PREDICTING ECOLOGICAL CHANGES IN THE FLORIDA EVERGLADES UNDER A FUTURE CLIMATE SCENARIO

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

February 14 & 15, 2013

Florida Atlantic University ♦ Boca Raton, Florida

FINAL REPORT

USGS science for a changing world
FAU FLORIDA ATLANTIC UNIVERSITY
Sea Grant Florida

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ACKNOWLEDGEMENTS

The preparation of this report required dozens of conference calls and email exchanges and an additional briefing webinar December 2012. The steering committee included a range of scientists spanning representatives from six federal agencies, water management representatives and five universities. They convened biweekly to examine the program and explore the best ways of moving the discussion of climate change issues from the more abstract science into the venue of decision-making, adaptive management, and operations. The South Florida Water Management District (SFWMD) played a special role in providing technical backup and staff time while Center for Environmental Studies (CES) provided staff and logistical support, partly under a US Geological Survey (USGS) cooperative grant.

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I. ABSTRACT

For resource managers, a major point is that climate change needs to be explicitly considered while the multi-billion dollar Comprehensive Everglades Restoration Plan (CERP) is implemented, or else that project may not achieve its intended outcomes. A careful process is needed that: (1) acknowledges that climate change is likely to affect the outcome of CERP; (2) makes use of new information, as it becomes available, about the expected changes in temporal distribution and intensity of RF so that modeling exercises can be updated and rerun as appropriate, so that (3) ecologists, engineers and water resource managers working together can identify solutions to future climate scenarios with balanced impacts on regional ecosystems and public & private uses of fresh water.

The *Predicting Ecological Changes In The Florida Everglades Under A Future Climate Scenario* meeting was held at Florida Atlantic University's Boca Campus in February 2013 with the purpose of bringing scientists and resource managers together to discuss these issues. More specifically, experts in Everglades ecology were asked to identify how hydrologic changes associated with possible future climate change regimes might influence ecosystem services, and to identify research gaps where it currently is not possible to make such projections with acceptable certainty. To do this, they were provided with output from the South Florida Water Management Model (SFWMM), a 2 x 2 km regional hydrologic model that was used in the planning process of CERP.

On day one of the meeting, participants first heard about the six model scenarios that were compared to the 2010 baseline. This was followed by presentations from a range of ecologists. Different assessments of the impacts of climate changes under scenario conditions were made for three distinct regions: Lake Okeechobee, Freshwater Wetlands, and Marine and Coastal areas. The assessments included discussions on peatlands, fish and aquatic fauna, plant species and plant communities, and wildlife. Marine and Coastal assessments were divided into Florida Bay, Coral Reefs, with additional presentations on particular species.

On day 2, meeting participants were divided into three breakout groups, each one having a diverse mix of scientists and resource managers. Each group was asked to answer three questions and record the results for presentation back to the full group with discussion. Additionally, the groups were asked to consider dynamics associated with ecosystem feedbacks that span the boundaries of Lake Okeechobee, freshwater wetlands and coastal and marine ecosystems. The ideas discussed in these break-out groups were synthesized into a list of Considerations for Restoration and Resource Decision Makers which is provided on page 14 of this report.

II. INTRODUCTION

Changes in climate and sea level are already having an impact in South Florida and projections for the future suggest that these changes will accelerate over the next several decades. Associated changes in rainfall, runoff, temperature, evapotranspiration and sea surface elevation will impact the hydrological and ecological systems of the natural and built environment.

Predicting Ecological Changes In The Florida Everglades Under A Future Climate Scenario is the latest in a series of meetings over the past three years. These meetings examined the current and future potential impact of sea level rise and other hydrological changes on select regions and processes of the greater Florida Everglades, and on the potential outcomes of implementing the Comprehensive Everglades Restoration Plan (CERP).

The first meeting, held in April 2011, examined the ecological models established for the southernmost Everglades which, for the most part, did not incorporate sea level rise into their projections. The meeting explored the needed revisions to those models based on the current projections of sea level rise. (Download the meeting summary)

In March 2012, a second meeting addressed hydrological changes, and focused primarily on technical issues of downscaling climate change models to Florida and examined other aspects of atmospheric variability. In addition, the participants explored major gaps in knowledge of current hydrological understanding of the Everglades system, particularly the role of evapotranspiration and ground flow. (Download the meeting summary)

The steering committee (Appendix A) that planned and delivered these meetings realized that ecologists had not been sufficiently represented and that a modified approach was needed to provide more actionable science that could directly aid the planning and mechanics of Everglades Restoration. In a series of brainstorming meetings, the following strategy evolved:

> ***Step 1:*** Bring key ecologists into the discussions and update them on the process and findings thus far.
>
> ***Step2:*** Develop realistic scenarios of future conditions upon which ecologists and hydrologists could base their predictions of future climate change impacts on the Everglades environment. This includes considerations of climate change interactions with and effects on restoration strategies, actions, and expected outcomes under different climate change scenarios, which while hypothetical, provide a specific and quantitative basis for calculations and judgments.
>
> ***Step 3:*** Involve managers and decision-makers from various agencies in the full discussion. Keep the National Research Council's Everglades Oversight Committee fully aware of the technical meeting and its conclusions.

To implement these steps, a webinar was organized and delivered (August 2012) to approximately fifty ecologists and hydrologists who had not attended the March 2012 meeting. The goal of the webinar, coordinated by the SFWMD, was to provide an overview of the March meeting and featured presentations by several key representatives from water management, University of Florida (UF), Florida State University (FSU) and the USGS. A second webinar in December 2012 was used to discuss model outputs with paper presentations.

The most recent meeting, in February 2013, was conducted in order to have experts in Everglades ecology identify how hydrologic changes associated with possible future climate change regimes might influence ecosystem services, and to identify research gaps where it currently is not possible to make such projections with acceptable certainty. Experts were provided with output from the South Florida Water Management Model (SFWMM), a 2 x 2 km regional hydrologic model that was used in the planning process of CERP. Different future climate scenarios were run and the ecologists were asked to answer three questions:

- How would key attributes of the ecosystem respond to the changes in hydrology provided in the model output?;
- What are the gaps in scientific information leading to unacceptable levels of uncertainty in both climatic and ecological predictions, including changes in environmental parameters needed to predict how these ecosystems may respond?
- What are some options for future resource management, and what are the scientific capabilities to support that management?

The South Florida Water Management District (SFWMD) used a set of climate change and sea level rise scenarios to run the SFWMM. This run was completed by December and made available for the hydrologists and ecologists to utilize two months prior to the February 2013 meeting. The organizing committee also believed that the presence of agency managers would enhance the impact of the presentations and discussions. Together with four representatives from the National Research Council, the manager's participation greatly enhanced the process and outcomes.

III. CLIMATE SCENARIO RUNS

Current projections of climate change and sea level rise have shown that the concept of "stationarity", previously used in traditional planning efforts, is no longer appropriate. Using the SFWMM, a study was undertaken to provide a set of climate change and sea level rise scenario runs. These runs were the basis for conversations among scientists and decision makers in order to identify the future work necessary to understand the implications of potential changes in the climate and sea level on Everglades Restoration. The results of this analysis should not be viewed as definite projections of what will occur, but as reasonable examples of what could happen in the greater Everglades region, based on best available information at this time.

A. SFWMM - The Model

The SFWMM is a regional-scale computer model that simulates the hydrology and management of water resources system from Lake Okeechobee to Florida Bay, covering an area of 7,600 square miles. The model simulates the major components of the hydrologic cycle in South Florida (see Figure 1) on a daily basis using climatic input. The components include rainfall, evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal-groundwater seepage, levee seepage and groundwater pumping. The SFWMM also incorporates water demands of all sectors and simulates current or proposed water management control structures and operational rules. The output of the model includes a myriad of performance measures covering urban, agricultural and environmental sectors that had been the basis of previous planning efforts.

B. The Scenarios

Six scenarios were developed. These scenarios were compared to a 2010 baseline, which included no changes except the planned components of CERP and their effects on regional hydrology. The scenarios included the following:

- +ET -- 1.5 ft sea level rise (SLR) plus increased temperature by 1.5 degrees C and associated increase in evapotranspiration (ET).
- +ET+RF – same increases in SLR, temperature and ET, plus a 10% increase in rainfall.
- +ET-RF – same increases in SLR, temperature and ET, plus a 10% decrease in rainfall.
- The above scenarios with changes in coastal canal levels to reduce the risk of saltwater intrusion.

Hydrologic output from the model runs of these scenarios was provided to teams of researchers with expertise in particular regions of the Everglades or particular processes (e.g., biogeochemistry), and they were asked to answer the three questions listed above and present their findings in oral presentations.

