Current Status of Across-Trophic-Level System Simulation (ATLSS) for the Wetland Systems of South Florida

GEER Meeting
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USGS, Florida Integrated Science Centers
Website: **atlss.org**

Overview of session

- Current status of Everglades models (DeAngelis 9:30 – 10:10)
- ATLSS High Resolution Hydrology (Carr 10:10 – 10:50)
- Modeling of fish in the mangrove estuaries, and a framework for a decision support system in that region (Cline 10:50 – 11:30)
- How ecological modeling can be extended to a landscape in which hydrology is described by a variable mesh model (Carr 11:30 – 12:10).
- Introduction to the ATLSS Data Visualization System (Hartley 1:20 – 5:20)

Outline

- Current status of the use of models in South Florida
- Review of ATLSS models
  - Spatially explicit species index models
  - Demographic modeling
- Other ATLSS Projects

Current status of ATLSS of models in South Florida

ATLSS models are now installed at the Interagency Modeling Center, SFWMD, West Palm Beach

Thank you:

Akin Owosina, Larry Stout, Jennifer Barnes, and others at SFWMD

Scott Wilson, Gene Nelson, Craig Conzelmann, Dustin Roszell, Steve Hartley and others at NWRC

Eric Carr, Jane Comiskey, Lou Gross and others at U. of Tennessee

Review of ATLSS Models

How can we forecast the possible effects of CERP on Everglades biota?

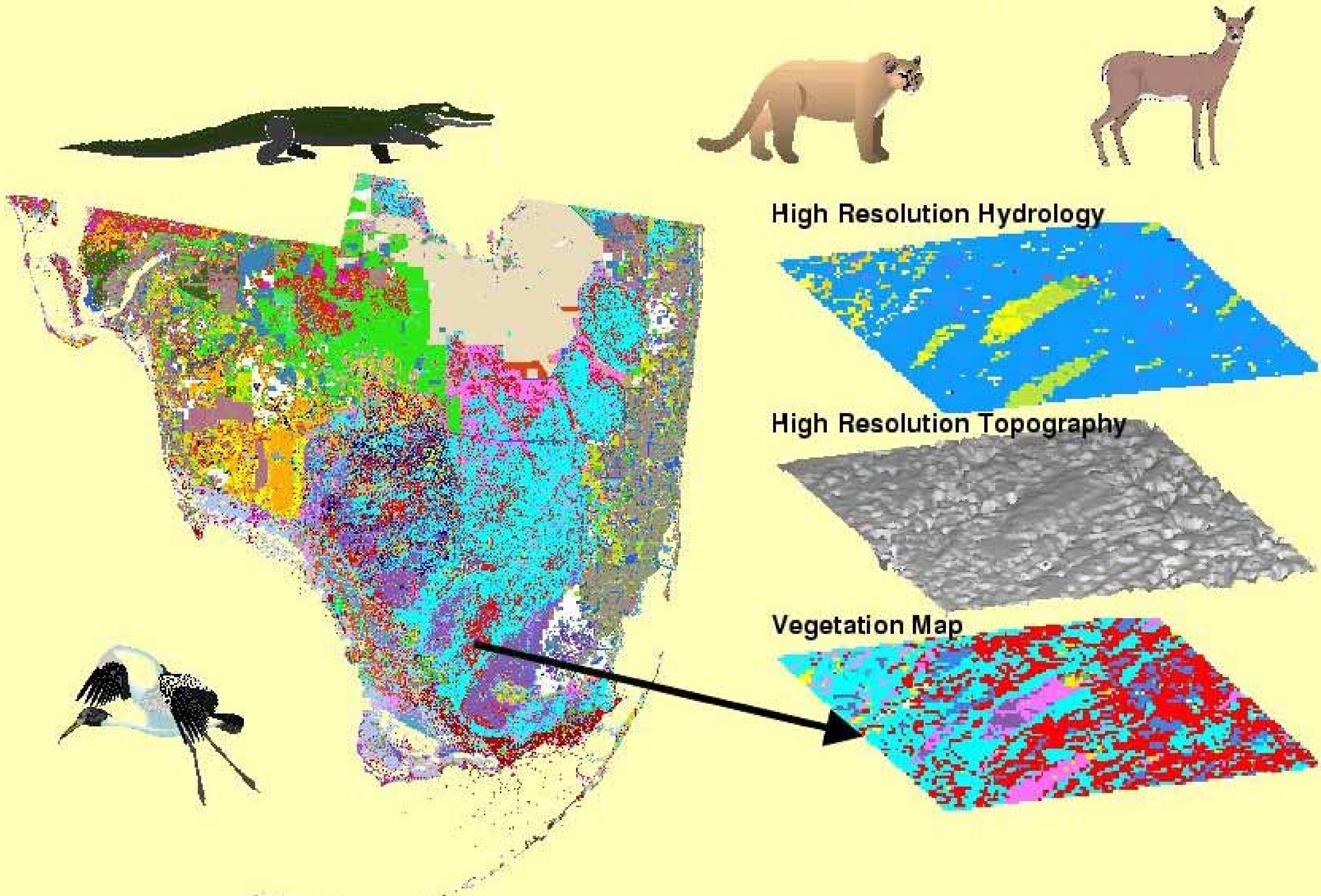
Much of the modeling being used in CERP is hydrologic and water quality modeling.

