RECOMMENDATIONS FOR EVERGLADES RESTORATION UNDER A FUTURE CLIMATE SCENARIO

SPONSORED BY UNITED STATES GEOLOGICAL SURVEY, FLORIDA SEA GRANT AND THE CENTER FOR ENVIRONMENTAL STUDIES AT FLORIDA ATLANTIC UNIVERSITY

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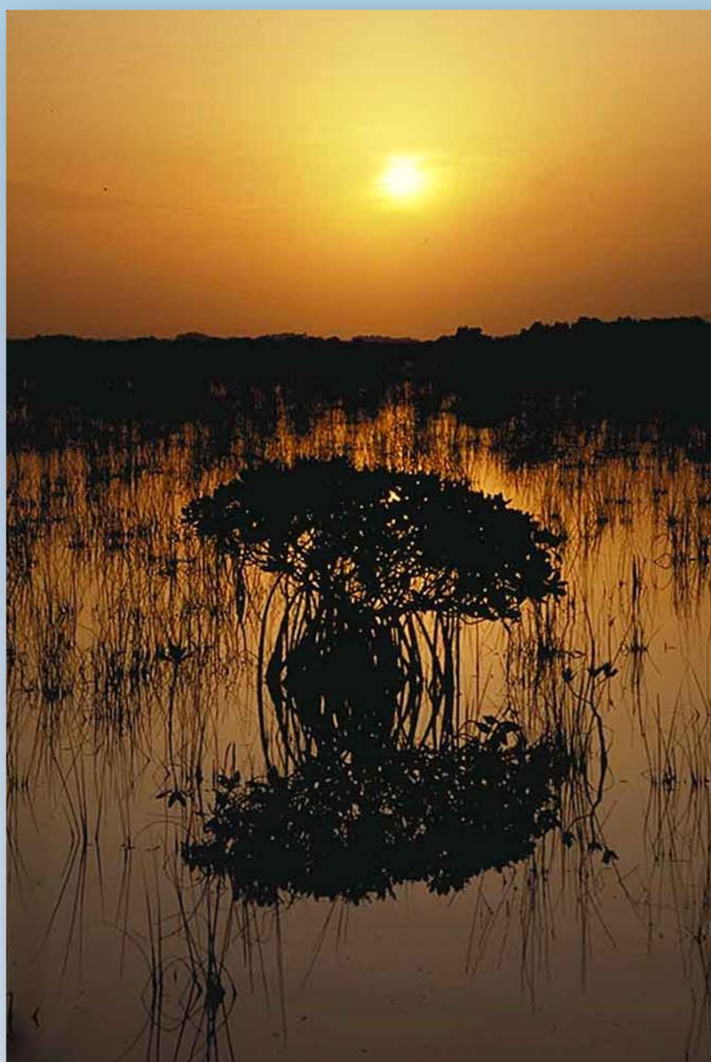
FINAL REPORT



USGS science for a changing world

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Recommendations for Everglades Restoration Under a Future Climate Scenario:

Technical Meeting 28-29 April 2014

Executive Summary

Recommendations for Everglades Restoration under a Future Climate Change Scenario convened eighty-four participants from academia, local, state and federal agencies, as well as public and private organizations. During the two-day technical meeting, seven interdisciplinary groups of experts addressed the question: *How can we effectively enhance restoration efforts throughout the Everglades watershed through an adaptive management process that incorporates current scientific knowledge of climate-related impacts?* The teams recommended actions to address current and future potential impacts such as increased temperature, changes in evapotranspiration and rainfall parameters for restoration efforts. The steering committee asked the groups to focus on 'no regrets strategies,' defined as strategies which remain cost-effective under a range of future climate scenarios and take into consideration other policy objectives. The teams also identified information gaps and prioritized future research needs.

The program and discussions were divided among seven working groups:
1. Water Management Response to Hydrology and Sea Level Rise
2. Managing Water Quality and Quantity in the Northern Everglades
3. Managing the Everglades by Influencing Biogeochemical Processes
4. Shifts and Challenges to Vegetative Communities
5. Managing Wildlife for Sustainability in a Changing Climate
6. Management Framework for Landscape Systems
7. Management Considerations for Coastal Systems

General Consensus

To successfully manage restoration projects in the Everglades, the impact of current and future predicted changes (in temperature and evaporation, rainfall and rainfall intensity, and sea level rise with salt water intrusion) must be taken into account. The overall conceptual knowledge that has been collected on current and future impacts should now be augmented with specific data. Monitoring these changes is a priority.

The groups emphasized and concluded that:
- While Everglades restoration focuses on the natural environment, the growing and changing human environment, both urban and rural, is closely interlinked, especially in the context of water supply and water management;
- Water storage will become even more critical in the future and the potential for increased capacity should be examined;

- While water storage is important, water conservation in agriculture and in urban environments is a vital medium- and long-term objective;
- Restoring water flow through the system, which is the critical goal of restoration in the Everglades, is even more important in the context of climate change;
- Increased water flow can reduce the impact of salt water intrusion, and increase the degree of peat formation, also reducing salt water intrusion;
- Maintaining and increasing peat formation is a vital component of a healthy Everglades system and should be given priority in all management initiatives;
- Appropriate adaptation efforts and areas most vulnerable to the impacts of changing conditions in both natural and urban areas need to be identified;
- Informed decision-making demands detailed data on potential changes in the amount, distribution and intensity of precipitation under future climate scenarios;
- The current cooperation on organizational issues between implementing agencies (as exemplified by the makeup of the meeting) is evident, but communication gaps were identified, including between counties and state and federal agencies; and
- The active presence of managers from several key agencies highlighted the need for ongoing communication with and education for the public, water managers and other decision makers.

RECOMMENDED MANAGEMENT STRATEGIES

Despite some uncertainties of magnitude and timing, based on the conclusions above, we recommend a number of management strategies that can safely be implemented as 'no-regrets measures.'

- Conduct a vulnerability analysis of Southern Florida and the Everglades similar to the US Army Corps of Engineers' study for the areas that would be most impacted by the next Super Storm Sandy.
- Improve our modeling of rainfall and evapotranspiration under future climate scenarios and the potential impact on the local hydrological cycle and thus water supply and management.
- Review and revise water management schedules and MFLs (minimum flows and levels).
- Encourage FDEP and local governments to engage in land acquisition to connect corridors for migration using FWC's existing state Wildlife Action Plan and Land Conservation Cooperatives (LCC) Work.
- Improve communication gaps, including between counties and state and federal agencies.
- Continue to involve managers from key agencies to maintain communication with and education for the public, water managers and other decision makers.
- Incorporate opportunities to increase water storage in existing and future Everglades projects.

