Sea Level Rise Adaptation in the Florida Keys:

Conserving Terrestrial and Intertidal Natural Areas and Native Species

A Workshop Synthesis

August 2012

The Nature Conservancy's Florida Chapter and U.S. Fish and Wildlife Service's Florida Keys National Wildlife Refuges Complex co-sponsored a workshop to engage stakeholders in information sharing and facilitated discussions of research and monitoring needs and adaptive management strategies for minimizing the consequences of sea level rise on terrestrial and intertidal natural areas and native species in the Florida Keys. On May 10-12, 2011, 90 land managers, biologists, regulators, scientists and conservationists gathered at Hawks Cay Resort near Marathon, Florida, to share information about past, current and future research, monitoring and management efforts focused on sea level rise in the Florida Keys, to lay a foundation for an integrated research agenda and long-term monitoring network, and to begin identifying best management practices for adapting to sea level rise.

Day one of the event included introductory presentations about climate change in general, impacts on peninsular Florida and impacts on the Florida Keys, followed by a "Managers' Panel" comprised of public natural resource managers explaining their organization's management approaches and issues. It also included field trips to middle and lower Keys natural areas where participants saw firsthand and discussed issues associated with sea level rise in this low-lying archipelago of limestone islands that support rich assemblages of plants and animals, some of which are endemic to the Keys and/or extremely rare, in addition to more than 70,000 permanent residents and millions of visitors each year.

Day two included presentations and panel discussions examining known and anticipated impacts on specific natural resources as well as existing and proposed management interventions. The evening was dedicated to engaging the general public via a poster session, summary presentations, a question and answer session with presenters, and soliciting public input about adaptation issues and approaches.

Day three utilized a breakout group format to develop and prioritize specific best management practices for maintaining or enhancing resilience and facilitating adaptation, specific research and monitoring needs, and specific communication and education methods. Ex-situ conservation strategies (e.g. seed banking and captive breeding) were also examined.

Our hope in issuing this workshop synthesis report is that natural area managers, scientists, conservationists, policymakers and other stakeholders can shift from the more traditional reactive stance based on past assumptions about environmental stability to a more proactive, multidisciplinary approach to conserving the Florida Keys natural areas and native species in the face of climate change.

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I. Introduction

> "Of all the ongoing and expected changes from global warming… the increase in the volume of the oceans and accompanying rise in the level of the sea will be the most immediate, the most certain, and most widespread, and the economically most visible in its effects."
>
> Orrin Pilkey and Rob Young
> *The Rising Sea* (2009)

The Florida Keys represent a truly unique portion of the natural and cultural heritage of the United States. They contain the northernmost stands of plant communities dominated by tropical species native to the West Indies, and three globally imperiled habitats: pine rockland, tropical hardwood hammock, and mangrove forests. These terrestrial and intertidal habitats support more than 134 federal and state listed threatened and endangered species and other rare endemics, including the Florida Key deer, Key Largo woodrat, Key Largo cotton mouse, Lower Keys marsh rabbit, Key tree cactus, Big Pine partridge pea, and Key silverside fish, which are found nowhere else in the world. Many species are already living at their limits of sustainability due to habitat loss, fire suppression, and competition from invasive exotic species, and they remain reliant on conservation strategies for their long-term persistence. The threat of sea level rise exacerbates the current challenges of managing small fragmented habitats in a low-island ecosystem.

Climate change and its interrelationships with existing problems of conserving fish and wildlife and their habitats is the transformational conservation challenge of the 21st century. The Intergovernmental Panel on Climate Change (IPCC) reported that the warming of the world's climate system is unequivocal based on documented increases in global average air and ocean temperatures, unprecedented melting of snow and ice, and rising average sea level (IPCC 2007). While the distributions and abundances of fish, wildlife and plants are naturally dynamic relative to a variety of environmental factors, climate change may drastically alter and accelerate the natural cycles that we are familiar with today. Some effects may include changes in precipitation, increased frequency and intensity of extreme weather events, rising sea levels and tidal fluctuations, and invasions of new exotic species. Consequently, climate change is a challenge not only because of its direct effects, but also because of its potential to amplify the other stressors that have and will continue to be major conservation priorities, such as habitat loss, habitat fragmentation, altered fire regimes, and invasive exotic species.

Low-lying islands such as the Florida Keys will face direct and dramatic impacts of climate change, particularly from a rising sea level coupled with predicted increases in coastal storm intensity. Such effects have already been experienced in the Florida Keys, providing a glimpse of what may be expected at ever increasing rates and extent in the future. For example, widespread mortality of Florida slash pine trees resulted from saltwater inundation due to Hurricane Wilma's storm surge in 2005. There have also been marked shifts in plant community composition along the coastal fringe due to higher spring tides from an incremental sea level rise over the past hundred years. Saline intrusion into a subsurface freshwater lens from this historic sea level rise has reduced the extent of pine rockland and freshwater wetland habitats on Sugarloaf Key, resulting in more salt-tolerant plant communities (Ross et al. 1994). Storm events have also caused considerable physical damage to beach berms and dune vegetation along vulnerable shorelines, impacting nesting habitat for sea turtles and shorebirds. Rising sea levels may decrease the availability and abundance of prey for wading birds that forage in shallow waters on the expansive tidal flats of the backcountry. Climate change is expected to amplify and hasten these effects, potentially at rates that exceed the normal resiliency of plant communities to recover, shift, or adapt accordingly (Stanton and Ackerman 2007, Clough 2008).

Climate change is happening now at an unprecedented rate. Sea level rise is one of the more predictable and most profound consequences of climate change. In the next one to three centuries, sea level rise is likely to nullify most, if not all, that has been done over the past century to protect the natural communities of the Florida Keys, many of which are currently protected as wildlife refuges, parks and nature preserves managed by federal, state, and local governments and private organizations (Figure 1). While the effects of climate change are expected to become more severe within the next 50-100 years, the level of uncertainty is high regarding the actual impacts and their extent both in time and space. Coordinated research and monitoring efforts are needed to enhance managers' capabilities for modeling and predicting environmental change, guiding implementation of strategies that enhance the resiliency and adaptability of natural communities to that change, as well as formulating criteria upon which to base decisions about direct interventions in species survival such as assisted migration or removal to captivity (Hoegh-Guldberg et al. 2008, Ross et al. 2009). Any such strategies must take into account the fact that Florida Keys residents and the government institutions that serve them will also need to resist and adapt to sea level rise and other manifestations of climate change.

In reality, our collective efforts will only "buy time" rather than ensure permanent protection for the Florida Keys terrestrial and intertidal areas and native species in the face of accelerating sea level rise. But buying time in the short term is critical for gaining knowledge and reducing uncertainty of when and how changes will occur, for allowing an orderly transition within species' capacity to adapt, for acquiring conservation lands elsewhere to allow natural movement or assisted migration of plants and animals for the long term, and for developing new technologies in ex-situ conservation.

This report provides a synthesis of workshop abstracts, presentations, and facilitated discussions. Complete workshop presentations and outputs are available at www.frrp.org.

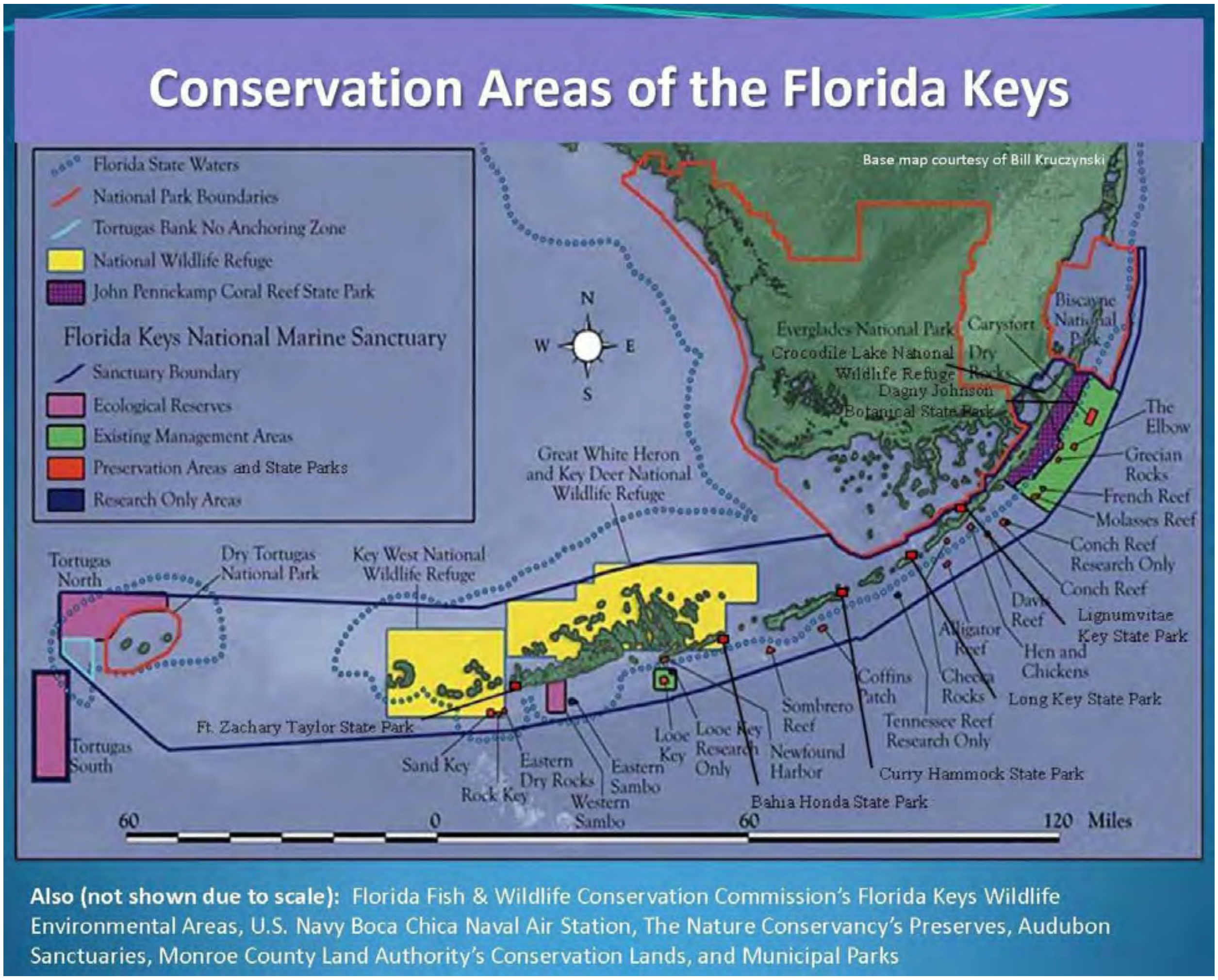

Figure 1. Conservation areas in the Florida Keys, Monroe County, Florida. Also not shown due to scale are John Pennekamp Coral Reef State Park (not labeled), Windley Key State Park, Indian Key State Park, Tropical Crane Point Hammock

II. Overview of Climate Change & Sea Level Rise

Topic: Climate change overview: A focus on sea level rise on southeast Florida

Presenter: Nancy Gassman, Energy and Sustainability Program, Broward County Natural Resources Planning and Management

- Greenhouse effect – natural warming vs. amplified warming
- Carbon dioxide has risen by 23% since accurate measurements began in 1958
- Today's carbon dioxide trend is unusual compared to the last ~800,000 years on Earth, and the rate of increase has accelerated since the Industrial Revolution
- Changing temperatures: since the mid-1970s, the average global temperature has risen more than 1 degree F; current warming rate is 2.9^{o} F per century; 8 warmest years since 1880 occurred since 2001; by 2100, expect air temperatures to increase 2 -10 ^{o} F;
- Florida has experienced exceptional drought conditions in recent years; extreme rain events; and more extreme temperature ranges including record cold.
- Indicators of a warming world include:
    - Decreasing glaciers
    - Decreasing snow cover
    - Spring arriving sooner
    - Permafrost retreating poleward
    - Melting ice sheets
    - Reduced sea ice cover
    - Increasing temperature over land
    - Increasing temperature over sea
    - Tree-line shifting poleward and higher elevation
    - Increasing humidity
    - Increasing sea surface temperature
    - Increasing ocean heat content
    - Increasing sea level
- Factors affecting sea level change:
    - Water related: thermal expansion, volume increase from glacial and ice sheet melt
    - Land related: erosion; land subsidence and uplift; glacial rebound; tectonics
    - Earth related: albedo (reflectivity); gravity and rotational effects resulting in non-uniform distribution of sea level rise (globally, sea level is rising and falling)
- The Southeast Florida Regional Climate Change Compact includes Palm Beach, Broward, Miami-Dade, and Monroe counties. Their objective is to develop a unified sea level rise projection based on best available science and expertise to use for planning purposes by county agencies and partners. Based on an 8-10 inch rise over the past century, and setting

the current baseline today, they agreed upon a unified projection of 3-7 inch rise by the year 2030, and a 9-24 inch rise by 2060. The Compact did not project beyond 2060, but acceleration of sea level rise is predicted due to trends in leading indicators and reinforcing feedback mechanisms. The Compact has also developed vulnerability assessment maps showing 2-foot sea level rise by area.

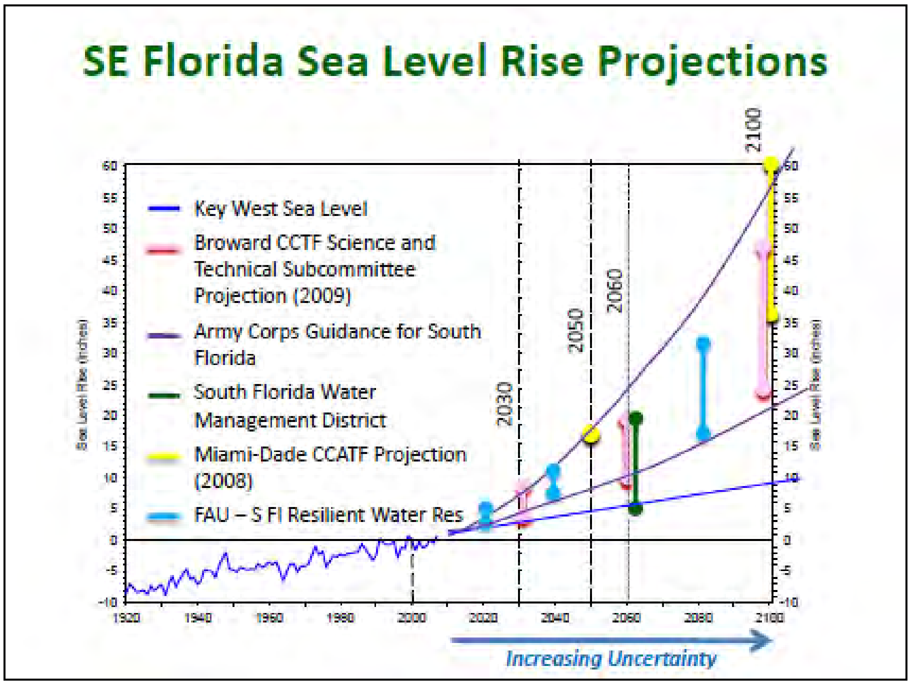

Figure 2. Sea level rise projections for southeast Florida (SFRCCC 2011)

Conclusions:

- Evidence supports that sea level is rising and will continue to rise
- Precise long term projections are not possible
- A substantial increase in sea level rise within this century is both possible and likely
- Southeast Florida Regional Climate Change Compact projection provides guidance to initiate planning now to develop adaptation strategies

Topic: Impacts of climate change and sea level rise in peninsular Florida - can we adapt?

Presenter: Reed Noss, University of Central Florida, Florida Institute for Conservation Science

Florida has an excellent record of past climate change from fossil pollen, vertebrate fossils, and other sources, going back thousands to millions of years. Fossil pollen shows relative vegetation stability, with cycles of pine vs. oak dominance in the peninsula over the past 65,000 years.

Vertebrate fossils show a long sequence of grassland, savanna, and scrub adapted animals in a probable warm-temperate to subtropical environment in the peninsular for over 10 million years. Projections by the International Panel for Climate Change (IPCC) of temperature change during the next century show Florida warming less than anywhere else in continental North America. Over the last several decades, records show an increase in temperature variability, with a trend toward colder winters and springs and warmer summers and falls. This increased variability will place more stress on native species and agricultural crops, but in general, the good news is that temperature-related impacts of global climate change may be less severe in Florida than in most other regions of the continent and the world.

