Summary of Arthur R. Marshall Loxahatchee National Wildlife Refuge 2004 Science Workshop

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A.R.M. Loxahatchee National Wildlife Refuge.
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Executive Summary

In May 2004, a science workshop was held with the purpose of providing a forum for discussing A.R.M. Loxahatchee National Wildlife Refuge science needs as well as providing an overview of research already being conducted on the refuge. Objectives of the workshop included: making a broader audience aware of the management issues on the refuge that need science support; illustrating current research on the refuge, and opportunities for others to conduct research on the refuge; and beginning (or continuing) dialog among researchers and refuge staff to provide a foundation for future collaboration and partnerships. The workshop consisted of plenary sessions, a poster session, and several breakout sessions. Over 60 people from eleven different groups attended. All who responded to the evaluation questionnaire indicated that the workshop met the stated objectives and that they would definitely (20) or probably (1) come to next years workshop.

The plenary provided background about the refuge and described general management needs. The poster session provided information to researchers on current research and monitoring at the refuge being conducted by refuge staff and others. The breakout sessions (General, Water Management, Lygodium) provided a forum for more structured discussions and resulted in information on what studies are being done that might help to address refuge management needs, and what additional studies were needed. In all cases, the information compiled provides a starting point for better addressing refuge science needs. Summaries provided here should be used by managers and researchers to facilitate future discussions.

In addition to providing information that can be expanded upon to meet needs at A.R.M. Loxahatchee NWR, the workshop provided valuable information on developing and conducting future workshops. The most substantive comments revolved around workshop content. It was clear from the comments that more information should be provided to the participants, facilitators, and note-takers on refuge goals and objectives, and on the desired outcomes of the breakout sessions. In addition, in future workshops, more time may be necessary to answer multiple focus questions and it may be better to more narrowly focus topics for discussion in order to achieve specific objectives and products.

The information gathered in this workshop will be presented at the 2005 A.R.M. Loxahatchee NWR Science Workshop. The 2005 workshop will be general in nature with the objective of providing a forum for communication. Additional workshops may be scheduled as follow ups to issues relating to water management and Lygodium discussed at the 2004 workshop. In addition, the lessons learned will be applied to development of workshops to address management oriented science needs at other refuges. It is anticipated that a workshop revolving around hydrologic issues at Florida Panther National Wildlife Refuge and Ten Thousand Islands National Wildlife Refuge will be conducted in 2005.

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Overview

Restoration and management of the Everglades and other ecosystems require a coordinated, integrated approach to addressing management issues using the best available scientific information. U.S. Fish and Wildlife Service (FWS) and National Park Service (NPS) manage and protect thousands of acres in south Florida and strive to do this based on the best available information. U.S. Geological Survey (USGS) is in an ideal position to provide scientific information that can be used by managers and decision makers. Recent reviews of two science focused programs, the Critical Ecosystems Study Initiative (CESI), and Science Coordination in South Florida, conducted by the National Academy of Science (2003) and the General Accounting Office (2003), respectively have identified improving science coordination, synthesis and integration of research data, and communication of research findings as high priority tasks that are necessary for Everglades Restoration. In addition, NPS, FWS, and USGS have signed a Memorandum of Understanding for Integration of Research, Planning and Interagency Coordination which was established to "...integrate and facilitate coordination among the Parties for all ongoing and future monitoring, research, planning, and interagency coordination activities supporting Everglades Restoration".

Communication is one of the challenges faced in developing a truly integrated science program that addresses management issues. Managers and researchers may have different perspectives on restoration issues and needs based on their different backgrounds and job responsibilities. Managers are faced with having to make day to day decisions based on existing information, regardless of the level of certainty, while researchers seek to increase the level of certainty through hypothesis testing which may require multiple years and multiple studies. Often there are disconnects between results from an individual study and how that contributes to the managers ability to make better decisions. A part of this disconnect comes from incomplete communication from managers as to their real issues and needs, and incomplete communication from researchers to managers on how their projects contribute to the fulfillment of the managers needs. Workshops are one way to improve communication among managers and researchers.

This report provides a summary of the first of several workshops that will be conducted focusing on management issues and science needs of National Wildlife Refuges. It includes: the program booklet for the 2004 Arthur R. Marshall Loxahatchee National Wildlife Refuge Science Workshop, which describes the purpose of the workshop and includes abstracts of each poster presentation; a summary of the breakout session discussions including a summary of linkages to management issues at A.R.M. Loxahatchee NWR and recommendations for future workshops both at A.R.M. Loxahatchee NWR and other refuges.

The information contained in this report can be used by researchers to better understand management needs at A.R.M. Loxahatchee NWR. It provides a summary of what research is currently underway at the refuge both by refuge staff and others. It also provides contact information for workshop participants and others conducting research that may be relevant to refuge needs. In addition, the lessons learned can be used by others in planning and executing future workshops.

Program and Abstracts

Arthur R. Marshall Loxahatchee National Wildlife Refuge

2004 Science Workshop

18 May 2004

Welcome to the 2004 Arthur R. Marshall Loxahatchee National Wildlife Refuge annual science workshop. The purpose of the workshop is to provide a forum for discussion of refuge science needs and to discuss what research is already being conducted on the refuge. We hope that this workshop will make a broader audience aware of the management issues on the refuge that need science support, current research on the refuge, and opportunities for others to conduct research on the refuge. We also hope to begin (and in some cases continue) a dialog among researchers and refuge staff that will develop into future collaboration and partnerships.

The format has been set up to minimize us talking at you and to maximize interaction among workshop participants. There are two plenary sessions that will provide an introduction to the refuge, current management issues, and overview of refuge biological inventory, monitoring, and research activities. The remainder of the day will include a poster session and a series of interactive workshop sessions. The poster session illustrates projects currently conducted on the refuge that directly relate to management issues and studies being conducted elsewhere that may (or could with slight modification) have direct relevance to refuge needs. The workshop sessions will focus on providing input on science needs to address both general and specific refuge management issues and strategies on how to meet them.

The success of the workshop will depend on you. We look forward to your input and participation. Sixty-nine people from 11 different groups pre-registered for the workshop. The breadth of disciplines represented should provide for a stimulating day of discussion. Thank you for your participation.

Groups represented by pre-registered participants	Number of people
Arthur R. Marshall Loxahatchee Foundation	5
Community Watershed Fund	1
Florida Atlantic University	4
Florida International University	3
Habitat Specialists, Inc.	1
National Park Service	2
South Florida Water Management District	16
University of Florida	8
U.S. Army Corps of Engineers	4
U.S. Fish and Wildlife Service	12
U.S. Geological Survey	13

Special thanks go to everyone who provided posters and abstracts, the facilitators and recorders, and the Friends of Loxahatchee Refuge for providing refreshments and lunch.

A.R.M. Loxahatchee NWR 2004 Science Workshop

Date May 18, 2004
Time 8:00-5:00
Location South County Civic Center, 16700 Jog Road, Delray Beach, FL 33446. The South County Civic Center is on Jog Road south of Linton Blvd. and north of Clint Moore Road.

8:00-8:30 **Registration**
8:30-8:45 **Introduction and purpose of workshop**
8:45-9:05 **Plenary 1.** Mark Musaus, Refuge Manager- A.R.M. Loxahatchee NWR, introduction and management issues
9:05-9:25 **Plenary 2.** Laura Brandt, Sr. Wildlife Biologist- Linking science and management, presentation of science management pyramid concept
9:25-9:30 **Preview of Posters**
9:30-11:30 **Poster Session**

11:30-12:30 **Lunch** * Provide for those who pre-registered

12:30-12:40 **Introduction to workshop format**
12:40-1:50 **Break out 1**- Focus questions related to general science management issues on the refuge.
1:50-2:20 **Synthesis of first break out**
2:25-3:40 **Break out 2** (Focus questions related to science needs revolving around specific management questions articulated for:

1. What science do we need to help us make decisions on strategies to reach maintenance control for Lygodium.
2. What science do we need to help us make decisions on water management issues.

3:45-4:45 Synthesis **of second break out**
4:50-5:00 **Wrap up and evaluation**

6:00- ? **Optional No Host Dinner at a local restaurant**

Wednesday (May 19)

Optional Field Trips to refuge

Tree islands- Meet at Lee Road boat ramp at 9:00
LILA- Meet at Marsh Trail parking lot at 9:00
Exotics- Meet at Lee Road boat ramp at 9:00

General Breakout Session

Objective: Develop a list of projects (and contacts) that are being conducted that relate to refuge management issues. The list will serve as a reference for refuge and ecological services staff working on refuge restoration issues. Identify potential partners for future studies and joint funding opportunities.

Supporting information: Posters and abstracts, Research and Investigations from 2003 Annual Narrative (Researchfrom2003narrative.pdf).

Focus questions:

What other studies are being done that relate to refuge management issues?
Who is doing them?
What issues do they address?
What would it take to apply the information to the refuge?
- Can it be transferred directly?
- Can the refuge be used as one of many sample sites?
- Does a study need to be designed specifically for the refuge?

Lygodium Breakout

Objective: Develop an action plan for research on the refuge that will help us to meet our Lygodium control goals.

Supporting information: LoxNWRlygodiummang.pdf, LygoMaintenancecontrol.pdf

Focus questions:

What science do we need to help us make decisions on strategies to reach maintenance control for Lygodium?
- What areas are missing from the diagrams of "How do we achieve maintenance control of Lygodium by 2017?"

- What specific studies are needed to address the areas identified?
- Are they being done? By whom?

Water Management Breakout

Objective: Develop a matrix of attributes that can be used as a guide for future water management decisions. Identify key science uncertainties related to those attributes.

Supporting information: Biological indicators.pdf, Watermanagement.gif

Focus questions:

What science do we need to help us make decisions on water management issues?

- What are we missing from the poster?
- What are our external constraints?
- For each area, what are the key things we need to know (drivers, stressors, ecological endpoints)?
- What are the specific studies needed to address the areas identified?
- Are they being done? By whom?

List of Posters by Topic

Abstracts of posters are listed alphabetically by first author

General Refuge Information (no abstracts)

Work conducted by refuge staff
Work conducted by others
Science needs for water management

Wildlife and Habitats

Alligator research at the Arthur R. Marshall Loxahatchee National Wildlife Refuge.
Brandt, Laura A. , Frank J. Mazzotti, Kenneth G. Rice, and H. Franklin Percival

Status of Apple Snails at Arthur R. Marshall Loxahatchee National Wildlife Refuge
Ren, Alex, Laksiri Karunaratne, Phil Darby, and Rob Bennetts

Got Matches? Fire Management at Arthur R. Marshall Loxahatchee National Wildlife Refuge
Hinckley, Jennifer L., Stefani L. Melvin, Laura A. Brandt

"Fine Tuning Everglades Restoration": the Loxahatchee Impoundment Landscape Assessment (LIL) Project.
West, Geoffrey, Mark Cook, Fred Sklar, Eric Cline, and Dale Gawlik

Tree Islands

USFWS Creating Successful Wildlife Management on Tree Islands in Arthur R. Marshall Loxahatchee National Wildlife Refuge
Darby, A.C., B. Arrington, L.A. Brandt, D. Ecker, G. Martin, F. Mazzotti, I.G. Rivera, and A. Traut

Linking Science and Management to Protect Tree Islands at Arthur R. Marshall Loxahatchee National Wildlife Refuge
Pannozzo, Pamela, L., Laura A. Brandt, Frank J. Mazzotti, and Kenneth G. Rice

Linking Belowground Biomass to Forest Structure and Hydroperiod on Tree Islands Located in Water Conservation Area 3
Coronado-Molina C., L. Bauman, M. Korvela, and F.H. Sklar

Impacts of 20th Century Anthropogenic Changes on Strand Tree Islands in Arthur R. Marshall Loxahatchee National Wildlife Refuge
Willard, Debra A., Bernhardt, Christopher E., Landacre, Bryan, Marot, Marci

Exotics

Gaining Ground on *Lygodium microphyllum*
Call, E.M., S. Duke-Sylvester, A.G. Snow, L.A. Brandt, D.L. DeAngelis**,** and L.J. Gross

Control of Invasive Exotic Vegetation at Arthur R. Marshall Loxahatchee NWR
Thomas, William, G., Jr, Stefani L. Melvin, and Laura A. Brandt

The life history of the invasive fern *Lygodium microphyllum*: from reproductive strategy to landscape dispersal
Volin, John C., Michael S. Lott, Jordan D. Muss and Dianne Owen

Water Quality

Arthur R. Marshall Loxahatchee National Wildlife Refuge Water Quality and Water Quantity Monitoring
Waldon, Mike, Bruce Arrington, A. Camille Darby, Matt Harwell, and Laura A. Brandt

USFWS Enhanced Water Quality Monitoring Plan for the A.R.M. Loxahatchee National Wildlife Refuge
Brandt, Laura A., Matt Harwell, and Mike Waldon

Internal Loading of TP and Other Constituents in the L-7 Canal Using a Simple Mixing Model
Waldon Mike, and Paul McCormick

Contributions of sediments to phosphorus concentrations in canals bordering the A.R. M. Loxahatchee National Wildlife Refuge
Diaz, O.A., S.H. Daroub, J.D. Stuck, T.A. Lang, M.W. Clark, and K.R. Reddy

Supporting Data Layers

Measuring and Mapping the Topography of A.R.M. Loxahatchee National Wildlife Refuge and the Florida Everglades
Desmond, Gregory B

Vegetation Mapping at Arthur R. Marshall Loxahatchee National Wildlife Refuge
Schall, Ted, Matt Love, and Ken Rutchey

Water Conservation Area 1 Regulation Schedule Overview
Sylvester, Susan B

ABSTRACTS

USFWS Enhanced Water Quality Monitoring Plan for the A.R.M. Loxahatchee National Wildlife Refuge

Brandt, Laura A., Matt Harwell, and Mike Waldon
U.S. Fish and Wildlife Service

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In FY04, Congress specifically appropriated $1,000,000 to the Arthur R. Marshall Loxahatchee National Wildlife Refuge for water quality monitoring and modeling. This poster describes planned monitoring to be conducted using this appropriation. Monitoring will be conducted in two field components that will improve the scientific understanding of water quality issues in the refuge and will provide information that can be incorporated into water management decisions for better protection of refuge resources. These studies are consistent with the long-term goals of the refuge's 15-year Comprehensive Conservation Plan and recommendations made by the Technical Oversight Committee for addressing exceedances observed in interim phosphorus levels within the refuge.

Data collected during this project will help to address management questions, including:

1) At what water levels does canal water move into the marsh?
2) How far does water from the canal move into the marsh?
3) What water management operations minimize movement of canal water into the interior of the refuge?
4) What are the ecological effects of canal water on refuge resources?

Alligator research at the Arthur R. Marshall Loxahatchee National Wildlife Refuge.

Brandt, Laura A. [1], Frank J. Mazzotti[2], Kenneth G. Rice[3], and H. Franklin Percival[3]
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Alligators are a conspicuous feature of the Arthur R. Marshall Loxahatchee National Wildlife Refuge and are considered a keystone species in the Everglades. Many aspects of alligator biology are closely tied to hydrologic conditions. Relative abundance, condition, nesting effort and success, and alligator hole occupancy are attributes that will be measured to track the responses of the Everglades to restoration activities. In the refuge, little historic information on these attributes is available, especially for the interior marsh. Data are needed to establish baseline conditions for future monitoring of the ecological effects of hydrologic management on habitats and wildlife. A program for alligator monitoring and research that addresses refuge needs for information on relationships between hydrologic management and ecological condition

that is consistent and coordinated with other system-wide alligator monitoring and research efforts has been developed.

The combination of studies on relative abundance, nesting, condition, and alligator holes, provide data on the short and long-term effects of water management on alligators. Condition provides a year to year assessment of alligator responses to habitat and hydrologic conditions. Distribution of nests, and relative abundance track longer term changes. Alligator hole distribution information will assist with assessment of responses of aquatic fauna and wading birds to hydrologic conditions. All provide information for evaluation of overall habitat conditions.

Gaining Ground on *Lygodium microphyllum*

Call, E.M.[1], S. Duke-Sylvester[2], A.G. Snow[1], L.A. Brandt[3], D.L. DeAngelis[4], and L.J. Gross[2]

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The Everglades ecosystem is under threat from invading species. One species that is spreading at an alarming rate is Old World Climbing Fern (*Lygodium microphyllum*). This native to Africa, Australia, Asia, and Melanesia was discovered as a naturalized population in 1965 in South Florida. The rapidity of this exotic's invasion can be explained by its efficient reproductive strategies. Spores are released from fern fronds in the tree canopy and dispersed by wind. Each fertile leaf has the potential to produce 20,000 spores. To address *L. microphyllum* infestation within A.R.M Loxahatchee National Wildlife Refuge, an optimal control model is being developed. The model incorporates information relating to spore dispersal patterns, levels of infestation, treatment costs, and effectiveness. This model will serve as a tool to aid managers in identifying the most efficient way to treat *L. microphyllum*.

Linking Belowground Biomass to Forest Structure and Hydroperiod on Tree Islands Located in Water Conservation Area 3

Coronado-Molina C., L. Bauman, M. Korvela, and F.H. Sklar
South Florida Water Management District

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Tree islands comprise only a small portion of the total area of the Everglades, however, they have been shown to provide substrate for 80% of the woody plant diversity including many less water tolerant upland and temperate plant species. The distribution and abundance of woody species have been shown to be dependent on natural processes, such as fires and long term hydrological conditions. At the same, we know very little about the processes that contribute to the formation and maintenance of tree islands.

Belowground biomass, measured by the presence of roots, is an important biological component on the organic matter dynamics of tree islands. Thus, to understand how organic matter, both aboveground and belowground, contributes to soil formation and maintenance of tree islands, we have been collecting field data with the purpose to determine the relative importance of hydroperiod and water depth on both forest structure and belowground dynamics.

Our results indicate that there is a pattern that links belowground biomass to the hydrologic regime and forest structure characteristics of the tree islands under study. These results suggest that woody vegetation subjected to longer hydroperiods allocate more organic matter to the belowground component, whereas woody vegetation subjected to shorter hydroperiods allocate less organic matter to belowground components. It is hypothesized that decomposition rates are most likely influencing biomass accumulation due to differing decomposition rates under varying hydrologic conditions. However, hydrology is not the only factor determining biomass partitioning. Accordingly, species composition, forest age, forest structure, soil type and nutrients also play important roles in the way woody vegetation allocates organic matter.

USFWS Creating Successful Wildlife Management on Tree Islands in Arthur R. Marshall Loxahatchee National Wildlife Refuge

Darby, A.C.[1], B. Arrington[1], L.A. Brandt[1], D. Ecker[1], G. Martin[1], F. Mazzotti[3], I.G. Rivera[2], and A. Traut[3]
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According to the National Wildlife Refuge System Act, the primary mission of the National Wildlife Refuge System is wildlife conservation. Five different vegetative communities occur on the refuge. One of the most valuable, as a wildlife resource, is the tree island community. As

the only high ground in an otherwise wetland landscape, tree islands provide habitat heterogeneity and are sites of high plant and animal biological diversity. Recent studies show that pop-up tree islands in the refuge provide habitat for a wide range of species and show different vegetative characteristics than tree islands in other parts of the Everglades. Therefore, refuge tree islands are likely to support a unique wildlife community.

As a part of the refuge landscape, the tree island habitat faces many threats, including altered hydropatterns and water quality, and invasion by exotic plants. These threats make the management and protection of the wildlife resource a greater challenge for the refuge. In response, the refuge has implemented a number of studies aimed at better understanding the use of tree island habitat by wildlife and how the resource responds to threats. These projects include inventories of vegetation, birds, small mammals, reptiles, amphibians, and ants. The elevation of refuge tree islands also has been studied and results used to further our understanding of what makes these tree islands unique in the Everglades system. These studies combined provide a description of the plant and animal communities on refuge tree islands. Please refer to articles provided for more information on the descriptive studies and plant and animal species lists

Measuring and Mapping the Topography of A.R.M. Loxahatchee National Wildlife Refuge and the Florida Everglades

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A major issue facing ecosystem restoration and management of the Florida Everglades is the availability and distribution of clean, fresh water. Surface water flow, and ecological modeling studies provide important scientific information needed for ecosystem restoration. These models require various input data, including elevation data that accurately define the topography of the Florida Everglades. Surface water levels and sheet flow in the Everglades are very sensitive to any differences in topography given the region's expansive and extremely flat terrain. Since conventional surveying techniques are impractical due to the large area and surface conditions, and because the terrain surface being surveyed is typically under water and obscured by vegetation, remote sensing technologies that produce elevation data, such as Lidar, IFSAR, and photogrammetry, cannot meet the 15 cm vertical accuracy requirement for the data. To meet this requirement, the U.S. Geological Survey (USGS) has developed a helicopter-based surveying instrument known as the Airborne Height Finder (AHF) System to produce the high accuracy elevation data needed by the scientific modeling community. The USGS is using the AHF system to perform topographic surveys of A.R.M. Loxahatchee National Wildlife Refuge and the Everglades to parameterize the various simulation models under development.

Contributions of Sediments to Phosphorus Concentrations in Canals Bordering the A.R. M. Loxahatchee National Wildlife Refuge

Diaz, O.A., S.H. Daroub, J.D. Stuck, T.A. Lang, M.W. Clark, and K.R. Reddy
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Understanding sediment properties stored within a system is important for a number of environmental issues including the accumulation of particle bound nutrients, release properties and their eventual transport. The objective of this study was to evaluate the effect of canal sediments on phosphorus (P) concentrations of water released from the Stormwater Treatment Areas (STAs) and their potential impact inside the refuge and downstream ecosystems. The major tasks of the study were to: (i) conduct an inventory of canal sediments bordering the refuge, (ii) quantify the major sediment P fractions, and (iii) estimate potential rates of P flux from these sediments. The inventory showed that there is over 4.8 millions m^3 of sediments, with an estimated P mass of 855,000 kg stored in L7/L39/L40 canals. Phosphorus fractions associated with Ca and Mg compounds were the dominant P forms in these sediments. However, sediments from the L40 canal showed significant concentrations of relatively available P, higher organic matter and lower bulk densities. These characteristics plus expected higher flows from a fully operational STA-1E increase the potential of resuspension and transport of sediment in this canal to downstream areas and inside the refuge. This study concluded that P flux might not be a significant constant contributor to the overall P load, however it may be a significant contributor during stagnant or quiescent conditions.

Got Matches? Fire Management at Arthur R. Marshall Loxahatchee National Wildlife Refuge

Hinckley, Jennifer L., Stefani L. Melvin, Laura A. Brandt
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Fire is a well-documented process that historically contributed to the formation and maintenance of the Everglades ecosystem. Wildfires occurred with some frequency as a result of lightning strikes and were critical to maintaining the mosaic of sawgrass ridges, wet prairies, sloughs, and tree islands that defines the Everglades. Due to the combined effects of fragmentation of the Everglades ecosystem and changes in hydropatterns across the Refuge, frequency of fires has decreased reducing the influence of this invaluable ecological process. Restoration and maintenance of the Everglades ecosystem incorporates fire management as an integral tool.

The Refuge has been without an active prescribed fire program for twelve years. There has been no long-term monitoring of fire effects on the habitats. The Refuge has identified a tremendous ecological restoration need to initiate a prescribed burn program.
To promote the fire management program's objectives at the Refuge many questions are being posed. These include determining ideal water levels for successful prescribed burns; efficiently monitor the effects of the burns and connections between use of fire and biological controls used to manage exotic plants. Understanding the most appropriate use of fire will enhance the adaptive decision making used at the Refuge.

Linking Science and Management to Protect Tree Islands at Arthur R. Marshall Loxahatchee National Wildlife Refuge.

Pannozzo, Pamela[1], L., Laura A. Brandt[2], Frank J. Mazzotti[1], and Kenneth G. Rice[3].
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Tree islands are sites of high species diversity within the marsh of the A.R.M. Loxahatchee National Wildlife refuge and are important for maintaining biological diversity. Anthropogenic changes in hydrology and invasive exotic species have impacted tree islands throughout the refuge. Sustaining tree islands in the refuge will require tools to assess the impacts of stressors such as hydrology and exotic species on tree island condition. This study will develop a rapid assessment protocol for determining the spatial pattern of tree island condition throughout the refuge. The protocol will set forth indicators of tree island condition, methods for using those indicators in the field, and a scored index in which the indicators can be used to assess tree island condition. A spatial database of tree island condition will be developed to enable managers to protect tree islands in good condition, and improve conditions for impacted tree islands.

Status of Apple Snails at Arthur R. Marshall Loxahatchee National Wildlife Refuge

Ren, Alex[1], Laksiri Karunaratne[1], Phil Darby[1], and Rob Bennetts[2]
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The golf-ball sized Florida apple snail is prey to numerous wetland organisms including alligators, turtles, wading birds, and most notably the endangered snail kite. As such, the apple snail has been identified as an indicator of restoration success for the Greater Everglades Ecosystem. The USFWS Snail Kite Recovery Plan identified a number of wetland units, including A.R.M. Loxahatchee National Wildlife Refuge (LNWR), as critical habitats for Snail

Kites. Snail abundance in these areas is critical since the Snail Kite eats only apple snails. Our research team has measured snail abundance in several of these wetlands units. We found four to five times fewer snails in LNWR relative to Water Conservation Area 3A (WCA3A), a wetland frequently used by snail kites. We also found that snails were more abundant in wet prairie relative to slough habitats. Wet prairies are dominated by emergent plants such as spike rush and maidencane. Sloughs are dominated by lily pads and tend to have little emergent vegetation. It may be that habitat parameters related to water management can enhance snail abundance (e.g., wet prairie habitat benefits from dry downs). However, we also have some preliminary evidence that suggests calcium levels and pH may limit snail abundance.

