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Restoring Wetlands on Abandoned Agricultural Lands in Everglades National Park, a Strategic Plan for guiding the Research, Monitoring, and Management of the "Hole-in-the-Donut" Restoration Program

SFNRC, EVERGLADES NATIONAL PARK, 40001 STATE ROAD 9336, HOMESTEAD FL, 33035-6733

RESTORING WETLANDS ON ABANDONED AGRICULTURAL LANDS IN EVERGLADES NATIONAL PARK

A Strategic Plan for Guiding the Research, Monitoring, and Management of the "Hole-in-the-Donut" Restoration Program

SOUTH FLORIDA NATURAL RESOURCES CENTER
EVERGLADES NATIONAL PARK

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In 1993, Everglades National Park, Dade County and the National Park Foundation, entered into a partnership to restore approximately 6,000 acres of former agricultural land in Everglades National Park, known as the "Hole-in-the-Donut" (HID). Through cooperation with Dade County, the Florida Department of Environmental Protection and the US Army Corps of Engineers, the HID was established as a Mitigation Bank, the first in Florida. Using the mitigation funds from permitted development projects in Dade County, the Park is undertaking a precedent setting program of exotic removal and wetland restoration for the entire Hole-in-the-Donut.

This restoration program has involved over a decade of development, planning, field experiments and reports, and permitting. Over approximately the next fifteen years the Park will implement this large-scale wetland restoration program. This program is one of the largest and most ambitious wetland restoration projects in the world and when completed will not only restore about 6,000 acres of short-hydroperiod wetland, but also provide enormous benefit to the habitats surrounding the HID that are in serious jeopardy from Brazilian Pepper invasion.

The National Park Service and Everglades National Park would never have been able to undertake nor afford a project of this magnitude on its own. Only through the tremendous cooperative spirit, support and desire to develop constructive and active partnerships by all the agencies and organizations involved, and in particular Dade County and the County's Department of Environmental Resources Managment, has the Park been able to achieve this milestone. The Park considers this program a model of cooperation and partnering among agencies that has lead to the implementation of a major element of Everglades Restoration.

Through the HID science program described in this strategic plan, the Park will be able to use the scientific information from this program to enhance our understanding of restoration and many of the effects that people have on Everglades environments, and help adapt our management as information becomes available. And, through this program of mitigation and science, Everglades National Park and Dade County will be able to ensure a comprehensive and successful program of exotic plant control and wetland restoration for one of the most important habitats in the Everglades.

This program is being implemented by the South Florida Natural Resources Center in Everglades National Park. Should you have any questions regarding the program please contact the Project Manager, Dr. Michael Norland at (305)242-7800 or by email at Mike_Norland@nps.gov.

Sincerely,

Richard G. Ring
Superintendent

RESTORING WETLANDS ON ABANDONED AGRICULTURAL LANDS IN EVERGLADES NATIONAL PARK

EXECUTIVE SUMMARY

This strategic plan focuses upon the research, monitoring, and modeling objectives that must be addressed to guide the management and restoration of the Hole-in-the-Donut (HID) and represents a synthesis of the scientific concepts and questions that relate to HID restoration. It is intended to provide structure and integration to the HID science program, and incorporate an iterative process for further refinement of the program and provide the framework, the protocol, and the process for implementing and directing HID restoration.

The restoration program has five broad goals: 1) define and characterize the structure and function of native communities as reference systems; 2) permanently remove invasive exotics from the HID and restore a self-sustaining ecosystem; 3) integrate research, monitoring and management; 4) fund research relevant to restoration that may also be applicable to other restoration questions and programs; and 5) evaluate cost effective restoration alternatives.

The objectives of the research element of the restoration program are: 1) determine the structure and function of the original ecosystem (reference condition); 2) given the reference condition, determine if "successful" restoration re-creates structure or function; 3) if not, determine why not; and, 4) if not, determine what alternatives may be available to change "undesirable" trajectories.

The purposes of this Strategic Plan are: (1) provide a document for investigators to use in developing scientific proposal for research related to HID restoration; (2) define the conceptual framework for developing a science plan for the HID; (3) guide the implementation of the science; (4) guide management of the restoration; (5) monitor the results of management; and (6) ensure feedback of research findings to the management decision-making process (adaptive management). The plan is intended for research scientists, and Everglades National Park. It provides information and guidance to scientists who need to understand the program's objectives and framework in order to develop research projects; it establishes mechanisms for review and oversight to the science program and products resulting from it; and it outlines the process by which modifications to the HID restoration activities and management will be made in response to research findings. It also will provide information about the HID science and management program to Everglades National Park's scientists and managers so they can apply scientific findings in modifying the overall HID restoration program as appropriate.

Key Words: Everglades National Park, Abandoned Farmland, Restoration, Strategic Plan, Hole-in-the-Donut, Wetlands

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Everglades National Park

Everglades National Park is a 600,000 ha subtropical wilderness in the continental United States at the southern terminus of Florida's wetland complex known as the Everglades. The principal ecosystem types within the Park include shallow-water marine habitats (226,000 ha), saltwater wetland forests and marshes (182,000 ha), freshwater marshes and prairies (231,566 ha), and upland complexes of pine and hardwood forests (8,000 ha).

One of the major factors controlling the distribution of the vegetation within the Everglades is the hydrological pattern, defined by the depth, timing, and duration of inundation as well as the quality and salinity of the source water. The flat topography, temporal distribution of rainfall, and proximity to the coast all interact to determine the hydrologic regime over the region. Surficial geology and overlying soil type also influence plant species composition and abundance. Disturbances, both natural (including fire, freezes, hurricanes, etc.) and anthropogenic perturbation (altered fire regimes, drainage, development, introduction of exotic pest plants) also have powerful effects on vegetation patterns.

Loope (1992) considers the Everglades among the top four National Park locations in the US in terms of the severity of exotic plant invasion. At least 217 introduced plant species (approximately 25% of the total flora) are known to occur in the Park (Whiteaker and Doren, 1990). Some of these, notably *Schinus*, are considered to be the most serious long-term threat to the Everglades ecosystem.

Multiple factors appear to promote the success of exotic plant species in southern Florida. Humans have accelerated the rate of species introduction by transplanting landscape ornamentals, and agricultural and medicinal plants. Southern Florida's island-like situation probably accounts for much of its susceptibility to exotic plant invasions (Myers, 1983; Loope and Mueller-Dombois, 1989; Loope, 1992). Although natural disturbances provide opportunities for weedy species to become established (Myers 1975, Wade et al. 1980; Ewel et al. 1982) these opportunities have been amplified by human activities. The most successful invaders are so well adapted to an altered niche that they out-compete native species (Meador 1977; Ewel et al. 1982).

A major site of exotic invasion within the Park is an area that was predominantly marl prairie now called The Hole-in-the-Donut (HID) (Figure 1). This area of approximately 2000 ha is virtually a monospecific stand of Brazilian pepper (*Schinus terebinthifolius*). *Schinus* is a major threat to the natural communities in the surrounding pine rockland savannas, mesic prairies and hammocks. Long Pine Key, habitat for numerous endemic and endangered species, represents the only intact habitat of South Florida Rock Ridge pine savannas left in the world. Control and removal of *Schinus* is critical to the restoration and long-term survival of this important habitat.