On the other hand, Florida is at huge risk of significant impacts from sea level rise. Florida is particularly susceptible due to a combination of low land elevations, a high water table, peninsular geography, vulnerability to tropical storms, and a large and growing human population that is largely concentrated near the coasts. Recent models project rises in sea level globally on the order of 75-190 cm for the period 1990-2100 under the range of future temperatures predicted by the IPCC, with higher levels (ca. 3 m) possible if polar ice sheet dynamics become highly nonlinear. Sea level rise in Florida, which lacks substantial areas of uplift or subsidence, is occurring at approximately the same rate as the global average. Coupled with interacting impacts from human population shifts and land-use changes – which will be exacerbated by sea level rise – this may constitute the most fundamental challenge facing biodiversity conservation in Florida.

Impacts of sea level rise in Florida have been observed for several decades, for example a decline of salt-sensitive tree species in low-lying areas of the Gulf Coast and inland migration of mangroves in South Florida. Projected sea level increases over coming decades will magnify these impacts on many taxa and natural communities. Ecologically-oriented options for adaptation to sea level rise in Florida include restoration and enhancement of habitat connectivity along coastal-inland gradients, protection of discrete movement corridors for some focal species, habitat restoration/creation in strategic areas, population translocation (assisted colonization) into appropriate habitat in areas high enough in elevation to escape projected inundation, avoidance of new development in areas critical for adaptation of natural communities and native species, and abandonment or relocation of existing development and infrastructure in areas that will likely be inundated. Ex situ conservation in zoos, botanical gardens, and seed/gene banks may be the only option, besides extinction, for some taxa if other measures fail.

> "There is evidence that coastal morphologic systems – barrier islands, deltas, estuaries, wetlands – move into a different equilibrium mode at higher rates of sea level change. Rather than increasing the rate of coastal retreat, at some point shorelines are overstepped by rapid rates of sea level rise."
>
> Donoghue (2011)

- Impacts from sea level rise in coastal areas:
    - Saltwater intrusion into subsurface freshwater aquifers
    - Increased coastal erosion
    - Higher storm surges
    - Inland inundation, ultimately at substantial distances from present shoreline
    - Loss and shifting of human and non-human habitat

- Specific examples:
    - Mangroves can migrate landward if sea level rises slowly (natural resilience and adaptability); however, sediment surface elevations may not keep pace with current rate of sea level rise so accelerated sea level rise may overstep mangroves' adaptive capacity
    - Many species and subspecies will lose all or a significant portion of their current ranges and face extinction or regional extirpation if they are unable to migrate landward:
        - Cape Sable seaside sparrow (6 of 7 populations eliminated at 1 m)
        - Bartram's scrub hairstreak butterfly (89% habitat lost at 1 m)
        - Atlantic salt marsh snake (virtually all habitat lost at 1 m)
        - Florida salt marsh vole (all habitat lost at 1 m)
        - Godfrey's spiderlily (95% loss at 1 m)
        - Florida panther (23% habitat lost at 1 m; 59% at 3 m; 83% at 6 m)
    - Many existing and proposed conservation areas will be lost:
        - 20% of conservation lands will be inundated at 1 m sea level rise
        - 38% at 3 m sea level rise
        - 51% at 6 m sea level rise

Topic: Past and future impacts of sea level rise on terrestrial ecosystems of the Florida Keys

Presenter: Mike Ross, Florida International University, Department of Earth and Environment, Southeast Environmental Research Center

Previous & Existing Studies

- Major Florida Keys plant communities
    - Tidal wetlands
        - Mangrove-dominated
        - Buttonwood-dominated
        - *Spartina* marshes
    - Freshwater-dependent habitat (restricted to Lower Keys due to peculiar geology)

        - Pine rockland
        - Freshwater marsh
    - Tropical hardwood hammocks

- Within-island habitat mosaic is relatively simple, determined by elevation and salinity (ranging from saline to brackish to fresh); Lower Keys have fresher groundwater, lower elevations, and drier climate compared to Upper Keys

- Vulnerability to sea level rise – Florida Keys ecosystems differ spatially in vulnerability to sea level rise
    - Pine rocklands and freshwater marsh most vulnerable due to dependence on fresh groundwater; pine rocklands doubly vulnerable due to dependence on both periodic fire and freshwater lenses
    - Lower Keys hammocks more vulnerable than Upper Keys hardwood hammocks due to lesser range of elevations
    - Risk also depends greatly on rate of sea level rise; for example, mangroves more vulnerable at higher rates of sea level rise
    - Should sea level rise another foot or so, the confluence of ramp and pulse disturbances (Figure 3) could signal the end of freshwater-dependent plant communities and native species in the Florida Keys

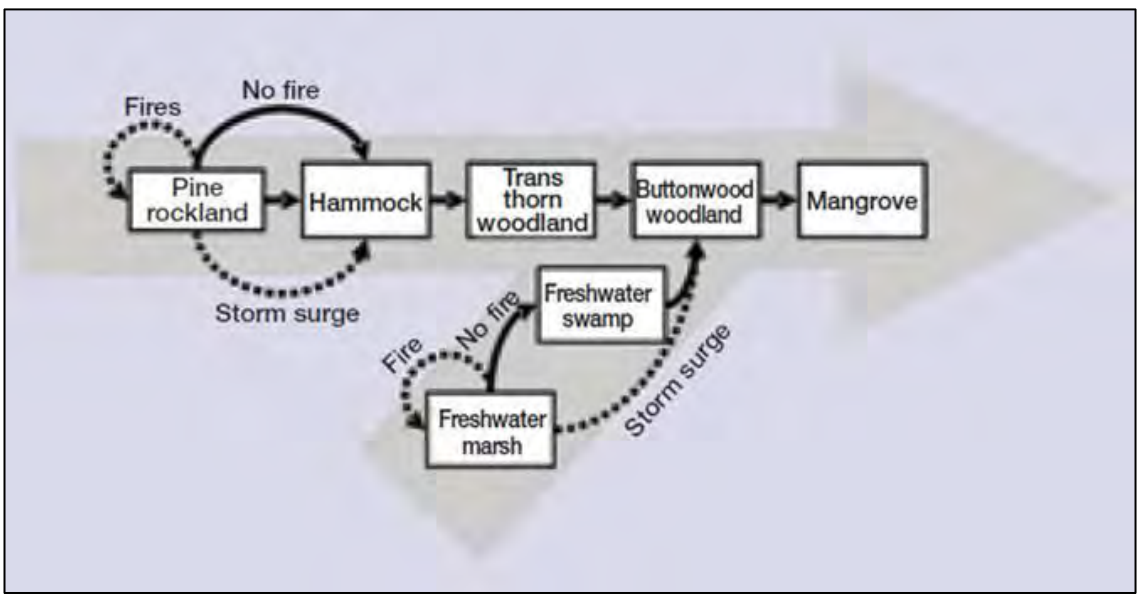

Figure 3. Sea level rise (ramp disturbance) alters longstanding regimes of fire, hurricanes and storm surges (pulse disturbance) with consequences for landscape patterns (Ross et al. 2009)

Proposed Studies/Actions

- Project future change in Florida Keys ecosystems based on improved physical and ecological models:
    - Hydrologic/vegetation sub-model that would project the extent and dynamics of fresh water resources, with vegetation responding accordingly
    - Storm surge/vegetation model that predicts the probability and direction of saltwater flooding, with vegetation response
    - High resolution, Keys-wide vegetation and topographic data
- Two-pronged planning approach for Keys terrestrial ecosystems:
    - Local prong – identify and defend core areas in existing conservation areas (e.g. National Wildlife Refuges)
    - Regional prong – expand conservation planning horizon outward in time and space across the Florida Keys and south Florida
- Assess the pros and cons of assisted colonization:
    - Pros - imminent threat of climate change and sea level rise to biodiversity (e.g. mass extinction of species); species translocations are likely to occur anyway and should be based on best science; legal and moral impossibility of doing nothing
    - Cons - experience with invasive species testifies to potential harm at recipient sites; ecological models to support risk assessment are not adequate to the task; redirection of limited conservation funds; difficulty in building political and scientific consensus
- Most critical policy needs:
    - Initiate a broad, public, interagency-led planning process for management of Florida Keys ecosystems, and the rare and endangered species dependent on them, that recognizes sea level rise for the unique threat it poses here
    - Develop and implement short-term strategies that would maintain significant representation of each Florida Keys ecosystem and species for as long as possible
    - Begin to consider policies, alternatives, and priorities for assisted colonization for Florida Keys taxa that face extinction due to sea level rise-driven habitat loss

Topic: Adaptation behavior in the face of global climate change and sea level rise: Survey responses from experts and decision-makers serving the Florida Keys

Presenter: Pallab Mozumder, Florida International University

We conducted a survey to elicit responses from decision makers serving the Florida Keys regarding vulnerability posed by global climate change and sea-level rise. Survey findings reveal deep concern among decision makers about adverse impacts at the local level. A large majority of respondents recognize the increasing likelihood of potentially irreversible socioeconomic and ecological repercussions in the Florida Keys. Yet very few federal, state and local experts report that their respective agencies have developed formal adaptation plans. Decision makers point out institutional and social barriers to adaptation and also convey their support for a host of measures to facilitate adaptation on an urgent basis. As a specific component, we investigated decision makers' willingness to support a proposed Community Adaptation Fund‟ (CAF) in the Florida Keys to marshal resources and lay the foundation for formal adaptation initiatives. We also explored potential sources for establishing the proposed CAF, and tested the feasibility of a diverse set of financing mechanisms. In the face of rising vulnerability, novel decision–making criteria, regulatory mechanisms and institutional structures need to be pursued for coastal communities to effectively adapt. We discuss implications of our findings in the context of enhancing adaptive capacity in the Florida Keys and beyond.

- Florida Keys are on the frontlines of climate crisis
    - Represents a unique ecosystem which contains a multibillion dollar tourism and nature-based economy
    - Accelerating sea level rise, extreme hydro-meteorological events (e.g. tropical cyclone activity, storm surge & other disturbance events) threaten to exceed the resilience of socio-ecological systems in the Florida Keys
    - Provides unique insights into emerging management challenges associated with adaptation to global climate change and accelerating sea-level rise
    - Survey responses reveal that Florida Keys decision-makers are:

- Concerned about climate change and sea level rise in the Florida Keys (as of 2008):
    - 74% highly concerned
    - 17% moderately concerned
    - 9% minimally concerned

- Projections of adverse climate change impacts in the Florida Keys:
    - 74% believe it is highly likely that there will be massive loss of coral
    - 73% believe it is highly likely that ecosystems will be degraded
    - 70% believe it is highly likely that there will be loss of private property

- Credibility of economic threat of a significant sea level rise to the Florida Keys:
    - 72% highly credible
    - 16% moderately credible
    - 12% minimally credible

- Survey responses reveal that Florida Keys decision-makers are currently operating with limited resources, direction and leadership, and they lack a formal institutional frameworks necessary to shape and execute climate change adaptation measures
    - 81% reported that their agency or organization does not have an adaptation action plan or they do not know if they have a plan
    - 84% reported insufficient budget
    - 76% reported insufficient staff resources
    - 79% reported lack of direction & leadership on climate change adaptation
    - 76% believe there is a lack of perceived importance to public officials or staff

- Actions supported:
    - Additional funding and assistance for climate science and adaptation
    - Public workshops, education, training
    - Better intergovernmental cooperation and coordination
    - Computational models projecting local site-specific impacts
    - A county adaptation task force

- Financial mechanisms supported by a majority of respondents:
    - Create a new "Community Adaptation Fund"
    - Revenue from Overseas Highway toll
    - Surcharge on motels and hotels
    - Increased park fees

III. Natural Communities: SLR Impacts, and Management Interventions

Topic: Monitoring sea level rise impacts in mangroves & lagoonal ecosystems of the Lower Florida Keys

Presenter: Charles D. (Chuck) Getter, Consultant

Mangroves and associated lagoonal waters are one of the dominant landscapes of the lower Florida Keys. This presentation describes an ongoing monitoring program in shallow (< 1/2 meter deep) mangrove and lagoonal ecosystems in the lower Florida Keys. Portions of this program began in the 1970s when sea levels were 4 inches (10cm) lower. Utilizing historical data and aerial photography from the fifties and the seventies we have identified specific shorelines where the greatest future changes may be expected. At certain of these shorelines we have installed permanent monitoring stations with vegetation plots (forest structure and function), fish & wildlife plots (forage and habitat use by imperiled species), rSETs (rod sediment elevation tables), and RTK (real time kinematic) surveys tied to tidal gauges. At these shorelines we have focused on monitoring the following three types of impact:

1) The first is along erosional shores where sediments and forests may be lost and/or significantly inundated during future storms. In certain cases, mangrove lagoons and ponds may be breached. In other cases, mangrove-dominated islands may be removed by storms.

2) The second is where marine sediments may be deposited and colonized by new stands of fringing red mangroves extending both landward and seaward. In many cases these landward migrating fringing red mangroves may displace dwarf black mangroves and salt marshes growing on muddy and rocky flats.

3) The third change may be the significant net gain/loss of associated ecosystems including seagrass beds, salt marshes, and supralittoral vegetation through succession, flooding, and/or changes in sediments and groundwater. We continue to monitor these stations and to increase the adequacy (coverage and frequency of measurement) of the monitoring system.

The purpose of this monitoring program has been to support management practices that consider sea level rise, mangroves, and the fish & wildlife associated with them in the lower Florida Keys.

Previous & Existing Studies

- Baseline data on beaches, mangroves, plants, animals and water quality from:
    - Graduate research at UM RSMAS (1973-1978)
    - Coastal mapping effort (1980-1981)
    - Set of long-term monitoring protocols that recently received approval during Deepwater Horizon oil spill (2010)
    - New monitoring starting in 2011: Photos and maps comparing 1959 aerial photo series to today, also LIDAR maps and SLR projections from TNC
- Permanent vegetation transects in dynamic ecotones: seagrass to fringing red mangroves zone, fringing red mangroves to black mangroves zone, black mangroves to supralittoral shrubs zone, and supralittoral shrubs to pine rockland zone
    - Seasonal monitoring of structure and productivity – all trees > 2.5 cm DBH in 10mx10m plot; mangrove seedlings and saplings, marsh plants in 1mx1m plot
- Fishes: Annual community structure, reproductive and population dynamics of seagrass, mangrove, saltmarsh and pond fishes. Imperiled key silverside and the goliath grouper.
    - Keys silverside used to be found throughout the shallow lagoons. Now that the lagoons are deepening, they are now found on the edges.
- Seeing chlorotic (yellowing) on seaward pine trees. Dead pine areas are invaded by supralittoral shrubs.

Proposed Studies/Actions

- High resolution topographic profiling of dynamic ecotones
    - Initiating Real Time Kinematic (RTK) GPS transects
    - Numerous habitat profiles
    - Apply specific findings to greater Keys-wide study area
- Monitor herbivory by key deer to determine if they affect rate of landward-expanding red mangrove

Topic: Constraints on coastal vegetation response to environmental change

Presenter: Mark Hester, Coastal Plant Ecology Laboratory, University of Louisiana-Lafayette

To increase our ability to make informed management decisions of mangrove community response to predicted climate change and sea-level rise scenarios, it is imperative to utilize both empirical data and conceptual ecological frameworks of plant responses to the environment. The distribution and abundance of a species in a given area is determined at three levels:

1) dispersal to the area,
2) physiological tolerance to abiotic conditions, and
3) biotic interactions, including competition, predation and pathogens, that ultimately shape the realized niche of the species.

Achieving a solid understanding of a species‟ fundamental niche is an essential starting point in determining the range of environmental conditions in which that species may potentially establish and persist. Hydrology is considered to be the „master variable‟ in wetland plant ecology. As such, determining marsh surface elevation relative to a standard tidal datum (e.g., NAVD88) is required to predict frequency, depth, and duration of flooding at a site under various sea-level rise scenarios. The rate of marsh surface elevation change (net surface elevation change) is controlled by rates of sediment accretion and subsidence, which can be accurately, determined via rod surface elevation tables (RSETs). The effects of tropical storm and hurricane disturbance on local sediment deposition or erosion are important drivers of post-storm hydrogeomorphic setting.

To understand future responses of mangrove communities in the lower Florida Keys, we suggest implementing an integrated approach of establishing transects across mangrove communities (from sub-tidal to supra-tidal), installing RSETs at key positions along transects that are tied into RTK elevation surveys and a local tidal datum. Mangrove community composition dynamics, species-specific indicators of plant health, and soil response/soil development metrics should be characterized along transects and integrated with manipulative field experiments to provide greater insights on the potential constraints of upslope migration of mangrove communities in response to sea-level rise.

