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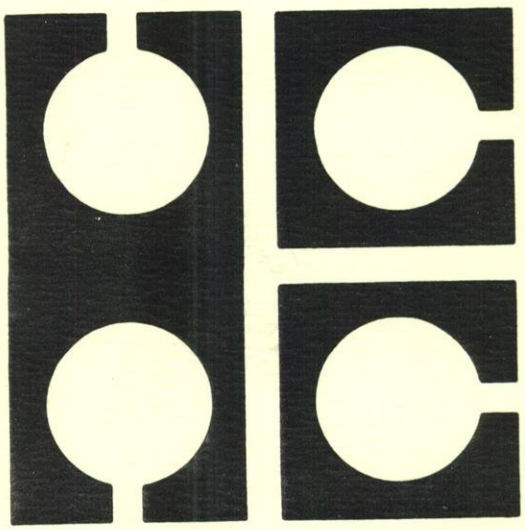
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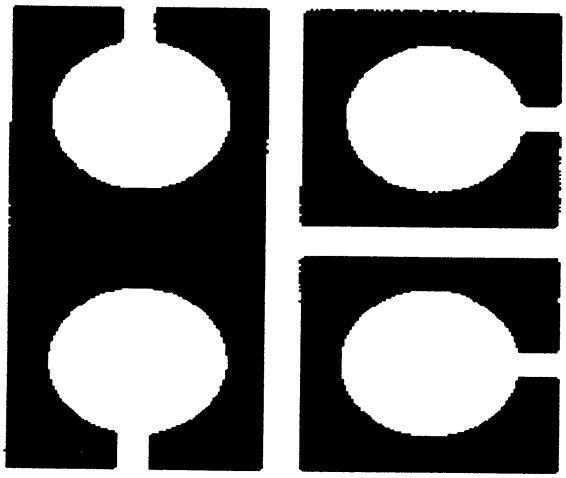
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May, 1999



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Proceedings of

The Twenty Sixth Annual Conference on Ecosystems Restoration and Creation

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INTRODUCTION

The Annual Conference on Ecosystems Restoration and Creation provides a forum for the exchange of results of scientific research in the restoration, creation, and management of freshwater and coastal systems. The conference is designed to be of particular benefit to governmental agencies, planning organizations, colleges and universities, corporations, and environmental groups. These proceedings are a compilation of papers and addresses presented at the Twenty Sixth Annual Conference.

As in years past, this year's conference would not have been possible without the assistance and cooperation of Mr. Roy R. "Robin" Lewis, III. Mr. Lewis has been an important contributor since the very first conference twenty six years ago. We are grateful for his help and participation. Appreciation is also extended to Fred Webb and Felix Haynes for providing administrative support for the conference.

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These proceedings could not have been completed without the time and efforts of the authors and reviewers.

To all these people, thank you.

ISLAND RESTORATION AND ENHANCEMENT IN BISCAYNE BAY, FLORIDA

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ABSTRACT

Dredging and filling in the early 1900's to create navigation channels and harbors in Biscayne Bay resulted in over twenty human-made spoil islands and two partially filled natural mangrove islands. Most of the islands are still under public ownership; however, eroding unconsolidated shorelines, tangled exotic vegetation, and debris build-up have discouraged use and limited habitat for birds and marine life. Further, the continual erosion of the island soils contributes to water quality degradation of Biscayne Bay. This paper reviews Biscayne Bay Island Restoration and Enhancement projects, components of which include stabilizing shorelines, removing exotic trees and fill, establishing flushing channels, and planting mangroves and native salt/drought-tolerant uplands vegetation. Over the last ten years of implementing the Biscayne Bay Restoration and Enhancement Program, Miami-Dade DERM has coordinated fourteen island projects through the cooperative efforts of federal, state and local agencies. Cost-effective techniques were developed and used in implementing these successful projects.

Key words: Island restoration, spoil islands, mangroves, native plants, creation, enhancement.

INTRODUCTION

A large body of scientific literature exists documenting the importance of coastal habitats to local fisheries, food web relationships, habitat value, and as shoreline stabilizers (Idyll et al., 1968; Odum et al., 1982; Lewis, 1990a). Biscayne Bay and its associated coastal habitats are some of Florida's most valuable natural resources. The bay is a shallow subtropical estuary located on the southeast coast of Florida . Extending approximately 56 km (35 miles) from north to south and varying in width from less than 1.6 km (one mile) to approximately 12.8 km (eight miles), it covers an area of 572 km^2 (220 square miles). The bay is bordered on the west by the Greater Miami area and on the east by a series of barrier islands and submerged vegetated banks.

Rapid urbanization and associated coastal development over the last 100 years has severely altered natural habitats in Biscayne Bay. The northern third of the bay (North Bay), which has been most severely impacted by development, is subdivided by six filled causeways and a major seaport facility. Low coastal wetlands have been virtually

eliminated in North Bay. Over fifty percent of the existing North Bay bottom area is barren, caused by the creation of deep dredge holes and associated spoil placement and chronic elevated turbidity levels (Harlem, 1979; Milano, 1983). High turbidity in the bay has been correlated with resuspension of unconsolidated bay bottom and spoil-island shorelines, eroding margins of dredge banks and unvegetated bottom sediments (Wanless et al.,. 1984).

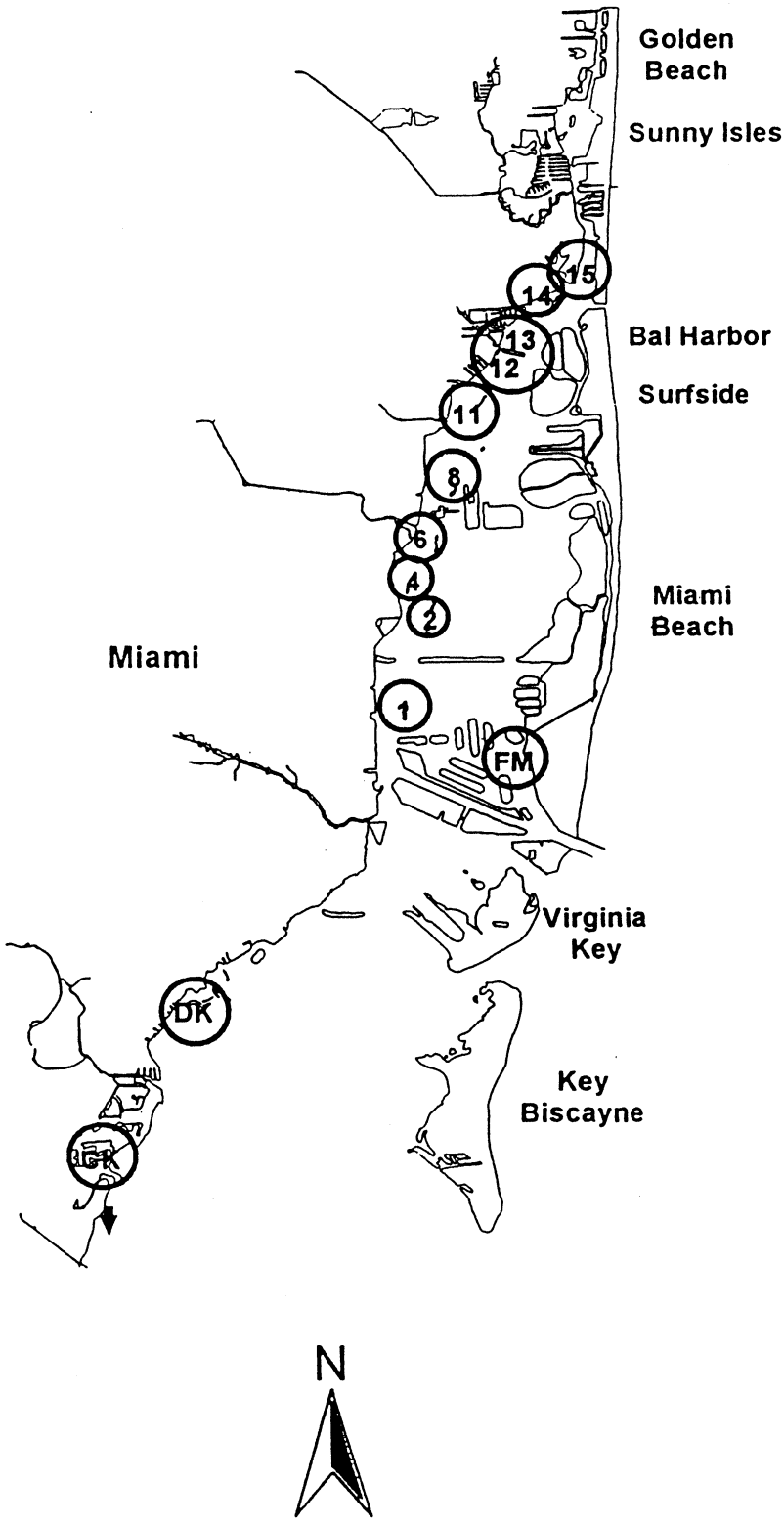
Morton (1977) contributed substantially to our understanding of the biological effects of dredging and spoil disposal on estuarine environments. During creation of the Atlantic Intracoastal Waterway (ICW) in the early 1900s, a series of spoil-fill islands were created adjacent to the navigational channel. Wanless et al. (1984) identified these eroding islands as a persistent source of turbidity, resulting in water-quality degradation. Biologically, excessive turbidity is usually undesirable, as it reduces the amount of light penetrating the water column and often limits productivity of bottom vegetation and phytoplankton.

Most of the spoil islands in Biscayne Bay are still under public ownership. Eroding shorelines and debris accumulation have discouraged use of many of these areas. Undeveloped, filled islands are predominantly vegetated with exotic species such as Australian pine (Casuarina equisetifolia), Brazilian-pepper (Schinus terebinthifolius), Burma reed (Neyraudia reynaudiana), seaside-mahoe (Thespesia populnea) and beach naupaka (Scaevola taccada).

Most existing data on emergent wetlands habitat enhancement on spoil islands is limited to the temperate-zone marsh grass Spartina alterniflora (Garbisch, 1974; Lewis and Dunstan, 1974; Kruczynski and Huffman, 1978; Lunz et al., 1978; Carangelo et al., 1979; Allen et al., 1986; La Salle et al., 1981), which does not occur in lower southeastern Florida. Techniques for mangrove planting and restoration in Florida have been well documented (Savage, 1972; Pulver, 1976; Teas, 1977; Goforth and Thomas, 1980; Lewis, 1990; Markley et al., 1992), but little information is available on restoration of mangroves on spoil islands. Specific limitations of mangroves (e.g. along eroding shorelines) have also been documented (Savage, 1972; Teas, 1977; Goforth and Thomas, 1980). Fernald et al. (1985) described the limitations of planting liner-size tropical hardwood hammock species under exotic-species canopies on spoil islands. Contributions have been made on spoil-island habitat creation and enhancement for bird populations (Maxwell and Kale, 1974; Morris and Miller, 1974; Lewis and Lewis, 1978; Schreiber and Schreiber, 1978; Soots and Landin, 1978; Toland, 1992; Paul et al., 1995).

Island restoration and enhancement activities are underway to stabilize eroding shorelines, restore historical dune communities and wetlands, eradicate exotic vegetation, and create wetlands, dune, coastal strand and tropical hardwood hammock communities. Limited recreational opportunities are also intended for these areas. This paper reviews the creation of 15.2 ha (thirty-eight acres) of tropical hardwood hammock community, 4.8 ha (twelve acres) of mangrove community, 4.4 ha (eleven acres) of coastal strand community and over 1.6 km (one mile) of dune community on fourteen stabilized islands in Biscayne Bay (see Figure 1).

Figure 1. Island Restoration and Enhancement Sites in Miami-Dade County, FL



METHOD

Environmental resource permits from the Army Corps of Engineers, Florida Department of Environmental Protection, Miami-Dade County Environmental Resources Management and local municipalities are required for all restoration activities; see Milano (1999) for details associated with the environmental permit process. The Department of the Army has a perpetual easement for maintenance dredging for the majority of spoil islands along the Intracoastal Waterway. As a result, a Department of Army Consent to Easement is required to allow shoreline stabilization and habitat restoration on a dredge disposal island. Island restoration designs are developed through review of historical documents (aerials for natural islands) and field investigations of site characteristics. Field investigations include topographical, biological, geotechnical, and hydrological and archaeological review of the prospective site. This information is used to identify and protect existing natural resources and to accurately quantify project elements. These elements are used to develop a detailed final design, an accurate cost estimate, environmental permitting applications, funding requests, and construction contract technical specifications and drawings. The final design consists of the types and areas to be stabilized, areas to be cleared of exotics, areas to be excavated, location of flushing channels and tidal creek network, species to be restored, elevation specifications, access routes, public facilities, etc.

A comprehensive biological evaluation is conducted to document on-site and surrounding biological communities, to identify environmental concerns, to define the biological goals and objectives, and to make specific recommendations concerning construction activities associated with the restoration and enhancement efforts (e.g. access route, selective clearing, environmental precautions). The biological assessment is a key element for required local, state and federal environmental resources permit applications. Observations of the surrounding natural community (if present) assist the restoration team in developing design criteria (e.g., species, planting elevations, hydrological connections, etc.). Selective clearing of exotics is conducted to remove unwanted competitive species and promote development of existing native communities. A topographic survey of the proposed shoreline or wetland restoration area is obtained by a certified land surveyor for the planning, design and construction phases of the restoration plan. The topographic survey is used to obtain a precise estimate of fill quantities to be removed or added. Hydrographic evaluations are performed to obtain information for wave energy, tidal regime, current-velocity information and surrounding bathymetry. Elevations are referenced to the National Geodetic Vertical Datum (NGVD) on all restoration documents (e.g., permit drawings, construction drawings). Hydrographic (wave and tidal conditions) and topographic information are used to develop cost-effective placement of limerock groins along eroding island shorelines. See Milano (1999) for wetlands geotechnical evaluation information.

Shoreline Stabilization

Eroding, unconsolidated fill shorelines are stabilized by placing limestone boulders [30 cm to 90 cm (one to three feet) in diameter], limerock boulders in combination with mangroves, or mangroves alone by using a new experimental encased-mangrove technique

(Riley, 1995). Habitat enhancement benefits of these methods include wave abatement, which reduces erosion and resuspension of sediments and related turbidity, and an increase in feeding, refuge and nursery habitat. The limestone revetment also creates a variety of stable habitats for attached and motile subtidal and intertidal marine organisms. On-site physical and biological conditions may limit planting or require a temporary, protective barrier (mangrove planter) to protect young mangroves from waves, floating detritus, and debris. After red mangroves produce prop roots, the temporary protective limerock barrier can be reduced and recycled into other shoreline stabilization projects. On sloping unconsolidated shorelines, limerock-boulder revetments should begin at an elevation at least 30 cm (one foot) below mean low water (or at the edge of any seagrass beds) and extend to an elevation of 60 cm (two feet) above mean high water. The slope of the revetment should not be greater than 2 horizontal to 1 vertical. The upper elevation is necessary to reduce erosion behind the structure and to prevent trash and debris from damaging planted mangroves behind the protective barrier during extreme high water events. Filter fabric is used under the rocks to contain uplands fill and soils in planted areas. Filter fabric may also be used to support boulders where the existing substrate is unstable. The width of a mangrove planter depends on uplands excavation limitations and waterward edge of seagrass. Exact volume of limerock boulders per linear cm of shoreline stabilization will vary depending on the water depth and slope of the project site. Averages range from 1.15 m to 2.68 m (1.5 to 3.5 cubic yards) per thirty centimeters of shoreline.

Community Planting Groups (See Appendix II for species commonly planted with each planting group.)

Wetlands Community See Milano (1999) for details of wetlands restoration.

Dune Community (DC) The dune community extends from the mean high-tide line +45 cm (+1.5') NGVD to the upper foredune. Dune community species have been planted at ten islands. Island dunes are created using on-site calcareous sand or locally available quartz sand. The Chicken Key dune system was restored successfully using on-site calcareous sand screened from spoil fill. All newly-planted dune vegetation is planted on 45 cm (18") centers and is protected for approximately two years at popular recreational islands using wood sand fencing. Prices range from $1.00 - $1.60 for liner-size plants [38.1 mm (1 1/2") dia. in multiunit trays].

Coastal Strand Community (CS) The coastal strand community extends from the back dune to the inner island hammock zone. Coastal strand species have been introduced at ten spoil islands. The coastal strand community assemblages interface with the dune and tropical hardwood hammock communities and are planted on 90 cm to 210 cm (3 to 7 feet) centers (all species and sizes). Prices range from $4.00 - $8.00 for 3.8 liter (1-gallon) material and $5.00 - $25.00 for 11.4 liters (3-gallon) material.

Tropical Hardwood Hammock (THH) Tropical hardwood hammock community species have been introduced at five spoil islands. THH species are planted on 210 cm – 300 cm (7-10 feet) centers (all species & sizes) . A 20.3 cm-30.5 cm (eight- to twelve-inch) layer of mulch is recommended for water retention over the entire planting site. Prices range

from $5.00 - $20.00 for 3.8 liter (1-gallon) material and from $20.00 - $90.00 for 26.6 liter (7-gallon) material.

Contract planting specifications include the size, quality, storage limitations, and excavation of plant holes, setting of plants, fertilizing, watering and maintenance. When large quantities of plants or unavailable species are desired, it may be necessary to contract for plant growout. Contracts typically specify 80% survival of planted material after 1 year. All plants are watered on a once-a-week schedule, regardless of rainfall until the completion of project construction. A maintenance performance bond for a minimum of one year is typically required from the date of final acceptance for all plantings. The terms of the maintenance or warranty period begin on the date of final acceptance of the work and continue for a minimum of one year. Vegetative monitoring is conducted at pre-established photo stations and by aerial qualitative assessments on a quarterly basis. Should the quarterly monitoring by DERM reveal that less than 80% of the plant material is surviving, the contractor is notified immediately and has fourteen calendar days to replant the total number of dead units.

Project Costs_Typical costs and contract line items for island restoration and enhancement projects are as follows:

Line item	Unit costs
Mobilization	10% of the total construction cost
Selective clearing, and removal of undesirable vegetation	$ 5,200 - $ 9,000 per .4 ha (acre)
Excavation and spoil disposal	$ 12.50 - $ 30.00 per .765 m^3 (cu. yd.).
Limerock boulders (rip-rap)	$ 24.00 - $ 50.00 per .9 metric ton (ton)
Filter fabric	$ 2.00 - $ 4.00 per .8 m^2 (sq. yd.)
Mangroves (1 year old)	$ 1.00 - $ 3.00 per unit
Uplands vegetation	$ 10.00 - $30.00 per 11.4 liter (3 gallon) (DC) $ 1.00 - $1.60 /liner (CS) $ 20.00 - $90.00 per 26.6 liter (7 gallon) (THH)
Mulch	$ 15.00 - $25.00 per .765 m^3 (cubic yard)

PROJECT IMPLEMENTATION

The implementation of restoration and enhancement plans is achieved by selecting outside contractors through a bidding process that defines the scope of work and specifications for the project; the contract is awarded to the lowest bid by a qualified bidder. The bid and contractor selection process typically requires between four and six months to complete. This process is initiated upon securing dedicated funding. Projects are scheduled to optimize planting windows (i.e. natural cycles, rainy season) and conducted in a manner to minimize environmental impacts (e.g. use periods of extreme high tides, avoid periods of bird nesting). Restoration cost savings are improved by detailing, within the bid document, cost-effective methodologies (e.g., soil turning, sand screening) for all project components

and suggesting contract alternatives (e.g., contractor ownership of excavated material, recycling of materials from other sites). Site accessibility directly affects costs for all project elements. Accessibility by water requires specialized marine vessels to transport equipment, materials and personnel, and averages out to be at least twice as expensive as land-accessible areas. The re-establishment of altered historical wetlands typically involves excavating, removing and disposing of large quantities of fill. Public restoration dollars are maximized through resourceful spoil disposal plans that reduce restoration costs. For example, a cost savings of $450,000 was realized during the Chicken Key restoration through a resourceful spoil disposal plan that allowed the contractor to own and market all fill materials removed from the island and through a cost-effective construction methodology plan.

As detailed in the project descriptions (Appendix I), island stabilization and enhancement have been funded primarily through the Florida Inland Navigation District (FIND) Waterways Assistance Program and the Biscayne Bay Environmental Enhancement Trust Fund. In addition, island restoration and enhancement grant monies have been secured through the Florida Department of Environmental Protection, the South Florida Water Management District, and local mitigation opportunities. Prior to construction, the project biologist marks all existing seagrass areas and desirable uplands vegetation within the project boundaries to minimize environmental impacts. During construction, the project manager inspects the site on a regular basis to ensure compliance with specifications. As-built surveys of all elevation modifications are required prior to approval for wetlands planting. All plant material is inspected prior to planting by the project biologist. Wildlife assessments, vegetative survival monitoring, and exotic vegetation control (herbicide treatment) are conducted on a quarterly basis until native communities are established. Typically, tropical hardwood hammock canopy development is achieved within four years when using 11.4 to 26.6 liter (3- to 7-gallon) material. Dune community development is very rapid. For example, Uniola paniculata (Sea-oats) liner material planted in April 1997 at the Chicken Key (CK) site was observed in June 1997 to be displaying seed and partial coalescence.

Fourteen islands have been successfully restored and soils stabilized using a variety of vegetative and non-vegetative techniques for approximately 3.8 million dollars. Four habitat types, consisting of approximately 90 species, have been successfully established using cost-effective techniques on these natural and dredge spoil islands in Biscayne Bay. Appendix I summarizes these projects and Appendix II details the species planted at each island.

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APPENDIX I: PROJECT DESCRIPTIONS

(See Appendix II for species used in each project)

CHICKEN KEY BIRD ROOKERY RESTORATION (CK)

Size: 2.8 ha (7 acres) **Completion Date:** 3/97

Location: Chicken Key, located in the Biscayne Bay Aquatic Preserve, south Biscayne Bay
26° 37'12"N, 80°17'15"W

Scope of Restoration:

* Clearing and removing 1.6 ha (4 acres) of exotic vegetation, including Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius, Scaevola taccada, Thespesia populnea, Hibiscus tiliaceus and Acacia auriculiformis
* Selectively clearing 1.2 ha (3 acres) of exotic vegetation
* Excavating 25,245 cubic meters (33,000 cubic yards) of dredge spoil from the north and central portions of the Key (Spoil sold by contractor reducing restoration cost)
* Restoring 366 m (1200 LF) of dune community
* Planting 45 m (150 LF) of experimental mangrove in encased tubes
* Planting 1.4 ha (3.7 acres) of red mangroves (Rhizophora mangle on (3 foot) centers
* Installing 3 flushing channels 2.4 m – 4.5 m wide
* Installing a network of tidal creeks 270 m (900 LF)

Funding: (% of total) Florida Dept. of Environmental Protection (FDEP) (34%), South Florida Water Management District (SFWMD) (24%), Biscayne Bay Environmental Enhancement Trust Fund (BBEETF) (42%)

Cost: $600,000

DINNER KEY ISLAND (DK)

Size: 2.8 ha (7 acres) **Completion Date:** Ongoing

Location: Biscayne Bay Aquatic Preserve, Miami, FL, central Biscayne Bay
25°46'08"N, 80° 12'54"W

Scope of Enhancement:

* Clearing and mulching 1.6 ha (4 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, Thespesia populnea, Schinus terebinthifolius, and Scaevola taccada
* Creating 1.6 ha (4 acres) of coastal strand/maritime hammock
* Stabilizing shoreline with mangroves and limerock boulders
* Installing an osprey nesting platform

Funding: Miami-Dade Seaport Department (100%)

Cost: $275,00

FLAGLER MONUMENT ISLAND (FM)

Size: 1.8 ha (4.5 acres) **Completion Date: 6/94**

Location: Biscayne Bay Aquatic Preserve, City of Miami Beach, Florida, south region of northern Biscayne Bay
25° 46'54"N, 80°9'6"W

Scope of Enhancement:

* Selectively clearing 1.8 ha (4.5 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius, Thespesia populnea and Scaevola taccada
* Creating 225 m (738 LF) of dune community
* Creating 1.6 ha (4 acres) coastal strand/maritime hammock
* Stabilizing 270 m (885 LF). of shoreline with limerock boulders
* Installing an osprey nesting platform

Funding: (% of total) BBEETF (50%), Florida Inland Navigation District (FIND) (50%)

Cost: $220,000

TEACHERS ISLAND (#1)

Size: 1.48 ha (3.7 acres) **Completion Date:** Ongoing

Location: Biscayne Bay Aquatic Preserve, Miami, Florida south region of northern Biscayne Bay
25°47'40"N, 80°12'10"W

Scope of Enhancement:

* Selectively clearing and disposing of exotic vegetation, containing predominantly Casuarina equisetifolia, Schinus terebinthifolius, and Scaevola taccada
* Creating 1.48 ha (3.7 acres) of dune/coastal strand community
* Stabilizing 96.3 m (315 LF). of shoreline with limerock groins

Funding (% of total): FIND (50%), BBEETF (50%)

Cost: $140,000

MORNINGSIDE ISLAND (#2)

Size: 1.7 ha (4.2 acres) **Completion Date:** 3/97

Location: Biscayne Bay Aquatic Preserve, Miami, FL, south central region of northern Biscayne Bay
25°45'06"N, 80° 10'15"W

Scope of Enhancement:

* Selectively clearing 1.6 ha (4 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, Schinus terebinthifolius, Thespesia populnea
* Creating 1.6 ha (4 acres) of dunes/coastal strand community
* Stabilizing 150 m (492 LF) of shoreline with limerock groins
* Creating .08 ha (0.2 acres) of mangrove wetlands
* Installing an osprey nesting platform

Funding (% of total): FIND (50%), BBEETF (50%)

Cost: $290,000

MANGROVE ISLANDS (#4) (2)

Size: 1.1 ha (2.8 acres) **Completion Date:** 8/96

Location: Biscayne Bay Aquatic Preserve, Miami, FL, central region of north Biscayne Bay
25° 49'30"N, 80°11'15"W

Scope of Enhancement:

* Selectively clearing exotic vegetation, containing predominantly Casuarina equisetifolia, Thespesia populnea using herbicides
* Enhancing 1.1 ha (2.8 acres) of existing mangrove wetlands

Funding: BBEETF (100%)

Cost: $5,000

LEGION ISLAND (#6)

Size: 2.8 ha (7 acres) **Completion Date:** Ongoing

Location: Biscayne Bay Aquatic Preserve, FL, central region of northern Biscayne Bay
25° 51'30"N, 80° 11'15"W

Scope of Enhancement:

* Selectively clearing exotic vegetation, containing predominantly Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius, and Thespesia populnea
* Stabilizing 150 m (492 LF). of shoreline with pvc-encased mangroves
* Creating 2 ha (5 acres) of maritime hammock/coastal strand community
* Installing an osprey nesting platform

Funding (% of total): FIND (50%) BBEETF (50%)

Cost: $150,000

PELICAN ISLAND (#8)

Size: 2 ha (5 acres) **Completion Date:** 1/92

Location: Biscayne Bay Aquatic Preserve, Miami, FL, central region of northern Biscayne Bay
25° 51'00" N, 80°10'00"W

Scope of Enhancement:

* Clearing and mulching 2 ha (5 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius and Scaevola taccada
* Creating 45 m (147 LF) of dune community
* Stabilizing 360 m (1,181 LF) of shoreline with limerock boulders
* Enhancing .16 ha (4 acres) of mangrove wetlands
* Creating 1.8 ha (4.5 acres) of maritime hammock/coastal strand community
* Installing an osprey nesting platform
* Installing a docking facility [61.2 m^2 (658 sq. ft.)]

Funding (% of total): FIND (50%), BBEETF (50%)

Cost: $300,000

QUAYSIDE ISLAND (#11)

Size: 2 ha (5 acres) **Completion Date:** 3/93

Location: Biscayne Bay Aquatic Preserve, FL, northern Biscayne Bay
25°54'35"N, 80°09'25"W

Scope of Enhancement:

* Clearing and mulching 2 ha (5 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, and Schinus terebinthifolius
* Creating 108 m (354 LF) of dune community
* Stabilizing 600 m (1,968 LF) of shoreline with mangroves .14 ha (0.34 acres) and limerock boulders
* Creating 1.8 ha (4.5 acres) of maritime hammock/coastal strand community
* Installing an osprey nesting platform
* Installing a docking facility [54 m^2 (581 sq. ft)]

Funding: (% of total) FIND (40%), FDEP (19%), BBEETF (41%)

Cost: $590,000

HELKERS ISLAND (#12)

Size: 1.6 ha (4 acres) **Completion Date: 4/93**

Location: Approximately 255 m (836 feet) west of the ICW and south of the 79th Street Causeway, Biscayne Bay Aquatic Preserve, North Miami, FL, northern Biscayne Bay
25°53'N, 80°09'W

Scope of Enhancement:

* Clearing and mulching 1.6 ha (4 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, Schinus terebinthifolius and Thespesia populnea
* Creating 144 m (472 LF) of dune community
* Stabilizing 264 m (866 LF) of shoreline with mangroves (0.27 acres) and limerock boulders
* Creating .2 ha (0.5 acres) of mangrove wetlands
* Creating 1.6 ha (4 acres) of maritime hammock/coastal strand community
* Osprey nesting platform

Funding (% of total): FIND (50%), BBEETF (50%)

Cost:$300,000

CRESCENT ISLANDS (#13) (2)

Size: .8 ha (2 acres) **Completion Date:** 1/92

Location: Biscayne Bay Aquatic Preserve, North Miami, FL, northern Biscayne Bay
25°52'30"N, 80°08'30"W

Scope of Enhancement:

* Selectively clearing .8 ha (2 acres) of exotic vegetation, containing predominantly Casuarina equisetifolia, and Thespesia populnea
* Creating 180 m (590 LF) of dune community
* Stabilizing 297 m (974 LF). of shoreline with mangroves and natural limerock boulders
* Creating .2 ha (0.5 acres) of mangrove wetlands
* Creating .14 ha (0.35 acres) of coastal strand community
* Installing an osprey nesting platform

Funding (% of total): BBEETF (40%), FIND (40%)
Cost: $200,000

LITTLE SANDSPUR ISLAND (#14)

Size: .6 ha (1.5 acres) **Completion Date:** 2/99
Location: Biscayne Bay Aquatic Preserve, northern Biscayne Bay
25° 53'30"N, 80° 8'30"W

Scope of Enhancement:
* Clearing and removing .4 ha (1 acre) of exotic vegetation, containing predominantly Casuarina equisetifolia, and Thespesia populnea
* Creating 66 m (216 LF) of dune community
* Enhancing .2 ha (0.5 acre) of mangrove
* Creating .4 ha (1 acre) dune/coastal strand community
* Stabililizing 186m (610 LF) of shoreline with limerock boulders
* Installing an osprey nesting platform
* Installing a wetlands flushing channel [3.6 m (12 ft. wide)]

Funding (% of total): BBEETF (50%), FIND (50%)
Cost: $170,000

SAND SPUR ISLAND (#15)

Size: 6.1 ha (15 acres) **Completion Date:** 6/93
Location: Oleta River State Recreation Area, Biscayne Bay Aquatic Preserve, North Miami Beach, FL, north Biscayne Bay
26 54'00"N, 80°08'15"W

Scope of Enhancement:
* Clearing and mulching 15 acres of exotic vegetation, containing predominantly Casuarina equisetifolia, Neyraudia reynaudiana, Schinus terebinthifolius, and Scaevola taccada
* Creating 2.1 acres of dune community
* Stabilizing 915 m of shoreline with mangroves and limerock boulders
* Creating 1 hectare of mangrove wetlands
* Creating 5.6 hectares of maritime hammock/coastal strand community
* Installing an osprey nesting platforms

Funding: (% of total) BBEETF (48%), FIND (44%), SFWMD (8%)
Cost: $531,000

Appendix II: Planted Species by Site (See Appendix I)

		Zone
Acacia choriophylla	15, 12, 11 8, 6, FM, DK	THH
Acoelorrhaphe wrightii	FM	CS
Amyris elemifera	15, 12, 11, 6	THH
Ardisia escallonioides	15, 12, 11, 6	THH
Ateramnus lucidus	15, 12, 11, 6	THH
Avicennia germinans	15, 13, 12, 11, 6, DK, CK	M
Batis maritima	CK	D
Blutaparon vermiculare	14	D
Borrichia frutescens	15, CK	D
Bumelia celastrina	12, 11, 6	THH
Bursera simaruba	15, 13, 12, 11, 8, 6, 2, 1, FM, DK	THH
Callicarpa americana	15, 6	THH
Calyptranthes pallens	15, 12, 11, 6	THH
Canavalia maritima	14, 2, 1, FM	D
Canella winterana	15, 12, 11, 6	THH
Capparis cynophallophora	15, 14, 12, 11, 6, 2, 1, FM, DK	THH
Capparis flexuosa	15, 12, 11, 6	THH
Casasia clusiifolia	15, 12, 11, 6, 2, 1	CS
Cassia sp.	15, 14, 2, 1, FM	CS
Chiococca alba	15, 12, 11, 6	CS
Chrysobalanus icaco	12, 11, 6, 2, 1	CS
Chrysophyllum oliviforme	15, 12, 11, 6	THH
Citharexylum fruticosum	15, 12, 11, 6, 2, 1, FM, DK	CS, THH
Coccoloba diversifolia	15, 12, 11, 8, 6, DK	THH
Coccoloba uvifera	15, 12, 11, 8, 6, 2, 1, FM	CS
Cocos nucifera	15, 12, 11, 6, 2, 1, FM	CS
Coccothrinax argentata	2, 1, FM	CS
Conocarpus erectus	15, 13, 12, 11, 8, 6, 2, 1, FM, DK	M
Conocarpus erectus sericeus	15, 12, 11, 6, DK	CS
Cordia sebestena	15, 13, 12, 11, 8, 6, FM, DK	THH
Croton punctatus	14,	D
Dodonaea viscosa	15, 14, 12, 11, 8, 6, FM, DK	CS
Erithalis fruticosa	15, 12, 11, 8, 6, DK	THH
Ernodea littoralis	14, 2, 1	D
Erythrina herbacea	15, 12, 11, 6, FM, DK	CS
Eugenia axillaris	15, 12, 11, 6	THH
Eugenia confusa	15, 12, 11, 6	THH
Eugenia foetida	15, 12, 11, 6	THH
Exostema caribaeum	15, 12, 11, 6	THH
Ficus aurea	15, 12, 11, 8, 6, DK	THH
Ficus citrifolia	15, 8	THH
Forestiera segregata	15, 12, 11, 6, 2, 1, FM, DK	THH
Gaillardia pulchella	14, 2, 1, FM	D
Guaiacum sanctum	15, 12, 11, 6	THH

Guapira discolor	15, 12, 11, 6	THH
Hamelia patens	14	CS
Helianthus debilis	15, 14, 12, 11, 6, 2, 1, FM	D
Hymenocallis latifolia	14, 12, 11, 6, 2, 1, CK	D
Ipomoea pes-caprae	15, 14, 12, 11, 6, FM,	D
Iva imbricata	14, 2, 1, FM	D
Jacquemontia reclinata	14, 2, CK	D
Jaquinia keyensis	15, 14, 12, 11, 6	D
Lantana involucrata	12, 11, 6	CS
Lysiloma bahamensis	15, 12, 11, 6	THH
Mallotonia gnaphalodes	2, CK	CS
Mastichodendron foetidissimum	15, 12, 11, 6	THH
Myrica cerifera	14, 2, 1	CS
Myrsine guianensis	15, 12, 11, 6	CS
Nectandra coriacea	15, 12, 11, 6	THH
Okenia hypogaea	14	D
Opuntia sp.	14	CS
Passiflora suberosa	14	CS
Picramnia pentandra	15, 12, 11, 6	CS
Piscidia piscipula	15, 13, 12, 11, 8, 6, FM	THH
Pithecellobium keyensis	15, 14, 12	CS
Pithecellobium unguis-cati	15, 12, 11, 8, 6, DK	CS
Psidium longipes	15, 12, 11, 6	CS
Psuedophoenix sargentii	15, FM	CS
Psychotria nervosa	15, 12, 11, 6	THH
Quercus laurifolia	15, 12, 11, DK	THH
Quercus virginiana	15, 12, 11	THH
Randia aculeata	15, 12, 11, 6, 2, 1, FM, DK	CS
Reynosia septentrionalis	15, 12, 11, 6	CS, THH
Rhizophora mangle	15, 12, 11, 8, 6, DK, CK	M
Sabal palmetto	15, 8, 2, 1, FM, DK	CS
Sapindus saponaria	15, 12, 11, 8, 6, DK	THH
Scaevola plumieri	15, 14, 12, 11, 6, 2, 1, FM, CK	D
Schaefferia frutescens	15, 12, 11, 6	CS
Serenoa repens	15, 14, 12, 11, 6, 2, 1,	D
Sesuvium portulacastrum	15, 14, 12, 11, 6, 2, 1, FM, CK	D
Sophora tomentosa	15, 14, 12, 11, 8, 6, 2, 1, FM, CK	CS
Spartina patens	1, 2, FM	D
Spartina spartinae	15, CK	D
Suriana maritima	15, 12, 11, 6, 2, 1, FM, CK	D
Swietenia mahogani	15, 12, 11, 8, 6, FM	THH
Thrinax morrisii	14, 2, 1	CS
Tournefortia gnaphalodes	15, 14, 12, 2, CK	D
Uniola paniculata	15, 14, 13, 12, 11, 8, 6, 2, 1, FM, CK	D
Zanthoxylum coriaceum	15, 12, 2, 1	CS
Zanthoxylum fagara	15, 12, 11, 6, 2, 1	CS

New and Innovative Techniques for Seagrass Restoration

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ABSTRACT

Reports of seagrass decline worldwide have been occurring for many years. The decline has been attributed to dredge and fill, pollution, and propeller scarring. Past techniques to restore seagrass beds have not always been successful with many transplanting projects having only a 20% survival rate. New techniques for seagrass recovery are presented that include: a seagrass formula for re-growth into prop scars, an injecting boat that can inject nutrients into prop scars, and a planting boat that can plant short shoots of *Halodule wrightii* in bare root or in peat pots. The planting boat can also plant seedlings of *Thalassia testudinum* grown from seeds.

INTRODUCTION

Seagrass communities are composed of flowering plants that form underwater "meadows" in the shallows of marine environments. Worldwide there are only 58 species of seagrasses, which are the only submerged angiosperms. These are not true grasses, and are taxonomically placed in the suborder Liliopsidae. Seagrasses form dense carpets of grass that may have as many as 4,000 blades per square meter in optimal conditions.

Seagrasses are unusual for flowering plants because of where they live. Seagrasses must live totally submerged in salt water and have strong anchoring systems to hold them in place as currents flow past them. They also have to have a unique reproductive system different from land plants. They create flowers, yet they must rely on currents for pollination rather than insects as the land plants do. In addition they must compete with one another and with the algae for space, nutrients and available light.

Seagrass beds are strongly influenced by environmental conditions. Currents, waves, sediments, turbidity, salinity, temperature, desiccation and boat propellers affect them. In some locations where the currents and waves are too strong the seagrasses cannot hold on to the substrate. Where sediments are too fine or contain inappropriate nutrients, seagrasses will not grow. If turbidity is too high, then the plants cannot thrive due to a lack of sunlight. In some parts of the world the salinity is too low to support seagrasses. For example, during the rainy summer month's freshwater runoff into bays can be extensive. This dilutes the saltwater to such an extent that seagrasses can be stressed. A

typical seagrass needs at least 20 parts per thousand of salt dissolved in the water (typical ocean water is 33 parts of salt per thousand parts of water). Sometimes the salinities will drop to as low as 10 parts per thousand stressing the grasses to the point that they may not survive.

Temperatures in shallow waters can be quite extreme. During the winter months if the temperature drops below 22 degrees C, and a tide is moving out, many seagrasses will be exposed to a temperature that is potentially lethal. In addition, when the tides are at their extremes, seagrasses may be exposed to the air long enough for them to dry out. These extremes may kill large quantities of seagrasses. Boat propellers are another source of damage to seagrasses. The propellers can cut through the grasses at such a depth they destroy not only the visible blades, but also the subterranean parts of the plants and the microbes that help to support the plants (Dawes et al, 1997). Boat damage has the potential of destroying extensive beds of grass before they can recover. Damaged seagrasses may take as long as 5 years to recover.

Damage to seagrasses has been occurring in Tampa Bay for many years resulting in a loss of about 80% of the seagrasses that were present over 50 years ago (Lewis and Estevez, 1988). In the past 5 years there has been some natural recovery of seagrasses due to water quality improvements, but not enough to offset the losses that have occurred.

The value of seagrasses

Available scientific literature gives several reasons for the importance of seagrasses. Among the reasons are the following:

1. Seagrasses tend to have very high growth rates and production rates. They tend to add to the overall productivity of a region because of their growth rates.

2. The leaves of seagrasses tend to support large numbers of epiphytic organisms with biological mass approaching that of the seagrasses themselves.

3. Seagrasses, and the organisms on them, produce large amounts of detritus, which become food for other organisms.

4. Seagrasses have extensive root systems and lateral rhizome structures that tend to hold sediments together and prevent erosion.

5. Seagrasses act as nutrient sinks and sources.

6. Seagrass beds become the home to many forms of juvenile organisms as well as adult organisms. In areas where seagrasses have been destroyed, the populations of shrimp, snook, and many other species, tend to decline dramatically.

7. Seagrasses are used as a food source for Manatees, which have been seen in and around Tampa Bay.

Seagrass Loss in Florida

Seagrass loss in Florida has occurred for many years and has been extensive. The primary reasons for seagrass loss have been dredge and fill, changes in water quality and propeller damage. Examples of seagrass loss in Florida as reported by Sargent et al was as follows:

- Florida has lost about 2 million acres of seagrasses.
- Indian River Lagoon has lost 30%.
- Charlotte Harbor has lost 29%.
- Tampa Bay has lost 80%.
- Ponce Deleon Inlet has lost 100%.
- St. Andrews Bay has lost 30%.
- Florida Bay has lost 60,000 acres since 1987.

The presence of prop scars in seagrass meadows has been a concern for a number of years. Sargent, et al reported that statewide there are about 63,989 acres of seagrass that have moderate to severe propeller damage. The most heavily scarred areas are in Monroe, Lee, Dade, Pinellas, and Charlotte counties. Monroe County leads the list with over 15,000 acres of moderate to severe damage.

Recovery of seagrasses into prop scars can take many years. Zieman (1976) stated that *Thalassia testudinum* (Turtle-grass) might require at least two years to begin to re-colonize a prop scar. Durako et al. (1992) stated that recovery to normal density would take from 3.6 to 6.4 years. Others have stated that complete seagrass recovery may take as long as ten years (Lewis and Estevez, 1988).

One of the reasons postulated for the slow re-growth of *Thalassia testudinum* into prop scars is the slow appearance of a new apical meristem on the rhizome (Dawes et al, 1997). Formation of a new apical meristem may take as long as 10 months. However, this only partially explains the slow re-growth. Ehringer in 1993 speculated that the loss of the anaerobic bacteria in the sediment due to the stirring effect of the prop was part of the problem. Perhaps the bacteria were a source of nutrients to the roots and rhizomes. It may take a period of time to re-grow the bacteria colonies and the resulting nutrient load in the sediment.

Seagrass planting programs have not been very successful. Fonseca, Kenworthy and Thayer reported in 1987 results of an extensive comparison of seagrass transplanting techniques. In one of their planting projects all manatee grass was gone and only 30 per cent of the shoal grass had survived. In another planting project in Tampa Bay, Florida by Fonseca, Kenworthy and Courtney 14 plots of seagrasses were planted with 6 losing 95

to 100 per cent of their plants. Another 5 sites were lost later. Fonseca, Kenworthy, Courtney and Hall reported in 1994 on another transplanting project in which 40 per cent of transplants of *Syringodium filiforme* survived. All of their transplants of *Halodule wrightii* failed to survive. Techniques have been tried using peat pots, bare root, staples, and a variety of other methods. Yet the survival of the transplants remains low.

Injection of prop scars

Experiments have been conducted by Ehringer in Tampa Bay since 1993 working with fertilizers and plant growth regulators in an attempt to re-grow seagrasses into prop scars. Experiments were conducted in Cockroach Bay, a small bay attached to Tampa Bay, and at the Fort Desoto Aquatic Preserve from 1993 through 1999. Injection of prop scars in Tampa Bay following numerous replications resulted in the average re-growth of *Thalassia testudinum* into a prop scar at 56% of complete recovery in one season. In this same series of experiments *Halodule wrightii* re-grew into prop scars at 76% of complete recovery in one season. The results of further experiments are listed below. The means of injection was an injector boat built by James Anderson of Ruskin, Florida.

James Anderson built a special boat and injection system in the winter of 1997. The boat was designed to inject a nutrient formula into the seagrass sediments. The machine has a series of small injectors that push about 10 ml. of formula into the sediment. The injectors are set in a circular pattern around a wheel. As the wheel rolls along the bottom, the nutrients are injected into the sediment with a force of about 20 pounds per square inch. There are two wheels that roll along the sediment parallel to each other injecting at the same time. There are two other wheels that roll behind the injector wheels that push sediment over the injector holes to seal the nutrient formula into the sediment. The boat contains a 100-gallon tank for mixing of the formula. The formula is pumped from the tank through a series of tubes down to the injectors.

A mixture of 100 pounds of prilled nitrogen 44% plus 2 ounces of synthetic cytokinin and 2 ounces of a synthetic gibberellin was mixed in 100 gallons of seawater. The seawater was pulled from the bay at the site of the injections. Injections were placed into the sediment about every 20 centimeters along designated prop scars. Injections were made at Fort Desoto beginning in May of 1997 and extended for 5 injections approximately every 7 to 14 days. An additional injection was made in May of 1998. Injections were also made in Cockroach Bay and in the Lignumvitae preserve in the Florida Keys.

A counting method was established to determine the number of new shoots that would potentially grow into the prop scars after the injections. A one-meter square PVC frame was made to place over PVC stakes placed in a square pattern over a prop scar. The center portion of the frame had a one-meter by 22-centimeter frame inside the larger frame that fit over the prop scar lengthwise. This frame was set over the stakes at each

counting period so that the seagrass shoots could be counted each time in the same manner. Six sites were established for counting in injected prop scars. Sites were set up as controls. The results from the injection sites was as follows:

- In Cockroach Bay experiments were conducted over a three-year period. Using the planting boat in this series of experiments *Thalassia testudinum* re-grew into prop scars at a rate estimated at 40 to 60% during the period. Each count was performed within 6 months of the injections. There were 30 replications of the experiment. Controls showed re-growth of less than 10%.

- In Fort Desoto at the start of this experiment 9.25 shoots were found in the prop scars (13.2%). The prop scars were injected with the injector boat. After 15 months the average number of shoots was 47.3, or 68% of complete recovery. Therefore, prop scar recovery had grown to the point of 68% of a normal seagrass bed in 15 months at Fort Desoto as a result of the injections.

- In the Florida Keys at the Lignumvitae Preserve experiments were conducted in the spring and summer of 1998. Two formulations of the seagrass formula were used. The first formula contained the same nutrients as listed above. The second formula added phosphorus. The results were averaged for each formula (average number of short shoots of *Thalassia testudinum* per unit of 22 cm by 1 meter) as follows:

	May 1998	October 1998
Formula #1	7.75	31.50
Formula #2	8.75	34.80
Control	4.00	4.00

The data show an increase in short shoots of *Thalassia testudinum* in the prop scars from the period of May 1998 to October 1998 that is not apparent in the controls. No new shoots were found in the controls. One of the injected sites did not have any shoots of *Halodule wrightii* in the counting area in May of 1998 but had 135 short shoots in the October count. The data for *Halodule wrightii* is not counted in the above data.

In the summer of 1999 two sets of injected scars were found and one set of controls. The data was as follows:

	May 1998	June 1999
Formula #2	4.50	28.50
Control	4.00	6.00

A complete recovery of a prop scar 22 cm by 1 meter would have about 70 short shoots of *Thalassia testudinum*. Under normal circumstances a complete recovery would take years. From the above October data formula #1 gained 45% and formula #2 grew 49.7% of complete recovery during the five months from May to October.

The planting boat

In early 1998 James Anderson of Ruskin, Florida designed, built and patented a seagrass planting boat. The pontoon boat floats over the seagrass beds while two workers on board "feed" the seagrasses into a planting wheel. The wheel pushes the seagrasses into the sediment at a precise depth. Depending upon the number of seagrasses to be planted per acre, the boat has the potential to plant an acre in a day or two.

This technique requires fewer workers, is faster than traditional methods, and is less expensive. In addition, since the planter floats over the seagrasses beds, there is no damage to the planted seagrasses by workers walking through the beds to plants new seagrasses. The planter has been used on a limited basis in Cockroach Bay, in Fort Desoto and in Laguna Madre waterway at Corpus Christi, Texas. The system plants *Halodule wrightii* in peat pots or in bare root. In 1998 and in 1999 thousands of short shoots of *Halodule wrightii* have been planted using the boat. At the time of this writing no final counts have been made of the seagrass beds where the planter was used. Earlier indications are that the planting system was very successful.

A seagrass nursery

A seagrass nursery was established in the field using plants removed from Fred Howard Park. The seagrasses were removed as part of a mitigation plan to widen the beach at the park. Approximately 1,000 square feet of seagrasses were planted at Mangrove Point, near Simmons Park in Tampa Bay. The site was chosen for the following reasons:

1. The site was privately owned. It does not have boat traffic through it.
2. The site had a few seagrasses growing in it along an opposite bank; therefore, the water quality could have been conducive to seagrass planting.
3. The salinity regime was within a normal range for seagrasses.
4. The site has an easy access for boats and the site is shallow.

Beginning on June 18, 1998 and several dates thereafter, seagrasses were planted at the site by hand. Plants were soaked in the seagrass formula prior to planting. Twenty-two boxes were planted on June 18, 1998. About 400 shoots were planted with the planting machine. In August about 15 more boxes of bare root plants were planted at the site by hand. As of June of 1999 over 60% of the plants had survived.

Planting seeds

Seeds of *Thalassia testudinum* typically float inshore in very large amounts in the months of August and September in Monroe and Dade Counties, Florida. About 3,000 seeds were collected in September of 1998. The seeds were placed in small peat pots and stored in saltwater tanks in upland tanks at a seagrass nursery in Ruskin, Florida. The seeds were kept at the nursery for about 6 weeks allowing them time to grow into small seedlings. The planting units were transported to the Florida Keys and planted at a site selected by personnel from the Department of Environmental Protection (DEP). The seedlings were planted using the planting boat. The use of peat pots proved to be a good choice because the units were set into the sediment in a manner that could not be dislodged by currents. By May of 1999 most of the seedlings have survived, but a final count has not yet been made.

DISCUSSION

Two often-repeated standards were: "you cannot grow seagrasses into an area where seagrasses have not previously grown," and "seagrasses cannot be stimulated to re-grow." The foundation for the statements was that a seagrass nutrient formula had not been successfully tested, nor was a plant growth regulator available to stimulate rhizome growth in *Thalassia testudinum*. Recent experiments have shown that both are available. In addition, with the use of a planting boat, seagrass restoration can occur on a larger scale with less expense. The following steps illustrate the technique for a future mitigation project:

1. **The donor site:** remove the seagrasses in a 10-inch swath for any length necessary. A length of 50 feet will result in the removal of enough plants for an acre of planting.

2. **Recovering the donor site:** use the injector boat to inject nutrients and plant growth regulators into seagrass beds for rapid recovery of the seagrasses in the 10-inch swath. For the example above, inject the site where the seagrasses have been removed. Experiments with *Halodule wrightii* have shown that a section 10 inches wide by 50 feet in length can recover in one season to one year. For mitigation purposes, this concept results in no net loss of seagrasses as a result of a transplanting program (in fact, there is a gain of seagrasses at the transplant site).

3. **Preparing seagrasses:** Most seagrasses, when removed from the sediment will lose their roots. The loss of roots slows down the growth process after they have been transplanted, and even causes some loss of the seagrasses. To prevent this the seagrasses from the donor site can be soaked in nutrients and plant growth regulators to increase the probability of growing new apical meristems on the cut rhizomes. With new apical meristems on the rhizomes, the plants can colonize the new site more rapidly. The plants may also be placed in peat pots in order to anchor the transplants into the sediment.

4. **Planting of seagrasses:** plant an acre of seagrasses per day using the seagrass planting boat. The seagrasses are taken from the aquaculture tanks in their peat pots or in bare root, and planted with the machine. The peat pots hold the plant in place. The peat pots will dissolve in less than one year, releasing a nutrient formula to the plant that keeps the plant alive and accelerates growth.

5. **Follow-up injections:** two months after planting, inject the seagrasses with the formula of nutrients and plant growth regulators. This process accelerates the spreading of the seagrasses by inducing apical meristem growth and providing appropriate nutrients for rapid growth. The above experiments have shown that it is possible to use this technique even in locations where seagrasses have not previously grown.

6. **Follow-up planting:** if some of the plants do not survive the transplanting process, the planting boat can easily go back into the bay and plant new seagrasses. This assures a complete recovery at the site.

This seagrass mitigation concept may now be a reality with the advent of a seagrass planter, a seagrass injector and a formula to grow seagrasses. A full test is now needed.

SUMMARY

Since 1991 a series of experiments has been conducted to attempt to re-grow seagrasses into propeller scarred beds. Analyses were made of the sediments of healthy seagrass beds and compared to that of a prop scar. From this series of experiments a formula was derived that replaced the loss nutrient in a prop scar. Following this, another series of experiments was conducted in order to find a formula for a plant growth regulator that would grow an apical meristem on a cut rhizome of *Thalassia testudinum*. The combination of nutrients and plant growth regulators was tested in prop scars in Cockroach Bay, Fort Desoto and in the Florida Keys. The result showed that about 56% of complete re-growth was possible in one season. The formula was injected into the sediment using an injector boat built by James Anderson. Mr. Anderson also built a seagrass planting boat that was capable of planting up to an acre of seagrasses in one day.

The boat has been tested in Tampa Bay, the Florida Keys and in Texas. The planting boat has been used to plant short shoots of *Halodule wrightii* in peat pots and bare root. It has also been used to plant seedlings of *Thalassia testudinum* grown from seeds in the Florida Keys. These new techniques, taken together, offer a wide range of mitigation possibilities for recovery of seagrasses.

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USING TOURISTS AS A RESOURCE FOR ENVIRONMENTAL PROJECTS

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ABSTRACT

1) There is a growing need for methods to do more environmentally friendly work with less money.
2) Florida's population is growing at nearly 1000 people / week
3) There is a definite impact on the state's natural resources (e.g. water use) by this increasing population.
4) Many organizations have traditionally relied on volunteers to accomplish mitigation or cleanups
5) There is a relatively untapped source of help - tourists.
6) Tourists are willing to pay (directly or indirectly) to help your programs.

INTRODUCTION

The Clearwater Marine Aquarium (CMA) received a grant in late 1996 to develop educational programming which would attract tourists into Clearwater (CW). The aim of the grant was not only to attract more tourists, but also to make them want to stay in the area longer. It was reasoned, if a person came for ½ a day or a couple of hours, they might just come to the beach. If that same person would merely double the amount of time they spent in Clearwater, then not only would they visit the beach, they might also have a meal or stay overnight, thus giving a local business more chances to increase business. The new program was named Marine Life Adventures! (MLA).

FOCUS

The Clearwater Marine Aquarium is the only tourist attraction in Clearwater (CW) according to the Florida Attractions Association. This means that when tourists visit the Tampa Bay area, there aren't many things to attract them west of Tampa. Many people were afraid that as the Florida Aquarium (FA) grew in prominence, it would out-shadow CMA. The idea for the FA grew out of the CMA. In 1978 the City of Clearwater agreed to lease an abandoned water treatment plant on Island Estates to the Clearwater Marine Science Center (CMSC). In that same year, the first classroom was opened. In 1980 a USDA Research Facility Permit was granted allowing the rehabilitation of dolphins, whales, and sea turtles. This has always been at the heart of the CMA's mission- the rescue, rehabilitation, and release of marine mammals and sea turtles.

In 1987, CMA's name was changed to the Florida Aquarium (FA) in anticipation of expansion into a greatly enlarged facility and focus. Disappointingly, the city of CW withdrew its support for the expansion. The FA and CMSC became separate entities and now there are two marine organizations instead of one and in 1995, the CMSC became the CMA.

The focus of MLA has always been more than just education. We believe that everyone who goes through an adventure with us should know when leaving, that they have done something positive or good for the environment. A small thing that any one person does may not seem like much when you look at it as an individual accomplishment, but when you think and see things incrementally, it adds up. An example of a small thing is how we teach tourist participants to recognize a Brazilian pepper (*Schinus terebinthifolius*). We then take that person in the field and have them find a Brazilian pepper and stand next to it. After they locate a plant, the Biologist on Board (BoB) sprays a basal application of Garlon IV to kill the plant. Next we have that same tourist plant a mangrove tree.

GAINS AND OUTCOMES

Overall, you can examine this scenario in five parts from the tourist's viewpoint: 1) the tourist learns what a problem Brazilian pepper is to Florida, especially from a wildlife standpoint. 2) They learn how to identify a plant and how it is being controlled. If we are lucky, the participant will then take with them that knowledge, and every time they encounter one of these plants during their vacation, they will recognize it. 3) The tourist will have helped plant a species of tree (restoring native vegetation) which would not have been done had it not been for their participation. 4) They will leave with a sense of having helped the environment; and 5) they will have had a good time on their outing. It's important the participants enjoy themselves - they are, afterall, on vacation.

