SUGGESTIONS FOR PLANTING AND MAINTAINING WETLANDS IN COASTAL ALABAMA

Prepared for the
Alabama Department of Environmental Management

By

Judy P.Stout
Marine Environmental Sciences Consortium

1990

NOTE TO READERS

This document is intended to provide information on wetland mitigation to permit applicants. The information contained herein should be considered only as guidance.

The mention of trade names or brand names is for illustrative purposes and does not constitute an endorsement of the product by ADEM.

The preparation of this document was financed in part through a federal grant from the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration as authorized by the Coastal Zone Management Act of 1972; administered by the Alabama Department of Environmental Management and the Alabama Department of Economic and Community Affairs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Recent surveys indicate that over 50% of the wetlands in the contiguous United States have been lost. Despite this loss, pressures continue to use wetlands for immediate economic gain. The natural self-maintaining values of these systems are rarely considered and their complexity and uniqueness are usually underestimated. A growing attitude assumes that wetland losses can be mitigated by restoring or creating wetlands of equal functional value. However there have been more failures than successes and there is evidence that at many sites we may have accepted loss of valuable resources in return for equal areas of inferior quality and dubious longevity. Visual characteristics are, in general, much easier to restore than subtle ecological functions and thus many wetland scientists feel that wetland duplication is impossible and simulation may be improbable.

In addition to restoration or creation of wetlands as mitigation directly related to a wetland loss, there are other reasons to attempt to restore or create wetlands. These may include 1) produce waterfowl and other wetland wildlife habitats; 2) minimize flood damage through increased flood storage capacity; 3) stabilization of natural shorelines or newly deposited dredge material; 4) improve water quality by trapping sediments and/or removing nutrients; 5) increase diversity of habitat; 6) provide nursery areas for recreational or commercial species; and 7) increase habitat once abundant in the area but now degraded or greatly reduced in area. The specific goals of a project will affect the configuration of the planned wetland and will in part dictate the criteria used to judge the success of the project.

This manual of suggestions has been compiled from existing literature to assist in planning and development of restored or new wetlands in coastal Alabama. The reader should realize at the outset that creation of wetlands is a risky undertaking without guaranteed success. Suggested methods contained in this manual have worked in other areas and are included because they appear to offer the greatest likelihood of success. The level of detail differs between wetland types and between plant species, a reflection of the relative amount of experimentation and reporting available for each. In order of decreasing information and increasing complexity of species communities and their environmental sensitivity (declining success rate) wetland types can be ranked as follows:

1. Salt/brackish marshes
2a. Submerged aquatic vegetation
2b. Freshwater marshes
3. Forested wetlands

Individual plant species common to these wetlands may be represented by more information and/or greater predictability of success than the whole wetland community.

As a developer or potential developer of wetland habitats you must be willing to accept each project as experimental and exercise the greatest care in site selection, site preparation, plant handling and, most of all, be prepared to make mid-course corrections such as supplemental planting, fertilization, new species introductions and protection from human impacts or disturbance by local fauna.

The four wetland types will be discussed individually in the following pages. Additional readings are suggested for greater detail or reviews of specific methods or plants. A list of directories of plant material sources is also included.

PLANNING

Just as wetlands are complex systems, preparation of a wetland development plan is also exceedingly complex. The complexity of preparing a plan is due both to the plethora of options and the uncertainties of success which are site and species specific. It is the rare land owner or developer who has the technical background to personally plan or implement a wetlands restoration or creation project. Planning should therefore be initiated by consultation with regulatory and management agencies and should involve a qualified environmental consultant during all phases of the work. Agency staff, as a rule, are not environmental consultants, and thus the burden of assuring performance and success fall upon the developer and his consultant. Selection of a capable consultant should be based on regional knowledge and wetlands experience. This is an especially critical step since improper planning and design severely jeopardize the chances of success and may be costly.

Goals

Various reasons for restoring or creating wetlands have been listed in the introduction. Design criteria and evaluation of results follow directly from the specific goals of a project. Goals which may be considered in relationship to the details of why a wetland is being planned might be:

-specific plant species establishment
-percent of planting surviving
-plant cover
-plant community composition
-primary productivity
-sediment stability
-faunal utilization
-water quality
-harvestable forest resources

Goals should be clearly defined and methods and levels of quantifiable estimates of achievement incorporated into the plan.

Compensatory Mitigation

In many cases when the nature of permit requests to alter wetlands involve developments that warrant the permitting of wetland loss, developers are now being required to mitigate the loss through compensatory replacement of wetlands. To achieve adequate compensation the philosophy has been that not only must the wetland aspect or landscape be created, but the function of the original wetland should be replaced. The goal of compensatory mitigation must be functional equivalency of the created wetland with the original wetland. The reader will realize in reviewing this document that there are varying degrees of experience and workable techniques for different species and wetland types, just in terms of the mechanics of establishing the habitat. For many species there is little or no information available and inadequate knowledge to duplicate some habitats (i.e. forested wetlands). Hence the predictability of success in establishment alone is moderate to poor. In addition, there is a scarcity of documentation to demonstrate the functioning of man-made wetlands.

Important questions arise: Can we with confidence expect to successfully create a wetland that will meet our project goals? What is the rate of success? Does the created wetland function like the original wetland? How long does it take to reach structural similarity to a natural wetland? Time to reach functional equivalency? How rare is this particular resource - locally, in the watershed, regionally? What is the impact of wetland functional loss followed by periods of reduced function?

Because (1) there is a gradient in prediction of success of different habitats; (2) wetlands are more important in some locations than others; (3) functions are absent or reduced until functional equivalency is reached; (4) different wetland types/species have distinctly different roles; and (5) wetland resources have been reduced to critically low levels, a ranking system of mitigation options has been suggested. Table 1 presents options available and Figure 1 provides a sequential ranking at each level of decision making in the planning process. The higher the cumulative score the greater the likelihood of contributing to maintaining levels of wetland acreage and value.

When planning your project, use of Figure 1 will give you a relative evaluation of your project design for a mitigation wetland.

The Plan

A thorough plan must be designed and approved before project initiation. It should provide details which answer the questions of - What to restore or create? Where? How? Monitoring elements? and Management? The plan should address the following project aspects in the text and with appropriate photographs and drawings.

-goals
-site location
-preconstruction site conditions
-site preparation methods and timing
-project elevations and topography
-hydrologic patterns to be achieved
-species to be planted
-propagule types (seeds, transplants, cuttings, natural recolonization, etc.)
-plant sources (commercial, native, locations)
-planting methods
    -removal and handling of transplants
    -collection and handling of native seeds
    -pretreatment of planting units
    -timing
    -spacing
    -fertilization
-site management
    -frequency of inspection
    -protection from: waves, animal disturbance, human impact, etc.
    -replanting
    -fertilization
    -pruning
    -mowing/discing
    -weeding
-performance (success) criteria (eg., % survival of plants, % vegetative cover, faunal diversity)
-monitoring plan (frequency, sampling, duration)

Site Selection

Site selection is a crucial element of the planning process. The nature of the site will affect the economics of site preparation and project construction, plant survival, degree of management required and longevity of the project. Accessibility of the site should be considered in regards to costs and logistics. Sites with land access should be utilized where possible. The exact nature of the site and its attributes are dictated by the project goals and specifications as listed in the previous section. Controlling aspects which should be considered in site selection are:

-Elevation in relation to water level - A surface must be created to provide the hydrologic regime to which the desired vegetation is adapted.

-Wave climate and currents - The susceptibility of the site to erosion should be evaluated. (See "Special Considerations").

-Salinity - The salinity of tidal and interstitial water determine the plant species.

-Slope and tidal range - These factors affect the areal extent of the intertidal zone, the zonation of plant species, drainage and erosion potential.

-Soil chemical properties - Availability of plant nutrients and the possibility of toxic contaminants should be considered.

-Soil physical properties - These affect trafficability, i.e., bearing capacity, for planting operations and erodibility.

Site Preparation

One of the most frequent causes of project failure, or costly and frequent maintenance, is lack of attention to site preparation. Contractors should be supervised during all phases by a qualified engineer or wetlands specialist. The site should be thoroughly inspected at the completion of preparation while equipment is still on-site to make any necessary corrections and modifications. Verification of elevations and topography should be performed. Grading must be implemented with high precision -- a few centimeters too high or too low, or creation of areas of pooling will prevent the establishment of the desired community.

Where sediments are subject to compaction, elevations should be checked after an adequate settlement period.

Knowledge of sediment settling and compaction rates, geochemical adjustment periods for dredge materials or exposed subsurface layers, and timing of extremes of hydrologic cycles must be utilized to plan the sequencing and timing of site preparation. The site should be ready at the optimum time for the planting phase of the project.

Additional Reading: 1 2, 16, 18, 29, 39, 60, 62, 89.

Table 1. Compensatory mitigation options. (Modified from 60).

MITIGATION TYPES	RECOMMENDED ACREAGE RATIOS
Restoration - former wetland, functions restored	1.5:1; 1:1 upfront
Creation - made from different community	2:1; 1:1 upfront
Enhancement - increase certain functions	3:1; 1:1 upfront
Exchange - change from one habitat to different	case by case
Preservation - purchase or donation and protection	case by case
TIMING OF MITIGATION	
Before (upfront) - most prudent; require if unknowns	
Concurrent - encouraged for typical projects	
After - discouraged	
LOCATION OF MITIGATION	
On-site - same locale in watershed or ecosystem	
Off-site - different locale or different ecosystem	
COMMUNITY TYPE	
In-kind - same species	
Out-of-kind - different species	

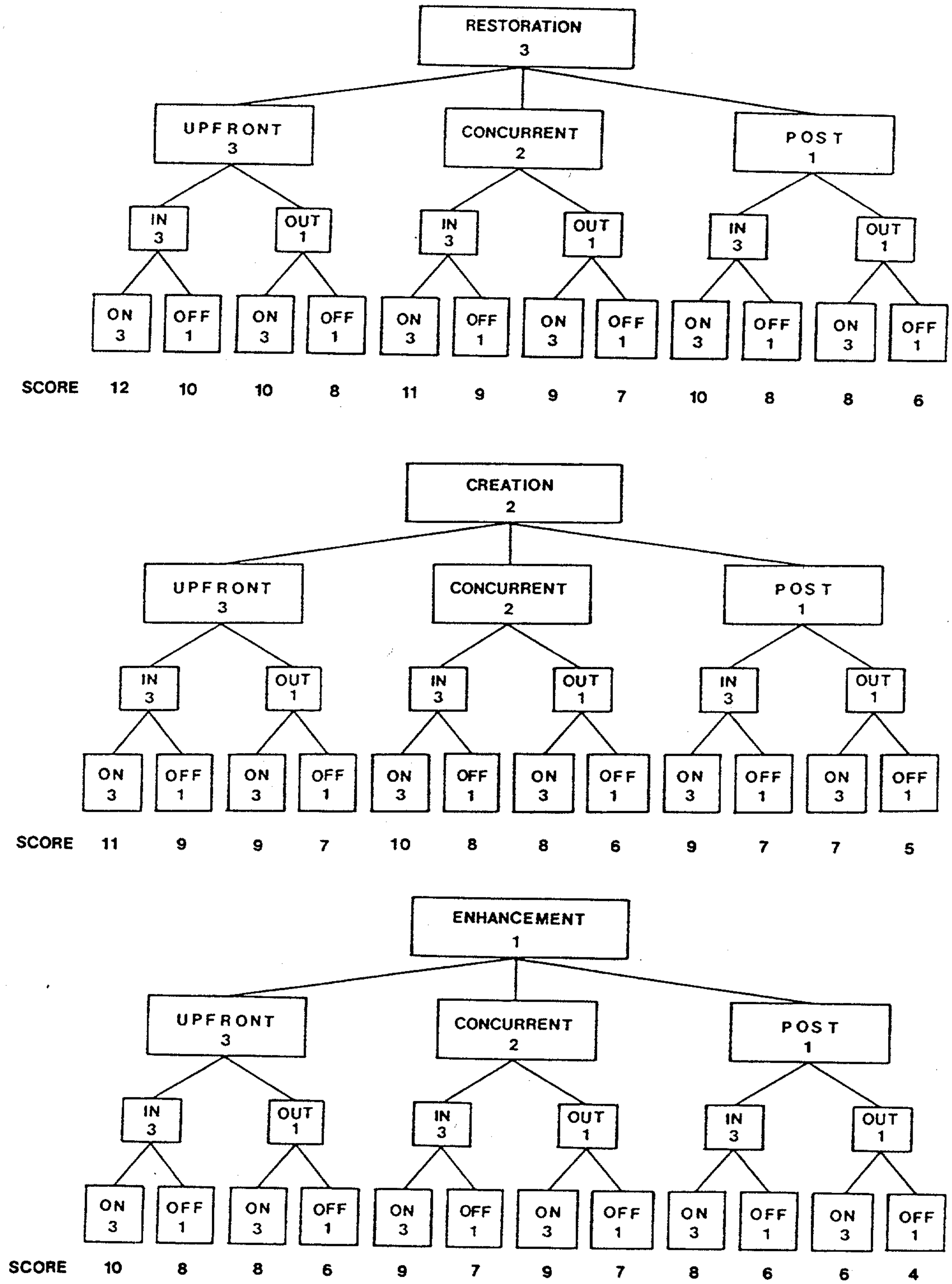


Figure 1. Options to be considered in the preparation and evaluation of mitigation plans with weighted rankings (From 59).

MONITORING

A program of site monitoring should be designed and implemented for each wetlands project. This is necessary for several reasons, depending upon the individual project.

