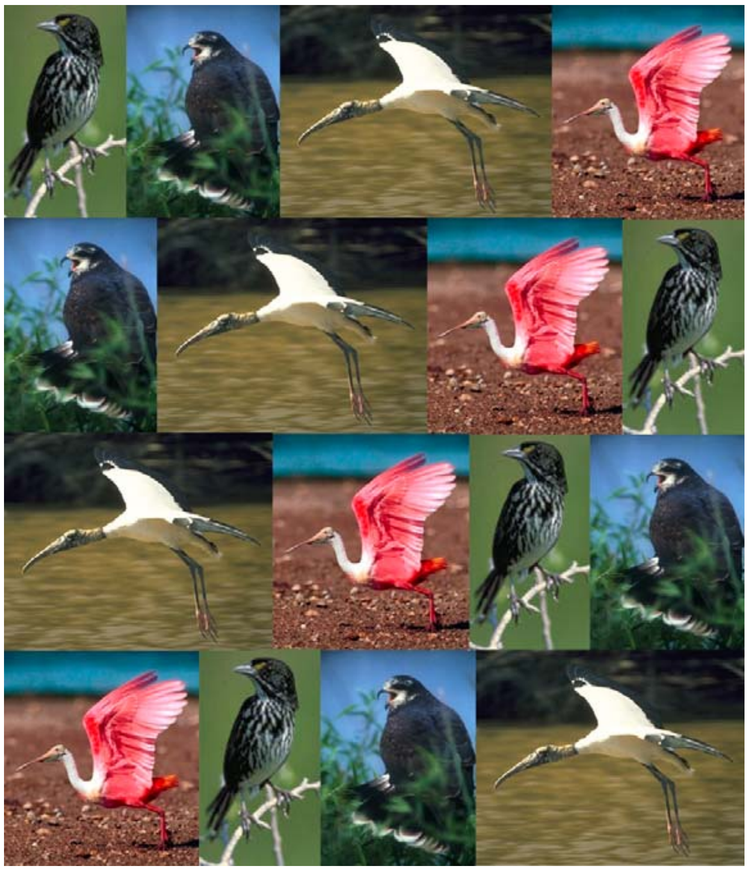
Sustainable Ecosystems Institute

Everglades Multi-Species Avian Ecology And Restoration Review

Final Report



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Everglades Multi-Species Avian Ecology And Restoration Review Final Report, November 2007

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NOTE: Copies of the scientific presentations, digital voice recordings and forum summary are available from SEI. A DVD copy of the webcast is available through South Florida Ecosystem Restoration Task Force.

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TABLE OF CONTENTS

1. INTRODUCTION

In August 2007, Sustainable Ecosystems Institute (SEI) convened an avian/ecosystem review group to address the ecology and management of federally listed endangered Cape Sable Seaside Sparrow, Everglades Snail Kite, and Wood Stork, and the state listed Roseate Spoonbill, particularly in relation to Everglades restoration. The effort was in response to a request from US Fish and Wildlife Service (USFWS) and sanctioned by the South Florida Ecosystem Restoration Task Force. This independent scientific review built on a previous Avian Ecology Workshop, held in March 2003 (SEI 2003).

The review and workshop format was based on the SEI process. This is an open and transparent science review method pioneered by SEI in order to help managers use the best science available when making critical decisions for species, their habitats, and entire ecosystems. The process has been used to resolve critical and controversial science based issues regarding endangered species, and the restoration and management of ecosystems.

The hallmarks of this method are

1. The Institute assembles a panel of scientists who collectively have the breadth of expertise necessary to address the issues at hand. The panel is specifically charged with addressing the underlying science and not to make policy.
2. SEI gathers relevant materials and engages with stakeholders to identify the critical issues and questions.
3. SEI believes that an open and public deliberation of science helps others to understand the scientific process. This is especially true when issues are controversial and complex. SEI convenes a public science forum. At that meeting, the panel listens to the presentation on available science, deliberates and debates the science, and subsequently issues its findings and conclusions. This open process allows all stakeholders to participate in the scientific process, to understand why certain conclusions have been reached, and to have a greater understanding of the quality and certainty around the current science. Meetings are facilitated by a scientific translator. Further details can be found on the SEI website or by contacting SEI.

PANEL CHARGE AND INTERPRETING FINDINGS

The goal of the workshop was to review new information gathered on the four species of concern and to provide scientific clarity that would allow managers to move forward with restoration. The overall charge to SEI and the panel was to review the scientific information of the four species of concern in a multi-species framework with respect to restoration (See Table 1). Thus, the science is viewed in light of natural processes, the current state of the ecosystem (resulting from natural events and human actions), and in the context of the steps that will be taken to restore a more natural system. The panel's conclusions and recommendations are presented within this framework. In other words, the panel recognizes that risks and benefits must be considered in relation to the natural and managed ecosystem, and a statement such as "maintaining water flows is likely to harm/benefit a species" is not a specific policy endorsement but rather a science based conclusion concerning the potential impact of current or future habitat conditions on the fate of the species of concern.

Table 1. Overview of Charge to the SEI and the panel.

1. Share new information and findings with the scientific community, resource managers, stakeholder, decision / policy-makers,
2. Evaluate existing information and identify information needs to support science-based decision making
3. Provide a science-based evaluation of potential impacts current and proposed management options
4. Revisit and further develop previous recommendations in light of scientific information obtained since previous reviews.

All of the panel's recommendations are presented within the context of this charge or in response to the specific questions posed to the panel by the USFWS.

On August 13-15th, 2007 in Marc Building Pavilion at Florida International University SEI assembled the panel of experts, scientists whose work has contributed to our knowledge of the species and system, decision-makers and other interested stakeholders. The panel consisted of avian ecologists with expertise in the relevant species and issues, vegetation experts, hydrologists, and an expert in ecosystem change/climate change. The breadth of knowledge in the panel reflects the complexity of the issues. The four species of concern must be considered individually, however their ultimate fate rests on the responses of the individual species in the context of restoration. Everglades restoration encompasses restoring water flows (hydrology), which is intended to restore habitats (vegetation). It also rests on the ability of the species to navigate through natural and human-induced changes (changing ecosystem). Thus the SEI panel brought together experts in all these areas.

Prior to the workshop, SEI contacted stakeholders to identify key information gaps and to gain insight on relevant issues involving these species and restoration. The panel was provided with relevant written reports and scientific peer-reviewed publications for background information. In addition, the USFWS submitted specific questions relating to the science and management of the species (see Table 2 and Appendix). Copies of the scientific presentations, digital voice recordings and forum summary are available from SEI. A DVD copy of the webcast is available through South Florida Ecosystem Restoration Task Force. Following the workshop the panel met weekly to deliberate the science. This scientific report details its conclusions and findings.

Table 2. List of additional questions submitted by USFWS.

Cape Sable Seaside Sparrow

Except for subpopulations B and E, subpopulations of Cape Sable Seaside Sparrows remain very small, including subpopulation A, which historically was one of the largest subpopulations. Furthermore, subpopulation A's geographic separation from the subpopulations east of Shark River Slough and its expansiveness have made it historically important.

The 2003 Avian Ecology Workshop found there were strong indications the Everglades Restoration would benefit sparrows, Snail Kites, Wood Storks, and Roseate Spoonbills. It also found that there were uncertainties for the species – particularly for the sparrow – during the period of transition to full Everglades Restoration. This stems from the changes in hydrology and vegetation that are likely to occur as projects move forward.

New modeling for some transitional projects such as the Combined Structure and Operating Plan, Everglades Agricultural Area A-1 Reservoir, and C-111 Spreader Canal, indicate that some parts of sparrow habitat (e.g., subpopulation A) could have longer hydroperiods that are less optimal for sparrow habitat maintenance and breeding.

Questions:

1. Despite significant measures implemented over the past decade to improve hydrologic conditions in subpopulation A, one of the historically large populations and the one with the largest geographic size, the number of sparrows in the area has remained very small. Furthermore, hydrologic modeling for Everglades Restoration projects such as CSOP (Combined Structural and Operational Plan) suggests conditions in subpopulation A will become wetter, with hydroperiods that are longer than needed to support sparrow habitat at known nesting locations. As a result, the best available science suggests subpopulation A as it is known today cannot be expected to support a significant sparrow population, at least in the foreseeable future. The 1999 AOU panel recommended having three large subpopulations of sparrows, but this has proved difficult to achieve. **Given what we know about habitat conditions available for sparrows now and the likely conditions under Everglades Restoration (especially as they relate to subpopulation A), what can be done now and in the future to ensure the species' long-term viability and promote recovery in the wild (e.g. habitat amount, habitat suitability, population sizes, population separation, etc.)?**

2. Is there merit in the conclusion that sparrows may require more proactive and interventionist management during transition to Comprehensive Everglades Restoration Plan (CERP) conditions? If so, what information is this based on?
    a. Are translocation and captive breeding potential options worthy of consideration at this time?
    b. How do we conservatively maintain sparrows during transition if there are expected to be periods of insufficient habitat availability?
    c. What specific steps can be taken now and into the future to ensure sparrow conservation during this period of transitional uncertainty?

3. What immediate management actions are appropriate, if any, to pursue to improve or maintain populations, regardless of restoration efforts?
    a. Where are specific locations for habitat enhancement and restoration to benefit

the sparrow?
    b. What specific actions should be considered (e.g., fire management)?
    c. Should predation control be implemented to a greater extent?

4. Is there still merit in the conclusion that sparrows will do well after Everglades Restoration is complete? What specifically should we do during Restoration planning and implementation to ensure that we maintain a favorable outcome?

5. How should we evaluate sparrow responses to expected CERP outcomes, both in the interim and with respect to full CERP implementation in terms of how much habitat may be available and where habitat may be available?

6. What is the expected effect of impacts to small subpopulations? How should these areas be addressed in the transition to full CERP?

7. If we have a scenario such as a large fire in subpopulation B followed by flooding which could significantly impact the subpopulation, how should we address the other subpopulations?

8. Can we currently suitably predict where sparrow habitat will occur after restoration, and how important is answering this question as specific CERP projects are analyzed?

9. What are the most important scientific questions that should be answered to improve sparrow conservation?
    a. What key information gaps, if any, remain that are critical to maintaining the sparrow population?
    b. What does the panel recommend for the highest priority next research steps?
    c. Are there key life history parameters to focus on improving our understanding?

Snail Kite

Drought conditions in 2000 and 2001 appear to be connected to a decline in the Snail Kite population. Specifically, the decline appears to be linked in part to reduced adult survival during this period. In addition, significant high water levels and low water levels appear to affect foraging opportunities for apple snails. Finally high rates of recession have been implicated in nest failure on some occasions. By restoring the natural hydrologic regime in the Everglades, it stands to reason that many of the aforementioned challenges could be addressed.

Questions

1. How much uncertainty/risk is there for the kite during the transition to full CERP? How much risk is prudent to accept given the current status of the species?

2. What specific steps can be taken in the transition to Everglades Restoration to improve habitat conditions for kites and other avian species?
    a. Are there temporal/transitional issues such as timing or sequencing of projects that are needed to safeguard kites?

3. What additional measures, if any, are appropriate to safeguard the kite population currently?

4. What specific steps can be taken to improve habitat conditions for kite nesting and foraging?

5. Where specifically is more water needed and at what times, and where is less needed?

6. How important for kite conservation is developing an integrated, system-wide hydrological operations plan in the Everglades?

7. What strategies would support apple snail production and maximize Everglades Restoration system-wide benefits?
   a. What actions, if any, should be taken to address invasive apple snail species, and does this have a connection to Everglades Restoration?

8. Within the network of kite habitats, can the panel recommend methods to support evaluation and decision-making about expected future resource conditions, both within Everglades and outside of the CERP footprint?

9. What are the most important scientific questions that should be answered to improve Snail Kite conservation?
   a. What key information gaps, if any, remain that are critical to maintaining the sparrow population?
   b. What does the panel recommend for the highest priority next research steps?
   c. Are there key life history parameters to focus on improving our understanding?

Wood Stork

The condition of Wood Storks across its range appears to be improving. More Wood Storks were identified in 2006 than had been documented in 40 years in the United States. This success stems from, at least in part, expansion of the species range northward. Colonies in south Florida, however, historically were very large, but have experienced notable reductions over time. At least three colonies of Wood Storks – Tamiami East, Tamiami West, and 2B Mud East – have been found in areas that are key parts of Everglades Restoration. Everglades Restoration should increase the hydroperiod in these locations.

Questions:

1. What impacts will Everglades Restoration have on specific stork colonies, and the overall population of Wood Storks in Everglades National Park and the Water Conservation Areas?

2. How will the decrease in short hydroperiod wetlands in the region from development activities affect nesting and foraging success?

3. How will the Everglades Restoration affect foraging opportunities for migrating/overwintering Wood Storks?

4. What is the significance of the Everglades to the stork population in light of current population trends?

5. Are any special considerations for this species necessary during transition to CERP?

6. What non-CERP actions/protections/threat reductions are necessary and appropriate to ensure that the stork population is maintained during CERP?

7. What can we do currently to improve the status of storks in southern Florida, both in conjunction with restoration and separately?

8. What are the most important scientific questions that should be answered to improve Wood Stork conservation?
    a. What key information gaps, if any, remain that are critical to maintaining the Wood Stork population?
    b. What does the panel recommend for the highest priority next research steps?
    c. Are there key life history parameters to focus on improving our understanding?

Roseate Spoonbill

Roseate Spoonbill populations have not changed significantly in recent years, and they continue to nest within Florida Bay. However, nesting has increased within colonies in Tampa Bay and near Merritt Island, and spoonbills have been reported nesting within inland colonies within the Everglades on several occasions. There have been efforts to improve monitoring and implement prey base sampling within spoonbill habitat in the southern Florida estuaries since the 2003 workshop.

1. Does new information continue to support that spoonbills will do well under CERP?

2. How important is the CERP footprint to spoonbills now and in the future?

3. What special considerations, if any, are necessary to ensure that we maintain spoonbills during transition to CERP?

4. Are spoonbill rookeries outside of CERP areas sufficient to maintain the spoonbill population regardless of CERP outcomes?

5. What are the most important scientific questions that should be answered to improve Spoonbill conservation?
    a. What key information gaps, if any, remain that are critical to maintaining the Spoonbill population?
    b. What does the panel recommend for the highest priority next research steps?
    c. Are there key life history parameters to focus on improving our understanding?

Over-arching questions

1. Are there conflicts between sparrow and Snail Kite management and are there any appropriate actions to address this concern?

2. Can the panel recommend different or improved methods to pursue detailed project development and evaluation related to restoration/development projects to better address key issues and uncertainties?

3. If detrimental impacts are expected to any of these species resulting from restoration, development, or other projects, does the panel have any recommendations on actions or efforts to mitigate impacts or gather information (e.g. if sparrow subpopulation A is being flooded or burned, should we attempt to relocate all the birds prior to this event, attempt

to monitor their responses in light of potential losses, etc.)?

4. Given limited funds, how would the panel recommend prioritizing immediate management and recovery actions among these species?

<u>Other wading birds (species) as indicators</u>

1. Are there indications that other wading bird/waterbird species may encounter significant problems during transition to CERP or as a result of other actions?

2. Do we have information to suggest that ibis/egrets or other species are better indicators of conditions for the suite of waterbirds within the Everglades system?

3. Is there a clear need to further investigate or understand other waterbird responses to CERP?

4. What key information gaps, if any, remain that are critical to maintaining wading bird populations?

2. CONCLUSIONS AND RECOMMENDATIONS

OVERALL CONCLUSIONS

There has been an impressive series of studies and new information produced since the last SEI multi-species workshop. This knowledge has enhanced our understanding of the species and ecosystem. Results from these studies suggest new ways for managing species through transition and help to indicate priorities for future research and management. These are discussed in detail in the summary below and in the specific sections of the report.

The panel recognizes that some controversy persists over the importance of water flow versus water levels in shaping the Everglades. However, the material we examined presents a compelling argument for water flow being absolutely central to restoring the defining characteristics of the Everglades. If sustaining the four bird species and the other native flora and fauna of the Everglades is a primary management objective, efforts should be made promptly to move forward with fully restoring flows to historic spatial and temporal patterns, beginning with the following projects: Modified Water Deliveries to Everglades National Park (ModWaters) and Water Conservation Area 3 Decompartmentalization and Sheet Flow Enhancement (Decomp).

An overarching conclusion of the panel is that the Status Quo is not an option if the goal is to restore the ecosystem and prevent the extinction of critically endangered species. Incomplete implementation of emergency measures and failure to complete more major plans in a timely way increases the risks to endangered species. Moreover it makes it more difficult and more expensive to recover them.

This forum focused on four species of concern, and most of the recommendations for specific actions address these species individually and within a multi-species approach. However many of the needs identified and recommendations proposed here are relevant to overall Everglades Restoration. For instance the need for a conceptual multi-species approach, a stronger and more appropriate science framework, and attention to consequences of climate change will help solve issues beyond those of the four species of concern.

CAPE SABLE SEASIDE SPARROW

An impressive amount of new information on the Cape Sable Seaside Sparrow has been developed since the last SEI workshop. This has provided the panel with a broader and deeper understanding of the species. Several new conclusions have emerged which have implications for management.

<u>Current Situation and Population Trends</u>

Since the declines of the mid-1990s the population as a whole has been stable. But trends are not uniform across geographic areas. Subpopulation A has continued to decline, despite emergency measures to sustain it, and is currently less than 5% of its size in 1981/1992. Subpopulations B and E, the two remaining large populations, have been stable with an estimated 2500-3000 sparrows constituting 80-90% of the total population. Subpopulation C remains small but is the only one that has increased since the mid 1990s. Subpopulations D and F are the smallest and arguably on the verge of extirpation (since 2000, only 1-3 singing males have been detected).

The panel concludes that under current conditions the Cape Sable Seaside Sparrow population is sufficiently small and its range is sufficiently restricted that it is vulnerable to environmental stochasticity (which can lead to extirpation). Moreover the likelihood of the population increasing under current conditions seems remote.

Water Management, Emergency Measures, and Progress towards CERP

The 2003 SEI panel concluded that implementation of Comprehensive Everglades Restoration Plan (CERP) will benefit the sparrow. This conclusion has not changed. However the fundamental problem is not simply whether CERP will benefit the species but rather whether CERP will be implemented properly and in time to ensure the survival of the species. Ongoing failure to carry out measures fully and in a timely way (identified by scientists in several studies and previous panels) has not been resolved. In some cases, short term management has become long term management because no progress has been made in restoring flows to historic patterns in areas occupied by endangered species. Delays in restoring historic flow patterns continue to increase the risk to the sparrow as well as to other species.

Perhaps the most startling information presented to this panel was that emergency management (i.e. Interim Structural and Operational Plan (ISOP)/ Interim Operational Plan (IOP)) designed to alleviate the pressure on sparrows may not have produced desired hydrologic conditions. The intent of emergency management was to create hydrological conditions that would support habitat suitable for sparrows and allow successful nesting, in order to stimulate population increase. It is quite clear that the sparrow population has not increased, there is compelling evidence that suitable habitat has decreased, and recent evidence that desired hydrological conditions may not have been achieved in some areas. It is notable that where management goals have been met (e.g. NP205) the population has responded positively. But elsewhere (e.g., P34) where water levels detrimental to the population may have continued to exist the population has performed poorly. Overall Subpopulation A has continued to decline and there is uncertainty about whether this is due to poor hydrological conditions, lack of suitable habitat, sparrow demography or a combination of these factors.

In the workshop, participants expressed concern about the effect of CERP on sparrow habitat based on new runs of the Natural System Model (NSM) which indicate wetter conditions in western Shark River Slough than did previous runs. The model coupled with empirical data suggest that at least some of the marl prairie occupied by subpopulation A will be converted (or revert back) to wetter habitat with the implementation of CERP. To address this situation, managers could adjust objectives and provide favorable conditions for sparrows rather than matching NSM output. But if it were the case that maintaining sparrow habitat compromised the restoration of the ecosystem (especially the ability to move water south to Everglades National Park and Florida Bay) this would be a legitimate reason to put some sparrow subpopulations at risk. That risk could be mitigated against, for instance by creation of new habitat and other interventions for the sparrow (see below).

The panel underscores that possible actions and combinations of actions have to be evaluated by whether or not they move the system toward or away from the overall goal of making the habitat and local environment suitable for the sparrow. But specific actions considered in isolation may distract from this goal. For example, one suggested option is to cease emergency management measures and once again allow regulatory releases of water through the S-12 structures during the sparrow's nesting season. Given the extensive previous work on the water level requirements of the sparrow, the panel concludes that without mitigation this action in isolation is likely to result in extirpation of subpopulation A and is unclear as to what extent it will benefit or otherwise impact the other subpopulations or other endangered species. However, because of the interconnected structure of the subpopulations (see below) there may be unintended consequences for the other subpopulations. Ultimately, if any action is expected to have a negative overall effect on the sparrow, its justification as a conservation measure would require a clear demonstration that there would be positive effects on other elements of the Everglades ecosystem.

<u>Population Structure</u>

Perhaps one of the more significant conclusions of the panel is that the model of population structure currently used to manage the sparrow is invalid. A fundamental change in the way that the Cape Sable Seaside Sparrow population structure is treated is appropriate.

The current model considers the populations more like a separate entity, but the panel concludes that the structure is probably best described as a connected set of subpopulations, in which the degree of connection is not yet fully known. Data, especially those collected since the 2003 workshop, indicate that populations are well connected, particularly those to the east of the Shark River Slough. There is likely to be sufficient movement that subpopulations can be "rescued" from extinction by dispersal from other subpopulations, as long as subpopulations are large enough to produce dispersers.

Several important conclusions and implications that follow from this important and new insight:

- The Cape Sable Seaside Sparrow has considerable capacity to colonize unoccupied suitable habitat.
- The Cape Sable Seaside Sparrow may be inherently more resilient than was previously suspected. Resilience will continue to decline, however, as population size and range size decline.
- Maintenance and creation of suitable habitat is more important than was previously recognized.

- Maintaining conditions that allow for population growth remains essential but an emphasis on birds only in areas where they currently occur is not the only option available and other options should be considered.
- The historic management approach of ensuring the maintenance of three distinct populations is invalid. *From a conservation biology standpoint, while data on movement indicate that the subpopulations are connected, there are increased risks to the species from having one interconnected set of subpopulations (e.g. environmental stochasticity) and thus additional populations, locations, and habitats are recommended (see below).*

Threats to the Species

Flooding and fire have long been recognized as among the main threats to the survival of the Cape Sable Seaside Sparrow. However, recent studies indicate that nest predation, particularly by rice rats and fish crows, may limit productivity. Nest predation rates increase when conditions are too dry or too wet, and thus it may be possible to improve nest success indirectly through water management, as well as directly through predator control. Work on other species suggests that mercury in the environment can affect nesting and mating behaviors at sub-lethal doses. Hurricanes have had major impacts in the past, and may again in the future. Climate change and accompanying sea level rise presents a new suite of challenges for managers (see below).

Habitat loss and habitat availability are key factors limiting the ability of the Cape Sable Seaside Sparrow to rebound. For instance, habitat change is clearly a factor in the decline of subpopulation A, although other factors may also be at play in this area. Habitat in subpopulation D remains largely unsuitable for sparrows. The Allee effect (whereby performance of individual sparrows declines below some population threshold, thereby hastening the trajectory towards extinction) may be a factor for the Cape Sable Seaside Sparrow.

New data necessitate a revised view of the impact of fire on Cape Sable Seaside Sparrow habitat. The data indicate that habitat quality as evidenced by sparrow density, survival, and reproduction is immediately reduced after fire and remains low for two or three years before returning to levels indistinguishable from unburned areas. There is no indication that unburned habitat becomes unsuitable over time due to plant succession in areas that have been monitored for more than a decade, but it may be the case that over longer time spans fire is necessary to maintain marl prairie habitat. Prescribed fire might be used to improve habitat conditions for the sparrows in subpopulations A and D by promoting conversion of marsh back to wet prairie.

Research and Science-Based Management Recommendations

Since the last workshop several promising areas of research have emerged, and additionally there remain areas of uncertainty. Some of the general research areas that would benefit management are as follows:

- A more detailed understanding of the causes of population declines and nest loss, including more information on the role of predation and environmental characterization of potentially important constituents such as mercury.
- The causes of the poor performance of subpopulation A are uncertain. Several alternatives (e.g., hydrology, habitat, demography) have been proposed and disentangling them would help to identify specific actions that could be taken to mitigate against future declines. Moreover, it is important to recognize that it might be too late to determine why subpopulation A has not recovered from the population crash of the mid-1990s. This recognition should prompt preemptive research planning to test alternative explanations should other subpopulations begin to decline.
- The extent to which unoccupied but suitable sparrow habitat exists is unknown and should be investigated. It is also important to attempt to predict where new suitable habitat might arise as CERP is implemented, particularly west of Shark River Slough.
- Additional information on colonization of unoccupied habitat is warranted. This includes studies on movement and connectivity between subpopulations.
- An evaluation of historical and/or paleo-records to determine the influence of fire on vegetation structure (or an experimental program with prescribed fire) could provide essential information needed to maintain habitat conditions for subpopulations A and D.
- An investigation into whether sparrow numbers are currently limited by habitat or productivity and whether the answer varies among different subpopulations and areas.

Specific Management and Science-Management Recommendations

A clear message from the panel is the crucial importance of implementing restoration fully and in a timely way.

Evaluate management and recovery options for the species under the new population structure model proposed here. This includes developing an understanding of the amount and distribution of suitable habitat and the development of options that increase the number and distribution of sparrow subpopulations (e.g. by translocation or habitat creation). New science is needed, but it is new management rather than new science that is the key to sparrow conservation, and current management does not take full advantage of the science that already exists.

Recommendations by Topic

Water and Fire Management

- Continue to protect subpopulation A from unfavorable hydrological conditions for foreseeable future, until principal water flows to northeastern Shark River Slough can be re-established.

- Determine extent of increased flows to western portions of subpopulation A under IOP, and causes thereof, and adjust accordingly.
- Complete C-111 and "leaky reservoir project" as soon as practicable and monitor associated effects on water flows and vegetation.
- Improve modeling tools by downscaling insights such as those gained from the more regional models to scales important to the Cape Sable Seaside Sparrow.
- Examine less costly alternatives to secure principal flows to northeastern Shark River Slough and explore means to preserve subpopulation A without sacrificing ecosystem restoration objectives using Incremental Adaptive Restoration (IAR) process suggested by National Research Council (2006).
- Continue long-term studies on vegetation changes in marl prairies as a result of the interactions among hydrological conditions, fire, periphyton and soil (marl or peat) formation.
- In marl prairies, focus more on converting areas that have shifted from wet prairie vegetation to marsh back to wet prairie. Determine if fire is needed to enable this conversion.
- Continue to monitor amount and distribution of sparrow habitat using remote sensing, aerial photographs, and ground plots. Focus more on vegetation rather than relying solely on water depths during the nesting season to define habitat availability.
- Manage water flows to prevent conversion of marl prairies to marsh and promote sparrow survival and reproduction.
- In order to maximize the likelihood that CERP will result in a spatially and temporally dynamic mosaic of communities that support sparrows, additional paleo-ecological studies need to be undertaken over a greater area.

Annual Censuses

- Continue annual helicopter surveys and ongoing studies to improve population estimates in low density situations.
- Continue to assess population and subpopulation trends based on presence/absence criteria.
- Determine detection probabilities in both high and low density circumstances.
- Refine multipliers used to estimate population size by extrapolation, to estimate uncertainty and account for variation among areas with different numbers of birds.
- Develop ground survey methods appropriate for surveying sparrows in low density situations.

Demography and Movement

- Collect basic demographic information with respect to habitat within all subpopulations on an annual basis.
- Capture and band juveniles and adults within established study plots in all subpopulations on a routine basis.
- Determine sex of banded birds via DNA from blood or feathers collected at time of banding.
- Conduct regular surveys for marked individuals outside of study plots to improve estimates of movement and survival.

Nest Predation

- Determine causes of increased nest loss associated with dry conditions and short-term increases in water levels.
- Increase nest monitoring to determine array of nest predators.
- Determine *Oryzomys* densities and movements in and around sparrow nesting habitat.
- Conduct studies of the potential for improving sparrow nest success using predator barriers.

Conspecific Attraction

- Conduct experiments to determine if sparrows can be attracted to suitable but unoccupied habitat using decoys and playbacks.
- Determine if sparrows adjust their territories or space use in response to playback and/or decoys.

Translocation

- Conduct experimental translocations of wild sparrows into suitable habitat to sustain distributions within Everglades National Park and test translocation protocols.

SNAIL KITE

Snail Kites (*Rostrhamus sociabilis*) are found in southern Florida, Cuba and Central and South America. However the subspecies in the USA (*Rostrhamus sociabilis plumbeus*) occurs only in southern Florida where it inhabits freshwater prairie and slough habitats of the Everglades, Lake Okeechobee, Kissimmee Chain of Lakes and other freshwater bodies.

Current Situation

Snail Kites use the network of heterogeneous wetland units located in central and southern Florida, which often serve as refugia during times of drought. Their dispersal probabilities are higher when prey are more plentiful and are not related to water levels as was once assumed. Recent studies suggest that bird movements are strongly influenced by habitat fragmentation, with kites moving extensively among contiguous wetlands but less so among isolated wetlands. Thus fragmentation can reduce dispersal which could be detrimental to the population during times of low water and/or times of poor food availability.

The Florida Snail Kite has declined significantly in recent years. A number of factors are believed to be responsible including elimination of Lake Okeechobee as a major breeding site, a region-wide drought in 2000-2001, and intensive drawdown in the Upper Kissimmee Chain of Lakes in the aftermath of the drought. Survival rates of juveniles are down, and nesting performance has been reduced. Declining recruitment has also become a major concern, particularly lack of recruitment of young into breeding populations. This may be the limiting factor for population growth and recovery of the species.

Conclusions and Recommendations

These conclusions and recommendations are divided into three main sections: general conclusions; Snail Kite nesting and foraging habitat; and Apple Snails. Responses to specific queries from the Task Force/USFWS are provided at the end of this report (see appendix).

General Conclusions

Snail Kite populations have clearly been affected by recent climatic and human impacts. These have resulted in changes in the vital rates of birds. However, the panel feels that the magnitude of their population decline may not be as great as reported.

More research is needed to resolve the discrepancy between the high adult survival rates (nearly 90%) and the reported precipitous decline in population numbers. Despite low production of young, it is not clear how there can be such a significant decline when adult survival is so high.

Previous radio tracking provided valuable insights; however, intensive efforts to monitor the movement patterns of adult kites using telemetry data have inexplicably been discontinued. These types of data are needed for managing the species through transition to CERP and beyond.

Recommendation

- Initiate intensive radio-telemetry research to document the movement patterns of adult Snail Kites under current environmental conditions. The primary goal should be to document relevant vital rates of the population and examine the veracity of recent estimates of population decline.

Nesting and Foraging Habitat

The required habitats for Snail Kites in Florida have been well documented. Birds typically nest over open water where depth is greater than 20 cm deep. They select areas to increase their proximity to their prey (Apple Snails) and to minimize exposure to predators.

Water Conservation Area 3A has consistently been the area to produce the largest proportion of Snail Kite offspring since the mid 1990s. This is in part because of water management in the Everglades. However, higher water levels in Water Conservation Area 3A now appear to be adversely affecting the bird.

Recommendations

- Water Conservation Area 3A is currently important to the persistence of Snail Kites in the Everglades. The panel feels that management should be adapted to account for the nesting and foraging requirement for the species. Water management should maintain lower water levels during the fall/winter months (Sept-Dec) to mitigate effects of longer hydroperiod and deeper water on vegetation, and should maintain higher water levels during the spring/summer (March-July) to provide for better conditions during the Snail Kite breeding season. These requirements and how best to achieve them should be fully considered and formally incorporated into the Army Corps of Engineers (USACE) Systemwide Operations Manual due for revision in 2010.
- Water Conservation Area 3A should not be the sole focus of Snail Kite conservation. Conditions for kites will be improved in not only WCA-3A but also other areas by ModWaters and Decomp.

Apple Snails

Apple Snails (*Pomacea paludosa*) are the nearly exclusive prey of the Snail Kite. In the past decade significant advances have been made in our ability to sample snail populations. Snails are more abundant in wet prairies than in open sloughs. Contrary to previous understanding, Apple Snails are adapted to and can survive periodic dry downs, but timing is critical. Drying every 2-3 years for 1-2 months will not adversely affect snail populations - a critical finding, given our current understanding that periodic dry downs are needed to maintain wet prairie habitats important to both Snail Kites and Apple Snails. Conversely, high water during the Apple Snail breeding season delays egg production, which can result in their destruction during summer rainy season.

The panel concludes that:

- High water levels are detrimental to Apple Snail reproduction as are extended dry down events.
- Continued flooding of WCA 3A followed by extreme dry downs will further reduce Apple Snail populations and increase stress on the Snail Kite.
- It is unknown whether or how the larger Apple Snail (*Pomacea insularum*), a recent non-native invader, will impact the Snail Kite. It has been suggested that

young Snail Kites have difficulty handling the larger snail. This situation needs to be monitored.

Recommendations

- It is essential to fully integrate the excellent ongoing studies on the effects of water levels and hydroperiod on vegetation communities, Apple Snails and Snail Kites (see Governance section for more details). Currently these studies are not well connected. This step is key to linking the specific hydrological and ecological conditions needed to restore the native Apple Snails, Snail Kite populations, and their preferred habitats. This integration is needed to provide more effective guidance to managers.
- We suggest developing an integrated suite of recommendations that identifies the range of acceptable water management strategies and expected outcomes, with respect to their short term and long term effects on the status of the vegetation communities, Apple Snails and Snail Kites, and their interactions.

