertilizer amounted $6,720, or $4 per foot of planting. The remaining monies were expen for transportation and equipment purchased for the project.

DISCUSSION AND CONCLUSIONS

Successful planting of native species for shoreline stablization, based on utilization of species adapted to local physical, chemical, and environmental conditions, has been demonstrated at a number of sites in the United States (Kadlec and Wentz 1974; Darovec et al. 1975; Woodhouse et al. 1972; Hunt et al. 1978). The Shoreline Erosion Control Demonstration Act was enacted in an attempt to develop and demonstrate as many methods as feasible for shoreline stabilization. A major stipulation included in the authorizing legislation required that demonstration methods be low cost and yet provide a reasonable and viable option for the average homeowner. The site selected in Louisiana ...

Table 3. Upper beach plantings - 1979.

PLOT NUMBER	SPECIES	DATE	SPACING	ROWS	# OF PLANTS	MATERIALS
A	P. australis	19 April	60.9 cm	12	792	rhizomes
B		NO PLANTINGS				
C	P. repens*					
D	S. patens (MS-4278)	30 July	60.9 cm	12	600	bare-rooted
E	S. patens (MS-4278)	30 July	60.9 cm	12	600	" "
F	S. patens (AM-2954)	30 July	60.9 cm	12	600	" "
G	S. patens (AM-2922)	30 July	60.9 cm	12	600	" "
H	P. repens*					
I	P. australis	19 April	60.9 cm	12	792	rhizomes
J	S. patens (MS-4278)	30 July	60.9 cm	12	600	bare-rooted
K		NO PLANTINGS				
L	P. repens*					
M		NO PLANTINGS				
N	R. bracteata	4 April	121.9 cm	4	330	cuttings
	S. patens	16 August	60.9 cm	1	24	transplants

(*) Not planted, already occurring on the site.

Table 4. Survival counts - upper beach, December 1979.

PLOT NUMBER	SPECIES	TOTAL PLANTINGS	SURVIVAL COUNT	PERCENT SURVIVAL
A	*P. australis*	792	0	0
B		NOT	PLANTED	
C	*P. repens**			
D	*S. patens* (MS-4278)	600	0	0
E	*S. patens* (MS-4278)	600	0	0
F	*S. patens* (AM-2954)	600	0	0
G	*S. patens* (AM-2922)	600	0	0
H	*P. repens**			
I	*P. australis*	792	0	0
J	*S. patens* (MS-4278)	600	0	0
K		NOT	PLANTED	
L	*P. repens**			
M		NOT	PLANTED	
N	*R. bracteata*	330	0	0
	S. patens	24	22	90

(*) Not planted, already occurring at the site. Plants present at the end of the growing season but no actual stem counts made for this species.

many of the problems and conditions typical for the state. Realizing this, an attempt was made to utilize native plant species found occurring along the central Gulf Coast in addition to engineered structures. Attempts at vegetation establishment in 1979 both succeeded and failed for a number of reasons which are discussed below.

Environmental Reasons

Lake levels in Lake Pontchartrain varied greatly in 1979, especially as a result of Hurricane "Bob" on 11 July and Hurricane "Claudette" on 24 July. In addition, operation of the Bonnet Carre' Spillway, connecting the Mississippi River and the western end of Lake Pontchartrain to release floodflows from the Mississippi River from 17 April to 23 May, elevated lake levels above 0.6m. Lake levels above 0.6m innundate the planting site. Lake levels were above 0.6m on numerous occasions in late summer and fall due to strong south-southeast to southwest winds. Sand was moved over the beach toward the marsh by the elevated lake levels and associated waves. Plantings were often removed before roots could penetrate to sufficient depths to achieve stabilization. Plantings in the lowest zone, from elevation +0.3m to +0.6m, remained in place longest if they were in marsh peat substrates; if in sand, they were quickly lost.

When lake levels were elevated due to storms, these same storms washed out fences of adjacent farms, allowing cattle to roam freely over the plots, apparently in search of higher ground and tender vegetation. Native torpedo grass on the site responded to fertilization to the point of having growth rates up to 0.4m on the organic soils. Elevated lake levels in mid-September washed out fences and cattle grazed the grass back to ground level. Cattle also grazed tops of the *S. alterniflora* in all plots. *S. patens* appeared not to have been grazed.

Condition of the Plant Materials

With the exception of the selection of S. patens, all plant materials appeared healthy and of good quality when planted. Selection AM-2954 plants were small (6.5-8.0 cm) so that when planted their tops did not extend much above the surface of the sand. In addition, all three selections were received as bare-rooted seedlings; many of the plants were dry, the roots were brittle, and the plants generally showed signs of dessication. This condition may have accelerated losses of S. patens planted on the site.

Offshore Structures

Plantings were scheduled after the completion of the offshore protective devices. Due to labor and materials delays, only the brush dike structure, completed in June, was in place before the end of the plantings. Other devices were finished in October or early November, several months after planting ceased. After their construction, any plants located behind them did not appear to remain any longer than those on unprotected plots. We feel that an adequate evaluation of the offshore structures in regard to protecting the plants set out in 1979 was not possible in light of these factors.

ADDENDUM

April 1980 Inspection

The spring 1980 planting count revealed a number of interesting findings. Numerous shoots of S. alterniflora 5-10 cm tall were observed in the intertidal zone. This would tend to indicate that: (a) although above-ground plant parts had been lost from the 1979 plantings, enough root material remained to produce the new shoots, and/or (b) rhizomal growth had spread the plants through the plots. In addition, sand movement due to wave wash revealed the presence of S. patens plants thought lost in the December 1979 inventory. These findings indicate sufficient plants may have survived so that, barring another cattle invasion, establishment of an intertidal plant zone may have been more successful than originally preceived.

During the rest of 1980, plants will be monitored to assess survival and growth rates. In addition, plantings are continuing by the Bogue Chitto - Pear River Soil and Water Conservation District in the intertidal zone to attempt re-establishment of plots which were destroyed in 1979.

ACKNOWLEDGEMENTS

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GROWTH, SEDIMENTATION/EROSION, WATER QUALITY IN TWO MARSH RESTORATION PROJECTS IN CLINTON AND STRATFORD, CT.

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ABSTRACT

During two growing seasons, restoration studies were conducted on a high marsh in Clinton and a low marsh in Stratford, Connecticut. Different stock forms and plant species were studied for growth response to elevation, substrate texture and nutrients, fertilizer, and water quality.

Sedimentation and erosion rates in response to distance from shore, plant populations, and stock form were studied on the low marsh. Water quality was sampled at the two sites and upstream of the low marsh to detect variation over distance, changes in quality due to daily and lunar tidal fluctuations, and to determine whether quality differences could affect plant growth.

Drainage, controlled partly by elevation and especially by substrate texture, proved the determining influence on plant growth with substrate nutrition and fertilizer having negligible influence. Water quality was potentially significant to plant growth. Success of different stock forms and species was noted. Evidence suggests that fertilizer may leach more readily than supposed.

The size of plant populations appeared a causative factor in regard to sedimentation and erosion rates. The mechanism by which an estuarine marsh received proportional amounts of substrate from river and tidal sources and from shoreline erosion was noted.

Water quality fluctuated diurnally and weekly, suggesting that estuarine marshes are influenced predominantly by their rivers at neap tide, by tidal water at moon tide. Distance appeared less significant than other factors in determining water quality differences between marsh sites. The Clinton site proved to influence its surrounding water quality. Nutrients settling out of the water column were noted, and results suggest that the length of time water stands on a site may influence its nutrition.

INTRODUCTION

The project was funded by National Science Foundation, directed by Area Cooperative Education Services, with cooperation from Yale University. It was planned as a restoration/teaching project to provide high school juniors and seniors of exceptional ability in science and mathematics with an opportunity to conduct marine field research. Ostensibly a six and seven week session in the summers of 1978 and 1979 resulting in two brief summary reports for the National Science Foundation, it became a two year research project yielding significant findings on site recovery, faunal response to site change, and techniques for working restoration sites and for obtaining data, developing equipment, greenhouse production of planting stock, and more, in addition to the topics reported on in this paper.

The four to six students and one research assistant involved each summer demonstrated that effective research can be done with this age group and staff size, working with one scientist. However a second scientist and assistant are almost essential, to help plan, supervise, execute and evaluate such a project.

This paper gives only an incomplete sample of project findings. For detailed information, write to Laurence Schaefer, E-P Education Services, c/o Area Cooperative Education Services, 800 Dixwell Avenue, New Haven, Connecticut and ask for the two working papers on the Tidal Wetland Restoration Projects (about 160 pages each) to be made available at cost of reproduction.

AREA DESCRIPTION

The Stratford low marsh is bounded by a three meter cement bluff, a cove, the Housatonic River, and its Long Island Sound estuary (see Figure 1). It is only a few hundred yards from Long Island Sound. Moving out from shore there occur, in sequence, high peaty shore (station #1), low mud shore (station #2), a ridge of peat turf mounds (station #3), and mudflats, studied at two locations (stations #4 and #5). These and one site farther along the shore (station #6) were the areas studied at Strat. A seventh station several miles upstream on the Housatonic River was test for water quality. Texture analysis revealed a predominating sand fracti in the high shore substrate, the other four stations containing mostly si and clay as their mineral fractions.

The Clinton site is a previously filled high marsh, uncovered in 19 79 and leveled for planting (see Figure 2). It is surrounded by the Indian River, native high marsh with mosquito ditches, and remaining filled areas. It is only a few hundred yards from Long Island Sound. In 1978, marsh gas escaping from the substrate showed it was not water-sat In 1979, tidal water upwelling through the substrate and the absence of marsh gas indicated complete saturation. Clinton substrate types are h clay, sand, peat, and pannes of deeply cracked clay with a thin surface deposit of sand, dry between tides but with water rising through the cr at high tide. Sand and clay mixtures also occur.

METHODS AND MATERIALS

Plant Growth: Stratford

Spartina alterniflora bare root stock was planted in both years at five stations. Peat pots were planted in all but station #5 in 1978 and at all stations in 1979, and plugs only on the low shore (station # in 1978 and everywhere but station #5 in 1979. Bare root stock for the 1978 planting was hydroponically raised in Maryland and had 15 cm long trailing roots. The 1979 stock had stiff, arched roots 5 cm long and w raised in peat pots and broken out for delivery. The 1979 bare root st had 1 or 2 stems, as opposed to 5 or 6 in 1978, and each plant set con of a single plant rather than several as in 1978. In both years the pl

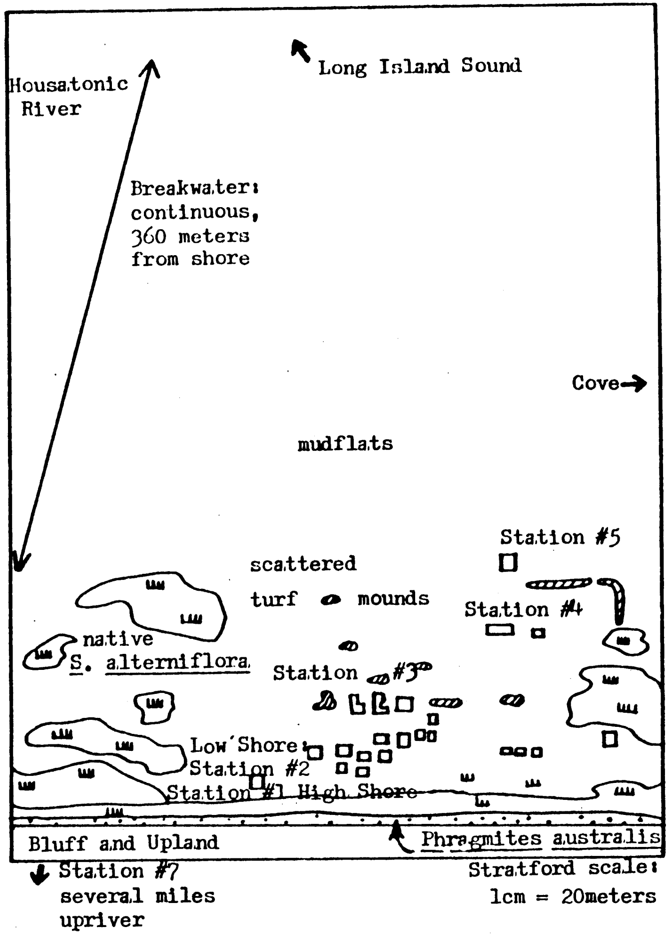

Figure 1. Stratford site; 1978 plots and 1979 general station locations.

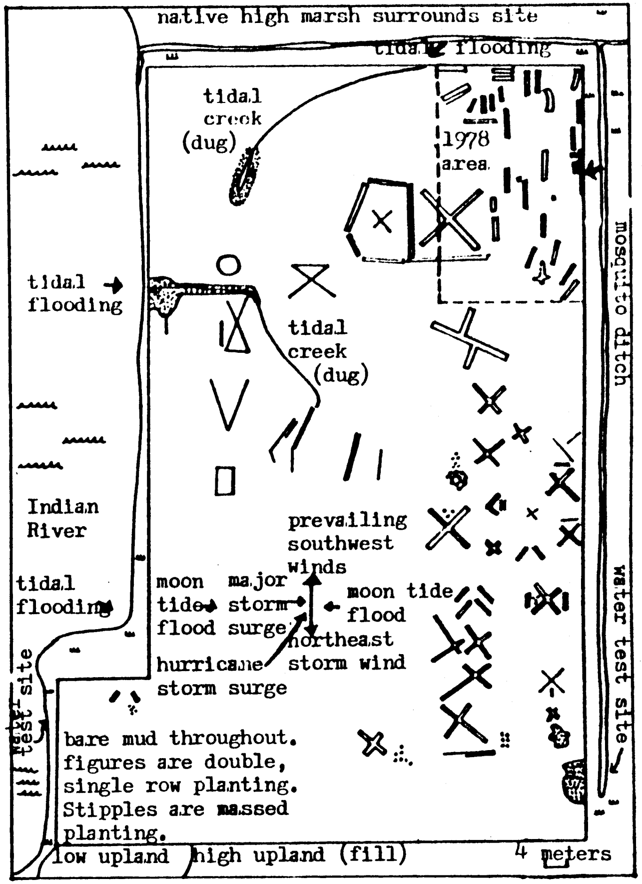

Figure 2. Clinton site.

were approximately 1 meter tall and had 3 to 5 stems each. The peat pots were approximately 15 cm tall and had approximately 7 stems each. The 1978 plugs came from a low, saturated peat island in the Housatonic River. In 1979, plugs were taken from the high shore area. These differences made direct comparison difficult, but the differences themselves yielded significant findings and enough similarity remained to provide a continuum of data.

In 1978, $5m^2$ plots were planted at each of the 5 test stations, at half or one meter density of on center planting, using 70 plants for half meter and 39 for one meter density. In 1978 approximately half the plots received 1 ounce of Osmocote 19-6-12 fast release fertilizer and half the plots none, one plot receiving a half dose. The fertilizer was applied through a hole made at the base of each plant one week after planting, as it was not available at the time of planting. In 1979 only 27 plants of each stock type were placed at each station. Three plants of each stock type received full, half dose and no fertilizer, applied at the time of planting (one ounce volume).

Height, circumference, number of stems, and number of shoots (stems 1/3 or less total stand height) were monitored. Two separate overall parameters, the number of plants and the measured amount of growth, each showing increase, steady state, or dieback, were studied to determine the most successful stock, growing area, and fertilizer dose.

Plant Growth: Clinton

The Clinton planting pattern demonstrates a successful method of covering a site with relatively few plants; of intercepting normal and storm tide and wind with planting patterns to spread seed, trap detritus, and provide erosion protection; of allowing successive filling-in of patterns with successful stock in later seasons; and of placing different stock together in double-row figures for growth comparison. In both years stock included Spartina alterniflora and Spartina patens peat pots and bare roots from Maryland, and S. patens plugs from the surrounding marsh. In 1978, some Distichlis spicata bare roots from Maryland were used, and in both years Distichlis plugs from the surrounding marsh were planted. In 1979 S. alterniflora plugs from Clinton and Stratford were planted, and S. alterniflora and S. patens peat pots grown at Yale were planted to cover the site, but were not monitored for growth success.

Stock was planted in all substrate types, with and without fertilizer and a loose potting mixture primarily of clay and water with some peat, to test their influence on plant growth. Only one panne was drained and it continued to fill during high tide. Native S. alterniflora and Salicornia sp. filled all pannes by 1979, demonstrating no need to stock or drain pannes as they accumulate seed naturally. S. alterniflora was planted around pannes and ditches as a seed source and to control erosion.

As at Stratford, height, circumference, shoots were monitored. Stems were abandoned as a growth parameter in 1979 due to lack of time to count them. A full fertilizer dose was 1 ounce (volume) of Osmocote.

Sedimentation and Erosion

Flexible transparent mylar strips, indelibly marked with three lines at two 10 cm intervals and pin-holed for further identification of the lines (see Figure 3), were implanted in the Stratford substrate near plants and in spaces between plants to determine the effect on sedimentation/erosion processes of the presence and absence of plants, their density, different stock types, and distance from shore. The strips were buried to the third line in from a short leader, with about 30 cm of mylar extending beneath the substrate surface, tied and stapled at the bottom end to a wooden anchor stick about 10 cm long. Distance from the substrate surface to the second line was recorded at placement, then monitored at intervals. Increased distance between substrate surface and the second line indicated erosion; decreased distance showed sedimentation. Strips were placed only in high fertilizer zones.

Water Quality

Water samples were taken at high tide and in low tide pools on the Stratford and Clinton planting sites, in the Indian River and mosquito ditch adjacent to the Clinton site, at station #7 on the Housatonic River, and at station #6 farther up the cove from the other Stratford stations. Parameters tested were salinity, carbon dioxide, alkalinity, pH, hardness. Samples were taken as close as possible to high and low tide at the neap and moon tide periods, to determine whether a regular bimonthly fluctuation in water quality occurs in response to the proportions of saline ocean and fresh river water flooding the sites and their adjacent estuaries and other water bodies at moon and neap tides, to confirm a daily fluctuation in quality, and to examine the possibility that plant growth and reproduction may be related to water quality fluctuations. LaMotte Oceanography Water Testing Kits were used.

RESULTS

Stratford Plant Success: by Stock Type

In 1978, plugs were the most successful stock for the number of plants excelling in height, number of stems and shoots. This was expected due to their short transplant distance and time in transit, and their large size. But in these parameters, and marginally in circumference, bare roots had the second greatest number of successful plants and overwintered equally well. Yet prior to planting they were ripped from a dense root mat, stored in water of insufficient quantity and varying salinity, and exhibited areas of beige roots and limp yellow standing growth. The peat pots, stiff and green at planting, had root protection in their pots, but had the smallest number of most successful plants. Considering growth magnitude rather than the comparative number of most successful plants, the peat pots were more successful than the bare roots, with plugs outgrowing both, presumably due to their larger starting size. Plugs, however, did the worst in circumference development.

In 1979, the bare roots (grown in peat pots and broken out) did so poorly in growth magnitude that they frequently escaped measurement, although when measured they showed weak but positive growth. In 1979, growth success for different stock types was as follows: for height, plugs were most successful, followed by peat pots with bare roots least successful. For stem numbers, plugs were most successful closely followed by peat pots. For shoot development, peat pots were most successful closely followed by plugs, with bare roots indicating weak but creditable activity. For circumference, little data was recorded but evidence suggests that peat pots were most successful, closely followed by plugs.

Stratford Plant Success: by Distance from Shore

Both years and especially 1978 showed a trend of worse growth farther out from shore (see Figures 4 and 5). The high shore stock (station #1) also overwintered best; the stock on stations #4 and #5 (the mudflats) disappeared during the winter. Growth was consistently poor on the turf mounds (station #3) which, although almost as high in elevation as the most successful high shore, contained less sand and more clay and silt in the mineral fraction of their substrate.

Stratford Plant Success: by Fertilizer Dose

In 1978, for development of height, stems, and shoots, growth was better with fertilizer than without in all but two plots. Growth appeared best in the plot with half a dose of fertilizer, but that could have been

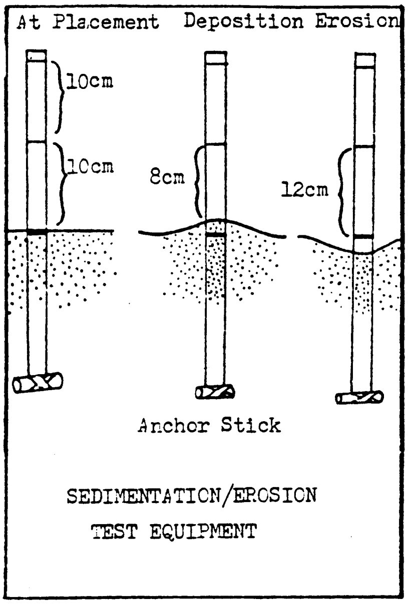

Figure 3. Sedimentation/erosion test equipment. Each wide bar contains measurements for stations 1 - 5, in order, moving out from shore. Narrowest bars represent October measurements; wider ones are July measurements. Each of the four widest bars is labeled with its growth parameter below it.

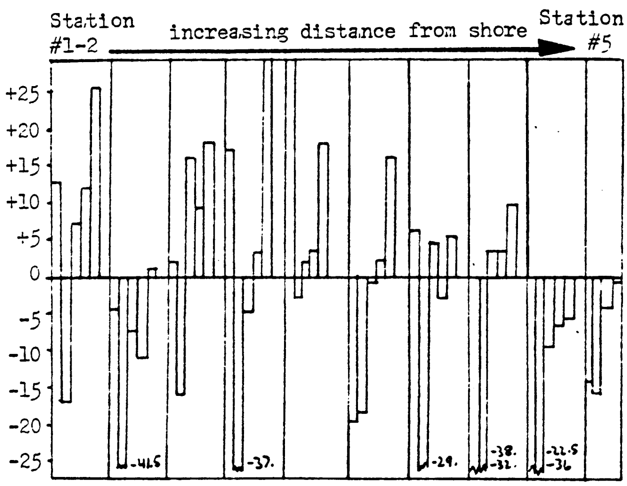

Figure 4. Stratford site 1978 bare root stock sample of worse growth farther from shore. Each wide band represents a planting station. The order of narrow bars in each station is as follows:
1) maximum stand heig
2) majority stand heig (= maximum height o greatest number of stems),
3) number of stems,
4) number of shoots,
5) circumference.

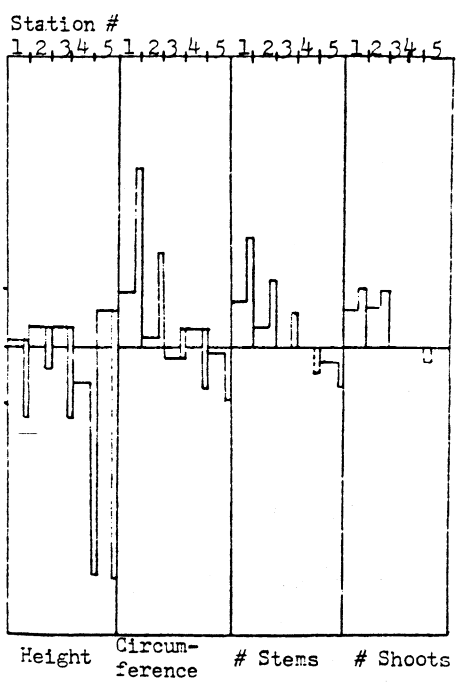

Figure 5. Stratford site 1978 peat pot stock, no dose; sample of worse growth farther from shore.

due to other influences. Yet in 1979, regarding height, all stock types had more plants doing best with a half dose or no fertilizer, and worst with a full dose. Regarding circumference, peat pots did best with none, worst with a full dose. Plug results were mixed, showing better growth with both more and less fertilizer. Regarding shoots, indication exists for better growth with half a dose than with no fertilizer. Bare root data is scanty, but weakly confirms these trends.

Clinton Plant Success: by Stock Type, Fertilizer Dose, Substrate, Potting Mix

Due to interrelationships between test parameters and the complex and detailed nature of Clinton data, this information has been reduced to several key findings.

1) S. alterniflora grew best on flooded areas and worst where high and dry. It spread from 1/2 meter density to a solid, tall mass by the second spring, and seeded in the first fall after planting.

2) Distichlis spicata bare roots from Maryland, inadvertently pickled in storage in a salt panne offsite (a shallow depression containing highly saline water at low tide), spread in rhizoidal wheels 78 cm in diameter by the second spring and seeded in the first fall. Distichlis plugs did better in dry clay than where the substrate was waterlogged. In 1978, very good Distichlis and S. patens growth occurred in peat, probably due to good aeration as the peat had a high gas exchange. In 1979, the peat felt wetter and the site was saturated, so the gas exchange (although not tested) was probably lower. The peat in 1979 was near an area crusted with salt. While both Distichlis and S. patens did poorly in peat in 1979, the Distichlis did better, indicating possible salt tolerance relative to S. patens.

3) S. patens peat pots from Maryland survived the same pickling conditions as the Distichlis, but spread circumferentially the least of

all 1978 stock planted at Clinton and had not seeded by the second fall. S. patens peat pots did best on high ground and worst in heavy clay both years. The heavy clay had water flowing through its bedding planes in 1979.

4) S. patens plugs spread farther than the peat pots and seeded in the first fall. By the second fall, they produced well over 90 seedheads per transplanted clump. In 1978 the healthiest transplants had seedheads, negating the theory that these should be removed to conserve plant strength. The plugs did worst when low and flooded. Larger plugs did best when a football-sized initial plug was cut into 4 or 5 pieces measuring approximately 10 cm across rather than 5 or 6 pieces of approximately 6 cm across.

5) Short transplant distance and storage time for the plugs vs. peat pots might account for their greater success, except that the Distichlis bare roots, also from Maryland as were the S. patens peat pots, suffered the same transplant stress and grew more successfully.

6) In pannes drained between the tides S. patens plugs in 1979 did better than Distichlis, possibly due to the tidal upsurge harming the Distichlis. The potting mixture, intended to loosen the stiff clay substrate also appeared to impair Distichlis growth.

7) In pannes, not until three months after planting with fertilizer did S. patens show better growth with fertilizer than without it; and by then the fast-action fertilizer should have dissipated.

8) In clay, as compared to growth in the pannes, S. patens grew inconsistently taller, but put on more shoots and circumference in the panne. The clay oozed water from its bedding planes when cut. The panne deeply cracked, drained completely between the tides. That drainage is critical to S. patens plugs is also suggested by very good growth in a mixture of sand and clay, which produced better S. patens circumference

and shoots than any pure clay or panne plot. The potting mixture inhibited circumference development until three months after planting, by which time the roots had probably grown beyond its localized drainage influence.

9) In clay, growth response to fertilizer was inconsistent, but height measurement showed better growth without it, and circumference development did progressively better with less fertilizer. By October this was not so, but by then the initial dose should have dissipated. Further indication of adverse fertilizer impact exists, in that there was more shoot production in clay with fertilizer and the potting mixture than without them, yet worse circumference development with them. Considering circumference increase as site colonization by long rhizomes produced by plants having the health and strength to grow them, and shoot production without circumference increase as only the replacement of stressed standing growth, shoot production alone may indicate stress. Thus, fertilizer and a loose, watery potting mixture composed largely of fine clay probably harms *S. patens* plugs.

10) In sand, *S. patens* and *Distichlis spicata* grew equally poorly in height development, but the *Distichlis* did better than the *S. patens* in circumference and shoot development. It is, therefore, the better stock for sand although both stocks decreased more in height than in any other substrate. The sand remained moist through the growing season, so nutrition was probably the limiting factor. Best growth and survival occurred on a half dose of fertilizer. If dead plants were discounted, best growth along occurred on a full dose. Thus in sand fertilizer may be needed, leaching away enough so as not to harm the plants. How much to use cannot be determined from this data as the half and full doses used may have leached to much less.

11) A very successful *S. patens* plot contained pure sand, pure clay

and a mixture of both, in different areas. That mixture and a second mixed sand/clay plot produced better circumference development than any in pure sand or clay, except for growth in the sand portion of the plot containing sand, clay, and the mixture of both. That sand probably received leachate of nutrients and clay particles from the clay portion. There was also better shoot production in these two sandy areas that presumably received clay leachate than in any other plot, and worse shoot production in their clay portions.

Sedimentation and Erosion: Effect of Plant Presence

In 1978, in plots of 39 and 70 plants, deposition and almost no erosion occurred near plants, while erosion and almost no deposition occurred between plants (see Figure 6). In 1979 the test plots contained only 9 plants each, and the smaller plant populations were only about 60% effective at inducing deposition: only about 20% more deposition occurred near plants as between them.

Sedimentation and Erosion: Effect of Stock Type

Data is only available for 1979. The greatest amount of deposition occurred in the bare root plots, on virtually bare substrate. The next most occurred with the plugs, and the least deposition with the peat pots.

Sedimentation and Erosion: Effects of Distance from Shore

In 1978, mylar strips were placed only on the high and low shore and on the turf mounds (stations #1, 2, and 3). The least deposition and greatest erosion occurred on the low shore. Most deposition and moderate erosion occurred farther out on the low shore, where it still received sediment from the high shore but was subject to less rapid tidal action and had a peatier, firmer substrate. The least erosion and second highest deposition occurred on the turf mounds (station #3).

In 1979, the least deposition and greatest erosion occurred on the

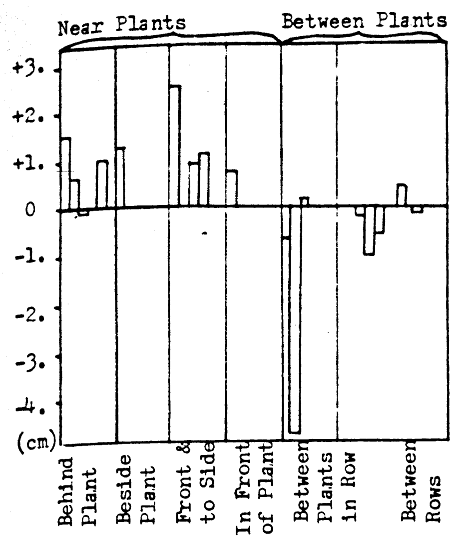

Figure 6. Sedimentation/ erosion 1978.

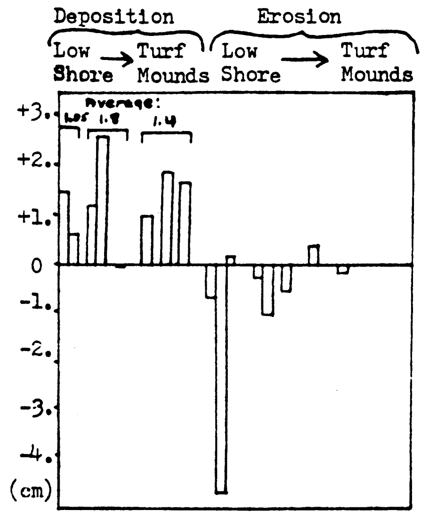

Figure 7. Sedimentation/ erosion; distance from shore.

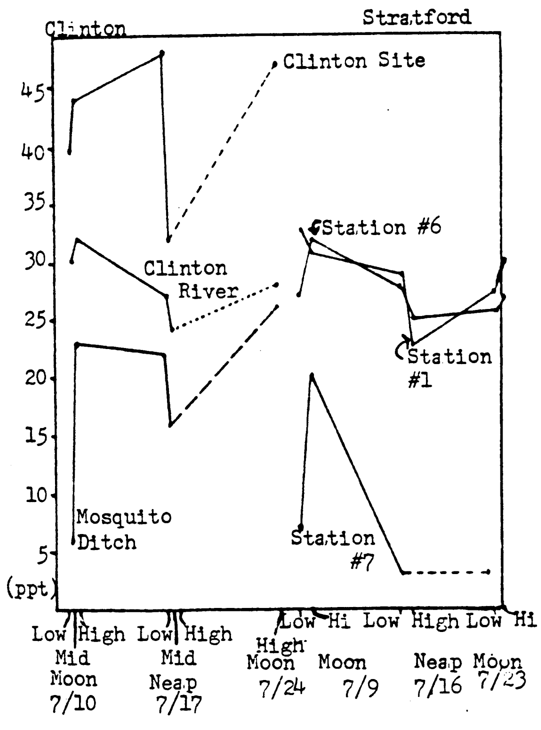

Figure 8. Water quality: salinity 1979.

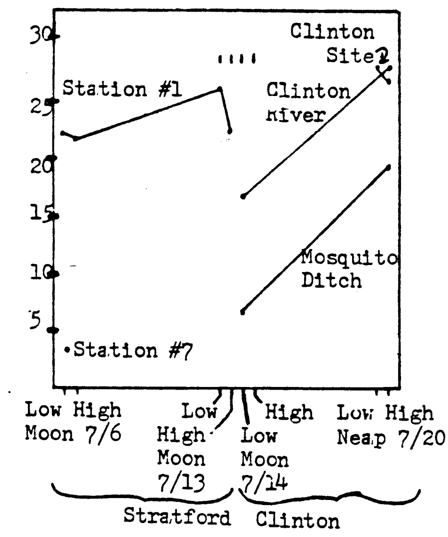

Figure 9. Water quality: salinity 1978.

high shore (station #1), and more deposition occurred on the low shore (station #2), with the most deposition occurring on the turf mounds (station #3). Stations #4 and #5 on the mudflats sustained both processes.

Water Quality

As the data obtained is extremely complex, it has been briefly summarized in a general list of results, followed by the main findings for each parameter.

General Water Quality Findings

1) Most tests indicated neap and moon tide fluctuations in water quality, due to more salt water flooding sites at moon tide and fresh water at neap tide. Sometimes the two moon tides differed in quality, possibly as the first was more extreme than the second.

2) Juncus gerardii flowered on the first moon tide at Clinton; S. patens flowered on the second.

3) The test sites varied, often significantly, in their water quality across as little as 70 meters (between the Clinton ditch and Indian River) or less (between stations #1 and #6, the only ones tested for water quality at Stratford).

4) Subterranean fresh water upwelling from beneath the adjacent shore is suspected at station #6 at Stratford, demonstrating that within 50 meters of the other stations a totally unexpected hydrologic phenomenon may occur. Better bare root growth in that plot than elsewhere suggests that S. alterniflora may grow better in fresher water than in more saline, although this could be attributable to other causes. "Sinkholes" throughout the Stratford site inshore of the mudflats (station #4) may be sites of subterranean upwelling. This was not tested. Confirmation would explain localized site disintegration and hole formation seemingly unconnected with surface water movement.

5) The Clinton site itself was found to change the quality of adjacent River and ditch water by drawing water up through its substrate and concentrating minerals in its substrate through surface evaporation. These leak back into the surrounding water bodies, especially at low tide.

6) Water quality differed between surface, middle and bottom layers of a high tide water column at Stratford indicating a settling out of hardness minerals (see Figure 16).

7) Evidence suggests that thick areas of plants at Stratford "combed" nutrients from the water the same way they slowed it down and trapped sediments. This may be why the plants at station #6, surrounded by thick stands of native grass, grew better than elsewhere on the site.

Results of Specific Water Quality Tests

Salinity

1) Station #7, several miles inland on the Housatonic River, had lower salinity than any other test site, with greatest salinity occuring at high tide (see Figures 8 and 9).

2) The Clinton mosquito ditch had lower salinity than the Indian River. In 1979, although both were more saline at high moon tide (when influenced by incoming salt water) than at low moon tide, both were saltier at low neap tide than at high neap tide.

3) In tide pools on both restoration sites, salinity (and hardness) were elevated at low tide.

4) Station #6 at Stratford had lower salinity at low tide than at high tide at both 1979 moon tide test periods.

5) Station #6 had greater salinity at neap high tide than did station #1. Station #6 is surrounded by denser stands of native *S. alterniflora* than is station #1.

6) The Clinton site, Indian River and mosquito ditch all had higher

salinities in 1979 than in 1978.

7) The Clinton site was less saline at low moon tide than at high moon tide (1979). This pattern was reversed at neap tide.

Carbon Dioxide

1) The Clinton site and surrounding water bodies contained more gas at low neap tide (when they were more fresh) than at high neap tide, and more at neap than at moon tide (see Figure 10. Also see Conclusions, Salinity, #5 for clarification of the apparent contradiction between this statement and the one immediately above regarding low neap tide being both more saline and fresh simultaneously at Clinton.).

2) Stations #1 and #6 at Stratford both contained more carbon dioxide at low neap tide than at either moon tide.