1. To document that project was implemented and, if appropriate, to demonstrate that design criteria spelled-out as conditions of a permit were met.

2. To assess needs for management actions and design corrections as wetland becomes established and matures.

3. To determine reasons for any problems or failure, for correction and future planing.

4. To evaluate achievement of project goals and any specified performance criteria.

5. To estimate degree of functional equivalency of created or restored wetland to natural wetlands of the same type.

Monitoring efforts may include qualitative observations, photographs, instrument records and quantitative sampling. The frequency, intensity and duration of a monitoring program will vary with the goals of the project, the complexity of the project design, general likelihood of success with similar wetland types (risk), the projected time to reach functional maturity for the particular wetland type, and the performance criteria outlined in the mitigation plan.

As a minimum monitoring program each site should have a time-zero assessment, two additional interim assessments during the first and second growing season and a final inspection. The time-zero inspection should be made as soon as project installation is complete and will provide "as constructed" details of the project for comparison to design criteria and requirements and a baseline for additional monitoring. This inspection should include a series of photographs taken from permanently marked reference points showing all aspects with ground reference points. Each element of the project design should be checked and actual conditions detailed (i.e. elevation, topography, hydrologic regime, tidal flooding, species planted, planting methods, density, fertilization, etc.). Divergence from the original design should be noted. Additional comments on problems and concerns should be appended. This inspection should be made by a team including a representative of the permitting agency and an agent of the developer. Other commenting agencies may be represented if desired.

A recommended schedule for subsequent monitoring and written reports is as follows:

Year 1 - quarterly after initial time-zero inspection.

Year 2 - twice: early summer and fall.

Year 3...on - annually in mid-summer.

The duration of a monitoring program depends upon the wetland type involved - three to five years for marshes and submerged aquatic vegetation and five to seven years for forested wetlands.

Parameters to be monitored may include: (some goals are given in parenthesis)

- photographic survey from fixed markers
- aerial photos
- % survival of planted materials (70%)
- growth of planted materials: percent ground cover for herbaceous species (80%), height increase and canopy cover of woody species
- aboveground:belowground biomass (g/m^2) for herbaceous species (decreases as wetland matures)
- natural revegetation: species and estimated percent cover (note exotics, weedy species and problems of competition with desired species)
- sedimentation v. erosion rates (net = 0)
- soil organics (increasing)
- soil nutrient status
- topography
- salinity
- hydrology
- waterfowl utilization
- high tide faunal utilization (wetland endemics and foraging species - numbers, diversity, size)

For permitted projects, conditions of the permit will detail the performance criteria and compliance timing for some or all of the above parameters. For the final site inspection, the new wetland should attain levels similar to nearby wetlands of the same type. (This is not possible for forested wetlands which may take 40-70 years to reach maturity.) Progress toward achieving these levels, or final levels designated by the permit, should be carefully evaluated at each site inspection. Failures or significantly slow progress may indicate the need for additional site management such as replanting, adding different species, modification of topography, sediment amendment, physical protective measures, fertilization and others.

Monitoring should be viewed as both a status evaluation and a tool to enhance the success of the project and future efforts. A well-planned, carefully constructed project that is fine-tuned through a good monitoring and management program has the greatest likelihood of meeting specified goals and serving as a valuable resource to the ecosystem.

Additional Reading: 12, 18, 20, 27, 34, 62, 67, 88

SPECIAL CONSIDERATIONS

Shoreline Energy Levels

Experience has indicated that wetlands can be established only on relatively sheltered, low energy shorelines. Exposure to wave action is a major factor in determining the types of propagules to use, the survival of plantings until stabilization is achieved, accretion/erosion rates, and persistence potential of the wetland.

Numerous characteristics may influence the wave climate severity on a shoreline including elevation, slope, tidal range, width of intertidal zone, fetch (distance over water that wind blows to generate waves), direction of wave exposure, sediment grain size, offshore depth, proximity to navigation (boat wakes) and shoreline configuration (straight, scalloped, headlands, coves, creeks, etc.). Assessment of each of these in consideration of site selection may include use of synoptic weather summaries, tide tables, navigation charts, photos, elevation benchmarks and field measurements.

Woodhouse (87) summarizing the results of numerous plantings of *Spartina alterniflora* on the Atlantic coast advised that transplants can be used successfully at sites with fetches <4 km and seed can be useful at sites with <1 km of fetch. Knutson et al. (56) found that fetch, shoreline configuration and grain size were useful indictors of wave climate severity and the probability of establishing vegetation by transplanting. Recommendations by Knutson et al. were:

1. Sediment grain size - <0.4 mm yielded approximately 84% successful establishment.
2. Fetch - a. average fetch (distance perpendicular to shore plus twice the distances at 45° to shore) 0-1,000 m best; 1,000-9,000 m acceptable.
   b. longest fetch 0-6,000 m best; 6,000-18,000 acceptable.
3. Shoreline configuration (in order of suitability) coves - meandering - straight - headlands.

Figure 2 is a copy of a numerical shoreline energy site evaluation form for rating potential success as provided in Knutson et al. (56).

In Mobile Bay, success of planting *Spartina alterniflora* sprigs on a spoil island was correlated with 1) direction of wave exposure 2) shoreline elevation and 3) total degrees of wave exposure (equivalent to shoreline configuration). The relative importance of each factor varied from site to site (86).

It is necessary when designing a project to determine the minimum planting width which is required to achieve vegetative protection of a shoreline in a given wave energy situation. Knutson et al. (55) have demonstrated the use of a wave damping model for *Spartina alterniflora* to calculate this width. This calculation can also be useful in determining the suitability of a site for vegetative stabilization - if the calculated minimum width is greater than the width of the shoreline at an elevation suitable for planting, one may conclude that vegetative stabilization is not likely to be effective at this site.

Protection of Plantings

Special planting and protection techniques may be used to enhance success of plantings in moderate wave environments. Test plantings with various kinds of protection have been used along the shores of a dredge island in Mobile Bay by the U. S. Army Corps of engineers

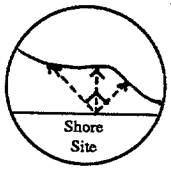
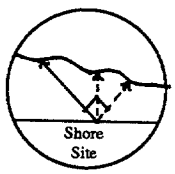
1. SHORE CHARACTERISTICS	2. DESCRIPTIVE CATEGORIES (Score Weighted by Percent Successful)				3. WEIGHTED SCORE
a. **Fetch-Average** Average distance in kilometers (miles) of open water measured perpendicular to the shore and 45° either side of perpendicular 	Less Than 1.0 (0.6)	1.1 (0.7) to 3.0 (1.9)	3.1 (1.9) to 9.0 (5.6)	Greater Than 9.0 (5.6)	
	(87)	(66)	(44)	(37)	
b. **Fetch-Longest** Longest distance in kilometers (miles) of open water measured perpendicular to the shore and 45° either side of perpendicular 	Less Than 2.0 (1.2)	2.1 (1.3) to 6.0 (3.7)	6.1 (3.8) to 18.0 (11.2)	Greater Than 18.0 (11.2)	
	(89)	(67)	(41)	(17)	
c. **Shoreline Geometry** General shape of the shoreline at the point of interest plus 200 meters (660 ft.) on either side	Cove 	Meander or Straight 	Headland 		
	(85)	(62)	(50)		
d. **Sediment** Grain size of sediments in swash zone (mm)	0.0 - 0.4	0.4 - 0.8	0.8 - or greater		
	(84)	(41)	(18)		
4. CUMULATIVE SCORE					
5. SCORE INTERPRETATION					
a. Cumulative Score	0 - 200	201 - 300	300 - or greater		
b. Success Rate	15%	50%	100%		

Figure 2. Vegetative stabilization site evaluation form (From 56).

(Waterways Experiment Station and Mobile District). Four techniques were found to increase survival of *Spartina alterniflora* two to three times over unprotected single stem transplants (1,2).

1. Plant rolls - burlap, 12' X 3' laid on ground; 1.5' strip of 3/8 oz./ft.^{2} Paratex placed down middle; sandy soil placed on Paratex; clumps of plants at 1.5' spacing placed on sand; burlap edges fastened shut with hog rings with plants emerging; roll buried by use of a jet-pump to depth of plant stem bases.

2. Paratex mats (1/5 oz./ft.^{2}) - single stemmed transplants inserted into soil through slits in mats spread on sediment and nailed between boards buried in sediment.

3. Tires - laid flat and strapped together with conveyor-belt material and anchored to tires buried outside the plot; single-stemmed plants placed in center of and between tires.

4. Burlap bundles - burlap square (18" X 18") wrapped around multi-stemmed transplants, secured with hog rings and buried to base of stems.

In terms of cost and survival, plant rolls and burlap bundles appear most competitive. Plant rolls were also successful in Florida plantings of *Spartina alterniflora, Spartina patens* and *Distichlis spicata* (64).

Upland Conversion

In selecting sites and methods of establishing wetlands, the conversion of uplands to wetlands might be considered. Grading to suitable elevations, creation of tidal access channels ("tidal creeks") and planting of wetland species has been successful in North Carolina (12) and in Alabama (85) for salt marshes. Species planted included *Spartina alterniflora, S. cynosuroides* (NC only), *S. patens* (NC) and *Juncus roemerianus*. The principal factors affecting establishment and growth of native species were elevation, soil moisture conditions after planting and nitrogen and phosphorus fertilization. Marsh vegetation was limited to a narrow specific elevation range which controlled the hydrology and interstitial salinity conditions. Supervision of construction crews during site preparation is critical to creating proper topography. Transplanting vegetation at the correct elevation in relation to local tidal regimes is an additional prerequisite to success.

Test of sediment fertility and pH should be made to determine the need for fertilizer or lime applications. Different plant species may react differentially to fertilizers. *Spartina alterniflora* and *S. patens* respond well to applications of either slow release forms of N and P amendments from ammonium sulfate and concentrated superphosphate. *S. cynosuroides* is less salt tolerant and may suffer salt damage if fertilizer comes in direct contact with plants. Soluble fertilizers should be placed at least 5 cm from the roots of *S. cynosuroides. Juncus roemerianus* has rarely responded significantly to fertilization. Low pH soils (<4) should be adjusted by the application of appropriate amounts of lime.

If topsoil from the site can be stockpiled during site preparation and reapplied after proper elevations are created, this may enhance planting success as a nutrient source. Mulch from wetlands being altered may also be applied if the sequencing of the project events allows and transportation to the created marsh is feasible.

Removal of fill material applied over historical wetlands to bring upland elevations back down to wetland levels may provide good success if the underlying original soils have not been significantly altered or polluted (84).

Sea Level Rise

The effect of tides occurs along all coastlines and includes a larger area than is affected by saltwater alone (i.e. tidal influenced rise and fall in water levels in freshwater coastal rivers and wetlands). The average and extreme levels of the sea affect the local range and inundation patterns of tides. Due to increasing greenhouse gases in the earth's atmosphere, a temperature rise of 1.5-4.5°C may be reasonable in the next 100-300 years (31). Sea level response to consequent water expansion and ice melt in the next century has been forecast at 60 to 300 cm (65). Lowest estimates of rates of sea level rise are around 5.6 mm/yr. (46, 82, 83).

Consequences of sea level rise in coastal wetlands, both natural and man-made may include:

-erosion of seaward edge
-reduced plant growth and therefore reduced organic sediment input and reduced suspended sediment trapping
-drowning of seaward portions unless accretion rates equal rates of sea level rise with subsequent wetland plant death at edges
-saltwater intrusion into brackish and freshwater areas and subsequent species changes
-creeks widen and system becomes more dissected
-increase in water wetland edge
-migration inland of wetlands until an upland barrier is reached
-for submerged aquatic vegetation an increasing length of light path (deeper water), altered wave patterns, sediment redistribution from erosion

The following recommendations are offered by Estevez (31) in planning wetland management relative to rising sea level.

1. Use Relevant Vertical Reference Data

   Neither mean sea level of 1929 nor the National Geodetic Vertical Datum are intrinsically meaningful with respect to modern wetland elevations. Sea level has risen since 1929 and so have wetlands. The National Ocean Survey redetermined local tidal datum planes in the 1970s, and these data should be consulted when planning tidal wetland projects. Elevations for new projects can also be established by surveying nearby natural marshes.

2. Establish Useful Life as a Design Criterion

   When time horizons for wetland projects are discussed at all, the usual sense is that the system will be expected to persist indefinitely. This is a desirable goal even though hurricanes, freezes and other natural forces set upper limits to the longevity of a specific wetland. It may be useful to intentionally design "utility wetlands" with shorter useful lives than "wilderness wetlands" (Clark 1986). Also, the time lines set for created wetlands may not need to be as long as ones set for restoration or mitigation wetlands.

3. Take Advantage of Upland and Inland Sites

   Wetland creation, restoration or mitigation projects in areas where sea level rise impacts will not be felt first include tidal rivers; the upper ends of bays and estuaries; blind ends of lagoons; and creeks and streams flowing to tidal waters. In some cases it may be sufficient to prepare low uplands for natural wetland recruitment, through removal of ditches, spoils or other barriers (see below).

4. Prevent and Remove Upland Barriers to Wetland Migration

   Extensive lowlands near tidal wetlands are important as incipient wetlands. Barriers include roads, fill, seaway, ditches and buildings. These structures could be removed; removed once depreciated; or never built in order to allow for wetland migration. Whether or not sea level rise accelerates, one meaningful measure would be protection of salterns. These tidal landforms are being converted into uplands, stormwater catchment basins, or other uses which will prevent wetland migration from occurring.