WOOD STORK

Current Situation

Historically, Wood Storks in the U.S. nested regularly only in south Florida, and shifted northwards at least partially in response to water management in the Everglades. It is generally believed that there were between 5,000 and 10,000 pairs nesting in south Florida in the 1930s. Wood Storks shifted generally north in the Everglades in the 1970s, associated with water management. Between the 1930s and 2001 there was a 61% decline in the proportion of nests in coastal mangroves and a 46% increase in the proportion of nests in the central-northern Everglades. The first recorded nesting by Wood Storks in the Water Conservation Areas occurred in 1989. The current Recovery Plan for Wood Storks calls for three-year running averages of 10,000 nesting pairs in the population as a whole, with 2,500 nesting pairs in Everglades National Park (or Everglades system as a whole) and Big Cypress Preserve combined. Total nests exceeded 9,000 in 2002 and 2003, with 1191 nests in the Everglades system (which includes the Water Conservation Areas). It is worth noting that Wood Stork populations have increased to near recovery goals in the absence of progress on CERP. The reasons for this increase are unknown.

Numbers of nesting pairs fluctuate over nearly three orders of magnitude among years, associated with suitability of hydrological conditions. Nest and chick rearing success are also highly variable, breeding attempts are largely abandoned in years when water levels rise after nests are initiated. In recent years, substantial numbers of juvenile Wood Storks have been tagged with satellite transmitters and results demonstrate the potential for genetic and demographic interchange throughout the breeding range of Wood Storks in the United States. Because few adults were tagged, migration patterns of adults are more poorly understood. No good estimates of adult survival exist.

Dependence of Wood Storks on dry down conditions for successful breeding is well established. Wood Storks are primarily piscivorous, although they eat a variety of organisms found in aquatic habitats. Wood Storks are especially dependent on high concentrations of small fish (2-25 cm long) when feeding chicks, and in the absence of water recession, prey densities and prey capture rates are insufficient to support chick growth and Wood Storks either do not nest or their nests fail.

Wood Storks require trees either on islands or surrounded by water for nesting. The principal requirement seems to be protection from predators. Historically, nesting in south Florida typically began in December-January but since the birds shifted their nesting north in the 1970s most nests have been initiated in February and March or later. Such delayed nesting pushes chick rearing into the wet season, and may have increased frequency of breeding failure in south Florida.

Conclusions and Recommendations

The overall outcome of water management in the Everglades system is that water recession, producing the numerous shallow pools with highly concentrated fish, occurs in fewer years and in fewer areas. By constraining the area that is hydrologically connected, this system has reduced topographic variation. Canals and water removal have reduced natural flows through the system, increasing the frequency of dry conditions. Levees have created artificial impoundments which maintain artificially deep water in other areas for longer periods of time. Water management for flood control and water availability has exacerbated deviations from "natural" hydrological patterns; some areas are too wet, while others are too dry. In particular the southern areas where the storks nested historically are too dry. Reduced flows have also increased saltwater intrusion into coastal mangrove habitats, which affects prey density.

An important paradox in our understanding of Wood Stork population dynamics is the recovery of the south Florida Wood Stork nesting population to near recovery goals during the late 1990s- early 2000s, before implementation of the CERP. It is possible that increased reproductive effort and success during this period merely reflects drought conditions in south Florida during this period, which reduced the frequency of hydrological reversals during the spring breeding period. The longer term need for deeper water to produce prey fish, however, suggests that if recent drought has increased reproductive success, this pattern cannot be counted on as a long term solution for stork management.

Recommendations: Data Needs for Management

Knowledge of the relationship between specific water management practices and favorable hydrological conditions for stork breeding require refinement. Spatial scale of current hydrological modeling efforts may not be adequate to predict timing and location of pools containing concentrated prey necessary for successful breeding.

Additional uncertainty exists about the importance of longer term hydrological patterns. It is important to note that current hydrological models of the Water Conservation Areas do not appear to indicate sufficient water recession in most years to support successful breeding by storks.

An improvement in our understanding of the direct relationship between hydrological conditions and initiation of nests by storks is needed.

There are gaps in our understanding of the demography of Wood Storks. Currently, no reliable estimate of adult survival exists. Temporal-spatial patterns of breeding suggest that individual birds have some flexibility to respond to local breeding conditions, but the extent to which individuals move among breeding locations is unknown. Understanding of such dynamics is key to understanding how storks might respond to specific management actions over the period of a decade or so.

ROSEATE SPOONBILL

Current Situation

The Roseate Spoonbill is one of six species of spoonbills worldwide, and the only species that occurs in the western hemisphere. Breeding colonies in the United States are restricted to coastal and a few inland sites in Louisiana and Texas, and the southern half of peninsular Florida. Breeding sites in Florida historically have encompassed coastal and inland sites from Tampa Bay on the Gulf Coast to Brevard County on the Atlantic coast and south to Florida Bay. Since 1992, Roseate Spoonbills have resumed breeding at several inland sites in the Everglades (e.g., Water Conservation Area 3A). The Roseate Spoonbill is a key indicator species for the restoration of the Florida Bay ecosystem under the CERP, because its reproduction is closely tied to regional patterns of hydrology.

Plume collectors and subsistence hunters caused spoonbill numbers to plummet and the population was believed to number fewer than 200 pairs by the early 1930s. Protection resulted in increases in the population and by 1978-79 numbers had reached 1,254 breeding pairs. Audubon scientists and staff have continued to monitor spoonbill nesting activities and success in Florida Bay since the 1984-85 breeding season. Numbers have generally ranged between 400 and 500 pairs each year (although there are wide fluctuations). No detailed population estimates exist for spoonbills other than the annual nest counts provided by regional ground and aerial surveys. There appears to be a close link between conditions in Florida Bay and the production of young and recruitment within Florida.

In Florida, mainland populations normally breed in the winter through the spring (late February or early March to June), whereas breeding in Florida Bay populations normally occurs in the fall and winter (November-March), albeit the timing in the latter colonies has become more irregular during the past 2-3 decades with human alteration of the natural water flows. Nesting by spoonbills in Florida Bay is timed closely with the seasonally low-water depths that occur during the dry season when abundant prey are concentrated into the remaining pools, creeks, and sloughs. Roseate Spoonbills consume a wide variety of small aquatic animals, including fish, crustaceans, and insects. Gradual and consistent declining water levels throughout the nesting period appear critical for adults to secure and supply the food necessary to raise young. Breeding success is high during seasons with gradual dry downs, and poor during seasons with high or fluctuating water levels.

Spoonbills nesting in Florida Bay seem to use about 11 major foraging locations within the coastal wetlands at any one time. It was previously believed that these birds left the Everglades in non-breeding periods. However, recent results using satellite telemetry suggest that many of the birds simply disperse across interior habitats where they are hard to observe.

As this species is a key indicator for Everglades restoration, there are additional data needs that will help inform restoration.

ACTIONS AND RECOMMENDATIONS

Implementation of CERP and MODWATERS

The restoration the natural timing and flow of waters into Florida Bay should benefit Roseate Spoonbill reproduction and result in an increased population within Florida Bay. Ongoing and planned modifications to the South Dade Conveyance System (i.e., changes to the C-111 canal and associated structures) should proceed as quickly as possible to improve reproduction within the spoonbill colonies located within the northeastern and central portions of Florida Bay. Some aspects are to:

- Complete C-111 and "leaky reservoir project" as soon as practicable and monitor associated effects on water flows and vegetation.
- Ensure that the ecologically important timing of hydrologic flows to Florida Bay is formally considered during the 2010 System Operations revision.
- Increase flows through northeastern Shark River Slough into Florida Bay are key to spoonbill conservation, and thus this species will especially benefit from ModWaters and Decomp.

Population Monitoring

Current practices for monitoring the size and reproductive success of within the Roseate Spoonbill colonies in Florida should be continued. Roseate Spoonbills breeding success is clearly sensitive to changes in the abundance, availability, and quality of prey, and consequently, comparative data on breeding success is essential for directly measuring habitat quality and indirectly measuring the effects of CERP implementation. Because very little is know about the population dynamics and demography of Roseate Spoonbills (cf. Dumas 2000), ongoing banding studies should also be continued.

Satellite Telemetry

Satellite telemetry should be continued to ascertain details of movements and micro-habitat use in the breeding and non-breeding seasons. As noted by Langan and Lorenz (2006), satellite telemetry can provide a variety of critical information crucial to the conservation of this species. Efforts should be made to place satellite transmitters on adult spoonbills in multiple colonies so that key foraging areas can be documented and correlations between hydrological conditions, prey populations and breeding success can be examined in more detail. Feather samples should be collected from all birds that are captured and equipped with satellite transmitters in order to document their sex via DNA analysis. The collection of body feathers will avoid more invasive procedures such as blood sampling, and the documentation of the sex of marked individuals would clearly be beneficial, and the collection of body feathers will avoid more invasive procedures such as blood collection. A number of private and commercial laboratories are now available to complete sex determination via feather, and such analyses can be completed for relatively minimal costs.

MULTI-SPECIES

The challenges of managing for multiple species have emerged as an important theme in Everglades restoration. Multi-species concerns involve two key factors. 1. A conceptual approach to the science and management of multiple species and 2. The potential for tradeoffs among species as actions are taken to restore more natural water flows and restore the ecosystem.

- An overarching conceptual framework for multi-species management is lacking for Everglades restoration. Additionally the scientific approach lacks the overarching framework needed to adequately address multi-species. A more integrated approach that fosters greater interaction among research groups, with the objective of finding solutions that optimize across the entire suite of restoration and legislated goals is recommended (see also governance below).

Multi-Species Management through Transition: Potential Tradeoffs

The 2003 SEI panel concluded that restoration would fully benefit all four species of concern. This panel concludes the same although new information adds to the underpinning of this conclusion. However specific management actions are needed to shepherd the species through transition to full restoration.

- The panel concludes that there are no true conflicts between the needs of these species, but until the desired water management system is created, there will be tradeoffs over which of the four species to allow to suffer most from ongoing ecosystem degradation.

All four species will benefit from restored water flows. However, the panel has some specific recommendations for managing transitions and addressing needs of multiple species.

- Managing water so that water levels peak in the WCAs during the wet season (June-September) followed by dry down beginning as early as October and release of water through Shark River Slough provide the best opportunity to produce hydrological conditions favorable to the four species addressed in this forum.

- CERP likely will result in wetter conditions for subpopulation A which may put that population at risk. Given the benefits to ecosystem restoration, the panel feels that this is an acceptable tradeoff, although we recommend attempting to minimize risk to subpopulation A through the incremental adaptive restoration (IAR) process recommended by the NRC (2006). Changes created through the implementation of CERP, are not comparable to opening the S-12 structures to release water within the existing water management system. (Opening the S-12 structures likely would extirpate subpopulation A).
- All four avian species require similar cycles of rising water and dry down, and CERP attempts to recreate this regime. In contrast, the panel is not convinced that isolated actions, such as the release of water through the S-12 structures alone, can create the desired extent and timing of water-pulse/dry down to produce the foraging conditions in the southern Everglades that storks and spoonbills require.
- The Snail Kite situation is more complex. The panel is not convinced that ponding in WCA-3A has adversely impacted them, given that the birds shifted to this area in the 1970s and 1980s when the system dried out elsewhere, and increased their dependence upon it under IOP. The panel recognizes that there are legitimate reasons why continuing to protect the sparrows is problematic to restoration, but believes there is still appreciable uncertainty in how the water management actions intended to help the sparrow adversely affect the Snail Kites.
- New information about Apple Snails, combined with studies of the Snail Kites themselves, indicate that the kites require particular dry down cycles in specific habitats in order to thrive. The appropriate conditions could be created in many locations within the Everglades, not only in WCA-3A. For instance, the area that contributed most to successful nesting in 2006 was Everglades National Park. Importantly, it does not appear that benefiting Snail Kites is a simple matter of releasing water through the S-12s within the current water management system, and thus does not represent a clear tradeoff with protection of sparrow subpopulation A.
- A better solution is to create a water management system that results in the possibility of appropriate conditions for Snail Kites in many areas throughout the system, such that they likely will exist somewhere each year but not necessarily in the same location each year. This mosaic of conditions will allow them to be successful under a highly variable rainfall regime. For instance, it is as important to restore appropriate conditions for kites in Lake Okechobee, WCA-3B, ENP, and other areas as it is to do so in WCA-3A. These same changes to the system promise to create the foraging conditions that storks and spoonbills require to nest successfully in the southern Everglades. They also promise to improve conditions for sparrow subpopulations B-F.
- The most disturbing information the panel received was that the design of ModWaters, has been compromised such that it will produce much less movement of water east and south than originally envisioned because the Tamiami Trail will remain an obstacle to desired flow patterns The single most positive step that could be taken to conserve the four bird species is to find the resources to fully

implement ModWaters. The second is to accelerate implementation of Decomp. Until these two projects are completed conservation of these four species will be a challenge.

SCIENCE-POLICY INTERFACE

Finally, we recognize that ecosystem restoration operates under several laws, policies, and mandates including, for instance, the Endangered Species Act. These laws offer little guidance to managers who must balance legal requirements for individual species management against constraints and consequences of ecosystem restoration. It is outside the scope of this review to address this issue but we raise it here to indicate the need for greater policy guidance on acceptable risks and decision making during restoration in Everglades and other comparable ecosystems.

HYDROLOGY

The panel addressed hydrology and hydrological modeling within the framework of the species of concern. The panel views the current modeling efforts as a necessary and appropriate tool for what they were primarily intended to do: simulate hydrologic response at the entire system scale. Regional models are suited for regional questions however, and there are local-scale ecological thresholds that appear to require simulations of hydrologic response at a smaller scale than the larger-scale models presented to the panel.

Based on our review, the panel highlights the following points and recommendations on hydrological modeling:

It is important that the right tool is applied to the right problem. Conceptual frameworks and recent work on these species show that the timing and magnitude of water flows are important forcing functions. Timing and magnitude of hydrologic flows are tractable goals of modeling, but must be simulated at the temporal and spatial scales important for the species. Quantified results from such a properly scaled and constructed model can inform better management of the overall system.

Use of models commonly falls primarily into two overarching activities; models are used for providing: 1) a quantified framework to look at the range of present conditions ("constrain the arm waving"); and 2) predictions of how the system responds when system drivers are outside the range of the calibrated conditions.

Models are by definition a simplification of reality. But, this simplification can involve different things depending on the objective of the model. Thus, the hydrologic models utility would be enhanced by discussion surrounding the need to balance complexity of process simulation with needs of the decision makers.

The hydrologic models need to balance complexity of process simulation with needs of the decision makers.

Climate change is affecting the hydrology of the Everglades but the current hydrologic models (and management designs) presented to the panel assume no long-term trends in precipitation, temperature, or sea level.

Because models can have multiple uses/predictions, it is important to not focus on "one model depiction of the world that gives all answers." A superior approach is to test various hypotheses of important processes early in the modeling effort, and have all members of the team vet the models.

Currently there appear to be four project objectives where models could be usefully applied:

- To provide hydrologic conditions for "backcasting" of what the system was in the past so as to better understand the historic species response.
- To help understand presence/absence of species in different parts of the system during different periods of time in the past.
- To provide hydrologic information to decision makers such that system operations can be targeted to meeting ecological thresholds when not in conflict with more critical operation goals.
- To allow project members to overlay ecological field data on a quantitative depiction of the physical system that "fills the holes" where data could not be obtained and is constrained by the underlying physics and calibration data.

The panel believes that the species of concern might benefit from the following actions.

a. Developing a process/forum/workshop to allow ecological concerns to be formally considered in the 2010 Systemwide Operations Manual revision. Formally interjecting consideration of ecological hydrologic goals/thresholds into the revision of the operating rules will help ensure that the best understanding of the ecological thresholds are heard, which in turn will allow them to be balanced against competing needs, and more likely to be enacted when not in competition thus facilitating adaptive management.
b. Develop or modify existing modeling approaches to provide hydrologic timing, duration, and magnitude of the appropriate scale for the ecological thresholds provided. In addition, a system should be developed whereby a decision maker can request a model run and have the results be internally released in a more real-time fashion even if with the qualifier "provisional results subject to revision".
c. Evaluating the present or future models should include post-audits using field data collected at the scale appropriate for the species. Because much of the previous modeling involved large scales not optimum for the ecological thresholds available, goodness of the smaller scale model calibration cannot necessarily be judged by the calibration or calibration

approach used in the larger scale regional models which are extensively documented.

OTHER FACTORS AND THREATS

VEGETATION

To the extent that vegetation – including species composition, relative abundance, productivity, and spatial distribution – affects the habitats and behaviors of the four avian species at issue, managing Everglades vegetation should be part of efforts to manage the birds.

Recent research has done little to change long-standing scientific understanding of the types and spatial distribution of plant communities within the larger Everglades system.

A more refined understanding, however, of the factors controlling broad spatial patterns in wetland vegetation has emerged only quite recently. There is call for renewed attention to the roles of fire and water flow in shaping vegetation patterns. Studies presented to this committee show that vegetation can change rather rapidly in the face of strong hydrologic forcing.

Recent paleoecological studies hold the potential for transforming how we have conceived the controls on vegetation dynamics in the marl prairies and ridge-and-slough landscape and on tree island formation and degradation. Efforts should be made to synthesize and integrate the results of existing studies, and similar studies should be continued and supported over larger areas within these iconic landscape features of the Everglades.

Decrease in the extent of the marl prairies, and the loss of connectivity caused by levees bounding and dissecting marl prairies, especially the eastern portion of the southern marl prairies, severely constrain options for managing existing marl prairies. This argues for a more refined understanding of the relationship between hydrology and the suite of communities that comprise the marl prairies.

Recommendations

- The linkage between vegetation, hydrology and the fate of the four species of concern needs to be much strengthened.
- Vegetation is clearly dynamic. Data on patterns and causes of historical vegetation changes needs to be better understood and incorporated into planning.

CLIMATE CHANGE AND VARIABILITY IN RELATION TO RESTORATION AND THE SPECIES OF CONCERN

During the past 40 years the climate of the southeastern United States has grown warmer and wetter, and most climate models suggest that this trend will intensify during the 21st century. The effects of increases in temperature will cascade among physical and biological systems in south Florida with impacts ranging from changes in the abundance of Apple Snails to large-scale changes in the structure and extent of wet prairies, aquatic sloughs, and mangrove forests.

Conclusions and Recommendations

Temperature and Precipitation

The monthly mean minimum and maximum temperatures in south Florida increased during the past century. An increase in temperature has several direct and higher-order effects on the Everglades system that are relevant to restoration design and operations planning. Three overarching messages emerge concerning temperature and precipitation trends and projections for Everglades water managers:

1) Droughts and flood events appear likely to intensify,
2) Efforts to restore more natural hydrologic regimes in the Everglades system will require greater water delivery flexibility than in a system absent climate change, and
3) Extrapolation of historic trends will likely underestimate future change.

Hurricanes and Lesser Tropical Storms

There is evidence that some species have already been impacted by past hurricanes and storms. Additionally, there is high confidence on the effects of hurricanes on forests. In the Everglades, Wood Storks and Roseate Spoonbills and other wading birds are dependent on woody structure and would be most likely to be impacted. If hurricane intensity increases as projected, future mangrove forests are likely to be diminished in average height and will contain a higher proportion of red mangroves.

Sea Level Rise

Considering the present trends and the consensus among scientists that an acceleration in the rate of sea level rise during this century is very likely, the following messages are relevant to Everglades restoration and management:

- As sea level rises, salt water will intrude further inland, thereby restructuring freshwater and brackish water plant and animal communities.
- Even if storms do not intensify as the climate and sea surface warms, accelerated sea level rise alone will amplify the effects of storm surge on coastal shorelines, wetlands and other low-lying features.
- Transition to more saline environments, inland expansion of mangroves, and contraction of freshwater and mesohaline habitats in the south Everglades appears inevitable and there are few practical coping strategies.

- The importance of freshwater flows to the gradual adaptation and sustainability of coastal brackish and freshwater habitats will increase as sea level rises.

It is also important to note that cumulative effects will likely have "surprising" impacts on species and ecosystems. While there is considerable uncertainty about the rates of change, there is fairly strong consensus regarding the direction of change for most of the climate variables that affect the south Florida ecosystem.

OVERARCHING SCIENTIFIC SUPPORT FOR MANAGEMENT AND POLICY: GOVERNANCE AND ADAPTIVE MANAGEMENT

Effective research efforts and integration of results into management and policy is essential to the success of the Everglades restoration. In this section, we offer some insights and suggestions for improving this link.

Conclusions and Recommendations

The current approach to research and integration is completely inadequate to meet the needs of Everglades Restoration. There has been much emphasis on traditional research approach of an individual researcher with his/her team of post-docs and students. While the quality of individual research is generally high, this approach does not work for such a large and complex effort. Indeed it contributes to some of the information challenges faced by managers and policy makers. We strongly recommend a more integrated effort where researchers integrate science, results, and convene to decide on research priorities in order to gather the science required by policy makers and managers.

A consortium approach would help to solve many of the "piecemeal" issues that arise when individual researchers with small teams are trying to tackle large scale multi-disciplinary problems.

A consortium structure can be built around a group of established scientists who represent a breadth of approaches to Everglades restoration (e.g. endangered species, hydrology, vegetation, climate change, etc.). The role of the science consortium would be to integrate research across scientists, to identify priorities for research, and to facilitate interactions and training among more junior scientists. Senior scientists would have roles similar to managing partners in the consortium, while an external advisory body helps provide oversight and independent advice. The PISCO program (Partnership for Interdisciplinary Studies of Coastal Oceans) offers a model approach that could be adapted to Everglades restoration.

There is currently no adequate framework for senior scientists to participate effectively at the executive decision-making level. This oversight greatly hampers progress at the scientific and management levels and should be remedied.

Adaptive management has remained more of a concept than a working tool for restoration. There are several steps that could improve this process so that it will work as envisioned.

3. CAPE SABLE SEASIDE SPARROW

HISTORY AND DESCRIPTION OF SUBPOPULATIONS

The Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*) was in the first group of species listed as federally endangered by the USFWS (Pimm et al. 2002). This subspecies is restricted to the Everglades ecosystem, and is disjunct from all other breeding populations of the species (Kushlan et al. 1982; McDonald 1988). There is ample basis for treating the Cape Sable Seaside Sparrow as a distinct population segment and significant evolutionary unit worthy of protection under the Endangered Species Act. Although a recent analysis indicates Cape Sable Seaside Sparrows are quite similar genetically to Atlantic Coast Seaside Sparrows (rather than other Gulf Coast Seaside Sparrows to which they are in closer geographic proximity; Nelson et al. 2000), they are distinct ecologically, being the only Seaside Sparrows to occupy inland freshwater habitats, a trait they shared with the now extinct Dusky Seaside Sparrow (Post and Greenlaw 2000). They are also quite distinct from other Seaside Sparrows in morphology (Robins and Schnell 1971) and song (MacDonald 1988), and were originally described as a distinct species, purportedly the last to be discovered in the continental United States (Hudson 1919).

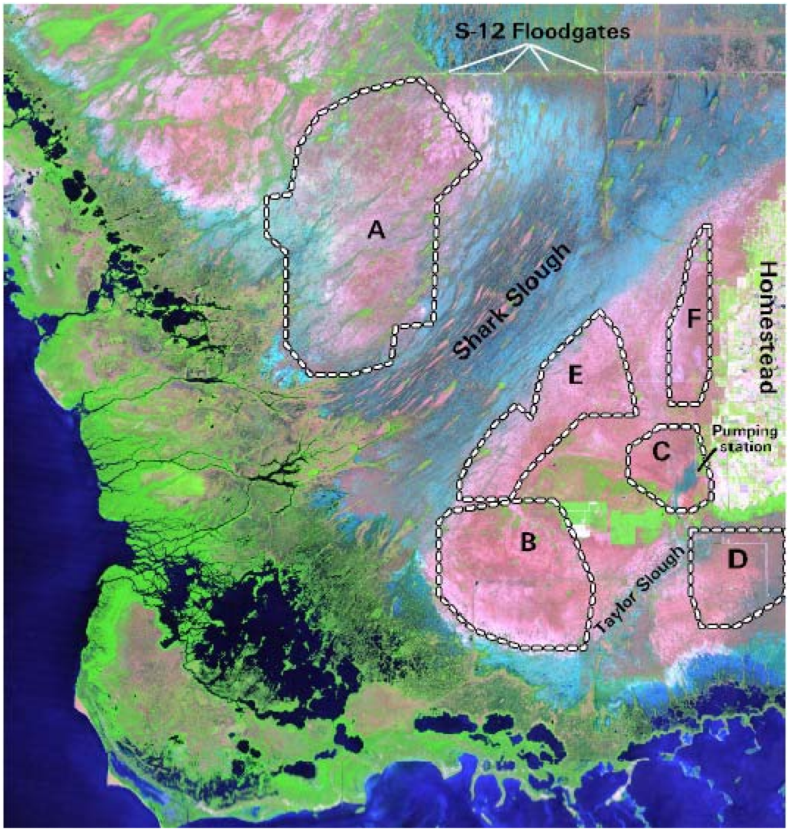
The history of knowledge of the Cape Sable Seaside Sparrow in the Everglades ecosystem is well documented (Post and Greenlaw 2000; Pimm et al. 2002), and the significance of that history with respect to current conservation was evaluated by a previous panel (Walters et al. 2000). The subspecies was first discovered in the Cape Sable region (Howell 1919) in coastal saltmarsh prairies dominated by *Spartina* grasses, a habitat similar to the salt and brackish marshes to which the species is confined elsewhere (Post and Greenlaw 1994). This population apparently was extirpated by the powerful hurricane that struck this site in 1935, and for several years thereafter the subspecies was thought to be extinct. It was rediscovered in the 1940s in the Ochopee and southern Big Cypress areas, again in saltmarsh prairies dominated by *Spartina*. The birds hung on in these areas, and in similar habitat in the interior of Cape Sable, in dwindling numbers through the 1970s, but as water management increasingly altered the hydrology of the Everglades, these habitats disappeared, and the sparrows with them (Pimm et al. 2002). All available evidence indicates that the birds have been gone from these areas for more than 25 years. But in the mid-1970s the sparrow was discovered further inland in the freshwater marl prairies, dominated by *Muhlenbergia filipes*, near Shark River Slough and Taylor Slough. It is in these regions and this habitat that they are confined currently, and have been since they were extirpated from the saltmarsh prairies.

Whether the sparrows originally occupied the inland, freshwater marl prairies as well as the brackish *Spartina* prairies, or shifted to the former as the latter disappeared, is an issue that probably never will be resolved. Nor is it likely that the hypothesis that the marl prairies represent marginal habitat for the subspecies (Post and Greenlaw 2000) will ever be definitively tested. Although not entirely irrelevant to current conservation, these are moot points. The salt marshes bordering the mangrove fringe that once marked the marine/Everglades interface, and that the sparrows once occupied, are virtually nonexistent today, and the restoration effort now underway will not restore those habitats. Clearly the future of the sparrow is tied to the freshwater marl prairies, and USFWS is committed to preserving them in that habitat. A previous panel concluded that the productivity of the birds in good marl prairie habitat “appears adequate to support a thriving population” (Walters et al. 2000), and the stability of some of the existing population units (see below) supports that conclusion. The panel supports the preservation of healthy populations of Cape Sable Seaside Sparrows in marl prairie habitat as a reasonable objective for both the Everglades restoration and application of the Endangered Species Act by USFWS.

THE MARL PRAIRIE SUBPOPULATIONS

To accomplish the daunting task of determining the distribution and abundance of the Cape Sable Seaside Sparrow in the inaccessible marl prairies of the southern Everglades. Bass and Kushlan (1982) devised a helicopter-based survey method. They superimposed a grid of 1-km^2 blocks on US Geological Survey (USGS) 7.5-minute orthophoto quadrangles, and defined census points as the intersections of the grid lines that fell in appropriate habitat. The census method involves flying to a point by helicopter, landing there and counting singing sparrows for 7 minutes, and then flying on to the next point. Each point is censused once during the morning (0630 to 0930) during the time of peak breeding activity (mid-March through May). An initial census was conducted in 1981, and annual censuses have been conducted since 1992. The initial survey revealed that the sparrows inhabited virtually all prairies of considerable size lacking in trees or not exposed to long hydroperiods, and occurred in much larger numbers in this habitat type than anyone imagined (Pimm et al. 2002). This and subsequent surveys documented that the sparrow is distributed across the marl prairies in 6 geographic units that have traditionally been termed populations. We will refer to these units as subpopulations for reasons discussed below. Subpopulation A is located west of Shark River Slough, subpopulations B, C, E and F are located east of Shark River Slough and west of Taylor Slough, and subpopulation D is located east of Taylor Slough (Figure 1).

Figure 1. Locations of Cape Sable Seaside Sparrow subpopulations. (From Pimm et al. 2002, Figure 5-1).



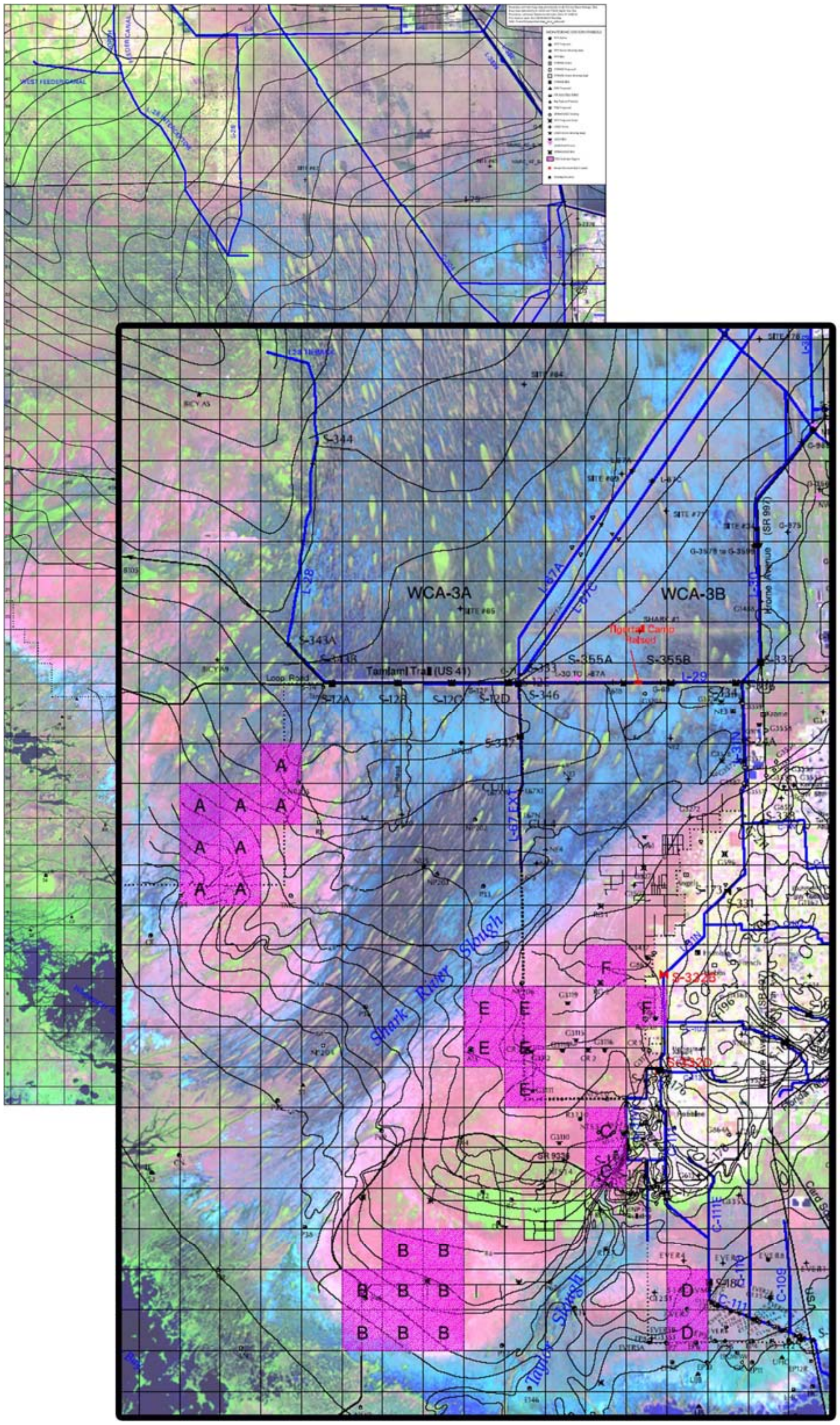
THE 2000 AOU REPORT

In both the original 1981 survey and the first of the annual surveys in 1992, the bulk of the sparrows detected were in two of the subpopulations, A and B. Subpopulation A, however, declined precipitously after 1992, in association with high water levels in the marl prairies west of Shark River Slough during 1993-1996. The surveys also indicated that the easternmost subpopulations C, D and F had declined greatly between 1981 and 1992, and were possibly continuing to decline. These declines prompted the first of the two recent panel reviews of science relevant to the biology and conservation of Cape Sable Seaside Sparrows. In November 1998, at the request of the agencies involved in management of the sparrow and the Everglades (technically the Science Coordination Team of the South Florida Ecosystem Restoration Task Force), a panel of scientists was assembled under the auspices of the American Ornithologists' Union's (AOU) Conservation Committee to evaluate the available, relevant science to help resolve debates about the causes of the declines and whether the declines placed the sparrow in jeopardy of extinction. This panel interacted with scientists studying the sparrow through a February 1999 workshop and other means, and published their findings in a 2000 report (Walters et al. 2000).