Topic: Pine rocklands

Presenter: Jim Snyder, Southeast Ecological Science Center, U.S. Geological Survey

Previous & Existing Studies

- What makes a pine rockland: limestone substrate, pines, palms, hardwood shrubs, and herb layer. There is no “upslope” ecosystem. Florida Keys pine rockland is slower growing and has lower productivity than the mainland pine rocklands; lots of Keys endemics

- Main threats: Development, improper fire regime, exotic species, and sea level rise
- SLR impacts on pine rocklands:
    - There are pine stumps found in mangroves in Key Largo
    - With less than 15 cm SLR in past 70-100 years, we lost 35% of pine rockland on Sugarloaf Key
    - Hurricane Wilma surge had a pulse effect on pine rocklands - Lowest areas lost pines; permanent plots for fire effects proved beneficial to understanding changes from hurricane surge

Proposed Studies/Actions

- Management Interventions
    - Identify core areas of best quality habitat
    - Maintain and enhance those areas
        - Prescribed fire
        - Eliminate hydrologic barriers/conveyances
        - Translocate rare species from marginal habitat
    - Where else to go?
        - Florida mainland – pine rocklands are also low elevation though less prone to storm surge; there is no suitable limestone outcroppings at higher elevations in Florida
        - Bahamas pineyards have vast amounts of pine rocklands of very similar structure and substrate

Topic: Sea level rise and rare plants of the Florida Keys

Presenter: Keith Bradley, Institute for Regional Conservation

Previous & Existing Studies

- Prior to modern disturbances the Florida Keys has at least 544 native species derived primarily from the tropics, but also 4 are completely endemic to FL Keys. We have lost 12% of our native species. Of what's left, 37% are known from five or fewer locations. 147 species are listed by U.S. Fish and Wildlife Service, Florida Fish and Wildlife Conservation Commission, Florida Natural Areas Inventory and/or Institute for Regional Conservation. Our flora has been hit very hard. What we haven't already lost is under great strain due to habitat development and fire suppression.
- Much of the pine rockland in the lower Keys was flooded by the tidal surge; surges are normal but with sea level rise, surges are expected to increase penetration and duration

to higher elevations; with rising sea level, habitats may not have opportunity to revert back to pre-surge conditions

- Prescribed burning in fire-adapted pine rocklands may increase resilience of rare plants to storm surge effects
    - Pre- Hurricane Wilma plots were checked again in 2007 - 60% of Big Pine Partridge Pea, 13.5% of *Chamasesyce*
    - In plots that were burned pre surge, *Chamaecrista* showed a better post storm recovery than unburned plots

- Future outlook: With 177 plant species known from 5 or fewer sites, there is much at risk; 49 species in particular are at high risk due to the places they inhabit and their population sizes: 24 are in hardwood hammock, 19 pine rockland, 15 coastal rock barren, and 7 dunes. We only have a half dozen rock barrens sites in the Florida Keys, most just above high tide.
    - High risk species: Cape Sable Whiteweed, Rough strongbark, Dune lilythorn (*Catesbaea parviflora*), Keys Joe Jumper (*Opuntia triacanthos*), Florida semaphore cactus (*Consolea corallicola*)

Proposed Studies/Actions

- Management Implications:
    - Proper management, particularly regular application of prescribed fire and control of invasive exotic plants, will be essential in higher elevation areas to increase population sizes and improved post-storm recovery since peripheral habitats will continue to decline

Topic: Geophysical and hydrogeological study of freshwater lenses on Big Pine Key

Presenter: Mike Wightman, GeoView, Inc.

Previous & Existing Studies

- 1980 - 20 monitor wells to establish lens geometry; all abandoned after study.
- 1987 - Wightman.
- 2009-2010 – Wightman (Geoview Inc.) repeated earlier work with new technology: salinity profiling, electroresistivity imaging (EM) to determine if the freshwater lens geometry had changed over time.
- The freshwater aquifer on Big Pine Key is truncated at the lithological contact between the Miami Limestone (low transmissivity) and Key Largo Limestone (high transmissivity). The saltwater interface occurs within 1-1.5 meters

- EM Profiling: Best freshwater lens by Koehns subdivision. And near Winn Dixie? More core habitat work there?
- Wet versus dry season: Big differences in past samplings, but not recently. Why? Rainy seasons were very different too in 2009-2010.
- Transition to highly brackish at 25' to salt at 30'
- Electrical Resistivity Imaging: Learned a lot, but very slow process.

Proposed Studies/Actions

- Future: 20 permanent monitoring wells to be placed throughout Big Pine Key should be monitored on a semi-annual basis.

Topic: The influence of disturbance, seasonality, and hydrogeologic controls on plant community boundary dynamics in the Lower Florida Keys

Presenter: Danielle Ogurcak, Florida International University

Lowland coastal forests worldwide are being threatened by the possibility of rapid increases in sea level and the impacts of hurricanes. Anticipated changes to vegetation communities and the resources that structure them as a result of climate change are at the forefront of current ecosystem research. While coastal forests have evolved along with sea-level rise and a particular frequency of hurricane activity, the increased sea-level rise of the past century (~23cm at Key West, NOAA 2001) along with possible increases in the frequency of major hurricanes will favor more salt-tolerant species at the expense of species reliant on fresh water. Plant succession leading to changes in communities and community boundaries will be driven by the legacies (nutrient pools and vegetation) remaining from disturbance events, set against a background of seasonal changes in the ever-dwindling resource supply. This research addresses the spatial and temporal relationships between pine rockland, hardwood hammock, and buttonwood community boundaries and nutrient and water availability on the low-lying islands of Big Pine and Sugarloaf Keys. Specific objectives to be addressed by this research include the following:

1) comparison of current and historic plant community boundaries and quantification of storm surge effects by community type from both Hurricane Wilma (2005) and Hurricane Georges (1998),
2) identification of the seasonal lateral extent of the freshwater lens and its spatial relationship to vegetation community boundaries, and
3) determination of how water and nutrient availability vary with seasonal changes in freshwater lens extent and how this is reflected in terms of plant stress within the dominant species comprising each community type.

The results of this research will provide insight into the inter-relationships and feedback mechanisms between community boundaries, available water and nutrient resources, and disturbance regimes in the face of accelerated sea level rise. The goal is to implement a combined approach of comparing the past to the present to provide a platform for prediction of future plant community change in the face of sea level rise.

Panel Discussion/Q&As

- Who are the winners and losers of a 2' by 2060 scenario? *Keith Bradley:* Coastal Barrens will be gone. Not sure if beaches will be able to accrete enough. *Chuck Getter:* Not sure if mangrove ecosystems will be winners. Monotypic stands of lower diversity of disturbance spp.
- What are our best tools: *Chris Bergh:* Fire is one of the few tools that we have that can address part of the problem of accelerated succession and simplification of the biota. Challenge will be to get it recognized because it is controversial and expensive and logistically complicated. *Keith Bradley:* And exotic plant control which also ties back into fire. *Danielle Ogurcak:* Herbaceous layer decreased less in areas that had received more fire. Doesn't have a lot of replication. What does Terrestris tell us? *Mark Hester:* Don't put a barrier to the areas to respond. No flood protection levies - lines in the sand give a wall for species to run into. Hard structures are big issues. *Mike Ross:* Mosquito ditch issues. Waste/stormwater treatment levels - distribute treated water back into critical lens areas. *Chris Bergh:* Restoration with mitigation monies such as Keys Environmental Restoration Fund. Canals that drain lenses might be retrofitted with liners to minimize freshwater loss. Saw an algae usually associated with freshwater at the inner end of the Eden Pines canal system on Big Pine Key, showing the amount of freshwater is already there.
- *Joyce Maschinski*: There are situations known where mangroves do not do well. Is there a possibility of a human activity that can mitigate those problems through deposition of some sort. Holland puts up barriers. *Mark Hester:* Yes, but will take some caution/thinking. LA has high subsidence. Moving sediment is an expensive solution and can have some negative tradeoffs. No regrets strategies are best.
- *Bob Glazer:* Guy at FIU at previous SLR conference felt that mangroves could keep up. Real question is: as a wildlife planner we are missing a key variable: vegetative succession modeling. *Chris Bergh:* Sea Level Affecting Marshes Model (SLAMM) is an option with limitations for tropical/subtropical systems; issues with the outputs because of the inputs (course resolution). Hope to do a better job with TNC's Keys Coastal Resilience Tool. *Mark:* Caveat is it's hard to model; don't over rely on them especially because of speed issue. Some habitats need soil suitability, which doesn't happen overnight.
- *Doug Parsons:* Comment of snapshot of value. The property valuation will go down with time, but the cost of adaptation will go up. When will we know when those two cross?

If we know they will, should we do things differently? *Chris Bergh:* Move from defense to offense. Some critters we won't save, so we should manipulate for the eventual habitat (marine). Make more adaptations to built environment than to the natural environment. Think about canals.

- *Jayantha Obeysekera*: Do we make different decisions as we go along? As we reach different scenarios? *Chris Bergh:* We plan for different scenarios. Now, we respond to existing impacts of SLR. For 1 foot, we figure out what we'd like to do and practice those adaptations and explore those management options' implications. Then we do that for 2' and so on and we try to identify which actions have no regrets regardless of the amount and rate of rise. We want to be able to teach others with similar vulnerabilities based on our efforts. We are a great place to do this.

IV. Native Species: Sea Level Rise Impacts and Management Interventions

Topic: Migratory Birds

Presenter: Ken Meyer, Avian Research & Conservation Institute

Previous & Existing Studies

- Short tailed hawk - Very rare. Peninsular migration. Everglades and Florida Keys are winter habitat. Used different population growth rates and planning assumptions. Supported modeling of responses to sea-level rise under various scenarios of human population growth, financial support for management, and degree of habitat loss/modification. . Northern harrier - Migrates through Florida Keys from Cuba (winter) to northern Canada. Lower Keys provide critical staging and stopover habitat that influences survival.
- Swallowtail kites - Migrate in small to large groups after staging in Florida. Satellite tracking revealed threats to passage and wintering habitats.. 16,000 km round-trip migration via Keys, including greater than 700 km over-water flights. This span will increase with sea level rise.
- White crown pigeon - Feed on the fruit of tropical hardwood hammock species, but nest on predator-free offshore mangrove islands. Both habitats are necessary, neither is sufficient in itself. Keystone species (relies on hammocks, but also serves as primary seed-dispersant). Nests preferably in black mangroves, which suffer high mortality from sedimentation associated with overwash during storms. May return to same individual fruiting trees for a couple of weeks. Most winter in the Caribbean, where hunting is common, with very high harvest pressure in some countires (e.g., Bahamas has a 6--

month hunting season with a 50-bird per day bag limit). Recreational users that disturb nesting birds are problematic in some areas of Refuge backcountry.

- Reddish egrets - One of only two wading birds not stable or increasing after widespread declines due to plume hunting. Foraging habitat consists of shallow tidal streams, with firm, unvegetated bottoms, that flow between deeper water; pools that drain and fill during each tidal cycle; and temporary ponds resulting from rainfall or salt water over-wash. Adult survival is poor, with extreme competition for feeding sites and vehicle collisions apparently the primary causes. Boca Grande Key is an important feeding site. Some fly as far as Cudjoe Key to feed or nest, but otherwise strong fidelity to very small year-round ranges in lower Keys.
- Great white heron - The other wading bird (with Reddish Egret) that has not recovered from the plume-hunting trade. As for the Reddish Egret, satellite telemetry has demonstrated strong fidelity to small, year-round activity ranges Habitat use also is very narrow, but for the heron, the single category used significantly more than expected based on availability was continuous seagrass bed, which are subject to damage and fragmentation caused by recreational boating.
- Main concerns for both Reddish Egrets and Great White Herons: Need for expansive seagrass beds and the steady degradation of this important habitat, human disturbances at nesting colonies, small populations in decline, dispersal and mortality of immature herons, effects of sea level rise on foraging habitat, reproduction differs between Florida Bay and Lower Keys.

Possible Management Interventions:

- Protect and enhance breeding productivity and year-round survival on islands, roosting beaches, migration stopover areas. Initiate population monitoring, minimize human-related predation, and promote habitat resilience.
- Design and implement robust monitoring protocols..
- Accommodate substantial variation in ecology and habitat associations; management must be very species specific.
- Identify and protect potential future range.
- Intensify present management planning and implementation. Adaptively manage like never before - hedge our bets, support stable or positive population growth.

Topic: Lower Keys marsh rabbit and silver rice rat

Presenter: Phillip Hughes, U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuges Complex

All native Lower Keys mammals other than bats exhibit local endemism, and all but the local raccoon (*Procyon lotor*) subspecies are reasonably considered imperiled to some degree. Throughout the Florida Keys, a strong majority of all quadrupeds and snakes share one if not both of these characteristics. The Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) (LKMR) and silver rice rat (*Oryzomys palustris natator*) (SRR) were Federally listed as endangered in 1990 and 1991, respectively. Many of the problems that these species face were set in motion many decades ago with the development of coastal and inland subdivisions, canals, mosquito ditches, and roads which resulted in habitat fragmentation and degradation. Development intensity declined with the advent of wastewater and evacuation issues and the National Key Deer Refuge, Clean Water Act, Federal listings (including critical habitat in the case of SRR), and Monroe County and State growth management endeavors.

Though reduced, those threats are not gone, and secondary impacts continue to plague both species. LKMR have continued to exhibit ongoing decline due to deterministic threats (cat predation, vehicle strikes) and presumably, greater imminence of stochastic threats, both demographic and genetic, due to small and declining population size. Some advocates of free-ranging cats suggest that the existence of historical impacts from development diffuses the importance of cats in the ongoing decline of LKMR. However, all such impacts (e.g., increased isolation, dispersal barriers, restricted range) are specifically magnified by cats. Cats are quintessentially proficient at accessing a broad range of niches and can profoundly influence vulnerable prey, particularly in small island settings. Additional omnivores invariably have the capacity to prey on vulnerable young, at least opportunistically. They do not pose the threats that cats do; however, if subsidized and overabundant, they could pose a substantial threat. All of these mammals have the capacity to exert non-lethal effects on LKMR; such interactions should be explored throughout the assemblage.

Impacts to the floral landscape that resulted from the major development period were not well documented. The magnitude of threats from relatively slower, ongoing changes in flora forced by sea level rise and fire controls remain poorly understood. Habitat management for ecosystem sustainability has been conducted, most notably fire in pine rockland communities. That has been a difficult occupation at times, but of critical importance. However, retaining fire within the bounds of pine rockland fire units has resulted in opportunity tradeoffs at the landscape level. Largely precluding this process in adjacent ecotones and communities forwent potential benefits to those systems and LKMR, and limited our capacity to learn about those systems and explore fire and sea level effects and interactions. LKMR largely inhabit relatively low elevation habitats in coastal belts and inland basins, plus ecotones. Accordingly, sea level will have a profound influence on them (as well as SRR [in mangrove]), as may storm surges.

LKMR exhibit metapopulation structuring. The potential range of the LKMR has yet to be adequately quantified and even the occupied range is difficult to fully elucidate in any given year. Additionally, realized habitat relationships are influenced by cats and by the altered spectrum of habitat components relative to what existed in the past. All of these conditions have important ramifications for regulatory, recovery, and research frameworks. These conditions dictate the need for a well-structured, adaptive response. The attendant uncertainties dictate that an experimental component is critical. The employment of decision support tools indicated that strategies for LKMR conservation should include both integrated predator management and habitat enhancement. Adaptive management that allows for probing the influence of practical habitat resiliency and predator management options on detectable components of LKMR viability is likely crucial for stability or recovery. The good news is that we have learned a lot, and we can do things to benefit LKMR and simultaneously reduce uncertainties.

Topic: Florida Key deer

Presenter: Nova Silvy, Texas A&M University

Previous & Existing Studies

- Have been located on 27 keys. 25-50 deer left in 1952. Pinelands on Big Pine Key: 1,988 acres and 517 acres on No Name Key. 1 foot sea level rise is a 400 acre loss on Big Pine Key.
- 126 freshwater solution waterholes on Big Pine Key, 16 on No Name Key. A half foot of sea level rise will lose 20 waterholes on Big Pine and 7 on No Name Key.

Proposed Studies/Actions

- Adaptation: Translocate to Cudjoe landfill.
- Clean out waterholes.
- Add water sources.
- Thin hardwoods.
- Captive Breeding in zoos.
- Translocation to other refuges.