3) Stratford station #7 contained more gas at high than at low tide.

Alkalinity

1) Tide pools at Stratford stations #1 and #6 seemed to concentrate alkalinity minerals to higher levels than those of incoming tidal water (see Figure 11).

2) Stratford station #7 had lower alkalinity than other sites closer to the Sound and had its greatest alkalinity on the high moon tides.

3) The Clinton ditch had low alkalinity at low moon tide, more at high tide.

4) Alkalinity and carbon dioxide peaked together on station #6 at times when fresh water appeared more prevalent than salt.

pH

1) Comparison of Figures 11, 12 and 13 show that the relationship between pH and alkalinity may not be as close as supposed.

2) The almost level pH curve at station #7 on the Housatonic River matches the moderation of its alkalinity curve, and contrasts the more

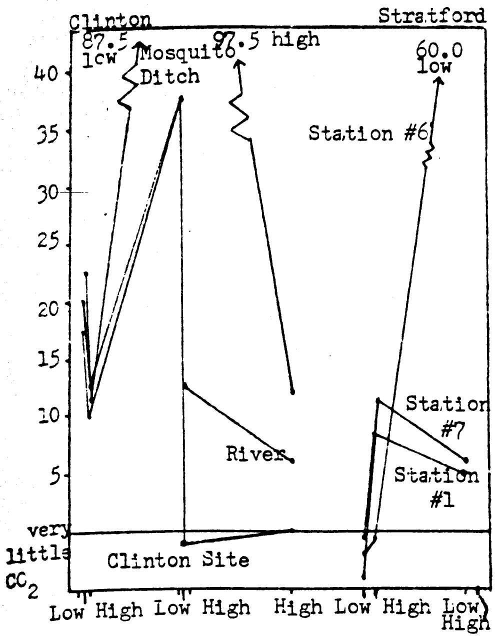

Figure 10. Water quality: carbon dioxide 1979.

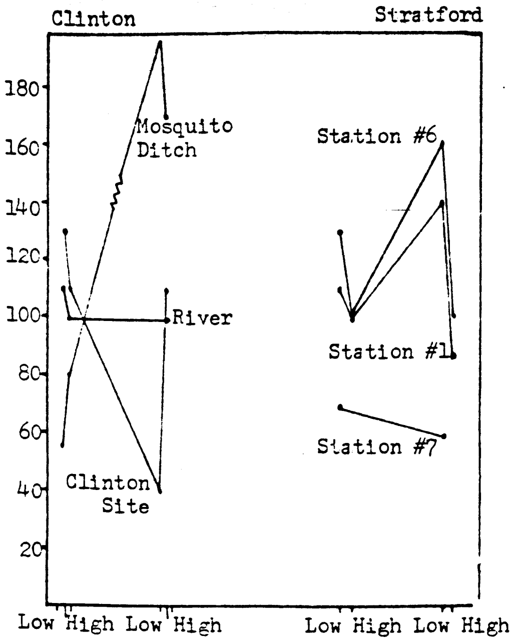

Figure 11. Water quality: alkalinity 1979 (carbonate, hydroxide, and bicarbonate).

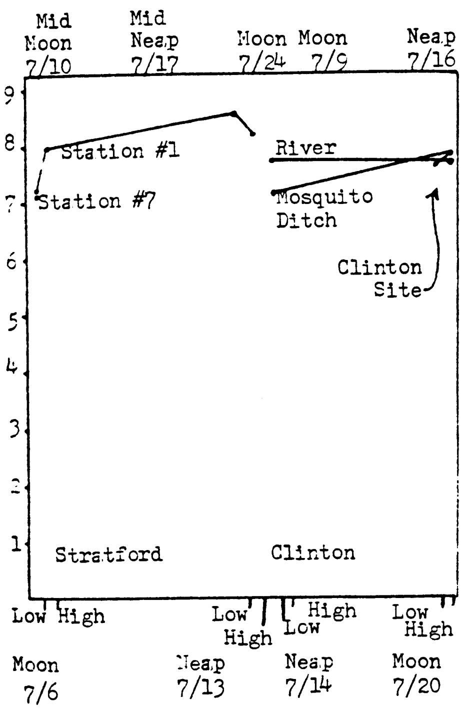

Figure 12. Water quality: pH 1978.

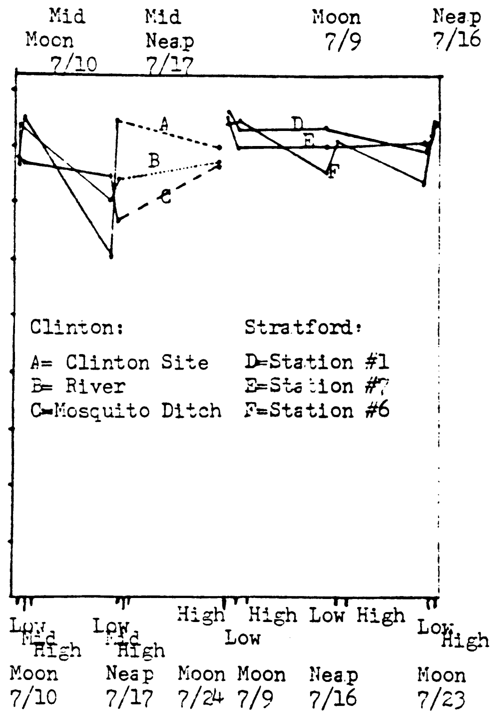

Figure 13. Water quality: pH 1979.

extreme range of the Clinton Indian River.

3) pH in the Clinton mosquito ditch was even more extreme than in the Indian River.

4) Station #6 at Stratford was more acidic than station #1.

5) All three Clinton test sites were more acidic and erratic in pH than the Stratford test sites.

6) The Clinton site was more acidic at low tide than high, and much more acidic at neap low tide than at any other time.

<u>Hardness</u>

1) Figure 14 shows that Stratford stations #1 and #6 are closely similar in hardness, and differ from station #7 upstream.

2) The Clinton site and Indian River are similar in hardness curves (see Figure 15).

3) All hardness curves (see Figures 14 and 15) reveal a consistent pattern of fluctuation between neap and moon tide water quality.

4) Higher hardness values (except for calcium) occurred at Stratford station #1 than at station #6.

5) Stratford station #1 reveals higher concentration of hardness minerals at low tide than at high, except at the first moon tide.

6) Stratford station #7 showed greater hardness at high than at low tide.

7) The Clinton site showed a higher mineral content at the second moon tide than either the Indian River or the mosquito ditch.

8) Clinton hardness values were higher in 1979 than in 1978.

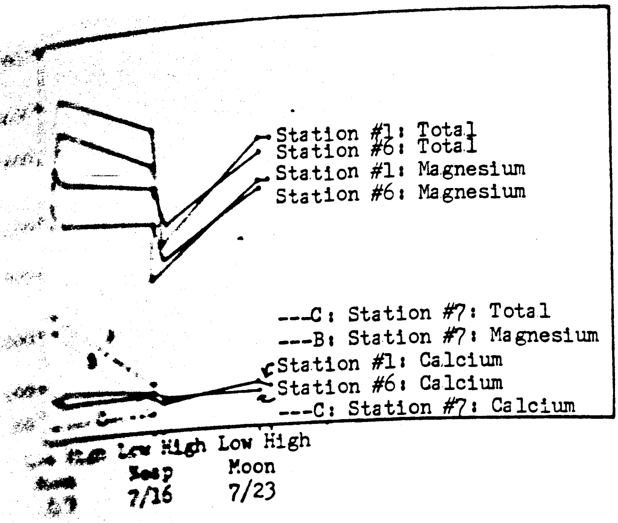

Figure 14. Stratford water quality 1979: total, magnesium, calcium hardness (ppm).

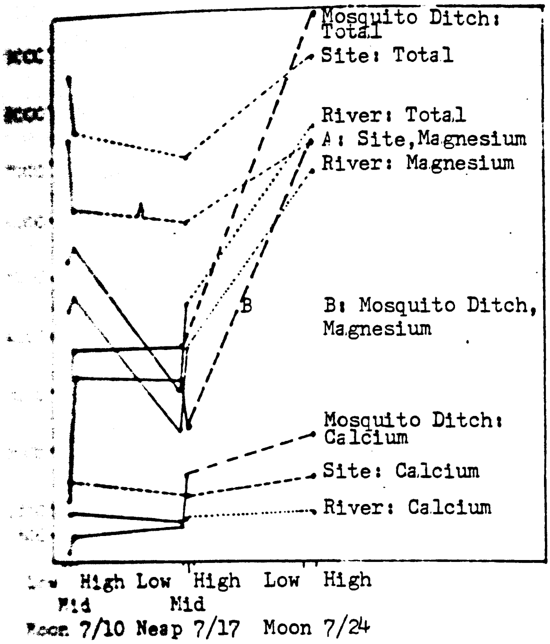

Figure 15. Clinton water quality 1979: total, magnesium, calcium hardness (ppm).

	Base	Center	Top
Calcium	500	750	500
Magnesium	8500	4000	3750
Total	9000	4750	4250
(ppm)			

← Direction of Settling

Figure 16. Stratification of minerals in high tide water column: Stratford 1978.

CONCLUSIONS

Stratford Plant Success: by Stock Type

S. alterniflora is said not to produce rhizomes in dense stands, which may explain why the Stratford plugs did so poorly in circumferential spread as compared to peat pots. The plugs were dug from dense stands. That a chemical inhibitor may suppress rhizome production in S. alterniflora is also suggested by S. alterniflora peat pots producing fewer shoots at Clinton than at Stratford, having been stored for a long time in densely packed trays at Clinton and for a much shorter time at Stratford.

The success of bare root stock in 1978 indicates that they deserve more attention as a potentially successful stock type for use in restoration work, especially as they are the cheapest stock to purchase. That they did more poorly in 1979 could have been due to their having been raised in a liquid solution in 1978. Having been used to liquid growing conditions, the bare root stock acclimatized readily to the waterlogged Stratford site whereas the 1979 bare root stock, raised in relatively well drained peat pots, died when placed in a waterlogged substrate. Thus, drainage appears critical to S. alterniflora. This is supported by better growth in four plugs taken from the low shore at Stratford and transplanted to the Clinton high marsh site, which grew better than two plugs similarly transplanted from high ground adjacent to the Clinton site. The Stratford plants appeared to be responding to a release from worse drainage and waterlogged Stratford conditions.

The reversal of peat pot stock beating or approaching plug success in 1979 shows that plugs cannot be taken from a well-drained high shore area, as in 1979, and successfully planted in saturated low mud, or on a high turf mound with little sand and much clay to impede drainage as occurred at station #3. The 1978 plugs were comparatively more successful having been accustomed to saturated conditions in the peat island from which they were taken. Thus vertical distance may be more important than horizontal distance in transplanting wetland plants. Further evidence of the importance of drainage to plant growth occurs on the Clinton site, where the potting mixture impaired growth.

Planting suggestions arising from these findings are to test bare root stock for success under different conditions and to raise bare root stock hydroponically. Also, take plugs only from drainage conditions worse than or equal to those in which they will be replanted. *S. alterniflora* should be tested for chemical rhizoid inhibitors. Hydroponic solutions may dilute these, or bare roots may produce more shoots under stress.

Stratford Plant Success: by Distance from Shore

The superior growth exhibited by *S. alterniflora* stock on the high shore as compared to the rest of the site confirms the importance of drainage to plant growth, as the high shore region stood higher than the other stations and contained more sand in its substrate, and was, therefore, better drained. It also had a firmer substrate for roots to grip. Further out, at stations #4 and #5, the substrate was so soft that roots and mylar strips easily pulled free and were lost. A planting suggestion is, therefore, to confine revegetation activity in a low marsh to the firm, well-drained high shore zone, avoiding mudflats and turf mounds unless the mounds are high in sand content. This practical consideration augments the sense of leaving mudflats as ecosystems in their own right (Corps. 1977)

Stratford Plant Success: Fertilizer Dose

The variability of growth success in response to fertilizer refutes the belief that fertilizer is always beneficial and necessary to wetland planting. The optimal amount to use is definitely questionable. That the larger plots of 1978 showed more consistency in growth may indicate that fertilizer leaching occurred in 1979 when dose zones were at most 1 meter apart (except on separate turf mounds) and sometimes much closer together. In the no dose zone of the high shore station, located at the top of the shore above the half and full dose zones, higher nitrogen levels found one week after fertilization may mean tidal movement carried the fertilizer up the shore. Research is needed to study fertilizer movement through different substrates, elevation levels and saturations, and its effect on different plant species. An even application to a restoration site could leach to localized overdoses and starvation and could impact surrounding natural marshes.

Clinton Plant Success: by Stock Type, Fertilizer Dose, Substrate, Potting

This information has been listed below as several key findings.

1) Because of its rapid spread by rhizomes and seed production and its affinity for flooded areas, *S. alterniflora* should be planted around pannes and creeks for erosion control and to provide vegetal diversity on a high marsh site.

2) *Distichlis spicata* also spreads very fast and well and should be considered as planting stock for well-drained, non-waterlogged areas on a high marsh. It may be salt tolerant.

3) *S. patens* peat pots may be a less successful stock type than *S. patens* plugs, although because of the impact plugging has on a native marsh this should be well tested before accepting it as a planting guideline. Evidence suggests best growth when the plugs are planted high and are not waterlogged and when they are kept relatively large.

4) Fertilizer probably harms *S. patens* and *Distichlis spicata* on a high marsh at a one ounce dose. The optimal dose to use apparently varies between sand and clay. The clay appears to hold the fertilizer

close to the plant, while the sand allows it to leach away. In sand, fertilizer may be needed for nutrition.

5) Better growth in sandy areas near clay than in areas of pure sand or clay suggests that drainage is the limiting growth factor in heavy clay, with nutrition the limiting factor in sand. The best planting medium may be sand enriched with a clay leachate.

Sedimentation and Erosion: Effect of Plant Presence

The greater success of the larger 1978 plant population at causing sedimentation indicates that plants interrupt water flow, slow it down, and reduce its sediment-transport ability, causing deposition. Between plants in a large enough population, water retains or perhaps increases its speed causing erosion.

The number of plants appears critical to their success at trapping sediment. A certain number of plants is apparently needed to slow water to a critical speed, below which individual plant interference causes deposition.

Sedimentation and Erosion: Effect of Stock Type

That deposition occurred most readily on the virtually bare substrate of the limp, sparse bare root plots shows that deposition in a low marsh occurs readily on bare substrate and is interrupted and influenced by the presence of plants. The tall, stiff plugs, which caused the second greatest amount of deposition, probably interrupted more of the vertical water column than did the shorter peat pots, inducing deposition from all through the water column because of their height. At this low density, the stiff short peat pots may only have caused currents at the substrate surface, preventing deposition.

Sedimentation and Erosion: Effect of Distance from Shore

The low shore zone (station #2, Stratford) received extremes of both erosion and sedimentation because it is in an area of rapid tidal action and because it receives materials washing from the high shore. Plug-digging at the base of the high shore in 1979, and planting on the high shore in both years may have disturbed enough substrate to cause substantial sedimentation as well as erosion on station #2 and to disrupt natural deposition processes.

Station #3, the turf mounds, received much sediment because they are high, and trap sand washing out from the high shore as well as silt and clay flowing in from the estuary. The preponderance of deposition vs. erosion at this location demonstrates that the volume of sediment deposited outweighs erosion.

The high shore zone (station #1) suffers the greatest erosion and receives least deposition because of its steepness and because it is farthest removed from the estuarine source of silt and clay, much of which is blocked by the turf mounds. This is an example of the condition of most tidal marshes in Connecticut, which are eroded back towards shore.

Stations #4 and #5 on the mudflats sustain deposition because they are close to the estuarine source of fine particles that comprise most of their substrate content. Their small sand content demonstrates that a river in general does not transport its relatively heavy sand to its estuary. That they receive more sediment by volume than the low shore plots (see Fig. 7) receive coarser sand, demonstrates the relatively larger number of fine silt and clay particles that are deposited by a river in its tidal wetland as compared to the smaller number of large sand particles that are eroded from the shore. The mudflats experience erosion because they are in a shallow area where waves break and because they are covered by receding and advancing tidal water for more time than any other place on the Stratford site. Their saturated, level substrate causes water to flow laterally across its surface, causing sheet erosion.

Some hypothetical planting guides based on these findings are:

1) Plant many plants and do not cut back standing growth to induce deposition.

2) Sparse planting may cause erosion, or prevent deposition, especially if plants are short and stiff.

3) Consider planting more densely inland from the erosion-prone marsh edge, to prevent a ridge of substrate from developing in the dense, sediment-trapping planting that is customary at the erosion-prone edge of a wetland, and pannes from forming farther back in the less densely planted zone.

4) Sources of sediment and erosion-prone areas can be effectively defined and monitored by the methods used in this study, but the mylar should be carefully mapped relative to permanent markers and photographed for relocation. It becomes buried, and it may wash away in the winter.

Water Quality

General conclusions and hypotheses regarding water quality and specific conclusions regarding the parameters tested are:

1) Reproductive cycles of wetland plants may respond to the regular monthly changes in water quality that occur on a tidal wetland. Testing is needed to discover whether this is true and whether wetland plants respond to the increased nutrient availability or to the increased water volume of the moon tides.

2) Difference in water quality occurring over short distances indicates that either the planting guideline that stock can be successfully transplanted across 100 miles of distance without undue stress is untrue, or that wetland plants are more tolerant of water quality changes than is realized. Stock used in this study generally survived movement from site to site, from fresh to salt water, and pickling through storage in salt

pannes, but some stock sustained less shock than other types. Thus wetland plants do appear tolerant but species vary in this regard.

3) That the Clinton site altered water quality within itself and in adjacent water bodies suggests that a disturbed wetland site may need several seasons to come into balance with its surrounding water bodies regarding water quality. The transitional faunal populations observed on other marshes and their reported temporary paucity on disturbed high marsh sites (Cammeno et al. 1974) may be due to this factor, which could be as simple as the length of time it takes the substrate to become re-saturated with water. Fiddler crabs, absent from Clinton in 1978 and abundant in 1979, indicate that this is so. The effect of a disturbed site on surrounding marshes and their fauna needs to be studied.

4) Settling of hardness minerals towards the bottom of the high tide water column suggests that, as well as the depth of the water column (Warren 1974) the length of time water stands on a site is important to the mineral enrichment of the site. If water were ponded on a site over mineral-rich moon tides, the site could perhaps be "artificially" fertilized with naturally occurring nutrients. The wind speed, direction and time of day may affect this nutrient settling, with more minerals settling during windless high tide periods such as between storms and in calm evenings when a site is protected from land breezes by a high shoreline. If confirmed, such information could assist wetland restorers in adjusting doses of artificial fertilizer to meet only those needs of a marsh that cannot be met naturally.

5) Thick areas of plants on a site may "comb" nutrients from the water, fertilizing themselves and leaving sparser areas of plants undernourished.

Wetland water quality is complex, revealing much about site mechanics that is important to restoration work and plant growth. Apparent contradictions in water quality data often reveal more about a site than do the more expected findings.

Conclusions of Specific Water Parameters

Salinity

1) A tidal river decreases in salinity with distance upstream, and experiences its greatest salinity at high tide, as demonstrated by Stratford station #7.

2) Receipt of fresh upland runoff lowered salinity in the Clinton ditch to a concentration below that found in the closely adjacent river, which also lies closer to the source of salt water. Higher salinity in the ditch at low neap tide than at high neap tide shows that the adjacent high wetland, recently disturbed and concentrating minerals in its substrate through surface evaporation, produces highly saline water that trickles into the adjacent water bodies at low tide affecting their water quality.

3) Evapoconcentration produced high levels of salinity and hardness in tide pools at low tide at both the Clinton and Stratford sites.

4) Low salinity in a tide pool on Stratford station #6 at low tide suggests upwelling fresh water coming from beneath the adjacent upland. That this did not occur at relatively nearby station #1 demonstrates that a site can influence its water quality to be very different at closely spaced areas.

5) Secretion of salt from the leaves of *S. alterniflora* may raise salinity locally, where plants are thickest, during a neap high tide when fresh river water should dominate the tidal mixture. This may explain the higher salinity at station #6 than at station #1 at neap high tides when one would expect station #6 to be more fresh.

6) Even a relatively saline high moon tide thoroughly rinses the

Clinton site of evapoconcentrated minerals, due to the large volumes of diluting water that are present. At low moon tides, the site draws up fresh river water by surface evaporation, and this dilutes any leftover salt. That this pattern is reversed at neap tide (see Figure 9) demonstrates how "fresh" river water drawn up through the site at neap low tide becomes laden with salt concentrated in the substrate, which is not rinsed out by an extremely high tide. This gives the site its greatest salinity at low neap tide rather than at high neap tide. This is confirmed by carbon dioxide patterns.

Carbon Dioxide

1) The Indian River and mosquito ditch contain more gas at low neap tide than at high neap tide because carbon dioxide can be dissolved more readily in fresh water than salt, and these water bodies do not receive tidal action at neap low tide. The river and ditch, fresher at low than at high tide, should have more gas at low tide and do. That the Clinton site also has more gas in its puddles at low tide (from which it should have "boiled off" as they heated up) confirms that fresh river water, with a high carbon dioxide content, is drawn up by surface evaporation at low neap tide. Numerous bubbles in the puddles may have been this gas.

2) In general, as at Stratford station #1, carbon dioxide is driven out of tide pools as they heat in the sun, leaving less carbon dioxide at low moon tides than at high. At Stratford station #6, greater carbon dioxide concentration at low neap tide than at either low moon tide suggest that this station has fresh water upwelling locally, carrying dissolved gases. The greater volume of salt water present at moon tides may force the fresh/salt interface back into the subterranean water passages.

3) The Housatonic River station #7 contains more carbon dioxide at high tide than at low because it is shallower at low tide with no incoming

flow damming up its fresh water. Gases "boil out" of the low relatively warm water. At high tide, although saltier, more fresh water is dammed up making the river deeper and more full of fresh water containing dissolved gases.

Alkalinity

1) Evaporation in low tide pools concentrates alkaline minerals on a wetland site.

2) The Housatonic River receives much of its alkalinity from incoming salt water, as demonstrated by Stratford station #7. The same is true for the Clinton mosquito ditch which receives fresh water runoff at low tide. Here, an alkalinity peak at low neap tide may indicate evapoconcentrated minerals leaking from the adjacent Clinton site.

3) A direct relationship may exist between carbon dioxide and alkalinity with high gas volumes (perhaps moving swiftly through the water column and then boiling off) leading to the precipitation of large amounts of alkaline minerals which require carbon dioxide for their formation. This is suggested by their simultaneous occurrence at Stratford station #6 at times when fresh water is suspected as being more prevalent than salt.

pH

1) The difference between pH curves for the Indian and Housatonic Rivers (station #7) clearly demonstrates that a river site lying closer to the source of tidal action such as the Indian River mouth experiences more extreme variation in its mineral content, while a site further upstream such as station #7 experiences more moderate variation.

2) The mosquito ditch receives more fresh water runoff from an adjacent upland than the River in proportion to its size and varies even more in water quality, containing almost pure fresh upland runoff at

certain low tides and some saline water at high tide.

3) That the Stratford site experiences fresh water upwelling at certain locations is suggested by a lower pH at station #6 than at station #1, indicative of fresh acidic water welling up at station #6.

4) More acid and erratic conditions at all three Clinton test sites as compared to Stratford suggests that a more restricted river mouth and less access to tidal water, such as occurred at Clinton relative to the wider Stratford river mouth, may reduce the amount of incoming tidal water and its influence on estuarine water quality. This is speculative and flows must be measured to confirm it.

5) Figure 13 demonstrates that the Clinton site is drawing up fresh water from the River through surface evaporation.

Hardness

1) Similarity between the hardness curves of the Clinton site and the Indian River support the conclusion that the site is drawing up river water through surface evaporation, and is leaking it back into the river with a concentrated load of minerals.

2) A definite monthly fluctuation in hardness occurs in estuarine wetlands due to the varying influences of fresh and salt water.

3) Dilution from upwelling fresh water can apparently occur locally on a site, as demonstrated by lower hardness values (except calcium) at Stratford station #6 as compared to station #1.

4) Evapoconcentration of hardness minerals occurs in low tide pools on wetland sites, as demonstrated by Stratford station #1. An exception occurs during the first high moon tide which, being extremely high, demonstrates how a relatively large volume of tidal water can outweigh even the mineral concentrations caused by evaporation.

5) A tidal river receives most of its hardness minerals from tidal

flooding, as demonstrated by Stratford station #7 which has greater hardness at high tide than at low.

6) Concentration of minerals in the Clinton substrate and incomplete rinsing with tidal water by the second, lower moon tide is indicated by the higher hardness levels in the site than in the surrounding water bodies at that time.

7) Higher overall Clinton hardness in 1979 reveals that more concentration of these minerals had occurred in the site by 1979 than occurred by 1978.

ACKNOWLEDGEMENTS

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TRANSPLANTING NEEDLERUSH (*Juncus roemerianus*)

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ABSTRACT

Needlerush (<u>Juncus roemerianus</u>) was dug at monthly intervals from a mid-marsh zone in a north Florida tidal marsh. Shoots and rhizomes were cut into approximately 20 cm and 6 cm lengths, respectively. The following treatments were employed in a 2 x 2 factorial design: 1. bud on rhizome, 2. no bud on rhizome, 3. with "Rootone" (commercial growth regulator), 4. without "Rootone." Selecting a propagule with a bud on the rhizome resulted in greater number of shoots and buds and greater height growth after a six month period in the greenhouse. Rootone had a deleterious affect on growth. Month of transplanting had no affect on survival, but transplanting in February and March resulted in better growth.

Editor's Note-The author could not be reached for clarification of several points concerning the research reported in this paper.

Needlerush (*Juncus roemerianus*) is the principal plant species in the tidal marshes of Florida. There are approximately 200,309 ha (Coastal Coordinating Council 1973) of tidal marshes in Florida. These marshes are productive in terms of plant biomass produced (Kruczynski, Subrahmanyam, and Drake 1978) and marine organisms supported (Subrahmanyam and Drake 1975; Subrahmanyam, Kruczynski and Drake 1976). In order to rapidly stabilize dredge spoil and increase the area of productive marsh, transplanting adapted marsh plants is necessary.

METHODS AND MATERIALS

Needlerush (roots, rhizomes, and leaves) were dug at monthly intervals from a middle marsh position at Wakulla Beach, Florida. Soil was washed from the roots and rhizomes. The rhizomes were cut into 5 to 7 cm lengths and the leaves into 18 to 23 cm lengths. Each rhizome had 1 to 3 leaves attached. Four different treatments were employed in a 2 x 2 factorial design: (1) no terminal or lateral bud on the rhizome (B1), (2) with terminal or lateral bud on the rhizome (B2), (3) without "Rootone" (T1), (4) with "Rootone" (T2). The "Rootone" was a commercial preparation containing 0.067% naphthylacetamide, 0.033% 2-methyl-1-naphthylacetic acid, 0.013% 2-methyl-1-naphthylacetamide, 0.057% indol-3-butyric acid, and 99.85% inert ingredients. This material was thoroughly dusted on the moistened roots, rhizomes and lower leaves of the T2 treated plants immediately before transplanting. Plants were assigned treatments at random and the 9 or 10 prepared transplants of each treatment were placed in a peat, sand, bark (1:1:1 by volume) medium in the greenhouse. These plants were watered sufficiently to keep the medium well moistened. After a six-month growing period plants were dug and the following parameters noted: (1) number of plants surviving, (2) maximum leaf length, (3) number of leaves, (4) number of buds, (5) root rating with 1 being poor rooting and 3, good.

RESULTS AND DISCUSSION

Tables 1 and 2 show the effect of treatments and month of transplanting on the survival and growth of needlerush. There were no significant interaction effects with any parameters measured. Neither the month of transplanting nor the presence or absence of buds had a significant effect on survival, which ranged from 57.5% to 85.0% by months. Treatment with "Rootone", however, decreased survival from 83.2% to 69.8%. The number of buds on the rhizome and the number of leaves after a six month growth period were greater where the original transplant had a bud. "Rootone" treatment reduced the number of leaves, but the reduction was not significant. Months also had an effect on bud and leaf development. Those transplanted in January, April, September, and December had fewer buds than those transplanted in February and March, and those transplanted in January, April, and September had fewer leaves than those planted in March. No measurements were reported for August and May because of aberrant results.

Growth in height was greatest when the transplant had a bud, but the use of "Rootone" resulted in reduced growth. Maximum height occurred on those transplanted in October, November, February, March and April, and the least with those transplanted in January and September. Neither "Rootone" treatment nor months had a significant effect on root rating. The presence of buds increased root rating, however, from 1.94 (poorest) to 2.28.

In selecting the best treatment, the use of a propagule with a bud is justified as more buds, more leaves, and greater height growth will ensue. This should result in faster coverage of the area being planted. The use of "Rootone" is deleterious and thus should not be employed. Although the month of transplanting did not affect survival it should be remembered that this was a greenhouse study and the plants may react differently in the field. Late winter or early spring transplanting resulted in good bud and shoot development and climatic conditions would probably be most favorable at this time.

ACKNOWLEDGEMENTS

This research was supported in part by a grant from the Scientific and Education Administration/CR, (USDA). I also want to thank Dr. Duane Meeter, Florida State University Statistical Consulting Center for his help in designing and analyzing the results of the experiment.

Table 1. The effect of months on the growth and survival of needlerush six months after transplanting.

Month of transplant	Survival, %	Buds, no.	Leaves, no.	Maximum height, cm
June	76.3 a*	5.75 bcde	16.50 d	83.0 bcde
July	76.9 a	6.00 bcde	13.00 abcd	73.0 bcd
Sept.	76.9 a	4.75 abc	9.25 ab	59.0 ab
Oct.	85.0 a	7.25 bcde	16.00 d	94.2 cde
Nov.	80.0 a	6.50 bcde	17.25 d	103.0 e
Dec.	75.0 a	5.00 ab	11.25 abcd	71.8 abc
Jan.	72.5 a	4.75 abcd	10.00 abc	48.8 a
Feb.	75.0 a	8.50 e	14.75 bcd	90.8 cde
Mar.	75.0 a	8.00 de	16.00 d	97.8 e
Apr.	57.5 a	2.50 a	9.25 a	85.0 cde

* The numbers are treatment means. No measurements are reported for Aug. and May because of aberrant results. Analysis of variance was calculated using the following transformations: survival - arcsin $\sqrt{\frac{\#\ survive}{\#\ planted}}$; number of buds - square root; number of leaves - square root; maximum height - log. Like letters indicate no significant differences among treatment means, as determined by using Duncan's Mutiple Range Test.

Table 2. The effect of buds and Rootone treatment on the survival and growth of needlerush six months after transplanting.

Treatment	Survival, %	Treatment	Leaves, no.
B1*	76.9 a	B1	11.95 a
B2	76.1 a	B2	14.70 b
T1	83.2 a	T1	14.70 a
T2	69.8 b	T2	11.95 b

Treatment	Bud, no.	Treatment	Max. height, cm
B1	4.55 a	B1	75.5 a
B2	7.25 b	B2	85.8 b
T1	6.35 a	T1	87.3 a
T2	5.45 a	T2	74.0 b

* B1 = no bud, B2 = bud, T1 = no Rootone treatment, T2 = Rootone treatment. Like letters indicate no significant differences between treatment means.

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THE USE OF MARINE REVEGETATION FOR EROSION CONTROL ON THE PALM RIVER, TAMPA, FLORIDA

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ABSTRACT

Because of severe erosion problems along the tidal portion of the Palm River in Tampa, Florida, a trial program to control the erosion using marine revegetation was undertaken. Sixty meters (200 feet) of river bank were excavated to a gentle slope and cleared of all vegetation. Marine vegetation, *Spartina alterniflora* and *Paspalum vaginatum*, was planted and the growth monitored. After six months, the *Paspalum* had covered almost 100% of the formerly eroding shoreline. Only about 20% of the *Spartina* survived, but those remaining were spreading rapidly. A comparison between the "soft" (vegetation) erosion control method with "hard" (riprap) erosion control construction just upstream revealed the "soft" method effective in controlling erosion. The costs of both erosion control methods were also compared.

INTRODUCTION

Because of severe erosion problems along several hundred feet of the tidal portion of the Palm River in Tampa, Florida (Figure 1), a trial program to control the erosion using marine vegetation was undertaken. A survey (Mangrove Systems, Inc. 1977) to assess the problem area and determine the feasibility of using marine revegetation to control the problem was undertaken in 1977. The survey revealed that erosion within the study area had resulted in the apparent loss of 259 square meters (26,000 square feet) of vegetation cover since 1964 based on comparison of aerial photographs. The largest erosion occurred as the result of intertidal vegetation removed during a dredge material spill cleaning at the request of upland owners.

The majority (estimated at 75%) of the area's intertidal zone was unvegetated and actively eroding. The presence of overhanging vegetation rooted above the water level (Figure 2) gave the false impression that the intertidal zone was largely (2/3 or more) vegetated. A closer view (Figure 3) reveals that native and exotic terrestrial plant species such as Brazilian pepper, wild grape, wax myrtle, upland grasses, and silverling were the dominant shoreline plant cover. These plants' roots are not tolerant of submergence and do not penetrate into the wet soils of the lower shore. The thick canopy of terrestrial vegetation also shaded the intertidal zone and prevented the establishment of intertidal plants. These two factors resulted in an unvegetated zone that eroded quite quickly, even with relatively minor wave action from passing boats. Similar problems have been noted by Krause (1977) for small lowland streams in Germany where alder, because its roots penetrated below the water, stabilized the slopes; but the more prevalent ash often established first and offered no protection from erosion.

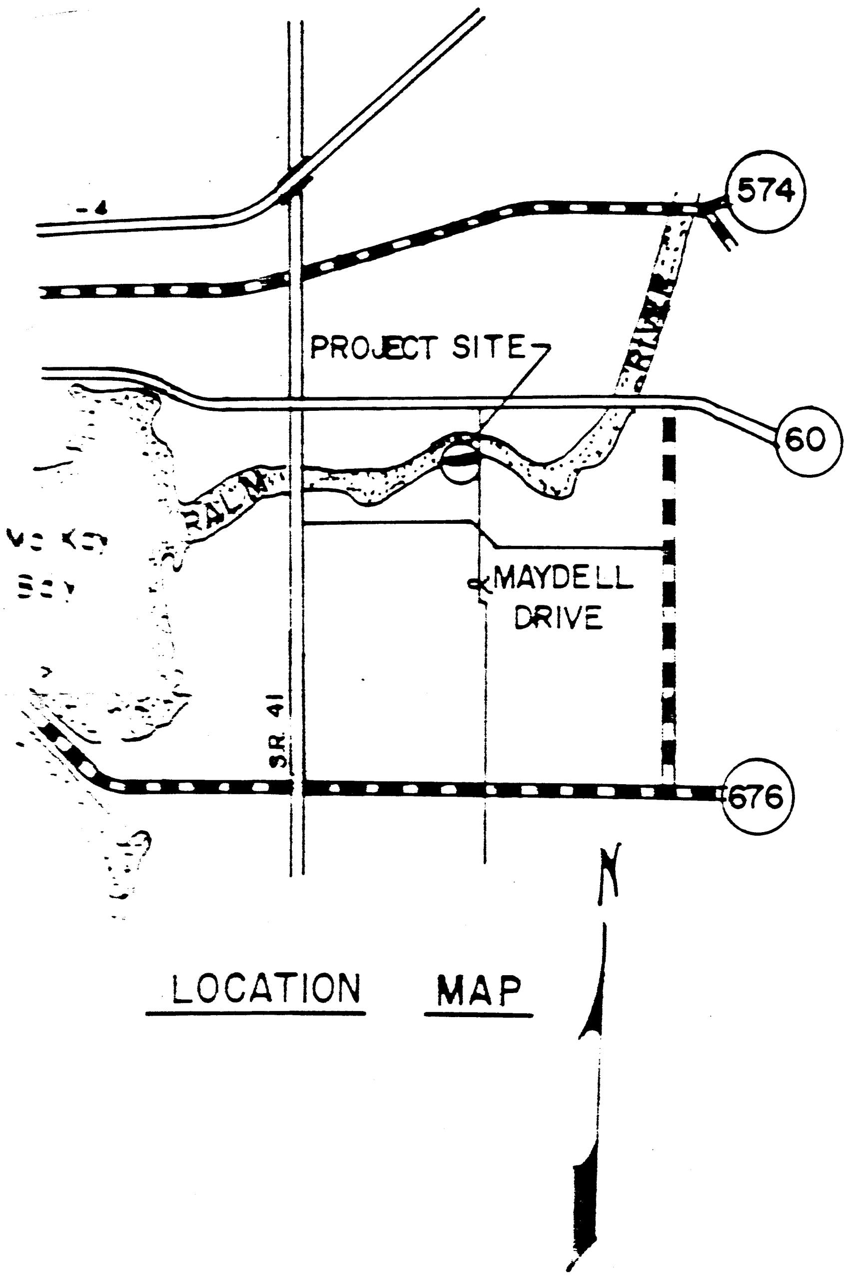

Figure 1

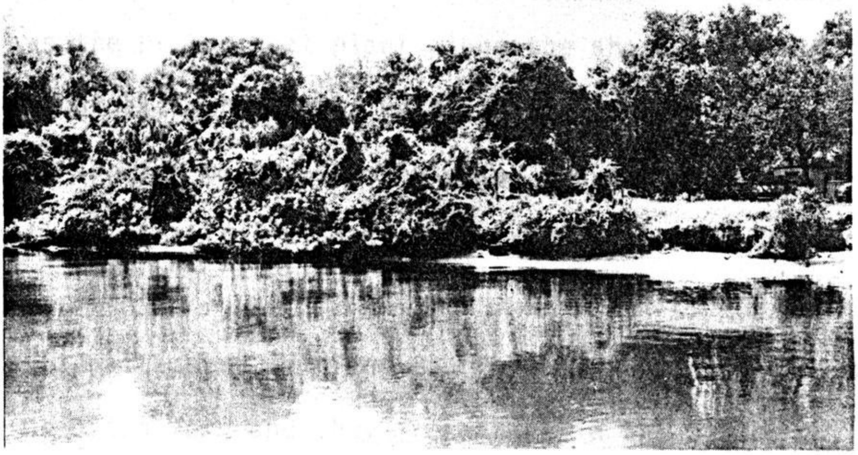

Figure 2. Shoreline view of site with apparent heavy vegetation growth in littoral zone.