The Park tried numerous methods in an attempt to restore the HID to native vegetation during and following final acquisition. However, the previous land-use of rock-plowing (a process that plows the surficial rock and breaks it up into a suitable substrate for farming) and farming, and the resulting invasion of *Schinus*, frustrated all efforts at restoration of the site. In 1975, *Schinus* was found in the HID in only one area of approximately 30 hectares. *Schinus* invasion became noticeable throughout the HID around 1980 - 1982, and became dominant around 1985 - 1986 and remains dominant today. During the early 1970s and into the late 1980s, the Park tested numerous methods to restore the HID and later to eliminate *Schinus*. These methods included:

Soil Compacting - 1976

An area of approximately 1 ha of farmed soil in former pineland was compacted--with large 12-ton rollers--in an attempt to recreate the dense character of the native limestone rock substrate. Compacting rates and species composition were evaluated on compacted and uncompacted farmed substrate and on natural substrate. Compaction tests indicated no difference between compacted and uncompacted farmed substrate, and vegetation analysis showed no differences in species colonization. Growth rates of the plants on compacted soils were slightly slower for the first few weeks or months after compacting than growth rates for plants on uncompacted soils. Compaction did not consolidate the substrate. After rain re-moistened the soil, and sufficient plant growth occurred on the site, the compacting activity was found to have had virtually no residual effect. The investigators recommended that no further compaction trials be conducted. Compacting appeared unsuccessful since the structure of the rock-plowed soil did not lend itself to consistent or permanent recompressing of the material into a hardened matrix.

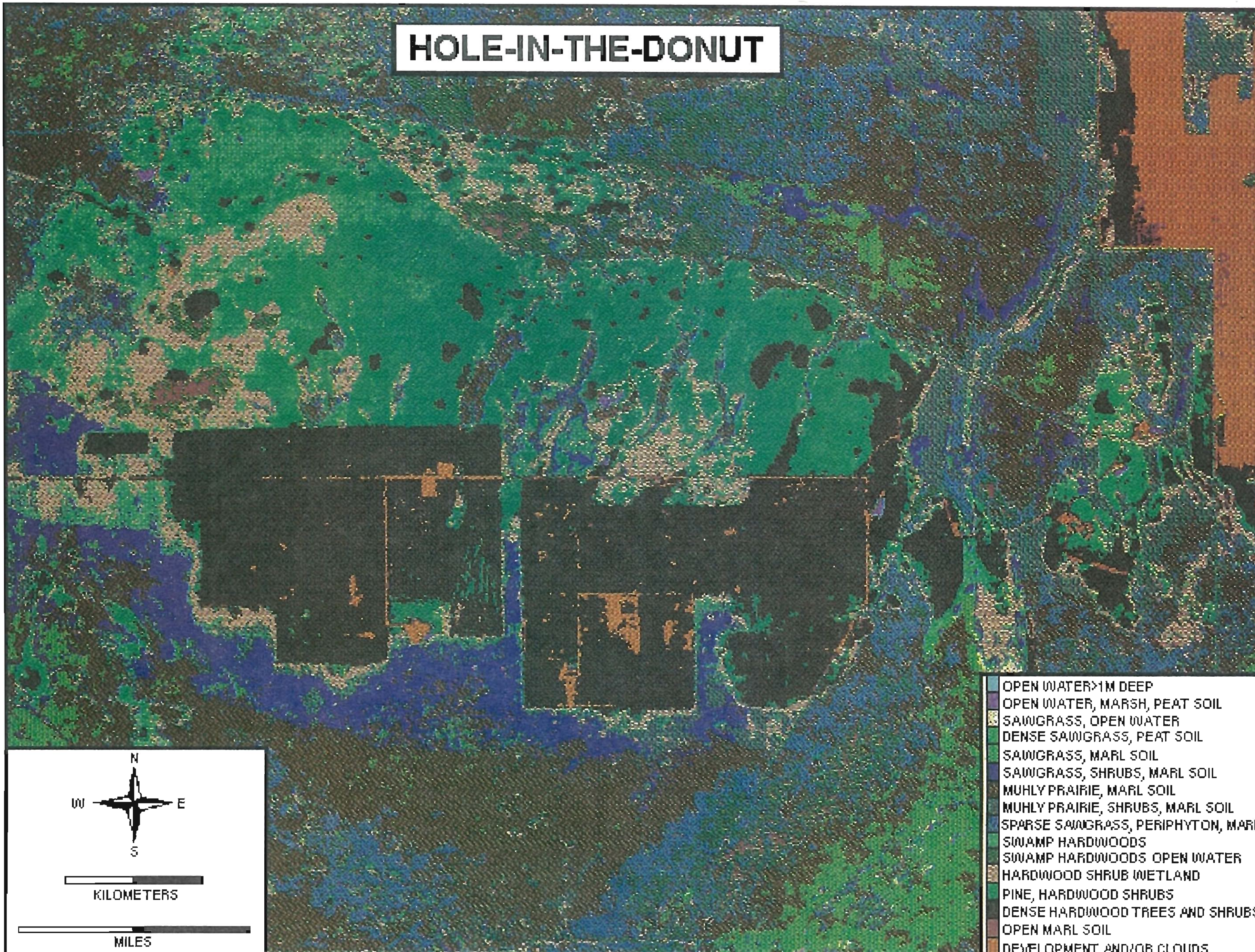

Figure 1. Aerial view of the entire HID restoration site and surrounding communities.

Pineland Restoration - Pine Planting - 1973 through 1977

Prior to *Schinus* invasion, pineland restoration was tried using several alternatives. Pine were planted as seedlings (potted and bare-root), Speedlings®™ (seedlings grown in specially designed containers to aid tap root development), transplants, potted plants (1 gallon containers with augured holes), and as seed. Approximately 30,000 pine plants were planted in various trials from 1972 through 1977. The management and follow-up of the plantings generally included watering once per week (for six weeks up to six months depending on the trial) until established, mowing, disking, or herbicide treatments between plants to prevent weed competition. Management and monitoring of pine continued for up to two years after planting in most cases. Within the first six weeks, mortality was >99% for bare-root seedlings and transplants, >90% for Speedlings®™, approximately 50% for potted seedlings, and < 20% for potted plants in augured holes. After two years of monitoring only some of the potted plants remained alive. While monitoring and management have not occurred since about 1977 - 1979, we have been able to document less than 15-20 surviving potted pines as of the last field survey in 1986. While no survey has been conducted since then, recent observations indicate that Hurricane Andrew may have removed most of the remaining survivors. Pine planting appeared unsuccessful because of the rapid growth of weeds and concomitant competition for light, space, water and nutrients. Most plants died prior to the end of the maintenance phase. This indicates that either the conditions even with maintenance were extremely unfavorable, or that site maintenance was not intense enough to ensure survival.