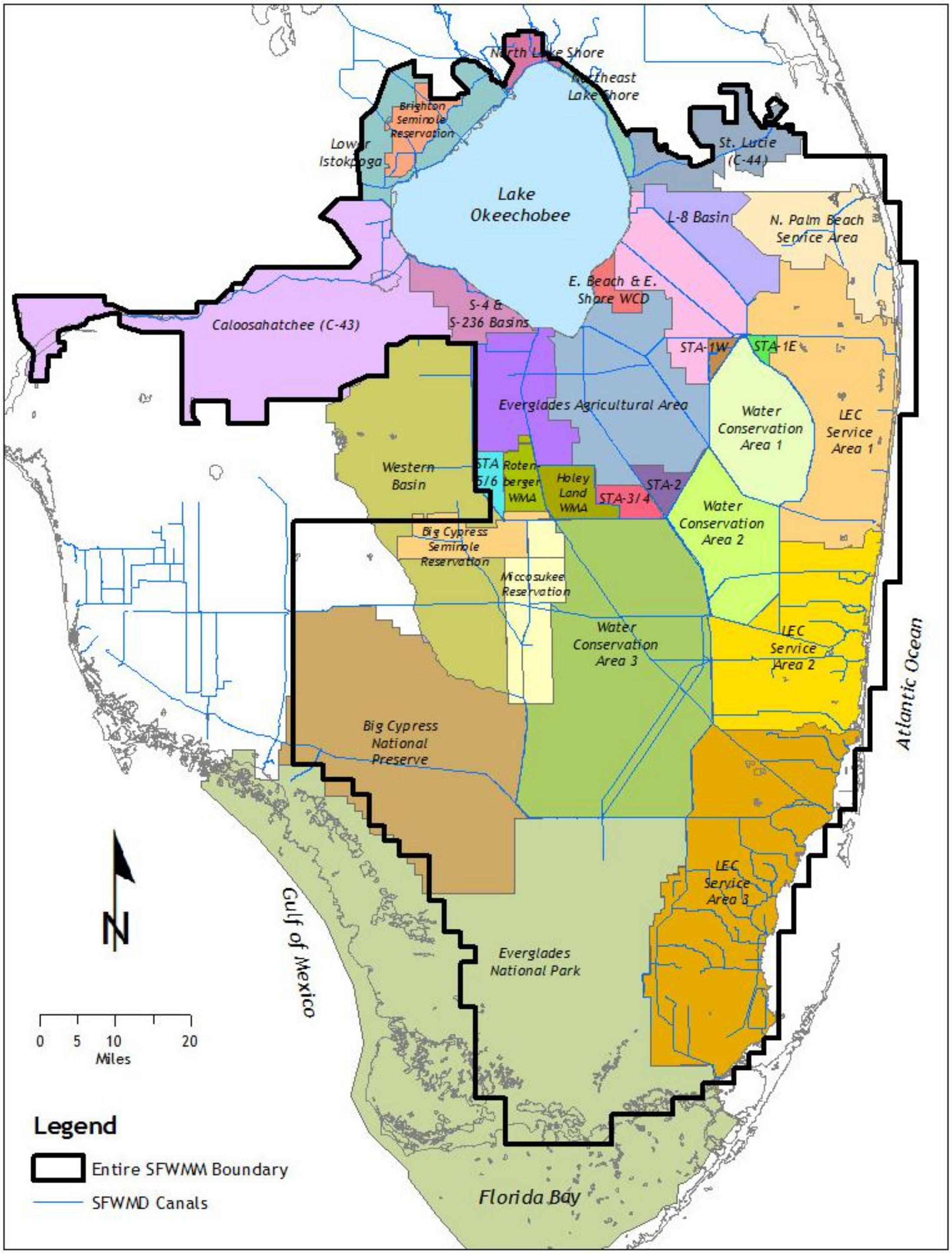


Figure 1. Regions within the Domain of the SFWMM

C. Rationale

Temperature and precipitation projections are based on the previous work reported in Obeysekera et al. (2011). This report is available from www.sfwmd.gov (->Scientists & Engineers->Technical Report and Publications-> Climate Change in South Florida). A summary of expected changes by circa 2050 is reproduced in Table 1. The sea level rise estimate is based on the SE Climate Compact report available from http://southeastfloridaclimatecompact.org/. Some of the relevant figures from these reports are reproduced in Figure 2.

Table 1. Summary of Median Climate Change for Circa 2050

Variable	GCM	Statistically Downscaled Data	Dynamically Downscaled Data
Average Temperature	1 to 1.5ºC	1 to 2ºC	1.8 to 2.1ºC
Precipitation	-10% to +10%	-5% to +5%	-3 to 2 inches
Reference Crop Evapotranspiration			3 to 6 inches

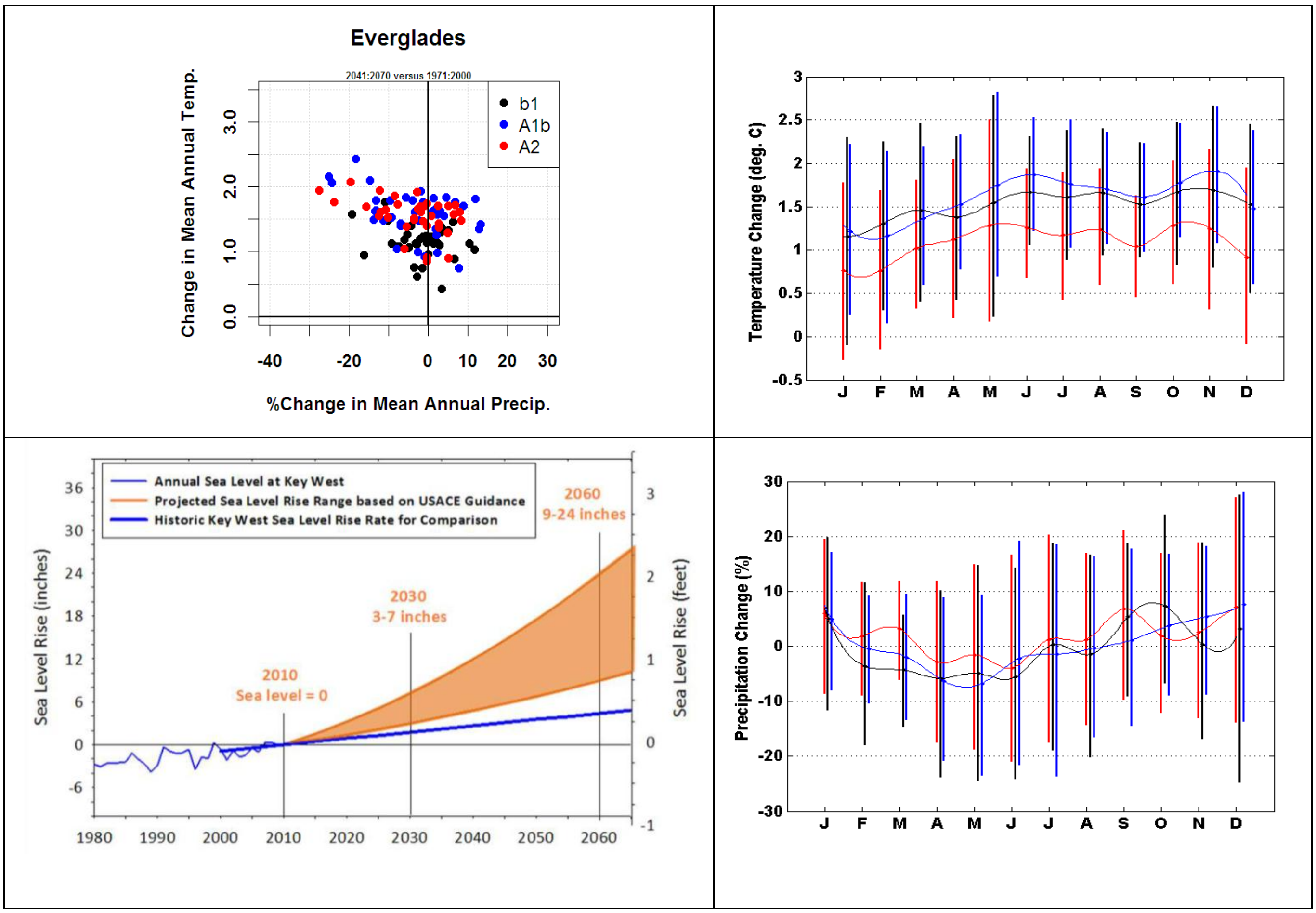


Figure 2. Projections of precipitation, temperature, and sea level rise for the 2050-2060 time frame from (a) analysis of statistically downscaled data (upper left panel); (b) GCM data for the SE region (two right panels); and (c) unified sea level rise projections of the SE Climate Compact (lower left panel). The temperature and precipitation projections are from Obeysekera et al. (2011) and the Sea Level Rise projections are from the unified sea level rise projections produced by the SE Climate Compact Working Group.

IV. DAY ONE: ANALYSIS OF ECOLOGICAL AND HYDROLOGICAL RESPONSES TO CLIMATE SCENARIOS

The meeting was held on the Florida Atlantic University Boca Raton Campus and with almost 100 people in attendance. Participants represented a diverse group of organizations including non-profits, consulting firms, US Fish and Wildlife Service, US Army Corp of Engineers, SFWMD, NOAA, Natural Resources Council, the National Wildlife Refuge and Park Service, FL Fish and Wildlife Commission and representatives from nine universities. PowerPoint presentations are available online and the abstracts for each presentation are given below. The agenda for the two-day meeting and each of the speaker's biographies are provided in Appendices B & C, respectively.

A. Setting the Stage

As a basis for predicting ecological change under future climates as developed in the scenarios, scientists can use our extensive knowledge of hydrological/ecological relationships and project changes in future plant and animal relationships that may ensue. Such projections can be based not only our understanding of current dynamics, but also draw on the information gleaned from the geological record, using the impact of past climatic changes on ecosystems and on individual species. To provide this background initial presentations by Lynne Wingard (on the past) and Jayantha Obeysekera (on the projected future) opened up the session.

- **Florida's History in Context: Past Patterns of Climate Change and Ecological Responses to *Change—Lynne Wingard***

Climate change is one of the most discussed subjects among the public today, and scientists are working together to predict what affects climate change could have on our planet in the future. One way to do this is to look at the climate data from the past. Past data, also referred to as paleodata, goes back thousands, and sometimes millions, of years. Over the last 3-4 million years, the floral and faunal communities have not changed much in response to climate change. This leads us to believe that the main drivers of habitat loss in the 20th century are land use and water management. Past records are not always the key to predicting future impacts of climate change. However, using both past and current records makes it easier to make predictions. There is a need to fill in information gaps in the paleodata in order to help us identify these indicators of climate change. In addition, we must compile, synthesize and analyze existing data sets from a variety of ecosystems to understand interconnections, and feedback mechanisms.

- **Screening analysis of Climate Scenarios—Jayantha Obeysekera, Jenifer Barnes, Moysey Ostrowsky**

In the current projections of climate change and sea level rise, the concept of "stationarity," that past climate is indicative of future climate, which is traditionally used in Greater Everglades Ecosystem restoration efforts, may no longer be appropriate. In this study, downscaled regional climate information derived from the General Circulation Models and sea level rise projections were evaluated to provide a reasonable set of initial scenarios for impact analysis. Based on the analysis for the 2060 planning horizon, a 1.5°C increase in temperature, ±10% change in precipitation, and a sea level rise of 1.5 feet were used to develop eight scenarios as input to a comprehensive hydrologic simulation model for the Greater Everglades. Depending on the particular scenario, the modeling results show significant changes to the water budgets with implications for water supply and ecosystems of the Greater Everglades. This preliminary screening of climate change and sea level rise demonstrates the need to incorporate their implications in ongoing restoration, system operations and water supply planning efforts. The subsequent abstracts are based on the Climate Scenario Runs previously discussed in this report.