Background

Nick Aumen of USGS welcomed participants and proposed the aforementioned challenge of**:** *How can we effectively enhance restoration efforts throughout the Everglades watershed through an adaptive management process that incorporates current scientific knowledge of climate-related* *impacts?* He outlined the meeting goal of defining recommendations for the attention of regional managers and decision makers, based on current science in the seven broad topic areas.

Leonard Berry, of Florida Atlantic University's Center for Environmental Studies, summarized the preceding technical meetings, summits, workshops and webinars conducted between February 2010 and January 2014 that formed the foundation and inspiration for this technical meeting. He explained that during the two most recent meetings of managers and scientists, a plan of action was highlighted for the April meeting:

1. Define the key issues,
2. Understand our present degree of knowledge,
3. Recommend adaptive strategies,
4. Design plans to address issues, and
5. Identify major knowledge gaps.

Jayantha Obeysekera, of the South Florida Water Management District (SFWMD), presented a summary of background and current scenarios and predictions noting several recent advances including:

- Climate scenario simulations run for recent workshops,
- Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC),
- National Climate Assessment Report (NCA),
- Updated sea level rise projections (NOAA, NCA, IPCC), and,
- A SFWMD initiative to develop *robust decision making under deep uncertainty* (workshop held September 2014).

Dr. Obeysekera noted that the dynamic 'non-stationary' nature of the system was now recognized and SFWMD was seeking *actionable science* based on more dynamic models. He noted the several different kinds of uncertainty involved - the natural variability of the system, the uncertainty associated with model spread and uncertainty arising from different scenario assumptions. He proposed the following current boundary assumptions to frame discussion at this meeting:

	Global prediction	Statistical Downscaling	Dynamic downscaling
Mean temperature C^0	1^0 - 1.52^0	1^0 - 2^0	1.8 – 2.1^0
Annual precipitation	-10% - **+** 10%	-5% - **+**5%	-3" - **+**2"
Sea Level Rise	1.5 feet		

He also suggested the meeting should address adaptive water management techniques, including scenario planning, learning-based approaches and flexible and low-regret solutions. These can help create resilience to uncertain hydrological changes and impacts due to climate change and defined:

- **No-regret actions** as those that remain cost-effective under a range of future climate scenarios and take into consideration other policy objectives;
- **Low-regret** actions are relatively low cost and provide relatively large benefits under predicted future climates; and,
- **Win-win** actions contribute to adaptation while also having other social, economic and environmental policy benefits, including those in relation to mitigation.

Steve Traxler of the U.S. Fish and Wildlife Service presented a new scenario analysis prepared for the Florida Peninsula Landscape Conservation Cooperative (FPLCC) combining assumptions about future climate change, patterns of human population growth and different mechanisms to acquire land for conservation. (http://peninsularfloridalcc.org/page/climate-change-scenarios)

Projected forward through 2060, he noted human population was predicted to grow to 31 million inhabitants, sea level could rise anywhere from 3" to over 40" and precipitation patterns affecting both wildlife habitat and human welfare were unpredictable. Using these assumptions, FPLLC had developed scenarios with iterative stakeholder and technical inputs, based upon Critical Lands and Waters Identification Project (CLIP) and MIT models to generate land use predictions for Florida. (http://myfwc.com/media/1770248/consideringclimatechange-wildlifeactionplan.pdf)

Within these different assumption polygons, the outputs varied from a worst case of almost completely urbanized Florida with isolated small natural refugia to a best case of human population distribution, integrated with connected corridors and viable natural habitat resilient to climate change. These models can be viewed on-line www.jem.gov/Modeling at scales ranging from statewide to local.

Meeting Structure and Process

The participants were divided among the seven previously listed topic areas and charged to produce three concrete deliverables by the end of the meeting:

1. A clear **objective** pertaining to the topic.
2. A series of '**no- regrets' recommendations** for managers to consider
3. Crucial **data gaps** within that topic necessary to advance the recommended actions.

The program was divided into three broad segments following the first plenary session:

- A breakout session then a second plenary session to develop one objective for each topic (i.e. WHAT should be done as a priority for each topic)
- A breakout session then a third plenary session on recommended action to achieve the objective (i.e. HOW should the objective be realized)
- A breakout session then a fourth plenary session to fine tune the objective and recommended actions, identify information gaps and coordinate among different topics and breakout groups.

At each stage, groups developed their ideas in break-out sessions and then came back together in plenary to report to each other, discuss and coordinate their ideas. Groups were charged to prepare and present their products in the meeting for discussion at plenary sessions, which were an opportunity to coordinate and harmonize the products from different groups. Each group had been assigned a leader and graduate student recorders and groups had assembled and circulated current papers and background resources in the month prior to the meeting.
www.ces.fau.edu/climate_change/everglades-recommendations-2014/resources.php

Discussions and Products Resulting from Working Groups

Water Management Response to Hydrology and Sea Level Rise

In this work group led by Glenn Landers and Jayantha Obeysekera, 13 participants addressed water management response to two primary areas of anticipated future changes: (a) hydrology and (b) sea level rise--the two major considerations in developing adaptation strategies for both the built and natural environments in South Florida.

Objective

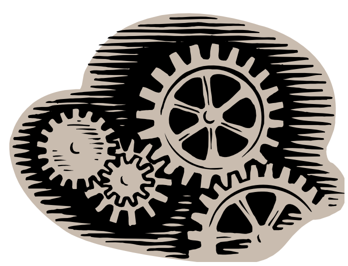
Integrate and synchronize water management solutions in the Everglades and developed areas in South Florida in the face of climate change and sea level rise in order to

- Define long and short-term water management risk to urban and natural systems
- Inform private and public sector investment decisions
- Provide and exchange tools, information and recommendations to other resource sectors (e.g. Transportation, Energy, and Agriculture)

Recommendations

1. REGIONAL ASSESSMENT: Develop a regional assessment that integrates natural system and built environment exposure to a broad range of sea level rise and climate scenarios.
2. NEAR TERM:
    a. Hold regional conversations that address rainfall tools needed, saltwater intrusion modeling, scope and action to initiate regional assessment. In addition there would need to be participation in policy meetings
    b. Develop processes and mechanisms to address current vulnerabilities by utilizing flexibilities w/in current water management operations to maintain or improve ecological functions, water supply and flood protection
    c. Perform pre-event screening level analysis to frame post event response discussions

The group generated a useful analogy of the Everglades management system as a watch-like mechanical construct in which many of the gears and wheels are not currently in contact and operate independently. They suggested that integrating these components would cause them to alter their relative rates of motion and operate more harmoniously together.