Vegetation Mapping at Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Since the process of building levees and canals in South Florida began in the early 20th Century, the Everglades has undergone major changes within its vegetation communities. These changes are the result of drastically changing hydroperiods and eutrophication of the Everglades ecosystem. Such changes in vegetation communities include the loss of tree islands, a reduction of the ecosystem's ridge and slough characteristics, and an increase in nuisance species such as cattail (*Typha* spp.). An invasion of exotics species, such as *Lygodium microphyllum* and *Melaleuca quinquenervia*, threaten to replace native South Florida vegetation communities within the Everglades.

Vegetation mapping within the A.R.M. Loxahatchee N.W.R. will indicate the spatial distribution and extent of exotic and nuisance species located throughout the refuge, while providing the first detailed vegetation map of the refuge. The maps will provide the necessary data to monitor how vegetation communities are responding to projects carried out under the Comprehensive Everglades Restoration Plan (CERP) and to the newly created Storm Water Treatment Areas (STAs). Vegetation mapping data will also be utilized to determine an effective treatment plan to better manage exotics and nuisance species.

Water Conservation Area 1 Regulation Schedule Overview

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Water Conservation Area 1 (WCA 1) is located within the Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR) and is part of the Central and Southern Florida Project for Flood Control and other Purposes (C&SF). Water levels in WCA 1 are regulated by the U.S. Army Corps of Engineers (USACE) using a regulation schedule to provide for a variety of project purposes including flood control; agricultural, municipal and industrial water supply; enhancement of fish and wildlife; prevention of saltwater intrusion; and water supply to Everglades National Park.

A regulation schedule provides instructions and guidance on how project structures are operated to maintain water levels in the WCAs and represents the seasonal and monthly limits of storage. The water level varies from high stages in the late fall and winter to low stages at the beginning of the wet season. This seasonal range permits the storage of runoff during the wet season for use during the dry season. In addition, it serves to maintain and preserve the vegetative structure within the WCAs that is essential to fish and wildlife and for the prevention of wave run-up damage to the levees from wind tides. The objective of a regulation schedule is to maximize benefits for the various and often competing interests in water use.

Control of Invasive Exotic Vegetation at Arthur R. Marshall Loxahatchee NWR

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Over 1,200 introduced plant species have become established in Florida, and are successfully reproducing and invading natural areas. Of these, 4% are serious pests that are adversely affecting native plant habitats. Melaleuca and Old World climbing fern (Lygodium) infest approximately 100,000 acres (70%) of refuge habitats. Lygodium alone infests some 25,000 acres (15%) of the Refuge. Control technologies have been perfected for Melaleuca, however, Lygodium is a rather recent invader, and much less is known about its biology, or effective methods of control. For these reasons, and its exponential spread in recent years, Lygodium is considered the most serious exotic plant threat to the Refuge and to the Everglades ecosystem.

An effective exotic plant management program incorporates many elements including: dedicated funding, assessing and detecting problematic species, implementation of an Integrated Pest Management plan, treatments, biological controls, monitoring, research, and education. Such an

integrated approach is the best strategy for controlling Lygodium and other invasive exotic plants. Long-term restoration and management of the Refuge and Everglades ecosystem will be dependent upon the ability to successfully control Lygodium and other invasive exotic plants.

The Life History of the Invasive Fern *Lygodium microphyllum*: From Reproductive Strategy to Landscape Dispersal

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We studied the life history of the highly invasive non-indigenous *Lygodium microphyllum* in South Florida across a range of ecological scales. Examination of its reproductive biology shows that *L. microphyllum* is able to mate by both selfing and outcrossing, lending support to our hypothesis that its reproductive strategy partially explains its invasiveness. To better understand the growth dynamics of *L. microphyllum*, young sporophytes were grown under three different light levels for 180 days and compared with seedlings of the native vine, *Vitis rotundifolia*. *L. microphyllum* has a significant growth advantage in low light conditions compared to *V. rotundifolia*. Its greater weight-based photosynthetic rate, as well as its ability to optimize allocation between stems and roots helps explain *L. microphyllum's* growth advantage. At the community level, the presence of *L. microphyllum* within the Big Cypress Swamp was dependent on moderately hydric conditions. Finally, we developed a landscape cellular automaton model of its spread throughout South Florida that was calibrated using actual data from 1978 to 1993. The projection to 2014 shows an alarming increase in *L. microphyllum* establishment across South Florida, particularly in the cypress-dominated wetlands of the Big Cypress Swamp.

Arthur R. Marshall Loxahatchee National Wildlife Refuge Water Quality and Water Quantity Monitoring

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The A.R.M. Loxahatchee National Wildlife Refuge developed as a rainfall-driven system with surface waters low in nutrients, especially phosphorus, and inorganic ions such as chloride, sodium, and calcium (low conductivity). Information from the refuge and other wetlands indicates that changes in major ions may cause undesirable ecological changes in flora and

fauna. There is concern that increases in canal water intrusion into the refuge interior may cause negative ecological consequences. Monitoring of water quality and water quantity in the refuge has occurred primarily for permit compliance, compliance with Consent Decree requirements, and to aid research. A pollutant-impacted fringe of marsh has developed between the relatively pristine interior marsh and the perimeter canals; however, most historical water quality monitoring has not focused on the impacted zone of interior marsh near inflows. The historic and current monitoring of water quality and water quantity has been critical for management decisions on developing an enhanced water quality monitoring plan for the refuge.

Internal Loading of TP and Other Constituents in the L-7 Canal Using a Simple Mixing Model

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In the 1950s and 1960s the Arthur R. Marshall Loxahatchee National Wildlife Refuge was surrounded by perimeter canals and hydrologically isolated from its watershed by levees. Stormwater runoff, primarily from the Everglades Agricultural Area, is pumped into the perimeter canal where it may mix into the rainwater-dominated interior wetland. The pumped stormwater has elevated concentrations of both Chloride (Cl) and Phosphorus (P). Data collected primarily by the South Florida Water Management District were analyzed in this study using a simple mixing model to provide a qualitative graphical assessment of P internal loading or loss within the perimeter canal. This graphical assessment identifies presence of sources and sinks of constituents. Chloride is used to estimate the fraction of each water sample originating in pumped inflow to the canal. Our analysis supports the hypothesis that there is an internal P loading source within the canal. It is conjectured that this source results from groundwater advection of re-mineralized P in sediment pore water. Recent studies have documented a large pool of P in the highly organic sediments deposited in the perimeter canal since construction. Sediment buildup in the canals appears to be a potential source of P to water entering the interior.

"Fine Tuning Everglades Restoration": the Loxahatchee Impoundment Landscape Assessment (LILA) Project

West, Geoffrey[1], Mark Cook[1], Fred Sklar[1], Eric Cline[2], and Dale Gawlik[3]
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Everglades restoration is an enormous effort including many projects and activities outlined in the Comprehensive Everglades Restoration Plan (CERP). The framework of CERP is built on the interpretation of performance measures designed to monitor an individual project's success. A series of assessment studies at the Loxahatchee Impoundment Landscape Assessment (LILA) project located at the Arthur R. Marshall Loxahatchee Wildlife Refuge will assist in developing performance measures for Everglades restoration. LILA consists of four 17-acre replicated macrocosms sculpted to mimic the key landscape features of the Everglades and will be used to test the response of tree island and ridge and slough communities to changing hydrologic treatments. Water depth, velocity, and flow rate will be manipulated using a controlled water delivery system allowing scientists to study restoration plans on a small scale before applying them to the natural system. LILA provides a unique opportunity to fill key information gaps of CERP and to provide the public with a rare opportunity to see restored Everglades habitats. What really sets LILA apart from other approaches is that the hydrology is controlled and replicated, producing much less variability than what is found in the natural system. A second strength of LILA is that the collective assessment studies provide a multidisciplinary package of scientific information whose worth is much greater than the sum of the individual studies. By using reliable science, LILA will test the success of the restoration process.

Impacts of 20th Century Anthropogenic Changes on Strand Tree Islands in Arthur R. Marshall Loxahatchee National Wildlife Refuge

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Tree islands are the centers of biodiversity within the A.R.M. Loxahatchee National Wildlife Refuge and the Everglades in general. To determine whether anthropogenically-derived changes are greater than those due to natural climate variability, we examined ecological proxies from sediment cores collected on two strand islands in the central and southeastern part of the refuge. These cores recovered the upper 60-80 cm of peat, representing the last 600-1,200 years of tree-island history. Tree-island vegetation existed at these sites for several centuries, and fluctuations in abundance of fern spores and tree pollen document climatically-driven fluctuations in hydrology. Changes in water management in the mid-20th century resulted in

abrupt changes in tree-island community composition at these sites, when *Myrica* and *Ilex* abundance increased more than fivefold.

Unprecedented changes in tree-island composition resulted from mid-20th century water-management practices at these sites. Further research on strand islands elsewhere in the refuge would clarify whether such responses characterize the entire refuge and whether pop-up islands show comparable responses. These pollen records provide a long-term perspective on the stability of tree-island vegetation in the refuge and provide key data for successful prediction of tree-island response to future water-management changes.

Session Summaries

General Breakout Sessions

There were four general breakout groups with approximately 15 people each. An attempt was made to spread agency representation among the groups, but no attempt was made to spread out subject expertise. A facilitator and note taker were assigned to each group.

Facilitators:	**Note takers:**
Nick Aumen	Arturo Torres
Matt Harwell	Pam Pannozzo
Agnes McLean	Jocie Graham
Jim Smoot	Laura Brandt

Participants and facilitators were given the following information for the basis of discussion:

Objective: Develop a list of projects (and contacts) that are being conducted that relate to refuge management issues. The list will serve as a reference for refuge and ecological services staff working on refuge restoration issues. Identify potential partners for future studies and joint funding opportunities.

Supporting information: Posters and abstracts, Research and Investigations from 2003 Annual Narrative (Appendix 1-Researchfrom2003narrative.pdf).

Focus questions:

What other studies are being done that relate to refuge management issues?
Who is doing them?
What issues do they address?
What would it take to apply the information to the refuge?
- Can it be transferred directly?
- Can the refuge be used as one of many sample sites?
- Does a study need to be designed specifically for the refuge?

The general session provided a good opportunity for others to see the kind of work going on at the refuge and related research going on in other parts of the Everglades. Each group approached the task of developing a list of projects and contacts a little differently. As a result, some projects are listed without project contacts. The lists include projects that are not being conducted by refuge staff. Additional refuge projects can be found in the Research and Investigations from the 2003 Annual Narrative (Appendix 1).

The initial project list from all the groups combined included 129 projects or topic areas. Each project was assigned a general category. The overall list was sorted by category, then project name, and contact. Duplicate entries were combined leaving a list of 117 projects that were grouped one of 25 broader categories (Table 1, and Table 2). Eighty-six of the projects had

contact names. Of the 31 projects without contacts, seven were associated with an agency, the rest had no contact or agency information.

The project list was reviewed to see how many of the ongoing studies match with refuge overarching questions or management needs (Appendix 2). An attempt was made to code projects as to whether they addressed a listed refuge need, not addressing a refuge listed need but could if conducted at the refuge, not addressing a refuge listed need, or not enough information. In most cases, it was not possible from the study title to tell whether the study would actually meet a refuge need. The list does provide a starting point for refuge staff to seek additional expertise within the categories delineated. Likewise, the list of overarching questions and specific questions related to areas needing research at the refuge (Appendix 2) provides a starting point for researchers to engage refuge staff in discussions on future projects.

Comments from Evaluation and Lessons Learned

The general breakout session received the most comments in the "liked least" section of the evaluation. Only about half the people who filled out an evaluation thought it should be continued in future workshops. Most of the comments revolved around the lack of clear direction for the session. Many found the interaction with other scientists useful, but were unclear on the purpose of the session. Because the facilitators and note takers did not all have the same view of the desired outcome of the session, it was difficult to synthesize the information that was obtained from the groups. Most of the focus of the discussions was on what studies were being done by whom, and not on what issues they addressed or how they could be applicable to refuge needs.

Solutions to the short comings of this session include: Making sure the facilitators and note takers understand what the desired outcome of the session is. Make sure the note takers are prepared to write a summary of the session from their notes. Provide a template for filling in the desired project and contact information and have participants prepare project lists before the workshop so that discussions can focus on whether the studies are providing information that can be used to address a refuge need. Send the list out to participants before the workshop along with information on refuge needs so that participants are better prepared to discuss how the studies relate to refuge needs. Acknowledge that the process of fleshing out the answers to the focus questions will take more than one session.

Table 1. General categories of projects from 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Project Category	**Number of projects**
Aerial photos	1
Alligators	1
Amphibians	1
Aquatic fauna	7
Bathymetry	1
Cattail	4
Coastal Restoration	2
Data integration	2
Evapotranspiration	1
Exotics	24
Experimental design	2
Fire	9
Hydrology	11
Long term plan	1
Models	8
Processes	2
Public Use Impacts	1
Rainfall	1
REMAP	1
Ridge and Slough	6
Tree Islands	12
Vegetation	4
Vegetation mapping	3
Wading birds	2
Water quality	10
Total Number of Projects	**117**

Table 2. Projects (and topics) listed by general breakout session at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Aerial photos	Aerial photo archives	2	USGS	Tom Smith	South Florida	
Alligators	Alligator distribution, condition, nesting	2	USGS/UF	Ken Rice, Frank Mazzotti	LOX, Greater Everglades	
Amphibians	Amphibian PAO analysis as a tool	1	USGS	Ken Rice		
Aquatic fauna	Crayfish	2	SFWMD	April Huffman		
Aquatic fauna	Crayfish in Lox and greater Everglades-MAP	2, 4	FAU	John Volin	LOX, Greater Everglades	
Aquatic fauna	Crayfish/fauna in wet season	2, 4	FIU	Joel Trexler, Shawna Baker	LOX, Greater Everglades	
Aquatic fauna	Crayfish/prey concentrations for wading birds	2, 4	FAU	Dale Gawlik	LOX, Greater Everglades	
Aquatic fauna	Exotic fish impacts	3	FIU	Joel Trexler		
Aquatic fauna	Fish as index of secondary production	3	FIU	Joel Trexler	ENP, WCA3	
Aquatic fauna	Periphyton	2				
Bathymetry	Tidal creek bathymetry in ENP	2		Mark Hansen	ENP	
Cattail	Accelerated recovery	1	SFWMD			
Cattail	Cattail and fire	4	SFWMD			
Cattail	Literature search on control/elimination of Cattails	2	DEP	Frank Nearhoff		
Cattail	Work by Duke	2	Duke	Jim Paul		
Coastal Restoration	Canada delta marsh program	2	Ducks Unlimited	Gordon Goldborough		
Coastal Restoration	LA coastal restoration project	2		Denise Reed		
Data integration	CERP data integration	1				
Data integration	SOFIA data integration	1				
Evapotranspiration	ET study in Lox by Ed Gremain	2	USGS	Ed Germain	LOX	
Exotics	ATLAS model for Lygodium	1				

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Exotics	Bio-control of exotics	4	USDA	Bob Pemberton		
Exotics	Bio-control of exotics	2	USDA-UF	Jim Cuda		
Exotics	Brazilian pepper bio control	2		Jim Cuda		
Exotics	Germination of lygodium in response to flooding	3	FIU	Tom Phillippi		
Exotics	Invasive species workshop in China	2	SFWMD	Shili Miao		
Exotics	Lobate Lac scale bio-control	1				
Exotics	Lygodium Bio-control development	1				
Exotics	Lygodium control	4	UF	Jim Cuda		
Exotics	Lygodium control	4	UF	Ken Langeland, Randell Stocker		
Exotics	Lygodium control- ENP	2	NPS			
Exotics	Lygodium control- herbicide application	2	SJRWMD-IFAS	Wayne Coburn		
Exotics	Lygodium control Jonathan Dickinson	2		Dick Roberts	Jonathan Dickinson State Park	
Exotics	Lygodium herbicide treatment	1				
Exotics	Lygodium life history	1				
Exotics	Lygodium management plan	2	EPPC			
Exotics	Lygodium spread, life cycle, landscape level	1				
Exotics	Lygodium surveys	2	SFWMD	Amy Ferriter		
Exotics	Melaleuca surveys	2	SFWMD	Amy Ferriter		
Exotics	Movement of spores and response to aerial spray	3	UF	Jeff Hutchinson		
Exotics	Optimization model for lygodium management	2	FAU	John Volin	DEP funded	
Exotics	Pattern analysis of lygodium	2	SFWMD	Godin		
Exotics	TAME Melaleuca study	2	USDA	Ted Center		
Exotics	Translocation of herbicide in lygodium	3	UF	Jeff Hutchinson		
Experimental design	Design for trophic level sampling	2, 3	FIU	Tom Phillippi		
Experimental design		2	USGS	Jim Nichols		

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Fire	Big Cypress and fire	2	USGS	Jim Snyder	Big Cypress	
Fire	Fire	4	FIU	Serge Thomas/Evelyn Gaiser		
Fire	Fire and pre-post burn water chemistry	2, 4	USGS	Bill Orem		sulfur and mercury impacts
Fire	Fire and WQ	4	NPS	Bill Horn	WCA3	Big Cypress
Fire	Fire at Jonathan Dickinson State Park	4	DEP-FPS	Dick Roberts		
FIre	Fire for vegetation control	1				
Fire	Fire in ENP	4	USGS	Jim Snyder		
Fire	Fire in WCAs	4	FFWCC	Mike Anderson		
Fire	Fire modeling	1				
Hydrology	Flow in Shark River Slough	2				
Hydrology	Flow measurements	2	USGS	Ray Schaffranek		
Hydrology	Flow studies	4	SFWMD	Chris McVoy, Sue Newman		
Hydrology	Flow studies	4	FIU	SERC?		
Hydrology	Flow velocity work in ENP and WCA3	2	UM	Solo Gabriel	WCA3 and ENP	
Hydrology	Ground water recharge in Lox	2, 4	USGS	Judsin Harvey, Greg Noly	LOX	
Hydrology	Hydrologic modeling	1				
Hydrology	Hydrologic variability and vegetation	2	USGS	Wiley Kitchens	WCA3	
Hydrology	Lake Okeechobee regulation schedule	4	SFWMD	Karl Havens		
Hydrology	Radar to remotely sense water depth	2	SFWMD/FWS	Godin		
Hydrology	Rain driven changes to regulation schedules	4	ACOE	Dave Nelson		
Long term plan	Accelerated recovery in impacted areas	2	SFWMD			
Models	Conceptual models	2				

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Models	Decision support system for SW FL feasibility study	2	UF	Leonard Pearlstine	SW Florida	
Models	Ecological	1				
Models	ELM	2	SFWMD	Karl Fitz		100 m resolution
Models	Flow models and nutrient transport	2	USGS	Chris Langvien		
Models	Habitat suitability	1				
Models	Nutrient transport flow models	4	USGS	Paul Glazer		
Models	Ridge and slough	1				
Processes	Processes affecting peat accretion	2	USGS Ca/WRD			
Processes	SF Bay transport of organics	2				
Public Use Impacts	Impacts of airboats	1				
Rainfall	NEXRAD data for rainfall	2	University of Miami			
REMAP		2		Pete Kala		
Ridge and Slough	Flow measurements and water chemistry	2	UF	Mark Clark		
Ridge and Slough	Flow/piston core that captures floc layer	2	USGS	Paul Glazer		
Ridge and Slough	LILA	2	SFWMD	Fred Sklar		
Ridge and Slough	Microtopography measurements	2	SFWMD	Chris McVoy	WCA3A&B	
Ridge and Slough	Pattern analysis of ridge and slough	2				
Ridge and Slough	Ridge and slough creation and maintenance	1				
Tree Islands	A rapid assessment method for tree islands	2	UF	Pam Pannozzo	LOX	
Tree Islands	Animals on tree islands with exotic control	4	FFWCC	Mike Anderson		
Tree Islands	Characterization of tree islands along hydrologic gradients	1	SFWMD	Fred Sklar	WCA3A, WCA3B	Seedlings, recruitment, forest structure, litter fall, tree growth, below ground biomass, monitoring tool, green house studies

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Tree Islands	Ecosystem history of tree islands	2	USGS	Debra Willard		
Tree Islands	Effects of hydrologic stress on trees	2	SFWMD	Sue Newman		
Tree Islands	Geology/map strands and substrate chemistry	4	USGS	Debra Willard		
Tree Islands	Mammals on tree islands	4	SFWMD	Carlos Coronado	WCA3	
Tree Islands	Nutrient & birds on tree islands	4	SFWMD	Carlos Coronado	WCA3	
Tree Islands	Tree island elevation	2	SFWMD	Fred Sklar		
Tree Islands	Tree island leaf litter/root production, below ground biomass	3, 4	SFWMD	Carlos Coronado, Laura Bauman	WCA3	
Tree Islands	Tree island nitrogen cycling and flow	4	FIU	Tiffany… Steve Overbar		
Tree Islands	Water quality of tree island pore water	1				
Vegetation	Estimating biomass from seeds in cores	2	FIU	Colin Saunders		
Vegetation	Grassy Waters vegetation and water levels	2, 4	SFWMD	Fred Sklar	Grassy Waters Preserve	
Vegetation	Vegetation/community gradients in Big Cypress	2	FAU	John Volin	Big Cypress	
Vegetation	WCA3A vegetation community structure	4	USGS	Wiley Kitchens		
Vegetation mapping	Cattail and exotic	1	SFWMD	Ken Rutchey	LOX, Greater Everglades	5 year cycle of monitoring, Includes density, mapping treatment areas
Vegetation mapping	Cattail in WCA2	1	SFWMD	Ken Rutchey	WCA2	5 year cycle
Vegetation mapping	Determine the appropriate scale for veg mapping	2	SFWMD	Ken Rutchey, Matt Love		
Wading birds	Wading bird nesting	4	UF	Peter Fredrick		
Wading birds	Wading bird SRF	2, 4	ACOE	Dave Nelson	LOX, Greater Everglades	
Water quality	Different species of methyl mercury	2		Brian Mealy		

Project Category	Project Name	Group	Agency	Contact	Study Area	Comments
Water quality	Hard water/soft water and diatoms	3	SFWMD	Scot Hagerthy	LOX	
Water quality	Historical water quality	3	USGS	Ben McPherson	LOX	Report Fall 04
Water quality	Impacts of water intrusion, conductivity	2, 4	USGS	Paul McCormick		
Water quality	Sulfur and methyl mercury, sulfur toxicity	2, 3	USGS	Bill Orem	LOX	
Water quality	Sulfur cycling along WCA2	2	UF	Andy Ogram		
Water quality	Synoptic sampling in refuge	3	SFWMD	Sue Newman	LOX	
Water quality	Water quality effects on vegetation and wildlife	1				
Water quality	Water quality- phosphorus loading	1				
Water quality	X,Y, Z transects	3	SFWMD	Sue Newman	LOX	

Water Management Breakout Sessions

There were three water management breakout groups with 12-14 people each. An attempt was made to spread agency representation among the groups, but no attempt was made to spread out subject expertise. A facilitator and note taker were assigned to each group.

Facilitators:	**Note takers:**
Nick Aumen	Arturo Torres
Agnes McLean	Jocie Graham
Jim Smoot	Pam Pannozzo

Participants and facilitators were given the following information for the basis of discussion:

Objective: Develop a matrix of attributes that can be used as a guide for future water management decisions. Identify key science uncertainties related to those attributes.

Supporting information: Appendix 3- Biological indicators.pdf, Watermanagement.gif (presented as a poster to each group)

Focus questions:

What science do we need to help us make decisions on water management issues?

- What are we missing from the poster?
- What are our external constraints?
- For each area, what are the key things we need to know (drivers, stressors, ecological endpoints)?
- What are the specific studies needed to address the areas identified?
- Are they being done? By whom?

Each group approached the tasks assigned a little differently as was done in the general session. All groups prepared a list of things missing from the poster, external constraints, and some version of what the key things we need to know about the listed attributes. Less attention was given to the specific studies needed and all groups described needs in broad categories.

The attributes listed as missing from the poster can be grouped into 12 general categories (Table 3). Some topics also were listed as external constraints to water management. External constraints were grouped into one of six categories (Table 4). Needs generally fell into one or more of 17 different categories (Table 5).

The list of general categories of needs was reviewed to see if the need also had been listed as an existing study during the general session. Of the 13 general categories of needs (Table 5), there were ongoing studies identified that addressed eight (Alligators, Apple snails, Exotics, Models, Targets for water management, Tree islands, Wading birds, Water quality). In no case were all of the specific topics being addressed by ongoing studies.

In a number of cases, the general category was related to an overarching issue or refuge identified question (Appendix 2), but was not explicitly listed. For example targets for water management (Table 5) are something the refuge needs for addressing how do hydrologic conditions affect key refuge resources… (Appendix 2); however, there is no specific question in Appendix 2 that states this or suggests that paleoecology to understand historic ecology (Table 5, specific topic) is one of the key questions. This example illustrates how the information compiled here can be used as a starting point for discussions among researchers and managers. In general, the questions and issues listed in Appendix 2 are broader in scope than the specific topics identified in the workshop and further discussions are needed to make the linkages between the specific studies and management needs.

Comments from Evaluation and Lessons Learned

Most people who completed the evaluation form found the water management break out very useful and felt that it should be continued in future workshops. A lot of information on general needs was gathered through interactions of the participants. Some participants felt that more background information on the refuge and refuge needs would have enhanced the discussions. This session provided a good general framework of ideas for developing a matrix for water management, but additional work is needed to complete that task. Future topic break outs should have an introductory presentation providing background and objectives of the break out. Follow up workshops focusing on specific management questions should be scheduled to present the synthesis and take any needed next steps.