B. Predicting Ecosystem Change in Response to Specific Climate Change Scenarios

Different assessments of the impacts of climate changes under scenario conditions were made for three distinct regions. These regions are:

1. Lake Okeechobee,
2. Freshwater Wetlands, and
3. Marine and Coastal areas.

The assessments included discussions on peatlands, fish and aquatic fauna, plant species and plant communities, and wildlife. Marine and Coastal assessments were divided into Florida Bay, Coral Reefs, with additional presentations on particular species.

1. Lake Okeechobee

- ***Climate Change Sensitivity Analysis—Karl Havens***

Based on prior observational and experimental research on Lake Okeechobee, and work on other lakes and wetlands experiencing varying hydroperiods, we projected how Okeechobee might respond to climate changes projected for 2060. Right now, Lake Okeechobee has an average low water level of about 12 feet and an average high water level of about 15 feet. To predict the future water levels of Lake Okeechobee, future scenarios were created by predicting what would happen if rainfall was increased or decreased, along with either an increase or a decrease of evapotranspiration. In a future scenario with a 10% increase or decrease of rainfall, along with an increase in evapotranspiration, the temperature of the water increases by 1.5 C° and the water level raises by 0.5 m. In this same scenario, there was a counter-balanced effect on lake water budget, and no real effect on hydrology. Another future scenario that had a decrease in rainfall and an increase in evapotranspiration resulted in large changes in hydrology, along with major negative effects on the water level. One of the most noticeable negative affect would be a 2 m, or more, decrease from the average high and low water levels, which could possibly last for multiple years. This drop in the water level, and duration of low water levels, goes outside the range of any prior prediction that has been made. If the water levels do drop that low, the marsh lands could be prone to fires and vegetation would be killed off periodically. It is difficult to predict what type of effect these predicted changes would have on the fish habitat, as well as the submerged aquatic vegetation. Such conditions however, would dramatically alter the lake's ecology and its services.

2. Freshwater Wetlands

Four separate groups of researchers looked at the impacts of how our Freshwater Wetlands might respond to climate changes projected by the model output. One group analyzed how the Everglades landscape might respond and determined that there would be major impacts to soils, vegetation, fish, wildlife, invasive species and that increased drought conditions would lead to reduced peat production, an increasing rate of peat loss and increased risk of fire. Another group analyzed the fish and aquatic fauna and determined, among other findings, that decreased rainfall scenarios dramatically decreased aquatic fish production with likely implications for apex predators that depend on these for prey. Yet another group of researchers analyzed plant species and community responses and found that the Everglades ecosystems are currently declining due to changes in the range of water-level fluctuations over a wet-dry cycle, and this cycle may be exacerbated by a decline in rainfall and increase in evapotranspiration. The final group researched the landscape scale responses to biogeochemical factors and, among their findings, determined that decreased rainfall and increased evapotranspiration would lead to more frequent drying events and organic soil oxidation and release of mercury and sulfate from soil, and an increase of methylmercury production.

- ***What Can the Everglades Landscape Expect from Climate Change? —Martha Nungesser, Colin Saunders & Carlos Coronado***

The Everglades is a large patterned peatland. Peatlands form and are maintained in areas where precipitation exceeds evapotranspiration, as is true of south Florida; the climate change scenarios predict a 7% increase in evapotranspiration and a 10% increase or decrease in precipitation. With an increase in evapotranspiration and a 10% decrease in rainfall, the Everglades could experience water level decreases of 0.5 feet to 3+ feet and a decrease in duration of surface water from 10-50% across the Everglades. This scenario would cause drought conditions leading to widespread fires, reduction of peat production, and elimination of peat accumulation. As peat dries out, it oxidizes and mineralizes, emitting CO_2 into the atmosphere. Previous drainage has led to widespread loss of patterning in the Ridge and Slough landscape, and additional drought would eliminate more patterning. Major shifts in flora and fauna could include a loss of hammock and tree island species and an increase in the growth of *Lygodium microphyllum* and other invasive exotic plant species in response to altered hydropatterns. Fish habitat would decrease with lower water levels over extended periods of time, altering community structure and prey species availability for wading birds and other aquatic predators. Paleoecological evidence indicates that changes of this magnitude have not been experienced in the 5000 year history of the Everglades. Climate change should be incorporated into restoration planning to help mitigate these impacts wherever possible.

- ***Fish and Aquatic Fauna—Joel Trexler, Mandy Banet & Chris Cattano***

Small fish, shrimp and crayfish communities play an important role in the Everglades as a food source for wading birds. When comparing the baseline population of these aquatic communities with the predicted results from the climate change scenario, it is apparent that there could be a major impact on these communities. All climate scenarios with decreased rainfall showed decreases in fish density when considered system wide, the scenario with a 10% decrease in rainfall yielded negative impacts in all seven regions considered. In Water Conservation Areas 3A and 3B, the small fish population could decrease by over 35%. The scenarios with a decrease in rainfall increased the frequency of drying events, which is well documented to result in decreased fish biomass. In these drier conditions, there could be an increase in the frequency of one of the two species of crayfish present, the Everglades' crayfish. However, it typically sustains a lower biomass than the slough crayfish, which prefers wetter conditions. With a decrease in rainfall and an increase in evapotranspiration, some areas see a dramatic decrease (70%) in small fish density/m2. Sea level rise is another factor associated with climate change and could also have an impact on the aquatic communities. In the Taylor Slough area, sea level rise affected only a small number of sites in these simulations. In the affected areas, sea level rise lengthened hydroperiods, which generally increases aquatic productivity; however, the brackish fish communities that are favored by such conditions are known to sustain less biomass than the freshwater fish communities. This could negatively affect the birds that rely on these small fish communities as a source of food.

- ***Predicting Ecosystem Change in Response to Climate Change Scenarios: Plant Species and Community Responses—John Volin, Arnold van der Valk, Paul Wetzel***

The annual and interannual water level fluctuations are the main variables that control the development of plant communities in the Everglades. When looking at future scenarios of climate change, the data show that there will be a small impact on the plant species that grow in the Everglades. Some species of vegetation, such as the wet prairies and sawgrass flats, are expected to be more widespread by 2060. The baseline interannual water level fluctuations are at about 1.95 m (6.5 ft.). These conditions appear to remain the same even when looking at the most severe climate change scenarios, which include a 10% decrease in rainfall. However, the average range of water level fluctuations is predicted to drop from 0.55 m (1.8 ft) to only 0.24 m (0.8 ft). Under the most severe climate change scenarios, there is a possibility that the length of interannual cycles may shift to longer dry phases in the Everglades. These longer dry phases could result in more frequent fires, which could have an overall negative effect on the Everglades vegetation. One aspect of the Everglades vegetation that may be effected is the length of time that a certain plant community may be there. The Everglades are currently declining because of a compression in the range of water-level fluctuations over a wet-dry cycle. Climate change will not reverse the compression, but it may be exacerbated by a decline in rainfall and increase in evapotranspiration.

- ***Landscape Scale Response to Climate Change: A Biogeochemical Perspective— Susan Newman, William Orem, Todd Z. Osborne, K. Ramesh Reddy***

Climate change can affect the landscape and the habitat of the Everglades in numerous ways. By using future scenarios of climate change, it is possible to predict what will happen to the biogeochemical properties of the Everglades. When examining the worst case scenario, a 10% decrease in rainfall and a 10% increase in evapotranspiration, there are major impacts on the carbon, nitrogen, phosphorus, sulfur, and the mercury cycles in the Greater Everglades area. In this scenario, the carbon cycle data shows that the northern and central peat lands could become overly dry even in wet years. Dry years are predicted to be even worse as drought would cause system-wide peat loss. The effects on the nitrogen cycle are closely related to the effects of the carbon cycle in this scenario. In this same scenario, there would be a greater phosphorus input as well as a conversion of organic to inorganic phosphorus. The sulphur and mercury cycles are closely tied together. With a decrease in rainfall and increased evapotranspiration, soils in the water conservation area would be at risk due to the release of sulphur from oxidation. Decreased rainfall and increased evapotranspiration would also lead to more frequent drying events, the release of mercury ions and sulfate from soil, and the increased production of methylmercury. The effect of increasing temperatures is important to consider as it could cause an increase in the microbial activity. However, there are uncertainties with this data. Some uncertainties include, the effect of increase saltwater on the stability of organic material, as well as if the increase sea level rise will cause erosion of accumulated carbon due to tidal flux or increase C due to mangroves expanding northward. To answer these uncertainties, research needs to be done to know what the salinity limits for the freshwater Everglades are, as well as researching whether peat growth can be manipulated with SLR.

3. Coastal and Marine Ecosystems

Increasing sea-level by 1.5 feet will make Florida Bay salinity more like that of the ocean, with salinity increasing in fresher areas and decreasing in hypersaline areas. This salinity response will be influenced by the potential growth or erosion of the bay's western mud-banks, which are biogenic and currently inhibit water exchange with the Gulf of Mexico. Both salinity and temperature strongly affect biota; higher summer temperatures may negatively affect seagrass habitat and fish. The Florida Keys' coral reef already has experienced negative effects. The most dramatic future changes likely will occur in coastal wetlands. Current rates of soil accretion and soil elevation increase are far less than the workshop scenario's sea-level rise rate. If inundated by the sea, coastal systems will expand and be disturbed by increased nutrient and turbidity releases from the former Everglades.

- ***Climate Variability and the Coastal Physical Environment (Florida Bay) - Erik Stabenau-***

The salinity regime sets the ecological environment in coastal ecosystems such as Florida Bay with extreme events leading to shifts in ecological communities. Salinity is variable and trending upward in Florida Bay and changes in salinity act in conjunction with other factors, including currents, temperature, and light with various feedback cycles. Sea level rise is expected to play an increasingly important role in coastal ecosystems. In Florida Bay, the rate of sea level rise relative to changes in bank height has an effect on mixing between basins, changing salinity levels and impacting the marine life that lives in the Florida Bay. The data show a clear signal that sea level rise in the coastal zones of Florida Bay is already affecting salinity. While salinity is highly variable, it has been increasing since 1995 and conditions are becoming more 'marine-like'. There are a few factors that need to be considered but perhaps the most important is changes in bank height. Banks are long narrow sills, stabilized by seagrass that limit exchange between basins. Using a coastal ocean model, when bank heights are projected to increase in conjunction with increase in sea level, there is not much change to salinity. However, if you run the same scenario without changing the height of the banks, you reduce estuarine habitat size and duration. Thus, if sea levels rise and the banks do not increase at the same pace, estuarine habitat will be lost and the ecosystem of Florida Bay will change with unknown consequences on its resiliency.