Data gaps & uncertainties

- Accuracy and availability of the regional climate projections at scales of interest to Everglades Restoration (e.g. 2-mile x 2-mile; daily).
- Projections of mean sea level and extremes
- Changes in extremes including rainfall and tropical storms/hurricanes
- Feasibility of implementing changes to restoration plans

Background & Discussion

Changes to hydrology may be due to a variety of factors including modifications to rainfall patterns (both averages and extremes) as well as increases in evapotranspiration altering the water budget in the Everglades system. Restoration planning to date has used the historical period from 1965 onwards as the basis for the development of options for restoring hydropatterns in the Everglades and balancing those with the needs of the built environment. Previous investigations have used a scenario-based approach for climate change and these need to be improved using the latest projections for the regional climate in South Florida.

With reference to sea level rise, records from the Key West, Miami Beach and other tide station locations around South Florida with roughly 40 years or more of continuous record indicate local historic rates of relative sea level rise varying from 2.20 to 2.90 mm/year (8.7 to 11.4 inches/100 years). Because of ongoing global climate change, the rate of relative sea level rise in South Florida is anticipated to accelerate significantly by 2100 and continue at higher rates well beyond 2100.

Conclusions

In view of climate change, the validity of the approach to use historical period needs to be investigated considering future potential changes in rainfall, evapotranspiration, tributary inflows and sea levels. Previous investigations have used a scenario-based approach for climate change and these scenarios need to be improved using the latest projections for the regional climate in South Florida.

The future timing and magnitude of changes in the rate of sea level rise is uncertain and the National Research Council has recommended consideration of multiple scenarios representing a range of potential future conditions. .

A high-level review of the previous projections of regional climate and sea level rise information along with the latest information that will become available in the near future is needed.

Discussion approach:

Discussion in this group started with the need to define the spatial scale of impacts and responses and the central importance of CERP as an existing mechanism for regional management. However, CERP does not currently integrate climate change effects. An actionable time scale of likely impacts and necessary responses would allow managers to respond first to what occurs first. The cost of any action vs. inaction should be balanced with the risks involved. Numerous agencies and entities are working on different parts of the uncertainties but need to be better integrated. The persistent underinvestment in water management (e.g., compared to development and transportation investments) constrains current action. Regional vulnerability analysis, considering combined risks of flooding, storm surge, rising sea level and precipitation changes to urban centers would help inform managers and prioritize water management and Everglades restoration. The group focused on defining barriers to effective coordination and Everglades management and the best way to adapt existing information and capacity. Effective change to regulatory and operational frameworks will require communication of the risks to stakeholders, particularly the insurance sector. The group identified a basic need for integration and communication among numerous agency and government players and effective communication of the available science.

Managing water quality and quantity in the Northern Everglades

The Northern Everglades group consisted of 12 participants directed by Karl Havens. (Attachment 2) The Everglades watershed proper requires an enhanced input of low-nutrient water. Currently, a large quantity of water enters the regional ecosystem in the watershed north of Lake Okeechobee, becomes polluted with phosphorus and nitrogen, and runs off quickly into Lake Okeechobee where much of it is discharged to the ocean via the Caloosahatchee and St. Lucie estuaries after major storm events. The challenge is to identify solutions that capture water after peak rainfall, hold as much of the water as possible for use during times of drought, and clean nutrients from the water before it is delivered to the Everglades.

The group focused on water management into and from Lake Okeechobee and based its discussion on an assumption of a hotter, warmer, drier future or hotter warmer with the same amount of rainfall which would result in rare discharge to estuaries from Lake Okeechobee. The lake levels will likely be low and delivery of water from the lake southwards to the Everglades will be a challenge due to topographic, structural and policy constraints.

Objective

Manage water in the Northern Everglades, providing adequate water in the lake to meet downstream needs when required, without causing irreversible harm to the lake ecosystem.

Recommendations (lowest to highest regrets)

1. Hydrologic modelling with new climate change assumptions to examine storage options. Evaluating ASR feasibility. Nutrient/ flow rates.
2. Reduce consumptive water use in all sectors
3. Review and revise water regulation schedules and MFLs to allow additional water flow south
4. Build deep storage in Lake Okeechobee and south of the lake
5. Re-plumb the lake to allow water release southward at very low stage

Data gaps & uncertainties

- Need better information regarding temporal distribution of rainfall and drought
- Need cost comparison of alternatives
- Need to know benefits per unit cost in terms of both peak flow attenuation and water storage for droughts
- Need to understand impacts within Lake Okeechobee
- Largest area of uncertainty involves the submerged vegetation zone of the lake, which likely will experience great variations in depth, sediment type and water quality
- Another area of uncertainty exists regarding potential for littoral zone to recover after very prolonged droughts and presumably expansion of woody vegetation, exotics and large-scale fires

Background & Discussion

Some of the possible options:

- Dispersed storage (minimally restrictive, least regrets)
- Regional storm water treatment areas (expensive)
- Revised regulation schedule for Lake Okeechobee (LO)
  (can be done as soon as levee is repaired, risks LO littoral zone)

- Strengthened levee (would require very expensive project, presumption that LO littoral zone is gone)
- Regional reservoirs and Storm water Treatment Areas (STAs) (expensive)
- Aquifer Storage and Recovery (ASR) (most expensive and uncertain)

In discussion, this group grappled with the uncertainty associated with future precipitation. Many models and researchers indicate that less precipitation overall, but possibly more intense episodes are expected in South Florida. However, recent runs of multiple models could not robustly differentiate between those with less rain and those with more. The effect of evapotranspiration , which may also vary with changes in temperature and vegetation, further confounds these predictions. The group conducted much of its discussion on the assumption of a drier future, but adjusted its no-regrets recommendations so that they would remain useful under any future scenario. The group considered increased storage to be one such option, although the effectiveness and cost of different options (surface vs. below ground/ Aquifer Storage and Recovery) were intensely debated. The group considered that restoration of southward flow from Lake Okeechobee would be beneficial under all scenarios. Numerous possibilities were discussed including restoring the original custard apple forest south of the lake, ASR and the Netherlands concept of allowing crop lands to flood and paying for losses rather than expensive infrastructure changes. The tradeoff between evapotranspirative losses, flooding, deep and shallow storage and geographic location north and south of the lake were considered.