Topic: Key Largo woodrat and Key Largo cottonmouse

Presenter: Dan Greene, Florida Fish and Wildlife Conservation Commission

Previous & Existing Studies

The Key Largo cotton mouse (KLCM: *Peromyscus gossypinus allapaticola*) and Key Largo woodrat (KLWR: *Neotoma floridana smalli*), both subspecies of the cotton mouse and Eastern woodrat, are endemic to Key Largo, Florida. Both subspecies were listed as endangered in 1984 in response to habitat loss and fragmentation from development. Since 2007, I have monitored 12-34 trapping grids distributed throughout the island’s hardwood hammocks using 7x7 trapping grids. Results for both subspecies have indicated potential declines in their populations. Due to fluctuations in the Key Largo cotton mouse populations, the current trend and status are unknown, but the minimum number known alive increased from 93 to 120 on 12 grids from March to December, 2007, but have recently decreased to 65 and 80 mice in December, 2010 and 2011, respectively. Using closed capture models and Pollock's robust design, estimates of the total population size of KLCM has decreased from approximately 20,000 (November-Dec, 2007) to 11,000 mice (December, 2010). For the Key Largo woodrat, there has been a continuous decline in the population, with the minimum number known alive on 12 grids decreasing from 17 animals (November-December, 2007) to 3 (December 2010). The exact causes for the decline of these subspecies are still unknown, but since 2007, the presence of non-native predators have been observed within the study area, and the depredation of both subspecies has been documented.

Management Recommendations:

- Resolve or minimize predation impacts, particularly from non-native predators.
- Continue monitoring populations to assess long-term fluctuations in population size.
- Continue restoring impacted habitat and test habitat alterations and artificial nest structures to determine effects on population.
- Better define habitat used by KLCM and KLWR and highlight management practices that benefit both subspecies.
- Enhance habitat connectivity to link the subpopulations of Key Largo woodrats.
- Reintroductions: Large plots of suitable sites in other areas in Key Largo.

Topic: High Soil Salinity Threatens Key Tree Cactus in the Florida Keys

Presenter: Joyce Maschinski, Fairchild Tropical Botanical Garden

Understanding reasons for biodiversity loss is essential for developing conservation and management strategies and is becoming increasingly urgent with climate change. Growing at elevations <1.4 m in the Florida Keys, U.S.A., the endangered Key tree cactus (*Pilosocereus robinii*) recently has experienced precipitous population decline. From 1994 to 2007 eight extant populations lost 81 percent of plants and 84 percent of stems. Concurrently, seven hurricanes with wind velocities >100 mph and storm surges exceeding 2 m occurred. Since 2007, four populations have declined further, and four have had increased numbers of stems. Previous studies suggested that high soil salinity was associated with Key tree cactus mortality in the lower Florida Keys. With increasing threats of sea level rise and storms, the future of Key tree cactus in the Florida Keys may teeter on its ability to tolerate salinity.

Previous & Existing Studies

To determine the salinity tolerance of Key tree cactus, under controlled greenhouse conditions we tested growth, physiological, and intercellular indications of salt tolerance of two Key tree cactus maternal lines - one growing in cultivation and a second collected from a high mortality site in the lower Keys. We used five salt concentrations: none; 2 mM NaCl equal to salinity at one proposed reintroduction site; 15 mM NaCl equal to salinity detected where plants had low mortality between 1994 and 2007; 40 mM NaCl equal to the threshold for osmotic stress in salt-sensitive plants and comparable to soil salinity associated with high mortality; and 80 mM NaCl equal to twice the sodium concentrations inducing osmotic stress, but below a lethal dose. Tolerance to salinity varied between the maternal lines. Maternal 1 stem growth increased with higher salinity, while maternal 2 had reduced growth in salt levels above 40 mM NaCl. Root: shoot ratios did not change with salinity for maternal 1, but decreased at 80 mM NaCl for maternal 2. Maternal 2 had slower growth, less transpiration, and greater water use efficiency, and was less salt tolerant than maternal 1. Neither cellular conductivity nor potassium ion concentrations varied across salinity levels or maternal lines, but tissue sodium ion concentrations of maternal 2 increased in the 80 mM NaCl treatment group. Reasons for the differences in salt tolerance between maternal lines may either be genetic or environmental and will require further research. Within the next two decades, the degree to which salinity threatens Key tree cactus may lie in its genetic diversity.

Worldwide rare species restricted to fragmented, low-elevation island habitats, with little or no connection to higher ground will require traditional conservation actions and movement to new locations. For the conservation of Key tree cactus we recommend continued monitoring of all populations and trial reintroductions. Reducing any stresses to existing populations would be beneficial. Specifically, we recommend fencing to protect plants from herbivory. Prior to any reintroduction within historic range or managed relocation outside of range, it will be important to assess soil salinity at a recipient site to determine its suitability for supporting Key tree cactus. Consider potential for habitat restoration to support existing Key tree cactus populations; for example fill in mosquito ditches and secure areas around Cactus Hammock to prevent future seawater inundation. Also translocation may be feasible - can thrive at higher elevations if transplanted such as in tropical hardwood hammocks and pine rockland; however, concern for impacts from key deer browsing or antler rubbing.

Topic: Hurricanes and Butterfly Trends in the Florida Keys: Implications for Sea Level Rise

Presenter: Marc Minno, Consultant

At least 120 different kinds of butterflies have been reported from the Florida Keys. However, butterflies have been disappearing from the Keys since the 1980s due to a number of factors likely including extreme weather events. There are currently more imperiled butterflies in southern Florida and the Keys than any other region of the United States (nearly 20 taxa). 2004 land cover data for the Keys were generalized into urban, upland, and wetland categories using a GIS. This information was then combined with a digital elevation model to predict changes in the extent of the generalized land cover types with 1-, 5-, and 10-foot increases in sea level.

Wetlands occupy more than half of the Keys and urban areas cover about 60% of the uplands. Some 85% of the wetlands, 25% of the uplands, but only about 10% of the urban area in the Keys would be inundated by a 1-foot rise above current sea level. A 5-foot increase would flood 100% of the wetlands, 80% of the uplands, and 75% of the urban areas. Nearly 100% of the Keys would be inundated by a 10- foot increase in sea level. Hurricane Andrew in August 1992 and Hurricane Wilma in October 2005 caused flooding similar to the 5-foot scenario.

Known butterfly losses in the Keys include 3 species gone in the 1980s, 1 in the 1990s, and 12 in the 2000s (2 extinctions and 2 extirpations from the U.S.), all of which were upland species. At least 9 imperiled butterflies that occur in uplands in the Keys and 1 that occurs in wetlands are at-risk from hurricanes, and could be wiped out by just one major storm. Sea level rise will only increase the risk to the imperiled butterflies in the Keys from extreme storms.

Research on the factors contributing to the decline and loss of imperiled butterflies in the Keys is an urgent priority. Short- and long-term conservation strategies considering sea level rise and extreme weather impacts to the butterflies are also needed.

Proposed Studies/Actions

- Identify, monitor and track remaining at-risk butterfly populations and protect wherever possible.
- Preserve genetic material for future research.
- Study impacts of hurricanes and tropical storms.
- Coordinate conservation efforts among agencies and non-governmental organizations.
- Develop conservation plans for 20 years in the future and update the plans every 5 years.

Topic: Mosquitos & Other Insects

Presenter: Larry Hribar, Florida Keys Mosquito Control District

Previous & Existing Studies

- Study in NE England : lower diversity of ground beetles, but not necessarily other kinds. More ground beetles were restricted to salt marshes.
- Flood giant land crab burrows which is habitat for a certain critter.
- Increase in salinity: Osmotic regulation by three aquatic dipterans. Some can osmoregulate, some cannot.
- *Aedes aegypti* mosquito larvae die if salinity of larval medium is changed drastically. But can survive in 50% sea water if concentrations changed gradually.
- Mediterranean study: honey bee and cabbage butterfly are gradually decoupling their first appearance from appearance of flowers of host plants.

- The olive fruit fly is being decoupled from fruiting of olive trees.
- Colorado potato beetle is slowly recoupling with potato plants and historically has shifted from one host to another.
- *Diptera* have faster generation time. Smaller adult size. More vector borne disease? Maybe not, since the vectors were always here.
- Do not expect a change in malaria distribution because some areas will become unsuitable for vectors.
- Flies as contaminators of food – may expect more infestation and mechanical transport of bacteria.
- Northward and southward changes seen for European butterflies.
- Insects can resist storms. Flushing of habitats. Some can take as long as 5 years to recover.
- Wood-boring beetles and termites carry fungal pathogens from tree to tree.
- For many insect species, we don't know more than their scientific name (if that). We don't know their range. We don't know what might come our way.
- We are an overlap zone, so things can come towards us from both directions. We have recent records of both tropic and Nearctic species showing up in the Florida Keys; question is whether they are new or just discovered?

Panel Discussion/Q&As

Panel Questions & Answers

What are the winners and losers? *Dan Greene*: Key Largo cottonmouse will do okay because they can go to all levels of canopy forests. Key Largo woodrat will have a hard time because they nest in ground structures. *Joyce Maschinski*: Keys Tree Cactus has shown to have salt tolerant genotypes which can help for a longer period of time. *Marc Minno:* Exotic fire ants and other exotics likely winners. *Ken Meyer:* For birds, it will be the health of what we have now. Need to think about habitat needs northward. *Phillip Hughes:* How we study and manage the Lower Keys marsh rabbit which will be portable to the mainland which will help the other subspecies of the rabbit. *Larry Hribar*: Flies will be winners because of the incredible mixing of neotropic and nearctic. A couple of shoreline flies very possible. It all depends on how high and how fast.

What are the most promising management approaches? *Larry Hribar:* Who wants to manage for flies? We won't know what the importance of the interaction until it's too late. May help insect-eaters adapt. *Dan Greene*: Control of free-roaming cats is important. Habitat is getting better in north Key Largo (saved from destruction), but Key Largo woodrats are doing worse - why? Key Largo woodrats were translocated to Lignumvitae Key soon after it was purchased by the state, but as the hammock healed, the woodrats disappeared – need to study woodrat-habitat relationships.

Panel & Audience Comments:

- Need to be able to parse out the different effects.
- Need to better understand fire effects.
- Buy and protect more habitat while there is still time.
- Better growth management.
- Look at the suite of species, and protect the largest swath.
- When the habitat is lost, they go to zoos.
- Shouldn't move endemics. Maintain healthy populations as long as you can by reducing stressors.
- For plant realms, herbivore exclusion may be an option within Refuges; but might be okay to let go because doing well in other areas in keys.
- Furthest extent may take this land mass out of the climate envelope. Big issues with Caribbean movement.
- Need to do freshwater solution hole work.
- Greatest butterfly diversity is in City of Key West. Why is that? Some have disappeared from Everglades National Park where there is no mosquito control spraying, but are doing fine in urban parks in Miami-Dade and Broward. Why? These are our treasures, found only in FL, losing these means losing Florida.
- The more that we preserve the more that potentially make it to the other side.
- Long term learning and the models are changing a lot. We don't know how things will change and it will help other lessons. Rodents are needed to feed raptors and snakes, etc.
- We need to bring the information to managers to help make the decisions. What are the points of no return? What are our options? What are our assumptions?
- Uncertainty may be our friend, because it gives us hope. We will achieve more by acting on hope and passion than our anger and helplessness.
- There will always be endangered species that must rely on conservation strategies.
- We get caught up in individual species. TNC paper that says "conserving the stage" will get high % of the biodiversity.
- Need to think about complementary, ecosystem approaches. Species respond individualistically though. And some will do better with different changes.
- What about moving these species to other areas? We haven't even successfully introduced local butterflies locally. Never mind other countries. If you don't know why it wasn't doing well in one place, how can you guess it will do well in a completely different place?
- What about adaptation in built environment? If we are backing out, what can we get permits to fill? And build up an island? Also Miami Rock Ridge opportunities.
- Many species have a disturbance regime, for example sea lavender on beaches, endemic plants in pine rocklands, papaya in hammocks. We don't know what it is and for a long time thought most species don't have one at all.

V. Modeling Tools

Topic: Visualization of sea level rise and storm surges in the Florida Keys

Presenter: Chris Bergh, The Nature Conservancy

- The Nature Conservancy (TNC) and other private and public interests have invested heavily in conservation in the Florida Keys but SLR stands to undo terrestrial conservation gains.
- It is difficult to get decision makers excited about taking action on SLR because even at its' most rapid it is difficult to perceive. Visualization tools can help.
- TNC's 2009 report "Initial Estimates of the Ecological and Economic Consequences of Sea Level Rise on the Florida Keys through the Year 2100" relied heavily on maps to help readers visualize potential future shorelines and changes in terrestrial habitat distribution.
- TNC's next effort to improve SLR visualization for the Keys is based on the Long Island Sound (NY and CT) online Coastal Resilience Tool. See http://coastalresilience.org/geographies/new-york-and-connecticut
- The Florida Keys Coastal Resilience Tool's "Future Scenarios Map" will allow users to select from a menu of features of interest (e.g. land cover, rare species habitat, roads, critical facilities such as hospitals) and display those features with 0, 1, 2, 3, and 4 feet of SLR or a Hurricane Wilma-like storm surge plus 0, 1, 2, 3, 4 feet of SLR.
- The basis of the bathtub modeling conducted is a LIDAR-derived digital elevation model.
- A "split screen" option will allow side-by-side comparison of two scenarios.
- A "bookmark link" option will allow users to send scenario maps via the internet.
- The Florida Keys Coastal Resilience Tools will be available in fall 2012 and TNC intends to use it to promote SLR and coastal storm hazard resilience and adaptation planning, and to raise public awareness.

Topic: Alternative future scenarios: climate change vulnerabilities and impacts on conservation in the Florida Keys

Presenter: Juan Carlos Vargas-Moreno, MIT Department of Urban Studies and Planning

- Looking at possible futures and simulate variations in finances, habitat, etc.
- Approach: Stakeholder-based participatory planning (get people responsible for making decisions involved up front and throughout). Scenario based simulation modeling (make uncertainties explicit and tangible, Package multiple variables to avoid combinatorial explosion). Evaluate conservation consequences (model and evaluate different conservation strategies in scale and with realistic budgets)

- Scenario planning: Internally consistent bundles of biophysical variables and socioeconomic and planning assumptions. Biophysical: sea level rise, temperature increase, precipitation volume, storm intensity. Social: population, land use and water planning assumptions, financial resources.
- Picked most realistic scenarios then made pictures of the future scenarios.
- FWC Vulnerability Assessments. Project goals: Direct and indirect impacts of climate change on wildlife habitat for a variety of taxa. Key deer was one chosen. First workshop was with wildlife experts' second workshop with managers.
- Research Needs: methods/data improvement. Slush and SLAMM modeling/impacts. Focusing areas to act. Incorporate humans.

VI. Identifying and Prioritizing Best Management Practices, Research, Monitoring, and Communication Needs

Breakout Group Process

Day 3 of the Workshop was almost entirely dedicated to facilitated breakout group discussions designed to identify and prioritize four things related to sea level rise:

- Best Management Practices (BMPs) for Resilience and Adaptation,
- Research Needs,
- Monitoring Needs, and
- Education, Communication and Outreach Needs.

Registered workshop participants were assigned to one of four natural community-specific groups or to the education group based on their known areas of specialization. Generalists and people whose areas of specialization were not known to the conference organizers were equally distributed among the groups. Each of the following groups consisted of 15 – 20 participants:

1. Tropical Hardwood Hammock
2. Pine Rockland/Freshwater Wetlands/Freshwater Lenses
3. Salt Marsh/Low Woodlands/Low Hammock/Buttonwood
4. Mangrove/ Lagoons/Salt Ponds/Beaches/Seagrass
5. Education, Communication, Outreach

Prior to the breakout session, a handout was provided with definitions and examples of best management practices, research, and monitoring. Facilitators requested that participants take a few minutes to privately write down their ideas about potential BMPs and then led round-robin discussions about those ideas, recording the essence of each one on a flipchart. With the group's approval, very similar ideas were then combined to refine the list. Each participant was then given three stickers and asked to place no more than one sticker on each of the three BMPs needs that they deemed to be the highest priorities. Sticker counts were tallied and the highest priority items from each breakout group were reported out.

An identical process was used to identify and prioritize Research and Monitoring Needs except that research needs and monitoring needs were separated from one another and participants were given three stickers for their top three research priorities and three more for their top three monitoring priorities. The top 3 highest priorities are presented below. Verbatim transcriptions of the entire flipchart content and sticker counts for each breakout group may be found in Appendix C.

The education, communication, and outreach needs and methods were gathered using a similar process but were not prioritized; the full set of notes are found in Appendix C. Appendix C also includes public comments that were voluntarily provided on flipcharts during the evening public presentation.