- ***Climate Change Effects on Mangrove, Seagrass and Macroalgae Communities of the Coastal Everglades— Marguerite Koch, Carlos Coronado***

Marine plant communities, including mangrove forests, seagrass meadows and macroalgae of the Everglades provide the foundation for numerous ecosystems. Using a 2060 scenario of sea level rise, temperature increases and elevated CO_2, various drivers were examined that could lead to a restructuring of these foundation plant communities. We also considered adaptation potentials and highlight areas of future research and modeling needs. At a 9.5 mm rise in sea level, coastal mangrove forests would not likely keep pace with rising sea levels. In this scenario, the rate of elevation change in the water level would be about 1.25 millimeters per year. In addition to the rise in water level, there would also be an increase in temperature. If there is a sustained increase of 1.5°C by 2060, then there will only be a slight impact on the plant communities. However, if temperature increases by 4°C by 2060, then there could be major impacts to the plant communities. The drivers of submerged plant communities are salinity, nutrients, and light. Shifts from benthic to open-water communities are predicted under 2060 sea level rise rates. There are scientific needs that must be addressed in the near future that can help better predict the impacts that could occur on the plant communities. There needs to be regional measurements and estimates of potential sea level rise rates. In addition, the models used for predicting climate change impacts should include the major drivers of seagrass, phytoplankton and carbonate sediment processes, as these plant communities provide the foundation for their associated ecosystems. These drivers include: light, nutrients, temperature and sea level rise. It is certain that climate change will have an impact on major ecosystems in the Everglades, but there are thresholds that need to better understood, particularly sea level rise rates, in order to better predict the exact impacts that will occur in these ecosystems.

- ***Climate Change Impacts on South Florida Coral Reefs— Margaret Miller, Bill Precht***

Much is already known about the effects of climate change on coral reefs. For example, increasing ocean temperature extremes cause mass coral bleaching, as well as disease and reproductive impairment. Some coral reefs off the coast of the Florida Keys have experienced almost 50% of the reef being bleached. Bleaching of coral reefs every 5 years could possibly lead to extinction of reef-building corals. Coral reefs in waters that are between 30-31°C, could result in abnormal embryonic development. Ocean acidification also has an effect on the coral reef communities, impairing the growth and reproduction of corals, as well as increasing the bioerosion of coral skeletons. Seagrasses could help ameliorate the effects of ocean acidification by absorbing excess CO2. It is still unknown whether sea level rise will have a major impact on South Floridacoral reefs. An 18 inch increase in sea level is not enough to “drown” coral reefs. There has been research that shows that coral reefs have been displaced by a sudden 10-36 mm/yr change in water level, but this does not imply that the coral reefs have been negatively impacted by the increase. More likely, impacts of sea level rise on coral reefs will occur via changes in coastal water quality via inundation as deteriorating water quality is expected to further impair corals’ capacity to endure warming stress. Adaptation potential of corals, as well as the effectiveness of “reef resilience” strategies, is uncertain. More research is needed to determine the impacts future climate change will have on coral reefs.

- **Climate Changes Impacts on Marine Ecosystems *(Holistic Analysis & Faunal Response) —Chris Kelble, Pamela Fletcher, Geoff Cook***

Saltwater recreational fishing is one of the most important revenue sources in the Everglades. Annually, saltwater recreational fishing produces about $880 million, along with about 6,000 jobs. The Spotted Seatrout is the 2nd most caught fish in the Florida Bay. Another important fish in the Everglades and in the Florida Bay is the Bay Anchovy, which occupies a key role in the food web. As an important revenue source, it is valuable to understand what impacts climate change will have on fish communities. A 1.5 foot increase in sea level rise and a 1.5°C increase in the temperature would impact the Spotted Seatrout community, as well as Bay Anchovies. If salinity levels increase, there would be a decrease in Bay Anchovy populations and an increase in mesozoplankton. The reason for the increase in the mesozooplankton is because the Bay Anchovy makes up 81% of the zooplanktivorous community. In addition, these increases could decrease the juvenile Spotted Seatrout population in the summer. However, it could also increase the juvenile Spotted Seatrout population in winter. Most of all, climate change pressures will have a dominant impact on ecosystem sustainability and service production. Even though predictions can be made on what could happen to the Spotted Seatrout and the Bay Anchovy in isolation under certain climate change predictions, this does not take into account ecosystem interactions that we know are important. The only way to accurately predict what could happen is by using ecosystem models.

- ***KEYSMAP (Florida Keys Marine Adaptation Planning) —Robert Glazer***

The Florida Keys are among the most highly vulnerable coastal areas in the U.S. with respect to a changing climate due to the low-lying topography, the reliance of the economy on a fragile coastal ecosystem, and the high degree of endemism. Yet the response of the ecosystem and its components under a changing climate is poorly understood. To investigate these responses, we coupled sea level rise and sea surface temperature models and used the results to examine a suite of alternative future scenarios. The scenarios were used to envision the first order response of key ecosystem components (Spiny Lobster, Loggerhead Turtles, Goliath Grouper). The project was designed to best inform managers as they develop responses to climate-driven impacts.

V. DAY TWO: DISCUSSIONS OF THE IMPLICATIONS OF SCENARIO RUNS

A. Evaluating Information Needs and Uncertainty Scenarios – Breakout Groups

The oral presentations by experts concluded on day 1 of the meeting. On day 2, meeting participants were divided into three breakout groups, each one having a diverse mix of scientists and resource managers. Each group was asked to answer three questions and record the results for presentation back to the full group with discussion. The three questions addressed in the breakout groups were:

> Question 1: In evaluating the response of the various ecosystem components to climate change, what research gaps exist that led to lower than acceptable certainty in your projections?
>
> Question 2: In evaluating the response, what additional information (from model output, etc.) would have helped you make your projections?
>
> Question 3: What are the greatest needs by management?

Additionally, the groups were asked to consider dynamics associated with ecosystem feedbacks that span the boundaries of Lake Okeechobee, freshwater wetlands and coastal and marine ecosystems. The ideas discussed in these break-out groups have been synthesized into a list of ***Considerations for Restoration and Resource Decision Makers*** which are detailed in the next section of this document.

B. Considerations for Restoration and Resource Decision Makers

Climate change will affect the outcome of Everglades restoration in a number of ways: through direct and indirect consequences of sea level rise and associated saltwater intrusion into the peninsula; through increased temperature and evapotranspiration that will impact the availability of water for both the natural and urban environment; and through changes in the amount, timing and distribution of rainfall. Rising seas may threaten the integrity of coastal peat soils and flood coastal plants. Increased temperature and longer-lasting droughts may severely reduce available freshwater. In addition, fire, invasive species and disease may interact with these changes to have unexpected adverse impacts to Everglades flora, fauna and ecosystem services.

The workshop identified that the effects of climate change must be carefully considered and that those effects deemed most likely to influence the outcome of CERP should be taken into consideration in the planning and implementation of regional projects. The workshop also identified that major uncertainties exist, from those associated with climate projections to those about specific changes in ecological structure and function. These uncertainties must be prioritized and then reconciled with timely research that can support decisions by resource managers.

The following list provides some examples of research and management needs.

Scientific Information and Understanding Gaps:

- Major factors determining the availability of freshwater in the greater Everglades are the future rainfall and the magnitude of evapotranspiration. Currently, evapotranspiration is estimated as a simple generic function of temperature. Site-specific relationships between all climate variables, including air temperature and evapotranspiration, need to be developed. Better rainfall scenarios also need to be developed.
- There is a potential for large-scale peat collapse and land loss due to intrusion of salt water at the southern end of the Everglades. To understand the magnitude and timing of these impacts, research is needed regarding the status and dynamics of factors influencing elevation change - especially the magnitude and variability of salt-water intrusion.
- The Florida Bay mud-banks are barriers that protect the Bay and the Everglades from wave energy and storm surges. Information is needed regarding how they will be affected by climate change, including their current elevation, rates of erosion, sedimentation, and net elevation change.
- Integrated hydrologic-ecological models are needed to evaluate current status and dynamics in response to climate change scenarios.
- Information is needed about how key processes like peat accretion and loss, and viability of seed banks, will be affected by prolonged periods of drying.
- We need to understand the vulnerability and resilience of populations to changing patterns of landscape connectivity.
- We need to learn how to build ecosystem resilience. We need to gain understanding of community and ecosystem dynamics and management influences on these dynamics sufficient to identify mechanisms that increase resilience. This need includes research to identify tipping points and to develop early-warning indicators.
- We need to understand the role of fire, invasive species and disease as they influence ecosystem responses to climate change.

Scientific Applications: A Path to More Effective Ecosystem-Based Management

- There is a need for improved communication, outreach and education, which engages both managers and the general public. Scientific understanding of the impacts of climate change must be communicated openly and honestly.
- We need to expand the scope of ecosystem analysis to encompass societal needs and dynamics, including economics and water demands. For South Florida, integrated ecosystem-human system planning and analysis should include consideration of the entire Kissimmee-Okeechobee-Everglades system and the adjacent marine system.
- Adaptive management is a recommended approach to build resilience needed to deal with climate change. A better understanding of the ecosystem resilience to change is also necessary.

- In collaboration with managers and the public, we must build an understanding of the importance of environmental variability in natural ecosystems, including recognition of the importance of pulsed events.
- Management decision support should incorporate indicators that minimize the risk of reaching critical tipping points.
- One recommended focus for management is the appropriate delivery of freshwater flows to coastal wetlands, which provide a critical defense of the Everglades landscape and water supplies in the face of sea-level rise. For South Florida, sea-level rise appears likely to be the element of climate change that will most strongly and quickly alter our environment and society.

VI. NEXT STEPS

A. Final Report and 4-Page Summary

This final report and a 4-Page Summary were drafted and circulated among the steering committee members for input. This report summarizes the two-day technical meeting and the 4-Page Summary was created to present the more significant highlights in an 'at-a-glance' format.

B. Recommendations by Steering Committee for next technical meeting

A general consensus emerged from the meeting on two main points.

1. The basic principle of Everglades Restoration, "getting the water right" by restoring as much as possible of the original hydrologic system, is even more important in the face of sea level rise and other climate changes;
2. Adaptive Management is critical in order to maximize management efficacy in the face of complexity and uncertain timing and magnitude of climate change.