But such models do not indicate the effects of landscape hydrology on populations and communities. There is a need for models that link hydrology to biota, including how hydrology affects habitat and demography of these populations.

…a project of the U.S. Geological Survey attempts to do this.

Across Trophic Level System Simulation

Computer Models of the Landscape and Biodiversity of South Florida



Objectives of ATLSS

ATLSS Program addresses CERP's need for quantitative projections of effects of hydrologic scenarios on biota of the Greater Everglades. It can provide guidance to monitoring in an adaptive assessment framework and help provide a better understanding of the Everglades system.

It does the above through creating a suite of models for selected Everglades biota, which can translate the hydrologic scenarios into effects on habitat and/or demographic variables of populations.

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Habitat Suitability Models

One main approach is use of ‘habitat suitability’ indices (which we also call spatially explicit species index’, or SESI, models).

That is, we develop a simple model that can tell us quantitatively how the quality of the habitat changes if we implement a particular plan.

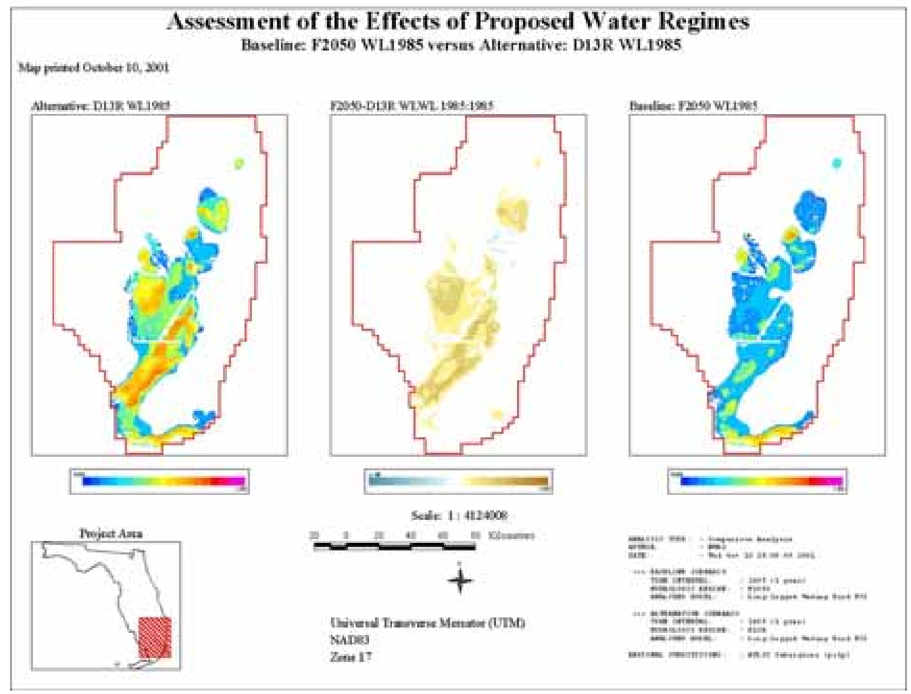
I will illustrate this with examples.

ATLSS Spatially Explicit Species Index (SESI) Models

The SESI models encode the knowledge of field ecologist on how environmental conditions, particularly vegetation and hydrology, affect species. Models exist for several species.

They provide a simple means of estimating the relative impacts of hydrological conditions upon different species populations in the Everglades.

The maps below show comparisons of habitat conditions for long-legged wading birds under two different scenarios for a particular year. The center map shows the difference.