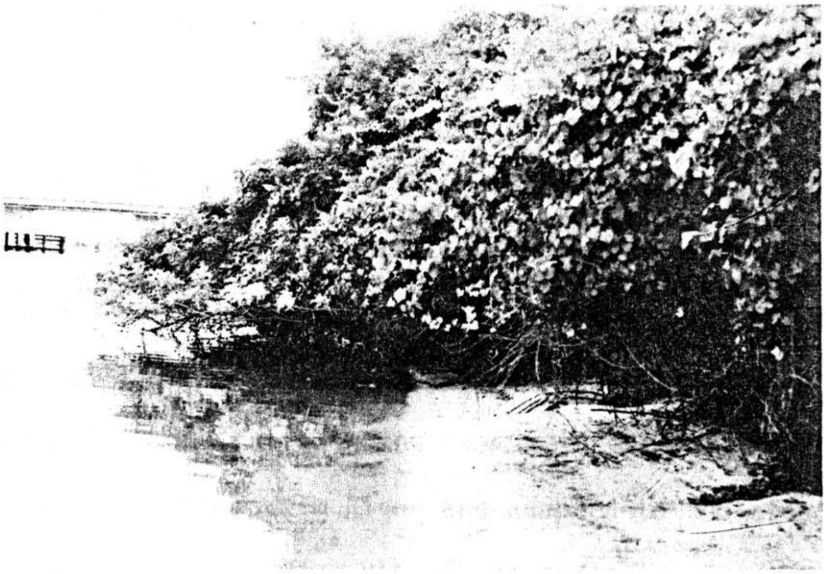

Figure 3. Shoreline view of same area as Figure 2. Heavy growth of brazilian pepper shadows but does not stabilize the shore.

Much of the vegetative cover of the eroding banks consisted of plant species not native to Florida (exotic). Most of them occurred in small numbers, but one in particular, the Brazilian pepper (*Schinus terebinthifolius*) was the predominant plant along the shore. Without native predators, it quickly outcompetes native plants and replaces them. It was the one species most responsible for preventing normal establishment of native intertidal plants to control erosion in the area.

Some residents had attempted to plant mangroves for erosion control. The number planted were too few, and they froze back in the winter of 1976-77.

The survey determined that land was available in the area to reslope and that planting marine vegetation was a feasible tool for erosion control in the area.

METHODS AND MATERIALS

Project Design

Sixty linear meters (200 feet) along the Palm River were to be cleared and sloped to 15:1 (horizontal:vertical) slope. The slope was to extend waterward beyond the 0.00 meter msl elevation. At least one and one half meters (five feet) of area at the proper elevation was to be provided on the slope for planting.

Native plants present in the Palm River and adapted to the area's salinity conditions were identified for use on the project. The plants chosen were *Spartina alterniflora* (smooth cordgrass) and *Paspalum vaginatum* (seaside paspalum). *Spartina* was chosen because of its previous use on other erosion control projects. *Paspalum* was chosen because it was noted to have been established naturally on the gently sloping north bank of the river, and where it had been established erosion was controlled.

The elevation range that the two species occupied along the Palm River were measured at several locations and the information was used in the planting design. A turbidity barrier used during construction also doubled as a wave absorber to protect the plants during the early establishment period.

Project Installation

After permits were received, the 60 meter (200 feet) test section was cleared (Figure 4) and sloped over the period from 30 May to 13 June 1979. The Paspalum and Spartina and sod were planted on 18-21 June 1979. Bahia sod was installed on the cleared areas above the marine vegetation. Residents added a few mangroves after the project was installed. Planting details are summarized in Table 1.

Burlap fabric was used to stabilize the slope until the plants could become established. The plants were placed in openings cut through the fabric. The marine grasses were fertilized with an 18-6-12 slow release fertilizer at a rate of one ounce per plant. The turbidity barrier was removed early in 1980.

Table 1. Planting details.

Plant	#	Planting Elevation (meter mean sea level)	Planting Pattern
Spartina alterniflora	1050	-0.12 m to +0.43 m	Plant and root plug installed/ 0.31 m centers
Paspalum vaginatum	350-400	+0.46 m to +1.07 m	Plant and root plug installed/ 0.92 m centers
Bahia sod	4,400 sq ft	above +1.07 m	Continuous sod

RESULTS

After seven months (Figures 5 and 6), the *Paspalum* showed tremendous growth and covered almost 100% of the planted area. The cordgrass was slower in growing and only about 20% of the plants remained in January. However, the remaining plants were established and spreading rapidly. The Bahia sod took readily with no problems. The mangroves planted by the residents survived with the exception of one large black mangrove.

DISCUSSION

Reasons for the poor performance of the *Spartina* include the late planting time (June rather than April), the small size of the plants when installed, unrestricted public access to the site further stressing the plants (by motorbikes, for example), and debris floating on shore and knocking plants over. Additionally, heavy rains in September caused runoff from upland areas that created an erosion gully across a small area of the project. The area was replanted after repairs were made. Repairs included a pipe underdrain to handle water moving toward the site from upland areas. In future plantings, the surface water flows across the general site area should be thoroughly investigated and appropriate drainage designed into the construction project. Also, upland owners can further complicate the problem through their own drainage/discharge projects leading to the planted site.

Maintenance

The planting will need regular maintenance to insure the continued effectiveness of the project against erosion. The maintenance plan for the area includes:

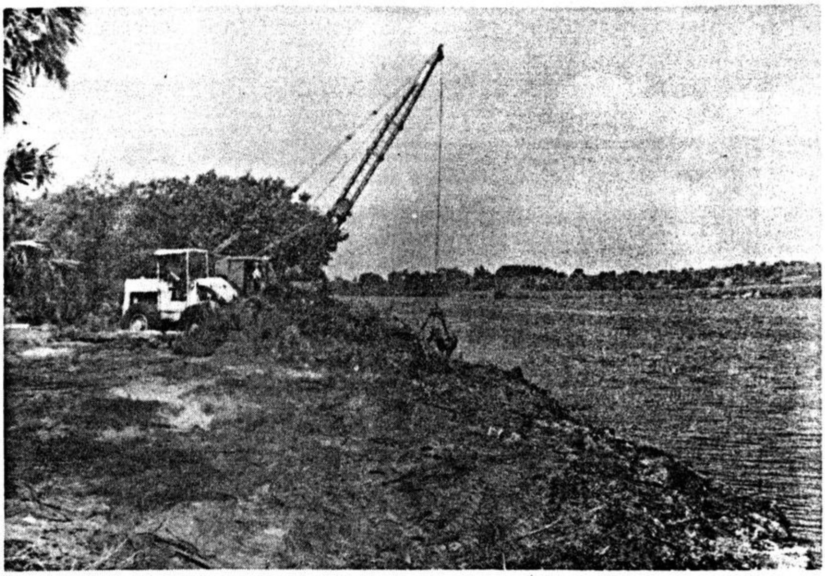

Figure 4. Site excavation underway in May 1979.

Figure 5. View looking east of the completed cordgrass plantings and mangroves, June 1979.

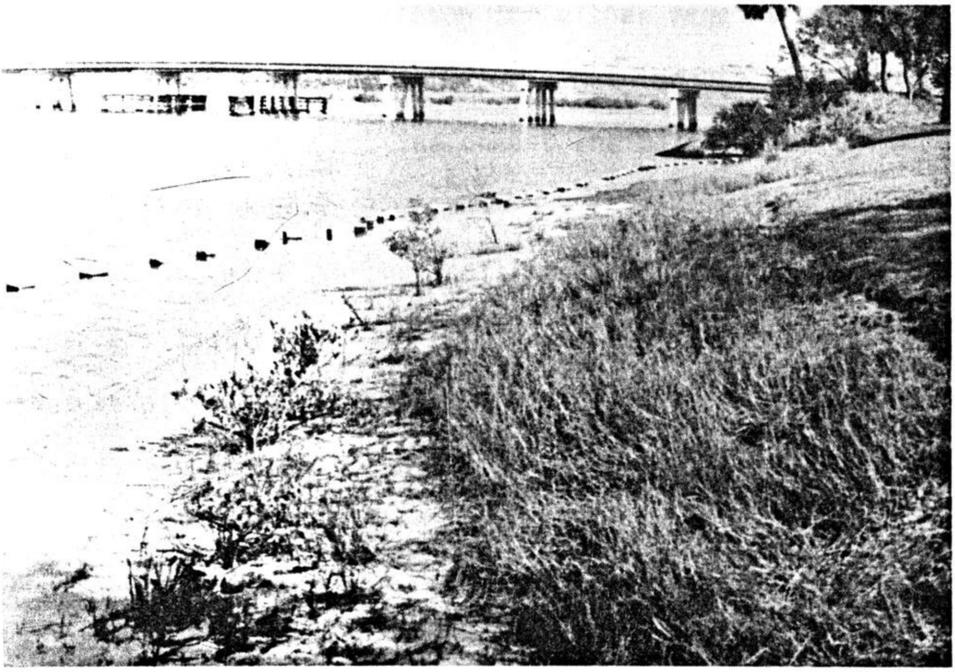

Figure 6. View of the site looking east, January 8, 1980.

1) mowing the Paspalum to a height of 1/2 meter (18 inches) every six months to exclude reinvasion of exotic woody species,
2) removing, every six months, floating debris that becomes stranded at the site,
3) controlling public access to prevent damage to the plantings.

Costs

The installation and plant material costs for the 60 meters (200 feet) of the project was $7,400 or approximately $123/meter. In direct comparison, a sand/cement bag revetment installed a short distance upstream in the Palm River would cost approximately $330/meter for about a 207 meter (900 foot) segment in 1979 dollars ($251/meter in 1977).

Erosion repairs to the project site have cost an additional $1,1200 to the construction cost. Overhead dollars for project administration, permitting, consultant studies/design were not included in the cost comparison for either vegetative or hardened erosion control measures. Regular maintenance will be required of the marine vegetation. Routine checks and patching of the sand/cement bags is also required.

Use of "hard" versus "soft" measures will depend on the land owner's situation and the nature of the erosion problem. However, the use of vegetation for erosion control has habitat and water quality enhancement benefits not found with the structural methods.

CONCLUSIONS

In summary, the project has shown that clearing and reshaping eroded banks combined with the use of marine vegetation has been successful in controlling erosion on the Palm River. The plants installed are established and spreading. Seaside paspalum demonstrated a remarkable growth; achieving almost 100% coverage of the planted area within seven months.

The use of a "soft" erosion control measure is cost effective when compared with hardened shoreline stabilization measures. Land owners with erosion problems, thus, have a choice in regard to controlling erosion depending on their individual situations. Lessons learned with regard to control of upland runoff, plant shock, and maintenance on this trial project will be of benefit in the planning and installation of future similar projects.

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LARGE SCALE MANGROVE RESTORATION ON ST. CROIX, U.S. VIRGIN ISLANDS - II. SECOND YEAR

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ABSTRACT

During the second summer of planting efforts, an additional 2.10 hectares of mangroves (Rhizophora mangle L. and Avicennia germinans (L.) Stern) were planted. This brings the total area planted to 6.15 hectares. A total of 86,000 red mangrove seedlings and 32,000 black mangrove seeds have been planted. Survival of red mangroves for the first year's planting was 50% prior to the passage of hurricanes David and Frederick. Some washout of plants did occur, but 40% of the original red mangrove seedlings are still in place and are growing rapidly.

Success with black mangrove seeds was very low (1-2%) but larger numbers of these seeds can be collected and broadcast in appropriate areas.

INTRODUCTION

The island of St. Croix (Figure 1) is located 145 km southeast of the island of Puerto Rico and is one of three U.S. Virgin Islands, the others being St. Thomas and St. John.

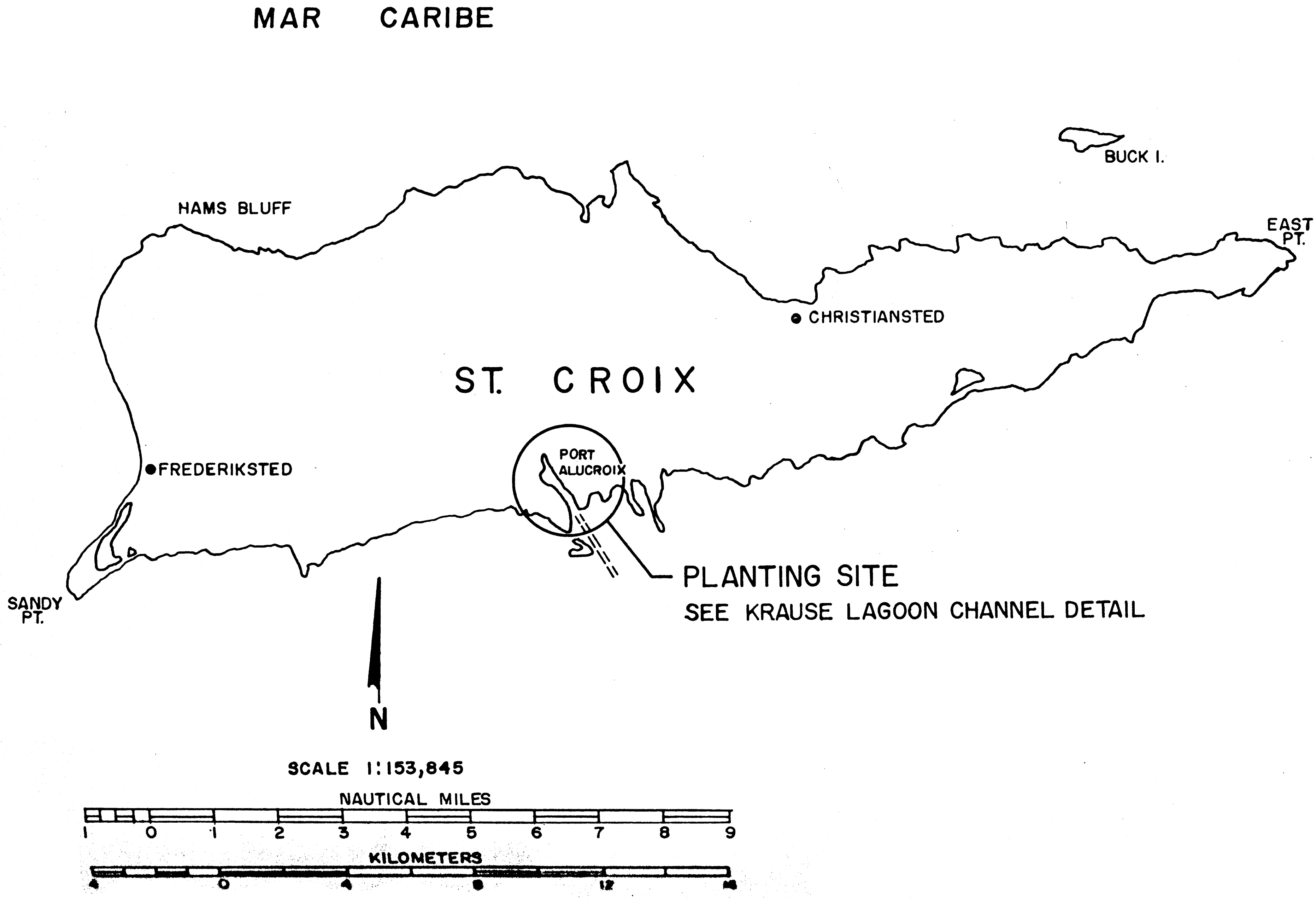
Mangrove habitats are limited in the Virgin Islands and the largest areas which did exist have been destroyed by land development (Island Resources Foundation 1977).

Those mangrove forests that remain are composed of the same three species of mangroves found throughout the Caribbean: *Rhizophora mangle* (red mangrove), *Avicennia germinans* (black mangrove), and *Laguncularia racemosa* (white mangrove).

During October-November 1972, Martin Marietta Alumina impounded a portion of an existing forest on the south shore of St. Croix through construction of a U.S. Environmental Protection Agency required cooling pond. The impounding and subsequent submergence of the root systems by flooding killed the impounded mangroves.

At the request of the U.S. Corps of Engineers, Jacksonville District, Martin Marietta Alumina agreed to undertake a mangrove replanting program to compensate for the loss of the impounded forest. It was agreed that attempts would be made to locate suitable planting sites up to a total of 12.1 hectares (the area of the impounded forest).

During the summer of 1978, 4.05 hectares of red and black mangroves were hand planted in appropriate areas (Lewis 1979). Figure 2 shows those planting areas. This second report follows the completion of the planting effort during the summer of 1979.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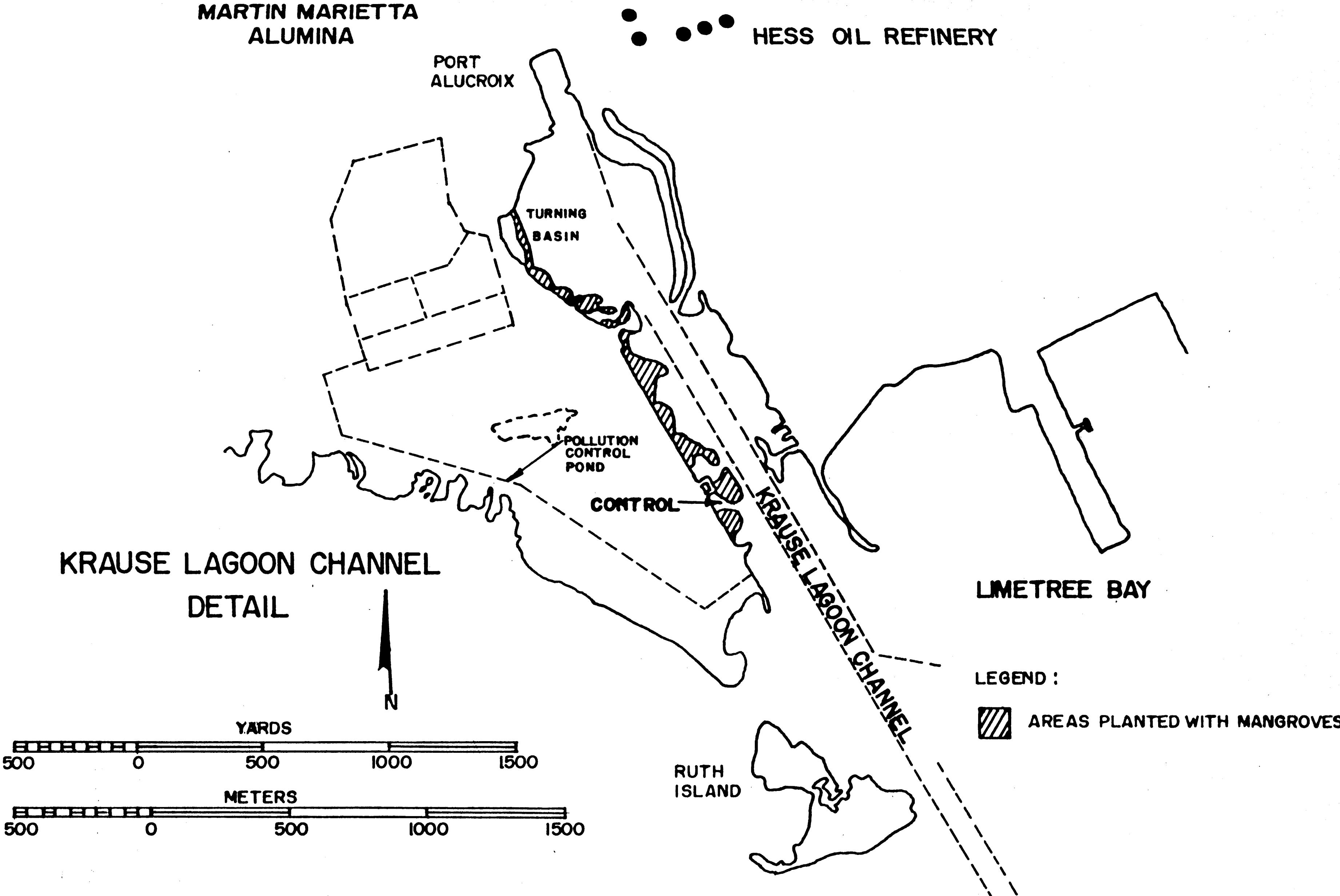

Figure 2. Krause Lagoon Channel detail showing areas of planted mangroves, July-August, 1978.

METHODS AND MATERIALS

At the completion of the first year's planting effort (Lewis 1979) 1.5 hectares of plantable area remained. This included 0.61 hectares in an impounded area owned by the Virgin Islands Port Authority, 0.28 hectares left as a control for the previous year's planting, 0.12 hectares on Ruth Island, an offshore dredged island, and 0.49 hectares located on both sides of the ship channel.

The ship channel mangroves previously had been severely damaged by an oil spill in 1971 during which 12.5 million liters of crude oil were spilled by the M.V. Santa Augusta in the adjacent HESS Oil Refinery ship channel (Figure 1). Approximately 5 hectares of mangrove forest (mostly Rhizophora mangle) were completely destroyed by the spill and had shown only minimal regeneration seven years later.

The Virgin Islands Port Authority refused to allow flow to be restored to the impounded mangrove area, so this area was eliminated from the planting program. An additional 1.21 hectares area outside the pollution control dike but inside a beach berm was then added to the program to make a grand total of 2.10 hectares available for planting.

The techniques were the same as previously described (Lewis 1979). Red mangrove seedlings were picked from trees at the site or in mangrove forests located elsewhere on the island (e.g., Salt River). Seedlings were transported in buckets to the site and hand planted on 0.8-1.0 m centers. Soil conditions were very soft and required the use of plywood boards to support the planter's weight. Four personnel picked and planted 21,000 seedlings over a period of six weeks (Figure 3).

Black mangrove seeds were picked from trees, transported dry in buckets and hand-broadcast in areas of low tidal energy and minimal current

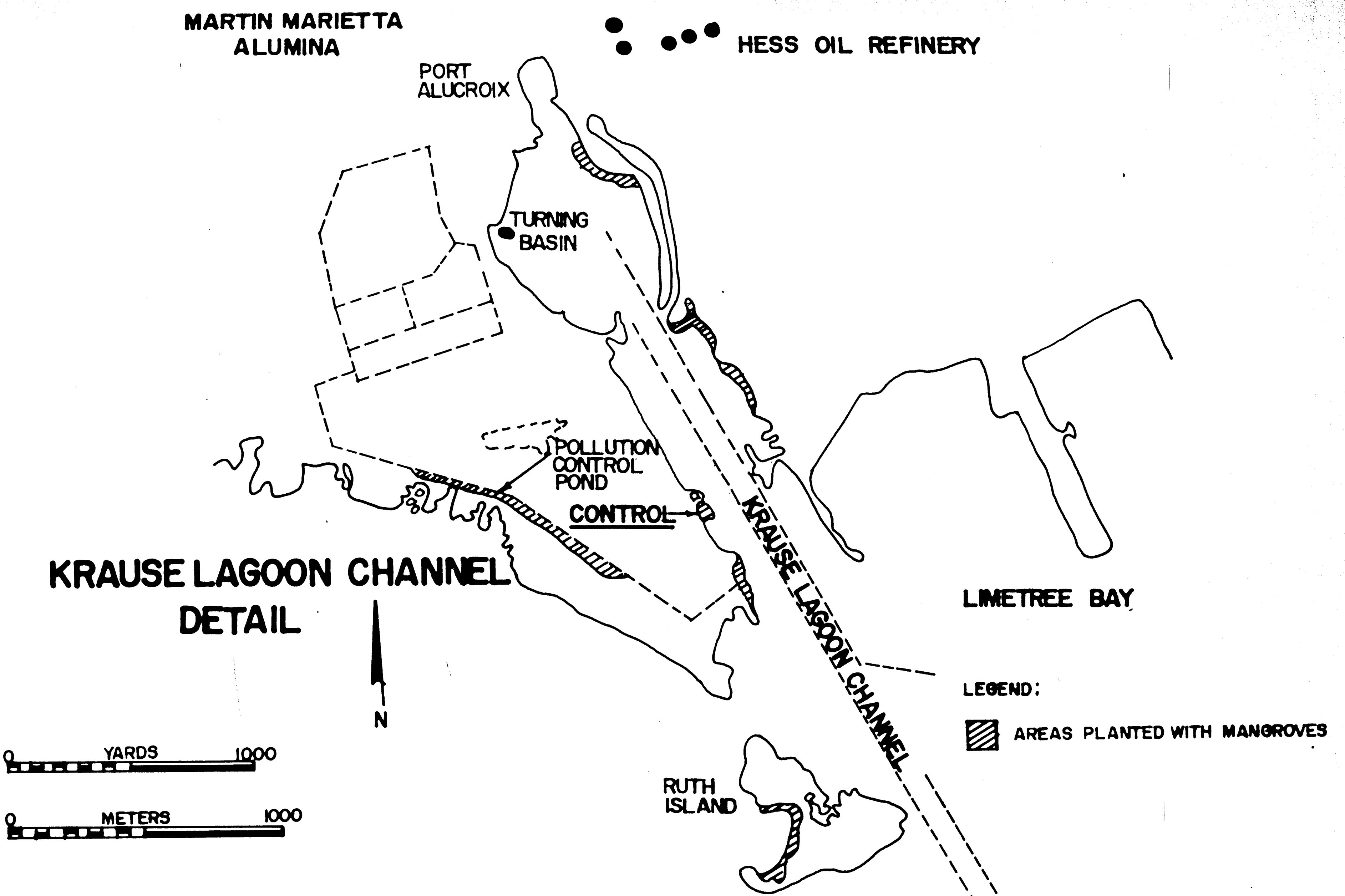

Figure 3. Krause Lagoon Channel detail showing areas planted with mangroves in July-August, 1979

flow. A total of 12,000 seeds were collected and broadcast.

RESULTS

Survival of planted areas for both summers varied from 0-100%. As previously reported (Lewis 1979) counts in sample plots showed approximately 75% survival of red mangrove seedlings after one year. At the end of 20 months survival was down to approximately 40% overall. The passage of hurricanes David and Frederick close to the island in the fall of 1979 resulted in some losses, but large areas of essentially 100% survival still remained (Figure 4). In addition, the 20 month old seedlings (Figure 5) have started putting out prop roots though no evidence of flowers has been seen. Figure 6 shows 8 month old seedlings planted in August, 1979. Table 1 compares height, number of stems, number of leaves, and number of completed and beginning prop roots on eight and twenty month seedlings. Height is somewhat greater in the 20 month seedlings, but the greatest difference is in the numbers of stems, leaves, and prop roots.

Survival of broadcast black mangrove seeds was low (1-2%), but time and manpower expenditures are much lower with this method. It only gives reasonable success in areas of very low wave energy and minimal currents. Growth of black mangroves from seed in some areas has been very rapid (Figure 7) with heights of 1 m and root growth extending 1 m out from the stem at the end of 20 months. Flower and seed production also were seen at the end of 20 months.

SUMMARY

A total of 2.1 hectares of red and black mangroves were planted during the summer of 1979. Combined with the 4.05 hectares planted in the summer of 1978, this brings the total to 6.15 hectares. In this area, 86,000 red mangrove seedlings have been hand planted and 32,000 black

Table 1. Characteristics of planted red mangrove seedlings, St. Croix, U.S.V.I.

	8 months (N = 10)	20 months (N = 10)
Height	43.5 ± 5.2 cm	52.9 ± 6.0 cm
Stems	2.3 ± 1.2	4.5 ± 1.8
Leaves	12.6 ± 4.9	45.8 ± 18.2
Prop Roots		
Completed	0.0	1.6 ± 1.2
Beginning	0.0	0.5 ± 0.5

N = Number of seedlings counted
values ± 1 standard deviation

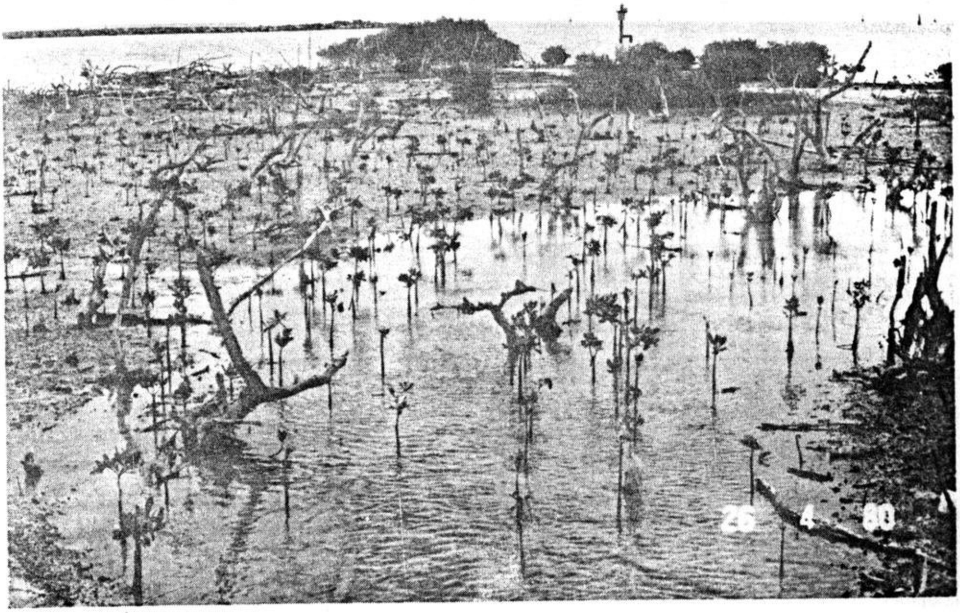

Figure 4. Mangrove planting area, St. Croix, 26 APR 80.

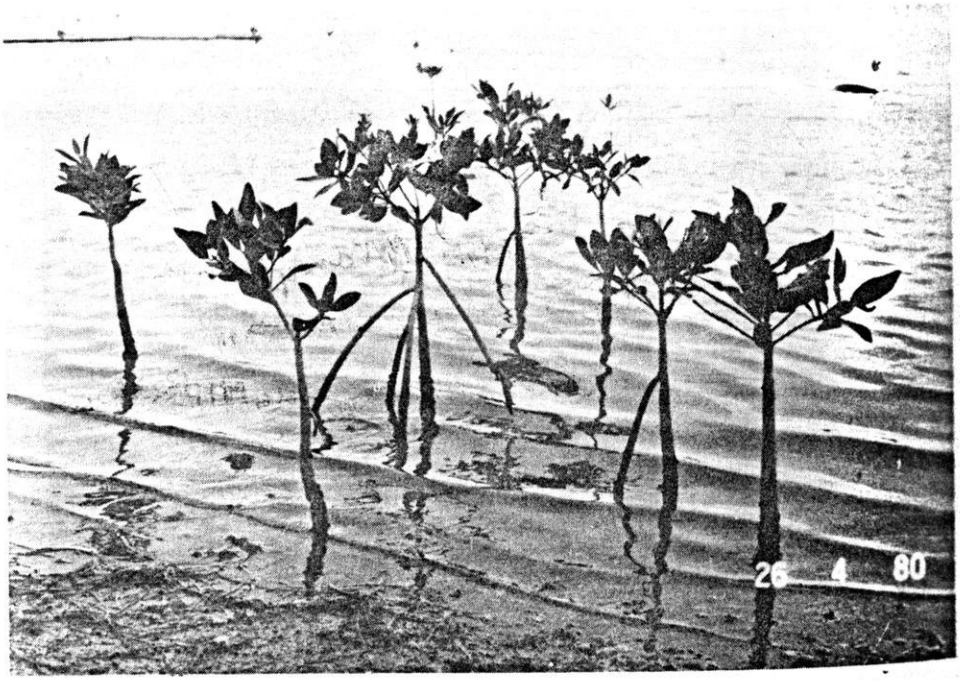

Figure 5. Twenty-month old red mangrove seedlings.

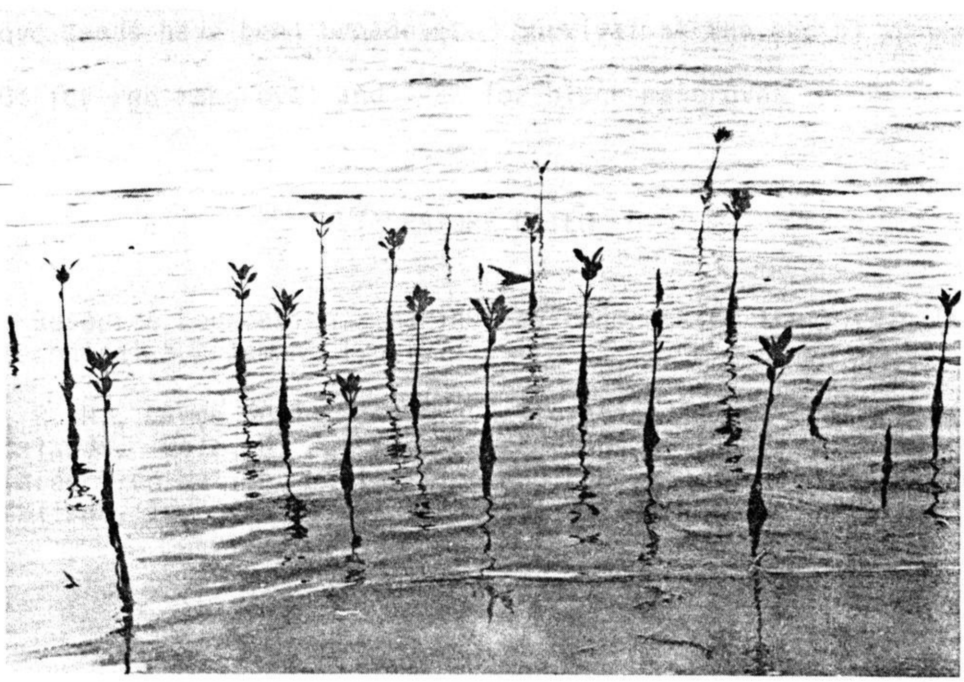

Figure 6. Eight-month old red mangrove seedlings

Figure 7. Twenty-month old black mangrove seedling.

mangrove seeds have been broadcast. Survival at the end of 20 months was 40% for red mangroves and 1-2% for black mangroves.