5. Dedicate Low-lying Uplands

   Governments and developers of large coastal properties should inventory the actual location and extent of lowlands adjacent to tidal wetlands and consider their long-term preservation as a land-use and planning tool. Property can be conveyed fully as part of site planning or perpetual easements could be dedicated. Such lowlands (but not salterns) could be used as freshwater wetlands for stormwater management, until they are encroached upon by tidal wetlands.

Of particular note, when constructing sites for the establishment of wetlands, care should be given to the placement of overburden materials removed to attain desired elevations. These materials should not be placed in a manner to prevent landward migration of wetlands as sea level rises. Spoil piles, berms and other configurations act as barriers and would ultimately result in total wetland loss. It may be necessary to remove materials to upland sites not adjacent to the wetland.

Plant Material Sources

It is extremely important that consideration be given to the source of plant materials for introduction to the project site. For all species, adaptations to local environmental and climatic conditions have resulted over time in distinct patterns of growth, reproduction, and physiological means of coping with natural stresses. Use of transplant materials adapted to conditions different from the project site may result in the following:

1. Introduced plants may die soon after planting.

2. Plants may survive initially only to have delayed death, especially when faced with seasonal changes or episodic events such as drought, low temperatures or pests to which they are not adapted.

3. Survival, but poor growth resulting in limited expansion and ground cover.

4. Failure to successfully reproduce, therefore reducing the extent of natural colonization and increasing the susceptibility to loss of the whole population.

Several approaches are suggested to minimize the risk of failure or limited success. The greatest likelihood of success will be with plants or seeds collected on-site (from or adjacent to area to be damaged or destroyed) from habitats with similar conditions to the new wetland. When forced to collect off-site, collect from an area as nearby as possible with matching site conditions of elevation, slope, soils, drainage and vegetation. Collect seeds from as many parents as possible or plants from various locations in the collection habitat to maximize the variability and hopefully provide broad capabilities for survival and success.

If it is not possible to use wild plants, try to find a nearby nursery which maintains stock source records and purchase materials from original conditions as similar as possible to those on your project site. If you must purchase stock of unknown origin, purchase excess numbers and buy from several sources to increase the diversity of genetic adaptability.

Though collection from wild plant sources is recommended, great care should be taken to minimize impact on the collection site and insure continued natural functioning of that community. Access to the site should be by foot only, not by vehicles. Routes in and out should be varied to prevent compaction and creation of deep trails. Removal rates are recommended later for some species, but the general approach is to leave plenty of natural vegetation to quickly recolonize the disturbed patches by runners or seeds, to maintain soil stability against erosion and to retain the habitat functions provided by the donor wetland. You don't want to destroy or severely alter the donor wetland and thus be in a mitigation-of-the-mitigation-impact situation! Common sense and good judgment must apply, although the mitigation plan and permit conditions may more rigidly specify removal rates and methods.

WETLAND TYPES

Salt and Brackish Marshes

Marshes are wetlands characterized by erect, rooted herbaceous plants. The vegetation is usually grasslike and dominated by perennial species. Coastal salt or brackish marshes occur naturally as extensive meadows, fringing margins of shorelines or as isolated patches within other habitats on low energy shores intermittently flooded by tidal water. The plant community varies slightly, dependent upon the average salinity of an area.

Few plants are adapted to the stresses of both a salty environment and being partially submerged, the controlling factors in salt and brackish marshes. This feature simplifies efforts to restore or create this wetland type. Plants typically occur in distinctive zones with only one or a few species dominating. Figure 3 depicts the typical patterns of plant distribution in Alabama salt or brackish marshes.

The regularly flooded area of the marsh (MLW to MHW) is vegetated by a band of smooth cordgrass (*Spartina alterniflora*), taller plants nearest the water and shorter plants further inland. Along shores of lower average salinities (5-15 ppt.) giant cordgrass (*Spartina cynosuroides*) may dominate, or replace entirely, smooth cordgrass at this elevation.

The largest area of the marsh is covered by black needlerush (*Juncus roemerianus*) and represents the area irregularly flooded by tidal water (approximately MHW to the extent of high spring tides). Needlerush is represented in mixed communities with other dominant species at the edges of its zone.

The high marsh is above the zone flooded by high spring tides, but influenced by the salt water of storms and tides blown inland by winds. Needlerush is found mixed with salt meadow cordgrass (*Spartina patens*) in this zone.

Slight depressions in the high marsh may trap tidal waters and become very salty (up to 45 ppt.) by evaporation. These salt flats or pans have few plants and only species especially adapted to high salinity. No efforts have been made to create this marsh community.

Along the transition from marsh to upland and in marsh areas of higher elevation several shrubs may occur including marsh elder (*Iva frutescens*) and eastern false willow (*Baccharis halimiflolia*).

For greater details on the ecology of salt and brackish marshes see reference 76. The distribution and composition of natural coastal marshes in Alabama can be found in references 78 and 79.

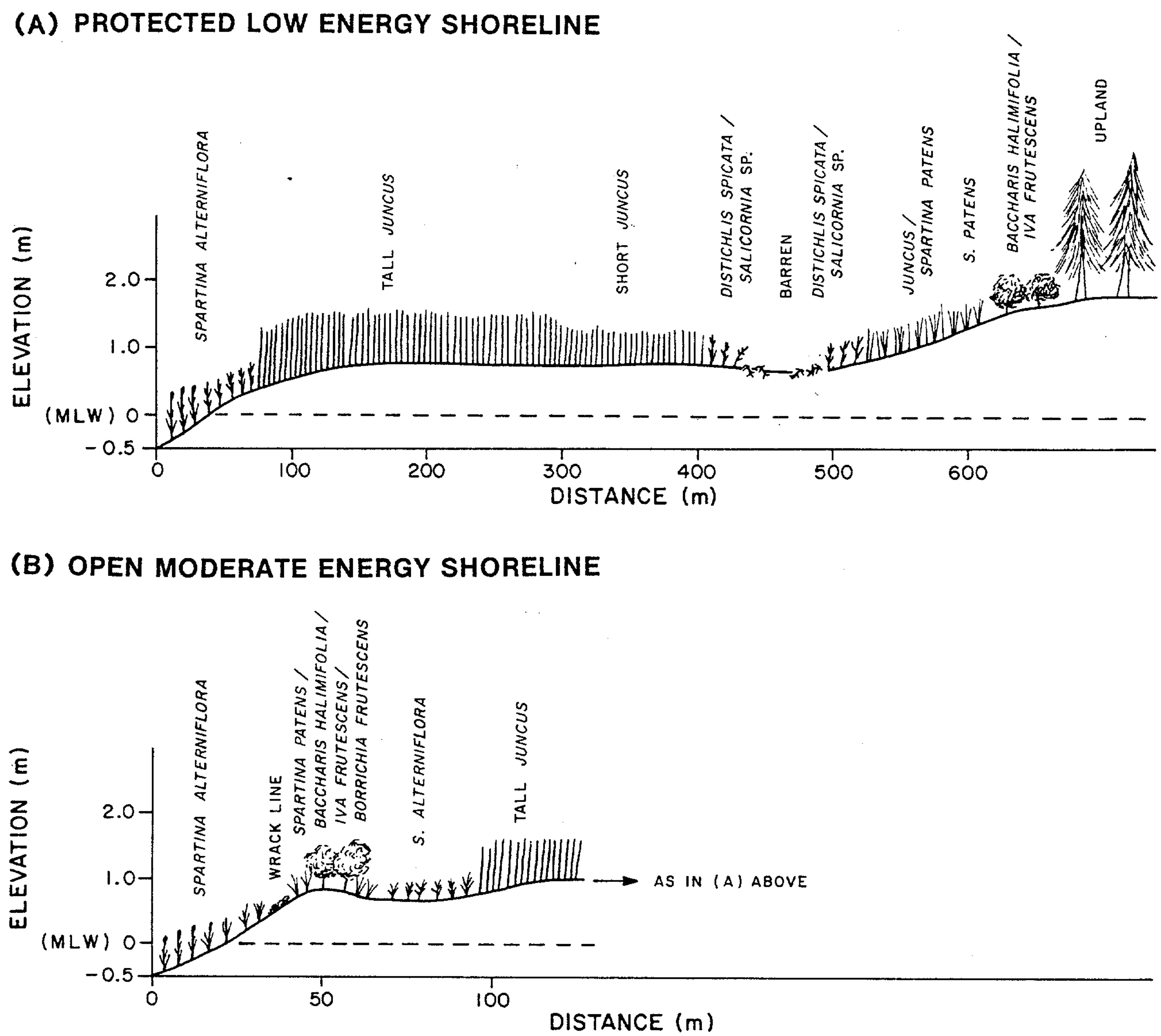
<u>Species Suggestions</u>

Spartina alterniflora - Smooth Cordgrass

<u>Siting</u>

Shoreline: Low energy coastal margins, scalloped not straight; fetch less than 4 km for transplants, less than 1 km for seeds.

Figure 3. Typical Alabama coastal salt marsh zonation after 76).



Soils Regularly inundated (60-80% of time), silty; allow dredged materials to stabilize at least 1 month; good drainage; minimum pH = 5.5-7.5.

Elevation/slope: Upper 1/3 of tide range MSL to MHW; slope 1-3% preferred (up to 10%); tall forms in lower with short forms in upper levels; no ponding.

Salinity: 5-35 ppt.

Planting Guidelines

Transplants

Field Dug - easiest removed from sandy soils; rapidly expanding young stands; remove from at least 5 m inside bed in alternating pattern removing no more than 2 plugs/m^2; 15 cm plugs with post hole digger or shovel to 10 cm deep; keep root-rhizome mat intact.

Seedlings - 5-10 seeds per pot in mixture equal parts sand, peat and topsoil; plant January-February for April planting; fertilize with Hoagland's solution, liquid or granular fertilizers at recommended rate on package; may be available commercially.

Planting: In spring (April-May) or fall (October-November) at original soil depth of stem; within 36 hours of digging; 0.5 m centers for rapid colonization or higher energy shore; 1.0 m centers in calm waters.

Fertilization: Slow release Osmocote (3 month, 14-14-14) at rate of 1 ounce per planting hole at time of planting; or if site allows mechanical access disc-in 100 lbs./ac. N as ammonium sulfate or urea and 100-200 lbs./ac., P as concentrated superphosphate (45% P_2O_5); especially useful for establishment on coarse soils or high energy sites.

Maintenance: Remove debris; early fall pruning especially of flower/seed heads may stimulate growth by reducing shading; replant to replace dead plants.

Special treatments: Higher energy, erosional shorelines may require use of burlap plant rolls, Paratex mats or other anchoring methods; hay bales or tire breakwaters may dampen waves; such situations create high risk of failure and potential frequent maintenance.

Seeds

Sources: Shoreside native stands; tall forms have higher yield.

Collection: By hand; November before seeds begin to scatter; collect annually.

Handling and storage: Store moist (not submerged) at 4°C 3-4 weeks; thresh seeds from stems; store threshed seeds in seawater (25 ppt.) at 4°C; maximum storage time 1 year with declining viability.

Seeding: Use only in upper intertidal; prepare soil by tilling; sow at rate of 100 viable seeds per m^2 (determine % viability by test planting); till in to 3 cm deep; late February - March.

Note: Seed heads are often infected by fungi which severely reduce the number of viable seeds; seeding should <u>only</u> be considered with seeds from healthy local stocks and only on shores with no wave energy; an efficient, economical method on a large scale but high risk of failure.

Additional Readings: 2, 6, 7, 12, 23, 25, 32, 41, 49, 59, 62, 72, 80, 85.

Juncus roemerianus - Black needlerush

Siting

Shoreline: Low energy coastal shorelines.

Soils: Irregularly inundated (10-20% of time); saturated; organic muck or sandy clay loam; pH 4.5-6.5.

Elevation/slope: MHW to high spring tide level; slope 1-5% (up to 10°).

Salinity: 5-26 ppt.

Planting Guidelines

Transplants: Remove alongside transect through young natural stands; maximum removal rate of 1-20 cm plug/m^2; prune upper 1/3 of leaves to reduce aerial transpiration.

Planting: February-March, at original soil depth within 36 hours of digging; 0.5 m - 1.0 m centers.

Fertilization: Variable results, probably not cost effective.

Seedlings: Field collect seeds in June; store refrigerated in paper bags; sow in greenhouse in November; transplant 3-5 cm seedlings to peat pots; transplant to field in April.

Note: Variable success with this species; invades new sites freely if nearby seed source; may be mixed in upper intertidal with *Spartina alterniflora* at about 1-5% of planting to allow seed source.

Additional Readings: 6, 12, 21, 23, 25, 32, 45, 49, 59, 85.

Spartina patens - Salt meadow cordgrass; Marsh hay

Siting

Shoreline: High coastal marshes.

Soils: Rarely inundated; well-drained, loose, sandy soils.

Elevation/slope: Above MHW to high spring tide level (may grade into upland); slope up to 15°.

Salinity: 5-25 ppt.

Planting Guidelines

Transplants: Field dug transplants yield poor success; best obtained from nursery stock.

Nursery stock: Harvest seeds September as in cultivated grasses, store dry in refrigerator; sow February-March in cultivated sandy soil (inland areas are suitable); field transplants may also be used to establish nursery areas in early spring; space plants 75-110 cm apart; harvest for transplanting after one growing season.

Fertilization: conventional 10-10-10 fertilizer surface broadcast at time of planting; reapplication twice during growing season.

Spacing: 0.25-.05 m centers.

Additional Readings: 6, 12, 25, 59.