SESI (Habitat Suitability) Model: Long-Legged and Short-Legged Wading Birds

ATLSS.org

Provides a relative estimate of quality of pixels as sites for nesting colonies of wading birds during the breeding season

Wading Bird Habitat Suitability Model

To construct such a model, we need three things:

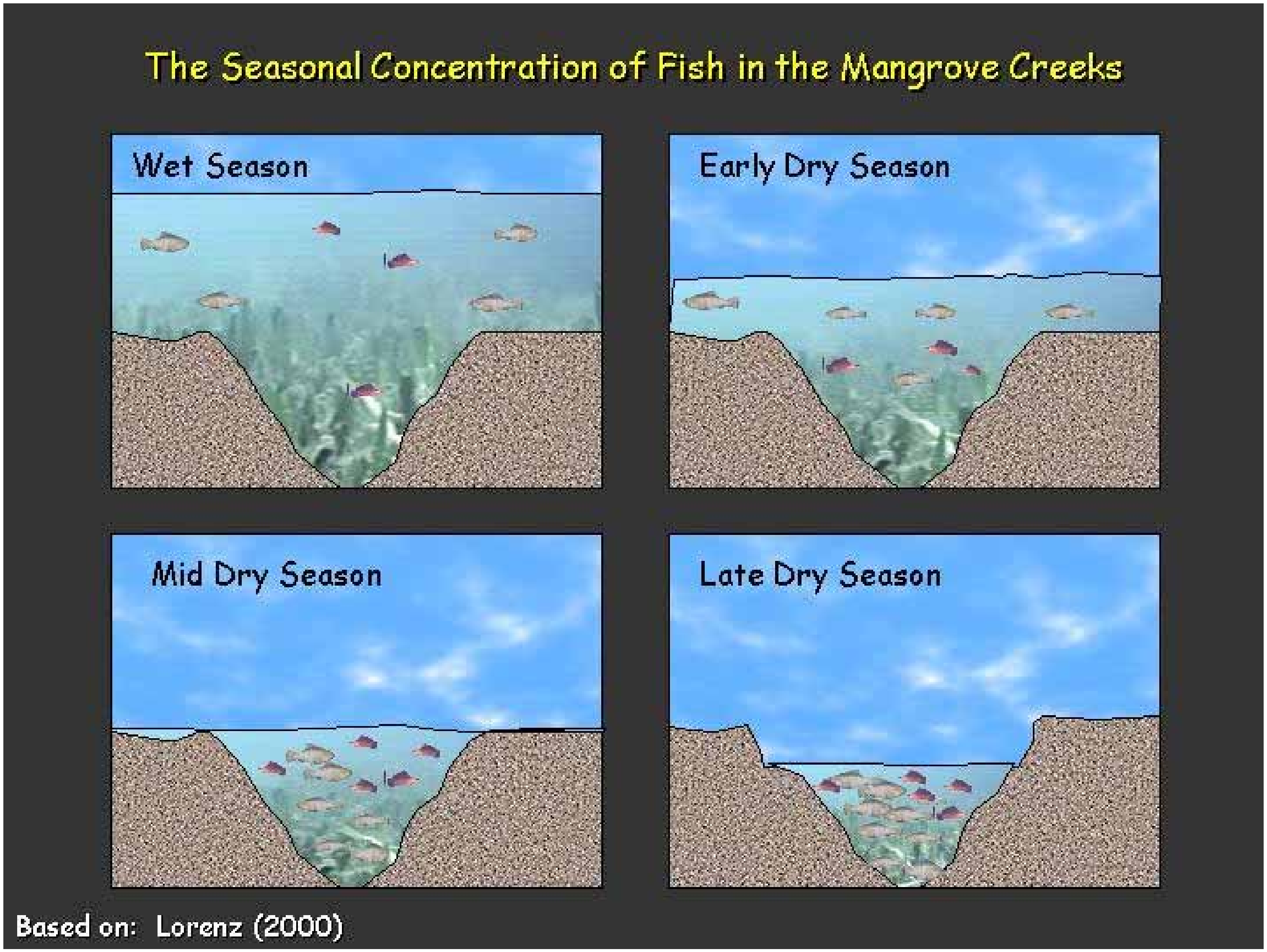
- An understanding of the ecology of wading birds in relation to hydrology
- A model of water depths across the Everglades landscape on a daily basis
- A knowledge of vegetation types across the Everglades.