If you examine the scenario from our viewpoint, you may reach some different conclusions. 1) A person has helped support your business and reduced your labor costs (economic gain). 2) They have helped eliminate a pest species (environmental gain). 3) They have replanted native vegetation (environmental gain). 4) They have spent a longer amount of time in your community and are therefore more likely to frequent other businesses in your area (economic gain). 5) That participant will go away with a sense of accomplishment, probably end up talking about your program to others, which might be the key to having others seek you out to repeat that experience (economic gain), and 6) the community in which you live will become a better place. They will have helped to beautify the community and that leads to increased property value (economic gain). You might disagree with the ranking of these gains, but I'm sure it can be agreed that the gains are real.

There are other examples that can be recorded, but it should suffice to say that the difference between using tourists and using volunteers is that the tourists will *pay* to do the work. Don't jump out of your chairs to dump those volunteers just yet - there are some potential pitfalls. Probably the greatest factor is that the tourist numbers fluctuate from season to season and month to month. Can you dependably rely on tourists being around when something needs

to be done right away? How do you attract those tourists anyway? Signs and brochures may not be enough. Might you end up spending large amounts of your budget with very little return? Can you have so many tourists that your existing staff cannot adequately service them? How do you handle liability?

Let us examine each of these points starting with economic gains. I'm sure we all learned in business classes that a business exists to survive. If a business doesn't want to prosper, the results are predictable - that business will die. It doesn't matter if we are talking not-for-profit or for-profit businesses or even governments. Sometimes a business will not survive no matter how hard we try or how much of a need is perceived for that business. Increased income and reduced labor costs are benefits when using paying customers to supplement your business. Increased costs may be incurred, as you may need a better insurance policy or updated equipment.

Environmental gains for some people are more important than economic gains. The long-term increase in the health of your community's environment will far outweigh a short- term loss or perceived inconvenience. For example, a boater may object to a change in course or a lower speed which might be posted in an area because their wake could potentially disturb the newly planted submerged grass plugs, mangroves, or fish condos (A fish condo is an artificial habitat installed underneath docks. These condos give filter feeders places to attach, providing natural filtering and cleaning of the bay's water. They also provide safe habitat for smaller organisms to escape predation by larger organisms in places where the natural habitat has been disturbed by the erection of a seawall). The long term result outweighs the short term inconvenience, as the grass may take hold or the mangroves root and the bay becomes a cleaner, healthier place and therefore a better place for the boater to spend their time or go fishing.

Aesthetic gains are sometimes easier to see than economic or environmental gains. Greener shorelines, cleaner water and better fishing are easier to see and sell to tourists. Aesthetic gains are as important as environmental gains because the two are intertwined. A better-looking environment usually means a healthier environment. Aesthetic gains may also cause an increase in tourism to your site thus fostering a need for better infrastructures to handle increased traffic, parking, etc. A payoff is that many improvements can be made to your neighborhood using revenues brought in by tourists instead of increasing taxes. Overall, the better our neighborhoods look the better our property values.

Finally let's take a close look at liability. There is an inherent risk associated with working outdoors. In the past, businesses dealt with liability by having participants sign waivers. Waivers don't work because you cannot waive gross negligence or liability. We have moved into a new arena. Our participants now sign an 'informed consent'. With an informed consent, you point out the reasonable and expected hazards plus demonstrate that you are making every possible effort to keep your participants safe. The informed consent holds up much better in court because you have shown that you actively tried to pursue the safest possible plan of action Don't forget about staff training. Your staff must be just as aware as you are about safety issues and potential hazards in order to have a favorable outcome during your

program.

What do I want to achieve?

Let's take a closer look at program development. Before you embark upon a program, you must first develop a goal or set of objectives. Don't do this in your head - write it out on paper and discuss it with your staff. Not only will this bring you and your staff closer, everyone will believe that they are part of the process of building and maintaining the business.

If you look long and hard enough, you will eventually find people out in the market who share the same philosophies and skills as yourself. Most of us don't have that luxury - time to wait and find the perfect combination in staff, coworkers, or management. Since everyone has something to give to your company, their opinions should count in some aspect of running the business. If you aren't in a position to chose who you will work with or the conditions in which the work must be done, that still is not a reason to outright discount someone's opinion.

After you have determined your goals, you may want to have a brainstorming session to determine how you will go about achieving your goals. It may be fine to say you want to use tourists to help in a mitigation project, but if there aren't any tourists around, you won't be successful in accomplishing your goals. Most of all, be organized. Disorganization is unprofessional. Always have a backup plan for rainy days or unexpected surprises.

How do I attract tourists?

There is no magic formula for attracting tourists to your facility. Flyers, posters, and brochures all have their place, and may draw in customers from long distances. Don't forget word-of-mouth advertising. A happy participant may tell four or five people and give you repeat business. An unhappy customer will definitely tell twenty or more. You might find it effective to have a staff member stand on the curb in a sandwich board and funny hat and hand out flyers. Please don't overlook the Internet. You will find increasingly that in order to stay competitive, you need to have a webpage with all the bells, whistles and funky graphics. Although the majority of the population is not online, many people have access through their jobs and increasingly are using the World Wide Web for their travel plans.

It takes time to build up to where a program can sustain itself. You have to remember that there are seasonal fluctuations in the number of visiting tourists. Use the low visitation times to do maintenance, repairs, or figure strategies for the coming season. You'll also find that you have to be aware of what is required in the project you are undertaking. If you are working to eliminate noxious exotic species, there might be times of the year when it is inadvisable to work with those species. Hopefully low tourist time would coincide but if not, having an alternate plan will allow you to continue working throughout the entire year.

Another opportunity not to be missed during slow periods is community service. Each business that connects with the community will benefit by having word of mouth advertising and more of a willingness by the local community to visit their business. Look for recreation centers, YMCAs, or church groups in less advantaged areas to fill some empty seats with those who might otherwise never have such an opportunity to experience and learn.

CONCLUSION- How do I determine success?

If your business meets all the goals you set aside, it might not be because you are overly successful. You might meet all your goals because you set your goals too low. It takes time to test your goals to see if they are too high or too low. The best measure of success in economic terms for the short term may be that your programs survive. Long term success isn't just surviving, it is surpassing your goals and prospering to the point where your business becomes self-sufficient.

Frequently we think that environmental success can't be measured as easily as economic success. We reason that since change is slow and you are looking for a cumulative effect, it may be years before any change is seen. In some cases, you may never see any change. We would therefore come to the conclusion that you must sometimes just have faith that as long as you do no harm, your efforts are not in vain.

MLA doesn't measure environmental success by waiting to see results. By doing simple things like carrying dip-nets aboard the boats and slowing down to remove floating debris from the waterways and shorelines, we have a visible and measurable method of determining the impact of our activity. MLA also counts the number of Brazilian pepper trees sprayed, mangroves planted, and native vegetation replaced to determine in a quantitative method the success of our program. We have reason to believe that qualitative results are accessed by quantitative results, ultimately leading to measurable success.

DICKINSON BAY OYSTER REEF/WETLAND RESTORATION DEMONSTRATION

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ABSTRACT

A high priority of the Galveston Bay Habitat Protection Plan is to restore, create and protect wetlands. The Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project will provide protection for newly created emergent wetlands on the east shore of Dickinson Bay, Texas. This information will be useful to Galveston Bay stakeholders during the implementation of the Galveston Bay Estuary Plan.

The Dickinson Bay Oyster Reef and Wetland Restoration Demonstration Project will provide essential demonstrative information concerning innovative ways for shoreline stabilization that will function as oyster reef and fish habitat, and will provide protection for newly created emergent wetlands on the south shore of Dickinson Bay.

The project consists of 427 meters of oyster reef creation and planting of smooth cordgrass along the shoreline next to the reef. This paper will give the results of the project including oyster spat set, establishment of vegetation and shoreline erosion rate measurement during the 1997-98 year.

INTRODUCTION

Galveston Bay ranks high among the nation's great bay systems, providing huge economic benefits to the region and state. Remarkably, the bay's natural resources are self-renewing since the bay remains healthy and productive. However, Galveston Bay, like many other U.S. bays, now faces significant problems related to habitat loss and species declines, conflicting human uses and pollution. Some management practices are already working to improve the bay. Other serious problems still need to be addressed if disasters noted in other U.S. bays are to be prevented. The bay's most serious problems, such as habitat losses and non-point source pollution, occurs at the ecosystem level, and will require interdisciplinary solutions involving both natural resource agencies and bay stakeholders.

The Galveston Bay System represents a huge economic, cultural, and environmental asset to Texas and the Nation. In order to maintain this value of bay assets for the future, and to address current problems which have been documented by the Galveston Bay National

Estuary Program, innovative habitat restoration projects are initiated. The objective of this demonstration project is to display technology and to educate users of the bay on the value of habitat.

A high priority of the Galveston Bay Plan Habitat Protection Plan is to restore, create and protect wetlands. The Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project attempts to provide protection for newly created emergent wetlands on the east shore of Dickinson Bay. This information will be useful to Galveston Bay stakeholders during the implementation of the Galveston Bay Plan.

This project consists of 427 meters of oyster reef creation and the planting of smooth cordgrass (*Spartina alterniflora*) along the shoreline adjacent to the reef. This report will give the results of the project including oyster spat set, establishment of vegetation and shoreline erosion rate measurement during the 1997-98 year of the contract.

This report is intended to provide information on the feasibility of using oyster reefs to not only provide much needed habitat but to determine it's effect on shoreline erosion. The site of Dickinson Bay suffers from a severe erosion rate and has very little shallow oyster reef habitat close to the shoreline. The scope of the contract is not enough time to document the effects of reef creation on erosion rates, but the Natural Resources Conservation Service is committed to monitor this site for the next five years and will be reported to the Estuary Program thru the Galveston Bay Council.

Study Site

The Environmental Protection Agency and the Texas General Land Office cooperative project report, "Wetland Restoration and Creation in Dickinson Bay and Dickinson Bayou", identified the south shore of Dickinson Bay as an ideal site for successful wetland restoration and the creation of oyster reefs.

This project will utilize a variety of methods of oyster reef construction, habitat enhancement and shoreline protection in one project. The oyster reef consists of a double row of fences thirty to sixty meters from the shore and consisting of four thirty-meter overlapping sections. The interior of

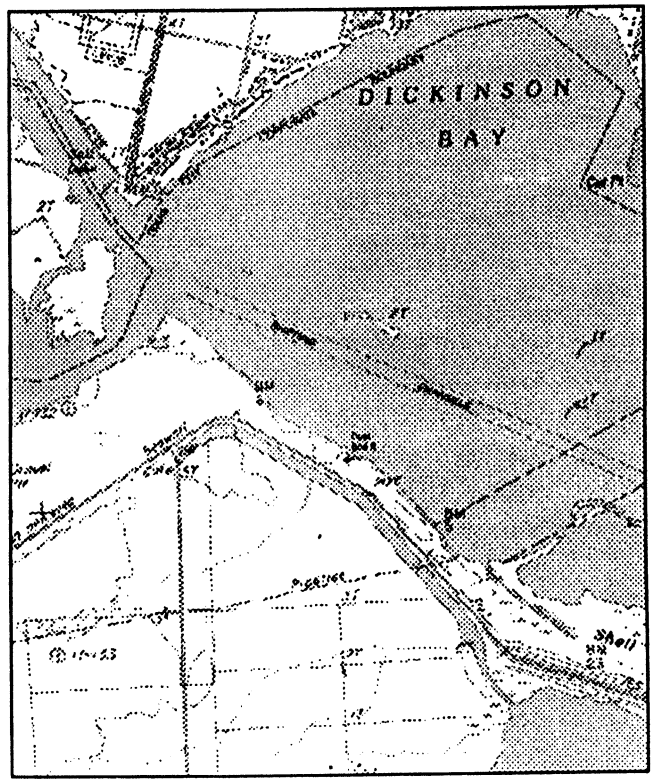


Figure 1

the fence will be filled with a base of recycled crushed concrete. Coal ash or oyster shell will be placed on top of the concrete at the most advantageous time for the settlement of oyster spat. Smooth cordgrass will then be planted in the protected area behind the fence.

The location of the study area is shown in Figure 1.

The Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project will provide essential demonstrative information concerning innovative ways for shoreline stabilization which will function as oyster reef and fish habitat and will provide protection for newly created emergent wetlands on the south shore of Dickinson Bay.

The final decision-makers for the results are the Natural Resources Conservation Service, the Galveston Bay Estuary Program, and the Environmental Protection Agency. Users (customers) of the results include federal agencies such as the U.S. Army Corps of Engineers, the Natural Resource Conservation Service, state agencies such as the Texas Natural Resources Conservation Commission, the General Land Office, and local authorities.

The primary task of the Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project is to create approximately 490 linear meters of oyster reef, to plant a wetland behind the reef and to stabilize approximately 70 linear meters of shoreline in Dickinson Bay using revetment mat.

Materials and Methods

Prior to the start of construction, the project area will be surveyed to assist in placement of the material for the oyster reef and to establish initial shoreline locations as a reference for shoreline erosion rates. A wooden support fence will be built in the configuration shown in Figure 2 to act as an initial support for the newly constructed reef. Wooden posts will be driven into the bottom of the bay at designated locations. Boards will be attached horizontally to provide additional support as shown in Figure 2. Oyster shell will be brought to the site by barge and placed in between the wooden support rails to create 490 linear meters of oyster shell reef. The final structure arrangement is shown in Figure 3.

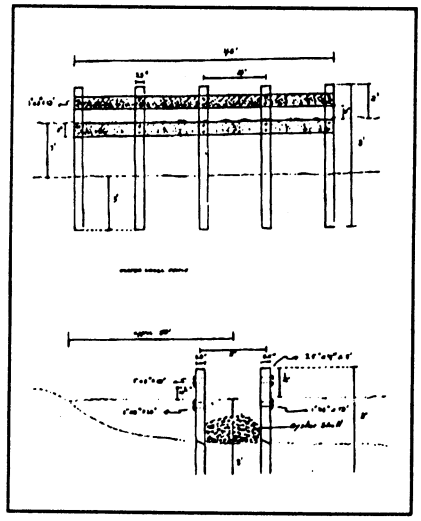


Figure 2

Once the oyster shell berm is constructed, smooth cordgrass *(Spartina alterniflora)* will be planted shoreward behind the artificial reef to create an emergent wetland habitat. Nearby to the reef construction, approximately 70 linear meters of shoreline will be covered with revetment mat. This revetment mat will be used to stabilize the shoreline for comparison to

erosion rates of other shorelines in the adjacent project area.

Upon completion of all shoreline stabilization structures, initial shoreline locations will be determined in relation to the established benchmarks. The adjacent control shoreline location is assumed to have had the same erosion activity as the test shoreline prior to construction.

Work began on the project in October 1996. A total of one full-time and five part-time employees worked on the project until August 31, 1997. The remainder of the time was spent on monitoring and maintenance.

The oyster fence was constructed first by installing the posts and then installing the two-by-four boards and the fence material. This process was very labor intensive and required a great deal of time to complete the installation. The posts were driven by hand. It took almost 6 months to complete the fence. If this oyster fence proves successful, reduction in both time and cost needs to be addressed.

The fence was filled with oyster shell beginning in March 1997. Shallow areas were filled with a custom-built barge, which proved difficult because only two yards could be hauled at time. A larger boat that could haul 16 yards at one time was used, but only at high tide. The process of filling the fence material took approximately 30 days. The fence material supported the oyster shell very well. Some of the boards did break, but the shell stayed in place.

RESULTS

Measurements required during the course of this project include:

Oyster Spat/Oyster Cover - Oyster spat/oyster cover will be determined following the placement of the oyster shell substrate on the crushed concrete. In addition, the total area of created oyster reef will be determined and photographic documentation recorded.

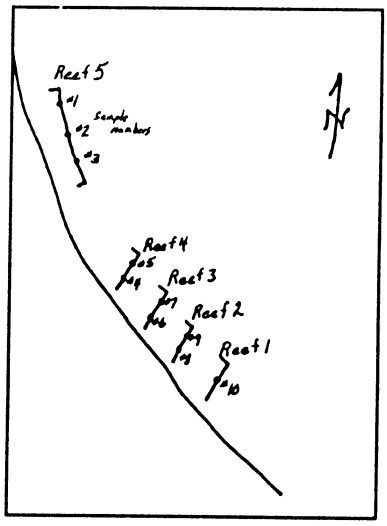
Cord Grass Survival Rates - Cord grass survival rates will be determined after approximately two weeks following initial transplanting. In addition, the total area of created marsh will be determined and photographic documentation recorded.

Oyster Spat/Oyster Cover Monitoring Activity

The initial monitoring of oyster spat/oyster cover for the Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project was completed on Thursday, September 4, 1997. The reef structures and sample locations are shown in Figure 3. Reefs # 1-4 each had a linear portion that consisted of 23, 2.35-meter segments as defined by the wooden upright posts of the constructed oyster shell fence. A small L-shaped structure was made at the end of each linear portion consisting of three 2.35-meter sections. Reef #5 consisted of 63, 2.35-meter

segments with small L-shaped structures consisting of three 2.35-meter segments at each end. The width of all reef structures was 0.76 meters.

Figure 3
Reef Segment Sampling Locations



The linear-portion segments of reefs #1-4 were numbered 1-23 going South to North. The linear-portion of reef #5 was numbered 1-63 going North to South. The sample locations for each reef was determined by randomly selecting from the numbered segments on each reef. The area sampled for each sample was 1.79 square meters with three replicates.

The approved Quality Assurance Project Plan indicated the following sampling procedure:

"Oyster spat / oyster cover will be determined by sampling randomly one square meter quadrants at 10 sites on the reef with three replicates per sample (30 samples total) approximately 30 days following the placement of the oyster shell mulch material on the reef. These samples will consist of oyster shell mulch material at the surface of the reef. Further sampling will be done as required. The oyster reef will be broken down into numbered segments and the segment numbers to be sampled will be chosen with a mathematical random number generator. All samples will be collected by hand and the samples placed into labeled buckets. The oysters are assumed to be *Crassostrea virginica* but specimens will be preserved if further identification is required. All specimens greater than five millimeters will be counted in each sample (alive or dead). The total areal extent of the oyster reef will also be determined. Photographic documentation will also be recorded to illustrate the size of the oyster reef "

It was determined that the replicate samples would consist of 20 clutch oyster shells per sample with three replicates to a segment sample area. Three groups of 20 mulch oyster shells were placed on the deck of a boat for enumeration of oyster spat/oyster cover. These samples were counted and the results recorded as indicated in Table 1 (no dead oysters were noted on this sampling date).

Table 1

Sample #	Reef #	Segment #	Replicate #	Total Spat/Sample	Mean	Standard Deviation
1	5	8	1	46	52.7	9.1
1	5	8	2	49		
1	5	8	3	63		

2	5	19	1	26	60.3	39.2
2	5	19	2	52		
2	5	19	3	103		
3	5	30	1	53	49.0	3.6
3	5	30	2	46		
3	5	30	3	48		
4	4	7	1	40	40.0	5.0
4	4	7	2	45		
4	4	7	3	35		
5	4	14	1	105	88.7	17.0
5	4	14	2	90		
5	4	14	3	71		
6	3	8	1	28	34.7	5.8
6	3	8	2	38		
6	3	8	3	38		
7	3	20	1	66	58.0	13.9
7	3	20	2	66		
7	3	20	3	42		
8	2	12	1	100	76.6	32.9
8	2	12	2	91		
8	2	12	3	39		
9	2	23	1	51	82.7	27.5
9	2	23	2	101		
9	2	23	3	96		
10	1	15	1	47	73.7	31.9
10	1	15	2	65		

10	1	15	3	109		

For all samples:

Mean = 61.6 ± 29.0 (at a 95% Confidence Level)

Standard Deviation = 25.6

Surface area of the 20-shell sample was determined by placing 20 oyster shells side-by-side on a flat surface and the area measured (length x width). It was determined that 20 oyster shells placed in this configuration had a total surface area of 0.09 sq. meters (0.24 m x 0.38 m). This surface area was doubled since both sides of the oyster shells were counted. Therefore, 0.18 sq. meters was assumed for calculation purposes to be the surface area of each sample taken. The surface area of each spat was assumed to be 0.000025 sq. meters (.005 m x 0.005 m) by definition. The percent oyster spat cover for each sample is shown in Table 2.

Table 2

Sample #	Percent Cover
1	7.3
2	8.4
3	6.8
4	5.6
5	12.3
6	4.8
7	8.1
8	10.6
9	11.5
10	10.3

For all samples:

Mean Percent Cover = 8.6 ± 3.0 (at a 95% Confidence Level)

Standard Deviation = 4.8

On this sampling date, the percent oyster spat cover was less than the stated goal of 20%. Further sampling will be required.

The second monitoring of oyster spat/oyster cover for the Dickinson Bay Oyster Reef/Wetland Restoration Demonstration Project was completed on Monday, January 12, 1998. Two sample locations per reef were chosen at random. The area sampled for each sample was 1.79 square meters with three replicates.

Three groups of 20 mulch oyster shells were placed on the deck of a boat for enumeration of oyster numbers. These samples were counted and the results recorded as indicated in Table 3 (some dead oysters were noted on this sampling date but were not counted due to their extremely low numbers).

Table 3

Sample #	Reef#	Segment#	Replicate#	Total Oyster/Sample	Mean	Standard Deviation
1	5	9	1	87	87.3	14.5
1	5	9	2	102		
1	5	9	3	73		
2	5	34	1	27	33.0	20.7
2	5	34	2	16		
2	5	34	3	56		
3	4	15	1	92	90.3	13.6
3	4	15	2	76		
3	4	15	3	103		
4	4	20	1	98	105.0	51.9
4	4	20	2	57		
4	4	20	3	160		
5	3	7	1	38	63.7	22.2
5	3	7	2	77		
5	3	7	3	76		
6	3	17	1	66	72.3	7.8

6	3	17	2	81		
6	3	17	3	70		
7	2	7	1	56	59.0	7.9
7	2	7	2	68		
7	2	7	3	53		
8	2	16	1	105	99.3	20.1
8	2	16	2	116		
8	2	16	3	77		
9	1	15	1	82	90.0	19.3
9	1	15	2	76		
9	1	15	3	112		
10	1	22	3	115	142.3	24.4
10	1	22	2	162		
10	1	22	1	150		

For all samples-
Mean -84.2 $\pm$ 23.0 (at a 95% Confidence Level)
Standard Deviation = 34.7

Surface area of the 20-shell sample was determined previously by placing 20 oyster shells side-by side on a flat surface and the area measured (length x width). It was determined that 20 oyster shells placed in this configuration had a total surface area of 0.09 sq. meters (0.24 m x 0.38 m). This surface area was doubled since both sides of the oyster, shells were counted. Therefore, 0.18 sq. meters was assumed for calculation purposes to be the surface area of each sample taken. The surface area of each young oyster was determined by measuring across the width of the oyster as the diameter and calculating the area assuming a circle. This calculation would provide a very conservative estimate of oyster surface area due to the fact that most of the oysters were elliptical and were longer than they were wide. The results are indicated below.

Table 4

Oyster #	Width(meters)
1	0.045
2	0.040
3	0.030
4	0.025
5	0.020
6	0.015
7	0.022
8	0.019
9	0.020
10	0.016
11	0.025
12	0.020
13	0.024
14	0.019
15	0.020
16	0.016
17	0.020
18	0.023
19	0.027
20	0.019

These data indicated:

Mean Young Oyster Diameter = 0.023 meters
Standard Deviation = 0.00742 meters

The mean young oyster surface area was calculated to be 0.0017 sq. meters. The percent oyster cover was thus:

Mean Number of Oysters/Sample) X Mean Young Oyster Surface area/Mean Sample Area) X 100
or

(94.2) X (0.00 1 7/0.18) X I 00 = 79.52%

This, value far exceeds the success target coverage of 20%.

It should be noted that the young oysters were not neatly aligned in rows side-by-side, but were rather randomly positioned at all angles. Some young oysters had attached to other young oysters such that the mulch material was entirely covered. It appeared that the majority of the young oysters had attached to the smooth side of the dead oyster shells that had been originally placed on the reef.

Environmental Data

Environmental data collected on the sampling date is as follows:

Water Temperature (Centigrade) - 18.3
Salinity (ppt) - 7.0
Secchi Depth (meters) -0.28

Wetland Plant establishment area was monitored on January 5, 1998 and again on June 4, 1998

As of June 4, 1998 we reported 386 plants alive out of 525 plants that were planted this translated to a 73% survival rate. The measured marsh acreage was 3,000 square meters

Five benchmarks were placed on the shoreline behind all of the treatments.
Erosion on Dickinson Bay (Meters of Erosion from permanent Benchmark.)
Data is from 6 , 12 , 18, and 24 months.

	trilock	control	parallel	angle N	angle S
6 mo	0.0	.6	.6	1.0	.6
12 mo	0.0	1.0	.6	1.0	.6
18 mo	0.0	3.0	1.3	2.0	1.3
24 mo	0.0	5.0	1.6	2.6	1.3

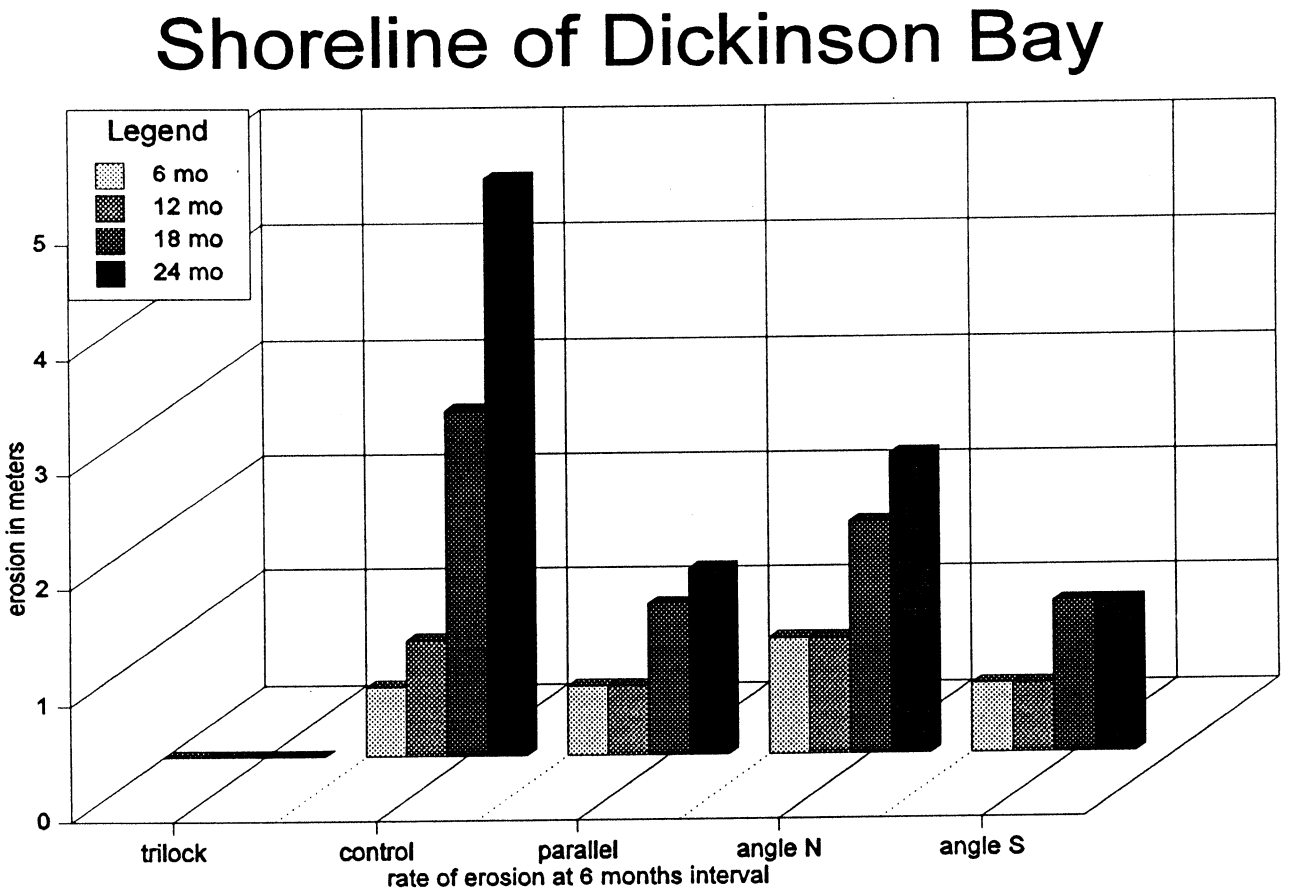


Table 5

Project Conclusions

As shown in the data collection for the oyster monitoring we have a well established growing oyster reef. There has been some damage to the fence over time but this has not materially effected the function of the reef. There is a good colonization of oysters not only on the top of the reef but also along the sides. It has been noticed that there is a small amount of sediment that has accumulated on the inside of the shell fence. This may be something we may consider monitoring in the future.

The cost of installation for the oyster shell reef was $78.83 per foot. This cost was higher than anticipated. The cost of labor was almost twice as much as the cost of the material.

This reef is built in an area where no oyster reefs are currently located. There are reefs in the area, and there are individual oysters on scattered tires and other hard objects. The bottom is unconsolidated soft bottom. This bottom material is not generally considered suitable material for oyster mulch.

In addition, this area of Dickinson Bay and the portion of Dickinson Bayou upstream from the area has been closed to oyster production for a number of years. The purpose of the oyster reef is not designed to be for harvesting. The major purpose of this reef is for habitat restoration. In addition, it is hoped it will have some effect on erosion and water quality.

Approximately 70 meters of shore protection was installed at an adjacent site. The principle investigators wanted to have a comparison using hard shore protection to see both the effects and to have a cost comparison to the oyster shell reef. Tri-lock concrete blocks were installed on a 3:1 slope from the top of the bank to 0 .8 meter below normal tide elevation. The tri-lock was installed according to manufactures recommendations and has not required any maintenance. It was anticipated that vegetation would grow in the interspace but all of the soil material was washed out. We will continue to monitor this site to see if vegetation will develop. The top of the bank that was disturbed during construction was seeded with common bermuda grass. There is no erosion occurring at this site.

The cost of the Tri-lock was $ 171.37/foot. This was higher than other shore protection such as bulkheading but the tri-lock is more aesthetically pleasing. It will also be a good alternative to concrete rip-rap if vegetation will grow and provide habitat.

We installed five reference stakes on the shoreline to monitor the long term erosion rates at each treatment. One reference stake was placed at a control site. Two of the reference stations showed 1 meter of erosion and two of the sites behind the angle reef showed .6 meters after one year. We consider that there has been no difference in the erosion rates between any of the treatments and a control area. We believe that this is due to the fact that the reef is new and the effects of the reef creation will increase as the reef develops. This will

be one of the most important areas to monitor in the future and the Principle Investigator has made a commitment to monitor the reference stakes for at least five years.

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INVENTORY AND ANALYSES OF BIOLOGICAL COMMUNITIES IN SOUTHERN GOLDEN GATE ESTATES, A WATERSHED FOR THE TEN THOUSAND ISLANDS, COLLIER COUNTY, FL: VASCULAR PLANT COMMUNITIES

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ABSTRACT

South Golden Gate Estates, in southwestern Florida, is a large wetland that was permitted for development several years ago. The early stages of development (drainage canals and roads) and land sale were undertaken, so that the hydrology of the area has been changed. The State of Florida has begun acquiring properties here, and the South Florida Water Management District, with the U. S. D. A. Natural Resource Conservation Service, has begun hydrologic restoration of the area. Most of the area is dominated by mixed cypress forest and marl prairie. These communities are often inundated much of the year, but in the South Golden Gate Estates, substrates are seldom under water. Monitoring the progress of restoration will in part be accompanied by measuring changes in water levels and plant communities. This outlines the first information and data collected before restoration commences, and compares current conditions with detailed information gathered over 50 years ago. Substrates in the area are mostly wetlands soils, and are indicated with recent classifications. Since drainage, fire frequencies and areas burned have increased and some communities now support significant populations of exotic Brazilian peppers (*Schinus terebinthifolius*). Cabbage palm (*Sabal palmetto*) appears to have proliferated, colonizing large areas. Vascular plant richness in most communities has remained similar to before drainage, but numbers of species that indicate wetland communities have decreased.

INTRODUCTION

The Southern Golden Gate Estates (SGGE) area, in southwestern Florida, was prepared for development several years ago. As part of this pre-development land preparation, a

system of drainage canals was installed to facilitate water delivery from the inland (wetland) communities to the Gulf of Mexico. Water formerly moved by sheet flow, slowly through this area from the inland wet prairie and cypress wetlands, into the Ten Thousand Islands estuary system. The water delivery system that was installed now carries water through the Faka Union canal, so the fresh water that formerly flowed through the estuary now is discharged in Faka Union Bay. This has likely affected the salinities of waters in this bay and the surrounding waters, so that water qualities may have been compromised throughout the downstream area. In addition to changes in water quality, the seasonal periodicity and volume of freshwater runoff into the estuary communities has been altered by establishing a point-source discharge of fresh water into the Ten Thousand Islands system. The submerged lands and associated mangrove forests of the Ten Thousand Islands estuary are mostly held in public ownership, and managed by state or federal regulatory agencies. Part of the inland tributary area (SGGE) is now being acquired by the State of Florida, so that restoration of hydroperiods and wetland communities will occur. This restoration will also restore fresh water inputs to the estuary system that will be similar to those that occurred before drainage (USGS 1996).

STUDY SITE

South Golden Gate Estates is ca. 94 mi^2 of freshwater wetland with occasional upland communities in southern Collier County. Communities in the southern part of the area, located 3-5 km north of US 41 (Tamiami Trail) are mostly hydric cypress and mixed hardwood sloughs, and marl prairies. Communities in the northern part of the area, south of I-75 (Alligator Alley), are often mesic or hydric pine flatwoods with cypress sloughs. Leighty et al. (1954) similarly indicated the area as largely bald cypress swamp with short grass prairie, and occasional mesic hammocks and flatwoods communities.

The area was altered perhaps most significantly in the late 1960's and early 1970's when the Faka Union drainage canal system was installed. This canal system consists of four north-south oriented canals that effectively drain the area's surface water to deliver it into the main Faka Union canal and directly to the Gulf of Mexico. Gore (1988) estimated that the Golden Gate and Faka Union Drainage canal system drains the Golden Gate Estates area 16 times faster than before canal installation, and has reduced wetland hydroperiods by 2-4 months. In addition, the Golden Gate canal system to the west, and the I-75 borrow canal (also connected to the SGGE drainage canals) drain much of the adjacent and surrounding areas. About 600 km of roads were constructed with borrow material from ca. 77 km of canals that had been installed, also in preparation for development. Most of these roads are oriented east to west and were placed every 0.8 km. These roads do not appear to significantly inhibit water flow, as land slope is gradual and water movement is slow; most substrates are rapidly permeable (Liudahl et al. 1998) and may allow flow beneath the roads. Since preparation for development, much of the area was sold to thousands of owners, but very few currently reside there. Collier County estimated that 26 persons (10-12 households) resided in SGGE in 1990 (Collier County 1999). In the mid-1980's the State of Florida began purchasing properties in the SGGE

(Ramsey and Addison 1996), to eventually place the area within public ownership, so that restoration could occur.

Restoration of wetland communities is expected to be concomitant with hydrologic restoration. This study was conducted to determine conditions of the communities extant in the SGGE area. This information can be compared to descriptions of communities that occurred here before drainage to estimate changes that have occurred after drainage; the data that are collected to describe the current communities will also be valuable to monitor the progress of the future restoration. Biological communities are identified in this study with their vascular plant components.

The primary objective of the wetlands restoration in SGGE will be to produce a system that is similar to the pre-drainage suite of communities in this area. No data describing the natural areas in SGGE are known to have been collected before drainage occurred. However, the area was surveyed in the 1940s as part of a detailed reconnaissance to map the soils of the county (Leighty et al. 1954). This survey included descriptions of the plant communities commonly found on the County's major soil types; part of these descriptions were lists of vascular plants commonly found in these communities. The descriptions and species lists in this survey will be used to compare current and future plant community data. These comparisons can be used to monitor the progress of restoration activities. Land managers should note that a return to ecological conditions that are the same as the pre-drainage situation is unlikely, but that a change to more hydric conditions similar to former communities is anticipated.

METHODS

Six biological communities that may be affected by restoration were selected for monitoring: 1) mesic pine flatwoods; 2) hydric pine flatwoods; 3) cypress or mixed cypress and hardwood slough; 4) hardwood hammock; 5) prairie; *Schinus*-dominated communities. These were located randomly in these communities, at least 20 m from the nearest road to minimize disturbances caused by roads. Five sites at least 3 km distant from the SGGE drainage system were also chosen for comparison. These sites were also established in the same representative communities (above). The *Schinus*-dominated community, however, was not sought for comparison, as this exotic may dominate nearly any terrestrial community in the area (Burch 1992).

Vascular plant species encountered at each site were recorded and a piezometer was installed at each site to determine surface water levels. Global positioning system (GPS) coordinates were recorded at each piezometer so that each site could be located. Descriptions of the sample areas were compared with the outlines of communities commonly found on soil types at each location, as described by Leighty et al (1954). Lists of species found at the sample sites were compared with lists in the ground cover classification legend used by the Soil Survey Party during surveys for the pre-drainage soil survey (Leighty et al. 1954). Numbers of wetland indicator vascular plant species were considered as indicators of hydric influence at each sample area. Wetland indicator

status of vascular plants was determined with the State of Florida Department of Environmental Protection Wetland Species Indicator list (Tobe et al.1998).

RESULTS AND DISCUSSION

Habitat communities were more mesic in the northern part of the study area, and were mostly hydric in the southern part. In the northern area, mesic pine flatwoods, with hydric pine flatwoods and cypress sloughs are common; in the southern area, marl prairies with mixed cypress and hardwood sloughs are common. Many of these areas resemble the descriptions provided by Leighty et al. (1954). However, the species encountered in this study differed from those recorded before drainage.

Many areas appeared to have changed since drainage. Plant species that are associated with more mesic communities have become common in cypress sloughs. This includes invasion by the exotic Brazilian pepper (*Schinus terebinthifolius*). Dominance or partial dominance of tree or shrub layers by *Schinus* is common in communities that were previously described as cypress sloughs, and now appear to be disturbed. These areas usually contain remnant living cypress trees, dead cypress trees, and hardwood trees often found in hydric communities.

Fires appear to have become more frequent throughout the study area. Fires commonly occur in pine flatwoods, and even more often in seasonally inundated prairies (Wade et al. 1980). In hydric mixed hardwood and cypress sloughs, however, fires are much less common. In areas where extreme changes appear to have occurred, few or no live cypress or hardwood trees were found. Dead, charred cypress trees or their stumps, however, were common. Gore (1988) noted that acres burned in Collier County increased significantly after completion of the Faka Union drainage system. The increase continued for several years after its completion.

Sabal palm (*Sabal palmetto*) trees have proliferated in some areas formerly dominated by cypress trees. In these places, occasional tall (apparently old) sabal palms are scattered, with many smaller sabal palms dominating the shrub or low tree canopy. The smaller sabal palms appear to be the same age, suggesting that they became established contemporaneously, and the larger, older individuals appear to be the parent population. The older-appearing sabal palms frequently grew with large root mats surrounding the trunk bases; no adventitious root growth was noted on the younger-appearing sabal palms. Little or no surface water inundation was noted at these locations.
Small (1936) indicated that growth of these roots may be a response to seasonal inundation, suggesting that these areas formerly were subject to seasonal inundation about the depth of the root masses.

Numbers of vascular plant wetland indicator species were lower at sample sites in this study than the indicator species included in lists of species typical of the communities found on soils before drainage (Leighty et al. 1954). Numbers of vascular plant species were greater in the southern (more hydric) part of the study area than in the northern

(more mesic) part, in both pre-drainage and the current studies. In the pre-drainage study (Leighty et al. 1954) the numbers of wetland indicator species was consistently about two-thirds the total number of vascular plants regardless of north-to-south location. In the southern part of the study area the number of wetland indicators was ca. 22, and in the northern part of the area the number of wetland indicators was ca. 12. In the current study, the total number of vascular plant species was about the same regardless of location, and the number of wetland indicator species was greater in the southern part of the study area, similar to the pre-drainage study. The change in numbers of wetland indicators from north to south in the study area occurred in the current study at about the same rate of change (slope) from north to south in the pre-drainage study. However, the total numbers of wetland indicator species in the current study ranged from ca. 12 in the southern part of the study area to ca. four in the northern part of the area.

Numbers of vascular plant wetland indicator species also were consistently lower in hydric communities supported by hydric soils. Twenty-three of the 26 sample sites in SGGE were located on hydric Pineda, Boca, Malabar, Hallandale, Ochopee, or Dania soil types. Wetland vascular plant indicators were considered as those listed as "Obligate" or "Facultative Wet" wetland indicators by the State of Florida Department of Environmental Protection (Tobe 1998). Sample areas on each of these soil types had fewer wetland indicators in 1997 than indicated in 1954 (Figure 1.). Similarly, hydric pine, prairie, and cypress communities had greater percents of indicator species in 1954 than in 1997, and mesic pine communities had a mean higher percent wetland indicators in 1997 (Figure 2.). Lower mean percents of wetland indicators were statistically significant in prairie and cypress swamp communities. Of the hardwood hammocks and *Schinus*-dominated communities analyzed in 1997, all were indicated as cypress swamp communities by Leighty et al. (1954).

CONCLUSIONS

Vascular plant communities in SGGE appear to have changed since the area was drained in the late 1960's and early 1970's. Numbers of vascular plants and types of communities found in 1997 were similar to those described before drainage, but percents of wetland indicators were lower in most communities. Disturbance by fire has also increased since drainage, so that many formerly hydric cypress communities have nearly disappeared or have been invaded by species more typically associated with mesic communities. Brazilian pepper (*Schinus terebinthifolius),* an aggressive exotic, has become common in many areas formerly dominated by mixed cypress associations. Also, numbers of sabal palms appear to be increasing in the areas that were formerly more hydric. Measures of community structure and vascular plant abundance will be used to monitor the progress of restoration. With hydrologic restoration of the area, biological communities are expected to become more hydric, and more similar to those described before the area was drained.

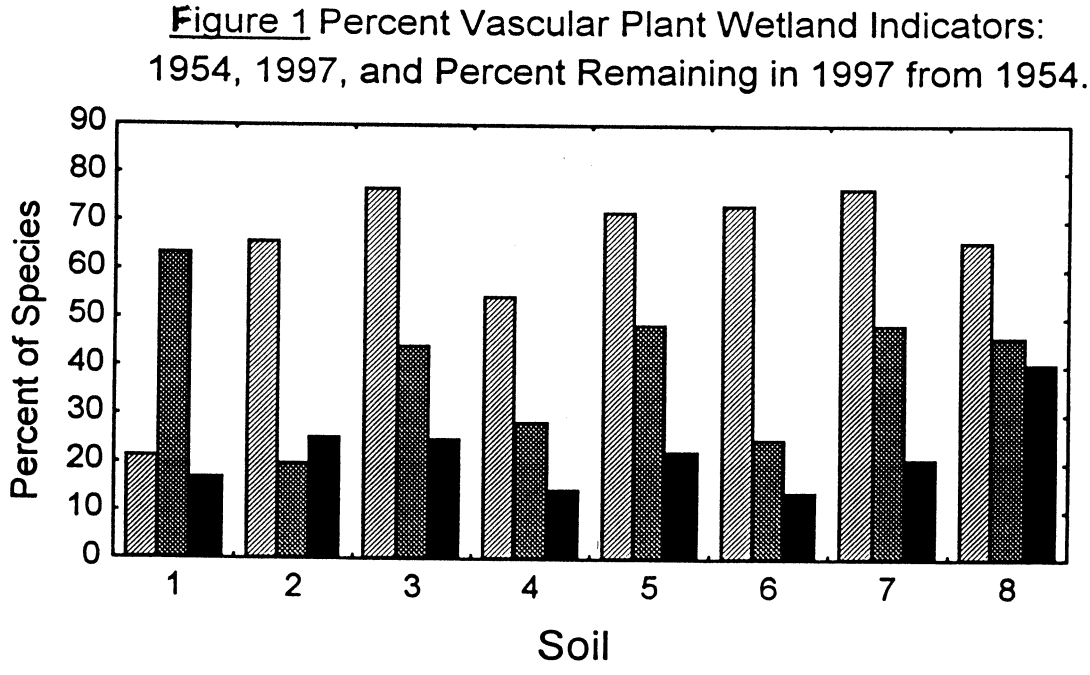


Figure 1. Percent Vascular Plant Wetland Indicator Species: 1954, 1997, and those Remaining in 1997 from 1954. Percents of wetland indicator species are indicated as mean numbers identified in sample quadrat on different soils. Hatched bars are mean numbers of wetland indicators listed in 1954; solid gray bars are mean numbers of wetland indicators identified in 1997; solid black bars are mean numbers of wetland indicators found in 1994 and 1997. Soil types indicated on the abscissa are: 1 - Basinger (n=1), 2 - Jupiter (n=2), 3 - Pineda (n=2), 4 - Boca (n=7), 5 - Malabar (n=4), 6 - Hallandale (n=7), 7 - Ochopee (n=2), 8 - Dania (n=1). Wetland indicators considered were species listed by the State of Florida, Department of Environmental Protection as "Obligate" or "Facultative Wet" wetland species.

Figure 2. Percent Vascular Plant Wetland indicators of Communities in South Golden Gate Estates: 1954, 1997.

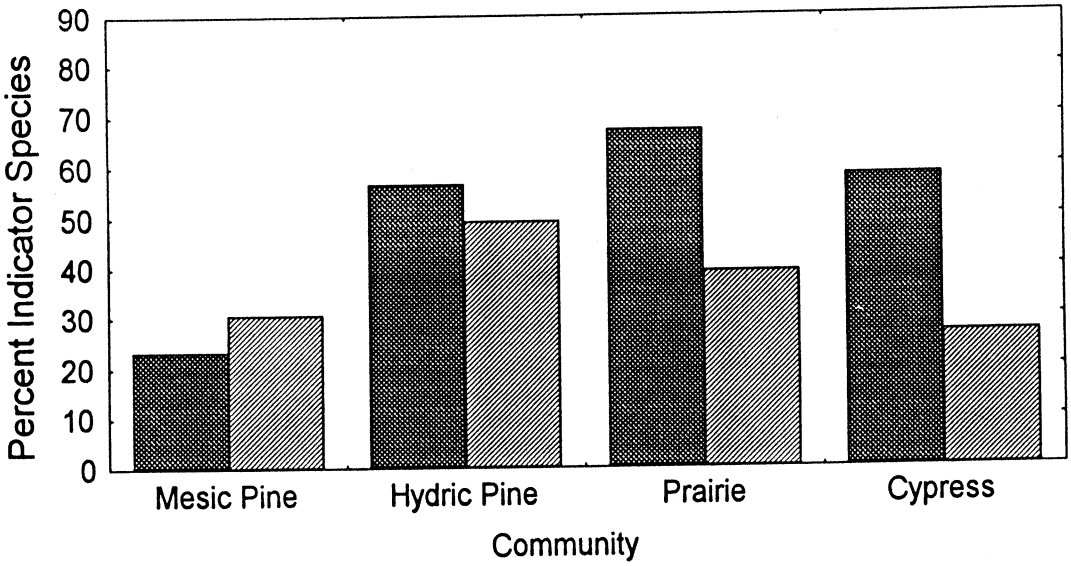


Figure 2. Percent of vascular plant indicators of wetland communities sampled in South Golden Gate Estates: 1954, 1997. Solid bars: wetland indicator species listed by Leighty et al. (1954); hatched bars: wetland indicator species identified in this study (1997). Wetland indicators considered were species listed by the State of Florida, Department of Environmental Protection as "Obligate" or "Facultative Wet" wetland species.

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WETLAND PLANT NURSERY DESIGNED TO TREAT NURSERY RUNOFF

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ABSTRACT

Our objective is to demonstrate an economical solution to treating agricultural runoff by constructing a wetland plant nursery that will produce ornamental and native wetland plants while cleansing runoff. Wetland plant material will be harvested and sold, and pollution reduction in the runoff monitored. A second set of treatment wetlands have been built to study the growth rate and nutrient storage capacity of several species of wetland plants. Over the next few years we will evaluate the economic impact of converting nursery production space into treatment wetland production space. Information gathered from both the on-farm demonstration and research sites will be extended to farmers and other agricultural businesses or professionals through outreach programming.

INTRODUCTION

Degraded water quality is a growing concern across the country, and in many cases may be linked back to agricultural operations as non-point sources of nitrate and phosphorous pollution (ASIWPCA 1985, Baker 1992, USEPA 1993). Containerized nurseries and greenhouses often produce nutrient laden runoff which may contribute to the nutrient loading of surface waters (HWQA 1992, Alexander 1993). This occurs when liquid fertilizer is applied through the irrigation system, or when nutrients are leached from fertilized fields or containers. In some operations it is estimated that up to 78% of applied irrigation water ends up as runoff (Furuta 1978). The necessity of frequent fertilizer and pesticides application, plus the large volumes of water needed to produce some crops, can contribute to ground and surface water pollution (HWQA 1992).

The role of wetlands in pollution and flood control has been recognized since the 1960's (Young 1996). Beginning in the 1970's Congress adopted a wetland policy of "no net loss" and mitigation, which required that new wetlands be created or restored as natural wetlands were lost to development (Young 1996). While wetland plants have often been collected from the wild for such mitigation projects, public policy has moved toward reducing or prohibiting such practices (Harbaugh et al. 1992). At the same time, water gardening has become one of the fastest growing specialties in landscape design and home gardening (Altekruse 1997). Ornamental emergent and floating aquatic plants represent some of the greatest demand and commercial value in the gardening industry today. Native wetland plants used for mitigation or constructed wetland efforts are also in high demand. With few wetland plant nurseries

operating in the Northeast, demand greatly exceeds supply. Given the demand and increasing popularity of the commodity, wetland plant production could represent a profitable niche.

Constructed wetlands have emerged as effective, low-cost methods of water treatment which have the potential to reduce agricultural non-point source pollution and contribute to agricultural sustainability (Hammer 1992). However, the costs of implementing treatment wetlands as a BMP are high, with little opportunity for cost recovery. We have initiated, at a wholesale plant nursery an economical solution to treating nursery runoff which incorporates into a treatment wetland the wholesale production of native and ornamental wetland plants. Our goal is to offer farmers an opportunity to produce a high demand crop while addressing non-point source pollution on their land.

MATERIALS AND METHODS

The treatment wetland will be located on a 80 acre nursery located in Middletown, RI. The wetland will treat runoff from a portion of a 5 acre container growing area. Standard fertilization consists of topdressing containers with a slow release, complete inorganic fertilizer (osmocote 18-6-12) in May of each year. Fertilizer leaches during the application of water by overhead irrigation. In current practice, runoff collects in a temporary storage pond where the water infiltrates into the ground or leaves the nursery through surface runoff.

Nursery runoff water will be pumped from the pond into a 35 m x 5m x 0.3m constructed wetland lined with 45 ml butyl rubber and filled with 4-7 mm diameter gravel. This wetland will be operated as a subsurface flow wetland with the water level being maintained just below the surface of the gravel. This prevents ponding for mosquito breeding and allows for wetland maintenance without having contact with open water. The wetland is planted with many taxa to increase sales potential by offering a large variety of material. Typha latifolia, Iris versicolor, Iris pseudacorus, Pragmites australis 'Variegata', Glyceria aquatica 'Variegata', Phalaris arundinacea 'Picta', Arundo donax, Arundo donax 'Variegata', Spartina pectinata 'Aureo-marginata, Hibiscus palustris, Clethra alnifolia, Sagittaria latifolia, Pontederia cordata, and Canna generalis were established in 2.5 m x 3 m blocks. These taxa were selected for their vigorous growth and high demand in the retail trade. Water is batch loaded into the wetland and monitored for total nitrogen and phosphorus reduction. A small pump was installed to circulate and aerate the water between batch loads. Data will be generated on removal rates relative to various residence times.

We also have established a series of 96 liter polyethylene wetland cells (0.25 m^2 x 0.3 m deep) in replicates of three. These cells were planted with six divisions of all of the taxa listed above with the exception of the Arundo donax and the Hibiscus palustris. The fresh weight of each taxa was recorded before establishment into the cells. Each cell was fitted with a drain plug and batch fed with nursery runoff with a seven day residence time. Water samples will be taken to assess nutrient removal by each cell on a weekly basis. At the end of the growing season all plant material will be harvested from the cells, number of divisions recorded, as well

as mean above and below ground biomass. Dried tissue samples will be ground and analyzed for N and P nutrient content.

DISCUSSION

These experiments will not only generate data on how the wetland removes nutrients from nursery runoff as a whole system but will also generate data about the growth rate and nutrient storage capacity of each of the individual species. The above treatment wetlands has been established under a passively heated polyhouse (unheated polyethylene covered greenhouses) to extend the usefulness of the wetland in northern climates. This extension of the season is critical to the use of treatment wetlands in northern regions because it allows the wetland plants to break dormancy and grow actively before the onset of irrigation runoff (early May). The polyhouse also elevates the water temperature of the system to increase microbial activity as well as allowing for the cultivation of marginally hardy or non-hardy taxa, such as Arundo donax 'variegata' and Canna generalis.

The treatment wetland will be managed on a production cycle starting with the establishment of stock blocks. Divisions will be made from the stock blocks once plants have resumed growth in late winter or early spring. These plant divisions will be potted into nursery containers for appropriate lengths of time ranging from 2 months to 1 year before sale. Harvesting divisions from the wetland will serve to remove nutrients from the system, as well as providing space for the expansion of remaining plants and the assimilation of more nutrients. These partial harvests also will offset the normal reduction nutrient removal efficiency that comes with maturation of the stand. Bareroot stock may also be harvested at any time during this production and sold to wetland construction and landscaping firms. The system is self perpetuating, deriving nutrition from the treated effluent, and involves only the labor of harvesting plant materials.

The cost of wetland construction for building materials, plant divisions, and labor was $7200. The farmers lost revenue from the land converted to wetland is approximately $4000 a year. We have 14 taxa in the wetland and anticipate to harvest and sell approximately 100 pots of each taxa for $3.50 to $5.50 a pot. Upon harvesting this plant material we will be harvesting between 8-12 kg nitrogen from the wetland.

An economic analysis will determine, over a 2 to 3 year period, the costs of system design, installation, maintenance, and the value of the plant materials produced in the wetland system. The economic cost-benefits of the production-treatment wetlands will be determined by comparing revenue generated from the sale of wetland plants with the costs of maintaining the treatment facility, including planting and harvesting. These cost-benefits will be compared to other land uses at the same nursery. Wetland construction will be considered a fixed cost deductible over several years. Plant value will be determined from production numbers and actual sales data.

From a scientific perspective, the data on water quality and plant growth we collect will reveal which plants most efficiently remove contaminants from agricultural wastewater. The success of using wetland biofilters for the production of ornamental wetland plants will be judged from system performance, economic analysis and surveys of program participants.

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AN EDUCATIONAL PROJECT TO RESTORE A SEASONALLY HYDRATED SUBTROPICAL HARDWOOD HAMMOCK AND SURROUNDING AREAS IN PALM BEACH COUNTY, FLORIDA.

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ABSTRACT

Efforts to restore a subtropical hardwood hammock and portions of the surrounding environment were combined with promotion of environmental stewardship and renewal of public resources. The project was performed at the Loxahatchee Nature Preserve Center (LPNC) in Palm Beach County during January and February, 1999. The hammock and associated wetlands have been invaded by extensive growth of exotic vegetation, Old World climbing fern, *Lygodium microphyllum,* Brazilian pepper, *Schinus terebinthifolius,* and cajeput, *Melaleuca quinquenervia;* and by nuisance animals, wild pigs, *Sus scrofa,* and raccoons, *Procyon lotor.* Volunteers from Palm Beach Atlantic College (PBAC) and the LPNC, supported by the Coalition of Christian Colleges and Universities/ Evangelical Environmental Network, removed exotic plants, cleared trails, and planted native vegetation in gardens. Selected native plants were tagged for signage. Environmental field techniques were presented to students in an Environmental Science Class from PBAC. Pigs and raccoons were trapped and relocated by the Florida Freshwater Game and Fish Commission. Educational displays and scrapbooks were prepared, as well as a documentary for the Internet which can be viewed at http:\\www.pbac.edu.

INTRODUCTION

Background

This project was developed as an environmental education and restoration project. Three organizations were primary participants: Palm Beach Atlantic College (PBAC), Loxahatchee Preserve Nature Center (LPNC) and the Coalition of Christian Colleges and Universities supported by the Environmental Education Network (CCCU-EEN). Funds were provided through a grant with CCCU-EEN, and by the PBAC Science Club supported by Palm Beach Exterminating Service.

This project was conducted as part of the laboratory section of the Environmental Science Class at PBAC. Fulfillment of class requirements included participation in selected environmental field procedures. Students also fulfilled requirements for community service that are required for graduation from PBAC. Similar activities have been carried out at the LPNC for several years. Staff in the PBAC Development Office received information that an environmental stewardship grant was available through a project called the "Global Stewardship Mentoring Program". A proposal was presented to the managers of the LPNC,

who agreed to allow the project to proceed.

In order to prioritize restoration efforts at the Nature Center, work sites were examined for invasive exotic vegetation and destructive animals. Surveys conducted during the last few years have shown extensive invasion of the LPNC southern hardwood hammock by the Old World climbing fern, *Lygodium microphyllum*, Brazilian pepper, *Schinus terebinthifolius*, and the cajeput or punk tree, *Melaleuca quinquenervia*. Feral hogs, *Sus scrofa*, roam the preserve, as do raccoons, *Procyon lotor*.