A number of follow up actions currently are being planned:

- A meeting that will include a small number of managers and scientists to identify immediate follow up action items, including key information gathering and monitoring that should be initiated immediately. Also, work will be done to identify adaptation actions that might be built into ongoing CERP projects.
- A technical meeting of a small number of scientists and managers is being planned for November 2013 to hone in on the key knowledge gaps tentatively identified at the February technical meeting. In addition, a short priority list of vital research activities will be created. This is research needed to allow for a better understanding of potential medium term threats and adaptation opportunities.
- The research findings from the February technical meeting will be published as a special series in Environmental Management in 2013.

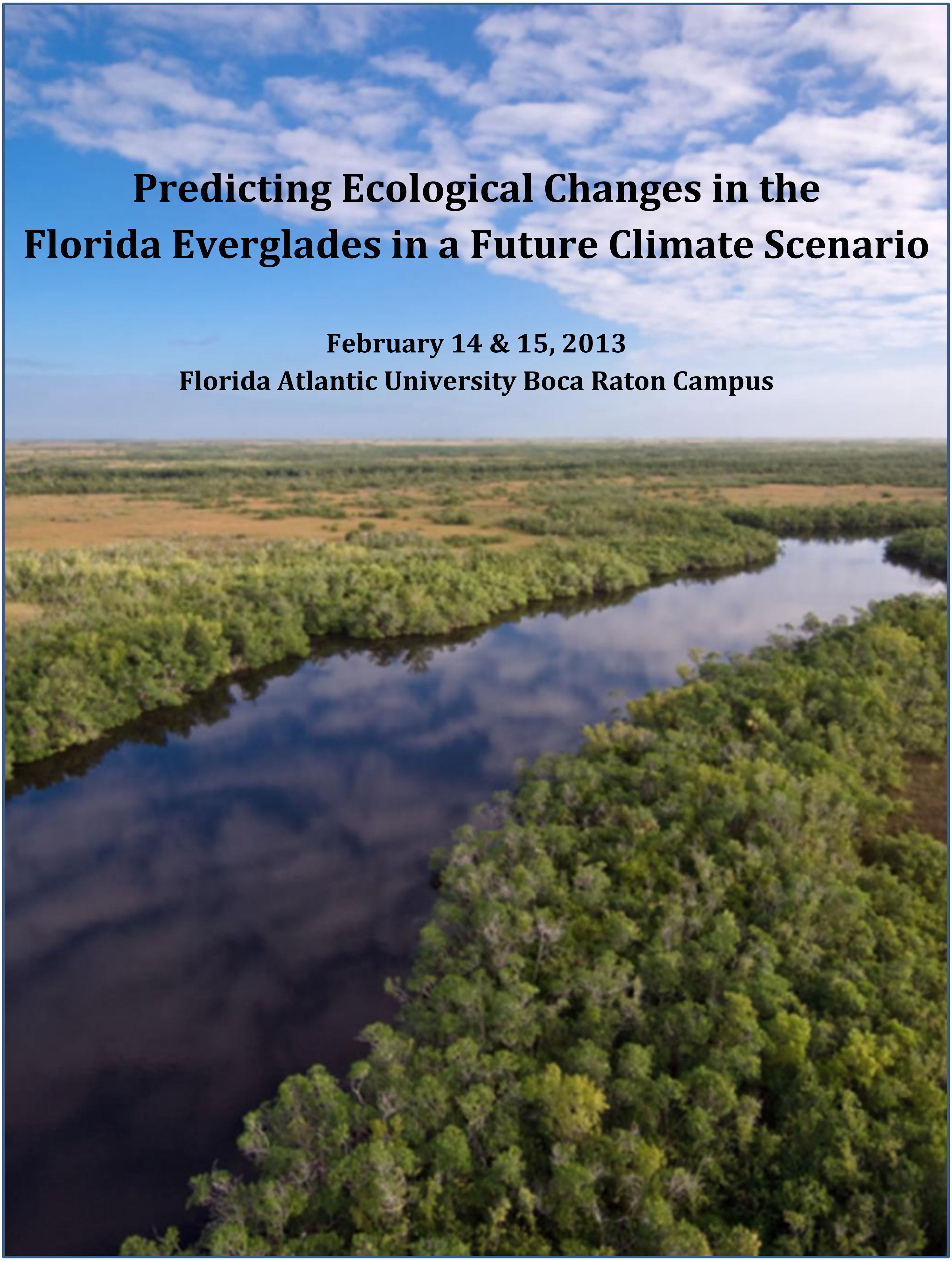
Steering Committee

- Leonard Berry, Director, CES, FAU
- G. Ronnie Best, Greater Everglades Priority Ecosystems Science, USGS
- Karl E. Havens, Florida Sea Grant, University of Florida
- Jayantha Obeysekera, Hydrologic & Environmental Systems Modeling, SFWMD
- Nick Aumen, Everglades National Park
- Glenn Landers, U.S. Army Corps of Engineers, Jacksonville District
- Vasu Misra, Meteorology, Center for Ocean-Atmospheric Prediction Studies, FSU
- Martha Nungesser, South Florida Water Management District
- Leonard Pearlstine, National Park Service, US Department of the Interior
- Stephanie Romanach, U.S. Geological Survey
- Dave Rudnick, Everglades National Park
- Russ Weeks, U.S. Army Corps of Engineers
- Steve Traxler, US Fish and Wildlife Service

Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario

February 14 & 15, 2013

Florida Atlantic University Boca Raton Campus



Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario

USGS, FAU Center for Environmental Studies, Florida Sea Grant Sponsored Technical Meeting

February 14 & 15, 2013

Florida Atlantic University Boca Raton Campus

Background

As reported in the various reports of the IPCC, and expected in the upcoming report in 2012, significant changes in climate and sea levels have been predicted, some of which may have major implications for the success of regional projects, such as Everglades Restoration. In a continuing effort to facilitate discussions and develop pathways for understanding the consequences of climate change and sea level rise and building a sound scientific basis for managing changing environments, FAU-CES, USGS, and the Florida Sea Grant have established an inter-agency steering committee to hold a technical meeting to assess our ability to forecast changes in ecological attributes of the Everglades under a future climate scenario. Results from this exercise will guide targeted research to address critical science uncertainties and improve ecological forecasts, and also update resource managers regarding the current state of our ecological understanding of climate change effects and ability to forecast these effects. In particular, the technical meeting will provide a platform on which scientists can assess their current ability to predict specific ecological trajectories in response to anticipated climate change scenarios. This meeting will also provide an opportunity for scientists and managers to jointly consider how we can plan and work together to improve our scientific understanding of impending changes and to wisely manage changing regional ecosystems and associated resources.

Purpose

The purpose of this technical meeting is to (1) have experts in Everglades ecosystems predict how key attributes may respond to specific future climate scenarios that include increased temperature, altered rainfall and runoff, higher evapotranspiration, rising sea level, greater climate extremes, and elevated atmospheric CO_2; and (2) identify gaps in scientific information leading to unacceptable levels of uncertainty in ecological predictions, including changes in environmental parameters needed by ecologists to predict how these ecosystems may respond; and (3) to consider options for future resource management and scientific needs and capabilities to support management adaptations.

Outcomes

This technical meeting will identify the best available information on climate and its hydrologic effects on south Florida natural ecosystems. This information will initiate discussions of whether our existing scientific knowledge is adequate to predict how the Everglades ecosystems will respond to anticipated climate changes. It will also provide direction to both researchers and funding agencies to address key scientific informational gaps and provide managers with climate change scenarios to use for restoration planning under an altered climatic regime.

Steering Committee:

- Leonard Berry, Director, CES, FAU
- G. Ronnie Best, Greater Everglades Priority Ecosystems Science, USGS
- Karl E. Havens, Florida Sea Grant, University of Florida
- Jayantha Obeysekera, Hydrologic & Environmental Systems Modeling, SFWMD
- Nick Aumen, Everglades National Park
- Glenn Landers, U.S. Army Corps of Engineers, Jacksonville District
- Vasu Misra, Meteorology, Center for Ocean-Atmospheric Prediction Studies, FSU
- Martha Nungesser, South Florida Water Management District
- Leonard Pearlstine, National Park Service, US Department of the Interior
- Stephanie Romanach, U.S. Geological Survey
- Dave Rudnick, Everglades National Park
- Russ Weeks, U.S. Army Corps of Engineers
- Steve Traxler, US Fish and Wildlife Service

AGENDA
Thursday February 14
Day 1

8:00 – 8:15 **Opening Introduction**

MJ Saunders, President, Florida Atlantic University

Introduction to the Topic, Goals, and Purpose:

Center for Environmental Studies, US Geological Survey, Florida Sea Grant

I. Setting the Stage (2060)

8:15 – 9:10 ***Historical Context – Patterns of Past Climate Change*** (Lynne Wingard)

Description of Specific Future Climate Scenarios Developed from Model Output (Jayantha Obeysekera)

- 1.5 C Temperature Increase
- 1.5 Foot SLR Increase
- +/- 10% Change in Precipitation
- 490 ppm CO2

9:10 – 9:30 **Q & A** (to include panelists Jenifer Barnes & Moysey Ostrovsky)

II. Predicting Ecosystem Change in Response to These Specific Climate Change Scenarios

9:30 – 10:00 ***Lake Okeechobee*** *(Karl Havens)* ***with Q & A***

10:00 – 10:15 **Break**

10:15 – 12:15 ***Freshwater Wetlands*** (Lead Nick Aumen)

a. Landscapes (Ridge/Slough/Tree islands; Marl Marshes; Everglades National Park)
   - Martha Nungesser, Colin Saunders, Fred Sklar
b. Wildlife (Wading birds, Fish, Reptiles, Endangered and threatened species, invasive species)
   - Joel Trexler, Stephanie Romanach
c. Plant species and communities, habitat, and invasive species
   - John Volin, Arnold Van der Valk, Paul Wetzel
d. Soil processes, nutrients, including encroachment of saltwater
   - Sue Newman, Todd Osborne, Bill Orem

12:15 – 1:15 **Lunch**

1:15– 2:00 **Q & A** (Panelists to include speakers & Ramesh Reddy)

2:00 – 3:00 ***Coastal and Marine Ecosystems*** *(Lead: Dave Rudnick)*

a. Physical characteristic changes (tidal ranges, salinity, habitats)
   - Erik Stabenau
b. Vegetation communities (seagrass, mangroves, macroalgae)
   - Marguerite Koch, Carlos Coronado

3:00 – 3:15 **Break**

3:15 – 4:15 ***Coastal and Marine Ecosystems (continued)***

c. Coral reefs and sea level rise, ocean acidification

- Margaret Miller, Bill Precht

d. Marine animal resources (oysters, fish nurseries, sea turtles, endangered and threatened species, invasive exotic species)
   - Chris Kelble, Bob Glazer

4:15 – 5:00 **Q & A** & **Wrap Up**

Friday February 15
Day 2

III. Evaluating Information Needs and Uncertainty Scenarios

8:30 – 9:00 Overview of the Day's Objectives & Process - Session Moderator: Karl Havens, Florida Sea Grant

9:00 – 12:00 Break-out Groups (Facilitators: Karl Havens/Leonard Pearlstine, Ronnie Best/Dave Rudnick & Nick Aumen/Len Berry)

Each group is asked to answer three questions and record the results for presentation back to the full group with discussion. **Question 1:** In evaluating the response of the various ecosystem components to climate change, what research gaps existed that led to lower than acceptable certainty in your projections? **Question 2:** In evaluating the response, what additional information (from model output, etc.) would have helped you make your projections? **Question 3:** What are the greatest needs by management?