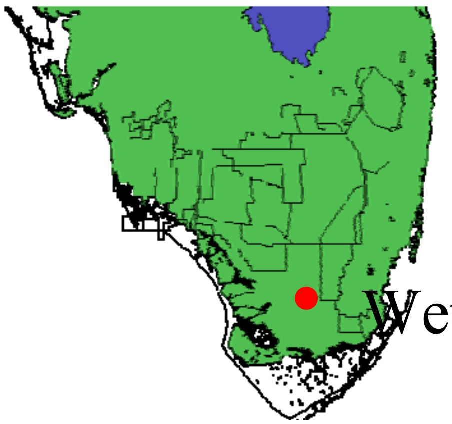
Wading Bird Habitat Suitability Index Model

First, the ecological basis for model:

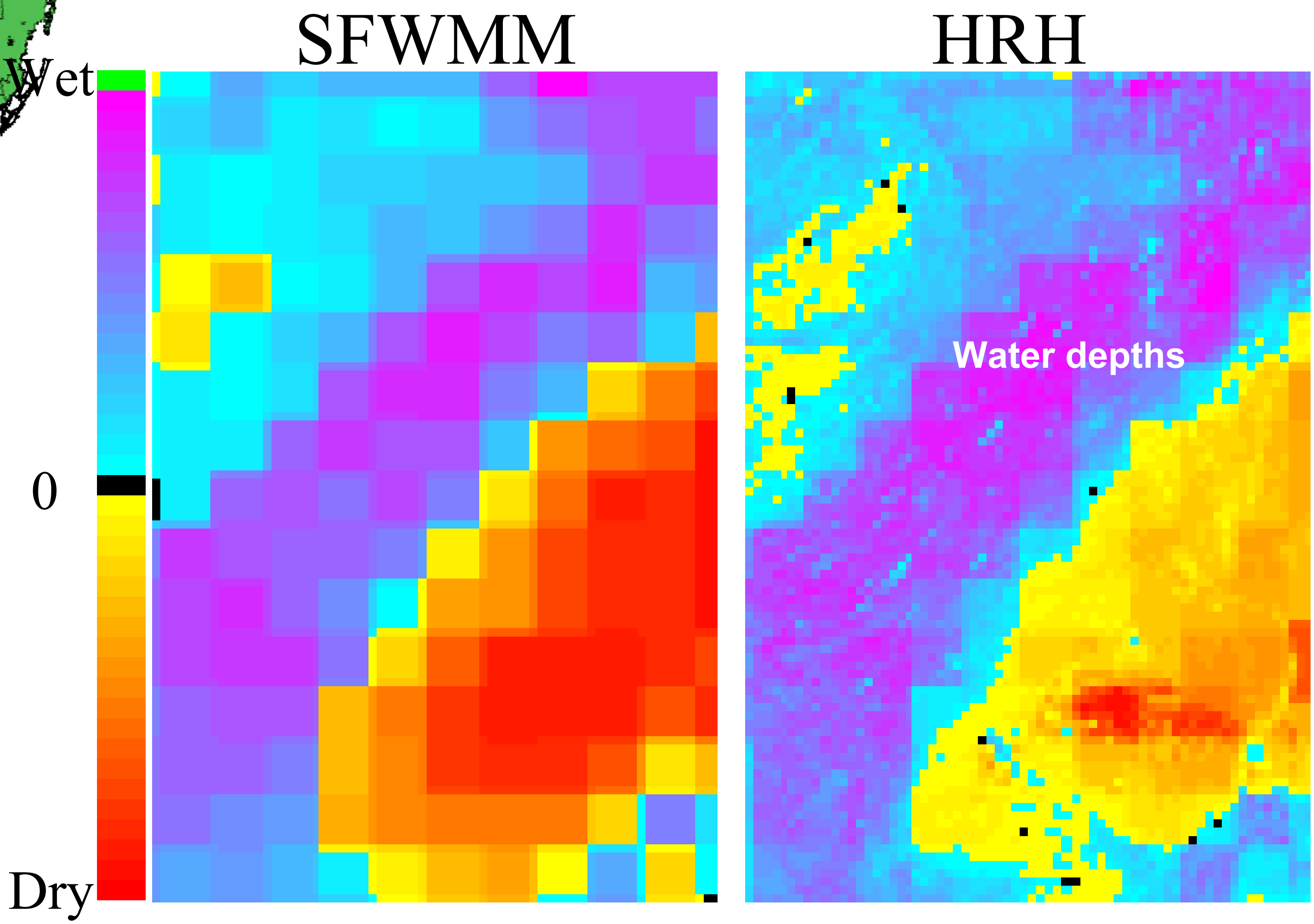
- **Wading birds can forage of fish for several kilometers from their breeding colony.**
- **Wading bird breeding can occur roughly between December and July (dry season) and wading birds require a continuous supply of available food for the entire period they are caring for eggs and young. This requires that a high enough fraction of their foraging area be in the correct water depth range, with water depths continuously decreasing, so that fish are concentrated.**
- **Wading bird breeding success depends on the number of continuous days during the breeding season in which foraging conditions are suitable, as well as the percentage of pixels in their foraging area that are appropriate habitat types.**

Fish populations grow rapidly during the wet season, and then are concentrated in ponds and creeks during the dry season, and available to wading birds.