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PLANTS ON SHORELINES

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ABSTRACT

The loss of littoral shoreline marshes has presented in the past and continues to present a major problem with respect to our efforts to control the pollution of our waterways. It is difficult to maintain water quality and biological integrity of aquatic systems when vegetated shorelines have been converted to beaches or concrete bulkheads. The majority of this littoral alteration is performed on a small scale by individual homeowners. Frequently, these shorelines are cleared of the "weeds" to create beaches following the construction of residences. Usually these denuded beaches begin to erode due to their unstable state, and some manner of bulkhead is constructed to check the erosion.

This pattern is difficult to break since it has been the accepted procedure for many years. Success depends largely upon education and efforts to instill in the public an appreciation of the advantages of a natural shoreline, in terms of practicality and economics, as well as aesthetics and biological productivity.

Ecoshores, Incorporated is attempting, in the course of the design and implementation of several projects, to provide alternatives to the accepted pattern. Our involvement in such projects is usually prompted by concern on the part of the property owner about existing or anticipated erosion problems. Solutions to these problems range from reestablishing littoral marshes on gently sloping, low-energy shorelines to constructing coquina or concrete revetments with open spaces for aquatic and/or intertidal plants on high-energy shorelines. The basic ingredients of these designs are energy absorption and permeability

PLANTS ON SHORELINES

For many years, the shorelines of Eastern and Central Florida have been subjected to the "dredge-and-fill", "straight bulkhead", "pull up the weeds and make a beach" mentality. The result has been that much of the wetlands bordering our estuaries, lakes and rivers have been lost to nickel-and-dime operations. Most vertical bulkheads are constructed by individual homeowners (except in large dredge-and-fill developments which usually displace wetlands), and cleared "beaches" become more prevalent along residential shorelines as the uplands become more developed. Unfortunately, these homeowners usually discover too late that the shoreline plants were performing a useful function. This lesson usually manifests itself in the form of accelerated erosion along the denuded "beach". The traditional method for dealing with such erosion problems usually involves the construction of some type of seawall, or bulkhead.

While the public is becoming more aware of our environment, it is still necessary to instill in most people an appreciation of the advantages of maintaining natural shorelines. In addition to the role littoral vegetation plays in the maintenance of water quality and the propagation of natural resources, the fact that there are practical and economic reasons for preserving littoral vegetation is often quite a factor in such an education.

Ecoshores, Incorporated is attempting to offer alternatives to the traditional erosion control methodology by the design and implementation of techniques and structures which replace or preserve shoreline vegetation. On gently sloping or low-energy shorelines, usually the most effective and least expensive option involves the creation (or re-creation) of a natural marsh system using adjacent or nearby marshes as a pattern for the transplanting program. Proper species diversity is the key to long-term stability, and consideration should be given to the placement of each plant species on the shoreline with respect to water levels, tidal ranges, etc. On steep or high-energy shorelines, the proper placement of aquatic or intertidal plants frequently requires some sort of support structure to insure the integrity of the system against heavy erosive forces. An essential factor in such a structure is that it must be permeable and have some slope in order to provide dissipation of wave energy and to prevent the build-up of hydrostatic pressure on the landward side. The permeability is a result of the placement of a layer of polypropylene filter mat upon the prepared slope. The filter cloth is held in place by coquina boulders or specially designed concrete slabs with holes or cavities which are planted with the proper shoreline species relative to their position on the slope. It should be noted that polypropylene is non-biodegradeable with one exception. It tends to deteriorate with prolonged exposure to sunlight. For that reason, care should be taken to insure complete coverage of the filter mat. The arrangement of the support structure is dependent upon site-specific conditions such as tide range, lateral current velocities and shoreline slope.

In general, these techniques have proven to be quite effective in the control of shoreline erosion over the course of one to two years of normal weather conditions and one hurricane of medium intensity (Hurricane David). As with any new design, the early stages of development required some trial-and-error experimentation with respect to the arrangement of the filter mat and the placement of various plants at different positions on the shoreline. With continued experience along these lines we hope eventually to design naturally vegetated systems for most types of shorelines that occur along Florida's diverse waterways.

Based on our experience and observations, we feel that shoreline designs which preserve or establish littoral vegetation are equal or superior to traditional bulkhead designs with respect to erosion control. Such techniques also contribute to the aquatic system in less obvious ways, like water quality maintenance, providing habitat, feeding and nursery sites for a variety of animals and birds, and supplying organic nutrients for the maintenance of the aquatic food complex.

ACKNOWLEDGMENTS

We wish to express our sincere appreciation to our clients for allowing us to experiment with their shorelines and putting bread on our tables in the process.

EXPERIMENTAL SEA GRASS MITIGATION IN THE FLORIDA KEYS

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ABSTRACT

An experimental seagrass mitigation project was initiated in February 1979 at Craig Key in the Florida Keys under the sponsorship of the Florida Department of Transportation. Plugs and short shoots of Thalassia testudinum Banks ex Konig, Halodule wrightii Aschers and Syringodium filiforme Kutzing were transplanted and are presently the subject of a two year monitoring program. In addition, seeds of Thalassia were planted in the field and laboratory in August 1979, and laboratory grown seedlings were moved to the field site in February 1980. A progress report on the success of the project to date is presented.

INTRODUCTION

Seagrass transplantation is gaining wide acceptance as a solution to the impairment of seagrass meadows. Addy (1947), using the north temperate eelgrass species, Zostera marina L., reported the first attempts to transplant seagrasses. A variety of persons have made attempts to transplant the tropical-subtropical species, i.e., Thalassia testudinum Konig, Halodule wrightii Aschers, and Syringodium filiforme Kutzing.

The evidence demonstrates that seagrasses form an ecosystem that has both physical and biological ramifications: (1) the system is as productive as any natural ecosystem on earth (McRoy and McMillan 1977); (2) it has great value in stabilizing and protecting coastlines from erosion (Coull 1970, Ginsburg and Lowenstam 1958, den Hartog 1970, Orth 1977, Scoffin 1970, Taylor and Lewis 1970, Wilson 1949, Wood et al. 1969, Zieman 1972); and (3) the presence of seagrasses is essential to the occurrence and growth of many species of marine life (Allee 1923, Blegvad 1914, 1916, David 1913, Kikuchi and Peres 1977, MacGinitee 1935, O'Gower and Wacasey 1967, Orth 1973, Petersen 1915, 1918, Santos and Simon 1974, Stauffer 1937).

Technology in seagrass restoration is, however, still somewhat in its infancy. Only six projects in the United States (Thorhaug 1974, 1979, Churchill et al. 1978, Fonseca et al. 1979, Goforth and Peeling 1979, Phillips 1978) have attempted restoration beyond the small experimental stage.

In the Caribbean and Gulf of Mexico marine systems, two seagrass species form dominant growths in coastal waters and have been tested for transplant success. Of the two, Halodule wrightii is a pioneering species, while Thalassia testudinum is a climax species (den Hartog 1967, 1970, 1971, More 1963, Phillips 1960, Strawn 1961). Halodule exhibits a wide adaptational response to substrate, temperature, salinity, and tidal zone stresses (Phillips 1960 and unpublished). Syringodium filiforme is often found mixed with Thalassia, but usually is less abundant (Phillips 1960). Transplant work with Syringodium has been limited to that of van Breedveld (1975) using plugs.

There are two forms of seagrass that may be used in transplantation, i.e., vegetative material or seeds. Vegetative material appears to be the most logical choice since it is present throughout the year, while seed production is seasonal, abundance and germination are unpredictable, and survival of seedlings in the field is low (Phillips 1972, unpublished). However, Thorhaug has described excellent success using Thalassia seedlings in the Biscayne Bay, Florida, area (Thorhaug 1974, 1976a, 1976b). In addition, transportation of seeds may be less expensive. Therefore, this technique should be investigated.

When using vegetative material, experience has shown that plugs (a mass of plants removed from the bottom intact in the sediment) gives the best results. In this case, the original sediment becomes the anchor for the transplanted material, inasmuch as the roothair-sediment interface is undisturbed. A modification of this technique is the use of turfs, which are generally intact squares of sediment and plants. The removal of a turf and its placement at a distant site is best done with plants with shallow rhizomes and an intertidal planting site (Ranwell et al. 1974). Plugs have been used to transplant Thalassia, Syringodium, and Halodule in the United States (Kelly et al. 1971, Phillips 1974, 1977, van Breedveld 1975). Success has varied quite a bit (0-100%) depending on the site. Investigation of this technique is essential.

Use of vegetative material can also take place in the form of turions (intact rhizomes and short shoots without sediment). This method often involved the use of anchoring devices to keep individual turions in place until regrowth has anchored them further with new rhizomes and roots. This method has been used with Thalassia, Syringodium, Halodule, and Zostera (Kelly et al. 1971, Phillips 1974, Eleuterius 1975). Success has generally been lower than that with plugs. However, it may be a viable method for seagrass vegetation.

All the work performed on the transplantation of the three tropical species, Thalassia, Syringodium and Halodule, except for Phillips (1977) and Thorhaug (1974), have been small experimental programs. Even with the larger scale programs, factors affecting the success or failure of a technique have not been adequately assessed. Therefore, a feasibility study which closely monitors several seagrass species, under similar physical conditions using different transplant techniques, is absolutely essential to formulate reasonable predictions as to the success or failure of a large scale program of seagrass restoration.

In order to determine the causal factors which are responsible for the success or failure of the applied methods, a rather intensive monitoring program of physical, chemical and treatment variables is required. In the case of the loss of submerged vegetation due to the replacement of 37 bridges in the Florida Keys, the Florida Department of Transportation felt a small scale, well documented, experimental project would be advisable prior to large scale mitigation attempts. For this reason, a contract was awarded to Continental Shelf Associates to undertake a two-year experimental seagrass mitigation project at Craig Key in the Florida Keys. Dr. Ron Phillips of Seattle Pacific University and Robin Lewis of Mangrove Systems, Inc., serve as consultants to Continental Shelf Associates and are co-principal investigators on the project.

SITE DESCRIPTION

The planting site is located on the southeast side of Craig Key, Monroe County, Florida (Figure 1). The site is a 1.6 ha borrow area that has silted in with fine calcerous sand and silt since its creation during dredging activities in the Florida Keys approximately 30 years ago. Water depths average 1.0 to 1.5 meters mlw over the site with a shallow (-0.5 to -0.8 mlw) sill surrounding the area and probably corresponding to the original undisturbed bottom. This adjacent area is well vegetated with *Thalassia testudinum*.

A large portion of the site is presently vegetated with green algae or colonizing seagrasses (*Thalassia*, *Halodule*, *Thalassia-Halodule* mixture). Only approximately 25% of the site is largely barren of any vegetation.

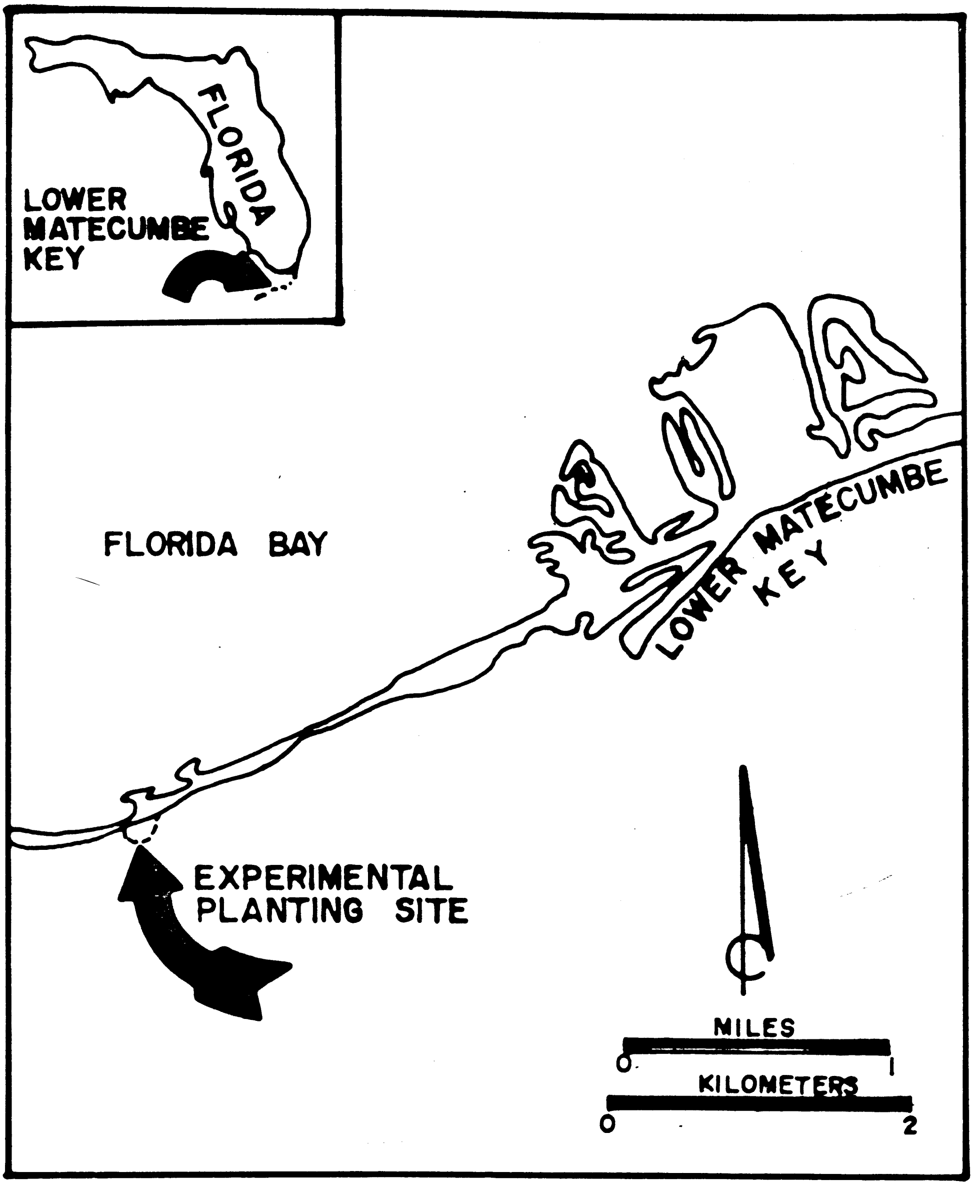

Figure 1. Location map for experimental planting site.

MATERIALS AND METHODS

Three types of plant material have been used in the experimental study. This includes plugs, turions, and seeds. Plugs and turions for all three species, Thalassia, Halodule and Syringodium, were planted between 13-16 February 1979. Thalassia seeds and seedlings were planted at the Craig Key site on 16 August 1979. (Seeds germinate very rapidly into seedlings and the seedlings were much more abundantly available than the seeds). New Halodule plugs and turions were planted in new plots on 11 February 1980. Thalassia seedlings which were raised in laboratory tanks for six months were planted in the field on 13 February 1980.

Plugs consisted of intact sediment and plant material in the dimension of approximately 22 cm X 22 cm X 10 cm high. Turions consisted of individual plants with rhizomes and roots cleaned of existing sediment. Turions were attached to small concrete anchors with plastic tiewraps before planting. Seeds and seedlings were abundant and collected in the intertidal zone of Craig Key and Lower Matecumbe Key (Lewis and Phillips in press). Small plastic tiewraps were investigated for use as seed or seedling anchors in August 1979, but were not used due to anticipated detrimental effects to the small seeds and delicate blades of the seedlings. In February 1980, the seedlings which had been raised for six months in a laboratory were larger and not as delicate as new seedlings. Therefore, one plot of seedlings was planted attached to concrete anchors with rubber bands and one plot was planted unanchored.

Table 1 provides a summary of the planting materials and techniques utilized to date. Each plot contains seven rows by seven rows of planting materials for a total of 49 sites planted in each plot. One plug or turion was planted at each of 49 sites within a plot. In August 1979, five seeds or seedlings were planted at each of 49 sites within a plot for a total of 245 seeds or seedlings per plot. In February 1980, one seedling was planted at each of 45 sites within a plot. Only one laboratory seedling was considered necessary to plant in each site as they were already established and substantial in size. There was an insufficient number of surviving laboratory seedlings to plant 49 per plot.

RESULTS

The following is a qualitative description of the progress and condition of the seagrass transplants one year after the beginning of the experimental study. Initial trends have been observed and are reported below. Final conclusions and recommendations cannot be made, however, until the completion of the monitoring program in February 1981.

In February 1979, single vegetative leafy shoots (turions) of Thalassia, Halodule, and Syringodium were fixed to concrete anchors and planted. On 10 FEB 1980, almost all traces of turion plantings of all three species were gone. Only one shoot of Halodule, ten shoots of Thalassia (no expansion or growth observed) and three Syringodium shoots remained. These same observations were true for plantings in sites with spacings of one and two meters.

Of the Thalassia seeds and seedlings planted in the field on August 16, 1979, only nine seedlings remained in the one-meter spaced spot. The surviving seedlings had an average of 4.0 blades, the longest of which averaged 7 cm long by 7.1 mm wide.

In the two-meter spaced plots of plugs, 37 of 49 Thalassia plugs remained, four of the Syringodium plugs remained, and none of the Halodule plugs were observed. In the case of Thalassia plugs, growth or expansion of the plant material over the bottom ranged from zero (i.e., plug of original size) to 50% enlargement (in up to four out of ten observations). All Thalassia plugs contained healthy viable plants which appeared similar to the surrounding native growth. Of the Syringodium plugs which remained, some expansion was observed.

In the one-meter spaced plots of plugs, 47 Thalassia plugs remained. Growth and vigor were identical to that observed in the two-meter spacing (i.e., plants were healthy and viable), but most plugs showed little expansion. The Halodule plugs appeared completely gone. In the Syringodium plot, not all plugs remained, but the plants in the remaining plugs were sending out colonizing runners (rhizomes) with new erect leafy shoots, such that it was impossible to detect discrete plugs. We estimated 35% coverage of the area of the plot (7 m X 7 m X 35%).

On 11 FEB 1980, an examination was made of the Thalassia seedlings which were planted on 17 AUG 1979 in the four aquaria and in the outdoor pool tank at the Florida Department of Transportation Lab at Marathon, Florida. Survival of seedlings in the indoor tanks ranged from 12% to 28%, while in the outdoor tank survival was 29%. Leaves in all seedlings from the indoor tanks were much longer and conspicuously much narrower than those from the outdoor tank. Leaves on the seedlings kept outdoors were shorter (a two-day failure of the water circulating system resulted in much leaf kill, according to Mr. Bob Mannix of DOT, who was monitoring the laboratory tanks), but leaf width appeared to be as wide as that on leaves of adult plants in native growth.

Theory on seagrass-ecological succession allowed the prediction that Halodule would have quickly colonized the bottom after transplanting. This was observed in both single shoots and plugs. Coalescence of adjacent plugs and even spreading growth from single shoots of Halodule occurred within six months. But, by October 1979, it was observed that all Halodule transplants had disappeared. The area must have received some surge in late August to early September from the passage of at least one hurricane (perhaps two). But, why Halodule was selectively completely removed after such early rapid colonization and presumable stabilization is not apparent at this time. Erosion was not the only answer as both Thalassia and Syringodium plugs remained.

Transplant evidence suggests that Halodule is indeed an early seagrass colonizing species. It may root too shallow in the substrate, at least in the early colonizing phase, to endure any noticeable errosive effect of surge. The original source of Halodule used in February 1979 was a shallow intertidal site with very small plants whose roots were close to the surface. To test differences in habitat source of Halodule, we installed two new transplant plots of Halodule (49 turions and 49 plugs, both with one-meter spacing) from a shallow subtidal site on 11 February 1980. These plants were much larger than those formerly used and were routed at least two times deeper than those from the intertidal location (i.e., at least 2-3 cm deep).

The evidence thus far suggests that Syringodium is intermediate in an ecological successional sequence between Halodule and Thalassia. Theory could not have predicted this as no evidence was available to predict this prior to the project. This species roots more deeply than Halodule, but not as deeply as Thalassia. It appears to grow faster than Thalassia, but not as fast as Halodule.

The evidence also substantiates the position of Thalassia as climax in ecological succession among the three seagrass species.

After one year it appears that plugs of seagrasses yield the best long-term survival and success; furthermore, that spacing of plugs on one-meter intervals gives the best long-term survival.

Transplants now completed will discern whether Halodule from two different tidal zones will yield differential survival. An analysis of the outcome of the Halodule planted 11 February 1980 will allow a conclusion as to whether Halodule or Syringodium will yield the better long-term survival and growth.

Table 1 lists the number of surviving seagrass transplants for each plot as observed six and twelve months after planting. A detailed analysis and interpretation of all data collected during the project will be performed and reported in the Final Report which will be available following the conclusion of the monitoring program in February 1981.

Table 1. - Surviving Seagrass Transplants as of 17 August 1979 and 14 February 1980. Planted 12-16 February 1979, 16 August 1979*, and 14 February 1980**.

	Transplant Plot	Number Planted	Number Surviving 8/17/79	2/14/80
TP-1	(*Thalassia* plugs, 1 m spacing)	49	49	47
TT-1	(*Thalassia* turions, 1 m spacing)	49	19	5
HP-1	(*Halodule* plugs, 1 m spacing)	49	33	0
HT-1	(*Halodule* turions, 1 m spacing)	49	14	1
SP-1	(*Syringodium* plugs, 1 m spacing)	49	30	35% of plot
ST-1	(*Syringodium* turions, 1 m spacing)	49	14	0
TP-2	(*Thalassia* plugs, 2 m spacing)	49	39	37
TT-2	(*Thalassia* turions, 2 m spacing)	49	9	0
HP-2	(*Halodule* plugs, 2 m spacing)	49	24	0
HT-2	(*Halodule* turions, 2 m spacing)	49	14	0
SP-2	(*Syringodium* plugs, 2 m spacing)	49	30	4
ST-2	(*Syringodium* turions, 2 m spacing)	49	7	3
TS-2	(*Thalassia* seedlings, 2 m spacing)	245*	245*	0
TS-1	(*Thalassia* seedlings, 1 m spacing)	245*	245*	9
TS-1/3	(*Thalassia* seedlings, 1/3 m spacing)	245*	245*	0
TS/H-1	(*Thalassia* seedlings among *Halodule*, 1 m spacing)	245	245*	0
HHP-1	(*Halodule* plugs, 1 m spacing)	49**	NA	49**
HHT-1	(*Halodule* turions, 1 m spacing)	49**	NA	49**
TSdA-1/3	(Laboratory raised *Thalassia* seedlings, 1/3 m spacing anchored)	45**	NA	45**
TSd/½	(Laboratory raised *Thalassia* seedlings, ½ m spacing unanchored)	45**	NA	45**

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DEVELOPMENT OF A TRANSPLANTED SEAGRASS (*Zostera marina* L.) MEADOW IN BACK SOUND, CARTERET COUNTY, NORTH CAROLINA

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ABSTRACT

Data are presented on physical, chemical, and biological development of a transplanted *Zostera marina* meadow. Within 16 months, a denuded *Zostera* meadow in Back Sound, Carteret County, N.C., has been restored to the local population equivalent (approximately 700 shoots m^{-2}). Currents are reduced 20% and substrate modification is evident. Sediment ammonium concentrations are equivalent to local, mature *Zostera* meadows. Benthic fauna have shown a significant increase over unplanted areas in number of individuals and species, species diversity, species richness, and species evenness. Bay scallop density demonstrates a strong positive correlation with *Zostera* density.

INTRODUCTION

The restoration and creation of seagrass meadows has been suggested as a method of managing and maintaining vital marine habitats. Although seagrass restoration has been regarded as beneficial to habitat development (Addy 1947, Kelly et al. 1971, Phillips 1974, 1978, Kenworthy and Fonseca 1977, Churchill et al. 1978, Fonseca et al. 1979), little direct evidence has been produced to substantiate this view. Also, seagrass restoration has not been well received due to numerous reports of failure and excessive costs in performing the plantings.

In a previous paper (Fonseca et al. 1979), we described a seagrass restoration project in a quiescent North Carolina estuarine area called Middle Marsh in Back Sound, Carteret County. The transplantation was performed in October 1978. That paper described a technique where whole _Zostera marina_ shoots were woven into synthetic meshes (20x20 cm) and planted on 1 m centers at a site denuded by the mechanical harvest of bay scallops. Experimental manipulation in planting arrangement and the selection of stock by current regime allowed testing of: 1) stock origin as a factor in growth responses using high (HEZ; 80 cm sec^{-1}) and low (LEZ; 20 cm sec^{-1}) current regime _Zostera_; 2) mixed species plantings of _Zostera_ and _Halodule wrightii_ (HEX and LEX respectively) as well as _Halodule_ (HAL) alone; 3) optimal transplanting seasons; 4) comparative cost analyses; and 5) developmental processes associated with seagrass recolonization. Also described in that paper was a stock-specific differential in growth rate, a negative impact utilizing mixed-species planting for that time of year, and a negative/positive response of _Halodule_ and _Zostera_, respectively, to a fall planting. In this paper we present additional data on the seagrass (Zostera marina) population, current flow changes, related physico-chemical aspects of sediment development, and benthic fauna in the transplant area.

AREA DESCRIPTION

The area of low current regime planting is located in Middle Marsh, Back Sound, Carteret County, North Carolina. A specific description may be obtained from Fonseca et al. (1979) and reading the results section of this paper.

METHODS AND MATERIALS

Seagrass biomass, population growth and reproduction

Seagrass biomass was sampled at randomly selected stations in the HEZ, LEZ and control areas with a coring device (325 cm^2) inserted to a depth of 20 cm in the sediment. The cores were extracted, rinsed free of sediment, and sorted into leaves, roots and rhizomes. Biomass was determined after drying samples to a constant weight at 100°C. Shoot densities were recorded in November 1978, February and May 1979, and February 1980 by counting the shoots within randomly selected planting units in each of the treatment plots. In February 1980, additional biomass cores were taken at four vegetated areas (HEZ and LEZ) at the transplant site and percent areal coverage was determined from visual observations.

Sexual reproduction of Zostera was monitored in May 1979. Flowering shoots of Z. marina were counted in the plant biomass cores to estimate reproduction potential, as a percent of flowering shoots and fertilized ova. The number of seeds for high and low energy origin planting stock also were counted.

Sediment parameters

Ammonium dissolved in sediment pore waters was monitored in March 1979 with diffusion chambers (Hesslein 1976), which were inserted into the substrate and allowed to equilibrate for ten days. Water samples for nutrient determination were removed from these chambers, stored on ice, and returned to the lab for analysis[1/].

Prior to the planting in October 1978, five random sediment cores were taken at the site (Fonseca et al. 1979) to determine average organic content (by combustion at 500°C) and percent silt-clay in the sediment profiles (at depths 0-1, 1-3, 3-6 and 6-9 cm). The values were compared with average values per strata in the HEZ and LEZ areas of the experiment, which were sampled in May 1979, eight months after the transplant.

Current flow

General on-site current velocities were determined during a spring tide in November 1978 by locating three TSK [2/] propeller-type flow meters on the site. Mean current velocity over the area was calculated. Only flood tide measures of velocity were made as current flow was directed away from the site on ebb tides. Flourescein dye releases traced flow patterns and were used to align the current velocity transect in the flood current direction. When planted *Zostera* patches had begun to coalesce, current velocities were measured along the transect using an electromagnetic, bi-directional current flow meter.

1/ W.J. Kenworthy. The interrelationship between seagrasses, *Zostera marina* and *Halodule wrightii*, and the chemical and physical properties of sediments in a mid-Atlantic (U.S.A.) coastal plain estuary. (In preparation). Master of Science Thesis, Dept. of Environmental Science, University of Virginia, Charlottesville, Virginia. 110 p.

2/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Faunal development

Counts were made of the bay scallop, Argopecten irradians, population in February 1979. Scallops associated with 50 randomly selected transplanted units were counted by SCUBA equipped divers. Ten randomly selected square meters of control area also were surveyed for scallops during the same sample period.

We sampled the macroinvertebrate fauna in October and November 1978 and in March and May 1979 by taking sediment cores (0.031 m^2) to a depth of 0.35 m. Two cores were removed from each replicate treatment and control plot as well as from two "outside" (disturbed, but farther from planting area control plots at each sampling interval). The organisms were separated from the sediment in the laboratory using a 0.5 mm mesh screen. Following screening, the residue was stained with rose bengal and stored in 10% SW-Formalin solution for later identification.

We collected 6,549 individuals of 89 species, consisting of both infauna and epifauna. Based on this collection we calculated a number of community parameters for each treatment and control: species diversity, $\hat{H}$ (Pielou, 1966a); species richness, D (Dahlberg and Odum, 1970); and species evenness, J (Pielou, 1966b). We also calculated the contribution of each major taxon to the total numbers collected in each treatment as well as the dominant species.

RESULTS

Seagrass biomass, population growth and reproduction

The first report on this project (Fonseca et al. 1979) described the fall (1978) and spring (1979) transplants in the Middle Marsh embayment.

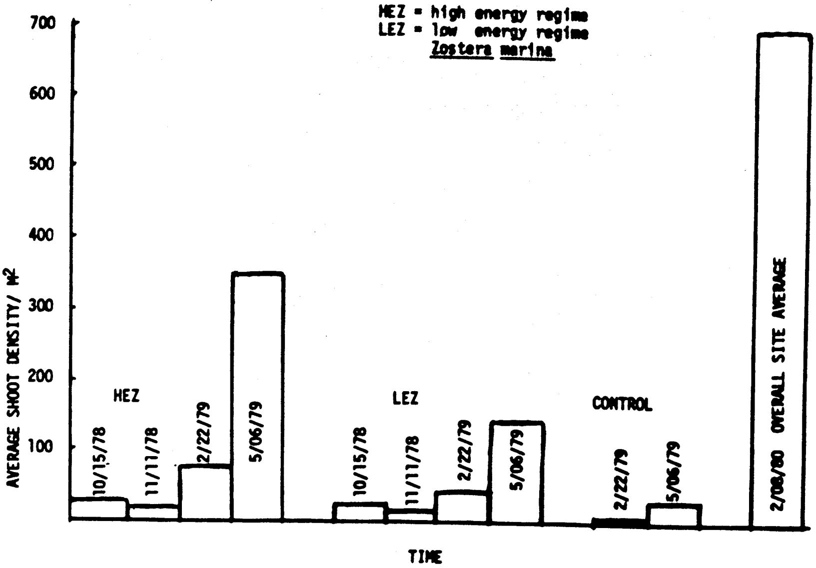

Figure 1. Average density of Zostera marina (M^{-2}) is plotted for each sampling time by original stock location designation. Data range from 1978 to 1980.

The spring planting generally was unsuccessful, and the results presented in Figure 1 show data for unmixed plantings of high and low current regime stock (Fonseca et al. 1979). As of February 1980, the site consisted of patches of Zostera with densities of approximately 700 shoots/m^2.

We sampled plant biomass at 8 and 16 months after planting and compared the transplants with control plots and adjacent, undisturbed sites to determine the degree that transplanted plots and control areas are growing relative to undisturbed, natural populations. Table 1 shows Zostera biomass as above and below ground components in the transplanted

Table 1. Top: leaf and root and rhizome dry weight biomass in transplant plots, control sites and adjacent undisturbed areas. Bottom: flowering data for high and low current regime *Zostera* shoots (HEZ,LEZ).

	Mean Biomass (g dw/m^2)	
	leaf	root & rhizome
High current regime origin (May 1979)	49.0	35.3
Low current regime origin (May 1979)	34.1	14.4
Control sites (May 1979)	3.2	1.7
Average over whole transplant site (Feb. 80)	35.5	51.6
Undisturbed adjacent areas (March 78)*	29.3	132.6
(June 78)*	79.8	171.5
(Feb. 79)**	26.9	39.2
(April 79)**	70.2	35.8

Flowering Data

#shoots sampled		#flowering shoots	%flowering	leaf biomass sampled	flowering biomass sampled	% flowering biomass
HEZ	105	14	13.3	49.1	22.8	46.4
LEZ	120	16	13.3	34.1	15.6	45.4

From Middle Marsh natural undisturbed population: (mean value ± standard deviation)
Spadices/flowering shoot (4.32 ± 1.87), # ovaries/spadix (12.82 ± 4.78), # fruits/spadix (1.77 ± 4.24).
Indicates 7.65 fruits/shoot or 13.8% of the ovaries produced contained seeds.

	# shoots	projected flowering shoots	ratio of seeds to m^2 of site
May 79	54,144	7,217	127.8
Feb. 80	302,400	40,310	713.8

* Data from H. Stuart, unpublished, Beaufort Laboratory, N.M.F.S., Beaufort, North Carolina.
** Data from W.J. Kenworthy, unpublished, Beaufort Laboratory, N.M.F.S., Beaufort, North Carolina.

plots at the initiation of the planting in May 1979 and in February 1980. Also included in the table are seasonal trends for 1978 and 1979 in adjacent, undisturbed stations. In May 1979, within 8 months of the transplant, there had been a 30 to 50 fold increase in leaf biomass in the transplanted site whereas the controls exhibited less than a three-fold increase. After one complete season of growth and two winters, the leaf biomass in the transplanted plots was similar to adjacent, natural areas. Data for below-ground biomass showed high current regime plants attained a biomass similar to natural areas within eight months and that the entire transplant site was similar to the natural area root-rhizome component within 16 months.

Data on flowering and sexual reproduction are summarized in Table 1. For both the high and low current regime stocks, 13.3% of the shoot population were flowering, representing about 46% of the leaf biomass. Previous work in this area (Kenworthy and Fonseca, unpublished, Beaufort Laboratory, NMFS, Beaufort, N.C.) has shown an average of 7.6 fertilized ova per flowering shoot (approximately 13.8% of all ova were found to be fertilized). From our total transplant population in May 1979 we estimate 55,200 seeds could have been made available to the area. Based on February 1980 shoot counts, fertilized seed crop should exceed 3×10^5 seeds for the transplant site.

Sediment parameters

In Table 2 we describe the sediment parameters relative to controls in the transplant site before and eight months after transplanting. Surface

Table 2. Mean values of percents organic matter and silt-clay for embayment planting. Control areas, high (HEZ) and low (LEZ) current regime stock areas and pre-planting values are presented.

	Percent Organic Matter				Percent silt-clay			
Depth(cm)	Pre-planting Oct. 1978	May 6, 1979 Control	HEZ	LEZ	Pre-planting Oct. 1978	May 6, 1979 Control	HEZ	LEZ
0-1	2.68	2.34	2.50	2.58	23.4	21.25	37.5	53.5
1-3	2.37	2.76	2.76	2.18	21.6	30.25	25.0	47.0
3-6	3.15	4.25	3.38	4.22	26.0	34.75	31.0	59.5
6-9	3.60	4.72	3.48	3.98	26.8	43.00	41.0	85.0

organic matter in the transplant area was only slightly greater than control plots in May 1979 and all surface samples were less than samples taken before planting in October 1978. Organic matter content of deeper strata in grassed areas was slightly higher than corresponding preplanting samples, while controls were slightly richer in organic matter in deeper strata. Percent silt-clay was higher in both control and grassed areas than in pre-planting cores at all strata. Only grassed areas had a consistently higher silt-clay content in the surface 1 mm.

Boundary stakes marking the transplant site were flush with the sediment surface at planting time, October 1978. During the period from October 1978 to May 1979 5 to 6 cm of sediment were deposited over the stakes, indicating a net deposition at the site.

The distribution of seagrass (as plant surface area (m^2) per m^2 of estuarine bottom) over the length of the transect and percent silt-clay and organic matter (by weight) increase with distance into the transplanted meadow (Figure 2 a,b,c).

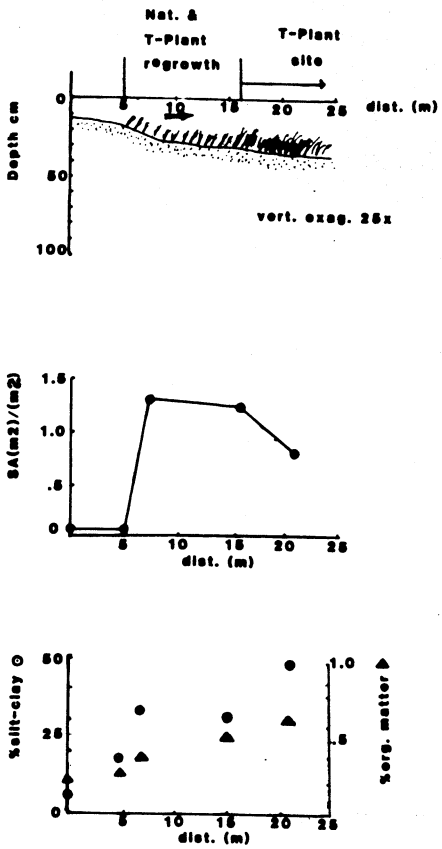

Figure 2. Graphs a, b, and c, top to bottom. Graph a shows an exaggerated profile of the current velocity transect into the transplant site. Graph b depicts Zostera canopy distribution on that transect in plant surface area (m^2) per square meter of bottom. Graph c describes % silt-clay and % organic matter in the surface (1 mm) sediments over the transect.