The Loop Trail in this hardwood hammock has been partially developed with mulch formed from recyclable products and provided by Palm Beach County Solid Waste Authority. Pieces of shredded plastic from the mulch dot the trail. Old World climbing ferns line most vegetation along the length of the trail and into the underbrush as far as the eye can see. Brazilian peppers are sparse and a very few young melaleucas became established during the rainy season. When the forest is seasonally hydrated, the forest floor becomes a swamp. Some of the organisms normally seen in wetter locations begin to colonize further into the hammock. Wetter soil provides an enhanced colonization opportunity for some exotics, such as the climbing fern and melaleucas. Brazilian pepper trees do not like prolonged periods of inundation. Wetland animals such as the southern leopard frog, *Rana utricularia*, and more water tolerant snakes move further into the interior. Ferns grow rapidly, and plants and animals that live in drier conditions may migrate or disappear.

Additional areas on the south side of the LPNC were also restored. Gardens that contained non-native plant species lined the entrance and provide habitat for native species of butterflies, bees, wasps and birds. Four such gardens were re-planted.

Sponsoring Organizations

Palm Beach Atlantic College is a Christian liberal arts college located in the heart of downtown West Palm Beach. It offers 40 programs of study, including 63 majors, 24 minors, five masters degree programs and a special bachelors for degree seeking adults. Faculty, staff and students at PBAC volunteer through the *Workship* program, where, *worship* and *work* are combined, to provide community service around the world. Faculty-staff, students participating in the Environmental Science course, and the Science Club formed the main working group from PBAC on this project.

The second sponsoring organization, (CCCU-EEN), is a coalition of organizations of higher learning supported by an association of Christian institutions that advocate global Christian environmental stewardship. In addition to providing grant funding, these groups furnished guidance relating to project development, and an environmental educator as a mentor and field worker.

Owned and operated by the City of West Palm Beach, the LPNC is a water catchment area that was formed primarily to provide water to neighboring communities, to preserve diverse natural habitats, and to serve as an environmental education resource for the public For this project, LPNC furnished several naturalists and managers, as well as work sites.

Students enrolled in the Environmental Science course received classroom lectures that included discussions of environmental concepts that provided a basis for the fieldwork to be performed at the Nature Center. This project provided an initial opportunity to determine whether field work performed by the students could be practically applied to restoring efforts in the LPNC. Basic ecological principles of ecosystem identification and management were incorporated with more physical aspects of plant and animal identification and the removal of invasive plants and animals. Other than a species list, results were not statistically analyzed and will not be presented here.

Purpose

The primary objectives of this work were 1) to promote environmental stewardship in local and global communities in accordance with Christian principles; 2) to apply environmental educational concepts through field work; 3) to help volunteers better understand ecosystem balance and management; 4) to help managers of the LPNC revitalize native ecosystems that are used as important educational resources.

SITE DESCRIPTION

The LPNC is located on an approximately 5280 hectare (ha) site in north-central Palm Beach County that was historically connected with the Everglades regional ecosystem.The western boundaries of the Nature Center were hydrologically separated from Everglades water sources approximately 20 years ago. This tract bordered the north-eastern front of the Everglades and provided a connection to the Loxahatchee River drainage further north. The Preserve was set up through mitigation efforts and consists of mostly wetlands, swamp and marsh areas. A few hammocks are included in the parcel. Today it remains an isolated remnant, containing diverse species of plant and animals, a mixture of species that are found currently in the Everglades and some that are characteristic of the coastal ridge.

Geographically, the catchment area is divided into a north section and a south section (Figure 1). A subtropical hardwood hammock and surrounding marsh/swamp dominate the north side. Within the past several years the north section has been upgraded to contain new headquarters for the Palm Beach County Office of the Florida Game and Freshwater Fish Commission (FGFWFC). The south side of the preserve is little more developed, providing more visible public access to a boat ramp, boardwalks, gardens and an educational building overlooking extensive marsh and swamp habitats.

MATERIALS AND METHODS

Several planning meetings between representatives of PBAC and the LPNC were held to organize the project. Copies of all minutes were sent to CCCU/EEN for approval. Assessment

of each proposed location was made, and a site plan was composed. A site map of the nature center property (Figure 1) was prepared to show the division of the catchment area into north and south sides along Northlake Boulevard, and to indicate work locations. The work force consisted of volunteers from all three sponsoring organizations. Work was performed on weekends during January and February 1999.

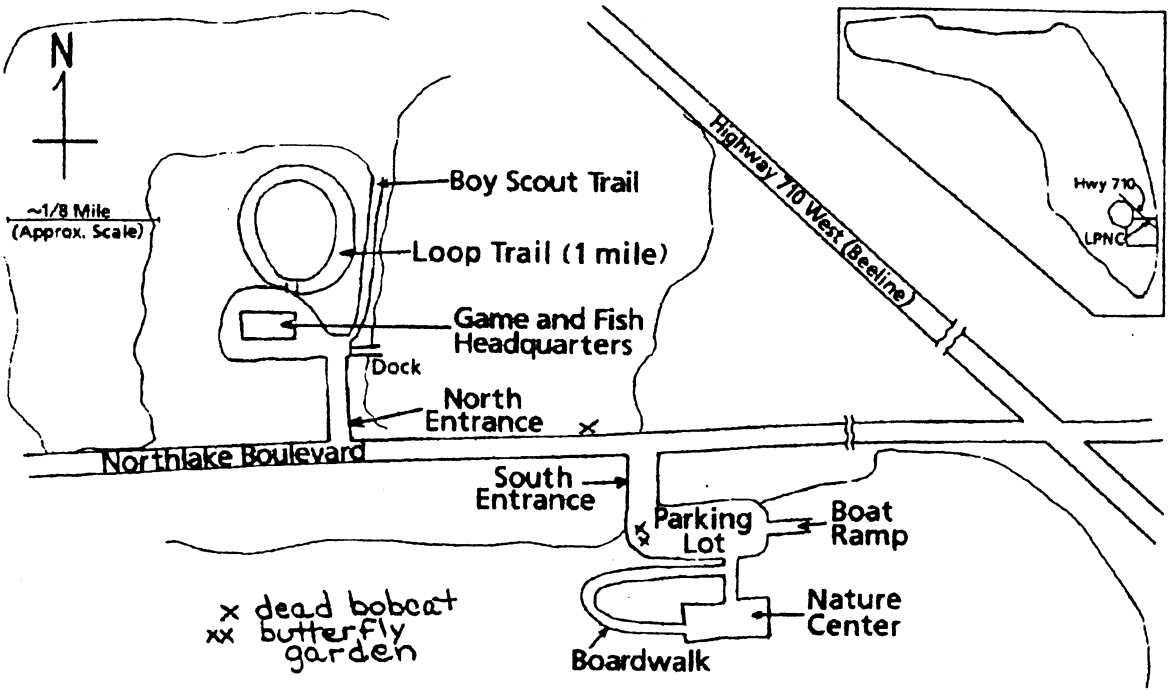


Figure 1. Map of Loxahatchee Preserve Nature Center showing both areas that were included in the project and are currently open to the public

The project, formulated along Biblical principles, included a variety of tasks. Devotions and verbal orientation were shared before each work session. Restoration efforts were directed at removing exotic vegetation, replacing non-native plants with natives and preparing signs for native plants. Environmental education included training students how to properly identify native flora and fauna, remove exotic plants and feral animals, apply basic principles of ecosystem balance and maintenance, and record all aspects of the work using field notes and photography.

Information relating to ecosystem balance and management and proper removal of feral pigs/hogs and exotic plant species was developed and prepared in handouts for all volunteers. Possibly harmful flora and fauna were identified including such interesting, but infrequently encountered organisms as the pygmy rattler (Figure 2), coral snake, wild hog, cottonmouth and alligator, as well as raccoons, poison ivy and Brazilian pepper. Descriptions were



Figure 2. Pygmy rattlesnake — a common feature in the subtropical hardwood hammock community (photo by Joyce Pleasant).

provided of their ecology, effects, and how to avoid contact or treat symptoms. Stinging insects, wasps and mosquitoes were also present.

Procedures to remove exotic plants were complex, as most of these plants propagate easily through spores or seeds. Old World climbing fern, *L. microphyllum,* must be pulled out completely, including the roots. All sections of vine were bagged in 40-gal (0.15 m^3) Hefty brand Lawn and Leaf Bags immediately so as to contain innumerable tiny spores. Although physical and chemical methods are available to kill and remove larger trees, no chemical herbicides were used during this project. Adult Brazilian pepper were chopped down in sections, and the roots dug out of the ground. Young melaleuca and Brazilian pepper trees were pulled out of the ground, including the roots.

Four gardens located in the south side of the LPNC were targeted for exotic plant removal and re-planting with mostly native plant species. Two rectangular gardens, about 56 m^2 each, line the entrance to the LPNC educational building, one 37 m^2 garden is located at the entrance to the boardwalk and the fourth, about 111 m^2, was a weedy butterfly garden located in the parking lot. Center managers worked with volunteers to remove exotic plants and weeds, and to develop a native plant list (Table 1). Native and replacement plants (purchased through Meadow Beauty Nursery) were placed into the ground in designated areas. Gardens were trimmed into more aesthetically pleasing forms. All portions of exotic plants that were removed from the hammock and the gardens were bagged. and were gathered at a designated site for pick-up by city workers.

Native plants were tagged in the hammock and gardens for future signage, and so that they would not be inadvertently removed. In the gardens, signs also indicated the type and larval

stage of representative insects and birds that utilize each designated plant.

Removal of raccoons and feral hogs from the hammock was accomplished by the Florida Game and Freshwater Fish Commission (FGFWFC). Nature center managers worked with the Commission to set up large baited cages to trap the hogs and raccoons. Animals captured during this project were removed to alternate locations.

Scientific techniques taught to the Environmental Science Class from PBAC were compiled by the author into a short laboratory manual and included use of random numbers, water quality testing, placement of transects, biodiversity methods and testing for pollution by use of biological indicators (Brower, 1990; Cox, 1990; and Enger, 1995). Students learned how to develop site maps, conduct surveys in a scientific manner, and apply random sampling techniques in order to identify and study flora and fauna and related environmental conditions. A list of representative plants and animals found in the hardwood hammock was composed.

Documentation of this project was prepared in several ways. Photographs were taken with a Nikon SLR and Sony Digital cameras. These photos were then compiled in a scrapbook for use as an educational tool at the Nature Center and were combined through Microsoft PowerPoint and Adobe Photo Shop into a documentary on the Internet to reach a global audience. The documentary can be located on the homepage of Palm Beach Atlantic College (pbac.edu). Pictures of representative plants and animals in the hardwood hammock, along with accompanying scientific life history data, were developed into an educational display for a kiosk at the head of the hammock trail (Figure 3).

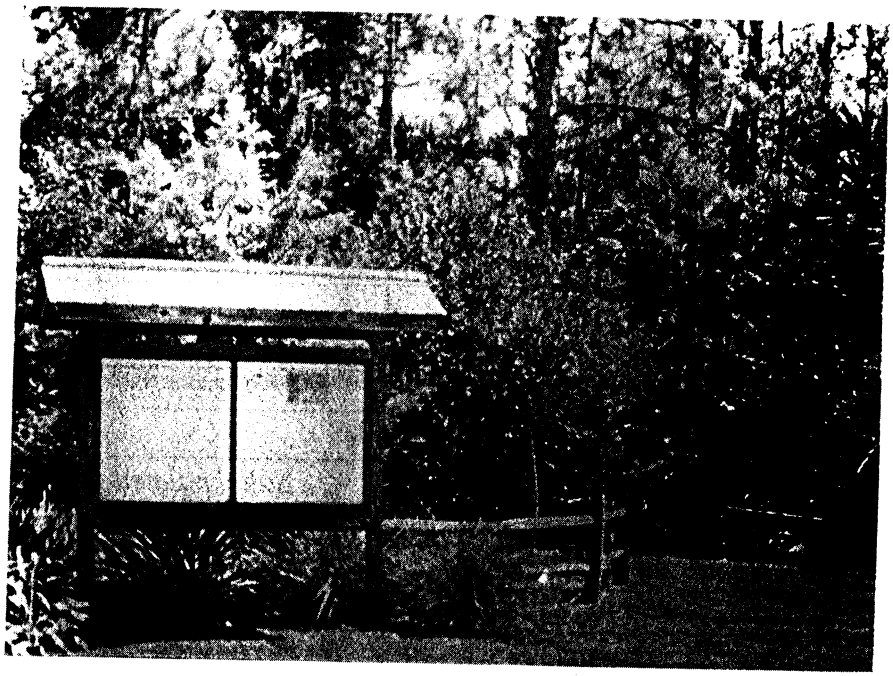


Figure 3. Informational Kiosk at the entrance to the Loop Trail

RESULTS

Field work was coordinated over an eight week period from January 23 through February 27. The rainy season was over, and as water levels receded from the hammock floor, mosquitoes which were present in large numbers in the hammock, diminished with drier conditions over time. The weather was mostly cool and overcast. There were no obvious problems caused by potentially harmful flora and fauna, with the exception of one slight case of poison ivy. Pygmy rattlers were seen in the hammock each work day, but merely provided great photographic opportunities. The cottonmouth and alligator are natural inhabits of marshes surrounding the hammock. Even though they have been infrequently sighted in portions of the hammock during periods of hydration, they were not seen during the period of time that this project was performed.

Shared devotions allowed each volunteer time to think about the reasons that they were taking part in this type of project. Participating in environmental activities renewed a sense of hope that natural habitats can be redeemed from man's destructive actions.

A list of representative flora and fauna found in the hardwood hammock was compiled by the students enrolled in the Environmental Science class (Table 1).

Table 1. List of representative organisms found in the seasonally hydrated southern subtropical hardwood hammock at the LPNC.

Animals	
Blue-gray gnatcatcher	*Polioptila caerulea*
Black racer	*Coluber constrictor*
Carolina anole	*Anolis carolinensis*
Garter snake	*Thamnophis sirtalis*
Gray catbird	*Dumatella carolinensis*
Palm warbler	*Dendroica palmarum*
Pileated woodpecker	*Dryocopus pileatus*
Pygmy rattlesnake	*Sistrurus miliarius*
Raccoon	*Procyon lotor*
Red-shouldered hawk	*Buteo lineatus*
Wild pig	*Sus scrofa*
Plants	
Cabbage palm	*Sabal palmetto*
Cypress	*Taxodium* spp
Laurel oak	*Quercus laurifolia*
Live oak	*Quercus virginiana*
Poison ivy	*Toxicodendron radicans*
Saw palmetto	*Serenoa repens*
South Florida slash pine	*Pinus eliotti var. densa*
Southern wax myrtle	*Myrica cerifera*

Exotic plant removal from the hammock yielded about 18kg of *L. microphyllum,* and a few young melaleuca and Brazilian pepper trees. At least 5 large Brazilian peppers were removed from the Loop Trail. Three hogs and about twelve raccoons were captured by the FGFWFC.

Approximately 18 native plants, trees and shrubs, were tagged for signs in the hammock, while about 11 species of butterfly/bird attracting plants (Table 2) were planted in the garden areas and were also tagged for future signature. Signs have been designed but were not ordered, due to a change in administration in the City of West Palm Beach, a time of transition for LPNC managers. Plants removed from these gardens filled 5 40-gallon bags

Table 2. Plant species list for replacement vegetation in the butterfly garden on the south side of the LPNC.

Bauer aster	*Eupatorium villosa*
Chapman's sensitive plant	*Senna mexicana*
Firebush	*Hamelia patens*
Keys porterweed	*Stachytarpheta jamaicensis*
Lantana	*Lantana depressa*
Marsh beggar-ticks	*Bidens mitis*
Purple passionflower	*Passiflora incarnata*
Red sage	*Salvia coccinea*
Rosemallow	*Hibiscus furcellatus*
Sensitive plant	*Senna ligustrina*
Swamp milkweed	*Asclepias incarnata*

Pictures taken with the Nikon camera were clearer than the more grainy photos taken with the digital camera. Photographs have been compiled for the project scrapbook, which will be presented to the LPNC when the Fall 1999 session begins at PBAC. The documentary was completed by the grant deadline date of June 31, 1999. Due to complications, the information for the kiosk has been prepared, but has not yet been placed at the center. The total number of volunteer hours, including faculty, staff, students and LPNC volunteers was 307. That total did not include making the documentary and finishing the scrapbook. Total costs for the entire project were around $1170.00, excluding costs of the signs which are to be purchase by the City of West Palm Beach. An itemized list of costs is presented in Table 3.

Table 3. Costs of LPNC Restoration Project.

Item	Cost ($)	Comments
Native Plants	580.00	
Signage		(not available)
Gloves	20.00	
Trash Bags	30.00	
Food	200.00	(for volunteers)
Film	32.00	(10 rolls@$3.20 ea)
Film Developing	100.00	(10 rolls@$10.00 ea)
Scrapbook	8.00	
Mentor	200.00	(motel, food, car rent)
TOTAL	**1170.00**	

DISCUSSION

Loxahatchee Preserve Nature Center is located along the north-eastern boundary of the historic Everglades drainage system. The Everglades is a transition zone containing varied flora and fauna from temperate and tropical areas. Sources of origin for native tropical plant species includes the Antilles-Caribbean area, while temperate zone plants could have been derived from many different locales. Some of the native plant and animal species that reside in the Everglades are also found in the LPNC (Table 1) in the hammock, marshes and swamps.

Native habitat is disappearing at an alarming rate. More than half of Florida's land area has agricultural or urban land uses (Langeland, 1998), resulting in severe damage to varied ecosystems and disruption of continuity for ranges of many plants and animals, including the Florida panther and Florida scrub-jay. Damage is caused to ecosystems in many ways, but activities that disturb soil (creating roads or firelanes) or alter hydrologic patterns make certain ecosystems, such as hardwood hammocks, more susceptible to invasions by exotic plants (Myers and Ewel, 1990). Because hammocks are found on the highest, driest land, most have shown signs of disturbance by humans (Davis and Ogden, 1994). In 1974 there were over 500 hardwood hammocks, including some tree islands, reported in south Florida. That number decreased to 125 by 1984 (Gleason, 1984).

Temperate hardwood forests or hammocks, as they are most often referred to in Florida, represent a transition between warm temperate forest in the north and tropical vegetation in the south. A typical southern subtropical hardwood hammock contains less diverse assemblages than those found in more northern areas. Southern hardwood hammocks often contain a great diversity of ferns, both tropical and temperate in origin. Hammocks in south Florida also are comprised of the largest numbers of epiphytic ferns, bromeliads and orchids seen in the continental United States (Myers and Ewel, 1990). Hammocks typically consist of a narrow band of vegetation containing representative plant and animal species (Table 1)

and are located on slopes between upland sand/clay hill pinelands and lake margins (Myers and Ewel, 1990) or on ridges adjacent to wet prairies and sloughs. Myers and Ewel (1990) provide a good description of hammock type based on soil moisture.

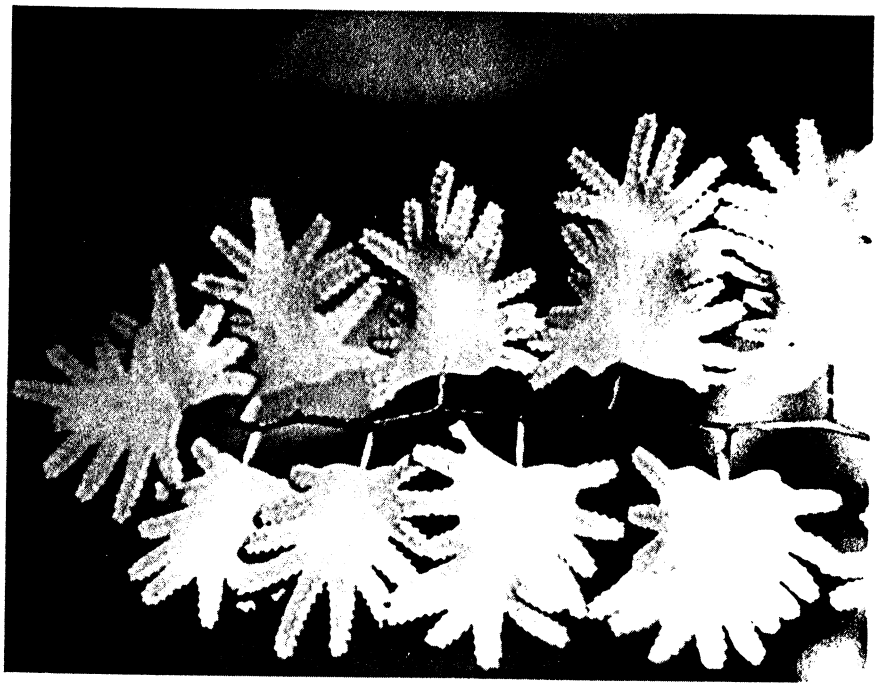


Figure 4. Spore-bearing segment of *Lygodium micropyllum* (photo by Jason Hedegard)

Plants that have been introduced into south Florida, have invaded native ecosystems, including hammocks and wetlands, and have become self-reproducing may be defined as exotic plants. These species probably have originated from a variety of locales, but were imported mainly for aesthetic or horticultural reasons (Gleason, 1974; Myers and Ewel, 1990; S.F.W.M.D, 1997; Robinson et al, 1996).

Scientists agree that negative effects on ecosystems are produced by unleashed growth of some species of exotic plants. While many animals and plants have been intentionally added to ecosystems in attempts to provide balance, others have crept in and damaged ecosystems in stealth. Exotics move into disturbed areas, actively displace natural flora, and cause disruption in habitat for native plants and animals (Myers and Ewel, 1990). Rapid and monospecific growth is often characteristic of the invaders. They produce millions of spores (*L. microphyllum*) (Figure 4) or seeds (*M. quinquenervia*) and are therefore difficult to remove without enhancing dispersal during the removal process. Seeds of *S. terebinthofolius* may not be as numerous as the other two invasive species, but these seeds have high viability (Ferriter, 1997).

Physical effects on host plants differ for each exotic species. Old World climbing fern ascends each host, to reach optimal conditions to receive sunlight and to achieve dispersal of spores by wind. These twining vines effectively smother the host, whether in tree islands, pine forests, or swampy wetlands, and block gas exchange and sunlight needed for photosynthesis by the host plant. The invaders themselves become hosts for growth of other vines. In the LPNC, cabbage palms, thatches and saw palmettos especially were invisible under heavy shrouds of *L. microphyllum.*

L. microphyllum also forms dense mats four feet or higher on the forest floor, and can mount vegetation into tree tops thirty feet and higher. Masses of vines were even thicker in vegetation beyond the designated work sites in the LPNC and in surrounding marshes and swamps. This plant alters fire-ecology when the vines catch fire and become air-borne. Burning mats from the forest floor can transport fire-sparks with them to nearby forest (SFWMD, 1997). Old World climbing fern grows rapidly and has many tiny roots that anchor it well into the soil. Therefore, it was very important to completely and carefully remove all portions of the vine and roots, including sporulating strands to prevent new vine formation.

Brazilian pepper causes medical problems in some people because it produces resin that is toxic and allergenic, causing respiratory and flu-like symptoms. During formation of monospecific stands, it colonizes aggressively and easily invades pineland and hammocks. It does not grow well in areas inundated for more than three to six months (Ferriter, 1997). This exotic plant decreases diversity of native plants and provides poor wildlife habitat. The LPNC hammock supported only a few adult pepper trees in the interior. Their roots grow well into the ground and the few large trees seen in the hammock were difficult to remove, as after cutting the trunk into sections, the roots had to be completely dug up. Saplings were more easily removed, by pulling them out of the forest floor.

Melaleuca may be the most invasive of these exotics in wetlands. It is an evergreen and is highly flood tolerant and fire-resistant. Inside the hammock, a few very young cajeput were seen only in one hydrated area along the northwestern margin of the Loop Trail. They were removed by the roots and bagged. Mature melaleuca were not found in the hammock, but occur in surrounding areas, especially in the south section of the preserve.

Two invasive animals, raccoons and feral hogs, were captured in traps in the LPNC hardwood hammock, but are frequently seen on the south side of the Nature Center. Capture of hogs was complicated by the large raccoon population present. Raccoons were attracted by the bait set out in the hog traps and sprang the trap doors, preventing hogs from entering the trap, before escaping through the slats of the cage.

Destructive habits of raccoons become more conspicuous as their natural habitat decreases. These predators eat small birds and mammals as well as eggs of a variety of species (Myers and Ewel, 1990; Davis and Ogden, 1994). Destruction of natural habitats, such as crayfish sites and bird nests, is common during food acquisition. As wetlands dry out, chances of visits by raccoons to sites of food availability increase. Through size alone feral hogs (pigs larger than 82 kg) (Figure 5) damage natural flora by moving through the forest knocking over and

breaking small trees and creating major holes that disrupt substrate. One pig weighing about 45kg can damage up to a half acre of land within several days (Senecal, 1999). Weathering, wind, rain or hail can cause these depressions to enlarge. Hogs also root in the ground for food, causing further destruction of the environment. They are particularly partial to young plants in seasonal ponds (Myers and Ewel, 1990). Hogs probably migrate into the Preserve from large adjacent wilderness areas to the west and north.

The last areas to be restored were the gardens on the south side of the LPNC. These are not natural areas, but were restored with native vegetation for educational purposes and insect displays. Gardens were so overgrown that it was difficult to identify the plants that were to be removed. A few species of plants in the butterfly garden (Figure 6) were non-natives, but were retained because they are very attractive to butterflies. Signs were designed for all native plants, but have not yet been ordered by LPNC managers.

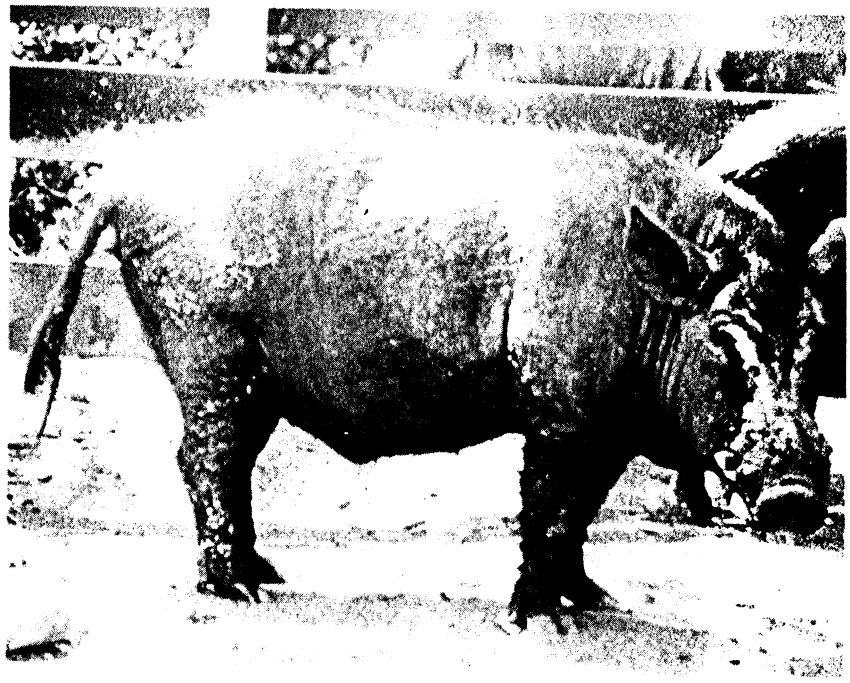


Figure 5. Wild hog like those that are found at the LPNC.

Ecological techniques introduced to the Environmental Science Class were a preliminary attempt to combine field methods with work projects. Some of the equipment, such as that used for quality testing, did not work properly in the field after being calibrated in the laboratory. A few of the field techniques were not effective for use in restoration efforts and will have to be re-designed. Results of these procedures were not statistically analyzed. Use of these methods provided educational benefits, but were not applicable to the outcome of

this project.

The documentary was more difficult and time consuming than had been projected during the conceptual stage of the project. Some of the digital pictures were not clear, and it was time consuming to scan and edit electronic photographs. Resolution of all pictures had to be reduced to 200 dpi or less in order to download properly across a wide range of computers. Some photographic clarity was lost.

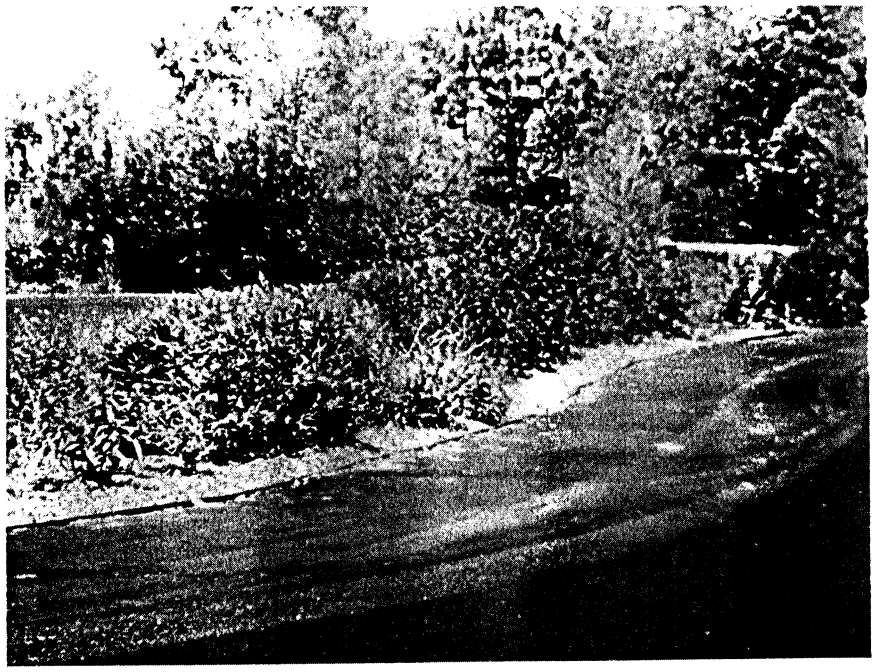


Figure 6. Butterfly garden on the south side of the LPNC after restoration.

CONCLUSIONS

Preservation of natural ecosystems has been neglected in Florida as well as in other parts of the world. As man's understanding of the environment increases, more importance is being placed on conservation and preservation of a variety of habitats. About 20 % of the state of Florida was being managed as parks, preserves and other designated areas by 1990 (Myers and Ewel, 1990). Management of these varied ecosystems requires carefully determined strategies. Habitat maintenance may be the key to saving the quality of individual ecosystems. Enhancing natural habitat by removing disruptive and invasive species must be continuing

effort in a manner that will allow the ecosystem to change through natural dynamic processes, and still remain healthy and balanced.

Small projects, like this one, can be easily modeled for classes or groups of volunteers. This type of grass roots effort seems to be growing in local communities. The flexibility and variety of work is well suited to all levels of volunteers from trained scientists to retirees and young school children. More volunteers and more funding are needed to enhance restoration efforts at the LPNC. Miles of melaluca, Brazilian pepper and Old World climbing fern await removal, and those invasive exotics are increasing daily. Populations of feral hogs and nuisance raccoons continue to grow out of control. This experience was valuable to students who learned how to apply scientific concepts and field methods to environmental stewardship. A more complete species list from the LPNC should be compiled that includes native, endangered, threatened and rare flora and fauna. Selected field methods similar to those performed during this project will be modified to include statistical analysis of specific data directly related to restoration efforts.

Results of man's interference with nature creates a need in public land areas to be vigilant to identify invasive plants and animals and to monitor and maintain land and water quality to promote natural diversity in healthy ecosystems. It is encouraging to note that increasing numbers of environmental projects, similar to this one in scope, are being performed around the world, sponsored by a wide range of agencies. This project provided an opportunity for participants to apply spiritual gifts in order to increase public awareness of environmental stewardship and to achieve public benefit from natural resources.

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PINE FLATWOODS HABITAT CREATION MANATEE PARK, LEE COUNTY, FLORIDA

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ABSTRACT

A three-quarter acre portion of Manatee Park in Lee County, Florida, will be converted from a fill area consisting of mowed herbaceous ground cover into a viable pine flatwoods that can support native flora and fauna. The first phase of habitat creation included the planting of forty-one species from nursery grown and recovered plant sources between May 1997 and November 1998. Three hundred twenty-three nursery grown plants and 532 plants recovered from sites permitted for development have been planted.

Seven native plant species that are considered difficult to transplant have been successfully relocated. Plant survival surveys conducted in late December 1998 and early January 1999 indicate 54% survivability in nursery grown plants and a 57% survival rate in recovered plants. Plant surveys to be conducted quarterly throughout 1999 should show higher survival percentages due to seasonal dormancy and longer establishment periods in some plants.

A natural ecosystem continuum will be established as the pine flatwoods are expanded in 1999 by the creation of oak/rosemary scrub and sabal palm/oak hammock habitats. When the transplanted flora within the created ecosystem area is well established, native wildlife such as the gopher tortoise will be introduced. Plant survivability and fauna utilization surveys will be conducted quarterly as the habitat creation continues through the cooperative efforts of the Native Plant Recovery and Replanting Effort, the Coccoloba Chapter of the Florida Native Plant Society, Lee County Parks and Recreation, Lee County Division of Planning, developers and plant nurseries.

INTRODUCTION

A three-quarter acre portion of Manatee Park in Lee County, Florida (Figure 1), will be converted from a fill area consisting of mowed herbaceous ground cover into a viable pine flatwoods that can support native flora and fauna. The pine flatwoods habitat creation is part of a master plan to provide examples of Southwest Florida habitats at one public location in Lee County, Florida. The example habitats will be used to educate homeowners, school groups, landscapers, developers, and tourists about native flora and fauna. The habitat creation areas will become functional ecosystems, and will be established to form a natural ecosystem continuum.

Upland restoration of Florida ecosystems is in the formative stages. Therefore this project will provide vital information about successful restoration methods and problems encountered.

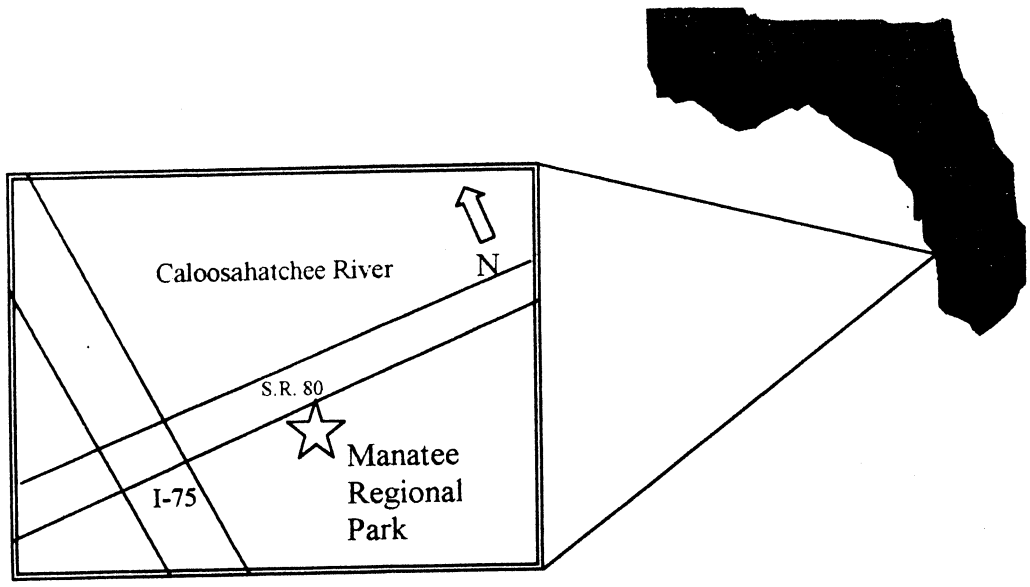


Fig. 1: Study site location – Manatee Regional Park, Lee County, Florida.

METHODS AND MATERIALS

The pine flatwoods creation area began with the donation of forty 1-gallon South Florida slash pine (*Pinus elliottii* var. *densa*) in May 1997. The donation was unexpected therefore no site preparation was conducted. Volunteers planted the trees in May 1997. Twenty 10-gallon South Florida slash pine were installed in July 1997. These pines were donated to the county as mitigation by a developer to abate a tree clearing code violation. Twelve of these pines were used to expand the pine flatwoods area. The remaining pines were planted randomly across the original site.

Rodeo was applied to the site prior to planting understory vegetation in February 1998. The herbicide was not applied within 30 cm of the previously planted pines to avoid stressing or killing the seedlings. Volunteers dug in 200 nursery grown midstory and ground cover plants. Yard waste mulch obtained from the county at no charge was placed around all plants to increase moisture and nutrient uptake. Wet newspapers were laid on the ground within 30 cm of the previously planted pines and mulch placed on top of the newspaper, as a means to kill the non-native herbaceous ground cover since herbicide was not applied near these seedlings.

Native plants were recovered from sites permitted for development beginning in the fall of 1997. Plant recoveries continue to be a major part of the project with 537 plants transplanted to date. The recoveries provide locally native plants with the only cost being the operation of the vehicles. Plant recoveries are conducted by volunteers only on properties permitted for development and with written authorization of the landowner. Replanting is typically done the same day or within a day of the recovery. Plants installed prior to November 1998 were mulched with yard waste mulch. After

November 1998, plants have been mulched with pine litter either obtained at recovery sites or purchased bales of pine straw. The pine litter collected at recovery sites should provide needed nutrients, natural bacteria and fungi, as well as being a potential seed source.

All plants were watered upon installation. The intent of this project is to create a habitat in which the plants survive on the natural rain cycle. However, periodic watering has been necessary to aid in the establishment of the plantings due to the unusually dry conditions in the summer of 1998 and winter of 1999 (Fig. 2).

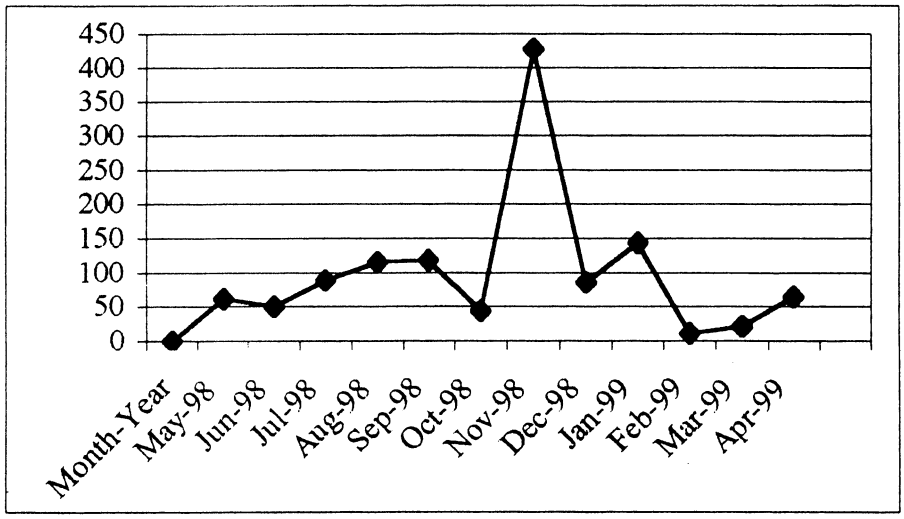


Fig. 2: Percent of average rainfall.

Seed collection and dispersal will begin in the fall 1999. The seeds should provide native plant growth within the large open areas of the habitat creation site. Seeding success will be compared to relocated plant and nursery grown plant survivorship.

Plant survivorship surveys will be conducted quarterly. The first survey was conducted in late December 1998 into early January 1999. A second survey was conducted in April 1999. Follow-up surveys are scheduled for July and October 1999.

This study focuses on the pine flatwoods habitat creation. However, other habitats being created as part of an ecosystem continuum include an oak/rosemary scrub and oak/sabal palm hammock.

RESULTS

Plant survival surveys conducted in late December 1998 and early January 1999 indicate 54% survivability in nursery grown plants and a 57% survival rate in recovered plants. Increased survivorship was anticipated for the April 1999 plant survey based on seasonality and establishment time. Differentiating between nursery grown and recovered plants in April was

difficult due to the percentage of weed coverage. Therefore, April survivorship was calculated on the combined plantings and recorded at 44%. Combined survivorship in January was 56%. Extreme dry conditions in March and April 1999 may be the reason for this decline. Survivorship within certain species showed marked differences between the January and April surveys (Figure 3).

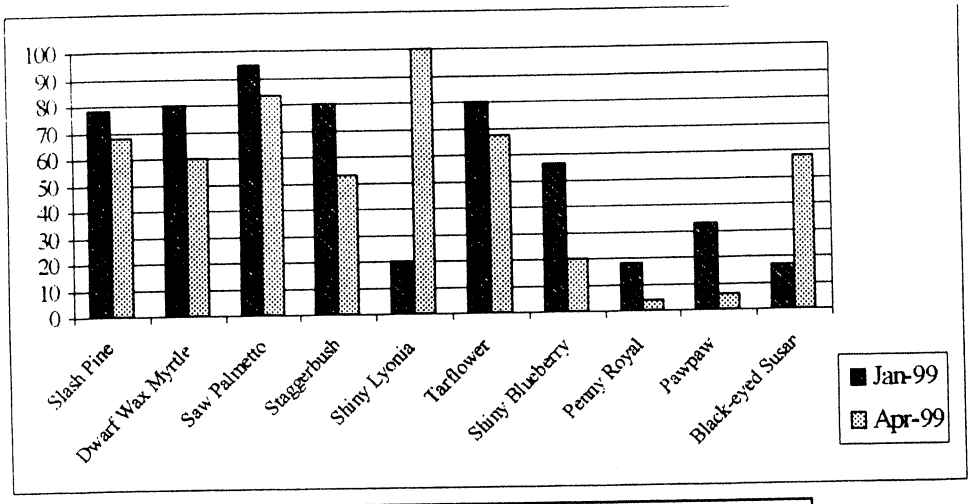


Fig. 3: January vs. April survivorship.

Interestingly, Shiny lyonia (*Lyonia lucida*) plants that were recorded as dead during the December/January survey had all resprouted. Although the overall survivorship between nursery grown and recovered plant sources is not significant, differences within individual species is noteworthy (Figure 4). Additionally, eight species considered difficult to transplant have been successfully relocated: South Florida slash pine, saw palmetto (*Serenoa repens*), tarflower (*Befaria racemosa*), staggerbush (*Lyonia fruiticosa*), pawpaw (*Asiminia sp.*), myrtle oak (*Quercus myrtifolia*), runner oak (*Quercus pumila*), and shiny blueberry (*Vaccinium myrsinites*).

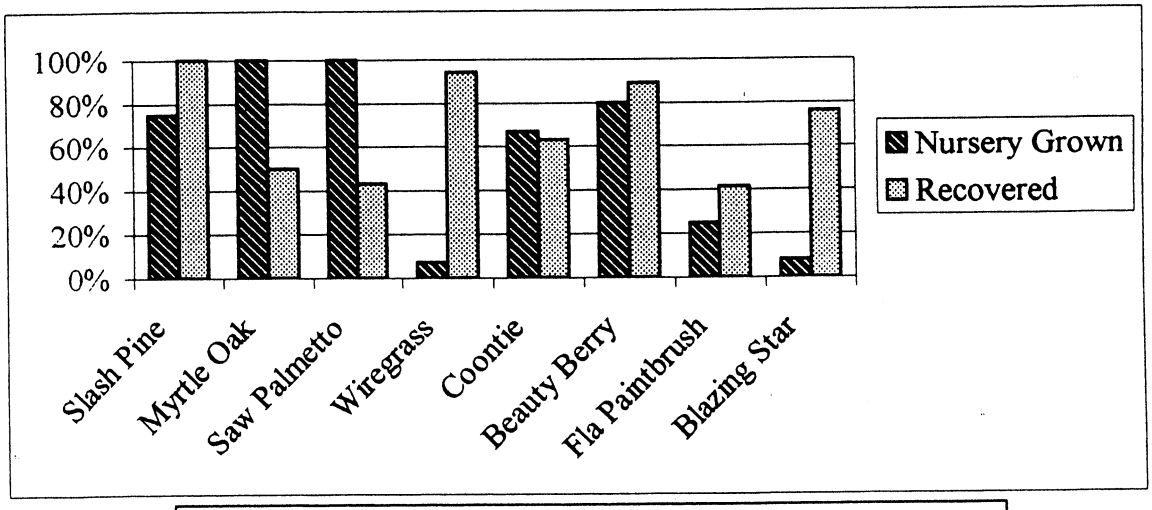


Fig. 4: Nursery grown vs. recovered plants survivorship.

A large-scale weed problem arose in the summer of 1998. Purple nutsedge (*Cyperus rotundus*) invaded most of the project site. The herbicide Manage was applied to the nutsedge, but it did not eliminate the sedge. Later it was learned that a surfactant mixed with Manage increases adherence to the sedge helping the herbicide infiltrate the plant cells and kill the sedge. In early fall 1998 two volunteers hand pulled the nutsedge over a two week period working over 120 hours to clear the site of this undesirable plant. The yard waste mulch used throughout the site was determined to be the purple nutsedge seed source. After this problem was realized, it was decided that only purchased pine straw or pine litter from natural pine flatwoods would be used as mulch. The purple nut sedge continues to reappear. In June 1999, Rodeo with dish soap added as a surfactant was applied to the purple nutsedge. The sedge is turning brown, and it is hoped the roots and underground "nuts" will be destroyed.

CONCLUSION

The pine flatwoods habitat creation at Manatee Park in Lee County, Florida, is the result of cooperative efforts between environmental organizations, government agencies, developers, and native plant nurseries. Each entity contributes differently to the project making it a success without having to spend the tens of thousands of dollars such a habitat creation would cost.

Members of the Coccoloba Chapter of the Florida Native Plant Society and the Native Plant Recovery and Replanting Effort (RARE) designed the project and organized workdays. Additionally, Coccoloba members have purchased 315 native plants and are the main labor force.

RARE located sites permitted for development and obtained authorization from the developers to access the site to recover native plants. Developers have readily agreed to plant recoveries on their properties. Information detailing the date, time and number of people accessing the site was given to the developer. A follow-up letter confirming the number and species of plants recovered, as well as, where the plants were transplanted was sent to reinforce how much the recovery contributed to the habitat creation project.

Lee County government has also contributed to the project. The Parks and Recreation Department provided the habitat creation site. Vehicles, water, herbicide, mulch, and labor have also been provided through Parks and Recreation. The Division of Planning/Environmental Sciences has arranged mitigation plantings to abate tree clearing code violations. For example, a developer as mitigation donated twenty-four ten-gallon South Florida slash pines.

Nurseries have donated and reduced prices on plants thus allowing a greater number of plantings. The pine flatwoods project was initiated after T.J.'s Nursery donated forty 1-gallon South Florida slash pine.

The following should be considered for habitat creation or restoration projects:

- Sites permitted for development provide a free source of large quantities of locally native plants.
- Recovered plants survivability is at a minimum equivalent to that of nursery grown plants.
- Difficult to transplant native plants can be successfully relocated.

- Know your mulch source. Mulch may bring undesirable plants onto the restoration site causing maintenance problems.
- Plan for removal of undesirable plants.
- Site preparation is not a necessity in creating a native habitat. However, site preparation including removal of undesirable plants and addition of native soil or mulch may reduce site maintenance.
- Developers are eager to participate in local community projects.
- Cooperative efforts between private and public organizations greatly reduce the cost of a native habitat creation or restoration project.

ACKNOWLEDGEMENTS

Thank you to Malt Finn for giving me the push to compile this paper. Also, a special thanks to the members of the following organizations and companies who have made this cooperative project a success: Coccoloba Chapter of the Florida Native Plant Society; RARE; Lee County Department of Parks and Recreation; Lee County Division of Planning/Environmental Sciences; Atlantic Gulf Communities; Li.'s Nursery; Perkin's Nursery; Dan's Nursery; and Natives Nursery.

HOPE FOR THE HYPERSTRESSED: REGENERATING A POST-INDUSTRIAL ECOSYSTEM IN PITTSBURGH

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ABSTRACT

This paper focuses on interdisciplinary applications of ecosystems restoration science and design to one of the most highly degraded urban environments on the continent: Pittsburgh's Nine Mile Run valley. Combined sewer overflows, illegal sanitary sewer overflows and an aged and widely crumbling infrastructure have rendered the stream ecosystem dysfunctional and patently dangerous. Terrestrial environments are no better off. Tons of slag dumped in the valley over decades have almost completely replaced historic floodplains and wetlands; the high pH slag slopes currently maintain a tenuous ecology. Throughout the valley, vegetation communities are fragmented and overwhelmingly represented by invasive, non-native species. A multi-faceted research, education and applied regeneration program has been spearheaded by a collaborative team drawn from Carnegie Mellon University, Penn State University and the Carnegie Museum of Natural History, supported by grants from the Heinz Endowments and the Pennsylvania Department of Conservation and Natural Resources. This paper outlines assessments and strategic progress to date, concluding with an overview of the ecosystems regeneration model which has evolved.

INTRODUCTION

This paper gives a broad overview of the natural (and unnatural) history of a small urban valley in Pittsburgh called Nine Mile Run. It then examines its disturbance regime and reviews several key strategies for regeneration.

The series of study phases that collectively comprise the Nine Mile Run Project was spurred by pending residential development on the slag plateaus that overlook the lower watershed, an endeavor of the City of Pittsburgh's Urban Redevelopment Authority. At the outset, the studies discussed below have been collaborative and interdisciplinary in nature. From Carnegie Mellon University's (CMU) STUDIO for Creative Inquiry are the 3 artists on the team: Tim Collins, Reiko Goto and Bob Bingham. John Stephen was environmental lawyer, a STUDIO Research Fellow, and David Dzombak of Carnegie Mellon University's Department of Civil and Environmental Engineering was water quality engineer. Sue Thompson and John Rawlins were the lead botanist and entomologist, respectively, from the Carnegie Museum of Natural History (CMNH). Andy Cole was wetland ecologist and Peggy Johnson was stream hydrologist, both from The Pennsylvania State University. The author, also from Penn State University, served as Research Fellow with the Carnegie Mellon University team between 1997 and 1998 and continues as a principal investigator with the project.

The Nine Mile Run Project has comprised three main project phases to date. Phase One was a community involvement initiative funded by The Heinz Endowments. Comprising a series of public workshops, field visits, and descriptive publications for dissemination throughout the 5 neighborhoods adjacent to the study area, it achieved a level of public dialogue ("discursive democracy") that was remarkable for an environmental project in the Pittsburgh region. Almost concurrent were scientific analyses and ecological planning efforts funded by the Pennsylvania Department of Conservation and Natural Resources, the state's first Rivers Conservation Plan grant addressing a highly degraded urban river valley. Phase Three--Brownfields Intervention--is in press at the time of this writing. Funded by The Heinz Endowments, it translates the scientific analysis and planning strategies of the second phase into detailed conceptual plans for site-scale aquatic and terrestrial restoration and creation, as well as design schemes for greenway access and interpretive facilities. It presents the combined efforts of the author (ecological designer), hydrologist, wetland ecologist and artist in consultations with area residents and agency representatives. This paper draws largely on analyses and strategies developed in Phases Two and Three of the project, as documented in Collins et al. (1998), Tamminga and Otten (1998), and Cole and Johnson (1998).

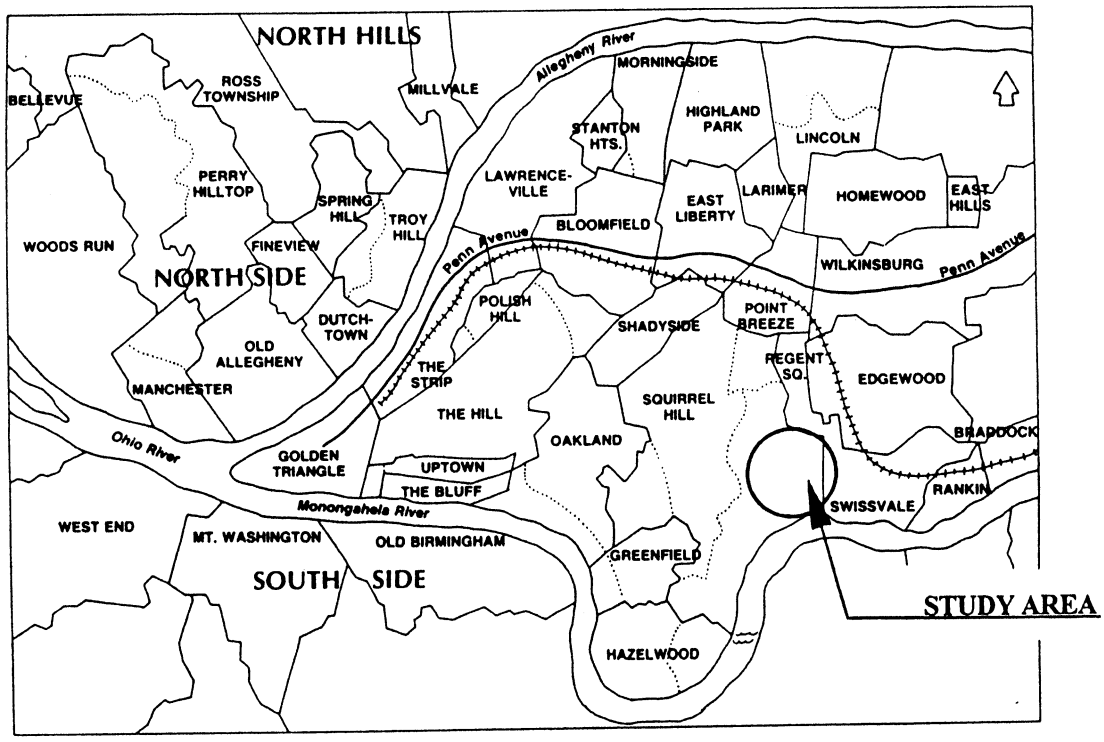


Figure 1. Study Area Location map

STUDY SITE

Nine Mile Run is the name applied to both a small urban stream along the City of Pittsburgh's east border and the 17 square km watershed through which the stream flows. The three study phases studies to date have concentrated primarily on the lower, nonculvertized 2.9 km of the stream. The creek outlets to the Monongahela River some 10 km upriver from Pittsburgh's famous Point State Park, where the Monongahela and Allegheny Rivers merge to form the Ohio River (Figure 1). The site comprises a complex of terrestrial and aquatic ecosystems, all of which are disturbed and most of which are post-industrial in nature. These systems, the study approach, and plans for ecosystems recovery are described in further detail below.

MATERIALS AND METHODS

The approach to addressing the highly challenging and long-term Nine Mile Run project was necessarily multi-faceted, inter-disciplinary, community-based and adaptive. Reflecting the theme of this conference, however, this paper will focus on the middle phase of work conducted between the May 1997 and August 1998, which examined the ecological, hydrological and landscape attributes of the study area from the perspective of both scientist and environmental design. A broad methodological framework was provided as a requirement of the funding agency, the Pennsylvania Department of Conservation and Natural Resources. As a prototypical urban Rivers Conservation Plan, however, the study team also developed distinct approaches that reflected the post-industrial nature of the site and the desire of local agencies and community stakeholders to become part of the process in its recovery. An underlying scholarly objective was the positing of an alternative, normative model to degraded landscapes across the region.

A number of themes were addressed, each responding to particular ecosystems. Water quality and sewer infrastructure assessments were spearheaded by Dr. David Dzombak (see listing of core team members, above), and facilitated by study co-director Tim Collins. Water quality assessments were made using standard protocol augmented with regular observations of stream detritus. Background data on City of Pittsburgh and surrounding municipality sewers were compiled and composite-mapped on the STUDIO for Creative Inquiry's GIS facility. Considerable on-site work was conducted to attempt to verify old infrastructural maps, track down unmapped and unclaimed pipes, outlets and standpipes, and document structural defects and leakage. Grab sampling for fecal coliform began in early 1997 to assess bacterial concentrations. Odor problems emanating from stagnant fecal pools were documented qualitatively on site, with the assistance of volunteer residents familiar with the area.

Biotic inventories adhered to a rigorous protocol developed by scientists from the Carnegie Museum of Natural History. These were conducted not only to gain a credible understanding of current conditions on site, but also to provide a baseline for future biodiversity and ecological integrity assessments. Terrestrial vegetation assessment and

mapping were conducted through the growing seasons of 1997 and 1998 by Dr. Sue Thompson and the author. Two vegetation transects were established across the valley that took in slag slope, riparian floodplain and wetland ecosystems. They consisted of a series of 10 m quadrats in which all woody plants 1 cm dbh or over were identified and recorded for that quadrat. Notes on herbaceous cover were also taken for each quadrat. The site's botany was tied to terrestrial invertebrate habitat using four circular adjacent vegetation analysis (AVA) radii (r=25 m) associated with the insect traps. Sites were selected to represent a diversity of habitat types in the study area, ranging from relatively undisturbed to the thoroughly degraded slag slope. Transects and radius site coordinates were determined using a hand-held global positioning system (GPS) Magellin Trailblazer XL unit, with altitudes determined using a barometric altimeter. The botany team vouchered all samples collected in the field; specimens remain curated at CMNH's herbarium. Floristic community mapping was prepared by the author using 1:2400 1984 and 1990 aerial photographs provided by the City of Pittsburgh, confirmed and updated through field 'truthing' during the summers of 1997 and 1998.

Invertebrates were the focus of terrestrial wildlife investigations because of their propensity for early colonization in highly degraded habitats and their relative abundance in the study area. As such, insects were considered particularly good indicators of biological diversity and ecosystem health in Nine Mile Run. Dr. John Rawlins and his team of CMNH staff entomologists addressed insect biodiversity, collecting specimens on site between June and November of 1997. At each of the four AVA study sites noted above a light trap was installed to collect nocturnal flying insects. Hand-collection of various insects using aerial nets, beating sheets and collecting jars augmented the traps during each collection episode. A tent-intercept trap to collect diurnal flying insects and a series of 10 pitfall traps to sample surface-crawling insects were installed at two sites, one in a valley slope woodland and one in the floodplain. Sorting and curating of samples was conducted at the nearby CMNH Section of Invertebrate Zoology.