Hardwood Planting - 1978 through 1982

Approximately 20,000 hardwoods grown in 2 gallon containers were planted during this project. The project involved clearing *Schinus* with bulldozers, planting of different native hammock species in augured holes, and watering the plantings for several months to allow the trees to become established. The intent of the project was to plant hardwood species in a pattern that would mimic hammock structure (with larger trees toward the center) and allow the native trees to develop a closed canopy thus preventing *Schinus* invasion into these sties. Maintenance of the areas between the trees continued for up to two years after planting. Survival was not monitored after project completion. The last field survey of the sites occurred in 1986. Many of the trees survived but the areas between and around the trees are now dominated by *Schinus*. The trees are simply isolated specimens in a matrix of *Schinus*. The canopy of hardwoods even where reasonably dense was insufficient to prevent *Schinus* invasion. This project was probably unsuccessful for two reasons. First, period of control of *Schinus* and other weeds in the areas between the trees may have been to short. Second, understory development, even with a longer-term maintenance schedule, ultimately included *Schinus* after maintenance stopped, which then developed into a matrix surrounding the planted trees. While many of the trees still survive, they had no effect on subsequent *Schinus* invasion.

Graminoid Re-establishment - 1972 through 1977

A number of graminoid species, including *Cladium* (Sawgrass) and *Muhlenbergia* (Muhly Grass), were planted in an attempt to reestablish the native graminoid communities present in the HID prior to farming. These plants were collected from the Park as seed and transplanted material. Numerous plots were established where seed, transplants, and sometimes both were planted. This project was carried out prior to *Schinus* becoming a noticeable threat and was seen only as a way of restoring natural features and vegetation. The plots were maintained for up to two years by watering and hand weeding. No germination or seedling establishment was recorded. Some transplanted graminoid clumps survived for several years after maintenance stopped. As of the last field survey in 1986, no surviving transplants were found in the plots that could be located. All known plot sites were completely dominated by *Schinus* or a mixture of *Schinus* with other woody plants (predominately *Ludwigia* and *Baccharis*). These projects appear to have failed because; 1) no germination occurred in seed that was placed in the sites (the reason for lack of germination is unknown), and 2) the grasses and sedges that were planted seemed ill suited to the disturbed substrate. Also, based on the locations of some of the plots, there may have been an insufficient hydroperiod when combined with the altered soil.

"Slough" Re-establishment and "Hammock" Construction - 1976

The first project that involved substrate removal was a "Hammock" construction project. The substrate from a small pineland transverse glade ("slough") was used to create a nearby mound of earth that was planted with hammock species. The purpose was to develop an "upland" environment where the hammock trees would develop. This project was done before *Schinus* was a noticeable threat to the area, and thus was seen only as a way of restoring natural features. While some of the trees are still surviving, the mound has been invaded by *Schinus* and the trees are predominantly isolated in a matrix of *Schinus*. However, the small transverse glade where the substrate was removed has remained free of *Schinus* since 1976, and is dominated by native wetland species. This site served as the first example for development of the current HID restoration project.

Schinus Control and Removal

Numerous attempts to control *Schinus*, often somewhat independent of other restoration activities, were made from about 1978 through 1989. These included mechanical and chemical control activities and fire, and involved several applied research experiments. These projects are too numerous to discuss at length here. However none succeeded in controlling *Schinus*. Detailed reports and records are available through the SFNRC, for most of the projects. Please refer to the Literature Cited and the HID Information Resource Directory (Appendix B of this plan) for more information. The HID Information Resource Directory contains a complete listing of all the available information on the HID project.

SCIENTIFIC OBJECTIVES

The objective of the research is to guide management actions towards the restoration goals of the project. Research, therefore, should also address alternative management options for restoring the site, and help managers set targets and measure the success of the project.

Implicit in the restoration goal is the intention to minimize or eliminate anthropogenic processes harmful to the natural ecosystem. Absent from this goal is any intent to modify the natural functions or to enhance the prospects of any single native species to the detriment of any others. This perspective has guided us in developing the scientific goals and objectives described below.

Scientific objectives and questions should be focused so that answers will provide guidance for restoration. Four key restoration questions are: 1) What is the structure, and resulting function, of the original ecosystem (reference condition)?; 2) given the reference condition, does "successful" restoration re-create structure or function ?; 3) if not, why not?; and 4) if not, what course corrections could be taken to change "undesirable" trajectories?

The above questions emphasize inquiry into concepts relating to: (1) ecological mechanisms that can transform disturbed vegetation assemblages to more natural communities and assemblages; (2) key interactions with areas outside the project area that control site characteristics and spatial heterogeneity (e.g. hydrology and landscape-scale movement of exotics); or (3) structural and functional characteristics of native communities. Alternatives could also include determination of: (4) appropriate assessment technologies and protocols for tracking success; or (5) alternative approaches to achieving restoration goals.

Management options and capabilities should remain regional in context, and the principal available options should relate to controlling physical or chemical factors (e.g., manipulation of water, fire, substrate, improved management practices, control of exotics, nutrient removal, etc.). In contrast, the success of restoration will be measured in biological terms. For example, the HID pilot restoration site has provided a new site frequently used by wading birds, ducks, and deer, and serves as edge habitat (primary habitat for deer and panther). Ecological functions such as these must serve as criteria for evaluating the success of HID restoration. Thus, interdisciplinary research must link physical and chemical factors to biological processes.

Over the next several decades, the HID will provide an unparalleled opportunity to test hypotheses regarding succession, and biotic/abiotic interactions in a subtropical wetland ecosystem particularly prone to natural disturbance with many superimposed anthropogenic disturbances. These are concepts which the Park considers key to understanding and managing the Everglades. Many researchers have either tried to apply temperate concepts or models, or implied that there is no succession. The Park believes that such concepts or models are not appropriate to the Everglades.

There also will be a need to integrate the science program temporally. In 10 years, as soil removal proceeds under the current restoration plan, there will be 10 sites of differing age since soil removal. Because these spatial and temporal increments of restored area will be experimental units, statistical analysis and modeling needs will be important considerations in experimental design.

It is important that investigators understand the significance of developing proposals that answer questions which are fundamental to the restoration. Questions of **primary** importance developed in a carefully considered proposal will be competitive for funding while **secondary** or **tertiary** questions will generally not be. It is also important that investigators understand that their work will be performed in an adaptive management context. This means that activities and management alternatives may occur or cause site changes (prescribed fires, construction methods, etc.) with time and increased understanding. Investigators should be prepared for possible changes in the context and landscape in which they are collecting information, especially if your project may extend for 3 or more years.

The HID program is, by design and implication, an entirely applied science program. Because its purpose is to restore natural structure and function to a highly disturbed area, any research conducted as part of this program must focus on the what, how, and why of the central restoration theme. Thus, a succinctly stated set of central research questions is needed to focus the individual and collective research studies from project inception to conclusion. Each proposal must speak to how the research project will; (1) incorporate the adaptive management approach and needs of the HID project; (2) integrate with other proposed and existing studies; (3) address the issues and approaches outlined in the HID science plan; and (4) address any of the central questions related to the overall restoration. As projects advance and new information becomes available, it will be equally important to consistently review progress, and define any new directions and management applications using a consistent, yet pliant framework.

Central Research Questions

1. What environmental factors characterize or control the community and ecosystem development resulting from restoration?

2. How do patterns and processes in restored wetlands (or other communities) compare to native wetlands (or other communities)?