Results of the analysis of interstitial ammonium concentrations in the profiles showed values ranging from 20 to 330 µm NH_4-N. The concentration of NH_4 increased with depth and reached a maximum at 12-15 cm depth; this is the very bottom of the rhizosphere. Ammonium values in the rhizosphere averaged approximately 100 µm.

Current flow

Calculations were performed from the topographic analysis (Figure 2a) to determine the current velocity (u) reduction by the transplanted seagrass at the end of the transect. Assuming an infinite width and a constant discharge (Q) as the depth (Z) varies:

$$Q = U_{sta.1}\, Z_{sta.1} = U_{sta.2}\, Z_{sta.2}$$

$$\text{if } Z_2 < Z_1, \text{ then } U_2 < U_1, \text{ so: } U_2 = \frac{U_1 Z_1}{Z_2}.$$

(sta.1= outside meadow, sta.2 = 16 m into meadow down direction of current flow).

Given a lunar maximum bottom current velocity at station 1 equal to 13.33 cm/sec with depth of 100 cm, and the transect deepening 21.9 cm by the end (Station 2), the expected velocity was 10.3 cm/sec. Velocity was measured at 5.6 cm/sec in the meadow at station 2, indicating an extra 4.7 cm/sec velocity reduction by the seagrass. This amounts to a natural, bathymetrically-induced current reduction of 22.5% versus the observed 42% or a net reduction of current by the seagrass of 19.5%.

Faunal development

Bay scallops (*Argopecten irradians*) rapidly colonized the planted area. Scallop density displayed a strong non-linear correlation with seagrass density:

$$Y = A \cdot X^b,\ a = 0.039,\ b = 0.702,\ r^2 = 0.982.$$

Macroinvertebrate populations were grouped into vegetated treatments and unvegetated controls based on the high degree of similarity between certain treatments. The former consisted of transplant treatments HEZ (high current origin), LEZ (low current origin), HEX and LEX (high and low current regime stock mixed with Halodule), and the latter of CON, OS and HAL (control, outside undisturbed natural meadow and Halodule, respectively; Fonseca et al. 1979). The failure of the Halodule transplant resulted in this treatment serving as an additional control plot and, as such, it was grouped with the original control and "outside" control plots. The continued lack of affinity of treatment HEX (high current regime stock mixed with Halodule) to either group prompted us to exclude it from the results. Faunal affinities (Sanders 1960) were calculated for all treatments and controls in each sampling interval to determine similarity indices between various treatment plots.

All community parameters measured increased with time from October to May for both vegetated and unvegetated plots (Table 3). No substantial

Table 3. Average values (N,S,$\hat{H}$, D,J) for all sample periods for vegetated and unvegetated treatments.

			Oct. (78)	Nov. (78)	Mar. (79)	May (79)
Density/m^2	N	Veg.	1321.4	1519.2	2934.7	6842.5
		Unveg.	1690.7	1954.4	3209.9	3896.2
#Species/0.038m^2	S	Veg.	16.0	20.0	33.3	51.3
		Unveg.	17.7	21.3	29.0	37.3
Diversity	$\hat{H}$	Veg.	1.0	1.03	1.26	1.40
		Unveg.	1.03	0.93	1.15	1.22
Sp. richness	D	Veg.	7.54	9.13	13.90	18.50
		Unveg.	7.83	9.27	11.61	14.73
Sp. evenness	J	Veg.	0.83	0.79	0.83	0.82
		Unveg.	0.83	0.70	0.79	0.78

HEZ, LEZ, HEX, LEX (vegetated treatments)*
CON, HAL, OS (unvegetated treatments)*
* Fonseca et al. 1979.

differences in these parameters were noted in either October or November samples. Overall densities remained similar in the Marcn samples but diversity, species richness, and evenness values were greater in the vegetated treatments. In May, all the measured community parameters increased markedly for vegetated treatments relative to unvegetated controls.

Faunal populations differed greatly between planted and unplanted, and naturally recolonizing areas (controls). October and November samples appeared to have essentially similar faunal compositions, with average affinities of 70-75%, both within and between treatments (Table 3). Faunal similarities remained in this range within treatments in the March samples, averaging 78% affinity within the unvegetated controls and 74% in the vegetated treatments. Affinity between control and treatments declined to 51%. Faunal similarity declined within treatments in the May samples, averaging 66% for vegetated treatments and 73% for unvegetated controls. Differences between treatments declined to 43.6%.

Numerically, the most important taxon in all treatments throughout the study was the Polychaete. In October and November, 1978 similar abundances of this group were observed in all treatments, averaging 67% (range 58% to 73%) and 70.0% (range 60 to 75%), respectively (Table 3). Within this group two spionid polychaetes, *Streblospio benedicti* and *Polydora ligni*, were overall dominants in all treatments in October, November and the March unvegetated controls. These species continued to dominate the unvegetated control fauna in the March samples along with an amphipod, *Ampelisca abdita*. In the vegetated treatments, another polychaete, *Spiochaetopterus oculatus*, replaced the spionids and the oligochaete. In both the vegetated and unvegetated treatments other taxa appeared in significant numbers; gastropods (14% and 7%), bivalves (16.2% and 11.3%) and amphipods (25% and 12%).

The differences noted in the March samples became more pronounced in the May samples. Polychaetes continued to dominate both the vegetated (41%) and unvegetated (47%) treatments, but with syllids and capitillids replacing the March dominants. Amphipods were the second most numerous group in both treatments, 35% and 33% respectively, with significant numbers of gastropods (12%) and bivalves (10%) persisting in the vegetated treatments.

DISCUSSION

Seagrass biomass, population growth and reproduction

Our data indicate that the transplanted shoot population has reached levels similar to undisturbed areas in a period of 400 days (comparisons in Table 1). The biomass results support our conclusions from population counts; we have had a high degree of success in restoring the damaged area. Biomass accumulated at a greater rate in transplanted plots than in the controls during the first growing season. In addition the biomass in replanted plots compared favorably with undisturbed plots after 16 months.

An important aspect of seagrass population growth is the potential contribution of new plants by sexual reproduction (Table 1). Not all seeds generated by the transplants remain in the immediate area where they dehisce, but their presence increases the potential for seedling recruitment in the season following transplantation.

Sediment parameters

The characteristics of the transplant site resembled those of a mature, well developed seagrass-sediment system where the larger nitrogen content assures its availability to the plants and animals. With increased plant abundance, currents are slowed considerably and a net deposition of fine sediment occurred. Silt-clay and organic matter content increased with distance into the transplanted seagrass meadow (Figure 2c). Also, the concentrations and patterns of the NH_4-N profiles are similar to sediments that were studied nearby in this embayment and other vegetated areas of the estuary[3/]. Typically, the embayments are sediment and organic matter traps. The organic materials deposited at these sites become incorporated into the sediment and nutrient remineralization processes recycle nitrogen to inorganic NH_4. The presence of large concentrations of an organic nitrogen substrate (seagrass and faunal components) is likely to stimulate nutrient remineralization processes. These conditions may have been partly responsible for success of the transplanted *Z. marina*.

Current flow

The combined increase in seagrass abundance, decrease in current velocity, increase in deposition of fine particles resulting in a decrease of water depth with a concomitant development of a characteristic ammonium profile demonstrates the influence that a developing plant canopy has on the immediate environment. The reduction in current described here is equivalent to those described by Fonseca in experimental flume studies[4/].

[3/] Kenworthy.

[4/] Fonseca, M. The interacton of a seagrass (*Zostera marina*) with current flow (in preparation). Master of Science Thesis, Dept. of Environmental Science, University of Virginia, Charlottesville, Va. 48 pp.

Faunal development

Analysis of the invertebrate community in the transplant sites demonstrated that the area is attaining biological characteristics similar to established, unperturbed seagrass meadows. The data indicate that the transplanted system has become a viable nursery area for at least one commercially valuable species. The numerical abundance of bay scallops (*Argopecten irradians*) were shown to be positively correlated with the density of seagrass.

Overall, we found a strong positive exponential relationship between blade density and density of fauna, N(r^2=0.912), and the number of species, S(r^2=0.914). Unvegetated controls (Homziak, unpublished data, Institute of Marine Science, University of North Carolina, Morehead City, N.C.) showed a strong positive linear relationship between density, N(r=0.912), and time, and species number, S(r=0.930), and time. We interpret this to represent the seasonal addition of species to the benthic fauna during late winter and spring recruitment. Vegetated treatments, on the other hand, showed faunal density and number of species values that increased exponentially over the same time (r^2=0.952 and 0.976, respectively), clearly demonstrating the effect seagrass meadows have in promoting either increased recruitment, enhanced survivorship, or both, to a large number of invertebrate species.

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MICROBIOLOGICAL CONTROL OF WATER HYACINTH (*Eichhornia crassipes*) IN EGYPT

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ABSTRACT

A potentially serious aquatic weed problem in Egypt is the water hyacinth (Eichhornia crassipes). Problems caused by it become increasingly critical as man's use of waterways, natural or artificial impoundments, and irrigation systems increases. Conventional methods of control have not been entirely satisfactory because of cost, overall ineffectiveness, or environmental pollution.

In the present investigation five Dematiaceous Hyphomycetes were tested for their capabilities of attacking the E. crassipes plant. Alternaria grisea was found to be strong in inciting pathogenesis in the plant, while the other tested fungal species, namely Alternaria alternata, Alternaria humicola, Cladosporium cladosporoiodes and Cladosporium herbarum, appeared to be slight or very weak pathogens inducing small zonate yellowish-brown spots on leaves.

The cell-free culture filtrate of A. grisea was capable of inciting the same syndrome as A. grisea spore suspension. The active substance was extracted, purified, and obtained as orange plate crystals; m. p. = 112-115°C; $[\alpha]^{26}_{D}$ = -15.2°C. It has a molecular formula of $C_{16}H_{22}O_{2}N$. It is soluble in chloroform, ether, butanol, benzene, ethyl acetate, butyl acetate, acetone, ethanol, methanol, and scarcely soluble in water. This necrogenic substance proved to be related to the victorin group of toxins. This substance appears to hold some promise as a possible biocontrol agent for water hyacinth.

INTRODUCTION

The aquatic weed problem is of considerable proportion and appears to be growing rather than diminishing in magnitude or even stabilizing. This is occurring despite the expenditure of considerable sums of money and human energy in the application of conventional methods of mechanical and chemical control. Water hyacinths continue to be among the most serious of aquatic plant pests in the world (Martin and Nailon 1977, Guerra 1976, Kassas 1972, Moursi 1976). Regarding the possibility of aquatic weeds infestation of the man-made lake of Aswan High Dam, Kassas (1972) states "It will take about 10 years to fill the High Dam reservoir of Egypt and the episode of dramatic fluctuations will result and provide habitat features that are not, in general, different from those of a natural lake. Invasion by water weeds will follow sooner or later, subject only to their migration efficiency and local conditions of water depth...."

In Egypt, surprisingly, until our research program for aquatic weeds' control was initiated, plant pathogens rarely had been considered as biocontrols. They have all the prerequisites of a biocontrol agent and, thus, offer an untapped reservoir of potential usefulness either alone or in an integrated program with fungi and perhaps insects.

In the present investigation we have dealt with the biological control of water hyacinth as one of the most noxious aquatic weeds in Egypt, particularly after the construction of High Dam. The purpose of the overall study is to determine: 1) the ability of some Dematiaceous Hyphomycetes to attack the plant, and 2) the potentiality of fungal metabolite to induce suppressing effect on _E. crassipes_ growth.

Water Hyacinths in Egypt

Water hyacinths (Eichhorniae) are represented in Egypt by two species, namely, Eichhornia azurea and E. crassipes (Takholm and Drar 1950). E. azurea (Sw.) Kunth is occasionally cultivated in the gardens of Cairo. Its leaves are not rosetted and the leaf petioles are not (or hardly) swollen. It flowers in June through August. E. crassipes (Mart.) Solms-Laub., on the other hand, is very common and widely spread in Egypt. Its leaves are rosetted with inflated bladder-like petioles and it flowers in May through September. Sometimes flowering extends to December.

E. crassipes is a free-floating pontederiaceous aquatic weed, native to South America. It was introduced into the United States in 1884 (Sculthorpe 1967). It flourishes in the swampy habitats with warm, slow moving, fresh (or brackish) water. As sea water contains excess salts, it becomes unfavorable for E. crassipes growth. The most favorable temperature for growth is 27.6 ^{o}C, and at lower temperatures E. crassipes growth tends to decrease (El-Fiky 1974). This may explain its absence in waters of the cold countries.

E. crassipes was introduced into Egypt as early as 1879-1892 during Khedive Tawfiq governorship. Hence, for many years it has been grown to a limited extent in certain pubic and private gardens of Cairo and Alexandria as an ornamental plant with beautiful flowers (Anonymous 1971).

During the last 15 years and after the establishment of High Dam at Aswan, the growth and distribution of water hyacinths in Egypt are increasing considerably and it is hard to find a canal, stream, or drainage system free of this weed infestation (Zahran 1976). Sculthorpe (1967) states "Once well established in an area, E. crassipes will successfully suppress competing species." This may show that the problem is so serious that safe and urgent solution is necessary.

MATERIALS AND METHODS

According to Conway et al. (1974) several species of Deuteromycotina were found to possess varying pathogenicity to water hyacinth. In the present investigation, five species of Dematiaceous Hyphomycetes, namely *Alternaria alternata*, *A. grisea*, *A. humicola*, *Cladosporium herbarum* and *C. cladosporoiodes*, were tested for their capabilities of attacking the water hyacinth growing in Egypt.

Pathogenicity Tests

On August 10, 1977, samples of healthy water hyacinths (*E. crassipes*) were collected from Damietta Branch of the River Nile in the vicinity of Mansoura City. The plants were kept in six glass jars (24 X 40 X 50 cm) filled to 2/3 of their heights with fresh water and maintained at air temperature (maximum 36^{o}, minimum 22^{o}C). Pathogenicity tests were conducted using the above mentioned fungal species to five jars of plants while those of the sixth one were left without infection (control jar). Inocula were prepared by growing the tested fungi on slant cultures of potato dextrose agar (Riker and Riker 1936) at 28^{o}C. The conidia of 7 day old cultures were suspended in sterile water, and the spore suspensions of each individual fungus were then combined and homogenized. Infestation was carried out by spraying water hyacinth with the inoculum of each fungus at the rate of 10 ml spore suspension per plant and keeping at open air conditions for 7 days. Meanwhile, daily observations of the syndrome were noted. This experiment was set up to find out the infective potency of the experimental fungi to *E. crassipes* plants.

A subsequent pathogenicity trial was carried out using only one fungus (A. grisea) to qualify the infestation syndrome and/or to ascertain validity of this organism in biocontrol. On September 1, 1977, new samples of water hyacinth, collected from the same location, were dispensed in five jars. One was left as a control, while the other four jars of plants were sprayed with the spore suspension of A. grisea. The jars were maintained at open air conditions (maximum temperature 34°C, minimum 21°C) and the syndrome was noted over a period of 45 days.

Deteriorative Potentiality of Fungal Metabolite

The fungus A. grisea was cultured in 250 ml conical flasks each containing 50 ml of potato dextrose liquid medium. The fungus-free fluid of cultures, incubated for ten days at 28°C, was obtained by centrifugation, then Seitz filtration. This cell-free filtrate was sprayed over the water hyacinth (new healthy samples) and kept in a group of jars for seven days. Meanwhile, the syndrome was noted.

Subsequent extraction of the fungal metabolite of the tested culture filtrate was undertaken using seven different solvents; namely, diethyl ether, chloroform, n-butanol, ethyl acetate, butyl acetate, benzene and petroleum ether at pH 5, 7, and 9. The extract of each individual trial was evaporated under vacuum and suspended in 10 ml of water. The obtained suspensions were sprayed over healthy plants of E. crassipes and the syndrome was noted.

RESULTS

Pathogenicity of the Tested Fungi

As indicated in Table 1, the tested fungi appeared to differ in their infective potency for the water hyacinth. Pathogenesis appeared on the sixth day of inoculation with the two Cladosporium species, while it started on the third day with Alternaria grisea and on the fifth day with A. alternata and A. humicola.

Table 1. Development of symptoms on *Eichhornia crassipes* due to infection with the tested fungal species during seven days.

Time elapsed after infection (Days)	*A. grisea*		*A. alternata*		*A. humicola*		*C. cladosporoiodes*		*C. herbarum*	
	Symptom	Sever.*	Symptom	Sever.	Symptom	Sever.	Symptom	Sever.	Symptom	Sever.
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	yellow spots	+	-	-	-	-	-	-	-	-
4	yellow spots	+	-	-	-	-	-	-	-	-
5	yellow spots	+++	yellow spots	+	faint yellow	+	-	-	-	-
6	yellowing of leaves	++++	yellow spots	+	faint yellow	+	faint yellow	+	faint yellow	+
7	yellowing of leaves and browning	+++++	yellow spots	++	yellow spots	++	yellow spots	++	yellow spots	++

* Severity of disease symptoms

\- No disease symptoms

\+ Slight syndrome; increasing number of + indicates increasing severity of disease symptoms

It is a well known fact that yellow or brown spottings mean damage in assimilation systems of plants, which sooner or later would be accompanied by deterioration of leaves and/or the whole plant.

From the results herein reported, it is apparent that A. grisea is the most active organism in inciting disease for water hyacinth, while A. humicola and A. alternata and the Cladosporium species are respectively weaker as disease inciters. The higher infective potency of A. grisea was the cause for using it in the last stages of this investigation so as to qualify its virulence and/or to ascertain validity of its application in biocontrol of E. crassipes.

Efficiency of Alternaria grisea as Water Hyacinth Deteriorative

The results shown in Table 2 clearly elucidate that after or within five days of spraying the spore suspension of A. grisea, the fungus exhibited its pathogenic effects. First, faint yellow spots appeared on the upper surface of E. crassipes leaves. These spots enlarged gradually and turned yellowish-brown in color after 10 days. Development of brown color and coalescence of spots led to blotches and blights on leaves on the 20th day. On the 30th day, these symptoms extended to petioles and stolon of the plant which appeared partially or totally killed as partial defoliation became a prominent feature after this period. Disappearance of the plant remains took place after 45 days and the contents of nearly all the jars turned into dark brown or dirty fluid. This may be due to tissue necrosis and/or bacterial decomposition of the deteriorated tissues of the E. crassipes plant.

Necrogenic Capability of Fungal Metabolite

The cell-free filtrate of a 10 day old culture of the candidate fungus A. grisea was found to be equally active as its spore suspension in inciting necrosis of water hyacinth tissue. This indicated that the fungus elaborates a toxic metabolite in the culture broth which usually induces such

Table 2. Development of symptoms on *Eichhornia crassipes* due to infection with *Alternaria grisea* during 45 days.

Time elapsed after infection (Days)	Description of Syndrome
2	No appreciable symptoms.
5	Small water-soaked yellow spots on the upper surface of leaves.
7	Enlarged spots of yellow color.
10	Enlarged spots of deep yellow color with brown colored margins.
14	Excessive spotting; some leaves manifest brownish spots and others tend to be necrotic; spots coalescence appeared in many areas of leaves.
20	The affected areas turn necrotic and appearance of blotchy lesions and/or leaf blights.
30	The aforementioned syndrome extend to petioles (bladders) and/or stolon of the plant, some parts get dried; partial defoliation, while others get dried.
45	The weed individuals disappeared and the contents of nearly all jars appeared to turn into dirty or dark brown colored fluid.

syndrome resulting in destruction of the cellular contents and collapse of the cell walls of water hyacinth.

Chloroform, ether, benzene, ethyl acetate, butyl acetate, and n-butanol, particularly at pH 5, were capable of extracting the active necrogenic substance. This was indicated by the necrosis induced by the aqueous suspensions of dried extracts of each solvent; however, chloroform proved, comparatively, the most efficient solvent.

Characterization of the Active Biocontrol Agent

The chloroform extract was evaporated under vacuum to the least volume and the necrogenic substance was precipitated by addition of petroleum ether. The crude substance, which was yellowish-brown in color, was purified by chromatography and obtained from ethanol as orange plate crystals. It has a melting point of 112-115 C and an optical activity of $[\alpha]^{26}_{D} = -15.2^{\circ}C$. It is soluble in chloroform, ether, butanol, benzene, ethyl acetate, butyl acetate, acetone, ethanol, methanol, and scarcely soluble in water.

The elemental analysis indicated that this substance contains carbon (72.62%), hydrogen (8.95%), nitrogen (3.62%), and oxygen (14.81%). The molecular weight was found to equal 262 as indicated by high resolution mass analysis. The molecular formula, therefore, is suggested to be $C_{16}H_{22}O_2N$.

The ultraviolet spectrum showed absorption maxima at 223, 278, and 352 nm. The infrared spectrum exhibited 5 bands at 2525, 2435, 1740, and 1275 cm^{-1}. The bands at 2525 and 2435 cm^{-1} correspond to OH group, while the bands at 1740 and 1715 cm^{-1} are assigned to C-N. The necrogenic substance, therefore, is a low molecular weight peptide.

Based on the foregoing results, the toxic agent synthesized by *A. grisea* can be identified as belonging to the victorin group of toxins. The name victorin was coined by Wheeler and Luke(1954) to include toxic agents produced by some species of *Helmenthosporium* and *Alternaria*.

DISCUSSION AND CONCLUSION

The biocontrol refers to the use of one or more kinds of organisms to stress a pestiferous population of other organisms whether by physical destruction, direct consumption, parasitism, or pathogenicity. A most important characteristic of the control agent is that it must not pose a threat to other species whose presence in the ecosystem is valued, and, in particular, it must not pose a threat to any economic species in any area where it may be introduced (Martin and Nailon 1977).

Plant pathogens have many characteristics that make them ideal candidates as biocontrols for aquatic weeds (Zettler and Freeman 1972, Rintz 1973, Freeman et al. 1976, Charudattan et al. 1976).

It may be recalled here that Conway and coworkers (1974) referred that most Alternaria species are saprophytic on water hyacinth and their pathogenicity is not confirmed. The results obtained from the present study proved the pathogenicity of Alternaria grisea which killed Eichhornia crassipes plants. Accordingly, this fungus may be used as a promising biological control organism for the floating aquatic weeds. Before suggesting its use on a large scale, the side effect of the candidate pathogen should be considered. First of all is the probability of infecting other cultivated plants near the areas of spore suspension spray. To overcome this problem, the active substance (necrotic agent) through which pathogenesis could be brought by the candidate fungus was isolated. The use of this substance instead of spore suspension will limit the growth rate or destroy E. crassipes only and may diminish the infection of other cultivated plants.

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ONE OPTION FOR THE USE OF MARSHES OF TABASCO, MEXICO

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ABSTRACT

In Tabasco, Mexico, marshes and swamps are now in the process of being dried. The finality of this has been the utilization of these areas for agriculture which has a great ecological cost and has not been very successful. In a study of the traditional uses of marshes and swamps in the Chontal area of Tabasco, we found that one of the management practices of the *Thalia* marshes is to use them for agriculture during the dry season. With this practice, the Chontal Indians have obtained very high corn production in comparison with the productivity of the modern dried fields. This ancient agricultural practice could be a good solution for the use of these areas and an alternative to the modern techniques. In this paper we analyze the corn cultivation in the *Thalia* marsh and we give data regarding productivity.

INTRODUCTION

In Europe and America, bodies of water have often been considered as unhealthy areas that limit the development of the country, and more than once it has been proposed as a unique alternative for these areas to be dried or filled with trash or other materials. In many cases, (Florida, France, etc.) the inefficiency of this measure has been probed, and serious ecological problems have been the consequences of those practices.

In Tabasco, Mexico (Figure 1) the purpose of solving the problems of unhealthiness caused by yearly floods in a zone of the state and the prior necessity to enlarge the agricultural surface as well as to increase the country's development resulted in the building of the Mal Paso dam during 1960-1964 at the limits of Tabasco and Chiapas. In this way, ninety-one (91) thousand hectares were liberated from annual floods. As a complement to this program, the "Plan Chontalpa" (Figure 1) was started in 1966. This consisted of building a drainage system to eliminate the excess of water and incorporate this zone in the agricultural activities of the region.

Even though this measure failed due to the loss of fertility in the area, the lowering of the water table, and other reasons, a similar project was planned for the region of Balancan-Tenosique. A superficial canal drainage system was built that affected 115,000 hectares.

From these problems has emerged the idea to find an alternative to the traditional techniques of using acuatic areas. Gomez-Pompa et al. (1976) proposed the use of the agricultural system of "chinampas" (raised fields), actually applied in the lakes of the Valley of Mexico which is highly productive.

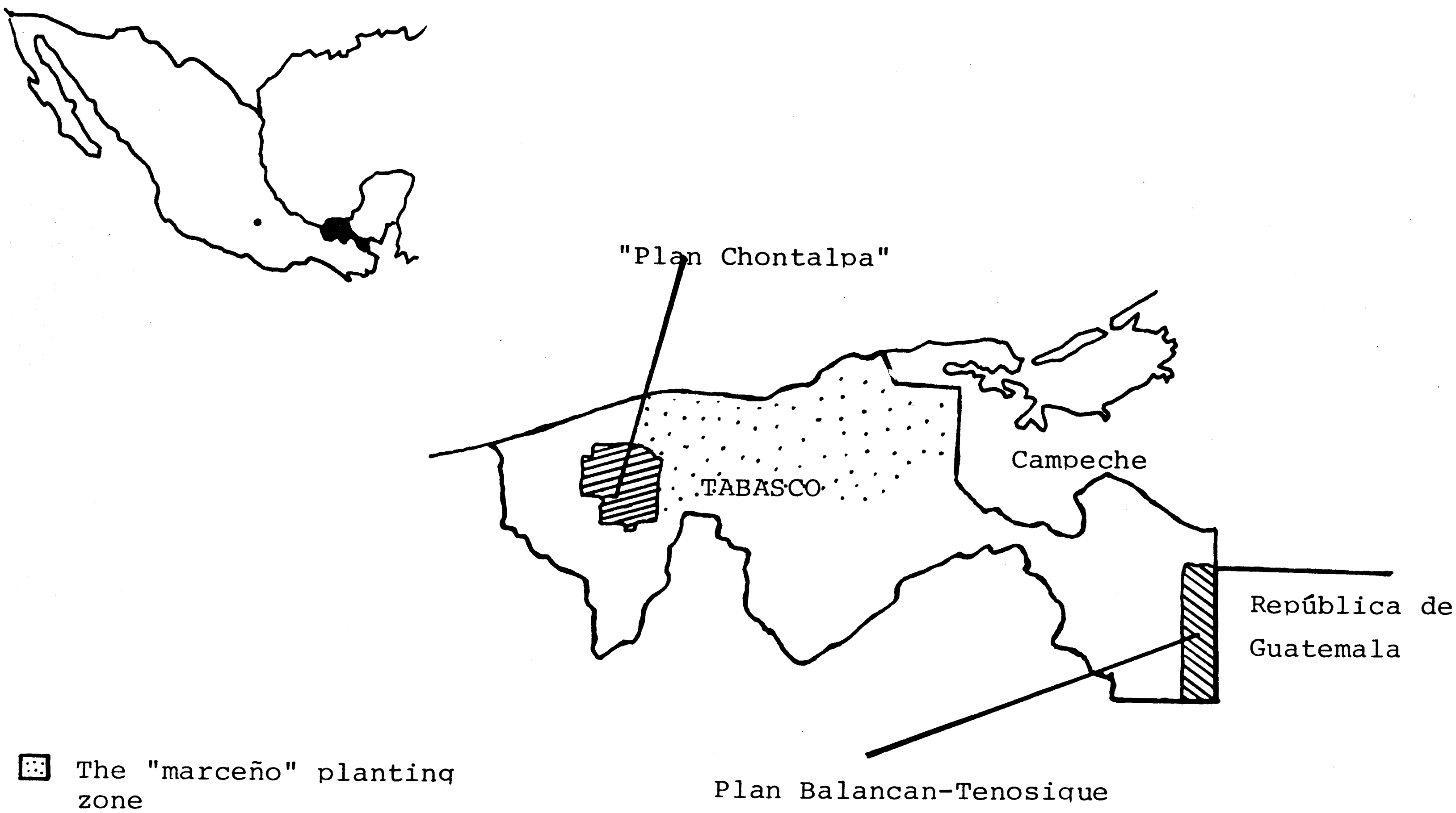

Figure 1. Location of Tabasco, Mexico.

Nevertheless, in an investigation of the traditional uses of bodies of water, an agricultural system using marshes and flooding areas known in the Chontal area of Tabasco as "marceno" or "March planting" was discovered. The "marceno" can be considered one of the last vestiges of highly productive agricultural systems practiced in marshes and flooding zones. This could have been of great importance in Prehispanic times for supporting not only local Indian inhabitants but also Mayas and neighbors by trading between the agriculturalists and the other regions.

SITE DESCRIPTION

In the area studied, the climate is warm and humid with rainfall in the summer months and a longer dry period in cold part of the year (winter-spring) separated by a short dry period (canicula or dog days). The winter rainfall is greater than 10.2%. Temperature oscillation is less than 5 ^{o}C with the warmest month before the summer solstice. Climate is classified Am(f)w"(i)g according to the system of Koeppen modified by Garcia (1973).

The area studied is drained by the Usumacinta and Mezcalapa River systems, both of which form a complicated delta of channel network (West et al. 1969). There also exists a great diversity of permanent and semipermanent bodies of water which cover up to as much as 60% of the total area of the state during part of the rainy season when these bodies of water overflow.

AGRICULTURAL USE

The "marceno" is practiced during the dry season of the year in the marshes and flooding areas of several municipalities of Tabasco. Among the most important municipalities are Nacajuca, Centla, Jalpa, and Cardenas. According to word of mouth, the "March planting" had great importance in the whole state. The marshes and flooding areas have a water table during three to seven months a year and the water level reaches a level from 30 to 250 cm during the season of higher precipitation. The planting is practiced according to the level of dropping water table during the period from February to the end of April, although the typical "marceno" is practiced when the water level drops below the surface in the month of March.

The "marceno" is practiced in marshes and flooding areas covered with pure stands of the following species: Thalia geniculata L. (hojilla), Scleria macrophylla Presl (navajuela), Echinochloa cruspavonis (H.B. & K.) Schultes (camalote), Panicum hirsutum Swartz (pelillo), Cyperus articulatus L. (chintul), and Eichhornia crassipes (mart.) Solms (jacinto). Those species are often mixed with weeds which are established during the culture. The above mentioned species can be substituted by the weeds. This happened in the Nacajuca zone due to hydrological changes caused by the building of the Mal Paso Dam. The more representative species of these areas is Thalia geniculata known in the region as "hojilla" or "hoja de popal". That species favors the culture of corn because it keeps soil moist and porous.

The culture basically consists of four procedures: planting, weeding, doubling-over and harvest, and post-harvest. After three or four days of land clearing with a machete or by burning, four to six corn grains are planted in each of the superficial holes made with a machete or a pointed stick (macana) one meter apart. Commonly there are two weedings; one thirty days after planting and one before the doubling-over of the corn stalk in preparation for the harvest. This facilitates the work and drives rats away from the corn. Procedures for the doubling-over and harvest depend on the variety of corn planted. "Cuarentano" corn and "mejen rojo" corn are local varieties which tolerate floods and have short life cycles. For these species the doubling-over is made two and half months after planting and the harvest is made twenty days after that. Once it is doubled-over, the corn resists moisture and the harvest can be made in canoes in case the rain comes early and the land suffers a premature flood.

An hybrid corn is planted also. The hybrid degenerates year after year because the seed for planting is taken from preceding crops. The hybrid corn is doubled-over three and a half months after planting and is harvested one month later. Hybrids have little tolerance to moisture and the plant is easily torn down by the action of winds due to the height of the plant.

After the harvest, the land is left until the next agricultural cycle or is left to rest for a year or more.

During floods, the vegetation is regenerated and the corn plants' residues, weeds, and the organic matter that comes by the overflowing of other bodies of water keep the productivity of these areas high.

During the 1977 agricultural cycle the grain production of mixed "mejen rojo" and "cuarentano" corn was evaluated. These two local varieties adapted to wet soil produced 4.5 tons/ha (expressed as dried grain) during a three and a half month period. The total dry weight of the corn plant, less the grain, was 15.3 tons/ha. In the same time period, weed biomass reached 3 tons/ha. In some places of the Nacajuca municipality, the countrymen registered harvests of 7 and 8 tons/ha, although this information, repeated by many people, has not been corroborated (Orozco-Segovia and Gliessman 1979).

Before the planting, the Thalia dry weight reached an average of 10 tons/ha. At harvest time, Thalia was regenerated to 3.8% of the before-planting dry weight due to the weedings. Two and a half months after the harvest, Thalia was regenerated to 22.5% of the before-planting dry weight. Two years after harvest, the community of Thalia seen in the field was almost completey regenerated.

DISCUSSION

In 1975, 1978, and 1979, it was reported that in the total surface designated for corn culture (marshes and flooding areas excluded) the mean production of corn grain was 1.3 tons/ha/year, which contrasts with "marceno" production (Comite promotor del desarrollo del estado de Tabasco 1976 and Sector Agropecuario Forestal 1979).

Regardless of the utilization of those marshes and flooding zones, the regional and state plans for development generally tend to dry those zones by draining, which diminishes the high agricultural potential.

Another reason to reduce the cultivation of marshes and flooding zones is the low demand for "mejen rojo" and "cuarentano" grain, even though hybrid corn, of great demand, does not tolerate moisture and offers very low security in getting a harvest.

Countrymen state that irregular rains and hydrologic changes due to hydraulic works also have contributed to increase their insecurity on seeding the "marceno". They prefer to seed just small surfaces with corn for domestic consumption and to plant the rest of the flooding areas and marshes with grasses to assure the family income by renting their land for cattle raising. These situations have caused the "marceno" practice to decrease in spite of its importance and perhaps it may be forgotten as an alternative for those areas.

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LAKE TARPON OUTFALL CANAL DREDGING STUDY

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ABSTRACT

Erosion along the shore of the Tarpon Outfall Canal has been a problem since construction. In an attempt to restore the original design slope (3:1, horizontal:vertical) of canal banks, slumped material was dredged and replaced on the banks. Any vegetation that might have established itself before the dredging was up-rooted. Only portions of the canal underwent dredging, and after August 1977 the dredging procedure was discontinued.

The purpose of this study was to monitor erosion conditions along the canal to determine the effects of dredging on the banks above the water line. Dredging as discussed in this report is concerned only with the littoral zone and not the cross-section area of the canal. Information on amounts and types of plants on canal banks was used to illustrate the importance of vegetation in controlling erosion.

The data indicate that dredging has increased the erosion along the canal and that emergent aquatic vegetation is the major contributing factor leading to bank stabilization. Report recommendations include: 1) a continued cessation of dredging along the canal, 2) the planting of desirable emergent vegetation, and 3) the discouragement of high-speed boat traffic in the canal.

INTRODUCTION

Severe erosion has taken place along the banks of the Lake Tarpon Outfall Canal since it became operable in 1971. For some years, dredging procedures have been employed in attempts to return the canal banks above the water line to the original design slope (3:1, horizontal: vertical), and as a result, vegetation has been stripped away from large areas along the canal. After August 1977, all dredging activity on the canal was terminated. Dredging to maintain the cross-section below the water line is still carried out periodically to meet the flood prevention capabilities of the canal. Consequently, vegetation along the canal banks was distributed in patches; slumped banks devoid of vegetation separated the patches. Observations of the canal emphasized the contrast in appearance between the dredged and undredged portions of the canal. Therefore, work was undertaken to assess the effects of dredging upon the erosional characteristics and design slopes of the canal. The influence of vegetation in stabilizing canal banks was also evaluated.

SITE DESCRIPTIONS

Site 1 is located on the east bank along the area that had been completely dredged. The site was devoid of both aquatic and shore vegetation except for grass growing on the bank at the time of the first sampling (Figure 1).