Spartina cynosuroides - Giant Cordgrass

This grass occupies the upper intertidal zone of brackish marshes (5 - 15 ppt.). Transplants are best if young (20-30 cm tall) and collected from uncrowded stands which are usually scarce and difficult to find. Survival of transplants has been low. Plants may be grown from seeds in peat pots following methods described for *Spartina alterniflora* using seawater diluted to 10 ppt for seed storage. Giant cordgrass will naturally colonize elevations at MHW and up to spring high tides on brackish shorelines.

Additional Readings: 6, 12, 25, 27, 59.

Distichlis spicata - Saltgrass

Siting

Shoreline: Coastal high marsh.

Soils Wet to saturated silty sands; irregularly inundated.

Elevation/slope: MHW to above spring tides in saline soils; slope 10-30°.

Salinity: 5-20 ppt.

Planting Guidelines

Difficult to establish, but readily volunteers into areas first stabilized with other species (*Juncus roemerianus*, *S. patens*); rarely a natural dominant; may be established from peat pot grown seedlings in February, but natural colonization seems most efficient.

Additional Readings: 6, 12, 59.

Other Species

Borrichia frutescens - Sea Ox-eye

Good species to mix with dominants (*S. patens*) in high marsh for bird food and to increase diversity. Does not transplant well. Best seeded amongst other plants above MHW on saturated, silty sands early spring or fall. Light fertilization may be helpful on high pH soils and dredged material. Reseeds prolifically.

Iva frutescens - Marsh-elder

Species may be used on high marsh edge as a buffer with upland. Seeds may provide food for birds and mammals. Plant nursery stock on moist, low-salinity soils with slow release fertilizer (14-14-14) spring or fall. Tolerant of high pH soils.

Tidal Freshwater Marshes

Tidal freshwater wetlands are located upstream from tidal salt marshes. They are characterized by salinity less than 0.5 ppt and daily lunar tidal fluctuations in water level. While salt and brackish marshes are dominated by only a few plant species, freshwater marshes support a large and diverse group of plant species. Zonation is not distinctive due to complex hydrologic patterns though species may be grouped into low and high marsh communities.

Low marshes are found occupying shallow flats in the large bays and on the gently sloping shores of slower moving water courses. This zone is frequently flooded but not on a regular, predictable schedule. Though the vegetation is emergent (partially above water) at all times, the roots and lower leaves and stems are covered by water on both a seasonal basis and on a tidally influenced basis.

Sedges, grasses and rushes are often the dominant vegetation of these marshes, including panic grass (*Panicum gymnocarpon*), wild rice (*Zizania aquatica* and *Zizaniopsis miliacea*), and saw grass (*Cladium jamaicense*), as well as numerous species of beak rushes (*Rynchospora* spp.), spike rushes (*Eleocharis* spp.), umbrella sedges (*Cyperus* spp.), and rushes (*Juncus* spp.). Occasionally other plants such as alligator weed (*Alternanthera philoxeroides*), arrowhead (*Sagittaria falcata* and *S. latifolia*) or cattails (*Typha latifolia* and *T. domingensis*) are the dominant vegetation. Other plants commonly encountered in the low marsh are pennyworts (*Hydrocotyle* spp.), numerous species of false loosestrife (*Ludwigia* spp.), golden club (*Orontium aquaticum*), arrow arum (*Peltandra virginica*), swamp lily (*Crinum americanum*), marsh fleabane (*Pluchea odorata*), pickerelweed (*Pontederia cordata*) and lizard's tail (*Saururus cernuus*).

As accretion of sediments continues in the low marsh the elevation rises slightly and the marsh becomes dominated by less flood-tolerant herbaceous species. This high marsh may occur as a continuous zone between the low marsh and higher forested wetlands, as isolated patches of higher ground within the low marsh or may represent the dominant marsh type on more stable, steeper shorelines. As in the low marsh, dominant vegetation is often grasses or sedges including common reed (*Phragmites australis*), cordgrass (*Spartina cynosuroides* and *S. patens*), switch grass (*Panicum virgatum*) and *Carex hyalinolepis*.

References 78 and 79 detail the natural occurrence of these wetland types in coastal Alabama.

Because of the complexity of the plant community and scarcity of information on individual species requirements, success with creation of freshwater marshes has been limited (29). The majority of freshwater marsh creation projects have been in isolated, non-tidal environments for restoration of phosphate mine sites (42), wildlife or waterfowl management or treatment of wastewater (54) and have consisted of low diversity or single species plantings, (24,41,85) or applications of mulch from natural wetlands (69,73).

Methods for and success of creation of this wetland type are poorly represented and inadequately discussed in the literature. Preliminary results indicate that freshwater species can be established by selective planting. Species utilized with some success have included sawgrass (*Cladium jamaicense*) (85), pickerelweed (*Pontederia cordata*) (40,73), maidencane (*Panicum hemitomon*) (73), soft rush (*Juncus effusus*) (73), and arrow leaf (*Sagittaria* sp.). Details of site preparation and planting methodology are lacking in most cases. Outlines below summarize available information.

Pontederia cordata - Pickerelweed

-3 month-old greenhouse grown seedlings in peat pots
-elevations = +0.20 - 0.73 m MLW, (approximately MSL-MHW) open shoreline
-planted May
-salinity <1 ppt.
-sandy soil
-side-dress with slow release 19-6-12 fertilizer at 410 kb/ha

Cladium jamaicense - Sawgrass (84)

-scrape removal of dredge material from filled wetland
-creekside
-elevation +2 feet MSL
-5-9 in. square plugs on 1 m intervals
-early spring planting

Zizaniopsis miliacea - Giant Cutgrass

-at elevation to provide fluctuating water levels
-soils not constantly saturated
-when seed stock becomes decumbent in native stands, cut stem in sections with 2 nodes each
-plant in pots 1 node below surface, 1 above at least 20 cm deep in pots at least 15 cm wide
-bottom water to provide moisture to 5 cm in pot
-transplant to site when good leaf growth and suitable water levels
-some success with planting un-rooted cuttings directly to site
-mineral soils give best growth

Mixed transplants (*Sagittaria lancifolia, Pontederia lanceolata, Juncus effusus, Panicum hemitomon*) (42)

-reclaimed phosphate mine, isolated
-elevation = 0.87-0.88
-inundation 30-83% of time

An additional promising technique for freshwater marsh establishment involves the application of a layer of natural marsh mulch (topsoil) over the new site. Seed banks in freshwater tidal marsh soils appear to be rich in species and high in seed viability (61). Heavy equipment (tractor scrapers or bulldozers) may be used to remove the upper 10-15 cm of soil from natural marshes and spread it over the site to be planted. A dense cover of diverse species composition will be created as seeds germinate (30,69,73). Caution should be taken however to site elevation. Excessive flooding may erode the mulch and inhibit seed germination. Elevations in the mulch source wetland should be determined as a guide for new site preparation. Removal of organic topsoil from natural wetlands will destroy that marsh so source sites should be limited only to areas scheduled to be destroyed by permitted construction activities. For reasons of economy, source sites should be readily accessible and within a practical transport distance of the new site.

Freshwater species readily invade new open habitats and may colonize sites artificially stabilized by plantings of single species or low species diversity to ultimately create a community similar to natural composition. The rate and extent of colonization will be dependent upon proximity of natural seed sources and ease of transport of seeds into new sites.

Efforts to create tidal freshwater wetlands should be viewed as high risk and essentially pilot projects. For best results adjacent marshes should serve as references relative to species composition, elevations, flooding frequency and duration for designing creation projects. Plantings should be closely monitored to assess success of methodology, make mid-course corrections and determine causes of any failures. Siting near natural wetlands may enhance success through natural species invasion supplementing plantings by other establishment techniques.

Submerged Aquatic Vegetation (SAV)

Submerged grassbeds are found in the shallow (<1 m) flats of bays, small tributaries and in quiet lagoons along the margins of the larger rivers of coastal Alabama. This type represents a major wetland community of the lower Mobile-Tensaw River Delta along both sides of the Cochorane Causeway (Hwy. 90) and Interstate 10 Bayway. Oligohaline (0.5 -5 ppt. salinity) species including wild celery (*Vallisneria americana*), bushy pondweed (*Najas guadalupensis*) and slender pondweed (*Potamogeton pusillus*) comprise the greatest acreage in natural beds of the delta and coastal rivers.

In the lower Mobile Bay estuary, Mississippi Sound and Perdido Bay estuary, SAV habitats support mixed or pure stands of the marine species widgeon grass (*Ruppia maritima*) and shoal grass (*Halodule wrightii*). For locations and composition of native Alabama SAV see references 78 and 79.

Of the most frequently occurring Alabama SAV species, the existing literature provides adequate suggestions only for the establishment of wild celery (58,77). A few projects have explored the use of widgeon grass for grassbed restoration but details of the methodology are lacking.

Critical to the success of SAV planting is selection of a suitable site. Not all shallow-water sites barren of submerged grasses will suffice. Barren areas may historically have supported SAV's but an environmental (i.e., hurricanes, drought, extreme temperatures) or human-induced (i.e. pollution, changes in water clarity or hydrology) disturbance may have resulted in loss. In these situations, one should determine if the causes of loss still persist or have been removed and restoration may be possible. Sites with no history of vegetative cover may not be suitable for artificial establishment.

Important criteria in site selection include:

1. DEPTH - must be adequate to minimize or prevent dewatering and exposure during low water (especially during passage of winter cold fronts) but not too deep to reduce light levels below needs of the plants. It has been recommended that light levels of 12.5% PAR during the growing season be used to delimit the maximum depth of grassbed planting (63). In Mobile Bay, plantings of wild celery with summer depths greater than 0.75 m failed to survive and beds shallower than 0.30 m dewatered during the winter and became sparse and patchy in plant cover (77). Use the depth ranges of similar grassbeds in the area to select a depth range for planting new sites.

2. SEDIMENT - best success on fine silty sediments (20-50% silt and clay). Do not plant on unstable dredge material or polluted sediments. Coarse sediments often indicate high energy areas unsuitable for SAV establishment and persistence (26,37,57). High rates of sediment deposition may exceed ability of transplants to produce new aboveground growth and result in mortality. Rates exceeding 0.098 cm/day have caused up to 50% loss in shoalgrass planting (37).

3. WATER QUALITY - Turbidity levels may preclude adequate light for photosynthesis and reduce or eliminate SAV's. High plankton production due to high nutrients in the water may contribute to turbidity and light reduction. Turbidity levels reflect the complex site-specific interactions of nutrients, suspended sediment load, coastal non-point sources, and wind and wave resuspension of sediments and must therefore be closely examined in site selection.

4. ENERGY LEVELS - Averages and extremes of currents and waves affect the ability of plants to persist and may structure the configuration of a successful project. SAV's are only patchy in higher energy environments and cannot persist where waves or currents are strong. Erosion of 1-2 mm/day of sediment around plants by waves or currents may cause 50% or more loss of transplants.

5. SALINITY - Species specific.

   wild celery - 0-3 ppt.
   water stargrass - 0-3 ppt.
   widgeon grass - 10-25 ppt.
   shoalgrass - 20-40 ppt.

Potential sites should be surveyed for critical conditions for 1 to 2 months prior to scheduled planting (see Table 2). The following choices for restoration sites are given in order of preference:

1. restore areas previously impacted by poor water quality that once had seagrass, and the water quality has improved,

2. convert filled or dredged areas that were once seagrass meadows back to original elevation and transplant onto them,

3. convert filled or dredged areas, irrespective of their previous plant community, to a suitable elevation for seagrass.

It is recommended that small pilot plantings be used to test the suitability of a site before major projects are undertaken. Sites with no history of SAV coverage should be considered very risky and avoided unless pilot plantings indicate high potential for success.

Table 2. Recommended limits for the major environmental factors identified as influencing SAV transplants (From 87).

Environmental Factor	Effect(s)	Abbreviated Monitoring Methodology	Duration of Monitoring	Recommended Limits
Temperature and Salinity	Temperature: planting season in relation to stress season. Salinity: geographic limit in the estuary.	Thermometer and salinometer or refractometer	Biweekly for at least one lunar cycle before planting.	Temperature: maximize growth time to next stress period. Salinity: 0-3 ppt. for wild celery; 10-25 ppt. for widgeon grass; 20-40 ppt. for shoalgrass.
Light-depth Interaction	Upper and lower depth limits of transplant survival.	Calculate attenuation coefficients with PAR-measuring instrument or observe depth range of contiguous seagrass population.	Biweekly...	Upper: mean low, low water. Lower: 12.5% of incident PAR avg. during monitoring
Currents	Site design, logistic problems of planting, PU growth response.	Maximum surface velocity using repeated measures of commercial flowmeter or floating log timings.	Over full tidal cycle at full moon (flood and ebb).	Upper only: 120 cm/sec.
Sediment Characteristics	Growth response: especially on new dredged material and chemically polluted sediment.	Monitor containment of dredged material. Suspected chemical pollutants; analyze especially for herbicides by standard methods.	Dredged material: 1 month for suspected chemical pollution. At least 1 sample with replication.	Let dredged material set at least 1 month. Chemical pollution, no known limits.
Sediment Fluctuation	PU survival	Measure absolute change (+/-) in sediment surface height relative to a fixed datum.	50 days before planting.	Less than 0.098 cm/day.

General references for additional reading include (34, 35, and 38).

Planting Suggestions

Similar methodologies for the transplanting of wild celery, in fresher water (0-3 ppt.), and shoalgrass in marine water (20-40 ppt.) have met with some success. Alabama plantings of wild celery using the following methods resulted in >75% survival and complete cover in two seasons.