Managing the Everglades by Influencing Biogeochemical processes

The Biogeochemical (Soils) group was organized and managed by Dave Rudnick and Sue Newman assisted by 16 participants (see Attachment 2). The response of the Greater Everglades to climate change and sea level rise is strongly influenced by biogeochemical processes, which are generally most associated with microbial and plant production and respiration, organic matter decomposition (with many oxidation-reduction reactions), and nutrient cycling in water and soils. Great attention has been given to the effects of nutrient enrichment (particularly, phosphorus) on the Everglades and hydrologic changes associated with climate change will alter future nutrient inputs to and cycling and transport of nutrients within the Everglades. Another major issue is how soil elevation dynamics in both freshwater and saline wetlands respond to changing hydrologic patterns, nutrient availability, and saltwater intrusion – all factors influenced both by climate change (with sea level rise) and Everglades restoration. Increases or decreases in marsh soil elevation may be the prime determinant of the spatial extent of saltwater intrusion and sea level rise effects in the Everglades. Of particular concern, saltwater intrusion may cause peat collapse in the brackish-freshwater Ecotone of the Everglades.

Objective

Maximize soil carbon sequestration to maintain and restore Everglades habitat diversity

Recommendations

1. Utilize existing operational flexibility to make soils wetter now.
   Increase stages, hydro period, and conveyance through the EPA
2. Increase magnitude of 1.
   a. Increase water storage
   b. Exercise US Sugar land option
   c. Change MFL – eliminate soil dry-out
   d. Revise schedules to increase water supply to the environment

Data gaps & uncertainties

- Build tool for soil vulnerability mapping and system-wide impact analysis
- Analysis should include: Salinity, hydrologic and nutrient effects on soil stability, accretion, & resilience.
- The relationship between nutrients and soil accretion rates, which may vary among regions and soils.
- Regarding capillarity, what water level really means dry peat, and thus fire risk?

Background & Discussion

In discussion the group recognized that the Oligohaline zone is a master indicator of the functioning of the whole system. Carbon sequestration is the same as soil building and depends on complex red-ox chemistry of wet and dry sediments. Major topics of discussion included:

- Need for soil elevation gain and increased sequestration of C, P, and possibly S & Hg. Main task: keep it wet.
- Oligohaline Ecotone is both highly vulnerable and highly important as a buffer for effects of sea level rise, delaying saltwater intrusion and land loss to provide a more stable transition. Loss of the Ecotone would have catastrophic effects both upstream and downstream in Florida Bay.
- Trade-off between quantity and quality. More storage is a no-brainer, possibly in EAA, north WCA 3A
- We are really good at "admiring the problem." To have our input mean something to decision makers, we need to have science-based reasons.
- Based on these considerations, the group identified a suite of factors that were amenable to influence: FW Flow (Reservoirs), Distribution of water and water quality (not just P), CEPP Sequencing, Adaptive, Plant management, Pulse management, Change land use/ water use, Shore energy buffer, Coastal recreation.

From these a general strategy was proposed:

- Overcome whatever is delaying current plans (CEPP, etc.)
- Authorize and take action on Mod Waters, Tamiami, CEPP; expedite
- What can we turn on now?
- More storage

Saltwater intrusion can contaminate the aquifer, which has a big impact on municipal as well as agricultural fresh water supplies. Directing more water south, plus better management practices for agricultural use of water, won't stop sea level rise, but would better protect soil and water supplies from saltwater intrusion.

Shifts and Challenges to Vegetative Communities

The vegetation group was led and managed by John Volin and Arnold van der Valk with 11 participants (see Attachment 2). The potential impacts of climate change in the Everglades can be examined at multiple scales. As for all wetlands, hydrology is the major driver that determines the distribution and structure of various the vegetation types in the Everglades. The number of dominant vegetation types (wet prairies, saw grass flats, ridges and sloughs, shrubs, and tree islands) historically and currently found in the Everglades is primarily a function of the magnitude of interannual water level fluctuations. A change of 25 to 30 cm in interannual water-level fluctuations is expected to change the number of vegetation types in a wetland, based on studies of other wetland types. Because changes of this magnitude are predicted this suggests that climate change could have a significant impact on the number of vegetation types or zones found in the Everglades.

How will tree islands, ridge and slough areas, wet prairies, etc. fare if the magnitude of interannual water level fluctuations are significantly altered? Which are most vulnerable to a change in hydrology? What implications do variations in the relative abundance of various vegetation types have for birds and animals in the Everglades? Based on contemporary and historical data, what kinds of changes within the Everglades are expected to occur in various areas (ENP, WCAs) because of a change in the magnitude of interannual water levels due to climate? Are some areas more vulnerable than others?

Objective

Restore the historic magnitude of interannual water level fluctuations incorporating the challenges of climate change, urbanization and water quality.

Recommendations

No Regrets:

1. Reduce urban and agricultural water consumption
2. Store water in soils/peats (higher lows)
3. Use set-aside programs to create private water storage areas (wetlands)
4. Identify areas that might be adversely affected by restoring historic water-level fluctuations.
5. Maintain agricultural subsidies to prevent the Everglades Agricultural Area from becoming developed.

Low Regrets

1. Create more water storage reservoirs. This would also benefit southern cities.
2. Increase number of STAs to improve water quality and associated storage reservoirs.
3. Reconsider "The River of Grass" to increase water delivery to the Everglades and to improve water quality.
4. Increase the amount of water to the Everglades during wet years. (higher highs).

Data gaps & uncertainties

- How reliable is our information about the magnitude of historic (i.e., predrainage) annual and interannual water level fluctuations in the Everglades?
- How much do we know about the relative abundance and distribution of various vegetation types prior to drainage? How reliable is this information?

