IMPACTS OF CLIMATE CHANGE AND SEA LEVEL RISE IN PENINSULAR FLORIDA – CAN WE ADAPT?

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Pine-Oak Cycles Over > 60,000 Years in Central Florida (Lake Tulane)

Pine in wet, warm periods
Oak in dry, cool periods
Grasses mirror oak more than pine
But savanna and scrub vegetation dominate the entire sequence

Source: E. Grimm
“The Pleistocene flora of the Lake Wales Ridge is similar to today. Only the quantities vary. The Lake Tulane record does not indicate major shifts in range distributions. Although more northern species of *Pinus*, *Quercus*, or *Carya* may conceivably have appeared during the Pleistocene, no identifiable northern taxa occurred, and characteristic taxa of the Florida scrub persisted throughout…”

Vertebrate fossils show a long and generally continuous sequence of grassland, savanna, woodland, and scrub-adapted animals living in mostly warm temperate and subtropical environments in Florida going back > 20 million years.
Temperatures are Predicted to Rise Less in Florida than Anywhere Else in North America (except Southern Greenland)

Source: Christensen et al. (2007) for IPCC
Everglades National Park
(60% of the Everglades is below 3 feet)
“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
(2009) *The Rising Sea*
Sea Level Rise Projections

- SLR is caused by melting of mountain glaciers and polar ice sheets and by thermal expansion of the oceans.
- Local (relative) SLR is a combination of global average trend and local factors such as subsidence or uplift.
- The IPCC (2007) predicted 18-59 cm global SLR by 2100, excluding effects of ice sheet melting.
- A “conservative” estimate of global SLR by 2100 is 1-2 m when taking into account polar ice melting (Pilkey and Young 2009) – some recent estimates are up to 5 m by 2100 (e.g., Hansen 2007).
Florida through Time

120,000 years ago
+ 6 meters

~ ½ from Greenland
~ ½ from Antarctica
FL Keys coral reef

18,000 years ago
- 120 meters

Sea level was still 20 m below present just 10,000 years ago

Today

Source: H. Wanless, University of Miami
Sea level history for the northern Gulf of Mexico since the last glacial maximum, based on approximately 300 radiocarbon-dated paleoshoreline indicators. Several periods of rapid sea level rise are indicated. From Donoghue (2011), adapted from Balsillie and Donoghue (2004)
“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, Climatic Change, in press)
Tide Gauge Observations

Average Rate ~ 1.8 mm/year

Source: O. Pilkey, adapted from Church and White (2006)
SLR projections 1990-2100 based on a relationship linking global sea level to global mean temperature. Model uses IPCC temperature projections associated with 3 emission scenarios (B1, A2, and A1F1). The IPCC forecast of SLR based upon the same emission scenarios is shown as the 3 vertical bars on the bottom right (AR4).

From Vermeer and Rahmstorf (2010)
1, 3, and 6 m sea level rise projections for Florida

SLR model from J. Weiss and J. Overpeck, University of Arizona
Refined by T. Hoctor, University of Florida

Legend
- Current sea level
- 1 meter rise
- 3 meter rise
- 6 meter rise
- Land beyond 6 meter rise

Miles
0 50 100 200
Florida has more to lose from sea level rise than any other state, yet has done less than any state to prepare for it (Pilkey and Young 2009)
Impacts of Sea-Level Rise in Coastal Areas

- Saltwater intrusion into FW aquifers
- Increased coastal erosion
- Higher storm surges
- Inland inundation, ultimately at substantial distances from present shorelines
- Loss and shifting of human and non-human habitat

Source: A. Coburn
What are we going to do about this?
Many engineers say “build seawalls...”
And levees...
Biological Impacts of Sea Level Rise in Florida are Already Apparent

Study traces tree deaths to sea-level rise

A 1992 aerial photo shows dead trees on a salt marsh island surrounding surviving cabbage palms in the Waccasassa Bay State Preserve in Levy County on Florida's Gulf Coast. A seven-year University of Florida study shows rising sea levels are the cause behind the dying trees.

By BRIAN GELLER
Sun staff writer

The change exposes the trees to damaging salt water.

Opening a photo album, Francis Putz turns to the images of dead trees.

Newspaper clippings and over-head black and white pictures show it: cabbage palm and cedar tree stands dying at Waccasassa Bay.

“We're losing these areas too rapidly,” said Putz, a University of Florida botany professor.

Complaints about death in the once-thriving stands brought researchers to the area in the early 1990s. And after years of research, the team now believes that increased saltwater exposure caused by rising sea levels is the culprit in the deaths.

And global warming, Putz says, is speeding up the sea-level rise.

Five scientists worked on the tree study, which was published in the September issue of Ecology. After launching the project seven years ago, researchers divided forested islands with differing elevations into 400-square-meter plots.