1. Dig transplants from robust natural beds in mid to late spring (late April-May) as soon as new leaf production is well underway. Excavate to approximately 10 cm. making sure rhizomes, good root systems and new shoots are collected. Removal rate not to exceed 3 plugs per m^2.

2. Gently rinse away sediment at source site as collected. Store under moist cloths or newspaper until replanted (not longer than 24 hours) in wash tubs or trash can.

3. Prepare planting units (PU) by selecting 3-6 shoots of wild celery, 10-15 for shoalgrass, with growing tips, wrap bundle of shoots with light card stock band (cut file cards) just above rhizomes and secure with paper covered twist tie.

4. Insert a wire anchor (coat hanger wire) approximately 20 cm. with "L" or "U" shaped top through bundle (Figure 4).

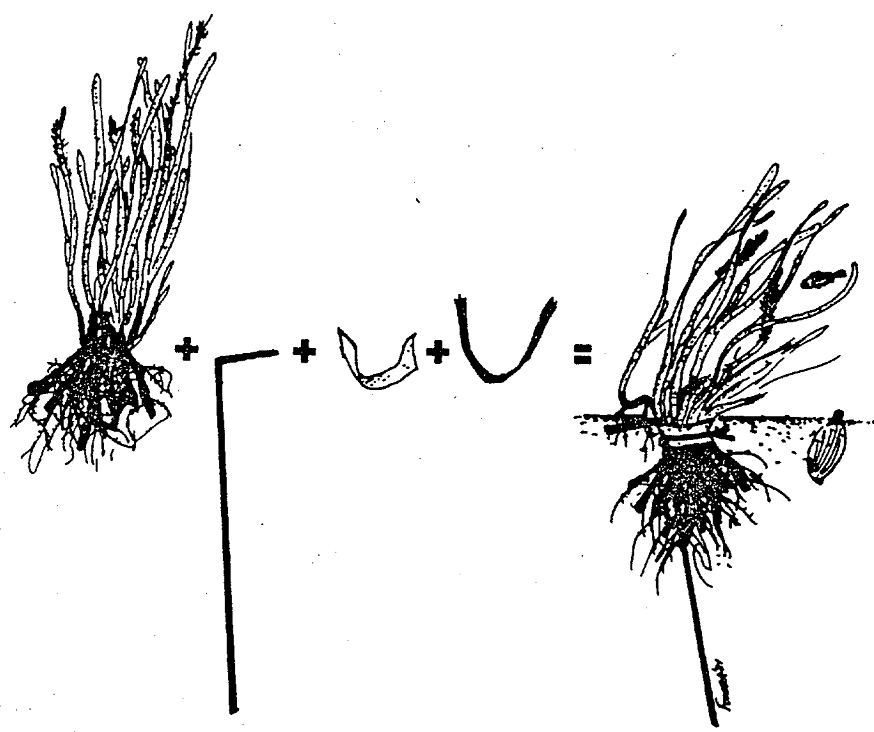


Figure 4. Breakdown of the components of a planting unit for use in all habitats (From 37).

5. Hand plant with small spade or dive knife; bury to cover all bleached non-pigmented tissue; 0.25-0.5 m centers; if currents exceed 50 cm/sec/daily expand spacing 10% on axis perpendicular to current flow and reduce 10% along major axis of current flow. (Plants tend to propagate more readily in a direction normal to the flow axis. Fonseca et al. 1985 (37) provide guidelines for estimating plant numbers of shoalgrass needed and costs of transplanting. Although their information is from the east coast it may be helpful in estimation. Additional anchoring methods may be employed such as attachment to wire frames or using long wire "staples" to hold down small sod blocks of grass (25 and 37).

6. At some sites it may be necessary to protect plants from grazing or uprooting by fish and invertebrates. To determine the potential disruption by animals, pilot plantings can be monitored before the major planting. If necessary light mesh fencing may be used to surround the beds until plants get established (70).

Two additional species have potential and plantings have met with limited success in establishing SAV beds. Widgeon grass sprigs comprised of lengths of rhizome with several shoots and a terminal bud may be "stapled" to the sediment or sod plugs planted in brackish waters of 10-25 ppt.

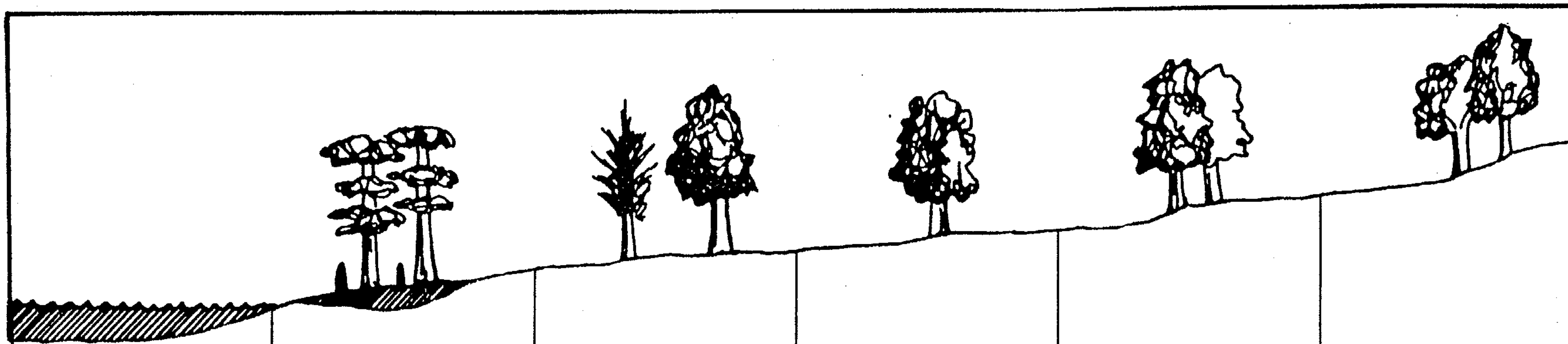
Cuttings of water stargrass (*Heteranthera dubia*) were propagated in the greenhouse in a Chesapeake Bay project. After reaching about 30 cm in height, transplants to field sites with high silt content exhibited good growth and flowered at the end of the first growth year. Stargrass is locally abundant in low salinity areas of coastal Alabama (0-5 ppt.). The plants have high growth rates and abundant foliage which may dampen wave or current energy and trap sediments. Kollar (57) suggests that stargrass may be tried in mixed plantings with wild celery to assist in early bed stabilization and increase diversity in the new bed.

Forested Wetlands - Swamps

Within the coastal zone of Alabama, forested wetlands occur primarily within the riverine floodplains of the Mobile-Tensaw River Delta and to a lesser extent, along tributary rivers feeding into the estuaries. Other wetlands dominated by trees and shrubs may be found isolated from rivers and receiving water from groundwater or surface flow. This group of wetlands is variously called bottomland hardwood forests, swamps or freshwater forested wetlands.

The plant species composition of wetland forests is complex and variable and is strongly influenced by the degree of flooding or inundation during the growing season and hydric soil characteristics. Over 100 species of woody plants occur in these periodically flooded areas, and all exhibit varying degrees of adaptation for survival in poorly-drained and poorly-aerated soils. Thus depending upon the interaction of many ecological factors, one can encounter a variety of communities on hydric soil associations. These may range from the very wet [e.g. bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*)], to moderately wet [e.g. overcup oak (*Quercus lyratta*) and water hickory (*Carya aquatica*)], to somewhat drier [e.g. American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), hackberry (*Celtis occidentalis*)], to even drier sites [e.g. live oak (*Quercus virginiana*), loblolly pine (*Pinus taeda*)], which may be inundated only about a week during the growing season (19). Figure 5 illustrates potential zonation in forested wetland types in coastal Alabama and extensive species lists have been compiled (see 78 and 79).

In contrast to marshes, forested wetland replacement is more complicated and requires a much longer development period. The complexity of these systems is severalfold: the diversity of the plant communities, variable hydrology, and narrow species tolerances. A wide variety of



Zone	Aquatic ecosystem		Bottomland hardwood ecosystem	Floodplain		Bottomland upland transition
	I	II	III	IV	V	VI
Name	Open water	Swamp	Lower hardwood wetlands	Medium hardwood wetlands	Higher hardwood wetlands	Transition to uplands
Water modifier	Continuously flooded	Intermittently exposed	Semipermanently flooded	Seasonally flooded	Temporarily flooded	Intermittently flooded
Flooding frequency Years/100	100	~100	51 - 100	51 - 100	11 - 50	1 - 10
Flooding duration, % of growing season	100	~100	> 25	12.5 - 25	2 - 1.25	< 2
Common Species	SAV, Marsh	Cypress Water tupelo	Green ash Water hickory Overcup oak Black willow	Sycamore Sweet gum Willow oak	Cherrybark oak Swamp Chestnut Oak	White oaks Black gum Hickories Loblolly pine

Figure 5. Zonation in southeastern forested wetlands.

forest establishment techniques have been employed but not yet developed with repeatable precision. Efforts thus far have been directed at vegetational establishment (mostly hardwoods and cypress). Functional equivalency has yet to be addressed for forested wetland projects. Prolonged establishment periods and largely unproven methodologies have generated caution from both the regulatory community and agencies supporting forest projects.

In the southeastern United States, there have been two concentrations of effort in forested wetland replacement. The first has been the reforestation of bottomlands that were cleared for agriculture and later abandoned, especially in the Mississippi Delta. The focus there has been to establish a forest canopy of selected tree species, particularly of oaks and other heavy-seeded trees with limited dispersal. Trees of other species and all undergrowth plants are ignored or are expected to become established by natural regeneration. The overriding concern is to produce a tree canopy over large tracts of land through application of silviculture approaches. The second kind of replacement has been associated with surface mining, primarily for phosphate in central Florida. There, the projects are intensive and restricted to small tracts on reclaimed lands. Plantings attempt not only to replace the full spectrum of tree species but also undergrowth components, with considerable attention given to establishing the appropriate hydrology and hastening soil development. Projects are too young at this time to assess the efficacy of the methods and status of habitat development.

Goals and Planting

Forested wetlands habitat development should be directed toward maximizing landscape diversity within the constraints imposed by land use. An assortment of community types and a high degree of intermixture, or edge, tends to increase an area's opportunity to attract and support any given species, and will result in a more diverse and sustained level of wildlife use. As the site ages, patches of forest and swamp vegetation should emerge which will further increase the site's landscape diversity and attract new, woodlands oriented wildlife species.

The establishment of diverse community types within a forested wetland area is an important consideration for improving the habitat value of individual sites. Shallow and deep open water areas intermixed with seasonal mud flats, herbaceous emergent zones and shrub swamps, provide alternative feeding areas, escape cover and nesting or roosting habitat for wetland wildlife. Fish populations are also benefited by access to productive emergent zones, littoral bedding areas and deep water refuges.

Insuring full utilization of areas developed as wildlife habitat may require special measures to increase their accessibility to species with limited dispersal mechanisms. Isolated habitats surrounded by relatively inhospitable land will populate more slowly and may never develop a trophic structure as complete as that in similar habitats interconnected by heavily vegetated travel corridors, or on areas in close proximity to undisturbed land.

Forested wetland habitat planning involves the complicated process of designing an appropriate hydrologic setting which will insure each area a proper water supply. The planning unit in this case is the drainage area. it encompasses all areas which will supply or receive water from the wetland basin and is not necessarily restricted to the particular site in question. Similarly, the range of habitat design options in each area is constrained to a large extent by the distribution and moisture holding characteristics of soil materials and the desired utilitarian functions of the drainage area. Table 3 indicates the range of physiochemical characteristics of the zones of typical natural forested wetland.

Table 3. Physiochemical characteristics of floodplain soils by zones as in Figure 5 (From 87).

Characteristic	*Zone* *II*	*III*	*IV*	*V*	*VI*
Soil Texture	Dominated by silty clays or sands	Dominated by dense clays	Clays dominate surface; some coarser fractions (sands) increase with depth	Clay and sandy loams dominate; sandy soils frequent	Sands to clay
Sand:Silt:Clay (% composition)					
Blackwater	69:20:12	-	74:14:12	-	-
Alluvial	29:23:48	34:22:44	34:20:45	71:16:14	-
Organic Matter, %					
Blackwater	18.0	-	7.9	-	-
Alluvial	4.5	3.4	2.8	3.8	-
Oxygenation	Moving water aerobic; stagnant water anaerobic	Anaerobic for portions of the year	Alternating anaerobic and aerobic conditions	Alternating: mostly aerobic, occasionally anaerobic	Aerobic yearround
Soil Color	Gray to olive gray with greenish gray, bluish gray, and grayish green mottles	Gray with olive mottles	Dominantly gray on blackwater floodplains and reddish on alluvial with brownish gray and grayish brown mottles	Dominantly gray or grayish brown with brown, yellowish brown, and reddish brown mottles	Dominantly red, brown, reddish brown, yellow, yellowish red, and yellowish brown, with a wide range mottle colors

Table 3. Continued.

	Zone				
Characteristic	*II*	*III*	*IV*	*V*	*VI*
pH					
Blackwater	5.0	-	5.1	-	-
Alluvial	5.0	5.3	5.5	5.6	-
Phosphorus (ppm)					
Blackwater	11.2	-	9.8	-	-
Alluvial	9.1	6.3	8.1	4.8	-
Calcium (ppm)					
Blackwater	607	-	346	-	-
Alluvial	1,079	752	669	186	-
Magnesium (ppm)					
Blackwater	98	-	36	-	-
Alluvial	154	140	145	39	-
Sodium (ppm)					
Blackwater	46	-	31	-	-
Alluvial	94	31	28	23	-
Potassium (ppm)					
Blackwater	48	-	29	-	-
Alluvial	51	28	32	20	-

Forested wetlands can be situated either above or below the mean water table, and can be either isolated or hydrologically connected to a lake or stream system. Their water will be supplied by ground water seepage, by rainfall catchment, surface runoff within the drainage area and flooding from adjacent water bodies. Figure 5 illustrates variations in flooding patterns by zones.