Table 3. General categories, and specific topics of items missing from the water management poster presented to the breakout groups at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Category	**Specific topics**
Climate	Seasonal weather conditions and seasonal hydrology, extreme events, future weather conditions
Fauna	Fishes, macro-invertebrates, other aquatic fauna, occurrence and distribution, T&E species
Historic	What were historic conditions?
Hydrology	Surface/ground water interactions, natural or managed variability, water movement, effects of altered hydrology
Integration	Decision support system
Land Use	Surrounding land use changes and regional spatial dynamics, effects on water supply
Soil	Soil processes including accretion and vertical profiles
Unintended consequences	Unintended consequences
Vegetation	Vegetation patterns, marsh community composition and structure
Water management	Pathways of water delivery, managed variability, more control of water going out then in, topographic effects on management
Water quality	Soft water low conductivity system affected by hard water canal water intrusion
Water supply	Water supply current and future needs

Table 4. General categories of external constraints and specific topics identified in the Water Management Break out at the 2004 A.R.M. Loxahatchee National Wildlife Refuge Science Workshop.

Category	**Specific topics**
Available resources	Budget, time, resources
Climate/weather	Extreme weather events
Land use	Changes in land use and existing surrounding land use
Legal constraints	Consent decree (federal water quality), regulation schedule, flood protection, water supply, legal rights of the refuge to water
Physical configuration/design	Refuge is impounded, topography, more control of water out then in, STA design and flood protection
Politics	Politics-water supply and water quality

Table 5. General categories of needs and specific topics listed in the Water Management break out groups at the 2004 A.R.M. Loxahatchee National Wildlife Refuge.

Category	Specific topics
Alligators	Direct effects on nesting success; distribution, abundance, health/condition; indirect effects on condition; relationship between hydrology and nesting effort; relationship to hydrologic patterns
Apple snails	Distribution, production, availability, and short term variations; effects of extremes; historic distribution and abundance; relationship to water quality
Climate	Understanding of global climate change impacts
Communication	
Education	Pubic, legislators, higher management, other agencies
Exotics	Effects of local environmental conditions; effects of hydrology
Fire	Historic patterns; role of historic fires; effects of peat fires vs surface fires
Integration	Understanding how cumulative long-term impacts affect the refuge; decision support tools to weigh and mitigate conflicts; integration of effects of water management at different spatial, temporal, ecological scales; whole system vs single system management
Models	Comprehensive models at appropriate scales; Conceptual ecological model; Hydrodynamic model
Public support	
Social science considerations	Understanding current and future land use and water use requirements
Targets for water management	Paleoecology to understand historic ecology; water regulation schedule optimization based on what?
Tools	Decision support/integration tools
Tree islands	Impacts of hydrology on tree islands biological diversity; tree islands elevation relative to slough; need healthy, sustainable, achievable target; historic vs current state; tree islands hydroperiod; what is the target?
Trust resources	Migratory and other birds; snail kites
Wading birds	Effects of hydrology on nesting; effects of hydrology on prey; natural vs human induced effects; nesting; spatial patterns
Water quality	Ecological effects of hard water; effect of changing sources; effects of chloride; effects of P; effects of S; mobilization of P in canal sediment; pore water intrusion; relationship of canal stage, operation, and intrusion

Lygodium Breakout

There were two lygodium breakout groups with 10-12 people each. An attempt was made to spread agency representation among the groups, but no attempt was made to spread out subject expertise. A facilitator and note taker were assigned to each group.

Facilitators:	**Note takers:**
Mark Musaus	Gayle Martin
Matt Harwell	Bill Thomas

Participants and facilitators were given the following information for the basis of discussion:

Objective: Develop an action plan for research on the refuge that will help us to meet our Lygodium control goals.

Supporting information: Appendix 4- LoxNWRlygodiummang.pdf,
LygoMaintenancecontrol.pdf

Focus questions:

What science do we need to help us make decisions on strategies to reach maintenance control for Lygodium?

What areas are missing from the diagrams of "How do we achieve maintenance control of Lygodium by 2017?"

What specific studies are needed to address the areas identified?
Are they being done? By whom?

One breakout group spent a considerable amount of time talking about maintenance control, the refuge performance measures for Lygodium and how the measure would be evaluated. The other group spent more time discussing what was missing from the diagram and creating a timeline of needs.

Group A

Florida legislation defines 'maintenance control' (ss.369.22(1)(d),F.S.) as "applying management techniques on a continuous basis to keep nonindigenous plant populations at the lowest feasible levels. Under maintenance control there is a reduction in: navigation restrictions, irrigation and flooding problems, sedimentation and lake aging, management costs, competition with native plants, loss of fish and wildlife habitat, and use of herbicides". There was agreement that lowest feasible level is a vague concept.

The refuge License Agreement requires: "Removing invasive or exotic plant and animal species such as Melaleuca, climbing fern, … to the best of its capabilities through mechanical, chemical, or biological means to restore this north everglades ecosystem to as historically natural a

conditions as possible." The performance measures further specify a 10% reduction in Lygodium by 2007, a 50% reduction by 2012, maintenance control by 2017. The baseline for measurement is 2002 when the License Agreement was signed. Questions and issues that were raised about maintenance control include:

A better defined target.
Is maintenance control holding the line if this is the lowest feasible level?
We know we can not get to zero Lygodium with current methods, so ecologically what is the level required?
How much of the habitat (tree islands and other communities) can be impaired without ecological harm? 10%?
Is maintenance control keeping it off the stems, preventing it from climbing in order to prevent long distance dispersal? Maintain it at lower structure to slow down the spread.
Are we going to say we are OK if 90% of the tree islands do not have Lygodium in the canopy?

The discussion progressed to what eradication methods would be acceptable. How much non target damage is acceptable? What strategies will be most effective? It is generally felt that attacking outliers is important. Different methods of control will be needed for dense infestation on big islands and sparser infestations on smaller islands. Bio controls will be a necessary tool.

The discussion finished up with a listing of what was missing from the diagrams provided. Missing areas included:

Public education
Experiments on affects of herbicides and rates
How do we accelerate bio-control development?
Educating policy makers on the importance of bio-controls.

Group B

The notes from Group B were sparse and represented only as notes on the diagram and a synthesis of what was needed by time period to reach maintenance control.

2004-2008 This is the timeframe when most learning needs to happen. Resources should be allocated to develop the tools needed for control. Suggested areas include:

Chemical effects on spore viability
Lygodium regeneration over time
Effects on native communities and wildlife
Early detection
Early treatment
Effects of hydrology on establishment
Effects of hydrology on treatment
Attacking outliers
Exploring the use and effects of fire
Follow up monitoring in prescribed and wild fire areas

Make decisions on testing extreme treatment options- heavy herbicide followed by fire
Treatments with current methods

2008 A critical science/management time window. By 2008 we should have specific information on what needs to be done to achieve our goals.

2008-2017 Focus on most effective control strategies

Of the items listed by the two groups, only using existing treatment methods is being fully implemented. There were some studies identified in the general session that address the needs identified in this session of effects of herbicides and rates, effects of hydrology, and follow up monitoring. In general, it was felt that public education that would lead to more support of control efforts and prevention of new introductions, acceleration of the development of bio-controls, and development of additional effective treatment methods, were critical for success in controlling Lygodium (and other exotics).

Comments from Evaluation and Lessons Learned

Only a little over half of the people who filled out the evaluation felt that this session was very useful. The others found it somewhat useful, but fewer than half recommended continuing it in future workshops. Similar comments were made about this session as for the other sessions: More information was needed on the refuge's needs; there needed to be a clearer focus of the desired outcome for participants, facilities, and note takers.

These limitations can be avoided in the future by starting the session with a refuge focused overview and a discussion of the specific products desired. Facilitators and note takers should be briefed ahead of time on the desired outcomes and given templates to complete when possible. A part of the note takers duties should be to synthesize the discussion in addition to recording ideas.

Recommendations for future workshops

This workshop provided a valuable communication mechanism. All of the participants who answered the question on the evaluation- Do you think the workshop met the stated objectives? (n=18) answered yes. Twenty of twenty-one respondents said they would come to next years workshop and one said they probably would (see Appendix 6). A number of useful comments and suggestions were provided on the evaluation form and are summarized below along with observations and recommendations of the author. The recommendations are in three parts: General, specific follow up workshops for A.R.M. Loxahatchee NWR, suggested format and timelines for workshops at other refuges.

General

Planning

Planning for this workshop started in March of 2004. A number of researchers commented that it would have been better to start the planning 4-6 months prior to the workshop so that they could better arrange their schedules. This was particularly true for those researchers presenting posters. Several researchers indicated that they would have like to present posters (and abstracts), but did not have time to prepare them. In addition, it was difficult to secure a facility with only two months notice.

> Planning for future workshops should start (announcements out to participants and securing facility) 4-6 months prior to the workshop date.

Read ahead materials were provided to participants two weeks prior to the workshop. A number of participants commented that receiving them further in advance would have been helpful.

> Read aheads should be provided to participants no later than 1 month before the workshop.

The list of people invited to this first workshop consisted of people who had A.R.M. Loxahatchee NWR Special Use Permits in the last five years, and various individuals from U.S. Geological Survey, South Florida Water Management District, U.S. Army Corps of Engineers, and other organizations known to be interested in the refuge. From one stand point this was good because most of the individuals were at least a little familiar with the refuge. On the other hand, this invitee list did not reach out to new researchers who might be able to contribute to refuge needs.

> The invitee list for future workshops should be critically reviewed with the purpose and desired outcome of the workshop in mind. In some cases the invitees should be those already familiar with the refuge, in other cases a broader scope of invitees will be desirable.
>
> Specifically target USGS centers and programs locally, regionally, and nationally.

Logistics

This workshop was attended by over 60 people. The main meeting room accommodated that many, but when converted to the poster session was crowded. The poster displays took up more room than anticipated. In addition, some people had a hard time figuring out which poster was where. The main room was used for three break out groups and many found having three groups in the one room somewhat distracting.

> Make sure the facility is large enough to accommodate the desired activities with plenty of room. Over estimate the size needed. If unsure of how much room is needed set up mock poster displays to get an idea of the space needed. Include the space needed for people to stop at each poster while allowing room for others to pass by.
>
> Provide a diagram of poster location.
>
> Arrange for individual break out rooms or locations for each group.

Facilitators and note takers for this workshop were volunteers who were not necessarily trained in facilitation or note taking. Each was provided with an information sheet and general instructions as well as the information contained in the Program and Abstract book. The results were mixed. Some of the notes did not really capture the content of the discussion which made it difficult to summarize and synthesize. In addition, some of the facilitators did not feel they really know what the desired outcomes of the sessions were.

> Arrange to have trained facilitators and meet with them before the workshop to ensure that they understand the desired outcomes.
>
> Add a section to the evaluation form on effectiveness of each facilitator.
>
> Arrange to have note takers who understand the issues and are prepared to write summaries of the sessions. Have them meet with organizers and facilitators before the workshop.

Refreshments for the workshop were made possible through the support of the Friends of Loxahatchee Refuge. Providing lunch to the participants meant that discussions could continue during lunch which facilitated communication. Providing coffee and snacks in the afternoon also helped to keep people at the workshop.

> Provide coffee, lunch, and snacks for workshop participants.

Content

The poster session provided a good venue for discussion and interaction. Seventeen of twenty respondents found the poster session to be very useful, while three found it somewhat useful.

Consider using a poster session to enhance communication opportunities either as a main focus of the workshop, or as a supplementary session. Provide refreshments for the poster session.

Although there were two plenary sessions and read ahead materials that provided some refuge background and context were distributed, there were questions repeatedly raised on refuge management including: What is the purpose of the refuge and what is it managed for? What are the current management directions? Do threatened and endangered species take precedence over other needs? What are our goals?

Refuge staff should as explicitly as possible describe the goals and objectives of the refuge and for management questions that will be discussed. This should be done in a document provided to participants before the workshop and then again orally at the workshop.

One of the initial sessions should include a presentation by refuge staff on refuge background, goals, and objectives with a question and answer session from the audience to make sure that refuge goals and objectives are clear.

Each break out group should start with an overview of the refuge goals and objectives in relation to the issue being addressed followed by a short question and answer session to make sure everyone has a common understanding.

Facilitators and refuge staff should clearly explain the desired outcome of the session in the context of management goals and objectives.

Another issue that came up was: How will any of the discussions or research feed back to management actions?

Discussions in breakout sessions need to be more narrowly focused with clearer objectives and desired outcomes so that linkages can be made between research and management actions.

Discussions should have a component that addresses the questions: How will this research or testing this hypothesis make any difference in how we manage the system? If we knew the answer, what would we do differently? If you could only do one thing to address this management issue what would it be?

Provide appropriate time for addressing the above questions, which may mean having fewer breakout topics covered in greater depth.

The synthesis sessions provided an opportunity for the groups to share information. Most people found them at least somewhat useful. There was a wide range of how the syntheses were presented and the amount of time used by each group. Some groups summarized the information and others just read off lists from the notes.

Have the facilitators and note takers work with a refuge staff person to synthesize the information and present it in a common format that relates back to the refuge management issues.

Limit the amount of time for each session summary.

Participants in general responded that they looked forward to the next workshop and were interested in seeing how the information collected from this workshop would be used.

Provide a workshop summary to participants.

Start off the next workshop with a summary of the previous workshop with discussion of how the workshop information has been used.

Specific follow up workshops for A.R.M. Loxahatchee NWR

A.R.M. Loxahatchee NWR is required under the License Agreement with the South Florida Water Management District to facilitate an annual meeting/workshop as a forum for discussing research and monitoring on the refuge with cooperators, universities, and agencies. This workshop fulfilled that obligation for 2004. The format for future workshops for fulfilling this obligation will vary from year to year. Although the 2004 workshop was very successful, having such a workshop every year would probably yield diminishing results, as new information takes several years to accumulate; therefore a workshop of this type will not be held until 2007 or 2008. In the interim years, the meeting/workshop to fulfill the terms of the License Agreement will focus on providing a forum for general discussions rather than focusing on specific issues. Workshops for specific issues will be held as needed.

The 2005 workshop will consists of four presentations and a discussion session followed by lunch and an opportunity for individual discussion. The presentations will include a summary of the 2004 workshop, a summary of high priority management issues that need science support from the refuge's perspective, a summary of existing research and monitoring on the refuge, and a summary of high priority management issues that need science support from the SFWMD perspective.

In addition to the required workshop, the refuge should consider having specific workshops that expand on issues raised in the Water Management and Lygodium Sessions of the 2004 workshop. High priority topics from these sessions include:

What are the hydrologic targets for tree islands/ridge and slough, alligators, wading birds, and apple snails in the refuge?
What management/operations are necessary to achieve the desired targets?
How will maintenance control be defined for meeting performance measures outlined in the License Agreement?
Are refuge strategies for control of Lygodium the most effective and efficient given current information?

Suggested format and timelines for workshops at other refuges

Conducting successful workshops at other refuges will revolve around how well the management issues and needs are articulated. Time should be spent prior to scheduling the workshop with refuge staff to identify what the management issues and decisions are and what key attributes the refuge will use when making the decision. In some cases this information may be outlined in the refuge's Comprehensive Conservation Plan, or other planning documents. In other cases, this may be the desired focus for the workshop. Specific questions that should be articulated and provided to workshop participants include:

What is the management issue?
What are the key attributes that will be used to make the decision?
What information about those attributes will be used to make the decision? (Identify key information needs vs what would be nice to know.)
How will the information influence the decision?
What is the level of resolution is needed to provide appropriate basis for the decision?
How certain do you need to be?

Refuge staff should walk through how the decision would be different with and without the information.

A summary document including: answers to the above questions, refuge background, and a summary of current research on the refuge relevant to the stated management issue should be prepared before the date of the workshop is set. Compilation of this information will help to define the purpose, desired outcomes, and invitees to the workshop.

The above document should be sent to potential participants with a questionnaire asking for information on other studies that might provide information for the focus issue (Table 6). Participants should be given four weeks to respond and reminded at two and four weeks. Four to six weeks should be allotted for synthesizing the information and sending it back out to the participants so they receive it at least one month before the workshop. The synthesis document should form the basis for the workshop discussion and should draw linkages between existing science and management needs and illustrate information gaps.

If participants will be presenting posters, presentations, or abstracts they should be notified four to six months prior to the scheduled workshop. This can correspond with the initial distribution of the summary of refuge background, current research, and management issues.

Conducting a successful workshop following this format will require extensive interaction with decision makers (in this case refuge management) in order to clarify and articulate the management issues and information needs. Others on refuge staff also will need to be involved with the preparation and logistics. Laura Brandt will be the point person for workshops in 2005 and 2006 and will require the assistance of trained facilitators and note takers. The workshop for 2005 is anticipated to revolve around hydrologic issues at Florida Panther National Wildlife Refuge and Ten Thousand Islands National Wildlife Refuge. Planning for this workshop will begin in February 2005.

Table 6. Example of information to be requested from participants prior to workshops. Participants could fill in information on Excel spreadsheet or provide a hard copy. Information need (in the gray box) would be selected from a list developed by refuge staff prior sending out the information request. Refuge staff would fill in information for studies they knew about. Participants would be asked to provide copies of publications and reports for use in the pre workshop synthesis.

Project Title	Post treatment monitoring of islands sprayed for the control of Lygodium
Contact	Laura Brandt
Contact Affiliation	USFWS
Contact Email	laura_brandt@fws.gov
Contact phone number	561-736-6004
Reports or publications	Brandt, Laura A., 2004. Effectiveness of different aerial spray for control of *Lygodium microphyllum* on tree islands in the A.R.M. Loxahatchee NWR- 24 month monitoring report. USFWS, A.R.M. Loxahatchee NWR, Boynton Beach, FL.
What information need does this study address?	Experiments on affects of herbicides and rates
Summary of how project relates to information need (no more than 5 sentences)	Rodeo was more effective than Escort in treating Lygodium using aerial spraying on tree islands. It appears that long-term non-target damage may be minimal for most species. Live Lygodium on the Rodeo treated tree island was 97% less than that observed pre-treatment after the first 12 months and 57% less than observed pre-treatment after 24 months. Live Lygodium on the Escort treated island was 66% less than that observed pre-treatment after the first 12 months and 8% less than that observed pre-treatment after 24 months. Yearly retreatments are necessary for continued control.

Appendix 1. Background for general session. Research and Investigations from 2003 Annual Narrative.

From Arthur R. Marshall Loxahatchee National Wildlife Refuge Annual Narrative 2003

5. Research and Investigations

Research and investigations conducted during 2003 fell into four broad categories: Refuge Species and Habitats, Contaminants, Special Use Permits, and South Florida Water Management District projects.

REFUGE SPECIES AND HABITATS

Projects described in this section were conducted by refuge personnel or in cooperation with refuge personnel. In many cases more detailed reports are available in the refuge biological files.

Alligator Studies

Night-time eye shine surveys

Objectives: To determine patterns of relative abundance of alligators in marsh and canal habitats in relation to water levels and season. Provide long-term monitoring for evaluation of refuge conditions and effects of the Comprehensive Everglades Restoration Plan (CERP).

Alligators have been identified as an important keystone species and as an indicator of Everglades restoration success. Their distribution and abundance is linked to hydrologic and environmental conditions. In addition, because they create and maintain alligator holes that act as refugia for many species during dry-downs, their distribution and abundance can influence overall marsh function. Because the alligator distribution and abundance are linked to hydrology and many of the changes that will occur during Everglades restoration will involve changes in water flows and location of canals, it is important to collect baseline data on alligator distributions in marsh versus canals and in relation to water levels in order to better evaluate overall impacts of Everglades restoration and to develop appropriate monitoring protocols.

During 2003, 19 night-time alligator transects were surveyed. This includes three canal transects and two marsh transects which are surveyed twice in the spring (March/April) and fall (September/October).

Table 2. Number of alligators observed along transects in the canals and marsh during the spring alligator surveys in March and April 2003.

Location and (transect number)	Date	Number of alligators	Number of alligators =>0.35m	Number of alligators =>0.35m/km
L-40	3/17/2003	213	174	17.4
L-39 (1)	3/19/03	48	44	4.4
Marsh (1)	3/24/03	87	58	5.8
Marsh (2)	3/24/03	56	47	4.7
L-40	4/7/2003	151	130	13
L-39 (1)	4/11/2003	50	47	4.7
L-39 (2)	4/11/2003	69	64	7.4
Marsh (1)	4/12/2003	88	62	6.2
Marsh (2)	4/12/2003	90	79	7.9

Table 3. Number of alligators observed along transects in the canals and marsh during the fall alligator surveys in September and October 2003.

Location and (transect number)	Date	Number of alligators	Number of non hatchling alligators >0.25 m	Number of non hatchling alligators >0.25m/km
L-40	9/15/03	70	68	6.8
L-39 (1)	9/17/03	28	27	2.7
L-39 (2)	9/17/03	211	209	20.9
Marsh (1)	9/18/03	154	71	7.1
Marsh (2)	9/18/03	110	64	6.4
L-40	9/30/03	46	45	4.5

L-39 (1)	10/01/03	17	16	1.6
L-39 (2)	10/01/03	7	7	0.7
Marsh (1)	10/02/03	95	58	5.8
Marsh (2)	10/02/03	94	48	4.8

The patterns of relative abundance (number/km) generally followed what has been observed in the past with more alligators observed during the spring surveys when water levels are lower. The exception is with the L-39 survey. In the first fall survey (9/17/03) lots (20.6/km) of large alligators were observed along transect 2 of the L-39 (this is the transect closest to the S-6); however in the second survey only two weeks later only 0.3/km were observed. Water levels were about the same during the two surveys. During the first survey, the area smelled slightly of dead fish and a number of alligators were observed with fish in their mouths. It appears that there was a fish kill or concentration of fish that drew the alligators to the area. This was an unusual event and a simple explanation for it's cause was not apparent.

Several changes were made to the survey protocol in 2003 to help ensure consistency of refuge surveys with those being conducted throughout the system, and to ensure that the data would be appropriate for use in the region-wide assessment of alligator relative abundance.

The major changes were as follows. From now on, surveys will occur twice in the spring and fall with the surveys separated by at least 14 days. The marsh survey route was divided into two transects of 10 km in length that start 1km from the L-40 and extend west into the refuge 21 km. The transects are separated by 1 km. Waypoints of the start and end points are listed below (WGS84). Two additional canal transects were added in the L-39 extending from the boat ramp to just past the S-6 pump station. As with the marsh transects, these transects are 10 km in length and separated by 1 km.

Table 4. Waypoints of start and end points for alligator survey transects in the interior marsh, L-39 and L-40 canals. All coordinates are WGS84.

Transect name	General location	Start waypoint	End waypoint
LoxMarsh1	E-W Bucket run trail- west	N26 29.125	N26 30.351
		W80 23.476	W80 18.577
LoxMarsh2	E-W Bucket run trail- east	N26 30.049	N26 29.552
		W80 18.127	W80 13.786
LoxL40	10 km north of Lee Rd. ramp	N26 34.758	N26 29.961
		W80 15.676	W80 13.339

LoxL39-1	West of Hillsboro ramp	N26 23.870	N26 21.454
		W80 23.326	W80 18.245
LoxL39-2	S-6 pump station and south/east	N26 29.144	N26 24.322
		W80 26.724	W80 23.674

Surveys will continue in 2004 and will both document trends in the refuge, and also provide data in support of the system-wide Monitoring and Assessment Plan for CERP. Refuge staff will work with USGS and University of Florida scientists to use the past five years of data for improvements to the monitoring protocols.

Relative density of alligator nests

Objective: To collect baseline data on the density of alligator nests in different parts of the refuge and relate these patterns to hydrology, landscape patterns, and habitat type.

Surveys for alligator nests during 1999 indicated that the density of nests in the refuge is high, but may be variable among areas. Differences in nest density may be related to landscape characteristics, habitat features, and hydrology. Everglades restoration efforts will potentially result in changes in hydrologic conditions within the refuge, which may in turn affect landscape patterns and habitat types. If alligator densities are strongly tied to landscape features (for example spatial configuration of tree islands and alligator holes) and habitat types (sloughs vs. sawgrass), then long-term changes in hydrology that change vegetation configurations may differentially affect alligator production throughout the refuge. This study will provide baseline data on patterns of alligator nests and how densities related to landscape and habitat patterns.

Nests were located from the ground using airboats. The same ten 1600 m X 1600 m plots that were surveyed in 2002 were searched for alligator nests by driving north to south transects 100 to 200 m apart. Tree islands and alligator holes were circled to locate trails and nests. Trails going into tree islands were searched on foot. Location (GPS coordinate), physical description of the area, and nest, as well as presence of female, were noted when a nest was located. Nests were flagged and revisited in August and September to determine if they had hatched.

Fifty-seven nests were located within plots during approximately 61 hours of surveys. An additional three nests were located outside of plots during surveys and three others were located during other activities (total of 63 nests).

The number of nests per plot ranged from one to fourteen and the number of nests per hour from 0.3 to 1.5 (based on the amount of time spent searching by airboat). The number of nests per ha surveyed ranged from 0.03 to 0.22. The number of nests located varied from plot to plot (Figure 2).