<u>Second,</u> <u>hydrology</u>. A 35-year series of water depths for each day on each 500 x 500 pixel (1966-2000) is available from a hydrology model.

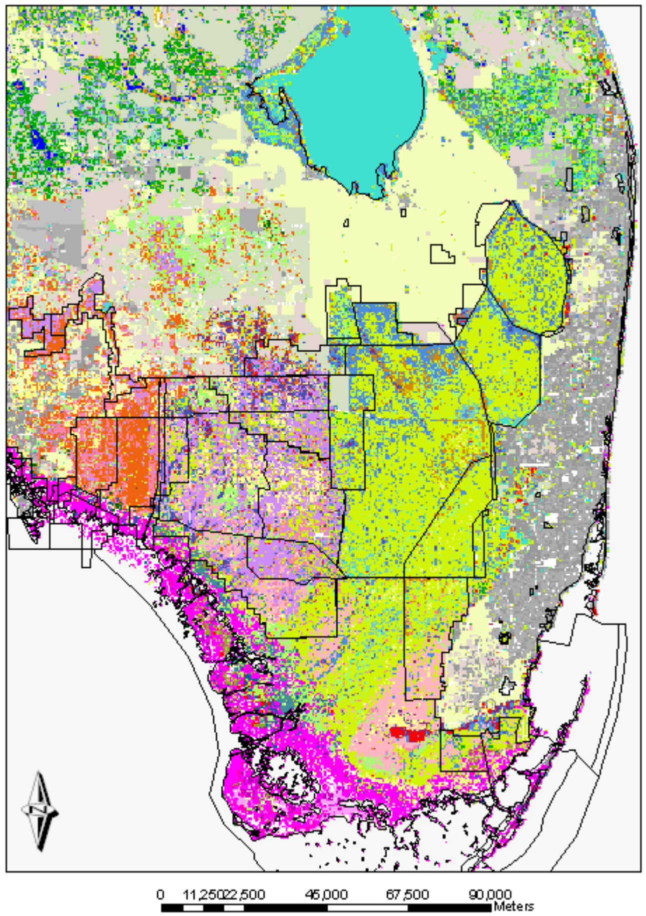


The landscape hydrology model is also used to simulate water depths for any proposed restoration plan.

Third, Vegetation Data

- 24 vegetation types have been mapped to 30 x 30 meters resolution.

- Using that data, the fraction of each vegetation type in each pixel can be computed.



Wading Bird Habitat Suitability Index Model

Using this information:

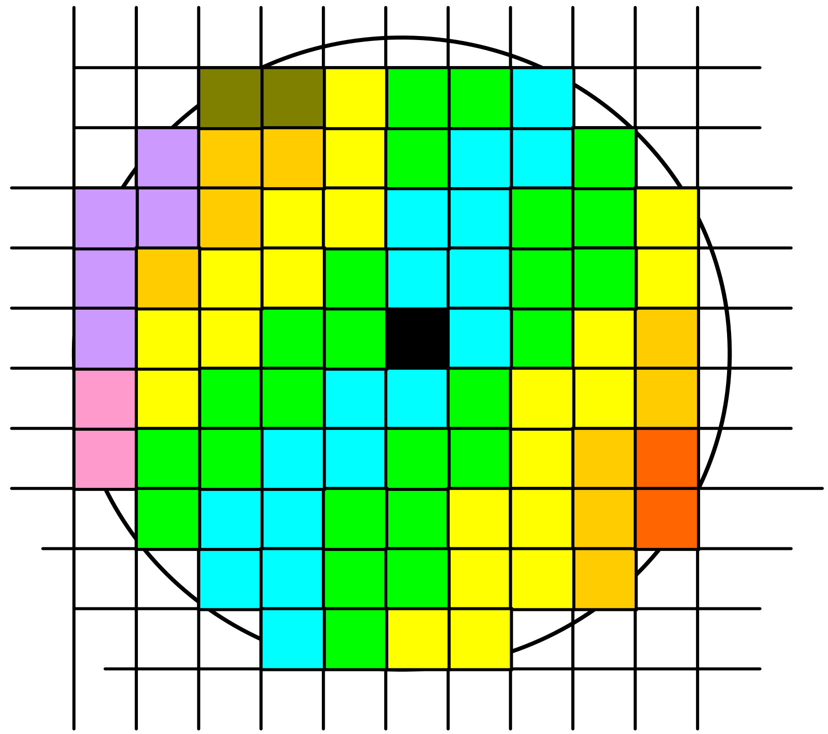
A Wading Bird Habitat Suitability Index can be computed for a wading bird colony on any 500 x 500 m pixel in the Everglades area.