Wetland assessments for the two known wetlands in the study area were conducted in November 1997 and during June and July of 1998 by Dr. C. Andrew Cole, wetland ecologist with Penn State University's Cooperative Wetlands Center (CWC). These intensive assessments were preceded by a more general wetlands reconnaissance throughout the lower watershed by the author in 1997. Both sites were surveyed according to standard CWC protocol. Parameters assessed included hydrology, plant community composition, and soil characteristics, with an emphasis placed on determining regional hydrogeomorphic (HGM) subclasses for comparison to the full slate of CWC reference wetlands across the state. Slotted PVC test wells were installed at each wetland during the late fall of 1997. Ground water data (depth-to-water and residence time within the 30 cm root zone) were electronically recorded at 6-hour intervals (Cole and Johnson 1998). Data was downloaded using hand-held Hewlett Packard infrared recorders, and hydrographs were prepared at CWC offices using standard Minitab v.12 software.

Stream stability assessments were conducted under the direction of Dr. Peggy Johnson, hydrologist at Penn State University. Visual assessment and mapping of bank erosion and bed scouring were made throughout the spring and summer of 1998. Ten cross sections in

a series extending from just below the Braddock Avenue outfall to the mouth of the creek were evaluated using a rapid assessment technique developed by Dr. Johnson. Ten stability indicators were rated (excellent to poor), then weighted and summed to arrive at an overall stability assessment for each cross-section. Bank pins to indicate lateral erosion through the six-month period were placed in 3 locations not susceptible to local scour, to corroborate observations of changes to channel morphometry. In lieu of accurate agency stormwater data, bankfull discharges were estimated using the hydrologic software PSU-IV, a model similar to the USGS regression equation for estimating peak discharges as a function of land use and drainage area (Cole and Johnson 1998). Later in the study, two instream electronic flow depth monitors were installed on bank-side structures to provide flow data; data will be monitored over the next few years and used to confirm secondary data on stream flow.

Landscape ecology and general habitat assessments were prepared by the author through a series of eight field investigations during the 1997 and 1998 growing seasons. Vegetation communities were classified into two major groups--Upland and Lowland/Riparian--and sub-classified by type of vegetation, degree of ecological fragmentation ("patchiness") and successional stage. Key aspects of this work included the identification and characterization of "important habitat" (a requirement of the Rivers Conservation Plan): remnant secondary forests, remnant riparian forests, wetlands, slag slopes, aquatic habitats and rock outcroppings. Considering the disturbed, post-industrial nature of the site, particular attention was given to interior forest habitat in the study area. The author also provided an overview of the status of invasive exotic and aggressive native species that were present in the study area.

Several supporting inquiries were prepared by consultants to augment Phases Two and Three studies. A fisheries survey of the lower, open-air portion of the creek was conducted by Penn State ichthyologist Dr. Jay Stauffer, Jr. and colleagues during the fall of 1998. His work consisted of in-situ surveys involving electro-shocking and seine netting followed by fish measurement, stomach content analyses and classification by species and major faunal groups. The report employed an ecological classification system that uses species present to predict an "elasticity index"--the ability of the aquatic ecosystem to recover once a structural or functional change has occurred (Stauffer and Stecko 1998). A review of stream benthic organisms was compiled from prior research conducted by Dr. Mary Kostalos (1971, in Mirani 1997) of Chatham College and Umi Mirani (1997), Ph.D. candidate, University of Pittsburgh. Their surveys employed direct collection and Surber sampling of stream organisms.

Public involvement prior to and during all stages of the study was an integral part of the process. A trailer was established as a community drop-in center near the geographic center of the study area. An events tent was erected for sizable workshops and field trips, and field research equipment and interpretive panels were housed in the adjacent trailer. Through 1997 and early 1998 a series of four thematic "public dialogues" were held in community centers associated with neighborhoods around the lower Nine Mile Run valley (transcriptions available in STUDIO for Creative Inquiry, 1998). Circulars

summarizing on-going research were distributed to all households around the lower valley, and an interactive web site was maintained by the CMU team.

Synthesis of the ecosystem, landscape assessments and strategy formulation were an outcome of several strands of activity. The primary evolution of ideas for recovery of Nine Mile Run took place through a series of study team workshops held both at the STUDIO for Creative Inquiry at Camegie Mellon University and the Department of Landscape Architecture at Penn State University on almost a monthly basis through 1998. Augmenting these events was a series of site-based roundtables, attended by community members and agency stakeholders, in which site-specific brainstorming of issues and regeneration alternatives took place. These served the dual role of fleshing out core study team documentation and confirming directions being explored. An extensive literature review of precedents in the restoration of highly degraded urban ecosystems (wetlands, streams, high-pH slag piles) was conducted by the author to inform the study team in the formulation of strategic alternatives. The preparation of regeneration vision, principles, goals, plans and strategies for the valley were jointly spearheaded by the author and project co-director Tim Collins, with specialty input provided by team scientists on a topic-by-topic basis. The development and refinement process was iterative and interactive in nature, benefiting greatly from consistent dialogue with the project steering committee and community participants.

RESULTS

Physiography/Topography. The study team found that Lower Nine Mile Run's historic floodplain was almost entirely buried under 15 stories of steel mill slag. Ninety-five ha of the original broad U-shaped valley-a result of post-glacial outwash from the last ice age-have been buried under the slag. In a few spots, the original floodplain can still be seen, and several exposures of 300 million year-old shale are still visible along parts of the south riparian slope. The slag, incised by the flashy little urban stream, has a topography characteristic of its method of disposal. Initially, railroad spurs connected to the Monongahela River barge system at a point just below the confluence, then dump truck tracks permitted the necessary access to create a series of terraces and slopes at slag's 1.5:1 angle of repose. As noted previously, the uppermost terraces are slated for a +700 unit residential development by the Pittsburgh Urban Redevelopment Authority.

Watershed Context. Water Quantity and Water Quality. The Nine Mile Run watershed is typical of small urban drainage basins in industrial cities. Approximately one third of the watershed is open space; older urban residential and commercial strips occupy the majority of the watershed. Besides the sewer overflow problem detailed below, the largely impervious developed surface has resulted in higher than natural stormwater flow rates with decreased time of concentration and reduced runoff period. All of the first- and second-order streams in the middle and upper portions of the watershed are buried except for the fairly healthy Fern Hollow Run, which passes through lower Frick Park into the study area near the soccer fields. The main Nine Mile Run channel is a third order stream and is about 75% non-channelized.

Dramatic stormwater pulses batter the lower riparian slopes and deposit city detritus of all kinds. At the primary culvert outlet at Braddock Avenue, at the top of the study site, a summer cloudburst can render the stream channel patently dangerous in minutes. The stream's pre-slag morphology has long been obliterated, and instability is the order of the day; any "natural" stretches are subject to continual bank erosion and stream bed downcutting. Stream stability ratings concluded that the stream study reach was "poor" for the majority of measurement sites upstream of the stable slag-reinforced section. High in-stream shear stresses and non-cohesive bank material were found to be contributing to mass wasting for a majority the cross-sections. Most of the steep banks lack even invasive vegetation, further indication of frequent erosion. Monitoring of bank pins have begun to confirm visual evidence of progressive bank widening along non-reinforced reaches of the stream. As the channel widens, it is able to accommodate ever larger storm water surges. Energy that in undeveloped stream corridors is easily dissipated to the floodplain is now increasingly accommodated below the bankfull level, further exacerbating storm flow damage.

The city's only remaining open-air stream along the lower, Nine Mile Run has been cited by the Environmental Protection Agency as one of the most polluted urban streams in the country. The valley has long served as a corridor for sanitary and combined sewers. Pittsburgh and its neighboring municipalities of Swissvale, Wilkinsburg and Edgewood, like other early industrialized cities in the mid-Atlantic and mid-West, installed a vast network of pipes which, in hindsight, seem astoundingly laissez-faire. Much of it is in disrepair and leaking. Some buried lengths of old pipe are long lost, uncharted, and often the subject of dispute as to municipal responsibility. Combined sewer overflows (CSOs), illegal sanitary sewer overflows and an aged and widely crumbling infrastructure contribute significant pathogens during low flows.

CSO outfalls overflow through diversion chambers that can handle only about 3.5 times the normal flow of sewage. Thus, overflow events occur regularly, since combined stormwater/sewage discharges take place during rainfall events greater than 0.1- 0.3 in/hr. The illegal sanitary overflow events behave similarly. An underground maze of cracked pipes and unauthorized direct sanitary line tie-ins are responsible for substantial contributions of raw sewage. To date these have not been well-quantified, despite the best efforts of the study team to obtain and compile agency mapping.

Nine Mile Run contributes to pollution problems in the Monongahela and Ohio Rivers. During 1997, the Allegheny County Health Department issued health advisories on 45 days of the recreational boating season, urging residents to avoid contact with the river water. In-stream grab sampling confirmed a serious health problem in lower Nine Mile Run as well. Fecal coliform counts in excess of the 200 CFU/100 ml stream contact standard set by. the Pennsylvania Department of Environmental Protection occurred on the stream 365 days a year since testing began two years ago. Bacteria concentrations in the order of 100,000 CFU/lOO ml are common. Odor problems at several of the CSO discharge points are severe, especially during dry weather, indicative of structural failure and ongoing leakage.

Another water quality issue regards sediment load, both from urban runoff upgradient and bank erosion (Figure 2) along the riparian corridor caused by sheer stress due to flashy storm events. Besides a few fluctuating point bars, most sediment is transported to the mouth, where small deltaic silt flats extend out into the Monongahela River. Although not specifically measured by the team, there is every likelihood that fairly continuous sediment movement and frequently high turbidity have almost completely extirpated fish populations, discussed below.

Depleted stream base flow is also a concern. As impervious surfaces speed the flow of precipitation toward stream channels, they prevent the infiltration of water into the soil, reducing recharge of the ground water that supports the base flow long after the most recent rains. Each autumn since observations began in 1997 has witnessed month-long no-flow conditions in Nine Mile Run, leading to a dearth of aquatic habitat, elevating stream temperature, and reducing dissolved oxygen. The result, among others, is a further depletion of stream benthic organism populations. An ironic situation has evolved: during normal whether patterns, sewers discharge into the stream; but during extended dry periods, any minimal stream flow infiltrates back into the decrepit pipe system. Clearly, an unsustainable and poorly maintained infrastructure throughout the watershed and within the channel proper has skewed base flow conditions toward both the dry and wet end of the spectrum.

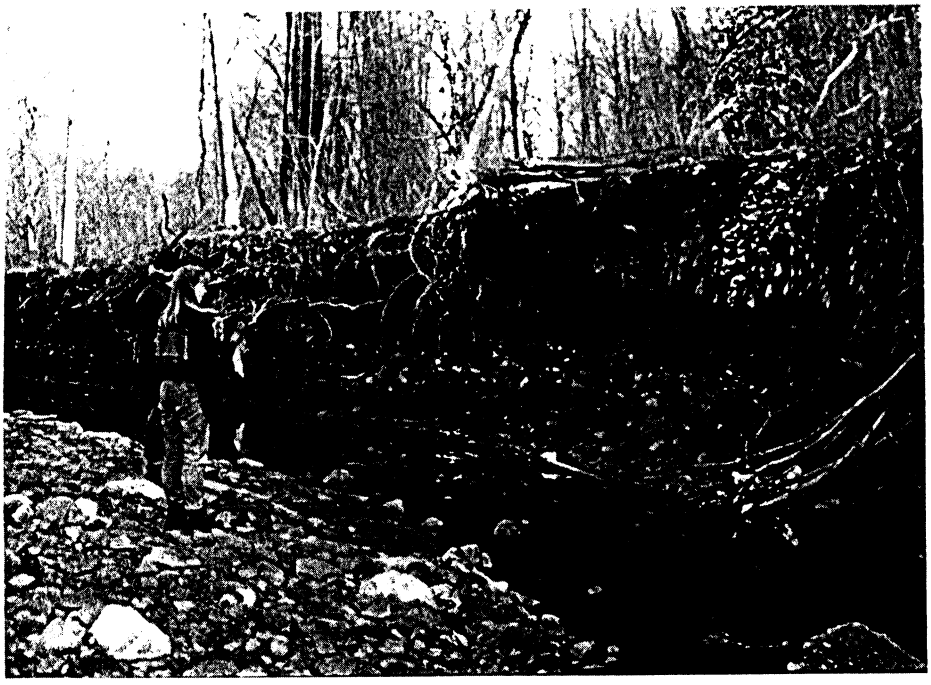


Figure 2. Bank erosion along Nine Mile Run (A. Otten photo)

The fish inventory confirmed informal observations that the ichthyofauna found in Nine Mile Run is depauperate. Only two species of fish were obtained during sampling: creek chub (*Semotilus atromaculatus*) and white sucker (*Catostomus commersoni*). Cleaner reference streams nearby along the Monongahela routinely accommodate 20-3 5 fish species (Stauffer and Stecko 1998). However, the elasticity index (potential to recover) for Nine Mile Run is very high due to its proximity to the biologically diverse Monongahela River--a large refugia from which recolonization could be initiated.

Wetlands. Two small remnant wetlands were found in the study area. The larger approximately 2 ha wetland was classified as a Palustrine emergent/scrub-shrub complex and sub-classified as a slope wetland under the HGM approach employed by the Penn State CWC team. The much smaller 0.1 ha wetland was found perched on a thin layer of clayey shale on a high bank overlooking the stream near the trailer site. A rather peculiar emergent palustrine wetland, it has been tentatively classed as a riparian depression. Both wetlands exhibited key wetland functions, but were also clearly under stress.

The primary wetland indicator, hydrology, showed the requisite periodicity for saturation, according to CWC hydrographs produced during the Phase Three study. The test well indicated a soil saturation time within the root zone of 55%, normal for slope wetlands in the state. Hydroperiods for the riparian depression, in contrast, fluctuated dramatically, inconsistent with typical stable water levels of riparian depressions in the state. A gleyed soil with a chroma of slightly less than 2.0 indicated hydric soils for the slope wetland, with higher and inconsistent numbers for the irregular riparian depression. While dominant species (>5% cover) for both wetlands tended toward upland species, the greatest number of total species were hydric. Hydrophytes collectively comprising almost two-thirds of the species. This may indicate either a drying trend (to be confirmed through ongoing well monitoring), or recent invasion of facultative and facultative upland species that thrive in disturbed urban wetlands. Fox sedge (*Carex vulpinoidea*), Lake sedge (*Carex lacustris*), bulrush (*Scirpus atrovirens*), cattail (*Typha angustifolia*), fowl manna grass (*Glyceria striata*), boneset (*Eupatorium perfoliatum*) and the introduced moneywort (*Lysimachia nummularia*) were some of the more frequent obligate and facultative wetland species encountered. However, disrupted groundwater flow, sediment loading and even localized garden refuse dumping are apparently stimulating the invasion of honeysuckle (*Lonicera spp.*), teasel (*Dipsacus sylvestris*), redtop (*Agrostis alba*) and riverbank grape (*Vitis riparia*). More ominous is the spread of aggressive multiflora rose (*Rosa multWora*), with seedlings evident throughout the site. A line of fill associated with an access lane along the up-gradient side of the larger slope wetland may be serving to disrupt surface and groundwater flow.

Terrestrial Ecosystems. Throughout the lower valley, both upland and lowland vegetation communities are fragmented and overwhelmingly represented by invasive, nonindigenous species. However, along the south slope of the valley and higher up into Frick Park are several large patches of relatively healthy, mature oak-hickory-maple secondary forest. From a landscape ecology perspective these mesic stands represent an extremely important ecosystem, the last remnant of relatively pristine second-growth forest, but quite isolated in the context of the surrounding city. In terms of interior

habitat, the Frick Park meta-woodland of 107 ha is just over the threshold size required for successful breeding of area-sensitive interior species such as Northern Waterthrush (*Seiurus noveboracensis*), Canada warbler (*Wilsonia canadensis*) and Pileated woodpecker (*Dryocopus pileatus*). Its function as a refugium for neotropical migrant birds and other wildlife cannot be overstated.

Several patches of micro-woodlands in the slag-dominated area below the highway overpass achieve a size of up to 30 ha, but possess an amoeboid geometry that precludes much interior habitat. Edge effects associated with 'feral' domestic cats and the parasitic Brown-headed Cowbird (*Molothrus ater*) have been observed. Forest patches are also stressed by ground-level air pollution, trampling, and infiltration by exotics such as the rapidly spreading garlic mustard (*Aliaria officinalis*) and Japanese honeysuckle (*Lonicera japonica*), as well as native wild grapes (*Vitis spp.*) around the edges and in forest gaps. One of the more important outcomes of our study was to document and suggest ways to reverse patterns of habitat fragmentation and isolation in order to facilitate genetic diversity and species resilience.

The Duquesne Slag Company saw the potential of the valley as a convenient dumping ground, purchasing their first parcel along the west bank in 1923. Over the next five decades, they would dispose of twenty million tons of carbon steel slag, almost completely filling in the valley and obliterating floodplains. As the team expected, the to-be-developed slag plateaus and contiguous side slopes maintain a dysfunctional ecosystem. The combination of high porosity, southern aspect, very low albedo, steep slope and unstable aggregate surface render this surface inhospitable to plant growth. Another key limiting factor is the slag pH, typically around 10, but as high as 11. Older slag has weathered to a pH of about 8, still a challenge to most plants.

Two types of natural succession are evident on slag environments. On older sectors, where it is suspected construction debris has been mixed with slag, a young successional forest has formed. Species are those typical of rubble piles: staghorn sumac (*Rhus lyphina*), Tree-of-Heaven (*Ailanthus altissima*), boxelder (*Acer negundo*), and scattered individuals of aspen (Populus *tremuloides*), and slippery and American elm (*Ulmus spp.*). Along with a fairly high diversity of ground flora, we have a useful local reference-site-in the-making when considering raw slag afforestation approaches.

The majority of the slag slopes, however, are newer and blacker. Here the study team found only a few meager striations of vegetation huddled in microtopographic dips (Figure 3) and clinging to pockets of organic detritus that seems to have blown over the edge. The feisty *Ailanthus* and a few scattered sumac and black locust (*Robinia pseudoacacia*) are functioning as dominant pioneers. Despite mildly allelopathic roots, *Ailanthus* appears to be providing shelter for non-native herbs such as white and yellow sweet clover (*Melilotus spp.*) and a diminutive grass identified as Japanese brome (*Bromus japonica*). Thus, *Ailanthus* provides an interesting dilemma in conceiving a regenerative model for NMR. On the one hand, it is considered a ubiquitous urban weed. On the other hand, it is a highly resilient colonizer that grows where little else can,

providing shelter and, through time, the organic build-up that allows smaller volunteers to gain a foothold, thus accelerating the process of succession.

In some cases uncommon associations between xerophytic plants and herbivores are taking place. The colorful orange moth *Atteva punctella* is a native generally found further south, but has been documented feeding exclusively on Ailanthus in lower Nine Mile Run. As with the botanical inventory, inventories of the slag's terrestrial invertebrate population found reduced species richness and a reduced number of individuals collected in comparison to other xeric habitats in the region, such as barrens or shale cuts. Conversely, the number of species considered unusual were present at greater densities than expected, especially introduced taxa and species associated with xeric habitats.

The historically broad floodplain of lower Nine Mile Run has been reduced through slag dumping to about 10% of its original size. In the upper portion of the study area in Frick Park, a scattered fringe of sycamore (*Platanus occidentalis*), willow (*Salix spp.*), ash, bass wood (*Tilia americana*), tulip poplar (*Liriodendron tulipifera*), sassafras (*Sassafras albidum*) and native dogwoods (*Cornus spp.*) were found. More typically, stream-side and floodplain vegetation is dominated by a host of non-indigenous species including the invasives Amur and Japanese honeysuckle (Lonicera spp.), Ailanthus, Norway maple (*Acer platanoides*) and, increasingly, garlic mustard and Japanese and giant knotweeds (*Polygonum spp.*). In one spot overlooking the Squirrel Hill tunnel, CMU botanists found a patch of kudzu (*Peuraria lobata*), reportedly a first for Pittsburgh. This species was later sighted by the author as a planted groundcover in several residential backyards in the upper watershed.



Figure 3. Ailanthus on a raw slag slope, Nine Mile Run (K. Tamminga photo)

As with the slag environment, slag-based riparian habitats displayed reduced species richness and population densities, but contained some intriguing biotics nevertheless. One of the CMNH light traps deep in the riparian slope harbored the moth *Semiothisa quadrinotaria*, certain indication of the Ohio buckeye tree (*Aesculus glabra*). Yet no buckeyes have been found. More mysterious, a species of African dung beetle (*Onthophagus taurus*) was collected in an intercept trap, likely the first record in Pennsylvania since its introduction into the United States in the late 1980's. Eight ground beetles species (*Carabidae*) were new for Pennsylvania, of which three of were not previously known north of South Carolina. It seems the alkaline slag slopes have created a special environment for a range of unexpected species.

DISCUSSION

The foregoing is a brief sketch of Nine Mile Run's varied ecosystems and their attendant challenges. The study team's work in Phase Two resulted in an ecosystems-based plan for its recovery, described in the Nine Mile Run Rivers Conservation Plan. It embraces several key principles for recovery and defines a framework for regenerative techniques slated for application over the next few decades. The plan has been adopted by the City of Pittsburgh and the Department of Conservation and Natural Resources. It has also been well-received by area municipalities, agencies including the Allegheny County Health Department, Allegheny County Sanitation Authority (ALCOSAN), and Pittsburgh Sewer and Water Authority, and a wide range of local interest groups.

It is important to stress that the study team spent a great deal of time in community workshops developing a concept of nature-in-the-city that would do justice to the past, present and post-industrial future of Nine Mile Run. It became amply clear as Phases One and Two proceeded that residents did not want to erase the history of environmental abuse; rather, they wanted a gentle, ecologically-based approach that would kick-start natural processes, using the resources already in the area. Community participants called for slag piles to remain, rather than be exported as environmental liabilities elsewhere. They wanted to see a return of native biodiversity, but they also wanted to celebrate the extant life of a tough ecosystem. And, finally, they wanted the process of recovery to be revealed and celebrated.

In response, the study team considered it vital to construct a wide spectrum of complimentary approaches, and to communicate these as a narrative in the search for healthier urban systems across the bioregion. We examined and debated various paradigms, guided by the overriding goal of rekindling ecosystem functions and reattaching the surrounding communities to a landscape that had been oppressed for decades.

We examined several general concepts for beginning the process of achieving a greater degree of ecological health and integrity in this urban context, each influenced by underlying notions of nature-in-the-city. 'Restoration' in its more literal sense of returning to prior, pristine ecosystem functions and structure could be applied to two small

wetlands and several larger floodplains with minimal overburden. A modified notion of 'reclamation' could be applied to the slag mountain; we favored restoration ecologist Bill Jordan's idea of 'healing', concerned with "getting the patient ecosystem back on its feet, making it more self-sufficient" (Jordon 1997). So we saw merit in the concepts of 'restoration,' 'reclamation,' and 'healing'-depending on degree of disturbance and projected use patterns-unified by the overarching concept of 'regeneration' within the NMR valley and larger watershed. The goal was to emphasize natural processes that could generate a newly sustainable urban ecology, one that could tolerate environmental scars.

In terms of regeneration approaches, the slag and stream/wetland slope ecosystems have thus far garnered the most attention. The study team, with community input, developed the notion that the slag represented less a 'constraint' to be 'overcome' than an opportunity in innovative learning and a testing ground for new ideas about human induced mega-disturbances such as Nine Mile Run. In a larger sense, we began to see the valley as a potential contributor to the continuing story of the culture-nature continuum so evident in the post-industrial city.

As a didactic response to conventional, 'instant' and unsustainable approaches to urban brownfields, we adapted Hodge and Hamer's (1995) typology for woodland creation on difficult urban sites (Figure 4). Six potential slag afforestation methods were profiled; two were based on natural succession processes, and four by planting strategies. As a general model, the table suggests that the greater the level of energy and material input into slag afforestation, the shorter the time for vegetative establishment, the higher the chances of failure. Based largely on assessments of the older slag slopes and the author's experience in ecosystems restoration in the Toronto area, we recommended adoption of the 'ecosystem design' end of the typology that stressed low-intensity management, site-informed planting palettes using native species, and a liberal timeline. Methods #2-#4 are proposed to be tested on the slag over the next several years, accepting that some sort of accelerated vegetative cover, or 'kick-starting' will be necessary to reverse ongoing degradation, restore watershed ecosystem functions, and enhance open space aesthetics in anticipation of slag plateau development. Methods #5 and #6 were considered ecologically risky, expensive, and inconsistent with the project's stated goal of pursuing ecosystem design principles and a high level of sustainability. The City of Pittsburgh and surrounding residents supported this experimental approach-in contrast to other brownfield projects in the region-and subsequently secured an $80,000 EPA grant for more detailed pilot studies.

Method	Management	Planting	Est. Failure Rate/ Time to Establish
1. Natural colonization	No management	Natural selection	Low / decades
2. Nurture colonization	Low-intensity management	Natural selection	Low / 3-10 years
3. Natural planting	Low-intensity management	Site-informed selection	Medium / 1-5 years
4. Nurture planting	Mid-intensity management	Site-informed selection	Medium / 1-3 years
5. Ideal-driven planting	Mid-intensity management	Idealized plant selection	Med.-High / instant-1 year
6. Forced-ideal planting	High-intensity management	Idealized plant selection	High / instant-1 year

Figure 4. Slag Slope Afforestation Approaches (Collins et al. 1998, p.64; adapted from Hodge and Hammer 1995).

Some of the ideas being developed to enhance the growing climate of the slag slope include the introduction of organic admixtures such as non-alkaline, high-quality sludge and mushroom compost. Microtopography manipulations to accelerate the process of organic accumulation were suggested by a variety of sources, bolstered by V-shaped batter boards, straw mats and the like to trap sediment and provide a seed germination layer. We hope to experiment with artificial perches on the slopes to accelerate the deposition of propagules by birds, and envision a system of posts and wires that could double as reclamation artifice and environmental art. Tree nucleation (islands of quick spreading trees) and the installation of deep soil pockets will be pilot tested, as will the introduction of mycorrhizal fungi to accelerate soil genesis. More research on alkaline tolerant species is needed, since almost all published research on reclamation is devoted to acid and pH-neutral growing media. A small greenhouse has been set up on site funded through the EPA grant, and the propagation of locally-collected species and the development of controlled stress-trials is on-going.

The stream and slope wetland complex upgradient of Commercial Avenue has undergone even more intense conceptual design than terrestrial ecosystems. Much of the Phase Three team's efforts have focused on achieving a plan that knits together objectives for water quality/quantity amelioration and restored biological health in the valley bottom between the Braddock Avenue outfall and Commercial Avenue.

The boldest gesture-currently under review by local agencies and the regional office of the Army Corp of Engineers-is a plan to recover the historic floodplain through the relocation of the existing soccer fields (Figure 5), removal of approximately 0.75 m of the topsoil/silt overburden over a 6 ha area, and re-alignment of the stream to a more centralized position in the restored floodplain. The newly functional floodplain would greatly aid in dissipating stormwater energy. The slope of the stream would be reduced through the reintroduction of sinuosity. Stone cross-vanes will be established on 90 m centers to deflect flow to the channel's center, reduce bed scour, and emulate riffles

midway between the new meanders. Along with lowered banks, the bankfull width would correspondingly be reduced. Below the culvert outfall at Braddock Avenue, a baffled chute spillway, two stilling basins, and trash control structures are proposed as hydrologic structures necessary to dissipate hydraulic energy and improve water quality. The planting of wetland vegetation will contribute to bank stabilization.

Phase Three concepts call for the moderate expansion of the slope wetland to a size of approximately 2.2 ha to enhance the aquatic-terrestrial continuum between Nine Mile Run proper and the Frick Park uplands. The removal of fill along the access lane, control of invasive species, and the reestablishment of natural contours in dumping spots should improve wetland function and resilience. Test wells will continue to be monitored, since groundwater-fed wetlands are notoriously difficult to manage and adapt. Finally, the team has proposed the creation of a constructed wetland in the area where Fern Hollow Run approaches the current soccer field. Approximately 2.0 ha in size, the new wetland would demonstrate a passive, more ecological approach to CSO treatment. Species being considered for both water polishing capabilities and biological values include soft rush, *Carex species*, and a variety of other native emergent hydrophytes.



Figure 5. Floodplain recovery area near confluence of Fern Hollow and Nine Mile Run (K. Tamminga photo).

These are just some of the key initiatives taking place in a rich mosaic of ecological and social challenges that make up the Nine Mile Run project. Although beyond the scope of this paper, numerous spin-off and complementary initiatives are also in the works.

Suffice to note that, if the past three years are any indication, it is this synergistic mix of rigorous and involved science, interdisciplinary explorations, heightened community interest and continuing agency support that promises a healthier, more vibrant Nine Mile Run.

ACKNOWLEDGMENTS

I wish to thank colleagues from the STUDIO for Creative Inquiry, Carnegie Museum of Natural History and Penn State University for their insights and enduring collegiality. Projects were supported by grants from the Pennsylvania Department of Conservation and Natural Resources and the Heinz Foundation.

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CYPRESS CREEK MITIGATION PROJECT

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ABSTRACT

In 1995, the Florida Department of Transportation (FDOT-District Seven) evaluated wetland mitigation alternatives to compensate for wetland impacts associated with Interstate-4 highway improvements. On-site and off-site alternatives concluded with selection of property owned by the Southwest Florida Water Management District (SWFWMD). The "Cypress Creek Mitigation Project" (CCMP) area covers 197 hectares (488 acres) which is a portion of a 2,734 hectares (6,756 acres) contiguous parcel owned and managed by the SWFWMD. Prior to the SWFWMD obtaining the property, the CCMP area was heavily disturbed by earthwork construction activities in the 1970's. Several large and deep canals were dredged adjacent to cypress wetlands and the associated fill material was placed in adjacent uplands. The largest canals were 24-30 meters (80-100 feet) wide and 5-6 meters (15-20 feet) deep. A drainage study concluded that historic drainage patterns had been circumvented around the perimeter of the cypress wetlands, substantially impacting the hydroperiods and flood stages. The fill areas were converted to pastures dominated with bahiagrass (*Paspalum notatum*) and substantial invasion of dog fennel (*Eupatorium capillifolium*). The goal of the mitigation project was to restore the natural wetland hydrologic regimes, construct wetland habitat within the canals, and create/restore native upland habitat.

INTRODUCTION

The CCMP is located in south-central Pasco County, Florida (Figure A). The permitted design includes an ecosystem management approach that enhances the existing native habitat while creating/restoring disturbed areas to historic habitat conditions (Figures B, C, D). Once the CCMP site was selected for the proposed mitigation, data collection (surveying, surface & ground water flow regimes, geotechnical evaluation, biological documentation) continued in 1995-1996. Mitigation design, permitting, and contractor selections were conducted in 1996-1997, and construction commenced in February, 1998.

THIS CONTRACT PLAN SET INCLUDES:

SUMMARY OF PAY ITEMS (1 SHEET)
MITIGATION PLANS

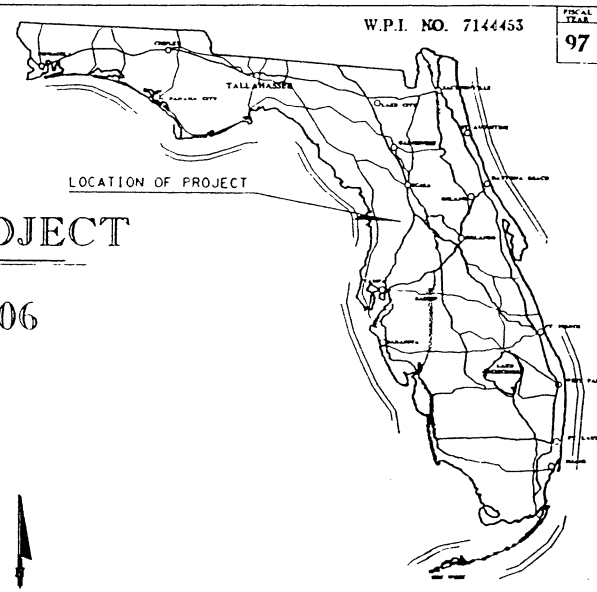
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FISCAL YEAR 97

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

PLANS OF PROPOSED
CYPRESS CREEK MITIGATION PROJECT

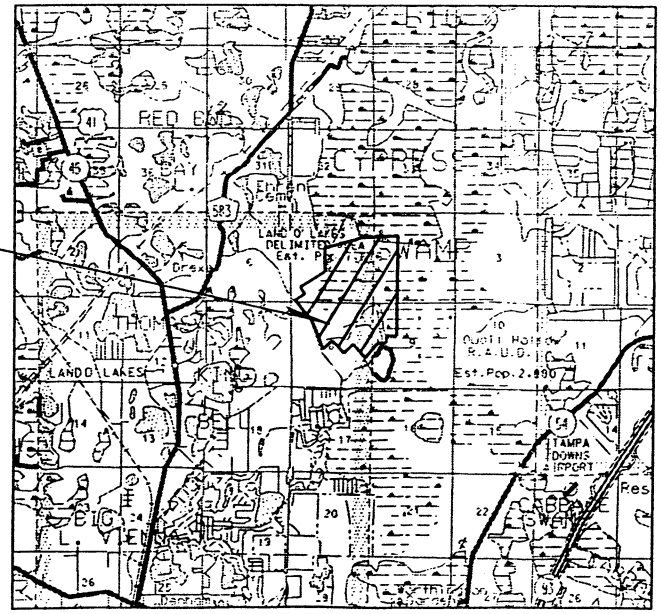
STATE PROJECT NO. 10190-3706
PASCO COUNTY



INDEX OF PLANS

SHEET NO.	SHEET DESCRIPTION
1	KEY SHEET
2	TYPICAL SECTIONS AND DETAILS
3	GENERAL NOTES
4-5	PLANTING NOTES
6-7	MITIGATION NOTES
8	SUMMARY OF QUANTITIES
9	SHEET LAYOUT
10-21	GRADING PLANS
22-36	SOIL SURVEY
37-44	PLANTING PLANS
45	UPLAND SECTIONS
46-47	WETLAND SECTIONS
48-49	PLANTING SUMMARY
50	SWPPP

LOCATION OF PROJECT



T 25 S
T 26 S

R 18 E
R 19 E

DATE: JUNE, 1997

PLANS PREPARED BY:

FLORIDA DEPARTMENT OF TRANSPORTATION
DISTRICT NO. 7
11201 N. McKINLEY DR.
TAMPA, FLORIDA 33612
(813) 975-6000

ENGINEER OF RECORD:
WILLIAM PEARCE, P.E.

THESE PLANS HAVE BEEN PREPARED IN ACCORDANCE WITH AND ARE GOVERNED BY THE STATE OF FLORIDA, DEPARTMENT OF TRANSPORTATION, ROADWAY AND TRAFFIC DESIGN STANDARDS. (BOOKLET DATED JANUARY, 1994)

ATTENTION IS DIRECTED TO INTERIM STANDARD DRAWINGS CONTAINED IN THIS SET WHICH ARE INTENDED TO REPLACE AND/OR SUPPLEMENT THE ABOVE MENTIONED STANDARDS.

ATTENTION IS DIRECTED TO THE FACT THAT THESE PLANS MAY HAVE BEEN ALTERED IN SIZE BY REPRODUCTION. THIS MUST BE CONSIDERED WHEN OBTAINING SCALED DATA.

GOVERNING SPECIFICATIONS: STATE OF FLORIDA, DEPARTMENT OF TRANSPORTATION, STANDARD SPECIFICATIONS, DATED 1991 AND SUPPLEMENTS THERETO IF NOTED IN THE SPECIAL PROVISIONS FOR THIS PROJECT.

REVISIONS:

REVISIONS		
DATE	BY	DESCRIPTION

MITIGATION PLANS APPROVED BY: WILLIAM PEARCE, P.E.

FIGURE A

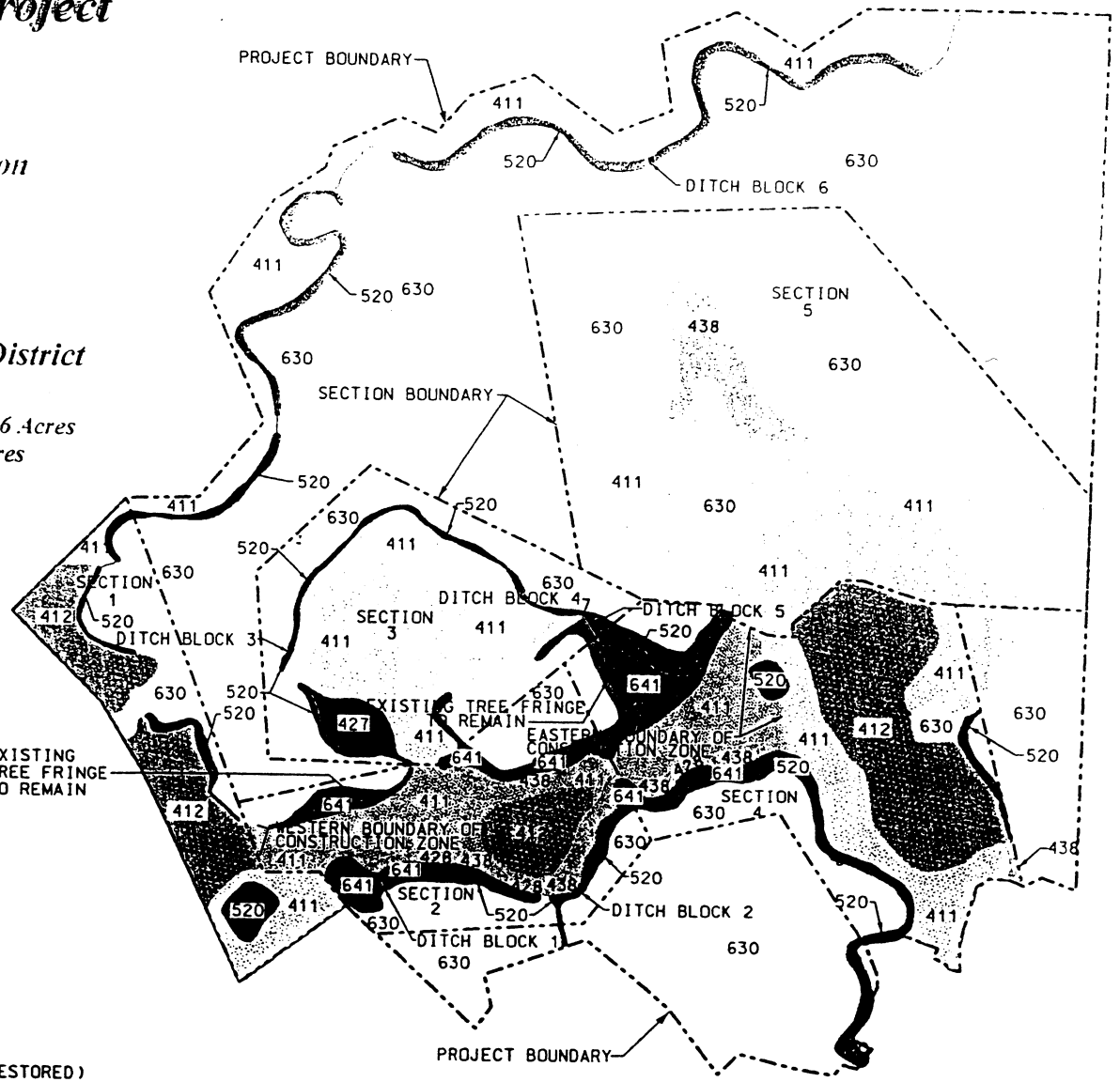
...\projects\cypresscrk\keysem01.dgn

Cypress Creek Mitigation Project

Constructed in 1998
by the
Florida Department of Transportation
District Seven

Property Owned
by the
Southwest Florida Water Management District

Wetland Hydrologic Restoration & Enhancement - 256 Acres
Upland Habitat Creation & Restoration - 212 Acres
Wetland Creation & Restoration - 20 acres



N

N.T.S.
(Approximately 1 inch = 600 feet)

LEGEND

- 411 PINE FLATWOODS
- 412 HIGH PINE
- 427 OAK HAMMOCK
- 428 CABBAGE PALM
- 438 MIXED HARDWOODS
- 520 OPEN WATER
- 630 WETLAND FOREST MIX
- 641 WETLAND MARSH(CREATED AND RESTORED)
- 411 CONSTRUCTION ZONE

10190-3706

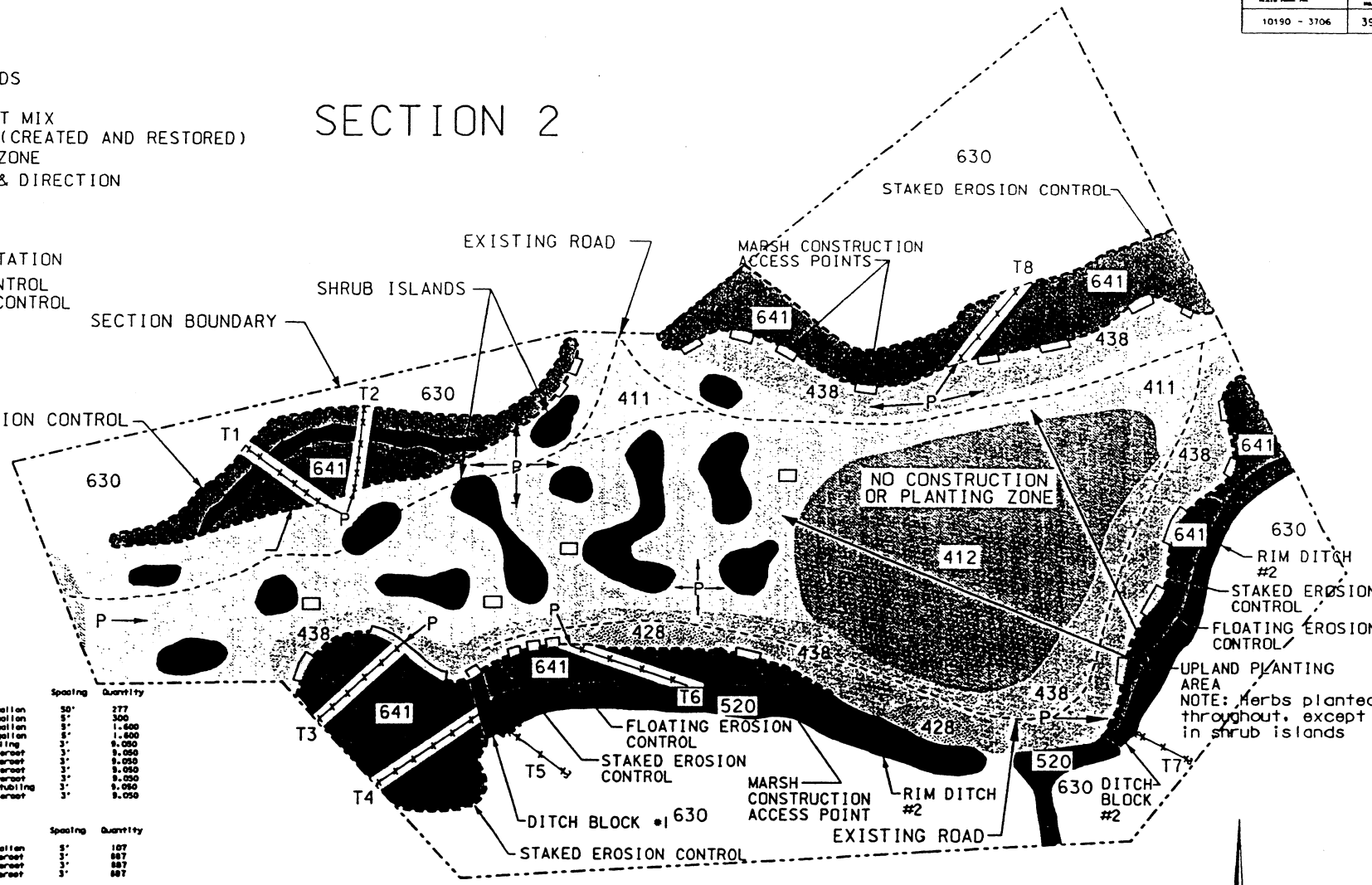
F.D.O.T. - DISTRICT 7

10190 - 3706	39

SECTION 2

LEGEND

412 HIGH PINE
428 CABBAGE PALM
438 MIXED HARDWOODS
520 OPEN WATER
630 WETLAND FOREST MIX
641 WETLAND MARSH(CREATED AND RESTORED)
411 CONSTRUCTION ZONE
PHOTOGRAPH POINT & DIRECTION
QUADRAT LOCATION
TRANSECT LOCATION
SHRUB ISLAND
UPLAND SAMPLING STATION
STAKED EROSION CONTROL
FLOATING EROSION CONTROL



411 Pine Flatwoods

Species		Spacing	Quantity
Longleaf pine (Pinus palustris)	1 gallon	50'	277
• Bolberry (Ilex glabra)	1 gallon	5'	300
• Rusty lyonia (Lyonia ferruginea)	1 gallon	5'	1,600
• Saw palmetto (Serenoa repens)	1 gallon	5'	1,600
Wiregrass (Aristida stricta)	tubling	3'	9,050
Broomsedge (Andropogon virginicus)	bareroot	3'	9,050
Lopsided Indiangrass (Sorghastrum secundum)	bareroot	3'	9,050
Hairy panicum (Panicum rhizomatum)	bareroot	3'	9,050
Pineywoods dropseed (Sporobolus junceus)	bareroot	3'	9,050
Partridge pea (Cassia fasciculata)	4" tubling	3'	9,050
Low panicum (Panicum spp.)	bareroot	3'	9,050

428 Cabbage Palm

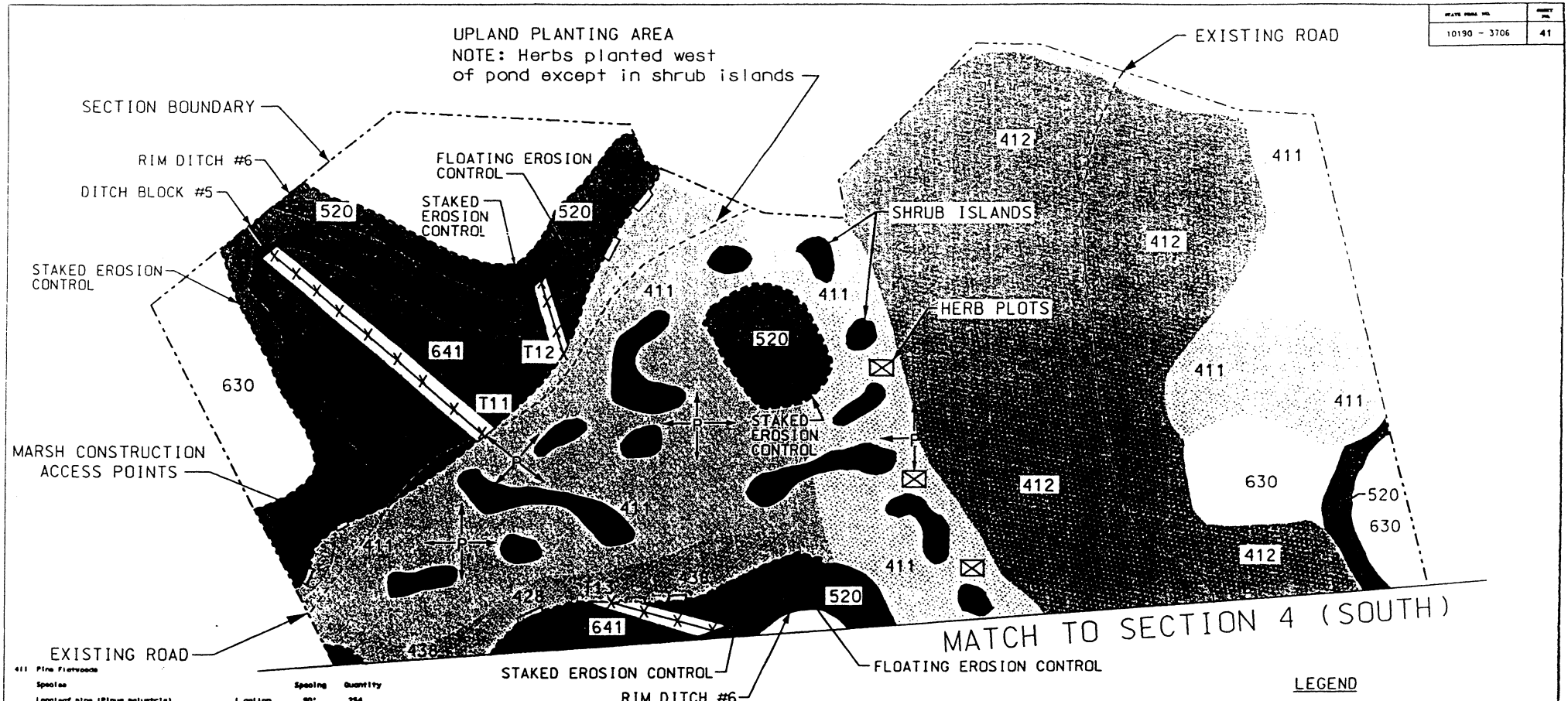
Species		Spacing	Quantity
Cabbage palm (Sabal palmetto)	1 gallon	5'	187
Carpetgrass (Axonopus affinis)	bareroot	3'	887
Seltzhgrass (Panicum virgatum)	bareroot	3'	887
Partridge pea (Cassia fasciculata)	bareroot	3'	887

438 Mixed Hardwoods

Species		Spacing	Quantity
Laurel oak (Quercus virginiana)	1 gallon	20'	113
Water oak (Quercus nigra)	1 gallon	20'	113
Sweetgum (Liquidambar styraciflua)	1 gallon	20'	113
Red maple (Acer rubrum)	1 gallon	20'	113
Fetterbush (Lyonia lucida)	1 gallon	10'	113
Saw palmetto (Serenoa repens)	1 gallon	10'	113
Carpetgrass (Axonopus affinis)	bareroot	3'	6,030
Seltzhgrass (Panicum virgatum)	bareroot	3'	6,030
Wiregrass (Aristida stricta)	tubling	3'	6,030
Pineywoods dropseed (Sporobolus junceus)	bareroot	3'	6,030
Partridge pea (Cassia fasciculata)	4" tubling	3'	6,030

641 Wetland Marsh

Species		Spacing	Quantity
Pickerelweed (Pontederia cordata)	bareroot	3'	4,825
Arrowhead (Sagittaria lancifolia)	bareroot	3'	4,825
Bulrush (Scirpus validus)	bareroot	3'	4,825
Sawgrass (Cladium jamaicense)	bareroot	3'	4,825
Maidencane (Panicum hemitomon)	bareroot	3'	4,825
Soft rush (Juncus effusus)	bareroot	3'	4,825
Water lily (Nymphaea odorata)	bareroot	3'	2,000
Spatterdock (Nuphar lutea)	bareroot	3'	2,000



SECTION 4 (NORTH)

411 Pine Flatwoods

Species		Spacing	Quantity
Longleaf pine (Pinus palustris)	1 gallon	20'	254
• Sailberry (Ilex glabra)	1 gallon	5'	250
• Rusty lyonia (Lyonia ferruginea)	1 gallon	5'	250
• Saw palmetto (Serenoa repens)	1 gallon	5'	250
Wiregrass (Aristida stricta)	Plugs	3'	7,018
Broomsedge (Andropogon virginicus)	bareroot	3'	7,018
Lopsided Indiangrass (Sorghastrum secundum)	bareroot	3'	7,018
Mairy panicum (Panicum rhizomatus)	bareroot	3'	7,018
Pineywoods dropseed (Sporobolus junceus)	bareroot	3'	7,018
Partridge pea (Cassia fasciculata)	4" rubling	3'	7,018
Low panicum (Panicum spp.)	bareroot	3'	7,018

428 Cabbage Palm

Species		Spacing	Quantity
Cabbage palm (Sabal palmetto)	1 gallon	5'	488
Carpetgrass (Axonopus affinis)	bareroot	3'	452
Saltshgrass (Panicum virgatum)	bareroot	3'	452
Partridge pea (Cassia fasciculata)	bareroot	3'	452

438 Mixed Hardwoods

Species		Spacing	Quantity
Laurel oak (Quercus virginiana)	1 gallon	20'	37
Water oak (Quercus nigra)	1 gallon	20'	37
Sweetgum (Liquidambar styraciflua)	1 gallon	20'	37
Red maple (Acer rubrum)	1 gallon	20'	37
Fetterbush (Lyonia lucida)	1 gallon	10'	294
Saw palmetto (Serenoa repens)	1 gallon	10'	294
Carpetgrass (Axonopus affinis)	bareroot	3'	1,307
Saltshgrass (Panicum virgatum)	bareroot	3'	1,307
Wiregrass (Aristida stricta)	rubling	3'	1,307
Pineywoods dropseed (Sporobolus junceus)	bareroot	3'	1,307
Partridge pea (Cassia fasciculata)	4" rubling	3'	1,307

641 Wetland Marsh

Species		Spacing	Quantity
Pickerelweed (Pontederia cordata)	bareroot	3'	4,235
Arrowhead (Sagittaria lancifolia)	bareroot	3'	4,235
Bulrush (Scirpus validus)	bareroot	3'	4,235
Sawgrass (Cladium jamaicense)	bareroot	3'	4,235
Maidencane (Panicum hemitomon)	bareroot	3'	4,238
Soft rush (Juncus effusus)	bareroot	3'	4,238
Water lily (Nymphaea odorata)	bareroot	3'	2,000
Spatterdock (Nuphar lutea)	bareroot	3'	2,000

• Shrub islands only

LEGEND

- 411 PINE FLATWOODS
- 412 HIGH PINE
- 428 CABBAGE PALM
- 438 MIXED HARDWOODS
- 520 OPEN WATER
- 630 WETLAND FOREST MIXED
- 641 WETLAND MARSH(CREATED AND RESTORED)
- 411 CONSTRUCTION ZONE
- P→ PHOTOGRAPH POINT & DIRECTION
- X QUADRAT LOCATION
- TRANSECT LOCATION
- SHRUB ISLAND
- HERB PLOT
- STAKED EROSION CONTROL
- FLOATING EROSION CONTROL

STATE PROJ. NO.	SHEET NO.
10190 - 3706	41

REVISIONS					
DATE	BY	DESCRIPTION	DATE	BY	DESCRIPTION

F.D.O.T. - DISTRICT 7

CYPRESS CREEK MITIGATION PROJECT

MATERIALS AND METHODS

Even though the pre-construction canal grades were very steep, the canals did have a dense littoral zone with an average width of 6-9 meters (20-30 feet) that were completely covered with cattails (*Typha* spp.). In order to minimize this potential cattail seed source of post-construction conditions, a total herbicide eradication program was conducted prior to construction. At the same time, over 4.8 kilometers (3 miles) of silt screens and floating barriers were installed to minimize impacts to existing upland and wetland habitat areas that were proposed for preservation. Preservation included a 6-9 meters (20-30 feet) band of existing trees and shrubs along the upland perimeter of the canals. Construction access points were designated to minimize impacts to the trees (predominantly red maple, *Acer rubrum*) and only remove wax myrtle (*Myrica cerifera*) which were prolific along the perimeter.

The intent of starting construction in the winter was to finish the majority of earthwork before the start of the normal rainy season in late June. Unfortunately, the climatic changes due to the El Nino resulted in dry season rain patterns that actually exceeded normal rainy season conditions. As a result, construction methodology had to be revised to continue. Instead of grading the upland areas to fill in the canals while the water levels were generally very low, the proposed ditch blocks were constructed first. The canals were hydrologically bisected by the ditch blocks, allowing each canal segment to be dewatered by pumping water over to the adjacent canal segment. Once drained, each canal segment was filled with the adjacent upland material and graded to the final proposed elevation, followed by pumping water back from the adjacent canal segment. Each canal segment required a period of 3-6 weeks to allow sediments and turbidity to settle before planting the wetland vegetation.

Some canals were completely filled to a depth of 0.5 meters (1.5 feet) below the proposed seasonal high water table for wetland plantings (Photograph 1). A few of the wider canals had a 15-18 meter (50-60 feet) wide littoral zone constructed with the remaining canal in open water to provide habitat for the various fish and reptile species (Photograph 2). On average, the western upland portion (Figure C) of the construction zone required grading of 0.6-0.9 meters (2-3 feet) of the upland fill back into the canals. The same grade cut applied to the majority of the eastern construction area (Figure D) except for an approximately 2.43 hectare (6 acre) triangular-shaped upland that is now referred to as the "Pork Chop Wetland" due to it's shape (Photograph 3). Prior to construction, this upland area had an average fill depth of 3.0 meters (10 feet) that was graded down and deposited into the adjacent canals.

A mixture of various wetland herbs were planted just prior to the rainy season. Dominant species included bare-root plantings of bulrush (*Scirpus validus*), arrowhead (*Sagittaria lancifolia*), pickerelweed (*Pontederia cordata*) with additional plantings of sand cordgrass (*Spartina bakeri*), soft rush (*Juncus effusus*), maidencane (*Panicum hemitomon*), sawgrass (*Cladium jamaicense*), and spatterdock (*Nuphar luteum*). Many sedge and rush species have naturally recruited to provide dense cover and a diverse assemblage of species.



Photograph 1 - One of the canals that was totally filled and planted; cypress wetland (left) hydrology is restored and the adjacent band of upland trees (right) provides a wildlife buffer.



Photograph 2 - One of the wider canals where a marsh littoral zone was constructed while leaving an open water component adjacent to the existing cypress wetland (left); allowing wading birds and mammals to forage along with the reptiles, amphibians, and fish.



Photograph 3 - View from the southern boundary of the "Pork Chop Wetland" to the northern tip of the marsh (upper left). Surface water flow is directed into the marsh from the adjacent filled and planted canal to the west (left) and outfalls into a canal with created littoral zone to the east (right). This shallow system has maximum surface water levels less than 0.3 meters (1 ft.); allowing sandhill cranes (right of center) and other wading birds to forage.