Site 2, which is on the west bank, is in an area with extensive torpedo grass (*Panicum repens*) growth. There is also a variety of shore plants growing on the bank. This area along with the entire west bank has not been dredged (Figure 1).

Site 3, another dredged area, is also non-vegetated except for some grass on the shore and is located on the east bank. After the initial sampling, the stakes could no longer be found (Figure 1).

Site 4, on the west bank, was not dredged. It lacked any shore vegetation, but the aquatic vegetation consisted of an extensive area of cattail with torpedo grass intermixed (Figure 1).

METHODS

Sampling

Four sites along the canal were sampled semi-annually (Figure 1). Determinations of the occurrence and percent coverage of the aquatic and shore plant species and any movement of the bank due to erosion were made during each sampling. At each site a transect line began at the top of the sloped bank and extended into the water perpendicular to the shoreline to the beginning of extensive growth of hydrilla (*Hydrilla verticillata*). The sites were chosen to represent equally both dredged and undredged areas.

Data for vegetation cover were taken from an area 0.5 meter on either side and along the length of the transect line. Terrestrial grasses were recorded as bare ground when percent cover of the shore plants was calculated. In order to show the realistic density of the shore plants, the area of the transect above where they were growing (i.e., only grass growing) was not used in the calculations (Figure 2). The entire area from the shore to the edge of the hydrilla was used in calculating percent cover of the aquatic vegetation.

Stakes were set up for marking each site and measurements were taken from them to determine erosion. A subsidence stake was placed either against the vertical cut bank (Figure 2) or a known distance from it so that measurements could be taken to detect movement of the bank. The height of the cut bank was measured during each sampling.

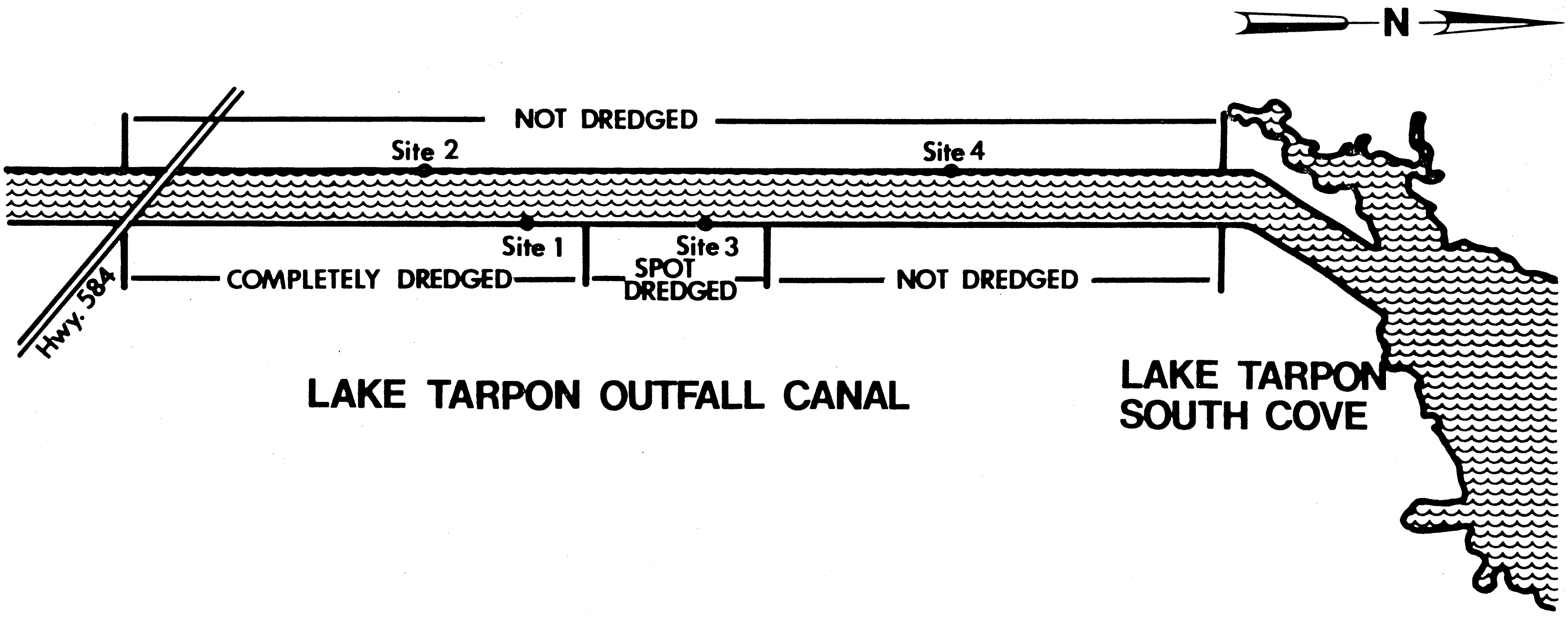

FIGURE 1. Lake Tarpon Outfall Canal Showing Location of Sites and Areas of Dredging

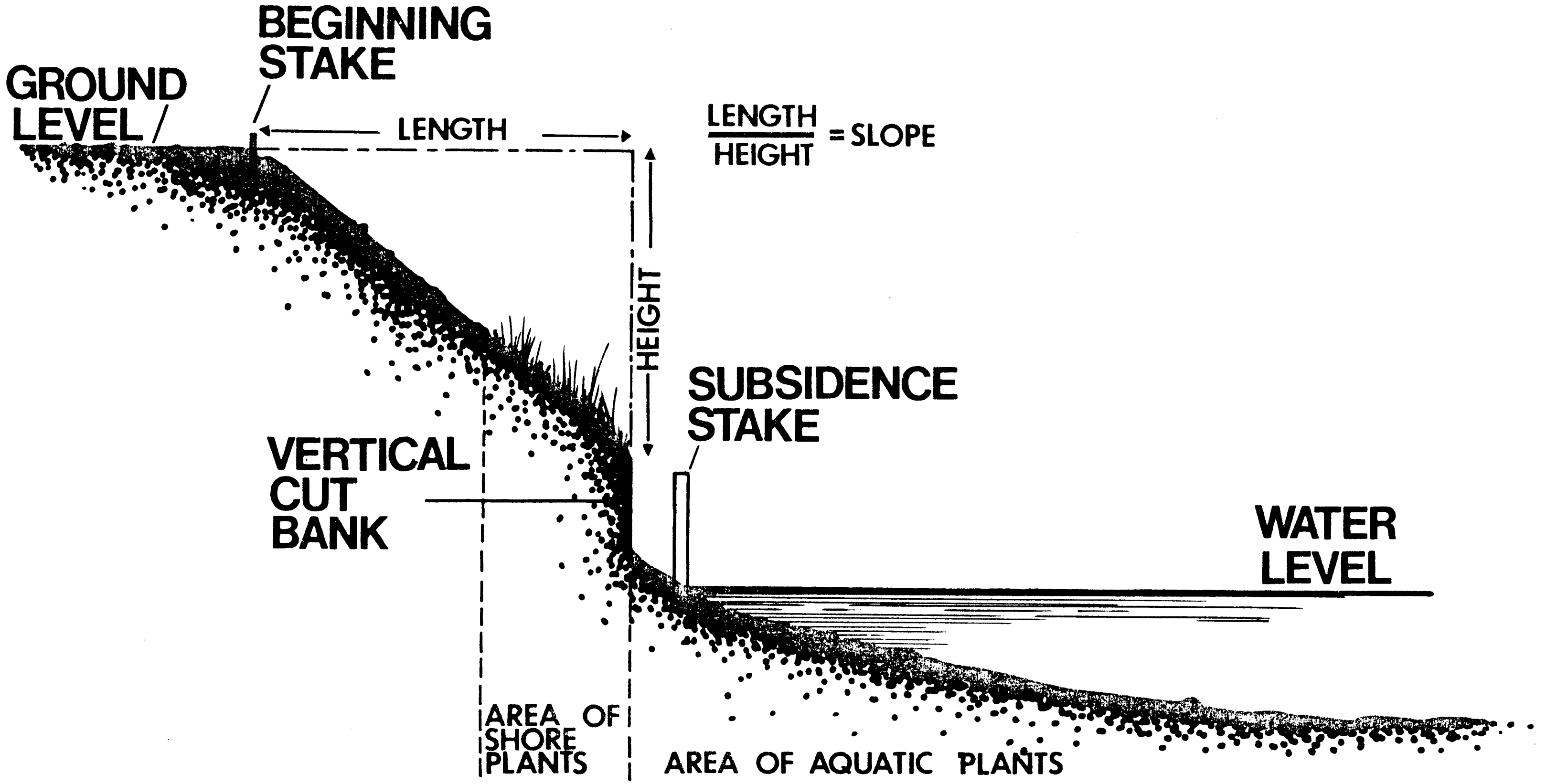

FIGURE 2. Cross-section of a Typical Bank of Lake Tarpon Outfall Canal Illustrating Areas and Methods Used for Gathering Data

The slope of the bank was calculated by measuring the distance from a stake placed at the top of the slope to the vertical-cut bank and determining the ratio of this to the height of the entire bank.

RESULTS AND DISCUSSION

Sites 1 and 3 remained virtually unvegetated during the study (Figure 2). After the initial sampling, the stakes marking Site 3 were lost, probably because of slumping that took place in this area. No further slope measurements could be taken; but, as the approximate area was still known, general observations could still be made. Severe erosion also took place at Site 1, and only a slight change in vegetation cover was seen. During the study the bank at this site was eroded shoreward 31 centimeters, causing the slope to change from 1.7:1 to 1.4:1 (horizontal:vertical) (Table 1). No shore or aquatic vegetation was located here at the initial sampling, but after one year a wax myrtle bush (_Myrica cerifera_) and some dog fennel (_Eupatorium_ sp.) were found growing on the bank. At the last sampling, the wax myrtle was no longer present, apparently lost by erosion. No aquatic vegetation established itself at this site during the study (Figure 3). The loss of the wax myrtle suggests the need for emergent aquatic vegetation to absorb the shock of wave action, enabling shore plants to colonize and stabilize the bank.

At Sites 2 and 4, aquatic vegetation was quite extensive (Figure 3). At Site 2, torpedo grass was very dense and extended a distance of 6 meters off the shore. The shore vegetation consisted mainly of wax myrtle, goldenrod (_Solidago_ sp.), and smart weed (_Polygonum_ sp.) averaging about 45% cover, and _Vigna luteola_, a vine that appeared after a year and eventually covered most of the existing vegetation. No noticeable erosion took place at this site (Table 1).

Table 1. Semiannual Variation in Slope, Erosion of Bank, and Vertical Cut Bank Height on Lake Tarpon Outfall Canal from Winter 1978 - Summer 1979.

	Site 1				Site 2				Site 3				Site 4			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Slope of Bank	1.7:1	1.6:1	1.6:1	1.4:1	2.7:1	2.9:1	2.9:1	2.9:1	1.2:1	----	----	----	1.9:1	1.9:1	2:1	2:1
Distance from Subsidence Stake to Bank	33 cm	48 cm	51 cm	64 cm	0 cm	0 cm	0 cm	0 cm	0 cm	----	----	----	43 cm	41 cm	51 cm	51 cm
Vertical Cut Bank Height	43 cm	64 cm	76 cm	81 cm	0 cm	0 cm	0 cm	0 cm	84 cm	----	----	----	53 cm	64 cm	56 cm	61 cm

Legend:

A = Winter, 1978
B = Summer, 1978
C = Winter, 1979
D = Summer, 1979

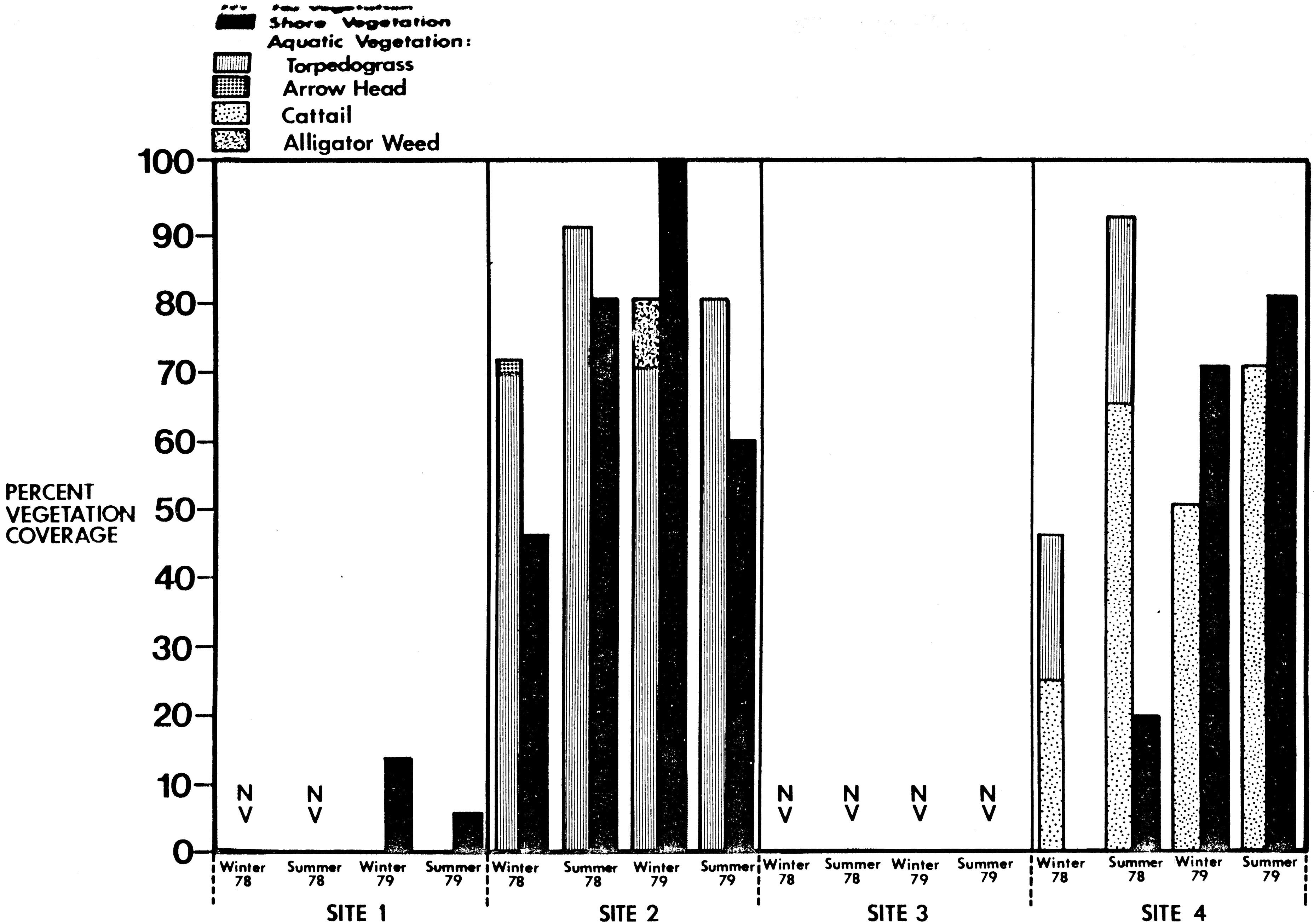

FIGURE 3. Percent Cover of Aquatic and Shore Vegetation in Lake Tarpon Outfall Canal Sites Recorded Semiannually from Winter '78 — Summer '79

Site 4 differed from Site 2 in its lack of shore vegetation and in that the aquatic vegetation consisted mainly of cattail (Typha sp.) with torpedo grass intermixed. The shore of Site 4 consisted mainly of grass with some dog fennel. Vigna luteola was first recorded in the winter of 1979 (65% cover) and spread to cover 80% of the shore by the summer. The torpedo grass gradually thinned out and disappeared as the cattail stand became more dense (20 to 80%) (Figure 3). Some erosion did occur at this site, moving the bank shoreward about 8 or 10 cm (Table 1). The fact that erosion did take place at this site and that none took place at Site 2, where there is extensive torpedo grass growth, suggests that torpedo grass may be more useful in protecting the shore from erosion.

At Site 4, it was apparent that extensive erosion took place at one time due to the high vertical-cut bank of 53 cm found during the initial sampling (Table 1). It appears that this erosion took place before the cattails had established themselves, again indicating the importance of some type of emergent vegetation to protect the shoreline from wave action.

In general, extensive erosion occurred all along the east bank in the areas that had been dredged. Areas which had not been dredged were much less susceptible to erosion, primarily because of the bank stabilizing properties of shoreline and emergent vegetation.

It should be mentioned that high-speed boat traffic contributes to the bank erosion in the Tarpon Outfall Canal. Signs prohibiting skiing were placed on the shore near the Highway 584 bridge, but as of yet have not been very effective.

CONCLUSIONS

(1) Dredging of the banks above the water line has increased the

erosion problem along the canal.

(2) Emergent aquatic vegetation appeared to be the most important factor leading to stabilization of the bank, and torpedo grass was shown to be the most effective of the naturally occurring plants found along the canal.

(3) Boat traffic is a factor contributing to bank erosion.

(4) The time required for colonization of aquatic vegetation appears to be considerable as only a few patches of vegetation were observed in the dredged areas two years after dredging had ceased.

(5) Once torpedo grass has established itself, vegetative spreading seems to take place quickly.

RECOMMENDATIONS

(1) Dredging should not be continued along the canal. If dredging is needed, it should be done only if ermergent vegetation is present to protect the bank or if planting is undertaken in conjunction with the dredging. Dredging to maintain the flood capability of the canal should not present any problems to the establishment of desirable littoral zone vegetation as long as proper care is taken during maintenance activities.

(2) Planting of desirable aquatic vegetation should be done in badly slumped areas to promote bank stabilization.

(3) Additional signs should be placed along the canal in an attempt to deter skiing.

SUCCESSION MONITORING IN WETLAND ENVIRONMENTS WITH REMOTE SENSING

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ABSTRACT

The structural (vertical stratification and horizontal distribution) changes occurring in wetland ecosystems during periods of ecosystem alteration are measured and monitored with satellite and aircraft remotely sensed data. Adequate documentation of the ecological succession, whether naturally or anthropogenically induced is obtained from multitemporal images of the altered area. In addition to monitoring the ongoing degradation of impacted wetland ecosystems, remote sensing is a useful tool for determining areas potentially susceptible to environmental impact by noting, over time, the stressed conditions in the vegetation, or changes in the abiotic environment denoting a significant alteration of local habitats. Two wetland areas undergoing ecosystem alteration are examined in this study. The first is a small interlevee depression lake in a freshwater marsh ecosystem. Its gradual rate of disappearance as well as the causes of the environmental impact responsible for the initiation of the successional processes are documented with remote sensing data. The second area is a predominately bottomland hardwood forest undergoing a successional change into a sparsely populated cypress/tupelo swamp. Remotely sensed data is used to measure the stressed conditions of the vegetation and to map the changes in distribution of the major plant associations.

INTRODUCTION

Many studies concerned with successional processes in wetland environments have made use of aerial photography to document the changes occurring in the study area. Obtaining a photographic record of an area during the process of succession provides a helpful visual aid in qualitatively assessing the changes occurring there. A wealth of quantitative information on vegetation types and densities, plant stress and growth patterns, plant species migration, and changes in the physical environment is available from aerial photography and satellite scanner data. Succession monitoring with remotely sensed data is accomplished by using multitemporal data sets, a variety of forestry photogrammetric and interpretation techniques, and field verification (Blanchard 1976).

The decline or destruction of a natural wetland ecosystem is usually the result of an alteration of the normal water regime; however, some notable exceptions, including chemical defoliation, logging, and insect damage do alter wetland environments as well. The list of possible water regime altering factors is nearly endless, but all known factors occur in one of two general catagories: first, natural alterations; and second, anthropogenically induced alterations. Natural alterations include floods and droughts as the major change producing agents. Engineered structures or practices, specifically dams, channelized streams, canals and navigational snagging and dredging have the potential to significantly alter the natural water regime.

Two wetland ecosystems that have suffered destructive changes to their natural water regimes are examined for this report. Remotely sensed data is used to monitor and measure the decline stage of the original ecosystem after the initial impact and the successional stages occurring over a period of approximately forty years.

AREA DESCRIPTION

Both study areas are located in the interlevee depression between the Mississippi River and Bayou LaFourche in southeastern Louisiana (Figure 1). The high natural levees of the present and former channels

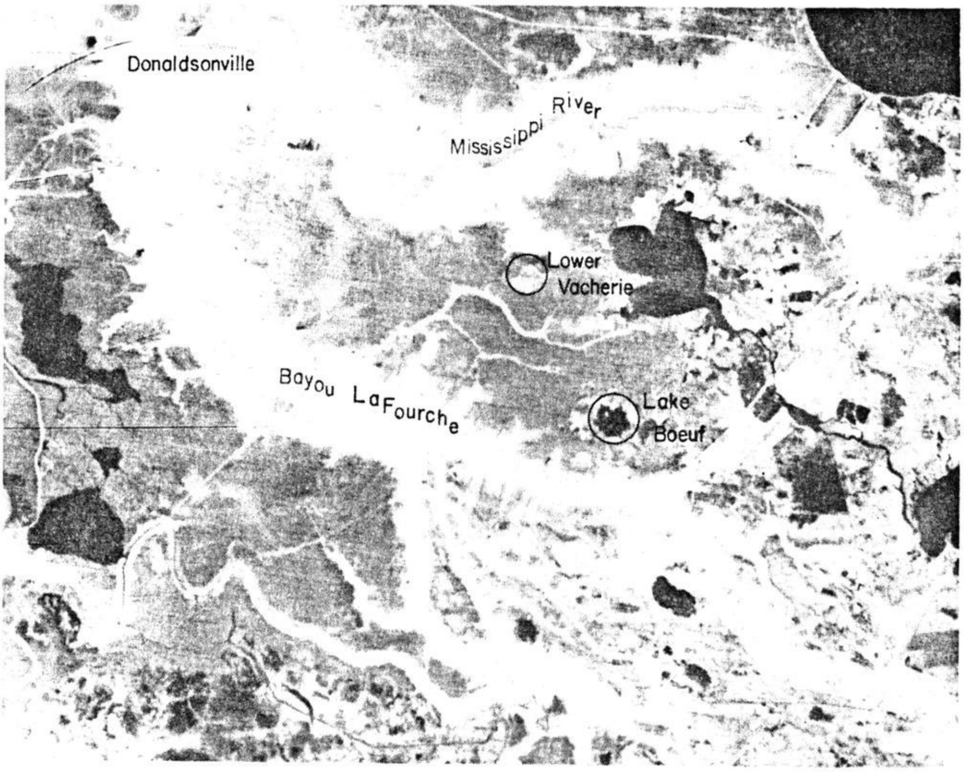

Figure 1. Study areas.

of the Mississippi River isolate the backwater area, and drainage is directly to the Gulf of Mexico by way of Barataria Bay. Although flooding from the Mississippi River is extremely infrequent, the average annual rainfall for this backwater area is over 158 cm. Topographic relief from Donaldsonville, LA at the head of the basin to

Barataria Bay is about 6 meters over a straight line distance of 65 km. Rainfall, which is expeditiously drained from the natural levee agricultural and urban land, overloads the flow capacities of the many small channels in the backswamp causing seasonal flooding in the spring and temporary floods from summer storms. Except in unusually wet years, the flood waters receed by midsummer and autumn is normally very dry allowing the bottomland hardwood forests to flourish. Cypress/tupelo swamps occur in low sloughs which are less frequently drained than the surrounding backwater area. The lower part of the interlevee depression gives way to fresh, brackish and saline marshes. The water regime in the marshes is similar to the upper reaches of the depression, however, dry periods are shorter or do not occur at all because of the hydrostatic conditions existing at these low elevations (typically less than 0.3 m above MSL).

Lake Boeuf Study Area

The first study area is a small, shallow (average depth of 1.2 m) interlevee depression lake in the freshwater marsh ecosystem. Lake Boeuf is located about 3.5 km north of Raceland, LA (Figure 2). The freshwater marsh vegetation surrounding the lake is dominated by *Panicum hemitomon*, *Phragmites communis* and *Typha latifolia*. Some trees occupy the disturbed areas and spoil banks in the vicinity of the lake. The dominant tree species is *Salix nigra*. Submerged and floating aquatics are also found in the lake and nearby channels. *Ceratophyllum demersum*, *Myriophyllum pinnatum*, *Eichhornia crassipes*, *Lemna minor* and others make up the aquatic vegetation.

In the late 1950's oil was discovered in the vicinity of Lake Boeuf. Numerous oil and gas well access canals were dredged through the soft marsh soils with little concern for the delicate ecological

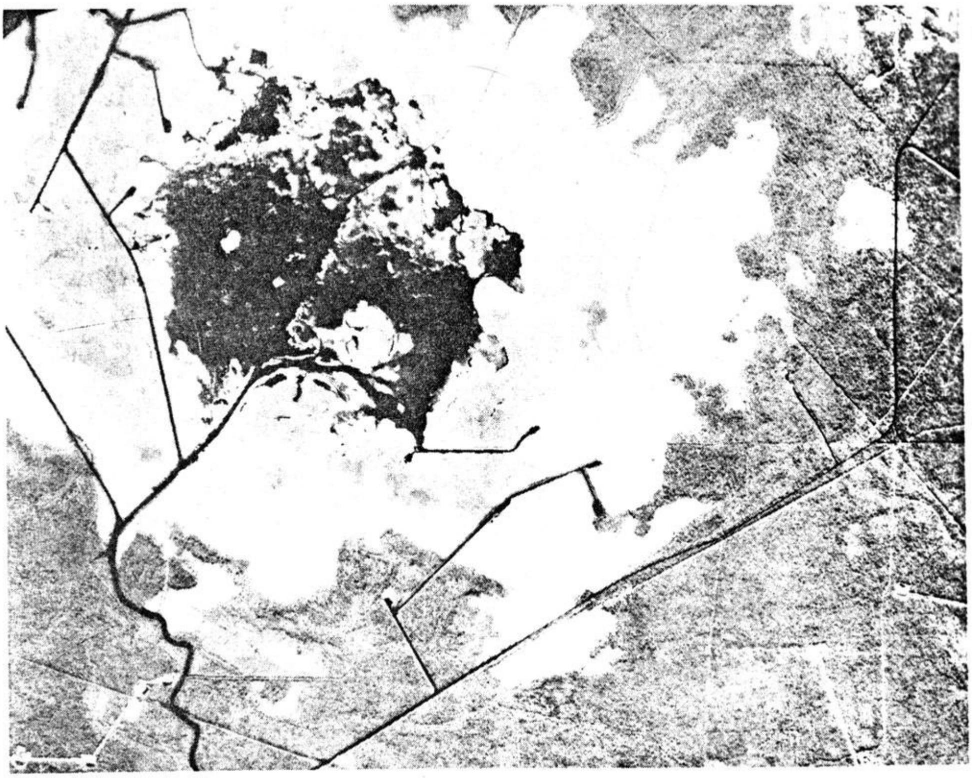

Figure 2. Lake Boeuf study area.

structure of the area. The canals unwittingly opened new and shorter routes for the water of Lake Boeuf to drain seaward. Prior to the canals, most channel flow (as opposed to sheet or overland flow during floods) was northward by Bayou Boeuf. However, during high water (but not overbank conditions) flow could reverse down Bayou Boeuf and water traveled southward into the lake. These seasonal flows kept Bayou Boeuf from developing a deposition problem, and Lake Boeuf maintained its size from the flushing action carrying much of the accumulated organic and inorganic matter out of the lake.

The alteration of the normal water regime of Lake Boeuf caused by the dredging of the access canals is changing the true lacustrine ecosystem of the lake into a freshwater marsh. The open waters of Lake Boeuf are filling in from inorganic sediments brought in by

Bayou Boeuf and organic matter accumulating from the seasonal blooms of aquatic plants. Flow velocities into the lake from Bayou Boeuf are reduced and occur over a longer span than previously sediments to be deposited in the lake. The seasonal flushing is also reduced by the existence of the canals allowing more organic matter to remain year long in the lake. The disappearance of the lake has been estimated to occur sometime in the mid twenty-first century (Whitehurst 1976); however, unusually frequent severe flooding in recent years may slow the filling process.

Lower Vacherie Study Area

The second study area is an 8.2^2 km bottomland hardwood forest located approximately 2.5 km south of Lower Vacherie, LA (Figure 3).

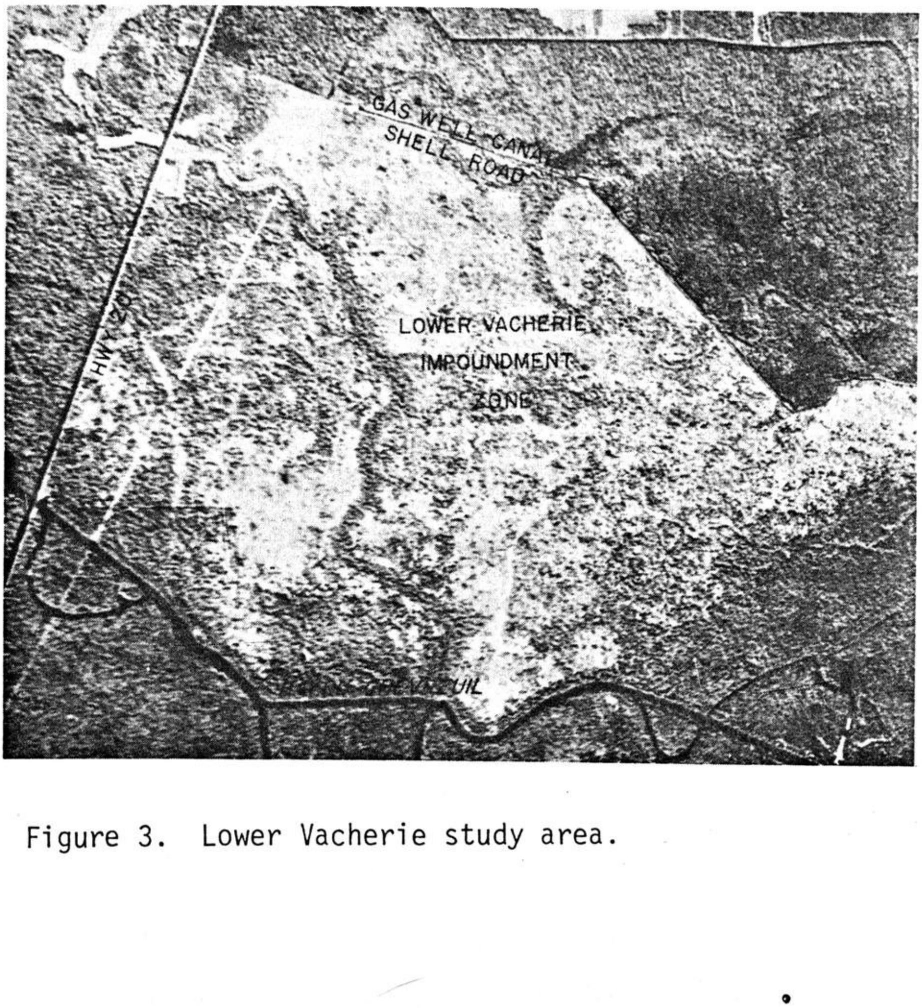

Figure 3. Lower Vacherie study area.

The dominant vegetation here is the bottomland hardwood association consisting of Quercus nigra, Q. phellos, Q. virginiana, Acer rubrum, and Carya spp. among numerous other species of trees and shade tolerant shrubs and herbs. All of these species, although not wetland species per se, benefit from the short periods of inundation during seasonal flood. Flood waters bring in nutrients from the agricultural fields on the natural levees, flush out toxins accumulated in the soils, and deposit new soil. None of the above species can survive a long period of inundation only the Taxodium distichum and Nyssa aquatica in low sloughs are adapted to perpetual or near perpetual flood conditions. Adaptation is not complete as Taxodium requires dry land for its seeds to germinate and its seedlings to become established.

The Lower Vacherie study area is topographically a basin within the larger interlevee depression basin. The study area is bounded on the north by the high natural levee of an old Mississippi River crevasse and more locally by a shell access road. To the west is the built-up roadbed of State Highway 20, Bayou Chevreuil marks the southern boundary, and an indeterminate boundary exists to the east where a slight rise in elevation prevents drainage into Lac Des Allemands.

Natural drainage prior to the dredging of Bayou Chevreuil was by three small streams flowing into Bayou Chevreuil. The seasonal flood waters overtopped the banks of Bayou Chevreuil and backed up into the three small streams, but water drained rapidly after flooding with only three to four months of the year having standing water. Dredge material from the deepening and channelization of the bayou was placed on the north bank increasing the height of the natural levee substantially. More importantly, the spoil material blocked the natural drainage channels at their confluence with the bayou.

A water surplus began to accumulate, and soon the volume of water was too great to be reduced by percolation through the soil or other means. A perpetually flooded condition existed in the study area.

The disruption of the normal cycle of flooding and drying caused by the dammed drainage produced a deleterious effect on the bottomland hardwood forest. The physical environment had changed from a bottomland forest community to a very shallow aquatic environment. Survival by all but the mature species of water tolerant plants was not possible in the newly created habitat. The niche did not remain vacant long as succession by opportunistic expansion by species better suited to the aquatic environment began very soon after the initial impact and decline of the existing vegetation.

MATERIALS AND METHODS

The remote sensing data sources used in this study are listed in Table 1. The archival aerial photography was used to establish the

Table 1. Remote sensing formats.

Date	Format	Platform Altitude	Source	Film
1940	22.9 cm x 22.9 cm	Low	USDA	B & W pan
1953	22.9 cm x 22.9 cm	Mid	USDA	B & W pan
1973	digital data	Space	NASA	
1974	22.9 cm x 22.9 cm	High	NASA	B & W IR
1976	70 mm	Low	NASA	Color IR
1977	digital data	Space	NASA	

base, or control conditions in the study areas prior to impact. Characterization of the areas prior to impact is essential for assessing the severity of ecosystem degradation and for comparison of successional stages. Contemporary aerial photography is used to measure the decline of the original ecosystem and to map the successional process. Satellite digital data are used to assess the applicability of this remote sensing data in succession monitoring. Many of the detailed photogrammetric measurements made with aerial photography are not possible with satellite data. However, the repetitive coverage, synoptic view and consistent data format of satellite data make it particularly suited to monitoring the successional processes in large areas.

The only two methods required for succession monitoring with remote sensing are comparison surveys over an appropriate period of time and the basic photo interpretation skills needed to recognize landscape changes. A more complete picture is obtained from a quantitative assessment of an ecosystem's decline and succession. Measurements for crown closure, density, spatial distribution of species or associations and plant stress from aerial photography are combined with data collected in the field to develop a scenario of changes occurring in the study areas. Digital processing of LANDSAT Multispectral Scanner (MSS) data is being tested as a potential monitoring tool. The precision of digital data processing make satellite data a good source for succession monitoring.

The length of time required for succession monitoring with remote sensing is, of course, dependent on the ecosystem being monitored and on the type of impact producing the impetus for change. Some ecosystems, especially wetlands, require many hundreds of years for a complete successional event (Olsen 1958). In the case of the two study areas addressed here, a span of nearly forty years was sufficient for considerable change to occur; but the terminal succession stage is still far in the future for both areas. If succession monitoring is considered as a linear event in time and each remote sensing data source is a point along that line, then enough points must be selected for a statistically valid approximation of the original line. If at all possible; data should be acquired prior to the initial impact or onset of succession.

In order to determine the extent of ecosystem decline at Lower Vacherie, a series of forestry photogrammetric measurements were made for the 1940, 1953, 1974, and 1976 aerial photography. Number of trees per hectare and crown closure percentages by stereoscopic estimation (Avery 1968) are compared over the years. Mapping the spatial distribution of species from 1940 to 1976 is accomplished by recognizing, where possible, the individual species by their crown shape (Avery 1960). Measurements for the areal changes are made by the dot grid method (Avery 1968). Plant stress is subjectively measured from the 1974 and 1976 infrared aerial photography. Differences in tones and textures of plants are compared for the study areas and control areas. Evaluation of stress by this method gives the experienced photo interpreter information about the stressed vegetation in comparison to healthy vegetation, but stress is difficult to quantify objectively.