Wading Bird Nesting Colony Suitability Is Determined by Foraging Suitability of Pixels Surrounding the Colony

The Wading Bird Habitat Suitability Index for a given pixel (potential site of a nesting colony) is determined by the 'collective foraging suitability' of the 500-m pixels in the 'core' area surrounding the colony pixel.

The core foraging radius for long-legged and short-legged wading birds, *ForagRadius,* is currently 1.5 and 3.0 km, respectively.

500 x 500 m pixels of various vegetation or other landuse types, surrounding the colony pixel



Black denotes pixel of the wading bird colony

Wading Bird Habitat Suitability Index Model

Using this information:

A Wading Bird Habitat Suitability Index can be computed for a wading bird colony on any 500 x 500 m pixel in the Everglades area.

How this is done is described in the following slides.

Wading Bird Nesting Colony Suitability Is Determined by Foraging Suitability of Pixels Surrounding the Colony

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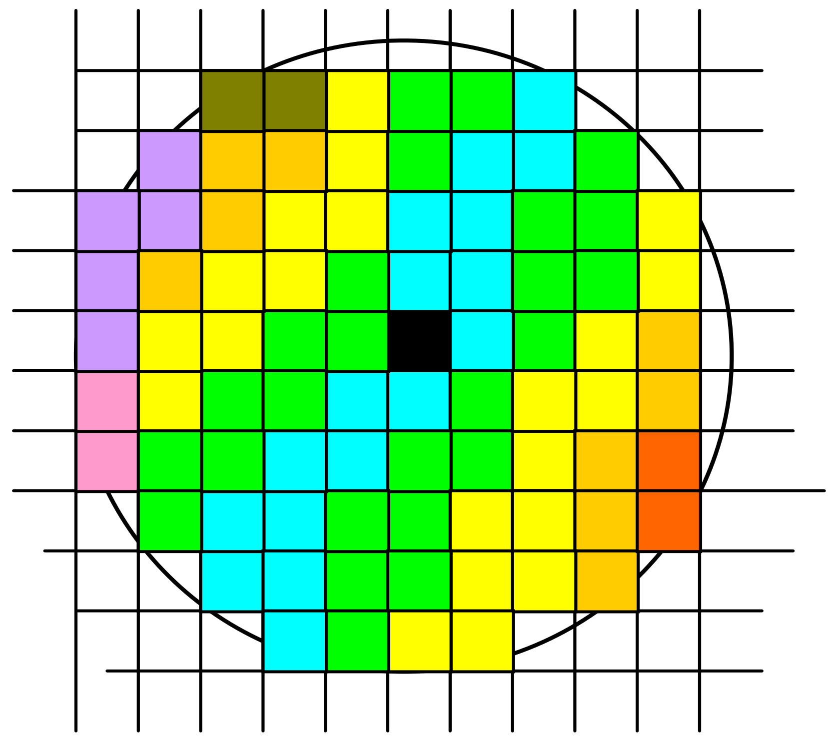


Black denotes pixel of the wading bird colony

Wading Bird Habitat Suitability Index Model

The Wading Bird Suitability Index for any 500-m pixel is based on the multiplication of two factors.