3. Can native or restored wetlands (or other communities) be kept free of exotics?

4. How do restoration activities affect other habitats, and *vice versa*?

5. What are the socioeconomic implications/values of restored (or natural) wetlands?

Core Subject-Matter Areas

1. General hydrological, meteorological, and physical data gathering and monitoring.

2. Nutrient cycling and biogeochemistry.

3. Macrophyte development (cover, richness, biomass, productivity, reproduction, etc.).

4. Soils development (structure and function).

5. Periphyton community dynamics (productivity, decomposition).

6. Trophic dynamics, food webs, consumer population dynamics.

7. Habitat utilization by species at different Trophic levels.

8. Energy flow, modeling, community and landscape-level synthesis and analysis.

Primary Goals

Successful restoration will require long-term, goal-oriented research that integrates past and emerging results into the management decision-making process. The proposed research agenda, discussed in detail below, addresses several broad and complementary yet flexible research goals. This program will provide a basic understanding of: 1) the ecological factors controlling structure and function; 2) results of past efforts; 3) a means to predict results of management alternatives, and; 4) measures of success. Primary goals include the following:

1) Determine what natural communities existed prior to farming and rock-plowing. The HID restoration area contained a heterogeneous array of plant communities, even though it was predominantly marl prairie (Krauss, unpublished report and vegetation maps, Everglades National Park), that provided a range of habitats for numerous species. A better understanding of those communities (developed from available historical information, and surrounding communities as examples), will help provide an "idealized" target for restoration. Although precise *in situ* restoration of native communities may prove impossible, an historical understanding provides a perspective on the extent and effectiveness of management restoration actions.

2) Review and examine the restoration methods that were previously tried (and those that may be proposed in the future), and why they were or were not successful. While much of the information available is not well documented, nor appropriate for statistical analyses, it should be more thoroughly examined and compiled in a comprehensive report summarizing the results of previous work. In addition, a comprehensive literature review of wetland ecosystem restoration is needed to place the HID effort in the larger ecosystem restoration context. New restoration methods that may be proposed for experimentation should also be carefully designed to avoid past analyses and data problems, and evaluated for cost and efficacy.

3) Understand anthropogenic effects within the context of natural system function and variation, and determine what factors are key in establishing a "preferred" restoration target. It is essential that we understand what ecological factors or forcing functions are causing the succession to wetland under the soil removal scenario and to *Schinus* where the soil is left. Farming was not solely responsible for causing the shift in succession from wetland to exotic forest. Areas farmed prior to the advent of rock-plowing or exotics returned entirely to native vegetation. Multiple factors appear to be involved. Separating anthropogenically-

induced changes from natural system variation will provide critical information to understand why some perturbations--or other factors, such as presence or absence of propagules--result in *Schinus,* whereas others result in wetlands.

4) Develop a basic understanding of the ecology of the evolving landscape by evaluating alternative hypotheses. Utilizing spatial and temporal data in an experimental (statistical) design and modeling context will help us understand the factors (and their interactions) that cause change in the HID restoration area.

5) Develop the capability to predict the response to perturbation of a subset of species or ecological processes that collectively may be considered indicators of key processes or functions of the HID restoration landscape. Restoration will require choosing among alternative management actions based on ecosystem responses. Relating the responses of these indicators to potential management alternatives is one way in which an ecological understanding becomes a key ingredient in the decision-making processes of agency managers.

6) Develop a series of "success criteria" or "performance measures" to establish the desired future condition(s) for the site. Key measures need to be made in parallel natural communities that serve as reference sites for evaluating successful restoration. The early vegetation successional patterns in the pilot mitigation site more closely resembled abandoned farm fields than wetlands, in species composition. This difference was evident both annually and seasonally (i.e. from wet to dry season) during the first 3-5 years after construction. Currently, the pilot site resembles a more natural range of everglades wetland associations in composition, albeit not in abundance or frequency. Changes in species composition between wet and dry season has virtually disappeared, and the frequency of important wetland plants (such as *Cladium*) has significantly increased.

Major Research Topic Areas

Management decisions on restoration must be based on a scientific understanding of the principles that direct succession toward a 'preferred' state under one scenario and an 'undesirable' state under another. The ultimate 'preferred' state is closely linked to the pre-farming conditions. Understanding the fundamental nature of the changes the area has experienced, and the various natural and anthropogenic processes determining its present and future status, is probably key to developing a successful long-term restoration program. The following comprehensive topics describe the major gaps in our present understanding of the restoration area, our continuing data needs, and the necessity of improving our management and predictive capacity. Carrying out these specified tasks will provide answers to the critical questions if restoration is to advance on a scientifically sound basis. Investigators should consider the following as a guide for the basis of hypotheses or research questions.

Much of the available scientific information focuses on pattern or structure of plant and animal communities. The processes that interact and interrelate with these patterns are often ignored. The Park believes it is crucial to develop linkages between process and pattern. Both are interrelated and neither can be isolated nor assumed to "drive" the other. If the HID research program is to provide an understanding of the forces associated with pattern and structure it must be able to link the processes and patterns, and describe their interrelationships. The following list of questions relating structure and function are considered to be the most important such questions facing the HID restoration program. Research proposals, individually or collectively should try to address a component of one or more of these broad questions that are broken out into topical areas. Within topical areas the questions are in lose priority.

Interactions of Structure with Function

1. How are structure and function[1] related in newly created wetlands in general, and specifically in oligotrophic Everglades wetlands?

2. Are "differences" in plant or animal communities/associations (*i.e.*, species composition, occurrence, use, cover, dominance, richness, etc.), independent of function and state condition in newly created wetlands?

3. Are plant or animal communities and associations structural representations of function and state variables in newly created wetlands?

4. How do the interactions of biotic and abiotic factors, including disturbance, determine the outcome of the restoration activity?

5. Can manipulation of the abiotic or biotic elements of the area redirect the outcome in a "preferred' way for a particular outcome?

6. What are the preferred structures and functions for the restoration site?

7. How do whole-system productivity and energy flow change as these newly created wetlands develop?

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[1] By structure we mean the composition, distribution, and relative abundance of species as well as the appropriate distribution of production and biomass and the key linkages among species. By function we mean the full set of hydrological and biogeochemical processes through which the flows of materials and energy support plant and animal assemblages.

8. How important is spatial variability/heterogeneity in understanding the interaction of structure and function in newly created wetlands?

Exotic Plant Establishment

1. Are native or newly created wetlands more or less easily invaded by exotic pest plants? If so why and what makes them so?

2. Why does alteration of the physical substrate by rock-plowing favor *Schinus* to the exclusion of almost everything else?

3. What is the interaction between elevation, hydrology, and nutrients in influencing survival and persistence of Brazilian Pepper (and other exotics)?

4. Do nutrients control establishment of Brazilian Pepper, or is it a combination of nutrients and other factors?

Restoration Alternatives

1. What role does the hydro-pattern play in achieving the biological objective of the restoration project?

2. Could the biological objectives of the restoration project be achieved without removing the substrate?

3. How does the chemistry of rock plowed substrate differ from unaltered substrate? Can the soil characteristics/chemistry of the altered substrate be changed and still lead to successful restoration?