- How long does it take for vegetation types to be lost or replaced by other types? Are some vegetation types more vulnerable to changes in hydrology than others? Is there a vegetation type that should be monitored as an indicator of climate change?
- How will changes in magnitude of interannual water level fluctuations affect fire frequency and intensity?
- How will future management of water in the Everglades affect the hydrology of the Everglades?
- Because of the introduction of invasive species, will new vegetation types develop that might replace some of the existing types?
- Even if the magnitude of the interannual water level fluctuations is unaffected, will there be a shift in the number of years of high, normal and low water during an interannual cycle? How could this affect the distribution and relative abundance of various vegetation types?
- What impacts will increased carbon dioxide have on primary production? Peat accumulation?
- What impacts will changes in temperature have on the composition of plant communities as well as on litter production and decomposition rates?

Background & Discussion

The objective of this group was to restore the magnitude of the historic interannual water-level fluctuations. The range is slough surface up to 1.5 to 1.6 meters. Therefore, water levels would be maintained so that soils always remain wet. Our one and only recommendation is increased water storage, both surface and groundwater. What we are proposing moves beyond CERP and includes even more storage in areas north of Lake Okeechobee, within Lake Okeechobee and within the Everglades Agricultural Area (EAA), the area that is the best choice for the most storage. There are two major data gaps for achieving this recommendation. The first is planning for distributive storage (hydrological, social, economic, political, etc.). One method to accomplish this is through new public-private partnerships (private STAs). The second is developing an impact assessment for urban environment (recharging aquifer, integrate flooding, etc.). Keeping the soils wet during wet years is important but also a challenge for land managers who are charged with flood prevention.

The major topics of discussion turned repeatedly to how to manage water levels with a higher degree of interannual variability. The group discussed the effects of such action, and current constraints, considered from both hard (infrastructure and plumbing) and soft (communication and politics) perspectives. The tradeoff between available water quantity and distribution of flow and water quality (nutrient loads) was debated with some preference toward allowing decreased quality, if this would ensure increased quantity. However, serious legal constraints and ecosystem response uncertainties were recognized. There is a potential to have novel ecosystems replacing the current system with similar hydrology and nutrient cycling but with important differences. Decreasing the interannual dries the system and produces more saw grass and invasion of exotics. Impacts of increased nutrients (specifically P) on vegetation and periphyton is uncertain and a concern. Current management strategies focus on engineering, flood control and water supply issues on an annual basis and are unresponsive to ecosystem or long term changes. A paradigm shift is necessary for plant communities to survive through a changing climate.

The group considered a suite of potential actions against the no-regrets criterion.

1. Storage
    A. Restoring Lake Okeechobee water quality levels – discussion of property that would have been a large area between Lake O and EAA where water could be stored. How is

this storage different from what we have asked for before? What does this storage do for interannual levels?
Answer: more water than what was projected in the 90's and in dry years you keep it moist.
B. How about storage POST-STA or between the STA's.
We need more storage because it may be drier in the future (due to climate change).
C. Storage is good whether wet or dry.
2. Change the way water is managed. Currently, it is done seasonally. Chris thinks that water managers are considering this interannual fluctuation but are constrained by various factors.

The group had an extended discussion of the current and potential function of the Everglades Agricultural Area and private lands as potential water storage areas. Incentivization for private storage, maintaining agricultural subsidies to ensure the land is not converted to urban use and changing current water management assumptions and paradigms were recommended.

Managing Wildlife for Sustainability in a Changing Climate

The wildlife group was organized and lead by Joel Trexler and Kristen Hart, assisted during discussions by Laura Brandt and three group members (Attachment 2). Their work focused on sustainability of ecosystem function, primarily related to food-web ecology, as well as threatened and endangered species and impacts of invasive species under a range of possible Everglades futures on a 30-50 year timeframe. Our primary recommendation to date has been that current restoration plans are rendered more critical for wildlife under the most likely scenarios of climate change and our work will continue to clarify and justify this recommendation. To do this, we will explore the impacts of future management of water with varying degrees of compliance with water quality standards; issues of nutrient supply and xenobiotics will be considered. We welcome additional climate scenarios, if any are available, in order to broaden the scope of inference of our recommendations. Finally, we will continue to work on documentation of model uncertainties. The greatest uncertainty lies with climate scenarios and we propose to work closely with the Everglades Landscape group to explore how these uncertainties are magnified as they are incorporated into ecological models of wildlife response.

Objective

Plan for and adapt to shifts in location of habitats and function of the ecosystem necessary to maintain sustainable populations of animal species society values under future conditions.

Recommendations

A. Support full implementation of CEPP
& implementation of restoration strategies and other assumptions of CEPP

B. Using existing information, counties should acquire critical coastal, refugia, and corridor habitats in coordination with DEP

C. USFWS in coordination with FWC identify priority species for development of Master Plan (ESA Exemption) and corridor analysis -- start the conversation and process now

Data gaps & uncertainties

- Need clear, explicit priorities for what species we want to focus on
  (trying to save everything saves nothing, use of umbrella /surrogate /indicated RSPs)
- Need to define time horizon
- Need to consider location of people
- Water quantity / quality / xenobiotics
- Who are the decision makers? At what level are decisions made?

Background & Discussion

Operating assumptions

- Discussion to focus strictly on wildlife, as other group is doing plants
- Wildlife are a part of ecosystem function
- We must build off past work-- for example, defining what society values
- Continue existing habitat management
- UPDATE: Most of the group did not have appreciation for the narrow scope of the God Squad, which is to approve exemptions to the ESA, which is essentially declaring jeopardy. This may be an outcome but we're not recommending that we seek jeopardy. The discussion centered around having flexibility to act even when endangered species protected under ESA are impacted.
- We want to develop a habitat management plan that allows us to be proactive in the face of ESA constraints.

Wildlife Recommendations

- FDEP and Local governments engage in land acquisition
- Use FWC's existing state Wildlife Action Plan, LCC Work
- Acquire refugia and corridor habitats (coastal & inland)
  to maximize benefits to priority species*

* Priority species include imperiled, umbrella, surrogate, etc. These represent other species and function of the landscape around which we focus management actions. Assumption is other species benefit.