- **One is a measure of the fraction of good habitat (vegetation type) surrounding a colony, *Neighborhood_HSI.***
- **The other is a measure of net effect of variation of water depth prior to and during the breeding season, *Hydrologic Modification.***

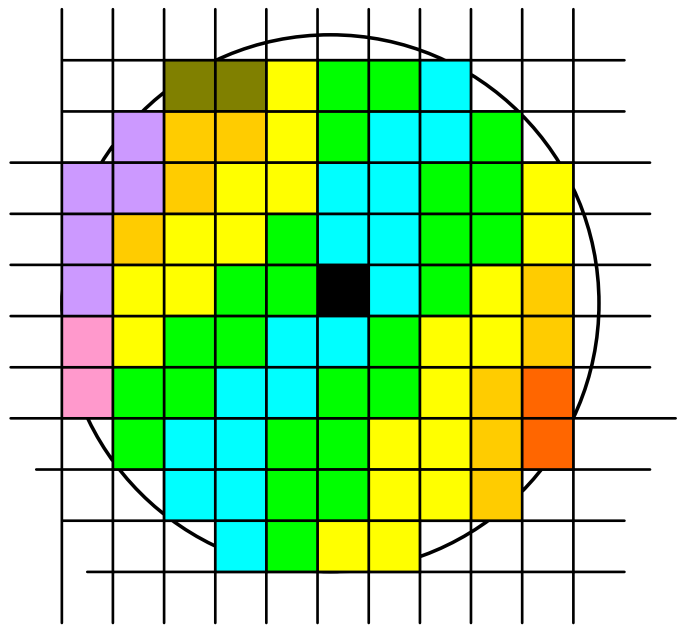
Factor 1. Formulation of ‘Surrounding Vegetation Type’ Value

Step 1.

Each 500-m x 500-m pixel in the core foraging area of the colony is assigned an HSI value computed from the fraction of its constituent 30-m cells that are usable habitat; i.e.,

- ***Freshwater marsh***
- ***Muhlenbergia***
- ***Eleocharis***
- ***Typha***
- ***Spartina***
- ***Mangrove***

A pixel with > 25% urban area has value 0.



Factor 1. Calculating Fraction of Suitable Habitat Pixels in Foraging Area Surrounding Colony

Step 2.

Next the colony pixel is assigned a '*Neighborhood_HSI*' value computed as the mean of the HSI values of the individual cells in its foraging area.

Neighborhood_HSI

= (Sum of 500-m pixel HSI values within foraging radius)/ (Number of pixels within the foraging area)

Only colony pixels that have a *Neighborhood_HSI* value of > 0.50 are considered possible colony sites (i.e., non-zero index).

Factor 2: Hydrologic Modification

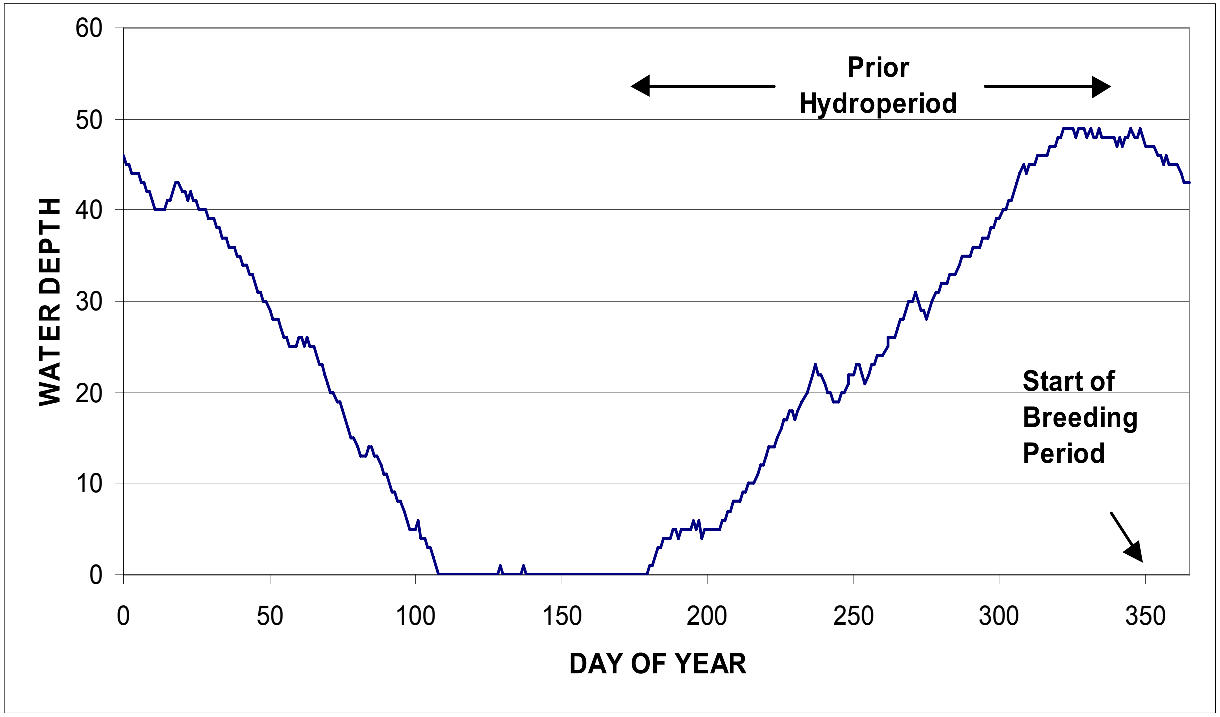
Habitat suitability will now be modified by the hydrology.