Vegetation Dynamics and Succession

1. What are the characteristics of successional velocity and trajectory after soil removal and other major soil disturbances in newly created wetlands?

2. Does germination and dispersal of propagules affect successional velocity or trajectory, and is this related to proximity of natural sites?

3. What are the seed sources for re-colonization of newly created wetlands?

Ideally, initial restoration actions would be so successful as to require no further management.

Program Objectives

We have identified four objectives for an expanded restoration essential to ensure a fully integrated restoration program. All must operate in combination to ensure the program's success. The expanded restoration, which has already been initiated, is expected to take approximately 15 years. The larger restoration program, which is described in this document, includes: 1) research intended to improve the restoration process as it proceeds; 2) restoration activities; 3) a monitoring program and; 4) a mechanism for linking research results to the restoration process and management of the HID area. The four objectives are:

1) to define and characterize the structure and functions of native Everglades communities that can be used as reference systems for the HID restoration.

2) to permanently remove invasive exotics from the HID and to restore a self-sustaining ecosystem, preferably closely resembling the structure and function, as well as the temporal dynamics, of reference systems[2] of the phytogeographic region (Brinson and Rheinhardt 1996).

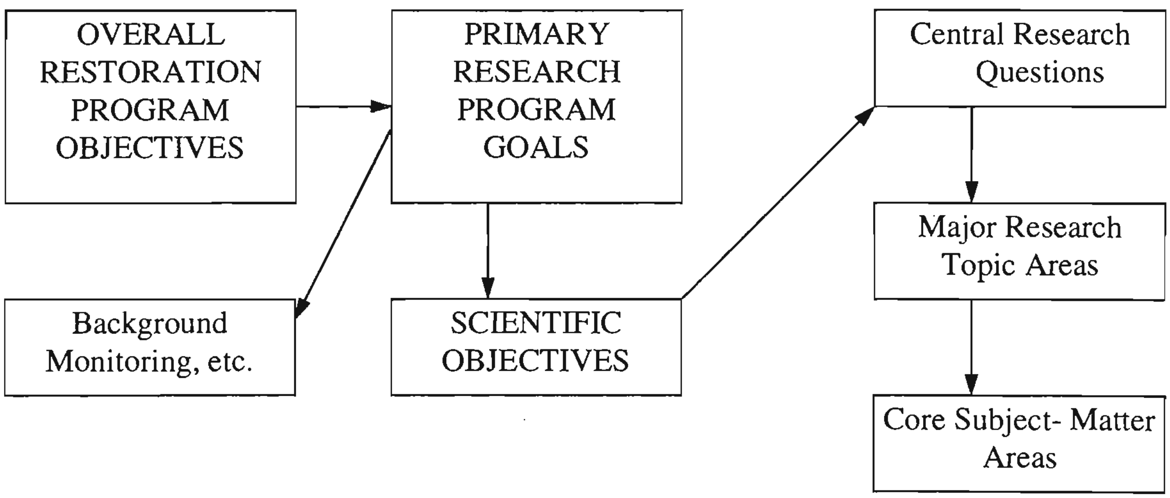
3) to integrate the research, monitoring, and management elements of the restoration program with each other in order to most efficiently and effectively restore and manage the HID site to ensure that the HID restoration program complements the broader south Florida ecosystem restoration efforts.

4) to fund research that is relevant to management actions directed toward HID restoration and that may be applicable to broader restoration questions and programs elsewhere, and to apply scientific findings to modify and improve the restoration and management of the HID as the restoration process proceeds. It is anticipated that what we learn from this research may be applicable to restoration efforts elsewhere.

[2] Reference systems must have their biological structure(s) defined. By structure we mean the composition, distribution, and relative abundance of species as well as the appropriate distribution of production and biomass and the key linkages among species. By function we mean the full set of hydrological and biogeochemical processes through which the flows of materials and energy support plant and animal assemblages. Reference systems are preferred targets but are not required targets.

Differentiating Objectives, Research Areas, and Research Questions

Objectives have been stated for three principal sections of the restoration program. The plan discusses objectives for the overall Restoration Program (see page 20) of which the broader research program is a component. It also discusses the objectives, stated as Primary Research Program Goals, for the research program (see page 16) that include many aspects of this programs scientific endeavors (e.g. background monitoring, assessment of past restoration efforts, etc.) beyond the current solicitation for research. And, more specifically, it outlines the Scientific Objectives of the research initiatives anticipated as a result of this solicitation for proposals (see page 13). Within the Scientific Objectives, Central Research Questions direct the focus of scientific inquiry, including identiying Major Research Topic Areas and Core Subject-Matter Areas. The following diagram is intended to provide an explicit illustration of the relationship of the objectives, research questions, and their general hierarchy.



Current Restoration Program

As a result of the success of two previous restoration projects [the 1976 slough reconstruction project described above, and a mesic prairie restoration in Dade County (Dalrymple 1993)], an experimental project was implemented in the Park in 1989 as off-site mitigation for private wetland development in Dade County. The project involved the complete removal of disturbed substrate (soil) on 18 ha and the partial removal of the substrate on an adjacent 6 ha (Doren et al. 1990a) (Figure 2). The goal was to determine if substrate removal would lead to the restoration of native wetland species and wetland function(s), and if so, whether complete substrate removal was necessary.