The AOU panel noted that the surveys, although tremendously useful, did not permit strong inferences about abundance because there are no measures of uncertainty such as sampling variances or estimates of detection probabilities associated with them (Walters et al. 2000). The panel nevertheless concluded a substantial decline in the number of singing males was a more parsimonious interpretation of the data from subpopulation A than alternatives such as a systematic change in detection probability as a result of altered habitat condition. The panel also concluded that the available evidence indicated that subpopulations C, D and F were smaller than they had been in 1981, but that the data did not allow any inferences about trends in these populations during the 1990s. A recent study by Cassey et al. (2007) analyzing occupancy of census sites (as opposed to abundance at census sites) enables stronger inferences about population trends and supports and clarifies previous interpretations of the survey data. This analysis indicates a decline across all the subpopulations between 1981 and 1992 that was most severe in subpopulation C and least severe in A, and a precipitous decline in A and steady decline in D after 1992 (Cassey et al. 2007).

The AOU panel's conclusions about the causes of decline of Cape Sable Seaside Sparrows reads like a synopsis of what ails the Everglades ecosystem. The broad sheet flow of water that historically occurred from Lake Okeechobee south to Florida Bay has been altered through a series of canals, levees, and pumps to provide flood control for the urban areas that have spread to the very edge of what remains of the natural habitats. To protect the urban areas east of the Everglades, and especially the one parcel located west of the Miami ridge known as the 8.5-square-mile-area, most of the water flowing south is shunted west where it ponds in Water Conservation Area 3A (WCA-3A) and is eventually released into western Shark River Slough via the S-12 structures (Figure 2). The L-67 levee extension prevents the water released into western Shark River Slough from flowing east. The end result is that the western Shark River Slough area where subpopulation A resides is vulnerable to extended periods of high water, and northeastern Shark River Slough is deprived of water, so that the prairies where subpopulations B, C, E and F reside are often too dry. Some of the water on the eastern side of the Everglades also is moved south through canals and released via the S332 pumping station into Taylor Slough, subjecting the prairie in which subpopulation D resides to high water. Flooding of subpopulations A and D is exacerbated in wet years such as 1993-1996 when more regulatory releases of water to the south occur.

Figure 2. Key structures in the water management system (adapted from map provided by Everglades National Park Service).



The AOU panel concluded that the decline of subpopulation A was caused by prolonged high water in the prairies it inhabited during 1993-1996 (Walters et al. 2000). Prolonged high water during the breeding season can prevent successful nesting; although there is uncertainty about how low water levels must be [Nott et al. (1998) proposed that 10 cm is the maximum water depth over which the birds will initiate nesting], the effect of high water is obviously true in the extreme, i.e., the birds cannot nest if the vegetation is under water. Also, prolonged high water causes a shift in vegetation from a diverse *Muhlenbergia*-dominated community to a less diverse sawgrass (*Cladium jamaicense*)-dominated one (Armentano et al. 1995; Pimm et al. 2002). There was good evidence that such a conversion had taken place in the prairie occupied by subpopulation D (Nott et al. 1998), as Kushlan et al. (1982) had predicted it would when the S332 pumping station was constructed. More controversial was the assertion that the overly dry eastern subpopulations were at risk as well due to increased likelihood of catastrophic fire (Pimm et al. 2002). The AOU panel concluded that there was good evidence that dry conditions at the eastern edge of Everglades National Park had elevated fire risk (Curnutt et al. 1998) and that fire had short-term negative effects on sparrow populations (Werner and Woolfenden 1983; Curnutt et al. 1998), but noted there were some studies suggesting that fire might have beneficial impacts on sparrow habitat over the long term (Craighead 1971; Werner 1975).

The AOU panel recommended the obvious long-term solution to the problems the sparrows faced in the late 1990s: management of the system should be altered to restore flow regimes that more resembled historic conditions, including especially increased flows into northeast Shark River Slough and reduced flows into western Shark River Slough to make the dry subpopulations wetter, and the wet ones drier (Walters et al. 2000). This objective, of course, is what the Army Corps of Engineers (USACE) and South Florida Water Management District (SFWMD) who manage the system have been attempting to do for decades, first through the Experimental Water Deliveries Program and then the Modified Water Deliveries to Everglades National Park (ModWaters) project. The former failed to reach objectives for restoring flows to northeast Shark River Slough due to severe flood control constraints, and in fact produced the high water events of 1993-1996, leading the USFWS to take regulatory action to halt the Program due to its adverse impacts on the sparrow (NRC 2007). The latter suffered numerous delays and at the time of the AOU review had yet to be implemented. The C-111 Project, designed to restore more historic flow regimes to Taylor Slough and thus benefit subpopulation D, suffered similar delays. The ModWaters and C-111 projects provided hope for some improvement in conditions for the sparrow populations, but more importantly, the newly devised Comprehensive Everglades Restoration Plan (CERP) promised to restore historic flow patterns on a grand scale (USACE and SFWMD 1999). The AOU panel viewed the CERP as the long-term solution to the sparrow problem.

The AOU panel also concluded that, because the long-term solution was some unknown number of years from implementation, short-term management actions were necessary to protect sparrow populations in the interim. The panel recommended that flows into western Shark River Slough and Taylor Slough should be reduced, and flows into northeast Shark River Slough increased “to the extent possible using existing structures”

(Walters et al. 2000). This recommendation provided a basis for emergency management action to protect the Cape Sable Seaside Sparrow (see below).

THE 2003 SEI PANEL

The focus of the CERP is at the ecosystem level. Its mantra is “get the water right”, and implicit in this approach is a faith that if historic patterns of water flow are restored all the species within the ecosystem will benefit. Given the enormous and varied changes to the system that the CERP entails (it includes 68 major project components; USACE and SFWMD 1999), irreversible historic changes, and the vagaries of weather and climate change, there is considerable uncertainty about the ecological impacts of the CERP (NRC 2003), yet to uphold requirements of the Endangered Species Act, the USFWS must ensure that restoration efforts provide for individual species. To better evaluate the likely impacts of the restoration on the four federally and state-listed endangered bird species inhabiting the Everglades, including the Cape Sable Seaside Sparrow, in 2003 the Department of Interior and South Florida Ecosystem Restoration Task Force asked the Sustainable Ecosystems Institute (SEI) to convene a panel of scientists to review the available information. The panel met with scientists studying these bird species and scientists, engineers, decision-makers and other interested stakeholders involved in the restoration at a workshop held in March 2003, and presented their findings in a report later that year (SEI 2003).

The SEI panel concluded that the restoration, once fully implemented, would benefit all four species and that there were no inherent conflicts between the habitat and other resource needs of these species (SEI 2003). That is, there would be a place for each species within the spatial and temporal variability of a fully restored system. However, the panel recognized that the transition from current conditions to full restoration could result in shifts in the location of suitable habitat, and that persisting through this transition would require the species to be resilient. The SEI panel further concluded that the Cape Sable Seaside Sparrow appeared to be much less resilient than the other species. It has narrow habitat requirements, a short lifespan and high annual reproductive effort and thus might be vulnerable to short-term fluctuations in habitat conditions during the transition, as evidenced by the rapid decline of subpopulation A. Most importantly, at the time of the 2003 review, there was no firm evidence of long-distance movements or colonizing ability in this species, which would be necessary for it to cope with shifts in the distribution of suitable habitat. The SEI panel therefore recommended that more attention be paid to forecasting habitat conditions during the transition from current conditions to full restoration and that particular attention be paid to the sparrow while employing an adaptive management approach in implementing the CERP. The panel ultimately foresaw the CERP as being highly beneficial to the sparrow, as well as to the other three avian species (SEI 2003). The CERP promised to solve what the SEI panel, like the AOU panel, perceived as the fundamental problem facing the sparrows, conditions that were too wet in the prairies of western Shark River Slough and Taylor Slough, and conditions that were too dry in those of northeastern Shark River Slough.

CURRENT SITUATION

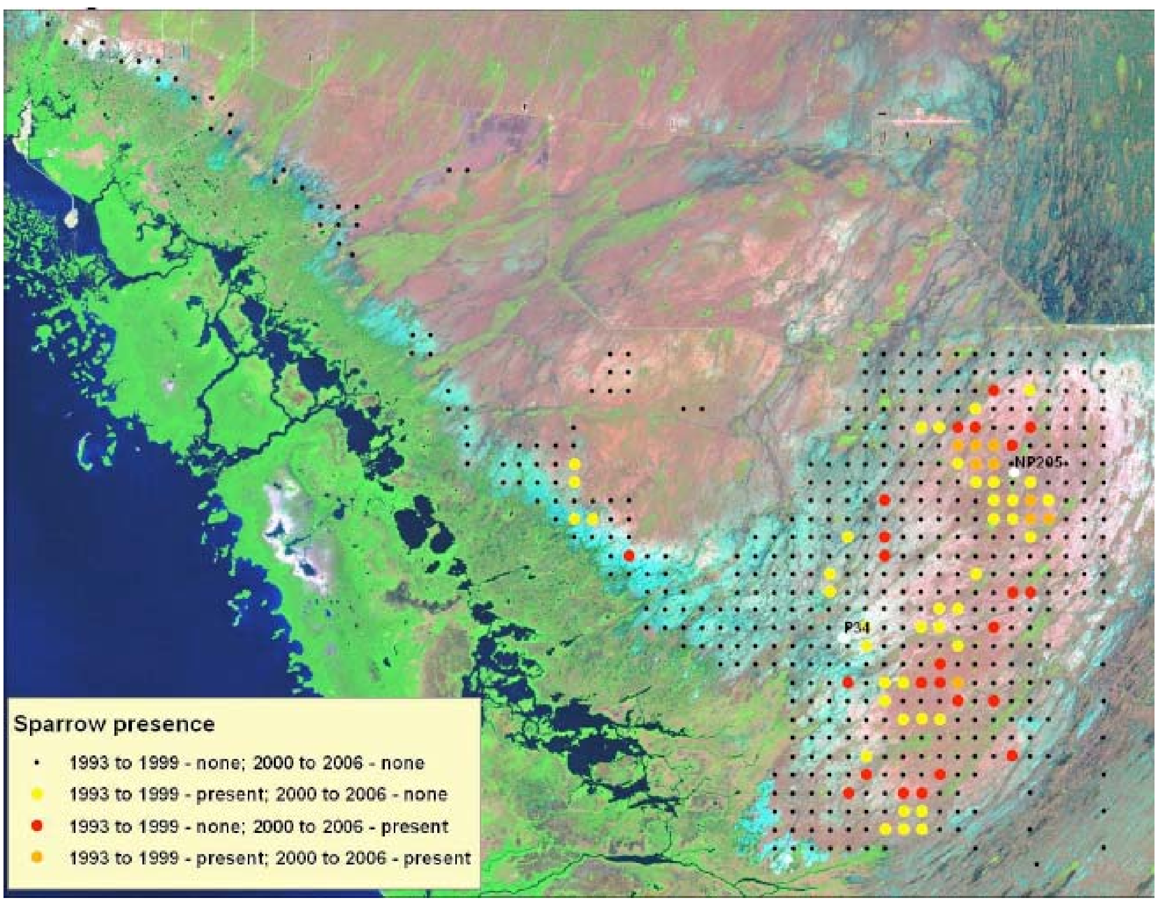
There have been several significant developments with respect to Cape Sable Seaside Sparrows since the AOU panel evaluated the impacts of previous water management and the SEI panel evaluated the projected impacts of the CERP. Additional research recommended by the SEI panel has been carried out. Emergency water management procedures to protect the sparrow over the short-term were implemented as the AOU panel recommended. Contrary to the AOU panel's expectation, however, this short-term management has become long-term management because no significant progress has been made toward restoring historic flow patterns in the areas occupied by the sparrows. Delays to the ModWaters and C-111 projects have continued, and the ecological benefits of the CERP to date have been largely limited to the northern estuaries (NRC 2007). The general problem of too much water to the west and too little to the east continues, with little hope of significant change any time soon. The AOU panel recognized that the short-term management required to protect the sparrow would run counter to the general goal of ecosystem restoration (Walters et al. 2000), and thus has potential to create problems for other species in the system if continued for more than a few years. The situation today is that the underlying problem has yet to be addressed, and what were intended to be stopgap measures to help the sparrow survive through a brief interval until the underlying problem was solved have persisted long enough that they may be becoming problematic themselves. The most obvious manifestation of this situation is that continued regulation of releases into western Shark River Slough has resulted in persistent, high water levels in WCA-3A that have altered ecosystems there. Further exacerbating the situation is that, despite the emergency management designed to protect it, subpopulation A has not increased. Ironically, the high water levels in WCA-3A may be somewhat responsible for this (see below). Another important development is the emergence of important new knowledge about sparrow biology, particularly with respect to movement and the effects of fire, with significant implications for conservation.

EMERGENCY MANAGEMENT

Following the high water events of the mid-1990s, USACE in consultation with USFWS, the National Park Service and SFWMD adopted temporary, emergency water management measures first in the form of an Interim Structural and Operational Plan (ISOP) and subsequently an Interim Operational Plan (IOP). ISOP and IOP were specifically designed to protect subpopulation A by restricting flow from WCA-3A through the S-343, S-344, and S-12 structures into the marl prairies of western Shark River Slough during the sparrow nesting season. The operational goal is to create at least 60 consecutive days of dry conditions during the nesting period, which is achieved by maintaining a water depth of < 6 feet at monitoring station NP205 for this period. IOP represents interim management, and is to be succeeded by the Combined Structural and Operational Plan (CSOP) when the ModWaters and C-111 projects are completed, as the latter are conceived as eliminating the conditions that necessitated emergency management by enabling greater flows to northeastern Shark River Slough.

Perhaps the most startling information presented to the panel was evidence that the intended hydrological consequences of ISOP/IOP may not have been met. ISOP/IOP succeeded in meeting the 60 day criterion at NP205 in every year since 2000 except 2003, and many of the remaining sparrows in subpopulation A are found in the portion of the prairie in which NP205 is located (Figure 3). This finding suggests that ISOP/IOP succeeded in creating desired hydrological conditions and maintaining sparrows in the portion of subpopulation A that is closest to the S-12 structures. However, water levels in the vicinity of the P34 water monitoring station to the southwest have remained high, and sparrows have largely disappeared from this portion of their former range (Figure 3). The best explanation for the result that the panel heard is that there has been unanticipated water flow from the northwest, and the overall distribution of the remaining sparrows is consistent with this hypothesis (Figure 3). Although ISOP/IOP restricts water releases from WCA-3A to the west through the S-343 and S-344 structures during the sparrow nesting season, the high water levels in WCA-3A may have caused water to flow west into Big Cypress through gaps in the L-28 levee and then, due to the funneling effect of the Dade County Jetport, south into the western and southern portions of the prairies inhabited by subpopulation A. Thus emergency management likely has not achieved hydrological targets a significant portion of the range of subpopulation A.

Figure 3. Locations of sparrows in subpopulation A. From Pimm et al. 2007, Figure 4.4.



POPULATION TRENDS

Estimates of error and detectability have yet to be developed for the helicopter-based survey data, so it remains difficult to draw strong inferences from these data. Further, the recent studies of Boulton et al. (unpublished data; SEI Workshop 2007) suggest that the 16-times multiplier that has been used to extrapolate from the number of singing males detected on the survey to give an estimate of the total population size may be too large for the smaller subpopulations. In the smaller subpopulations, territories are larger and densities lower than has been estimated in the larger populations. Placing a confidence interval around the multiplier, and adjusting the multiplier for variation in population size and density across the subspecies' range, would provide better information about uncertainty in population size. Still, when combined with the analysis of occupancy data by Cassey et al. (2007), the surveys provide a clear and consistent picture of recent population trends, if not actual size. Since the declines of the mid-1990s (see above), the Cape Sable Seaside Sparrow population as a whole has been stable (Pimm et al. 2007; Cassey et al. 2007). Population trends are not uniform across the various subpopulations, however. Subpopulation A, despite being the target of the emergency management measures, has continued to decline (Cassey et al. 2007). This decline has not been uniform spatially, but has been concentrated especially in the areas most subjected to unanticipated flows from the northwest, such as the P34 area, whereas the birds closest to the S-12 structures in the NP205 area have fared better. This subpopulation is currently <5% of its size in 1981/1992. That subpopulation A has not only failed to increase, but has continued to decline with ISOP/IOP in place, was unanticipated and is a cause of much concern, not only because subpopulation A remains on the verge of extirpation, but also because this unsuccessful management action has had impacts on other elements of the ecosystem.

Subpopulations B and E, the two remaining "large" subpopulations, have been stable since the mid-1990s. Concerns have been raised about adverse effects of fire, which Pimm et al. (2007) maintain is responsible for a drop in numbers in subpopulation B in 2005 and 2006. Collectively, these two subpopulations have contained an estimated 2500-3000 sparrows since the late 1990s, and constitute 80-90% of the entire population. Subpopulation C remains small, but it is the only subpopulation that has increased significantly since the mid-1990s (Cassey et al. 2007). Subpopulations D and F currently are the smallest populations and both are arguably on the verge of extirpation. Since 2000 only 1-3 singing males have been detected in the helicopter-based surveys in these subpopulations each year, and in the case of subpopulation D, none have been detected in some years. Subpopulation D has continued to decline since the mid-1990s, whereas subpopulation F has been stable, albeit at an extremely small size.

POPULATION STRUCTURE

To date, the Cape Sable Seaside Sparrow population has been treated as a set of six distinct populations. Little information previously existed on sparrow movements, and so these population units have been treated as though they were demographically distinct. New evidence, however, suggests that movement among them occurs regularly. Radio-telemetry has shown that most movements are fairly short (< 400 m), as previously presumed, but that sparrows sometimes move as much as several kilometers (Dean and

Morrison 2001). Banded birds also have been found to make longer distance movements between population segments, with several movements of 20-30 km recorded (Boulton, Lockwood et al. unpublished data; SEI Workshop 2007). Documented movements have involved birds from all population units, both males and females, and birds of different ages. Rapid re-population of areas from which birds had disappeared due to fire, once the vegetation had recovered (LaPuma et al. 2007), further supports the notion that regular dispersal occurs – at least over distances of a few km – and that the sparrows have some capability to find and occupy suitable habitat when it is available.

Given the limited data on long-distance movements, it remains unclear how often sparrows move between population segments, how the rate of movement varies with distance between sites, or how rapidly one can expect new areas to be re-colonized after local extinction. Moreover, it is possible that movement rates could be higher than current data suggest for two reasons. First, banding effort has not been equally distributed throughout all population units and searches for marked birds have not been exhaustive. Second, short-term movements in which birds explore distant areas in search of suitable habitat but then return to their site of origin would go largely undetected unless concerted effort was made to re-sight banded birds throughout the year. Although such movements would not necessarily result in dispersal, they would indicate the potential for birds to settle elsewhere if conditions were suitable.

These results suggest that a fundamental change in the way Cape Sable Seaside Sparrow population structure is treated is appropriate. It seems clear that the population segments to the east of Shark River Slough are well connected. In addition, three of the eight long-distance movements that have been documented since 2002 involved birds moving across Shark River Slough (Boulton, Lockwood et al. unpublished data), suggesting that eastern population units might be connected to unit A as well. Collectively, these new movement data suggest that the implicit assumption that there are six distinct populations is not accurate. Given current knowledge, the population structure is probably best described as a connected set of subpopulations, in which the degree of connection is not fully known. Certainly the six subpopulations do not constitute a single, fluid demographic unit (although several or all of the five eastern subpopulations might). However, there likely is sufficient movement that subpopulations can be “rescued” from extinction (e.g., Stacey and Taper 1992) by dispersal from the other subpopulations. Interestingly, La Puma et al. (2007) show that individuals living in areas that experience fire do not move to nearby unburned areas. It appears that impacts of catastrophes such as fire and flooding likely are manifested in changes in survival of affected individuals rather than increased movement.

The new information on movement indicates that the Cape Sable Seaside Sparrow likely has some capacity to colonize unoccupied, suitable habitat. This ability was suspected (e.g., Post and Greenlaw 2000), but in the absence of any evidence that it existed, management recommendations from previous panels have been based on the premise that the sparrow might be fairly sedentary (Walters et al. 2000; SEI 2003). We therefore draw several conclusions that differ from the findings of previous panels. First, we conclude that the sparrow may be more resilient than was previously suspected (SEI 2003); that is, it is probably better able to respond to shifts in the spatial distribution of its habitat during the transition from current conditions to a fully implemented CERP than was previously recognized. Similarly, the creation of suitable habitat through management could result in natural colonization of currently unoccupied areas. Second, we suggest that maintenance and creation of suitable habitat may be more important, relative to local demography, to the persistence of sparrow subpopulations than was previously recognized. Maintaining vital rates that allow for population growth remains essential, but an emphasis on birds only in the areas where they currently occur is not the only option available to managers. Expanding the total area of suitable habitat, especially in areas within known dispersal distances, might prove more effective for managing this particular species than previously considered. Third, we conclude that the historic management approach of ensuring the maintenance of three distinct populations is invalid. In recent times (i.e., since 1981), there have been at most only two populations, and perhaps only one. More important than trying to delineate populations, is recognizing that protecting the subspecies from catastrophic events will require maintaining sparrows over as wide an area as possible. This recognition actually provides a more compelling rationale for maintaining subpopulation A than the need to maintain three populations did, since subpopulation A is the only subpopulation west of Shark River Slough. It also suggests more emphasis should be placed on maintaining subpopulation D as the southeastern-most subpopulation.

KNOWN THREATS

The threats to Cape Sable Seaside Sparrow subpopulations stem from two sources, flooding and fire, which are both natural components of the Everglades ecosystem. The intent of emergency water management has been to protect one of the subpopulations, A, from adverse effects of flooding. As discussed above, flooding is thought both to reduce reproductive success when high waters occur during the nesting season and to cause changes in vegetation that render habitat unsuitable for sparrows when hydroperiods are prolonged. The former effect is thought to operate through greater rates of nest predation at higher water levels (Lockwood et al. 1997; 2005). The contention that water depths above 10 cm limit nesting habitat and inhibit nesting (Nott et al. 1998; Pimm et al. 2002), and that 60 days of suitable conditions are required to fledge one brood and initiate a second, resulted in the operational objective of ISOP/IOP to provide water depths below 10 cm for at least 60 days at the NP205 water monitoring station. Because of this management objective, the portion of subpopulation A in this area has not been subjected to the threat of high water (Pimm et al. 2007). However, Pimm et al. (2007) present evidence that other portions of subpopulation A such as the area around the P34 water monitoring station have experienced high water levels during the nesting season (apparently due to flows from the northwest, see above) that may have limited their productivity. Lack of demographic data from subpopulation A make it difficult to determine the extent to which this spatially variable threat has contributed to the continuing decline of subpopulation A, but the high water hypothesis proposed by Pimm et al. (2007) fits all of the available data.

Habitat change clearly is a factor in the decline of subpopulation A. There has been a shift toward more marsh vegetation and less wet prairie vegetation in subpopulation A since the high water events of the mid-1990s, and there is no indication that the vegetation is moving back toward wet prairie. If anything, the vegetation is continuing to shift toward the marsh end of the spectrum (Ross et al. 2004; Sah et al. 2007). *Muhlenbergia*, once a dominant plant on these prairies, is almost nonexistent today. Sawgrass marsh is predominant even in the area near NP205 in which lower water levels have been achieved during the sparrow nesting season, although the shift toward wetter vegetation in recent years appears to be greater in the central part of subpopulation A than in the NP205 area. As had occurred in subpopulation D previously (see above), habitat has shifted toward vegetation unsuitable for sparrows in subpopulation A since the mid-1990s (see also Pimm et al. 2002; 2007).

It is unclear whether subpopulation D experiences water levels during the nesting season that could limit reproduction. It is quite clear, however, that the habitat in this area remains largely unsuitable for sparrows. What was almost entirely wet prairie in 1981, and had shifted to a mix of wet prairie and marsh vegetation by 1992, is almost entirely marsh today (Ross et al. 2004). Thus the continuing decline of subpopulation D parallels a continuing shift toward unsuitable condition in its habitat. Moreover, the situation in subpopulation D provides clear insight into what might be expected in subpopulation A if conditions there continue to follow their current trajectory.

Although subpopulations E and B are not usually thought of as vulnerable to the threat of flooding under current management conditions, portions of the area they occupy have shifted toward wetter habitat types under ISOP/IOP (Ross et al. 2004; Sah et al. 2007). Still, the vegetation in these areas remains at least as dry in 1981, and these subpopulations have not experienced prolonged high water during the nesting season. These subpopulations have instead been viewed as vulnerable to the second threat to sparrows, fire. The AOU panel was not convinced of the contention of Pimm et al. (2002) that fire posed as great a risk to the subpopulations near northeastern Shark River Slough as flooding did to subpopulations A and D, but instead concluded that occasional fire might be required to maintain sparrow habitat (Walters et al. 2000). Subsequent data on the response of sparrows and sparrow habitat to fire indicate that the AOU panel may have underestimated the risk posed by fire. The data indicate that habitat quality as evidenced by sparrow density, survival and reproduction is immediately reduced after fire and remains low for two or three years before returning to levels indistinguishable from unburned areas (La Puma et al. 2007). There is no indication that unburned habitat becomes unsuitable over time due to plant succession in areas that have been monitored for more than a decade (La Puma et al. 2007). It may be the case that over longer time spans fire is necessary to maintain marl prairie habitat, however. Both subpopulation B and subpopulation E (as well as subpopulation F) have experienced major fires that burned significant portions of their habitat since 2000 (La Puma et al. 2007; Pimm et al. 2007).

The habitat occupied by subpopulations C and F shifted toward vegetation indicative of drier conditions between 1981 and 1992, becoming essentially entirely wet prairie, and has remained primarily wet prairie since (Ross et al. 2004). As the subpopulations experiencing the driest conditions under current management (described as “dusty and

desert-like by Boulton, pers. comm.), they have been vulnerable to fire, but not flooding. Recent work by Lockwood et al. (2006) indicates that extremely dry conditions result in elevated nest predation through mechanisms that are not yet understood. Extremely dry conditions may be viewed as a newly discovered threat to which subpopulations C and F are especially vulnerable.
A third potential threat to sparrows comes from hurricanes. The hypothesis that the decline in subpopulation A could be attributed to Hurricane Andrew has been found to be poorly supported (Walters et al. 2000), but it remains possible that future hurricanes could impact the subspecies. The major source of this concern is simply that as the sparrow population declines and becomes more concentrated in space, there is an increased risk that a hurricane could affect a large proportion of the population at the same time.

Lastly, as is true for many aspects of the Everglades ecosystem, there are potential threats and substantial uncertainties associated with climate change and sea level rise. We discuss likely effects of the latter on flooding and vegetation in a separate section below.

CURRENT UNCERTAINTIES

The amount of critical new information about the sparrow that has emerged in the last few years is impressive. Certainly this panel has a much broader and deeper understanding of Cape Sable Seaside Sparrow biology with which to work than did the previous two. Still, answers to old questions invariably suggest new questions, and thus several areas of uncertainty remain. The causes of the poor performance of subpopulation A are uncertain. Unexpectedly high water in portions of its range and changes in vegetation clearly contributed to poor performance, but it is not clear that these factors are sufficient to account for continuing decline despite emergency management designed specifically to promote this subpopulation. Moreover, the precise mechanism of decline is unclear - high waters could result in nest flooding, or they might make nests more vulnerable to predators. Disentangling these alternative explanations would help to identify specific actions that could be taken to mitigate against further declines. Lack of demographic data from subpopulation A hampers our understanding of declines and the likelihood for recovery in that formerly very important part of the sparrow's range.

Many of the areas of inquiry that are suggested by the poor performance of subpopulation A apply to other subpopulations as well. A more detailed understanding of the causes of nest loss, especially the role of predators, would be valuable. Although it is well established that most nest failures are caused by predation, the key predators, their abundance, and their interactions with sparrows are poorly known. Consequently, little is known about the potential for predator control to benefit populations. Lockwood et al. (2006) show that short-term spikes in water levels lead to increases in nest predation, as do extremely dry conditions. These findings suggest a very different approach to managing water levels to promote sparrow nesting success than the current strategy of simply staying below a threshold water level. That contaminants, particularly mercury, could be contributing to poor performance of the birds in this area is another possibility that might be explored.

A key uncertainty is the extent to which unoccupied but suitable sparrow habitat exists. Given that recent data indicate that sparrows have the dispersal capabilities necessary to locate unoccupied suitable habitat, the degree to which such habitat exists could be used as an indicator of what is limiting sparrow numbers. An abundance of such habitat would indicate the importance of things that affect vital rates and thus keep numbers below carrying capacity, such as nest predation tied to unfavorable hydrology. There is evidence that at least some such habitat exists in some subpopulations (Jenkins et al. 2003a; b). Lack of such habitat indicates that it is habitat availability, not vital rates, that is limiting. These two conclusions would result in very different recommendations for increasing the population size. The degree to which changes in vegetation are correlated with subpopulation performance suggests that the lack of habitat might be most important, as does the failure of population density to increase or for displaced birds to appear elsewhere following fire (La Puma et al. 2007). New detailed data on the distribution of individuals in the eastern subpopulations C, D and F also point to the absence of suitable habitat as a factor in the small sizes of these populations (Lockwood et al. 2006). Currently, however, it is uncertain whether it is most important to manage for an increase in particular vegetation communities or to focus attention on trying to improve nest success rates.

Finally, another possible, albeit more speculative, explanation for poor performance of subpopulation A, as well as subpopulations C, D and F is that there is an Allee effect whereby the performance of individual sparrows declines below some threshold population density. The importance of conspecific attraction and other social interactions on the dispersion, settlement, and reproductive behavior of sparrows is a worthwhile area of investigation in the panel's view. This information also would allow a better assessment of the potential for enhancing settlement in unoccupied areas of suitable habitat if such areas could be identified or created through management.

CONSEQUENCES OF STATUS QUO

LIKELY POPULATION TRAJECTORIES

Although the sparrow population size has been relatively stable for a number of years and there is no reason to presume that it will decline substantially in the immediate future, the long-term prognosis is not good under current conditions. The crash of subpopulation A in the mid-1990s demonstrates the potential for catastrophic events to cause substantial declines over very short time periods. In the highly dynamic Everglades ecosystem it is quite possible that events will occur in the future that could have equivalently large effects. The two remaining large subpopulations (B and E) are both vulnerable to prolonged drought in that such conditions might result in catastrophic fire. Recent evidence suggests that such an event would result in the loss of the affected portion of the population rather than relocation of those individuals (LaPuma et al. 2007), as occurred in subpopulation A when it was subjected to prolonged high water. Prolonged dry conditions apparently have adverse conditions on productivity as well (Lockwood et al. 2006). Subpopulations A and D remain vulnerable to the effects of flooding. In summary, under current conditions the Cape Sable Seaside Sparrow population is sufficiently small and its range is sufficiently restricted that it is extremely vulnerable to environmental stochasticity.

Even if catastrophic events do not arise, several of the subpopulations (D, F, A and perhaps C) are small enough that demographic stochasticity puts them at risk. Loss of these small subpopulations seems quite likely under current conditions, simply due to chance demographic events (e.g., all young produced in a population in a given year are of the same sex; all birds within a subpopulation happen to die in the same year). Although the loss of these small subpopulations may not substantially affect the total number of sparrows, the resulting range contraction would make the overall population even more vulnerable to a catastrophic event that adversely affects all remaining individuals. The loss of subpopulations A and D, because of their geographic locations, would result in especially significant range reductions (see above).

There is evidence that subpopulations A and D are continuing to decline (Cassey et al. 2007), and that this decline is due at least in part to continuing unfavorable conditions rather than stochastic effects alone. The panel is especially concerned by evidence of continuing changes in habitat that are harmful to the sparrows in the areas containing these two subpopulations (Pimm et al. 2002; 2007; Ross et al. 2004; Sah et al. 2007).

The likelihood of the population increasing under current conditions seems remote. Lack of recovery has apparently resulted from the failure of water management measures under ISOP/IOP to have the predicted effect of reducing flooding in the western portion of the Everglades, and the slow movement towards achieving the goals of ModWaters whereby substantial amounts of water would have been shifted to the east and allowed to flow under the Tamiami Trail. This combination of events has maintained undesirable conditions that have limited the potential for population growth and resulted in gradual declines in some areas. Some subpopulations (A, D) continue to be chronically exposed to high water, others (B, C, E, F) to conditions that are too dry.

MANAGEMENT OPTIONS

Many of the fundamental problems underlying the difficulties that plague the sparrow remain unchanged since the assessment of the AOU panel nearly a decade ago (Walters et al. 2000). Until managers of the system increase capacity to allow greater flows to northeastern Shark River Slough and reduce the volume of water in WCA-3A and flows to western Shark River Slough, any recovery of sparrow subpopulations is unlikely. Emergency management designed to reduce flows to western Shark River Slough to protect one subpopulation (A) did not produce recovery of that subpopulation, and the large volumes of water that remain in the western part of the system appear to be largely responsible for that failure. Restoration efforts in the form of the ModWaters and C-111 projects and the CERP are designed to alleviate the underlying hydrological problems that plague the sparrow, but until they are implemented the chances that the sparrow's plight will improve are remote, and the chances that it will decline further for the various reasons outlined above are high.

The panel underscores that, ultimately, possible actions and combinations of actions have to be evaluated by whether or not they move the system toward or away from the overall goal of making the habitat and local environment suitable for the sparrow. But specific actions considered in isolation may distract from this goal. For example, one option that has been suggested is to cease emergency management measures and once again allow regulatory releases of water through the S-12 structures during the sparrow's nesting season. Given the extensive previous work by others, the panel believes that, in isolation, this action is likely to result in the extirpation of subpopulation A, and is unclear if it would benefit or otherwise affect the other subpopulations or other endangered species. But, ultimately, it is the expected effect on the habitat for the sparrow that is critical; if such an action is expected to have a negative overall effect on the sparrow, its justification as a conservation measure would require a clear demonstration that there would be positive effects on other elements of the Everglades ecosystem. The panel found no conclusive evidence that such action would in all cases benefit any of the other three endangered bird species that we examined substantially (see below), and thus conservation benefits would have to be found elsewhere.