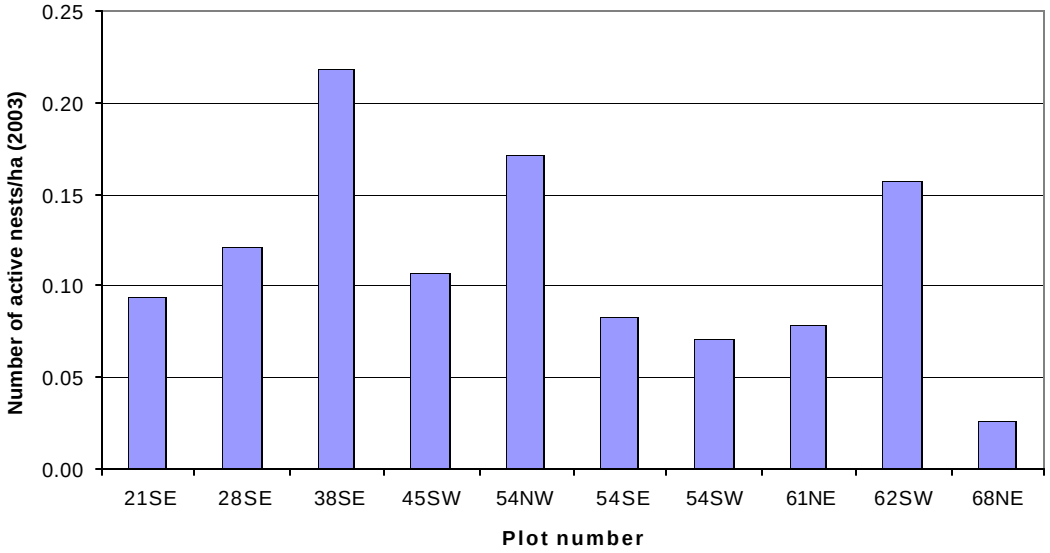

Figure 1. Number of alligator nests located per hectare of interior marsh surveyed for 10 plots in the refuge during 2003.

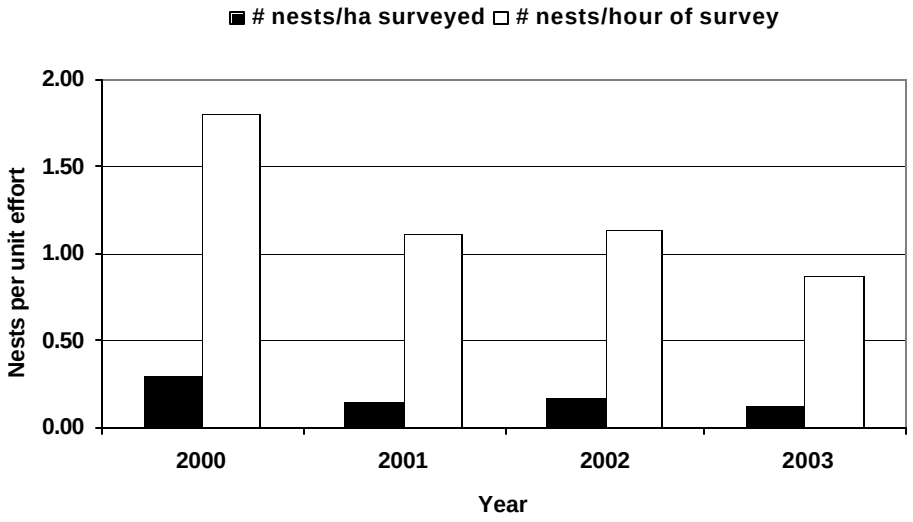

Figure 2. Alligator nests located per unit of effort in plots surveyed in the refuge 2000-2003.

The average number of active nests/hour (0.87 nests/hour +/- 0.13) and the average number of active nests per ha found in 2003 (0.12 nests/ha +/-0.02) is the lowest recorded since the study began in 2000 (Figure 3).

Nest fate was determined for 59 nests. Fifty-five of these (93%) had hatched, one was flooded, and three predated. Nest fate was not determined for three nests and one false nest was found.

Table 5. Number of alligator nests located 2000-2004 and their fate.

Year	Number of nests located	Number of nests know to have hatched (%)	Number failed because of depredation	Number failed because of flooding	Number failed because of unknown causes
1999*	14	14 (100%)	0	0	0
2000**	36	33 (92%)	4	0	1
2001**	35	20 (57%)	14	0	0
2002	47	30 (71%)***	1	3	8
2003	63	55(93%)****	3	1	0

* Data from Brandt and Mazzotti (2000)
** Data from Chopp (2003)
*** Hatch status of five nests was not assessed
**** Hatch status of three nests was not assessed and there was one false nest.

A draft report on the last four years of data was prepared and it will be finalized in 2004 or early 2005 after the final year of the initially proposed project. Surveys will continue in 2004 with the addition of a more intensive evaluation of the effects of detection probability on survey results.

Brandt, L.A. 2003. DRAFT. Relative density of alligator nests in the Arthur R. Marshall Loxahatchee National Wildlife Refuge 2000-2005. Year 4 Interim Report.

Alligator captures for condition

Objective: Phase II- Apply the index to alligators from different areas and through time to evaluate the effects of restoration.

This project is a collaborative effort with University of Florida, USGS, ENP, and FWC and is part of the effort to collect data for evaluating the success of CERP. Alligator condition can be assessed by examining the relative "fatness" of an animal and is calculated using a length and volumetric (mass, tail girth, etc.) measurement. Fifteen alligators are captured twice a year, once in the spring and once in the

fall, to assess condition in different locations and over time. Captures are being made in the refuge, Water Conservation Area 2 and 3, and Everglades National Park. During 2003, 19 female and 11 male alligators ranging in size from 95-250 cm were captured.

This collaborative study will continue during 2004. During 2004, USGS and UF scientists will analyze the spatial and temporal patterns in the data to develop appropriate sampling regimes that will allow us to compare the condition of alligators in the refuge (and other areas) from year to year and season to season. This will provide us with additional information on short and long-term effects of hydrologic and habitat conditions on refuge wildlife as well as providing data on one of the performance measures identified in the Monitoring and Assessment Plan for CERP.

Secretive Marsh Bird Surveys

Objectives: Survey to determine the presence and number of secretive marsh bird species using refuge impoundments. These surveys were also used as a pilot project to test regional secretive marsh bird survey protocols developed by Dr. Courtney Conway (USGS).

Several species of rails are known to winter in southern Florida. These species tend to occur at the edges of dense vegetation and are very secretive. Compartments C-9 and C-10 are managed to encourage use by secretive marsh bird species, with relatively low water levels and dense sawgrass. Because these birds are so difficult to observe, a unique method for surveying them has been developed. A recorded tape of calls is played for a set amount of time and followed by a period of silence to listen for responses. During January and February, 15 survey points were set up at 400 meter intervals around impoundments C-7, C-8, C-9, C-10, and Lower A. Points were marked physically using red stakes and GPS coordinates were recorded. Audio recordings of secretive marsh birds were obtained and practice recordings were made to train the volunteers. Target birds for the surveys were Least Bitterns and King Rails in the spring (breeding birds) and King Rails, Yellow Rails, Black Rails, and Virginia Rails in the winter. Breeding bird surveys were conducted four times between late February and May by two volunteers. Data from spring surveys of all points are summarized in Table (6). Winter surveys were conducted in December and will continue into February 2004.

American bitterns and yellow rails were present on the refuge during the winter months only. By the first March survey they had left the area for northern breeding grounds. The most common species were the least bittern and king rail, both breeding species in south Florida. These two species were observed during most surveys and likely occur in greater abundance than recorded.

Table 6. Summarized spring 2003 secretive marsh bird observations.

Species	Feb 10	March 3	March 17	May 13	Total
American Bittern	0	1	0	0	1
Least Bittern	0	8	2	4	14
King Rail	5	2	4	5	16
Black Rail	0	0	0	0	0
Yellow Rail	1	0	0	0	1

An annual vegetation survey was conducted for all points in June by a biological intern stationed at the refuge. The most dominant vegetation species at each survey point is listed in Table 7. Number of responses by target species had a weak negative correlation to the amount of percent of open water at a site, while percent of vegetation showed a weak positive correlation. Most responses occurred in the Lower A impoundment where sites were dominated by cattail.

Table 7. Dominant vegetation at each survey point.

Compartment	Point	Dominant Vegetation	Percent Cover
C7	1	*Pontedaria cordata*, pickerelweed	20
C8	2	*Panicum hematomon*, maidencane	5
C9	3	*Pontedaria cordata*, pickerelweed *Typha*, cattail	10 10
C10	4	*Panicum hematomon*, maidencane *Juncus megacephalus*, large-headed rush *Paspalidium geminatum*, Egyptian paspaladium *Pontedaria cordata*, pickerelweed	5 5 5 5
C10	5	*Panicum hematomon*, maidencane *Paspalidium geminatum*, Egyptian paspalidium	10 10
C9	6	*Pontedaria cordata*, pickerelweed	35
C8	7	*Eleocharis interstincta*, jointed spikerush	35
C7	8	*Pontedaria cordata*, pickerelweed	20
A	9	*Typha spp.*, cattail *Pontedaria cordata*, pickerelweed	10 10

A	10	*Pontedaria cordata*, pickerelweed	10
A	11	*Typha spp.*, cattail	15
A	12	*Typha spp.*, cattail	25
A	13	*Cyperus difformis*, flat sedge	15
A	14	*Typha spp.*, cattail	35
A	15	*Pontedaria cordata*, pickerelweed	15

Snail Kite Nesting Surveys

Objectives: Survey to determine the extent of snail kite nesting on the refuge and provide data on potential nest locations to researchers conducting regional snail kite surveys. Determine the productivity and nesting success of this listed species on the Refuge.

The snail kite is an endangered raptor species common to south Florida and historically nesting in the refuge interior. The entire refuge has been designated as critical habitat for snail kites. Nest surveys were conducted annually in March by University of Florida researchers to monitor reproductive success (see SUP section of D.5 and section G.2. Threatened and Endangered Species). No snail kite nests were found on the Refuge during the 2003 nesting season.

Wading Bird Nesting Surveys

Objectives: Determine nesting effort and success of wading birds, including the endangered Wood Stork, on the Refuge. These surveys are designed to provide consistent data for use in regional assessments of nesting effort and success.

See Section G.4 for a summary of the survey results.

Mapping and Characterizing Aquatic Refugia

Part 1- Mapping and accuracy assessment

Objectives: To map aquatic refugia (including alligator holes) in the refuge using aerial photography**.**

Dry season refugia for aquatic animals are assumed to be a critical component of the Everglades landscape and are an important attribute in the conceptual models being used to develop the monitoring and assessment plan for the Comprehensive Everglades Restoration Plan (CERP). Dry season refugia include alligator holes and other depressions that hold water in the marsh during dry-downs. The relationships among dry season refugia, aquatic fauna, wading birds and alligators are recognized as a

key uncertainty in the CERP monitoring and assessment plan, and the distribution and occupancy of alligator holes has been identified as a performance measure for the freshwater marsh conceptual model. However, the ecology of these aquatic refugia has remained almost completely unstudied. The project will integrate GIS/GPS technology, field biology and photo-interpretation provide the missing information, which has become critical for making ecosystem restoration decisions. The data will provide an important step in defining the role of aquatic refugia in the freshwater Everglades. Because of the interdependence of wading birds, aquatic fauna and aquatic refugia, this project is critical to the evaluation of all CERP projects and science objectives that deal with the potential effects of changes in hydropatterns. Thus, it is essential to collect these data prior to major hydrological changes, so that the influences of CERP projects can be evaluated.

Potential alligator holes and other aquatic refugia were identified from digital, color infrared (CIR) aerial photographs from the National Aerial Photography Program by Karen Minkowski, University of Florida, Tropical Research and Education Center (see 2002 narrative). During 2003 an accuracy assessment was conducted on those data and the data were used to select sites for alligator hole characterization.

A subset of mapped alligator holes were randomly selected from the high and low confidence groups using the Excel random number generation function. A total of 109 low confidence holes and 41 high confidence holes were field checked to determine if they were actual holes. A Garmin GPS and airboat were used to locate the holes in the field. If a hole did not exist at the exact coordinates all areas within a 30 m radius were searched for potential holes. The accuracy of the GPS coordinates were assumed to be ± 30 m. A hole was determined by size and the difference in depth from the surrounding marsh depth. If an area appeared clear of vegetation, 4-5 depth measurements were taken in the hole and in the surrounding marsh using a marked pvc pole in tenths of meters. If the hole depths were 50 cm or greater than the average marsh depth then the area was classified as a hole or refugia. If an area appeared like a hole but was only 25 to 50 cm deeper than the surrounding marsh then size was the determining factor. Refugia were usually less than 2 m x 2 m and/or had a depth difference of less than 50 cm for most of its area. The average water depths and the dimensions of the hole or refugia were estimated by sight. A general description of the hole and surrounding area were documented in a field notebook. If a hole did not exist at the coordinates ± 30 m, the average water depth and a description of the area were still recorded. If a hole was seen while traveling to predetermined locations its coordinates in UTM (Nad 83) were taken and the same procedures were followed as above.

A total of 150 mapped holes were ground-truthed. Of the 150 randomly selected holes 19 were inaccessible by airboat due to dense vegetation. Another 19 holes were randomly selected of the same type to replace the inaccessible holes. Of the 150 mapped holes 46 were determined to be holes and 10 were identified as refugia. Holes mapped with high confidence of all types had 49% accuracy. Holes mapped with low confidence had 33% accuracy. Accuracy includes the actual number of refugia and holes assessed by ground truthing that were mapped from the aerial photos. Holes and refugia were not identified separately in the mapping process.

Within each type (1, 1a, 2, 3, & 4) the high confidence holes had better accuracy except for type 2 (Tables 1 and 2). Type 2 were seen as dark 'slash' through or along edge of tree island or dense sawgrass, generally in direction other than northeast-southwest (which is very likely a shadow, but could be masking a gator hole). When both the high and low confidence holes were grouped together type 1 were the most accurate (47%). The accuracy of type 1a, 2, 3, and 4 were 37%, 23%, 43%, and 37% respectively.

Forty-seven new holes were mapped. Data on these holes are located in the files Newholes.xls (Excel) and Newholes.mps (MapSource).

Table 8. High confidence holes

Type	# checked	# of holes found	# of refugia	% accuracy
1	8	3	2	63
1a	8	4	1	63
2	9	1	0	11
3	8	5	0	63
4	8	4	0	50

Table 9. Low confidence holes

Type	# checked	# of holes found	# of refugia	% accuracy
1	22	8	1	41
1a	22	4	2	27
2	21	5	1	29
3	22	6	2	36
4	22	6	1	32

Holes in the south central area of the refuge were easily distinguished from the surrounding marsh. These holes were mostly within white water-lily areas and were obviously free of vegetation and were usually lined on one side by emergents. Holes in the north end were harder to identify. In areas that were predominately emergents such as an eleocharis wet prairie, open areas of white water-lily appeared as holes until closer inspection.

Depth was not always the best indicator of a hole. In areas near the canal water depths were higher naturally, usually close to 1 meter. Several mapped holes appeared like real holes when seen in the field, i.e. clear of vegetation and/or signs of alligator presence. However, the hole depth was within 10-20 cm of the surrounding marsh depth.

This project is a collaborative between the University of Florida (Dr. Frank Mazzotti,) and the refuge. It is funded by the Cooperative Ecosystem Study Initiative.

Part 2- Characterizing Aquatic Refugia (alligator holes)

Objectives: To perform an ecological characterization of alligator holes in the refuge by addressing morphological and biological attributes of alligator holes.

The American alligator is considered to be a keystone species in the Florida Everglades. Alligator holes are assumed to be critical component of the Everglades landscape, due to their potential role as a dry season refugia for aquatic animals. Although researchers consider alligator holes to be an essential component of the Everglades ecosystem, the mechanisms through which they structure plant and animal communities have received limited study. We now have qualitative and quantitative information describing the effects of alligator holes on plant and animal diversity at alligator holes in Big Cypress National Preserve and Water Conservation Area 3. Big Cypress and WCA 3 differ dramatically from the refuge in peat depths. Big Cypress and WCA 3 have a limestone substrate with only approximate 1 m of peat on top of it, while the refuge has 1.25 to greater than 4.5 m of peat on top of bedrock. These differences in peat depth could create significant differences in the structure and function of alligator holes on the refuge when compared to those in WCA 3. Furthermore, the structure and function of alligator holes may depend on temporal and spatial variation in the landscape, such as the surrounding vegetation matrix and local hydrology. Thus the function of an alligator hole in one location at a certain time may be completely different than that of another alligator hole at another location and time. To understand these differences, it is necessary to conduct an ecological characterization of alligator holes across the Everglades landscape.

Figure 3. Alligator hole in refuge interior. Note open water area surrounded by marsh vegetation and woody vegetation (right corner).

Thirty alligator holes identified in the mapping and accuracy phase of this study were selected for sampling. These holes were located primarily in the central portion of the refuge. Holes were selected using a multi-stage random selection procedure. Fifteen marsh reference sites were chosen by adding random distances from -2000 to +2000 m to the X and Y coordinates of the first 15 alligator holes chosen by the random selection process outlined above. Logistical constraints and an injury prevented us from completing all of the sites selected, so we confined our study to the analysis of 26 holes and 14 marsh sites.

At each study site, we established 2 transects for use in quantifying plant community composition and for measuring peat and water depths. At holes, the transects bisected the ponded portion of the hole through its longest and widest parts, and extended for 10 m beyond any ecotone occurring at the sides of the pond. At marsh reference sites, we established 2 transects, each 30 m in length, oriented in the N-S and E-W directions. We conducted the same types of measurements at both holes and marsh reference sites.

Along each transect the water depth was recorded at every half-meter interval using a marked PVC pole. Peat depth, defined as the distance from the surface of the substrate to the underlying bedrock, was measured at every two-meter interval using the marked PVC pole and a piece of rebar of known length. Peat depth measurements were not taken on tree islands or on floating vegetation mats.

Vegetation, including emergent aquatic plants, submerged vegetation near the surface, vegetation in the boundary area, and extending 10 m into the surrounding marsh was measured using a line transect method that gives percentage cover and relative abundance of a species. (Barbour et al. 1987). Species abundance, richness, and diversity were derived from these measurements. Measurements were made along half-meter intervals across the transect and each half-meter interval of each transect was recorded as pond, ecotone, or marsh.

The alligator holes sampled in this study averaged 125.1 m^2 in surface area (N = 26). Median hole size was 86.3 m^2. The smallest hole had a surface area of 3.5 m^2, and the largest had a surface area of 633.2 m^2. All but one of the alligator holes reported on in this study appeared to be active, based on the actual presence of an alligator or the presence of well-defined trails. Holes were highly variable in both size and shape, with 11 of the 26 holes approximating circularity and the remaining 15 showing irregularity in shape. Both size and shape of alligator holes can only be considered an approximation, however, since alligators generally extended for an unknown distance beneath adjacent vegetation mats or tree islands.

At the time of sampling, pond water depths were significantly deeper than those for the surrounding. The average water depth for the ponds was 105.11 cm. The average water depths for the surrounding marsh and ecotones, respectively, were 54.18 cm and 32.75 cm. The average water relief for alligator holes was 55.65 cm below the surrounding marsh. The ecotones were significantly more shallow than the surrounding marsh, with an average water relief of 16.95 cm above the surrounding marsh. Four alligator holes lacked an ecotone completely. The average water depth at the marsh reference sites was 50.39 cm, which did not differ significantly from the average water depth at the marshes surrounding the alligator holes.

The 10 most abundant plant species at the holes, listed in order of importance, were as follows: 1) white water lily (*Nymphaea odorata*), 2) sawgrass (*Cladium jamaicense*), 3) floating heart (*Nymphoides aquatica*), 4) eastern purple bladderwort (*Utricularia purpurea*), 5) annual spikerush (*Eleocharis geniculata*), 6) pickeral weed (*Pontedaria cordata*), 7) Tracy's beakrush (*Rhynchospora tracyii*), 8) arrow arum (*Peltandra virginica*), 9) swamp fern (*Blechnum serrulatum*), and 10) leafy bladderwort (*Utricularia foliosa*). Sawgrass, swamp fern, and wax myrtle (*Myrica cerifera*) were the three most abundant plants in the ecotone. White water lily, sawgrass, and eastern purple bladderwort were the most abundant plants in the marsh surrounding the holes, and in the ponds themselves. White water lily, floating heart, and spatterdock were the most abundant in the ponds themselves. Spatterdock was observed in only two holes, however, and its presence as the third most abundant plant at the holes was due to one very large hole that was virtually covered in spatterdock. If spatterdock is taken out of the list, eastern purple bladderwort is the next most abundant plant in the holes.

Marsh, ecotone, and pond transects were all included to obtain one plant diversity value per gator hole. Species richness for alligator holes ranged from 9-34 species. Average species richness was 21.11. Diversity ranged from 0.49-2.75, with an average diversity of 1.89. Species richness was significantly higher in the ecotone and in the surrounding marsh than it was the pond. Species richness in the ecotone and in the marsh were not significantly different from each other. Mean species richness was 16.5 for the ecotone and 14.7 for the surrounding marsh. Mean species richness for the pond areas was 6.8.

For marsh reference sites, the 10 most abundant plant species listed in order of importance were: 1) white water lily, 2) eastern purple bladderwort, 3) annual spikerush (Eleocharis geniculata), 4) leafy bladderwort, 5) floating heart, 6) sawgrass, 7) Tracy's beakrush, 8) maidencane, 9) *Utricularia gibba*, and 10) rush fuirena (*Fuirena scirpoidea*). Species richness for marsh sites ranged from 10-19 species, with an average diversity of 12.35. Diversity ranged from 0.87-2.20, with an average of 1.39.

Transformed species richness (lnS) was significantly higher at alligator holes than at marsh reference sites. Diversity (H') was also significantly higher at alligator holes. While no single area at a hole (pond, marsh, ecotone) was significantly higher in species richness or diversity from the reference marsh sites, when alligators holes are viewed as a hole, they are significantly richer in species and diversity than are the marsh reference sites. The reason for the increased species richness and diversity is probably related to the variety of habitats associated with the hole, rather than to the plant community in any one region of the hole.

Our preliminary results show that alligator holes are associated with localized increases in plant diversity in the refuge. Alligator holes act as small-scale disturbances and impact their surroundings by providing a variety of habitats. The variety in habitats is associated with the topographic highs and lows of alligator holes, which support a variety of plant species. Still, it is only when viewed as a whole that alligator holes significantly impact their surroundings in the refuge. Future research should provide further insight into how alligator holes function in the landscape and whether there are different types of holes on the refuge that function differently. The effects of hydrology and spatial arrangement on alligator hole structure and function should also be addressed.

This project is a collaborative between the University of Florida (Dr. Frank Mazzotti,) and the refuge. It is funded by the Cooperative Ecosystem Study Initiative.

Characterization of Lygodium microphyllum spore dispersal within the refuge

Objectives: To quantify dispersal distance of L. microphyllum spores and provide baseline data, in the form of a dispersal curve, for a refuge based L. microphyllum management model.

Old World climbing fern (*Lygodium microphyllum*) is a Category 1 exotic species. This native of the old world tropics was first collected from a nursery in Delray Beach in 1958 and a naturalized population was subsequently discovered in 1965 in Martin County. Today *Lygodium* is expanding at an alarming rate, destroying vast expanses (over 9,000 acres in the refuge) of precious habitat. The rapidity of this exotic's invasion can be explained by its efficient spore dispersal and reproductive strategies. Spores are released from vines high in the tree canopy and dispersed mainly by wind. *Lygodium* plants produce tremendous amounts of spores, each leaf has on average 100 sori, each sorus has approximately 200 spores, and each fertile leaf has the potential to produce 20,000 spores. Because a single spore can grow to become a reproducing adult, the ramifications are overwhelming. While one study has addressed the seasonality of *Lygodium* spore production, no one has examined the range of spore dispersal. If the bulk of spores were produced near the source, then eradication efforts can be concentrated in and around dense infestations, but if the majority of the spores are carried a great distance then additional efforts may need to be expended to detect and treat small patches before they become reproductive.

A study was initiated to document the spore dispersal distribution of *Lygodium* within the refuge. Two Burkard seven day volumetric spore traps were used to monitor spore dispersal. The traps collected a fixed volume of air per unit time and allowed for continuous 7day sampling events.

The first trap (Trap 1) was located at a fixed position within the most highly impacted areas of the refuge to provide a baseline measurement of the maximum number of spores in the air column. The second trap (Trap 2) was positioned at 2 km increments away from the first trap occurring at 2 km, 4 km, 6 km, 8 km, and 10 km away from the highly impacted area. A logging anemometer was deployed next to Trap 1 to help account for wind-induced variability.

A year of spore data was collected at the high impact sight (Trap 1). Equipment failure led to some missing weeks of information. There are durations where wind information was unavailable due to technical problems. Figure 5 illustrates the number of spores collected by Trap 1. The average wind speed is also plotted.

The positioning of the Trap 2 at 2 km increments along a transect is close to completion. Additional transects may be completed to augment sample size and increase confidence in the spore dispersal curve. A more exact knowledge of spore dispersal will help focus eradication and control efforts as well as providing fundamental data on the reproductive biology of L. microphyllum. This project will be completed in 2004 and the data will be used in a larger effort to model *Lygodium* spread and control on the refuge (see section J.1 Cooperative Programs).

Effectiveness of different aerial spray for control of Lygodium on tree islands (24 month post-treatment monitoring).

Objectives: Determine which of four aerial spray concentrations are most effective for the control of Lygodium on tree islands. The basic question is: which application results in the greatest mortality of Lygodium and the least mortality to native species.

Lygodium microphyllum is classified as a Category I exotic species. Since its first introduction to South Florida in the late 1950s it has expanded rapidly and now is widely distributed across southern Florida peninsula. It was first confirmed on the refuge in 1989. Since then it has spread to cover over 9,000 ha. Much of the infestation is on tree islands in the interior portion of the refuge. This exotic has been shown to change plant community composition on tree islands and poses a serious threat to maintaining the integrity of refuge habitats. Control methods are under development and include mechanical control, which is labor intensive especially on the tree islands in the interior, and investigations into effective aerial sprays. Aerial sprays have the potential to provide a more cost effective means of control in situations such as at the refuge, provided that they effectively kill Lygodium while not significantly harming native communities. This study will provide data on the effectiveness of various aerial sprays for the control of Lygodium.