Swamps perched above the mean water table tend to loose water through soil infiltration and generally will have a more erratic and wider-ranging hydroperiod than a similarly sized basin located closer to or below the average water table. In other words, ground water seepage can compensate for surface water losses due to evaporation and plant transpiration, and thereby moderate the fluctuations inherent in seasonal rainfall patterns. Soil permeability, of course, will ultimately affect the rate at which ground and surface waters can be exchanged, and therefore must be considered when planning an area's water budget. For recommended site selection parameters see Table 4 and details in reference 5.

Water supply is also affected by exchanges with contiguous or hydrologically connected lake or stream systems. In turn, the wetland will affect both the quality and supply of water to that lake or stream. Consequently, wetlands have a utilitarian role affecting cultural water supplies which will usually influence the planning decisions for each drainage area. Cultural benefits derived from wetlands include their contributions to water quality by plant nutrient uptake and reduce turbidity caused by their capacity to reduce stream flow, their stabilization of shorelines by buffering wave action, and their capability of reducing floods by retention of storm surges.

As these various planning considerations indicate, the development of a final, detailed project plan is highly constrained by the characteristics and setting of each site, and by the land use, habitat and utilitarian roles desired. While there is no "cookbook" which details specific options for each site, there are a number of procedural considerations which have emerged which can assist in the development of individual, site-specific plans.

Site Preparation

Onsite preparation activities include earth moving, subsized revegetation and any follow-up procedures for assisting in the protection and maintenance of the emerging habitats. Basins should be contoured to create the desired wetland surface area within the range of elevations over which the water is expected to fluctuate. The assistance of a hydrologists or soil scientist (or both) may be necessary.

Accurately predicting the range of surface water level fluctuation can be a difficult planning problem, and a reasonable estimate is the best that can be achieved in many instances. However, on sites where an overflow discharge capability can be arranged, the height of the outfall will establish an interim high water line for the basin and allow for more accurate planning. A temporary control structure would be useful since this would permit necessary adjustments in the basin's storage capacity prior to contouring a permanent, self-maintaining outfall swale.

To promote a diversity of community types, and to increase shoreline edge, contours should be varied throughout and below the zone of fluctuation. When utilizing hydrologically connected wetlands to optimize a lake or stream system for fish production, care should be taken to insure that these shallow sub-basins will not become isolated prior to their natural annual drawdown. Deep connecting channels constructed at or below the base elevation of each subbasin, will insure a continuous water body year-round, and allow the fish population access to deep water refuges during periods of surface water decline. On the other hand, wetlands

Table 4. Factors in site selection for southern hardwood trees (From 5).

Factor 1. Physical Condition	Factor 2. Moisture availability	Factor 3. Nutrient Availability	Factor 4. Aeration
Soil-site Property	Soil-site Property	Soil-site Property	Soil-site Property
1. Soil depth and presence of artificial or inherent pan	1. Water table depth	1. Geological source	1. Soil structure (in rooting zone)
2. Texture (in rooting zone)	2. Artificial or inherent pans	2. Past use and present cover	2. Swampiness
3. Compaction (in surface foot)	3. Topographic position	3. Organic matter (A-horizon)	3. Mottling
4. Structure (in rooting zone)	4. Microsite	4. Depth of topsoil (A-horizon)	4. Soil color
	5. Structure (in rooting zone)	5. Soil age 5. Past use and present cover	(in rooting zone)
	6. Texture (in rooting zone)	6. pH (in rooting zone)	
	7. Flooding		
	8. Past use and present cover		

which become isolated at low water, but which are continuous with permanent water during the wet season, have the capacity to trap and concentrate fish so that they can be readily consumed by birds and other predators.

Vegetation Establishment

Methods of plant subsidy include transplanting of whole plants or viable plant parts, direct-seeding and mulching with topsoil and litter from a native community. In planning a planting program, the selection of species should be limited to those which are native or those which otherwise are particularly valuable food or cover producers. They should also be species which are not expected to quickly colonize a site on their own. Generally, as the distance of a site from the potential seed source or donor community increases, the amount of plant subsidy needed increases. Trees are always likely candidates for planting since their seed production and dispersal mechanisms are generally more deficient than those of herbs or shrubs, and since forest and swamp communities are major contributors to landscape and wetland diversity. Trees selected for planting should include an assortment of conifers and hardwoods which are compatible with the soil conditions onsite.

To maximize the distribution of individuals over the planting area, small, easily transported propagules are the most effective. For example, tree seedlings may be more effective than larger trees. However, for species which are proficient seed producers, planting of whole, mature individuals can be an effective method of providing an onsite seed source. Automation of the labor-intensive planting methods where possible improves efficiency and reduces reclamation costs. Planting bare-root seedlings, using a tractor-mounted planter; discing tubers, rhizomes and other marsh plant parts; and direct-seeding conifer and hardwood trees using a helicopter or tractor can be useful techniques for habitat establishment projects.

Establishing the species in its appropriate moisture zone will strongly influence ultimate success. Seedlings show notably variable planting success relative to the inundation zone in which they are established. In instances where the various moisture zones are not adequately predictable at the conclusion of contouring, it may be beneficial to delay the planting effort for a complete growing season to allow the passively establishment species to indicate appropriate planting areas. Flooding tolerance of common species are provided in Table 5 and 6. (See also Figure 5).

After a site is constructed, contoured and planted, passive seed dispersal by wind, water and animal carriers may gradually establish a vegetation cover and help form distinct wetland community types within appropriate inundation zones. However, self-dispersal and site compatibility are highly species-specific. Furthermore, the number of species which may eventually colonize a site is largely dependent on: (1) the distance of individual sites from a natural seed source; (2) the nearby natural plant community type (marsh, uplands, etc.); and (3) the dispersal mechanisms or aggressiveness of the species. Where possible, the location of reclamation sites near native undisturbed communities maximizes the potential for re-vegetation by natural plant succession.

The developing plant communities on new sites should be protected from grazing and mowing. The upland and emergent communities which initially develop have considerably more wildlife value than a pasture or manicured lawn. However, this early successional vegetation has a large percentage of annual herbs and shrubs which can be highly combustible during the dry season. Fire lines should be established and maintained for at least several years to help protect emerging forest and swamp areas from periodic fires which could damage or destroy young trees.

Table 5. A comparison of water-tolerance ratings for selected forested species.

	NWI Status[a]	Waterlogging Tolerance Rating Group[b]
Nyssa aquatica (Water tupelo)	OBL	Most
Cephalanthus occidentalis (Buttonbush)	OBL	Most
Salix nigra (Black willow)	OBL	Most
Fraxinus caroliniana (Water ash)	OBL	Most
Taxodium distichum (Cypress)	OBL	Most
Forestiera acuminata (Swamp privet)	OBL	Most
Gleditsia aquatica (Water locust)	OBL	Highly
Carya aquatica (Water hickory)	OBL	Highly
Quercus lyrata (Overcup oak)	OBL	Highly
Betula nigra (River birch)	OBL	Moderately
Diospyros virginiana (Persimmon)	FAC	Moderately
Acer rubrum (Red maple)	FAC	Moderately
Fraxinus pennsylvanica (Green ash)	FACW	Moderately
Ulmus americana (American elm)	FACW	Moderately
Quercus phellos (Willow oak)	FACW	Moderately
Carpinus caroliniana (Ironwood)	FAC	Weakly
Celtis laevigata (Sugarberry)	FACW	Moderately
Liquidambar styraciflua (Sweetgum)	FAC+	Moderately
Carya illinoensis (Pecan)	FAC+	Weakly
Pinus taeda (Loblolly pine)	FAC	Moderately
Cornus florida (Dogwood)	FACU	Least
Fagus grandifolia (Beech)	FACU	Least
Quercus alba (White oak)	FACU	Least
Sassafras albidum (Sassafras)	FACU	Least

Notes: [a]Taken from Reed (1986) (68), see Table 6A.
[b]Taken from Hook (1984)(48), see Table 6B.

Table 6. Definitions for Table 5.

A. Definitions for National Wetland Inventory (From 48).

Obligate (OBL). Always found in wetlands under natural (not planted) conditions (frequency greater than 99 percent), but may persist in non-wetlands if planted there by man or in wetlands that have been drained, filled, or otherwise transformed into non-wetlands.

Facultative Wetland (FACW). Usually found in wetlands (66-99 percent frequency), but occasionally found in non-wetlands.

Facultative (FAC)≥. Sometimes found in wetlands (33-66 percent frequency), but also occurs in non-wetlands.

Facultative Upland (FACU). Seldom found in wetlands (1-33 percent frequency) and usually in non-wetlands.

Non-wetland (UPL). Occurs in wetlands in another region, but not found (< 1 percent frequency) in wetlands in the region specified. If a species does not occur in wetlands in any region, it is not on the list.

B. Definitions for Waterlogging Tolerance Rating (From 68).

Most Tolerant. Those species that are capable of living from seedling to maturity in soils that are waterlogged almost continually year after year except for short durations during droughts. The soils are typically anaerobic in character but are less so where the water is moving. Some species in this group adapt by producing soil water roots that oxidize their rhizosphere, accelerate anaerobic metabolism but at a controlled rate and tolerate the toxic compounds typical of highly reduced waterlogging soils.

Highly Tolerant. Those species capable of living from seedling to maturity in soils that are waterlogged for 50 to 75 percent of the year. Waterlogging typically occurs during the winter, spring and 1-3 months of summer.

Moderately Tolerant. Those species capable of living from seedling to maturity in soils waterlogged about 50 percent of the time. Waterlogging typically occurs in portions of the winter, spring, and early summer.

Weakly Tolerant. Those species that are capable of living from seedling through maturity in soils that are temporarily waterlogged for durations of 1-4 weeks and usually accounting for 10 percent of the growing season.

Least Tolerant. Those species that are capable of living from seedling through maturity in soils that are occasionally waterlogged for durations of a few days only, usually accounting for less than 2 percent of the growing season.

Planting Suggestion - Direct Seeding

Wetland establishment by direct seeding has several advantages over transplants. Seeding requires less labor, is faster and may thus cost 25-30% of the costs of other methods. Some sites may be suitable for tractor-pulled planters yielding more efficient and economic planting. Through collection of native seeds and commercial sources there is a greater number of species available. Many species can be successfully sown both fall and spring providing a longer planting period. With seeds, plants are not traumatized by digging, pruning and root disturbance which may retard initial growth.

However, seeding also may have drawbacks which must be considered. Germination is directly controlled by the hydrologic period, requiring seasonal draining and flooding. None of the forested wetland species will germinate if permanently flooded. The hydroperiod must be managed and species selected to optimize germination rates. An additional germination requirement of many species is full sunlight, so combined seeding and transplanting designs should include layouts with open plots for seeding. It may also be necessary to remove competitors by mowing or discing until young trees are taller than competitors. There may be considerable loss of seeds due to seed predators and protection may be necessary. Some success in reducing loss to animals has been noted when sites were large and open without cover for the animals.

Seed collection and storage: Collection should be done October-January, but collection time for each species should be only after seeds are mature and fruits are ready to be shed or immediately after shedding. Eliminate any seeds which appear discolored or have signs of insect damage. Seeds can be separated into two groups based upon general handling requirements.

The moisture content of acorns is the key to maintaining quality. At full maturity acorns contain about 40-50 percent moisture. A loss of about 5 percent moisture can be tolerated, but a drop of 15 percent usually means loss of viability. During collection, random acorns should be cut open to check moisture conditions. If the cotyledons are dry and/or shrunken, the acorns should be rehydrated in a tub of water. All acorns collected can be floated in water with frequent stirring for up to 24 hours. Any acorns which float should be discarded. Only sinkers should be retained.

Place acorns in 4-6 ml thick polyethylene bags, tie the bags shut, and put in cold storage (35-40° F). Red oak species may be stored at least 3 years, but white oak acorns can only be stored for several months. It is best to sow white oak within a couple of months of collections instead of trying to store them.

Species with smaller seeds (i.e. sweetgum, sycamore, yellow-poplar and ash), are usually dried to low moisture content for extraction and storage. After collection, fruits should be spread in a single layer for drying. Piles of green fruits overheat, and seed quality is lost quickly. If dried outdoors on sheets, full sunlight is sufficient. Indoors drying on screens or shelves can be improved by use of fans to increase air movement. As soon as dried multiple fruits are open or disintegrating, they should be tumbled (sweetgum) or broken up by maceration (sycamore and yellow-poplar). A Dybvig macerator works well. Loose seeds should be dried to moisture contents of 6-10 percent and stored in airtight containers at 4° C. Storage at colder temperatures (-18° C) may preserve viability up to 10 years or more.

Requirements for stratification in cold (2° C) moist conditions prior to planting vary. Sycamore has no dormancy and does not require stratification for spring planting, but a short 1 to 2 week stratification may improve rate and uniformity of emergence. Sweetgum should be stratified for 30 days prior to spring planting. Ash and yellow-poplar require at least 60 days of stratification. Fall sowing may be best for these species.

Seeding: Site preparation to reduce competing vegetation is desirable. Methods include burning, mowing and discing. Seeding is easier and done better on extensively prepared sites, but the nature of the site and costs of preparation may limit the extent of this step.