In contrast, virtually any new management, emergency or otherwise, that resulted in diversion of more water to the east is likely to benefit the sparrow, as well as the other three species examined (see below). Another emergency management measure that might be considered is prescribed fire. Sah (SEI Workshop 2007) presented evidence that areas that have shifted from wet prairie to marsh vegetation are unlikely to revert back to wet prairie, even under favorable hydrological conditions, unless they are burned. Further research on this topic is needed to pursue the possibility that prescribed fire might be used to improve habitat conditions for the sparrows in subpopulations A and D.

However, a more refined and integrated view of fire management is needed to support decisions regarding use of prescribed fire. The model proposed by Lockwood et al. (2003) shows the dynamic interplay of hydrology, fire, vegetation and soil accumulation in determining whether the dominant vegetation is sawgrass or the wet prairie dominated by muhly grass in which Cape Sable Seaside Sparrows are most abundant. To this complex interplay, recent studies by Gaiser and colleagues (Gottlieb et al. 2005, Gaiser 2006, Thomas et al. 2005) add the critical role played by periphyton in maintaining marl prairie through marl formation. According to Gaiser (personal communication to panel, September 24, 2007), what she and her colleagues have found to date is that "periphyton production in the marl prairie, particularly in places dominated by Muhlenbergia, is higher than elsewhere in the Everglades (or any other wetland we have been able to find in the literature). Periodic drying seems to stimulate production in two ways – by creating a more consolidated benthic substrate for algal colonization and by re-mineralizing nutrients from the previous wet season. After re-hydrating, the periphyton sequesters most of the phosphorus out of the water column and pore water, and photosynthesis drives up the pH which causes marl to precipitate biotically and abiotically. Periodic drying keeps organic materials from accumulating. This cycle promotes the calcareous system which is also a good sink for P." She also notes that water levels in the area of subpopulation A are much higher than at the marl prairie sites, which has promoted the recent organic soil formation reported by Sah to this panel and a floating periphyton community that is much less productive than in areas occupied by Cape Sable Seaside Sparrow on the east side of Shark River Slough where hydroperiods are shorter (Gaiser personal communication to panel, September 24, 2007). This is a promising line of research that managers might make more use of in attempting to predict and manage for creation of new suitable habitat for sparrows.

COLONIZATION OF UNOCCUPIED HABITAT

New data on sparrow movement that indicates that the subspecies has greater resiliency than was previously evident (see above) increases hope that the sparrow can persist through current unfavorable conditions and the coming restoration. This information suggests, for example, that small subpopulations extirpated due to chance events might be reestablished, and subpopulations suffering after large fires might be able to recover. Under current conditions, however, it seems unlikely that dispersal can drive establishment of new subpopulations or recovery of existing ones, due to a lack of unoccupied habitat, lack of excess individuals, or both. Uncertainty remains over each of these assumptions, however. Without better demographic information from subpopulation A, the cause of its recent decline under emergency management remains uncertain. Lack of substantial population growth can be explained by high water conditions over a considerable portion of the range of subpopulation A. However, the habitat that was successfully protected would seem to permit a larger population than currently exists; yet the subpopulation continues to decline. It is possible, for instance, that suitable habitat remains in portions of subpopulation A that are currently unoccupied and that this habitat has not been filled due to a lack of dispersers from elsewhere (Jenkins et al. 2003a; b). Also, current reproductive rates may be insufficient to produce enough recruits to allow the population to expand into new areas. More detailed demographic modeling, however, is needed to test this assumption (Elderd and Nott 2007).

Despite these uncertainties, it would be unreasonable, given current knowledge, to expect the population to spread to new areas without the creation of more favorable habitat or an increase in population growth rate. Under current conditions it seems as though all of the subpopulations are chronically exposed to what historically would have been extreme conditions, toward either the wet (subpopulations A and D) or dry (subpopulations B, C, E and F) end of the hydrological cycles that characterized marl prairies. Extreme conditions affect both habitat (fire effects due to drought, conversion of prairie to marsh under wet conditions) and productivity. Whether sparrow numbers are currently limited by habitat or productivity is unclear, and the answer may vary among subpopulations.

CONSEQUENCES OF CERP

The CERP represents a promise of a better future for the Everglades ecosystem. The previous SEI panel concluded that the CERP, once fully implemented, would improve conditions for all four bird species by redistributing water to better match flow patterns that existed prior to the human-engineered water management system, but that there was more uncertainty about the impact of CERP on the Cape Sable Seaside Sparrow than for the other three species, especially during the transition from current conditions to full implementation (SEI 2003). First, there was more uncertainty about the extent to which CERP would create conditions favorable to short hydroperiod prairies compared to other habitat types examined. Second, there was little evidence that the sparrow had sufficient resiliency to shift its distribution as the location of suitable habitat shifted in space during the transition. The second concern has been reduced by new data indicating considerably more capacity for dispersal than was evident previously (see above), but remains an issue because the overall reduction in population size makes the pool of birds from which potential dispersers can derive smaller. On the other hand, it was evident to the panel that managers are now much more worried about the first concern than they were previously.

Increased concern about the effect of CERP on sparrow habitat arises from new runs of the Natural System Model (NSM) that indicate wetter conditions in western Shark River Slough than did previous runs. Output from the NSM is postulated to represent historic hydrological conditions, prior to the engineered water management system, for given locations. Its output is used to set restoration targets, and one can argue that the objective of CERP is to re-engineer the system to match the output of the NSM (NRC 2003). Sometimes the hydrological output from the NSM does not match empirical ecological data (i.e., pollen cores indicating previous vegetation) with respect to the historic plant community at a particular location. That is, the community that the empirical data indicate was present at the site could not have existed under the hydrological conditions that the NSM indicates were present. In the case of the marl prairies west of Shark River Slough, however, the available empirical data appear to support the NSM output. Bernhardt and Willard (2006) reported that pollen cores taken from marl prairies in the Rattlesnake Ridge area within Big Cypress Preserve, located in the northwestern part of subpopulation A, indicate that this region was comprised of sawgrass marsh and other wetter habitats rather than marl prairie prior to the engineered system. They suggest that marl prairies developed in this region in response to drier conditions imposed by the implementation of water management. These empirical data suggest that the model results indicating that at least some of the marl prairie occupied by subpopulation A will convert to wetter habitats under CERP are realistic. Managers' intent on protecting sparrows could simply adjust their objectives for areas inhabited by sparrows that are predicted to become unfavorable under CERP, rather than attempting to match NSM output. Alternatively, if maintaining sparrow habitat means compromising goals for ecosystem restoration, especially the ability to move sufficient water south to Everglades National Park and Florida Bay, there would be a legitimate case for putting some sparrow subpopulations at risk. Such an action would be in the spirit of management recommended by the previous SEI panel, where habitats might be expected to shift in space during the restoration process, but where species are presumed to have sufficiently resiliency to abandon some areas and colonize others as conditions change (SEI 2003). This panel, like the last one, believes that some risk to individual species is justified in order to accomplish long-term, system-wide restoration. But, it is important to recognize that the longer it takes for CERP to move forward, the greater the risk to individual species becomes. Whether the CERP could be modified to maintain marl prairies in the area of subpopulation A or some portion thereof without compromising ecosystem restoration objectives is a possibility that should be examined, as should the possibility that drier conditions in other areas will result in new marl prairie habitat that might be suitable for sparrows. Also, it is not at all clear that all of the marl prairie occupied by subpopulation A will become unsuitable, as pollen cores have been collected from only one area at the edge of the current range. Collecting more cores from more areas is desirable in order to better understand the distribution of marl prairie prior to the engineered system. This information would help guide decisions about where marl prairie habitat will be maintained, restored, or converted to marsh during CERP.

Another change in the CERP since the previous panel is that a much more active adaptive management approach is now being used to achieve ecological objectives (NRC 2007). The panel recommends that this approach be applied in managing the wet prairies inhabited by sparrows as CERP is implemented in an attempt to achieve the dual objectives of providing suitable sparrow habitat while improving ecological conditions in the regions south of the prairies.

Although concerns about the Cape Sable Seaside Sparrow expressed to the panel focused on future impacts of implementing CERP, the immediate effects of recent developments since the 2003 panel are equally troubling. It is quite clear to the panel that the benefits to the natural system of the CERP and associated projects have been significantly delayed, and thus the sparrows will have to endure the threats they face currently for much longer than was anticipated in 2003. The Decomp (Water Conservation Area 3 Decomparmentalization and Sheet Flow Enhancement) Project, viewed as the centerpiece of ecological restoration and one of the 10 CERP projects approved in the initial authorizing legislation (i.e., WRDA 2000) for the restoration, has been significantly delayed. Decomp involves removal of levees and canals and raising of the Tamiami Trail in order to enable broad sheet flow through the Water Conservation Areas and on through Shark River Slough and Taylor Slough into Florida Bay. It is the only one of the 10 projects approved by Congress in the authorizing legislation to have been delayed – initially scheduled for completion in 2010, it has now been delayed by at least 10 years, with a current scheduled completion of 2020 (NRC 2007). ModWaters lays the foundation for Decomp by providing for flood control and removing some barriers to sheet flow to enable movement of more water through northeastern Shark River Slough. The AOU panel's recommendation of emergency management to protect the sparrows was based on the premise that implementation of ModWaters would soon alleviate the crisis and thus emergency management would be needed only temporarily (Walters et al. 2000). ModWaters has yet to be implemented, although it is finally progressing such that managers will be able to move more water east within the next year. This development will provide some relief, but the capacity of the system to deliver water to northeastern Shark River Slough will still be far less than is needed for restoration of the natural system, so the problems the sparrows face will be somewhat reduced but still unsolved. Furthermore, ModWaters has been delayed so long that project costs have increased to the point that the original design of the project has been compromised, and therefore some of its elements, most importantly raising of a portion of the Tamiami Trail, have been shifted from ModWaters to Decomp. The end result is that ModWaters, even when completed, will provide significantly less capacity to move water through the eastern portion of the ecosystem than originally envisioned. Thus, without emergency management to prevent it, the western prairies likely will remain vulnerable to extended periods of high water, and the eastern prairies to overly dry conditions, for another 15 years at least, until Decomp is implemented. The inability to change the water management system in ways that have long been seen as necessary to restore the ecosystem, in a reasonable time frame, has clearly put the Cape Sable Seaside Sparrow at risk.

ACTIONS AND RECOMMENDATIONS

In this section we first summarize the primary conclusions we have drawn in the analysis of the status of the Cape Sable Seaside Sparrow presented above and then present our recommendations for this species. We present a brief summary of our reasoning for each set of recommendations.

CONCLUSIONS

Under current conditions the Cape Sable Seaside Sparrow population is sufficiently small and its range is sufficiently restricted that it is extremely vulnerable to environmental stochasticity. The likelihood of the population increasing under current conditions seems remote. Until managers of the system increase capacity to allow greater flows to northeastern Shark River Slough and reduce the volume of water in WCA-3A and flows to western Shark River Slough, any recovery of sparrow subpopulations is unlikely. The panel underscores that possible actions and combinations of actions have to be evaluated by whether or not they move the system toward or away from the overall goal of making the habitat and local environment suitable for the sparrow. But specific actions considered in isolation may distract from this goal. For example, one option that has been suggested is to cease emergency management measures and once again allow regulatory releases of water through the S-12 structures during the sparrow's nesting season. The panel concludes that this action is likely to result in the extirpation of subpopulation A, and is unlikely to benefit or otherwise affect the other subpopulations. It is quite clear to the panel that the benefits to the natural system of the CERP and associated projects have been significantly delayed, and thus the sparrows will have to endure the threats they face for much longer than was anticipated in 2003. The inability to change the water management system in ways that have long been seen as necessary to restore the ecosystem, in a reasonable time frame, have clearly put the Cape Sable Seaside Sparrow at risk.

Perhaps the most startling information presented to the panel was evidence that the intended hydrological consequences of ISOP/IOP may not have been met. The best explanation for the result that the panel heard is that there has been unanticipated water flow from the northwest, and the distribution of the remaining sparrows is consistent with this hypothesis. Thus emergency management likely has not produced desired conditions over a significant portion of the range of subpopulation A.

Whether sparrow numbers are currently limited by habitat or productivity is unclear, and the answer may vary among subpopulations. A key uncertainty is the extent to which unoccupied, but suitable, sparrow habitat exists. The causes of the poor performance of subpopulation A are uncertain, but habitat change clearly is a factor. It is unclear whether subpopulation D experiences water levels during the nesting season that could limit reproduction, but it is quite clear that the habitat in this area remains largely unsuitable for sparrows. Another possible, albeit more speculative, explanation for poor performance of subpopulation A, as well as subpopulations C, D and F is that there is an Allee effect whereby the performance of individual sparrows declines when population density falls below some threshold. The importance of conspecific attraction and other social interactions on the dispersion, settlement, and reproductive behavior of sparrows is a worthwhile area of investigation in the panel's view.

Empirical data support model predictions that suggest at least some of the marl prairie occupied by subpopulation A will be converted to wetter habitats with the implementation of the CERP. Managers' intent on protecting sparrows could simply adjust their objectives for areas inhabited by sparrows that are predicted to become unfavorable under CERP, rather than attempting to match NSM output. Alternatively, if it were the case that maintaining sparrow habitat meant compromising goals for ecosystem restoration, especially the ability to move sufficient water south to Everglades National Park and Florida Bay, this would be a legitimate reason to put some sparrow subpopulations at risk. Whether the CERP could be modified to maintain marl prairies in the area of subpopulation A without compromising ecosystem restoration objectives is a possibility that should be examined.

The data indicate that habitat quality as evidenced by sparrow density, survival and reproduction is immediately reduced after fire and remains low for two or three years before returning to levels indistinguishable from unburned areas. There is no indication that unburned habitat becomes unsuitable over time due to plant succession in areas that have been monitored for more than a decade, but it may be the case that over longer time spans fire is necessary to maintain marl prairie habitat. Prescribed fire might be used to improve habitat conditions for the sparrows in subpopulations A and D by promoting conversion of marsh back to wet prairie. A more refined and integrated view of fire management is needed to support decisions regarding use of prescribed fire.

New information on movement indicates that the Cape Sable Seaside Sparrow may be more resilient than was previously suspected and likely has some capacity to colonize unoccupied, suitable habitat. We conclude that maintenance and creation of suitable habitat may be more important, relative to local demography, for the persistence of the overall population units than previously recognized. Maintaining vital rates that allow for population growth remains essential, but an emphasis on birds only in the areas where they currently occur is not the only option available to managers. Population structure is probably best described as a connected set of subpopulations, in which the degree of connection is not fully known. Therefore the historic management approach of ensuring the maintenance of three distinct populations is invalid.

WATER AND FIRE MANAGEMENT

The fate of the sparrow is tied to the fate of the marl and mixed-marl prairies within Everglades National Park. Anthropogenic alterations in hydrology have resulted in vegetation changes (Jenkins et al. 2003a; b; Ross et al. 2004; Sah et al. 2007) and fire frequencies (Curnutt et al. 1998; Jenkins et al. 2003b; La Puma et al. 2007) that have affected both the marl prairies and the sparrow. The conservation of the marl prairies and the sparrow clearly depends on "getting the water right" under the CERP (Lockwood et al. 2003). Unfortunately, because implementation of CERP projects aimed at restoring the natural flow of water to northeastern Shark River Slough (i.e., ModWaters and subsequently Decomp) have been seriously delayed the sparrow will suffer an increased risk of extinction for the foreseeable future.

Recommendations

- Continue to protect subpopulation A from unfavorable hydrological conditions for foreseeable future, until principal water flows to northeastern Shark River Slough can be re-established.
- Determine extent of increased flows to western portions of subpopulation A under IOP, and causes thereof, and adjust accordingly.
- Complete C-111 and "leaky reservoir project" as soon as practicable and monitor associated effects on water flows and vegetation.
- Improve modeling tools by downscaling insights such as those gained from the more regional models to scales important to the Cape Sable Seaside Sparrow.
- Examine less costly alternatives to secure principal flows to northeastern Shark River Slough and explore means to preserve subpopulation A without sacrificing ecosystem restoration objectives using Incremental Adaptive Restoration (IAR) process suggested by National Research Council (2006).
- Continue long-term studies on vegetation changes in marl prairies as a result of the interactions among hydrological conditions, fire, periphyton and soil (marl or peat) formation.
- In marl prairies, focus more on converting areas that have shifted from wet prairie vegetation to marsh back to wet prairie. Determine if fire is needed to enable this conversion.
- Continue to monitor amount and distribution of sparrow habitat using remote sensing, aerial photographs, and ground plots. Focus more on vegetation rather than relying solely on water depths during the nesting season to define habitat availability.
- Manage water flows to prevent conversion of marl prairies to marsh and promote sparrow survival and reproduction.
- In order to maximize the likelihood that CERP will result in a spatially and temporally dynamic mosaic of communities that support sparrows, additional paleo-ecological studies need to be undertaken over a greater area.

ANNUAL CENSUSES

Monitoring the extent and size of the sparrow subpopulations is a critical component of recovery and underlies the process of adaptive management. The AOU panel (Walters et al. 2000) concluded that the population estimates generated by the annual range-wide sparrow survey (Kushlan and Bass 1983) do not allow for strong inferences on abundance due to the inability to determine underlying probabilities associated with detection probabilities and calculated population sizes. As noted above, the recent analysis by Cassey et al. (2007), which examines occupancy rather than abundance at census sites, allows stronger inferences concerning population trends and largely supports prior interpretations of the survey data (Curnutt et al. 1988; Nott et al. 1988; Walters et al. 2000; Pimm et al. 2002), and the contention that the total sparrow population has remained fairly constant since the mid 1990's (Pimm et al. 2007). Efforts to re-design the sparrow survey (Pimm et al. 2007), estimate errors and detection probabilities (Lockwood et al. 2006), and develop survey methods appropriate to low density situations (Lockwood et al. 2006; Cassey et al. 2007) are underway, and should continue to have high research priority.

Recommendations

- Continue annual helicopter surveys and ongoing studies to improve population estimates in low density situations.
- Continue to assess population and subpopulation trends based on presence/absence criteria.
- Determine detection probabilities in both high and low density circumstances.
- Refine multipliers used to estimate population size by extrapolation, to estimate uncertainty and account for variation among areas with different numbers of birds.
- Develop ground survey methods appropriate for surveying sparrows in low density situations.

DEMOGRAPHY AND MOVEMENTS

Documentation of variation in demographic parameters is essential for examining the links between habitat conditions and limiting factors, and for developing predictive models of extinction risk. Although a great deal of demographic information has been collected on the sparrow (Lockwood 1997; Pimm et al. 2002; Lockwood et al. 2006), much of this information has been gathered from study plots within the larger subpopulations, B and E. While gathering demographic information on the smaller subpopulations will remain logistically problematic, we agree with Cassey et al. (2007) that there is a clear need to understand how sparrows are behaving, reproducing, and surviving within low occupancy situations.

Recent information on the movements of marked birds indicates that long distance dispersal between subpopulations may be more common than previously appreciated (Boulton and Lockwood unpublished data). Clearly additional information on the dispersal of juveniles and adults is needed to fully understand the structure and dynamics of the sparrow subpopulations and improve models of extinction risks (cf. Elderd and Nott 2007).

Recommendations

- Collect basic demographic information with respect to habitat within all subpopulations on an annual basis.
- Capture and band juveniles and adults within established study plots in all subpopulations on a routine basis.
- Determine sex of banded birds via DNA from blood or feathers collected at time of banding to provide information on sex ratios.
- Conduct regular surveys for marked individuals outside of study plots to improve estimates of movement and survival.

NEST PREDATION

Baiser and Lockwood (2006) recently completed the most thorough examination of nesting success in Cape Sable Seaside Sparrows conducted to date. They monitored 330 sparrow nests in subpopulations B (n=180) and E (n=150) over 9 years. In total, 197 (60%) nests succeeded (i.e., produced at least 1 fledgling), 120 (36%) failed (i.e., fledged no young), and the fate of 13 (4%) was unknown. Of the 120 nests that failed, 116 (96%) failed due to predation, 3 (3%) failed due to flooding, and 1 (1%) failed due to parental abandonment. These results confirm predation as the principal cause of nest failure (Lockwood et al. 1997; Pimm et al. 2002), and are similar to findings in other races of Seaside Sparrow (Post and Greenlaw 1994).

While a host of potential reptilian, avian, and mammalian nest predators co-occur with the Cape Sable Seaside Sparrow (Pimm et al. 2002), preliminary findings with nest cameras indicate that the Rice Rat (*Oryzomys palustris*) is a regular predator on eggs and nestlings (Baiser and Lockwood 2006). In northern Florida, Post (1981a) found that Rice Rats and Fish Crows (*Corvus ossifragus*) accounted for most nest losses in Seaside Sparrows. Although Rice Rats primarily consume aquatic organisms, such as immature flies, snails, and crabs (i.e., Negus et al. 1961; Sharp 1967; Kruchek 2004), they are opportunistic feeders that will shift their diet to exploit other available resources (e.g., bird eggs, insects, seeds, herbaceous plants, and dicot vegetation) (Kale 1965; Sharp 1967; Orians 1973; Post 1981a; b; Kincaid and Cameron 1982). Rice Rats are highly aquatic and regularly inhabit emergent plants in standing water and at wetland margins (Goertz and Long 1973). They can readily swim underwater for 10 m (Escher et al. 1961), and resident populations can reach high densities [17.8/ha in sedge habitat in Louisiana (Negus et al. 1961), 5/ha in spring and 25/ha in late fall and early winter in coastal Texas (Kruchek 2004), 28-59/ha in coastal Texas (Abuzeinuh et al. 2007), and 31/ha on tree islands in Everglades National Park during the wet season (Smith and Vrieze 1979)]. Smith and Vrieze (1979) documented that Rice Rats bred during the wet season in Everglades National Park, but vacated the tree islands and moved to more mesic sites during the dry season. In contrast, reproductive activity in coastal Texas and Virginia was lowest in summer and autumn (Kruchek 2004), and populations remained high even through prolonged periods of inundation (Abuzeinuh et al. 2007). Post (1981b) suggested that the activity of Rice Rats influences the habitat distribution of Seaside Sparrows in a northern Florida salt marsh, and that the two species compete in terms of vertical space for nesting sites.

Nest predation is highly variable between locations and years (Lockwood et al. 2001). Lockwood (1997) reported that an increase in surface water corresponded to an increase in sparrow nest predation rates, whereas Baiser and Lockwood (2006) found that predation increased both during short-term spikes in water levels and during dry years. Although the connection between short-term spikes in water flows and increased predation remains unclear at this time (Baiser and Lockwood 2006), this finding is consistent with predation by Rice Rats and probably reflects their increased movements as water levels increase. However, Baiser and Lockwood (2006) have suggested that reduced food availability during dry years may require females to make longer and more frequent foraging trips, thereby increasing the probability of nest detection and subsequent predation. Because sparrows forage during the day and Rice Rats are primarily nocturnal, this hypothesis implies predation by a visual, diurnal nest predator, such as the Fish Crow.

A high priority should be placed on identifying sparrow nest predators to ascertain the potential for control. Based on the available evidence, studies of Rice Rat densities and movements in and around Cape Sable Seaside Sparrow habitat during the breeding season are warranted, and should be undertaken. Abuzeinuh et al. (2007) developed a trapping technique (i.e., using foam blocks to support live traps) suitable for inundated habitats, and a variety of techniques are available to track the movements of individual rodents (cf. Boonstra and Craine 1986, Goodyear 1989). Additionally, it would seem advisable to experiment with metal nest barriers (Post and Greenlaw 1989), which significantly reduced Rice Rat and avian predation on Seaside Sparrow nests in northern Florida [i.e., 20 of 42 (48%) protected versus on 2 of 34 (5%) unprotected nests were successful], in order to increase sparrow reproductive success. Although such efforts would be time and labor intensive, their application could be critical to preventing the near-term extinction of small, isolated sparrow subpopulations.

Recommendations

- Determine causes of increased nest loss associated with dry conditions and short-term increases in water levels.
- Increase nest monitoring to determine array of nest predators.
- Determine *Oryzomys* densities and movements in and around sparrow nesting habitat.
- Conduct studies of the potential for improving sparrow nest success using predator barriers.

CONSPECIFIC ATTRACTION

The general phenomenon of animals cueing on the presence of conspecifics to determine the suitability of habitat patches or to direct their movements among habitat patches has been termed "conspecific attraction" (Stamps 1988; Smith and Peacock 1990). The concept of conspecific attraction has important implications for habitat selection and metapopulation theory. While habitat selection theory typically assumes that individual fitness declines with density, conspecific attraction predicts positive density dependence at intermediate densities (Stamps 1988; 2001; Stephens and Sutherland 1999; Ward and Schlossberg 2004; Fletcher 2006). Similarly, while metapopulation theory typically assumes dispersal and colonization events to be stochastic processes, conspecific attraction leads to a much more deterministic colonization process because immigration is reduced and suitable habitat patches may remain unoccupied (Stamps 2001; Smith and Peacock 1990; Ray et al. 1991; Reed and Dobson 1993; Fletcher 2006). The use of conspecifics as positive proximate cues in selecting habitat is thought to have evolved for at least three ultimate reasons: (1) reduced search costs; (2) reduced settlement costs; and (3) Allee effects (i.e., density dependent increases in predator detection/deterrence, territory defense, mate attraction, extra-pair copulations, foraging efficiency, etc.) (Stamps 1988; 2001; Green and Stamps 2001; Ahlering and Faaborg 2006; Fletcher 2006).

Conspecific attraction operates as a mechanism of breeding-site selection in a variety of avian species. Many semi-colonial and colonial birds appear to use conspecifics to assess breeding sites (e.g. Danchin et al. 1998; Brown et al. 2000; Serrano and Tella 2003; Alonso et al. 2004), and models and vocal playbacks have been used to attract individuals and establish new colonies in a variety of species (Kress 1983; Kotliar and Burger 1984; Kress and Nettleship 1988; Dunlop 1987; Podolsky 1990; Dunlop et al. 1991; Podolsky and Kress 1992; Jeffries and Brunton 2001; Martinez-Abrain et al. 2001). Conspecific attraction also has been demonstrated in a number of territorial species by documenting patterns of territory occupancy or order of nest establishment (Mueller et al. 1997; Etterson 2003), or experimentally by using vocal playbacks and/or decoys in both unoccupied (Alatalo et al. 1982; Ward and Schlossberg 2004; Ahlering et al. 2006) and occupied habitat patches (Hahn and Silverman 2006; 2007; Fletcher 2007). In some species, young birds and failed breeders appear to use conspecific cues in making immediate settlement decisions at the onset of the breeding season (e.g., Ward and Schlossberg 2004; Hahn and Silverman 2006). In other species, young birds and failed breeders appear to make future settlement decisions based on "public information" (i.e., adult presence or reproductive success) obtained during or at the end of the breeding season (e.g., Doligez et al. 2002; Serrano et al. 2004; Nocera et al. 2006; Piper et al. 2006). These findings have naturally stimulated considerable discussion about the potential for using conspecific cues in conserving and managing passerine populations in fragmented habitats (cf. Ward and Schlossberg 2004; Ahlering and Faaborg 2006; Fletcher 2007).

Cape Sable Seaside Sparrows, like many other territorial passerines, show considerable philopatry as adults (Pimm et al. 2002). While the habitat parameters associated with territory occupancy are well known (Dean and Morrison 2001; Pimm et al. 2001), relatively little information is available concerning the cues that individuals use in making settlement decisions. Dean and Morrison (2001) found that juveniles flock in the late summer and move across the habitat interacting with residents prior to settling (Dean and Morrison 2001). Initial studies on marked birds suggested that most juveniles move relatively short distances prior to settling (Lockwood et al. 1997; Dean and Morrison 2001; Pimm et al. 2002), but this work was all conducted in the relatively large subpopulation B and may not be representative of all populations. More recent data on banded juveniles and adults suggest that much more frequent movement occurs between subpopulations (Boulton and Lockwood unpublished data), and that the sparrow exhibits a metapopulation-like structure. If sparrows are in fact using conspecific cues in making settlement decisions, small subpopulations could be subject to higher rates of emigration even if suitable habitat remains. Whether conspecific attraction is affecting the slow recovery in subpopulation A or the observed trends in other small subpopulations (i.e., C, D, F) remains unknown at this time. Careful experimentation to determine the importance of conspecific attraction is warranted and could have important implications for sustaining small sparrow populations, attracting sparrows to unoccupied habitat, and improving the success of translocations.

Recommendations

- Conduct experiments to determine if sparrows can be attracted to suitable but unoccupied habitat using decoys and playbacks.
- Determine if sparrows adjust their territories or space use in response to playback and/or decoys.

TRANSLOCATION

As a supplement to the Cape Sable Seaside Sparrow Recovery Plan (USFWS 1999), Jenkins and Pimm (1999) have prepared protocols for the translocation of the Cape Sable Seaside Sparrow. These protocols are quite comprehensive, follow the IUCN Guidelines for Re-introductions (1995), and rely heavily on the knowledge base of previous animal translocations conducted for conservation and other purposes (cf. Wolf et al. 1996; Griffith et al. 1989; Cunningham 1996). The protocols address three separate possible scenarios where translocation should be considered for sustaining and recovering viable, free-ranging wild sparrow populations:

(1) *Translocation of wild birds to re-establish extirpated subpopulations within Everglades National Park.* Based on the success of previous translocations in other species, Jenkins and Pimm (1999) correctly note that the re-establishment of any subpopulation will require the restoration of suitable habitat, the translocation of adequate numbers of birds, and multiple re-introduction attempts. Assuming that suitable sparrow habitat is available, they sensibly recommend translocating at least 40 birds during the normal dispersal period over a period of several years. The requisite actions and procedures - from site selection through post-release monitoring and evaluation - are enumerated.

(2) *Translocation of wild birds outside their native range*. This scenario considers the possibility that current management actions cannot preclude the sparrow’s extinction within Everglades National Park, and that wild birds will need to be introduced to suitable habitat outside the native range. This protocol specifically addresses the introduction of the Cape Sable Seaside Sparrow into the former habitat of the now-extinct Dusky Seaside Sparrow (*Ammodramus maritimus nigrescens*) along the east coast of Florida (i.e., St. Johns River estuary within the Merritt Island and St. Johns National

Wildlife Refuges). The protocol enumerates the original cause of the Dusky Seaside Sparrow's decline (cf. Baker 1978; Sykes 1980; Post and Greenlaw 1994), pre-requisite investigations (i.e., absence of other Seaside Sparrows, amelioration of the causes of extinction, and an assessment of current suitability of the destination sites), and introduction and monitoring procedures similar to those noted above.

(3) *Captive breeding*. This scenario addresses the establishment of captive populations to provide offspring for re-establishing or augmenting wild populations. The prerequisite studies and procedures that are outlined are similar to the scenarios given above. Jenkins and Pimm (1999) correctly note that while other subspecies of sparrow have been bred successfully in captivity (Post and Antonio 1981; Webber and Post 1983), translocations involving captive-bred as opposed to wild-caught individuals have generally been much less successful (cf. Wolf et al. 1996; Griffith et al. 1989).

We believe that the restoration of the sparrow within its native habitat must remain the focus of current recovery efforts, and consequently suggest that the translocation of wild-caught individuals from large to small subpopulations within Everglades National Park (scenario 1) is the only option that should be considered in the near-term. There is evidence that some small subpopulations contain suitable but vacant habitat (cf. Jenkins et al. 2003a; b), and experimental translocations might prevent the extinction of these subpopulations as a result of chance alone. Experimental translocations would also allow direct testing and assessment of translocation protocols.

Introductions of sparrows outside their native range (scenario 2) and captive breeding (scenario 3) are not recommended at this time. Past attempts to either introduce endangered species outside their native range or reintroduce captive-bred animals to the wild generally have shown poor success (Wolf et al. 1996; Griffith et al. 1989). While captive breeding has been used in the recovery efforts for a number of endangered species, the technique is costly and has significant limitations and risks (cf. Snyder et al. 1996; McDougall et al. 2005). We concur with the AOU Committee (Walters et al. 2000), and suggest that captive breeding should only be considered for the sparrow if other conservation actions fail.

<u>Recommendation</u>

- Conduct experimental translocations of wild sparrows into suitable habitat to sustain distributions within Everglades National Park and test translocation protocols.

IMPROVING COMMUNICATION AND COORDINATION

Improving communication and research coordination would greatly benefit the Cape Sable Seaside Sparrow and other species. This is discussed in more detail in the governance and adaptive management sections below.

4. SNAIL KITE

BACKGROUND

The Snail Kite (*Rostrhamus sociabilis*) occurs in southern Florida, Cuba, and Central and South America (Sykes et al. 1995). The subspecies that occurs in the United States (*Rostrhamus s. plumbeus*) is only found in southern Florida and is the focus of this report. This gregarious, medium-sized raptor has a highly specialized diet and feeds almost exclusively on a species of freshwater Apple Snail (*Pomacea paludosa*) (Howell 1932; Stielglitz and Thompson 1967; Snyder and Snyder 1969; Sykes 1987a; Beissinger 1988). It is found primarily in the freshwater prairie and slough habitats of the Florida Everglades, Lake Okeechobee, Kissimmee Chain of Lakes, and other freshwater bodies in southern Florida. For more information on the life history and ecology of this raptor, see (Beissinger 1988; Bennetts et al. 1994; Sykes et al. 1995; Rodgers 1995).