RESULTS

By 1940 when the first USDA aerial photography was flown for the region, Lake Boeuf had begun to fill in from natural causes. The rate of disappearance was very slow and may have reached an equilibrium point. The impact from the oil and gas well access canals stepped up the filling in process, and by 1974 about 30% of the lake's water area and 60% of its volume had disappeared from 1940 (Whitehurst et al. 1976). The land/water interface and the areal extent of the lake water were measured from aerial photography and volume from field data. LANDSAT MSS data processed on an image processing system to measure the seasonal fluctuations in water surface area over a four year period showed that the decrease in lake size is not a seasonal trend. Although the lake does expand during high water, the net loss of water area and volume transcends seasonal irregularities.

Changes in the water regime at Lower Vacherie have had three major impacts on the natural vegetation: (1) the bottomland hardwood species have become stressed or killed by the increase in inundation period, (2) the cypress/tupelo swamp association occurring in low sloughs faces extinction as well, and (3) the high water level and open canopy have allowed the floating aquatics to extend their range from the waterways to the backswamp where they proliferate freely.

A reduction of over 50% in the crown closure in some parts of the study area has been measured from the 1940-1976 photos. The numbers of living trees per hectare have had a similar reduction. The major species occurring in the area now in terms of ground coverage is the tiny Lemna minor and other duckweeds. The area has truly become an aquatic habitat.

Only a small portion of the remote sensing tools available to ecologists, botanists and others are described here. The biological sciences are turning to remote sensing for monitoring, documentation and quantification of the biotic environment. Succession monitoring in wetland ecosystems with remote sensing is a viable technique using standard measuring and interpretation methods. More work needs to be done on more and different ecosystems to develop a methodology applicable to any contingency.

ACKNOWLEDGMENTS

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AN ASSESSMENT OF WETLANDS ESTABLISHMENT TECHNIQUES AT A FLORIDA PHOSPHATE MINE SITE

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ABSTRACT

The Florida Game and Fresh Water Fish Commission is cooperating with International Minerals and Chemical Corporation and the U.S. Fish and Wildlife Service in conducting a three year project to determine techniques for establishing wooded and herbaceous wetland habitat on a 55-acre phosphate mine site in Central Florida. Study site selection, design and final contouring, plant material selection, and the planting effort were directed toward evaluating the growth and survival of wetland and transitional plant species in response to geo-physical and hydrological conditions found after phosphate mining. Preliminary results of the first year's monitoring activities are presented for the study site, including surface and subsurface hydrology, water quality, soil chemistry, invader plants, wildlife utilization, and the survival of planted tree seedlings and freshwater marsh plants.

INTRODUCTION

Wooded and herbaceous Central Florida wetlands associated with lakes, ponds, streams and depressions include wet prairies, freshwater marshes, hardwood swamps, cypress swamps, and bayheads. These communities are important in terms of life support, productivity, and potential benefit to society. In addition to providing important fish and wildlife habitat, they serve to stabilize bottom sediments, reduce stream turbidity and siltation, and assimilate nutrients and pollutants. Wetlands also store surface water; have aesthetic, recreational, and educational value; and may provide groundwater recharge.

Central Florida phosphate miners stripmine approximately 2,478 hectares (6,000 acres) of land each year resulting in the total onsite disruption of existing soils, topography and drainage features, plant communities and wildlife populations. Due to economic considerations, past reclamation programs have resulted in extensive lake systems and well drained land managed as improved pasture. Reclamation of wetland habitats could serve to partially mitigate long-term mining impacts on fish and wildlife populations, but definitive procedures for restoring habitat values and beneficial ecological functions of mined lands are non-existent.

Therefore in July 1978, the Office of Environmental Services of the Florida Game and Fresh Water Fish Commission began a three-year study to develop and demonstrate procedures for establishing functional, self perpetuating wetland habitats and transitional areas on phosphate mined land. Our objective was to design and construct a wetland test area on mined land to: (1) evaluate the growth and survival of introduced plant materials and document natural plant invasion; (2) document wildlife utilization and evaluate the habitat quality of the emerging community; (3) describe interrelated components of the system including soil properties, surface and subsurface hydrology, water quality, and rainfall; and (4) evaluate the wetland site design in terms of future improvements, application, and recommendations. This paper is a report of progress covering the first 20 months of study from July 1978 to March 1980. A formal scientific report covering all aspects of the project will be delivered to the U.S. Fish and Wildlife Service in late December 1980, while a handbook on wetland habitat reclamation will be completed by July 1981. This study is funded by the U.S. Fish and Wildlife Service and is being performed in cooperation with International Minerals and Chemical Corporation (IMCC).

AREA DESCRIPTION

The wetland test area was constructed on a 22.3 hectare (55 acre) tract adjoining the Peace River south of Bartow, Florida (Figure 1).

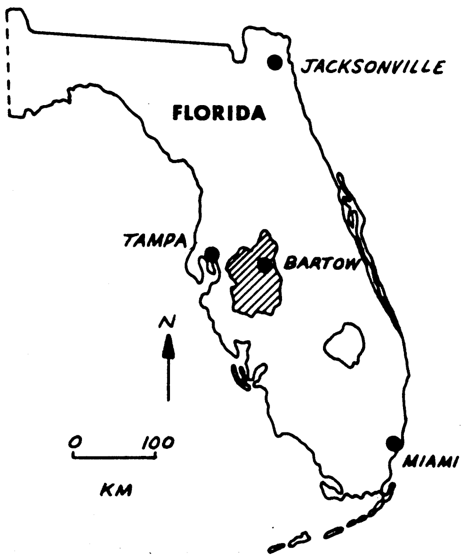

Figure 1. Central Florida land-pebble phosphate district showing study site location at Bartow, Florida.

The site was mined between October 1967 and March 1968 and selected due to its proximity to a source of native plant materials, sloping topography, and broad range of surface soil material. The Peace River floodplain borders the site on three sides. Low-lying hydric areas in the floodplain are dominated by bald cypress (*Taxodium distichum*), and pop ash (*Fraxinus caroliniana*), which grade into transition areas characterized by red maple (*Acer rubrum*), Florida elm (*Ulmus americana* var. *floridana*), cabbage palm (*Sabal palmetto*), water oak (*Quercus nigra*), sweetgum (*Liquidambar styraciflua*) and sugarberry (*Celtis laevigata*). Xeric sites are dominated by live oak (*Q. virginiana*), laurel oak (*Q. hemisphaerica*), southern magnolia (*Magnolia grandiflora*), and mockernut hickory (*Carya tomentosa*).

METHODS AND MATERIALS

The IMCC reclamation section completed test site construction during November 1978, following a design to allow testing of wetland plant establishment. Spoil piles were leveled in the summer of 1978, and the site's lowland area contoured to create distinct northern and southern basins connected by a shallow meandering channel at normal water levels. A 0.2 hectare (0.5 acre) pond excavated in the northern basin provides a continuous sanctuary for aquatic life during low water. An earthen berm/access road was constructed around the lowland area for surface water storage, and outfall pipes were installed to fix the normal high water line. An adjacent 80.9 hectare (200 acre) reclaimed pasture also serves as a drainage area for the site.

Monitoring equipment installed included rainfall gauges, surface water level staff gauges, a continuous water level recorder, and nine regularly spaced piezometers (shallow wells) which were drilled to a depth of 9.1 meters (30 feet). Four permanent water quality stations were also located. A final topographic map of the completed site was prepared (Figure 2) and the test area was divided into a permanent grid of 176, 30.5 meter (100 foot) square plots. Composite soil samples were collected and analyzed.

The test plots selected for planting represent the range of site conditions including soil differences and potential soil moisture regimes or inundation zones. The biology of individual species was also considered in making plot assignments.

A total of 10,400 tree seedlings representing 16 species were planted during January and February 1979 in 26 multispecies plots. Four to five species were planted at 1.5 meter (five-foot) centers in each plot according to a planting guide which randomly assigned each species. Approximately 2,100 seedlings were also randomly planted at appropriate elevations throughout the site. The wetland and transitional species were planted in as many plots as possible to evaluate their success over the full range of site conditions. Bare-root seedlings purchased from the Florida Division of Forestry were used since we required large numbers of each species of the same age class.

Herbaceous freshwater marsh plants were also transplanted to the site from nearby wetland habitats. A total of 12, 6.1 meter (20 foot) square marsh test plots were planted in May 1979 with the following species and numbers of clumps (1-4 individual plants): arrowhead (*Sagittaria lancifolia*) 52, pickerelweed (*Pontederia lanceolata*) 57, maidencane (*Panicum hemitomon*) 42, and softrush (*Juncus effusus*) 23. Approximately 5,000 maidencane rhizomes were also planted in January 1979.

A monitoring program (Table 1) was initiated in early June 1979 to

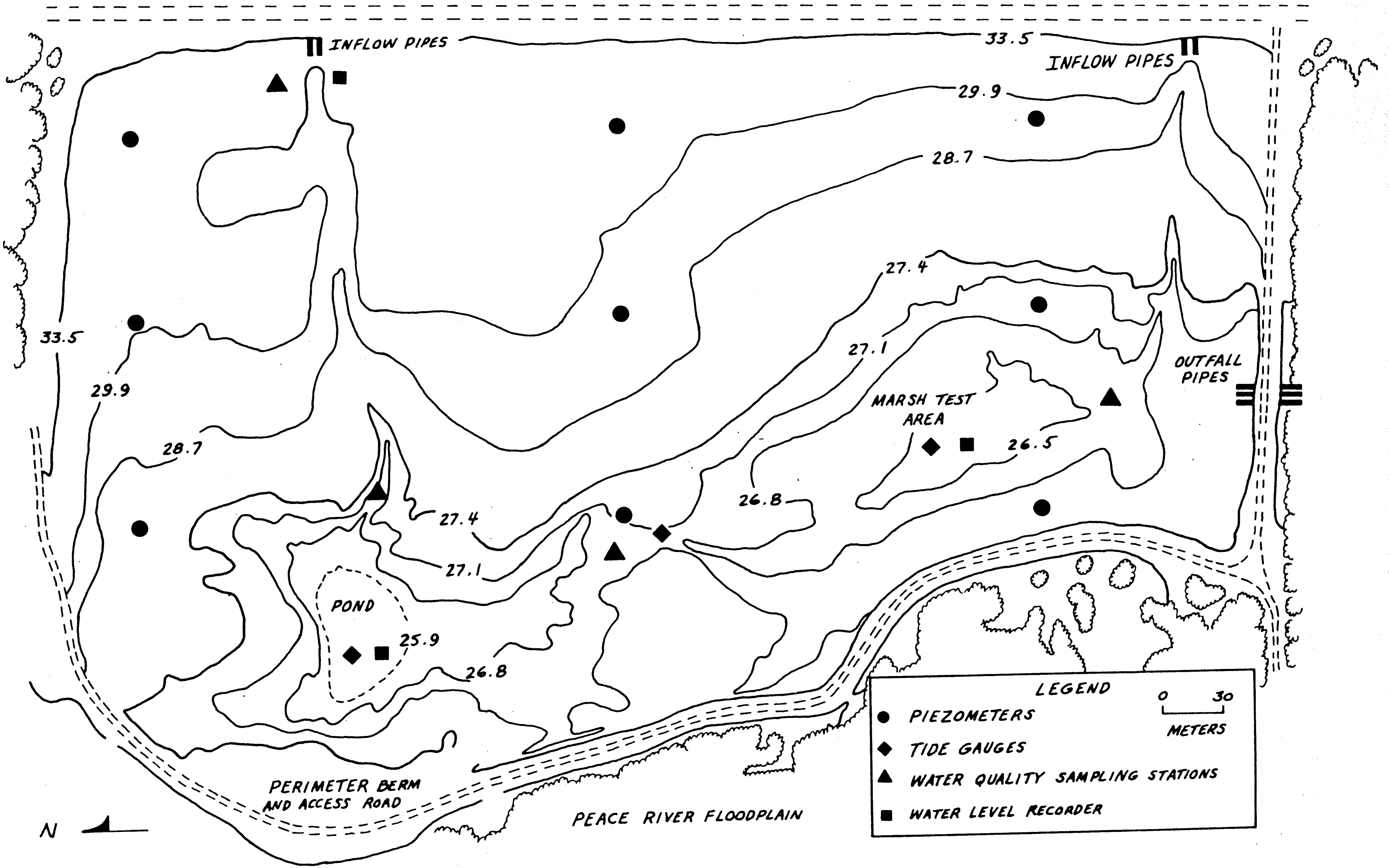

Figure 2. Wetland test site showing abbreviated topographic features and monitoring locations.

Table 1. Monitoring schedule on Peace River wetland test site.

	D	2W	W	BW	M	Q	A
WATER							
Rainfall Gauges	X						
Surface Water Levels	X						
Piezometers				X			
Water Quality			X				
VEGETATION							
Natural Plant Invasion					X		
Marsh Test Plots					X		
Tree Seedlings							X
WILDLIFE							
Bird Surveys		X					
Small Mammal Trapping						X	
Reptiles & Amphibians		X					
Fish						X	
Wildlife Use (Qualitative)	X						
Photographic Stations					X		

D=Daily
2W=Twice weekly
W=Weekly
BW=Bi-weekly
M=Monthly
Q=Quarterly
A=Annually

characterize: (1) the survival and growth of the various plantings, (2) natural plant succession trends, (3) surface and subsurface hydrology, (4) surface water quality, and (5) trends in wildlife utilization.

Information on natural plant invasion was gathered by recording percent coverage by species using replicated hoop drops, while all planted plots were surveyed to document survival of tree seedlings and marsh plants. Birds were surveyed by recording the total number of individuals and species during timed walks of the area. Small mammal species were recorded using Sherman live trap transects while information on reptiles and amphibians was gathered using two pitfall traps with sheet metal drift fences. Fish were sampled using a dip net and a 15.2 meter (50 foot) seine net; and tracks, scats, and other wildlife sign were also recorded. Monthly photographs were also taken at 16 stations on the site to document water level and vegetational changes.

RESULTS

Soils

Soils data compiled from all planted plots on the study site are given in Table 2. The analysis was performed by IMCC's Agronomic Services in Terre Haute, Indiana following a computer program designed to evaluate soil properties for shade tree culture. The pH values ranged from 5.9 to 8.4, and no lime was needed. Available phosphorus values were all above the upper limit of routine reporting. All potassium results were very low; calcium and nearly all magnesium levels were very high; while sulfur levels were adequate. Therefore high application rates of potash were recommended to enhance plant growth.

Although most samples were generally low in manganese, iron, copper, zinc, and boron, no additional applications were recommmended since most trees and shrubs are very efficient in obtaining these elements. Since the percentage of organic matter was very low in most samples, frequent applications of nitrogen were recommended to maintain steady plant growth.

Hydrology

Changes in surface and ground water levels were closely correlated with rainfall (Figure 3). A natural drawdown event which lasted approximately 50 days exposed the bottom of the southern basin and created drying conditions from late March through early May 1979.

Table 2. Soils data from planted test plots on wetland study site.

	Kilograms per Hectare									
	P	K	Ca	Mn	Mg	Fe	Cu	Zn	S	B
Mean	538.7	47.3	11198.8	17.2	870.2	51.1	1.2	16.9	68.5	.64
Minimum	508.9	24.7	11198.8	3.4	213.0	2.2	.6	2.2	37.0	.22
Maximum	560.5	67.3	11198.8	32.5	2226.1	16.6	1.7	43.7	140.0	1.35

	Percent Organic Matter	Cation Exchange Capacity	Cation Saturation Percent			pH	-----Percent-------		
			K	Ca	Mg		Sand	Silt	Clay
Mean	.4	29.8	.17	84.0	10.5	7.1	85.7	3.7	10.7
Minimum	.1	27.2	.1	75.0	2.8	5.9	78.0	2.0	4.0
Maximum	.9	33.3	.2	91.8	24.9	8.4	94.0	9.0	20.0

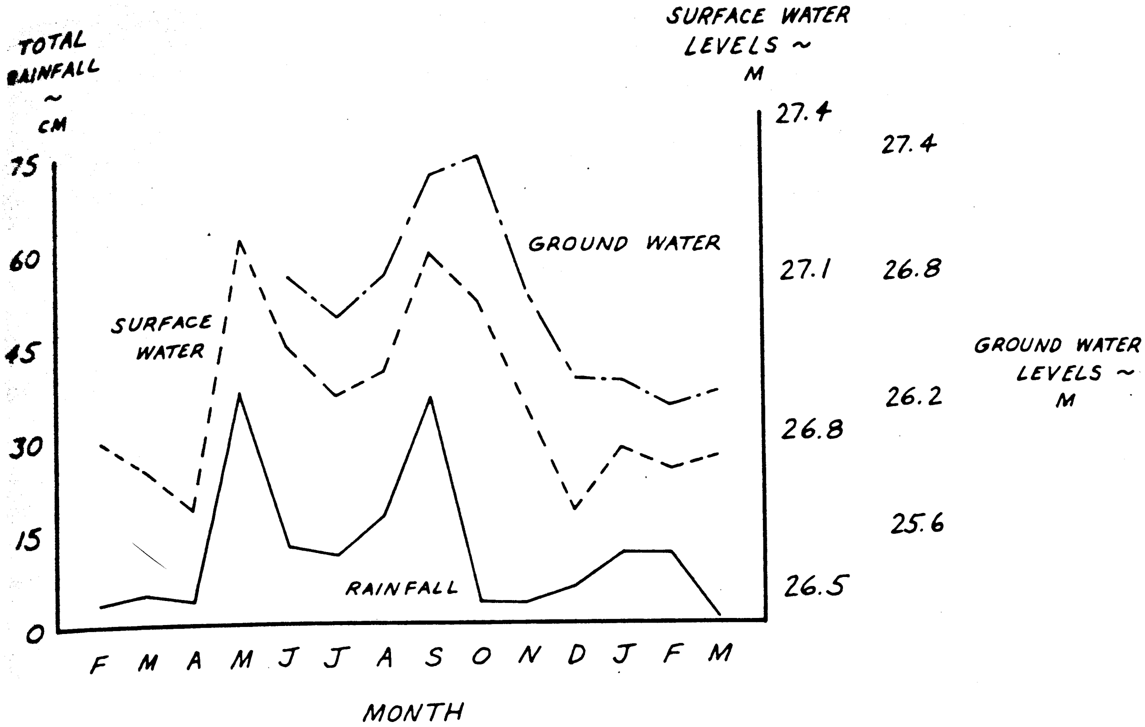

Figure 3. Relationship between total rainfall and average surface and ground water level changes on wetland test site from February 1979 to March 1980.

During 366 days of observation these elevations in meters (feet) above mean sea level were inundated the following percentage of the study period: 27.6 (90.5) 0.3%, 27.3 (89.5) 2%, 27.0 (88.5) 29%, 26.7 (87.5) 85%, and 26.4 (86.5) 94%. Extremely high water levels caused by abnormal rainfall events associated with a low pressure area storm and Hurricane David were recorded during the months of May and September 1979,respectively.

Water Quality

The overall water quality data (Table 3) from the wetland test site indicate an alkaline situation as the average pH value ranged from 7.1 to 10.6 with a mean of 8.9. Alkaline conditions are probably due to an abundance of rocks and sediment containing calcium carbonate which has been deposited on the surface as a result of mining.

Table 3. Water quality data taken at the wetland test site from June 1979 through March 1980.

	Fluoride mg/l	Phosphorus mg/l	Kjeldahl Nitrogen mg/l	Nitrate Nitrogen mg/l
Mean	1.5	3.8	1.6	.14
Minimum	.5	.4	.3	.1
Maximum	2.7	21.3	7.7	.8

	pH	Turbidity	Suspended Solids mg/l	Total Akalinity ppm CaCo3
Mean	8.9	38.6	30.6	38.9
Minimum	7.1	2.6	2.0	12.1
Maximum	10.6	330.0	159.0	71.5

Vegetation

The preliminary survival data of planted tree seedlings is given in Table 4. Figure 4 gives the predicted survival model versus elevation for bald cypress, based on our data. Several species including bald cypress, red maple, and sweetgum, show promise as candidate plants for reclamation use, especially when plot specific survival is considered. At the conclusion of the study, recommendations will be made to maximize growth and survival of individual species based on potential inundation zones and other related factors.

Our preliminary data shows close to 100 percent survival of the transplants in our marsh test plots coupled with vigorous growth, flowering, fruiting, and dissemination and recruitment of new individuals. We

Table 4. Survival of planted tree seedlings on wetland test site.

Species	Overall Survival	Plot specific Survival Minimum	Plot specific Survival Maximum
Bald cypress (*Taxodium distichum*)	84.5	56.1	97.5
Red maple (*Acer rubrum*)	61.5	20.0	90.1
Green ash (*Fraxinus pennsylvanica*)	85.4	57.5	99.0
Sweetgum (*Liquidambar styraciflua*)	72.3	27.6	90.0
Tupelo gum (*Nyssa aquatica*)	29.5	5.6	65.2
Catalpa (*Catalpa bignonioides*)	79.1	58.4	91.0
Cottonwood (*Populus deltoides*)	19.8	0.0	50.0
Sycamore (*Platanus occidentalis*)	68.0	51.0	80.2
Live oak (*Quercus virginiana*)	28.0	19.0	41.4
Longleaf pine (*Pinus palustris*)	6.5	1.0	14.9
Loblolly pine (*Pinus taeda*)	43.9	26.0	61.4
North Florida slash pine (*Pinus elliottii* var. *elliottii*)	58.4	45.9	73.0
South Florida slash pine (*Pinus elliottii* var. *densa*)	29.2	25.3	33.3
Sand Pine (*Pinus clausa*)	54.0	45.0	60.6
Spruce pine (*Pinus glabra*)	70.3	37.8	90.9

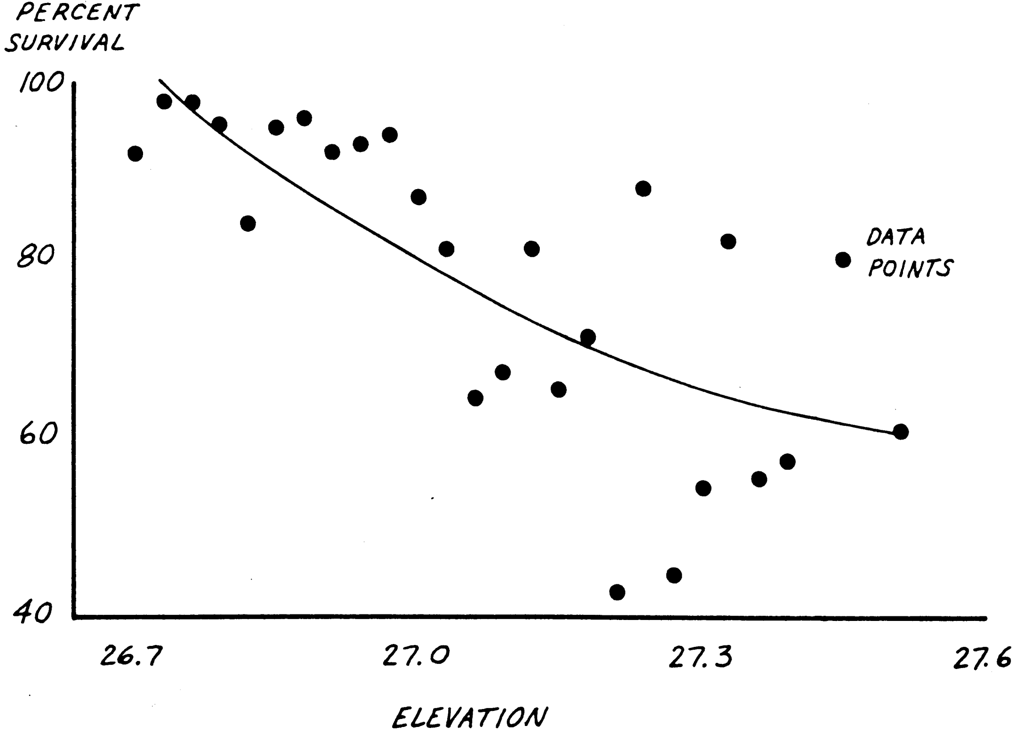

Figure 4. Bald cypress seedling survival relative to elevations on the study site.

recorded approximately 470 new arrowhead and pickerelweed plants scattered in the previously inundated transition zone around the southern basin at the end of the first growing season. We suspect these new plants were disseminated from our marsh test plots since: (1) the new plants were the same species planted in the marsh study plots, (2) all new plants were found in the southern basin where the marsh plots are located, and (3) the marsh test plots contained some of the highest concentrations of new plants.

Plant invasion of the wetland area was rapid during the first growing season (Figure 5). Table 5 lists some of the typical species recorded on the test site.

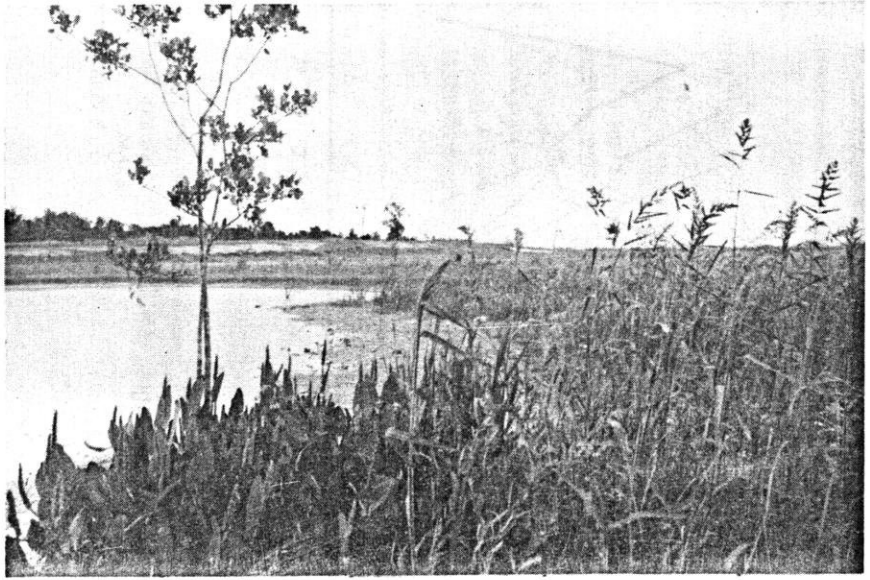

Figure 5. Wetland study site showing Density of Vegetation in May, 1980.

Table 5 Typical invader plants recorded from wetland and transitional areas on the test site.

Acer rubrum	Red maple
Alternanthera philoxerioides	Alligator weed
Cephalanthus occidentalis	Buttonbush
Cyperus retrorsus	Sedge
Cyperus iria	Sedge
Cyperus globulosus	Sedge
Cyperus haspan	Sedge
Cyperus surinamensis	Sedge
Cyperus distinctus	Sedge
Eichhornia crassipes	Water hyacinth
Fimbristylis autumnalis	
Hydrocotyl umbellata	Water pennywort
Juncus effusus	Soft rush
Lemna sp.	Duckweed
Ludwigia palustris	
Ludwigia decurrens	
Ludwigia octovalis	
Ludwigia repens	
Lindernia anagallidea	False pimpernel
Najas guadalupensis	Naiad
Paspalum urvillei	Vasey grass
Paspalum repens	Torpedo grass
Panicum dichotomiflorum	
Pistia stratiotes	Water lettuce
Polygonum punctatum	Water smartweed
Sacciolepis striata	
Salix caroliniana	Carolina willow
Scirpus validus	Bulrush
Thalia geniculata	Fireflag
Typha lattifolia	Cattail

Wildlife

Wildlife use of the study site during the first year was excellent (Table 6) in terms of both the kinds of species and numbers of individuals represented. The following species and numbers of individuals observed during single surveys include: wood stork (32), hooded merganser (44), blue-winged teal (35), wood duck (2), Florida duck (4), dowitcher (22), common snipe (19), least sandpiper (20), glossy ibis (15) white ibis (15), American avocet (5), river otter (1), and bald eagle (2).

We found a significant correlation between surface water level changes and wildlife use on the test site. Receding surface water levels result in an increase in the average number of animals observed, mean numbers of species, and diversity index (Figure 6).

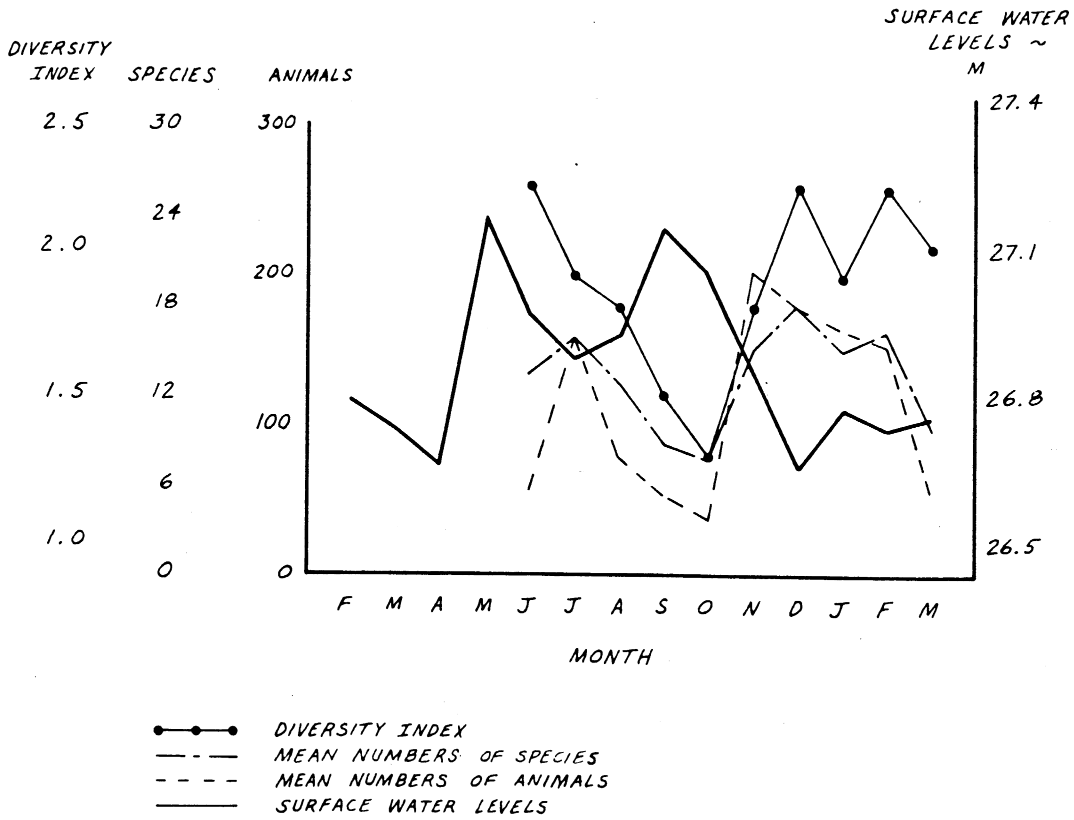

Figure 6. Relationship between surface water level changes, average numbers of animals and species observed, and diversity index.

Table 6. Wildlife species recorded on wetland test site from February 1979 through April 1980

FISHES

Threadfin shad
(Dorosoma petenense)

Golden shiner
(Notemigonus crysoleucas)

Mosquito fish
(Gambusia affinis)

Least killifish
(Heterandria formosa)

Golden topminnow
(Fundulus chrysotus)

Warmouth
(Chaenobryttus gulosus)

Bluegill
(Lepomis macrochirus)

Red-eared sunfish
(Lepomis microlophus)

REPTILES-AMPHIBIANS

American alligator
(Alligator mississipiensis)

Mud turtle
(Kinosternon subrubrum)

Florida softshell
(Trionyx ferox)

Banded water snake
(Natrix fasciata)

Garter snake
(Thamnophis sirtalis)

Black racer
(Coluber constrictor)

Eastern indigo snake
(Drymarchon corais couperi)

Rat snake
(Elaphe obsoleta)

Cottonmouth
(Agkistrodon piscivorus)

Eastern diamondback rattlesnake
(Crotalus adamanteus)

Southern Toad
(Bufo terrestris)

Oak Toad
(Bufo quercicus)

Southern cricket frog
(Acris gryllus)

Pig frog
(Rana grylio)

Southern leopard frog
(Rana pipiens)

BIRDS

Pied-billed grebe
(Podilymbus podiceps)

White pelican
(Pelecanus erythrorhynchos)

Double-crested cormorant
(Phalacrocorax auritus)

Anhinga
(Anhinga anhinga)

Florida duck
(Anas fulvigula)

Blue winged teal
(Anas discors)

Wood duck
(Aix sponsa)

Hooded merganser
(Lophodytes cucullatus)

Turkey vulture
(Cathartes aura)

Black vulture
(Coragyps atratus)

Marsh hawk
(Circus cyaneus)

Red-tailed hawk
(Buto jamaicensis)

Red-shouldered hawk
(Buteo lineatus)

Bald eagle
(Haliaeetus leucocephalus)

Osprey
(Pandion haliaetus)

American kestrel
(Falco sparverius)

Bobwhite
(Colinus virginianus)

American egret
(Casmerodius albus)

Snowy egret
(Leucophoyx thula)

Cattle egret
(Bubulcus ibis)

Great blue heron
(Ardea herodias)

Louisiana heron
(Hydranassa tricolor)

Little blue heron
(Florida caerulea)

Green heron
(Butorides virescens)

Black-crowned night heron
(Nycticorax nycticorax)

Wood stork
(Mycteria Americana)

Glossy ibis
(Plegadis falcinellus)

White ibis
(Eudocimus albus)

Roseate spoonbill
(Ajaia ajaja)

Limpkin
(Aramus guarauna)

Table 6 Continued

American coot
(Fulica americana)

American avocet
(Recurvirostra americana)

Black-necked stilt
(Himantopus mexicanus)

Killdeer
(Charadrius vociferus)

Greater yellowlegs
(Totanus melanoleucus)

Lesser yellowlegs
(Totanus flavipes)

Short-billed dowitcher
(Limnodromus griseus)

Long-billed dowitcher
(Limnodromus scolopaceus)

Least sandpiper
(Erolia minutilla)

Common snipe
(Capella gallinago)

Ring-billed gull
(Larus delawarensis)

Forester's tern
(Sterna forsteri)

Mourning dove
(Zenaidura macroura)

Ground dove
(Columbigallina passerina)

Smooth-billed ani
(Crotophaga ani)

Ruby-throated hummingbird
(Archilochus colubris)

Belted kingfisher
(Megaceryle alcyon)

Scissor-tailed flycatcher
(Muscivora forfic)

Eastern phoebe
(Sayornis phoebe)

Barn swallow
(Hirundo rustica)

Rough-winged swallow
(Stelgidopteryx ruficollis)

Blue jay
(Cyanocitta cristata)

Fish crow
(Corvus ossifragus)

Mockingbird
(Mimus polyglottos)

Robin
(Turdus migratorius)

Blue-gray gnatcatcher
(Polioptila caerulea)

Water pipit
(Anthus spinoletta)

Loggerhead shrike
(Lanius ludovicianus)

Myrtle warbler
(Dendroica coronata)

Palm warbler
(Dendroica palmarum)

Yellowthroat
(Geothlypis trichas)

Bobolink
(Dolichonyx oryzivorus)

Red-winged blackbird
(Agelaius phoeniceus)

Boat-tailed grackle
(Cassidix mexicanus)

Common grackle
(Quiscalus quiscula)

Brown-headed cowbird
(Molothrus ater)

Cardinal
(Richmondena cardinalis)

American goldfinch
(Spinus tristis)

Savannah sparrow
(Passerculus sandwichensis)

Vesper sparrow
(Pooecetes gramineus)

Field sparrow
(Spizella pusilla)

Swamp sparrow
(Melospiza georgiana)

Song sparrow
(Melospiza melodia)

MAMMALS

Opossum
(Didelphis marsupialis)

Shorttail shrew
(Blarina brevicauda)

Raccoon
(Procyon loter)

River otter
(Lutra canadensis)

Stripped skunk
(Mephitis mephitis)

Red fox
(Vulpes fulva)

Bobcat
(Lynx rufus)

Rice rat
(Oryzomys palustris)

Hispid cotton rat
(Sigmodon hispidus)

House mouse
(Mus musculus)

Eastern cottontail
(Sylvilagus floridanus)

Armadillo
(Dasypus novemcinctus)

DISCUSSION AND CONCLUSIONS

The phosphate overburden spoils we studied are of sufficient quality to support the establishment of both woody and herbaceous wetland and transitional plant species. Natural plant invasion on our site was rapid and survival of the test plantings was good.

Our sampling program shows that the test site aquatic system developed rapidly producing an abundance of forage organisms including fishes, amphibians, aquatic insects and invertebrates. Wildlife use of the study site was excellent, both in terms of the types of species and numbers of individuals represented.