As the grades of the constructed wetlands were finalized, brown-top millet seed, fertilizer, and hay mulch were tilled into the uplands to provide a temporary vegetative cover through the summer of 1998. The upland plantings started after the millet was established and primarily included nursery-grown 102 mm (4 in.) plugs. The dominant upland plantings included 76,000 plugs of wiregrass (*Aristida stricta*) with additional coverage provided by partridge pea (*Cassia fasculatata*), hairy panicum (*Panicum rhizomatum*), carpetgrass (*Axonopus affinis*), switchgrass (*Panicum virgatum*), and broomsedge (*Andropogon virginicus*). There were also over 11,000 saw palmetto (*Serenoa repens*) and 3300 tree saplings planted in the uplands; predominantly longleaf pine (*Pinus palustris*). Hairy indigo (*Indigofera hirsuta*) also propagated with the millet. Even though this legume is often considered a nuisance species, for this particular site it actually assisted with the vegetative cover needed to help control erosion.

In the spring of 1999, exposed soil areas where vegetation did not establish were hand seeded with tropical cargetgrass (*Axonopus furcatus*). This carpetgrass is one of the few native species that are commercially available in seed and provides an alternative cover to bahiagrass. Herbicide has been and will continue to be used to control exotic & nuisance species from generating in the planted wetlands. Due to the minimal surrounding seed source

and extensive pre-construction herbicide eradication of the over 8.1 hectares (20 acres) of wetland plantings, less than a 0.1 hectare (0.25 acre) needs to be sprayed every two months to control undesirable vegetation. Within a year after planting, the created wetlands exceeded success criteria with a minimum cover of over 80%. The upland plantings have not been as prolific, but it was anticipated that it will take at least 3-4 years after planting so that a prescribed burn can minimize the cover of undesirable species and allow the plantings to seed and germinate.

Beyond the construction zones, additional activities were conducted within the existing upland habitat areas. In areas where dense wax myrtle growth limited habitat conditions, the SWFWMD used a hydro-ax, a modified tractor that cuts and mulches large, woody shrubs. Once the shrubs were cut and allowed to dry, the SWFWMD initiated prescribed burns to control the myrtles. The FDOT will continue to work with the SWFWMD to control undesirable vegetation with herbicide, mowing, and prescribed burns for three years. After which, herbicide should not be needed and the SWFMWD will continue prescribed burns every 3-4 years.

Over 20 herb plots (15 m x 15 m, [50 ft. x 50 ft.]) were established within bahiagrass dominated upland areas. These plots were either sprayed with herbicide or scalped with bulldozers to control the bahia; followed by plantings of native species along with recruitment of surrounding native seed sources. Since the property needs to be accessed for prescribed burns, other maintenance activities, camping, hiking, and bike riding, over 3.2 kilometers (2 miles) of existing dirt roads that are impassable during the rainy season were graded 102 mm (4 in.) and backfilled with crushed shell.

RESULTS

The CCMP is one of the first FDOT mitigation projects that deviated from the normal type-for-type on-site mitigation that has been traditionally conducted around Florida. It is also one of the first mitigation projects that included a joint effort between the FDOT and another state agency on public lands. The CCMP area was one of the most disturbed parcels owned by the SWFWMD. The extensive earthwork (over one million cubic yards) and costs associated with restoring the property limited the opportunity for the WMD to restore the site without assistance. At the same time, the limited on-site mitigation opportunities for FDOT included expensive parcels within an urbanized area. Working together, both agencies were able to exceed their goals with an environmentally better product and a substantial economic value to the taxpayers.

The CCMP is an example of an overall ecosystem restoration and management plan that serves to restore state-owned land while providing better use of taxpayer's money over traditional wetland mitigation techniques. Total construction costs for CCMP was $1.2 million, mitigating for 6.9 hectares (17 acres) of natural wetland impacts and over 16.1 hectares (40 acres) of impacts to man-made wetlands. In comparison to the on-site wetland mitigation option proposed for the roadway project, CCMP covers an area four times larger

yet still saved $13-14 million in tax money.

DISCUSSION

No matter how much experience one has with mitigation projects, there are issues that are not foreseen during the design phase that can present problems during construction. Some of these issues can be planned for during the design phase, but not easily adopted during construction. The following information may be helpful to others involved with mitigation design. Even though almost all of these "helpful hints" were considered during design of CCMP, the degree of their importance was not realized until during or after construction.

Erosion Control - Proper planning and installation of erosion control practices are critical during design and construction. Establish a multi-phase erosion control plan so that enough material (i.e. silt screens, hay bales, barriers, etc.) are properly quantified during design. Some designs only account for the pre-construction erosion control quantities and locations. That quantity may be only half or less than what is needed as the project progresses through construction.

Construction Methodology - Communication with the Contractor is one of the most important components throughout the construction process. Due to the high rainfall and surface water conditions at CCMP, a completely different construction method had to be used to continue earthwork. Without reviewing alternative methods during the design phase and communicating those options to the Contractor, a project can be delayed for substantial periods with very expensive consequences.

Earthwork Balance - Major earthwork construction projects routinely determine the cut and fill volumes. However, the location of the cut material relative to the fill locations are not always cross-referenced, resulting in unnecessary cost of carrying fill from one area of the project to the other. If this earthwork sequencing is not determined during the design phase, it should be reviewed with the Contractor prior to construction.

Vegetative Cover - With constructed wetlands, the planted species are desired to ultimately increase density and proliferate in the wetland. With constructed upland habitat, the site may require temporary vegetative cover with species that are desired to decrease cover in time. Most desirable upland plant species do not generate, reproduce, and spread at the rate of many hydrophytic species. Patience and maintenance is more critical, recognizing that the ultimate maintenance control will generally be prescribed burning. However, temporary cover such as brown-top millet for the summer and winter rye during the dry season is generally required for areas where construction results in large areas of exposed soils. This is particularly important for efforts to control erosion. Seeding with bahiagrass will provide the necessary erosion control but is a permanent cover that will substantially reduce the chance to establish desirable native upland herbs, particularly wiregrass which has been shown to not compete well with bahia when trying to germinate and recruit.

If a suitable donor site is available for upland herb species, collecting seed during the fall, dry storage through the winter, and direct seeding in the late spring is a viable option. Unfortunately, such donor sites are not readily available and collecting and dispersing seed has to be timed accordingly. That was not an option for the CCMP, but the use of the tropical carpetgrass has been shown as a possible annual replacement of temporary cover. The carpetgrass has not formed a dense cover to compete with the wiregrass or other natives. Even though the carpetgrass prefers wetter soil conditions, which is good along the wetland perimeters, with sufficient rainfall it has readily covered drier soil areas. As opposed to collected seed, which has high composition of leaves, duff, and stems, the commercially available carpetgrass seed contains no duff and has a 70% germination rate. The apparent drawbacks of using the seed include hand dispersal because the seed is too small for spreader calibration and minimal discing requirements. The seed should be disced as close to the surface as possible to obtain moisture which hinders use of tractor-pulled discs that tend to disc too deep. Expense is a problem with the carpetgrass seed but not much more than bahiagrass seed, and will provide a permanent supplemental cover compared to trying to establish cover with only native grasses. Keep in mind the presence of possible wildlife grazing on planted material. Some desirable species can be decimated by foraging mammals, as was the case with the partridge pea by deer at CCMP.

Even though it was the intent to not use bahiagrass seed or sod under post-construction conditions, the use of the carpetgrass seed or other native grasses in some high surface water runoff areas and around structures proved to be a fruitless effort. Constantly setting additional silt screens and trying to establish vegetative cover for the sake of not utilizing bahia is just not feasible under some circumstances. However, in the case of CCMP, those bahia sodded areas are concentrated within catchment swales and slopes that cover a total area less than 0.2 hectares (0.5 acre). Recognizing those problem areas during the construction process and accounting for the use of permanent grass cover will save time, money, and frustration in trying to establish cover.

Patience, Communication, & Open Mind !!! - When a large mitigation project has so many designers, contractors, and workers on the site, there is a tendency for people to have conflicting concepts. When one method does not appear to be working, some are willing to alter the design without considering the site characteristics or climatic conditions. For the CCMP, it became apparent that the climatic conditions dictated construction methodology which resulted in a more efficient method. When extreme drought conditions occurred, the Pork Chop Wetland lacked a wetland hydroperiod for four months after construction; forcing some to question the grading design. However, patience prevailed as the summer rains proved that the wetland would hydrologically function as designed. The first example demonstrates where open minds and communication were needed to alter the construction methodology to stay on schedule. The latter situation demonstrates where patience and open minds were required to stay with the design even though there was an immediate response to take drastic measures. Creating any type of habitat takes time, patience, and the ability to work within the constraints and benefits the environment provides.

ACKNOWLEDGMENTS

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A very special recognition is noted to the SWFWMD-Land Management Division (Kevin Love, Mary Barnwell) whose property, expert planning, and field assistance were very important, and without whose efforts the project could not have been constructed.

MANAGING NUISANCE PLANT SPECIES IN FORESTED WETLANDS ON RECLAIMED PHOSPHATE MINED-LANDS IN FLORIDA

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ABSTRACT

Florida regulations require that "nuisance" species, including the native primrose willow (*Ludwigia peruviana*) and cattail (*Typha spp.*), be limited to less than ten percent of the cover on reclaimed wetlands. Chemical and mechanical control of these species is expensive and may injure desirable trees and understory vegetation. It was hypothesized that shade-tolerant trees could grow through, overtop, and shade out the shade-intolerant "nuisance" species. This study, conducted on reclaimed phosphate mined lands in central Florida, compared tree growth in the presence of primrose willow or cattail with tree growth when these species are removed (cut or herbicided). It also examined the effects of a developing tree canopy on primrose willow. The effects of elderberry (*Sambucus canadensis*) on tree growth were also studied. Growth of baldcypress (*Taxodium distichum*) was greater with primrose willow removal, but growth was substantial in the presence of primrose willow. Popash (*Fraxinus caroliniana*) and red maple (*Acer rubrum*) height growth was greater in the presence of primrose willow than when the primrose willow was removed by careful application of triclopyr herbicide. In five or six years, 80 to 100% of the baldcypress, popash, red maple and water hickory (*Carya aquatica*) were able to grow through and overtop the 2.3 to 2.7 m tall primrose willow. The developing canopy of the trees drastically reduced the leaf area index of primrose willow. About 80% of the baldcypress and pondcypress (*Taxodium ascendens*) trees overtopped the 2 m tall cattail in seven years at one site, but popash did not compete well with cattail at sites with standing water throughout the year. Baldcypress and popash grew as well in a planting of elderberry as in the weeded treatment. Costly control of primrose willow and cattail is probably not necessary in the reestablishment of forested wetlands in Florida if adapted trees are planted at sufficient density and site conditions allow vigorous tree growth.

INTRODUCTION

Primrose willow (*Ludwigia peruviana*) and cattail (*Typha latifolia* and *T. domingensis*) are wetland species native to Florida (Ramamoorthy and Zardini 1987; Dressler et al. 1987). However, due to their invasiveness, the Florida Department of Environmental Protection-Bureau of Mine Reclamation (FDEP-BMR) lists these native species as "nuisance" species. This designation is legally important in the reclamation of forested wetlands on phosphate mined lands, because one success (release) criterion on many FDEP-BMR permits limits "nuisance" species to less than 10% of the total cover (FDEP-BMR, personal communication).

To comply with this criterion, a combination of herbicide application, mowing and hand labor has often been required to control primrose willow and cattail. Are these control measures necessary ecologically or just legally or aesthetically? Such efforts are not only expensive but may damage desirable plants as well as the targeted "weeds." On forested wetlands, an alternative approach may be possible. Our own observations and those of others (Richardson et al. 1994; Clewell and Raymond 1991; Hawkins and Ruesch 1988; Miller et al. 1988; Clewell 1981) suggest that several tree species can grow through, overtop, and shade out the "nuisance" species. Thus, it could be more cost-effective to plant a sufficient number of shade tolerant trees and be patient.

With regard to the competitive effects of primrose willow on tree growth on phosphate mined lands, Clewell and Raymond (1991) stated that primrose willow's canopy might even have a beneficial nurse crop effect. As for cattail, Rushton (1988) detected no differences in the heights (after one year) of baldcypress (*Taxodium distichum*) seedlings grown on reclaimed clay settling ponds whether the sites were cleared of cattail or not at the time of planting.

Clewell (1981) observed vigorous green ash (*Fraxinus pennyslvanica*) growing in a cattail stand, and suggested that densely planted ash might grow through, overtop, and replace cattail. Erwin et al. (1985) observed that cattail appeared to initially reduce baldcypress and Florida maple (*Acer saccharum floridanum*) seedling survival, but seedlings that survived this competition appeared to have high growth rates. Miller et al. (1988) observed that planted trees initially seemed to be overcome by cattail but later became visible as the trees grew taller. They also observed that previously dense cattail thinned dramatically under the expanding crowns of Carolina willow (*Salix caroliniana*) and that red maple grew well beneath the willow canopy.

The first objective of this study was to determine how primrose willow and cattail affect the growth of several wetland tree species. The second, and longer term, objective was to determine if these tree species could overtop and shade out the primrose willow and cattail. An additional objective was to examine the interactions of elderberry with wetland trees and evaluate the ability of elderberry to displace primrose willow. The results reported here update and expand the data of Johnson and Richardson (1996).

METHODS

The research was conducted in central peninsular Florida (Polk County) at several reclaimed phosphate surface mines on regraded overburden soils. To evaluate the effects of primrose willow and cattail competition on tree growth, two stands of primrose willow and two stands of cattail were selected on reclaimed wetlands. A third primrose willow stand was used in a study of the effects of tree canopy development on primrose willow. An additional primrose willow site was used in the study of elderberry competition.

Primrose Willow Competition. At each of the two primrose willow sites, the stand was mowed during the dry season with a tractor drawn mower and eight replicate blocks of paired

plots were located within similar hydric regimes. Within each block, a plot was randomly selected to be the weeded plot and the other plot to be the unweeded check plot. The primrose willow in the unweeded plots was allowed to regrow, and the primrose willow in the weeded plots was repeatedly mowed with a gasoline-powered trimmer at the P1 site or herbicided at the P2 site.

Clear Springs (P1) Site. This primrose willow stand was on a reclaimed, seepage wetland at the IMC-Agrico Clear Springs Mine (11 km southeast of Bartow). On 12 May 1989, five baldcypress trees, grown in 15 cm diameter pots, were planted 2 m apart in each plot. The primrose willow in the weeded plots was mowed three to four times during each growing season with a motorized trimmer through 1992. The weeded plots were mowed for the last time at the end of March 1993 and then herbicided two times with triclopyr (Garlon^{R} 3A, 15 ml of 44.4% triclopyr concentrate per liter) between April and early August 1993, after which weed control efforts ceased. Triclopyr was used because baldcypress has shown tolerance to the herbicide, while primrose willow is effectively controlled.

Baldcypress heights were measured at the time of planting and each subsequent winter. Diameters at Breast Height (DBH) and crown diameters (average of two perpendicular measurements) were measured at the end of the fourth and sixth growing seasons. Primrose willow height was also measured.

McCullough Creek (P2) Site. This stand of primrose willow was on a reclaimed wetland along McCullough Creek at the Mobil Fort Meade Mine (3 km northwest of Fort Meade). On 10 November 1992, five trees each of baldcypress, popash (*Fraxinus caroliniana*), and red maple (*Acer rubrum*), grown in 35 cm x 10 cm sacks, were planted 2 m apart and randomly placed in a 3 x 5 grid arrangement in each plot. The primrose willow in the weeded plots was sprayed two times each growing season with triclopyr herbicide during the first four years. In the 5th and 6th years, a mixture of triclopyr plus glyphosate (15 ml Garlon^{R} 3A concentrate plus 15 ml Rodeo^{R} [53.8% glyphosate] concentrate per liter) was used because the mixture appeared to be more effective on vines. During these sprayings, the trees were protected with plastic bags. As needed, vines were unraveled from trees and spot sprayed with the herbicide mixture in all treatments to minimize any confounding effects of vines on the experiments.

Tree mortality was assessed in June of 1993. Dead trees were then replaced to assure sufficient numbers of trees for the growth comparisons in subsequent years. The replacement trees were planted later and thus were smaller at any given time than the original trees, but this was accounted for in the data analysis. Tree heights and basal diameters (at 15 cm height) were measured at the time of planting and at the end of each subsequent growing season. The height of the primrose willow nearest to each tree was also measured. Tree growth at the P2 site was more complicated to analyze than at the P1 site, because the denser and more tangled primrose willow at the P2 site leaned on the saplings, causing some trees to be bent in the unweeded plots. Tree heights were measured to the highest point above ground, which was not always the apical bud in bent trees. Therefore, data from the unweeded plots are presented as averages of the straight trees alone and also as averages of

the straight plus bent trees combined.

Tree Canopy Effects (T1 Site). The effects of the developing canopy of three tree species on primrose willow were studied by planting the trees relatively close together (1.2 m apart vs. the usual 2 m) and observing the trees and the primrose willow. The T1 primrose willow site was in a reclaimed flood plain wetland adjacent to McCullough Creek at the Mobil Fort Meade Mine (3 km northwest of Fort Meade). Similar to the other studies, the primrose willow was mowed in August 1993 and allowed to resprout. Three replicate blocks were located within similar hydric regimes ("wet", "medium", or "dry") which were related to their distance from the stream. Four plots within each block were randomly assigned to be either a baldcypress, popash, water hickory (*Carya aquatica*), or check plot. On 22 September, 1993 each tree plot was planted with 35 trees (grown in 35 cm x 10 cm plastic sacks) in a 5 x 7 grid arrangement with 1.2 m between trees. The check plots were flagged in the same 5 x 7 arrangement for comparing primrose willow measurements.

Tree heights and basal stem diameters (at 15 cm) were measured each year. Leaf area index (LAI) of the primrose willow was measured by counting the number of leaves coming into contact with a vertical pole placed midway between trees (Bonham 1989, Frank and McNaughton 1990). Primrose willow height was also measured at the same locations as LAI.

Elderberry Competition. The research plots were located at a site occupied by primrose willow along the reclaimed stream and flood plain of Rocky Branch at the Mobil Fort Meade Mine, 6 km northeast of Fort Meade. Treatments were designed to test the effects of elderberry on tree growth, and to observe the competitive interactions between elderberry and primrose willow. Primrose willow was cut to a height of 0.5 m and allowed to regrow only in the "primrose willow plus elderberry treatment". In the "elderberry only" and the "weeded" treatments, primrose willow was killed by herbiciding with a mixture of trichlopyr (15 ml Garlon^{R} 3A [44.4% a.i.] per liter) and glyphosate (15 ml Rodeo^{R} [53.8% a.i.] per liter). Elderberry plants (grown in 15 cm diameter pots) were planted 1 m apart in both the elderberry only and primrose willow plus elderberry treatments. In May 1996, five baldcypress and five popash trees (grown in 35 cm x 10 cm plastic sacks) were planted 2 m apart in each plot, and there were eight replicate plots per treatment. The weeded treatment was sprayed two times per year with the herbicide mixture to control primrose willow, vines, etc. The popash and baldcypress trees were protected with plastic bags when the weeded plots were sprayed. Primrose willow was removed manually from the elderberry only treatment. Vines were removed as at the P2 site. Tree heights, stem diameters and crown diameters were measured at the end of each growing season. Heights of primrose willow and elderberry were also measured each year.

Mobil Cattail Site. The stand of cattail was in a reclaimed wetland at the Mobil Fort Meade Mine, 2 km north of Fort Meade and 3 km east of U.S. Highway 17. Overburden at the site had been graded in 1991 and planted with a variety of tubeling trees between September 1991 and February 1992. The trees (mostly baldcypress and pondcypress, *Taxodium ascendens*) that had been previously planted by Mobil Mining and Minerals Corporation were located, mapped, and marked with tags and flagging.

Eight replicate blocks of paired (weeded and untreated) plots were located within similar hydric regimes and cattail densities. Weeded plots were initially cut with machetes in early May 1994 and were maintained three to four times each growing season by cutting resprouts below the water surface with pruning shears. Cattails in the unweeded check plots were not cut, but allowed to continue growing. In each plot, five baldcypress and five popash trees, grown in 35 cm x 10 cm plastic sacks, were planted in an irregular random arrangement among the existing trees no closer than 1.5 m apart at the end of May 1994. Thus the cattail removal treatment began in the second year for the trees planted in the winter of 1991-92 rather than at the start of the experiment as with the trees planted in 1994.

Trees heights, stem diameters (at 50 cm height to assure being above water), and crown diameters were measured at the end of each growing season. Tree heights were measured vertically from the ground to the highest growing point. Cattail height and water depth were also measured next to each tree.

Cargill Cattail Site. This stand of cattail was located at the Cargill Hooker's Prairie Mine (14 km southwest of Bartow) in "Cell B", an experimental wetland containing a layer of phosphatic clay on top of overburden. In each plot, five baldcypress and five popash trees were randomly planted 2 m apart in a 2 x 5 grid arrangement in May 1994. There were no previously planted trees. Otherwise, the methods were the same as at the Mobil cattail site.

Statistical Methods. The growth statistics compare only those original trees that remained alive throughout the experiment. Parameters from all sites were statistically analyzed with the STATISTICA^{R} (StatSoft 1995) package. Treatment effects were analyzed with parametric (2-way ANOVA) or nonparametric (Mann-Whitney U and Kruskal Wallis) statistics, based upon tests for violations of assumptions of ANOVA. Mean separations with ANOVA were done with Duncan's Multiple Range test.

RESULTS

Primrose Willow Competition with Trees

Clear Springs (P1) Site. There was very little difference in baldcypress height between the two treatments in the first three years (Figure 1). Tree height was actually slightly greater (difference significant at $P<0.05$) in the presence of primrose willow the first year, but growth was enhanced by primrose willow removal in subsequent years. By the sixth year, the compounding of yearly growth enhancement had led to a 25% greater height with primrose willow removal ($P<0.01$). Nevertheless, baldcypress height growth was substantial in the presence of primrose willow. The trees in the unweeded check plots averaged 5 m tall after the sixth year, over 2m taller than the primrose willow canopy. Baldcypress trees in the unweeded check plots first began to surpass the average primrose willow height of 2.7 m (Figure 2) by the end of the second year, when 18% of the trees were taller than 2.7 m. The percentage of trees taller than 2.7 m increased to 48% after the third year, to 60% after the fourth year, and to 85% after the sixth year.

Primrose willow competition had a greater effect on stem diameter and crown diameter than on tree height. Baldcypress diameters at breast height (DBH) in the sixth year averaged 8 cm with primrose willow as compared to 12 cm in the weeded plots ($P<0.01$). After the fourth year, baldcypress trees in unweeded plots containing primrose willow had developed an average crown diameter of 109 cm as compared to 145 cm in the weeded plots ($P<0.01$). After the sixth year, baldcypress in the primrose willow plots had developed an average crown diameter of 144 cm as compared to 189 cm in the weeded plots ($P<0.01$). There was no difference in percent survival of baldcypress after six years between the treatments (weeded plots had 100% tree survival and unweeded check plots had 98% tree survival).

McCullough Creek (P2) Site. Survival was determined in June 1993, seven months after planting of trees at the P2 site. Red maple survival was low, but it was greater in the presence of primrose willow (42%) than with primrose willow removed (30%). Popash survival was 100% with primrose willow and 87% with primrose willow removed. Baldcypress survival was 86% in both treatments.

Dead trees were replaced after the June 1993 survival assessment, and survival determinations in subsequent years included the replacement trees. After the 6th year, survival of baldcypress was greater with herbicide removal of primrose willow (97%) than in the presence of primrose willow (57%). In contrast, herbicide removal of primrose willow reduced survival of popash (unweeded check 82%, weeded 51%) and red maple (unweeded check 70%, weeded 38%), even though great care was taken to protect the trees from the herbicide spray with plastic bags.

The pattern of baldcypress height growth (Figure 3) at the P2 site was similar to that at the P1 site, but tree growth was slower at the P2 site. Average height of the baldcypress trees in the unweeded check surpassed the height of the primrose willow in the third year at P1, but not until the fourth year at P2 (compare Figures 1 and 3). Baldcypress crown diameter in the 6th year was greater ($P<0.05$) in the weeded treatment (152 cm) than in the presence of primrose willow (90 cm). As with height growth, crown diameter in the weeded treatment was less at the P2 site than at the P1 site (189 cm) in the 6th year.

Popash and red maple differed from baldcypress in their responses to primrose willow removal. Although popash had greater height in the herbicided treatment in the 2nd year ($P<0.05$), height was greater in the unweeded check in the 4th and subsequent years ($P<0.01$) (Figure 4). In the third and subsequent years, red maple tended to be taller in the presence of primrose willow than when the primrose willow was removed by herbicide application, but the differences did not become significant ($P<0.05$) until the 4th and subsequent years (Figure 5). Crown diameter of popash in the 6th year was greater ($P<0.10$) with primrose willow present (246 cm) than in the herbicided treatment (195 cm). Crown diameter of red maple tended to be greater, although not significantly so, in the presence of primrose willow (210 cm in 6th year versus 192 cm in the weeded treatment).

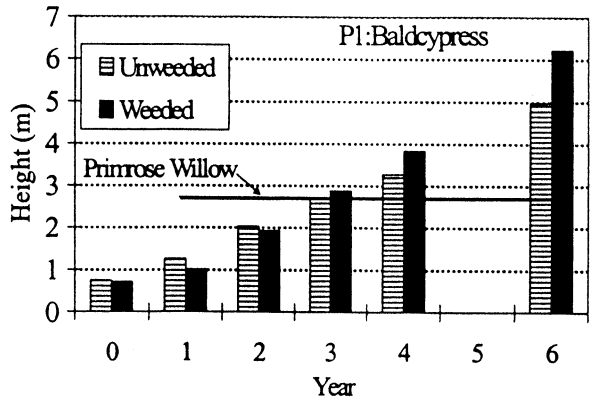


Figure 1. Yearly height of baldcypress as affected by primrose willow competition at Clear Springs site (P1)

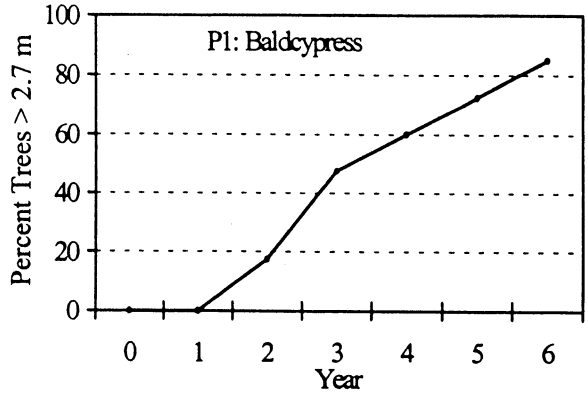


Figure 2. Percentage of baldcypress trees taller than the primrose willow canopy (2.7 m) at Clear Springs site (P1)

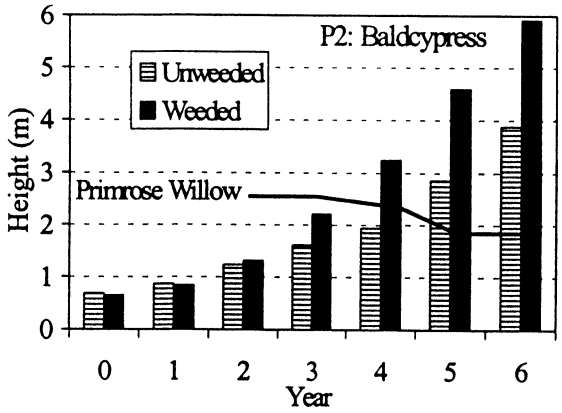


Figure 3. Primrose willow effects on baldcypress heights at McCullough Creek competition site (P2)

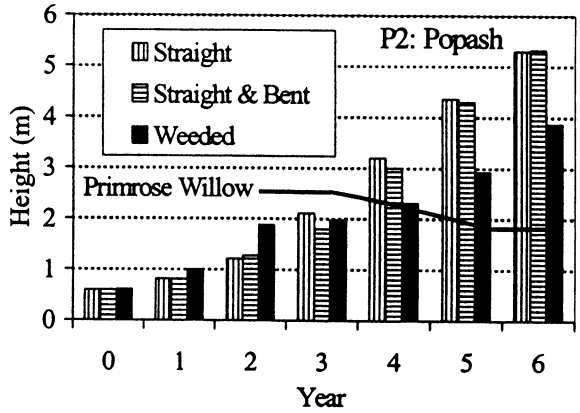


Figure 4. Primrose willow effects on popash height at McCullough Creek competition site (P2)

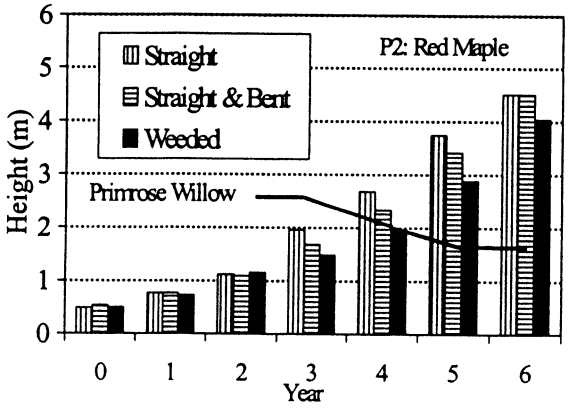


Figure 5. Primrose willow effects on red maple height at McCullough Creek competition site (P2)

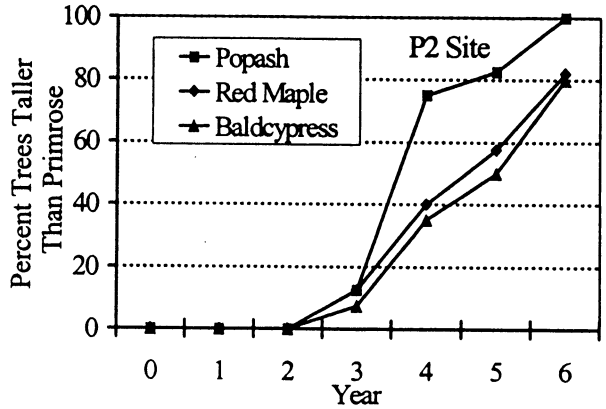


Figure 6. Trees taller than primrose willow at the McCullough Creek competition site (P2)

Popash, red maple, and baldcypress were all able to grow in the presence of primrose willow and overtop it (Figure 6). A few trees began to overtop the primrose willow as early as the 3rd year, and by the 6th year, 80% of the red maple and baldcypress and 100% of the popash were taller than the primrose willow. An interesting observation at the P2 site was a decrease in primrose willow height near the trees as the baldcypress, popash and red maple overtopped 110the primrose willow in the fourth and subsequent years, indicating a competitive inhibition of primrose willow by the trees (Figures 3, 4, 5).

At the P2 site primrose willow was more dense and tangled than at the P1 site and was more prone to lean on and bend some of the planted test trees. The bending effect on baldcypress was small, but about 40% of the popash and red maple were bent to some degree in the 3rd and 4th years (compare straight vs. straight plus bent tree heights in Figures 4 and 5). However, the bending effect appeared to be temporary and disappeared by the 5th for popash and the 6th year for red maple when a large percentage of trees had overtopped the primrose willow.

Tree Canopy Effects on Primrose Willow

Popash, water hickory and baldcypress grew well in the presence of primrose willow (Figure 7). As early as the second year more than 50 % of the popash trees, and about 20 percent of the baldcypress and water hickory trees, had exceeded the average height of the primrose willow (2.3 m) (Figure 8). By the 5th year nearly 100 % of the popash, 78 % of the water hickory and 73% of the baldcypress were taller than the primrose willow. The trees exerted a competitive effect on the primrose willow as indicated by a significant ($P<0.05$) reduction in the leaf area index (LAI) of the primrose willow in the plots with trees compared to the plots without trees (Figure 9). The reduction in leaf area index of primrose willow was more pronounced in the 5th year (1998) than in the 4th year (1997), and it was proportional to the size (height and crown diameter) of the trees. Popash had the greatest effect on reduction of primrose willow LAI, followed by water hickory and then baldcypress. In the 5th year, crown diameters were 2.2 m for popash, 1.4 m for water hickory, and 0.8 m for baldcypress.

Elderberry Competition

Baldcypress grew as tall in the elderberry only treatment as in the weeded treatment and significantly ($P<0.05$) less in the primrose willow plus elderberry treatment in the third year (Figure 10). Baldcypress stem and crown diameters were greatest in the weeded treatment (4.6 cm stem, 66.7 cm crown), slightly but not significantly less in the elderberry only treatment (4.0 cm stem, 60.4 cm crown), and significantly ($P<0.05$) less in the primrose willow plus elderberry treatment (2.5 cm stem, 46.6 cm crown) in the third year.

Popash height by the third year was greatest in the elderberry only treatment, followed by the weeded treatment, and was least in the primrose willow plus elderberry treatment (Figure 11). Popash stem diameters were similar in the weeded and elderberry only treatments (both 3.0 cm), which were about 1.5 times that in the primrose willow plus elderberry treatment (2.0 cm). Crown diameters of popash were similar in all three treatments in the third year (47 to

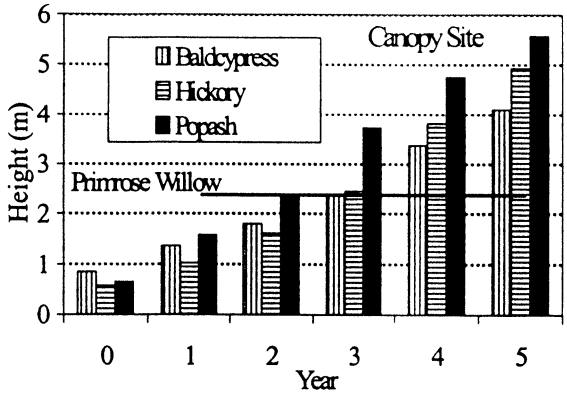


Figure 7. Tree heights in a primrose willow stand at the McCullough Creek canopy site

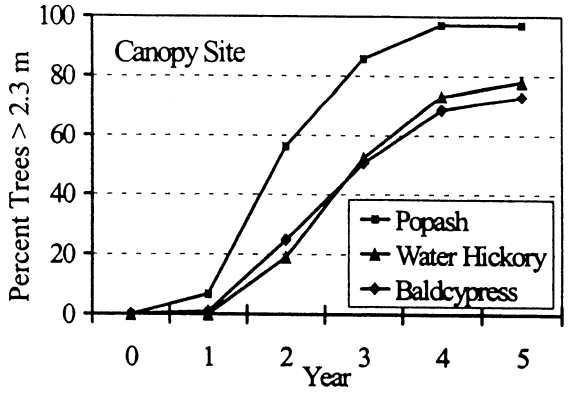


Figure 8. Trees taller than primrose willow (2.3 m) at the McCullough Creek canopy site

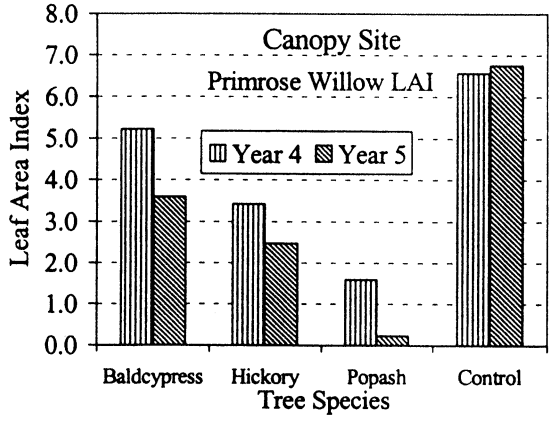


Figure 9. Tree canopy effects on leaf area index of primrose willow at the McCullough Creek canopy site

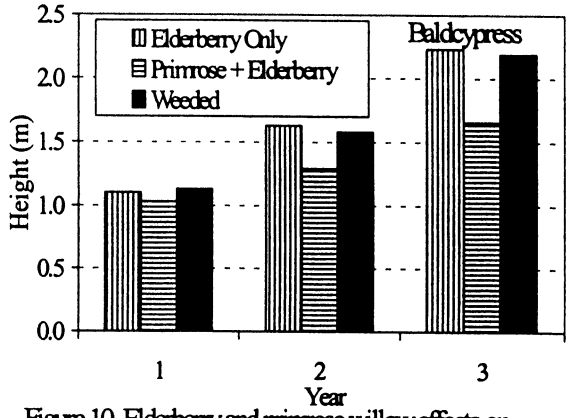


Figure 10. Elderberry and primrose willow effects on baldcypresss height at Elderberry competition site

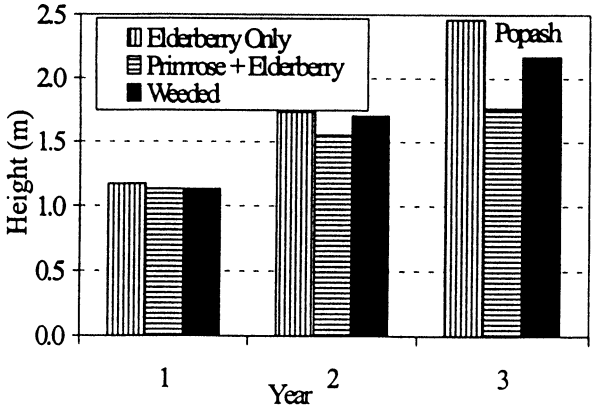


Figure 11. Elderberry and primrose willow effects on popash height at Elderberry competition site

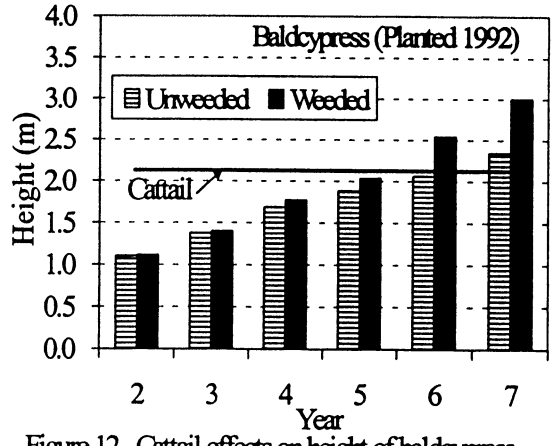


Figure 12. Cattail effects on height of baldcypress (planted 1992) at Mobil cattail site

50 cm).

Both tree species were able to grow in the presence of elderberry, and at the end of the third growing season, 73% of the popash and 60% of the baldcypress were taller than the 2.2 m tall elderberry in the elderberry only treatment. In the primrose willow plus elderberry treatment, 30% of the popash and 23% of the baldcypress were taller than the elderberry, and 22% of the popash and 11% of the baldcypress were taller than the primrose willow. This was because popash and baldcypress growth was less in the elderberry plus primrose willow trea112tment and because primrose willow (2.6 m) was taller than elderberry. It is still too early to distinguish any effects of primrose willow or elderberry on each other.

Cattail Competition

Mobil Cattail Site. Cattail removal beginning in 1994 enhanced growth of pondcypress and baldcypress planted in 1992 (Figures 12 and 13). Nevertheless, these trees have been able to grow in the presence of cattail and to surpass the height of the cattail (Figure 14). Pondcypress grew faster than baldcypress, resulting in 89% of the pondcypress, compared to 76% of the baldcypress, surpassing the 2 m height of the cattail in the 7th year. Baldcypress and pondcypress stem diameters at 50 cm high were similar, and in the 7th year, stem diameters were twice as great in the weeded treatment (nearly 8 cm) compared to the unweeded cattail treatment (less than 4 cm). Crown diameters were also twice as great with cattail removed (more than 70 cm) versus with cattail present (less than 40 cm). Mortality of baldcypress and pondcypress was less than 1%.

Cattail removal enhanced the growth of baldcypress and popash trees planted in 1994 (Figures 15 and 16), but the effect was more pronounced with popash. Popash height in the 5th year was 69% greater with cattail removed, while baldcypress height was 47% greater with cattail removed. When grown in the presence of cattail, 40% of the baldcypress had overtopped the cattail by the 5th year, but only 3% of the popash were taller than the cattail. Baldcypress stem diameter with cattail removed was nearly three times that with cattail present (5.7 cm versus 2.0 cm) in the 5th year, and crown diameter with cattail removed was more than double that with cattail present (68 cm versus 25 cm). Popash stem diameter was nearly three times as great with cattail removed (2.8 cm) versus with cattail present (1.0 cm), and the same was true for crown diameter (37 cm diameter with cattail removed versus 13 cm with cattail present. Through the 5th year, popash survival was 88% in the weeded treatment and 98% in the unweeded treatment, while baldcypress survival was 98% in the weeded treatment and 100% in the unweeded treatment.

Cargill Cattail Site. After five years, baldcypress averaged 1.7 m tall either with or without the 3.3 m tall cattail. Crown diameter of baldcypress was slightly, but not significantly, greater when cattail was removed (42 cm without cattail vs. 35 cm with cattail). Baldcypress stem diameter at 50 cm was significantly greater without cattail (3.4 cm) than with cattail (2.1 cm), while survival was 83% without cattail and 50% with cattail. Popash tended to be slightly, but not significantly, larger when cattail was removed: height was 1.5 m without vs. 1.4 m with cattail; crown diameter was 40 cm without vs. 35 cm with; and stem diameter was

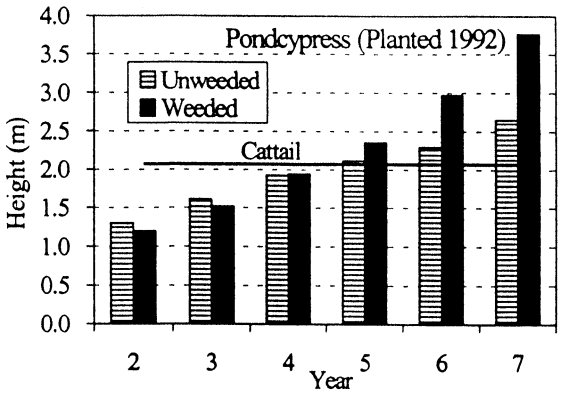


Figure 13. Cattail effects on height of pondcypress (planted 1992) at Mobil cattail site

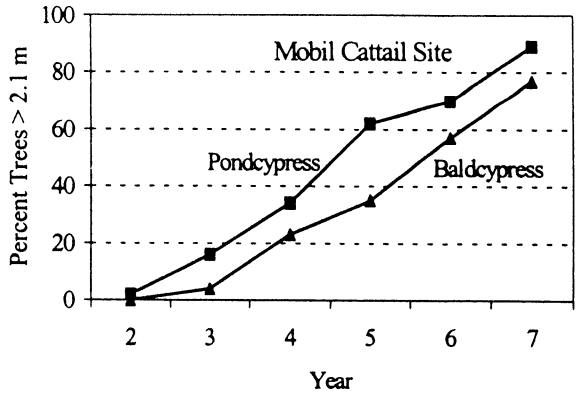


Figure 14. Trees (planted 1992) taller than cattail (2.1m) at the Mobil cattail site

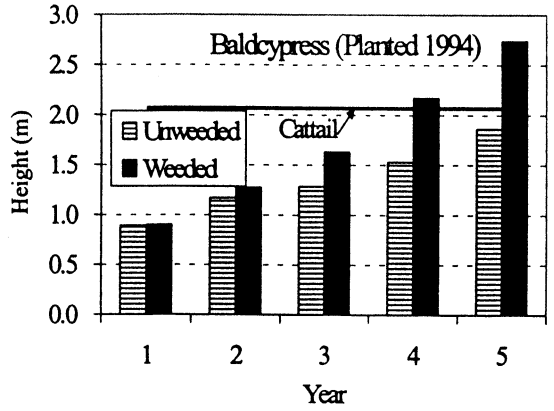


Figure 15. Cattail effects on height of baldcypress (planted 1994) at Mobil cattail site

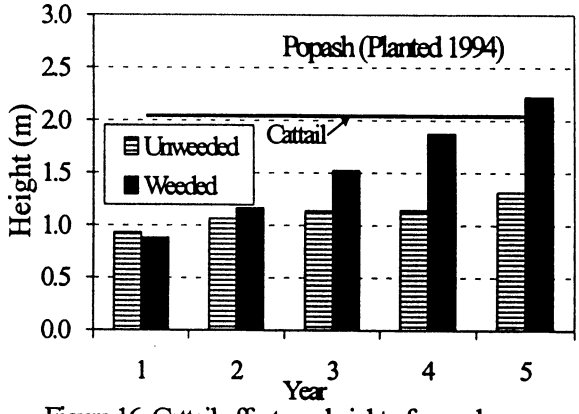


Figure 16. Cattail effects on height of popash (planted 1994) at the Mobil cattail site

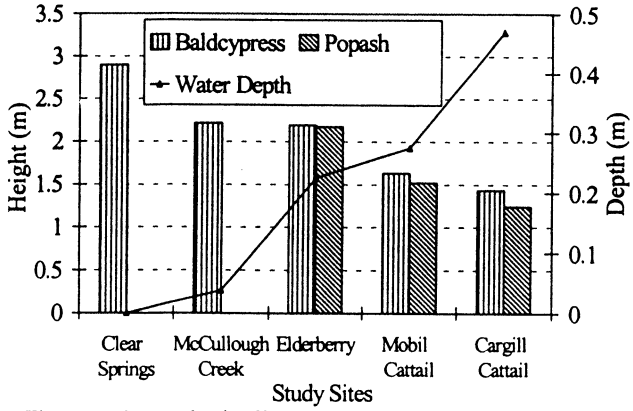


Figure 17. Water depth effects on heights of 3 year old trees in weeded plots at several reclaimed wetland sites

1.8 cm without vs. 1.2 cm with cattail. Popash survival was 45% without vs. 28% with cattail. Water depth averaged nearly 20 cm greater, and cattail height was more than 1 m taller, at the Cargill site than at the Mobil site. Tree growth in the weeded treatment was less at the Cargill cattail site than at the Mobil site, but growth was similar at both sites in the unweeded treatment, even though the cattail was much taller at Cargill.

DISCUSSION

Primrose Willow Competition. Although primrose willow competition can affect wetland tree growth, the tree growth is still substantial. Baldcypress, popash, red maple and water hickory trees were able to grow through and overtop the primrose willow. As the trees have overtopped the primrose willow, their expanding crowns have exerted an inhibitory effect on the prim114rose willow, as shown by reductions in primrose LAI. Thus chemical, mechanical and manual control measures, which are often expensive, may not be necessary in establishing forested wetlands on reclaimed phosphate mined lands. The data and our observations indicate that if trees are planted at a sufficient density they will eventually develop a canopy cover that will shade out the primrose willow, thus reducing primrose willow cover as required by FDEP regulations. How long will it take? After only five years, popash at the canopy site at a very close spacing of 1.2 m had nearly eliminated the primrose willow (Figure 9). Of course, slower developing trees or more widely spaced trees will take longer to achieve canopy closure.

Cattail Competition. Removal of cattail enhanced the growth of baldcypress, pondcypress and popash at the Mobil site. However, baldcypress and pondcypress were able to eventually overtop the cattail at the Mobil site without cattail control efforts. In contrast, popash's very slow growth in the presence of cattail indicates that popash may not compete as well with cattail as baldcypress does, and popash may not displace cattail without control efforts or it may take much longer. We have not yet attempted to measure the effects of baldcypress or pondcypress on cattail at our study sites. However, we have been shown photographs by William Hawkins (formerly with Mobil, now with FDEP) of an older depressional wetland, and we have visited the site, at the Mobil Fort Meade Mine in which baldcypress has been observed to displace cattail.

Site Factors. Our general observation has been that wetland trees grow slower in standing water than in better-drained conditions. This is illustrated in Figure 17, which shows tree heights of baldcypress and popash in the third growing season in the weeded plots in relation to average yearly water depth at several sites. This finding suggests that the potential value of small hummocks to improve wetland tree growth (possibly through effects on root zone aeration). Baldcypress is more tolerant of flooded conditions than popash. For example, popash grew faster than baldcypress and competed better with primrose willow at the relatively drier canopy (T1) site, but baldcypress grew faster than popash and competed better with cattail at the wetter Mobil cattail site.

How do tree growth rates in wetlands on reclaimed phosphate mined lands compare with

growth rates on unmined lands? Baldcypress growth at the P1 site was rapid. Even with primrose willow competition, tree height was greater on this reclaimed mine site than was height of comparably aged trees on unmined mitigation wetlands as determined by Denton (1990). DBH was also greater, but crown diameter was slightly less in the presence of primrose willow on this reclaimed mined site than on the unmined wetlands. Baldcypress height, DBH, and crown diameter were all much greater on the weeded P1 plots than on the several mitigation wetlands. Baldcypress height growth was slower at the P2 site than at the P1 site, but it was still comparable to the better mitigation wetlands on unmined land (compare Denton 1990).

Herbicide Effects. We found that cattail removal by cutting enhanced popash growth, but removal of primrose willow by herbicide spraying (triclopyr or triclopyr plus glysophate) inhibited popash growth. This finding suggests that the herbicide(s) had a detrimental effect on popash even though we attempted to protect the trees from the herbicide spray by covering the trees with plastic bags and by carefully directing the spray on the weeds and not the trees. However, there may have been some root absorption of herbicide that fell on the saturated soil or standing water. In contrast to popash (and red maple), baldcypress was not harmed by the herbicide at the P2 site. Our experience, and that of others, indicates that baldcypress has some tolerance to triclopyr herbicide and triclopyr could be used to selectively control primrose willow and other broadleaf weeds in a baldcypress stand. However, although herbicides are valuable tools for managing vegetation, possible detrimental effects of herbicidal treatment on some desirable trees, and perhaps various understory species as well, is another argument for being patient and allowing the trees to grow and shade out primrose willow.

Elderberry Effects. Elderberry appears to have some potential as a forested wetland "nurse crop." In all the experiments with primrose willow, baldcypress grew better when the primrose was removed, but baldcypress grew as well in the presence of elderberry as in the weeded treatment. Both popash and baldcypress grew better in association with elderberry than with primrose willow plus elderberry. It is hypothesized that elderberry will occupy space that otherwise might be inhabited by primrose willow, and the elderberry should provide canopy cover and habitat for shade requiring understory plants, but it should in turn be shaded out by the developing canopy of the taller wetland trees. At the Rocky Branch elderberry study site, primrose willow (2.6 m) was a little taller than the elderberry (2.2 m). It is unclear if this height difference was a factor in the observed effects on tree growth or if it may be a factor in the competition between primrose willow and elderberry.

Early Successional vs. "Nuisance" Species. Perhaps, rather than look at primrose willow and cattail as nuisance species, we should view them as early successional species that may have value in ecosystem development, such as capturing or tying-up nutrients for the system, accumulating organic matter, and in hummock formation. An interesting observation with cattail was that continual removal resulted in a lower ground elevation, and a 6 cm greater apparent water depth, due to the lack of buildup of cattail debris (or perhaps an actual reduction in organic matter) in the weeded plots compared to the unweeded cattail plots. The presence of primrose willow leads to earlier canopy closure, which may be beneficial for

shade requiring understory development. We observed an abundance of ferns and begonias beneath the shade of the primrose willow at the P1 site, but in the plots where primrose willow was removed, the result was a ground cover of sun-loving weedy species. Elderberry may also have an important role in forested wetland succession, such as early canopy closure, but it appears to be less competitive to tree growth than primrose willow and may thus have greater potential as a useful forested wetland nurse crop. Carolina willow (*Salix caroliniana*) has also been proposed as a wetland forest nurse crop (Miller et al. 1988), but its taller stature may require a longer time for other wetland tree species to overtop and shade it out compared to elderberry.

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A COMPARISON OF BAY SWAMP RECLAMATION TECHNIQUES IN FLORIDA PHOSPHATE MINES

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ABSTRACT

Bay swamps are found throughout Florida. However, agencies are reluctant to approve impacts to these wetlands until wetland reclamation and creation techniques have substantiated that these forested wetland systems can be re-created. Agencies concerns seem to be centered around the time lag between impact and successful reclamation of a functioning forested bay swamp system including a mature vegetative structure, adequate hydrology and wildlife habitat. IMC-Agrico has completed construction of several bay swamp reclamation projects on its central Florida reclaimed lands. These projects have utilized a variety of techniques, including the planting of bay trees and other hardwoods in designed wetlands constructed on sand tailings or overburden cap, or planting with a mulched muck layer on sand tailings or overburden cap. A third technique includes bay tree stump and tree transfer with supplemental bay tree plantings in a designed wetland constructed with a mulched muck layer on sand tailings. Site preparation and material utilized in these projects have been observed to be as important as manipulation of hydrology during the establishment phase and proper prediction of the post reclamation hydrology. Preliminary monitoring results suggest that these systems can be reclaimed. Continued research will suggest the efficacy of the techniques utilized, and perhaps suggest additional techniques to be used in the future.

INTRODUCTION

Bay swamps are found throughout Florida. The acreage tabulation of bay swamps in Florida, however, depends upon the bay swamp definition utilized, and further upon the method utilized to determine aerial extent. Various definitions for bay swamps exist depending on the reasons for defining such a system, (e.g., for regulatory classification or to define mitigation success). One published definition of a bay swamp is:

"a hydric community along first order streams where acidic detritus aggrades and is not scoured. A headwater forest characterized by presence of evergreen hardwoods [sweet bay *(Magnolia virginiana)*, swamp bay (*Persea palustri)*, and loblolly bay *(Gordonia lasianthus*)], which grow intermixed with deciduous hardwood taxa" (Clewell 1990).

Although the above is generally accepted for areas called bayheads, a more appropriate definition may also include: "forests where evergreen hardwoods predominate and *Nyssa biflora* (black gum) is the only important deciduous hardwood" (Clewell 1990). A more general definition has been provided by Monk (1965), who defined bayheads as forests that are dominated by broad-leaved evergreen trees growing on soils high in organic matter and

subjugated to seasonal flooding.

The Environmental Protection Commission of Hillsborough County (EPCHC) has defined bay swamp mitigation success, and thereby the bay swamp vegetative cover, as any hardwood forested swamp with at least 51% bay trees, including *Magnolia virginiana*, *Persea palustris*, *Gordonia lasianthus* and *Nyssa sylvatica* (EPCHC Correspondence, 12/8/98). Other definitions include *Persea borbonia* (red bay), while others eliminate *Nyssa sylvatica* and *Persea borbonia* (Clewell 1990, Monk 1965). The bay swamps, as defined above, occurring on IMC-Agrico property in five southwest central Florida counties (Desoto, Hardee, Hillsborough, Manatee, and Polk) consist predominantly of:

1) connected headwater swamps
2) interior portions of some hardwood swamps associated with riverine stream floodplains, and
3) isolated bay swamps that have become connected to waters of the State via agricultural ditching practices.

According to Closing the Gaps in Florida's Wildlife Habitat System ("GAP report", Cox et al. 1994), which utilized remote sensing techniques to categorize vegetative communities, the state of Florida has approximately 53,400 hectares (131,900 acres) of bay swamps. Of this total, Polk County has approximately 2,000 hectares (5,434 acres) of bay swamps. The "GAP report" does not list an acreage value for Hillsborough, Hardee, Manatee and Desoto Counties, presumably since these counties have a bay swamp component of less than the 100 hectares (247 acres) per km^2 that the authors of the "GAP report" used as a cutoff. The authors of this paper, however, did assume that if the raw data for all four counties were added together, the total area of bay swamp would probably exceed 1-square kilometer (100 hectares or 247 acres) in area. The assumption that some bay swamps are found in these areas is supported by the fact that bay swamps are encountered on IMC-Agrico property in the five southwest central Florida counties listed above. In fact, the acreage of bay swamps that occur on IMC-Agrico property belies the acreage predicted by the "GAP report". This may be partly due to the fact that many of the IMC-Agrico bay swamps are less than five acres in size and may be difficult to differentiate due to the level of precision inherent with remote sensing, as well as the lack of a detailed vegetative community census across the state.

Agencies are reluctant to approve impacts to any wetland type, especially forested wetland systems, until restoration techniques have confirmed that the wetland type to be impacted can be re-created. For bay swamp wetlands, agency concerns seem to be centered on the time lag (i.e., whether it can be re-created, the degree, and length of time required for creation) between impact and successful reclamation of a functioning forested bay swamp system. Typically, a functioning or viable wetland system contains a mature vegetative structure, adequate hydrology and wildlife habitat. Mature vegetative structure, as defined by most mitigation/reclamation permit criteria from the regulatory agencies (Florida Department of Environmental Protection - FDEP and EPCHC), consists of a canopy of trees greater than 10 centimeters (4 inches) dbh and/or greater than 4 to 5 meters (12 to 16 feet) in height that is reproducing successfully. For bay swamps, adequate hydrology can be defined as that hydrology which is necessary to sustain wetland community characteristics, while wildlife

habitat is defined as that which supports and sustains native wetland dependent fauna.

Chapter 62-340, Florida Administrative Code, Delineation of the Landward Extent of Wetlands and Surface Waters, provides definitions of several wetland related characteristics, including canopy, sub-canopy, and groundcover. Although these characteristics are utilized for wetland delineation within the state of Florida, these same characteristics, when applied to reclaimed wetlands, due to their relatively young ages, often utilize different definitions of the same terms. Trees planted in reclaimed wetlands range from bare root to 38 liter (10 gallon) containerized stock depending on permit criteria. Typical plantings are 3.8 liter (1 gallon) containerized stock which are 0.5 to 1 meter (2-3') tall and less than 1 centimeter (0.5") dbh. For reclaimed wetlands, canopy is generally defined as any trees greater than 2.5 centimeters (1 inch) dbh and over 2 meters (6 feet) in height. Subcanopy is generally defined as trees greater than a 0.3 meters (1 foot) in height and less than the canopy criteria. The subcanopy layer is often called the shrub layer. All tree species with individuals less than 0.3 meters (1 foot) in height are typically assigned to the groundcover or recruit category.