Top Action Items
Additional recommended actions prioritized (1 - 5 year)

1. Public education
2. Identify corridors
   Scenario evaluation
3. Pick priority species.
4. Purchase all under coastal property
5. Construction of more STAs

FWS & FWC Develop Master Plan

1. Identify priority species for management decisions
2. For other vulnerable species (Threatened & Endangered), identify captive breeding, habitat enhancement, or relocation options
3. Seek approval of plan to endorse actions and consequences to selected Endangered and

Threatened Species. The discussion centered on having flexibility to act even when endangered species protected under ESA are impacted. We want to develop a habitat management plan that allows us to be proactive in the face of ESA constraints.

Management framework for landscape systems

The Landscape group with eleven participants (see Attachment 2) was organized and led by Martha Nungesser (SFMWD) and Leonard Pearlstine (NPS).

Landscape scale analysis of the Everglades requires synthesis of the major physical and biological processes that govern these wetlands. As changes in climate and sea level alter these processes, we anticipate peat loss in the ridge and slough landscapes, alterations in tree island and marl prairie community structure, saltwater incursion inland in coastal areas, loss of species synchronization, and adaptive changes in plant and animal communities, including novel communities incorporating non-indigenous and opportunistic species. Scientists can anticipate and monitor these shifts as they occur through focused data collection, integrated models, remote imagery, and intimate knowledge of the Everglades wetlands. Scientific collaboration with decision-makers may help promote ecosystem resilience, transition strategies, and changes in ecosystems services and water supply provided by the Everglades.

Objective
To identify possible ecosystem trajectories under different climate change scenarios to facilitate a healthy, shifting system that includes spatial connectivity to enhance buffering capacity.

Recommendations

The group's final recommendation considered 25 varied activities focusing on landscape level analyses, the need for predictive modelling and the role of landscape modelling in recording and predicting future system responses. They proposed three general areas for 'no regrets' action under the heading of 'Preparing for Change' and falling generally into the area of mapping, modelling and informing managers of these results.

1. Map Landscapes to protect peat performance and evolution (identify areas that are changing)
    a. Map over multiple time periods
    b. Identify hydrologically related changes and causes
    c. Conduct a baseline inventory of landscapes
2. A key data gap is the lack of spatially explicit water budgets and projections of stage in all environments. Fill knowledge gaps to enable better hydrological forecasting.
    a. Determine ecosystem trajectories
    b. Identify landscape evolution
    c. Determine volume-depth relationships to calculate stage-storage volumes
    d. Conduct risk vulnerability assessments
    e. Determine resilience by community types
3. Develop decision making tools

   a. Decision trees
   b. Models
   c. Visualizations- EDEN like

Data gaps & uncertainties

See above

Background & Discussion

Discussion topics included:

- The spatial continuity of the whole system.
- The dynamic nature of ongoing and future changes.
- The need to manage water to buffer climate changes and consider extreme as well as average levels.
- Available and needed data to predictably model the system and assess system vulnerability and risks.

An initial listing of possible actions included:

1. Prioritize freshwater ecosystems by sustainability
2. Increase storage
   a. No development of EAA, acquire to conserve for water storage and quality management
   b. Define inputs for urban storage
      i. Recycle to aquifer
      ii. Mitigate flooding
   c. Hold water at high level (hurricane) to release later
3. Strategies to mitigate effects on urban agricultural and environmental components
4. Communicate to all stakeholders why these are needed

In its second discussion session the group proposed that key actions would protect and preserve peat and soil function. They proposed a peat performance evaluation, understanding that peat is the core element of carbon cycling in the system. EDEN provides a visual method for hydrological forecasting. There is a need, in spatially explicit terms of area, to inventory and map landscapes of different community/ecosystem types and their condition, health and connectivity to prioritize areas for action. USGS is getting images and processing Landsat archives from the 1980s. So far, they've processed 300 images of different spatial-filling data gaps to obtain complete information. Scale is important in the detection of short term change--e.g. vegetation encroachment into sloughs requires much finer scales.

Relationship between the volume of water and depth changes is being done by USGS using past data from EDEN. The group proposed a short term technical meeting integrating a group of mappers and landscapers to discuss overall strategy that could include:

- Increasing flexibility in operational changes
- Adaptive management set of priorities: flood control/water supply; integration of water control plans; expanding operational flexibility; regulatory flexibility
- Integrate estuarine models into existing freshwater models to accommodate the freshwater-saltwater interface
- Long term goals—integrate the saltwater systems and water management system
- More storage in the system within the peat integrating lake, rivers and peat

Management considerations for coastal systems

The Coastal group was led by Marguerite Koch and Chris Kelble with 9 participants (see attachment 2). Coastal systems of the Greater Everglades, which include extensive estuaries and saline wetlands, are influenced by watershed and coastal management, as well as by sea level rise and climate change. Previous workshops identified known sensitivities and hypothesized responses of estuarine benthic communities and coastal wetlands' soils and plant communities to the combination of freshwater flow restoration and sea level rise and climate change. Sea level rise may be the strongest driver of future changes in these communities. The Florida Keys coral reef system is sensitive to local fisheries management, watershed management, and climate change, but the strongest driver currently impacting the reef is increasing temperature. Thermal stress not only directly impacts corals, but also influences disease vulnerability and interacts with water quality conditions to indirectly influence coral mortality. For most of the coastal system, management of fresh-water inputs (quantity, timing, distribution, and nutrient content) and fisheries are primary tools that can be used to moderate and mitigate sea level rise effects. This session seeks to provide specific recommendations to increase the effectiveness of this mitigation and the resilience of this entire coastal ecosystem in the face of sea level rise and climate change.