Observations of Snail Kites in Florida have been reported since the early 1900s. Starting in the 1930s, and throughout the 1940s and 1950s, there were numerous accounts that kite populations were declining (Howell 1932; Bent 1937; Sprunt 1945; 1954; Wachenfeld 1956). In the 1960s, biologists began to obtain counts from organized surveys aimed at monitoring the status of the population. Stieglitz (1965) conducted a widespread survey in Florida and reported only seeing 10 birds. While the inaccessibility of the Everglades and other areas of Florida no doubt contributed to these lower numbers, it suggested that the population size of kites during the mid 1900s was very low. Prior to the federal listing of this subspecies as endangered in 1969, Sykes initiated more formal surveys in an effort to document the population status of Snail Kites in Florida (Sykes 1979; 1982); these surveys were later continued by Rodgers et al. (1988) and Bennetts et al. (1999). These efforts were limited in their ability to develop precise population estimates; however, they provided an index of the Snail Kite population that, while highly variable, suggested a generally increasing trend.

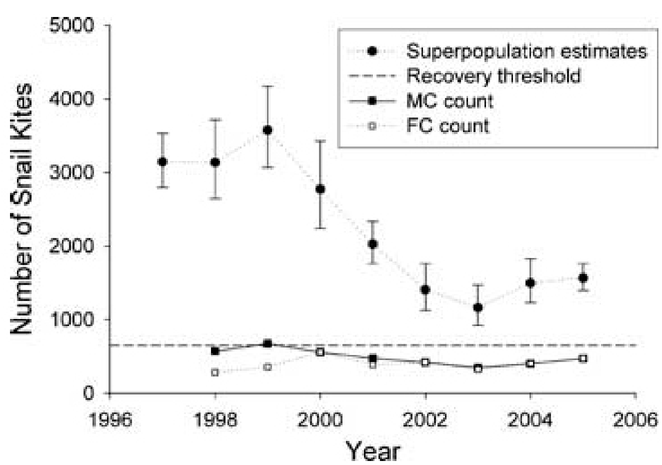
Snail Kites live in a highly variable wetland environment where weather, human intervention, and other factors can dramatically affect hydroperiods (i.e., water levels). The nature of these impacts on kites is extremely complex, as there are both temporal and spatial components to their influences. Historically, lower numbers and restricted distributions of kites have been linked to droughts and periods of major drainage in Florida (Howell 1932; Bent 1937; Sprunt 1945; 1954; Wachenfeld 1956; Stielglitz 1965). In more recent decades, research has attempted to determine if these lower numbers reflected an actual decrease in population size (i.e., through greater mortality and/or reduced productivity) or were a consequence of fewer kites being detected because they had dispersed to areas where surveys were not being conducted.

CURRENT SITUATION

Recent research has shown that the Snail Kite population in Florida uses the network of heterogeneous wetland units located in central and southern Florida (Bennetts and Kitchens 1997a, 1997b), and that wetlands within this network can serve as refugia during times of drought. Bennetts and Kitchens (2000) also reported that during their study, dispersal probabilities of kites were higher when prey were more plentiful and were not related to water levels, as has been reported in the past (Beissinger and Takekawa 1983; Takekawa and Beissinger 1989). They went on to suggest that their findings were not in conflict with the results of previous researchers; instead these differences in dispersal behavior may have been a function of the different resource conditions under which the kites were being studied. Higher dispersal probability under higher food conditions may, as Bennetts and Kitchens (2000) hypothesized, be a form of "exploratory behavior" during periods of food abundance. Subsequent research conducted by Martin et al. (2006) used statistical techniques to estimate detection probabilities; these analyses have determined that kite movements were strongly influenced by habitat fragmentation. That is, kites moved more extensively among contiguous wetlands, but less so among isolated wetlands. They concluded that if fragmentation reduced the exploratory behavior and dispersal ability of kites, it could have detrimental effects on the population during periods of low water and/or food availability.

Recent population studies have reported significant declines in the Florida Snail Kite population (Figure 4, adapted from Martin et al. 2007b). They attributed this overall decline to a number of factors that operated in concert to adversely affect the kite population. These included: the elimination of Lake Okeechobee as a major breeding site, as it had been during 1985-1995; a major region-wide drought in 2000-2001 that affected nearly the entire wetland network used by kites; and following the 2000-2001 drought, an intensive drawdown in the Upper Kissimmee Chain of Lakes that facilitated extensive aquatic weed control activities as a part that system's restoration activities.

Figure 4. Comparison of the estimates of population size (using a "superpopulation approach" that accounts for detectability) with annual counts. Data for two count surveys are plotted in the figure: first count survey (FC); maximum count (MC) survey. Kite numbers and estimates of population size from 1997 to 2000 were obtained from Dreitz et al. (2002). Estimates from 2001 to 2005 are results of the present study. Error bars correspond to 95% confidence intervals. The recovery target for Snail Kites (650 birds), set by the USFWS in 1999, is also presented.



As a result of this "perfect storm" of occurrences, there have been significant changes in the Snail Kite population (Fig. 5, adapted from Martin et al. 2006). These changes can be seen both in the survival rates of adults and juveniles, and in the nesting performance of the population. Estimates of adult annual survival rates of Snail Kites decreased significantly during the 2000-2001 drought (from approximately 86% to 72%); however, since 2002, these rates appeared to have recovered to pre-drought levels (also see Fig. 2 in Martin et al. 2006; Fig. 5-1 in Martin et al. 2007b). Annual survival rates of juveniles during the period for which data are available (1992-2006) are highly variable, although they were highest during non-drought years (56%; 1993-1997), moderate during moderately dry years (26%), and lowest during the 2000-2001 drought (7%) (Figure 6).

Figure 5. Apparent survival (φ) between 1992 and 2003 of adult and juvenile Snail Kites, obtained using the most parsimonious model in Table 3 of Martin et al. 2006. Error bars correspond to 95% confidence intervals. During non-drought years (1992–2000 and 2002–03), φ of adults were similar in E and O; and in K and J. During drought (2000–02), φ of adults were similar in E, O and J, but different in K. For readability, only φ in E and K are presented for adults. φ of juveniles were averaged across regions. Arrow indicates the beginning of the drought that started in January 2001. Estimates between 1992 and 1999 were consistent with Bennetts et al. (2002).

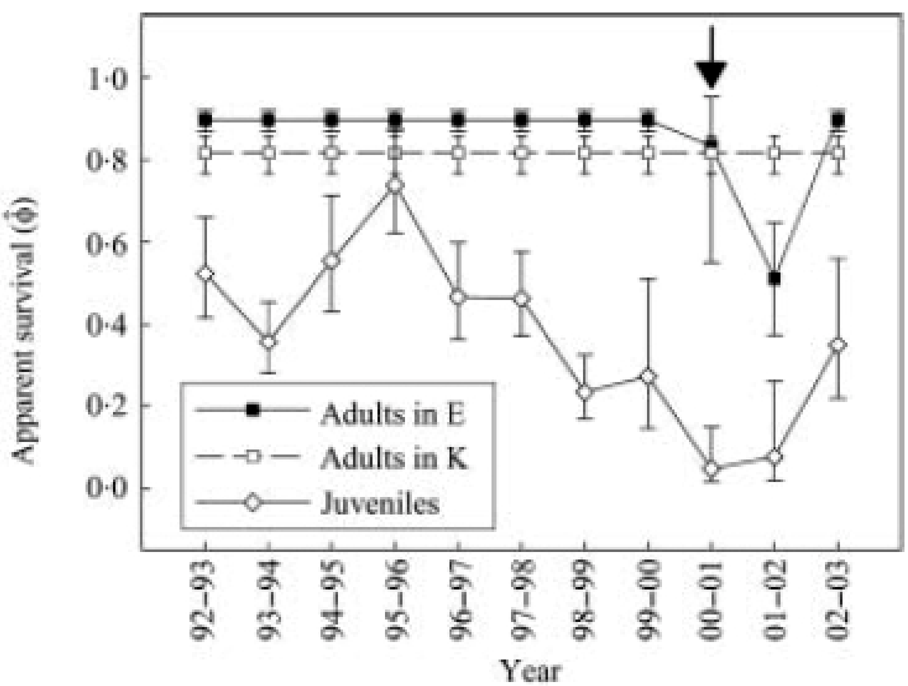
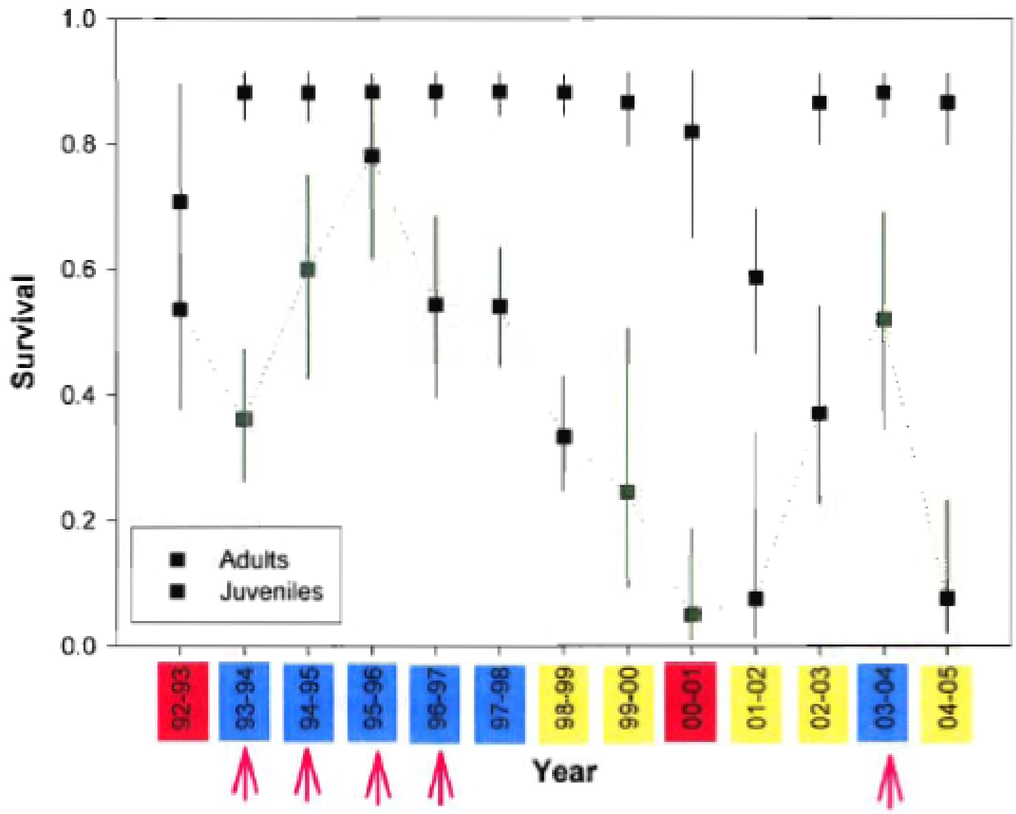


Figure 6. Model averaged estimates of adult and juvenile survival between 1992 and 2005. The colors correspond to the hydrological conditions: red indicates drought years, yellow indicates moderately dry years, and blue indicates wet years (see Figure 7-2 in Martin et al. 2007b for details about how the categorization was established). The pink arrows indicate years during which water levels were above or close to Zone E for the period May to July (juvenile survival was generally higher during these years).



Declining recruitment rates have also become a major concern. During their study, Martin et al. (2007a; b) recorded declines in the number of Snail Kite nesting attempts, nest success, and the number of young fledged (Figs. 7 and 8, adapted from Martin et al. 2007b). Of particular concern, is the lack of recruitment of young into the breeding population, given the rebounding survival rates during the last few years. It is this lack of productivity that Martin et al. (2007b) believe is now limiting the population growth and recovery of these Snail Kites.

Figure 7. Number of young (nestlings close to fledging) Snail Kites marked each year from 1992 to 2006: both uncorrected counts (black line) and corrected counts (with detection derived from regression equation, detection varied between 0.16 and 0.35; red line) are plotted.

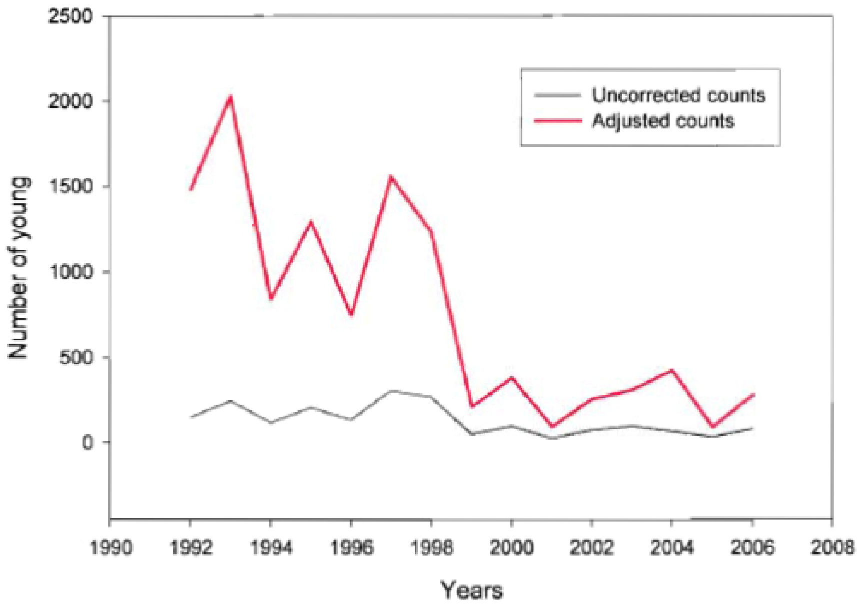
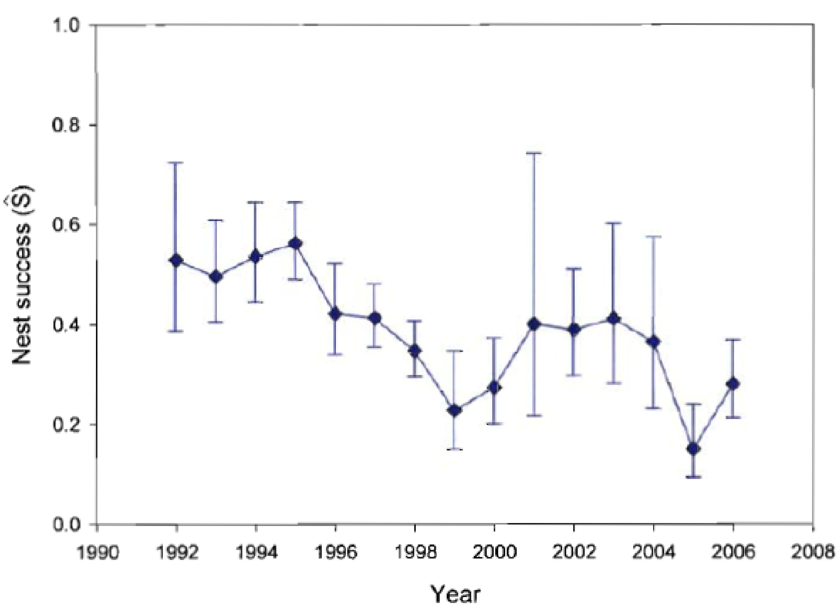


Figure 8. Nest success between 1992 and 2006 (estimates from 1992 and 1997 were taken from Dreitz et al. 2001). Error bars correspond to 95% confidence intervals.



CONCLUSIONS

Snail Kite populations have clearly been affected by recent climatic events (e.g., hurricanes, drought) and human invention (e.g., habitat restoration activities, water management). These things have resulted in changes in the vital rates of these birds; however, we believe the magnitude of their population decline may not be as great as reported. More research is required to resolve the apparent discrepancy between the high adult survival rates (nearly 90%) and the reported precipitous decline in population numbers. Even though very few young have been produced in recent years, and the kite population is consequently aging, it is not clear how there can be such a significant decline when adult survival is so high. Previous radio-tracking of adult kites has provided many valuable insights into the movement patterns, habitat requirements, and demography of Snail Kites in Florida (Bennetts et al. 1999; Bennetts and Kitchen 2000); however, intensive efforts to monitor the movement patterns of kites using telemetry data have inexplicably been discontinued. We believe these kinds of data will be needed to resolve the apparent discrepancy between adult survival rates and recent estimates of population decline.

Recommendation

- Initiate intensive radio-telemetry research to comprehensively document the movement patterns of adult Florida Snail Kites under current environmental conditions. The primary goals of this project should be to document relevant vital rates of the kite population and examine the veracity of recent estimates of population decline.

SNAIL KITE NESTING AND FORAGING HABITAT

BACKGROUND

The habitat requirements of Snail Kites in Florida have been well documented. With respect to nesting habitat, Snail Kites typically nest over open water (Sykes 1987b; Beissinger 1988), where water is more than 20 cm deep (Sykes 1987c; Bennetts et al. 1988; 1994). Kites are believed to select these areas to increase their proximity to Apple Snail prey and to minimize exposure to terrestrial predators (Beissinger 1984; Sykes 1987c).

In the Everglades, nests are built almost exclusively in woody vegetation (Bennetts et al. 1988; Snyder et al. 1989). Southern willow (Salix caroliniana) is the most common substrate used for nesting; however, Bennetts et al. (1988) found that this plant was used less than was expected based on its availability. Several other woody plant species also were used as nesting substrates, since they provided good lateral structural support; these included dwarf cypress (Taxodium spp.), pond apple (Annona glabra), punk tree (Melaleuca quinquenerva), and cocoplum (Chrysobalanus icaca) (Bennetts et al. 1988; 1994).

In the lake region of Florida, kites frequently nested in sawgrass (Typha spp.) (Snyder et al. 1989) or bulrush (J. Rodgers, Jr. unpubl. data, cited in Bennetts et al. 1988). These substrates were generally poor structures for supporting nests and resulted in nests collapsing when waters receded or during high winds (Beissinger 1988, Snyder et al. 1989). High use of these unsuitable structures in this region probably was due to the lack of suitably-located woody vegetation.

The foraging habitat used by Snail Kites is directly related to the prey they are specially adapted to capture (i.e., Apple Snails). Since Apple Snails become available to kites when they climb emergent vegetation to breathe and/or lay eggs, those habitats that support Apple Snails and that are sufficiently open for aerial feeding by kites are preferred foraging areas. Wet prairies are especially suitable. Historically, suitable foraging habitat in the Everglades was typically characterized by an interspersion of emergent vegetation with open-water communities (Stieglitz and Thompson 1967; Sykes 1987c; Bennetts et al. 1988). Past estimates of the relative amount of open water to emergent vegetation in Snail Kite habitat ranged from 30-40% (Stieglitz 1965; Stieglitz and Thompson 1967; Sykes 1987c; Bennetts et al. 1988).

CURRENT SITUATION

Water Conservation Area 3A has consistently been the area that has produced the largest proportion of Snail Kite offspring since the mid-1990s (see Fig. 4-1 in Martin et al. 2007b). In previous decades, kites nested in much greater numbers further north in WCA 1, 2A, 2B and Lake Okeechobee (Sykes 1983; Bennetts et al. 1994). This shift in nesting concentrations has been attributed, at least in part, to changes in hydroperiod. The higher water levels and longer hydroperiods created by impoundments have degraded traditional nesting vegetation and forced kites to move their nesting areas to higher elevation sites (e.g., further south and west in WCA 3A). Foraging areas also have been affected. Martin et al. (2007b) report on a vegetation study they recently conducted in routinely used Snail Kite foraging areas, and quantified how vegetation composition changes with increased water depth and longer hydroperiods. They found that as water depths and hydroperiods increased, the wet prairies and emergent sloughs were changing rapidly to more Nymphaea odorata-dominated, deep water communities. The lack of emergent vegetation in these deep water communities, combined with the floating aquatic vegetation they support, reduces the availability of Apple Snails to Snail Kites and make these habitats less desirable for foraging (Kitchens et al. 2002; Bennetts et al. 2006).

These findings are consistent with numerous other ecological, paleo-ecological, and modeling studies that have shown that water management in WCA-3A has decreased the number and extent of tree islands and degraded ridge-and-slough topography (Sklar and van der Valk 2002; SCT 2003; NRC 2003; Ogden 2005a; Willard et al. 2006; Larsen et al. 2007). The overall effect largely has been what Larsen and others (2007) refer to as a topographic flattening of the landscape. They make a compelling case that topographic heterogeneity in the Everglades is the result of a complex set of feedbacks involving flow rates, water levels, nutrient concentration, differential peat accumulation, sediment supply, and sediment deposition. To the extent that kites depend on trees located over open water with emergent vegetation for foraging, continued impoundment of water in the Water Conservation Areas will negatively affect their abundance.

CONCLUSIONS

Since WCA 3A is currently so important to the persistence of Snail Kites in the Everglades, we believe that management of the water levels should be adapted to account for the nesting and foraging requirements of this species. Information presented by Martin et al. (2007) suggest that nesting and foraging habitat are being adversely affected by the higher water levels currently being maintained in WCA 3A, and that this impounding of water is impacting survival and reproduction.

Recommendation

- Water management should maintain lower water levels during the fall/winter months (September-December) to mitigate effects of longer hydroperiod and deeper water on vegetation, and maintain higher water levels during the spring/summer (March-July) to provide for better conditions during the Snail Kite breeding season. Several other recent studies have reduced the uncertainty around the importance of drawdown and water flow to maintaining tree islands and ridge-and-slough topography in Snail Kite habitat.

APPLE SNAIL

BACKGROUND

Apple Snails (*Pomacea paludosa*) have long been recognized as an important component of the aquatic food web of the Florida Everglades, particularly as the nearly exclusive prey of the Snail Kite (Bennetts et al. 1994; Sykes et al. 1995; Darby et al. 2005). In spite of their importance in the diet of this endangered species, there has been very little historical research on the distribution, abundance, or habitat preferences of Apple Snails. Efforts to quantify the distribution and abundance of Apple Snails have been difficult, since available methodologies were rudimentary at best (Sykes 1983; Owre and Rich 1987; Bennetts et al. 1988).

CURRENT SITUATION

In the past decade significant advances have been made in our ability to sample Apple Snail populations. This has lead to a much more complete understanding of many aspects of their life history (Darby et al. 1999; 2002; 2003; 2005). In their ground-breaking work on Apple Snails, Darby and colleagues have demonstrated that snails are much more abundant in wet prairies, particularly those with low to moderate stem densities, than in open slough habitats. Contrary to previous understanding, they found that Apple Snails are adapted to and can survive periodic dry downs, but that timing is critical (Darby et al. 2003; 2005). For example, up to 80% of all snails can survive a four-week drying event; 80% of adults can survive a 12-week drying event. It is now believed that a drying event every 2-3 years that lasts for 1-2 months will not adversely affect Apple Snail populations. This finding is significant, given our current understanding that hydrologic regimes that include periodic dry downs are needed to maintain the wet prairie habitats important to both Apple Snails and Snail Kites.

Conversely, high water during the Apple Snail breeding season has been shown by Darby et al. (2005) to delay the production of egg clusters until later in the spring, often resulting in their destruction during the summer rainy season. Current data suggest that the egg cluster production would be greatest if water levels started to decline in January and gradually fell to less than 40 cm by late April to late May.

CONCLUSIONS

High water levels are detrimental to Apple Snail reproduction, as are extended drying events. Continued flooding of WCA 3A, followed by extreme dry downs is expected to further reduce Apple Snail populations and put additional stress on an already vulnerable Snail Kite population. It also is currently unknown to what extent the much larger Apple Snail (*Pomacea insularum*), which is not native and has recently invaded the region, will compete with the native species and/or create foraging challenges for Snail Kites (especially juveniles) who attempt to feed on this larger species. Anedoctal observations by researchers suggest that Snail Kites (especially juveniles) have a difficult time handling these larger Apple Snails, which could potentially impact their food consumption. The degree to which these exotic snails compete with the native species also has not been determined, so the degree to which *P. insularum* disrupts Snail Kite foraging behavior is unknown.

Recommendation

- Several excellent studies of the effects of water levels and hydroperiod on vegetation communities, Apple Snails, and Snail Kites have been completed and/or are ongoing. However, we believe it essential, at this time, to fully integrate these investigations so that the specific hydrological and ecological conditions needed to restore the native Apple Snail and Snail Kite populations, and their preferred habitats, can be more clearly linked and effectively articulated to managers. For example, an integrated suite of recommendations that identifies the range of acceptable water management strategies and expected outcomes, with respect to their short and longer-term effects on the status of vegetation communities, Apple Snails and Snail Kites, and their interactions, would be greatly beneficial.

5. WOOD STORK

POPULATION STATUS

Historically, Wood Storks in the U.S. nested regularly only in south Florida (Kushlan and Frohring 1986; Coulter et al. 1999), although sporadic nesting occurred in all coastal states between Texas and South Carolina (Ogden et al. 1987). Historic population numbers are somewhat unclear but it is believed that between 5,000 and 10,000 pairs nested in south Florida in the 1930s (Coulter et al. 1999; Ogden 1994), and Kushlan and Frohring (1986) believe there is no evidence for more than 10,000 pairs in south Florida at any time in the past century. No nests were known from Georgia or South Carolina in the early 20th century. Approximately 7,000-8,000 nests were recorded at Corkscrew in Big Cypress Swamp in 1912. Other concentration areas were primarily at Cape Sable, where 500 nests were recorded in 1932. Drainage of Big Cypress Swamp in the late 1960s-1970s was associated with an 80% decline in nesting storks there (Kushlan and Frohring 1986). Canal construction and a 1935 hurricane substantially reduced numbers of nesting pairs in the Cape Sable area during the 1930s. Crozier and Gawlik (2003) assessed all historical data and reported that Wood Storks declined 78% in the Everglades (Everglades National Park and the Water Conservation Areas) between the 1930s and 2001. Ogden (1994) estimated slightly greater percentage declines between the 1930s and late 1980s. The overall decline was associated with a general shift from coastal mangrove swamps to more inland nesting areas. Declines in Big Cypress and in the Cape Sable area were associated with increases in inland southern breeding colonies in Everglades National Park or the Water Conservation Areas (Kushlan and Frohring 1986). Colonies east of Miami which developed in the 1960s, declined through the 1970s and disappeared in the 1980s associated with loss of foraging habitat along the southeastern Florida coast. Wood Storks shifted generally north in the Everglades in the 1970s, associated with water management around more southern breeding locations. Between the 1930s and 2001 there was a 61% decline in the proportion of nests in coastal mangroves and a 46% increase in the proportion of nests in the central-northern Everglades (Crozier and Gawlik 2003). The first recorded nesting by Wood Storks in the Water Conservation Areas occurred in 1989 (Crozier and Gawlik 2003). The first nesting (in modern times) in Georgia and South Carolina were in 1976 and 1981, respectively (Coulter et al. 1999).

The current Recovery Plan for Wood Storks calls for three-year running averages of 10,000 nesting pairs in the population as a whole, with 2,500 nesting pairs in Everglades National Park (or the Everglades system as a whole) and Big Cypress Preserve combined. Total nests exceeded 9,000 in 2002 and 2003 (2005 Wood Stork report), with 1191 nests in the Everglades system (which includes the Water Conservation Areas). Numbers in the Everglades system were down from a running average for 2000-2002 of 1870 pairs (2005 Wood Stork report). It should be noted that proposed performance measures for CERP include locations of breeding colonies of wading birds (Ogden 1994). It is not clear that the historically large colonies that occurred in the mangrove estuaries of the southern Everglades can be restored, even with a modified hydrological regime under CERP.

Dependence of Wood Storks on dry down conditions for successful breeding is well established (Kahl 1964; Kushlan et al. 1975; Ogden 1994). It is, thus, noteworthy that Wood Stork populations have increased to near recovery goals in the absence of progress on CERP (Ogden 2005b). Increases in Wood Stork populations in south Florida over the past decade, despite lack of progress on CERP, indicates substantial gaps in our understanding of Wood Stork population structure, demography, and possibly wetland habitat requirements.

DEMOGRAPHY AND POPULATION STRUCTURE

Substantial effort has been devoted to estimating reproductive success (nesting and chick rearing to fledging) of Wood Storks (Kushlan et al. 1975; Ogden et al. 1978; Rodgers and Schwikert 1997; Crozier and Cook 2004), which is known to be episodic. Numbers of nesting pairs fluctuate over nearly three orders of magnitude among years, associated with suitability of hydrological conditions (Frederick and Ogden 2001; Crozier and Gawlik 2003). Nest and chick rearing success are also highly variable, breeding attempts are largely abandoned in years when water levels rise after nests are initiated. Frederick and Ogden (2001) showed that years of especially high breeding success tended to follow severe droughts, suggesting that, in addition to the importance of hydrological conditions in the time of breeding, the long term hydrological cycle also influenced reproduction in Wood Storks.

In recent years, substantial numbers of juvenile Wood Storks have been tagged with satellite transmitters (Borkhataria et al. 2006); juveniles from southern Florida moved north into northern Florida, Alabama, Georgia and South Carolina, demonstrating the potential for genetic and demographic interchange throughout the breeding range of Wood Storks in the United States. Because few adults were tagged, migration patterns of adults are more poorly understood. Neither natal nor breeding dispersal (breeding in different colonies among years) have been described. Spatial dynamics of colonies between the 1930s and the present, however, suggest the potential for substantial dispersal in Wood Storks, at least at the time scale of decades. No estimates of adult survival exist for Wood Storks (Bancroft et al. 1992), although only 5 of 7 (71%) of radio-tagged adults survived one year (Borkhataria and Frederick 2005). Simulation modeling suggested that adult survival >0.92 was required for stable or increasing populations. Juvenile survival appears to be variable. Of 27 juveniles tagged in 2002, 44% survived their first year, 67% survived their second year, and 87% survived their third year (Borkhataria and Frederick 2005a). In contrast, only 1 of 17 (6%) juveniles from the 2003 cohort survived their first year.

Understanding of demography and population structure are not adequate to know whether increases in the number of nesting pairs in south Florida since the mid 1990s resulted from local reproduction or dispersal from other breeding locations.

FORAGING ECOLOGY

Wood Storks are primarily piscivorous, although they eat a variety of organisms found in aquatic habitats (Coulter et al. 1999). In south Florida, 85% of dietary biomass was comprised of five types of fish: sunfish (*Lepomis* sps. and *Ennescanthus gloriosus*), yellow bullhead (*Ictalarus netalis*), marsh killifish (*Fundulus confluentus*), flagfish (*Jordinella floridae*), and sailfin molly (*Poecillia latipinna*) (Ogden et al. 1976, 1978). Wood Storks are especially dependent on high concentrations of small fish (2-25 cm long) when feeding chicks (Kahl 1964; Ogden et al. 1976; Coulter 1987). High quality foraging sites occur in isolated pools, associated with the concentration of prey during periods of water recession (Gawlik 2002). In the absence of water recession, prey densities and prey capture rates are insufficient to support chick growth and Wood Storks either do not nest or nests fail (Kahl 1964; Ogden et al. 1994).

NESTING HABITAT AND RELATIONSHIP BETWEEN BREEDING COLONIES AND FORAGING LOCATIONS

Wood Storks require trees either on islands or surrounded by water for nesting (Rodgers et al. 1996; Coulter et al. 1999). They nest in a variety of species, including cypress (*Taxodium* spp.), mangroves, black gum (*Nyssa biflora*), water tupelo (*Nyssa aquatica*), pines (*Pinus* spp.) and oaks (*Quercus* spp.) (Rodgers et al. 1996; Coulter et al. 1999). The principal requirement seems to be protection from predators. Use of coastal mangroves for nesting has declined in the past two decades. Ogden (1994) hypothesized that declines in nesting in south Florida coastal mangroves reflected declines in the prey base, associated with reduced fresh water flows. An alternative hypothesis – that the current relatively continuous mangrove canopy does not provide islands, surrounded by water, that are preferred by breeding Wood Storks – cannot be ruled out. Uncertainty exists about reversing the pattern of reduced use of coastal mangroves, given expected effects of sea level rise on coastal marshes. Consequently, inland nesting areas will continue to be important for management of south Florida Wood Stork populations for the foreseeable future (Bancroft et al. 1992).

Wood Storks foraged at locations ranging from 0.5-74.5 km ($\bar{x}$ = 10.3 km) from nesting colonies (Herring and Gawlik 2007). Travel costs to foraging sites an average distance from colonies represent <10% of daily energy expenditure per foraging trip (Bryan et al. 1995), but, clearly, energy costs of traveling to sites further from nesting colonies might not be sustainable and could result in reproductive failure. Energetic costs of traveling to foraging sites when feeding chicks, therefore, likely place an upper limit on the distance between nesting colonies and foraging areas, which likely restricts the location of nesting colonies. Historical shifts in the distribution of nesting colonies of Wood Storks have, in fact, been attributed to a lack of foraging locations sufficiently close to colonies (Kushlan and Frohring 1986).

SEASONALITY

Historically, nesting in south Florida typically began in December-January but as early as November (Ogden 1994; Coulter et al. 1999). Since the 1970s most nests have been initiated in February and March (USFWS 1999), and in a recent study, chicks were being provisioned by early April and were fledged in June or early July (Herring and Gawlik 2007). Such delayed nesting pushes chick rearing into the wet season. Rain during this period raises water levels (Sklar et al. 2002), disperses fish (Kahl 1964; Kushlan et al. 1975), and this change in timing of fledging from peak dry down to rising water levels is thought to cause increased frequency of breeding failure in south Florida (Ogden 1994).