Several hardwood forested wetland reclamation projects, containing bay swamp components, have been constructed during the past 20 years on IMC-Agrico's reclaimed mine lands in the central Florida phosphate district. These bay swamp reclamation projects have utilized a variety of techniques, segregated generally by reclaimed substrate and planting methods. One technique utilized the planting of bay trees and other hardwoods on a sand tailings backfill topped with overburden. This technique was utilized at the Big Four Mine - Floodplain Demonstration Bay Swamp (AMAX-BF-1) and a portion of the Big Four Mine – South Prong of the Alafia River Bay Swamp (South Prong Sand Tails). A second technique has been to plant bay trees and other hardwoods on a mulched muck layer overlying sand tailings or overburden cap. This technique has been used at both Fort Green Mine - Hardee Lakes Bay Swamp (Hardee Lakes) and a portion of the Big Four Mine - South Prong Bay Swamp (South Prong Muck). A third technique involves the direct transfer of bay trees and stumps--along with supplemental bay tree plantings–on a mulched muck layer, overlying sand tailings. This technique has been utilized at the Four Corners Mine – Alderman Creek Bay Swamp (ACBS), the most recently completed reclamation project of the four sites.

IMC-Agrico's experience on these projects has shown that site preparation, material utilization and scheduling are as important as the prediction and manipulation of post-creation hydrology. Preliminary monitoring results of these four bay swamp reclamation projects support the belief that viable bay swamp wetlands can be reclaimed. It is the intention of this paper to present the different techniques utilized in each of the four case studies and to draw some preliminary conclusions. Due to the various ages of the projects, (ACBS - approximately four months old at the time of report preparation; South Prong Sand Tails and Muck - approximately two years old; Hardee Lakes - approximately eight years old, and AMAX- BF-1 - 20 years old), statistical comparisons between the case studies have not been made. Any apparent trends noticed between the various ages of bay swamps have been noted and comparisons suggested. Continued research will suggest the efficacy of the techniques utilized, and perhaps recommend additional techniques to be used in the future. The following summarizes pertinent introductory information for each of the four bay swamp

reclamation projects.

Hardee Lakes

The Fort Green Mine - Hardee Lakes Restoration Project covers a tract of land in Sections 1, 2, 11, and 12, T33S, R23E, Hardee County. The entire tract covers an area 259 hectares (640 acres) in size and includes two large lakes, forested upland greenway corridors, pasture and wetland hardwood forest. Under conditions of the regulatory approvals, IMC-Agrico was required to create wetland forest mitigation and reclamation for dredge and fill permit-related conditions. The bay swamp that is the subject of this report is an area 0.6 hectare (1.5 acre) in size and is located in the center portion of the wetland hardwood forest mitigation area. Mining of the parcel was conducted from the middle of 1988 through December 1989. Reclamation activities within the entire project commenced in May 1989, and were completed through revegetation in August 1991. Seepage through a sand tailings blanket, in addition to direct input from precipitation, provides the dominant water source supporting the hardwood forested wetland. Groundwater and surface water flow from the hardwood forested wetland are ultimately integrated into the Payne Creek watershed, a tributary of the Peace River.

In March 1990, after achieving the required final graded elevations, muck was transported to the site from another IMC-Agrico wetland permitted for mining disturbance. The "borrowed" muck was applied to the graded areas at depths varying from 2.5 to 30 centimeters (1 to 12 inches). The purpose of the muck base was to provide a seed source and substrate for the newly constructed wetland. All earthwork within the project boundary was completed in early 1991. Since that time, several planting events have been completed in the 0.6-hectare (1.5-acre) bay swamp area. The original plantings were completed in August 1991, with supplemental plantings conducted in 1994 and 1995 to increase the number of species to that typically found in bay systems. Because the entire forested wetland was planted as a collective unit, specific numbers of planted trees for the bay swamp portion cannot be segregated from the total number of trees planted throughout the project.

Nuisance and exotic species maintenance was conducted regularly in the early stages of development, but has not been needed within the last few years. Following establishment of the tree and shrub strata very little nuisance and exotic species cover has been observed.

South Prong Sand and Muck Bay Swamp

The Big Four Mine - South Prong Bay Swamp is located in Section 35, T31S, R22E, Hillsborough County. Mining of the site was conducted in 1990. The area was back-filled with sand tailings and initial rough grading commenced in 1993. Bay swamp reclamation activities commenced in October 1996 with final earthmoving and grading, including the creation of a seepage slope area parallel to the northern edge of South Prong of the Alafia River. Seepage from the surrounding uplands, in addition to direct input from precipitation, provides the majority of water inflow for the bay swamp. Groundwater and surface water flow from the bay swamp are ultimately incorporated into the South Prong of the Alafia River.

The entire bay swamp project encompasses 4.0 hectares (10.0 acres). Of this, 2.2 hectares (5.5 acres) received a muck cap, while 1.8 hectares (4.5 acres) did not. Viable organic muck material, from a wetland permitted for mining activities, was harvested, hauled to the reclamation site, and spread over the 2.2 hectares (5.5 acres) at varying depths from 2.5 to 30 centimeters (1 to12-inches). Hummocks and furrows were created throughout the bay swamp to simulate the irregular bottom commonly encountered in natural forested wetlands. A total of 10,000 trees of varying sizes from eight different wetland bay and hardwood tree species was planted (approximately 2470-trees/hectare or 1000-trees/acre) throughout the site in November 1996.

A total of 3,000 trees, or an average of 741 trees/hectare (300 trees/acre) of *Magnolia virginiana* trees, was planted within the site. The site also received an average of 494 trees/hectare (200 trees/ acre) or 2,000 trees each of *Gordonia lasianthus* and *Persea palustris*, 247 trees/hectare (100 trees/acre) on average or 1,000 trees total of *Nyssa sylvatica*, an average of 370 trees/hectare (150 trees/acre) or 1,500 trees total of red maple *(Acer rubrum)*, dahoon holly (*Ilex cassine*), laurel oak (*Quercus laurifolia*) and water oak (*Quercus nigra)* were planted at a density of 500-total trees or an average of 124 trees/hectare (50 trees/acre).

AMAX-BF-1

The Big Four Mine - Floodplain Demonstration Bay Swamp (AMAX-BF-1) is located in Section 23, T31S, R22E, Hillsborough County. AMAX-BF-1 was created as Development of Regional Impact (DRI) approved floodplain wetland reclamation to demonstrate that mined floodplains could be reclaimed. Mining related activities were conducted from 1977 to 1978. Reclamation of the AMAX-BF-1 site was completed in 1979 by contouring overburden on lands utilized in the mining process, specifically the recharge ditch and berm along Boggy Branch, a tributary of the South Prong of the Alafia River. Contouring was conducted to create compatible elevations to allow the expansion of the Boggy Branch floodplain. The main hydrologic inputs are derived from precipitation and groundwater seepage, although the area is also subjected to backwater flooding during seasonal heavy rains.

The entire AMAX-BF-1 project consists of 12.6 hectares (31 acres) of mixed hardwood and bay swamp. A 2.4 hectare (6 acre) flag marsh, to be dominated by *Iris virginica* (blue flag) was ringed with *Taxodium distichum* and *Gordonia lasianthus*. Potted *Taxodium distichum* and *Gordonia lasianthus* saplings 45 centimeters (18 inches) in size were planted at densities equal to 988 trees/hectare (400 trees/acre). Herbaceous vegetation was planted at sufficient densities to provide adequate percent cover.

Alderman Creek Bay Swamp Demonstration Project

The Four Corners Mine – Alderman Creek Bay Swamp Demonstration Project (ACBS) is located in Section 33, T32S, R22E, Hillsborough County. The demonstration bay swamp is a 3.2-hectare (8.0-acre) forested wetland constructed on reclaimed phosphate mine lands. The ACBS area was back-filled with sand tailings and contoured to design elevations in 1997. A seepage slope area was created to parallel the west bank of Alderman Creek, a tributary to

the North Fork of the Little Manatee River. The main hydrologic inputs for this system include precipitation and groundwater seepage. This system is part of the Alderman Creek watershed.

Muck, trees, stumps and trunks were direct transferred from a donor bay swamp approved for mining. The muck, trees, stumps and trunks were transferred beginning December 21, 1998 and completed on January 14, 1999. Supplemental transfers of bay trees, primarily *Gordonia lasianthus*, from other donor sites were conducted during February and March 1999.

MATERIALS AND METHODS

A 10-meter (32.8 feet) wide belt transect of varying length was established at two of the sites (Hardee Lakes - 61 meters long (200 feet); AMAX BF-1 - 122 meters (400 feet) long. Four permanent belt transects totaling 325 meters in length (1065 feet) have been established within the South Prong Muck and Sand Bay Swamp. Each of the sand tailed only and muck portions of this bay swamp contain two permanent belt transects. A census of the entire ACBS bay swamp area was conducted in January and February 1999. All trees within the belt transect or wetland (ACBS) over 2.5 centimeter (1 inch) dbh were recorded along with their respective heights. All woody stems with less than 2.5 centimeter (1 inch) dbh (shrub layer) within the belt transect were also recorded. This information allowed the number of stems per hectare (acre) for trees and shrubs to be calculated.

Trees were subjectively separated into several size categories by height and dbh measurements in order to distinguish between original plantings and volunteered or recruited individuals. Trees within the 7.5 to 9+ meter (25 to 30'+) tall and 7.5+ centimeter (3"+) dbh range were assigned to the original planting survival/mature canopy category. Trees within the 6 to 7.5 meter (20 to 25') tall and 5 to 7.5 centimeter (2 to 3") dbh range were assigned to the older recruits or original planting survival/sub-mature canopy category. Trees within the 4.5 to 6 meter (15 to 20') tall and 3.5 to 5 centimeter (1.5 to 2") dbh range were assigned to the second period of recruits/tall subcanopy category. Trees within the 2.5 to 4.5 meter (8 to 15') tall and 2.5 to 5 centimeter (1 to 2") dbh were assigned to recent recruits/short subcanopy category, while shrub layer tree species were assigned to the most recent recruits category.

Observations of fish and wildlife utilization were documented based on visual observation of individuals, or detection of their vocalizations or other sign.

RESULTS

Hardee Lakes

The Hardee Lakes monitoring results indicate that there are 7064 shrubs/hectare (2860 shrubs/acre) within the bay swamp portion of the site. The dominant species found within the

shrub layer are *Acer rubrum* with 2536 shrubs/hectare (1027 shrubs/acre) or 36% of the total number of shrubs and *Myrica cerifera* with 2289 shrubs/hectare (927 shrubs/acre) or 32% of the total number of shrubs. The subdominant species found in the shrub layer is *Magnolia virginiana* with 1696 shrubs/hectare (687 shrubs/acre) or 24% of the total number of shrubs (Table 1). There are 1984 trees/hectare (807 trees/acre) within the bay swamp portion of the site. The dominant tree species within the bay swamp portion is *Magnolia virginiana* with 984 trees/hectare (400 trees/acre) or 50% of the total number of trees. The sub-dominant tree species is *Acer rubrum* with 721 trees/hectare (293 trees/acre) or 36% of the total (Table 2).

Table 1. Hardee Lakes Bay Swamp Shrub Density.

Shrub Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	2535.9	1026.7	35.9
Gordonia lasianthus	16.5	6.7	0.2
Ilex cassine	32.9	13.3	0.5
Liquidambar styraciflua	148.2	60.0	2.1
Magnolia virginiana	1696.1	686.7	24.0
Myrica cerifera	2288.9	926.7	32.4
Nyssa sylvatica	32.9	13.3	0.5
Persea palustris	131.7	53.3	1.9
Quercus laurifolia	65.9	26.7	0.9
Quercus nigra	16.5	6.7	0.2
Salix carolinana	82.3	33.3	1.2
Sambucus canadensis	16.5	6.7	0.2
TOTAL	7064.3	2860.1	100.0

Table 2. Hardee Lakes Bay Swamp Tree Density.

Tree Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	721.4	293.3	36.4
Liquidambar styraciflua	49.2	20.1	2.5
Magnolia virginiana	983.5	399.9	49.6
Nyssa sylvatica	65.6	26.7	3.3
Persea palustris	82.0	33.3	4.1
Quercus nigra	82.0	33.3	4.1
TOTAL	1983.7	806.6	100.0

The planting and recruit density results (Table 3) suggest that a stratified canopy representing a mature forest has established within this wetland over the past 8 years. Reproduction and/or volunteer recruitment appear to be prevalent within the Hardee Lakes bay swamp. The high density of woody canopy species within the shrub layer suggests that successful reproduction is occurring. The prevalence of recent plantings/recruits larger than those individuals in the shrub layer suggests that there has been a combination of high survival of the 1994 and 1995

planted individuals and high recruitment of saplings from original plantings and/or recruitment from adjacent preservation area individuals.

Table 3. Hardee Lakes Bay Swamp Planting/Recruit Density (# per hectare/# per acre).

Scientific Name	Original survival 25'+	Original/ 1° recruit 20-25'	2° plant/2° recruit 15-20'	2° plant/ 3°recruit 8-15'	Shrub <8'
Acer rubrum	49.2/20.0	114.8/46.7	229.5/93.3	327.9/133.3	2535.9/ 1026.7
Gordonia lasianthus	--	--	--	--	16.5/6.7
Ilex cassine	--	--	--	--	32.9/13.3
Liquidambar styraciflua	16.4/6.7	16.4/6.7	--	16.4/6.7	148.2/ 60.0
Magnolia virginiana	229.5/ 93.3	147.5/ 60.0	131.1/ 53.3	475.4/ 193.3	1696.1/ 686.7
Nyssa sylvatica	32.8/13.3	16.4/6.7	16.4/6.7	--	32.9/13.3
Persea palustris	--	32.8/13.3	32.8/13.3	16.4/6.7	131.7/53.3
Quercus nigra	16.4/6.7	--	32.8/13.3	32.8/13.3	16.5/6.7
TOTAL (# per ha/# per ac)	344.3/ 140.0	327.9/ 133.4	442.6/ 179.9	868.9/ 353.3	4610.7/ 1866.7

Results of wildlife observations from 1995 to 1998 indicate a cumulative total of 24 species are utilizing the Hardee Lakes project (Table 4). Woodstork (*Mycteria americana*), little blue heron (*Egretta caerulea*), and white ibis (*Eudocimus albus*), all listed by the Florida Game and Fresh Water Fish Commission (FGFWFC) as protected species (1996), were observed on-site.

Table 4. Wildlife Observations at Hardee Lakes 1995-1998

SPECIES	COMMON NAME	SPECIES	COMMON NAME
Avian		**Avian**	
Agelaius phoeniceus	Red-winged blackbird	*Hirundo rustica*	Barn swallow
Anhinga anhinga	Anhinga	*Iridoprocne bicolor*	Tree swallow
Ardea herodias	Great blue heron	*Mycteria americana*	Wood stork
Casmerodias albus	Great egret	*Pandion haliaetus*	Osprey
Cathartes aura	Turkey vulture	*Quiscalus major*	Boat-tailed grackle
Ceryle alcyon	Belted Kingfisher	*Quiscalus quiscula*	Common grackle
Colaptes auratus	Common flicker	*Sayornis phoebe*	Eastern phoebe
Egretta caerulea	Little blue heron	*Thryothorus ludovicianus*	Carolina wren
Eudocimus albus	White ibis	*Vireo griseus*	White-eyed vireo

Table 4. (continued) Wildlife Observations at Hardee Lakes 1995-1998

Falco sparvarius	American kestrel		
Amphibian		**Fish**	
Anolis carloinensis	Green anole	*Gambusia affinis*	Mosquito fish
Hyla cinerea	Green tree frog	**Mammal**	
Hyla squirella	Squirrel treefrog	*Procyon lotor*	Raccoon

South Prong Sand

The South Prong Sand Tailings Bay Swamp monitoring results indicate that there are approximately 1449 trees/hectare (587 trees/acre) existing within the site (Table 5). *Magnolia virginiana* dominates the sand tailed only portion of the South Prong Bay Swamp with 863 trees/hectare (349 trees/acre) or 60% of the total trees within the sand tailed only area. *Persea palustris* is the sub-dominant tree in the sand tailed only portion with 166 trees/hectare (67 trees/acre) or 12% of the total trees. Data on shrub layer composition is not applicable to this site; due to the relatively young age of the planted trees, the vegetation has not yet separated into different canopy heights. It should be noted that the definition of a tree for this site is "a woody species exceeding the herbaceous stratum in height", which is different from the standard definition of a tree.

Table 5. South Prong Sand Tailed Only Bay Swamp Tree Density.

Tree Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	110.9	44.9	7.7
Gordonia lasianthus	31.6	12.8	2.2
Ilex cassine	142.5	57.7	9.8
Magnolia virginiana	862.8	349.3	59.5
Nyssa sylvatica	110.9	44.9	7.7
Persea palustris	166.2	67.3	11.5
Quercus laurifolia	7.9	3.2	0.5
Quercus nigra	15.8	6.4	1.1
TOTAL	1448.6	586.5	100.0

South Prong Muck

The South Prong Mucked Bay Swamp monitoring results indicate that there are approximately 761 trees/hectare (308 trees/acre) existing within the site (Table 6). *Magnolia virginiana* dominates the mucked portion of the South Prong Bay Swamp with 408 trees/hectare (165 trees/acre) or 54% of the total trees. *Nyssa sylvatica* is the sub-dominant tree in the mucked portion with 131 trees/hectare (53 trees/acre) or 17% of the total trees. Data on shrub layer composition is not applicable to this site; due to the relatively young age of the planted trees, the vegetation has not yet separated into different canopy heights. It should be noted that the definition of a tree for this site is "a woody species exceeding the herbaceous stratum in height", which is different from the standard definition of a tree.

Results of wildlife observations documented from 1997 to 1998 indicate a cumulative total of eight (8) species are utilizing the South Prong Sand and Muck wetlands (Table 7). This

total includes four (4) avian species, three (3) amphibian species and one (1) fish species.

Table 6. South Prong Mucked Bay Swamp Tree Density.

Tree Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	85.7	34.7	11.3
Gordonia lasianthus	65.5	26.5	8.6
Magnolia virginiana	408.3	165.3	53.6
Nyssa sylvatica	131.2	53.1	17.2
Persea palustris	70.6	28.6	9.3
TOTAL	761.3	308.2	100.0

Table 7. Wildlife Observations at South Prong Sand and Muck 1997-1998

SPECIES	COMMON NAME	SPECIES	COMMON NAME
Avian		**Amphibian**	
Agelaius phoeniceus	Red-winged blackbird	*Bufo terrestris*	Southern toad
Anhinga anhinga	Anhinga	*Hyla cinerea*	Green tree frog
Buteo lineatus	Red shouldered hawk	*Rana grylio*	Pig frog
Casmerodias albus	Great egret	**Fish**	
		Gambusia affinis	Mosquito fish

AMAX-BF-1

The AMAX-BF-1 monitoring results indicate that there are 9394 shrubs/hectare (3803 shrubs/acre) found within the bay swamp portion of the site. The dominant species in the shrub layer is *Gordonia lasianthus* with 4701 shrubs/hectare (1903 shrubs/acre) or 50% of the total shrubs. The sub-dominant species in the shrub layer are *Acer rubrum* with 2190 shrubs/hectare (887 shrubs/acre) or 23% of the shrub total and *Myrica cerifera* with 1960 shrubs/hectare (793 shrubs/acre) or 21% of the total (Table 8). There are approximately 976 trees/hectare (397 trees/acres) existing within the bay swamp portion of the site. *Gordonia lasianthus* dominates the bay swamp with 689 trees/hectare (280 trees/acre) or 71% of the total trees. The sub-dominant tree species is *Acer rubrum* with 156 trees/hectare (63 trees/acre) or 16% of the total trees (Table 9).

Table 8. AMAX-BF-1 Bay Swamp Shrub Density.

Shrub Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	2190.1	886.7	23.3
Gordonia lasianthus	4701.2	1903.3	50.0
Ilex cassine	16.5	6.7	0.2
Itea virginiana	271.7	110.0	2.8
Liquidambar styraciflua	74.1	30.0	0.8
Myrica cerifera	1959.5	793.3	20.9
Pinus elliottii	90.6	36.7	1.0
Quercus nigra	8.2	3.3	0.1
Taxodium distichum	82.3	33.3	0.9
TOTAL	9394.2	3803.3	100.0

The planting and recruit density monitoring results indicate that a stratified canopy representing a mature forest has established within this wetland over the past 20 years (Table 10). Reproduction and/or volunteer recruitment appear to be prevalent within the AMAX BF-1 bay swamp. The high density of woody canopy species within the various subjective height and dbh categories, including the shrub layer, suggests that successful reproduction is occurring.

Table 9. AMAX-BF-1 Bay Swamp Tree Density.

Tree Species Scientific Name	#/hectare	#/acre	Percent of total
Acer rubrum	155.9	63.3	16.0
Gordonia lasianthus	689.1	280.0	70.6
Liquidambar styraciflua	41.0	16.6	4.2
Magnolia virginiana	8.2	3.3	0.8
Pinus elliottii	24.6	10.0	2.5
Taxodium distichum	57.4	23.3	5.9
TOTAL	976.2	396.5	100.0

Table 10. AMAX-BF-1 Bay Swamp wetland tree planting/recruit density (# per hectare/# per acre).

Scientific Name	Original survival 25'+	Original/1° recruit 20-25'	2° recruit 15-20'	3° recruit 8-15'	Shrub <8'
Acer rubrum	8.2/3.3	--	8.2/3.3	139.5/56.7	2190.1/886.7
Gordonia lasianthus	213.3/86.7	106.6/43.3	188.7/76.7	180.5/73.3	4701.2/1903.3
Ilex cassine	--	--	--	--	16.5/6.7
Liquidambar styraciflua	8.2/3.3	8.2/3.3	--	24.6/10.0	74.1/30.0
Magnolia virginiana	--	8.2/3.3	--	--	--
Pinus elliottii	24.6/10.0	--	--	--	90.6/36.7
Quercus nigra	--	--	--	--	8.2/3.3
Taxodium distichum	8.2/3.3	--	16.4/6.7	32.8/13.3	82.3/33.3
TOTAL (# per ha/# per ac)	262.5/ 106.6	123.0/ 49.9	213.3/ 86.7	377.4/ 153.3	7163.0/ 2900.0

Results of opportunistic wildlife sightings during the Spring 1999 wetland vegetation monitoring indicate that at least four (4) mammalian and one (1) avian species utilize the site (Table 11).

Table 11. Wildlife Observations at AMAX-BF-1 1999.

SPECIES	COMMON NAME
Mammal	
Diasypus novemcinctus	Armadillo
Odocoileus virginianus	White-tailed deer
Procyon lotor	Raccoon
Sus scrofa x Sus vitatus	Feral hog
Avian	
Dryocopus pileatus	Pileated woodpecker

ACBS

The ACBS results presented in this summary include data collected for trees and stumps transferred before the end of March 1999. Only those trees and stumps larger than 2.5 centimeter (1 inch) dbh have been included. A total of 970 trees (n=539) and stumps (n=431) were direct transferred from the donor wetland to the demonstration wetland, for approximately 300 trees and stumps transferred per hectare (121 trees and stumps/acre) of demonstration swamp (Table 12). The majority of trees and stumps transferred were *Magnolia virginiana*. Preliminary results suggest that 70% of the trees and stumps transferred were surviving two to three months after the transfer (Table 13). There are no apparent trends, which is to be expected at this early stage, between stump and tree survival. As evident in Table 14, a stratified canopy and subcanopy were transferred.

Table 12. ACBS Bay Swamp Tree and Stump Density.

Species Scientific Name	# trees	# stumps	Total	#/hectare	#/acre
Magnolia virginiana	410	399	809	249.7	101.1
Gordonia lasianthus	42	6	48	14.8	6.0
Nyssa sylvatica	23	13	36	11.1	4.5
Persea palustris	28	4	32	9.9	4.0
Persea borbonia	7	0	7	2.2	0.9
Acer rubrum	4	2	6	2.0	0.8
Ilex cassine	24	5	29	8.9	3.6
Quercus laurifolia	0	2	2	0.7	0.3
Ulmus floridana	1	0	1	0.2	0.1
Total	539	431	970	299.5	121.3

Table 13. ACBS Bay Swamp Tree and Stump Species Percent Survival.

Species Common Name	% tree grow	% stump grow	% tree none	% stump none	% tree brown	% stump brown	# grow per ha/ac
Magnolia virginiana	71.0	71.4	23.2	28.1	5.9	0.5	177.8/72.0
Gordonia lasianthus	71.4	83.3	26.2	16.7	2.4	0.0	10.9/4.4
Nyssa sylvatica	39.1	61.5	60.9	38.5	0.0	0.0	5.2/2.1
Persea palustris	67.9	75.0	7.1	25.0	25.0	0.0	6.9/2.8
Persea borbonia	71.4	0.0	14.3	0.0	14.3	0.0	1.5/0.6
Acer rubrum	50.0	100.0	50.0	0.0	0.0	0.0	1.2/0.5
Ilex cassine	62.5	100.0	37.5	0.0	0.0	0.0	8.9/3.6
Quercus laurifolia	0.0	50.0	0.0	50.0	0.0	0.0	0.2/0.1
Ulmus floridana	0.0	0.0	100.0	0.0	0.0	0.0	0.0/0.0
TOTAL	68.9	71.7	25.0	27.8	6.1	0.5	212.6/86.1

These results should not be considered definitive, as summer stresses may change the percent survival either up or down. *Nyssa sylvatica* individuals were just beginning to leaf out from winter dormancy when the monitoring occurred, and growing season results may differ. It should be noted that root sprout incidence may occur even though the tree or stump has no growth associated with it during the monitoring event. Numerous root sprouts were documented and were included in these results when associated with a stump or tree. Numerous root sprout or seed germination individuals have also been observed at the demonstration swamp, but are not included in this report. In addition numerous flowers and buds were observed for *Magnolia virginiana*, *Gordonia lasianthus* and *Ilex cassine* individuals. Future monitoring events will document flowering and seed production, while reproduction and seed germination success will be studied.

Table 14. ACBS Strata Transfer Survival Density (# per hectare/# per acre).

Scientific Name	Mature canopy 25'+	Sub-mature canopy 20-25'	Tall sub-canopy 15-20'	Short sub-canopy 8-15'
Gordonia lasianthus	0.9/0.3	0.4/0.2	3.7/1.5	5.9/2.4
Ilex cassine	2.2/0.8	0.8/0.4	2.7/1.1	3.2/1.3
Magnolia virginiana	69.9/28.2	22.2/9.0	30.9/12.6	54.9/22.2
Nyssa sylvatica	3.2/1.4	0.3/0.1	0.3/0.1	1.4/0.5
Persea borbonia	--	--	--	1.9/0.8
Persea palustris	1.8/0.6	0.8/0.4	1.2/0.5	3.0/1.1
TOTAL	78.0/31.3	24.5/10.1	38.8/15.8	70.3/28.3

In the six month period of documenting wildlife observations at the ACBS, a total of 30 avian species, two (2) amphibian species, one (1) fish species, and two (2) mammal species were observed utilizing the site (Table 15). Five of the observed species, snowy egret *(Egretta caerulea, Egretta thula)*, *Mycteria americana*, Florida sandhill crane (*Grus canadensis pratensis*), and roseate spoonbill (*Ajaia ajaja*), are listed by the FGFWFC as protected species (1996). In April 1999 a *Grus canadensis pratensis* nest with two eggs was found within the wetland. The nest was actively maintained and protected by two adult cranes for a duration of one (1) week. During a period of lowering water levels the nest was found abandoned and the two (2) eggs apparently predated by raccoon (*Procyon lotor*) individuals.

Table 15. Wildlife Observations at ACBS, December 1998-May 1999

SPECIES	COMMON NAME	SPECIES	COMMON NAME
Avian		**Avian**	
Agelaius phoeniceus	Red-winged blackbird	*Elanoides forficatus*	Swallow-tail kite
Ajaia ajaja	Roseate spoonbill	*Eriolia sp.*	Sandpiper
Anas fulvigula	Mottled duck	*Gallinago gallinago*	Common snipe
Ardea herodias	Great blue heron	*Grus canadensis pratensis*	Florida sandhill crane
Bubulcus ibis	Cattle egret	*Himantopus mexicanus*	Black-necked stilt
Buteo lineatus	Red shouldered hawk	*Larus atricilla*	Laughing gull
Casmerodias albus	Great egret	*Melanerpes carolinus*	Red-bellied woodpecker
Ceryle alcyon	Belted kingfisher	*Mycteria americana*	Wood stork
Charadrius semipalmatus	Semi-palmated plover	*Pandion haliaetus*	Osprey
Charadrius vociferous	Killdeer	*Parula americana*	Northern parula
Coragyps atratus	Black vulture	*Pelecanus erythrorhynchos*	American white pelican
Corvus brachyrhynchos	American crow	*Plegadis falcinellus*	Glossy ibis
Dumetella carolinensis	Gray catbird	*Quiscalus major*	Boat-tailed grackle
Egretta caerulea	Little blue heron	*Sturnella magna*	Eastern Meadowlark
Egretta thula	Snowy egret	*Zenaida macroura*	Mourning dove
Amphibian		**Mammal**	
Acris gryllus dorsalis	Florida cricket frog	*Odocoileus virginianus*	White-tailed deer
Rana grylio	Pig frog	*Procyon lotor*	Raccoon
Fish			
Gambusia affinis	Mosquito fish		

CONCLUSIONS

Preliminary results indicate that over a period of less than 20 years a bay swamp forested wetland (AMAX-BF-1) can be created in central Florida. Agency reclamation releases of the AMAX-BF-1 site from Hillsborough County and the FDEP, Bureau of Mine Reclamation were granted in 1982, three years after reclamation completion. Although reclamation success criteria have significantly changed since the early 1980s, it would appear that the forested wetland designed to be a floodplain bay swamp was indeed successful after three years. The Hardee Lakes bay swamp mitigation site has not been released as successful mitigation or land reclamation at the time of this document preparation. However, the results presented in this document suggest that the bay swamp portion of this mitigation area would have met success criteria after only 8 years following planting/reclamation.

The time lag concerns with mitigation/reclamation of forested wetland systems, particularly bay swamps, embrace numerous considerations. Among these are the concern whether a system can be replaced; if it can be replaced, to what degree will the system be replaced or improved; and the actual physical time period that the ecosystem does not receive the benefits of the wetland. While conclusions can be drawn as to the success of reclaimed bay swamp systems in relation to permit conditions, no claims are made as to the successful establishment of bay swamp ecosystems. The trends of AMAX-BF-1, illustrated by the attainment of permit conditions, and Hardee Lakes Bay Swamp, illustrated by its trending towards successful reclamation, support the idea that the time lag related concerns can be partially alleviated. The ACBS appears to have a head start on attaining viable wetland reclamation as governed by permit criteria. The South Prong Bay Swamp - Sand and Muck are in the early establishment phase (2 years) and trends can not be completely discerned at this time. If the AMAX-BF-1 and Hardee Lakes Bay Swamp sites are good litmus tests for reclamation, then the South Prong Bay Swamp - Sand and Tail sites appear to be heading in the right direction. The fish and wildlife species observed at the Hardee Lakes Bay Swamp, the South Prong Sand and Muck Bay Swamp and most notably ACBS, are indicative of highly functional wetlands, that provide a broad range of habitat and foraging opportunities for wildlife.

Future plans for these reclamation sites individually are as follows. The AMAX BF-1 Bay Swamp area will continue to self-organize and progress through community succession towards a climax forested wetland community. The Hardee Lakes Bay Swamp area will continue to self organize and future monitoring should show increased tree growth and reproductive success as it evolves into a mature forested wetland. The South Prong Sand and Muck Bay Swamps will receive supplemental tree plantings as needed and will continue to be monitored annually until attainment of success criteria. The ACBS will receive initial plantings of bay trees to attain permit required tree densities and will be monitored annually until attainment of success criteria. All sites will be periodically visited to document reproductive success and make opportunistic wildlife surveys.

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DEVELOPMENT OF A WETLAND CONSERVATION PLAN FOR MISSION/ARANSAS WATERSHED AREA: OVERVIEW OF THE PROCESS

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ABSTRACT

The establishment of working partnerships between local governments, agencies, and natural resource personnel was identified as an integral component in the development of wetland conservation plans. The primary purpose of this demonstration project was to develop a local wetland conservation plan for the wetlands within the Mission/Aransas Watershed using the tools contained in *Texas Coastal Wetlands: A Handbook for Local Governments*. The diversity of wetlands and land uses within this planning area are representative of rural areas along the Texas coast. Therefore, the completed Mission/Aransas Watershed Wetland Conservation Plan will serve as a model for other Texas coastal communities. Local governments are concerned with balancing community growth while protecting our remaining natural resources. The planning area of this project encompasses several municipalities in which their citizens depend primarily on agricultural, ranching, and small businesses to make a living. Planning opportunities that seek to incorporate economics and wetland conservation have been limited; however, management strategies designed to streamline evaluation procedures and identify ecologically-sensitive habitats are necessary in planning future community growth. The plan was developed by the creation of a planning team including local government, private citizen, business, and natural resource representatives. Identified wetland issues included: wetland restoration and enhancement, wetland mitigation banks, alternate uses of wastewater effluent, shoreline protection, water quality monitoring, environmental education, and ecotourism. Specific wetland sites were evaluated for each of these issues within the Mission/Aransas Watershed and plan alternatives were considered at several public workgroup meetings. A wetland plan was developed based upon the alternatives developed by the wetland scientist contractors and submitted for review and comments to each local government in March 1999. The final Mission/Aransas Watershed Wetland Conservation Plan was adopted in August 1999. Completion of this demonstration project demonstrated the important role of local governments in managing coastal wetlands on a long-term, area wide basis, provided a model for other coastal communities, and 3) will contribute to the "no net loss" goal for coastal wetlands.

INTRODUCTION

The concept of wetland preservation or restoration is generally directed in the interest of animals that depend on these systems for survival (e.g., waterfowl, fish, etc.). Wetland systems are critical to maintaining clean water resources, storing floodwaters, reducing

erosion, and providing recreational opportunities for residents and visitors. Loss of wetlands often increases costs to society to repair or replace these functions that wetlands provide. With increasing population size in coastal areas, the development of a wetland conservation plan is essential to plan for future economic growth while, at the same time, protecting the natural resources people equate with coastal communities.

The development of a wetland conservation plan in the Mission/Aransas Watershed highlighted several issues. First, the plan is designed to provide voluntary alternatives for local government and public use. Nonregulatory approaches are fairly new in the scope of land use planning; however, several programs are now available that provide technical and financial assistance. Development of this plan highlighted the opportunity these programs bring to coastal planning efforts. Second, the burden of responsible planning rests primarily with local government officials who often are involved in adhering to or resolving regulatory mandates when dealing with local issues. This plan enabled the local government to meet with natural resource agency personnel, academic staff, and nonprofit organization volunteers who are interested in assisting in community projects. Third, the goals, objectives, and alternatives developed in the plan are intended to serve as tools well into the twenty-first century as local government leadership changes and economic/ecologic planning is implemented. The advantage of voluntary planning over regulatory compliance in coastal development will increase as public awareness and understanding of wetland functions and values increase.

The overriding goal in developing a plan at a regional level with both local government and public input is to provide a planning tool for future development. Responsible planning results in well-designed, self-sustaining communities. Development of proactive relationships among local government officials and natural resource personnel and scientists provides a mechanism to identify and reconcile problems and promote sound decision-making. Long-term planning focused on economic growth and protection of coastal resources results in communities that preserve their coastal setting and increase their value for future generations. Finally, and most importantly, development of a wetland conservation plan demonstrates the value of asserting local control in managing coastal wetlands.

STUDY SITE

The Mission-Aransas estuary encompasses the northern region known as the Texas Coastal Bend. Geographically, the Coastal Bend has been variously defined; however, it generally refers to the curvature or bend in the central Texas coastline and includes the counties of Calhoun, Refugio, Aransas, San Patricio, Nueces, and the northeastern half of Kleberg. Politically, the Coastal Bend includes the twelve-county area encompassed by the Coastal Bend Council of Governments: Aransas, Bee, Brooks, Duval, Jim Wells, Kenedy, Kleberg, Live Oak, McMullen, Nueces, Refugio, and San Patricio.

The study area for the conservation plan for the Mission/Copano bay area encompasses three

coastal counties within the Coastal Bend: Aransas, Refugio, and San Patricio (Figure 1). The counties surround the Mission-Aransas estuary, which is comprised of Aransas, Copano, Mesquite, Mission, Port, and St. Charles bays. The largest bay is Aransas, followed by Copano and Mesquite bays. Two rivers flow into this bay complex, the Mission River emptying into Mission Bay, and the Aransas River emptying into Copano Bay.

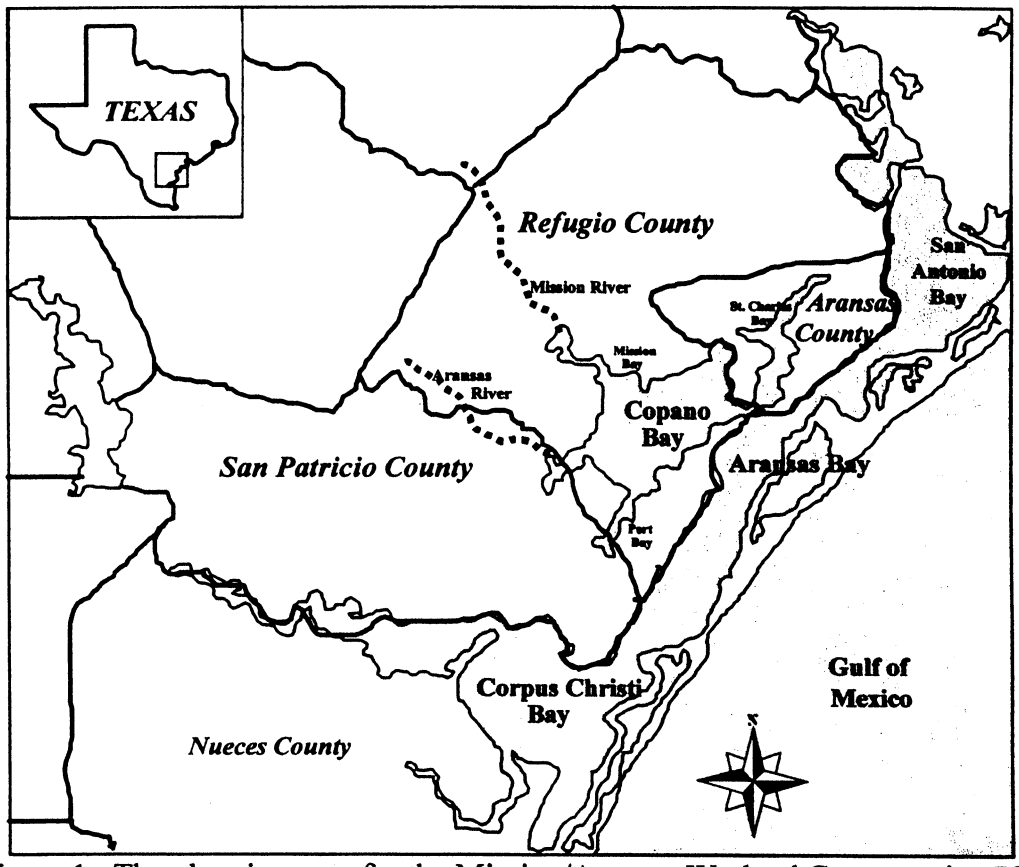


Figure 1. The planning area for the Mission/Aransas Wetland Conservation Plan, includes portions of Refugio, San Patricio, and Aransas counties.

Tidal exchange in the Aransas Estuary is due to astronomical tides, meteorological conditions, and density stratification (Armstrong, 1987). Due to shallow bay depths and a relatively small tidal prism, wind exerts a much greater influence on bay circulation than astronomical tides (Morton and McGowen, 1980). Substantial exchange of water between the Gulf of Mexico and the Aransas Estuary occurs from wind-generated tides (Ward et al., 1982).

Although all three counties within the Mission/Copano study area are adjacent to one another, land use patterns among the three are quite different. Land use is divided into three major categories: uplands, transitional lands, and wetlands. Uplands are further divided into developed lands, cultivated lands, grasslands, woodlands, shrublands, and bare lands. Among the three counties, San Patricio has the highest percentage of cultivated lands followed by Refugio and Aransas, respectively. Aransas County has the highest percentage of both bare lands and developed lands. Most bare lands in this area are delineated as bay shoreline

beaches, creating a significant tourism focus in the county and extensive urban development. Refugio has the most rural land use of the three counties, with the majority of the land identified as agriculture or ranching; limited urban development is centered around Refugio, Woodsboro, Bayside, Tivoli, and Austwell.

Wetland types and distribution also vary among the three counties. Broadly, three major wetland classifications are found within the study area: marine, estuarine, and palustrine. More specifically, four types of estuarine communities, three palustrine communities and one marine community, exist within the three counties. Both Aransas and San Patricio counties have a large portion of saltmarsh wetlands, although none are found within Refugio County. However, Refugio is the only county to have estuarine emergent and palustrine unconsolidated wetland. Refugio also has the highest amount of freshwater wetlands, which can be attributed to this county's containing both river systems (Aransas and Mission). The wide range of wetland types found within these counties creates diverse and important habitats for a wide variety of vegetation and fauna.

MATERIALS AND METHODS

The project was organized according to six tasks, associated steps (Table 1), and timelines (Table 2). The contractors were in charge of ensuring tasks were completed and also evaluated the effectiveness of the approach for future planning. Several methods were employed to generate interest and involvement, including newsletters, presentations, workshops, workgroup meetings, and field site visits. The involvement of agency personnel, local government leaders, and landowners assisted the contractors in developing draft goals and objectives. Alternatives were formulated within each objectives and potential funding opportunities identified. County judges and commissioners, as well as board members of the soil and water conservation districts, reviewed the plan. At the conclusion of the project, each county adopted the goals and objectives of the plan. In addition, both soil and water conservation districts endorsed the plan.

An evaluation of the process, task by task, was completed to assist future groups in developing region-specific wetland conservation plans. Recommendations were also made to ensure continued cooperation from the workgroup members.

Table 1. Overview of tasks associated with the plan development.

Tasks
1 - Create a work group to establish goals and objectives, identify existing programs, and develop conservation strategies
a. Identify and form a multi-disciplinary team.
b. Identify wetland-related issues and problems facing community.
c. Define goals and objectives.
d. Identify and evaluate all existing regulatory and nonregulatory wetland protection mechanisms.
e. Develop conservation strategies that incorporate pollution prevention and watershed

approaches.

2 - Inventory wetland resources, threats, and land use patterns
a. Identify land-use patterns and economic trends within planning area
b. Identify location and status of wetland information (i.e., status and trends, wetland quality, etc.)
c. Locate wetlands within planning area
d. Identify essential data needs to accomplish wetland plan
e. Identify appropriate buffer zones surrounding wetlands

3 - Evaluate wetlands within the Mission/Aransas Watershed planning area and develop plan alternatives for public review at workshops
a. Develop evaluation criteria to rate wetland sites
b. Use criteria to rate individual wetland sites for restoration, enhancement, creation, acquisition, or mitigation banking
c. Develop at least three plan alternatives for public consideration
d. Hold work group workshops for plan alternative review and comments
e. Incorporate comments into plan prior to public review

4 - Conduct public workshops, seminars, and field days to inform public about the plan's objectives and development, present plan alternatives, and solicit citizen input
a. Provide project overview at CCBNEP STAC meeting
b. Determine appropriate locations for plan overview and development overviews to increase public awareness of project
c. Hold Public Workshop 1(several locations) to inform public of plan objectives and approach
d. Collect and synthesize information for Workshop 2
e. Hold Public Workshop 2 (several locations) to solicit public comments on plan alternatives
f. Organize Field Days to visit wetlands within Mission/Aransas Watershed planning area

5 - Select plan alternatives and develop action items
a. Identify and evaluate wetland conservation tools applicable to the plan goals and objectives
b. Consult with city, state, and federal agencies for potential conservation programs to implement plan alternative
c. Draft list of recommended action items with description of how each could be implemented with potential funding sources

6 - Draft and Finalize Plan.
a. Draft plan based on alternative selected by local government
b. Submit plan to Texas General Land Office for content and layout approval
c. Submit plan to the local governing body for review and approval, and secure its adoption.
d. Complete revisions to plan
e. Deliver final wetland plan to the Texas General Land Office and EPA Region 6.

Table 2. Timeline of project in relation to tasks in Table 1.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Task 1	X	X	X	X	X	X	X	X	X	X								
Task 2		X	X	X	X	X	X	X										
Task 3	X	X	X	X	X	X	X	X	X	X	X	X						
Task 4	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X
Task 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Task 6								X	X	X	X	X	X	X	X	X	X	X

RESULTS

The overriding principle of a voluntary wetland conservation plan is to promote the importance of natural features in the landscape in conjunction with traditional land uses and urban development. Defining a goal for the Mission/Aransas Watershed area was necessary to develop objectives related to public and private interests within the planning area. In addition, the goal needed to be long-range in scope to address future plans and ensure that natural resources would be available to succeeding generations. Therefore, the following goal was formulated: Preserve the quantity, quality, and diversity of wetlands and living resources in the Mission/Aransas Watershed for future generations.

The Mission/Aransas Watershed encompasses many different types of habitats, so there are both freshwater (palustrine) and saltwater (estuarine) wetland types in the planning area (increased diversity). With a goal that encompassed the entire watershed, all surface drainages, land uses, urban and rural populations, and associated wetlands and bays were included. The cumulative impact of historic, present, and future projects in the planning area has affected and will affect both the amount (quantity) of wetlands, as well as the health (quality) of the remaining wetlands.

Because the Mission/Aransas Watershed Wetland Conservation Plan involves only voluntary participation, the objectives established to achieve the Goal include only voluntary alternatives. Maintaining programs that gather information to assess the quantity and quality of our wetlands is essential. Therefore, the *Monitoring Objective* was developed to promote and support long-term monitoring programs in the planning area: Establish long-term, monitoring programs in the Mission/Aransas Watershed that provide appropriate data to evaluate the health of wetlands, rivers, and estuaries.

Currently, several state-funded programs collect water quality, sediment quality, and biologic data in the Mission/Aransas Watershed. With continuing cutbacks on state funding, these programs must prioritize sampling stations along the Texas coast. Through public and private support, existing programs may continue and areas in need of further sampling may be included in future budgets. Local governments and private citizens can provide support of these programs in the interest of having appropriate data for resource evaluations.

The following alternatives address this voluntary support:

- Support agency initiatives to continue long-term monitoring programs. Local governments and citizens should promote continued funding for water quality and habitat monitoring.

- Support agency efforts to increase monitoring sites. Local governments should promote increased funding for water quality and habitat monitoring within the Mission/Aransas Watershed area.

- Initiate volunteer monitoring through agency and academic programs. Efforts to increase school classes and citizen group participation in volunteer monitoring programs should continue using available programs.

- Increase public awareness of the health of rivers, wetlands, and bays. This alternative can be accomplished by establishing public outreach locations for monitoring updates; increasing contacts within permitting agencies for notification of all permit applications; and increasing the number of newspaper articles highlighting status and trends of wetland protection, restoration, and monitoring.

While regulatory mandates are established to prevent or minimize degradation of water and sediment quality and biologic organisms, many voluntary actions can be utilized to prevent degradation. These actions include wise management of our upland areas and decisions regarding releases of treated waters into our creeks, rivers, wetlands, and bays. Best management practices can minimize erosion, thus increasing water quality as well as preserving the natural resource (in many cases, soil) for sustained agriculture or range uses, or habitat for resident and migratory species. The *Stewardship Objective* was developed to promote positive steps toward maintaining and improving water and sediment quality in the planning area and avoiding future degradation of these wetlands: Prevent degradation of wetlands in the Mission/Aransas Watershed through use of best management practices and avoidance of sensitive areas.

In many cases in coastal communities, upland land use practices, alterations to water flow, use of surface and groundwater, releases of untreated and treated wastewater, and changes in creek and river channel configuration have resulted in degradation of water quality. Comprehensive evaluations of current practices as well as planned activities should include the effects these changes have on creek, river, wetland, and bay health.

The following alternatives were formulated to assess strategies that would improve these systems or reduce potential adverse effects of unwise management practices.

- Evaluate potential degradation to wetlands caused by alterations of water flow and develop best management practices to prevent water quality degradation and changes to

wetland composition. Potential effects should be determined on wetland quality if additional, long-term freshwater inflow enters the wetland and best management practices developed to minimize changes to the composition of the wetland plants and animals. Potential effects on wetland quality should be determined if upstream, freshwater inflow becomes limited (e.g., dam, impoundment, pumping, etc.) to wetlands downstream and best management practices developed to minimize or eliminate changes in composition of wetland plants and animals.

- Evaluate potential degradation of wetlands caused by trampling of vegetation and develop best management practices to prevent habitat degradation. Natural wetlands should be protected from livestock grazing and watering by providing alternate water sources and develop rotational grazing strategies to allow regrowth. Access areas of state-owned wetlands should be provided for recreational activities (e.g., fishing, castnetting, crabbing, photography, etc.).

- Evaluate potential degradation of wetlands caused by excess sediment deposition and develop best management practices to prevent changes in wetland elevation. Removal of vegetation along shorelines and drainage areas should be avoided or minimized during upland construction. Silt barriers should be used in construction areas. Channeling natural watercourses should be avoided to prevent scouring of wetlands as a result of high-velocity runoff.

- Evaluate potential degradation of wetlands caused by nutrient or pollutant/contaminant loading and develop best management practices to prevent water quality degradation and plant and animal dieoffs. Nutrient loading should be eliminated or minimized from agricultural and grazing lands runoff, as well as wastewater treatment and aquaculture facility effluent by creating vegetation filters between upland and wetland or by implementing no-discharge practices. Point source pollution should be eliminated from industrial discharges into wetlands by rerouting and disposing of chemicals, oil by-products, and brine discharges. Nonpoint source pollution should be eliminated from urban areas into wetlands by increasing public awareness about the degrading effects of pollution from stormwater runoff (e.g., trash, detergents, household cleaners, oil, etc.).

Onsite alterations or land-use practices upstream of the wetland have altered many of the remaining wetlands in the Mission/Aransas Bays watershed. Voluntary restoration projects can be undertaken at both the local government and private citizen levels. Technical and financial assistance is also available, depending on the projected timeframe of the project and the type of wetland restoration. The *Restoration Objective* was developed to increase the quality of wetlands in the planning area, with the focus on restoring wetland functions: Restore the functions of degraded wetlands in the Mission/Aransas Watershed.

Wetland restoration projects not only improve wetland quality onsite, but also improve the adjacent areas in terms of water and sediment quality and wildlife/fisheries habitat. Local government officials in the planning area have the capability of providing networking between state and federal agency biologists and natural resource managers, university scientists, local

school districts, and private citizens. Coordinating local efforts on private and public lands, both within and among counties, will increase the overall health of the watershed.

The following alternatives were formulated to use programs and human resources available for wetland restoration projects.

- Promote wetland restoration in wetland areas that have been degraded from natural and human-induced alterations. Owners of wetlands should be contacted that may have viable restoration sites. the utilization of the Texas Wetland Registry and Coastal Bend Land Trust should be promoted to link willing wetland landowners with restoration partners. Landowners should be provided with information materials that identify programs and incentives to restore degraded wetlands. Restoration efforts should be coordinated between agencies and foundations and landowners to increase restoration success at the watershed level.

- Develop broad-scale restoration efforts in sub-watersheds within the Mission/Aransas Watershed. Mitigation banks should be established that would restore large areas of wetlands and provide income for wetland owners.

Wetland loss has occurred within the Mission/Aransas watershed, although most losses occurred prior to the 1950s. The remaining wetlands in the planning area are critical to the continued functioning of the area, and all efforts should be maximized for voluntary protection of these wetlands. The *Protection Objective* addresses the importance of preserving our wetland resources for future generations: Preserve wetlands in the Mission/Aransas Watershed through stewardship, management, and conservation.

Stewardship involves the willing participation of local governments and private citizens to voluntarily promote wetland preservation. Both management and conservation efforts are utilized to provide this protection as well as maintain economic goals in the planning area. These natural areas not only provide important water quality improvement functions and habitat for fish and wildlife, but also increase the aesthetic value of our coastal community.

The following alternatives were designed to combine both economic and ecologic goals.

- Balance economic use and development with stewardship programs that preserve wetland quality. Buffer areas should be established between wetlands and uplands. Limited access should be provided to sensitive areas. Education programs should be promoted to increase awareness of wetland functions and values.

- Periodically assess wetland quality and quantity to ensure wetland preservation. Available information should be available to assess status of wetlands in planning area. An approach should be developed to assess riparian corridors along creeks and rivers in the watershed.

- Develop management plans to avoid destruction of wetlands. Riparian corridor areas should be established that would minimize vegetation removal and intensive grazing. Shoreline protection options should be evaluated and environmentally sensitive strategies implemented when appropriate.

- Use a land trust to provide options for wetland protection. A land trust should be established to include the Mission/Aransas Bay watershed. The land trust may accept donations of coastal properties with wetlands and other coastal habitats. Conservation easements should be developed with willing landowners. Partnerships with landowners should be initiated through development of wetland management plans.

Discussion and Conclusions

Process Overview

Each task was evaluated to access the approach of this project. Recommendations for future projects were also incorporated based upon our experience in developing this region-specific wetland conservation plan.

Task 1: The first task involved creating a work group. Over 100 work group members provided various involvement, expertise, and suggestions throughout the project. During the initial stages of the project, newsletters highlighting meetings, resource materials, and progress were sent to each workgroup member. We feel this was an excellent way to keep members aware of the project development. Wetland issues were identified during presentations to county commissioner's court and city council meetings. The goals and objectives were to be developed during workgroup meetings; however, low participation necessitated the contractors developing the goal and objectives and then meeting one on one with each local government to refine them. Agency workgroup members provided most of the regulatory/nonregulatory wetland protection mechanisms. The conservation strategies were developed by the contractors and matched with particular issues raised by local government officials and citizens.

Task 2: The second task involved identifying the wetland resources and land use patterns in the planning area, as well as determining the realized and potential threats to the natural habitats. These data were also available from natural resource agencies in reports and publications recently completed by the Corpus Christi Bay National Estuary Program (now the Coastal Bend Bays and Estuaries Program). Data gaps were identified as well, and funding sources were sought to provide more information for resource planning in the future. Buffer zone information was limited and identified as a data gap, as was quantity and quality of riparian habitat, comprehensive water quality and fisheries data.

Task 3: Criteria for evaluating wetlands in the planning area was identified at two levels, comprehensive evaluation and rapid assessment techniques. Most of the wetlands in the planning area are privately owned and access was limited. We were unable to

comprehensively evaluate a majority of the wetlands, but did have extensive knowledge of those landowners that had participated in technical assistance programs. We also determined that this evaluation task could not be completed during the timeline of the project. Cooperative landowners did allow access and we used these areas as examples in the final plan.

Task 4: We did present the plan overview and progress to county commissioner's and city council meetings throughout the project, at rotary club meetings, and held a two-day workshop/field trip session at the middle of the project. Participation was low, and consisted primarily of those members who had supported the plan from the beginning. Citizen input, however, was higher, at a one-on-one basis with the contractors. We found that most individuals who had wetlands on their property were aware of their value, but did not want to be regulated on how they managed them. We believe we made significant inroads with these people and through them with their friends, relatives, and neighbors.

Task 5: The fifth task involved identifying appropriate wetland conservation tools to implement the plan's goals and objectives, as well as identifying potential financial and technical assistance. These alternatives were summarized in the final plan as projects ready for implementation and templates for future projects.

Task 6: The original timeline listed the draft plan as being completed in the 12th month (October 1998) and presented for review to local governments. We did not anticipate this task falling on election year for county and city officials. Some of the commissioners up for reelection were not eager to place wetland conservation as part of their platform, and those running against them were not familiar with the plan. Two of the three county judges were not running, although they had been very supportive of the plan development. Having the plan adopted with a current commissioner's court would not set the appropriate stage for implementation with a new court. Therefore, we decided to postpone adoption of the plan until spring, and concentrated our efforts on assisting in writing grants to implement some of the alternatives. The plan was adopted by the county commissioners's courts in late August 1999. The timeline for this task was not achieved, primarily due to the time-intensive review and revision process. Reviews and approval being conducted during the summer exacerbated this extension of time. Compilation of a summary document should be incorporated into the tasks as well as the budget. Decisions concerning the printer and graphics layout should also be finalized prior to the printing of the draft. It is recommended that the plan be placed on the website to increase availability.

Future Recommendations

In summary, the following recommendations are suggested to improve the organization and/or involvement of local governments and private citizens.

- Example case studies should be compiled first to introduce benefits of wetland conservation.
- Contractor should provide the proposed goals and objectives to local governments for

refinement.

- Extensive implementation should not be expected within the planning phase.
- Mandatory requirements on local governments still take precedence over volunteer conservation plans.
- Flexibility in the plan should be included to ensure the development of a long-term planning tool.
- Private landowners must be involved early in the process to ensure future partnerships.
- Increasing public awareness on the value of wetlands must employ a long-term approach.
- Wetland scientists should be involved in local/regional issues to gain credibility and trust with the public.

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The continuous exchange of ideas and suggestions by all work group members was greatly appreciated and resulted in a document that will be useful in wetland conservation planning and implementation within the Mission/Aransas Watershed. County Judges Charles Stone (Refugio), Josephine Miller (San Patricio) and Agnes Harden (Aransas) assisted in local government coordination and input through the first year of the project. County Judges Miller (San Patricio), Roger Fagan (Refugio), and William Adams (Aransas) assisted in finalizing and approving the final plan. Special thanks to County Commissioners Ron Hicks (retired), Janis Gillespie, and Richard Martinez (Refugio), Nina Trevino and Gordon Porter (San Patricio), and Larry Barneby (Aransas) for their involvement in work group meetings.

The overview of the development of the plan and recommendations provided within will assist other groups with similar goals along the Texas coast.