Objective

Spatially & temporally integrate water, land, infrastructure, and coastal marine management to make natural & built systems more sustainable (natural trajectory) in the face of climate change and sea level rise

Recommendations

1. Manage upstream water to deliver sufficient freshwater at the right quality, quantity, timing and distribution to coastal ecosystems (get the water right for coastal ecosystems)
2. Develop comprehensive regional/local governance and planning framework to implement integrated ecosystem based management
   Utilize existing legislative authority, organizations and plans (e.g., National Ocean Policy; Coastal and Marine Spatial Planning; National Fish, Wildlife and Plants Climate Adaptation Strategy)
3. Amend FL constitution to explicitly consider climate change in all public decisions including feasibility of strategic coastal adaptation

Data gaps & uncertainties

1. Need to restore water quality and hydrographic monitoring on SW shelf (ended in 2011) and reinvigorate monitoring in FL Bay, FL Keys and Biscayne Bay
   a. High resolution dynamic models to evaluate impacts of local sea level rise, climate change, and upstream water management actions on critical coastal habitats, particularly the mangrove coastline.
   b. Sediment accretion rates, subsidence, uplift and underlying geologic processes to accurately project local sea level rise
   c. Robust approaches to integrate economics and other societal issues into coastal planning under climate change
2. Direct effect of climate impacts (temperature, rainfall, ET) on coastal ecosystems
3. Robust decision making tools that address uncertainty & vulnerability of both human and natural coastal systems

4. Effective communication with local community and other stakeholders on restoration efforts and impacts of climate change and sea level rise (interactions)

Background & Discussion

Climate change and sea-level rise, habitat loss, pollution, and overfishing are the main things affecting coastal systems worldwide. It is important to note that Everglades National Park (ENP) is 2/3 marine. The major objective of this group is as follows: Spatially and temporally integrate water, land, infrastructure, and coastal marine management to make natural and built systems more sustainable (natural trajectory) in the face of climate change and sea-level rise. The group agrees that there are three major actions that should be implemented to better prepare our vulnerable coastal systems. First, there is a need manage upstream water in order to deliver sufficient freshwater at the right quality, quantity, timing and distribution to coastal ecosystems. We need to get the water right, especially for coastal ecosystems. Second, there is a need to develop comprehensive regional/local governance and planning framework to implement an integrated ecosystem based management. We must utilize existing legislative authority, organizations and plans (e.g., National Ocean Policy, Coastal and Marine Spatial Planning, National Fish, Wildlife and Plants Climate Adaptation Strategy). Fourth, we should amend the FL constitution to explicitly consider climate change in all public decisions including feasibility of strategic coastal adaptation. However, to achieve our objective, the following information gaps need to be addressed. There is a high need to restore water quality and hydrographic monitoring on SW shelf (ended in 2011) and reinvigorate monitoring in FL Bay, FL Keys and Biscayne Bay.

High resolution dynamic models are also needed to evaluate the potential impacts of local sea level rise, climate change, and upstream water management actions on critical coastal habitats, particularly the mangrove coastline. Additionally, sediment accretion rates, subsidence, uplift and underlying geologic processes need to be understood to accurately project local sea level rise. Another information gap is robust approaches to integrate economics and other societal issues into coastal planning under climate change. We also do not understand the direct effect of climate impacts (temperature, rainfall, ET) on coastal ecosystems. Robust decision making tools that address uncertainty & vulnerability of both human and natural coastal systems will also help fill in the gaps. Finally, effective communication with local community and other stakeholders on restoration efforts and impacts of climate change and sea level rise (interactions) is necessary.

Conclusions and Discussion

Conclusions

To successfully manage restoration projects in the Everglades, the impact of current and future predicted changes (in temperature and evaporation, rainfall and rainfall intensity, and sea level rise with salt water intrusion) must be taken into account. The overall conceptual knowledge that has been collected on current and future impacts should now be augmented with specific data. Monitoring these changes is a priority.

The groups emphasized and concluded that:

- While Everglades restoration focuses on the natural environment, the growing and changing human environment, both urban and rural, is closely interlinked, especially in the context of water supply and water management;

- Water storage will become even more critical in the future and the potential for increased capacity should be examined;
- While water storage is important, water conservation in agriculture and in urban environments is a vital medium- and long-term objective;
- Restoring water flow through the system, which is the critical goal of restoration in the Everglades, is even more important in the context of climate change;
- Increased water flow can reduce the impact of salt water intrusion, and increase the degree of peat formation, also reducing salt water intrusion;
- Maintaining and increasing peat formation is a vital component of a healthy Everglades system and should be given priority in all management initiatives;
- Appropriate adaptation efforts and areas most vulnerable to the impacts of changing conditions in both natural and urban areas need to be identified;
- Informed decision-making demands detailed data on potential changes in the amount, distribution and intensity of precipitation under future climate scenarios;
- The current cooperation on organizational issues between implementing agencies (as exemplified by the makeup of the meeting) is evident, but communication gaps were identified, including between counties and state and federal agencies; and

The active presence of managers from several key agencies highlighted the need for ongoing communication with and education for the public, water managers and other decision makers.

Recommended Management Strategies

Despite some uncertainties of magnitude and timing, based on the conclusions above, we recommend a number of management strategies that can safely be implemented as 'no-regrets measures.'

- Conduct a vulnerability analysis of Southern Florida and the Everglades similar to the US Army Corps of Engineers' study for the areas that would be most impacted by the next Super Storm Sandy.
- Improve our modeling of rainfall and evapotranspiration under future climate scenarios and the potential impact on the local hydrological cycle and thus water supply and management.
- Review and revise water management schedules and MFLs (minimum flows and levels).
- Encourage FDEP and local governments to engage in land acquisition to connect corridors for migration using FWC's existing state Wildlife Action Plan and Land Conservation Cooperatives (LCC) Work.
- Improve communication gaps, including between counties and state and federal agencies.
- Continue to involve managers from key agencies to maintain communication with and education for the public, water managers and other decision makers.
- Incorporate opportunities to increase water storage in existing and future Everglades projects.

Information Gaps

Most groups incorporated their implied information gaps into their primary recommendations, asking for further analysis, modelling and data collection.

Group	**Information gap**
Hydrology	Vulnerability and risk parameters (implied)
N. Everglades	Regional precipitation scenarios (Implied)

Biogeochemical	• Soil vulnerability map with system wide impact analysis that includes salinity, hydrologic and nutrient effects on soil stability, accretion and resilience • The relationship between nutrients and soil accretion rates: the answer may differ among regions and soils • Regarding capillarity, what water level really means dry peat, and thus fire risk?
Vegetation	• Planning for distributive storage (hydrological, social, economic, political, etc.). • Developing an impact assessment for urban environment (recharging aquifer, integrate flooding, etc.)
Wildlife	• Evaluation scenarios of climate change impacts on wildlife • Analysis of corridors, vulnerable coastal lands and acquisition potential • Priority process to identify key species
Landscape	• Lack of spatially explicit water budgets and projections of stage in all environments • Trajectories of landscapes under different hydrologic conditions • Risk, vulnerability and resilience analysis
Coastal	• Water quality and hydrographic monitoring on SW shelf (Florida Bay, Florida Keys and Biscayne Bay) • Direct effect of climate change on coastal ecosystems • Decision making tools that address uncertainty and vulnerability • Effective communication with local community and other stakeholders

Methodology

The seven groups produced a total of 38 recommendations with considerable duplication and overlap. Individual recommendations from the groups were compiled, grouped by similarity and scored by the emphasis assigned to that action by each group (Highest priority recommendations =3, secondary recommendations=2, mentions=1). Major topics were ranked by total numeric score, resulting in 13 broad themes (See attachment 3- Excel sheet).