HYDROLOGY AND REPRODUCTIVE BIOLOGY

Hydrological patterns influence reproductive effort and success of Wood Storks by their influence on abundance and concentration of prey fish in sufficiently close proximity to breeding colonies (Herring and Gawlik 2007). Predevelopment, prey fish were produced in large numbers during the wet season (approximately May through October), when extensive areas of the Everglades were flooded (Ogden 1994). Water recession, beginning in October, concentrated fish in small pools, where they were vulnerable to foraging storks and other wading birds (Kahl 1964). Concentrations of fish were up to two orders of magnitude higher in small pools during the dry period (Kahl 1964) than at other times of year. Such concentrations are necessary to provide sufficient prey capture rates for feeding chicks and storks abandon foraging areas when fish concentrations are inadequate to support high capture rates (Gawlik 2002). Before extensive water management projects in the Greater Everglades area, topographic variation combined with a greater spatial extent than currently exists and natural hydrological patterns created high prey concentrations under a greater variety of hydrological conditions (Ogden 1994). This phenomenon resulted from the fact that high water was deposited over a larger area with greater topographical diversity than exists in the current system. Consequently, during water recessions, isolated pools with high fish densities were "left behind" over a greater area and a longer period of time (Sklar et al. 2002). As a result, foraging conditions producing prey capture rates sufficiently high to rear chicks persisted through the chick rearing period in a greater proportion of years than has been the case in recent decades.

The system of levees and canals constituting the South Florida Water Management System has had several important effects on hydrology vis-à-vis Wood Storks and their food base. First, by constraining the area that is hydrologically connected to this system has reduced topographic variation in the Everglades ecosystem (Sklar et al. 2002). Second, canals and removal of water for human use have reduced natural flows through the system, increasing the frequency of dry conditions (Ogden 1994). Third, levees have created artificial impoundments thereby maintaining artificially deep water in other areas for longer periods of time (Ogden 1994). Water management for flood control and water supply have exacerbated deviations from "natural" hydrological patterns; some areas are too wet, while others are too dry. Reduced flows have also increased saltwater intrusion into coastal mangrove habitats, which is thought to have reduced fish production and prey availability for storks and other wading birds. This reduced prey base has been hypothesized to underlie shifts of breeding storks from coastal mangroves to more interior nesting locations (Ogden 1994).

The overall outcome of water management in the Everglades system is that water recessions that produce numerous shallow pools with highly concentrated fish, occur in fewer years and in fewer areas (Ogden 1994). Adequate recession since the 1960s has typically occurred later in the water year (March-June) versus late fall (October-December) during the pre-1960s period (Ogden 1994). Consequently, wet season rains have produced more reversals in water recession during the nesting and chick-rearing periods in recent decades, resulting in more frequent breeding failures in storks (Ogden 1994; Frederick et al. 2004). Reduced spatial extent and topographic variation of Everglades habitats since development of the South Florida Water Management System also means that foraging conditions adequate for chick rearing occur under a smaller range of hydrological conditions than was true historically (Ogden 1994; Gawlik 2002).

An important paradox in our understanding of Wood Stork population dynamics is the recovery of the south Florida Wood Stork nesting population to near recovery goals during the late 1990s- early 2000s, before implementation of the CERP (Ogden 2005b). It is possible that increased reproductive effort and success during this period merely reflects drought conditions in south Florida during this period, which reduced the frequency of hydrological reversals during the spring breeding period. Detailed assessment of water conditions during the relatively successful period form 1998-2004 may provide a mechanism for understanding conditions conducive to successful stork reproduction under the current distribution of breeding birds.

DATA NEEDS FOR MANAGEMENT

While the general requirements of successful reproduction by Wood Storks are certainly well understood, knowledge of the relationship between specific water management practices and favorable hydrological conditions for stork breeding require refinement. The spatial scale of current hydrological modeling efforts may not be adequate to predict timing and location of pools containing concentrated prey necessary for successful breeding. Habitat suitability modeling of Wood Stork foraging locations using existing SFWMM 4 mi^2 grid cells, however, suggests the potential for preliminarily linking of hydrological conditions to Wood Stork population dynamics. An important refinement of this approach would include linking among-year variation in hydrological conditions to variation in reproductive success at the 4 mi^2 scale. The EDEN modeling effort (http://sofia.usgs.gov/projects/eden/) has considerable promise for improving our understanding of the linkage between hydrological variables and Wood Stork breeding and population biology. Additional uncertainty exists about the importance of longer term hydrological patterns. For example**,** Frederick and Ogden (2004) reported that Wood Storks historically bred more successfully following periods of extended drought when hydrological conditions became favorable again, suggesting complexity in the factors governing their prey base. It is important to note that current hydrological models of the Water Conservation Areas do not appear to indicate sufficient water recession in most years to support successful breeding by storks.

Improvement in our understanding of stork biology in two other areas would certainly enhance efforts to mange water to benefit storks. First, the direct relationship between hydrological conditions and initiation of nests by storks is not well understood. Ogden (1994) has hypothesized that foraging conditions for adult storks at the time of egg formation may limit breeding through their effects on nutrient and energy balance. For birds as large as storks, however, additional nutrient requirements for producing eggs should represent a relatively small proportion of daily maintenance requirements (Lasieski and Dawson 1967; Lack 1968). Consequently, foraging conditions at the time of nest initiation may be less important to the nutrient balance of adults at that time than to providing information to adults about what foraging conditions might be like two months hence when requirements for feeding chicks are at their peak. Optimal water management might differ depending on which role conditions at the time of nest initiation play.

A second key area where improved understanding is needed is in the demography of Wood Storks. Currently, no reliable estimate of adult survival exists. Estimates of juvenile survival are currently being generated (Borkhataria and Frederick 2005a) but these have not yet been related to local ecological conditions. Additionally, the composition (age, natal origin, etc.) of local breeding populations is currently unknown. Consequently, basic management questions cannot be answered. For example, the frequency and success of breeding effort needed to maintain stable populations is unknown. While temporal-spatial patterns of breeding suggest that individual birds have some flexibility to respond to local breeding conditions, the extent to which individuals move among breeding locations is unknown. Understanding of such dynamics is key to understanding how storks might respond to specific management actions over the period of a decade or so.

6. ROSEATE SPOONBILL

DISTRIBUTION

The Roseate Spoonbill is one of six species of spoonbills worldwide, and the only species that occurs in the western hemisphere. Unlike other spoonbills, Roseate Spoonbills possess brightly colored, as opposed to white, plumage. Roseate Spoonbills range from the southern U.S. through the West Indies and Middle America, and into South America. The range in South America is poorly known, but extends east of the Andes to northern Argentina. The Florida and West Indies populations appear disjunct from those in South America due to rarity in the Lesser Antilles, and from the other populations in Louisiana, Texas and Middle America due to distributional gaps along the U.S. Gulf Coast and the Yucatan Channel (cf. Robertson 1983; Dumas 2000). Breeding colonies in the United States are restricted to coastal and a few inland sites in Louisiana and Texas, and the southern half of peninsular Florida. Breeding sites in Florida historically have encompassed coastal and inland sites from Tampa Bay on the Gulf Coast to Brevard County on the Atlantic coast and south to Florida Bay. Breeding colonies are currently are found along the Gulf Coast around Tampa Bay [i.e., Alfia Bank (Hillsborough County); Tarpon Key (Pinellas County); and Washburn Sanctuary (Manatee County)], along the Atlantic Coast in areas adjacent to the Kennedy Space Center (Brevard County), and along the south coast in northeastern, central and northwestern Florida Bay (Dade and Monroe Counties). Since 1992, Roseate Spoonbills have resumed breeding at several inland sites in the Everglades [i.e., Water Conservation Area 3A (Broward County) and Corkscrew Swamp Sanctuary (Collier County)] in small numbers (Fredrick and Towles 1995; Bjork and Powell 1996; Dumas 2000).

POPULATION STATUS

The Roseate Spoonbill is presently listed as a Species of Special Concern in Florida (Wood 1997), and has been selected as one of the key indicator species for the restoration of the Florida Bay ecosystem under the Comprehensive Everglades Restoration Plan (CERP) because its reproduction is closely tied to regional patterns of hydrology (Lorenz et al. 2002a,b).

Historical accounts from the early 1800s suggest that Roseate Spoonbills were common and that large breeding colonies occurred in Florida Bay (Allen 1942; Powell et al. 1989). During the latter half of the 1800s, and continuing through the early 1900s, spoonbill numbers were greatly reduced as a result of harvesting by plume and subsistence hunters, and the impacts of these activities on reproduction. Despite the prohibition of plume hunting and the increased protection of breeding colonies in the early 1900s, the Florida spoonbill population continued to decline, and was believed to number fewer than 200 pairs in Florida Bay by the early 1930s. These birds nested sporadically in small numbers in mixed species colonies at Cuthbert Lake, Lane River, Shark River and Charlotte Harbor, and in one larger colony (Bottle Key) in eastern Florida Bay (Grimes and Sprunt

1936; Allen 1942). By 1935, continued human predation on adults and eggs appeared to eliminate all colonies except the Bottle Key colony, which had been reduced to about 15 pairs and was believed to be the only remaining active colony (Allen 1942, 1963; Powell et al. 1989). When Allen (1963) resumed his Florida Bay surveys in 1950, he found that spoonbill numbers and active breeding colonies had both increased since the 1930s.

In their thorough review of population trends in wading birds in Florida Bay from 1935-1988, Powell et al. (1989) noted that the spoonbill nesting population doubled approximately every 10 years between 1955 and 1978. The breeding population increased dramatically during the 1978-79 season reaching 1,254 breeding pairs. No nesting information is available for the subsequent five years, but by 1984 when surveys were reinitiated the nesting population had decreased to about 400 pairs. With the exception of the 1993-1994 nesting cycle, Audubon staff has continued to monitor spoonbill nesting activities and success in Florida Bay since the 1984-85 breeding season. The number of nesting pairs varies substantially between years at the Florida Bay colonies (Ogden 1978; Powell et al.1989; Bjork and Powell 1994), but generally has ranged between 400 and 500 pairs each year (Lorenz 1999, 2006). Presently, 80-90 percent of the Roseate Spoonbills breeding in Florida nest on the mangrove islands within the boundaries of Everglades National Park (Bjork and Powell 1996; Lorenz et al. 2002b).

No detailed population estimates exist for spoonbills other than the annual nest counts provided by regional ground and aerial surveys. Robertson et al. (1983) have noted that the expansion in range to the Tampa Bay region in 1975 coincided with the increased productivity of the Florida Bay population, suggesting a close link between the production of young and recruitment within Florida. The extent to which breeding and non-breeding Gulf Coast populations are influenced by migrants from outside the U.S. remains poorly understood (Robertson et al. 1983; Dumas 2000).

Historical changes in land and water management practices have clearly altered Roseate Spoonbill nesting patterns within Florida Bay through their influence upon the quality and availability of food resources. As noted by Lorenz et al. (2002b), the principal anthropogenic alterations to spoonbill foraging grounds within Florida Bay resulted from filling of wetlands for urban development within the upper Florida Keys, and the progressive alteration of natural water flows into the Florida and Biscayne Bays. These latter changes in the timing and amount of water flowing into the mainland estuaries north of Florida bay have adversely affected spoonbill reproduction by altering the abundance, availability, and quality of spoonbill prey. Planned changes to the South Dade Conveyance System (see Light and Dineen 1994; Lorenz et al. 2002b) should improve spoonbill nesting patterns and breeding success in Florida Bay.

FORAGING ECOLOGY

While Roseate Spoonbills obtain prey using both visual and tactile cues, tactolocation is the principal foraging method. The partially opened spoonbill is swept sideways in a semi-circular motion through the water column or mud substrate while walking slowly forward. When a prey item touches the highly sensitive spoon, the bill is snapped shut, and the prey item is tossed quickly into the back of the throat (Allen 1942; Dumas 2000). This highly specialized feeding methos requires that Roseate Spoonbills forage in open, shallow freshwater, brackish water, and hypersaline sites where the water depth is less than 20 cm deep (Powell 1987; Lorenz et al. 2002b; Lorenz 2003). Roseate Spoonbills consume a wide variety of small aquatic animals, including fish, crustaceans, and insects (Allen 1942; Dumas 2000 and references therein). Powell and Bjork (1990) reported that crop samples from nestlings (n=25) from two colonies in separate parts of Florida Bay contained 80-90% small fish (primarily *Cyprinodontidae* and *Poeciliidae*) with the remainder being comprised of mostly shrimp (*Palaemonetes* spp.).

NESTING PHENOLOGY

In Texas and Louisiana, Roseate Spoonbills breed in the early spring through summer, April - July (Dumas 2000). In Florida, mainland populations normally breed in the winter through the spring (late February or early March to June), whereas breeding in Florida Bay populations normally occurs in the fall and winter (November-March), albeit the timing in the latter colonies has become more irregular during the past 2-3 decades with anthropogenic alteration of the natural water flows (Allen 1942; Bjork and Powell 1994; Dumas 2000).

In Roseate Spoonbills, courtship and nest-building proceed together over a period of about 20 days and culminate with egg laying. Clutch size ranges from 1-5 eggs, but is normally 3 or 4. Incubation begins with the laying of the first egg, and lasts about 22 days for each egg, and the young hatch asynchronously. Both sexes participate in incubation and alternate their attendance at the nest 2-3 times per day (Allen 1942; White et al. 1982; Dumas 2000). Nestlings require parental attendance for brooding and protection against predators for a period of about 1 month, and an unbroken supply of food for a period of about 42 days. After that time, chicks are more self-reliant, but are still unable to depart the colony for another period of about 42 days. During this period, the young congregate around the colony site and are still attended and fed by the parents periodically (Allen 1942; Dumas 2000; Bartell et al. 2004).

Like other species of wading birds inhabiting the Everglades, nesting by spoonbills in Florida Bay is timed closely with the seasonally low-water depths that occur during the dry season when abundant prey are concentrated into the remaining pools, creeks, and sloughs (Allen 1942; Kushlan 1978; Bjork and Powell 1984; Loftus and Kushlan 1987; Frederick and Collopy 1989; Bjork and Powell 1996; DeAngelis et al. 1997; Lorenz 1999, 2003). Gradual and consistent declining water levels throughout the nesting period appear critical for adults to secure and supply the food necessary to raise young (Bjork and Powell 1994). Available evidence clearly indicates that breeding success is high during seasons with gradual dry-downs, and poor during seasons with high or fluctuating water levels (Bjork and Powell 1994; Lorenz et al. 2000, 2006; Lorenz and Frezza 2007).

MOVEMENTS

Spoonbills nesting in Florida Bay seem to use about 11 major foraging locations within the coastal wetlands at any one time (Bjork and Powell 1994). Based on the foraging flight data gathered by Bjork and Powell (1994), Lorenz (2002) calculated that the mean foraging flight distance for nesting adults in Florida Bay colonies was 12.4 ± 5.8 km, and that the data were skewed toward shorter flights (83% of flights less than16 km).

Although it was formerly believed that spoonbills left the Everglades region during the non-breeding period, recent results using satellite telemetry suggest that many of the birds simply disperse across interior habitats where they are hard to observe (Langan and Lorenz 2006). At least one adult was documented moving about 110 km to an interior colony in the Everglades and re-nesting after its first nesting attempt failed in Florida Bay (Frederick and Towles 1995; Bjork and Powell 1996). Results obtained from 10 birds marked with satellite transmitters in 2006 show considerable variation in movements following the breeding season, with a number of the birds relying on wetlands within Everglades National Park (Langan and Lorenz 2006). One of the birds captured for satellite telemetry in 2006 on Tern Key had been banded in 1990, and was breeding in the natal colony at 15+ years of age (Langan and Lorenz 2006).

Allen (1942) noted young birds near independence following adults (possibly parent) to more distant feeding locations. Movements of juveniles marked in the Tampa Bay region and in Florida Bay with patagial tags and radio-transmitters indicate that they disperse widely to coastal and interior areas on the mainland (Powell and Bjork 1990; Robertson et al. 1993). Some of these birds made northward movements of over 400 km during the first few months of independence.

ACTIONS AND RECOMMENDATIONS

Implementation of CERP and MODWATERS

The restoration the natural timing and flow of waters into Florida Bay should benefit Roseate Spoonbill reproduction and result in an increased population within Florida Bay. Ongoing and planned modifications to the South Dade Conveyance System (i.e., changes to the C-111 canal and associated structures) should proceed as quickly as possible to improve reproduction within the spoonbill colonies located within the northeastern and central portions of Florida Bay. Some aspects are to:

- Complete C-111 and "leaky reservoir project" as soon as practicable and monitor associated effects on water flows and vegetation.
- Ensure that the ecologically important timing of hydrologic flows to Florida Bay is formally considered during the 2010 System Operations revision.
- Increase flows through northeastern Shark River Slough into Florida Bay are key to spoonbill conservation, and thus this species will especially benefit from ModWaters and Decomp.

Population Monitoring

Current practices for monitoring the size and reproductive success of within the Roseate Spoonbill colonies in Florida should be continued. Roseate Spoonbills breeding success is clearly sensitive to changes in the abundance, availability, and quality of prey, and consequently, comparative data on breeding success is essential for directly measuring habitat quality and indirectly measuring the effects of CERP implementation. Because very little is know about the population dynamics and demography of Roseate Spoonbills (cf. Dumas 2000), ongoing banding studies should also be continued.

Satellite Telemetry

Satellite telemetry should be continued to ascertain details of movements and micro-habitat use in the breeding and non-breeding seasons. As noted by Langan and Lorenz (2006), satellite telemetry can provide a variety of critical information crucial to the conservation of this species. Efforts should be made to place satellite transmitters on adult spoonbills in multiple colonies so that key foraging areas can be documented and correlations between hydrological conditions, prey populations and breeding success can be examined in more detail. Feather samples should be collected from all birds that are captured and equipped with satellite transmitters in order to document their sex via DNA analysis. The collection of body feathers will avoid more invasive procedures such as blood sampling, and the documentation of the sex of marked individuals would clearly be beneficial, and the collection of body feathers will avoid more invasive procedures such as blood collection. A number of private and commercial laboratories are now available to complete sex determination via feather, and such analyses can be completed for relatively minimal costs.

7. MULTI-SPECIES

The challenges of managing for multiple species have been frequently raised in the 2003 SEI meeting and again in the 2007 forum. In this section, we address this topic by exploring conceptual frameworks and research structures for tackling multi-species needs as well as more specific issues of potential trade-offs for the four species of concern, and constraints in management.

To date there has been little integration of the research work conducted on different species – rightly or wrongly, this situation leaves an impression of separate groups of investigators working independently on "their" species without much communication among groups and without a collective plan to integrate knowledge. Consequently, the policy debate has become one in which species are often pitched against one another, with the work of different research groups used to back up the different "sides".

An alternative and more effective model is to develop a research environment in the Everglades that fosters greater interaction among research groups, with the objective of finding solutions that optimize across the entire suite of restoration and legislated goals. Such a strategy would bring different groups of researchers together to objectively determine whether or what trade-offs actually exist among species, and how best compromises can be made. (This is discussed in more detail in the governance section).

One approach to addressing issues posed by multi-species concerns is through the development of a single model that explicitly links ecological/hydrological changes in the ecosystem to habitat/population models for the individual species. Such an endeavor would facilitate the ability to see how a change in a hydrologic driver ripples to all species of interest, and would allow one to optimize across species and determine exactly what trade-offs really exist. Currently, many discussion of trade-offs seems speculative.

That said, it does not appear to the panel that the needs of the different species are as much as odds as they are often portrayed. Clearly all are affected by the current water management regime in south Florida. The Cape Sable Seaside Sparrow continues to occupy the same marl prairie habitats that it has for several decades but suffers from overly wet conditions in western Shark River Slough and overly dry conditions in northeastern Shark River Slough. In contrast Snail Kites, Wood Storks, and Roseate Spoonbills have shifted their distributions within the Greater Everglades as conditions in areas they used historically deteriorated. In this sense, these species continue to exhibit greater resiliency than the sparrow. These three species are impacted by changes in hydrological regimes that affect foraging conditions and nesting cycles and thus their resiliency, with respect to their life history as well as distribution, is constantly tested. The panel received input that indicates that at least for the Snail Kite, there is concern that this resiliency may have reached its limits.

The four species of birds we consider in this report should all benefit from returning hydrology to a pattern more closely resembling that which existed prior to human engineering of the Everglades system. Both Wood Storks and Roseate Spoonbills require water recession during the winter-spring period to concentrate their aquatic prey sufficiently that chicks can be adequately provisioned to support growth and successful fledging. Cape Sable Seaside Sparrows require recession so that habitat is not flooded during the nesting season. Apple Snails, the principal food for Snail Kites require relatively dry conditions for successful reproduction. Snail Kites forage for Apple Snails most effectively over flooded emergent vegetation, and require these conditions for successful chick rearing during the late winter-early spring period. Management of water in the WCAs and consequences for Everglades National Park over at least the past three decades have not produced appropriate water levels at the correct time of year on a regular basis for any of the avian species in question. We believe managing water so that water levels peak in the WCAs during the wet season (June-September) followed by dry down beginning as early as October and release of water through Shark River Slough provide the best opportunity to produce hydrological conditions favorable to the four species we considered. Critical questions about the efficacy of such an approach and specific details of water management to achieve conservation goals remain.

First, it is unclear whether sufficient water can be released down Shark River Slough to increase fresh water flows to Florida Bay to required levels until CERP is fully implemented, or at least until Decomp is operational. Second, hydrological models indicate that habitats occupied by subpopulation A of the Cape Sable Seaside Sparrow will become wetter under CERP. It is certainly true, however, that dry downs in WCA3 on the schedule necessary for Wood Storks could produce drier conditions for much of subpopulation A during the critical nesting period. Finally, it is unclear whether recession beginning in October can produce isolated pools containing high concentrations of aquatic prey required by Wood Storks, while still maintaining some areas of flooded emergent vegetation required by Snail Kites during February through May. Certainly, the decline in spatial extent of the Everglade topographic diversity will make meeting this last objective more difficult but our understanding of details of hydrological patterns are not sufficient at present to predict an outcome. We believe it is essential that managers and scientists, working together, implement long overdue changes in water management as quickly as possible and combine this management action with appropriate monitoring of hydrology and the avian populations of interest to refine water management to best meet the needs of the four species of birds we considered as well as other residents of the greater Everglades system.

Thus, similar to the 2003 panel, the current panel does not perceive the current situation as representing a conflict between the needs of the Cape Sable Seaside Sparrow and the Snail Kite, but rather that continuing degradation of the ecosystem has reached the point that there is immediate concern about both of these species rather than just the former. We see the major problem not as the impact of emergency management for the sparrow, but as the continued failure to be able to move significant quantities of water further east, through northeastern Shark River Slough, in order to achieve more and broader flow south to Florida Bay. Because of this situation the combination of hydrological conditions that all four species require are not being reliably produced. Discontinuing emergency management in order to release more water into western Shark River Slough clearly will have adverse impacts on sparrow subpopulation A without benefiting any of the other subpopulations. It does not appear that such a change in water management will benefit Wood Storks and Roseate Spoonbills significantly because it will result in too much water being released too far west to efficiently achieve desired conditions for these species in Everglades National Park and Florida Bay. Also, the benefits of such action to the Snail Kite are not at all certain, given the complexities of its distribution and relationship to hydrology. Such action likely would halt continued degradation of nesting (i.e., tree islands) and foraging (i.e., ridge-and-slough landscapes) within WCA-3A, but it will not restore habitats there, nor will it result in improvements to other areas used by kites such as Lake Okeechobee and the other WCAs. Instead of focusing solely on terminating emergency management, it is the panel's opinion that a larger view of the system is needed, and that the most effective action is to move forward with ModWaters as originally envisioned (i.e., including raising of a portion of the Tamiami Trail) and Decomp as quickly as possible. We will now develop these arguments in more detail.

MULTI-SPECIES APPROACH AND TRADEOFFS

The goal of Everglades restoration is to recover a degraded ecosystem to as natural a state as possible such that it contains the full complement of species, habitats, and processes. In 2003 the SEI panel was asked to address one of the key assumptions of this approach, which is that restoring the Everglades through the CERP would in fact benefit all species. The SEI panel wrote:

"Assuming that the hydrology and habitat will be successfully restored, the Panel concluded that a multi-species approach in this case is facilitated by a lack of apparent trade-offs: project design and management for one or another target species will, ultimately at least, benefit all of them. We believe that this is the case not because of similarities among species in their habitat (food, foraging, breeding) requirements; indeed, the target species are diverse in these requirements. Rather, it is the case because a restored Everglades system with natural or near-natural water flows will support a wide range of conditions with broad spatial and temporal variability, within which we expect all target species to be accommodated. This is not to say that all species will benefit equally from natural water flows when CERP is fully implemented. There likely will be intermediate and transition stresses that will vary among species, and different species will be required to adapt behaviorally in different ways and to different extents to restoration processes. The degree to which species accommodate to changes in the system, during transition and thereafter, will require documentation via extensive and intensive monitoring, and necessitate a flexibility of management response via adaptive management of the processes as they are put into operation."

The above statement also reflects the opinion of the 2007 panel. We recognize that new information has been obtained since the 2003 report that relates to this statement in significant ways, however. The Cape Sable Seaside Sparrow may have more capacity to colonize new habitats than previously realized, but CERP likely will result in wetter conditions for subpopulation A than previously recognized. Thus CERP may put subpopulation A at risk in order to achieve ecosystem restoration objectives that will benefit storks, kites and spoonbills, as well as a host of other species. The panel feels that this is an acceptable tradeoff, although we recommend attempting to minimize risk to subpopulation A through the incremental adaptive restoration process. Changes created through the implementation of the multifaceted CERP, however, is different than an isolated action such as opening the S-12 structures to release water within the existing water management system. Indeed, as an isolated activity, opening the S-12 structures likely would extirpate subpopulation A, as nearly occurred in the mid-1990s, without producing the ecosystem-wide ecological benefits that CERP will achieve. The panel was struck by the fact that all four avian species require similar cycles of rising water and dry down, which essentially represent the same hydrological regime applied to different habitats and regions. This is not surprising, as the broad sheet flow from Lake Okechobee south to Florida Bay that characterized the Everglades prior to human influence, combined with the annual rainfall cycle, produced this regime. The CERP attempts to recreate this regime, and this is the basis of the panel's conclusion that all four species can thrive under the CERP. In contrast it remains unclear if release of water through the S-12 structures alone can create the desired extent and timing of water-pulse/dry down to produce the foraging conditions in the southern Everglades that storks and spoonbills require.

The Snail Kite situation is more complex. It is difficult to argue that ponding of water in WCA-3A resulting from protection of sparrow subpopulation A under ISOP has adversely impacted Snail Kites when the kites shifted their distribution from more northern areas into WCA-3A when ISOP was implemented (Martin et al. 2007b, Figure 4-1). Clearly there have been striking changes to habitats within WCA-3A as a result of the emergency measures which have had adverse impacts on components of the system, damage to tree islands and flooding of tribal areas being two conspicuous ones. The panel recognizes that there are legitimate reasons why continuing to protect the sparrows is problematic, but are unclear if protecting Snail Kites is one of them. Excellent new information about Apple Snails, combined with studies of the kites themselves, indicate that the kites require particular dry down cycles in specific habitats in order to thrive. The appropriate conditions could be created in many locations within the Everglades, not only in WCA-3A. For instance, the area that contributed most to successful nesting in 2006 was Everglades National Park. Similarly, release of water through the S-12s may or may not create such conditions, within WCA-3A or farther south, depending on the timing and amount of water released. Benefiting Snail Kites is not a simple matter of releasing water through the S-12s within the current water management system, and thus does not represent a clear tradeoff with protection of sparrow subpopulation A.

A better solution is to create a water management system that results in the possibility of appropriate conditions for kites in many areas throughout the system, such that they likely will exist somewhere each year but not necessarily in the same location each year. This mosaic of conditions will allow the kites to be successful under a highly variable rainfall regime. There has long been a consensus that the best way to achieve this is to restore more sheet flow from Lake Okechobee through the Water Conservation Areas, and more flow to northeastern Shark River Slough in the southern part of the system. It is as important to restore appropriate conditions for kites in Lake Okechobee, WCA-3B, and other areas as it is to do so in WCA-3A. These same changes to the system promise to create the foraging conditions that storks and spoonbills require to nest successfully in the southern Everglades. They also promise to improve conditions for sparrow subpopulations B-F. The most disturbing information the panel received was that the design of ModWaters, which represents a critical first step toward greater sheet flow generally and more flow through northeastern Shark River Slough specifically, has been compromised such that it will produce much less movement of water east and south than originally envisioned because the Tamiami Trail will remain an obstacle to desired flow patterns. The implementation of this long-delayed project in 2008 was to have alleviated the problems that plague WCA-3A and sparrow subpopulation A to a large degree. It no longer appears to have that ability. The single most positive step that could be taken to conserve the four bird species is to find the resources to fully implement ModWaters. The second is to accelerate implementation of Decomp. Until these two projects are completed conservation of these four species will be a challenge. There are no true conflicts between the needs of these species, but until the desired water management system in created, there will be tradeoffs over which of the four species to allow to suffer most from ongoing ecosystem degradation.

POLICY CONSIDERATIONS

The panel recognizes that ecosystem restoration does not operate in a policy vacuum. Biology, hydrology, and engineering are the scientific and technical underpinnings of restoration, but managers who make decisions based on the best science available do so within the policy environment. Yet policy involves other societal factors (e.g., flood control and water storage) that can be at odds with management actions solely focused on target species. This creates a specific set of challenges. For instance, laws such as the Endangered Species Act (ESA) have requirements that determine how science is used and the basis for decisions. While it is not the work of this panel to provide legal or policy recommendations, it is within the panel's charge to address areas where such a nexus can result in unique scientific challenges and opportunities, and to suggest ways to navigate them.

The ESA addresses the plight of individual species in their habitat. However the statute and accompanying policy offer little guidance on how to apply the ESA in the larger context of multi-species ecosystem restoration. Thus Everglades restoration is often in "unchartered waters" having to balance the biological needs and legal requirements of imperiled species within the overarching framework of multi-species and ecosystem restoration. This situation can often create the perception of trade-offs among species some of which may be real, while others are simply policy-driven. Thus scientists often need to pay closer attention to issues such as "trade offs" because of the framework in which managers have to make decisions. These questions are not confined to the four species of concern in this report. With sixty eight Everglades species listed as threatened or endangered addressing multi-species restoration will require a conceptual framework that takes such factors into account.

To fully assess potential trade-offs and identify acceptable risks to species and restoration, there is a need for a common, and easily comparable, conceptual framework for all species. Demographic models for all species are needed, each with a link that relates demographic paramenters to changing habitat conditions. This requires hydrological and vegetation modeling tools and links that are at the correct scale for the species-related question being asked. However, by using a common set of habitat (e.g., hydroperiod, vegetation, etc.) parameters, researchers will be able to use these models to predict simultaneously how a change in conditions is expected to affect each of the species. That this is not currently possible, makes it difficult to identify the true options and trade-offs and characterize them with any precision.

8. HYDROLOGY

The panel views the current modeling efforts as a necessary and appropriate tool for what they were primarily intended to do: simulate hydrologic response at the entire system scale. Regional models are suited for regional questions, however, and there are local-scale ecological thresholds that appear to require simulations of hydrologic response at a smaller scale than the larger-scale models presented to the panel. Inquiries after the panel's meeting pursued this question of smaller scale modeling appropriate for the four species of interest here. Although this follow-up provided the panel with a valuable insight into the state of these types of efforts, we may yet be unaware of other uncompleted modeling efforts that could address concerns raised here.

Given that hydro-ecological applications of a model often have different objectives of modeling, it can be worthwhile stepping back and evaluating what is currently available, and what is needed to answer the hydrologic questions for the four species of interest here. This can be done with a number of levels of formality, but can include such things as the following.

Characterize elements of the model. Formulations vary among writers and organizations, but it is generally useful to identify which of the entities in the model represent.

- Goals of management in themselves (e.g., "endpoints")
- Indicators (which may be endpoints, but could be correlates or surrogates)
- Control points (elements, such as levee releases, under experimental or management control)
- Experimental variables (including future climate and sea level rise scenarios)

The conceptual models for the four species provide a beginning schematic that can facilitate this characterization.

Visualization and communication—The proposed work plans are complex, and the objectives of the hydrologic operations varied. As a result it is often difficult for interested parties to follow which scenarios are being simulated, and how that ripples down to the local scale and location of interest. Standardization of reporting and work on visualization of hydrological model inputs and outputs can help transfer the results of the model to the ecologists that are using the model results. At a minimum, the model results should be reported using the same metrics as the ecological thresholds provided for the species of interest.

Based on our review, the panel highlights the following points on Modeling:

1) **It is important that the right tool is applied to the right problem. Conceptual frameworks and recent work on these species show that the timing and magnitude of water flows are important forcing functions. Timing and magnitude of hydrologic flows are tractable goals of modeling, but must be simulated at the temporal and spatial scales important for the species.**

Quantified results from such a properly scaled and constructed model can inform better management of the overall system.

Although somewhat stating the obvious, this underscores the importance of the quantitative framework of a properly constructed model that can connect and synthesize point-measurements/field efforts in ways that cannot be attained using other methods. Moreover, model results can fill in areas of the system, both in space and time, which cannot be covered with field sampling. Ecologists and other non-modelers should make sure that important spatial and temporal scales are provided to the modelers, and that the modeling development includes a number of discussions between the model and non-model elements. These discussions should be conducted during initial, intermediate, and late phases of modeling, are important for getting "buy-in" for modeling from the other project components, and are critical for ensuring that the model is as useful as the scope of the modeling effort allows.