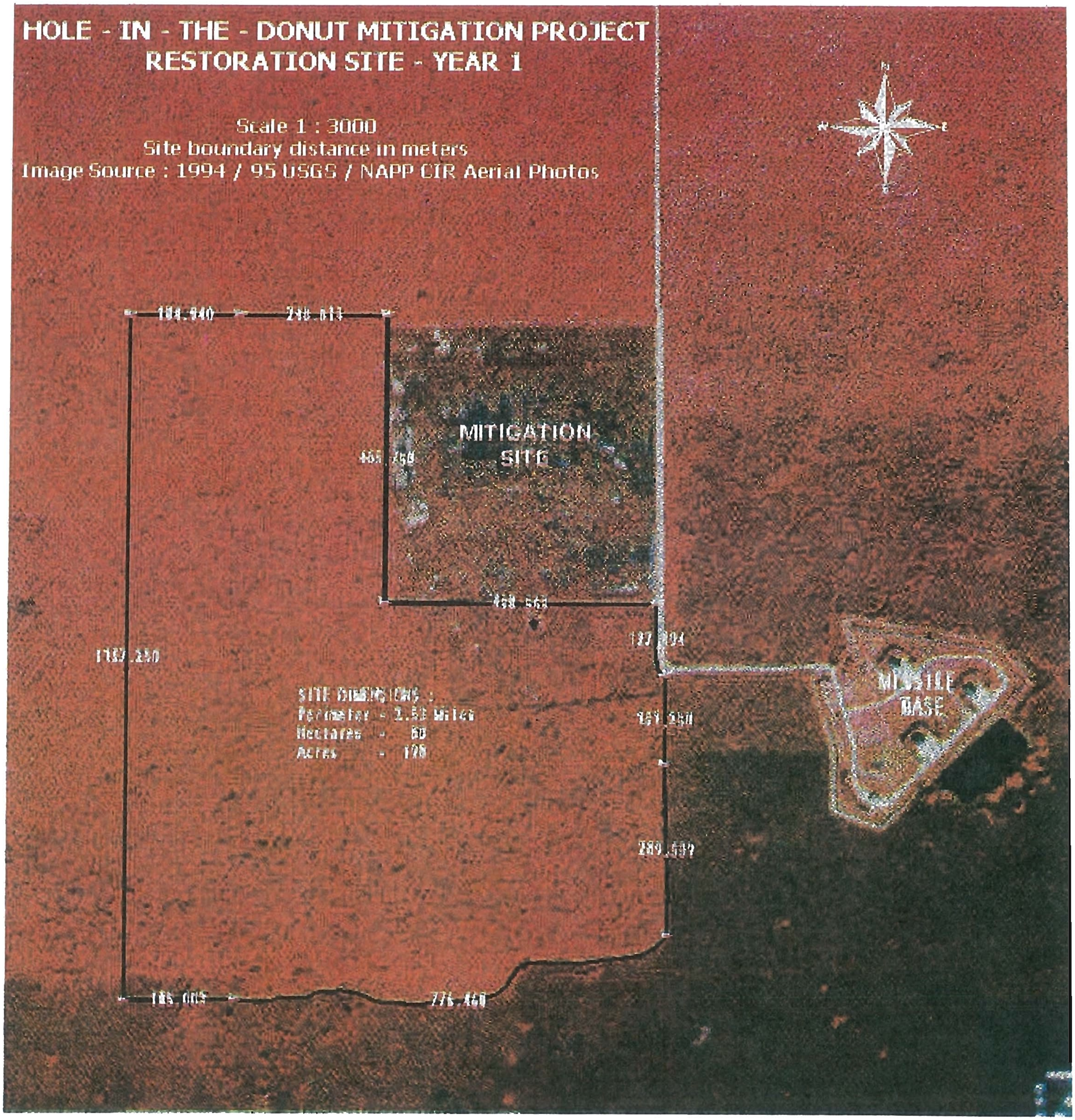


Figure 2. Arial view of pilot HID restoration site and outline of current restoration site.

In these small scale trials, only complete removal of the farmed substrate -- marl and rock-land plowed and pulverized by a process called rock-plowing, to a substrate suitable for agriculture -- has shown promise for restoration of native flora and fauna. However, we do not yet have enough scientific knowledge to understand the mechanisms involved in restoration through the removal of the substrate, or if other alternative mechanisms also might be successful, less costly or more efficient.

Total substrate removal effectively eliminated invasive exotic vegetation (particularly *Schinus* and *Ardisia*) and restored wetland species (Figure 3), while the area of partial removal was rapidly re-colonized by *Schinus* (Figure 4) (Dalrymple 1994). Thus, convincing data from the 1989 test project site (Doren and Dalrymple, in prep.), the two previous soil removal sites within the HID, and several such sites in the East Everglades, indicate that the restoration of native wetland species is possible through the complete removal of the fundamental disturbance--the artificially created substrate--with concomitant hydrological improvement(s) (in areas where drainage has not undermined possible hydrological improvements). While substrate removal may prove to be only one of several alternatives for successful restoration, it is currently the only technique that has had positive results, and is currently the primary approach for the expanded restoration program for the entire HID area (see Doren et al. 1990b, Dalrymple 1989, Dalrymple 1994, Dalrymple et al. 1993).

Our current understanding of the successional changes in the HID that have occurred or may be possible are reflected in Figure 5. This figure is a transition model that illustrates the community associations that were or are part of the HID area, and the transitions that have resulted as a consequence of the various activities that have occurred. While we know what activities have occurred, we still can only speculate as to the fundamental causes, or to what future transition states may be possible.

From the information available and from field observations, we propose two hypotheses that seem to explain the lack of re-establishment of *Schinus* on the sites where farmed substrate has been completely removed. First, (even though seed germination is common on the site) removal of the substrate appears to prevent the establishment and recruitment of *Schinus* seedlings. Two mechanisms appear to be involved: (1) The absence of substrate for root development, and (2) removal of nutrients with the substrate. Second, dry season and wet season extremes appear to result in complete mortality of *Schinus* seedlings. Two mechanisms appear to be involved: (1) the site is completely dry for 2-5 months, and drought seems to be a major factor in eliminating many remaining seedlings in the slightly higher elevations; and, (2) in areas of lower elevation containing moist native marl or peat soils remaining after soil removal, *Schinus* seedlings survive the dry season. However, when heavy rains occur these lower areas

Figure 3. This area of the pilot restoration site, where soil was completely removed, clearly shows coverage by wetland plant assemblages without *Schinus* development (September 1996).

Figure 4. This area of the pilot restoration site, where only a portion of the soil was removed, clearly shows a succession of woody plants with dominance toward *Schinus*, (September 1996). This experiment was performed to determine if all of the disturbed substrate must be removed for successful restoration.