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HABITAT BANKING FOR CONSTRUCTION OF AN AIRPORT SURVEILLANCE RADAR AT STOCKTON, CALIFORNIA

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ABSTRACT

A cost-effective mitigation option for constructing the Stockton Airport's ASR-11, the FAA's latest airport surveillance radar, was habitat banking. Through consultations required by the National Environmental Policy Act, both the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (DFG) informed the FAA that the proposed location was grassland habitat for the western burrowing owl, a species of concern protected by the Federal Migratory Bird Treaty Act. Additionally, the FAA planned to commence construction during nesting season. The agencies initially informed the FAA that construction during this season was precluded to prevent harm or harassment to the birds. The FAA negotiated on-site mitigation allowing for construction during the nesting season. Additionally, there was a requirement for land acreage compensation in the ratio of 6.5 to 1. The FAA made payment to a habitat bank, part of the San Joaquin Multi-Species Habitat Conservation Plan (SJMSCP) in lieu of farmland dedication to compensate for the construction of the ASR-11. The purpose of the SJMSCP is to identify conservation areas for wildlife habitat, determine areas that will be affected by development and acquire land for preserving wildlife habitat and open space, and habitat banking.

INTRODUCTION

Habitat banking was used by the Federal Aviation Administration (FAA) as part of satisfying an environmental requirement in siting an Airport Surveillance Radar, ASR-11, to serve Stockton Airport, California (SCK). The ASR-11 is the latest radar for tracking aircraft in airspace around an airport. With the ASR-11, air traffic controllers can track aircraft take-offs and landings. The equipment is critical for air safety. For SCK, it was critical for assuring the steady air shipment of the region's berry crop. SCK is surrounded by agricultural lands. Construction commenced in 1998 and the radar was operating in 1999. The SCK ASR-11 was the first of a nationwide deployment of about 200 radars. A key siting constraint is that the radar must be located between a half-mile to a mile from the runway. The operationally-preferred site was burrowing owl habitat.

The Burrowing Owl

The western burrowing owl (*Athene cunicularia*) is about nine inches tall, with distinctive tall legs, a brown back with white spots and a striped abdomen. Its habitat is characterized by open space and grasslands. The owl's nest and roost in burrows,

especially those created by California ground squirrels. The burrowing owls have a commensual relationship with the ground squirrels. The California ground squirrel is considered a nuisance species or vector by the California Department of Fish and Game (DFG). The burrowing owls also use artificial burrows, e.g., construction materials, pipe, for protection, shelter and nests. These burrows are used during the breeding season, February through August, for nesting. During the non-breeding season, September through January, the owls use the burrows for shelter. Fledglings often disperse to other burrows near the nest site, usually in August.

The burrowing owl is protected as a species of concern under the Federal Migratory Bird Treaty Act (MBTA) and California state law. In California, the U.S. Fish and Wildlife Service defers burrowing owl issues to the California Department of Fish and Game (DFG). It is illegal to take or possess any migratory bird designated under the MBTA. As a matter of fact, the burrowing owl does not migrate; it is present year round. Additionally, under California Fish and Wildlife Code, it is illegal to take, possess, or destroy a protected bird, or take, possess or destroy nest or eggs. Penalties involve personal liability.

SITING CRITERIA

For FAA, compliance with the MBTA came under the umbrella preparing an environmental assessment following the National Environmental Policy Act, as amended. Mitigation sequencing (40 CFR 1508.20) requires FAA to consider

- avoiding burrowing owl habitat,
- where avoidance is not feasible, minimizing impacts to burrowing owls and their habitat, and
- compensating to offset impacts.

In this instance, the FAA's operationally preferred site in this burrowing owl habitat was critical for the mission of air safety. This optimum radar coverage for SCK would ensure that the nation continues to have the safest air traffic system in the world. The FAA minimized impacts by on-site mitigation and compensated by negotiating to use the habitat banking tool.

MITIGATION MEASURES

Mitigation measures were agreed upon between the California Department of Fish and Game (DFG) and the FAA to prevent impacts to the western burrowing owl (*Athene cunicularia*) at the preferred site for the proposed ASR-11 to serve SCK. Given these mitigation measures, it was determined no adverse impacts to the western burrowing owl would occur as a result of the installation and operation of, and acquisition of land for the proposed ASR-11.

Based on recommendations contained in a DFG letter dated August 7, 1997, the FAA conducted surveys for the western burrowing owl at the preferred site for the proposed ASR-11 to serve SCK. The surveys were conducted in accordance with DFG-approved protocol. A total of four surveys were conducted; an initial survey and three follow-up surveys spaced at 10-day intervals. Reports documenting the results of those four surveys were submitted to DFG.

The survey area consisted of the proposed construction and staging area, utility and access corridors, and a buffer area, totaling approximately 3.5 ha (8.8 acres). No active burrowing owl nests were encountered at the ASR-11 parcel; however, two burrowing owl complexes were observed an the adjacent property. The closest occupied burrow was approximately 65.8 meters (216 feet) south of the future area of ASR-11 construction disturbance. The second complex was further from the ASR-11 site, about 15.2 meters (50 feet) south-southeast of the first burrow complex. Based on their distance from the ASR-11 site, the FAA and DFG determined that no direct impacts to the owls would occur during the construction or operation of the proposed radar.

In order to prevent impacts to burrowing owls and to preserve the availability of the preferred site while the environmental assessment process was being completed, the FAA began implementing mitigation measures authorized by the DFG. Early in the nesting season (after February), the FAA engaged a qualified biologist to install one-way doors on the burrows located within the area of proposed construction disturbance (Passive Relocation). After 48 hours lapsed, the one-way doors were removed and geotextile fabric and hardware screening were placed on the 48.8 X 48.8 meter (160 x 160 ft) construction and staging area, and access and utilities corridors. The placement of the fabric and screening was monitored by the biologist. The fabric and screening was removed as construction proceeded.

The FAA conducted the following additional measures to prevent impacts to burrowing owls:

1) To prevent indirect construction impacts on the owls at the adjacent property, the FAA installed a buffer fence to prevent construction personnel and vehicles from approaching within 42.7 meters (140 ft) of the nearest occupied owl burrow. The buffer fence was semicircular with a 30.5 meter (100-ft) radius. To the greatest extent possible, construction personnel confined their activities to the 48.8 X 48.8 meter (160 x 160 ft) construction and staging area and utility and access corridors, thereby staying over 61.0 meter (200 ft) from the nearest owl burrow.

2) Prior to the start of ASR-11 construction, a qualified biologist conducted a brief training program for FAA and construction personnel. That program covered the appearance of the burrowing owl, its typical habitat, behavioral characteristics, and legal status. This enabled personnel to identify and avoid harm to the owls during construction. Details of the training program were developed in consultation with the DFG.

Because active nests were located within 100 meters of the proposed radar site, the FAA would have been required to compensate for the habitat loss of one acres of habitat by purchasing 2.63 ha (6.5 acres) of farmland in the airport vicinity (mitigation ratio 6.5:1). Farmland in that vicinity costs $30,000 per acre. The City of Stockton Planning Department limits farmland sites to a minimum of 259 ha (640 acres). This is the smallest parcel that could be sold. This would have been prohibitively expensive. Additionally, the FAA would be responsible for land management, monitoring and administration.

Because land costs would be prohibitive, FAA negotiated to use habitat banking in lieu of land purchase to satisfy the compensatory requirement and expedite facility construction. Habitat banking credits were purchased from the San Joaquin Multi-Species Habitat Conservation Plan (SJMSCP) at $1,500 per acres-credit of preserve land. With the mitigation ratio of 6.5 to 1 this totaled an extremely reasonable payment of $9,750.

With the approval of the DFG, the FAA purchased 2.63 ha (6.5 acre) credits from the the Council of Governments, the implementing entity for the SJMSCP. Target taxa for the habitat preserve lands include plants, amphibians, birds, fish, insects, invertebrates, and mammals. The Plan operates in the 1,399 square miles of the Mokelumne River, Calaveras Stanislaus and San Joaquin River watersheds. The airport is in the service area for banking Services of the SJMCSP habitat project. Cooperating agencies include the DFG, USFWS, U.S. Department of Transportation (including FAA), San Joaquin County Council of Governments and local governments.

DISCUSSSION AND CONCLUSION

Habitat banking benefits both aviation safety and habitat protection by:

- Reducing the time cost and uncertainty associated with purchase of land meeting the requirements of compensatory habitat;
- Leaving the management, monitoring and maintenance of complex, dynamic habitat lands to specialists associated with habitat banks;
- Discouraging on-site, or airport vicinity habitat restoration or creation, minimizing bird interference with aircraft operations, radar coverage and airport development for enhanced safety and capacity; and
- Allowing the FAA to use implementation funds for habitat mitigation strategy more effectively.

SCK was the first airport scheduled to receive an ASR-11. Delay would have slipped the implementation schedule six to eight months, adversely affecting the radar equipment production schedule and overall funding profile, placing the future of the program in jeopardy. Therefore, the estimate of cost savings programmatically runs into several millions of dollars.

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AN ANALYSIS OF FOREST COMMUNITIES IN THE TOWN OF LINCOLN, MA: A BASELINE INVESTIGATION FOR A LONG TERM RESEARCH PROGRAM

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ABSTRACT

A botanical survey of forested conservation land in the Town of Lincoln, MA was conducted during the summer of 1998. This study was sponsored by the Lincoln Land Conservation Trust and the Lincoln Conservation Commission. Its primary purpose was to provide a baseline study against which future changes in the biota of the town could be measured. It also provided an opportunity to investigate distributional and compositional properties of the various upland communities in Lincoln.

Cluster analysis of the data showed clear community distinctions, but no overarching geographic patterns. Patchiness seems to characterize the forests of Lincoln. Sites within an individual conservation property tend to cluster together, indicating a high degree of similarity. An analysis of the occurrence of European Buckthorn (*Rhamnus cathartica*), an invasive exotic (Weatherbee, et al., 1998), did not indicate that it was excluding other species at the present time. This study did provide an important baseline from which to measure its spread in the future.

INTRODUCTION

This study was intended, primarily, to define plant communities in locations throughout the conservation land in Lincoln, MA. It was sponsored by the Lincoln Land Conservation Trust and directed by a Forest Committee created by the Lincoln Land Conservation Trust (LLCT) and the Lincoln Conservation Commission (LCC). The assistance of the Lincoln Land Conservation staff and many Lincoln residents was indispensable to this study. Community boundaries, sizes, and species composition were determined and quantitative data was collected as described below. A basic understanding of the ecology and communities of a region is critical to the development of appropriate management strategies. The ultimate purpose of this study therefore, is to provide community descriptions and boundaries for land conserved in the Town of Lincoln, Massachusetts. This information establishes an environmental baseline for conservation land and may be useful to the town in planning decisions.

Conservation land in Lincoln has been affected by a variety of factors. Interactions between plants, the environment, and man have impacted the plant communities found in Lincoln today. In colonial Lincoln farming was the primary profession (MacLean, 1987).

Forests were cleared to make way for farmland. Most of the conservation land in Lincoln was part of a farm at one time, which changes the vegetation found today. Instead of old growth woodlands a variety of successional communities are found in Lincoln.

Although the primary influence on the distribution of flora in Lincoln is the glacial geology of the area as it was formed approximately 11,000 years ago many more recent events have also significantly affected the structure of plant communities in the Town. In 1904 the Chestnut Blight Fungus was discovered in Lincoln (LCC). Humans accidentally introduced this foreign tree disease to the area. It spread to neighboring places and destroyed chestnut trees throughout Lincoln and surrounding New England areas. This loss has had a significant impact on forest structure in the town (LLCT, 1992). The wooly Adelgid beetle has appeared in Lincoln in the past couple of years and it's spread is a matter of great concern in the town (LCC).

In 1938 a major hurricane hit New England. Many tall old trees were blown down by the force of the wind. This made room for younger trees to develop. Stumps of trees can still be found and changes in vegetation occurred due to this event. Both man and nature have had an impact on Lincoln's land and the plant communities found there today are reflections of past events.

METHODS

Lincoln is a small suburb, west of Boston. In 1957, the Lincoln Land Conservation Trust was established to maintain the rural character of the town by holding land in trust for the benefit of the inhabitants of Lincoln. The land conserved in Lincoln is distributed throughout the town and has been acquired throughout the years with the help of various people.

Eleven properties were selected for this study by the Lincoln Forest Committee. These properties were selected by the Forest Committee on the basis of their usage levels, history, and biological interest. The botanical communities at each site were surveyed using random plot analyses. Each community within each site was studied separately. Additionally, a total species list for each site was constructed. A variety of statistical analyses were used to compare different sites and plant communities throughout the town.

Four different plant communities were defined by the Forest Committee for study; oak woods, hemlock groves, pine woods, and red maple swamps. Each of these communities was distinguished by the predominance of the eponymous tree type. Within each property the number of communities and their boundaries were determined and mapped.

An artificial grid system was laid over maps of each property and a random number generator was used to select reference points for detailed study. Three plot sites were thus selected within each community in each property. Thus a property that had a red maple swamp within an oak forest would have six study plots; three in the red maple swamp and

three in the oak woods. All plots were discrete with no overlap between them. If the random number generator selected plots that did overlap the second plot was discarded and the next number in the sequence was used. If a community was not large enough to enclose three plots which did not overlap, fewer plots were studied in order to avoid duplicating data. This event occurred three times.

The grid reference for each plot was located and used as the center point for three concentric squares, in which detailed analyses of the flora were conducted. The smallest square had 2m sides and was used to census the herbaceous plants and grasses present. Next all of the shrubs and trees with a DBH less than two inches were censured within a 10m square. Finally a 50m square was used to census trees with a diameter over two inches. A rebar stake was inserted in the soil to mark the center of each plot and enable future researchers to relocate the plots. The squares were measured and staked out using nylon twine and tent pegs. Once the plots were marked all of the individual plants in each square were identified and counted. This procedure was repeated at all of the eleven properties.

The data thus gathered were analyzed using a variety of different methods. A Ward's clustering method was used to compare different plots to each other and investigate the relationships between sites. This clustering method was selected because it stresses presence - absence data first and then uses the proportions of species that were present to construct groupings. In this manner it was possible to investigate the nature of the plant communities and the conservation properties in the town. These analyses were performed using JMP 3.1 statistical program.

The presence of European Buckthorn (*Rhamnus cathartica*), an invasive exotic, was also analyzed. In order to form a baseline for future work, and to get an idea as to whether or not this species poses an immediate problem in Lincoln the proportion of buckthorn at each site was measured. To determine whether buckthorn might be excluding other species the proportion of buckthorn was used as a dependant variable while the number of species from each site was used as a dependant variable in a linear regression analysis. This analysis was designed to show whether or not buckthorn was reducing the species diversity on conservation land. Regression analyses were conducted using Statview SE. All analyses were performed on a Macintosh Power PC 7200.

RESULTS

Detailed descriptions of each property would be out of place in this document, but are available in Mainelli, 1999.

Dendrograms comparing sites and communities were constructed using JMP, a statistical computer program in order to compare data from each plot. The more similar one plot is to another, the closer they cluster on the dendrogram. Sites that are particularly unique cluster separately or farther apart from others. The dendrogram comparing all sites and all plots contains so much data that no true pattern emerges.

The dendrogram comparing all two meter plots (Figure 1) shows various clusters. Sites of interest that clustered separately are PHP2, CSM1, BPRMS1, and CSRMS. This means these sites were the most unique out of all the two meter plots from every site. Comparing all ten meter plots (Figure 2) FPM3, CNM2 and CSM3 stand out as different. Comparing all fifty meter plots (Figure 3) CNRMS3, AWRMS1, CSM2, and FPM2 clustered separately.

The dendrogram comparing the pine communities from each site (Figure 4) shows that Adam's Woods had the most variable pine communities. All three plots from the other sites cluster together showing they are more related, while the plots from Adam's Woods are spread out.

The dendrogram comparing the red maple swamps from each site (Figure 5) shows Tanner's Brook was the least diverse. It's three plots cluster close together and are therefore more similar to each other. Codman North's plots one and three are closely related, but plot two was not as similar. The two meter plots for red maple swamp show a simple progression. The ten meter plots become more variable, but the fifty meter plots showed the most variability. Thus, the dendrogram for red maple swamps overall has variability mostly based on the fifty meter plots (Figure 6).

The dendrogram comparing hemlock groves (Figure 7) shows a simple progression at the two meter level. Adam's Woods is distinct in all three levels and clusters separately. Codman North shows that it is not similar to other sites nor is there similarity between plots. Plot two in Codman North clusters even further apart from any others at the ten meter level. Farm Meadow Forest plot one was distinct from the others on the fifty meter level.

The dendrograms comparing oak communities (Figures 8-11) are included for every level. The overall oak dendrogram (Figure 8) does not have a clear pattern. FPM2 and CNM2 stand out as unique. The two meter oak plots (Figure 9) show three similar groups emerging. The ten meter oak plots Figure 10) show two distinct similar groups. The fifty meter plot (Figure 11) has one similar cluster at the top, but not many more similarities in the rest of the dendrogram.

Using a number of species as an indication of diversity, a bar graph was constructed (Figure 12). It shows the number of species for each of the eleven properties in this study.

Site diversity was also measured in relation to the proportion of Buckthorn, an invasive species, in each plot. The first graph shows the proportion of the number of species and percent of Buckthorn in ten meter plots Figure 13). The second graph shows this relationship in the fifty meter plots (Figure 14). Linear regression analysis showed that there was no significant correlation between the proportion of buckthorn in a plot and the total species diversity of that plot.

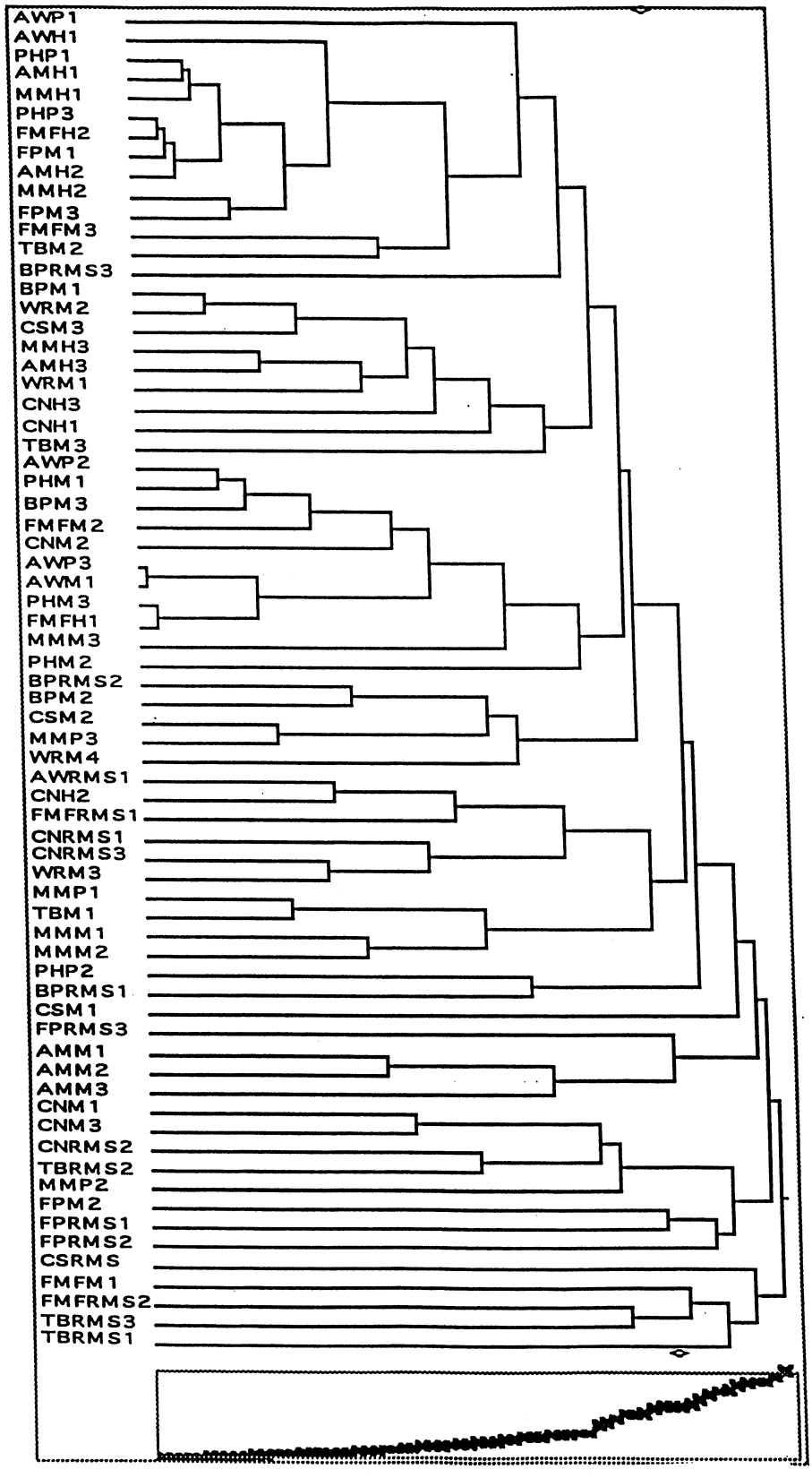


Figure 1. A dendrogram showing the relationships of the herbaceous vegetation found at each plot.

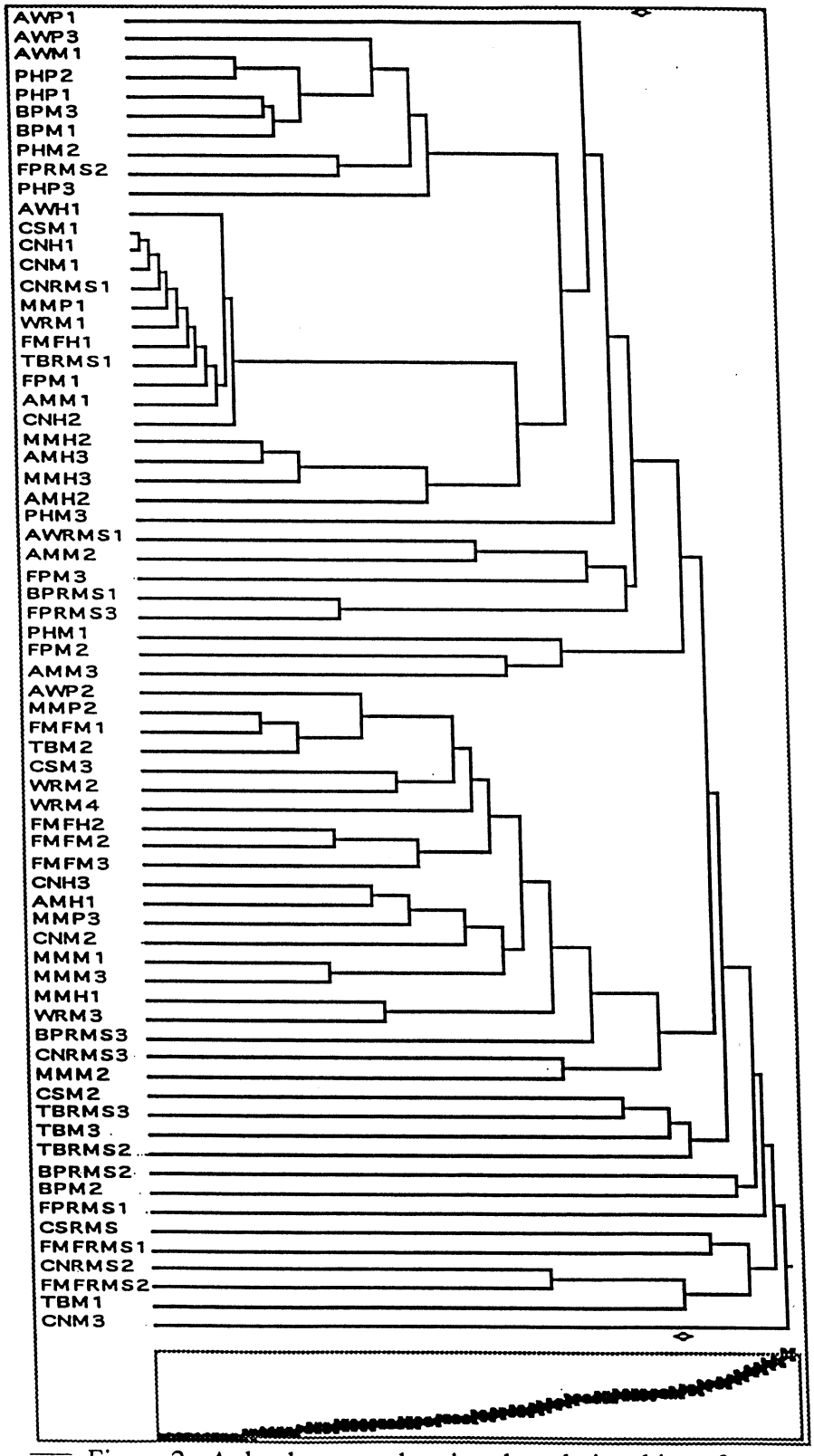


Figure 2. A dendrogram showing the relationships of the shrub layer found at each plot.

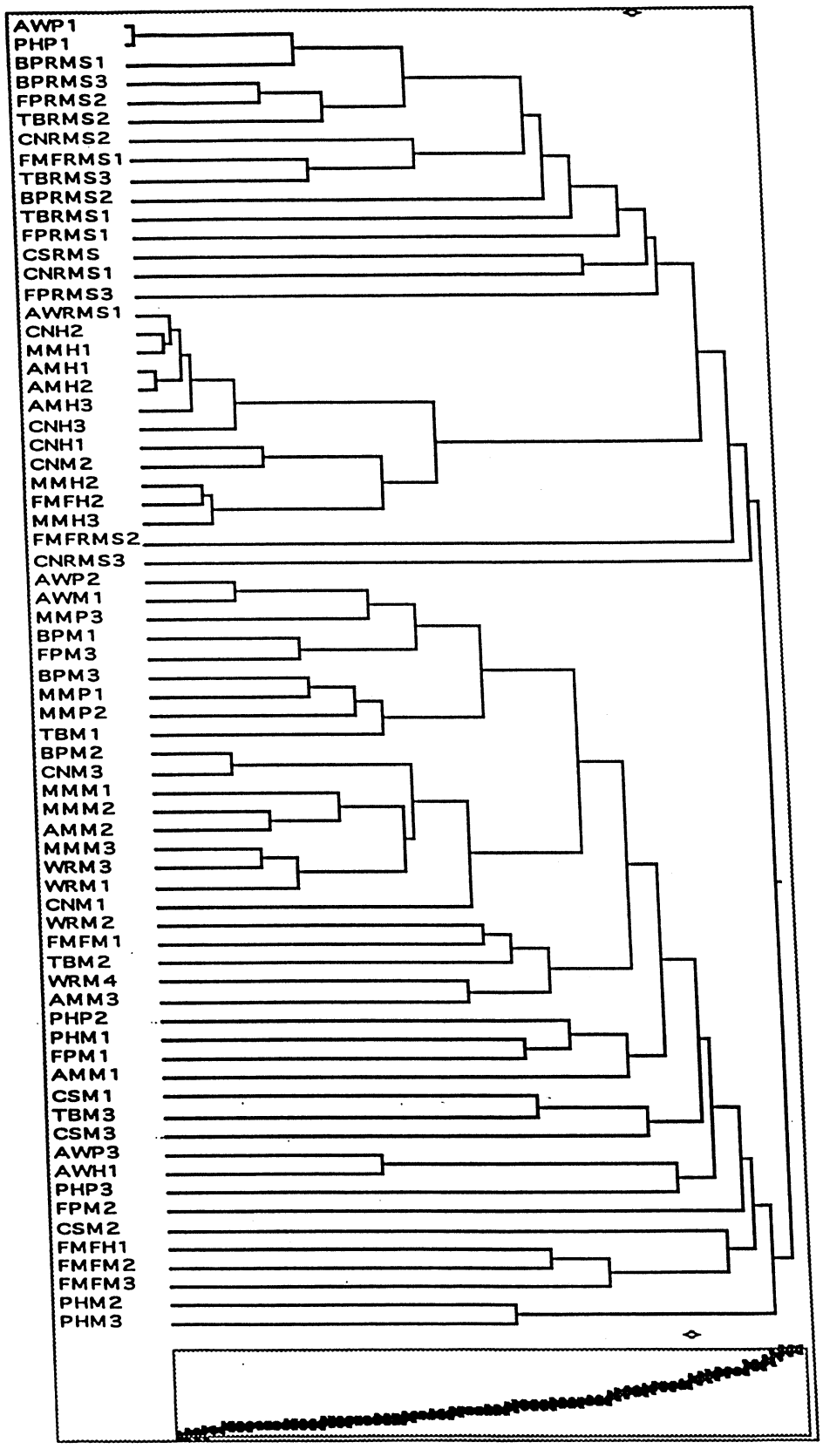


Figure 3. A dendrogram showing the relationships of the tree floras vegetation found at each plot.

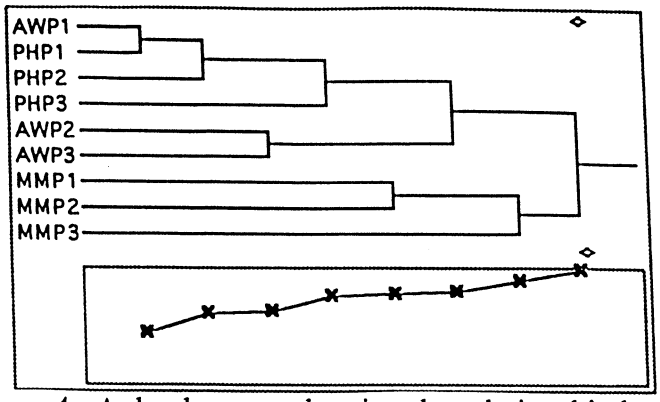


Figure 4. A dendrogram showing the relationship between various pine woodlands in Lincoln. This plot is based on the comprehensive plot censuses.

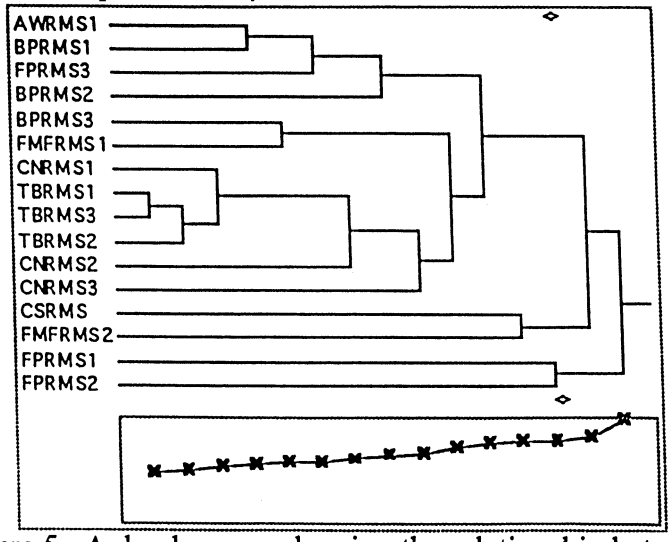


Figure 5. A dendrogram showing the relationship between various red maple swamps in Lincoln. This plot is based on the comprehensive plot censuses.

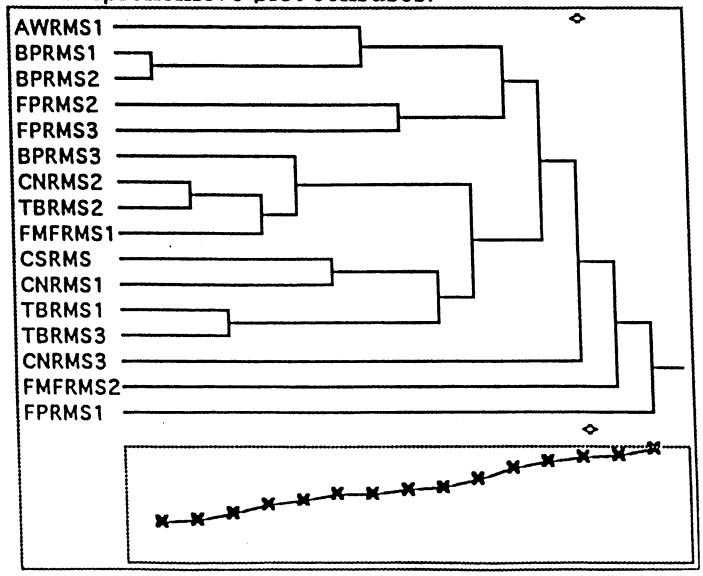


Figure 6. A dendrogram showing the relationship between various red maple swamps in Lincoln based on the trees identified in the 50m plots.

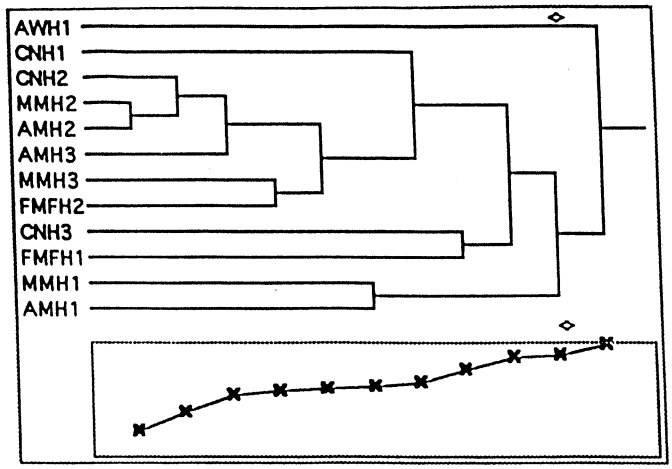


Figure 7. A dendrogram showing the relationship between various hemlock woodlands in Lincoln. This plot is based on the comprehensive plot censuses.

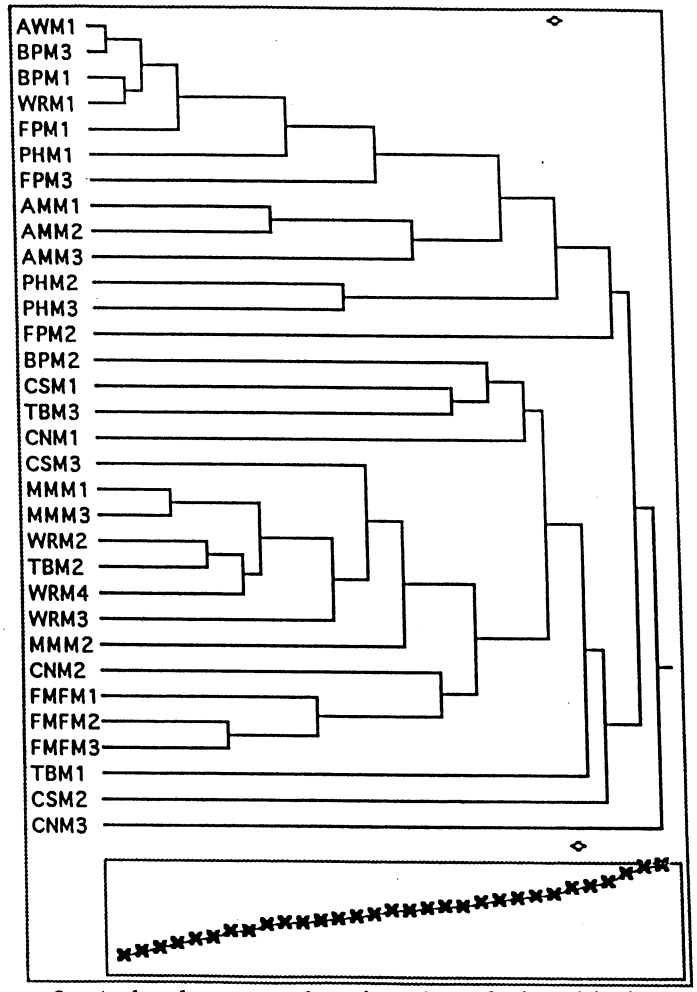


Figure 8. A dendrogram showing the relationship between various mixed hardwood forests in Lincoln. This plot is based on the comprehensive plot censuses.

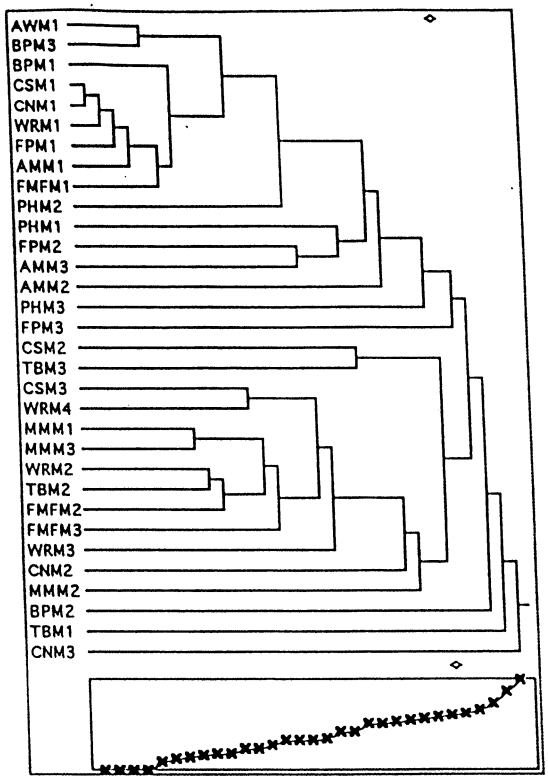


Figure 9. A dendrogram showing the relationship between the herbacious communities (2m plots) of the mixed hardwood forests in Lincoln.

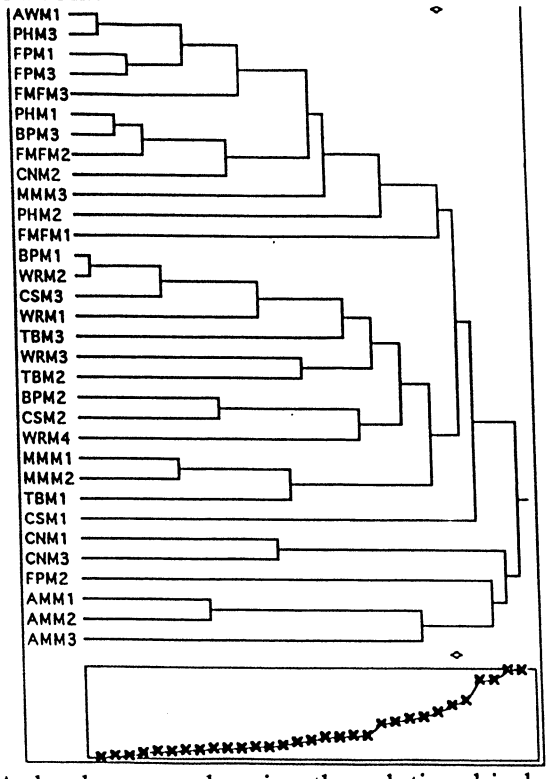


Figure 10. A dendrogram showing the relationship between the shrub communities (10m plots) of the mixed hardwood forests in Lincoln.

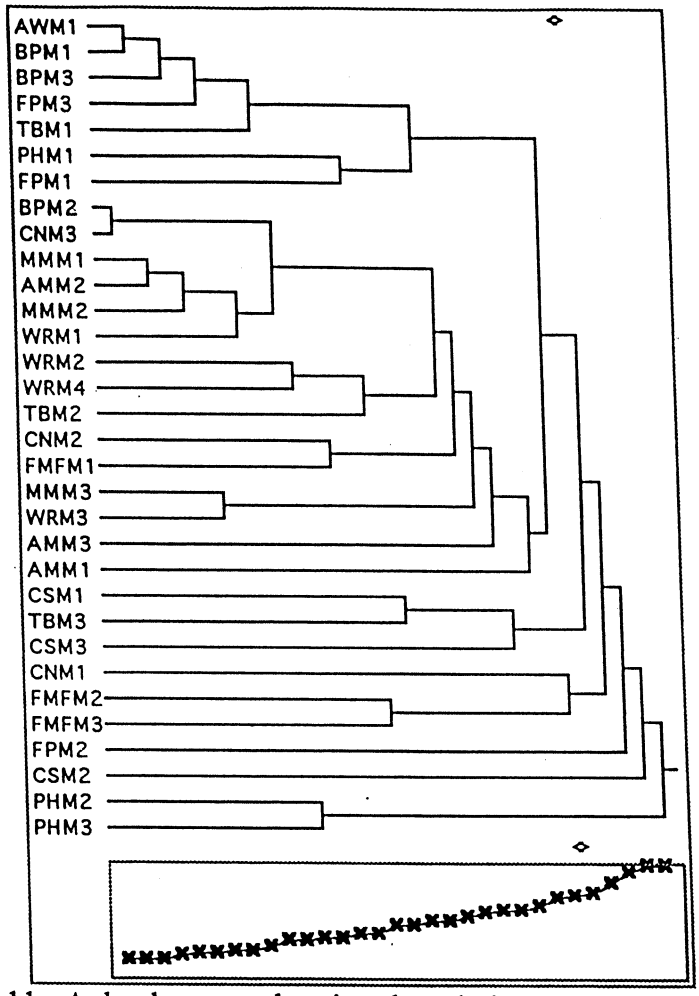


Figure 11. A dendrogram showing the relationship between the tree communities (50m plots) of the mixed hardwood forests in Lincoln.

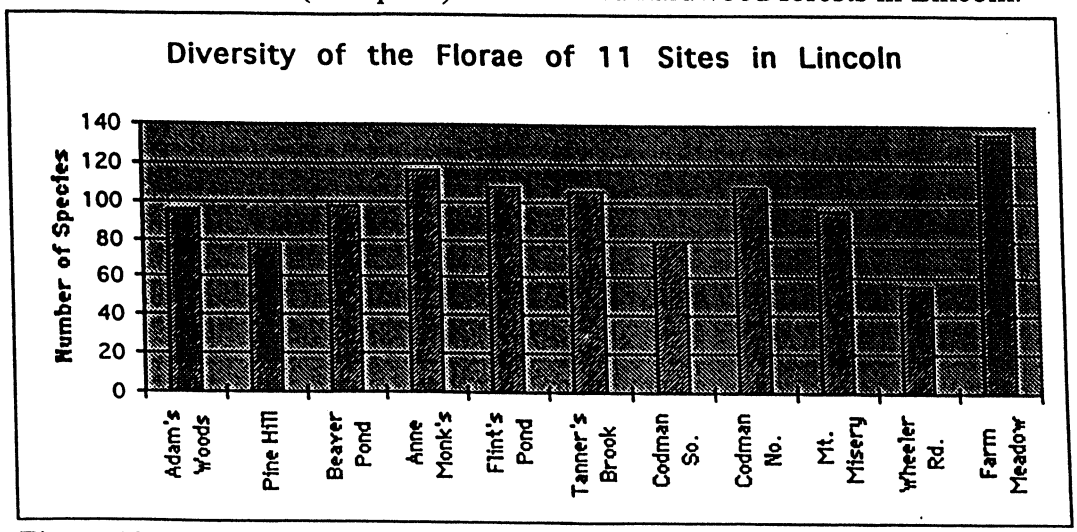


Figure 12. This histogram displays the number of species found at each site surveyed in this study. Wheeler Rd. is clearly the least diverse site, with only 56 species, while farm Meadow is the most diverse with 135 species.

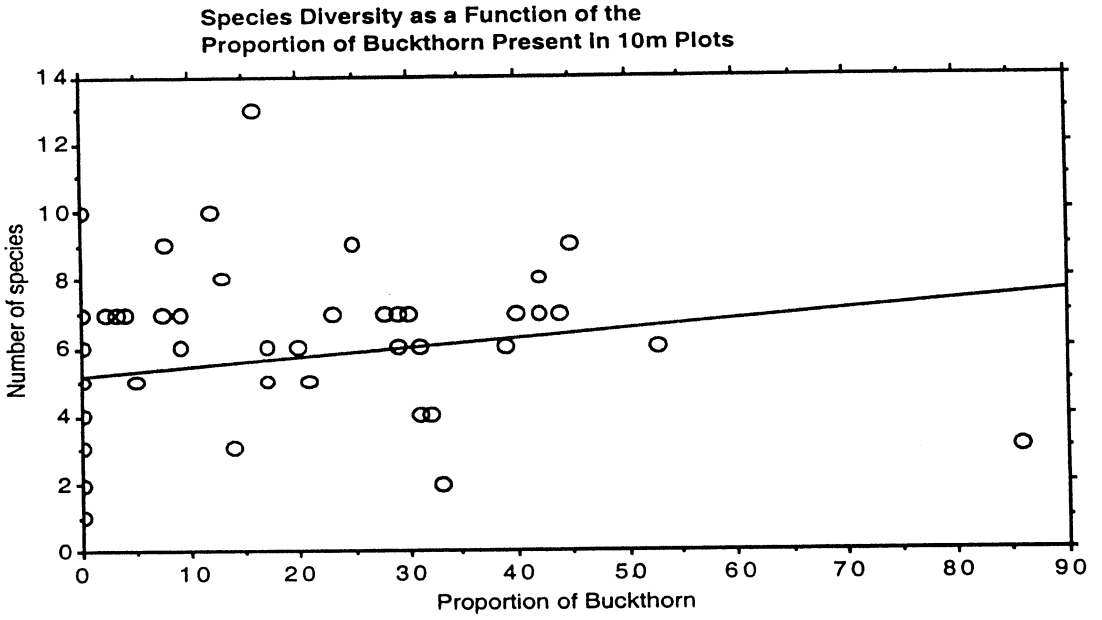


Figure 13. A linear regression analysis shows that the proportion of European Buckthorn present in a site does not significantly affect the diversity of shrub species at the site (p=.09).

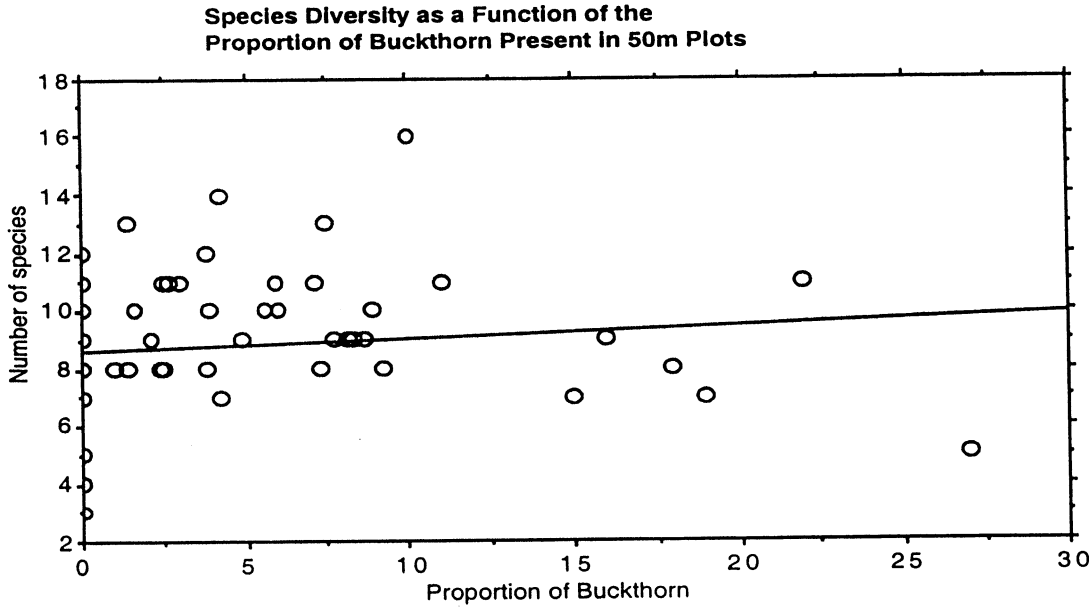


Figure 14. A linear regression analysis shows that the proportion of

European Buckthorn present in a site does not significantly affect the diversity of tree species at the site (p=.42).

DISCUSSION

Site descriptions show some qualitative similarities and differences between sites and communities. Hemlock communities in every site are composed of tall hemlocks that create a canopy allowing little understory to grow underneath. Light is not able to get past the hemlocks to allow growth underneath. Almost all the trees in these communities are hemlocks. Hemlock communities were also checked for Hemlock Woolly Adelgid (HWA), an insect causing damage to hemlocks throughout New England. No cases of HWA were found. Pine communities are similar to hemlocks, but have a more diverse understory and include more species of trees, especially birch. Pine and oak woods were mixed together in many sites throughout Lincoln including Adam's Woods and Pine Hill.

Red maple swamps were found in seven of the eleven properties. In all wetlands the most abundant tree was red maple and the understory was usually dependent on the amount of moisture. Very wet areas tended to have less vegetation in the understory, but in most places the understory was very dense. Oak communities were the most numerous and took up the most space. These communities were also the most variable as far as species diversity, understory density, and canopy density.

Stone walls throughout many sites show the historical uses of the land. Virtually all of the conservation land in Lincoln was farmed some time in the last century. The stone walls are remnants of pastures, meadows, and farm land.

The statistical analyses revealed some interesting patterns. At the two meter level, certain plots were quite distinct. PHP2 clustered separately in a dendrogram because of the predominance of pink lady slipper. In the summer at least one lady slipper was found in most sites, but they were not abundant in any area. BPRMS1 also clustered separately because of the presence of pink lady slipper. CSM1 stood out because it was, one of the few plots to contain Massachusetts fern. CSRMS was diverse for a two meter plot and included common greenbrier, royal, NY, and Cinnamon ferns which made it stand out.

The ten meter level shows FPM3 standing out, due to its high diversity and abundance of blueberry. CNM2 is unusual because it contains both Bladdernut and American Hazelnut. CSM3 was distinguished by its unusually high proportion of Buckthorn.

In the fifty meter level most plots stood out because they contained rarer species. CNRMS3 stands out because it included chokeberry, which was not found in many plots. AWRMS1 was low in diversity and only contained two species, witch hazel and buckthorn. FPM2 stood out because it contained black cherry. CSM2 also had a high proportion of Buckthorn.

More information can be obtained by comparing communities rather than comparing plots. Adam's Woods had the most variable pine communities and was also a highly diverse area. It was the only site that contained all types of communities within it. The pine communities clustered out as the most variable amongst of all the sites because at Adam's Woods the pine and oak communities are mixed together and it is hard to

distinguish boundaries between them. Pine communities at other sites clustered together showing the similarity one would expect between them.

In red maple swamps the dominant tree is red maple. This makes differences at the fifty meter level due to a few random species of trees mixed in. Codman North shows the most variability. The second plot stood out more from the first and third because it had a high amount of poison ivy, less diversity at the ten meter level, and a high amount of Buckthorn. Tanner's Brook shows the least variability.

The hemlock communities are all similar, but Adam's Woods clustered separately on all three levels. This is because there is virtually no understory in this plot. One wintergreen and one baby red oak were present. Farm Meadow Forest had more species of trees on the fifty meter level than most. Codman North was unique because its plots were not very similar to each other. Plot two was the most unique because many *Viburnum* were found in it.

The oak dendrograms show groups at each level. The two meter level shows three groups. The top cluster is similar because they all contain only bracken fern. The middle cluster contains bracken fern and additional species such as Canada Mayflower. The last cluster includes sites with an abundance of Canada Mayflower, which was by far the most common species at the two meter level for all sites and communities.

The ten meter level in the oak communities shows two groups. The top group of plots clustered together because they all contain a high amount of early low blueberry. Most of them also contain huckleberry. The second group of plots all contain a lot of Buckthorn and most contain many *Viburnums* as well. Most oak communities had an understory dominated either by *Vaccinium* or *Viburnum* and the dendrogram supports this by the two groups that emerged. Buckthorn was very common and was particularly prominent in Codman South.

The fifty meter level in oak communities shows one group at the top. The rest of the plots are variable. The group clustered together due to the diversity of trees in each plot. Most of them contained numerous species of oaks, red maple, and birches, chestnuts, or hickories. Within each site oak plots were similar to each other. There is less variability between oak woods, making them somewhat homogenous.

The bar graph shows that Farm Meadow Forest was the most diverse property. It contained the highest number of species for any site. This is probably due to its large size and numerous types of communities. Wheeler Rd. was the least diverse because it is rather small and only contained an oak community.

The graphs of site diversity as a function of the proportion of Buckthorn present show that for the ten and fifty meter plots Buckthorn did not effect the number of species found. Buckthorn is an invasive species and it is important to determine if it is taking over the habitat of other plant species.

This study gives a community description, species list, and statistical data to characterize each property in the Town of Lincoln. This information should be useful the in making planning decisions. Further study may build on this information and perhaps the study could be repeated in future years to note changes in the florae of the town.

ACKNOWLEDGMENTS

This work was sponsored by the Lincoln Forest Committee. The cooperation of the Lincoln Conservation Commission was also essential to its completion. In particular, we would like to thank Buzz Constable and Geoff McGeohan for their help. Much of the research done for this report was conducted in The Lincoln Public Library. Our attendance at the 26th Annual Conference on Ecosystem Restoration and Recreation was funded by the Biology Department at Boston College and we would like to thank Bill Petri and Dick Monheimer for their assistance in this matter.

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COST SAVINGS FROM PROPERLY MANAGING ENDANGERED SPECIES HABITATS

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ABSTRACT

Insufficient habitat management, specifically for the threats of invasive exotics and fire suppression, threatens many endangered species. A survey of management costs for federally listed species endangered by the aforementioned threats compared the cost differences between initial "restoration" control, an accrued debt reflecting deferred maintenance, and subsequent maintenance after the threat has been "controlled". Analysis of ~40 cost estimates (from 270+ scientists and wildlife managers contacted) indicates that the initial control costs are approximately 1.8 to 350 times greater than the maintenance cost, which indicates a substantial investment. Without continued maintenance management, these costs may triple in one to tens of years, depending on the threat. Migration of exotic species from unmanaged lands will require active management on both public and private lands. More funding for public lands and incentives for private landowners to conduct adequate active management will allow for the attainment of minimal maintenance costs, after undergoing the high initial restoration costs, and the realization of these "cost savings".

INTRODUCTION

The reduction of federally listed species' habitats will require active management to ensure their survival (Myers and Ewel 1990, Simberloff et al. 1997). In some cases, the required active management consists of prescribed burns and/or removing exotic species. Of the 1,880 species listed under the Endangered Species Act as of 1 January 1996, Wilcove et al. (1998) estimates that exotic species threaten 49% of these species while the disruption of fire ecology threatens 14 %; some of these species face both threats.

Inadequate funding has hampered the recovery process for many federally listed species. The current rate of expenditure for endangered species has lagged compared to the number of endangered species listed (Dobson et al. 1997). The cost of maintaining federally listed species threatened by alien exotic species and fire suppression [on both public and private land] is estimated at US$ 32-42 million 1997 dollars annually (Wilcove and Chen 1998). These costs include management for these two threats in addition to the expenses incurred in monitoring for these species.

Delaying necessary management will likely increase the cost of recovery and habitat management. Removing alien exotic species is most effective when a sufficient number has been removed to prevent the reproduction and the continued growth of the population.

Preventing the establishment of these exotic species and controlling exotics at their initial low population is probably the most cost effective measure (Noss and Cooperrider 1994, Simberloff et al. 1997). Thus controlling for alien species and fire suppression can generate potential savings in the future.

This work attempts to document the difference between the costs of controlling these threats compared to the costs of minimal maintenance management; thus substantial savings may be realized with adequate active management. In this highly charged political climate, this evidence may help allocate and secure additional funds for the Endangered Species Act. Additional money will allow for the continued work to save endangered and threatened species on public lands, and provide incentives such as tax deductions to private landowners who wish to protect federally listed species.

THE THREAT OF EXOTICS AND FIRE SUPPRESSION

Exotic species pose a threat by competing, crowding and smothering native species, changing an area's water table, altering a region's fire frequency or intensity, changing the soil fertility or chemistry, and enhancing predation or disease (Vitousek 1986). Exotic plants may also supplant native vegetation which may be required by other imperilled organisms.

Periodic fire events have been a part of the ecology for some communities. Fire suppression policies have allowed later successional communities to replace fire adapted habitats. Fragmentation and urbanization have also prevented fire from spreading to other fire adapted habitats.

Exotic species and fire suppressed habitats occur over a large range in the U.S. Noxious weeds, most of which are exotics from Eurasia, are present on 3.2 million hectares of the 108 million hectares controlled by the Bureau of Land Management (BLM). This figure may increase to 8 million hectares by the year 2000 (Partners Against Weeds).

These threats are especially pronounced in certain areas. Hawaii records 4,258 exotic species on the islands (Eldredge and Miller, 1995). California faces similar threats from exotics. Parts of Florida face the threat of both exotics and fire suppression. In Florida and other states, mainly those in the southeast, fire suppression has allowed exotics to proliferate (Simberloff et al. 1997).

MANAGEMENT

Controlling exotic species requires a large investment of money, time and labor. Large animals, namely feral ungulates, may be trapped or hunted, and often require fencing to adequately control the population. Smaller animals, especially rats, require extensive poisoning projects. However, plants and invertebrates, specifically insects and molluscs, are more difficult to control. Herbicides and pesticides may also harm beneficial native

organisms, and sometimes the federally listed species itself. In these cases, the only viable option may be very expensive and labor intensive manual removal. Although biological control may be a viable option, it may require several years and millions of dollars (Andres 1981, Harris 1993). Also, conventional control may need to be used to supplement biological control.

Prescribed burning has also helped control exotic species in fire-adapted habitat. Many habitats burn in a cycle of once every few years. These fires control the undergrowth of shrubs and trees, mainly hardwood trees, which would succeed and replace fire adapted organisms. Removal of this woody underbrush requires labor intensive manual methods or machinery. In some cases, this underbrush can not be burned because it accumulates as fuel wood that would burn as longer and hotter fires, destroying fire adapted organisms. Natural periodic fires are relatively low in heat and sweep quickly through the habitat (e.g. long-leaf pine stands). Natural-like prescribed burns provide high quality habitat necessary for fire adapted species such as the food plants for gopher tortoise (*Gopherus polyphemus*), allowing the tortoise to grow faster and attain sexual maturity at younger age (Mushinsky et al. 1994).