Theme	**Priority score/group emphasis**	
Assessment and Vulnerability analysis including mapping	24	TOP TIER
More water storage	20	

Increased Flow through Everglades and to coast	17	
Modelling hydrology and precipitation	13	Second Tier
Acquiring/conserving land and corridors	12	
Interagency and Regional coordination	11	
Review and revise water management schedules and MFLs	11	
Use existing capacity and infrastructure to increase flow and storage	10	
Fully implement CEPP	7	Third Tier
Reduce water consumption (all sectors)	6	
Communication, education and messaging to public, managers and decision makers	5	
Prioritizing ESA species	3	
Constitutional amendment to include climate change in water management decisions	3	

Notes from Conveners

As scientists, the groups focused on the technical issues in their fields of expertise. However, the surrounding discussions and presence of managers from several key agencies made evident the commitment to fostering communication between implementing agencies, the public and decision makers.

Equally evident from the discussions, dividing the groups by topic was a convenient way to manage the content but obscured the essential connectivity among the different components of the system. Numerous discussion points and recommendations crossed over and were common or linked to the interests and discussions of other groups. Effective action and management response to climate change will need to integrate different sectors and spheres of influence and sometimes conflicting needs and drivers.

Discussion

Plenary Discussions

In the plenary discussions, several broad topics of concern across groups were identified and discussed. Contradictory or opposing trends on some issues need to be resolved.

Water Quality vs. Water Quantity: The degree to which the demand for more water flowing through the Everglades system could be met by allowing discharge of water of lower quality (i.e. with slightly higher levels of dissolved nutrients). Significant issues were the current legal constraints on water quality, and the cost, practicability and infrastructure needs of improving water quality prior to release.

Flood control: High water impacts on the built environment, both agricultural and urban, are a major preoccupation of regional managers and a driver of current policy and process. However, several 'low regret' actions call for higher water levels or allowing higher highs, which challenges the capacity to absorb storm inputs during wet periods. The possibility of more intense precipitation events in a changed climate future exacerbates this concern.

Scale: Discussions in several groups revolved around what spatial and temporal scale was the most appropriate in which to consider likely climate change effects and responses. In the spatial/geographic arena, the 'system' may be the CERP area as currently defined, a wider (north to south) 'Everglades system' comprising most of the currently unaltered land and Lake Okeechobee or the broadest concept of a complete Kissimmee-Okeechobee- Everglades- Florida Bay watershed. At the temporal level the whole scale ranged from annual, inter-annual, and multiyear at 5, 10, 50 and 100-year intervals.

Balancing social values with ecological needs: An apparent contradiction emerged between ecologically driven recommendations to increase water flow and the social pressure to protect present built environmental structure (e.g. by armoring, diking, etc.). However, 'social values' covers a broad gamut of concerns from property rights and economic interests to the conservation concerns of both near and distant people. There was consensus that water management cannot and should not be driven entirely by social or political considerations in the absence of scientific data and prediction. However, integrating the social and political considerations into current and future management policy is required. A key to successfully achieving this is the effective communication of science information to all interested sectors.

In the final discussion, an emphasis on improved integration among current management agencies was strongly promoted. The need to accelerate interagency coordination and specifically to produce improved predictions of future precipitation patterns was a major need. Managers noted that they do not need to completely remove uncertainty in order to make effective management decisions--in fact, decisions are routinely based in "bounded uncertainty." However, managers need tools and processes to evaluate the range and severity of consequences that would flow from decisions made in uncertain settings. Methods of risk analysis, viability analysis and sensitivity analysis of proposed management actions are needed. Managers also emphasized their need for information in understandable and easily communicated formats. The published literature, and even technical reports, are the factual basis for information exchange, but are not an effective mechanism for translating that information into management friendly communications. There is a need for visualization and 'translation' of actionable science to a form that the public, policy makers and managers can quickly understand. This was particularly germane to the recognition that much on-the-ground climate change response and adaptation is and will be applied at the local government level. While a broad range of federal and state agencies have jurisdiction, regulatory control, infrastructure and capacity to manage climate change response, day-to-day and local action will strongly influence many important factors such as reduced water consumption, development and building patterns and standards.

Proposals to address this improved coordination included:

- Integration of information from this meeting to existing interagency forums
- Production of a 2-3 page Executive Summary of the conclusions of this meeting
- Convening an interagency, regional discussion group to transfer information

The actual water management actions proposed by the groups were considered in the light of two current realities: the rate of climate change and consequent effects may be relatively slow (decadescenturies) compared to planning and management action horizons and there is an extensive existing structure of regulatory schedules, MFLs and infrastructure. Consequently, an immediate and low regrets response would be to use and adapt existing capacity to move in the direction of proposed action such as increased flow, higher stages and inter-annual variations. Water storage capacity is already built into current structure and policy such as CERP and Restoration Strategies and can be increased incrementally over time toward long term goals, rather than needing immediate, expensive action.

Integrating this approach into current management activity would be enhanced if there were better recognition by the public at large of the substantial ecosystem services and benefits that will be derived from better Everglades management. Benefits include flood control, protection from storm surge and protection of water supply from salt intrusion.

The meeting closed with acknowledgements and thanks to the funding supporters, organizers, the organizing committee and staff, participating agencies and individuals, the student recorders and all participants. (See listing separate)

Resources

Please find the meeting agenda on our website:
http://www.ces.fau.edu/climate_change/everglades-recommendations-2014/pdfs/agenda.pdf

Please find background presentations, data, reports and a reference list on our website:
http://www.ces.fau.edu/climate_change/everglades-recommendations-2014/resources.php

Please find a list of participants and organizers attached.

For more information please contact Mary Beth Hartman, Conference & Outreach Coordinator
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