Summary of Top 3 Highest Priorities for Each Natural Community

Tropical Hardwood Hammocks

Best Management Practices

- Control invasive plants and animals including feral cats
- Habitat restoration and enhancement
- Land acquisition to protect corridors and connectivity

Research

- Mapping distribution and community structure of high hammock throughout the Keys
- Identify thresholds/triggers for species management decisions
- Genetics of species of concern to maintain genetic integrity

Monitoring

- Species diversity and habitat transition over time in response to sea level rise and changing climatological conditions
- Status of indicator species to guide or inform adaptive management
- Early detection and rapid response to potentially invasive species

Pine Rocklands/Freshwater Wetlands/Freshwater Lenses

Best Management Practices

- Active prescribed fire program; provide unburned refugia in burns; burn Little Pine

- Focus management on highest elevation to highest quality for implementing exotic plant and vertebrate control and fire management
- Remove invasive plants from private property within Refuge

Research

- Model hydrology to identify restoration needs (ditches, culverts, etc.)
- Evaluate correlation between marsh rabbit and feral cat, raccoon, and fire ant habitat occupancy; predation on rare mammals

- Determine current status and management needs for American alligator

Monitoring

- Fire management effects on imperiled species
- Document changes in vegetation structure and composition to track sea level rise and climate change effects; include effectiveness of fire program and surge impacts from Wilma; track longer-term climate changes
- Exotics: iguanas, invasive plants

Salt Marsh/Low Woodlands/Low Hammock/Buttonwood

Best Management Practices

- Habitat engineering i.e. proactive "engineered" landscape to establish or maintain the full range of habitats and functions; for example exotic plant and animal control with emphasis on plants; artificial freshwater habitat
- Use fire as a tool where appropriate to restore transitional habitat
- Restore hydrology – fill mosquito ditches, road removal/configuration, culverts

Research

- Vegetation succession models and species response models based on down-scaled climate models and disturbance events and human interactions
- Determine which taxa (plants and animals) are completely or primarily dependent of the Florida Keys and develop priorities based in part on their global conservation status
- Explore community boundary processes at buttonwood transition; research into efficacy of translocation strategies (link with vegetative succession models); trophic dynamics in a changing landscape

Monitoring

- Baseline and ongoing water and soil sampling including targeted monitoring of soil and water nutrients and toxins (e.g. heavy metals, pharmaceuticals, poly-aromatic hydrocarbons, etc.)

- Sediment dynamics
- Continually calibrate models including fire and vegetative succession using remote sensing and permanent plots

Mangrove/ Lagoons/Salt Ponds/Beaches/Seagrass

Best Management Practices

- Mitigation as a regulatory (adaptation?) tool; public does have opportunity to restore on their property but off-site mitigation is considered more effective because it is usually larger scale and more ecologically sound; Audubon's Keys Environmental Restoration Fund; highlight need to avoid, then minimize, then mitigate as final recourse
- Setbacks – 50 year planning timeframe; buffer zones landward of shore; don't develop close to where water is in contact with island; minimize impediments to upslope habitat movement; allow transition of habitat
- Protect natural shoreline; educate public on benefits of mangroves; mangrove shorelines should not be converted to vertical sea walls and hardened shoreline; don't allow mangrove trimming

Research

- What are critical habitat qualities/properties that we plan to restore/create; quantify/identify what makes desirable habitat
- Demonstration project to show buffer zone success; development doesn't occur, migration of shoreline can occur, and mangroves limit erosion
- Role of previously altered hydrology with and without disturbance; alterations include mosquito ditches, canals, impoundments (i.e. roads and causeways); how do they block or build up water behind islands/bridges, berms from dredge spoil; mangrove restoration impacts on hydrology

Monitoring

- Long-term monitoring of large and small islands, mainland and backcountry, lagoons and mangroves as red mangroves expand seaward and landward and black mangroves diminish; ecological surveys including important criteria such as deposition and erosion
- Institute mangrove monitoring with remote sensing to track abundance and disturbance, including black mangroves
- Continue existing monitoring programs for seagrass, coral reef/hard bottom, and water quality (Florida Keys National Marine Sanctuary's Water Quality Protection Program)

VI. Ex-situ Conservation Strategies

The final session included a large group discussion about ex-situ conservation strategies. Given a worse case future scenario of the Florida Keys being inundated by rising sea level, the workshop participants brainstormed ideas and concerns in regards to translocating endemic species to other locations or captive facilities, or whether taking no action and allowing "nature to take its course" was a viable option. Below are general notes on the large group discussion on this topic:

- Woodrat example. Those raised in zoos are not raised naturally. Captive breeding in the natural areas will help the young be better adapted.
- What about Key deer? They don't have a population problem now. What if we move them to Key Largo because it's higher? We could put deer in Crocodile Lake NWR if needed.
- Big difference between opportunity to augment or translocate within native ranges to the eventuality of not having a native range that exists. We need to think about that now. Some endemic species won't have an appropriate spot. Key deer on the mainland, even if fenced, will experience some mixing and then won't be key deer. How much can we hold onto? If we get to the point where we cannot maintain them here, we need to think about how much effort it would take .There are 544 species of native plants and over half are in cultivation, or have been. Those that are not cultivated tend to be wildflowers, but the learning curve is simple to fix this. These species are pretty easy to grow. Most of these plants are found elsewhere.
- We need to think now about the plants that have 5 or fewer populations left. These would be great to start putting into in-situ so that we can have the medium term option to plan for.
- Takes 10-20 years to make things like this happen. If we move our species somewhere else, we are moving exotics, which isn't a good option. If you want to move them upslope, you need to do it now so that they are healthy later. Need to buy uplands now or buy built environments and turn them into upland habitats.
- Tree snails and reptiles were ignored in this workshop. We need to put more thought into this.
- Each species has a responsible party who will need to take action. Research suggestions at this workshop called for prioritization. We need a methodology for this. Consider ecological effects of the species in new habitats, whether it grows elsewhere, uniqueness, etc. We have to deal with this.
- If we don't take a leadership role, private individuals will take the lead and make bad decisions.
- Our agencies have no time for new species, much less the species already listed.

- Theoretical publication last year by Hoegh-Guldberg - Very simple screening tool. Where could the species be moved? Could it be moved without harm? Doesn't provide all answers, but does provide a way to look at things.
- There is risk for most introductions. US Fish and Wildlife Service and others are working on some big picture thinking to help answer these questions. But they are legally bound if it's listed. Species do move on their own; we shouldn't assume that an endemic wouldn't move.
- Island biogeography tells us that species got there somehow. Everything is exotic at some point. Colonization and dispersal limitations can tell a lot about how things will move. Movement is part of the ecological process.
- Geographic and trait-based risk assessments may need to be turned on its head by using it to find out what natives wouldn't become invasive in other areas.
- Didn't mean that every moved species would become invasive, but we do need to believe that it will survive on own because we don't want to take care of everything.
- Look at what species are elsewhere at higher quality sites and better manage them there and not here.
- Look for guidance on assisted migration (e.g. Mark Swartz, UC Davis - http://www.torreyaguardians.org/standards.html)..
- We have Wilderness that has proved that the best management is to leave it alone. I want to hold on to everything for as long as I possibly can. I don't want a "godsquad" decision on something we don't know everything about. Preserve those most vulnerable. We need to think outside of the box. It will be a loss to everybody. We need to let people know what is at stake here. Most folks don't know these special plants even exist.
- From our standpoint, we don't have our sight on moving anything around too much. Reintroductions within the Keys have been attempted and not always worked. We don't know what some of these imperiled species even need to keep them alive where they've always been. How can we spend money on a guess as to where they should go?
- We spent the last 2 days of this workshop talking about in-situ conservation measures because we intend to fight off the need for ex-situ measures as long as we can. This ex-situ discussion does need to be had and continued though.
- Endangered Species Act says that we need to save species within their native range, not move them to a new range.

X. References and Suggested Further Reading

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APPENDIX A - WORKSHOP AGENDA

Wildlife photos by Michelle Wisniewski

Sea Level Rise Adaptation in the Florida Keys:
Conserving Terrestrial and Intertidal Natural Areas and Native Species

Meeting Purpose: Engage Florida Keys terrestrial natural area and native species managers, regulators, the scientific community and the public in information sharing and facilitated discussion leading to initiation of integrated research and monitoring activities and adaptive management strategies for minimizing the consequences of sea level rise.

Tuesday, May 10, 2011

9:00 am **Welcome:** Workshop Objectives and Introductions

9:30 am **Keynote Panel: Introduction to Climate Change & Sea Level Rise**

- Nancy Gassman, Broward County – *Climate change overview*
- Reed Noss, University of Central Florida – *Impacts of climate change and sea level rise in peninsular Florida - Can we adapt?*
- Mike Ross, Florida International University – *Sea level rise impacts in the Florida Keys*

10:30 am **Break**

10:45 am **Managers' Panel: Agency Management Approaches and Issues**

- Pallab Mozumder, Florida International University – *Survey results of Florida Keys managers' perceptions about climate change*
- Robert Ford - *U.S. Fish & Wildlife Service*
- David Hallac - *National Park Service*
- Carrie Backlund - *Naval Air Station Key West*
- Pat Wells - *Florida Park Service*
- Doug Parsons - *Florida Fish & Wildlife Conservation Commission*
- Jay Obeysekera - *South Florida Water Management District*
- Roman Gastesi - *Monroe County*
- TBD - *NOAA Regional Climate Services*

12:30 pm **Fieldtrip Logistics** (pick up your bag lunch)

12:45 pm **Depart for Fieldtrip to Middle and Lower Keys Natural Areas**

6:30 pm **Cookout Dinner** at National Key Deer Refuge Headquarters (Big Pine Key)

8:00 pm **Depart for Hawks Cay**

Wednesday, May 11, 2011

8:00 am **Coffee**

8:30 am **Welcome:** Review of Agenda for Day 2

8:40 am **Presentations: Natural Communities, SLR Impacts, and Management Interventions**

- Chuck Getter, Consultant - *Mangroves & lagoonal ponds*
- Mark Hester, University of Louisiana-Lafayette - *Coastal wetlands*
- Jim Snyder, U.S. Geological Survey - *Pine rocklands*
- Keith Bradley, Institute for Regional Conservation - *Rare plants*

10:00 am **Break**

10:15 am	**Presentations: Natural Communities, SLR Impacts, and Management Interventions** *continued*	
		Mike Wightman, Geoview Inc. - *Freshwater lenses*
		Danielle Ogurcak, Florida International University - *Plant community boundary dynamics*
		Chris Bergh, The Nature Conservancy – *Visualization of sea level rise and storm surges in the Florida Keys*
11:15 am	**Panel Discussion/Q&As**	
12:00 pm	**Lunch** (provided)	
1:00 pm	**Presentations: Species, SLR impacts, and Management Interventions**	
		Ken Meyer, Avian Research & Conservation Institute – *Birds*
		Phillip Hughes, USFWS - *Lower Keys marsh rabbit & silver rice rat*
		Nova Silvy, Texas A&M University - *Key deer*
		Dan Greene, FFWCC - *Key Largo woodrat &Key Largo cottonmouse*
2:20 pm	**Break**	
2:45 pm	**Presentations: Species, SLR Impacts, and Management Interventions** *continued*	
		Joyce Maschinski, Fairchild Garden - *Key tree cactus*
		Marc Minno, Consultant – *Butterflies*
		Larry Hribar, Florida Keys Mosquito Control – *Mosquitoes*
		Juan Carlos Vargas-Moreno, MIT Department of Urban Studies and Planning – *Climate change scenarios: vulnerabilities and impacts of conservation in the Florida Keys*
3:45 pm	**Panel Discussion/Q&As**	
4:45 pm	**Wrap Up Day 2**, Logistics for Evening Session	
5:00 pm	**Dinner** at Hawks Cay Restaurants (on your own)	
6:00 pm	**Evening Public Session: Dessert Reception, Poster Session, Workshop Synthesis, Q&A with Speakers and Audience, and Open Discussion**	
9:00 pm	**Adjourn**	

Wednesday, May 12, 2011

8:00 am	**Welcome:** Review of Agenda for Day 3
8:15 am	**Breakout Groups:** *Identifying and Prioritizing Best Management Practices for Resilience and Adaptation, and Communication & Education Needs*
9:15 am	**Groups Report Out**
9:45 am	**Break**
10:00 am	**Breakout Groups:** *Identifying and Prioritizing Research and Monitoring Needs, and Communication & Education Methods*
11:15 am	**Groups Report Out**
11:45 am	**Full Group Discussion:** *Ex-situ Conservation Strategies*
12:15 pm	**Next Steps and Closing Remarks**
12:30 pm	**Adjourn**

On behalf of The Nature Conservancy, the U.S. Fish & Wildlife Service, and NOAA Coastal Services, we thank you all for your participation in this workshop!

Organizing Committee ~ *Chris Bergh, Shirley Gun, Anne Morkill, Kristie Killam, Chuck Getter, Heidi Stiller*

APPENDIX B - WORKSHOP ATTENDEES

SEA LEVEL RISE ADAPTATION IN THE FLORIDA KEYS
Conserving Terrestrial and Intertidal Natural Areas and Native Species
May 10-12, 2011 Hawks Cay Resort, Duck Key, FL 33050

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APPENDIX C – TRANSCRIBED FLIPCHART NOTES & RANKING SCORES FROM BREAKOUT GROUPS AND PUBLIC MEETING

Note: The numbers indicate ranking *scores* (1 means it only received one vote)

Natural Communities

Tropical Hardwood Hammock

Best Management Practices

5- CONTROLLING INVASIVES - PLANTS/ANIMALS, INCL FERAL CATS

5- HABITAT RESTORATION & ENHANCEMENT

5- LAND ACQUISITION TO PROTECT CORRIDORS & CONNECTIVITY

2- MINIMIZE FRAGMENTATION

1- PROTECTING HAMMOCK RESOURCE - ENFORCEMENT (POACHING), REGULATION

1- EDUCATION & OUTREACH

1- IDENTIFY & PRIORITIZE HABITAT

1- DEVELOP A MANAGEMENT STRUCTURE, PRORITIZATION AND IMPLEMENTATION OF BMP

0- MANAGE INTERFACE BETWEEN PUBLIC & PRIVATE LANDS

0- MAINTAIN NATURAL AVENUES OF DISPERSAL & PROPAGATION

0- COMPREHENSIVE ENDANGERED SPECIES MANAGEMENT - PLANTS & ANIMALS

0- BETTER COMMUNICATION AND COLLABORATION BETWEEN LAND MANAGERS AND RESEARCHERS

0- BALANCE HABITAT MANAGEMENT WITH SPECIES MANAGEMENT

0- CONSIDER ASSISTED MIGRATION OF APPROPRIATE SPECIES

Research

4- MAPPING DISTRIBUTION & COMMUNITY STRUCTURE OF HIGH HAMMOCK THROUGHOUT THE KEYS

3- THRESHOLD TRIGGERS FOR SPECIES MANAGEMENT DECISIONS

3- GENETICS OF SPECIES OF CONCERN TO MAINTAIN GENETIC INTEGRITY

3- IDENTIFY LIMITING FACTORS TO SPECIES RECOVERY

2- METHODOLOGY FOR ASSISTED PROPAGATION & TRANSLOCATION OF SPECIES (PLANTS & ANIMALS)

2- IMPORTANCE OF HABITAT HETEROGENITY TO NATIVE SPECIES

2- MOST EFFECTIVE RESTORATION/ENHANCEMENT TECHNIQUES FOR HAMMOCK

1- IMPACTS OF EXOTIC SPECIES ON COMMUNITY STRUCTURE

1- DEVELOP BETTER PREDICTIVE MODELS RELEVANT TO SELECTION & IMPLEMENTATION OF BMPS

0- IDENTIFY INDICATOR SPECIES (PLANTS & ANIMALS)

0- POPULATION DYNAMICS OF FOCUS SPECIES

0- ADAPTABILITY OF SPECIES TO CHANGING CONDITIONS

0- IDENTIFY IMPACT OF CR 905 & UTILITY CORRIDOR AND OPTIONS TO MINIMIZE

0- QUANTIFICATION OF RECOLONIZATION OF SPECIES OF CONCERN

Monitoring

6- SPECIES DIVERSITY AND HABITAT TRANSITION OVER TIME IN RESPONSE TO SLR AND CHANGING CLIMATOLOGICAL CONDITIONS

4- STATUS OF INDICATOR SPECIES TO GUIDE OR INFORM ADAPTIVE MANAGEMENT

4- EARLY DETECTION AND RAPID RESPONSE TO POTENTIALLY INVASIVE SPECIES

4- SUCCESS OF RESTORATION & ENHANCEMENT PROJECTS INCLUDING EXOTIC PLANT & ANIMAL REMOVAL PROJECTS AND METHODOLOGIES

1- EFFECTS OF MAN-MADE & NATURAL DISTURBANCE TO HAMMOCK

1- SOIL & GROUNDWATER SALINITY, HYDROPERIOD AND ELEVATION RELATED SUCCESSION

1- CLIMATOLOGICAL DATA

<u>Pine Rockland/Freshwater Wetlands/Freshwater Lenses</u>

Best Management Practices

6- ACTIVE RX FIRE PROGRAM; PROVIDE UNBURNED REFUGIA N BURNS; BURN LITTLE PINE

4- FOCUS MANAGEMENT ON HIGHEST ELEVATION TO HIGHEST QUALITY FOR IMPLEMENTING EXOTIC CONTROL, FIRE MGT & VERTEBRATE CONTROL