METHODS

Surveys were sent to wildlife managers, refuge managers and scientists. Most letters were sent by electronic mail. Information was requested from additional agencies, including the Fish and Wildlife Service, Bureau of Land Management, the Forest Service, state personnel, and The Nature Conservancy land managers. The letter requested information on:

1) A cost estimate for habitat restoration and habitat maintenance at the site for managing exotic species and conducting prescribed burns. The manager was asked to elaborate on the difference in cost between minimal maintenance and habitat restoration to attain the minimal maintenance level for these two threats.

2) The extent of cost increases if management is deferred for some time, for example for 1, 3, 5, 10, 25, etc. years? In otherwords, after the period of neglect, what is the cost to restore the habitat to a condition that requires only minimal maintenance?

3) The number of years of neglect that would likely cause the species' extinction (or more accurately extirpation)?

The message also provided an example of either a prescribed burn management in Florida by Rodger Hammer of the Metro-Dade County Park and/or exotic tamarisk control by Curt Deuser of the Lake Mead National Recreation Area . The Florida example discussed the large cost difference between the restoration of fire adapted habitat and subsequent prescribed maintenance burns. Similarly, the tamarisk control discussed the large cost difference between the initial removal of tamarisk and later spot herbiciding to prevent its re-establishment. A phone number, mail and electronic mail address were included.

RESULTS

SUMMARY ANALYSIS

Of the over 270 scientists and wildlife managers contacted, less than 40 provided cost estimates. Many managers replied that they were unable to provide estimates because of the difficulty of separating the costs of treatment from the overall budget and/or an individual's salary. In some cases, for areas that had been restored, managers were unable to estimate how many years of neglect would lead in the reversion of the habitat to its pre-restored state. Many managers understandably have been conducting active management to prevent the degradation of the habitat. A literature search identified few cost estimates related to the management of these threats.

Analysis indicates that the initial control/restoration costs are approximately 1.8 to 350 times greater than the maintenance costs, which indicates a substantial investment in the project (Table 1). Without continued maintenance management, these costs may triple in one to tens of years (Table 2). In many cases, costs increase over time for neglected management (an undiscounted and 6% discrete discount rate were considered). The rate of the cost increase for some of these threats may cause the management costs to double, relative to the maintenance costs, before the next management cycle.

For each project, the cost of continued management was compared to the cost of conducting deferred management. The accumulated cost of continued management was then subtracted from the cost of deferred management for the same time period; the time period used was the time when maintenance costs increased to the deferred maintenance costs.[1] Cost figures were discretely discounted at a 6% rate.

The first 8 (counting the first two cases as one) of the 19 results show that neglecting management and later restoring the habitat is more expensive than conducting regular maintenance (Table 2). The benefits of continual maintenance for these projects (prescribed burns in scrub habitats, saltcedar control, and feral pig eradication) are greater than the costs of neglecting the management for these threats and controlling the threats later.

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[1] For example, for the management of salt cedar at the lake Mead National Recreation Area, herbicide is used every 2 to 3 years at a maintenance costs of $8.5/acre for areas that have been controlled (in year 0). However, if management is deferred for 10 to 15 years, the cost to return the habitat to the controlled state will cost $675/acre. To determine the low range figure of cost savings, the cost of biennial maintenance costs for 15 years per acre was summed using a 6% discount rate to attain a cumulative per acre figure of ~$38.4 (7 treatments in a 15 year period at a 6% discount rate: ~$38.4 = $7.6 + $6.7 + $6.0 + $5.3 + $4.7 + $4.2 + $3.8). This amount of ~$38.4 was then subtracted from the deferred maintenance cost of $281.7 ($675/acre discounted at 6% per year for 15 years), resulting in a $281.7/acre cost savings for regular management. Dollars per acre cost were then multiplied by 2.471 to obtain dollars/ha.

As also seen in Table 2, there may also be negative cost-saving values ranging to $-8,396 per ha ($-3398 per acre). In other words, it is more cost effective to defer habitat management for certain projects than to manage the habitat regularly. However, for some habitats, in the amount of time that management costs exceed deferred management costs, the species in question may be extirpated. This was seen for 3 cases (the karner blue butterfly, European beachgrass and yellow lupine bush removal). In these 3 cases, the individuals contacted were able to estimate the years of neglect that would lead to the species local extirpation.

For cattail control and largemouth bass eradication at Ash Meadows NWR, it was found that in the short term, deferred management does not exceed the cost of regular management (Table 2). However, if management continues to be deferred, the situation changes. Thus in terms of cost effectiveness, it would be more efficient to conduct cattail control after 5 years of deferred management. Similarly for largemouth bass control, it would be more cost effective to control bass after 10 years. Costs appear to escalate to some threshold level where after 5 years for cattails and 10 years for largemouth bass control deferred management is not cost effective. However, again, this does not consider the impact deferred management has on the species' status, especially for the threat of largemouth bass. Thus, in situations in which regular maintenance have negative cost savings relative to deferred management, prolonged neglect may lead to eventual cost savings beyond the parameters considered in this assessment, i.e., additional costs related to endangered species recovery.

As expected, the discount rate will have a substantial effect on the cost savings obtained from proper habitat management. In general, costs savings increase; for negative cost saving values, these values increase positively. At a zero discount rate, an additional four projects would show positive cost savings from proper management: saltcedar control, other non native fish control and noxious weed control at Ash Meadows NWR, and prescribed burns for pondberry. A 0% discount rate does not make tree removal for pondberry more cost effective. At a 0% discount rate, as seen in the cattail and largemouth bass eradication case, prescribed burns for the Dismal Swamp shrew become cost effective when management is deferred after 25 years.

Also, the use of the 6% discount rate accounts for the negative costs savings after 25 years of deferred management of prescribed burns for pondberry (but the positive cost savings after only 10 years). With a 6% discount rate, the sum of the accumulated discounted regular maintenance costs, $133/ha, are greater than the discounted 25 years deferred management cost, $116/ha. At a 0% discount rate, there are positive cost savings for regular management after both 10 and 25 years of deferred management. The sum of the cumulative regular maintenance costs, $297/ha ($59/acre every 5 years), is less than the deferred management costs of $494/ha.

Table 1: Ratio of restoration or control cost to maintenance costs (Ranked)

Site	Threat	Years of neglect	Ratio of restoration or control cost to maintenance cost	Contact
Beachgrass restoration for beach layia, Humboldt Bay wallflower	European beach grass, iceplants	not given	350	(1)
[(1)]Kudzu eradication	kudzu	not given	80 to 140 (32-37)	(2)
Ash Meadows Naucorid and listed fish (amargosa pupfish, warm springs pupfish, speckeled dace)	Saltcedar	not given	100	(3)
[(2)]Big Bear Valley- Baldwin Lake Preserve	exotic grasses and lupines	not given	80	(4)
Desert tortoise, Nelson Bighorn Sheep (rare), Southwestern willow flycatcher	Salt cedar	10 to 15	79.4	(5)
Scrub habitat	Fire Suppression	20 to 25	40 to 60	(6)
Smith's blue butterfly (*Euphilates enoptes smithi)*	Exotic plants	5 to 20	50	(7)
Scrub habitat	Fire Suppression	10 to 20	30	(8)
Bosque del Apache NWR	Salt cedar	10 to 15	35.7 to 61.9	(9)
Coastal scrub habitat	Fire Suppression	10 to 25	20 to 30	(10)
Yellow bush lupine control for Humboldt Bay wallflower, beach layia	yellow lupine	not given	26	(1)
Coastal scrub habitat	Fire Suppression	10 to 15	10	(10)
Prairie	Fire Suppression (& weeding)	not given	2 to 10	(11)
Hakalau Forest	ungulates	not given	5.8	(12)
Non-forested Marsh unit (Dismal Swamp Shrew)	Fire Suppression	25 to 30	5.7	(13)
Prairie	Rhamus ssp.	not given	3.8	(14)
Prairie and oak barrens	musk thistle	5	3	(15)
Okeefenoke Scrub Habitat (Indigo Snake & Gopher tortoise)	Fire Suppression	not given	3	(16)
Ash Meadows Naucorid and listed fish (amargosa pupfish, warm springs pupfish, speckeled dace)	Cattails	not given	2.7	(3)
Eastern Neck NWR	Johnson grass & canadian thistle	5	3[(3)]	(17)
Jester Park woods and grassland	Lonicera ssp.	not given	2.2	(12)
Oak barrens for Karner blue butterfly (NH)	Fire Suppression	4	2	(18)
Non-forested Marsh unit (Dismal Swamp Shrew)	Fire Suppression	10 to 15	1.8	(14)
Santa Cruz Island Preserve	feral sheep	not given	$1.2 M total spent, $5k/yr	(19)
Santa Cruz Island Preserve	feral pigs	not given	$2.5 M total spent, $~30k/yr	(19)
Santa Cruz Island Preserve	fennel	not given	$1.25M total spent, $1k/yr	(19)

[(1)]Figure given for initial restoration; at current "transition" restoration cost, ratio at 32-37

[(2)]Bear valley sandwort (*Arenaria ursina*), Ash-grey Indian paintbrush (*Castilleja cinera*), Southern mountain wild buckwheat (*Eriogonum kennedyi var. austomontanum*), San Bernardino bluegrass (*Poa atropurpurea*), Califonia dandelion (*Taraxacum californicum*)

[(3)]$25/acre treatment cost constant, more land need to be treated with neglect

Table 2: Estimated Cost savings of continued active management vs. deferred management (0% discount rate, 100 ha)

Threat managed for species and/or habitat	Years of neglect to increase maintenance costs, if provided (amount of increase)	Years of neglect to cause species' extirpation	Approximate cost savings per ha (unless otherwise noted)	Contact
Prescribed burns for Scrub Habitat	10 to 20 (increase to $37,065 from $1,236/ha)		$4,434 to $19,084	(1)
Prescribed burns for Scrub Habitat	20 to 25 (increase to $49,420to $74,130 from $1,236/ha)		$3,390 to $19,316	(1)
Prescribed burns for coastal scrub habitat	10 to 15 (increase to $2,471 from $247/ha) and 10 to 25 (increase to $4,942 to $7,413)		$756 to $4,001	(2)
Salt cedar control for desert tortoise, bighorn sheep, and southwestern willow flycatcher	10 to 15 (to initial restoration costs of $1,544/ha, maintenance $21/ha)		$600 to $887	(3)
Salt cedar control at Bosque del Apache NWR	10 to 15 (to initial restoration costs of $751 to $1,300/ha, maintenance $21/ha)**		$217 to $682	(4)
Pig control at Hakalau Forest NWR	1 (maintenance costs, $531/ha) tripled)		$445	(5)
Cattail control at Ash Meadows NWR♣	3 to 25 (per stream-mile: $69 eradication; $766 after 3 years, $219 after 5 years, $313 after 10 years, $625 after 25 years)	no number of years	$77 to $106 per stream-mile	(6)
Kudzu eradication	5 ($62/ha maintenance, restoration $247/ha)		$32	(7)
Largemouth bass control at Ash Meadows NWR for Ash Meadows Speckled Dace♣	3 to 25 (per stream system: $1,000 eradication, $1,800 after 3 years, $1,200 after 5 years, $2,000 after 10 years, $5,000 after 25 years)		($-103) to $165 per stream system	(6)
Prescribed burns for pondberry	10 to 25 (per ha: maintenance $59; $247 after 10 years, $494 after 25 years)		$62 to ($-133)	(8)
Saltcedar control at Ash Meadows NWR♣	3 to 25 (per ha: $247 eradication; $250 after 3 years, $259 after 5 years, $297 after 10 years, $371 after 25 years)		($-38) to ($-161)	(6)
Tree removal for pondberry	10 to 25 (per ha: maintenance $124; $247 after 10 years, $371 after 25 years)		($-22) to ($-193) per stream system	(8)
Other non-native fish control at Ash Meadows NWR for Ash Meadows Speckled Dace♣	3 to 25 (per stream system: $1,000 eradication; $1,020 after 3 years, $1,040 after 5 years, $1,100 after 10 years, $1,500 after 25 years)		($-144) to ($-651)	(6)
Noxious weed control at Ash Meadows NWR♣	3 to 25 (per ha: $494 eradication; $499 after 3 years, $509 after 5 years, $544 after 10 years, $618 after 25 years)		($-74) to ($-351)	(6)
Prescribed burns for Dismal Swamp shrew	10 to 30 (maintenance $138/ha: increase $247/ha after 10 to 15, and $791/ha after 25 to 30 years of neglect)		($-52) to (-$556)	(9)
Musk thistle eradication	5 (maintenance costs, $49/ha, tripled)		($-96)	(10)
Canadia thistle and Johnson grass eradication*	5 (hectares treated tripled, from 494 to 1,483 ha)		(-394%/ha)	(11)
Prescribed burns for Karner Blue butterfly	4 (maintenance costs doubled), 8 (maintenance costs quadrupled)	3-4	(-398%/ha) to (-1021%/ha)	(12)
Fennel control at Santa Cruz Island Preserve	5 to 10 (maintenance costs, $247/ha, double or triple in 5 to 10 years)		($-487) to ($-1,406)	(13)
European beachgrass removal for Humboldt Bay wallflower and beach layia	5 to 10 (maintenance $247/ha; costs increase $12 to 25/ha)	10	($-838) to ($-1,668)	(14)
Yellow bush lupine removal for Humboldt Bay wallflower and beach layia	5 to 10 (maintenance $1,236/ha; costs increase $12 to 25/ha	5	($-4,262) to ($-8,396)	(14)

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*cost per ha figure does not change, but the number of has needing treatment increases
**using assumption of tamarix re-establishment from C. Deuser
♣threat eradicated

ANALYSIS FOR FIRE SUPPRESSED HABITAT MANAGEMENT COSTS

Certain biomes experience greater degradation with delayed management than others. Although grasslands may be replaced by later successional vegetation, these plants does not create extensive fuel wood vegetation as in fire adapted habitats which succeed to hardwood forests (pers. comm. Dale Sablo of TNC, Michael Amaral of FWS, Margaret Shea TNC). As shown in Table 2, deferred management costs increase at a relatively faster rate for fire adapted habitats such as pine barrens. Fire adapted habitats burn periodically, sometimes between as little as 2 to 5 years, to 50 years. Thus, without regular managed burns, cost figures may quickly increase, as later successional plants encroach the habitat. Because burning neglected fire adapted habitats will produce uncharacteristically intense hot fires, accumulated herbaceous fuel material must be removed manually, or with rotary drums, hog-chokers or similar machinery increasing management costs.

Factors other than the fire frequency of the habitat and the severity of the neglect influence prescribed burn costs. Controlled burns in the Metro Dade area cost $1236 per ha ($500 per acre) for regularly managed habitats; in areas where fire has been excluded for 20 to 25 years, the costs for burning and restoring the area costs about $49,420 to 74,130 per ha ($20,000 to 30,000 per acre) (spent over 2 to 3 years) (R. Hammer, Metro Dade County Parks and Natural Areas Management, Florida, pers. comm.). For other management areas, the costs may be as low as $36.20 per ha ($14.65 per acre) (Dubos et al. 1997). These differences may be caused by the scale of the burn, and the location of the habitat. In the Metro Dade area, management involves conducting prescribed burning in small patches of a few acres. These habitat patches are also near multi-million dollar homes and areas of human habitation, which requires more labor and equipment to control the fire (according to R. Hammer, these maintenance fires provide the additional benefit of reduced catastrophic fires and thus lower fire insurance premiums). In other areas, successive winter-dormant season burns may adequately reduce fuel-load; this may require burning the habitat several times over several years until the habitat has been "restored" (pers. comm. Ron Fernet, Okefenokee NWR, GA).

In some areas, instead of burning the forest, timber harvesting mimics the disturbance habitats would experience from periodic catastrophic fires. This type of management is prevalent in parts of Florida in stands of long-leaf pine forests. Harvesting to simulate natural disturbances also occurs on Kirtland's Warbler habitat (pers. comm. Mike Decapita, FS MI). Examples like this should be approached with caution; the habitat of a federally listed species should be managed for the benefit of the species, rather than to maximize profit.

Analysis for Exotic Animal Species Management Costs

Controlling exotic species generally depends on the taxa of the species. Removal of exotic animals often requires traps and fences, due to its mobility. Usually, large land areas are broken into several more manageable units. Early attempts to control feral ungulates (wild goats, pigs and deer) at Volcanos National Park (VNP) on the island of Hawaii reflects the need for a comprehensive control effort. From 1917 to 1971, snares were the only means of ungulate control. Although the snares trapped ungulates, not enough snares were used; source populations outside allowed additional animals to enter the park. As a result, it was estimated that the population of feral ungulates had not changed during the course of this control effort. A comprehensive ungulate control plan was later instituted, and feral ungulates were adequately controlled at VNP in about 10-20 years (Alan Holt, TNC Hawaii, pers. comm., based on conference proceedings).

Subsequent comprehensive feral ungulate control efforts require relatively large amounts of resources. At Hakalau NWR and the Santa Cruz Island Preserve, fences must be transported to relatively isolated areas by boat and/or helicopter. In addition to building fences, these fences must be maintained, snares monitored, and, where used, hunting dogs housed and fed. Until ungulates are eradicated in fenced unit, the population has the potential to grow quickly. At Hakalau Forest NWR, the pig population within a fenced area tripled the next year without continued ungulate control; because of administrative problems, management was compromised and more money was spent to control these "new" pigs (Jack Jeffrey, Hakalau Forest NWR, pers. comm.).

Analysis for Exotic Plant Species Management Costs

After the removal of feral ungulates, managers discovered that the ungulates had somewhat controlled non-native vegetation. The removal of feral ungulates on the Santa Cruz Island preserve allowed other exotic plants to proliferate, which posed a greater threat to the native vegetation than the ungulates (pers. comm. Rob Klinger, TNC). Similarly, in Hawaii, cattle maintained in certain areas control exotic blackberry and banana poka, preventing seed dispersers from spreading exotic weeds which would outcompete the native vegetation (pers. comm. Jack Jeffrey, Hakalau Forest NWR).

In many parts of the southwest, the exotic saltcedar (*Tamarix*) has dominated much of the landscape. Because of the tremendous impact of saltcedar, extensive research has been invested in controlling it. Taylor and McDaniel (in press) cited a figure of approximately $750 to $1300 per hectare to initially control saltcedar. Curt Deuser (pers. comm.) cited similar figures of $600 per acre, about $1700 per hectare, to initially control saltcedar, and

about $8.5 per acre, or $21 per hectare, to conduct maintenance control of the area. Deuser also maintains that maintenance type management is needed immediately the next year (the year after initial management), with similar management every two or three years later (year 4 or 5). Maintenance primarily consists of herbicide application (Curt Deuser pers. comm.), thus the costs will be considerably greater than the $21 per ha figure for sensitive areas where herbicides should not be used, such as drinking groundwater areas.

DISCUSSION

GENERAL ENDANGERED SPECIES MANAGEMENT

Future recovery efforts will also require greater cooperation between agencies (Fish & Wildlife Service, Bureau of Land management, Forest Service, state environmental agencies) and private land owners (corporations and individual citizens). Management will need to address endangered species conservation on private land. About 56% of all federally listed species have 81 to 100% of their habitat on private lands. The status of species protected by the Endangered Species Act shows that (on both public and private land) only 9 % of species are recovering, 33% are declining, 27% are stable, and the status of 31% is unknown. Some landowners will not permit government agencies on their property, fearing that if an agent discovers an endangered species, the landowner will face restrictions on their land. Understandably, information is available for 51% of the species that occur on private land (Wilcove et al. 1996).

Restoration activities may require habitat revegetation. Revegetated plants may serve as a resource base for federally listed species (the endangered species' food source), allowing for the species and recovery. Revegetation also may help prevent the re-establishment of exotics after its removal. Extensive initial revegetation, in addition to restoration costs, decrease the costs of subsequent maintenance costs. These high initial restoration costs and low maintenance costs lead to the high ratios seen for some of the projects in Table 1 (especially beachgrass restoration).

Exotics may re-establish themselves in an area from other populations, via seeds or physical movement. Unless these exotics are controlled in peripheral areas, periodic monitoring and management will essentially be required to continue in perpetuity. In one example, a site in Kentucky was cleared of the exotic musk thistle. However, this habitat, managed for prairie and oak barrens, has been continually invaded by musk thistle seeds blowing onto the restored area from neighboring private lands (pers. comm. J. Bender, Stewardship Coordinator for Kentucky State Nature Preserve Commission). Thus habitat management poses an additional problem when adjacent areas, especially privately owned land, fail to adequately control the

exotics that occur on their property.

CASE STUDY: SALT CEDAR

Management may require gradual removal of exotics. In the case of saltcedar, this exotic may simultaneously benefit and harm endangered species. The exotic saltcedar (*Tamarix* spp.) has replaced most of the other trees and undergrowth that provides insect habitat and nesting sites for the southwestern-willow flycatcher's food resource (U.S. Fish and Wildlife Service, 1995). Also, saltcedar occurs on the riparian habitat of approximately 50 federally listed species and potentially listed species in the western U.S. (Hunter 1984, Hunter *et al.* 1987, Anonymous 1995). Thus controlling for tamarix (and exotics and the habitat in general) may benefit other species, and prevent their listing as an endangered species.

The distribution of saltcedar is estimated at about 607,050 hectares in arid and semi-arid areas (Brotherson and Field 1987), which includes approximately 6,475 hectares in CA (Johnson 1987). Extrapolating from the cost control figures provided by Curt Deuser (converting the figures to $1657.25/ha for restoration, and $21/ha for maintenance), the total cost of initially controlling saltcedar totals $1,012 million. Continued maintenance would total $4.25 to 6.37 million annually (with 2 to 3 years between maintenance treatment). Using the figures determined by Taylor and McDaniel (in press), initial restoration would total $455 million to 790 million.

Development of saltcedar biological control may still be a few years away; in December 1994, an Environmental Assessment was started for the release of the mealybug *Trabutina mannipara* and the leaf beetle *Diorhabda elongata*. Even with the use of biological control, researchers have estimated that saltcedars will not be controlled for 5 to 10 years, and that 20 to 25% of the biomass will remain. These researchers do not know if saltcedar may still spread at these densities and cause environmental degradation (Biological Control of Saltcedar). Even with the use of biological control, additional saltcedar control may cost a percentage of the $455 to 1,012 million initial control cost, an amount considerably greater than the maintenance cost.

However, even with the physical removal of saltcedar, saltcedars will continue to thrive, and native plants will not survive, unless natural flooding is allowed to promote native plants while drowning young tamarix. However, much of this water has been diverted for irrigation. As a result, tamarix tolerate the salts in the runoff that returns to the waterways and outcompete native vegetation (C. Deuser, pers. comm.).

SOCIAL CONSIDERATIONS IN HAWAIIAN CONSERVATION

Removing large ungulates often presents unique social problems. Some individuals have moral objections to the lethal control or removal of ungulates. Native Hawaiians object to the loss of pigs, goats and deer that have been part of their cultural hunt. Because of public pressure, pigs were removed from Hakalau Forest NWR with hunting methods, which is more expensive and time consuming than snares (Jack Jeffrey, Hakalau Forest NWR, pers. comm.). Discussing the subject of exotic control with several Hawaiian wildlife managers, they indicate that some of the fence breaches may have been "suspicious" in nature. Human consumption of feral Hawaiian pigs presents an additional public health problem. Because of concerns of secondary exposure to human hunters, the anti-coagulant poison used heavily in sugar cane fields to control rats was discontinued after the early 1980's. The poison must now be placed in tamper-proof bait stations (Hilton and Pank 1981, Engeman and Pank 1984).

However, rats are a prominent threat to federally listed Hawaiian species (pers. comm. with several Hawaiian refuge managers). Aerial distribution and bait stations of the anti-coagulants brodifacoum have successfully eradicated Kiore (the New Zealand rat *Rattus exulans*) from 250 hectare islands (Clout and Saunders 1995). The New Zealand Department of Conservation plans to eradicate Kiore from islands as large as 3,000 ha (Clout and Saunders 1995). Successful elimination of Kiore from large islands shows potential for similar control on the Hawaiian islands.

Controlling for rats and mice may present additional benefits, especially for agricultural regions. In Hawaii, it is estimated that rats conservatively cause $6 million dollars annually in sugar cane damage (Tobin and Sugihara, 1992). In addition, the Hawaiian agricultural industry estimates that the refusal from potential markets of Hawaiian exports because of alien pest infestation of crops amounts to $300 million per year in lost revenue (USDA APHIS Activities in Hawaii). These damages have been assessed; additional cost savings may be realized in the insurance industry. However, this demonstrates the need to conduct comprehensive, area wide control measures on both public and private lands, or else populations may re-invade from other sites. Similarly, funding will need to address control efforts on both private and public lands.

CONCLUSIONS

Immediate restoration may be imperative in areas imminent with attaining threshold levels of species- an alternative steady-state area consisting of exotic and fire intolerant species rather than the native species. The proliferation of exotic and fire intolerant species may cause a positive feed back encouraging further establishment of exotic and fire intolerant species, and

a negative feed back to native species reintroduction. We may expect to see slow and expensive rehabilitation for areas in which thresholds have been passed (Noss and Cooperrider 1994).

Thus acting now may allow for substantial savings in the future and the recovery of species threatened by exotic species and fire suppression. Once achieved, maintaining minimal maintenance both protects imperilled species and saves money in the recovery cost. Neglecting management for even a few years may cause the cost for maintenance control to increase to the high levels spent to initially control the problem. Neglecting management for even a few years may also cause the local extinction of a species.

Because many federally listed species and exotic species occur on private lands, incentives must be provided for private citizens to manage their lands for the benefits of these species. Conversely, without comprehensive area-wide control, exotic species may re-establish themselves from other sources. Adequate management may eventually provide the greatest cost savings- the delisting of a species. Ultimately, the existence of a single species should not be valued in dollars. Each species provides wealth to the individual who recognizes its priceless value.

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" Utilizing Skilled Volunteer Assistance To Develop A Natural Resource Area Management Plan For A Waterfront Park In Florida "

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ABSTRACT

In late 1998 it was decided to explore alternatives for suitable utilization of a 35-acre natural resource area within Philippe Park, Safety Harbor, Florida. Emphasis is placed on ecological education and conservation of existing habitats within this area. The preliminary stage of this program utilizes skilled volunteers working under the direction of the park supervisor to prepare the initial project program, feasibility study and conceptual design. A Technical Advisory Committee (TAC) is utilized to provide assistance with coordination of ecological and regulatory issues. Currently this project is "a work in progress". This paper addresses the initial organization of the team and implementation of the planning process.

Philippe Park is a 122-acre waterfront park on Tampa Bay, Florida. It is one of 22 parks maintained by Pinellas County Park Department. There are significant natural, historical and archaeological sites within Philippe Park boundaries. As mentioned above the park contains a 35-acre wetland area consisting primarily of a mangrove ecosystem.

The park is staffed with 11 employees, headed by a Park Supervisor. Their primary function is operation and maintenance of the park. Limited resources are available for inventories and planning at the field, or park level, thus, the decision to utilize skilled volunteers to facilitate this process. Once a program is developed the Park Department Headquarters manages the major studies and contractual work.

Project Program

In order to systematically develop the preliminary analysis and planning for this project a phased program was established. The functional phases for this program are shown in Figure 1.

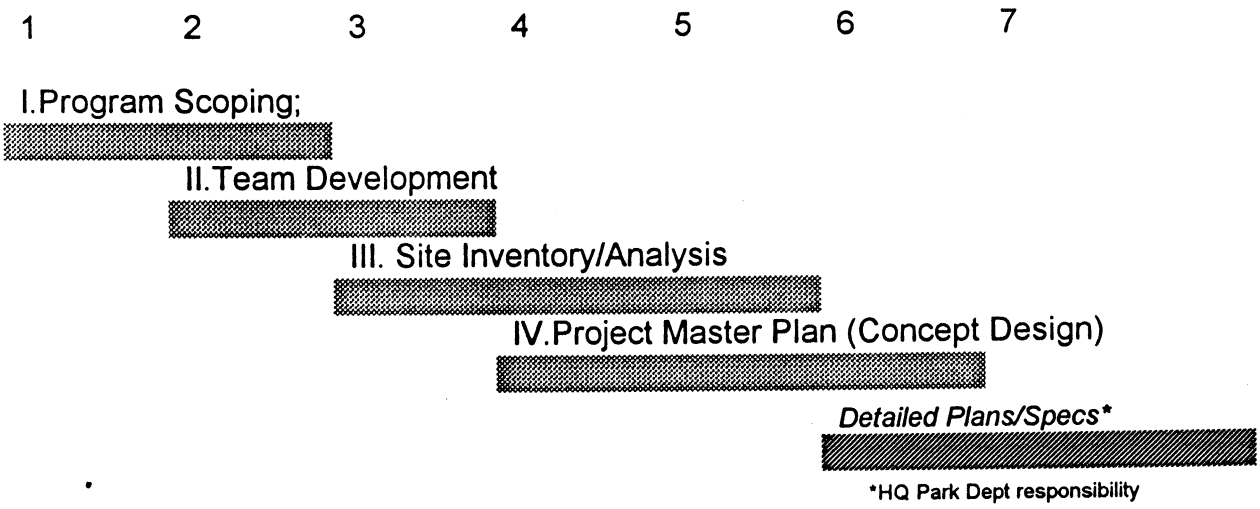


FIGURE 1 PROGRAM PHASES

The activities for these four phases are:

I. Program Scoping. This phase involves the establishment of goals and approaches to development of the program. Project alternatives are formulated and chosen. At this point the team organization and qualifications are defined. A Technical Advisory Committee (TAC) is also recruited to assist with the program.

II. Team Development. This phase involves the recruiting and training of the skilled volunteers to staff the team. Skilled Volunteers are defined as individuals whose background, because of prior education and/or experience, qualifies them to perform assigned tasks on the planning team without additional professional training. Because these individuals are volunteers this phase will take longer to complete than if it was done with an existing organization. Interns from local universities are used to collect data and assist with assembly of information. Recruitment of the team was facilitated by assistance from the Pinellas County Volunteer Services Department.

III. Site Inventory /Analysis. This phase catalogs the physical conditions of the natural resources and adjacent areas. An ecological planning approach will be utilized. Results of these inventories will be added as layers to the Park Department's CADD system. This will provide a capability for continuous update of information. Available GIS information from other County and State agencies will also be utilized. An analysis or impact assessment of the proposed alternatives is made during this phase as well as a determination of the environmental regulatory compliance and mitigation measures that will be required.

IV. Plan Formulation, This phase produces the conceptual plan and schematic designs that would be used as the basis for the final project master plan, engineering and construction documents that might be required. As noted above the final decision and project documents would be developed by the Park Department staff. Included in this phase is the development of preliminary schedules and cost estimates.

THE PROJECT TEAM

Figure 2 shows the organization of the project team.

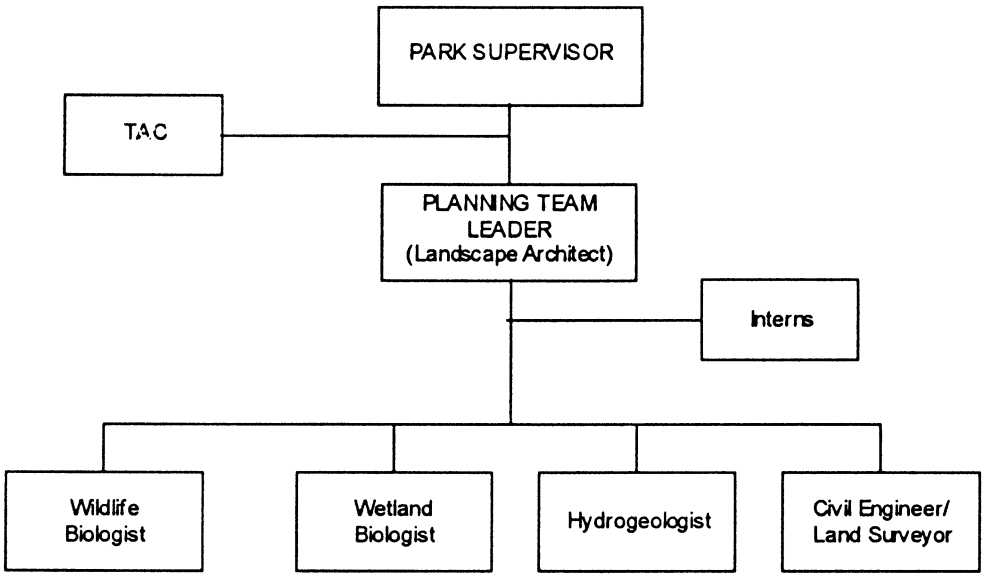


Figure 2, Team Organization

The core disciplines for the team include a landscape architect, wetland biologist, wildlife biologist, hydrogeologist, and a civil engineer/land surveyor. Supporting these disciplines are interns from local universities and colleges. Additional assistance may be provided by agency employees performing in an on-the-job training (OJT) status in order to improve their qualifications for career advancement. This work would be in an unpaid basis and with prior approval of their supervisors.

THE DELIVERABLES

The Volunteer planning team responsibility is to develop and prepare a proposed program for utilization of the natural resource area in Philippe Park. The team reports directly to the Philippe Park Supervisor. This program will produce the following deliverables:

1) The Natural Resource Area Management Program
2) The Site/Inventory and Analysis
3) The preliminary Project Master Plan

SUMMARY

The natural resource area planning project is a work-in-progress. Final results will be achieved in 12 to 18 months. The Park Department will achieve several benefits from this approach. Among these are: ability to perform site analysis and design at the operational level, reduction of preliminary capital improvement costs, access to a broader range of expertise, improved coordination with other agencies and stake holders. Perhaps the most important benefits from using volunteers in this process will be facilitation of the public involvement process.

PARTNERSHIP WITH LOCAL SCHOOLS TO MONITOR BIOLOGICAL SUCCESS CRITERIA

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ABSTRACT

Pinellas County Department of Environmental Management (PCDEM) formed partnerships with Plumb Elementary and St. Paul's School to monitor biological success criteria at two restoration sites. The first, the Maple Swamp Restoration Project is an environmentally and hydrologically disturbed ecosystem within the Allen's Creek watershed. It is being restored to enhance wildlife habitat, improve water quality and alleviate flooding and erosion problems. Students from Plumb Elementary School with PCDEM staff monitor animal track stations and herpetological funnel traps throughout the school year at this site. Restoration construction commenced in late 1998. The second, the Allen's Creek Oligohaline Habitat Restoration Project, involved the excavation of vacant upland and planting of native plants to create two acres of oligohaline wetlands. St. Paul's School students monitor plant growth and plant survival at the site. Preliminary data suggest that wildlife use, including birds and marsh rabbits, has increased after site restoration. Native plants have also volunteered at the site thereby increasing plant diversity. Both projects provide an effective mechanism for environmental education through direct public involvement.

INTRODUCTION

The Allen's Creek Watershed is a typical urban stream in the central portion of Pinellas County. The Allen's Creek watershed is within the boundaries of Pinellas County, the City of Clearwater and the City of Largo. The watershed management plan was adopted by the Board of County Commissioners in October of 1996 and by the City of Largo Commission in May of 1997. Several projects identified in the watershed management plan have been implemented. Pinellas County worked with two local schools and local residents to measure success criteria for two watershed restorations, the Maple Swamp Habitat Restoration Project and the Allen's Creek Oligohaline Habitat Restoration Project. The Maple Swamp project combined stormwater treatment, habitat restoration, and educational and recreational use at a single site. Pinellas County, the City of Clearwater and the Southwest Florida Water Management District funded the design and construction of this project. The Oligohaline Habitat Restoration Project converted upland residential lots to a meandering low salinity tidal stream and wetland system to enhance habitat for aquatic species' use including snook,

redfish, spotted seatrout and blue crabs. Pinellas County and the Southwest Florida Water Management District funded the design and construction of this project.

Public participation was incorporated in both projects to promote environmental education. Pinellas County Government formed partnerships and offered assistance in environmental projects at local schools near the project sites. Teachers and students volunteered to help monitor plant growth and diversity and wildlife use at both project sites. Furthermore, teachers have incorporated environmental lessons from these projects into their science curricula.

STUDY SITE

Maple Swamp Habitat Restoration Project

The project site covers approximately 25 acres of county and city owned properties lying east of Hercules Avenue and north of Lakeview Road in Pinellas County. The site is adjacent to Plumb Elementary School and within a mile of Oak Grove Middle School and Clearwater High School. Historically, this area was a large maple swamp that served as a biological filter and provided good habitat for wildlife. The creek's main channel meandered through the swamp. The area was heavily degraded from fill, peat mining and soil removal for construction sites. The removed soil left wet depressions that support nuisance or exotic vegetation such as primrose willow, Brazilian pepper and cattail. In areas where peat was mined Brazilian pepper trees and air potato vines have invaded. The project diverted and meandered the main channel through a restored maple swamp and a small lake. The restored swamp will help treat stormwater thereby improving downstream water quality. The small lake will provide additional water storage during storm events. Exotic and nuisance vegetation were removed and replaced with desirable native plants and trees throughout the site. Construction is expected to be completed in August of 1999.

Oligohaline Habitat Restoration Project

An oligohaline (low salinity) wetland marsh was constructed on the southwest corner of Belleair Road and St. Paul's Drive within the Allen's Creek watershed in central Pinellas County (see Figure 1). The site is less than a mile from St. Paul's School. Historically, this site was a tidal marsh dominated by black needle rush. An upland forest drained to the branches of Allen's Creek that meandered through the saltwater marsh. The area was filled to create residential lots. The two-acre upland parcel dominated by Brazilian pepper, an exotic and invasive plant, was excavated to create two small islands surrounded by meandering streams with intertidal and subtidal zones. The tidal zones were planted with marsh grasses including *Spartina alterniflora, Spartina patens, Spartina bakerii, Paspalum vaginatum, Distichlis spicata* and *Juncus roemerianus*. Transitional buffer zones were created and planted with salt tolerant native plants including *Iva imbricata, Helianthis debilis, Borrichia frutescens and Ipomea pescaproe*. Upland areas were planted with native trees and shrubs. An educational sign was installed at the site to depict and explain the purpose of the

project and identify the plants and animals that utilize the site. This site is one of the few places in Allen's Creek where salinity is appropriate for oligohaline juvenile fish.

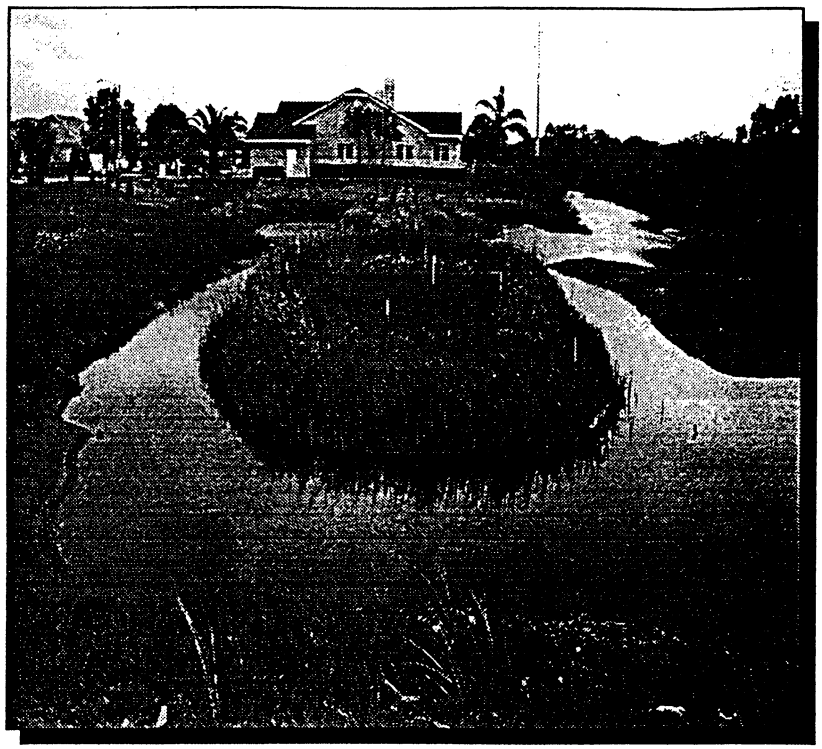


Figure 1. Oligohaline habitat restoration project.

MATERIALS AND METHODS

Maple Swamp Habitat Restoration Project

The project has incorporated data collection on plants, fish, birds, mammals, amphibians, and reptiles observed using the project site before and after restoration. The information will be used to assess restoration success by evaluating the number and types of animals using the restored habitat. To monitor wildlife activity, the County formed a partnership with Plumb Elementary School which is located adjacent to the project site.

Drift Fence Array

Two drift fence arrays were used to sample the study area. The drift fence arrays were installed to intersect movement corridors of animals which are often channeled by topographic contours or vegetation boundaries. The arrays were placed 100 meters apart to sample spatial differences in herpetofaunal communities. Each array had 12 funnel traps consisting of six double ended funnel traps and six single ended funnel traps. Each funnel trap had a moist cellulose-based sponge in a small plastic container to supply water to captured animals.

The traps were deployed on Mondays and removed on the following Fridays. Trap catch was checked daily from Tuesday through Friday to minimize mortality of captured animals. The student participants took turns doing different tasks whenever they visited the sampling stations.

Mammal Track Stations
Six mammal track stations were set up throughout the project area, each near a water source. The mammal stations were checked for animal footprints daily from Monday through Friday.

Training
A hands-on training course on how to conduct wildlife surveys was given to all project participants. This included a discussion of:

- ❑ the importance of native plants;
- ❑ why exotic plants are not beneficial to the community;
- ❑ the impacts of native and exotic plants on wildlife;
- ❑ how to take water temperature;
- ❑ how to read the staff gauge;
- ❑ how to take apart a funnel trap;
- ❑ how to put a captured animal in the specimen box;
- ❑ how to hydrate the sponges and their containers;
- ❑ how to take a captured animal out of a funnel trap (children were not allowed to handle snakes or take them out of the traps);
- ❑ safety tips;
- ❑ how to fill out a drift fence capture data sheet;
- ❑ how to use the field guide books;
- ❑ what they can do with what they learn at the sampling stations.

During the first field visit to the sampling stations, the teacher and students were accompanied by a County biologist. The County biologist supervised and provided further training to the students.

Sampling Period
Wildlife monitoring with the students started in October 1997 and ended in May 1998.Each class volunteered to check the traps and mammal track stations for one week. Students also noted water temperature and meteorological data for each monitoring day. PCDEM staff accompanied the students daily for 15 consecutive sampling days during the months of April, June and September.

Classroom Applications
The teachers and students were encouraged to integrate their monitoring experiences into their classroom curricula. The students were also encouraged to research the animals found in the Maple Swamp as to their preferred habitat and food preference and any other information that could be gathered and discussed in class. For example, the animals can be

measured for total length and catalogued in a database.

Evaluation
Opinions on the program and any suggestions from the teachers and students were solicited at the end of the sampling period through an evaluation form.

Additional Monitoring
County staff seined the main creek channel to determine fish species utilizing the project site. The Clearwater Audubon Society, County staff and a few student volunteers surveyed bird activity once a year. Additionally, a rainy evening survey of reptiles and amphibian was completed to supplement the herpetological sampling effort.

Oligohaline Habitat Restoration Project
The project includes a monitoring component that collects information on the species diversity of juvenile fish and plants. Fish monitoring was conducted every six weeks. Plant species diversity was surveyed once a year by documenting and identifying the types of plants inhabiting the site. Additionally, St. Paul's School students in Grades Six, Seven and Eight monitored the plant species assemblage at marked stations at the site.

Fish Sampling
Three stations were chosen to represent the different habitat communities and salinity regimes at the project site. Pinellas County staff used seines at low tide to capture juvenile fish approximately every six weeks from March 1998 through December 1999. Specimens captured were identified, counted and released. The standard lengths of targeted species were measured and recorded. Targeted species include snook, redfish, spotted seatrout, mullet, bluegill, largemouth bass and blue crab.

Plant Monitoring Stations
Initially, wire flags were used to mark 20 monitoring stations throughout the site. The wire flags were replaced with PVC pipes because the wire flags could be easily pulled out. Most of the wire flags were missing during the second month of monitoring. A 1 meter square defining the study area was measured around each PVC marker. Each monitoring station was assigned to a pair of students. They measured the growth of shrubs, trees and ground cover within the limits of the monitoring station once a month during the school year (see Figure 2).

Training
All project participants attended a laboratory workshop on how to monitor plant growth. This included a discussion on:

- ❑ the importance of native plants;
- ❑ why exotic plants are not beneficial to the community;
- ❑ the impacts of native and exotic plants on wildlife;

- ❑ how to measure a quadrat;
- ❑ the key characters of a plant including plant habit, leaf arrangement, leaf shape, leaf margin, leaf type, flower arrangement and flower form;
- ❑ how to measure the growth of a tree, shrub, vine or ground cover;
- ❑ how to fill out the data sheet;
- ❑ what they can do with what they learn at the sampling stations.

Several plant samples were brought into the classroom to familiarize the students with plants at the project site. Each defining characteristic for each plant was discussed at the workshop. During the first field visit to the restored site, both the teacher and students were accompanied by a County biologist. The County biologist supervised and provided further training to the students and teachers.



Figure 2. Students measuring tree growth.

Additional Monitoring
The project site was randomly surveyed by County staff and a local botanist annually for plant species utilizing the restored habitat. Students kept a running tally of bird species and other animals they observed while monitoring plant growth.

RESULTS AND DISCUSSION

Maple Swamp Habitat Restoration Project
Drift fence arrays can be used with a combination of pitfall and funnel traps. Only funnel traps were used in this project to protect any captured animals from small mammals like raccoons or opossums which inhabit the Maple Swamp area. This method excludes the capture of turtles. However, turtle observations during field visits were noted.

Monitoring results
Monitoring results before restoration indicate depauperate diversities of mammals, amphibians, reptiles, birds and fish, relative to other Allen's Creek habitats. Table 1 summarizes the results of the wildlife monitoring project. The project site supports urban wildlife with the dominance of opportunistic species including raccoons, opossums,

Table 1. Summary of Maple Swamp wildlife monitoring results.

Animal	Number of Species			
	1996	1997	1998	Overall
Frogs	2*	9**		9
Lizards	1*	2**	3***	5
Snakes		2**		2
Turtles		3**		3
Birds		30	35	45
Fish	7	8		8

NOTES: *Drift Fence monitoring for October 1996.
**Drift Fence monitoring all year round for 1997.
***Drift Fence monitoring from February to March 1998.

brown anoles, black racers, northern cardinals and *Tilapia sp.* Other species using the site include river otters, rabbits, red ear turtles, southern leopard frogs, garter snakes, hawks,

herons and bass. The existing vegetation is dominated by nuisance and invasive species including Brazilian pepper, primrose willow and air potato. This information will serve as baseline data and will be compared to wildlife use data after restoration is completed.

Benefits

Students at Plumb Elementary School assisted County staff by monitoring wildlife activity at Maple Swamp from April 1997 to April 1998. Clearwater Audubon Society members conducted two annual bird surveys at the project site (1997 and 1998). Project volunteers helped the County obtain information on wildlife use at the project site by maintaining and monitoring the wildlife sampling stations. They also protected the monitoring station from vandals. Their participation saved the County time and money and gave them a sense of ownership of the project.

Students and teachers of Plumb Elementary School, Audubon Society members and parent volunteers were exposed to an impaired ecosystem with habitat, water quality, and flooding problems. They learned the importance of native plants, the dangers posed by exotic and invasive plants, and the habitat requirements of urban wildlife. They gained a better understanding of what comprises a healthy ecosystem and environment. Furthermore, lessons learned from the monitoring program were carried and integrated into other curricula normally taught in the classroom and at home, enhancing the overall educational experience for students, teachers, and parents. For example, a teacher converted part of their classroom to a swamp by using a recording of sounds that emanate from a wetland forest, Spanish moss, and rubber snakes, lizard and spiders. It also included an activity center using several animal footprints for stenciling, coloring and making tracks in a tray of sand. The classroom make-shift swamp also had reference books on Florida reptiles, amphibians, butterflies, birds and wildflowers. Other classes collected leaves for identification and used them as subjects for writing composition and art.

Oligohaline Habitat Restoration Project

This project incorporated public participation from its inception. More than 200 student, teacher and parent volunteers with County, City and District staff planted the site in April 1997 with 3500 upland and salt tolerant wetland plants. During the planting event, the students observed a killdeer guarding her nest of four eggs from curious volunteers. The area was marked off limits during the planting days. Fourteen species of trees, shrubs and grasses were planted at the site.

Plant monitoring results

Plant survey and monitoring data indicate that native species have volunteered at the site since it was planted. These include seaside goldenrods, marsh elders, native sedges and black mangroves. Likewise, some undesirable species have inhabited the site but have since been physically removed. The railroad vines were outcompeted by grasses and were eaten by rabbits inhabiting the project site. Most of the installed plants survived except a few wax myrtle and laurel oak trees. The dominant species at the site changed from Brazilian pepper

(Schinus terebinthifolius) to marsh grasses (*Spartina sp.* and *Distichlis spicata*). More importantly, the students witnessed the transition of the site from two residential lots to a low salinity wetland with upland buffer zones.

Benefits

The project site provides a living classroom within walking distance of St. Paul's School. Students walk to the site once a month and measure the growth of trees and shrubs within their assigned plant monitoring stations. They have learned and become familiar with the plants and other wildlife that inhabit a low salinity wetland and the transitional buffer zones around it. They also helped the County collect information on the survival of installed plants, document wildlife use, and measure plant growth and diversity. Their participation saved the County time and money and gave them a sense of ownership of the project. They also act as sentinels of the site by reporting any unusual activities or changes. St. Paul's School students have adopted the project site and conduct periodic clean ups, clearing trash and debris. Last year, the students participated in the "Biodiversity Program through the Jason Project" and used the plant monitoring stations as their miniature ecosystems. They shared their data via the Internet with other students in the nation.

The success of this project also encouraged the school and their students to restore their own shoreline. The school is bordered on the east and south by channels of Allen's Creek. In 1998, the school removed Brazilian pepper on their southern banks and planted them with native wetland species. The students have observed wood storks and other wading birds feeding at their restoration site. This year they were awarded a grant to restore their eastern shoreline. Removal of nuisance and exotic plant species started this summer and is expected to be completed in early August 1999. Planting is scheduled in late October.

Fish monitoring results

Fish sampling at the site resulted in the capture of commercial and recreational marine species including red drum, spotted seatrout, grass shrimp and blue crab. Several classes observed County staff seine the site for juvenile fish. Each commercially important species was discussed during the on-site workshop. The discussion included the habitat requirements of each species and their importance.

Bird survey

Birds including herons, egrets, ibis, osprey, killdeer, terns and rabbits were also observed by the students during their monitoring days. A student observed bird species utilizing the site at dawn and dusk for her science project. Bird utilization at the project site has dramatically increased from almost non-existent to highly visible. The students watch birds hunting or feeding at the site on their way to and from school.

CONCLUSIONS

Both projects contributed to the goals of the Allen's Creek watershed management plan by improving water quality, increasing floodplain area and providing enhanced opportunities for wildlife. This is also consistent with the goals of the Pinellas County Comprehensive Management Plan and the Tampa Bay Estuary Program Comprehensive Conservation and Management Plan. In addition, both projects contribute to the social and public education components of the watershed management plan.

Incorporating community involvement as part of these habitat restoration projects provided an avenue to increase environmental awareness, expose students to different Florida habitats and increase public acceptance and participation. Local residents showed a sense of ownership in both projects by supporting and facilitating student field trips and by keeping a watchful eye on the site. This strong community involvement will help ensure the long-term success of the Maple Swamp Restoration and the Oligohaline Habitat Restoration Project.

ACKNOWLEDGMENTS

The author thanks Plumb Elementary and St. Paul's School students, teachers and parents for participating in the projects, staff of the Pinellas County Department of Environmental Management Environmental Resources Management Division for their help and support, Andy Squires for his critical reading, and Pinellas County Department of Environmental Management for the opportunity to work on both projects.

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South Florida Ecosystem Restoration

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Presented by:
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The South Florida Ecosystem Restoration and Sustainability project consists of nearly 200 environmental restoration, growth management, agricultural, and urban revitalization projects, programs, and initiatives that are designed to make South Florida more sustainable in the future.

Goals

- restore the natural hydrology of South Florida;
- enhance and recover native habitats and species; and
- revitalize urban core areas to reduce the outward migration of suburbs and improve the quality of life in core areas.

Premises

- on their current courses the natural and built environments of South Florida are not sustainable; and
- the environment, society, and economics of South Florida are not discrete systems but are related interlinking subsystems that make up the South Florida ecosystem.

Vision

- a landscape whose health, integrity, and beauty is restored and is nourished by its interrelationship with South Florida's human communities.

Who:

Participants in the restoration effort include

- six federal departments (12 agencies)
- seven agencies and commissions of the state of Florida
- two American Indian tribes
- 16 counties and scores of municipal governments
- representatives from major state industries
- commercial and private sectors, special interest groups

Restoration activities are generally guided and coordinated by the South Florida Ecosystem Restoration Task Force, its Florida-based Working Group, various advisory boards (e.g., the Governor's Commission for a Sustainable South Florida), and other technical working groups (e.g., the Science Coordination Team, Public Outreach Steering and Support Team, and project coordination teams). These entities interact and cooperate with one another through federal and state mandates, formal agreements, treaty and trust responsibilities, ordinances, partnerships, and coalitions.

Where:

The ecosystem restoration project area extends from the Chain of Lakes south of Orlando to the reefs surrounding historic Fort Jefferson southwest of the Florida Keys. The area encompasses all the terrestrial and aquatic habitats in this area. It also includes the metropolitan areas of Miami, Fort Lauderdale, West Palm Beach, Fort Myers, and other growing communities in South Florida. As defined the ecosystem covers approximately 10,800 square miles (28,000 square kilometers) and includes 11 major physiographic provinces.

Why:

Water is the common lifeline for the natural and built environments. Engineered flood control and water distribution systems, agriculture, growth, and development have disrupted the region's water quality, quantity, timing, and distribution (i.e., the hydropattern). Agricultural runoff and urban stormwater have introduced high levels of phosphorus, mercury, and other contaminants into the water system, polluting lakes, rivers, estuaries, and the Everglades. Abnormally high discharge of stormwater into estuaries and coastal waters has severely degraded aquatic habitats that support fish,

birds, and other species. Groundwater is threatened by saltwater intrusion and other marine-induced pollutants. These impacts have significantly stressed the natural system. Evidence of these impacts include

- 50% reduction in the original acreage of the Everglades
- 90%—95% decrease in wading-bird populations
- 68 threatened or endangered species
- 2 million acre-feet of water lost from the system through discharge annually
- 1 million acres of the ecosystem under health advisories from mercury contamination
- phosphorus contamination of Lake Okeechobee, the Everglades, and surrounding wetlands the rampant spread of invasive, exotic plants and the displacement of native species. Rapid population increase, development, and urban sprawl along the state's coastal areas have similarly stressed the built environment.

Agricultural areas in the interior face related problems stemming from growth and urban sprawl. Indicators of stress in the built environment include

- 16% reduction in agricultural lands
- high numbers of sites contaminated by hazardous materials (brownfields)
- greater unemployment, lower income and education levels, and a high prevalence of poverty in urban cores
- repetitive water shortages and salt water intrusion
- increased demands for roads, utilities, and services in response to the outward growth of suburbs
- decreased tax bases in urban cores / overly stressed infrastructures

How:

Restoration efforts are guided by three linked strategies.

Adaptive Management. Restoration participants recognize that not all the data needed to restore the ecosystem is in hand. They also recognize the need to move forward. Therefore, restoration efforts employ an overall strategy that implements action where possible, while continuing to collect and refine data. This iterative, feedback approach,

termed adaptive management, relies heavily on predictive modeling and support studies to identify management alternatives and evaluate their potentials. It also employs extensive monitoring to assess the progress of management actions and to provide feedback for refining both restoration actions and predictive models. This approach provides the structure for initiating critical projects immediately, the flexibility to modify activities when needed, and the coordination to ensure accountability.

Innovative Management. The restoration effort further recognizes that decisions must be based on sound science. Yet, science alone is not the answer. Using systemwide management techniques that deal with issues holistically, are outcome-oriented, and overcome institutional barriers are also important. Because the ecosystem does not recognize governmental jurisdictions, successful restoration efforts must also employ integrated governance to coordinate the activities of federal, state, tribal, regional, and local governmental entities and to find ways to streamline management and funding. Finally, broad-based partnership and public outreach are essential for building a consensus on needed actions and for maintaining good lines of communication with the public and among restoration partners.

Action. Critical projects are underway to restore the regional hydropattern, recover endangered species and habitats, and revitalize urban cores and manage growth. Projects like the Kissimmee River Restoration Project, Everglades Construction Program, and the Water Preserve Areas Project demonstrate that more natural hydropatterns can be reestablished. The Multi-Species Recovery Project underscores the need to address issues holistically and on a regionwide basis. The innovative Eastward Ho! Initiative shows how public, private, and governmental entities can work together to breathe new life into urban areas and foster more sustainable lifestyles. Finally, the South Dade Land Use / Water Management Planning Project and the Florida Keys Carrying Capacity Study provide excellent examples for a more sustainable future. These ambitious projects show that a sustainable South Florida can become a reality.

When:

Now, and the next 50 years. Reestablishing a healthy and sustainable ecosystem, including both the natural and built environments, is a massive undertaking that will take decades to complete and will require long-term funding commitments. The progress made to date shows that the current methods work and will continue to be improved. Ultimate success will depend on continued consensus and cooperation among restoration partners, shared responsibilities, and consistent funding. Restoring the South Florida ecosystem will secure the future of South Florida and will provide valuable examples of restoration methods and strategies that can be applied elsewhere.