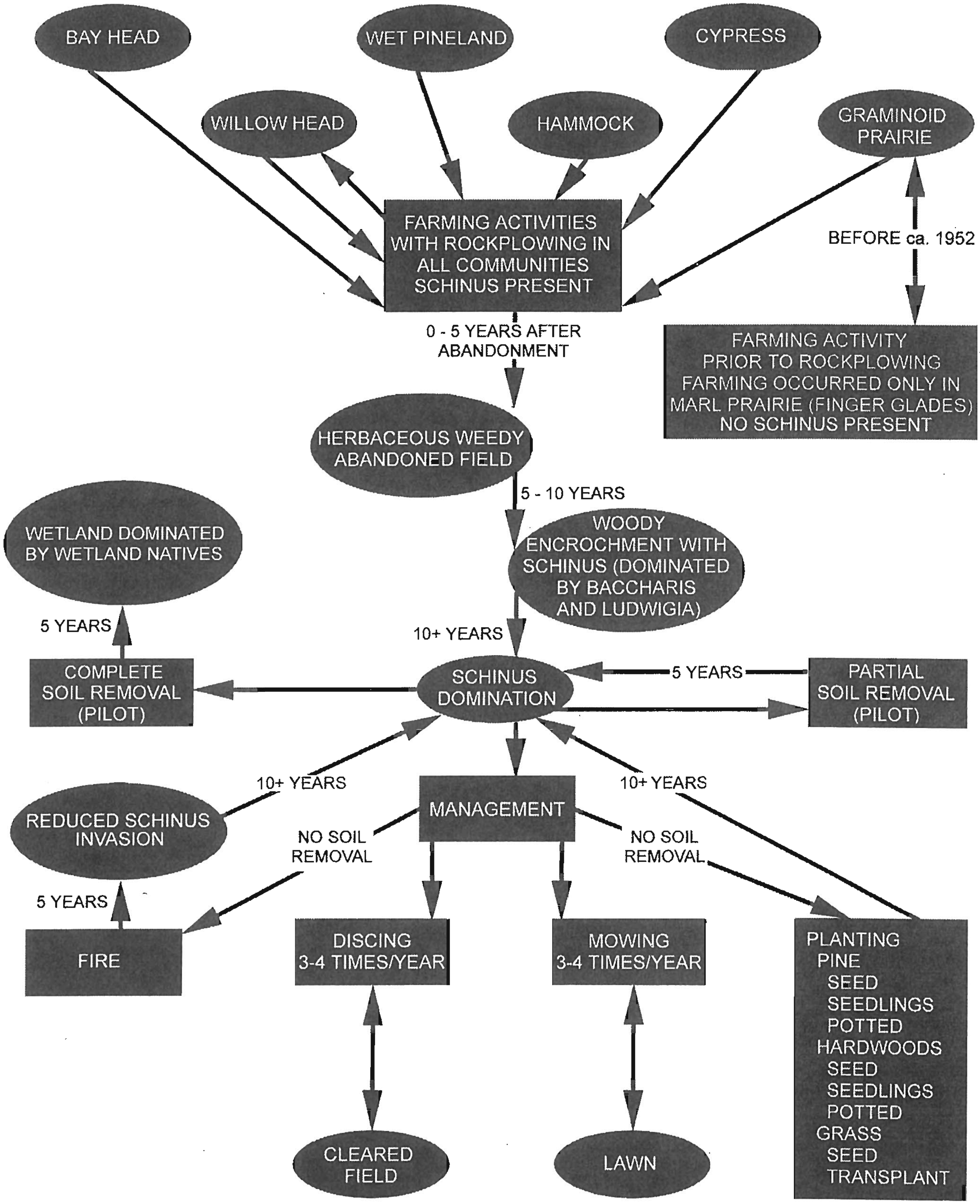


Figure 5. Transition Model depicting current understanding of vegetation transition in the HID. These transitions incorporate a time frame beginning prior to farming activities (ca. 1900), to the present. The model describes the vegetation associations and communities, farming or management actions affecting those communities, and their subsequent transition through time.

rapidly fill up with water and the seedlings are quickly "drowned". Findings from the pilot study indicate that *Schinus* seed rain continues, leading to germination, but seedling mortality rates of 100% have, so far, been the outcome for the eight year study.

RESOURCE MANAGEMENT FRAMEWORK

The Plan

This plan to guide the HID restoration program is a synthesis of the following: 1) a preliminary research outline developed by Everglades National Park's South Florida Natural Resources Center and the Target Restoration Team, (see page 31); 2) a statement of work developed as part of the Request for Proposal for the construction and basic monitoring contract; 3) the Florida Department of Environmental Regulation Mitigation Bank Permit, 4) the US Army Corps of Engineers Section §404 Clean Water Act Permit; 5) previous research (Dalrymple 1994, Dalrymple 1993, Doren et al. 1990a, Doren 1990b, Ewel et al. 1982, Ewel 1986, Krauss 1987, Loope and Dunevitz 1981, Whiteaker and Doren 1990, Azis, et al. 1994; and 6) three previous science planning meetings (November 6, 1995; April 1 - 2, 1996; November 15, 1996) of the Target Restoration Team, and one joint meeting of the Target Team and the Science Oversight Panel, (see page 32) January 9, 1997. In addition to these project specific elements, this plan follows the conceptual framework for science planning and restoration related to the South Florida Ecosystem Restoration Initiative developed by the Federal Task Force on Everglades Restoration. It incorporates many similar organizational, planning, and implementation protocols found in the *Science Plan for Florida Bay, a science planning document provided to the interagency Working Group on Florida Bay*, April 1994; and the *South Florida Ecosystem Restoration: Scientific Information Needs*, Science Sub-Group Report, September 1994. In preparing this plan, we intentionally incorporated all conceptual elements of these documents to maintain a uniform approach to science application and systematic implementation in the broader framework of the South Florida Ecosystem Restoration Initiative.

The implementation of this plan is iterative, as is the whole restoration program. It is implicit to adaptive management that planning will also adapt and change as new information becomes available. The Park intends to adapt this plan to ensure its currency and applicability through, public input, scientific peer review, and periodic revisions.

Administrative Responsibilities and Research Activities

No single organization has sufficient management control or scientific expertise to independently answer the broad research questions raised by attempts to restore wetlands. Only through cooperation, collaboration, and peer review can we expect to make complementary contributions and encourage synergy in the scientific enterprise entailed in this precedent-setting project. Everglades National Park has the principal responsibility for leading deliberations on the HID restoration planning, for setting research/restoration goals, and for coordinating the science programs. The Park intends to carry out this responsibility by encouraging and developing a collegial and integrated program of research leading to a comprehensive understanding of the scientific questions underlying the concepts of restoration. It will be the Park's job to develop this restoration-research-management program, to implement it, to adapt it and to make it successful. This document describes several mutually inclusive and supportive approaches to develop an integrated and adaptive science program toward the successful restoration of the HID.

Funding

The expanded project will be funded in a manner similar to the pilot project--through funds set aside as off-site mitigation for the loss of wetlands in other areas of southern Florida. In 1992 Dade County passed an ordinance establishing the Freshwater Wetland Mitigation Trust Fund to evaluate and manage growth and development in two areas of the County, the Bird Drive Basin and the North Trail Basin, within the Urban Development Zone. The Fund was created by the Dade County Commission for use in acquiring, restoring, enhancing, managing, monitoring, and studying freshwater wetlands within Dade County. Two-thirds of the funds (a cumulative total of approximately $44 million in 1992 dollars) from this trust are directed to the National Park Foundation (which, for this project, serves as fiduciary agent for Everglades National Park). The HID project area serves as the off-site mitigation bank for these two urban development zones and for other permitted wetland losses within the Mitigation Service Area. The HID project Mitigation Service Area was expanded in May, 1997, by the Florida Department of Environmental Regulation (through a minor permit modification) to include all of Dade County. The Park has a unique opportunity to work cooperatively with the Metropolitan Dade County Department of Environmental Resources Management (DERM), the Florida Department of Environmental Protection (DEP), and the U. S. Army Corps of Engineers (COE), to restore approximately 2,000 ha of former wetlands within the Park.

Adaptive Management

Adaptive Management is a process whereby scientific information is used to support and adapt management/restoration actions within natural systems. Conceptually, this process is iterative. To support restoration, the science program must be adaptive, long-term, and goal-oriented. The results of management actions are continually monitored, and this information is again used to further adapt management and restoration activities, both linking and redirecting scientific inquiry as appropriate to support the long-term management of the natural system. Biological, administrative, and logistical considerations argue that restoration of the HID will be a long-term process, and that the first iteration must achieve significant restoration benefits. The system's inherent complexity also suggests that the best tactic for testing and evaluating alternatives is predictive modeling. Modeling is central to the process of linking research findings and restoration actions. Modeling must be *a priori*, and an active part of the research, rather than simply be a *post hoc* data collation exercise.

The recommended scientific approach embraces a closely linked and integrated program of monitoring, research, modeling and adaptive management. Through monitoring we can track critical ecosystem functions and provide baseline data for model parameters. Using research, we can develop an understanding of the biotic and abiotic processes regulating succession, and their underlying causal relationships. Through modeling, we can develop predictive tools to assess system response to change, to hind-cast historical conditions, and to develop, adapt, and select management alternatives.