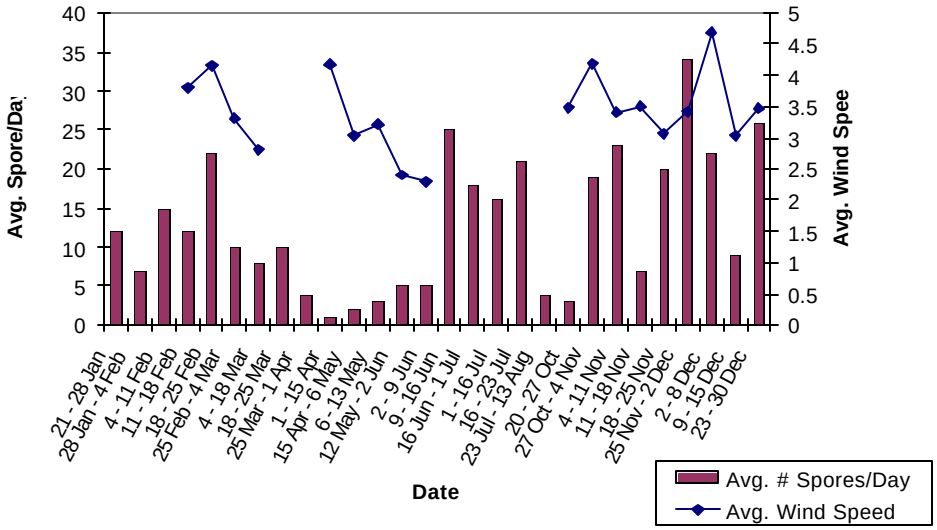

Figure 4. *Lygodium* spore density at a trap placed in an area with dense *Lygodium* infestation in the north central portion of the refuge.

Two heavily infested strand tree islands in the northern portion of the refuge were selected for the aerial treatments. Islands were selected so that they were large enough for two treatments to be applied to each island. The eastern island (26 35.34, 80 21.64) is island Alpha and the western one Bravo (26 35 78, 80 22.02). The islands are approximately 3.3 ha (8.2 ac) and 5.2 ha (12.9 ac), respectively. Alpha is approximately 500 m x 50-100 m and Bravo 400 m x 115-155 m (length x width).

Pre-treatment vegetation sampling occurred in June and July 2001 using the vertical line intercept method. Three transects were sampled on each island. Vertical structure measurements were taken at 5 m increments along the transect (except for the northern transect on island Alpha which was at 10 m increments) at points 0.5 m north of the transect line (to avoid areas disturbed by running the transect). A 12 m level rod was extended at each sample point and the upper and lower bounds of each species within 2.5 cm of the pole recorded. In addition, for each species interval it was noted if the vegetation was live or dead. Details of pre-treatment sampling were presented in the 2001 Annual Narrative and in the report: **Effectiveness of different aerial spray for control of Lygodium on tree islands- Pre-treatment monitoring** prepared by Laura Brandt and Frank Mazzotti and submitted to Randall Stocker (University of Florida, Center for Aquatic Plants).

On October 5, 2001, a South Florida Water Management District (SFWMD) contractor applied two rates of two different herbicides on Lygodium on the two study islands. Two different rates of the herbicide Rodeo, 3.75 pts. and 7.5 pts. per acre were applied to the west and east side of island Alpha, respectively, covering an area of approximately 1.7 ha (4 ac.) Two different rates of the herbicide Escort, 1 and 2 oz. per ac. were applied to the west and east side of island Bravo, respectively, covering an area of approximately 4.4 ha (9 ac.). Followup monitoring occurred in March and October 2002 and October 2003.

Details on the 12 month monitoring can be found in the report: **Effectiveness of different aerial spray for control of Lygodium on tree islands- 12 month monitoring** prepared in January 2003 by Laura Brandt and Frank Mazzotti and submitted to Randall Stocker (University of Florida, Center for Aquatic Plants).

Data from the 2003 sampling have not been analyzed; however, observations during the sampling and via aerial over flights indicate that Lygodium is coming back strongly on both islands. Additional treatments and monitoring should be continued to determine effective frequency of aerial treatments. A full report on the 24 month monitoring will be prepared in 2004.

Invasive exotic (Lygodium) monitoring study on the refuge

Objective: To monitor the regrowth of Lygodium in treated areas and document the response of native species richness and composition.

Currently, Old World climbing fern (*Lygodium microphyllum*) infests ~48,000 acres of the refuge interior. The heaviest infestations of Lygodium occur on native tree islands in the north-central interior. A DEP contractor treated approximately 140 tree islands in this location on an estimated 309 acres from October to December 1999. Total project cost to the DEP was $155,000. In 2001, the DEP allocated $60,000 for re-treatment of Lygodium for all islands within this area.

Ten of the roughly 140 treated tree islands were randomly selected for study. Data were collected for percent coverage of Lygodium and native vegetation in the ground (0-1m), shrub (1-2m), and overstory layers (>2m) within a 4 X 5 meter quadrat placed in roughly the center of the island. Coverages were visually estimated and all plant species were identified. In addition, photo points were

established on each selected island. The northwest corner of the quadrat will also serve as the interior photo point and an exterior photo point was placed on the east side of each tree island to help document Lygodium and native vegetation regrowth over time. Data and photos will be collected twice annually.

The 6th and 7th visits to the ten original and five new (est. July 2002) Lygodium plots were conducted on January 16 and 28, and June 19 and 26, 2003. The results are summarized below.

~3 years post-treatment

Lygodium was detected in the ground layer in 10 plots, however, in nine plots the percent coverage of Lygodium in the ground layer was less than 5%. Lygodium was detected in the shrub layer in 60% of the plots and was #5%, and in the overstory layer in 40% ranging from 5% to 10%. Overall, the majority of tree islands that were properly and thoroughly treated by contractors remain relatively Lygodium free nearly three years post-treatment, and overall infestation on the majority of tree islands appeared to be light. The mean number of native species in the ground layer was 3.2, 1.7 in the shrub layer, and 2.4 within the overstory layer.

In addition, five new plots established in July 2002 were monitored. New plots were established on islands experiencing moderate to heavy Lygodium regrowth, and these plots will serve to track re-treatment effectiveness. Percent coverage of Lygodium in the ground layer ranged from <5% to 20%, in the shrub layer <5% to 45%, and in the overstory layer 10% to 35%. Lygodium coverage remained essentially the same as that documented when plots were established. The mean number of native species in the ground layer was 2.4, 2.8 in the shrub layer, and 1.8 within the overstory layer. Lygodium seems to affect percent coverage of native species rather than species richness (Brandt and Black, 2001), e.g., the number of native species documented in plots during visits.

~3.5 years post-treatment

Lygodium was detected in the ground layer of the 10 original plots and ranged from <5% to 30%. Lygodium was detected in the shrub layer in 80% of the plots ranging from <5% to 10%, and in the overstory layer in 50% of the plots (#5%). Data indicate that Lygodium is slowly increasing within the plots, but in general, the majority of tree islands that were thoroughly treated remain relatively Lygodium-free. Overall, Lygodium coverage was visually estimated as light to moderate.

Visual observations indicated that native species richness increased within the original plots by a factor of one when compared to January 2003 observations. The mean number of native species in the ground layer was 4.5, 2.7 in the shrub layer, and 2.9 within the overstory layer. Annual variations in native species richness within plots appear to be directly related to seasonality with more species being recorded during summer visits than winter visits. Germination and growth of natives could be triggered by early summer rains.

In the five new plots, percent coverage of Lygodium in the ground layer ranged from less than 5% to 70%, in the shrub layer from 10% to 40%, and in the overstory layer from 10% to 25%. The mean number of native species in the ground layer was 4.6, 3.4 in the shrub layer, 3.0 within the overstory layer. Again, native species richness within each vegetative layer within new plots increased by an average of one species.

After four years post-treatment, many of the treated Lygodium islands remain relatively Lygodium free indicating that although ground treatments are extremely expensive, they can effectively control this species on a small scale over a short-term period if performed correctly. However, it was noted during visits that improperly treated tree islands were once again moderately to heavily infested with Lygodium.

Figure 6. Example of Lygodium re-growth on study island; the result of poor treatment.

The dead fern biomass has degraded dramatically over the last year, but some Lygodium biomass remains on the ground, in the shrub, and in the overstory layers. Prescribed fire may be tested on several islands as a means to remove dead fern biomass and to restore tree island plant community structure. A monitoring protocol is in the early development phase.

A comparison between percent cover and number of native species at approximately the same time of the year in the ground layer 6 months and 3.5 years post-treatment indicates an increase in the percent

cover of native species in seven of ten plots (70%) further supporting results of Brandt and Black (2001) mentioned previously. However, the number of species detected within plots has remained relatively constant over the duration of the study.

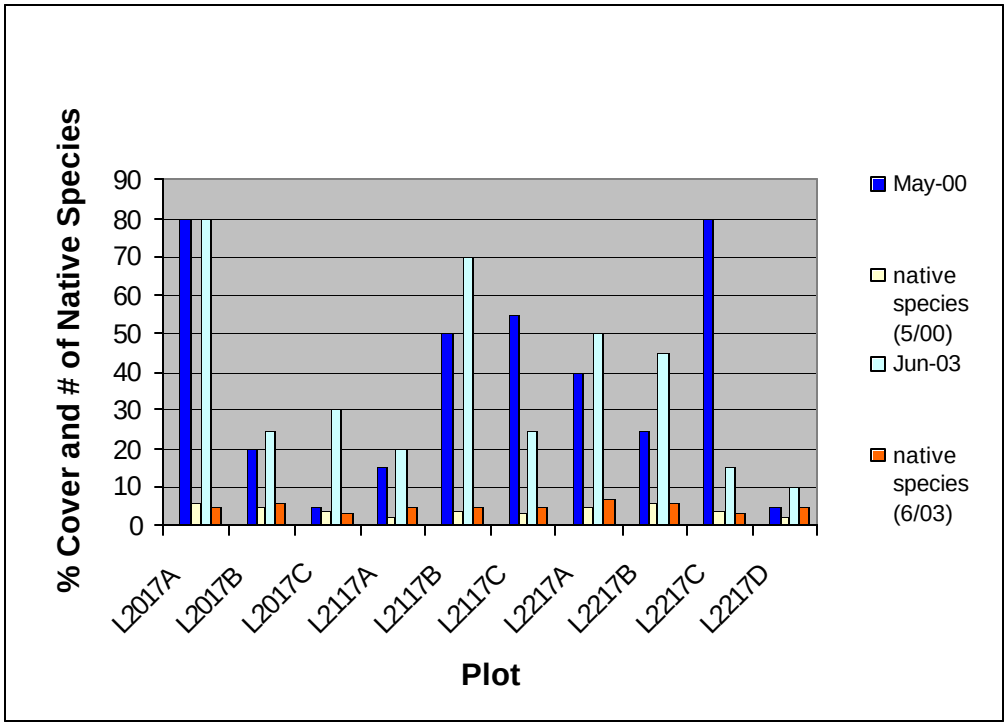

Figure 7. % Cover and # of Native Species in the 10 original Lygodium plots 6 month-and 3.5 years post-treatment.

The results of this study have direct implications on future expenditures and control operations for the long-term management of Lygodium on the Refuge. Results clearly show that properly treated islands experience little Lygodium re-growth within 3 years. For cases like the Refuge, re-treatment prior to the third year may be unnecessary allowing funds to be directed to treatment of more severe infestations. Findings also show that it is theoretically possible to achieve maintenance control of this species on the refuge, or at least, achieve a level of control where Lygodium is no longer impacting the ecological function of tree islands.

A three year evaluation summary report appeared in the Spring 2003 issue of Wildland Weeds magazine titled "Monitoring Ground Treatments of Old World Climbing Fern (*Lygodium microphyllum*) on the Arthur R. Marshall Loxahatchee NWR" by William G. Thomas, Jr and Laura A. Brandt.

Melaleuca seedling germination monitoring study (2000 drought-related study)

Objective: To document the establishment of melaleuca seedlings on exposed peat in wet prairies and sloughs during and following low water conditions.

Certain environmental stresses such as fires (wild and prescribed), temperature fluctuations, chemical applications, mechanical removal, and weather events such as hurricanes and drought, generally cause melaleuca trees to release seeds and thus become established in adjacent areas. Massive seedfalls result in the formation of dense impenetrable heads. Melaleuca is an extremely hardy tree and can adapt to all environmental conditions, whether natural or not. Refuge staff felt that the drought-like conditions, which prevailed for much of CY 2000 and the early part of 2001, may have stressed trees into releasing seeds, causing the additional spread of melaleuca throughout the refuge interior. By mid-April 2001, much of the marsh interior had 'dried out', the exception being the southern most portion of the interior. Although the spread of melaleuca to pristine areas is common knowledge to most natural area managers and biologists, no research or studies to document the potential impact to exposed peat have ever been conducted at the Refuge.

Six photo points were established in March 2001 at a mature un-impacted melaleuca head in the marsh interior (26°N 30.20, 80°W 16.53) to document melaleuca seed germination/seedling establishment during and following low water conditions, i.e., drought. Photo points to the north, northwest, east, southeast, southwest, and west of the head were established to document areas with visible exposed peat as a sub-project to the overall refuge drought monitoring study.

Figure 8. Melaleuca study head in refuge interior.

The six photo points established in March 2001, at the height of the drought, were visited February 28 and August 20. Photos were taken at all six points during each visit. On February 28, one floating peat island was observed on the southwestern corner of the island; otherwise, both wet prairies and sloughs still contained water. No melaleuca seedlings were observed on the floating peat island nor in wet prairie or slough habitats depicted in photo points. Surface water levels for all photo points depicting wet prairie, or slough habitats surrounding the melaleuca head averaged 39 centimeters.

The following interesting observations were noted during the February 2003 visit. The study head was inadvertently aerially treated during herbicide applications to dense melaleuca heads in the interior during late January 2003. The study site was not marked so the helicopter applicator was not at fault. Spray operations were not expected to reach this far north or west, nor expand from the delineated treatment area boundary. The majority of trees in the study head were brown and defoliated, the exception being a cluster of scattered melaleuca in the southern portion of the island. Copious amounts of seeds were observed floating on the water surface on the edge of the island, and many of the seeds had germinated. Large amounts of seeds were floating amongst bladderwort and other submersed vegetation. If water levels were to continue to drop, it was expected that there would be significant seedling establishment on the island's edge, and in wet prairie and slough habitats.

The August 20 visit revealed that the one floating peat island observed on the southwestern corner of the island was infested with copious amounts of seedlings, some of which were up to three feet tall. Again, no melaleuca seedlings were observed in wet prairie or slough habitats depicted in photo points. Surface water levels surrounding the melaleuca head averaged 54.57 centimeters. Recommendations at this point are for the study to be terminated as the original objectives of the study can no longer be met following the herbicide application and resultant mass seedfall.

Some simple conclusions can be drawn from the study. It appears that unless there is some catastrophic stressful event to trees within a head, whether natural or planned, infestation to neighboring wet prairie or slough habitats under natural conditions appears to be low, and occurs at a relatively slow pace. However, it will be interesting to note during future visits if there is considerable seedling establishment around the head following the herbicide treatment given the fact that there is still a significant amount of water in adjacent habitats. If there is significant seedling establishment in wet areas, it will further support studies indicating that melaleuca seeds can germinate, sink in the water column, and root in the peat under high water conditions. In effect, seedlings will survive until conditions are favorable (low or no water), to ensure growth, survival, and subsequent establishment (refer to Meskimen's study, 1962). It will also be interesting to note if the majority of seedlings establish next to the island or far into adjacent habitats. The island itself was extremely dry with the exception being the edges of the island which remained moist, i.e., excellent germination stratum.

Mapping and Monitoring of *M. callizona* and its Host Plants in South Florida: Summary Year 2003

Primary Investigator: Teresa Cooper, University of Florida

Objective: To examine, count and photograph refuge bromeliads (air-plants) while looking for the invasive, exotic weevil (*Metamasius callizona*)

During 2003, surveys were completed monthly (except May) along the following refuge's "mapped areas": Board Walk A (BWA), Side Walk A (SWA) and Hypotenuse Triangle A (HTA). Surveyors included refuge volunteers Walters, Reeves, Slaytor, Weinstat and Fleck. A total of 116 bromeliads were monitored, 10 of which died and 15 disappeared. The causes for death and disappearance have not yet been established, though the majority occurred in BWA. In addition, sixteen bromeliads were among those that "fell out" (those that fell into the mapped area from the trees above) and killed by weevils. The greatest number of fall out was discovered between March and September.

This project is scheduled to continue through 2004.

Water elevation surveys analyzing groundwater intrusion and flow attributing to additional phosphorus contamination (conducted by: Jessica D. Phillips, Wellington High School Research Student**)**

Objectives: Determine the direction of groundwater flow in Impoundment Lower A. Phosphorus contaminated water enters Impoundment Lower A from the L-40 canal through a pump, which is then transported to other compartments by a series of culverts. Data results from this groundwater flow study will determine: 1). If contaminated groundwater seepage is occurring within Lower A, and if so; 2). Is Lower A effluent (being fed by groundwater) or influent (feeding the groundwater); and 3). Determine if the source or origin of the seepage is from the L-40 canal to the west or from an agricultural area further east.

This research concluded the study conducted at the refuge to determine if phosphorus contaminated groundwater seepage occurs within impoundment Lower A. As part of the historic Everglades, Lower A has several known water sources including naturally occurring rainfall and artificially pumped drainage containing phosphorus from the L-40 canal. Through field experimentation, a determination could be made as to whether Lower A was effluent, being supported by groundwater or influent, supporting the groundwater. It also provide the direction of groundwater flow.

This research used a series of four piezometers to measure 1. Surface water and 2. Groundwater levels within Lower A to determine if groundwater seepage was occurring. The piezometers were placed in a straight east to west direction, permitting analysis of groundwater flow patterns within Lower A.

To determine seepage, the two measurements obtained form each piezometer were compared. Lower A. would be effluent, if the hydrologic head within the piezometer was higher. A greater surface water

level would indicate Lower A was influent, and if equal, then the area is supported by both. To determine groundwater flow, differences in water levels were compared for each testing site/date. The piezometer with the greatest hydrologic head, would indicate the source of groundwater.

In conclusion, the piezometer data determined that Lower A was effluent, or supported by groundwater, sustaining the hypothesis. In opposition, the piezometers indicated that groundwater flowed into Lower A. from the east and not the west, as initially speculated.

Full details of this project can be found in the report: **Water elevation surveys analyzing groundwater intrusion and flow attributing to additional phosphorus contamination** prepared by Jessica D. Phillips (Wellington High School Research Student**).**

CONTAMINANTS

Contaminants and Nutrients

Contaminant investigations were conducted in 2003 by refuge staff in order to expand the refuge's knowledge of pesticides, heavy metals, and nutrients that may be present in the sediment and water of selected habitats. This information is important for future refuge management decisions, since high levels of contaminants and nutrients may adversely affect wildlife populations. During 2003, the following studies continued: (1) Contaminants and Nutrients in the Strazzulla Marsh, and (2) Contaminants and Nutrients in the Cypress Swamp. The following are summaries for each project. Data and reports for each project can be found in the refuge's biological files.

Contaminants and Nutrients in the Strazzulla Marsh–Year 3 Summary

Baseline data for contaminants and nutrients has historically been unavailable for the Strazzulla Marsh, which provides almost 1600 acres of Everglades habitat for a variety of wildlife species, including endangered snail kites and threatened sandhill cranes. This wetland also provides suitable habitat for the more "secretive" marsh birds, of which many populations are currently in national decline. Neotropical migratory passerines are common to this area during the peak migration periods. This is an important part of the Everglades ecosystem which has received little management in the past, and of which little is known about the quality of the water and sediments in the marsh.

The existing water quality conditions in the A.R.M. Loxahatchee National Wildlife Refuge (NWR) are influenced by development-related activities. Hydrologic alterations have led to significant changes in the landscape by opening large land tracts of South Florida for urban development and agricultural practices. The construction of extensive drainage networks has disrupted natural drainage patterns in the region with an extensive array of levees and canals. Nonpoint source (storm water) runoff and point sources of pollution (wastewater discharges) are now part of the normal hydrological regime in many areas. Several pollutants of concern could be present in the study area.

Objectives: (1) To develop a baseline of pesticides, metals, herbicides and nutrients for the Strazzulla marsh, and (2) To help identify potential water quality threats from outside sources.

This project began in May 2001, and will continue through April, 2004. Funding each year has been provided through the U.S. Fish and Wildlife Service contaminants funding programs.

Sediment and water samples were collected from 7 stations in the Strazzulla marsh. Sediments were analyzed yearly for total organic carbon, grain size, heavy metals and pesticides. Water samples were analyzed quarterly for heavy metals and pesticides, and monthly for phosphorus and chlorides.

During 2003, low levels of mercury and lead were found in the Strazzulla marsh sediments. Low levels of the pesticide DDE were also found in the marsh at two locations, yet these values are not considered risky to the environment. Phosphorus in Strazzulla sediments ranged from 11-250 mg/kg, with an average of 82 mg/kg at each site. Whereas areas >400 mg/kg total phosphorus are considered to be impacted sites, the Strazzulla marsh sites show little or no impact from outside sources.

Mean water total phosphorus values ranged from 9-67 ppb at the Strazzulla marsh sites, from May 2002-May 2003. Ortho phosphorus values were considerably lower, with means ranging from 6-25 ppb. Mean chloride values ranged from 5-13 mg/l, indicating a system not highly influenced by agricultural runoff. The STRZ06 site consistently showed higher phosphorus and chloride values, which may be due to (1) it's influence from a nearby canal (within 20 feet) and/or (2) an unknown source of water entering this part of the marsh which may contain high nutrients. Although the Strazzulla is not considered to be "pristine habitat" (when compared to 10 ppb total phosphorus) it is less impacted than interior parts of the refuge, adjacent to the L-7, L-39 and L-40 canals.

Contaminants and Nutrients in the Cypress Swamp– Year 3 Summary

No baseline water or sediment data have historically been available for the 400 acres of cypress swamp habitat on the refuge, which provides habitat for wading birds, neotropical migratory birds, and numerous mammals, reptiles and amphibians, including several federally listed threatened and endangered species. This is an important part of the south Florida ecosystem which has received little pro-active management in the past. The cypress swamp receives runoff from farms and old agricultural areas known to have been heavily-treated with now-banned organochlorine pesticides such as toxaphene and DDT. These contaminants have been implicated in recent bird die-offs in South Florida.

The existing water quality conditions in the refuge are influenced by development-related activities. Hydrologic alterations have led to significant changes in the landscape by opening large land tracts of South Florida for urban development and agricultural practices, and by the construction of extensive drainage networks. Natural drainage patterns in the region have been disrupted by the extensive array of levees and canals such that nonpoint source (storm water) runoff and point sources of pollution (wastewater discharges) are now part of the normal hydrological regime in many areas. Several pollutants of concern could be present in the study area.

Objectives: (1) To develop a baseline of phosphorus, mercury, pesticides and herbicides water quality information for the cypress swamp, and (2) To help identify potential water quality threats from outside sources

The cypress swamp receives water through adjacent farm field runoff each year, most of which comes during the rainy season. This water brings chemical fertilizers, pesticides and other elements into the swamp habitats. This project began in May, 2001 and is funded through the U.S. Fish and Wildlife Service contaminants funding programs. It will continue through April, 2004.

Sediment and water samples were collected from eight sites in the swamp. Sediment samples taken in May, 2003 were analyzed for total phosphorus, organic carbon, grain size, metals and pesticides. Water samples for metals and pesticides were taken quarterly. Water samples to test for total phosphorus, ortho-phosphorus and chlorides were taken monthly.

Contaminants found in the swamp include DDT, DDD, DDE, mercury, endosulfan, chlordane, alpha-chlordane, gamma-chlordane and permethrin. In large quantities these elements can pose a significant risk to wildlife, yet the levels found in the swamp were low and not considered to pose a high risk to aquatic or terrestrial species.

Phosphorus found in sediments ranged from 58 mg/kg-1200 mg/kg, with an average of 340 mg/kg at each site. Three sites were considered to be highly impacted (>400 mg/kg). Mean total water phosphorus values ranged from 277-1735 ppb during the May 2002-May 2003 period of the study. Mean ortho-phosphorus and chloride values ranged from 223-1293 ppb and 37-65 mg/l, respectively. These phosphorus and chloride values reflect a cypress swamp that is greatly influenced by agricultural runoff.

Contaminants Investigations: Refuge Boneyard and Firing Range Berm

Site Characterization, Investigation and Assessment, Former Equipment Boneyard and Firing Range

The former equipment boneyard (boneyard) is located on the refuge's fee title lands, east of Lower A compartment and 2,600 feet north of Lee Road. It is a piece of land (140 feet by 260 feet) that was utilized to store materials, chemicals, equipment and solid wastes during the 1960s through the early 1980s. Solid waste was buried throughout the boneyard.

The former firing range is located approximately 1,500 feet south of the boneyard, and was used by refuge law enforcement staff to hone and maintain their marksmanship. It consists of a cleared area, one main berm approximately 10 feet high, and two lateral berms.

URS Corporation of Boca Raton, Florida, completed a site characterization, investigation and assessment of the refuge's boneyard and firing range berm during 2003. The final report detailed the findings and conclusions of the subsurface investigations. URS found approximately 689 cubic yards of arsenic-impacted soils, and 1182 cubic yards of solid waste in the Boneyard. Approximately 98 cubic yards of lead-impacted soils were identified in the main berm of the firing range. In August, 2003, Biologist Arrington prepared cleanup proposals for both affected areas, and submitted them to the regional office for consideration. As of this writing it is not certain as to whether these projects will be funded in FY 2004.

SPECIAL USE PERMITS (SUP)

Special Use Permits (SUPs) are issued to non-refuge personnel for the purposes of scientific research and monitoring. The following abstracts allow the reader to briefly review what has been done by the participating scientists. Full reports of the projects can be obtained by contacting the primary investigators or the refuge.

