Sea-Level Rise Impact on Florida
Key Deer Abundance

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Florida Key Deer

- Diminutive subspecies of white-tailed deer (*Odocoileus virginianus clavium*)
- Listed as endangered in 1967
- Endemic to the Lower Florida Keys
- Core population primarily Big Pine and No Name keys
Historic and Current Key Deer Range
Florida – 10,000 years ago

How did this happen?
Wide-ranging species
Sea Level Rise

Key West, Florida (1910-2015)
Key Deer Status?

- Sea level rise (SLR) considered threat to species and its habitat
- Effort to determine species needs and future conditions via deer model
- Overview of model and framework used (emphasis on SLR)
Model and SSA Overview

- Population Needs
  - Upland Habitat
  - Freshwater Availability

- Environmental Drivers
  - Sea-Level Rise

- Catastrophes
  - Hurricanes
  - Disease

- Parameter estimates – Development, Roadkills, etc.
Key Deer Habitat Preference

- Key deer prefer upland areas (pineland, hammock, developed) based on telemetry data
- Uplands = Deer
- Like to keep their hooves dry!

![Graph showing vegetation habitat ratio with categories: PL, HM, DV, FM, BW, MG. The graph indicates preferred and avoided areas.]

Point-Study Area
Range-Study Area
Point-Range

Vegetation

PL  HM  DV  FM  BW  MG

PREFER
AVOID
Vegetation and Freshwater Holes

[Map showing vegetation and freshwater holes with labels for different areas such as Saltwater, Freshwater "Lens", Water Hole, Annette Complex, Johnson Complex, Little Pine Complex, Big Pine, No Name, Bahia Honda, West Summerland.]
Island Tiers – *Habitat and Density*

<table>
<thead>
<tr>
<th>Tier</th>
<th>Islands</th>
<th>Deer</th>
<th>Water Holes</th>
<th>Uplands (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Core (2)</td>
<td>85%</td>
<td>48%</td>
<td>1,655</td>
</tr>
<tr>
<td>II</td>
<td>Moderate Marginal (6)</td>
<td>13%</td>
<td>23%</td>
<td>1,102</td>
</tr>
<tr>
<td>III</td>
<td>Transition (9)</td>
<td>2%</td>
<td>29%</td>
<td>1,004</td>
</tr>
</tbody>
</table>
Model and SSA Overview

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Scenario Selection

- Literature currently indicates that sea-level rise is most likely to be high (Scenario 3, 4, or 5). Probably Scenario 5 or higher
- We chose Scenarios 2, 3, and 5 to provide a full range of possibilities.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2040</th>
<th>2070</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>USACE/NOAA Low Rate (m) (C1)</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>USACE Intermediate/NOAA Intermediate Low (m) (C2)</td>
<td>0.2</td>
<td>0.3</td>
<td>0.6</td>
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<tr>
<td>NOAA Intermediate High (m) (C3)</td>
<td>0.3</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>USACE High (m) (C4)</td>
<td>0.4</td>
<td>0.7</td>
<td>1.6</td>
</tr>
<tr>
<td>NOAA High (m) (C5)</td>
<td>0.5</td>
<td>1.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Sea-Level Rise Scenarios

- USACE Intermediate/NOAA Intermediate Low (C2)
- NOAA Intermediate High (C3)
- NOAA High (C5)

Sea-Level Rise (m)

2040 2070 2100

High Medium Low
Sea Level Rise – Low (C2)

C2 Inundation (0.58m)
Year 2100
Sea Level Rise – Moderate (C3)

C3 Inundation (1.28m)
Year 2100

Current Sea-Level (2017)
Sea Level Rise – High (C5)

C5 Inundation (2.07m)
Year 2100

[Map showing inundation areas with labels for various islands and regions, including Upper Sugarloaf, Cudjoe, Knockemdown Complex, Big Torch, Middle Torch, Little Torch, Big Pine, Annette Complex, Johnson Complex, Little Pine Complex, Scout, No Name, and Bahia Honda.]
Habitat Loss – Uplands (Tier I)
Model and SSA Overview

- Population Needs
  - Upland Habitat
  - Freshwater Availability

- Environmental Drivers
  - Sea Level Rise

- Catastrophes
  - Hurricanes
  - Disease

- Parameter estimates – Development, Roadkills, etc.
Screwworm Mortality – Numbers

$n = 135$

![Bar chart showing deer mortalities by month.](chart.png)
Hurricane Irma

- Direct hit by Hurricane Irma (Sep 10, 2017)
- Category 4 storm
  - 130 mph (max. sustained winds)
  - 10-14 feet storm surge
- Destroyed 25% of dwellings in the Florida Keys
Freshwater Impacts

- Waterholes (≈86%) were impacted (>15 ppt)
- Recovery has been variable since September 2017
Deer Model

Measures of “Risk”

Habitat Area

Sea Level Rise

Carrying Capacity

Growth Rate

G Mean

G Var

Population Change

Tier Population

Disease

Catastrophe

Hurricane
Model Use

- Different sea-level rise projections (C2, C3, C5) resulting in decrease of uplands or $K$
- Model simulations ($n=999$)
- Varied model time steps (2040, 2070, and 2100)
- Determined abundance under various scenarios
Results – Population Trajectories

Tier I Islands

- Base
- C2: -32%
- C3: -87%
- C5: -96%

Year

Population

- 2020
- 2030
- 2040
- 2050
- 2060
- 2070
- 2080
- 2090
- 2100
Model Limitations

- Vegetation and freshwater availability changes prior to inundation
- Model is conservative look at habitability of Lower Florida Keys over the next 75 years
- There are many SLR estimation models. The models we used are subject to change.
Population Impacts – Sea Level Rise

- SLR will have significant impact via loss of uplands
- At low-moderate SLR scenarios (very unlikely to happen) and short-time frames (<40 years), modest (∼1% or larger) population growth rates can outpace SLR impacts
- At higher SLR scenarios and/or longer-time horizons will be challenging for deer
Questions?