It may appear that the science related to the restoration of the HID is, like the project itself appears, very site specific--to remove artificial substrate and monitor wetland response. However, the causal factors that lead to *Schinus* dominance under certain conditions and wetland restoration under others are neither understood nor evident. Understanding the interactions of biotic and abiotic factors that determine form and function is the key to successful restoration and management of disturbed systems. Although southern Florida appears to have a high ratio of undisturbed to disturbed habitats, it is important to understand that there are essentially no areas in southern Florida that can be characterized as anthropogenically undisturbed. This argues for the importance of restoration efforts system-wide, in sustaining and where possible, reclaiming natural lands.

Existing Monitoring Framework

As a result of the pilot project, a number of monitoring programs have been implemented to provide a basic level of data as a "research context". These data include: 1) water level and duration data for the site from 1989 to present (water level and duration data for other hydrological wells in the surrounding areas are also available); 2) elevation data to approximately 2 m^2 resolution; 3) vegetation data from existing 10 X 10 m^2 plots; 4) *Schinus* occurrence and phenological data; and 5) meteorological data (rainfall, relative humidity, temperature, insolation, wind speed and direction).

In addition, the HID Information Resource Directory (appendix B of this plan), an annotated outline of all information pertaining to the HID that is currently on file with the South Florida Natural Resources Center, Everglades National Park, or on the Everglades Information Network and Digital Library (EINDL) World Wide Web site is available. The HID Information Resource Directory includes information on: current monitoring and research project information, news clippings (1963 through present), memoranda, letters, notes, field notes, data, soil samples, maps (including project plot locations and site information), photographs, slides of all past research and current restoration activities, drawings, and digital images, published and unpublished reports, agreements, legislation, NEPA compliance documentation, permits, etc.. More recent publications including this Strategic Plan, Guidelines for Proposal Preparation (appendix A), the HID Information Resource Directory (appendix B), and other reports are available on the HID home page, in the EINDL World Wide Web site. The Uniform Resource Locator (URL) is: **http://everglades.fiu.edu/**

Scientific Integration, Review and Oversight

Many scientists may be generally interested in the HID restoration program itself and others in actually conducting research needed to understand the biotic and abiotic processes that will result in successful restoration. In order to accommodate the identified interests and provide a sound framework for this scientific endeavor, the South Florida Natural Resources Center in Everglades National Park has identified four requirements for organizing the scientific process. First, integration of the scientific interests and individual research projects is critical to ensure the many scientists are working for a common goal and understanding. Second, peer review and scientific oversight of the individual and collective research are important to achieve integration and keep individual projects focused on the unified goals. Third, establish protocols for development, peer review, and acceptance of funding for research proposals [including a set of protocols for preparing, submitting, and approving research project proposals (see Guidelines for Proposal Preparation, appendix A)] to provide direction and focus for investigators. Fourth, establish a mechanism for synthesizing and incorporating scientific findings into the restoration and management of the HID. To accomplish this, the Park is coordinating with two groups of scientists: the Target Restoration Team and the Science Peer Review and Oversight Panel.

Target Restoration Team

This informal group consists of individual scientists and managers from Everglades National Park, other government agencies, and academia, who are either involved in managing some aspect(s) of the HID program, are providing technical support, or are performing research directly involved with the restoration. The primary purpose of the Target Restoration Team is to ensure that individual research projects are integrated. The Target Restoration Team concept also facilitates communication, coordination, and scientific collaboration among the individual scientists and managers, however they may be involved with HID restoration. The Target Team was initiated by the South Florida Natural Resources Center in April 1996.

Coordination of scientific methods and data is critical if the restoration program is to be successful in synthesizing and applying scientific information. For example, plant taxa must be agreed upon by all investigators in order for data that are ultimately used by the Park to be consistent within and between projects. The Target Restoration Team plays a critical role in bringing scientists together to ensure consistency of data within and between individual projects.

The Target Restoration Team will meet as needed, but probably no less than 2-3 times per year. The members of the team will perform the following functions:

1) Implement individual research projects as approved and/or funded by the Park (see Guidelines for Proposal Submission, Appendix A).

2) Attend Team meetings to enhance information exchange and ensure continued integration of individual efforts into the overall science program.

3) Provide information and data, as appropriate, to other HID science program collaborators who need such information in their research efforts (such as modeling, development of sampling protocols, environmental assessments, etc.).

4) Occasionally serve as individual technical reviewers of research proposals [see Guidelines for Proposal Submission (Appendix A)], ensuring that technical elements of the proposals are rigorous and appropriate for the region, and are clearly relevant to research needs defined in the HID Science Plan. [Note: this review is for technical elements only; all proposals will undergo peer-review by scientists who are not competing for funding under this program.]

5) Review the scientific progress of the overall program and of the individual research projects through science conferences.

6) Respond to the recommendations of the Science Peer Review and Oversight Panel.

7) Respond to South Florida Natural Resources Center management decisions and issues.

8) Obtain information updates on overall HID program developments and changes, status of permits or other Park policy changes, site conditions, etc.

Science Peer Review and Oversight

The key challenge of the HID restoration program is to produce applied research products that can be adapted for management. Support and recommendations from other experienced scientists and managers, particularly those familiar with other large-scale wetland research and restoration programs, are essential for long-term direction and oversight. So that these recommendations have the most objectivity, value and continuity to the Park's HID restoration program, the individual scientists who provide them are not eligible for research funding through this program. The Park has established a Science Peer Review and Oversight Panel of five independent scientists.

We have identified six basic tasks of the individual members of the Science Peer Review and Oversight Panel. These elements are flexible and may be modified as appropriate. Each panelist provide their individual recommendations to the Park.

1. Provide broad scientific review on major program elements, plans, research proposals, program modifications, and management decisions that the Park must make as the restoration program advances.

2. Periodically make individual presentations to higher level agency management and organizations (e.g., Federal Task Force, Task Force Working Group or Science Sub-group, applicable government agencies, university administration, etc.) at meetings where HID restoration may be an important agenda item.

3. Attend periodic science conferences regarding the HID restoration program, and provide recommendations for improving the development, organization, and structure of the program.

4. Provide a leadership role for selected special topic workshops the Park may sponsor to address strategic research questions.

5. Occasionally be available for telephone or electronic mail consultations on special issues that would benefit from the Panel member's experience in other restoration programs.

6. Maintain a flexible role that in the future may expand to cover a broader complement of ecological and biological research program oversight and review. While the HID restoration program is a major one, it is part of a larger South Florida Ecosystem Restoration Initiative, and the panelist's review would be inherently valuable in a broader restoration context.

The Science Peer Review and Oversight Panel shall be composed of individual scientists who have both fundamental and applied knowledge from at least one of the following scientific disciplines:

Soils Science, Ecosystem Ecology, Wetland Ecology, Disturbance Ecology, Vegetation Ecology, Community Ecology, Ecological Modeling, Restoration Ecology of Wetlands or Agricultural wetlands, Population Biology, Autecology of wetland plants or animals, Aquatic Ecology, Tropical Wetland Biology, Wetland Microbiology, Ecophysiology or Physiological Ecology.

These scientific disciplines cover the potential arena of scientific questions or issues that may arise from the research being planned for the HID restoration project. While it is not possible to reasonably cover all these disciplines, nor to anticipate every scientific question, those disciplines that are represented by the individual panelists should at least be representative of the key restoration questions that can be anticipated through research activities.

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