SUP # 41560-02009

Ecology of Common Salvinia, *Salvinia minima*, in South Florida

Principal Investigators: Philip Tipping and Ted Center, U.S.D.A. Invasive Plant Research Laboratory

Objective: To elucidate the ecology of *S. minima*

The original study site was the pond next to the visitor's center at the refuge. Another site was added in the same drainage area in 2003. Monthly visits to the site have been conducted since May, 2002. Data captured includes density of *S. minima* and *Cyrtobagous salviniae* (Coleoptera: Curculionidae), growth stage, pathogen load on *C. salvinae*, presence and density of other herbivores, feeding damage on *S. minima*, and density and diversity of competing vegetation. In addition, *S. minima* tissue and water samples were collected each month for analysis. Populations of *S. minima* have now gone through two cycles with surface coverage of 100% in May, 2002 changing to less than 1% in June, 2002. It wasn't until February, 2003, that coverage began to increase again, reaching 90% in June, 2003 before once again crashing to 1% in July. However, unlike 2002, surface coverage has steadily increased since then. For the first time an unknown species of Microsporidia pathogen was detected in *C. salviniae* (weevil) at two sample dates in the summer. The low level of infection and brief appearance of this pathogen indicates that it is not a significant regulating factor on weevil populations. The ability of the weevil to suppress *S. minima* may promote increased diversity for aquatic plants and the organisms that utilize them in the refuge. It may also influence future control decisions for this weed. Longer-term studies will be necessary to understand the factors that regulate this plant-herbivore relationship.

SUP # 41560-02010

Establishment and Dispersal of the Melaleuca Psyllid, *Boreioglycaspis melaleucae*, on *Melaleuca quinquenervia* in Loxahatchee National Wildlife Refuge

Principal Investigators: Philip Tipping, Paul Pratt and Ted Center, U.S.D.A. Invasive Plant Research Laboratory

Objectives: To establish a psyllid, *Boreioglycaspis melaleucae* (Hemiptera: Psyllidae), on *Melaleuca quinquenervia*, and record the pattern and rate of dispersal
An island in the north-central refuge infested with *M. quinquenervia* was used as the original release site and received more than 10,000 insects in 2002. In 2003, the site was visited in January and July

with 1,500 adults released at the first visit. Psyllids were present on the island at both dates, indicating that establishment had likely occurred. Psyllids were not found on adjacent islands, yet it is known that the psyllid can disperse rapidly and over long distances when their densities are high. Accordingly, 30,000 adults were released in November, 2003, in melaleuca stands near the north-eastern portion of the refuge. Although the impact of *B. melaleucae* on field populations of *M. quinquenervia* has yet to be quantified, this insect readily kills large saplings under greenhouse and screenhouse conditions. If the insect can be established, it may provide significant suppression of the plant which, because of the permanently flooded nature of the refuge, largely escapes attack by another biological agent, *Oxyops vitiosa* (Coleoptera: Curculionidae). The researchers plan to monitor the spread of the psyllid populations in the refuge through 2004 and may make additional releases as needed to ensure establishment.

SUP # 41560-02011

Everglades Tree Island Development and Response to Hydrologic Change

Principal Investigators: Debra Willard and William Orem, U.S. Geological Survey

Objective: To determine the timing of tree-island formation, the sensitivity of tree-island plant communities to natural and anthropogenic environmental changes, and geochemical parameters that may have influenced their development

The study relies on pollen and geochemical analyses of sediment cores collected on tree islands throughout the historic Everglades. During 2002, the permittees collected cores on three tree islands in Loxahatchee NWR (refuge): Strand Island 1 (26/26.884'N, 80/ 16.730'W), Strand Island 2 (26/ 25.365'N, 80/ 17.925'W), and a pop-up island, Cocoplum 4 (26/ 26.386'N, 80/ 16.589'W). On Strand 1, a transect of three cores was collected, including the center of the island, the southern tip of the island, and the marsh. On Strand 2, one core was collected on the center of the island and another was collected in the adjacent marsh. One core was collected on Cocoplum 4. The cores range in length from ~60-90 cm. Analyses have been completed on a core collected in the center of Strand 2 and the nearby marsh, including pollen analysis, radiocarbon dating, and lead-210 dating.

Results from these cores indicate that substantial changes in plant communities have occurred in the refuge since construction of the Water Conservation Area in the early 1960s. On tree islands, this change is manifested by much greater abundance of *Ilex* and *Myrica* and changes in composition of fern assemblages. It is likely that other compositional changes occurred that are not preserved in the pollen record, which is biased toward wind-pollinated plants. In the marshes, peat accretion rates increased at least twofold after 1900, with even greater increases at the Strand 2 marsh after 1960. Ongoing geochemical analyses of these cores will determine if the altered accumulation rate is correlated with changes in nutrient status. Initial canal construction in the early 20th century had only minor impacts at these sites. Pollen will be analyzed from additional samples to clarify patterns in these cores and determine the best correlations between the observed changes and past management practices at the refuge.

SUP # 41560-02019

Genetic Variation in *Taxodium*

Principal Investigator: Sydney Bacchus, Tom Warnke and Edgar Lickey, Applied Environmental Services

Objective: To detect the genetic variation in non-coding chloroplast and nuclear DNA regions in *Taxodium* (Cupressaceae)

The delimitation and circumscription of taxa within *Taxodium* has been a contentious issue among many researchers. Three entities are usually recognized (bald-cypress, Montezuma bald-cypress, and pond-cypress), but the rank at which these taxa are recognized varies among authors. Previous work based on morphology, allozymes, and an anonymous nuclear DNA locus indicate that although there are differences between taxa, these differences may become blurred in sympatric populations and in intermediate habitats. Natural populations of Montezuma bald-cypress are allopatric from both bald and pond-cypress, and recent work indicates that there may be temporal reproductive isolation between bald and pond-cypress. These data suggest that there is probably limited gene flow between taxa, but genetic data to test this hypothesis is currently lacking. To assess genetic variation within and among populations of *Taxodium*, both non-coding chloroplast and nuclear DNA sequences are being evaluated. A survey of over 11,000 bp of non-coding chloroplast DNA between one bald and one pond-cypress revealed only three indel and four nucleotide substitution differences between individuals. Sequences of two nuclear genes (*G3PDH* and *PGI*) are also being explored. Restriction digestion of PCR-amplified fragments of both chloroplast and nuclear regions will be used to assess the geographic and taxonomic distribution of genetic variation.

SUP # 41560-02021

Development of a *Lygodium* Invasion Index, based upon a comparison of Remote Identification Techniques for Assessing *Lygodium microphyllum* on Tree Islands in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (refuge)

Principal Investigators: Fred Sklar and Faithe Clarke, South Florida Water Management District

Objectives: (1) To compare the accuracy of four meter multi spectral IKONOS imagery, versus 1:24,000 scale color infrared aerial photography for the detection of *Lygodium microphyllum* on tree islands; (2) To develop a density-based invasion index as a tool for categorizing the degree of infestation of *Lygodium microphyllum* on the tree islands; and (3) To determine the spatial distribution of *Lygodium microphyllum* in relation to selected tree island soil properties

Twenty four soil cores were extracted from six tree islands in two regions of the refuge between October 29 and November 25, 2002. In both regions, one island without *Lygodium microphyllum* and two invaded islands were selected for sampling. Samples were collected by vertically inserting a

24 inch aluminum coring tube into the soil. Soil samples were analyzed to determine percentage ash content, bulk density, percentage moisture content, soil pH value, total nitrogen concentration, and total phosphorus concentration.

Among the soil properties analyzed, none indicated a statistically significant difference between islands invaded with *Lygodium microphyllum* in the north, versus those islands invaded in the south. Based upon this very limited soil study, there does not appear to be any significant difference between islands in the north and south, nor islands with and without *Lygodium*. However, further analysis may be needed, specifically to determine if there is a relationship between the soil properties investigated and the spatial distribution or incidence of *Lygodium microphyllum* in the refuge.

SUP # 41560-02022

Field Research and Monitoring Studies to Support Derivation of a Class III Water Quality Criterion for Phosphorus in the Arthur R. Marshall Loxahatchee National Wildlife Refuge: Year Eight (2003) Progress Report

Principal Investigator: Sue Newman, Everglades Division, South Florida Water Management District

Objective: To examine the sensitivity of the refuge to phosphorus (P) enrichment

Routine sampling continued in 2003 and surface water quality was similar to that reported in 2000-2002. Average alkalinity at interior transects sites was 3-fold higher in 2003 compared to values reported in 1996-1999, suggesting the continued intrusion of hard-water into the soft-water interior.

Soil cores collected in Dec 2002, indicate that two years following cessation of dosing, TP concentrations in the benthic floc in the highest loaded mesocosms (1.6 and 3.2 g P /m^2/yr) were elevated (470 mg/kg) compared to unenriched controls (330 mg/kg), however they were not significantly different. Similarly, water lily leaf growth and tissue (leaf and rhizome) nutrient (TP and TN) concentrations were monitored annually after the cessation of P dosing to examine the recovery process. Rhizome samples were collected during the winter season, while leaves were taken in summer, the peak growing season. Preliminary data showed after two and half years, TP concentrations of leaves and rhizomes in the highest P dosed mesocosms (3.2 g P /m^2/yr) decreased and were similar to the control mesocosms receiving no P dosing.

Future research plans include continuation of chemical and biological monitoring at the transect sites and assessment of recovery in the mesocosms. Future field sampling in the refuge will evaluate soil and vegetation characteristics of Lygodium invaded tree islands, including soil and plants. The permitted also plans to define spatial conductivity patterns within the refuge in collaboration with refuge staff.

SUP # 41560-03008

The collection of the Fern *Actinostachys pennula* in Relation to Lygodium Biological Control Research.

Principal Investigators: Robert Pemberton, Luke Kasarjian, Jr, and Gary Buckingham, U.S.D.A. Agricultural Research Service, Invasive Plant Research Laboratory

Objective: To collect specimens of the ray-spiked fern, used for testing host specificity for candidate Lygodium biological control agents

Collections of *Actinostachys pennula*, the ray fern, (Schizaeceace) were made from two Everglades tree islands in Lygodium research plots developed with the Institute for Regional Conservation. Collections were made on two dates for use in host specificity testing of candidate biological control agents for *Lygodium microphyllum* in the Florida Biological Control Quarantine in Gainesville. On January 29, 2003, two fertile fronds were collected. On February 6, 2003, 10 fertile fronds and two old cinnamon fern stem bases were collected. One stem base had 31 (10 fertile) fronds and the other 8 (4 fertile fronds). These cuttings and plants were tested against the pyralid moth *Neomusotima conspurcatalis*, a leaf feeder from Southeast Asia. No egg laying nor development occurred on *A. pennula*. The full testing indicated that the moth is a narrow specialist of a few Lygodium ferns, primarily *L. microphyllum*. It was unable to use any of the four Caribbean Lygodium species. The moth will be petitioned for release before the Technical Advisory Group on Biological Control of Weeds during 2004.

SUP # 41560-03011

2003 Wading Bird Survey

Principal Investigator: Peter Frederick and Madeline Sickle, University of Florida

The 2003 Wading Bird Survey (SUP #41560-03011, P. Frederick and et. al.) is extensively covered in detail in Section G-4., Marsh and Waterbirds.

SUP # 41560-03012

Transport Mechanisms of Dissolved and Particulate Phosphorus in the Water Conservation Area Canals in South Florida

Principal Investigators: Samira Daroub, University of Florida

Objective: To study the vertical and longitudinal gradients on both dissolved and particulate phosphorus during pumping events from STA-1W

No work was completed in 2003. However, water sampling for the phosphorus transport studies will be scheduled for 2004, with emphasis to include part of the dry season and early wet season events. Additional studies are needed to evaluate the dissolved P removal and contribution mechanisms, rates, capacities and seasonal responses.

SUP # 41560-03015

Methylmercury in the Everglades

Principal Investigator: David Krabbenhoft, U.S. Geological Survey

Objective: To determine how methylmercury in the Everglades responds to changes in mercury, sulfur and nutrient loading

No work was completed on this project in 2003.

SUP # 41560-03019

Wildlife Surveys in Refuge 'C' Impoundments

Principal Investigators: Frank Mazzotti and Elise Pearlstine, University of Florida

Objective: To conduct surveys for birds, reptiles, amphibians, small mammals, fish and invertebrates at selected "C" impoundments

A total of 18 visits were made between the dates of January 1 and December 31, 2003, in the evenings after sunset and mornings at dawn. Observers stopped at established points along the road on the edge of each impoundment. Surveys were conducted in impoundments C6, C7, C8, and C9. There were seven points for wildlife observation and nine points for minnow traps. Minnow traps were set for either overnight or for 20 minutes depending on survey needs. Bird counts were made for a ten minute count period; anurans were counted at night for ten minutes. All surveys were both visual and aural. In addition to animals in the aquatic environments of the impoundment, those inhabiting the scrub and roadside habitat at the edges were counted. Any observations of reptiles and mammals made during nocturnal observations were also recorded.

In all, 3899 animal observations were made, which included 1538 anurans, 1152 birds, 1169 fish, 36 reptiles and 4 mammals. The permitted counted 10 species of fish, 10 species of anuran, 6 reptile species, 50 bird species and 3 species of mammal. Observations were generally centered in the inundated portion of the impoundments, but also included a number of upland species. Observations were limited in impoundments C6 and C7 to the months of May through September when rice fields were being surveyed in the Everglades Agricultural Area (EAA). These impoundments were used as a control for the rice study. Observations in impoundments C8 and C9 were carried out from October 2002 through October 2003 for purposes of comparison with general wildlife surveys in the EAA. For the months May through September, 2003, data were collected on all four impoundments and compared to the average abundance for three taxa – fish, anurans and birds. Abundance was generally greatest in May and June. In general, species richness was similar for all impoundments.

SUP # 41560-03020

Topographic Surveys of the Loxahatchee National Wildlife Refuge

Principal Investigator: Greg Desmond, U.S. Geological Survey

Objective: To complete a topographic survey of the Loxahatchee National Wildlife Refuge (refuge), that will produce accurate digital elevation data to parameterize hydrologic models that are being developed for Everglades ecosystem restoration planning and implementation purposes

The refuge topographic surveys are being conducted using the USGS-developed Airborne Height Finder (AHF) system. The AHF is a helicopter-based instrument that is able to measure the terrain surface, which is typically submerged under water and obscured by vegetation, in a noninvasive, nondestructive manner. Using an airborne Global Positioning System (GPS) hovering platform and a high-tech version of the surveyors plumb bob, the AHF system distinguishes itself from remote sensing technologies in its ability to physically penetrate vegetation and murky water, providing reliable measurement of the underlying topographic surface. The AHF surveys require the use of ground-based GPS receivers that are used as geodetic control reference points. The reference stations are positioned such that AHF data collection operations stay with 15 km of the geodetic control points. The AHF survey is collecting data points every 400 meters in a grid pattern throughout the Refuge.

To date, all geodetic control points required for AHF operations within the refuge have been surveyed and established. Two 10-day field trips to conduct AHF surveys have been completed. Field data collection for approximately 40% of the Refuge has been completed and data processing is in progress.

Current and developing hydrological simulation models used for Everglades ecosystem restoration activities require very accurate elevation data to produce meaningful output results. The hydrodynamic modeling community will use the results of the AHF topographic surveys as it works towards the goals of the Comprehensive Everglades Restoration Plan (CERP).

Two or three more AHF data collection field trips will be necessary to complete the topographic surveys of the refuge. Data processing will ultimately result in the development of digital elevation models (DEM's). Once produced, the DEM's will be posted on the USGS South Florida Information Access (SOFIA) web site (http://sofia.usgs.gov) for dissemination.

SUP # 41560-03021

Snail Kite Demography

Principal Investigators: Wiley Kitchens and Julien Marten, University of Florida

Objective: To study the demography of snail kites throughout central and southern Florida during the 2003 breeding season.

The refuge is classified as critical habitat for the endangered snail kite, and is monitored for snail kite use each year. Data from the refuge is being used to develop population models for this species. Recent demographic results show alarming trends concerning the snail kite population in Florida. Kite abundance has steadily declined since1999 (in 2003 the population size was estimated to be half that of 1999). The reasons for this severe decline are still unclear, though the number of nests and consequently the number of young fledged currently exhibit negative trends.

Refer to sections D5 and G2 for detailed 2003 refuge-related snail kite information.

SUP # 41560-03022

2003 Exotic Bark Beetle Delimiting Survey

Principal Investigators: Yvette Ogle and Stefani Krantz, Florida Department of Agriculture

Objective: The objectives of this project are to (1) delimit the distribution of two species of exotic wood boring beetles and (2) to survey for other exotic species of economic concern that have high establishment potential as specified by the Eastern Region Cooperative Agricultural Pest Survey guidelines and the Exotic Ambrosia Beetle Survey of the Southeastern United States; Forest Health Evaluation Monitoring Project

The two target species of this survey are *Xyllosandrus mutilatus* and *Euwallacea fornicatus*. *Xyllosandrus mutilatus* has been previously detected at Archbold Biological Research Station and *Euwallacea fornicatus* is known to be established in Mississippi.

Sites were selected in urban and natural areas throughout central and southern Florida. Sampling sites were selected based upon their vicinity to areas where exotics would likely be introduced, or their proximity to areas where *Xylosandrus mutilatus* had already been found. GPS data was recorded for each survey site. The refuge was selected as a survey site because it is a large natural area with appropriate habitat types and it is directly adjacent to the urbanized coast of Florida and proximate to several nurseries in the Palm Beach Area.

Each Lingren Funnel trap was baited with 4 high release ethanol lure pouches. The collecting cup was filled with non-toxic antifreeze. These pouches were replaced once in the middle of the 8 week long sampling period. Each trap was checked in 2 week intervals. When traps were checked, the fluid in the collecting cup was filtered into a plastic bottle and all insects found in the trap were placed into a glass canning jar filled with 70% isopropanol. The non-toxic antifreeze was collected in plastic bottles and properly disposed of at the Division of Plant Industry office in Gainesville, Fl. Samples were sorted at the Division of Plant Industry office in Gainesville by James Walker, Stefanie Krantz and Bud Mayfield. Trap samples were carefully screened for *Xylosandrus mutilatus* and *Euwallacea fornicatus* and specific determinations were made for all other Scolytids except for those in the genus *Hypothenimus*. The beetles in families other than Scolytidae that were collected were identified to species by Mike Thomas when the time to make determinations was reasonable, or when the species was thought to likely be an exotic. Voucher collections were made of all beetles collected. The

voucher collection is housed at the Division of Plant Industry CAPS Section. Determinations were made under the supervision of Michael Thomas, and with the assistance of Robert Rabaglia.

The species of beetles collected at the refuge consisted of four exotics *(Premnobius cavipennis, Xyleborinus saxeseni, Xylosandrus compactus* and *Xylosandrus crassiusculus),* three natives *Xyleborus affinis, Xyleborus pubescens* and the Powder-Post Beetle (scientific name unknown) , and three disputed species (*Cryptocarenus heveae, Cryptocarenus seriatus* and *Xyleborus ferrugineus*). *Xylosandrus mutilatus* and *Euwallacea fornicatus* were not found on the refuge. The complete list of beetles collected at all sites surveyed will be released to the survey participants once the final survey report is completed.

Examination of the status of the Scolytids found at the refuge reveals that the fauna is dominated by species that are exotic or whose status is being disputed. The ecological impacts of the widespread occurrence of exotic Scolytids in Florida has not been thoroughly studied so one can only speculate about the impacts that this may have on Florida natural ecosystems.

Fortunately the species found at the refuge do not attack healthy trees, but they are decomposers that attack senescing trees. Therefore, they pose no eminent threat to healthy trees. Also, the options that are available involve using pesticides or removing senescing trees or logs. These actions could be detrimental to other species that live in the refuge. Therefore, at this time there may be no need to take immediate action.

These types of studies will hopefully help to raise awareness about the prevalence of exotic arthropods in Florida's ecosystems, and bolster the support for policies that protect ecosystems from exotics. These include public awareness campaigns, early detection programs, public policy that helps to support programs that regulate and screen imports, and research about the impacts of exotics and eco-friendly methods of mitigating their effects.

SUP # 41560-03024

Long-term trends of mercury in the fisheries of the Florida Everglades

Principal Investigators: Ted Lange, Doug Richard and Beth Sargent, Florida Game and Freshwater Fish Commission

Objective: To evaluate mercury trends in fisheries of the Everglades region

Monitoring of spatial and temporal trends of mercury concentrations in largemouth bass and sunfish has been conducted at 14 sites in the Everglades since the early 1990s. Study sites are located in Everglades National Park, Water Conservation Areas 1 and 2, and Arthur R. Marshall Loxahatchee National Wildlife Refuge (refuge) where monitoring has been conducted since 1995.

In the refuge, fish collections were made using electro-fishing equipment mounted on a jon boat or an airboat. During September and October 2003, largemouth bass and sunfish were collected from both the L-7 Canal and the Marsh (site LOX4) for long-term monitoring. Three largemouth bass were collected from each site for addition to an archive of whole fish being maintained for future use in contaminant studies. In addition, largemouth bass and sunfish were collected from the L-39 Canal near the southern end of the refuge and from the L-40 Canal near the refuge headquarters for analyses of mercury. These additional samples will be used to re-evaluate current fish consumption advisories in place for all waters of the refuge due to mercury contamination. No analyses of mercury in fish collected in 2003 have been completed at this time.

Decreases in mercury concentrations have occurred during the study in both largemouth bass and sunfish in the refuge. Standardized mercury concentrations (EHG3) in largemouth bass at L-7 have decreased 46% between 1995 and 2002 while they have decreased 32% at LOX4 (Marsh) between 1994 and 2001 (Figure 9). Data for 2002 from LOX4 are not reported due to the extremely small size of all specimens.

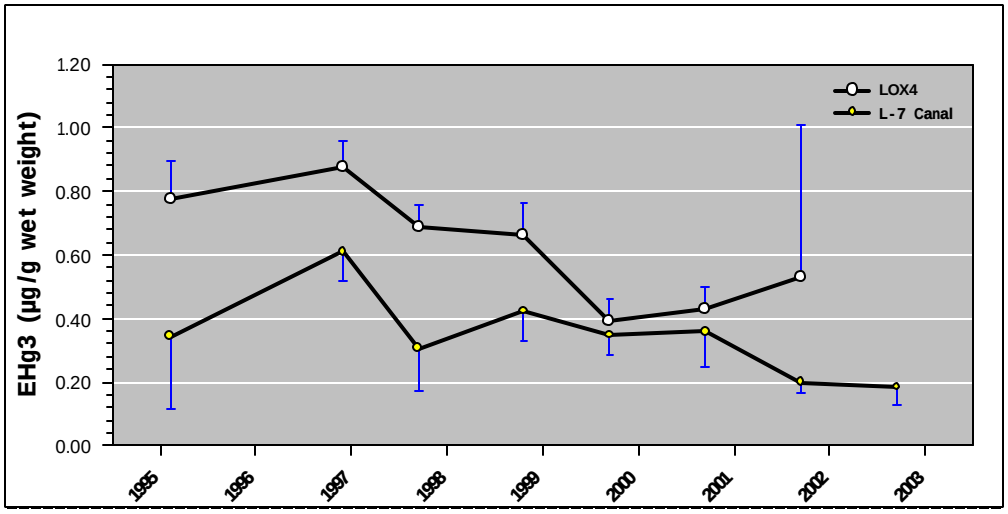

Figure 8. Standardized mercury concentrations (EHg3) in largemouth bass collected from refuge marsh site LOX4 and the L-7 Canal. The 95% confidence interval is shown. The mean THg concentration is shown for LOX4 in 2001 due to small numbers of fish collected.

Everglades Protection Area Monitoring

In 2003 the refuge continued implementing responsibilities in the research plan developed by the Everglades Technical Oversight Committee in 1992, as described in the project below.

Monitor water column total phosphorus concentrations at 14 marsh stations (and one canal site) within the refuge to ensure compliance with the terms of the settlement agreement (U.S.A. vs. South Florida Water Management District (SFWMD), et al. [Case No. 88-1886 CIV HOEVELER]).

15-Station Monitoring:

Objectives: To determine estimates and trends of mean total phosphorus concentrations throughout the A.R.M. Loxahatchee National Wildlife Refuge and monitor compliance with the terms of the Settlement Agreement under U.S.A. vs. SFWMD, et al. (Case No. 88-1886 CIV HOEVELER).

As in past years, refuge personnel continued to collect monthly water samples for the SFWMD in accordance with a contract with the District. Water samples are taken to estimate total phosphorus concentrations as well as a variety of other parameters at 14 fixed interior marsh stations and the S5A canal site. Sampling at the S-6 canal site was discontinued in 2001 because of water diversion into STA-2. Water quality sampling by the SFWMD still continues at the nearby S-10-E site. During 2003 the refuge also took replicate samples each quarter, for analysis at the SFWMD and Florida Department of Environmental Protection labs. See section F. Habitat Management for a summary of monitoring completed in 2003.

Phosphorus concentrations vary monthly because they are calculated as a function of water stage measured at gauging stations in the refuge. For the past year's record (June 2002-June 2003), only one exceedance occurred on the refuge, when the geometric mean concentration was 11.2 ppb total phosphorus. The interim and long-term level targets were 9.7 and 8.3 ppb, respectively.

The District also monitored two sites for sediment contaminants in June, 2003 (LOX8 and LOX10). These sites are located in the central interior and the western edge of the refuge, respectively. Both sites had detections of DDE and mercury which were above the threshold effects concentration but below the probable effects concentration. No adverse impacts are expected to occur as a result of these contaminant levels.