In addition to dynamics identified within each break-out group, please consider dynamics associated with ecosystem feedbacks that span the boundaries of each group.

1. Lake Okeechobee
2. Freshwater wetlands
3. Coastal and marine ecosystems

12:00 – 1:00 Lunch

IV. Considerations for Restoration and Resource Decision Makers

1:00 – 3:30 Session moderator: Nick Aumen

Panel approach with managers and speakers interacting, reporting back answers to the above questions, addressing the panels, and discussing with the audience in an organized manner – one group at a time.

- Each break-out group leader reports back the answers to the three questions (30 minutes)
- Questions / answers and discussions from the audience
- What are the major 'lessons learned' from this exercise – the things of greatest importance to guide future planning and research related to this topic?
- What information and forecasts are most important for managers to address changing environmental and societal pressures associated with climate change and sea level rise?

Panelists: Temperince Morgan, Eric Bush, Shannon Estenoz, Mark Musaus, Sylvia Pelizza, Billy Causey, Ramesh Reddy, Steve Traxler

3:30 – 4:00 **Wrap up**

This workshop was sponsored and hosted by:

United States Geological Survey

Florida Center for Environmental Studies

Florida Sea Grant

Florida Atlantic University

For More Information Please Contact:

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Predicting Ecological Changes in the Florida Everglades in a Future Climate Scenario
Technical Meeting Sponsored by:
US Geological Survey, FAU Center for Environmental Studies, Florida Sea Grant
February 14 & 15, 2013

SPEAKERS & STEERING COMMITTEE

Nick Aumen, Ph.D.

Nick Aumen is an aquatic ecologist and Water Quality Branch Chief for Everglades National Park and oversees a technical team tracking the progress of South Florida ecosystem restoration. His team assesses the potential impacts of restoration programs on Everglades National Park and other sensitive federal lands. Formerly, Nick was the Research Director at the South Florida Water Management District, directing a team of 120-plus scientists and engineers conducting research in support of ecosystem restoration. He held a faculty position in biology at the University of Mississippi and was a tenured Associate Professor of Biology until 1991, when he returned to Florida. Nick serves on the Executive Committee of the Interamerican Water Resources Network. He served on the national Board of Directors of the Sierra Club, a 130-yr-old environmental organization with more than 750,000 members, and served two terms as Vice-President and one as Treasurer.

Leonard Berry, Ph.D.

Dr. Leonard Berry is the Founder and Director of the Florida Center for Environmental Studies (CES), Distinguished Professor of Geosciences at Florida Atlantic University (FAU) and the Director of the Climate Change Initiative at FAU. He has worked on environmental research and development training programs for USAID, UNDP, UNDP, UNESCO, GEF, UNEP and the World Bank. He has worked on climate change issues in Florida for the last 12 years and globally for over 30 years. He is a core member of the Inter-American Water Resources Network, The Southeast Florida Regional Climate Change Compact's sea level rise technical working group, Florida Department of Economic Opportunity Community Resilience Group, Public Water Supply Utilities Climate Impacts Working Group, National Council for Science and the Environment, and the Water Web Consortium, an international water information group. In April 2012, he testified to the United States Senate full committee on Natural Resources and Energy on the impacts of sea level rise in Florida.

Ronnie Best, Ph.D.

Ronnie Best is a research coordinator with the U.S. Geological Survey. He is the Coordinator of the USGS's Greater Everglades Priority Ecosystems Science. Dr. Best retired from the University of Florida's College of Engineering where he was Director of UF's Center for Wetlands & Water Resources and a member of the faculty of the Environmental Engineering Sciences Department. Dr. Best joined the federal service in 1995 as Branch Chief for the Wetlands Ecology Branch at USGS's National Wetlands Research Center. Dr. Best moved to South Florida where he has served as Coordinator of USGS's Greater Everglades Science since 2001. Dr. Best conceived of and initiated the Greater Everglades Ecosystem Restoration (GEER) Conference(s) and the National Conference(s) on Ecosystem Restoration. Dr. Best has over three decades of research and teaching experience in the area of ecology, ecological engineering, and restoration and management of wetlands, most of which has been in Florida. He has over 70 publications.

Eric Bush, SAJ

Eric Bush has worked for the Jacksonville District, U. S. Army Corps of Engineers since 2001. He currently serves as Chief of Planning and Policy Division, responsible for strategic leadership and management of 90 professional employees engaged in water resources planning, environmental, and economics work supporting the District's ecosystem restoration, navigation, shore protection and flood damage reduction missions. Prior District assignments include Assistant Division Chief of Planning and Policy Division, and Assistant Chief of Everglades Division. He also worked for the State of Florida's Department of Environmental Protection from 1991 - 2001.

Billy Causey, Ph.D.

Billy Causey is the Southeast Regional Director for the National Marine Sanctuary Program of the National Oceanic and Atmospheric Administration. He had managed National Marine Sanctuaries in the FL Keys since 1983, when he became the Manager of the Looe Key National Marine Sanctuary. As the manager of this marine protected area he developed the education, science and enforcement programs and sustained an interagency partnership between the state and federal governments. Billy has been the lead National Oceanic and Atmospheric Administration (NOAA) official in the development of the management plan for the Keys Sanctuary, including development of this nation's first comprehensive marine zoning plan. He led efforts to establish the largest network of fully protected areas in the continental US. He serves as the liaison with local, state and other federal agencies responsible for management of natural resources in the Southeast Region. Billy's academic interests are in coral reef ecology, coral reef fishes, sustainable management, impacts from climate change, marine policy and marine zoning.

Carlos A. Coronado, Ph.D.

Carlos A. Coronado has been working for the South Florida Water management District since 2000. He currently serves as a Lead Scientist within the Everglades Systems Assessment Section. He is responsible of the Tree Island Program that deals with the restoration and management of Tree Islands located in the WCA's. He is also responsible of the Mangrove Ecology Program that has a main objective to understand how mangrove ecosystems will response Sea Level Rise. Prior to the District he worked as a Research Associate at Louisiana State University (LSU) and the University National of Mexico (UNAM).

Shannon Estenoz

Shannon Estenoz is the Director of Everglades Restoration Initiatives for the US Department of the Interior. Shannon's Everglades career spans fifteen years including roles as Executive Director of the Environmental & Land Use Law Center, Everglades Program Director of the World Wildlife Fund, three terms as National Co-Chair of the Everglades Coalition, and Sun Coast Regional Director of the National Parks Conservation Association. Governor Crist appointed Shannon to the Governing Board of the South Florida Water Management District where she served as Chair of the Water Resources Advisory Commission and of the Broward Water Resources Task Force. She is a member of the Broward Board of County Commissioners Water Advisory Board. Shannon received a 2001 National Wetland Award; Conservationist of the Year awards in 2002, 2003, and 2009 from the Florida Wildlife Federation, the Arthur R. Marshall Foundation, and Everglades Coalition respectively; the 2010 Marjory Stoneman Douglas Environmental Award from Friends of the Everglades; and the 2010 Champion of the Everglades Award from Audubon of Florida.

Robert Glazer, Ph.D.

Robert Glazer works for the Florida Fish and Wildlife Conservation Commission where he serves as the Climate Change Research and Monitoring Working Group co-leader. He participated in developing the National Fish, Wildlife and Plants Adaptation Strategy and is co-PI with MIT/GeoAdaptive for a new project developing adaptation plans in the marine environment (KeysMAP). In 1994, he received the first Florida Jaycees Outstanding Young Environmentalist Award. In 2006, he received the Southeastern Association of Fish and Wildlife Agencies Fisheries Biologist of the Year award. Since 2004, Bob has served as Executive Director of the non-profit Gulf and Caribbean Fisheries Institute.

Karl Havens, Ph.D.

Karl Havens is Director of the FL Sea Grant College Program at the University of FL, and a Professor in the UF Program for Fisheries and Aquatic Sciences. Prior to arriving at UF in 2004, he was Chief Scientist for Lake Okeechobee research at the South FL Water Management District, where he was actively involved in the process leading to the development of the Comprehensive Everglades Restoration Plan. He has published more than 170 peer-reviewed journal articles, as well as books, review papers and book chapters-dealing mainly with lake ecology and eutrophication. His current research focuses on global patterns in plankton size structure, fish predation, changes in lake water temperature linked with climate change, and synergistic effects of climate change and nutrient input on lakes and estuaries.

Chris Kelble, Ph.D.

Chris Kelble is an oceanographer with the National Oceanic and Atmospheric Administration's Atlantic Oceanographic and Meteorological Laboratory. Dr. Kelble is an expert on the effects of salinity on the plankton community of Florida Bay. He notes that the greater Everglades ecosystem, including Florida Bay, has undergone significant anthropogenic manipulation over the past century. These actions resulted in a series of ecologically undesirable events in the Everglades ecosystem. It is necessary to understand the variability in, and relationship between, salinity and ecology to fully evaluate the potential effects of CERP and climate change on Florida Bay. Dr. Kelble has championed the recognition of phytoplankton bloom status as an indicator of water quality condition in the southern estuaries of Florida.