Seeding may be done with mechanical seeders or by hand. Acorns are adaptable to either, but smaller seeded species may be best sown by hand. Seeds should be planted 2-4 inches deep for best germination and to inhibit some animal damage. Time of sowing is more dependent on site hydrology than season and may be accomplished for most species from spring through fall, when surfaces are moist, but drained of standing water. Young plants should have a period of establishment before flooding occurs.

Additional Readings: 3, 5, 8, 9, 10, 20, 42, 43, 44, 47, 48, 50, 81

<u>Planting Suggestions - Seedlings/Transplants</u>

Although it is possible to transplant young seedlings of wetland trees or shrubs from natural stands, this approach is labor intensive and even with great care may be traumatic enough to the plants that survival is low. Nursery stock from commercial sources or developed specifically for the project may yield better results. With exceptions of cottonwood, sycamore, yellow poplar and some of the oaks, hardwood planting results have been highly variable. Lack of success has often been attributed to the quality of seedlings planted, lack of adequate site preparation, and failure to control competing vegetation (47). Animal damage control may also be needed in many areas.

Species appropriate to the goals of the project and hydrologic conditions of the site should be selected (see previous discussions). Vigorous seedlings of good size should be used. Root-collar diameters should not be smaller than 0.25 inches and preferably 0.30 inches or more. Heights of 24 to 30 inches are desirable. Care should be taken to prevent roots from drying or freezing. General planting guidelines are given in Table 7.

Additional Readings: 3, 5, 24, 30, 41, 44, 47, 48, 81.

<u>Natural Revegetation</u>

Natural revegetation may be passively employed, especially to restore degraded or perturbed wetlands. Sites which should be considered for natural revegetation are:

1.Those that are narrow and no greater than two tree heights from surrounding seed sources.

2.Those exposed to flood waters bearing seeds.

3.Those in which the original soil and hydrological regime have suffered little or no alteration. Undisturbed soils are often revegetated from sprouts of cut trees or soil seed banks.

Table 7. Hardwood and cypress planting information.

Species and form of stock	Prune roots to: (in)	Good top length[b/] (in)	Adaptable to machine planting	Usual first-year growth	Survival on wet sites	Animal damage	Insect damage
Cottonwood cuttings	—	20[c/]	Yes	Good	Very poor	Deer, beaver	Borers, leaf beetles
Cottonwood seedlings	8	24	Yes	Good	Very poor	Deer, rodents, beavers	Borers, leaf beetles
Sweetgum seedlings	8	24[d]	Yes	Poor	Poor	Rabbits, deer, rodents, beavers	Forest tent caterpillar
Green ash seedlings	8	24	Yes	Good	Good	Rabbits, rodents, beavers	Ash borer, fall webworm
Sycamore seedlings	8	24	Yes	Poor to good	Poor	Deer	Sycamore lace-bug, bagworm[g/]
Sycamore cuttings	—	20[e/]	Yes	Poor to good	Very poor[f/]	Deer	Sycamore lace-bug, bagworm[g/]
Yellow-poplar seedlings	8	24	Yes	Good	Very poor	Deer, rodents	Tuliptree scale
Oak seedlings	8	24[d/]	Yes	Poor to fair	Nuttall, willow, water, overcup, others very poor	Rabbits, rodents, beavers	Twig girdlers, cicadas
Black walnut seedlings	8	15	Probably	Poor	Very poor[f/]	Rodents	Walnut caterpillar
Water tupelo seedlings	8	24	Site may prohibit	Fair	Good	Deer	Forest tent caterpillar
Baldcypress seedlings	8	24	Site may prohibit	Fair to good	Good	Rabbits	Spider mites, bagworm
Sweet pecan	8	18	Yes	Poor	Poor	Deer, rabbits, beavers	

[a/] McKnight and Johnson (1980) from Bonner, F. T. 1965. Seeding and Planting Southern Hardwoods. Auburn University Hardwood Short Course Proc. 1964: 28-40.

[b/] Determined mainly on basis of handling ease. All species can be top-pruned except ash, which forks because of its opposite-bud morphology. Root collar diameter should be 3/8" or larger.

[c/] May be shorter on sites where drought never occurs.

[d/] Seedlings should not be lifted from nursery until leaves have fallen off.

[e/] Only basal cuttings seem to root well.

[f/] Very exacting in site requirements; plant only on moist, well-drained soils.

[g/] The disease Anthracnose can be serious in localized areas.

Species richness from natural regeneration may be inadequate especially if seeds reaching the project site represent only a few species. Plantings of additional species may be appropriate to establish desired community composition and diversity. It should not be expected that a near natural community can be achieved by natural regeneration processes alone.

Additional Reading: 21, 43.

PLANT MATERIAL SOURCES

All plant materials used in planting projects should come from as near the project site as possible. If materials are purchased from commercial sources they should be from stock (seeds or cuttings) native to the geographic region of the project. Genetic and ecological variability of non-native sources often results in project failure due to different environmental tolerances and climatic adaptations. Nursery or greenhouse produced materials should be acclimated to field conditions (especially temperature and salinity) before planting.

Listings of sources of plant materials can be found in the following:

Allen, J. A. and H. E. Kennedy, Jr. 1989. Bottomland hardwood reforestation in the lower Mississippi valley. 29 p.

U. S. Forest Service
Southern Hardwoods Laboratory
P.O. Box 227
Stoneville, MS 38776

Association of Florida Native Nurseries. No date. Plant and service locator.

Central Florida Native Flora, Inc.
Keifer Road, P.O. Box 1045
San Antonio, FL 33576-1045
(904) 588-3687

Environmental Concern, Inc. [1]-Shrubs and trees for wildlife habitat development; [2]Plants for landscaping shores, ponds and other wet areas.

Environmental Concern, Inc.
P.O. Box P
210 West Chew Avenue
St. Michaels, MD
(301) 745-9620-2082

Florida Sea Grant. No date. Commercial sources of salt-tolerant vegetation in Florida. 3p.

Florida Sea Grant Program
Building 803
University of Florida
Gainesville, FL 32611

Soil and Water Conservation Society. 1987. Sources of native seeds and plants. 36 p. $3.

Soil and Water Conservation Society
7515 Northeast Ankeny Rcad
Ankeny, IO 50021

Soil Conservation Service. 1978. Plants for a purpose. 11 p.

U. S. Soil Conservation Service
Plants Materials Center
Coffeeville, MS

REFERENCES CITED

1. Allen, H. H., S. O. Shirley and J. W. Webb. 1986. Vegetative stabilization of dredged material in moderate to high wave-energy environments for created wetlands. Pp. 19-35, in, F. J. Webb (ed.), Proc. 13th Ann. Conf. Wetlands Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL.

2. Allen, H. H., J. W. Webb and J. O. Shirley. 1984. Wetlands development in moderate wave-energy climates. Pp. 943-955, in, Proc. Conf. Dredging '84, Waterway, Port Coastal and Ocean Division, ASCE/Nov. 14-16, 1984, Clearwater Beach, FL.

3. Allen, J. A. and H. E. Kennedy, Jr. 1989. Bottomland hardwood reforestation in the lower Mississippi valley. U. S. Fish Wildl. Serv., Slidell, LA and U. S. Forest Serv., Stoneville, MS 29 p.

4. Association of Florida Native Nurseries. No Date. Plant and service locator.

5. Baker, J. B. and W. M. Broadfoot. 1979. A practical field method of site evaluation for commercially important southern hardwoods. U. S. Forest Serv. Gen. Tech. Rept. 50-26, New Orleans, LA. 51 p.

6. Barnett, M. R. and D. W. Crewz. 1990. An introduction to planting and maintaining selected common coastal plants in Florida. Florida Sea Grant Report No. 97. 108 p.

7. Beeman, S. 1983. Techniques for the creation and maintenance of intertidal saltmarsh wetlands for landscaping and shoreline protection. Pp. 33-41, in, F. J. Webb (ed.). Proc. 10th Ann. Conf. on Wetland Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL.

8. Bonner, F. T. 1977. Handling and storage of hardwood seeds. Pp. 145-152, in, Proc. 2nd Symp. on SE Hardwoods, U. S. Forest Serv. State and Private Forestry, Atlanta, GA.

9. Bonner, F. T. 1986. Good seed quality - how to obtain and keep it. Pp. 31-36, in, Northeastern Area Nurserymen's Conf., State Coll., PA.

10. Bonner, F. T. and J. A. Vozzo. 1985. Seed biology and technology of *Quercus*. U. S. Forest Serv. Gen. Tech. Rept. 50-66, New Orleans, LA. 21 p.

11. Broome, S. W. 1985. Elevation, moisture, and fertilization affect restoration of brackish water marshes (North Carolina). Restoration and Management Notes 3(1):36-37.

12. Broome, S. W. 1989. Creation and restoration of tidal wetlands of the southeastern United States. Pp. 37-72, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.

13. Broome, S. W., E. D. Seneca and W. W. Woodhouse, Jr. 1982. Establishing brackish marshes on graded upland sites in North Carolina. Wetlands 2:152-178.

14. Broome, S. W., E. D. Seneca and W. W. Woodhouse, Jr. 1986. Long-term growth and development of transplants of the salt-marsh grass *Spartina alterniflora*. Estuaries 9(1):63-74.

15. Broome, S. W., E. D. Seneca and W. W. Woodhouse, Jr. 1988. Tidal salt marsh restoration. Aquat. Bot. 32:1-22.

16. Carter, V. 1986. An overview of hydrologic concerns related to wetlands in the United States. Can. J. Bot. 64:364-374.

17. Carter, V. and N. B. Rybicki. 1985. The effects of grazers and light penetration on the survival of transplants of *Vallisneria americana* Michx. in the tidal Potomac River, Maryland. Aquat. Bot. 23:197-213.

18. Chabreck, R. H. 1989. creation, restoration and enhancement of marshes of the north central gulf coast. Pp. 127-144, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.

19. Clark, J. R. and J. Benforado. 1981. Wetlands of bottomland hardwood forests. Elsevier, Amsterdam. 401 p.

20. Clewell, A. F. and R. Lea. 1989. Creation and restoration of forested wetland vegetation in the southeastern United States. Pp. 199-327, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.

21. Coultas, C. L. 1980. Transplanting needlerush (*Juncus roemerianus*). Pp. 117-124, in, R. R. Lewis, III (ed.), Creation and restoration of coastal plant communities. CRC Press, Inc., Boca Raton, FL. Proc. 7th Ann. Conf. on the Restoration and Creation of Wetlands, Hillsborough Community College, Tampa, FL.

22. Cutshall, J. R., R. Glennon and L. T. Biles. 1989. Vegatative propagation of giant cutgrass for fesh marsh erosion control. pp. 239-241, in W. G. Duffy and D. Clark (eds.), Marsh management in coastal Louisiana: Effects and issues--Proc. of a Symp. U.S. Fish. Wildl. Serv. & LA Dept. Nat. Res., U.S. Fish Wildl. Serv. Biol. Rept. 89(22). 378 p.

23. Darovec, J. E., Jr., J. M. Carlton, T. R. Pulver, M. D. Moffler, G. B. Smith, W. K. Whitfield, Jr., C. A. Willis, K. A. Steidinger and E. A. Joyce, Jr. 1975. Techniques for coastal restoration and fishing enhancement in Florida. Fla. Mar. Res. Publ. No. 15. 27 p.

24. Dowling, H. M. 1987. Wetland habitat creation - wetland mitigation: new answers to old problems. Pp. 110-119, in, T. A. Lowery (ed.), Symp. on Nat. Res. of the Mobile Bay Estuary, Miss.-Ala. Sea Grant Publ. No. MASGP-87-007. 208 p.

25. Eleuterius, L. N. 1974. A study of plant establishment on spoil areas in Mississippi sound and adjacent waters. U. S. Army Corps of Engrs. Field Rept., DA(NO1-72-C-0001), 327 p.

26. Eleuterius, L. N. 1975. Submergent vegetation for bottom stabilization. Pp. 439-456, in, L. E. Cronin (ed.), Estuarine Res. Vol. II. Geology and Engineering, Academic Press, NY.

27. Eleuterius, L. N. and J. I. Gill, Jr. 1981. Long-term observations on seagrass beds and salt marsh established from transplants, in, Proc. 8th Ann. Conf. Wetlands Restor. and Creation, Tampa, FL.

28. Erwin, K. L. 1989a. Wetland evaluation for restoration and creation. pp. 15-45, in J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. II. Perspectives. 172 p.

29. Erwin, K. L. 1989b. Freshwater marsh creation and restoration in the southeast. Pp. 239-271, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.

30. Erwin, K. L., G. R. Best, W. J. Dunn and P. M. Wallace. 1985. Marsh and forested wetland reclamation of a central Florida phosphate mine. Wetlands 4:87-104.

31. Estevez, E. D. 1987. Implications of sea level rise for wetlands creation and management in Florida. Pp. 103-113, in, F. J. Webb (ed.), Proc. 14th Ann. Conf. on Wetlands Restor. and Creation, Hillsborough Comm. Coll., Tampa, FL.

32. Falco, P. K. and F. J. Cali. 1977. Pregermination requirements and establishment techniques for salt marsh plants. U. S. Army COE, Waterways Exper. Sta., Vicksburg, MS, Misc. Pap. D-77-1. 43 p.

33. Florida Sea Grant Program. No date. Commercial sources of salt-tolerant vegetation in Florida. Fla. Sea Grant Program, Gainesville, FL. 3 p.

34. Fonseca, M. S. 1989. Regional analysis of the creation and restoration of seagrass systems. Pp. 175-198, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b, Vol I. Regional Reviews. 473 p.