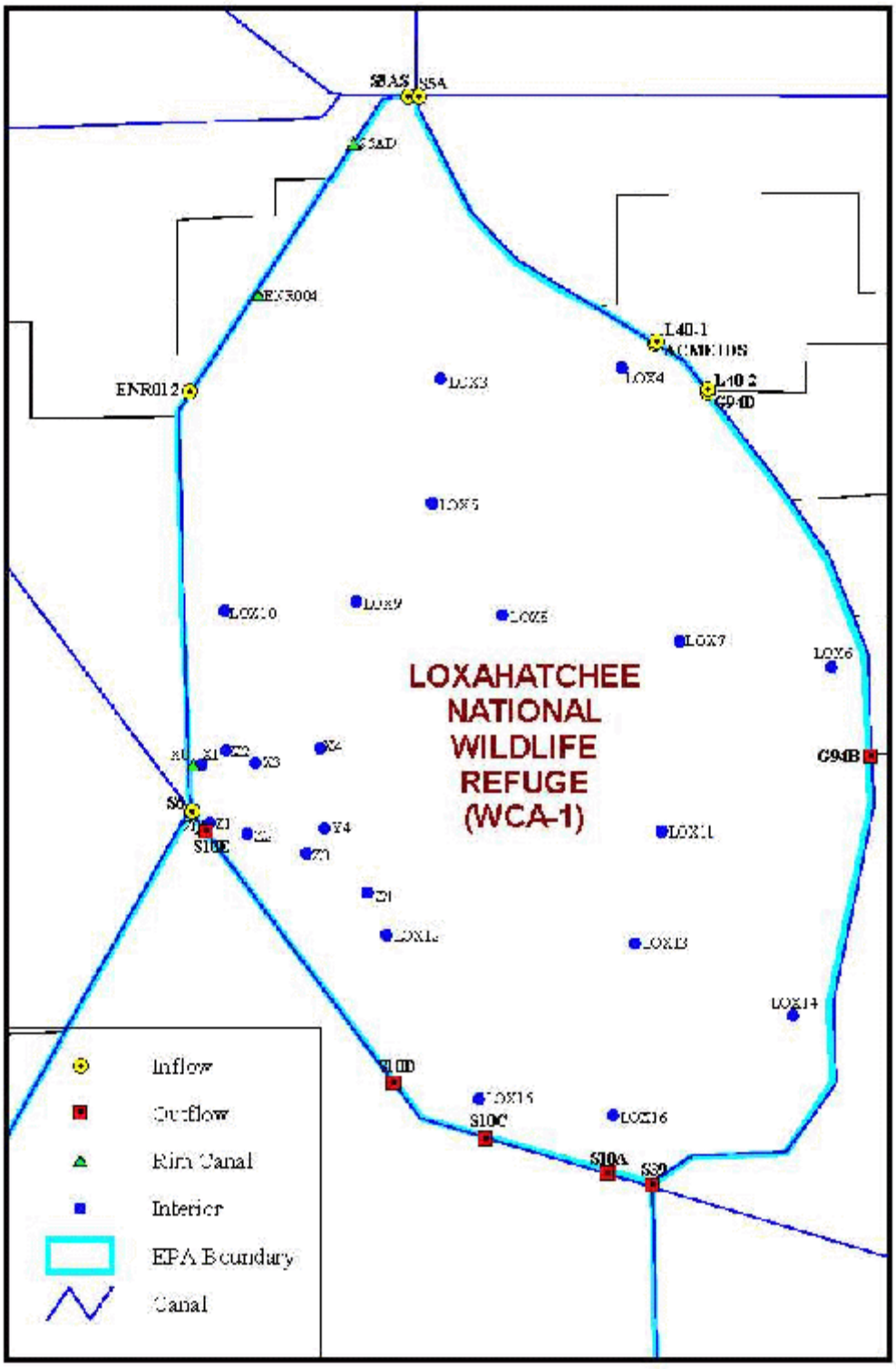

Figure 9. A.R.M. Loxahatchee NWR water quality sampling sites.

PROJECTS CONDUCTED BY SOUTH FLORIDA WATER MANAGEMENT DISTRICT (SFWMD)

The following projects were proposed or conducted by staff at the SFWMD. The following abstracts allow the reader to briefly review what has been done by the participating scientists. Full reports of the projects can be obtained by contacting the primary investigators or the refuge.

Everglades Soil Mapping

Principle investigator: Sue Newman

Objectives: Determine soil nutrient status throughout the Greater Everglades.

One hundred thirty-five soil cores were collected in the refuge from April 28-May 1, 2003. All core collection sites were accessed via helicopter to minimize impact to refuge resources At each site, where possible, three soil layers were collected; unconsolidated benthic matter, 0-10 cm and 10-20 cm soil depth increments. Triplicate soil cores were collected from 10 sites to assess site variability. Soil cores were collected using a thin-walled stainless-steel coring tube and sectioned in the field. Samples are currently stored on ice prior to completion of nutrient analyses at the University of Florida.

Monitoring White Ibis and Wood Stork Colonies

Principle investigators: Dale Gawlik and Gea Crozier

Objectives: The objective of this project is to gather information on the nesting status and water conditions of each White Ibis and Wood Stork colony in refuge.

Colonies with Wood Stork (an Endangered Species) and White Ibis (a Species of Special Concern) nests are monitored once a month during the nesting season (i.e., March - June) using aerial surveys. Surveys are conducted from a helicopter flying at an elevation of 300 - 400 ft, and the number of nests, stage of nesting, and water conditions around each colony are recorded. During 2003 we monitored three colonies in the refuge (Lox 70, N26 26.25, W80 14.581; Canal North, N26 33.585, W80 15.061; Lox 99, N26 26.35, W80 23.51). In Lox 70 and Canal North colonies, our maximum counts were approximately 3150 and 563 White Ibis nests, respectively. In the Lox 99, colony our maximum count was approximately 103 White Ibis nests. No Wood Stork nests were found in the refuge this year. Heavy rains during the nesting season caused considerable nest failure across the Everglades, and higher than normal nesting asynchrony was observed. This was likely the result of birds re-nesting after they abandoned due to water level reversals. The results of the colony surveys were reported on a monthly basis to South Florida Water Management District water managers and refuge biologists to keep them up to date on current conditions in the marsh and the progress of nesting colonies. These data provide timely information on nesting patterns (i.e., magnitude, location, timing) of Wood Stork and White Ibis which helps water managers make more informed water management decisions and set priorities for water management activities. These data will also help us to understand the impacts of various hydrologic conditions (i.e., heavy rain events, drought) on colony formation and abandonment. We plan to continue monitoring White Ibis and Wood Stork colonies in the refuge until the completion of the 2005 nesting season.

Appendix 2. Background and management issues from A.R.M. Loxahatchee NWR 2004-2009 Inventory, Monitoring, and Research Plan.

The following information is modified from the A.R.M. Loxahatchee NWR 2004-2009 Inventory, Monitoring, and Research Plan.

Refuge Background

The A.R.M. Loxahatchee National Wildlife Refuge, located in Palm Beach county, encompasses 143,924 acres of northern Everglades wetlands including sloughs, wet prairie, sawgrass, tree islands, impoundments, and cypress swamp. It was established under the Migratory Bird Conservation Act and the Fish and Wildlife Coordination Act in 1951. The refuge is unique in that the interior portion of the refuge, also known as Water Conservation Area 1 (WCA1), is managed through a license agreement between the U.S. Fish and Wildlife Service and the State of Florida and South Florida Water Management District. Water levels in WCA1 are regulated by a schedule designed to produce optimum benefits among competing interests (U.S. Army Corps of Engineers 1995). These interests are flood protection, water supply (agricultural, municipal, and industrial), fish and wildlife enhancement, prevention of saltwater intrusion, and water supply to WCA2 and WCA3 and Everglades National Park (ENP). Over 370 vertebrate species an unknown number of invertebrates and plants including at least 63 imperiled species occur on the refuge (USFWS 2000).

Refuge Management Areas

There are three major management areas on the refuge: the **refuge interior** (WCA1), the impoundments, and the cypress swamp (Figure 1). The refuge interior is 141,374 acres of Everglades marsh with thousands of tree islands. With the exception of the higher tree islands, most areas are inundated for at least part of the year. Sloughs and alligator holes are the deepest water areas, and except for very dry years, tend to hold water throughout the year. Wet prairies are shallower than sloughs, but also have an extended hydroperiod and generally hold water for all but one or two months of the year. Sawgrass stands are slightly drier than wet prairies and occur in three forms. Throughout most of the marsh, sawgrass occurs on elevated ridges or at the fringe of tree islands. In the western and southern portions of the refuge interior are very large expanses of sawgrass studded with pockets of wet prairie and slough; this is habitat more typical of the central Everglades. Tree islands are another major habitat type. These islands are generally 1- 3 feet higher than surrounding land elevations and are considered one of the signature features of the refuge. Tree islands play an important ecological role by providing habitat for a wide range of plant and animal species. As in other parts of the Everglades, invasive and exotic species have impacted refuge habitats. Cattails are the primary invasive species. As of 1990, approximately 6,000 acres in the southwestern portion of the refuge were cattails (Richardson et al. 1990). More current estimates do not exist; however, it is obvious that cattails are expanding (Childers et al. 2003). The four major exotic species that impact the refuge are *Melaleuca quinquenervia* (Paper bark tree), *Lygodium microphyllum* (Old World climbing fern), *Schinus terebinthifolius*, (Brazilian pepper), and *Causerina equisetifolia* (Austrailian pine). Melaleuca and Lygodium are the biggest threats impacting approximately 60% or 90,000 acres of the interior (Thomas 2001).

The **impoundments** consist of approximately 700 acres on the east side of the refuge. They are divided into a three compartments: A, B, and C. **Compartment A** consists of 350 acres of a mixture of cypress trees, willow, wax myrtle, sawgrass, cattail, and other wetland plants. **Compartment B** is 76 acres of primarily spatterdock, Eleocharis, and sawgrass, with

cattail and willow along the edges. Compartments A and B are located to the north of Lee Road and are rarely visited by the public.

Compartment C contains 276 acres of marsh divided into eleven individual impoundments consisting of a mosaic of native and exotic vegetation including sawgrass, Eleocharis, spatterdock, water lily, pickerelweed and Sagittaria, catttail, paragrass, and exotic grasses. C-6 and C-7 are the impoundments immediately adjacent to the marsh trail parking lot and receive the majority of the visitor use. C-3 and C-4 have recently been transformed into a South Florida Water Management District experimental site (Loxahatchee Impoundment Landscape Assessment- LILA, see Sklar et al. 2002) and will be managed with experimental flows for the next 10 years. The goals and objectives for managing the impoundments have been outlined in the Arthur R. Marshall Loxahatchee National Wildlife Refuge Habitat Management Plan for Compartments A, B, and C, the Cypress Swamp, and Strazzulla Marsh 2001-2005 (Bailey and Martin 2001) and are primarily focused on providing suitable natural habitat for wading birds, shorebirds, and other wetland species so the public can view and learn about Everglades wildlife.

The **cypress swamp** is 400 acres of primarily cypress forest on the very eastern edge of the refuge. Pond cypress is the dominant tree species with red maple, willow, and wax myrtle occurring occasionally. Brazilian pepper and Lygodium are the main exotic species that also occur in the swamp. More details on the characteristics and management objectives can be found in Bailey and Martin 2001.

The remaining land held in fee title is in 1,450 acres on the west side of the refuge called **Compartment D**. Currently no management occurs in this area.

The vision of the refuge as stated in the 2000 CCP (USFWS 2000) is:

> *"To serve as an outstanding showcase for ecosystem management that restores, protects and enhances a portion of the unique northern Everglades biological community. This public asset provides for the enjoyment and enhanced quality of life for present and future generations."*

One of the four goals for the refuge outlined in the CCP is to *"Restore and conserve the natural diversity, abundance, and ecological function of refuge flora and fauna."* The refuge faces four major challenges in meeting this goal:

1) loss of remaining natural areas adjacent to and in proximity to the refuge;
2) water quality;
3) water quantity (amount, duration, timing, distribution, and flow); and,
4) exotic species.

Loss of remaining natural areas

Loss of spatial extent of natural areas throughout South Florida is one of the major stressors on the Everglades ecosystem. Continued loss of habitats and conversion of agricultural areas on the east and west sides of the refuge to urban uses have the potential to impact the ecological integrity of the refuge. In the cases of wide-ranging species such as wading birds, waterfowl, and other migratory birds, habitat changes outside the refuge will influence what

species use the refuge. Results of surveys for these species must be reported with outside influences in mind. The refuge has little control over actions outside of its boundaries and must work with partners to increase the awareness of the impact of continued habitat loss on refuge resources. Though addressing the impacts of outside development on regional populations is outside the scope of what refuge staff can do, it is an important question that should be addressed so that patterns of species distribution and use on the refuge can be better understood.

Water quality

Water quality is a major issue in the refuge and throughout the Everglades. The Everglades is a naturally oligotrophic ecosystem with historic phosphorus levels in the range of 7-14 ppb and conductivity values of about 100 micro-siemens. Agricultural and urban development has resulted in inputs of high nutrient water with high dissolved solids (conductivity). Present water quality conditions in the refuge differ from historic conditions. In some areas, particularly near discharges, results from water quality sampling show higher values of conductivity, total dissolved solids, alkalinity, sulfate, unionized ammonia, and phosphorus then are found in the more interior, pristine sites (SFWMD 2002).

In 1988, the Federal Government filed a suit against the State of Florida charging that the State was violating water quality standards. The result was the requirement for the development of Stormwater Treatment Areas (STAs) and specification of interim and long-term concentration limits for phosphorus in the refuge and Everglades National Park (1991 Federal Settlement Agreement; Case No. 88-1886-CIV-HOEVELER). Interim limits have been in effect in the refuge since February 1999. Since February 1999 the interim limits have been exceeded eight times. The long-term limits that go into effect December 31, 2006 are more stringent than interim limits and there is concern that the number of exceedances will increase. To date, there is not a clear understanding of the causes of these exceedances and hypotheses for their occurrence range from natural variation to the movement of high phosphorus water from the canals into the interior.

The Arthur R. Marshall Loxahatchee National Wildlife Refuge Water Quality Monitoring Plan prepared in March 2003 (Arrington 2003) outlines four major areas of water quality concern on the refuge: phosphorus, conductivity, mercury, and pesticides. General issues or questions related to water quality include:

- What are the status and trends in water quality in the refuge interior, cypress swamp, and impoundments?
- What impacts do refuge management activities (exotic control, prescribed fire, impoundment management) have on water quality?
- What are the impacts of regional water management (regulation schedules, Stormwater Treatment Area operations, changes in water management related to the Comprehensive Everglades Restoration Plan) on refuge water quality?
- How will changes in water quality effect ecological resources in the refuge?

In March 2004, an Enhanced Water Quality Monitoring and Modeling Work Plan (Brandt et al. 2004) was developed that will address some of the issues related to patterns of water quality and impacts of water management.

Water quantity

Historically, the hydrologic patterns in the refuge were driven by rainfall (Parker et al. 1955). During most of the year, rain that fell directly on the refuge was the primary hydrologic input. In wetter periods inputs from upstream, such as overflows from Lake Okeechobee, also were important. In fact, it may well be that these events were as important in shaping the landscape as were the average conditions. Natural flows were generally south and east following the topography of the region. Hydrologic changes to the refuge and the rest of the Everglades started in the 1800s with the connection of Lake Okeechobee to the Calossahatchee River to the west. Additional canals and levees were constructed primarily for flood control and "reclamation" of the Everglades (Light and Dineen 1994). By 1917 four major canals (West Palm Beach, Hillsboro, North New River, and Miami) draining water from Lake Okeechobee to the east were in place and the dynamic sheet-flow from the lake to the refuge had been altered. Further hydrologic alterations occurred with the completion of the St. Lucie canal to the north in 1931. From 1952-1954 the eastern levee of the refuge (L-40) was constructed and by 1961 the entire refuge was bounded by canals. The result was impoundment of an area that historically had been a flow-through system. Water now enters the refuge from rainfall and via the surrounding canals and pools behind the dike in the south until it is released into Water Conservation Area 2A to the south through the S10s or for water supply through S39 or G94A, B, and C. The result is longer hydroperiods with deeper depth in the south and shorter hydroperiods with shallower depths in the north than occurred historically.

Water levels in WCA1 are regulated by the SFWMD and U.S. Army Corps of Engineers (COE) according to a recommended schedule to produce optimum benefits among competing interests. The purposes of the water management are flood control and water storage, water supply (agricultural, municipal, industrial), fish and wildlife enhancement, prevention of saltwater intrusion, and water supply to the other WCAs and to Everglades National Park (USFWS 2000). Under the current refuge regulation schedule, adopted in May of 1995, water levels are allowed to fluctuate between 14 feet and 17.5 feet m.s.l. (Figure 2). In theory, this schedule keeps the refuge from completely drying out every year with the exception of extreme drought years. Annual extreme dry outs can reduce fish populations (available prey), reduce apple snails and other invertebrates, provide additional areas for the germination of exotic plants, and increase fire risks which can accelerate the spread of exotic plants. There are a number of overarching questions relating to water management that will influence the long-term ability of the refuge to meet wildlife and habitat management goals. They include:

- How do hydrologic conditions affect key refuge resources such as tree islands, apple snails, aquatic fauna, alligators, and vegetation communities?
- Is the current water regulation schedule the optimal schedule for protecting refuge resources given current and future water management plans?
- What are the cumulative impacts of change in water flows (amounts and location) into the refuge?
- How will CERP projects and Stormwater Treatment Areas affect hydrologic conditions in the refuge, especially the northern interior?
- How will regional CERP projects affect the refuge water budget?

Exotics

More than 1,200 introduced plant species have become established in Florida and now comprise 31% of all plant species in the state. Approximately 225 of these introduced species are reproducing and invading natural areas. Currently, over 35 Category I or II exotic plants have been documented at the refuge (Thomas 2001). Four of these species, Melaleuca, Old World climbing fern (Lygodium), Brazilian pepper, and Australian pine are of particular concern and have the potential to seriously impact native habitats. Two species, Melaleuca and Lygodium cover more than 90,000 acres (60%) of the refuge. Both species pose a threat to native species and habitats on the refuge. Pure stands of Melaleuca, also known as heads, may become so dense that they are impenetrable to humans and wildlife. Dense heads may impede normal water flow due to sediment accumulation. Research has shown that Melaleuca causes higher water loss than native sawgrass due to increased evapotranspiration. Melaleuca affects a land manager's ability to use prescribed fire as a management tool. The volatile oils contained in the leaves of Melaleuca produce intense, uncontrollable fires and the massive seedfall resulting from fires allows the tree to become quickly established in adjacent areas, eventually out-competing and replacing native vegetation. In addition, dense Melaleuca provides poor wildlife habitat (Laroche 1994) and is only occasionally used for nesting and roosting by birds.

Lyogdium also has the potential to impact native plant and animal species. Research has shown that tree islands with dense infestations of Lygodium have different plant community composition than those without Lygodium (Brandt and Black 2000). In addition, Lygodium can affect wildlife by altering habitat and by creating physical hazards. Darby and Mackercher (2002) documented the "capture" and death of a deer by Lygodium. The refuge has an obligation, because of both the refuge purposes and the License Agreement with the South Florida Water Management District to address exotic species issues. Major questions and issues revolving around exotic species include:

- What are the impacts of exotic species on native habitats and wildlife?
- What are the best strategies and tools for controlling Melaleuca and Lygodium?
- How do we keep other exotics from becoming established?
- What impacts do exotic control efforts have on refuge resources?
- How can maintenance control be achieved by 2017?

In the face of the above challenges the refuge is responsible for managing for "Wildlife First". Service policy dictates that refuges will:

1. Collect baseline information on plants, fish and wildlife;
2. Monitor, as resources permit, critical parameters and trends of selected species and species groups on and around Service units; and,
3. Base management on biologically and statistically sound data derived from such inventory and monitoring.

Overarching questions that relate to this responsibility include:

- What habitat management techniques (fire, mechanical manipulation, water level

manipulation) should we use where and when to improve refuge habitats?
- What impacts do our management actions have on target and non target habitats and species?
- How do we maintain habitats and populations in response to above challenges?

The overarching management questions, along with examination of species or groups of species of critical importance to the refuge, can be used to guide inventory, monitoring, and research efforts. Sections I-IV below, generally follow the format outlined in the Refuge Manual (section 701 exhibit 2, Appendix 1) for organizing surveys. Generally this requires identifying the status of species lists, identifying species, habitats, and issues to be considered for study, determining the relative importance of these groups for accomplishing refuge goals, determining the type of survey needed, identifying high priority research areas, and determining if refuge staff should/can conduct the survey.

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Specific questions related to areas needing research at the A.R.M. Loxahatchee National Wildlife Refuge. The questions relate back to the general questions and issues presented in the background section.

High priority- Tier 1 projects with research areas

Alligator

What effects do different water regimes have on nest density, nest success, and condition?
How are alligators affected by changes in water quantity and quality?
What is the importance of alligator holes to the functionality of the marsh interior e.g., what wildlife species are found in or utilize refuge alligator holes?
What is the importance of alligator holes during the spring wading bird breeding season, and what species are dependent upon them?
What impact does hunting, if implemented, have on refuge alligator populations?

Effectiveness of management actions - Exotic control

What combinations of treatments work most effectively to control Lygodium and Melaluca without damaging native vegetation and wildlife?

What herbicide, or combination of herbicides provide the best Lygodium control?
What treatment technique, aerial or ground, or combination thereof provides the best

option for Lygodium management?
Is there a difference in treatment effectiveness for Lygodium using different application methods on different types of tree islands e.g., strand or bayhead?
Are spray treatments or biocontrols more effective for long-term control of exotics on the refuge?
How much Melaleuca regeneration is occurring in treated Melaleuca stands?
How effective are biocontrols released on the refuge?

How do Lygodium and Melaleuca respond to prescribed and wildfires?
Does fire increase vulnerability of exotic plants to biocontrols?
What detrimental impacts will future exotic treatments have on Spike ray fern populations on the refuge?

Effects of STA1E on canal sediments

At what discharge rates do sediments in the canal become suspended?
What affect does the suspension of additional sediment have on canal water quality (particularly phosphorus, conductivity, and toxins) and aquatic wildlife?
Are suspended sediments in the canal transported into the interior marsh or down the canal?
How far into the interior marsh will impacts from canal water be observed?

Effects of STA1E on interior habitats

How will discharges from STA1E change water flows and nutrient inputs into the refuge interior?
What changes will occur in phosphorus and conductivity levels in the adjacent marsh as a result of a fully functional STA1E?
Will discharges contribute to additional influx of, or establishment of aquatic invasive exotic plants such as hydrilla and cattail?
What changes will occur to refuge habitats, aquatic species, and micro topography as a result of the implementation of STA1E?
How can negative impacts of STA1E operations be minimized?
What impacts does an operation STA1E have on refuge waterfowl populations (are waterfowl using the STA instead of the refuge)?

Monitor hydrologic conditions

What is the distribution of water depths in the interior at various stages?
How much water intrudes into the interior from the canal at different stages?
What are the current flow patterns that result from rainfall and water management?
How will these flows change with implementation of STA1E and other changes in water management?
How do seasonal hydrologic fluctuations contribute to the establishment of invasive exotic plants such as Lygodium?
How do seasonal hydrologic fluctuations impact refuge wildlife (alligators, tree islands, apple snails, periphyton)?

Phosphorus patterns

What are the current distribution patterns of phosphorus in the refuge?
Where does phosphorus move into the interior of the refuge?
What water management conditions maximize and minimize phosphorus impacts on the refuge interior?
How are refuge habitats and wildlife affected by current patterns of phosphorus?
How will phosphorus patterns change with implementation of STA1E and other changes to water management?
How will prescribed fire impact phosphorus patterns in the refuge?

Spike ray fern (*Schizaea pennula*)

What is the current distribution of Spike ray fern in the refuge?
What are the habitat requirements of Spike ray fern?
What effect does current water management have on survival, establishment, etc. of Spike ray fern?
How is Spike ray fern affected by Lygodium infestation?
What detrimental impacts will future exotic treatments have on Spike ray fern populations on the refuge?

Tree island

What are the characteristics of a "healthy" tree island?
How can the condition/health of tree islands be efficiently monitored?
What is the current condition of tree islands throughout the refuge?
What are the effects of extended wet cycles on tree island health?
What tree species will thrive on tree islands under prolonged flooding conditions?
What water regime (hydroperiod, depth, timing) is most appropriate for tree island growth/maintenance?
Will water regimes appropriate for tree islands also support other critical refuge habitats and wildlife?
Given the current hydrology of the refuge, what will be the impact on the condition of tree islands over the next 50 years?
What is the biological diversity of strand versus bayhead tree islands, and are hydrologic changes affecting each in a different way?

Apple snail

What is the distribution and abundance of apple snails throughout the refuge?
How do hydrologic and water quality conditions affect apple snail reproduction and populations in the interior?
What management activities in the impoundments will increase apple snail abundance?
Are apple snails an important part of the food base for refuge wildlife?
Are apple snail populations being affected by any current management practices (exotic control,

prescribed fire, etc.)?

Cattail distribution

What is the current distribution of cattail in the interior?
How has the distribution of cattail changed over the last 50 years and how are the changes linked to water quality and quantity?
What is the potential distribution of cattail given current water quality and water management (e.g., where will it spread)?
How will future cattail distribution impact native habitats and recreational opportunities (waterfowl hunting and fishing)?
What species of birds use dense cattail as compared to adjacent native habitats?
What influence does cattail have on preventing further water intrusion into the canal interior?
Will cattails increase adjacent to STA1E discharges?