4- REMOVE INVASIVE PLANTS FROM PRIVATE PROPERTY WITHIN REFUGE

3- CONTROL INVASIVE/FERAL VERTEBRATES (CATS)

2- GIVE CONTRACEPTIVES TO KEY DEER ON No NAME KEY

2- EXCLUDE DEER FROM SOME AREAS AFTER FIRE TO ALLOW RECOVERY OF SOME VULNERABLE PLANTS

1- THIN THATCH PALMS (RESEARCH NEEDED)

1- MANAGE/MAINTAIN FRESHWATER SITES TO MAINTAIN WATER HOLES FOR WILDLIFE

1- RESTORE PR THAT HAVE SUCCEEDED TO HAMMOCKS

1- USE MECHANICAL CLEARING IN WUI

1- REDUCE/ELIMINATE MOSQUITO CONTROL

0- ACQUIRE PROPERTY

0- DETERMINE OWNERSHIP/USE OF FURTHER UNINDATED LANDS

0- REMOVE UNINTENDED FOOD SOURCES FOR SMALL VERTEBRATES (RACOONS, RATS, ETC)

0- ELIMINATE PRIVATE USE OF F/W LENS

0- USE TREATED WASTEWATER TO RECHARGE LENS

0- PLUG/FILL DITCHES DRAINING PR WETLANDS

0- WHERE NECESSARY, MECHANICALLY THIN IN MARSHES PRIOR TO FIRE

0- FACILITATE UPSLOPE MIGRATION OF RARE PLANTS

Research

4- MODEL HYDROLOGY TO ID RESTORATION NEEDS (DITCHES, CULVERTS, ETC)

2- EVALUATE CORRELATION BTW MARSH RABBIT AND FERAL CAT, RACOON, FIRE ANT OCCUPANCY. PREDATION PRESSURE ON RARE MAMMALS.

2- DETERMINE CURRENT STATUS AND MGMT NEEDS FOR ALLIGATORS

2- PRESERVATION OF GENETIC MATERIAL OF IMPERILLED ENDEMICS OR UNIQUE POPULATIONS

2- CAN STORM-DAMAGED PINELANDS BE RESTORED? HOW TO USE FIRE?

1- METHODS FOR CAPTIVE BREEDING TRANSLOCATION OF VERTS & INVERTS (IMPERILLED)

1- METHODS FOR MONITORING PR HERPS

1- EVALUATE STORM, FIRE, EXOTICS, ETC. AS SOURCES OF IMPERILLMENT

1- POPULATION STATUS OF INDIGO SNAKES

1- HOW DO BOX TURTLES SURVIVE IN OUTER KEYS?

1- ARE FIRE-MANAGED PINELANDS MORE RESILIENT TO STORM SURGE & WHY?

1- EFFECTS OF TOXOPLASMOSIS & OTHER DISEASES CARRIED BY EXOTIC/FERAL VERTEBRATES ON LISTED VERTEBRATES

1- WHETHER FEDERAL LISTING INHIBITS CONSERVATION MONITORING, RESEARCH & ACTION

1- SHOULD THATCH PALMS BE THINNED FOR PR RESTORATION? INTERACTION W/SURGE? IF SO, HOW?

1- REPRODUCTIVE SUCCESS ON MARSH RABBITS

1- VOTE FOR NO MORE NEED FOR RESEARCH OR MONITORING. IMPLEMENT

0- QUANTIFY IMPORTANCE OF FW LENS FOR PINELAND MARSH SPP

0- METHODS FOR EX SITU MAINTENANCE OF IMPERILLED PLANTS - ENDEMICS PRIORITIZED

0- IMPACTS OF TREATED WASTEWATER ON BIOTA AND GROUNDWATER QUALITY

0- BEST INDICATORS FOR ECOSYSTEM HEALTH & RESILIENCE

0- EFFECTS OF MOSQUITO CONTROL ON VERTS & INVERTS

0- EFFECTS OF HERBIVORY (DEER) INTERACTING W/SLR ON PR VEGETATION

Monitoring

6- FIRE MGMT EFFECTS ON IMPERILLED SPP

5- DOCUMENT CHANGES IN VEG STRUCTURE & COMPOSITION TO TRACK SL & CLIMATE CHANGE EFFECTS. INCLUDE EFFECTIVENESS OF FIRE PROGRAM, SURGE IMPACTS FROM WILMA, TRACK LONGER-TERM CC CHANGES

5- EXOTICS: IGUANAS, INVASIVE PLANTS

3- DISTRIBUTION, ABUNDANCE, DIVERSITY OF IMPERILLED BUTTERFLIES AND PLANTS & HERPS & LISTED VERTEBRATES

2- GROUNDWATER LEVELS & QUALITY IN BPK

2- TARGETED SURFACE/GROUNDWATER MONITORING AFTER STORM SURGE

0- DISEASE IN KEY DEER

<u>Salt Marsh/Low Woodlands/Low Hammock/Buttonwood</u>

Best Management Practices

4- HABITAT ENGINEERING (PROACTIVE ENGINEERED LANDSCAPE TO ESTABLISH OR MAINTAIN THE FULL RANGE OF HABITATS & FUNCTION) eg EXOTIC PLANTS AND ANIMALS CONTROL WITH EMPHASIS ON PLANTS; ARTIFICIAL FRESHWATER HABITAT

3- USE FIRE AS A TOOL WHERE APPROPRIATE TO RESTORE TRANSITION

3- RESTORE HYDROLOGY – fill MOSQUITO DITCHES; ROAD REMOVAL/CONFIGURATION; CULVERTS

2- AUGMENT AND RESTORE NATIVE (NATURALLY INTRODUCED) PLANTS, EG. EPIPHYTES; TRANSLOCATE RARE PLANTS INTO APPROPRIATE HABITAT

2- RECHARGE freshwater lens through water REUSE AND RECLAMATION eg RUNOFF ENGINEERING, EG. ALLOWING FOR PERCOLATION W/ROOFS AND PARKING LOTS; PROCESSES TO ENSURE HIGH WATER QUALITY FROM RUNOFF

Research

4- VEGETATIVE SUCCESSION MODELS & SPECIES RESPONSE MODELS BASED ON DOWNSCALED CLIMATE MODELS AND DISTURBANCE EVENTS AND HUMAN INTERACTION

3- DETERMINE WHICH TAXA (PLANTS & ANIMALS) ARE COMPLETELY OR PRIMARILY DEPENDENT ON FL KEYS AND DEVELOP PRIORITIES BASED IN PART ON THEIR GLOBAL CONSERVATION STATUS

2- EXPLORING COMMUNITY BOUNDARY PROCESSES AT BUTTONWOOD TRANSITION; RESEARCH INTO EFFICACY OF TRANSLOCATING STRATEGY (LINK WITH VEGETATIVE SUCCESSION MODELS); TROPHIC DYNAMICS IN A CHANGING LANDSCAPE

1- FATE OF CONTAMINANTS AND EFFECTS ON PLANTS & ANIMALS

1- COST/BENEFIT AND UNINTENDED CONSEQUENCES OF FIRE (BEST APPROACHES)

1- EFFECTS OF INCENTIVES FOR LAND BUY-OUTS

0-INDIGENOUS & EARLY SETTLER PRACTICES (CHARCOAL) AND ROLE IN HABITAT INTEGRITY; ROLE OF INDIGENOUS AND EARLY SETTLERS & NATURAL FIRE PRACTICES (PALEOECOLOGY)

Monitoring

1- BASELINE AND ONGOING WATER & SOIL SAMPLING INCLUDING TARGETED MONITORING OF SOIL & WATER, EG. HEAVY METALS, PHARMACEUTICAL, PAHS, ETC. AND NUTRIENTS; SEDIMENT DYNAMICS

2- CONTINUALLY CALIBRATING MODELS INCLUDING FIRE & VEGETATIVE SUCCESSION USING REMOTE SENSING AND PERMANENT PLOTS; DISTRIBUTION AND DYNAMICS OF PRIORITY SPECIES (DEMOGRAPHIC & INDIVIDUAL BASED RESPONSES)

Mangrove/ Lagoons/Salt Ponds/Beaches/Seagrass

Best Management Practices

3- MITIGATION - REGULATORY TOOL ; PUBLIC DOES HAVE OPPORTUNITY TO RESTORE ON PROPERTY BUT OFF-SITE MITIGATION IS MORE EFFECTIVE - USUALLY LARGER AND MORE ECOLOGICALLY SOUND; KEY ENVIRONMENTAL RESTORATION FUND - $ FOR MIGITATION GOES INTO THIS FUND; HIGHLIGHT AVOID, MINIMIZE, then MITIGATE final recourse

3- SETBACKS - 50 YR PLANNING FRAME; BUFFER ZONES LANDWARD. DON'T DEVELOP CLOSE TO WHERE WATER IS IN CONTACT WITH ISLAND; MINIMISE IMPEDIMENTS UPSLOPE, ALLOW TRANSITION HABITAT

2- PROTECT NATURAL SHORELINE; EDUCATE PUBLIC ON BENEFITS OF MANGROVES; MANGROVE SHORELINE - NOT ALLOW VERTICAL SEA WALLS AND HARDENED SHORELINE; repeal mangrove trimming law

1- PROTECT/FOCUS ON UNPOPULATED ISLANDS

1- PROTECT CRITICAL HABITAT FOR SPP W/SPECIAL NEEDS, EG. BEACHES FOR TURTLES

1- PROTECT FLUSH ON SALT LAGOONS

1- MAINTAIN OLD BRIDGES AND LEAVE BRIDGES THAT ALONE ARE ALREADY INACESSIBLE; PLACE GRAVEL OR SOME MEDIUM FOR BIRD HABITAT

Research

8- WHAT ARE CRITICAL HABITAT QUALITY/PROPERTIES THAT WE PLAN TO RESTORE/CREATE? QUANTIFY/ID WHAT MAKES DESIRABLE HABITAT

4- DEMONSTRATION PROJECT TO SHOW BUFFER ZONE SUCCESS - DEVELOPMENT DOESN'T OCCUR, MIGRATION OF SHORELINE & EFFECTIVENESS OF MANGROVES 4

4- RESEARCH ON ROLE OF PREVIOUSLY ALTERED HYDROLOGY UNDER DISTURBANCE AND NOT - MOSQUITO DITCHES, CANALS, IMPOUNDMENTS (ROAD), CAUSEWAYS AND HOW THEY MIGHT BLOCK OR BUILD UP WATER BEHIND ISLAND/BRIDGES, BERMS FROM DREDGE SPOIL, MANGROVE RESTORATION/HYDROLOGY

3- VEGETATIVE SUCCESSION TOOL FOR THE KEYS THAT INCORPORATES THE PHYSICAL ASPECTS - BEACH DUNE ECOSYSTEM, MANGROVE ECOSYSTEM; RESEARCH TO SHOW/UNDERSTAND PROCESS LEVEL DRIVERS OF SUCCESSIONAL CHANGE; STRONG VISUALIZATION OF HABITAT MOVEMENT - IMPROVING ELEVATION MODEL, MODELING PHYSICAL PROCESS

3- VIABILITY OF GEO-ENGINEERING TO ENCOURAGE SEDIMENT TRAP? ENVIRONMENTAL CONSTRAINTS TO RESTORATION.

3- LONG TERM TRANSECTS FOR ELEVATION DIFFERENCES, SEDIMENT DYNAMICS AND CONSTRAINTS ON UPSLOPE MANGROVE (DIFFERENT SPP) MIGRATION. WHAT ARE THE PHYSIOLOGICAL TOLERANCES TO FLOOD/HYDROLOGY FOR BIG AND SMALL KEYS

2- VIABILITY OF RECHARGING FW LENS, EG. WITH STORMWATER GRAY WATER

2- LOOK AT LAGOONAL RELATIONSHIP FOR BIRDS AND HOW THEY MOVE/PERSIST OVER TIME - DRIVERS FOR WHAT MAKES LAGOON SPECIAL, DETERMINE THE PREDICTORS

2- INVESTIGATE INNOVATIVE WAYS FOR PLANT RESTORATION

2- RESEARCH OF MANGROVE CHANGE/LOSS IN BACK COUNTRY AND RESPONSE TO HURRICANES/SLR

2- SOCIO-ECONOMIC RESEARCH ON SLR IMPACTS TO THE KEYS

Monitoring

8- LONG-TERM MONITORING OF LARGE AND SMALL ISLANDS, MAINLAND AND BACK COUNTRY, LAGOONS AND MANGROVES AS RED MANGROVES EXPAND SEAWARD AND LANDWARD AND BLACK MANGROVES DIMINISH. ECOLOGICAL SURVEY INCLUDING IMPORTANT CRITERIA. INCLUDE IN THAT - MONITOR DISPOSITION/EROSION.

4- NO MANGROVE MONITORING IN THE KEYS NOW. THIS SHOULD BE INSTITUTED W/REMOTE SENSING TO TRACK ABUNDANCE AND DISTURBANCE, INCLUDING BLACK MANGROVES

4- CONTINUE EXISTING MONITORING PROGRAMS FOR SEAGRASS, CORAL REEF/HARD BOTTOM & WATER QUALITY

4- MONITOR HABITAT UTILIZATION BY SPP

4- INSTALLATION OF MONITORING WELL NETWORK ON ISLAND(S) - ENOUGH WELLS DON'T EXIST, PLACEMENT WOULD VARY ACROSS HABITATS

2- ADAPTIVE MANAGEMENT/MONITORING LINKED TO MANAGEMENT ACTION

1- MONITOR LONG-TERM TRENDS OF BUFFER ZONE AREA

1- MAPPING AND VISUALIZATION

1- DO GEOGRAPHICAL TRANSECTS (EM) ON KEY (IMPORTANT) KEYS. EM = ELECTRO MAG… SEE MIKE WIGHTMAN PRESENTATION FOR EXPLANATION

Public Comments

ADDITIONAL IDEAS TO HELP NATURAL AREAS AND NATIVE SPECIES COPE W/SLR

- MAKE SURE FDOT USE WHITE ASPHALT AND/OR PERMEABLE CONCRETE VS BLACK ASPHALT. (MARATHON JUST REPAVED W/BLACK & WHITE). FLKEYS OVERSEAS HERITAGE TRAIL SHOULD HAVE BEEN PERMEABLE FOR RECHARGE…
- AFFORDABLE HOUSING BUILT OVER PARKING LOTS
- ENCOURAGING PLANT SPP THAT THRIVE IN SALT ENVIRONMENT
- ENCOURAGE USE OF BUS RUNS/CAR POOLS = CUT EMISSIONS
- WASTE MGMNT TRUCKS RETURNING EMPTY TO KEYS SHOULD BRING CLEAN FILL TO BUILD ROADWAYS AND HABITAT HIGHER
- MINE MOUNT TRASHMORE FOR CLEAN FILL TO RAISE/MAKE NEW HABITATS

HOW CAN LOCAL RESIDENTS HELP ADDRESS SLR IMPACTS ON NATURAL AREAS AND NATIVE SPECIES?