2) **Use of models commonly falls primarily into two overarching activities; models are used for providing: 1) a quantified framework to look at the range of present system conditions ("constrain the arm waving"); and 2) predictions of how the system responds when system drivers are outside the range of the calibrated conditions.**

The first is especially important when in a potentially controversial setting as it focuses discussion on system parameters and physical processes rather than on qualitative predictions based primarily on professional judgment. The second is often the primary reason models are built. These predictions may simply be running a calibrated model to one new set of conditions; or, the model can be a heuristic model where an ensemble of scoping simulations provides a quantified "envelope" of possible outcomes for a range of possible stresses/changes. Model predictions are of primary importance for the Everglades system in that the modeling tools must be able to provide "what if" scenarios that explore potential operational changes and their effect on the timing and magnitude of hydrologic flows. This requires a deterministic framework that uses physics of the system to extrapolate future conditions. Regression based approaches such as the EDEN work, which are well-suited for describing current conditions, cannot fill in space and time for conditions not represented by the historic data used to constrain the regression. Thus, although these tools have a more appropriate spatial resolution for the ecological questions being asked, they cannot provide insight into what the future hydrologic regime might be for new system configurations such as that of ModWaters or Decomp. In addition, accurate model prediction at scales that are ecologically relevant will require good connections to the larger, system-wide modeling as much of the water that is simulated in the local areas important for these four species is coming from outside the local area. Uncertainties and errors in specification of hydrology from the local area boundaries derived from the larger models will ripple to the smaller local scale.

3) **Models are by definition a simplification of reality. But, this simplification can involve different things depending on the <u>objective</u> of the model. Thus, this**

objective drives the initial discussion of what to include in the conceptual model that forms the basis of model construction.

The utility of any model is directly dependent on the conceptual model used to provide the relevant problem processes, scales, and conceptualizations. In hydroecological objectives such as those present in the Everglades, a conceptual model that encompasses all these model characteristics cannot be discerned by the modeler alone. That is, conceptual models must be developed using the best available knowledge, whether in or outside any given project team. From the world of possible compartments/habitats/life stage histories/processes, the conceptual model development should include discussion on which components are most important (that is, which are the species most sensitive to). For example, biologists should convey all important "thresholds" to the extent that they are known to exist. These thresholds will direct the model emphasis so that the model is not overly complex and unwieldy, and ensures that the model is not "measuring with a micrometer and cutting with a chainsaw." The panel believes that great strides have been made by the ecologists working with these species in the last four years; indeed, in some ways the work on identifying ecological thresholds for these four species has outpaced the abilities of the hydrological models to predict when they will be crossed. Nonetheless, these concepts have to be continually re-evaluated to ensure that the tool being created is the best available for the hydroecological question being asked.

4) **The hydrologic models need to balance complexity of process simulation with needs of the decision makers.**

Building a quantitative model that encompasses every possible aspect of a conceptual model is often not a useful approach. The model development time for an overly complex model is commensurately longer, the potential for construction and input errors larger, and the model runs are often longer and more unstable (Hill 2006). Moreover, such a tool is often poorly suited for the problem as its underlying parameters are more apt to be insensitive or correlated, which in turn results in problems with calibration non-uniqueness (as changes to some parameters have little effect or can be offset by changes in others). A more targeted model that is constructed to address a specific prediction of interest avoids or reduces many of these problems. However, care needs to be exercised so that such a fine tuned model is properly employed and not overextended beyond what it is suited for. Thus, there will be a suite of possible models included in testing as there are usually more than one prediction of interest and more than one hypothesis to test. The panel heard of need for "more simple" tools that can quickly be applied to problems or questions that arise. Although care has to be taken that the tool fits the need, a model that is so unwieldy or enmeshed in a process that takes inordinately long periods of time to go from simulation request to model result is often no better than no model at all. That is, decision makers often need to make decisions in a time-sensitive fashion; thus, if model results are not provided in a timely fashion it is likely that the factors that drive the decision will be the same as if no model were available.

5) **Climate change is affecting the hydrology of the Everglades but current hydrologic modeling (and management design) presented to the panel does not**

discuss consideration of long-term trends in precipitation, temperature or sea level.

While it is widely acknowledged that sea level rise is altering the salinity of the southern Everglades, modeling efforts to date often do not consider that sea level is rising and that the rate of sea level rise is very likely to accelerate in the coming decades. Moreover, changes in temperature and rainfall patterns are also expected under future climate change, which in turn will greatly affect the hydrology of the region (see next section). An increase in mean, maximum, and minimum temperatures, which are very likely in the next 20 years and beyond, will affect evaporation, surface water flows, soil moisture, fire frequency, and water availability for all species of concern in the Everglades. While specific local changes in precipitation cannot be reliably projected on the habitat scale, it is very likely that rainfall will occur in more intense events with more consecutive dry days on the system scale. Droughts are likely to intensify and the propensity for wildfires and tropical storms appears very likely to increase in south Florida. Evaluations of "scenarios" of sea level rise and climate change run through a hydrologic and ecosystem modeling framework would provide important insight to guide the design, construction, and operation of restoration projects in the Everglades.

6) **Thus it follows that, because models can have multiple uses/predictions, it is important to not focus on "one model depiction of the world that gives all answers".**

Such an encompassing model design often results in a modeling process that takes too long and a mediocre model that doesn't fit anything well. A superior approach is to test various hypotheses of important processes early and often in the modeling effort. This design and evaluation of such testing should be vetted by all pertinent members of the restoration (modelers and non-modelers). With this feedback, the universe of possible models can be culled to a short list of useful tools. Likewise, scenarios of climate change and other potential system operation can be evaluated in a timely fashion, which in turn facilitates communication between the hydrologic underpinnings and the related ecological components, and the adaptive management elements that depend on modeling results.

Given the presentations and discussions with the project members, there appear to be four project objectives where models could be usefully applied:

- To provide hydrologic conditions for "backcasting" of what the system was in the past so as to better understand the historic species response. In some cases, where the current system operation is similar to past periods of interest, the current EDEN model may suffice. In other cases a more deterministic/physically based approach is needed.
- To help understand presence/absence of species in different parts of the system during different periods of time in the past.

- To provide hydrologic information to decision makers such that system operations can be targeted to meeting ecological thresholds when not in conflict with more critical operation goals.
- To allow project members to overlay ecological field data on a quantitative depiction of the physical system that "fills the holes" where data could not be obtained and is constrained by the underlying physics and calibration data. Such a use provides information on the conditions where species are not present as well as the conditions measured where the species are.

In addition, from the presentations and discussions, it appears that the species might benefit from the following actions.

- Developing a process/forum/workshop to allow ecological concerns to be formally considered in the 2010 Systemwide Operations Manual revision. The panel heard of cases where the operating rules can thwart a proposed system operation modification, not because it was in conflict with a competing system operation goal, but because it moved the system outside of the allowed operating parameters. Moreover, operating rules are not flexible (by design) once they are placed into operation. Formally interjecting consideration of ecological hydrologic goals/thresholds into the revision of the operating rules will help ensure that the best understanding of the ecological thresholds are heard, which in turn will allow them to be balanced against competing needs, and more likely to be enacted when not in competition. Adaptive management will be more difficult to implement without these considerations. It is the panel's opinion that the flexibility allowed in system operation is likely to be more effective when the system starting point is nearer to the target condition. Thus, developing appropriate operating rules that get in the "ballpark" of what is needed by the species of interest will help facilitate the hydrologic conditions needed by the species.
- Develop or modify existing modeling approaches to provide hydrologic timing, duration, and magnitude of the appropriate scale for the ecological thresholds provided. From the discussions presented to the panel it appears that water level predictions need to be on the order of centimeters, with a temporal resolution on the order of days for selected periods of the year. In addition, a system should be developed whereby a decision maker can request a model run and have the results be internally released in a more real-time fashion even if with the qualifier "provisional results subject to revision." There should be an explicit recognition that such interim products may change over time as more is known about the systems and the species.

Evaluating the present or future models should include post-audits using field data collected at the scale appropriate for the species. Because much of the previous modeling involved large scales that are not optimum for the ecological thresholds available, goodness of the smaller scale model calibration cannot necessarily be judged by the calibration or calibration approach used in the larger scale regional models which are extensively documented. Moreover, it should be recognized that calibration alone commonly may not reduce prediction uncertainty sufficiently (Moore and Doherty 2005, 2006). Assumptions that may be important for the success of field actions should be tested with field data.

9. FUTURE CONDITIONS & MANAGEMENT

CLIMATE CHANGE AND VARIABILITY

During the past 40 years the climate of the southeastern United States has grown warmer and wetter and most climate models suggest that this trend will intensify during the 21st century (Twilley et al. 2001; Burkett et al. 2001; IPCC 2007). Since there is very little topographic relief, relatively subtle changes in precipitation and runoff could significantly alter the hydrology of the Everglades from the interior to the coast. The key climate "drivers" in the Everglades region are temperature, precipitation, sea level rise, and tropical storms. The interactive effects of these drivers could have important implications for restoration efforts, as well as the sustainability of ecosystem services such as flood water retention, ground water recharge, and maintenance of biodiversity. The rate of increase in temperature is projected to be much higher during the next 20-50 years and extreme temperature events are likely to increase more than the average climate over the course of the next century (IPCC 2007). The effects of this increase in temperature will cascade among physical and biological systems in south Florida with impacts ranging from changes in the abundance of Apple Snails to large-scale changes in the structure and extent of wet prairies, aquatic sloughs, and mangrove forests.

TEMPERATURE AND PRECIPITATION

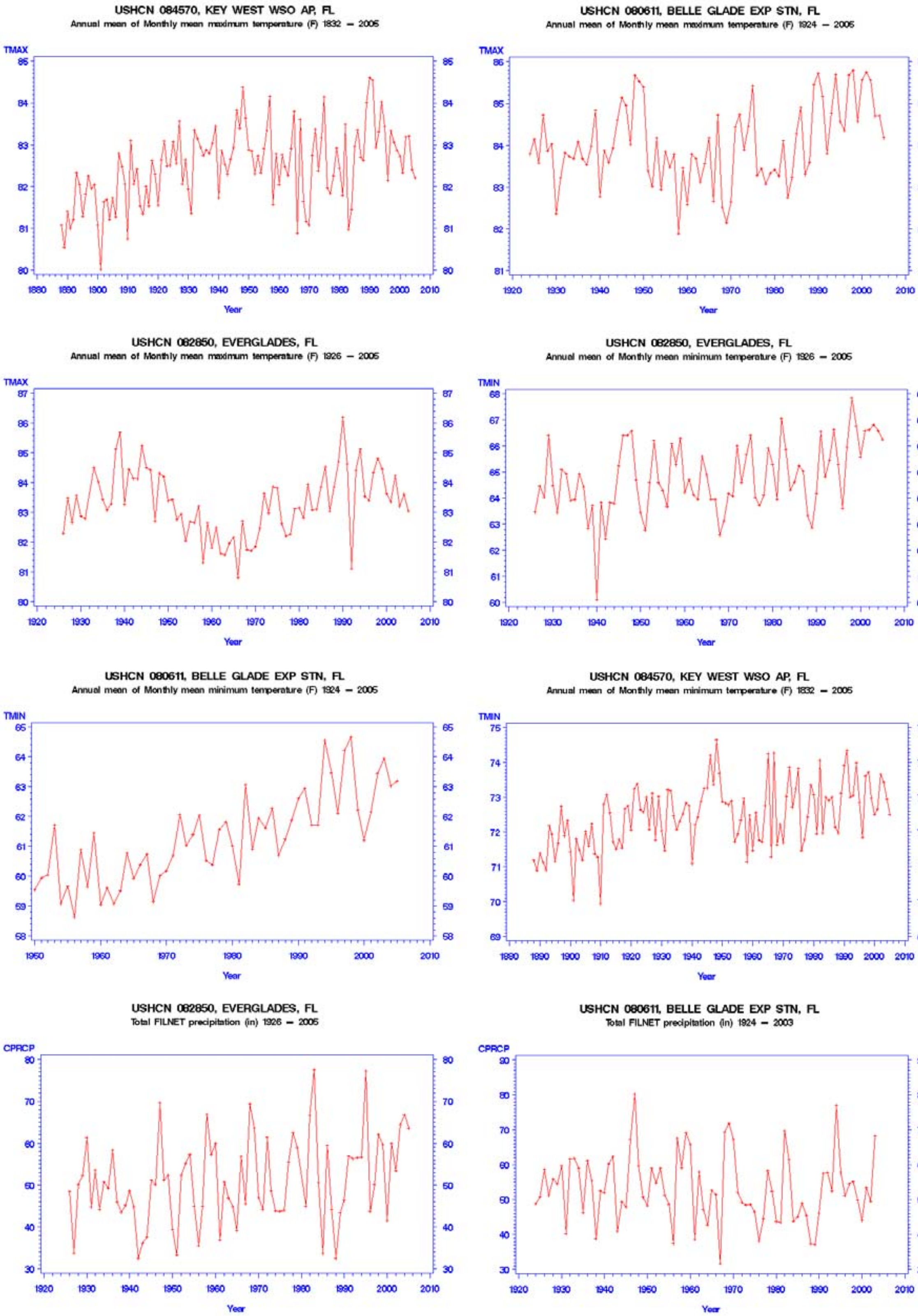
The monthly mean minimum and maximum temperatures in south Florida increased during the past century at each of the three 3 long-term weather stations in the region (Everglades, Key West, and Belle Grade, Figure 9). The very strong positive trends in minimum monthly temperatures imply significantly warmer nights and winters. An increase in temperature has several direct and higher-order effects on the Everglades system that are relevant to restoration design and operations planning, including:

1) increased evapotranspiration rates, which lowers water levels, leads to vegetation stress, and affects the flow of nutrients and fresh water to the coast,
2) decreased winter minimum temperature, which increases growing season length, alters the distribution of native and non-native plant species, and tends to enhance net primary productivity (and potential fire fuel load),
3) decreased soil moisture that leads to more frequent and intense wildfires,
4) decreased summer dissolved oxygen levels and increased water temperature, which affect the availability of avian prey,
5) physiological (thermal) stress in target avian species, and
6) changes in phenology that may decouple avian species from their food sources.

Historical trends in precipitation are generally increasing but highly variable across south Florida, like most other parts of the U.S. Southeast, and models of future precipitation for the region also produce divergent results (NAST 2000; IPCC 2007). While the southern Everglades weather station shows a striking increase in precipitation since 1926, the Belle Glade station near Lake Okeechobee does not (Figure 9). Precipitation records near the Tamiami Trail suggest that wet season rainfall (June-December) has increased during the past 15 years compared to the 1970s-80s (Martin et al. 2007). The historical record also reveals high interannual variability in precipitation with record dry conditions in one year followed by a record high year the next.

Figure 9. Monthly mean minimum and maximum temperature and total monthly precipitation at south Florida weather stations. (Source: C.N. Williams, M.U. Menne, R.S. Vose, and D.R. Easterling, NOAA National Climate Data Center, Ashville, N.C. 2007. (http://cdiac.ornl.gov accessed September 10, 2007. Note: Key West station lacks FILNET precipitation data.) (See next page)

Historical Temperature and Precipitation in South Florida



Interannual variability in south Florida rainfall is strongly connected with the El Nino Southern Oscillation (ENSO). Above average rainfall and below average temperatures are typically expected during El Niño phase (warm conditions in the equatorial Pacific) of the ENSO cycle, while the La Niña phase (cold condition in the equatorial Pacific) indicates a higher drought potential. Some climate models suggest that El Niño cycles will become more intense during the coming decades as the temperature of the atmosphere and ocean warm (Timmerman et al. 1999). The ENSO cycle of 1997-2000 demonstrates how extremes in rainfall create enormous consequences for wildlife frequency and intensity (Twilley et al. 2001). Drought intensity in Everglades wetlands used by Snail Kites, for example, reflects the influence of ENSO phase with effects most pronounced during the dry season (Martin et al. 2007). The North Atlantic Oscillation (NAO) can also have pronounced effects on the Florida dry season by reducing storminess and rainfall during neutral ENSO conditions, and increasing storminess and rainfall during moderate El Niño conditions (Hagelmeyer and Almeida 2003).

Climatologists have developed several types of forecast schemes for predicting ENSO variations based on Pacific Ocean currents and subsurface thermal structure. While ENSO forecasts are not perfect, they are sufficiently skillful at this point that farmers, corporations, municipalities, states, and national governments have used them to prepare for El Niño and La Niña events. Understanding the effects of El Niño phase on precipitation patterns in south Florida could help restoration planners anticipate good and bad years for vegetation reestablishment, years when soil moisture will tend to be lower and wildfires more likely, and seasons when pumping may be needed to augment freshwater delivery to habitats of endangered species. The three overarching messages, however, about temperature and precipitation trends and projections for Everglades water managers are:

1) Droughts and flood events appear likely to intensify,
2) Efforts to restore more natural hydrologic regimes in the Everglades system will require greater water delivery flexibility than in a system absent climate change, and
3) Extrapolation of historic trends will likely underestimate future change.

HURRICANES AND LESSER TROPICAL STORMS

As the atmosphere and sea surface warm, we can anticipate an increase in the intensity of hurricanes making landfall along the U.S. Gulf of Mexico and South Atlantic coastlines. While factors such as wind shear, moisture availability, and atmospheric stability also influence tropical cyclone genesis and evolution, increasing sea surface temperature has been correlated with hurricane intensity in the Atlantic tropical cyclogenesis regions where hurricanes that make landfall in south Florida are formed (Emanuel 2005).

The precise contribution of increasing sea surface temperature to tropical cyclone formation during recent decades is the subject of several recent scientific studies. Some analyses indicate that the increasing intensity of hurricanes since 1970 is driven by natural multidecadal variability (Pielke 2005; Landsea et al. 2006), but most recent studies support the hypothesis that hurricanes are increasing in the Atlantic cyclogenesis region as a result of sea surface temperature increases related to anthropogenic warming (Webster et al. 2005; Emanuel 2005; Mann and Emanuel 2006; Hoyos et al. 2006; Trenberth and Shea 2006). Some studies conclude that the increase in recent decades is due to the combination of natural, cyclic fluctuations and human-induced increases in sea surface temperature (e.g., Elsner 2006). Sea surface temperature has increased significantly in the main hurricane development region of the North Atlantic during the past century (Bell et al. 2007, Figure 10) as well as in the Gulf of Mexico (Smith and Reynolds 2004, Figure 11). Based on modeling, theory, and published empirical studies, the IPCC (2007) concludes that the observed increase in intense tropical cyclone activity in the North Atlantic since about 1970 correlates with a concomitant increase in tropical sea surface temperature. The IPCC further projects that tropical cyclone activity is likely to increase during the 21st century.

Figure 10. Sea surface temperature trend in the main hurricane development region of the North Atlantic during the past century. Red line shows the corresponding 5-yr running mean. Anomalies are departures from the 1971–2000 period monthly means. (Source: Bell et al. 2007)

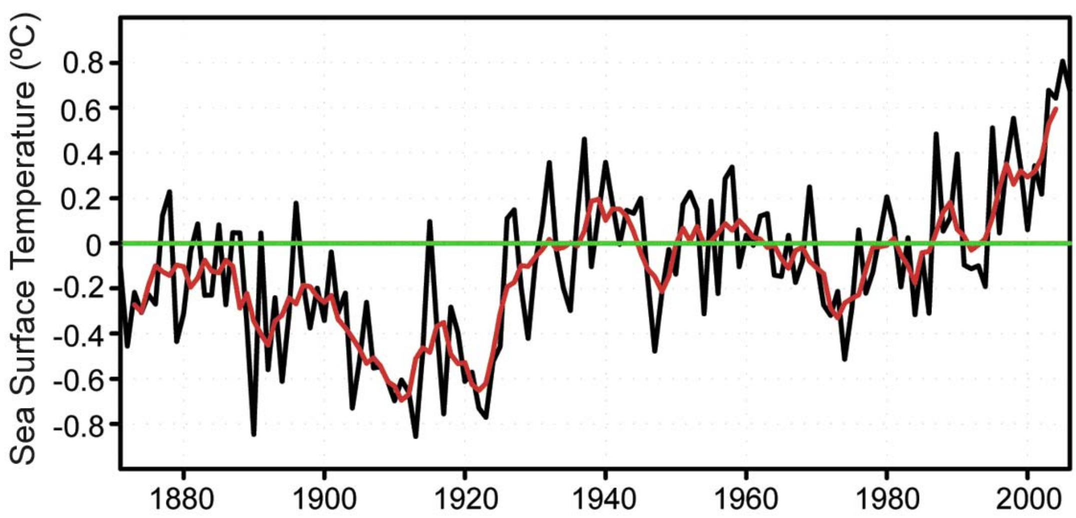
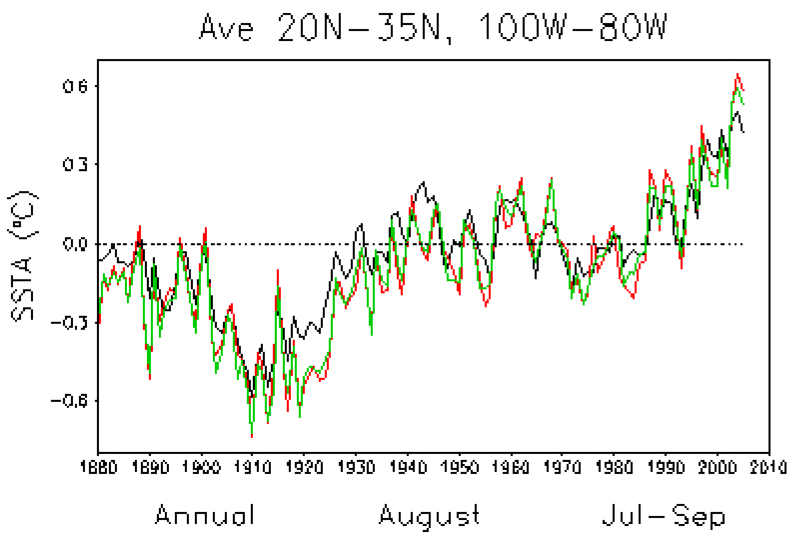


Figure 11. Sea surface temperature (SST) trend in the Gulf of Mexico region derived using the ERSST v.2 database. The plot displays the SST anomalies averaged annually, as well as the anomalies determined from the averages for August only and for the July-September peak of the hurricane season. (Source: Smith and Reynolds 2004)



El Niño conditions create upper atmospheric winds that tend to inhibit hurricane formation, while La Niña conditions favor hurricane formation. The probability of at least 3 hurricanes making landfall along the Southeast US coastline is near 0% during an El Niño and 50% during a La Niña event (Burkett et al. 2001). Average summer wave heights have been increasing along the South Atlantic coastline since 1975 and are attributed to a progressive increase in hurricane activity (Komar and Allen 2007).

The greatest damages to the built environment from hurricanes are caused by storm surge, but wind damage can have more important consequences for avian habitats in south Florida. Mangrove community structure, for example, is highly influenced by wind damage during hurricanes (Doyle 2003; Twilley et al. 2001). An increase in sea surface temperature is likely to increase the probability of higher sustained winds and surge levels per tropical storm circulation (Emanuel 1987; Holland 1997; Knutson et al. 1998). An intensification of Atlantic tropical storm activity portends an increase in disturbance of coastal and interior habitats of south Florida. Storm surge effects can be particularly severe if a Category 3, 4, or 5 hurricane makes landfall along the shallow south Florida coastal margin when the tide is high and barometric pressure is low.

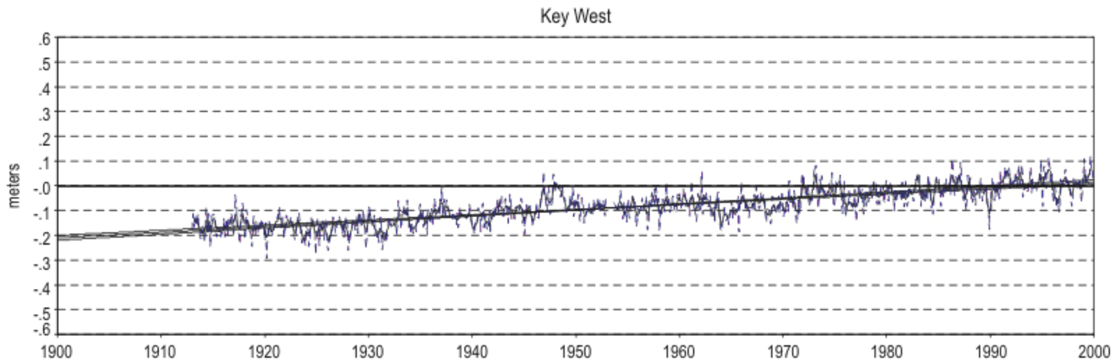
Lightning strikes are commonly associated with thunderstorms and convective activity in south Florida - to the point that the region has been called the “lightning capital of the world” (Hodanish et al undated). Sun and others (2001) documented a significant increase in cumulonimbus cloudiness across the United States during 1948 to 1993. The largest changes in the frequency of cumulonimbus cloudiness occurred in the intermediate seasons, especially in the spring. The increased frequency of cumulonimbus cloud development is consistent with the nationwide increase in the intensity of heavy and very heavy precipitation observed by Karl and Knight (1998) and Groisman and others (2004). Cumulonimbus clouds are commonly associated with afternoon thunderstorms in the region and most fires started by lightning strikes occur during the spring and summer seasons (Costa 2002), which is when conditions are generally driest in the Everglades. The historical and projected increase in temperatures for the region suggests a potential increase in the probability of severe convective weather during the coming decades (Dessens 1995; Groisman et al. 2004). If convective activity increased in the Everglades region, the combination of more lightning strikes, lower soil moisture, and higher fuel loads would very likely increase the potential for major wildfires.

Birds can be directly affected by storms, as in the well documented case of Red Cockaded woodpeckers during Hurricane Hugo. The 1935 Labor Day hurricane had a significant impact on the Cape Sable Seaside Sparrow (Pimm et al. 2002). Although the direct impacts of other hurricanes on specific avian populations are not well documented, there is high confidence in the effects of hurricanes on forest structure (Doyle 1998; Twilley et al. 2001). In the Everglades region, Wood Storks, Roseate Spoonbills and other species that are dependent upon woody structure for nesting would be most adversely affected by an increase in forest damages associated with hurricanes. The impact of major hurricanes results in wide area forest damage of varying degrees from devastating blowdowns to intact, but defoliated canopies. If hurricane intensity increases over the next century as projected, future mangrove forests are likely to be diminished in average height and will contain a higher proportion of red mangroves (Doyle et al. 2003).

SEA LEVEL RISE

The sea level trend at Key West, Florida during 1913 to 1999 was 2.27 mm/yr (0.74 ft/century) with a standard error of 0.09 mm/yr based (Figure 12). This was slightly higher than the global average (1.7 mm/yr) during the 20th century (IPCC 2007). It is also important to note that the historical rate of sea level rise in the region is higher off the Florida coast than the global rate, as reconstructed from tide gauges and satellite altimetry measurement since 1950 (IPCC 2007).

Figure 12. Sea level trend at Key West, Florida (2.27 millimeters/year (0.74 feet/century), standard error 0.09 mm/yr) based on monthly mean sea level data from 1913 to 1999. (Source: IPCC 2007)

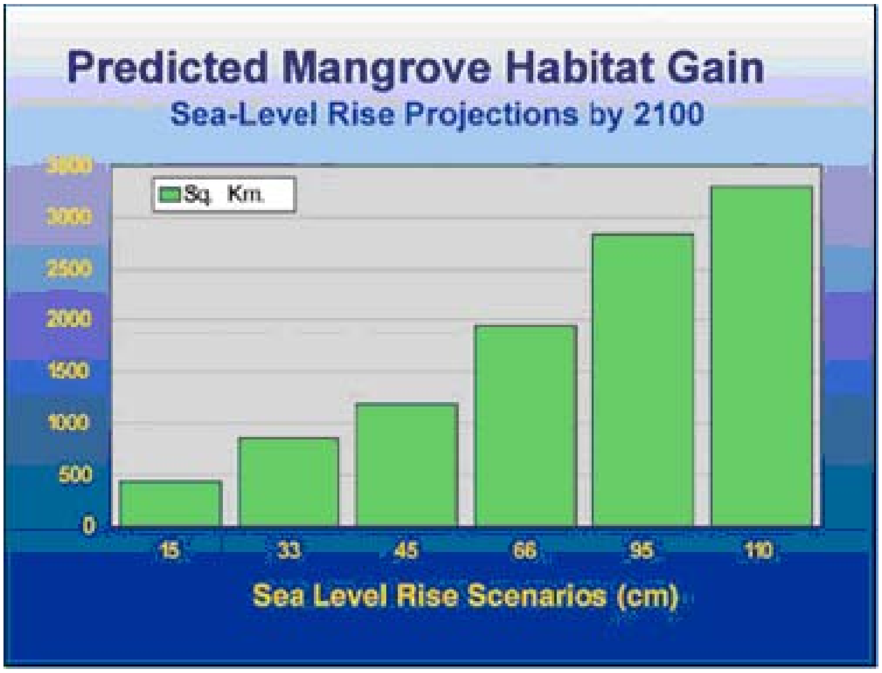


Sea level has risen more than 120 m since the peak of the last ice age (about 20,000 B.P.) and over the 20th century by 1-2 mm/year (Douglas 1997; Gornitz 1995; IPCC 2001). The rate of global sea level rise since 1963 is estimated at 1.8 mm/yr (IPCC, 2007). More recent analysis of satellite altimetry data for the period 1993 to 2003 shows a global average rate of sea level rise of about 3.1 (2.4 - 3.8) mm per year. Whether the faster rate since 1993 reflects decadal variability or a long-term acceleration over the 20th century rate is unclear. There is high confidence, however, that the rate of observed sea level rise was greater in the 20th century compared to the 19th century (IPCC 2007).

Accelerated sea level rise is also one of the most certain consequences of human-induced warming of the Earth's atmosphere. The IPCC Third Assessment Report (TAR) (2001) projected an increase of 0.9-0.88 cm in average global sea level by year 2100 with a mid-range estimate of 0.45 cm. The range of projected sea level rise through 2100 is slightly lower and narrower in the IPCC Fourth Assessment Report (AR4). The midpoint of the projections in sea level rise differs by roughly 10 percent and the ranges in the two assessment reports would have been similar if they had treated uncertainties in the same way (IPCC 2007). The IPCC 2007 sea level rise projections do not include rapid dynamical changes in ice flow from Greenland or Antarctica. If realized, some of the model-based projections could more than double the rate of sea level rise over the past century. Even if greenhouse gas emissions were stabilized at present levels, sea level rise will likely accelerate during the next 100 years (IPCC 2007).

Sea level rise will generally increase marine transgression on natural estuarine shorelines (Pethick 2001) and the frequency of barrier island overwash during storms, with effects most severe in habitats that are already stressed and deteriorating. Salt-water intrusion and increased mean water levels will lead to a change in plant and animal communities. In the Florida Big Bend region, for example, sea level rise has been identified as a causal factor in the die off of cabbage palm (*Sabal palmetto*) (Williams et al. 1999). Sea level rise, coupled with milder winters, are likely to expand mangrove populations in south Florida (Doyle et al, 2001) (Figure 13). Historical trends in the migration of the mangrove/graminoid marsh ecotone since 1940 indicate that this natural transition is already occurring in the southeastern Everglades, at the expense of coastal prairie and *Cladium jamaicense* marsh (Ross et al. 2000).

Figure 13. Predicted mangrove expansion in south Florida at the expense of freshwater habitats over the next century under for various estimates of sea level rise (Source: Doyle et al. 2001).



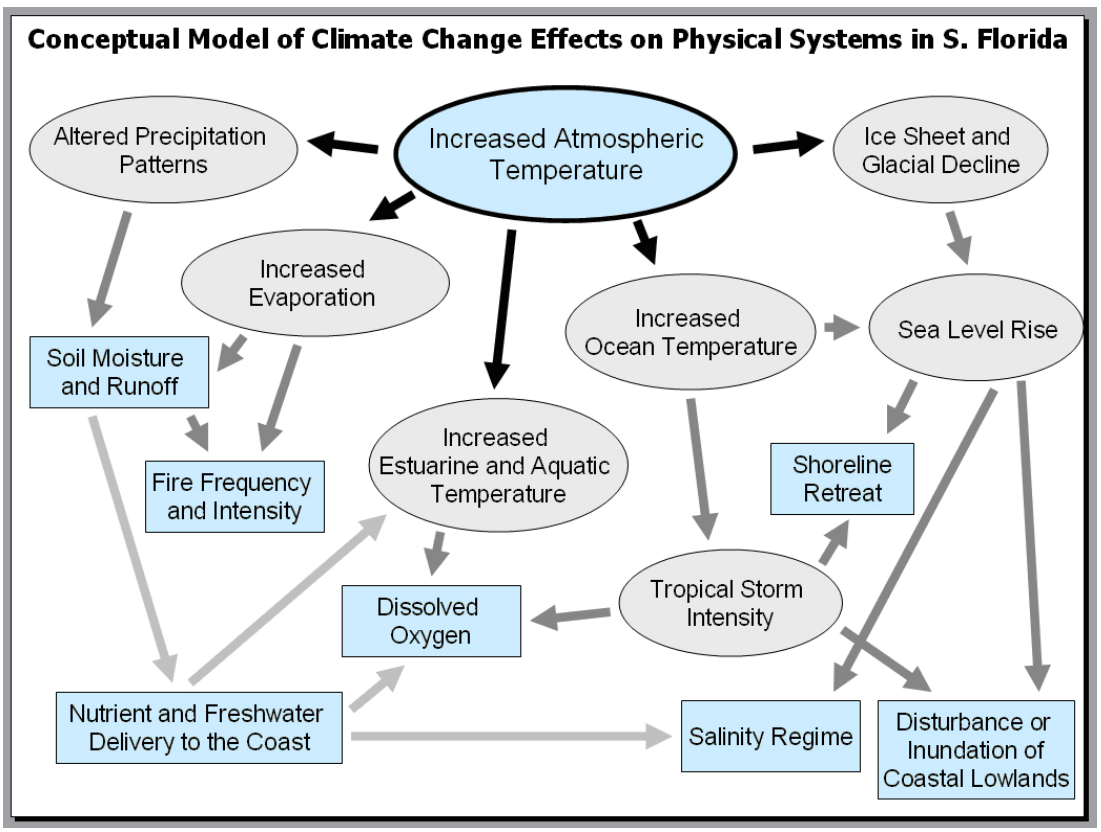
Considering the present trends and the consensus among scientists that an acceleration in the rate of sea level rise during this century is very likely, the following messages are relevant to Everglades restoration and management:

1) As sea level rises, salt water will intrude further inland, thereby restructuring fresh and brackish water plant and animal communities.
2) Even if storms do not intensify as the climate and sea surface warms, accelerated sea level rise alone will amplify the effects of storm surge on coastal shorelines, wetlands and other low-lying features.
3) Transition to more saline environments, inland expansion of mangroves, and contraction of fresh water and mesohaline habitats in the south Everglades appears inevitable and there are few practical coping strategies, however.
4) The importance of freshwater flows to the gradual adaptation and sustainability of coastal brackish and freshwater habitats will increase as sea level rises.