Periphyton community composition

How does the periphyton community differ across the refuge interior?
Are differences in periphyton communities related to hydrologic conditions, phosphorus gradients, conductivity, or other factors?
What is the importance of periphyton as it relates to overall refuge food chain?
How does phosphorus impact refuge periphyton populations?
How does the current water regulation schedule impact refuge periphyton populations?
How has the periphyton community changed from historic composition?

High priority-Tier 2 projects with research areas

Effectiveness of management actions-Fire

How are refuge habitats and wildlife affected by prescribed burns?
Does reintroduction of prescribed fire in the refuge interior improve conditions for refuge wildlife such as waterfowl or wading birds, i.e., is there an increase/decrease in wildlife use within a burned area?
Is prescribed fire contributing to the establishment of invasive exotic plants such as Lygodium or contributing, through phosphorus release, to the establishment/spread of cattail in the marsh interior?
Is fire an effective tool for managing exotic vegetation?

- How does fire impact exotic vegetation vulnerability to biocontrols ?
- How does fire impact biocontrols?
- Can prescribed fire be used as a management technique to control Lygodium on bayheads without herbicide treatments?

Can prescribed fire be used to restore the ecological integrity of tree islands following herbicide treatments to control invasive exotic plants?
Is prescribed fire effective at reducing dead Lygodium biomass without killing native trees?

Marsh vegetation community composition

What is the current status of the marsh vegetation community composition?
What are the expected long-term changes given current and planned future water management practices?
How is marsh vegetation community composition changing as a result of hydrology, invasive plants, lack of fire, wildfires, etc.?

Appendix 3. Background for water management session. Biological indicators and Water management poster.

3/2/01
Prepared by: Laura.A. Brandt, Senior Wildlife Biologist, A.R.M. Loxahatchee NWR

Key features used to evaluate appropriateness of water levels in the A.R.M. Loxahatchee NWR

Natural hydropatterns- South Florida has distinctive wet (June-November) and dry (December-May) seasons. Historically, water levels in the Everglades fluctuated in response to the amount of rainfall during these seasons. Water levels were generally highest at the end of the wet season, beginning of the dry season and receded slowly throughout the dry season. Many of the plants and animals in the Everglades are adapted to this pattern and have reproductive cycles that are linked to the natural hydrologic patterns. In general, the water levels in the refuge should mimic this pattern as much as possible, with unnatural high or low water events kept to a minimum. The current regulation schedule provides a guide for maintaining this natural pattern (see attached copy of the schedule). Water levels in the refuge are maintained between 4.4 and 5.4 m (14 and 17.5 ft NGVD) depending on the time of year. Decisions on appropriate management for wildlife and habitats are then based on attributes of key species (see below).

Maximum and minimum water levels (effects of high and low water)- High and low water events occurred naturally throughout south Florida and were historically tied to rainfall patterns. In many areas water management practices have decoupled extreme highs and lows (flood and drought) events from the natural cycles. Droughts may have naturally occurred on a 10-14 year cycle. Marsh dry out and flooding on a natural cycle are not necessarily bad, and probably need to occur for a healthy ecosystem; however, effects of dry out (associated with natural cycles of rainfall or water management) include mortality of aquatic fauna, increased fire risk, and an increased potential for spread of exotics such as melaleuca and lygodium. Effects of flooding include mortality of terrestrial vertebrates, vegetation mortality, especially low or moderately flood tolerant species found on tree islands, changes in tree island structure, and potentially an increased potential for colonization of exotics (lygodium) due to tree stress. Extended flooding of tree islands will result in loss of vegetation, and ultimately loss of the island itself as has been observed in areas adjacent to the canals where water levels are 0.6 to 0.9 m (2 to 3 ft above what they were historically. The biggest questions regarding minimum and maximum water levels are how much for how long and at what frequency is “good” or “bad”.

Apple snails- Apple snails are the primary food source for the endangered snail kite and can make up 75% of the diet of limpkins. In addition, they provide food for wading birds, alligators, turtles and other wildlife. The life cycle of the snail is highly adapted to seasonal hydrologic conditions. Eggs are laid between March and October with the peak of laying between April and June. If water levels during this time period drop below 10 cm (3.9 in) reproductive output decreases as snails stop moving around to mate and lay eggs. Egg clusters are laid between 0 and 1 m (0 to 38 in) above the water level with a

mean of 0.2 m (9.1 in) and a median of 0.15 m (6 in) (Perry 19??) or approximately 0.1-0.25 m (3.9 to 9.8 in) above the surface (Turner 1996). Submersion of egg clusters during their 16-22 day incubation delays their development and increases mortality. To maximize apple snail reproduction, marsh water levels during the April to June period should not decrease to < 10 cm (3.9 inches) or increase greater than 0.13 m (5 in) over a 16 day period. This will provide conditions suitable for mating and egg laying and will avoid snail egg mortality.

Dry downs also can affect apple snail populations through direct mortality (any time of the year) and decreased reproduction (March-October). During dry downs snails will not mate, so no young will be produced that year. Water levels below 10 cm (3.9 in) during peak mating and egg laying (April-June) will result in decreased snail abundance in the following year. Hatchling snails will die after 2 weeks of dry down. Larger snails are more resistant to dry periods; however, extended periods with little or no water post hatching (particularly May through August) will increase mortality of the smaller size classes resulting in decreased numbers the following years. Unnatural extended dry seasons should be avoided.

Alligators- Alligators construct their nests at the end of June, beginning of July with hatching occurring in August and September. The height of the clutch cavity in an alligator's nest is correlated with the water levels during nesting. Lower water levels in June and July will result in lower clutch cavities, that could be more susceptible to flooding. Average height of clutches above ground was 25 cm (9.8 in) and above water 37 cm (14.6 in) during 1999, which was a wet June. This is similar to averages observed elsewhere. If water levels between July and September rise >25 cm (9.8 in) above average water levels at the end of June alligator nests may be flooded, particularly those along the canals.

Alligators concentrate in areas with water during the dry season. This may be in alligator holes or in canals. Extreme concentrations promote aggressive interactions between alligators and often result in the death of smaller/weaker individuals. If suitable sources of water (gator holes or canals) are not available alligators overheat and die. Mortality also may occur in canals as a result of collisions with boats.

Wading Birds- Wading birds nest January through May and respond to changes in water levels during this time period by following the "drying front" where prey items are concentrated. Too rapid drying over large areas will reduce the availability of prey and will limit the areas where birds will nest (nest sites must have suitable foraging sites within the distance that it is energetically feasible for the birds to obtain enough food for their young). Deeper water at the beginning of the dry season may delay nest initiation. Generally, water levels < 10 cm are good for foraging. If drying rates drop below 0.2 cm/day (0.08 in), 3 cm (1.18 in) over a two week period, wading birds frequently abandon their nests. Birds also may abandon nests when water level reversals of >3 cm (1.18 in) occur. Reversals in water levels, artificially reducing the drying rate during the

nesting period (January-May), or artificially increasing water levels prior to May 15 are undesirable.

Tree Islands- Tree islands are the only high ground in the wetland matrix within the interior of the refuge. As such, they provide habitat including foraging, nesting, and resting sites for terrestrial and semi terrestrial wildlife. The suitability of the habitat for a given species will depend on the island size, elevation, and plant community structure and composition. Plant community structure will depend in part on the local hydrologic conditions. Higher or drier sites will support species that are less flood tolerant than sites that are flooded. Many of the islands in the interior are bayhead islands which are made up of moderately flood tolerant species such as dahoon holly, willow, wax myrtle, and cocco plum. Higher elevation islands also support red bay a slightly less tolerant species Exact flood tolerances of tree islands and associated species is unknown, however, if the islands are inundated for more than 4-6 weeks during a season it is suspected that trees will be stressed. Therefore, we try to minimize the amount of time islands are flooded. Flooding of tree islands in the central portion of the interior of the refuge is known to occur. Preliminary examination of data from 1997 and 1999 indicate that when the 1-7 and 1-8 gauges were above 5.2 m (17 ft) tree islands as far north as 26 33 had some standing water. Tree islands further south flooded earlier, deeper, and were flooded longer. Studies are currently underway to better understand the relationship between tree islands and water levels. Based on the above observations, extended periods where all gauges were above 5.2 m (17 ft) would be undesirable. Additionally, extended periods of dry outs are undesirable as they allow the colonization of shrubby vegetation along the margins of tree islands, and make the islands more susceptible to fire. Fires in the north portion of the refuge during 1989 killed many trees on both strand islands and bayheads. In addition, many of these islands are now blanketed with lygodium.

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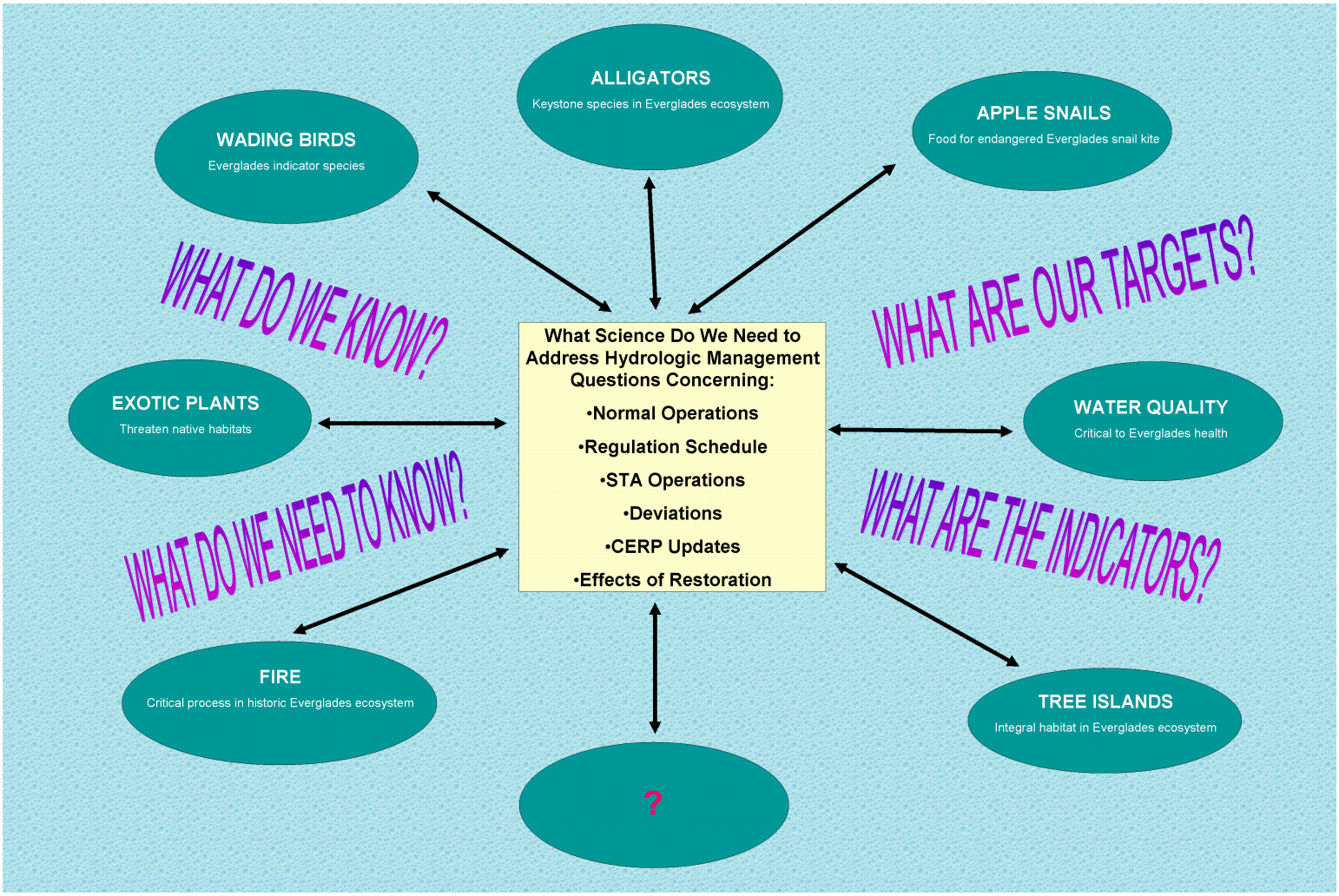
	Why important	Critical time of year	Undesired conditions
Apple snails	Apple snails are the primary food source for the endangered snail kite. They also are fed on by a number of other wildlife.	March-October. Especially April-June.	Rapid changes in water level that result in flooding of eggs (increase of > 0.13 m (5 in) in a 16 day period) or leaving young stranded. Too dry conditions during mating (water level <10 cm (3.9 in). Extended dryouts particularly May through August)..
Wading birds	Indicator of "healthy" Everglades.	January-May	Deep water at the beginning of nesting. Reduced drying rates (< 3 cm/14 days), reversals in water levels of greater than 3 cm, or increases in water levels prior to 15 May. Early extreme dryouts that can result in a decrease in prey base.
Alligators	Alligators are a keystone species in the Everglades. They contribute to the landscape mosaic by maintaining alligator holes that retain water in the dry season and create "high ground" by constructing nests.	May-September	Rapid rise or lowering of water levels during incubation. The height of the clutch in an alligator's nest is correlated with average water levels at the end of June. An increase in water level of >25 cm (9.8 in) in July-September may flood nests. Dry conditions in April and May may reduce reproduction by making it more difficult for males to locate and mate with

			females. Extended dry conditions that cause alligators to become concentrated in high densities, or conditions that dry out alligator holes.
Tree islands	Provide high ground in an otherwise wetland mosaic. Provide habitat heterogeneity used by many plants and animals.	All year	Conditions that would promote tree island flooding. Extended periods when interior gauges are above 5.2 m (17 ft) Conditions that would dry out islands allowing establishment of shrubby vegetation and exotics and increase the potential for fire.


ALLIGATORS
Keystone species in Everglades ecosystem
WADING BIRDS
Everglades indicator species
APPLE SNAILS
Food for endangered Everglades snail kite
WHAT DO WE KNOW?
WHAT ARE OUR TARGETS?
What Science Do We Need to Address Hydrologic Management Questions Concerning:
•Normal Operations
•Regulation Schedule
•STA Operations
•Deviations
•CERP Updates
•Effects of Restoration
EXOTIC PLANTS
Threaten native habitats
WATER QUALITY
Critical to Everglades health
WHAT DO WE NEED TO KNOW?
WHAT ARE THE INDICATORS?
FIRE
Critical process in historic Everglades ecosystem
TREE ISLANDS
Integral habitat in Everglades ecosystem
?

Appendix 4. Background for Lygodium session. A.R.M. Loxahatchee NWR Lygodium management and Lygodium maintenance control diagram.

A.R.M. Loxahatchee NWR Lygodium Management

Background and Authority

Over 1,200 introduced plant species, 31% of all plant species documented in Florida, have become established in Florida. Approximately 225 of these species are successfully reproducing and invading natural areas. The introduction of invasive exotic plants is the second greatest threat to biodiversity next to habitat destruction. Over $90 million per year is spent in Florida by local, state, and federal agencies to control invasive exotic plants.

Management of invasive pest plants is one of the priorities established by the South Florida Ecosystem Restoration Task Force (SFERTF). The Everglades Forever Act of 1994 requires the South Florida Water Management District (SFWMD) to establish a program to coordinate with other state, local, and federal government entities to manage exotic pest plants with emphasis in the Everglades Protection Area.

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (refuge) Comprehensive Conservation Plan identifies invasive pest plant management as the highest priority and proposes that populations of several of the more aggressive Category I exotic pest plants be reduced to "maintenance control" levels within the next fifteen years (2015). In addition, reduction of exotics to maintenance control by 2017 is a performance measure agreed to by the SFWMD and the refuge in conjunction with the signing of the refuge License Agreement in 2002. Melaleuca and Lygodium (Old World climbing fern) are the two invasive exotics that cover over 90,000 acres (60%) of the refuge. Lygodium alone covers approximately 15%, nearly 25,000 acres, of the refuge. Research on the biology and control technologies have been under development for at least 10 years for Melaleuca. Because Lygodium is a fairly recent invader much less is known about its biology and methods of control.

Lygodium also poses a threat to threatened and endangered species in the refuge, to native plant communities, and to the South Florida ecosystem. Long-term restoration and management of the refuge and the entire Everglades Ecosystem will depend on our ability to successfully achieve maintenance control levels of this and other exotic pest plants. Lygodium is one of the species that the Noxious and Exotic Weed Task Team (NEWTT), established by the SFERTF, has prioritized as one whose management and control is considered critical in the short term for Everglades restoration.

It is critical that the information needed to maximize control efforts be developed in the next five years before Lygodium impacts significantly more acreage on the refuge, thus increasing the ultimate cost of control both on the refuge and throughout south Florida. Spread models for Lygodium show that within 10 years it will be in every habitat in south Florida (Volin, unpublished data).

Management Questions

Question 1. What is Maintenance Control?

Question 2. How do we know we have achieved maintenance control?

Question 3. How do we prevent the spread and reduce the current distribution of Lygodium?

What is Known

Questions 1 and 2 are linked. We will not be able to determine when we have reached maintenance control until we can quantify and then assess what 'maintenance control' is. Florida legislation defines 'maintenance control' (ss.369.22(1)(d),F.S.) as "applying management techniques on a continuous basis to keep non-indigenous plant populations at the lowest feasible levels. Under maintenance control there is a reduction in: navigation restrictions, irrigation and flooding problems, sedimentation and lake aging, management costs, competition with native plants, loss of fish and wildlife habitat, and use of herbicides". However, until 'maintenance control' is adequately quantified we will only have a subjective standard by which to measure whether we have achieved it.

The Florida Exotic Pest Plant Council Lygodium Task Force has prepared a Lygodium Management Plan for Florida (Ferriter 2001) that discusses our current and rather limited knowledge about the species and summarizes strategies and needs for future management. Efforts have been underway since 1993 to map the distribution of Lygodium within the South Florida Water Management District via aerial surveys. Identification of dense concentrations and outlier populations is a first step in developing a treatment strategy.

Initial research efforts on methods using fire and herbicides to control Lygodium have been conducted by Roberts and Richardson 1994, Stocker et al. (1997), Stocker (in review) and Timmer and Vandiver (unpublished). In addition, the South Florida Water Management District has conducted aerial applications of herbicides in Dupuis Reserve (Ferriter 2001) and the refuge (Brandt and Mazzotti 2003). Effectiveness of these treatments as well as non-target effects is currently being evaluated.

The South Florida Water Management District and USDA-ARS are conducting limited biological control research to develop possible biological control agents. However, this program is not adequately funded and physical control elements of a management program are needed while biological control agents are being developed to prevent Lygodium from invading large areas of south Florida. Because of the nature and rate of spread of Lygodium some experts think that biological control will be the only long term effective management tool.

Little is know about the ecological requirements of Lygodium in Florida. Lygodium is documented to grow in both wetland and upland habitats and reproduces throughout the year. Research on reproductive ecology of Lygodium is being conducted by Dr. John Volin at Florida Atlantic University in order to better understand possible weaknesses in its life cycle to help determine more effective control approaches.

Efforts are currently underway to integrate what we do know about Lygodium at the refuge, control technologies, and costs into a decision tool that the refuge manager will be able to use to

evaluate alternative control strategies and optimize the use of existing resources for Lygodium management. (Duke-Sylvester et al. Unpublished abstract).

What is Needed

Quantitative definitions of "ecologically acceptable" will be required in order to establish measurable targets for maintenance control. Ecologically acceptable levels can be determined through field studies. Research shows for example, that in tree islands with almost 100% cover of Lygodium there is a significant reduction in the abundance of native plant species (Brandt and Black, 2001). Determining what percent cover of Lygodium begins to alter the flora and fauna will help quantify management targets and prioritize control efforts.

Developing effective control methods and approaches for Lygodium control will require continued partnerships among agencies and universities. Efforts to develop biological control methods need to have increased priority and funding. Additional work is needed to identify the most cost effective and ecologically beneficial chemical and physical control treatment for Lygodium in refuge habitats. Ongoing studies of the effectiveness of various control methods should continue while biological control programs are in the development phase. A better understanding of weaknesses in the life cycle of Lygodium, and factors that inhibit Lygodium growth may enhance our ability to effectively control this species.

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How do we achieve maintenance control of Lygodium by 2017?

1a). What is maintenance control? (*Reduction of pest plant populations to an economically or ecologically acceptable level*)

1b). How do we know we have achieved maintenance control?

2a). How do we prevent the spread of Lygodium?

2b). How do we reduce the distribution and populations of Lygodium?

What is economically acceptable?

What is ecologically acceptable?

3a). Where do we treat?

3b). What are the appropriate methods for treatment?

3c). When do we treat/retreat? (Season and now vs. later)

How do we achieve maintenance control of Lygodium by 2017?

1a). What is maintenance control? (*Reduction of pest plant populations to an economically or ecologically acceptable level*)

1b). How do we know we have achieved maintenance control?

What is economically acceptable?

What is ecologically acceptable? (*Levels that do not alter the natural structure and function of the habitat*)

Reduction to levels that no longer cause “harmful impacts”

How do we know we have reduced Lygodium to target levels?

What is the natural structure of the habitat?

What is the natural function of the habitat? (*What species use the habitat and how*)

• Studies of vegetation composition and structure

•Studies of key wildlife occurrence and use

•Effective detection methods (see recent “Detection Workshop”)

How much Lygodium causes ecologically harmful impacts?

•Studies in areas of different levels of invasion
- •vegetation composition and structure
- •key wildlife occurrence and use

•Synthesis of data and determination of “harmful impacts”

How do we achieve maintenance control of Lygodium by 2017?

2a). How do we prevent the spread of Lygodium?

2b). How do we reduce the distribution and populations of Lygodium?

3a). Where do we treat?

4a). What is the current distribution of Lygodium?

4b). Where is it likely to spread?

What is Lygodium's colonization potential?

Where are there potential colonization sites?

•Effective detection methods (see recent "Detection Workshop")

•Studies on life history characteristics including
- •dispersal ability
- •germination
- •survival and growth
- •suitable habitat
  - •substrate, habitat, hydrology

•Effective vegetation and habitat mapping at appropriate scale
•Hydrologic modeling at appropriate scale

•Integration and synthesis of basic life history, vegetation, hydrology, and other data layers to assess risk (Decision Support Tools)

How do we achieve maintenance control of Lygodium by 2017?

2a). How do we prevent the spread of Lygodium?

2b). How do we reduce the distribution and populations of Lygodium?

3b). What are the appropriate methods for treatment?

3c). When do we treat/retreat? (Season and now vs. later)

4c). What treatment methods are available?

4d). What methods are most effective?

4e). What treatment methods are most efficient?

When are we least likely to increase risk of spread?

- Comparative studies of aerial and ground treatments
- Comparative studies of different herbicides
- Development and testing of biocontrols
- Studies on the use of other potential control methods including fire

- Studies on timing of reproduction
- Studies on contribution of different life stages to risk of spread

- Integration and synthesis of basic life history, vegetation, hydrology, risk, effectiveness and efficiency of control methods (Decision Support Tools)

Appendix 5. List of pre-registered attendees

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Appendix 6. Summary of evaluation forms

Like Best of W/S	
	*Good Communication
	*Idea exchange with other professionals
	*Plenary/Posters
	*Intro/Plenary; Posters; and Topic breakouts
	*Exchange of ideas and information. Meeting various research people
	*Poster sessions - mixing
	*Interactions with others/Information transfer
	*Lygoduim breakout
	*Breakout and Poster review
	*Interactions between people, very clear and productive
	*Exchange of scientific data
	*Poster session
	*Poster session, talking and interacting with peers
	*Networking
	*Topic breakouts
	*Contacts/interactive discussion
	*Opportunity to meet and discuss issue with others
	*Exposure to the variety of research areas of various agencies
	*Open and lightly guided exchange of information
	*A gathering of the minds, yielding a synthesis of work and questions
	*The opportunity to discuss science and management issues with a diverse group
	*Discussions
	*Talking to people about what they were doing
	*Networking with other researchers
	*Very interactive
	*Poster session
	*Specific breakouts and synthesis
Like Least of W/S	
	*Hard to determine exact good to which FWS see from refuge
	More Birds? Preserve northern Everglades ecosystem?
	*Plenary
	*General breakout
	*General breakout
	*General breakout less productive than anticipated
	*Discussion limited to one day
	*Lack of direction and background for topic breakouts
	*General breakout
	*More focus on discussion points would have helped
	*General breakout was least useful, but the "who's working on what" part was informative
	*Redundant breakout groups
	*General breakout
What would you do differently?	
	*Drop general breakout, emphasize specific breakouts
	*have only one breakout per topic, shorten these, and then allow time for each group to
	present results for audience to add to these. Write down the final results as the
	synthesis
	*Extra background on Loxahatchee management goals and constraints, also legal
	mandates
	*Offer a chance for short oral presentations of results from previous year's research.

	"What we know"						
	*Focus of general **NOT** what's missing but						
	Ask questions if will answer to study of change management?						
	*Make it a two-day workshop to allow additional time for further exchange of ideas						
	*Frame more questions from "If my manager calls me on the phone, what will his/her						
	questions be_____"than, "What would be interesting to know issues"						
	*Have 2-3 keynote presentations!, Eliminate general breakout session						
	*Shorter plenary session, longer breakouts on topics						
	*Develop a conceptual model and the model to define what's missing						
	*Make it longer 1 1/2 day						
	*Having a time limit on reporting from each breakout group, have copies of all main						
	main points from breakout sessions e-mailed to all participants						
	*Somewhat more clarity on what breakout groups needed to do						
	*Bagels/Pastries. Also it would be interesting to know how the organizer concretely						
	use the results of this meeting what is the follow-up?						
	*Stimulate more one-on-one interaction with people of different agencies/universities to						
	understand organizational issues and constraints						
	*Diagram of poster placement rather than the preview session						
	*Give read ahead materials further in advance						
	*A better understanding of what the LWLR manages for. What does it see as the most						
	importance: animals; plants						