- SUPPORT THE USE OF PRESCRIBED FIRE
- KEEP YOUR CAT INDOORS. REMOVE FERAL CAT COLONIES. NO TNR (TRAP/NEUTER/RELEASE)
- HELP PREVENT THE SPREAD OF EXOTICS (RESPONSIBLE PET OWNERSHIP, ETC)
- PUT OUT WATER/FRESHWATER FOR RECEDING WETLANDS
- PLANT NATIVE PLANTS/REMOVE NON-NATIVE LANDSCAPING (NO LAWNS)

- LEAVE POISONWOOD
- DO NOT DISTURB NESTING BIRDS WHEN BOATING (SEASONAL)
- CONSIDERING INNOVATIVE HOUSING DESIGN (HOUSES THAT RISE WITH WATER)
- STOP USING WELLS - DEPLETING FWL
- SUPPORT HOOKUP TO CENTRAL SYSTEM
- ENCOURAGE LOCAL GOVERNMENTS TO REMOVE UNDERGROUND STORAGE TANKS, LANDFILLS THAT WILL BECOME POLLUTION SOURCES
- PURCHASE CARBON CREDITS TO OFFSET CARBON FOOTPRINT
- CLEAN OUT FRESHWATER POOLS FOR KEY DEER
- MAKE AN ADAPTATION PLAN FOR YOUR HOUSEHOLD/HOME
- SUPPORT PROTECTION AND MANAGEMENT THAT ALLOWS INLAND MIGRATION OF HABITATS
- USE SOFT RATHER THAN HARD METHODS OF SHORELINE PROTECTION

WHICH SPECIES ARE YOU MOST CONCERNED ABOUT AND WHY?

- UPLAND/PINE ROCKLAND HABITAT SPP - MOST LIKELY TO BE THREATENED BY SLR MORE SO THAN MANGROVE/SALT PONDS
- MIGRATORY BIRD HABITAT
- KEY DEER - SYMBOLIC INDICATOR OF HEALTH OF A LARGE HABITAT
- LIONFISH, PYTHONS, ET AL - HURTING THE NATIVES!

Communication, Education and Outreach Methods and Needs

Education Summary: K-12: teach the teachers. Design by grade level to capture sunshine state standards, and FCAT necessities. Find civic groups to help sponsor field trips. Use video games. Use Facebook. Work with school board support. Monroe County Environmental Education Association. General Public: Master Gardener adaptation. No regrets strategies. No Climate Change info. Media training. Online training.

Identify our Audience: Private Landowners, General Public, Children, Policy/Decision Makers, Media, Civic/Community Leaders, Corporate World, Voters, Visitors, Teachers, School Board, "Believers"

Ways to Make Message Relevant

- Listen to the Audience
- Incorporate Economics in the Message, How adaptation can save them money.
- Especially for business makers/policy makers who might tend to ignore science.

- From previous communication workshop in Miami- relate to water supply, real estate, wildlife, health,
- economics, patriotism, energy independence, political stability, saving species
- Involve the community, invite media to events

Develop a Consistent Message

- Language is Important, Have people who specialize in communication review.
- Increasing our resiliency
- Sea level rise is Real, measurable, there are steps we can take to adapt, and everyone has an important role (possible solutions)
- Avoid "sensitive" words - climate change, conservationist vs. environmentalist, "green" is polarizing like "treehugger."
- Have a message that engages people, a positive message, like even if sea level rise is a hoax, here is what we get. Renewable energy, clean air, water, etc.
- Discuss impacts, loss of tourism, loss of habitats, but put a positive spin on educating for community resiliency
- Use analogies to educate: Spare tire in car, even though chances are little, we still prepare. Similar to SLR, build taller buildings for hurricane impacts
- Harden power lines, these same infrastructure enhancements can also help us fend of impacts of sea level rise.

What are we currently doing to communicate/educate about SLR?

- NOAA Weather - School Field Trips
- Video Conference with Scientists
- Brochures
- CACCE Coastal Area Climate Change Education, USF http://guides.lib.usf.edu/cacce

Focus for the Future

- Make Science Important Again
- Conduct a Workshop for Communication/Education people, similar in format to the Hawks Cay workshop,
- whose focus is to answer these questions, develop a message and takes the BMP's, and priority Research and Monitoring adaptations into account.
- Look for community leaders who are willing to engage the community at school board, BOCC etc.
- Identify who "we" are; how do we get together to formulate a comprehensive education/communication plan
- Have MCEEAC or similar organization assist in organizing a workshop for communicators or educators

What Content should we focus on?

- K-12

- Providing relevant information to teachers, provide curriculum for coastal schools like the Keys.
- To avoid conflicts with FCAT's and Florida Sunshine Standards use non-formal educators to teach sea level rise
- For example- SeaCamp, Dolphin Res Ctr, Turtle Hospital, summer programs, focus on one grade (4th has ecological indicators in standards)
- Also: Some independent schools have more flexibility with their curriculum and field trips
- Get Kids to Act, Kids can inspire parents and community
- Provide experiential education opportunities to students, kids learn through experiences
- For SLR in Keys, avoid the big Climate Change issue that tends to polarize and focus on SLR impacts locally
- UM has a Safe Routes to School day where students walk to school to mitigate their carbon footprints; but this might be polarizing,
- Content-Don't reinvent the wheel, use NOAA KW SLR data,
- Develop "Solution Science Fairs" where students think creatively and pose adaptation solutions
- If you want to get SLR into textbooks, curriculum and tests, you have to get involved at school board and state politics level

Methods of Engaging Students

- Social Media-Facebook
- Get kids outdoors, nature clubs as afterschool or summer programs, civic associations may pay for buses, substitutes
- Get kids to create activities for younger students, give them incentives
- Create a "community adaptation fund"-may be hard to do in today's economy
- Computer programs- NSF has funded a Risk Reduction Computer Program that lets college students investigate risk/rewards of insuring their homes in hurricane prone areas; could this be adapted to include SLR as a variable?
- Kids like computer programs like Zoo Tycoon where they get rewarded economically for making the right decisions in running an env business
- Use FKCC students as leaders

Methods of Engaging the General Public

- Identify Resources (example- Eaarth, 350.org, ways to communicate climate change)
- Use the local media to relay the message
- Make sure we develop a consistent message and stay on point when discussing SLR with media
- Focus on adaptations, develop a FAQ's sheet with answers,
- Use "no regrets" terminology
- Ideas from cartoon "what if SLR is a hoax" we get renewable energy, energy independence, clean air and water, preserving habitats, etc.

- Cost benefit analyses; use Hurricane Wilma as example, what adaptations could have prevented damages, focus on developing resilient community
- Write editorials to the media,
- Use Monroe Co Extension Svc's Master Gardener and Naturalist Programs as models for Master
- Synthesize science on Big Pine Key and elsewhere for greater use – education, website (like FKNMS's WQPP)

APPENDIX D. POSTER ABSTRACTS

Environmental Constraints on Establishment and Growth of Black Mangrove

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Black mangrove (*Avicennia germinans*) is an integral component of mangrove communities in the Florida Keys. Hydrogeomorphic setting is an important modulator of wetland plant species zonation that will be strongly influenced by sea-level rise. The response of mangrove communities to sea-level rise scenarios needs to be more fully understood, especially in terms of potential constraints on upslope migration.. We conducted a series of manipulative experiments in conjunction with a field survey to increase our understanding of constraints on black mangrove establishment and sustainability in Louisiana; however, our findings have applicability to other portions of the black mangrove‟s range. To more clearly define the environmental conditions in which black mangrove can successfully establish and grow, we determined the responses of different age classes of black mangrove seedlings to the following environmental factors: water level, salinity level, and rapid sand burial. These data were supplemented with field surveys of marsh surface elevation associated with the presence of adult mangroves, seedlings, and recently established propagules. Seedling growth response displayed non-linear trends to changes in water level, salinity level, and sand burial with optimal responses occurring as follows: marsh surface elevations of 15 to 30 cm above mean water level, 24 to 48 ppt salinity, and 0 to 10 cm of sand burial. The field survey revealed that mangroves (both adults and seedlings) occurred at a mean height of 8 cm above mean water level that corresponded with a mean flooding frequency of 26%, although many mangroves occurred at elevations of 10-25 cm above mean water level. These findings provide an increased understanding of the fundamental niche space of black mangrove that can be utilized to inform management planning on response to sea-level rise, potential constraints on upslope migration, and long- term sustainability.

Big Pine Key, Florida: Sea Level Rise Scenarios

Chris Bergh, The Nature Conservancy, cbergh@tnc.org

Sea level rise is one of the more predictable and most profound consequences of climate change. In the next one to three centuries, sea level rise is likely to undo most, if not all, that has been done over the past century to protect the terrestrial plants, animals and natural communities of the Florida Keys. In 2007 The Nature Conservancy acquired high resolution Digital Elevation Models derived from airborne Light Detection and Ranging (LIDAR) data for Big Pine Key. Future shoreline locations and distribution of major habitats of Big Pine Key in the year 2100 were estimated using sea level rise scenarios described in the scientific literature. In every scenario the island becomes smaller and marine and intertidal habitat moves upslope at

the expense of upland habitat. In the best case scenario, 18 cm (7 in) of sea level rise, 1,840 acres (34%) of Big Pine Key are inundated resulting in the loss of 11% of the island‟s upland habitat. Three other scenarios are modeled for Big Pine Key. With are rise of 140 cm (4.6 ft), the highest modeled rise, about 5,950 acres (96%) of the island would be inundated with all upland habitat lost. Now is the time for a coordinated effort to identify the long-term impacts of sea level rise on the Florida Keys and to begin taking near-term steps to minimize the negative consequences of those impacts. Mitigation of the root causes of sea level rise must be paired with carefully planned and implemented local strategies to help terrestrial natural areas and native species resist and ultimately adapt to inevitable change. Any such strategies must take into account the fact that Florida Keys residents and the government institutions that serve them will also need to resist and adapt to sea level rise.

Potential Impacts of the Indo-Pacific Lionfish (*P. volitans* and *P. miles*) on Fish Assemblages in Near Shore Benthic Habitats of the Florida Keys

Nicholas A. Bernal, University of Miami, Department of Biology, nbernal@bio.miami.edu

Since the first recorded Tropical Western Atlantic sightings of the Indo-Pacific Lionfish (*P. volitans* and *P. miles*) in the 1990s, this mid-level predator has become a common component of shallow-water fish assemblages from mangrove creeks to seagrass beds and coral reefs throughout the Caribbean. Although the origins of this cryptic invasion are unknown, the recent success of lionfish, specifically in near shore habitats, has been documented through increasing abundance in the Florida Keys since the first invasion in January 2009. Coupled with the looming threat of sea level rise, this invasive species poses one of the greatest challenges to maintaining the long term biodiversity in critical near shore habitats, many of which serve as essential fish nursery habitat for commercially viable species. Although the long term impact of lionfish on near shore fish assemblages in the Keys is unknown, better understanding of how sea level rise may alter these threatened habitats is critical in the development of an invasive species management plan. This comparative study examines data from The Bahamas, where a lionfish invasion has already impacted fish communities in varying near shore habitats, and models some potential impacts that a similar invasion may have on the near shore benthic habitats of the Florida Keys. By comparing this analysis to the latest scientific models predicting sea level rise throughout the Keys, it is possible to identify the most threatened near shore habitats where both factors may severely alter native fish assemblages in the near future. With little options for mitigating future impacts of sea level rise, this data may be useful for fisheries managers who can implement best practices to regulate lionfish populations in vulnerable habitats.

GIS Based Methodology for the Evaluation and Identification of Transportation Infrastructure Vulnerability to Sea Level Rise

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The low-lying topography of regions in Florida makes the transportation in those regions vulnerable to sea level rise (SLR) and other climatic changes. Sea level rise could significantly impact transportation infrastructure through flooding and reducing the effectiveness of flood control and storm water drainage systems, some of these effects are already occurring. Transportation infrastructure not directly impacted could experience traffic operation, safety and management problems. Therefore SLR could cause a sequence of effects that would impact the entire state's transportation network. The vulnerability of physical transportation infrastructure will require the development of new design criteria and standards for more resistant and adaptive facilities and systems. Consequently, current transportation planning will need to incorporate potential impacts of SLR and associated storm surge, on the design, construction, operation, and maintenance of transportation infrastructure.

The purpose of this research is to provide a methodology for assessing and mitigating the impacts of SLR on Florida transportation modes and infrastructure for planning purposes. Researchers in this study conducted a comprehensive literature review and analysis of SLR projections, past and current studies, models and methodologies; and developed a down-scaling process for evaluating the vulnerability of roadways for State, regional, and localized SLR projections. This approach integrates the Florida Department of Transportation (FDOT) information system with existing LiDAR and other GIS data to facilitate the identification of roadway sections that are most likely to be affected by frequent to continuous flooding due to SLR. This approach has been used to evaluate transportation in Florida Keys and identify State road sections that are potentially vulnerable to a projected 1.5 ft rise of sea level by 2060.

Conservation genetics of the Sargent's Cherry Palm, *Pseudophoenix sargentii*

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Pseudophoenix sargentii, once a critically endangered palm inhabiting coastal areas of Florida and the Caribbean, has shown a marked increase since reintroductions have augmented the wild populations in the Florida Keys. The habitat of the Sargent‟s cherry palm has been degraded by agricultural encroachment, grazing, over-harvesting and hurricane effects. To assess the genetic contribution of these reintroductions and to understand the current genetic structure of the species, ten microsatellites were analyzed from 124 individuals. The individuals sampled came from wild populations on Elliott Key, Long Key, and the Bahamas, as well as the Fairchild *ex situ* collection. The individuals on Elliott Key, where reintroductions had occurred, had age classes and wild vs. reintroduced individuals analyzed separately. Several populations displayed evidence of genetic drift, inbreeding and decreased gene flow with all populations displaying significant deviations from Hardy-Weinberg equilibrium. All populations displayed positive Fis values except the *ex situ* collection and the reintroduced individuals on Elliott Key.

All pairwise Fst values were significant except comparisons between certain age classes on Elliott Key. AMOVA analysis partitioned 82.3% of the genetic variation within populations. Principal coordinate analysis based on genetic distance and Bayesian clustering analysis supported three distinct populations. The reintroductions on Elliott Key have contributed to an increase in the overall genetic diversity of the focal stand by increasing heterozygosity and lowering the inbreeding coefficient.

Feasibility of Evaluating the Impacts of Sea Level Rise on Foraging Habitats of the Little Blue Heron in the Great White Heron National Wildlife Refuge

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Habitats in the Great White Heron National Wildlife Refuge (hereafter Refuge) sustain local avian diversity and play a large role in supporting regional or statewide populations of wading birds, many of which are in decline. A major threat to these species in the Refuge comes from likely changes in habitat as a result of sea level rise. Quantifying the degree of climate-driven habitat change for sensitive wading bird species is a precursor to long-term conservation planning, but it is fraught with difficulties. Wading birds forage heavily in the intertidal zone where estimates of future sea levels must be coupled with the predicted elevation of intertidal ground surface, which is dynamic and affected by sea levels. Here we evaluate the feasibility of predicting changes in Little Blue Heron foraging habitat as a function of sea level rise in a test area of the Refuge. We first define an envelope of Little Blue Heron foraging habitat based on water depth preferences in the Everglades and vegetation preferences from the literature. The change in foraging habitat over time will be quantified by combing sea surface elevations under several climate scenarios (including the Intergovernmental Panel on Climate Change 2001 scenarios) with estimates of intertidal ground surface elevation from the Sea Level Affecting Marshes Model (SLAMM), a widely used model for estimating the impacts of sea level rise on the Atlantic coast. Model fit will then be assessed by comparing predicted habitat suitability in the test area based on current water levels and habitat distributions, to the distribution of Little Blue Herons observed on field surveys. Surveys will be conducted by boat using the double observer method. The presence and absence of birds in grid cells will be compared to predictions from the model using confusion matrices. Confusion matrices will be further processed to generate receiver operating characteristic (ROC) and the collective area under the curve (AUC) plots, which provide a measure of model usefulness. A sensitivity analysis will be conducted on model parameters to assess the effects of uncertainty related to habitat definitions, vegetation characterization, ground surface elevation, and sea level. Results will be used to both assess the prospects for improving the model in the future and for focusing future research efforts. The results of this project will address whether the available data and their associated uncertainties could lead to a wading bird model that is sound enough to guide management decisions in the Florida Keys related to sea level rise.

Status of Freshwater Resources and Future Management Implications of Sea Level Rise in the Lower Florida Keys

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The Miami oolite limestone formation found in the lower Florida Keys allows for the development of subsurface freshwater lenses as well as extensive surface freshwater wetlands. Rainwater collects in shallow, impermeable limestone basins and solution holes distributed throughout the lower Keys, supporting a diversity of endemic flora and fauna. Two hundred seventy-seven freshwater wetlands in the lower Florida Keys (No Name Key to Sugarloaf Key) were re-surveyed during January 2010-January 2011. Water chemistry data collected included salinity, temperature, and dissolved oxygen. Evidence of fish and wildlife was recorded for each wetland and in the surrounding vicinity and included birds, fish, mammals, reptiles and amphibians. Presence of invasive exotic flora and fauna were also documented. This data was compared to baseline inventories from the late 1980‟s to assess whether the holes still existed, their condition (salinity changes, sedimentation, human impacts), and continued suitability for native fish and wildlife. Future impacts of sea level rise, saltwater intrusion, and storm surges on quality and quantity of freshwater will also be evaluated to develop strategies for restoration and protection of this vital resource.