CUMULATIVE EFFECTS ON SOUTH FLORIDA ECOSYSTEMS

Changes in climate can have widespread effects on physical and biological systems of low-lying coasts. Model results, climatic trends during the past century, and climate theory all suggest that extrapolation of the 20th century temperature record would likely underestimate the range of change that could occur in the next few decades. Regional "surprises" are increasingly possible in the complex, nonlinear earth climate system, which is characterized by thresholds in physical processes that are not completely understood or incorporated into climate model simulations. While there is still considerable uncertainty about the rates of change that can be expected, there is a fairly strong consensus regarding the direction of change for most of the climate variables that affect south Florida ecosystems. Precise outcomes of the changing climate on habitats and individual species in the Everglades are difficult to predict because of the complexities, interactions, and uncertainties involved (Figure 14).

Figure 14. Conceptual model of key climate drivers and their interactive effects on physical systems in south Florida.



10. OVERARCHING SCIENTIFIC SUPPORT FOR MANAGEMENT AND POLICY: GOVERNANCE AND ADAPTIVE MANAGEMENT

Adaptive Management allows natural resource managers to act in the face of acknowledged uncertainty. It is used to effect changes, to learn more about the system, and to make course corrections as needed. Adaptive Management is a formal process that has several key elements including:

1. Clear conceptual models;
2. Stated objectives;
3. Implementation tests/actions;
4. Monitoring and evaluation against performance measures;
5. Decisions or course correction based on results.

To maximize effectiveness, participants in the adaptive management process need to have a common understanding of the goals, respective roles, what constitutes success, and how information will be evaluated and incorporated when course corrections are needed. When poorly understood, or without one or more of the key elements listed above, adaptive management can be little more than a series of ad hoc changes.

The parties engaged in the restoring the south Florida ecosystem have embraced the concept of adaptive management. The process is described in the Monitoring and Assessment Plan (MAP). The Comprehensive Everglades Restoration Plan's MAP was developed by an interagency, interdisciplinary team known as Restoration Coordination and Verification (RECOVER). The Adaptive Assessment Team (AAT) of RECOVER has the lead responsibility for creating the monitoring and assessment plan, and for conducting an on-going review of how well it is working. In addition, the AAT has the responsibility to use the information that is provided by the monitoring program to assess system responses, as a basis for recommending improvements in the restoration plan where needed. In 2000, the MAP was reviewed by a National Research Council panel that made several key recommendations to the group (NRC, 2001). A 2004 report by the National Research Council (NRC) concluded that "Adaptive management in the Comprehensive Everglades Restoration Plan is currently more of a concept rather than a fully executed management strategy" (p. 58, NRC 2004).

The purpose of this section is not to repeat the work or recommendations of the NRC. (We refer the reader to the NRC comprehensive report for an excellent review and series of recommendations.) Instead we focus on governance approaches and other challenges that hamper full implementation of an adaptive management strategy. The issues identified here relate to the four species of concern (the focus of this report) but also more broadly to restoration of the Everglades ecosystem including all of its threatened and endangered species.

The underlying premise of Everglades restoration can be summed up by "get the water right." This includes the timing, flow rate, quantity, direction, etc. The assumption is that by "getting the water right" the decline in species will be halted and the ecological processes essential for a functioning ecosystem will, by default, also be restored. However, there is considerable uncertainty around these issues. This is particularly pertinent when, for instance, species may be at sufficiently low densities that process like demographic stochasticity are key drivers and "getting the water right", while a necessary first step, alone does not ensure their recovery. Thus extensive ecological research and monitoring is needed on an ongoing basis.

By focusing on hydrology alone, scientists and managers may miss gathering and incorporating additional important information that can enhance the effectiveness of system operation. Moreover, the additional information can provide additional flexibility such that one management objective can be reached without directly harming another. This type of holistic view of the system underscores the need for other variables to be incorporated into an adaptive management framework. These include elements such as fire (prescriptive fire is a tool), sea level change, human impediments to movement of species among eological units, space or lack thereof for habitats to develop as hydrology is restored, human water supply and flood storage, vegetation structure, accretion rates, non native species, and other factors related to climate changes. A systems approach could help in bringing these together in a tractable and useful way.

In implementing Everglades restoration by adaptive management three main groupings can be recognized.

- ***Senior policy makers/managers*** who make major decisions.
- ***Water resource engineers and hydrologists*** who simulate and manage the mechanics of the system and the flow of water. As "getting the water right" is the main premise, these professions have major roles in decisions and implementation of flow regimes, and giving a reality check as to what is possible and what is not.
- ***Ecologists*** who monitor the responses of endangered species and the ecosystem. This work of these scientists has at times been seen as "follow up research" to evaluate whether the plan is working for individual species (especially endangered species) and the ecosystem as a whole. But advances in research have allowed for greater precision in setting ecological targets and performance measures. This in turn provides managers and hydrologists a foundation from which to set more specific management targets and water regimes respectively.

Historically, when course corrections or major decision are made in response to information, a group of senior and executive level managers convene to make them. The assumption is that the science has already been gathered, analyzed, synthesized, discussed, and finalized, and that the relevant science has "made it up the chain". Thus the presence and input of scientists is seen as irrelevant or even undesirable to decision making at this higher level. However the panel feels that the lack interaction between the full suite of "senior executive scientists" and their equivalent in senior managers hinders the advanced discussions that are needed for best management actions. This is even more problematic because of the need to operate the system with consideration for multiple uses and species, where what is good for one set may not be good for all. However, discussion between senior scientists and senior managers can more flexibly facilitate the flow of ancillary information that can help good decision making, such as how strict a given requirement might be and what uncertainties underlie a given prediction. We recommend a framework that includes adequate and better interactions among senior level individuals from policy/management, hydrology and ecology. Such an approach will help alleviate some of the issues raised in the NRC MAP report. For instance, it would allow for more timely identification of situations where specific restoration goals may be at odds with the general goals of ecosystem restoration.

SCIENCE GOVERNANCE AND STRUCTURES

Everglades restoration is a complex task that will require close collaboration among specialists in several disciplines. Closer interactions among scientists working on the four species of concern, along with other experts on hydrology, vegetation, climate change, operations, etc. are much needed. A consortium approach would help to solve many of the "piecemeal" issues that currently arise when individual researchers with small teams focused on a subset of the system are trying to tackle large-scale multi-disciplinary problems. Currently much of the science in the Everglades ecosystem has evolved within a more traditional framework, whereby a single Ph.D. researcher and associated post-docs and graduate students embark on a long term study of a specific question. We can, for instance, identify Cape Sable Seaside Sparrow science teams, Wood Stork researchers etc. As noted elsewhere in this report, the work of these individuals has been excellent and we have seen great advances in the science of the species of concern since the last SEI workshop. However, the current research approach is inadequate to meet the large and integrated scientific needs of Everglades restoration.

Consider for a moment the scale of the issues. The Everglades ecosystem consists of 46,000km^2. It comprises a large diversity of different habitats, including subtropical uplands, lakes, wetlands, estuaries, and coastal bays, each with their own set of species and ecosystem processes. It has 68 species listed as threatened or endangered. 1. 5 million acres are infested with exotic or invasive plants. Wading birds have declined by 85-95% since European settlement. Urban ecology has become an important component because 6.5 million residents live immediately adjacent to the Everglades. Half of the uplands and wetlands have been lost and the remainder is engineered and heavily managed. Given this backdrop, an "individual researcher/single species" approach is not sufficient to meet information and policy needs for restoration of such a huge and diverse ecosystem.

A consortium structure can be built around a group of established scientists who represent a breadth of approaches to Everglades restoration (e.g. endangered species, hydrology, vegetation, climate change, etc.). Promoting greater collaboration can greatly advance the scientific knowledge base, enhance our understanding of the responses of interconnected species and habitats to restoration, as well as identifying risks and key gaps in knowledge of the system as a whole. Moreover, interactions with policy makers and managers at senior as well as operating levels can ensure that scientists are aware of policy needs and that policy makers are aware of research advances. This structure would help to alleviate two major impediments to effective restoration including: (1) a lack of distilled relevant and integrated information and (2) ineffective transfer of new scientific knowledge to other scientists and to policy makers at the appropriate levels.

The role of the science consortium would be to integrate research across scientists, to identify priorities for research, identify synergies in the various research and operation efforts, and to facilitate interactions and training among more junior scientists. Senior scientists would have roles similar to managing partners in the consortium, while an external advisory body helps provide oversight and independent advice. The collective expertise is used to develop critical new cross-disciplinary approaches and solutions relevant to restoration and to help identify and resolve critical issues such as potential tradeoffs among species. Research needs, grant proposals, and reviews can be organized through such a consortium to ensure that the scientific needs of restoration are being met and duplicate work efforts are identified and reduced. An example of a consortium structure we propose is that of The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a research consortium involving marine scientists from four universities along the U.S. West Coast that addresses multi disciplinary science and policy issues on a large scale. Given the similarities to issues faced in the Everglades restoration effort, we believe it serves as an appropriate model for an approach that could be adapted for Everglades restoration.

In summary, the Everglades is an integrated and widely variable ecosystem; the governance structure should recognize and address this fact. As such, we recommend a broader and greater systems approach that brings together key researchers into a coordinated program that can be adequately funded and populated with the necessary numbers of scientists to address the key issues.

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APPENDIX

PANEL RESPONSES TO USFWS QUESTIONS

CAPE SABLE SEASIDE SPARROW

1. Given what we know about habitat conditions available for sparrows now and the likely conditions under Everglades restoration, what can be done now and in the future to have the best chance of maintaining the species in the wild (e.g. habitat amount, habitat suitability, population sizes, population separation, etc.)?

   The most important step is to implement ModWaters and Decomp as rapidly as possible. During the transition to a fully implemented CERP adaptive management will be particularly important in the case of the sparrow in order to maintain subpopulations without sacrificing ecosystem restoration objectives. More emphasis on identifying where new habitat might be created during the transition is appropriate.

2. Is there merit in the conclusion that sparrows may require more proactive and interventionist management during transition to Comprehensive Everglades Restoration Plan (CERP) conditions? If so, what information is this based on?

   Yes. Conclusions are based on information such as continuing low numbers, restricted distribution, sensitivity of the species to changes in habitat and especially lack of shifts in distribution (in contrast to the other three species) in recent decades.

   a. Are translocation and captive breeding potential options worthy of consideration at this time?

      Translocation of wild-caught individuals from large to small subpopulations is the only option that should be considered in the near-term. Introduction of sparrows outside their native range and captive breeding are not recommended at this time.

   b. How do we conservatively maintain sparrows during transition if there are expected to be periods of insufficient habitat availability?

      A serious commitment to adaptive management will be required to achieve this. This may entail active management which includes habitat development, possibly translocations, and certainly monitoring.

   c. What specific steps can be taken now and into the future to ensure sparrow conservation during this period of transitional uncertainty?

Developing a more strategic and preemptive management strategy, rather than reacting to problems as they arise, would be useful. To illustrate, the panel heard about areas in which habitat might be lost, but nothing about where new habitat might be gained.

3. What immediate management actions are appropriate, if any, to pursue to improve or maintain populations, regardless of restoration efforts?

    a. Where are specific locations for habitat enhancement and restoration to benefit the sparrow?

    This cannot be answered until restoration efforts get underway and real data (as opposed to modeling projections) on how and where habitat is changing are available. If the compromises in design and function of ModWaters described to the panel do indeed come to pass, it will not be until Decomp is implemented that such changes will begin to occur. Until that time the best strategy is to continue to protect and maintain existing habitat (including subpopulation A).

    b. What specific actions should be considered (e.g., fire management)?

    One action that could be explored right away is use of prescribed fire to convert marsh back to wet prairie.

    c. Should predation control be implemented to a greater extent?

    It is premature to do this on a large scale, but small-scale studies of the effectiveness of predator barriers are appropriate. A greater understanding of factors affecting nest predation rates, and of the factors that regulate populations (including habitat availability and possibly contaminants such as mercury), than currently exists is needed to determine whether large-scale predator control will be effective in increasing sparrow numbers.

4. Is there still merit in the conclusion that sparrows will do well after Everglades restoration is complete? What specifically should we do during restoration planning and implementation to ensure that we maintain a favorable outcome?

    Yes, that conclusion has not changed, except that there is more uncertainty about the future of subpopulation A. The larger issue is whether the sparrow can survive through first what promises to be a very long period before significant restoration even begins, and then second a lengthy transitional period. See answer to question 2c above.

5. How should we evaluate sparrow responses to expected CERP outcomes, both in the interim and with respect to full CERP implementation in terms of how much habitat may be available and where habitat may be available?

   Clearly monitoring sparrow numbers and distribution will continue to be important. It seems obvious that managers would want to project where habitat will change in relevant ways through modeling, and then monitor habitat change as restoration efforts occur.

6. What is the expected effect of impacts to small subpopulations? How should these areas be addressed in the transition to full CERP?

   This is covered in population structure above. The small populations are highly vulnerable to demographic stochasticity.

7. If we have a scenario such as a large fire in subpopulation B followed by flooding which could significantly impact the subpopulation, how should we address the other subpopulations?

   It is not clear that this would necessitate doing anything differently in the other subpopulations. Managers will already be doing everything they can for each subpopulation. This question presupposes more active intervention in population dynamics, an approach the panel does not endorse.

8. Can we currently suitably predict where sparrow habitat will occur after restoration, and how important is answering this question as specific CERP projects are analyzed?

   The panel was presented with no direct information about attempts to predict where new sparrow habitat may arise, and it is not clear to us that this is even being attempted. It is unlikely that the tools presented to the panel have sufficient resolution to identify small scale areas of specific habitat under full CERP implementation or during the various transitional phases that occur between current conditions and full CERP implementation. Rather, the tools appear to give a broad system-level view which then has to be translated in some manner to the habitat scale of interest. The ability to better simulate the hydrologic and vegetational response on the correct temporal and spatial scales is desirable. If one is willing to assume, based on the new movement data, that the Cape Sable Seaside Sparrow has sufficient capacity to colonize new habitat within a reasonable range, then a model that can provide a characterization of the amount and type of habitat in an ecologically important area may suffice, even if it does not have the resolution to predict the habitat at a given location.

9. What are the most important scientific questions that should be answered to improve sparrow conservation?

a. What key information gaps, if any, remain that are critical to maintaining the sparrow population?
b. What does the panel recommend for the highest priority next research steps?
c. Are there key life history parameters to focus on improving our understanding?

These are addressed under specific recommendations.

SNAIL KITES

1. How much uncertainty/risk is there for the kite during the transition to full CERP? How much risk is prudent to accept given the current status of the species?

   In recent years, most Snail Kites have nested in WCA 3A. Current hydroperiods in WCA 3A have not been conducive to successful nesting and unless changes are made that reduce high water conditions early in the season, breeding will continue to suffer. Kites are highly mobile and are known to nest in alternative locations throughout southern Florida when conditions in their primary nesting areas are not suitable. This life history characteristic will help to reduce the risk to the population during the transition to full CERP; however, population numbers will likely continue to decline, particularly if drought conditions continue, especially if alternative sites become increasingly scarce and fragmented. Managers need to bear in mind that the current crisis has arisen not because of restoration activities, but because restoration continues to be delayed, leaving the system in an increasingly degraded state. The kites likely will do better during the transition than they are doing now, pre-transition. It is difficult to argue that it is ponding of water in WCA-3A under ISOP is the fundamental problem for Snail Kites when the kites shifted their distribution from more northern areas into WCA-3A when ISOP was implemented. The appropriate conditions for kites could be created in many locations within the Everglades, not only in WCA-3A. For instance, the areas that contributed most to successful nesting in 2006 was Everglades National Park.

2. What specific steps can be taken in the transition to Everglades restoration to improve habitat conditions for kites and other avian species?

   Managers need to find ways to reduce the extreme fluctuation in water levels (i.e., high water early in the nesting season and extreme low water later in the season), so that kites can successfully nest and forage in WCA 3A. The most important step is to get the transition underway in order to begin to move away from current conditions, which clearly are problematic.

   a. Are there temporal/transitional issues such as timing or sequencing of projects that are needed to safeguard kites?

Given the dispersal abilities of kites, attention should be given to the timing of major projects so that the cumulative effects on kites can be anticipated. Recent management actions on Lake Okeechobee, the Kissimmee Chain of Lakes and in WCA 3A, coupled with a severe drought event, appear to have had a dramatic impact on Snail Kites reproduction and population status. To the extent possible, thought should be given to the likely impacts of these types of major restoration projects before they are implemented.

3. What additional measures, if any, are appropriate to safeguard the kite population currently?

   None are apparent at this time.

4. What specific steps can be taken to improve habitat conditions for kite nesting and foraging?

   Management of the hydroperiod within the natural range of variability will help to maintain the wet prairies and emergent sloughs that Apple Snails prefer and kites need for foraging. Restoration of season sheet flow over broad areas will help ensure that appropriate conditions occur somewhere within the system despite annual variation in climatic conditions.

5. Where specifically is more water needed and at what times, and where is less needed?

   In areas where Snail Kites are nesting, high water levels are detrimental to nesting vegetation and Apple Snail reproduction; extended dry downs also increase the risk of predation of kite nests and increase the mortality of Apple Snails. Less extreme fluctuations in water levels are required for both kites and Apple Snail populations to thrive.

6. How important for kite conservation is developing an integrated, system-wide hydrological operations plan in the Everglades?

   It is very important, in that it should enable managers and biologists to better understand how water levels will change throughout the year. Understanding when and how much variation will occur in water levels clearly has a major impact on the vegetation and prey required by Snail Kites, so reducing the uncertainty associated with the timing and extent of water dry downs will help conservation efforts associated with Snail Kites.

7. What strategies would support Apple Snail production and maximize Everglades restoration system-wide benefits?

Apple Snail populations can survive dry down events, but after two months it appears that mortality of snails begins to increase. It is believed that a drying event every 2-3 years that lasts for 1-2 months will not adversely affect Apple Snail populations. Extended high water also can adversely affect Apple Snails, by inundating emergent vegetation and flooding eggs. Habitat alterations as a result of extended high water also make the habitat less suitable for Apple Snails. Recent evidence suggests that egg cluster production would be greatest if water levels started to decline in January and gradually fell to less than 40 cm by late April to May. This rescission rate should also benefit Snail Kites.

a. What actions, if any, should be taken to address invasive Apple Snail species, and does this have a connection to Everglades restoration?

   It is unclear to what extent the invasive Apple Snail species is competing with the native species; however, research should be launched to examine this issue and to develop techniques for reducing and/or eliminating the spread of the invasive species. Apple Snails are a critically important component in the food web of the Everglades. If they are replaced by this much larger exotic species it would have significant effects on many bird species that rely on the smaller native Apple Snail, including Snail Kites. Quantifying the energetic repercussions for kites (especially young birds) of a switch from native to invasive Apple Snails, and their likely effects on survival, would be valuable. Quantifying the energetic repercussions for kites (especially young birds) of a switch from native to invasive Apple Snails, and their likely effects on survival, would be valuable.

8. Within the network of kite habitats, can the panel recommend methods to support evaluation and decision-making about expected future resource conditions, both within Everglades and outside of the CERP footprint?

   A great deal of work has been accomplished documenting the habitat network kites have used in recent years. It is important that these habitats continue to be monitored in some way (either directly or using remote sensing) to document their future condition and the degree to which Snail Kites use them if/when conditions in WCA 3A and elsewhere are not suitable for nesting.

9. What are the most important scientific questions that should be answered to improve Snail Kite conservation?

   Recent research has provided new information on how altered hydroperiods can stimulate changes in vegetation community structure and adversely affect Apple Snail reproduction and survival. Snail Kite breeding ecology and population dynamics also have received significant attention; however, further refinement of our ecological understanding of the linkages between hydroperiod, vegetation community structure, and the population status of Apple Snails and Snail Kites is required. The panel believes this can be best accomplished by more formally *integrating future research that is conducted on these interconnected components of the Everglades ecosystem.*

a. What key information gaps, if any, remain that are critical to maintaining the Snail Kite population?

   Information on adult Snail Kite survivorship and movement patterns is insufficient and needs to be acquired to confirm recent reports of significant declines in the population.

b. What does the panel recommend for the highest priority next research steps?

   More research on adult Snail Kite movement patterns and survivorship are essential.

   Stronger integration and coordination of ecological research projects involving vegetation (i.e., nesting and foraging) habitat, Apple Snails, and Snail Kites is overdue. Better coordination and interaction among these studies should enable researchers to better document some of the key habitat and food webs relationships that exist in the Everglades, particularly as it relates to Snail Kites.

c. Are there key life history parameters to focus on improving our understanding?

   Nesting success, recruitment of young into the breeding population, and the survival of immature and adult kites are key to understanding how water levels affect Snail Kite populations.

WOOD STORK

1. What impacts will Everglades restoration have on specific stork colonies, and the overall population of Wood Storks in Everglades National Park and the Water Conservation Areas?

   This question cannot be answered yet because hydrological modeling and understanding of hydrological conditions at specific stork colonies is not sufficiently detailed. Generally it should be expected that increasing water in the WCAs and in Everglades National Park during the wet season and releasing more water early in the dry season should produce hydrological conditions favorable for Wood Storks. Uncertainty over the suitability of colony sites in light of changing mangrove habitat and sea level rise also makes this question difficult to answer.

2. How will the decrease in short hydroperiod wetlands in the region from development activities affect nesting and foraging success?

Again, hydrological modeling is not yet sufficiently precise. One expects that a decrease in short hydroperiod wetlands will make water management to benefit Wood Storks more difficult to achieve. It is necessary, however, to simulate effects of CERP (and modifications) at finer spatial scales than has currently been done.

3. How will the Everglades restoration affect foraging opportunities for migrating/overwintering Wood Storks?

   Foraging during the wet season could deteriorate because of the reduced availability of short hydroperiod wetlands and the need to hold water in the WCAs. Again, however, more detailed modeling is needed.

4. What is the significance of the Everglades to the stork population in light of current population trends?

   Significance is high. A large proportion of Wood Stork nesting occurs in the Everglades ecosystem.

5. Are any special considerations for this species necessary during transition to CERP?

   None foreseen.

6. What non-CERP actions/protections/threat reductions are necessary and appropriate to ensure that the stork population is maintained during CERP?

   Careful monitoring of reproductive effort and success so that modifications of CERP can be made as part of adaptive management.

7. What can we do currently to improve the status of storks in southern Florida, both in conjunction with restoration and separately?

   Management opportunities are currently limited. Research targeted at immediately improving understanding of key issues will go farthest toward improving management in the near future.

8. What are the most important scientific questions that should be answered to improve Wood Stork conservation?

a. What key information gaps, if any, remain that are critical to maintaining the Wood Stork population?

   Demographic data (adult survival, dispersal, recruitment of juveniles) and linking demographic parameters to ecological variables of interest are key.

b. What does the panel recommend for the highest priority next research steps?

   The highest priority is refining hydrological modeling so better temporal spatial predictions can be made about suitability of foraging conditions during breeding. Second most important is improving survival and recruitment estimates so managers know what level of reproductive success is needed for population growth.

c. Are there key life history parameters to focus on improving our understanding?

   Adult survival, postfledging survival, and movement. Relate these parameters to ecological variables that can be managed.

   - *Management opportunities are currently limited. Research targeted at immediately improving understanding of key issues will go farthest toward improving management in the near future.*

   - *Demographic data (adult survival, dispersal, recruitment of juveniles) and linking demographic parameters to ecological variables of interest are key.*

ROSEATE SPOONBILL

1. Does new information continue to support that spoonbills will do well under CERP?

   The spoonbill population in Florida appears fairly stable; moreover, recent nesting activity in WCA 3A suggests that they are moving into areas not occupied for a number of years. Additional information on breeding success, demography, and movement patterns is still required before a clear understanding whether or not they will do well under CERP

2. How important is the CERP footprint to spoonbills now and in the future?

   The CERP footprint will help to ensure that spoonbills continue to exist in Florida. Healthy populations in Florida Bay are perhaps most important to the future of spoonbills; however, implementation CERP should provide additional nesting and wintering areas needed under different environmental conditions.

3. What special considerations, if any, are necessary to ensure that we maintain spoonbills during transition to CERP?

   Maintaining appropriate flow to Florida Bay and ensuring that the transition is as short as possible. Continue monitoring of nesting activity and efforts to document movement patterns throughout south Florida, so a better understanding of their nesting and wintering habitat requirements is obtained.

4. Are spoonbill rookeries outside of CERP areas sufficient to maintain the spoonbill population regardless of CERP outcomes?

   Perhaps, but at lower population levels that would be more vulnerable to extreme environmental variation.

5. What are the most important scientific questions that should be answered to improve spoonbill conservation?

   What are the attributes of the habitats in WCA 3A and other areas in inland wetland sites that are attracting nesting spoonbills, and how can the hydroperiods created under CERP support the foraging and nesting needs of this species? Also, if birds are staying in the Everglades system, unnoticed, after breeding, and then are there are other possible breeding colonies in the system that no one knows about?

   a. What key information gaps, if any, remain that are critical to maintaining the spoonbill population?

      Because the relationship between the foraging conditions and reproductive success at various breeding colonies has been well established,, continued annual monitoring of breeding colonies in terms of their size, location, and reproductive success remains crucial to evaluating CERP outcomes. Identification of important non-breeding season foraging and roosting locations within ENP and elsewhere in Florida will also be important for long the long-term maintenance of spoonbill populations.

   b. What does the panel recommend for the highest priority next research steps?

      Current practices for monitoring the size and reproductive success within Roseate Spoonbill colonies in Florida should be continued in order to evaluate CERP effects. Satellite telemetry should be continued in order to identify key foraging areas during the breeding and non-breeding seasons, and clarify relationships between hydrological conditions, prey populations, nesting and renesting phenology, breeding success, and annual and seasonal movement patterns.

c. Are there key life history parameters to focus on improving our understanding?

Very little information is available on the demography of Roseate Spoonbill populations. Ongoing banding studies should be continued in order to ascertain key demographic parameters (i.e., age of first breeding, annual survivorship, longevity, dispersal, etc.) essential for developing quantitative population models.

OVER-ARCHING QUESTIONS

1. Are there conflicts between sparrow and Snail Kite management and are there any appropriate actions to address this concern?

   In principle there should not be, but as restoration continues to be delayed all species are likely to become more vulnerable and less resilient and thus management-induced conflicts will become more and more likely. We see the major problem not as the impact of emergency management for the sparrow, but as the continued failure to be able to move significant quantities of water further east, through northeastern Shark River Slough, in order to achieve more and broader sheet flow from Lake Okeechobee south to Florida Bay. Discontinuing emergency management in order to release more water into western Shark River Slough clearly will have adverse impacts on sparrow subpopulation A, and the benefits of such action to the Snail Kite are not at all certain, given the complexities of its distribution and relationship to hydrology.

2. Can the panel recommend different or improved methods to pursue detailed project development and evaluation related to restoration/development projects to better address key issues and uncertainties?

   This question is addressed in the section on governance and adaptive management. In brief, agencies critically need to try to find ways to overhaul the way in which the research community is operating. Incentives (e.g. grant funding) and requirements (e.g., via requirements of grant contracts) are probably the most obvious option to foster a more collaborative and scale appropriate method of research. The highly specific nature of several of the questions posed to the panel serves to emphasize the need for a more integrated research community that can provide specific answers to agencies in a timely manner. As part of a more integrated approach, senior scientists with expertise in relevant physical and biological sciences should be made a more integral part of project development and evaluation. In this way, monitoring programs can be developed and implemented in ways that best evaluate the success of the restoration effort and collect the data most needed to inform adaptive management.

3. If detrimental impacts are expected to any of these species resulting from restoration, development, or other projects, does the panel have any

recommendations on actions or efforts to mitigate impacts or gather information (e.g. if sparrow subpopulation A is being flooded or burned, should we attempt to relocate all the birds prior to this event, attempt to monitor their responses in light of potential losses, etc.)?

Rigorous and statistically valid monitoring programs need to be put in place that can document the responses of populations of concern and help managers develop the most appropriate conservation/mitigation actions. Agencies should attempt to monitor population responses to all major management actions.

In the case of sparrow subpopulation A, in principle it is a good idea relocate birds that are very likely to be impacted by flooding or burning, but only if there is good evidence that there is an appropriate place to move them to. Currently, such evidence appears to be lacking and anything more than small-scale experimental relocation would be premature at the present time.

One could also frame the question in terms of what should be done for kites if there continue to be signs of problems for them under current management. Most of the specific responses to such "what ifs" are addressed in the relevant species sections, but there is an overarching answer that if there was a solid conceptual model designed to integrate thinking across multiple species then managers would be in a much better position to (a) identify trade-offs ahead of time, and (b) seek alternatives.

4. Given limited funds, how would the panel recommend prioritizing immediate management and recovery actions among these species?

As a general guiding principle, species that are critically endangered are at greater risk from habitat changes and will require more careful monitoring and interventions throughout transition.

However as an additional approach we suggest considering taxonomic distinctiveness (already embodied to some extent under the ESA) and the existence and status of populations elsewhere. For instance, one approach might be to consider species as follows: Spoonbills are doing well in lots of other places and are not federally listed, so they can be considered to represent a relatively lower priority. Storks are doing well throughout most of their US range, with the Everglades situation something of an exception. There is also a good chance the historic nesting conditions will never return in the Everglades, so they may also be a lower priority. In the U.S., Snail Kites are limited to Florida, but they are abundant in South America and occur elsewhere. There are taxonomic differences among populations, but the differentiation is not known to be great. Consequently, the loss of kites from the Everglades certainly would be very bad, but would not have severe global repercussions. The sparrow population represents a well-recognized subspecies, that is morphologically and somewhat ecologically distinct, and that occur nowhere else. Thus, it perhaps warrants a higher priority *ranking. This ranking is one of several possible options, and is intended to lay out the type of issues that should be considerations rather than a preferred option recommended by the panel.*

All of the above is presented with two important caveats: (a) in the panel's view, no one species should hold up system-wide restoration and (b) this framework ranking ignores all the other listed species that occur in the Everglades, which is probably not appropriate.

When it comes to ranking actions and setting priorities within species, a conceptual model that allows agencies to carry out some sort of sensitivity-type assessment (ideally quantitative, but that might not be possible) would be the best way to guide researchers and managers to the areas of each bird's life history that require greatest attention.

Other more specific suggestions include:

- *In all ranking assessments, it is also important to factor in climate change, the fact that some species can move more easily than others, and that long-lived species may respond differently and at different rates than short-lived ones (e.g. sparrows).*
- *Take whatever pro-active action is possible to reduce the length and extreme fluctuation in hydroperiod in the Water Conservation Areas. If water levels fluctuate predictably in ways that minimize conversion of wet prairies to open water sloughs, then Apple Snail populations can flourish. Avian species that depend on this snail for food, such as the Snail Kite, will then have a much greater chance of weathering the transitional period and beyond.*
- *Wood Storks have increased in abundance in the north, but have abundance goals in the south (coastal mangroves). There should be more scientific and policy evaluations of why the southern populations are needed, and whether the goals are in fact attainable or practical in light of current knowledge, habitat structure, mangrove responses to changes in salt/fresh water interface, and predictions of climate change.*

OTHER WADING BIRDS (SPECIES) AS INDICATORS

1. Are there indications that other wading bird/waterbird species may encounter significant problems during transition to CERP or as a result of other actions?

   None that were brought to the attention of the panel.

2. Do we have information to suggest that ibis/egrets or other species are better indicators of conditions for the suite of waterbirds within the Everglades system?

   No.

3. Is there a clear need to further investigate or understand other waterbird responses to CERP?

   Not at this time.

4. What key information gaps, if any, remain that are critical to maintaining wading bird populations?

   There is a wealth of data on long term monitoring of wading birds. Existing programs should continue, but the panel does not believe there are critical information gaps that need to be addressed at this time.

ABBREVIATIONS

AAT: Adaptive Assessment Team
AOU: American Ornithologists' Union's
AR4: Fourth Assessment Report
CERP: Comprehensive Everglades Restoration Plan
CSOP: Combined Structural and Operational Plan
Decomp: Water Conservation Area 3 Decomparmentalization and Sheet Flow Enhancement
ENSO: El Nino Southern Oscillation
IAR: Incremental Adaptive Restoration
IOP: Interim Operational Plan
IPCC: Intergovernmental Panel on Climate Change
ISOP: Interim Structural and Operational Plan
MAP: Monitoring and Assessment Plan
ModWaters: Modified Water Deliveries to Everglades National Park
NAO: North Atlantic Oscillation
NRC: National Research Council
NSM: Natural System Model
RECOVER: Restoration Coordination and Verification
SEI: Sustainable Ecosystems Institute
SFWMD: South Florida Water Management District
TAR: Third Assessment Report
USACE: Army Corps of Engineers
USFWS: US Fish and Wildlife Service
USGS: US Geological Survey
WCA: Water Conservation Areas
WCA-3A: Water Conservation Area 3A