Our study demonstrates that with proper design and construction, reclaimed phosphate land can provide important habitat for wildlife species which utilize wetlands and transitional areas. The continued protection of important regional wetlands and other habitats coupled with a reclamation policy for wetland habitat restoration, could eventually serve to partially mitigate long term mining impacts on fish and wildlife resources and restore natural systems functioning. A clearer understanding of the ecology of phosphate mined lands, coupled with improvements in disposal methods for mining related waste products will aid in the overall reclamation process.

A COST/BENEFIT ANALYSIS OF TWO LARGE COASTAL PLANTINGS IN TAMPA BAY, FLORIDA.

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ABSTRACT

Between late 1978 and mid-1979, two major coastal vegetation plantings were completed on dredge material in Hillsborough Bay, Hillsborough County, Florida. On the dredge material extension of Sunken Island (West Alafia Banks), 1.64 ha of smooth cordgrass (Spartina alterniflora) was planted via 12 cm plugs on 1 m centers, rows 2 m apart. After 14 months, this planting exhibited 93.4% survival. On dredge material island CDA-D, 0.52 ha of Avicennia germinans (63%) and Laguncularia racemosa (37%) was planted via 0.3 - 1.9 m transplants on 2 m centers. After 13 months, this planting exhibited 73.3% survival.

The nature of these two plantings permitted a comparison of their cost and man power requirements. The labor requirements for smooth cordgrass were 995 man-hours/ha as opposed to 2541 man-hours/ha for mangrove transplanting. Smooth cordgrass required $4566/ha for plugs ($1.03/plug) while mangrove transplants cost $11,459/ha ($3.92/transplant). These costs are for comparison only, as they entail primarily labor and neglect most indirect costs experienced. The economic and ecological advantages and disadvantages of labor intensive planting of smooth cordgrass plugs and mangrove transplants are discussed.

INTRODUCTION

The importance of estuarine vegetation such as marsh grasses and mangroves has been well documented (see Woodhouse et al. 1974 for review). Also important is a cost effective means of stabilizing dredge material, preferably using this estuarine vegetation. This is especially true in an active port area such as Tampa Bay where dredging and deposit of this material is an ongoing process. Tampa Bay offers a unique geographic location where both *Spartina alterniflora* marshes and mangrove swamps are found in sufficient quantities to serve as source areas for plantings.

An analysis of labor intensive planting techniques was permitted when the Young Adult Conservation Corps (YACC) awarded a contract providing labor for coastal vegetation work. The first site chosen was the dredge material extension of Sunken Island (SI, West Alafia Banks), leased and managed by the National Audubon Society. Smooth cordgrass (*Spartina alterniflora*) was the plant chosen for this site for three reasons: 1) to stabilize the low wave energy substrate; 2) to increase bay productivity, increasing food and foraging area for shorebirds; and 3) to create nesting habitat for clapper rails (*Rallus longirostris*) and willets (*Catoptrophorus semipalmatus*). The second site chosen was dredge material island CDA-D, owned by the Tampa Port Authority. Mangroves were transplanted onto CDA-D as partial fulfillment of mitigation requirements in connection with the Port of Tampa's 22nd St. shrimp facility (Fehring et al. 1979). Mangroves were available from the site of construction along the 22nd St. Causeway.

The three major goals of this study are to: 1) develop successful labor intensive smooth cordgrass and mangrove transplanting techniques, 2) analyze the cost effectiveness of these techniques, and 3) analyze the benefits of these plants and the required methods. The development of successful techniques is accomplished through trial of various methods. An analysis of costs is possible by recording time and material expenditure through the duration of the work. Benefits are analyzed through monitoring the plantings and their impact to the immediate environment.

SITE DESCRIPTIONS

Sunken Island (Figure 1; 27°51' N, 82°25'W) is located at the mouth of the Alafia River in Hillsborough Bay, Florida. A dredge material extension was pumped up in November 1977. The eastern shoreline of the extension was chosen for planting due to the low wave energy, favorable intertidal elevation and inundation schedule. The substrate is composed of sand and silt.

Dredge material island CDA-D (Figure 1; 27°53"N, 82°25"W) is located south of Pendola Point in Hillsborough Bay, Florida. CDA-D was created with dredge material in spring-summer 1978. An open intertidal area on the west side was chosen because of low wave energy and proper elevation. The substrate is primarily sand and crushed shell.

MATERIALS AND METHODS

Planting Methods

Sunken Island (SI) was planted with 12 cm plugs of smooth cordgrass. The plugs were removed at approximately 1 plug/m^2 via post-hole digger from existing marshes along the southern bank of the Alafia River and on Whiskey Stump Key. The plugs with substrate and rhizome intact were transported by boat to SI. Plugs were planted on 1 m centers in rows 2 m apart (Figure 2) after clipping the blades to approximately 10 cm above the substrate. The clipping was done to reduce transpiration and , therefore, possible shock due to root damage. The smooth cordgrass was planted between 0.23 and 0.88 m mean low water (mlw).

Planting was done on SI from 16 Oct 78 to 13 Mar 79. A total of

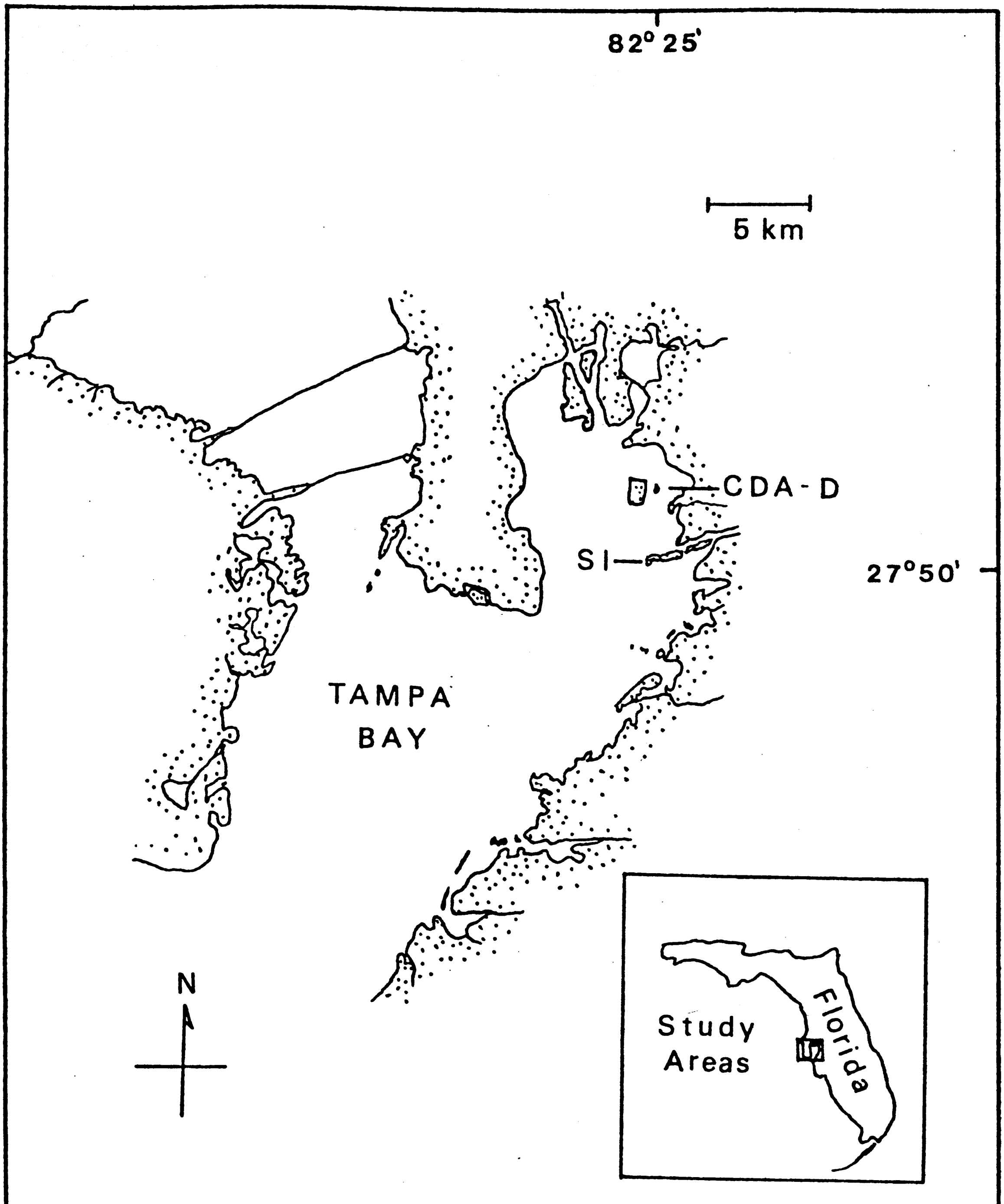

Figure 1. Map of study areas, Sunken Island (SI) and CDA-D.

7261 plugs were placed in a 1.64 ha area.

CDA-D was planted with 0.3-1.9 m transplants of black mangrove (Avicennia germinans) and white mangrove (Laguncularia racemosa). The mangroves were removed by shovel and the root ball wrapped in burlap. Transplants were taken at random from the west end of the southern shores of the 22nd St. Causeway and transported via boat to CDA-D. Planting was done on 2 m centers. Terminal meristems (6 cm) were clipped from 30% of the plants, chosen at random. The planting ranged from 0.58 m to 0.88 m mlw.

Planting was done on CDA-D from 16 Jan 79 to 29 Jun 79. A total of 1513 mangroves (63% blacks and 37% whites) were placed in a 0.52 ha area.

Cost Analysis

Four aspects were defined for the cost analysis. 1. Labor charges were calculated by multiplying the man hours on each project by the minimum wage at time of writing ($3.10/hr). This was done to insure consistency in calculations. No cost for supervision was included. 2. Boat cost was calculated based on a daily rental charge of $50. The daily value chosen was based on market availability when the projects were initiated and included gas and maintenance costs. 3. Vehicle costs included lease, gas and maintenance costs for transporting the workers to the project site. 4. Materials included tools needed for the project (i.e. shovels, post-hole diggers, burlap and wood flats).

RESULTS

Plantings

After 14 months the SI smooth cordgrass exhibited 93.4% survival (Fig. 3). Losses appeared to be concentrated at the upper (and secondarily the lower) extreme of the planting. The 12 cm plugs have now spread to

Figure 2. Photograph showing placement of smooth cordgrass plugs on 1 m centers with rows 2 m apart.

Figure 3. Photograph showing same area as in Fig. 2, 14 months later.

almost obscure the original rows. Seed production and seedling development was observed the first growing season.

After 13 months the CDA-D mangroves exhibited 73.3% survival (Fig. 4). Losses were primarily in the lower areas. No difference was found between black and white mangrove survival or between cropped and non-cropped plants. In many cases, severe winter weather and shock produced leaf drop the first year. However, most of these mangroves have recovered. A small number (ca. 10) of mangroves produced flowers last season and are producing seeds this year.

Cost Analysis

Table 1 shows the four major cost areas and values for SI and CDA-D. Sunken Island required more labor, boat time, vehicle time, and materials than CDA-D. However, on a per unit basis the smooth cordgrass was more cost effective to establish than mangroves (SI = $4,565/ha, $1.03/plug; CDA-D = $11,459/ha, $3.92/transplant). Perhaps a more useful figure is the man power expenditure for both sites: SI = 995 man-hours/ha; CDA-D = 2541 man-hours/ha. Once more, the smooth cordgrass is more effective to establish.

Table 1. Four major cost areas for Sunken Island and CDA-D.

COST	SUNKEN ISLAND	CDA-D
Labor	$5059.20	$4017.60
Boat	$1700.00	$1350.00
Vehicle	$612.00	$489.10
Materials	$117.00	$79.00
Totals	$7488.20	$5935.70

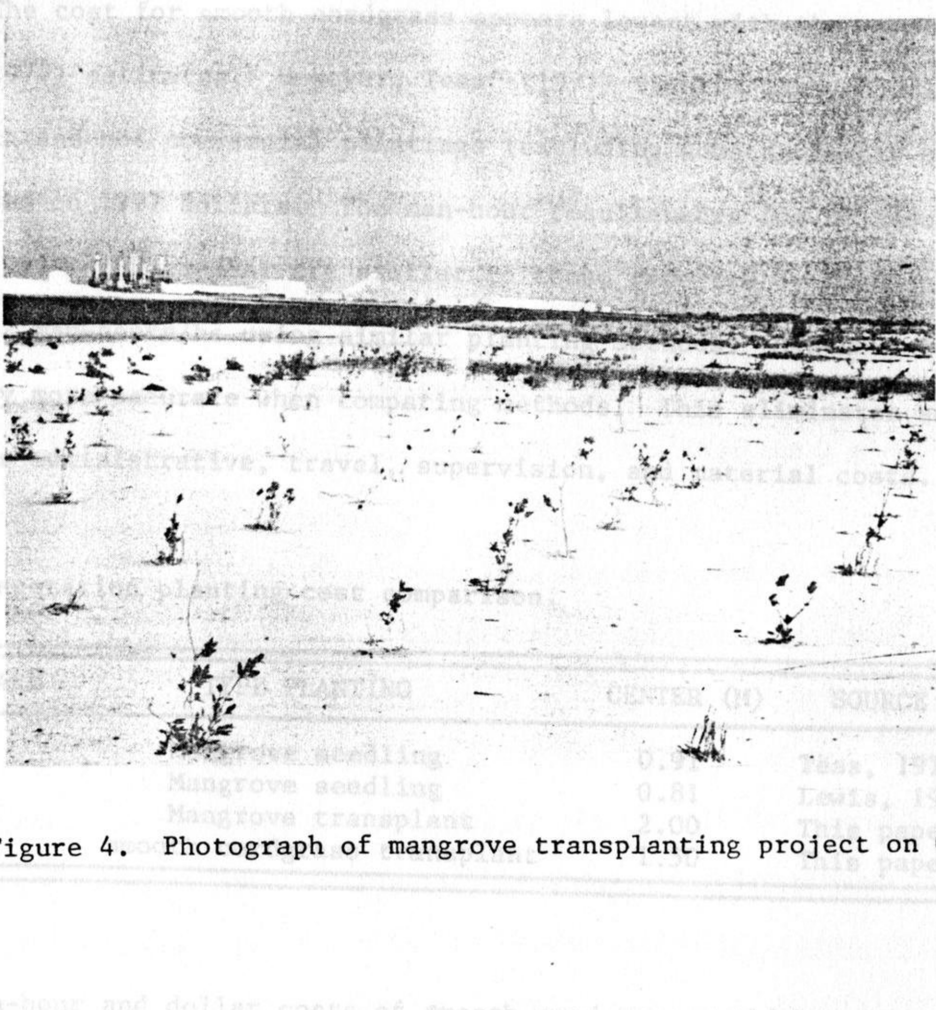

Figure 4. Photograph of mangrove transplanting project on CDA-D.

DISCUSSION

The planting of smooth cordgrass plugs appears more cost effective than mangrove transplants both on a unit area and unit plant basis. Table 2 compares the findings of this study with other published work. It must be reiterated that the costs included in this study are not complete. No supervision, administrative, follow-up costs or profits are taken into account. The cost for smooth cordgrass appears lowest with the exception of Teas' (1977) estimates. However, Teas' (1977) figures were calculated for research and not commercial plantings (excluding some necessary costs) and are based on 1977 dollars. The man-hour requirements for SI smooth cordgrass (995 man-hours/ha) are similar to those reported by Knutson (1977), 1112 man-hours/ha using similar planting methods. Man-hour figures are probably more accurate when comparing methods. This eliminates such variables as administrative, travel, supervision, and material costs.

Table 2. Vegetation planting cost comparison.

COST/HECTARE	TYPE PLANTING	CENTER (M)	SOURCE
$2,510	Mangrove seedling	0.91	Teas, 1977
$12,500	Mangrove seedling	0.81	Lewis, 1979
$10,960	Mangrove transplant	2.00	This paper
$4,218	smooth cordgrass transplant	1.50	This paper

The man-hour and dollar costs of smooth cordgrass could be reduced more if the plugs were either divided or made into sprigs for planting. If sprigged, the cost of planting could be reduced by as much as 30 - 60% since a minimum of 3 or 4 sprigs are found in each plug. The time frame for sprigs spreading to cover a newly planted area would be approximately three years (Lewis & Lewis 1977), as opposed to the 1.5 years found with plugs. A reduction in cost by sprigging (to $.38 - $.67/plug) places planted smooth cordgrass into the cost range of commercially grown nursery material (before installation of the nursery stock).

There is a cost to the environment aside from the dollar values discussed. Removing plants from established marshes has the potential to be destructive. The 12 cm cordgrass plugs removed did not prove harmful to the source sites. Culm densities returned to their original values within one year. Removal of mangrove transplants created a greater impact, due to the greater size. There also is the disadvantage that mangroves cannot spread and grow back into disturbed areas as smooth cordgrass does. However, there are times when removing mangroves is advantageous, such as the CDA-D project where transplants were utilized which would otherwise have been destroyed. It can also be argued that selective removal of mangroves for planting from below a dense canopy will net positive results. That is, the source area is not impacted and additional plantings are created.

Both the SI and CDA-D plantings provide benefits to the immediate surroundings. Both smooth cordgrass and mangroves increase the primary and secondary productivity in an area. It appears cordgrass provides more primary production (up to 2000 g $C/m^2/yr$; Thayer _et al_. 1978) than mangroves (up to 1020 g $C/m^2/yr$; Thayer _et al_. 1978). Smooth cordgrass serves as foraging, nesting, and breeding sites for clapper rail and willet, while mangroves provide this for brown pelican (_Pelecanus occidentalis_), white ibis (_Eudocimum allus_) and other species of colonial water birds (Schreiber & Schreiber 1978). The time frame for newly planted smooth cordgrass to achieve this end is shorter than that for mangrove transplants (_ca_. 1 yr versus ca. 10 - 12 yr). A planting of smooth cordgrass can serve as a source area for additional planting within 18 months. Mangroves require a much greater time to reach this state.

When weighing the benefits of labor intensive transplanting of smooth cordgrass versus mangroves it must be remembered that some situations call for one or the other. For example, where mangroves are expressly required or are coming from an area to be destroyed, they are obviously preferred. However, it appears that smooth cordgrass transplanting is the more cost-effective and productive means of vegetation establishment in areas where it is found. A smooth cordgrass marsh will also encourage the establishment of mangroves (Lewis & Dunstan 1975).

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ECONOMIC ASPECTS OF WETLAND RESTORATION IN THE PRAIRIE POTHOLE REGION

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ABSTRACT

Restoration of drained wetlands has been proposed as mitigation for natural wetlands destroyed by large scale water projects in North Dakota. Wetlands drained for agricultural use on private land would be restored. Problems may arise for local economies when land that supported agricultural production is reverted to wetland. Specific concerns include threats to local public decision makers' autonomy, changes in tax revenue, loss of local employment opportunities, loss of local business revenues, and poor management of lands under public ownership.

An input-output framework is proposed as an analytical method for estimating the economic impacts of cropland to wetland reversion on rural agricultural based economies. Levels of personal income generated in the region under each land use are compared. The emphasis on a closed, local economy is necessary because local decision makers possess legislative authority over decisions regarding land-use.

The example presented suggests that regional personal income levels are lower after restoration than before. This outcome is highly sensitive to assumptions regarding drained wetland productivity, crop prices, and levels of other local dollar flows.

INTRODUCTION

The prairie pothole region of North America produces about one-half of this continent's waterfowl (Crissey 1969). This region covers about 777,000 square kilometers in the prairie provinces of Canada and the U.S. upper midwest. One-half of the duck production in the lower 48 states occurs in the prairie pothole region (Hammack and Brown 1974). This area is also important for waterfowl migration since it is in the Central flyway with the Mississippi flyway on its fringe.

With the exception of the unglaciated southwestern part of the state, North Dakota is an important part of the prairie pothole region. Natural surface drainage is immature; potholes, lakes, and other centers of local, interior drainage, mark much of the state. Artificial drainage has reduced the area of wetlands to nearly one half of their post-glacial, pre-settlement acreage. Wetland types I, III, IV, and V (Shaw and Fredine 1971) have been drained by farm operators to increase their cropland area, square-up fields, and eliminate nuisance areas. These wetland soils are rich and will produce excellent crops when adequately drained.

North Dakota's water problems include both excesses and deficits. Spring snowmelt oftentimes causes excessive runoff which spreads out over the flat land areas and fills countless depressions. With a short growing season, farm operators are eager to get their crops planted in the spring. Sheetwater flooding (shallow flooding on fairly flat land) and overtopped wetlands hinder timely field work. At the other end of the spectrum, water is frequently in short supply during the growing season. Most of the state receives a mean annual precipitation of 35 to 56 centimeters. With this low level of annual precipitation, the failure to receive adequate rainfall during crucial growing periods can mean large reductions in crop yields.

In response to these water problems, state and federal agencies have proposed large scale water projects. The Garrison Diversion Irrigation project was initially designed to deliver irrigation water to several hundred thousand acres in semi-arid regions of the state with hopes of stabilizing farm incomes. Wildlife habitat mitigation is an important feature of this plan. Habitat, including wetlands, that is destroyed by project features is to be replaced elsewhere through restoration or creation.

One suggested nonstructural measure to control sheetwater flooding in the Devils Lake Basin (DLB) of North Dakota was to restore selected type III and IV wetlands. Several studies have suggested that wetlands acting as temporary storage areas reduce runoff hydrographs both in peak flow and amount of runoff (U.S. Army Corps of Engineers 1976, Moore and Larson 1979, and Cernohous 1980).

Wetlands available for restoration are those that have been drained by individuals either at their own expense or with government assistance (Leitch and Danielson 1979). These former wetlands are usually providing the owners with some type of income, either crop sales or as an input into livestock production. As a result, some payment is required to induce the owner of the drained wetland to restore that wetland. The case to be considered in this paper is outright purchase of the wetland area by the federal government, although other arrangements could be made (i.e. easement payments).

The objectives of this paper are to: (1) suggest a framework for economic evaluation of the impact on rural economies of the reversion of cropland to wetland, (2) present an example of the personal income flows for cropland and wetland, and (3) discuss the implications of changes in dollar flows and suggest alternative policy actions to mitigate any adverse effects.

STUDY AREA

The study area for this analysis is the prairie pothole region in general and the Devils Lake Basin (North Dakota) in particular (Figure 1). Periodic floods in this 9,658 square kilometer basin in north central North Dakota have caused losses of agricultural production leading to a depressing effect on the economy of the region (Devils Lake Basin Advisory Committee 1976, Leitch and Scott 1977).

Cash crops, comprised mostly of small grains, account for the majority of agricultural income in the study area. Over one-half of the nation's durum is grown in North Dakota with a large part of that produced in the "Durum Triangle" within the DLB. Other cash crops produced here include wheat, barley, flax, sunflower, and potatoes. Approximately 86 percent of the DLB is cropland.

Glaciation left the DLB pockmarked with wetlands that became important waterfowl production and migration areas. High soil fertility and high wildlife production seem to go hand in hand where prairie wetlands are concerned (Shaw and Fredine 1971). Many of these wetlands have been preserved through U.S. Fish and Wildlife Service easement or land purchase programs and state Game and Fish Department acquisition. One DLB county has nearly 75 percent of its land area in some type of binding wetland program. Local citizens, businessmen, and politicians, as a result of past wetlands preservation activities by the federal government have become apprehensive of further wetlands restoration or acquisition. They need reliable economic information on the impact of cropland to

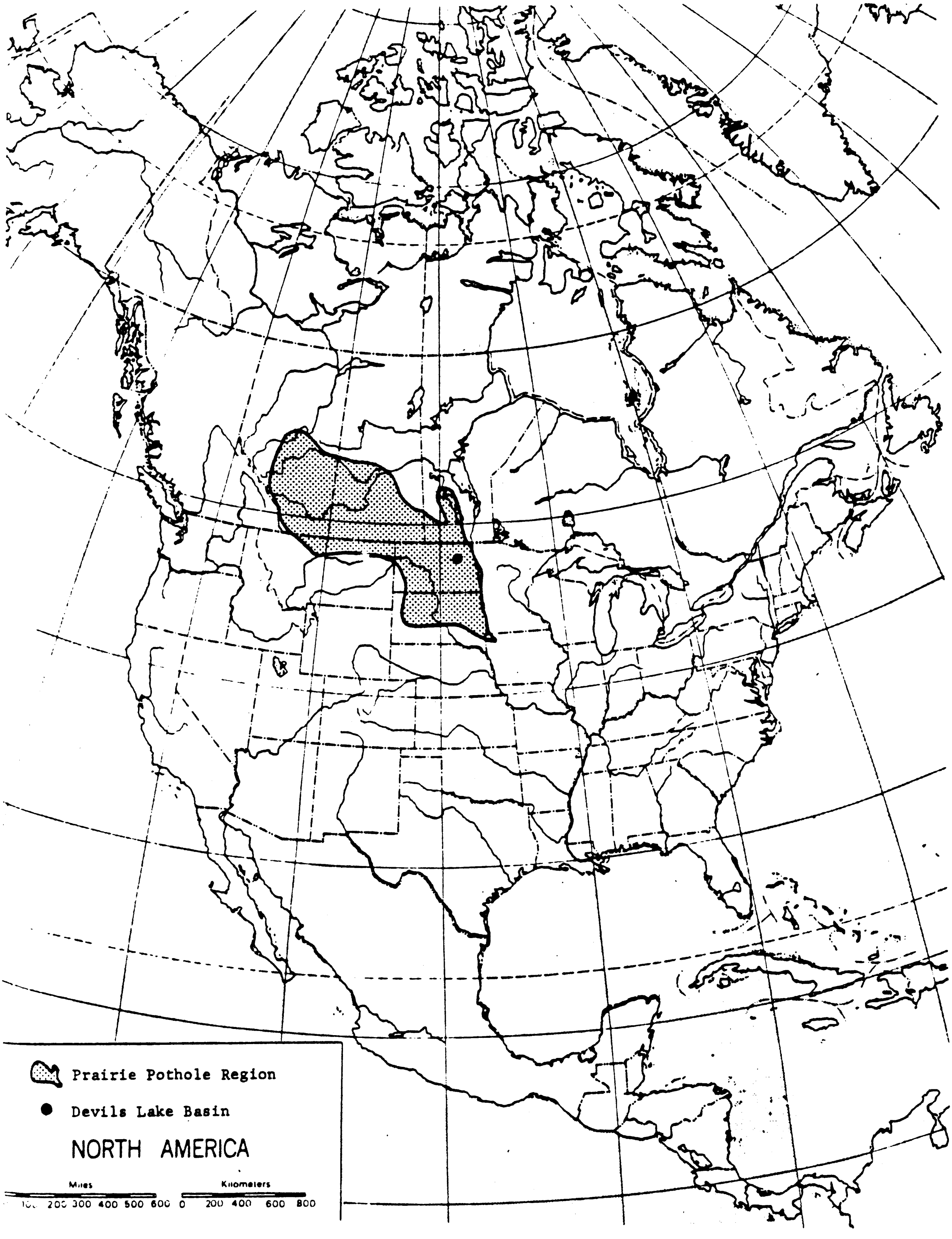

Figure 1. Prairie pothole region and the Devils Lake Basin.

wetland reversion before giving their approval to such projects.

REGIONAL IMPACT ASSESSMENT

Regional economists long have been concerned with the economic impact of plant location, large scale water projects, changes in industry structure and natural resource development. A variety of techniques has evolved to estimate these impacts on regional economies. Some of the basic approaches are input-output, economic base, location quotient, expenditures, shift-and-share, gravity/potential, and most recently, econometric methods (Maki 1979, Isard 1975, Emerson and Lamphear 1975). Many of these have been applied in forecasting changes due to relatively important shifts in industry structure, whereas this paper is concerned with ultramarginal shifts in land-use which in turn affect levels of industry income flows only slightly.

Input-output (I-O) analysis is a technique for tabulating and describing the linkages or interdependencies between various industrial groups within an economy. The economy considered may be the national economy or an economy as small as that of a multicounty area. The primary advantage of I-O over the other assessment methods is the level of interindustry detail possible. The effects of changes in one sector's sales can be followed through all the other sectors independently.

The actual development of I-O interdependence coefficients (multipliers) involves three steps. First,a transactions table is constructed that shows the purchases and sales by each of the sectors to each of the others. This is the most difficult and costly step in I-O analysis and is often accomplished using secondary data or modifying existing models. Next, the technical coefficients table is developed from the transactions table, expressed as decimal fractions of column totals. The final step is to subtract the technical coefficients table from an identity matrix and invert the result. The total of each column of the multiplier matrix shows how much activity will be generated in the system by one dollar of new income to a sector (sale to final demand), both directly and indirectly.

Advantages and theoretical and empirical problems of the I-O approach are discussed in detail in the literature (Emerson and Lamphear 1975, Isard 1975, Goode and Tolley 1966). In general, advantages of I-O are: (1) It allows a determination of the impacts of changes in demand on individual industries as well as the community as a whole. (2) Once constructed, I-O models can be used to estimate impacts from a variety of industry changes. (3) There are less expensive short-cut methods to fit I-O models to regions, which make the cost compatible with other regional tools. Basic disadvantages of I-O are: (1) The cost to do an analysis from scratch. (2) A basic assumption of I-O is that each sector can be represented by a single, linear, homogenous production function. This is very likely not true. (3) It is basically an economic base model, assuming that growth is stimulated through sales outside of the region. This requires assuming constant economies of scale and fully employed resources. (4) The multipliers estimated within the model are often misused by those unfamiliar with I-O analysis. Some models estimate short run impacts, while others estimate long run impacts. The distinction is with the assumption of which sectors are endogenous and which are exogenous. In addition, it is unknown just how long it takes the system to work through a full multiplier effect.

In view of the advantages and in spite of the disadvantages, I-O analysis has come to be the most popular tool for estimating regional impacts. It is especially useful for estimating marginal changes which occur with wetlands restoration.

Data requirements of the model are one of its drawbacks. First, an area specific I-O model is necessary. This can be constructed from scratch, modified from other areas, or built up using nonsurvey techniques. Second, the pattern of money flows within the region both before and after final demand changes are required.

The North Dakota I-O model (Senechal, 1971) was adjusted using location quotients to more accurately reflect the structure of the DLB economy. Personal income multipliers for the relevant sectors were applied to changes in incomes in those sectors to estimate the overall impact of restoration. Personal income is that portion of the value of final sales that goes to households and is an indication of the level of economic well-being of area residents.

A CASE STUDY

A water management plan for the DLB calls for restoration of approximately 5,265 hectares of drained wetlands, representing roughly 1,400 separate type III and IV wetlands. The income generating activities of farming a hectare of drained wetland are expenditures for productive inputs and spending of profits. Assumptions made concerning cropping of drained wetlands were: (1) they are well drained and equally as productive as adjacent upland, (2) the crops grown on drained wetlands are the same as on adjacent upland, (3) since only a small part of their total land holdings would be reverted to wetland, farmers remain in the community and spend the interest from the land sale in the same way as they spend their farming profits.

The wetland owner values land for its value as a productive input in crop production and for other reasons such as speculation or an inflation hedge. Table 1 shows that the profit a farmer can earn from a hectare of land is $54.90 per year, for a capitalized value of $549.00 at a 10 percent discount rate. This is about 75 percent of the market value of cropland in the DLB (Johnson, 1980). To make the farmer at least as well off in the form of annual cash flow would require a $549 payment, but to make him as well off considering full market values of the land to him would require a payment 1.33 times as large, or $730. Whether the land payment were for foregone cash flow or market value of land would determine the personal income generated as a result of spending the interest.

Other income flows generated by the restored wetland would include: (1) Those dollar flows resulting from restoration expenditures. In this case restoration would simply require a ditch block and letting the area revert to a wetland naturally. Thus this item is so small (about $65 per pothole) that it can be ignored. (2) Increased crop sales due to improved flood protection. A one hectare restored wetland was assumed to protect 1.1 hectares from flooding downstream (DLB Advisory Committee, 1976). (3) Savings in flood damage prevented on roads and bridges, which lead to lower levels of local taxes. (4) Hunter expenditures for goods and services in the DLB. And (5) payments in lieu of taxes on restored wetland. There may also be income flows generated outside of the basin as a result of farming or restoring wetland, however, the purpose herein is to estimate only those flows that directly affect the personal income of basin residents.

Table 1 summarizes the income and expenditure flows and the resulting personal income generated in the DLB due to both drained and restored wetland. The personal income generated in the basin due to

TABLE 1. Annual income and expenditure flows generating personal income from drained and restored wetland, dollars per hectare*

Income or expenditure activity	Dollar flow	Personal income multiplier[a]	Basin personal income
		Drained Wetland	
Crop production expenses[b]	$158.60	0.75	$118.95
Farm operator profit[b]	54.90	1.41	77.41
			$196.36
		Restored Wetland	
Land payment to owner[c]	$54.90	1.41	$ 77.41
(market value)	(73.00)		(103.00)
Flood damage reduction:			
Agricultural-expense[b]	26.23	0.75	19.67
-profit[b]	8.72	1.41	12.30
Transportation[d]	7.44	1.00	7.44
Hunter expenditures[d]	61.00	0.38	23.18
In lieu tax payment[e]	6.10	1.00	6.10
			$146.10
			(171.69)

*The dollar values used in this table are representative of relative conditions in 1975. Agricultural prices have shifted since then as well as land values and other dollar flows. As such the relationships illustrated here should be viewed as providing an example of the method and should not be taken to represent current conditions.

[a]Senechal, 1971. The personal income multiplier shows that portion of the dollar flow ends up as personal income. Seventy-five percent of the crop production expenses end up as personal income, the other 25 percent is leaked out of the basin for input purchase. The farm operator profit multiplier is greater than one because it includes the payment to the farmer, with a 1.0 multiplier, plus a 0.41 multiplier within the basin as the profit is spent and induces further personal income. The local government (tax) multiplier is 1.0 because local taxes could be reduced by the amount of savings, and taxes are direct withdrawals from personal income.

[b]Adopted from Leitch and Scott, 1977.

[c]Annualized value of a lump sum payment at 10 percent interest rate.

[d]Devils Lake Basin Advisory Committee, 1976.

[e]Leitch and Danielson, 1979.

farming a hectare of drained wetland is $196.36, while that from a hectare of restored wetland is from $146.10 to $171.69, depending on the level of land owner payment. Since the land owner is as well off with the payment as farming the wetland, the only shortcoming is with basin residents' level of personal income. To make up the deficit would require an additional $17.50 annual return to the former owner or a payment to some set of basin residents.

IMPLICATIONS

Regional input-output analysis can be used to estimate the level of compensation necessary to make the regional economy as well off after a land use change as before. If the restoration payment to the landowner and the other income generating activities result in an equal or greater level of basin personal income, then the local decision makers concerned with economic impacts should be no less than indifferent to the restoration. However, personal income may be redistributed. Basin businesses who catered to the agricultural sector may relinquish business to businesses catering to recreationists. Assuming resources (i.e., labor and capital) are not fixed within the confines of the basin, their redistribution may have economically offsetting impacts.

If the activities after restoration generate less personal income than farming did, then some form of compensation may be required to maintain personal income at its prerestoration level. The landowner could be paid an amount in addition to that required for him to sell, but this would represent a windfall gain; or local governments could be given offsetting payments. Revenue sharing to local governments would result in a redistribution of income from those who lose personal income as a result of the change in wetland to all local residents who pay taxes, and may be difficult to administer.

The net outcome of this analysis is sensitive to the assumption that drained wetlands produce as well as adjacent cropland. Wetlands are, however, often poorly drained and as a result can be poor cropland. Further, the level of crop prices significantly influences the outcome. Use of this procedure for decision making would require ascertaining productivity of wetlands under study and use of a long run crop price.

Another critical assumption was that production expenditures on cropland were left idle after cropland was reverted to wetland. In fact, these monies may be spent on output increasing inputs on remaining cropland and would not be entirely lost to the region.

The purpose of this analysis was not to compare benefits and costs of wetland restoration, but rather to illustrate some of the economic impacts that restoration may have on local economies. These impacts are estimated so policy makers have an idea of the impact of large scale water project mitigation requirements on local economies. Therefore, no attempt was made to measure all the benefits and costs of wetlands restoration, especially those that might occur outside of the basin.

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