Dan Kimball, Superintendent

Dan B. Kimball serves as the Superintendent of Everglades and Dry Tortugas National Parks. As superintendent, Kimball is responsible for preserving, protecting, restoring, and managing both of these units of the National Park System. Since 2004, he has led the parks' involvement in restoration of the Everglades, the largest ecosystem restoration project in history. He led in the establishment and implementation of a marine protected area in the Dry Tortugas. Kimball served as Assistant to the National Park Service Deputy Director in Washington, D.C. In 2010, he served as an Incident Commander, representing the US Department of the Interior at the Florida Peninsula Command Post in response to the Deepwater Horizon/BP Oil Spill. A 28-year veteran of the NPS, Kimball has previously held positions with the U.S. Environmental Protection Agency, the Office of Surface Mining and with environmental consulting firms. He has received a number of awards including the Southeast Region's Superintendent of the Year Award (2007) and the Presidential Rank Award – Meritorious Executive (2009).

Marguerite Koch-Rose, Ph.D.

Marguerite Koch is a professor in the Biological Sciences Department of Florida Atlantic University's Charles E. Schmidt College of Science and the assistant director of FAU's climate change program. Dr. Koch hosts an active research program in marine ecology. She has worked across a broad range of habitats from the Bering Sea, Alaska as a fisheries biologist, to studying the biogeochemistry of sea grass ecosystems in the Virgin Islands. Her primary research interest is in the sustainability and productivity of marine habitats, primarily tropical marine ecosystems, such as sea grass, mangroves and coral reefs. A focus on tropical stressors has led to Dr. Koch's keen interest in climate change effects on coastal marine ecosystems. Her present research focuses on biogeochemical changes in tropical marine ecosystems and ecophysiological responses of marine plants under a rapidly changing climate and increases in pCO_2, including thermal stress and ocean acidification.

Glenn Landers, SAJ

Glenn Landers is a Professional Engineer with the U.S. Army Corps of Engineers in Jacksonville, FL. He has 30+ years of combined planning, engineering and project management experience with the USACE involving large scale water resources and civil works projects. He is the Jacksonville District's technical lead for sea level change and other climate related studies for the Comprehensive Everglades Restoration Plan (CERP). He is a technical advisor to the SE FL Climate Compact counties and is active in developing climate adaptation guidance and strategies at local, state and national levels. This includes two USACE national teams - an interagency team developing planning and engineering guidance to supplement the existing Engineering Circular on Sea Level Change, plus an internal team identifying USACE projects subject to sea level change and study needs to quantify potential impacts.

Margaret W. Miller, Ph.D.

Margaret Miller is an ecologist in the Protected Resources Division/Benthic Ecosystem Assessment & Research at the Southeast Fisheries Science Center of the National Oceanographic Atmospheric Association. She began work for NOAA-Fisheries in 1997 as the sole benthic ecologist at the Miami Lab and has supported its growing coral reef program. She is an active field researcher and diver. Her current research foci include coral early life history, coral restoration, population studies of elkhorn and staghorn corals and their threats. Most recently, Dr. Miller has published works on coral mass bleaching and reef temperatures at Navassa Island and the effects of ocean acidification on coral in the Caribbean Sea.

Vasu Misra, Ph.D.

Vasu Misra is an assistant professor of meteorology at Florida State University's Ocean – Atmospheric Prediction Studies. His research interests are in climate variability and predictability. He likes to work with a variety of numerical models to understand climate variations from diurnal, intra-seasonal to inter-annual time scales. These numerical tools include regional atmospheric models, atmospheric general circulation models and coupled ocean-atmosphere models. While Dr. Misra is keen on understanding the predictability of a model, the challenges of real-time climate prediction have also been part of his research vocation. Phenomenologically, he has worked on ENSO, the South American and the Asian Monsoons, Tropical Atlantic Variability, US hydroclimate and some aspects of equatorial African climate.

Temperince Morgan

Temperince Morgan currently serves as the State Policy Chief for the Office of Everglades Policy and Coordination at the SFWMD. In her role as State Policy Chief, she is responsible for directing restoration policy, planning, project management, and regulatory activities in support of the SFWMD's Everglades Restoration programs. She oversees implementation of activities related to the Everglades Forever Act and Northern Everglades Protection Program. She coordinates the development of policy positions on state related issues including water quality standards and TMDLs, water resource policy including MFLs and reservations, legislative proposals, and other restoration and regulatory related issues. Before joining the District, Temperince worked for the FL Department of Environmental Protection and was responsible for overseeing permit processing, compliance and other regulatory coordination with the District and U.S. Army Corps of Engineers on environmental restoration projects. She worked on a variety of water quality issues including nutrient criteria, TMDLs, and designated uses.

Mark Musuas

Mark just recently retired as the Deputy Regional Director for the Southeast Region of the U.S. Fish and Wildlife Service after a 38+ year career. He has served as assistant refuge manager at Choctaw (AL), J.N. Ding Darling (FL), Piedmont (GA), and Tennessee (TN) NWRs, and as the deputy project leader at Savannah Coastal Refuges (GA). In 1998, he was selected as the Project Leader for the Arthur R. Marshall and Hobe Sound National Wildlife Refuges in South Florida. In May 2007, he accepted the position of Chief of the Division of Visitor Services and Communications for the National Wildlife Refuge System in the headquarters office in Arlington, VA. He served in the role of Deputy Regional Director, based in Atlanta, GA, from January 18, 2010 until December 28, 2012. He received the Refuge Manager of the Year Award in 2000 and the Take Pride in America, FWS Federal Land Manager of the Year award in 2005.

Sue Newman, Ph.D.

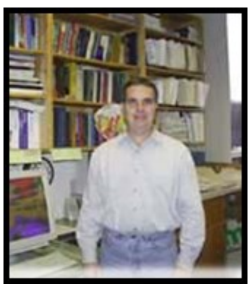
Sue Newman is the senior scientific leader of the Marsh Ecology Research Group in the Everglades Systems Assessment Section at the South Florida Water Management District. Her expertise is in wetland biogeochemistry and ecology. Dr. Newman has conducted research in the Everglades for over 20 years. Current research projects include the Active Marsh Improvement (AMI) Projects, a series of multi-disciplinary field projects designed to actively manage vegetation and change the trophic dynamics in nutrient impacted areas. She oversees the Decomp Physical Model (DPM), a multi-agency, multidisciplinary, landscape-scale project designed to address uncertainties associated with sheet flow and canal backfilling on restoring the Everglades ridge-and-slough landscape.

Martha Nungesser, Ph.D.

Martha Nungesser is a Senior Environmental Scientist at the South Florida Water Management District. Her professional experience in climate change began in 1988 with a project at Lawrence Berkeley National Lab, followed by her interdisciplinary doctoral research and post-doctoral research, both including climate change. Her doctoral research at the University of Virginia focused on development and maintenance of microtopography in boreal bogs and its resilience under climate change. As a post-doc at the U.S. Forest Service, she investigated responses of terrestrial ecosystem productivity across the continental U.S. to altered climate scenarios. More recently, Dr. Nungesser's research at the SFWMD has determined how the Everglades Ridge and Slough patterns have responded to water management changes from 1940 onward using historical aerial photographs. This time series indicates the regional effects that drainage and impoundment (altered water depths) have had on ridge and slough patterning. Her expertise in peatland microtopography, climate change, and ecosystems ecology provide her with a unique perspective on the potential impacts of shifting climate in South Florida.

Jayantha Obeysekera, Ph.D.

Jayantha Obeysekera (Obey) is the Chief Modeler at the South Florida Water Management District. He has more than 25 years of experience practicing water resources engineering with emphasis on computer modeling and implications of climate variability in planning and operation of complex water resources systems. He has published nearly 40 research articles in refereed journals and over 50 others in the field of water resources. He was a co-principal investigator for a US NSF funded project on the investigation of the tsunami impacts on coastal water resources in Sri Lanka. Currently, he is serving as a member of the National Climate Assessment and Development Advisory Committee (NCADAC). He is an Affiliate Research Professor at Florida Atlantic University.



Bill Orem, Ph.D.

Bill Orem is a scientist with the U.S. Geological Survey. His research focuses on mercury accumulation in wetlands sediments. He travels regularly from his office in Reston, Virginia, to South Florida to study mercury accumulation in the Everglades region. His area of expertise is mercury methylation in wetland sediments. The following projects are a major part of his work: The Aquatic Cycling of Mercury in the Everglades (ACME) Project; Geochemistry of Wetland Sediments from South Florida; Linking Land, Air and Water Management in the Southern Everglades and Coastal Zone to Water Quality and Ecosystem Restoration; Spatial and Temporal Patterns and Ecological Effects of Canal-water Intrusion into the A.R.M. Loxahatchee National Wildlife Refuge and the Synthesis of South Florida Ecosystem History Research

Todd Osborne, Ph.D.

Todd Z. Osborne, Professor of Biogeochemistry, University of FL, has a diverse program focusing on biogeochemical processes in soil and water in a variety of ecosystems throughout FL. Currently, Dr. Osborne is working in Everglades restoration science with several projects investigating biogeochemical cycling of phosphorus, sulfur and carbon within the Greater Everglades. These research initiatives include fire effects on biogeochemical cycling of phosphorus, and impacts to water quality and exotic species, sulfur biogeochemistry and relationships to mercury, phosphorus mobility in Everglades soils, and spatial variability of soil nutrients at the landscape scale. Other Everglades research currently being conducted in Dr. Osborne's program includes conservation of the ridge and slough landscape mosaic in the central Everglades via research on hydrologic modulators of plant productivity and community structure. Recently completed work on nutrient gradients in the Taylor Slough basin of Everglades National Park have gained the attention of ecologists and Park Service land managers and resulted in new theories concerning nutrient cycling at the landscape scale in Everglades restoration science.

Leonard Pearlstine, Ph.D.

Leonard Pearlstine is Landscape Ecologist at Everglades National Park. His education and 26 years of experience have been multi-disciplinary and directed toward applied research in natural resource management. Prior to his position at the National Park Service, Leonard spent over 20 years as research faculty in the University of Florida's Department of Wildlife Ecology and Conservation and the USGS Cooperative Fish and Wildlife Research Unit. He leads the Park's ecological modeling team and serves as a member of the National Park Service Climate Change Science Working Group. He is the Everglades National Park point-of-contact for the Peninsula Florida Landscape Conservation Cooperative.