35. Fonseca, M. S., W. J. Kenworthy and G. W. Thayer. 1988. Restoration and management of seagrass systems: a review. Pp. 353-368, in, D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews and T. H. Shear (eds.), 1988. The Ecology and Management of Wetlands. Vol. II. Management, Use and Value of Wetlands. Timber Press, Portland, OR. 394 p.

36. Fonseca, M. S., W. J. Kenworthy, F. M. Cheap, C. A. Currin and G. W. Thayer. 1984. A low-cost transplanting technique for shoalgrass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*). U. S. Army COE, Waterways Exper. Sta., Vicksburg, MS, Environ. Impact Progr. Instruction Rept. EL-84-1. 16 p.

37. Fonseca, M. S., W. J. Kenworthy, G. W. Thayer, D. Y. Heller and K. M. Cheap. 1985. Transplanting of the seagrasses *Zostera marina* and *Halodule wrightii* for sediment stabilization and habitat development on the east coast of the United States. U. S. Army COE, Environ. Impact Res. Progr. Tech. Rept. EL-85-9, Waterways Exper. Sta., Vicksburg, MS. 63 p.

38. Fredette, T. J., M. S. Fonseca, W. J. Kenworthy and G. W. Thayer. 1985. Seagrass transplanting: 10 years of U. S. Army Corps of Engineers research. Pp. 121-134, in, F. J. Webb (ed.), Proc. 12th Ann. Conf. Wetland Restor. and Creation, Hillsborough Comm. Coll., Tampa, FL.

39. Garbisch, E. W. 1989. Information needs in the planning process for wetland creation and restoration. Pp. 9-13, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b, Vol. II. Perspectives. 172 p.

40. Garbisch, E. W., Jr. and L. B. Coleman. 1978. Tidal freshwater marsh establishment in upper Chesapeake Bay: *Pontederia cordata* and *Peltandra virginica*. Pp. 285-298, in, R. E. Good, D. F. Whigham and R. L. Simpson, Freshwater Wetlands: ecological processes and management potential, Academic Press, NY. 378 p.

41. Garbisch, E. W., Jr., P. B. Woller, W. J. Bostian and R. J. McCallum. 1975. Biotic techniques for shore stabilization. Pp. 405-426, in, L. E. Cronin (ed.), Estuarine Research, Vol. II, Geology and Engineering, Academic Press, NY.

42. Gilbert, T., T. King and B. Barnett. 1981. An assessment of wetland habitat establishment at a central Florida phosphate mine site. U. S. FWS Biol. Serv. Progr. FWS/OBS-81/38. 96 p.

43. Haynes, R. J. and L. Moore. 1988. Reestablishment of bottomland hardwoods within national wildlife refuges in the southwest. Pp. 95-103, in, J. Zelazny and J. S. Feierabend, Proc. of a Conf.: increasing our wetland resources. Nat'l. Wildl. Fed., Washington, DC. 364 p.

44. Haynes, R. J., J. A. Allen and E. C. Pendleton. 1988. Reestablishment of bottomland hardwood forests on disturbed sites: an annotated bibliography. U. S. Fish Wildl. Serv. Biol. Rept. 88(42). 104 p.

45. Hoffman, W. E., M. J. Durako and R. R. Lewis. 1985. Habitat restoration in Tampa Bay. Pp. 636-647, in, S. F. Treat, J. L. Simon, R. R. Lewis and R. L. Whitman, Jr. (eds.), Proc. Tampa Bay Area Sci. Info. Symp., May 1982. Burgess Printing Co., Minneapolis, Minn. 663 p.

46. Hoffman, J. E., J. B. Wells and J. G. Titus. 1983. Future global warming and sea level rise. In, F. Sigbjarnarson (ed.), Iceland Coastal and River Symposium. National Energy Authority, Reykjavik, Iceland.

47. Hook, D. D. 1988. Criteria for creating and restoring forested wetlands in the southern United States, Pp. 51-60, in, J. Zelazny and J. S. Feierabend (eds.), Proceedings of a conference: increasing our wetland resources. Nat'l. Wildl. Fed., Washington, DC. 364 p.

48. Hook, D. H. 1984. Waterlogging tolerance of lowland tree species of the south. South. J. Appl. Forest. 8(3):136-149.

49. Hunt, L. J. 1979. Principles of marsh establishment. Pp. 127-142, in, D. P. Cole (ed.), Proc. 6th Ann. Conf. on Wetlands Restor. and Creation, Hillsborough Comm. Coll., Tampa, FL.

50. Johnson, R. L. and R. M. Krinard. 1987. Direct seeding of southern oaks - a progress report. pp. 10-16, in, Proc. 15th Ann. Hardwood Symp. Hardwood Res. Coun., Memphis TN.

51. Josselyn, M. (ed.). 1982. Wetland restoration and enhancement in California. Proceedings of a workshop, Feb., 1982, Hayward, CA. Calif. Sea Grant Rept. No. T-CSGCP-007. Tiburon Center for Environmental Studies, Tiburon, CA. 110 p.

52. Kennedy, H. E., Jr. and R. L. Johnson. 1984. Silvicultural alternatives in bottomland hardwoods and their impact on stand quality. Pp. 6-18, in, Proc. 14th Ann. Sou. For. Econ. Workshop, Memphis, TN.

53. Kenworthy, W. J., K. M. Cheap, C. A. Currin and G. W. Thayer. 1984. A low-cost transplanting technique for shoalgrass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*). U. S. Army COE, Environmental Impact Res. Progr. Instruction Rept. EL-84-1.

54. Knight, R. L., B. H. Winchester and CH2M Hill. 1985. Ecology, hydrology, and advanced wastewater treatment potential of an artificial wetland in north-central Flroida. Wetlands 5:167-180.

55. Knutson, P. L., R. A. Brochn, W. N. Seeling and M. Innskeep. 1982. Wave damping in *Spartina alterniflora* marshes. Wetlands 2:87-104.

56. Knutson, P. L., J. C. Ford, M. R. Innskeep and J. Doyler. 1981. National survey of planted salt marshes (vegetative stabilization and wave stress). Wetlands 1:129-157.

57. Kollar, S. A., Jr. 1985. SAV reestablishment results - Upper Chesapeake Bay. Coastal Zone '85, Vol. I, Pp. 759-777.

58. Korschgen, C. E. and W. L. Green. 1988. American wild celery (*Vallisneria americana*): ecological considerations for restoration. U. S. Fish Wildl. Serv., Fish and Wildl. Tech. Rept. 19. 24 p.

59. Kruczynski, W. L. 1982. Salt marshes of the northeastern Gulf of Mexico. Pp. 71-87, in, R. R. Lewis, III (ed.), Creation and restoration of coastal plant communities. CRC Press, Inc., Boca Raton, FL. 219 p.

60. Kruczynski, W. L. 1989. Options to be considered in preparation and evaluation of mitigation plans. Pp. 143-158, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. II Perspectives. 172 p.

61. Leck, M. A. and K. J. Graveline. 1979. The seed bank of a freshwater tidal marsh. Amer. J. Bot. 66(9):1006-1015.

62. Lewis, R. R., III. 1989. Creation and restoration of coastal plain wetlands in Florida. Pp. 73-101, in, J. A. Kusler and M. E. Kentula (eds.), Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.

63. McRoy, C. P. 1974. Seagrass productivity: carbon uptake experiments in eelgrass, *Zostera marina*. Aquaculture 4:131-137.

64. Meeker, F. J. and S. Nielsen. 1986. Observations concerning the establishment of marsh vegetation (principally *Spartina alterniflora*) by use of the plant roll technique. Pp. 134-144, in, F. J. Webb (ed.), Proc. 13th Ann. Conf. Wetland Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL.

65. National Academy of Sciences. 1983. Changing climate. National Academy Press, Washington, DC.

66. Orson, R., W. Panageoton and S. P. Leatherman. 1985. Response of tidal salt marshes to rising sea levels along the U. S. Atlantic and Gulf coasts. J. Coastal Res. 1(1):29-38.

67. Quammen, M. L. 1986. Measuring the success of wetlands mitigation. pp. 242-245, in, J. A. Kusler, M. L. Quammen and G. Brooks (eds.), Proceedings of the national wetland symposium: mitigation of impacts and losses. Assoc. of State Wetland Managers, Berne, N.Y. 460 p.

68. Reed, P. B., Jr. 1986. Wetland plants of the United States of America 1986. U.S. Fish Wildl. Serv., WELUT-86/W17.01, Natl. Wetl. Inven., St. Petersburg, FL.

69. Ross, D., C. Kocur and W. Jurgens. 1985. Wetlands creation techniques for heavy construction equipment. Pp. 210-220, in, F. J. Webb (ed.), Proc. 12th Ann. Conf. Wetland Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL.

70. Rybicki, N. B. and V. Carter. 1986. Effect of sediment depth and sediment type on the survival of *Vallisneria americana* Michx. grown from tubers. Aquat. Bot. 24:233-240.

71. Sapp, D. C., M. L. Cameron and J. P. Stout. 1976. Alabama coastal marsh inventory. Ala. Geol. Surv., Unique Rept. No. AL-ADO-X996-CAM-11.

72. Seneca, E. D. 1980. Techniques for creating salt marshes along the east coast. pp. 1-5, in, J. C. Lewis and E. W. Bunce (eds.), 1980. Rehabilitation and creation of selected coastal habitats; Proc. of a workshop. U. S. Fish and Wildl. Serv., Biological Services Program, Washington, DC. FWS/OBS-80/27. 162 p.

73. Shuey, A. G. and L. J. Swanson, Jr. 1979. Creation of freshwater marshes in west central Florida. Pp. 57-76, in, D. P. Cole (ed.), Proc. 6th Ann. Confer. Wetlands Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL

74. Soil and Water Conservation Society. 1987. Sources of native seeds and plants. Soil and Water Conservation Society, Ankeny, Iowa. 36 p.

75. Soil Conservation Service. 1978. Plants for a purpose. U. S. Soil Conservation Service, Plant Materials Center, Coffeeville, MS. 11 p.

76. Stout, J. P. 1984. The ecology of irregularly flooded salt marshes of the northeastern Gulf of Mexico: a community profile. U. S. Fish Wildl. Serv. Biol. Reprt. 85(7.1). 98 p.

77. Stout, J. P. and K. L. Heck. 1990. Reintroduction of oligohaline grassbeds, Mobile Bay, AL. Pp.???, in, F. J. Webb (ed.), Proc. 16th Ann. Confer. Creation and Restor. of Wetlands, Hillsborough Comm. Coll., Tampa, FL. In Press.

78. Stout, J. P. and M. J. Lelong. 1981. Wetland habitats of the Alabama coastal area. Part II. An inventory of wetland habitats south of the Battleship Parkway. Ala. Coast. Area Bd., Tech. Publ. CAB-81-01. 24 atlas pages.

79. Stout, J. P., M. J. Lelong, H. M. Dowling and M. T. Powers. 1982. Wetland habitats of the Alabama coastal zone. Part III. An inventory of wetland habitats of the Mobile-Tensaw River Delta. Ala. Coast. Area Bd., Tech. Rept. 81-49A. 25 p. and 9 maps.

80. Tanner, G. W. and J. D. Dodd. 1985. Effects of phenological stage of *Spartina alterniflora* transplant culms on stand development. Wetlands 4:57-74.

81. Theriot, R. F. 1988. Flood tolerance indices for palustrine forest species. Pp. 477-488, in, D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilber, R. Banks, L. H. Stolyz, C. Brooks, T. D. Matthews and T. H. Shear (eds.), The ecology and mangement of wetlands. Vol. I. Ecology of Wetlands. 592 p.

82. Thomas, R. H. 1986. Effects of changes in stratospheric ozone and global climate, in, J. G. Titus (ed.), Sea Level Rise, Vol. IV.

83. Titus, J. G. 1988. Greenhouse effect, sea level rise and coastal wetlands. USEPA, Off. of Wetland Protection, EPA-230-05-86-013. 152 p.

84. Vittor, B. A. and Associates. 1987. Mitigation plan LL and E Petroleum Marketing, Inc., U.S. Army COE, Mobile District, AL, Permit No. AL80-00167-L. 5 p.

85. Vittor, B. A., J. R. Stewart, Jr. and A. L. Middleton. 1987. Creation of a brackish tidal marsh at West Fowl River, Alabama. Pp. 120-129, in, T. A. Lowery (ed.), Symp. Nat. Resources of the Mobile Bay Estuary. Miss.-Ala. Sea Grant Consortium, Publ. No. MASGP-87-007. 208 p.

86. Webb, J. W., H. H. Allen and J. O. Shirley. 1984. Marsh transplant establishment analysis along the northwest shoreline of Theodore disposal island, Mobile Bay, Alabama. Pp. 184-200, in, F. J. Webb (ed.), Proc. 11th Ann. Conf. Wetland Restoration and Creation, Hillsborough Comm. Coll., Tampa, FL.

87. Wharton, C. H., W. M. Kitchens and T. W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. USFWS FWS/OBS-81/37. 133 p.

88. Woodhouse, W. W., Jr. 1979. Building salt marshes along the coasts of the continental United States. U. S. Army, Coastal Engr. Res. Centr., Fort Belvoir, VA. Spec. Rept. No. 4.

89. Zedler, J. B. and M. M. Weller. 1989. Overview and future directions. Pp. 465-473, in, J. A. Kusler and M. E. Kentula (eds.), 1989. Wetland creation and restoration: the status of the science. USEPA Publ. No. 600/3-89/038b. Vol. I. Regional Reviews. 473 p.