Putz said many of the people who complained about the dying trees had not noticed that the seedlings had been dying for years before.

"These were the living dead," he said. "There was no regeneration."

In fact, one of the study's main findings was that the stands suffer the effects of rising seas before the death of the canopy makes those effects obvious, said Kimberlyn Williams, a former UF assistant professor of botany.

TREES continued on Page 8A
Results of SLAMM forecast 2004 to 2100 with 1m SLR. (a) modeled distribution of coastal wetland systems in 2100. (b) change in coastal wetland system distribution.

From Geselbracht et al. (2011, *Climatic Change*)
Results of SLAMM forecast 2004 to 2100 with 2 m SLR. (a) modeled distribution of coastal wetland systems in 2100. (b) change in coastal wetland system distribution.

From Geselbracht et al. (2011, *Climatic Change*)
“The White Zone”
Everglades NP
Mangroves:
- Can migrate landward if sea level rises slowly (resilience)
- Sediment surface elevations are not keeping pace with current rate of SLR

(Gilman et al. 2008)
Results of Studies to Date

- During postglacial periods of abrupt SLR, Gulf of Mexico shorelines were drowned in place and overstepped (Donoghue 2011)
- Ecosystem-level impacts of current SLR in Florida will be profound: estuaries, beaches, mangroves, salt marshes, and virtually all ecosystems in extreme southern Florida and other low-lying coastal areas will be severely reduced within decades
- 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
- Many existing and proposed conservation areas will be lost
1 m SLR would result in 20% of existing conservation lands lost
3 m SLR would result in 38% of existing conservation lands lost
6 m SLR would result in 51% of existing conservation lands lost
Number of FNAI-Tracked Terrestrial Taxa with All Known Florida Populations Inundated at Given Sea Level Rise:

<table>
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<th>1 m</th>
<th>3 m</th>
<th>6 m</th>
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<tr>
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<td>4</td>
<td>12</td>
<td>38</td>
</tr>
</tbody>
</table>

Source: FNAI
Six of the 7 populations of the **Cape Sable Seaside Sparrow** would be virtually eliminated by a 1-meter SLR. All would be gone at 3 meters.
Can the Cape Sable Seaside Sparrow Evolve a Habitat Preference and the Ability to Maintain a Viable Population in a Community Other Than Marl Prairie?
Bartram’s Scrub-Hairstreak
*Strymon acis bartramii*

Legend
- Open water
- hairstreak habitat:
  - 1 meter SLR
  - 3 meter SLR
  - 6 meter SLR
  - Habitat beyond 6 meter SLR

Other sea level rise:
- 1 meter rise
- 3 meter rise
- 6 meter rise

Bartram’s Scrub-Hairstreak

89% loss with 1 m SLR
99.9% loss with 3 or 6 m SLR
The Atlantic salt marsh snake will lose virtually all of its present habitat with just a 1 m rise in sea level.

Data Source: FFWCC
Florida (Duke’s) salt marsh vole will be gone with 1 m SLR

Data Source: FFWCC
Godfrey’s Spiderlily

95% loss with 1, 3, or 6 m SLR

Gil Nelson
The Florida Panther will lose 23% of its primary, secondary, and dispersal habitat with 1 m, 59% with 3 m, and 83% with 6 m SLR
People are likely to move inland into currently undeveloped lands, some of which are of high priority for conservation!
Options for Responding to SLR:

- **Coastal Hardening**: Apply traditional engineering approaches such as seawalls, levees, dikes, and beach nourishment that attempt to maintain a static shoreline position – ecologically and economically unsustainable!

- **Managed Retreat (Withdrawal)**: Allow for movement of species and ecosystems landward as sea level rises and abandon structures that cannot be moved. Relocate people and populations of other species, as needed (assisted colonization).

- **Ex Situ Conservation**: Zoos, botanical gardens, seed banks, gene banks
### Types of New Conservation Lands Needed to Respond to SLR

**Short Term**
- Alongshore/coastal uplands (i.e., parallel to coastline)
- Corridors to upland habitats

**Long Term: Relatively Stable**
- Upland refugia
- Corridors between upland habitats and running northward
The Everglades: Is Restoration the Wrong Paradigm?

In the near term, restoration efforts that provide a strong freshwater “head” through the Everglades can help reduce the impacts of sea level rise.

However, given that 60-80% of Everglades National Park will be inundated with just a 1 m rise, we need to expand the restoration mission and plan for species movement landward over coming decades.
Conclusion

- This has happened many times before – during the last couple million years much of Florida has been regularly inundated by the sea.
- However, at present sea levels are rising faster than they have for thousands of years, and human infrastructure makes adaptation (e.g., colonization of inland areas) much more difficult.
- We need to consider conservation and land-use planning within a broader temporal and spatial context – and integrate adaptation for humans with adaptation for nature.
Acknowledgments

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