Sylvia Pelizza

Sylvia Pelizza is employed by the U.S. Fish and Wildlife Service as the Southeast Region's Area IV Refuge Supervisor and Project Leader for the Arthur R. Marshall Loxahatchee National Wildlife Refuge. Sylvia has worked for the Service for over 31 years on refuges throughout the United States. She has managed both salt-water and freshwater habitats on the east coast; freshwater wetlands and native prairie in the Dakotas; saline wetlands and desert habitats in the southwest; freshwater wetlands and tropical forests on the island of Oahu in Hawaii; and now a most unique wetland habitat, the Everglades, in southern Florida. Sylvia has experience in working with prescribed fire as well as wildfire suppression as a Type II wildland firefighter. She enforced federal laws as a collateral duty law enforcement officer for 19 years. She worked on nine refuges with endangered species issues as well as worked collectively with Congressional staff, local, federal, state, and county agencies, non-profit organizations, established advisory groups, scientists, consumer groups and the media.

William Precht

William Precht is a carbonate sedimentologist and has been studying coral reefs since 1978. He was first introduced to coral reefs at Discovery Bay Marine Lab in Jamaica as an undergraduate student and has been working there ever since. His research interests include combining ecological and geological methodologies to decipher "change" in reef communities through time and space. Using this integrated approach, he (with collaborators Richard B. Aronson and Ian MacIntyre) has been able to assess the geological and ecological novelty of many of the recent maladies affecting Caribbean coral reefs. This includes deciphering local anthropogenic signals from overarching global effects. Specific research has included the effects of coral disease and coral bleaching on the trajectories of reef coral communities. Since completing his graduate degree in Marine Geology and Geophysics he has specialized in the restoration and rehabilitation of various coastal resources, especially coral reef, sea grass and mangrove systems. Currently, Mr. Precht is the Program Manager of the Damage Assessment, Restoration, and Resource Protection Program (DARRP) for NOAA's Florida Keys National Marine Sanctuary.

Ramesh Reddy, Ph.D.

Ramesh Reddy, a University of Florida graduate research professor and UF Research Foundation professor in the Institute of Food and Agricultural Sciences, is Chairman of the Department of Soil and Water Science. Dr. Reddy's major research interests are in microbial and chemical processes regulating the cycling of nutrients and other contaminants in wetlands and aquatic systems as related to ecosystem function and water quality. He is the author of more than 240 scientific papers. Reddy is a Fellow of the Soil Science Society of America and the American Society of Agronomy and has received numerous professional awards during his career.

Stephanie Romanach, Ph.D.

Stephanie Romanach is a Research Ecologist at the USGS Southeast Ecological Science Center. She uses a combination of field observations and predictive ecological models to explore the impacts of climate change and ecosystem restoration on wildlife. The results of her work are used in the Everglades restoration decision making process. Before joining USGS, Stephanie's research focused on incorporating science into natural resource decision making through projects such as endangered African wild dog conservation and ecology, bushmeat trade and rural livelihoods, the role of trophy hunting in wildlife conservation, and large carnivore (lion & hyena) population dynamics.

David Rudnick, Ph.D.

David Rudnick is estuarine ecosystem ecologist who has researched nutrient cycling and the functional connections of estuaries and watersheds. He also has been engaged in planning, implementing and assessing Greater Everglades Ecosystem restoration, focusing on Florida Bay. In 1993, he started at the South Florida Water Management District and developed their program to research Florida Bay for the purpose of Bay restoration. He was the technical lead for several SFWMD projects, including development of a State Minimum Flows and Levels Rule for Florida Bay, the identification of Florida Bay's restoration needs for the Comprehensive Everglades Restoration Plan (CERP), and assessment of CERP's coastal effects. In January 2012, he joined Everglades National Park as their Science Coordinator with the responsibility for synthesizing scientific information and identifying and filling information gaps.

Colin Saunders, Ph.D.

Colin Saunders is a Senior Environmental Scientist in the Watershed Management/Everglades Division of the South Florida Water Management District.His major projects include: Tree Island Nutrient Enrichment and Controlling Mechanisms; Tree Island Elevation Responses to Hydrology and Modeling Soil Dynamics. Currently, Dr. Saunders is the technical lead of the Decompartmentalization & Sheet flow Enhancement Physical Model (DPM) science team. His research interests include: WCA3, DPM, ecosystem modeling, nutrient dynamics; paleoecological reconstructions of wetland vegetation and hydrologic changes and relationships with paleo-climate driversy and global change ecology.

Fred Sklar, Ph.D.

Fred H. Sklar is Director of the Everglades Systems Assessment Section at the South Florida Water Management District. Dr. Sklar helped to create the Everglades Systems Research Division at the South Florida Water Management in 1993 as part of a legal mandate to restore the Everglades. He has studied the hydrological and nutrient processes associated with ecosystem imbalance, the nature of landscape patterns, and the integration of management, restoration and science using adaptive management as an applied experimental framework. Dr. Sklar manages a unique, 80-acre Everglades “living laboratory” known as LILA (Loxahatchee Impoundment Landscape Assessment) to study the hydrological properties of tree islands, sloughs and ridges. Dr. Sklar is a member of the American Society of Limnology and Oceanography and the Society of Ecosystem Restoration. Dr. Sklar is a recipient of the SFWMD Timer Powers Award for fiscal efficiency and the phosphorus threshold investigations that lead to the establishment of the 10 ppb phosphorus rule for the Everglades.

Erik Stabenau, Ph.D.

Erik Stabenau is an oceanographer & coastal ocean modeler with the National Park Service and a member of the Interagency Ocean Observation Committee DMAC Steering Team. Dr. Stabenau has been investigating the impact of Comprehensive Everglades Restoration Plan (CERP) related changes in upstream freshwater flow on salinity in Biscayne and Florida Bay. Reducing salinity levels in the coastal basins is an important goal of the CERP, however, predicting the success of such projects is challenging, since cycles and trends in salinity in the natural system may be larger than salinity changes attributed to restoration activities. He works at the South Florida Natural Resource Center for Everglades & Biscayne National Parks.

Steve Traxler

Steve Traxler works for the US Fish and Wildlife Service as a Senior Fish and Wildlife Biologist. Steve has been working on Everglades adaptive management issues since 1998. Recently he is working on adaptation planning for the Peninsular Florida Landscape Conservation Cooperative (LCC). The LCCs are a Department of Interior sponsored stakeholder based self-directed partnership focused on the threats such as climate change and urbanization from a strategic habitat conservation methodology. Steve’s projects include Everglades RECOVER (System wide evaluation, monitoring and adaptive management team) and climate change. Previously, he has worked on Everglades restoration projects on the estuaries such as the Indian River Lagoon, Florida Bay, and Biscayne Bay. Steve also works with a local marine conservation non-profit focused on sea turtle research and education called Inwater Research Group, Inc.

Joel Trexler, Ph.D.

Joel Trexler is a Professor of Biological Science and Director of Marine Science in the Department of Biological Sciences of Florida International University. His lab focuses on spatial ecology and the effect of migration on community dynamics, life history patterns and their implications for community assembly, and the controls on dynamics of Everglades aquatic communities. He is actively involved in monitoring of aquatic communities and analysis of time series data as indicators of management and restoration success in the Everglades.

Arnold Van der Valk, Ph.D.

Arnold. Van der Valk is a professor of Ecology, Evolution & Organismal Biology. He has been the chair of the Ecology and Evolutionary Biology interdepartmental graduate major and director of Iowa Lakeside Laboratory. He is a fellow of the Society of Wetland Scientists (SWS) and the president–elect of its North Central Chapter. Dr. Van der Valk's research interests include: wetland plant ecology and the restoration of wetlands, the use of wetlands as nutrients sinks, and the role of tree islands in the Everglades and wetlands ecological history. Dr. Van der Valk has worked with scientists, managers, and policy makers all around the world on ways to improve the management and restoration of wetlands and is the author of a widely used introductory textbook on wetland ecology, *The Biology of Freshwater Wetlands* published by Oxford University Press.

John Volin, Ph.D.

John Volin is Professor and Head of the Department of Natural Resources and the Environment and co-Director of Environmental Sciences at the University of Connecticut (UConn). Before joining UConn, John was Professor and Director of the Environmental Sciences program, a program he helped establish, at Florida Atlantic University. His research is primarily focused on invasive species and restoration ecology. While in Florida, John was a member of the Science Coordination Group of the Comprehensive Everglades Restoration Plan; the Research Committee Chair for the Florida Exotic Pest Plant Council, a member of the Greater Everglades Wetlands Module Group, where he chaired both the Everglades Landscape and Trophic Subgroups, among many other Everglades-related activities.

Russ Weeks, SAJ

Russ Weeks is Chief of the Hydrologic Modeling Section of the U.S. Army Corps of Engineers in Jacksonville, FL, a position he has held since 2002, and where he has worked since 1989. He currently supervises water resource engineers supporting the Corps missions of flood damage reduction, environmental restoration, navigation and recreational uses at Corps facilities. He has worked on the Kissimmee River Restoration project since 1991 and has been deeply involved with all project phases including planning, engineering and design, construction, operations/maintenance, monitoring and litigation support. Russ helped establish the Interagency Modeling Center (IMC) and his staff has performed hydrologic analyses for the various project components of the Comprehensive Everglades Restoration Plan. He previously served on the Corps System Wide Water Resource Program and has made several presentations at national conferences on the climate change modeling needs for the Everglades Restoration.

Paul R. Wetzel, Ph.D.

Paul R. Wetzel is an Environmental Research Coordinator and Co-Director of the Sustainable Food Concentration at Smith College in the Center for the Environment, Ecological Design, and Sustainability. Dr. Wetzel is interested in vegetation dynamics, landscape differentiation, and ecosystem ecology and how that knowledge can be applied to ecosystem restoration.

G. Lynn Wingard, Ph.D.

Lynn Wingard has been a geologist with the USGS since earning her Ph.D. in 1991. Her research is focused on the application of paleoecologic techniques to the interpretation of Holocene marine and estuarine ecosystems. For the last 20 years, she has been conducting research in support of the South Florida Ecosystem Restoration. As part of this effort, she has served on numerous science advisory and writing teams. Currently, she is a member of NOAA's Marine and Estuarine (MARES) Goal Setting for South Florida group, and the Southern Coastal Systems sub-team of RECOVER. In addition, she is co-chair of the USGS Ecosys-