Sea Level Rise and Storm Surge in the USVI: Visualizing Risk and Vulnerability for Effective Coastal Ecosystem Management

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Islands of the Caribbean, including the United States Virgin Islands (USVI) are characterized by extremely high levels of biodiversity and endemism, which are threatened by climate change, including sea level rise (SLR). The loss of this biodiversity and endemism can be mitigated by ecosystem based adaptation strategies. This in turn will help support healthy and functional coastal ecosystems like beaches and mangroves that businesses and communities are dependent upon. One barrier to ecosystem based adaptation is the limited access to data and tools and absence of conversation about sustainable coastal zone management. With generous funding from the National Oceanic and Atmospheric Administration (NOAA) and the Royal Caribbean Ocean Fund, The Nature Conservancy (TNC) mapped sea level rise scenarios for the USVI using the International Panel on Climate Change (IPCC) A1B global circulation model (GCM) (ipcc.ch). A Sea, Lake, and Overland Surge from Hurricanes (SLOSH) analyses was also performed, which modeled a 1989 Hurricane Hugo type storm taking into account projected sea level rise scenarios for the year 2100. The outputs from these analyses were placed into a online user-friendly visualization tool for key stakeholders so they can begin the conversation about proactively planning and initiating sustainable measures to address the impacts of climate change in the USVI. TNC‟s Global Coastal Resilience website (coastalresilience.org)is a high-profile, user-friendly website developed to provide communities, planners, businesses, civil society and officials with easy access to information on projected changes in sea level and coastal storm impacts. Several SLR scenarios from varying geographies are showcased, one of the first being Long Island Sound. Using a similar analysis, the USVI effort modeled work done in Long Island Sound. Accompany the website is the web map (http://dev.global.coastalresilience.org/). Both are being refined and improved based on partner feedback regarding clarity and ease of use.

Coastal Areas Climate Change Education Partnership (CACCE) for the Southeast US and Caribbean Sea)

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The Coastal Area Climate Change Education (CACCE) Partnership, funded by the National Science Foundation, seeks to develop new ways to educate citizens about global climate change. The core theme is sea level and impacts of climate change in the southeastern United States and the Caribbean Sea. We describe an innovative educational and research model, namely Multiple Outcome Interdisciplinary Research and Learning (MOIRL), in which stakeholders engage in varied research and learning activities leading to multiple outcomes. In the CACCE Partnership the stakeholders include: students (K-16 and graduate); teachers and education researchers; informal science educators; scientists and engineers; business and industry; policy makers; and community members. CACCE combines interdisciplinary research with action research and community-based participatory research in a way that is best described as “transdisciplinary”. Learning occurs in all spheres of interactions among stakeholders as they engage in scientific, educational, community and business activities through their legitimate peripheral participation in research communities of practice. We will describe the process of seeking and building partnerships, and call for a dialogue with groups pursuing climate and climate change education.

Effects of salinity on common woody species of Buttonwood Forest and Coastal Hardwood Hammocks in Everglades National Park

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We examine the effects of salinity on a rare plant species and five indicator species of Buttonwood Forests and Coastal Hardwood Hammocks of Everglades National Park (ENP) using experimental and observational data. We use juvenile trees (1-2 years) of *Piscidia piscipula* and *Swietenia mahogany* indicator species of the Coastal Hardwood Hammocks, *Conocarpus erectus* and *Capparis flexuosa* indicators of Buttonwood Forests, and *Eugenia foetida* a species transitional between buttonwoods and hardwoods, to salinity treatments consisting of 5, 15 and 30 parts per thousand of sea-salt and a control. Based on results of stomatal conductance, growth rate, and leaf turnover, we classify study species into two groups: salt sensitive (*Piscidia piscipula, Swietenia mahogany*) and salt tolerant (*Conocarpus erectus*, *Capparis flexuosa*, *Eugenia foetida*). Two salt tolerant species exhibited no mortality whatsoever and showed some decline in stomatal conductance and growth rates in response to high salinity levels (≥ 15‰). Buttonwood responded dramatically to salinity treatments at the outset, but within 7 month all but plants in 30 ppt had similar rates of stomatal conductance. *Eugenia foetida* did not adjust its conductance rates and showed significantly higher rates of conductance in low salinity and control compared to high salinity. *Capparis flexuosa*, had greater number of leaves in high compared to low salinity levels and control. While salt-sensitive species had significantly lower stomatal conductance rates in all salinity treatments compared to control and showed up to 50% mortality in 30 ppt salinity. Thus salinity levels of 30ppt are dangerously high for two hardwood hammock species, other species survive high salinity levels up to period of 7 months.

Climate Adaptation Knowledge Exchange

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The Climate Adaptation Knowledge Exchange (CAKE, www.cakex.org) is a joint effort by EcoAdapt and Island Press to create an innovative community of practice on climate change adaptation. CAKE, an interactive online destination, is about supporting the changes that conservation and restoration have to make to keep up with the changing planet. CAKE is intended to support individuals interested in developing the discipline of adaptation to climate change by facilitating the identification of important information and its accessibility; building a community via an interactive online platform; connecting practitioners to share knowledge and strategies; and networking with other relevant materials around the web. This poster will showcase the different components of CAKE, including the availability of a georeferenced database of adaptation case studies, a directory of adaptation-interested people, a virtual library of resources that can support adaptation efforts, advice for conservation and information exchange, and links to tools and data that are available to support and build the adaptation community. We invite you to learn from and join CAKE.

South Florida Water Management District Regional Geospatial Data Updates that Support Sea Level Rise Vulnerability Studies in the Florida Keys

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To support modeling and planning efforts, including sea level rise (SLR) studies, the South Florida Water Management District (SFWMD) has been updating several regional geospatial datasets, including topographic digital elevation models (DEMs), tidal surfaces and land cover/ land use layers. Also, in coordination with several agencies, including NOAA's Coastal Services Center (CSC), SFWMD is assisting with SLR vulnerability analysis activities by the Southeast Florida Regional Climate Change Compact Counties (Monroe, Miami-Dade, Broward and Palm Beach). This poster depicts examples of these efforts and associated work products within the Florida Keys, including: DEMs using the 2007-08 LiDAR data from the Florida Division of Emergency Management (FDEM); NOAA's VDatum tidal surface and the initial Mean Higher High Water (MHHW) tidal surface extrapolated inland by CSC (currently under revision by SFWMD); SLR vulnerability probability surfaces developed from Z-scores and documented elevation uncertainty; and comparison of SFWMD's latest (2009) Land Cover/ Land Use dataset to historical datasets.

Accelerating Sea-Level Rise – Projections and Implications for South Florida

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Accelerating greenhouse gas buildup, ice sheet melt, summer Arctic pack ice thinning, Arctic tundra melt, and methane hydrate melt will cause accelerating sea level rise through this century. Combined ocean warming and expansion, glacier melt, and ice sheet melt should produce at least 150-180cm sea level rise this century. Planning for this century must include adapting to a sea level rise that will be at least 150-180cm by 2100 – and accelerating. This will result in abandonment of all sandy barrier islands; essential abandonment of Monroe, Miami-Dade and Broward Counties; and inundation of significant portions of the world‟s major deltas. If this sea level rise has reached 150cm at the end of the century, it will be rising 30 cm per decade and accelerating. We will have to adapt the coastal infrastructure to a rapidly shifting coastline. In addition, anticipated accelerated warming and ice melt leads to the significant probability that ice sheet sectors will collapse and result in one or more pulses of very rapid sea level rise. Rapid pulses of rise occurred repeatedly over the past 18,000 years as climate moved from the last ice age to the present interglacial and sea level rose from –120 meters to the present. Past sea level response to climate change demonstrates that very rapid sea level rise pulses are a normal and expected response to significant climate change, and they must be anticipated in the future near. Biological and cultural assets too valuable to lose (e.g. seed banks, Library of Congress, unique coherent cultural hubs) or too critical to be inundated or disrupted (e.g. nuclear power and waste disposal sites, critical military and transportation centers, agricultural centers) should be moved above the reach of any possible major sea level rise pulses and associated chaos. The authors suggest above 50 meters elevation.

Species at risk from climate change: the case of Florida Keys endemics

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Species distributions are a response to multiple factors, including climate, habitat, and interactions with other species. Threatened and endangered species often have small geographic ranges, either as a function of natural processes or because of human activities. Because many endangered species are often range-limited, recovery efforts largely focus on maintaining or restoring suitable habitat. Twenty-first century climate change stands to exert significant additional challenges to maintaining suitable habitat for species via direct effects (e.g. changes in temperature and precipitation) and indirect effects (e.g. changes in availability of habitat because of changes in land use, sea level rise, and effects of climate on vegetation communities). As a first step towards development of integrated predictive models, we are constructing climate envelope models for threatened and endangered species occurring in peninsular Florida. These models focus on effects of temperature and precipitation and can be linked with models of changes in land use, sea level rise, and ecological communities. Here we present preliminary predictions of twenty-first century climate change on two species endemic to the Florida Keys, Key Deer (*Odocoileus virginianus clavium*), and Key Largo Woodrat (*Neotoma floridana smalli*), as well as a species whose range in the USA is limited to coastal areas along the extreme southern peninsula of Florida, American Crocodile (*Crocodylus acutus*). The models generally predict an expansion of climatically suitable areas in peninsular Florida by the end of the century, although for some species climate „bottlenecks‟ may occur during mid-century. These spatially-explicit models integrated with habitat requirements, changes in land use, and sea level rise provide a tool to help us predict where climate may be suitable for a species and can help us to identify where we may need to think critically about how to provide suitable corridors or migration pathways that facilitate long-term species sustainability.

Elevation as a critical factor in the establishment of Black Mangroves

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Understanding the environmental constraints on the establishment of black mangrove propagules is a crucial component for predicting black mangrove habitat sustainability, particularly when faced with both acute and chronic events such as hurricane landfalls and global sea-level rise. How various environmental factors limit black mangrove propagule establishment are not fully understood. We employed a natural elevation gradient occurring in a back-barrier salt marsh in conjunction with a continuously recording water-level gauge to assess the effects of elevation on the establishment of black mangrove propagules under field conditions. Experimental plots were established with or without enclosures at four elevations (low, mid-low, mid-high, high) in five blocks yielding twenty total experimental units. Use of enclosed and unenclosed plots enabled us to evaluate loss of propagules from plots through tidal action. Experimental plots were monitored monthly from November of 2005 to September of 2006 for black mangrove propagule establishment, survival and growth of established propagules, and loss of unrooted propagules from plots. Soil moisture, salinity, conductivity, and pH were determined monthly during the study. Soil organic matter and texture were determined at beginning and end of the study. Treatment elevation significantly affected final propagule establishment, whereas enclosure did not have a significant effect. Establishment was greatest at the high elevation in both the enclosed and unenclosed plots (70% and 72% establishment, respectively). The mid-low elevation demonstrated the lowest establishment success in the enclosed and unenclosed plots at 38% and 4%, respectively. Survival was greatest in the unenclosed plots at the high and mid-high elevations with 47.3% and 39.8% of the propagules that established surviving, respectively. No propagules survived in the unenclosed plots at the two lower elevations. Critical factors in black mangrove propagule establishment appear to be sufficient stranding time (to allow for rooting) and adequate soil moisture in a relatively low-energy environment.

Severe Long-term Decline in the Number of Loggerhead Turtle Nests in the Key West National Wildlife Refuge

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Loggerhead turtle (*Caretta caretta*) nests were systematically monitored from 1990- 2009 on Woman, Boca Grande and Marquesas Keys in the Key West National Wildlife Refuge (KWNWR). Time-series trend analysis for the 20-year period revealed a downward trend in the number of nests ($P < 0.0001$). More nests were found annually from 1990-1999 (Period 1) than 2000-2009 (Period 2) ($P < 0.001$). At all beaches, the percent of crawls that were nests was lower during Period 2 than Period 1. The number of nests, eggs laid, and hatchlings produced declined 52%, 56%, and 49%, respectively during Period 2, with the steepest declines occurring in the Marquesas Keys. Significantly fewer nests were found during Period 2 than Period 1 on Boca Grande Key ($P = 0.04$) and at 3 of 4 beaches in the Marquesas Keys: Long ($P = 0.002$), Main ($P = 0.002$), and Short ($P = 0.008$). For 803 nests of a known outcome, 467 (58%) nests were on dunes and 336 (42%) were on beaches. Turtles that nested in the dunes produced more hatchlings per nest than those that nested on beaches ($P < 0.001$). As a group, dune nests produced 15.6 more hatchlings per nest than beach nests. Assuming a 2-year nesting interval and 3 annual clutches per breeder, the number of breeders declined by 53% during Period 2. The hatching rate (45%) was low and the proportion of false crawls (63%) was high during the study period. Sea water inundation of nests negatively affected hatching rates and productivity. The marked decline in the number of breeders and nests, low productivity, a high proportion of false crawls, tidal flooding coupled with ongoing beach erosion, and sea level rise collectively threaten the nesting loggerhead turtle population in KWNWR.

White-crowned Pigeon Nest Surveys, 2000-2010: Impact of the 2005 Hurricanes and Post-hurricane Recovery

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In the U.S., the frugivorous White-crowned Pigeon (WCPI) nests solely in the Florida Keys on backcountry mangrove islands. Nesting birds fly to mainline keys (islands linked by US Highway 1) to forage in uplands with fruit-bearing trees. From 2000-2010, 372 flight line counts were performed at selected mangrove islands in the lower Florida Keys to obtain an index to the nesting population and population trend. The 2005 hurricane season drastically impacted WCPI nesting. Hurricane Dennis (9 July) caused the virtual cessation of nesting for the year and greatly reduced annual recruitment. Hurricane Wilma (24 October) severely damaged the bird‟s upland foraging areas and further devastated the mangrove nesting areas. In 2006, the number of nests in the study area was lower than in any other year. In KWNWR, the number of WCPI nests was lower (46%) every year from 2006-2010 than any year before the 2005 hurricane season. In contrast, nesting rose sharply in GWHNWR after 2007, and from 2008-2010 the number of nests was higher each year than any of the other previous 8 years. Possible reasons for the marked difference between these 2 refuges in the post hurricane recovery of the nesting populations are discussed. Owing to climate change, eustatic sea level rise and a projected rise in hurricane frequency and intensity acutely threaten the bird‟s remaining upland foraging areas, already forever greatly reduced by development in the Florida Keys.

Green Iguana Proliferation in the Key West National Wildlife Refuge: A Hurricane By-product and a Threat to the Imperiled Miami Blue Butterfly?

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The green iguana (*Iguana iguana*) is a neotropical folivore that is exotic to and widely distributed in southern Florida. Prior to my study, its distribution in the Key West National Wildlife Refuge (KWNWR) was unknown. During 2011, green iguana burrows and tracks were found on 12 islands, and 3 large gravid females (42-61 eggs) were captured on 1 island. Iguana burrows were found from Crawfish Key to the westernmost island in the Marquesas Keys, a distance of 28 km. In 2005, Hurricane Wilma‟s storm surge in the KWNWR removed the dense vegetation from both the dunes and the sand berms landward of the mangroves. All iguana burrows were found in remnants of the once-large clearings created by this hurricane. Because green iguanas do not nest in heavily shaded areas hurricanes may be important for creating or maintaining openings in an otherwise densely vegetated landscape. Iguana burrows and tracks were found on all 8 areas that harbor the imperiled Miami blue butterfly (*Cyclargus thomasi bethunebakeri*). Once widespread in southern Florida, this butterfly is now restricted to islands in the KWNWR, where its lays eggs only on emerging Blackbead (*Pithecellobuim guadalepense*) leaves. That the green iguana is syntopic with the Miami blue may merit concern. Were this reptile to consume blackbead leaves, it could consume Miami blue eggs and larvae. The inherent problems that confound control of green iguanas on remote islands spread over a large area are discussed.

A Probabilistic Method for Estimating Sea Level Rise Exceedances

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A method for estimating the probability of exceeding given stages of sea level rise at given times during the 21st Century is presented based on published semi-empirical correlations of historic sea level rise and global climate change model forecasts for a range of plausible IPCC scenarios. Tide gauge measurements in Florida are shown to be statistically indistinguishable from global average sea level rise. Projected probabilities that sea level could rise by 3, 4, and 5 feet by 2100 are approximately 89%, 42%, and 6% respectively. Sea level rise of 3 feet or more could have dire consequences to Florida’s coasts, the Everglades, the Keys, and low-lying urban South Florida.