The following rule is based on the dynamics of water depth in the core foraging area around the colony pixel.

In particular, the dynamics of water depth in each foraging pixel in the core area is examined over the course of the breeding period and the time leading up to it.

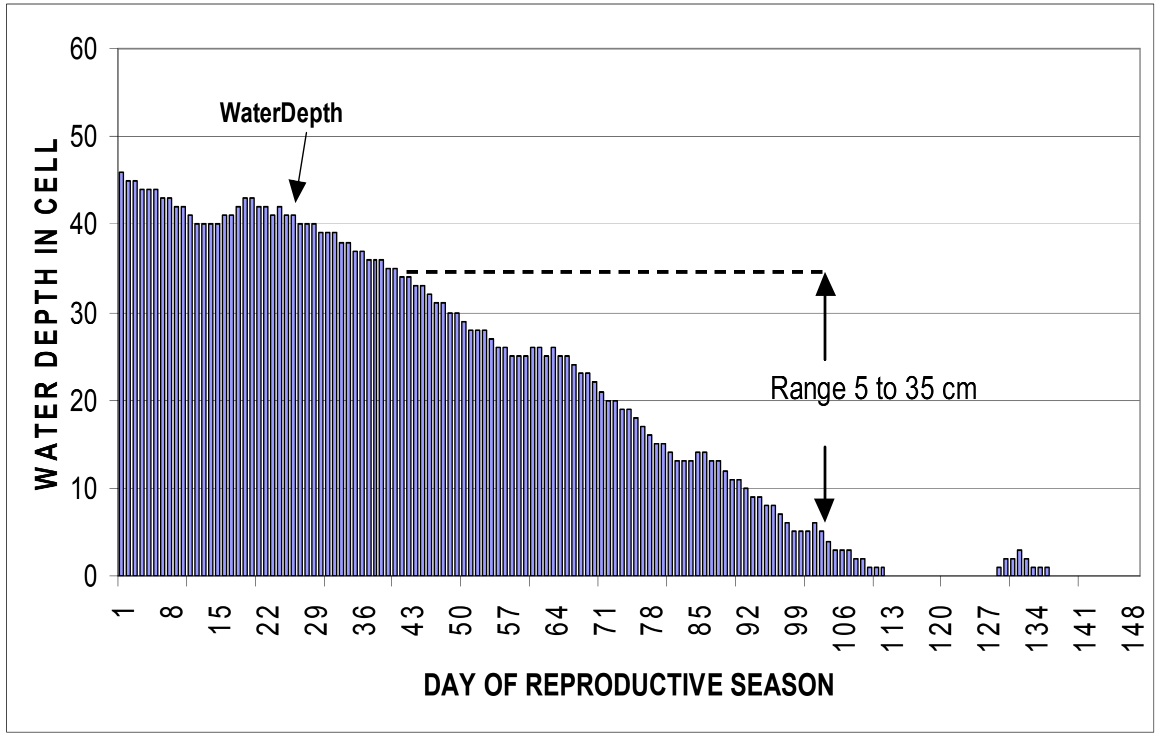
Factor 2, Part A. To Be Useful a Pixel Must Be Flooded for a Long Enough Period Prior to Breeding Period

Only 500 x 500 m pixels that were flooded for at least 120 days prior to the breeding season are included in the set of surrounding pixels in calculating a foraging index for a wading bird colony at the central pixel.



Factor 2, Part B. Water Depth Requirements

At any given time during the breeding season, only pixels that are in certain water depth ranges are usable and contribute to the foraging suitability of the core area of the colony.



Long-legged wading birds:

MINDEPTH to MAXDEPTH: Currently 5 to 35 cm

Short-legged wading birds:

MINDEPTH to MAXDEPTH: Currently 1 to 20 cm

Factor 2. Part C. Good Hydrologic Conditions Around Colony Pixel Must Have Sufficient Continuity

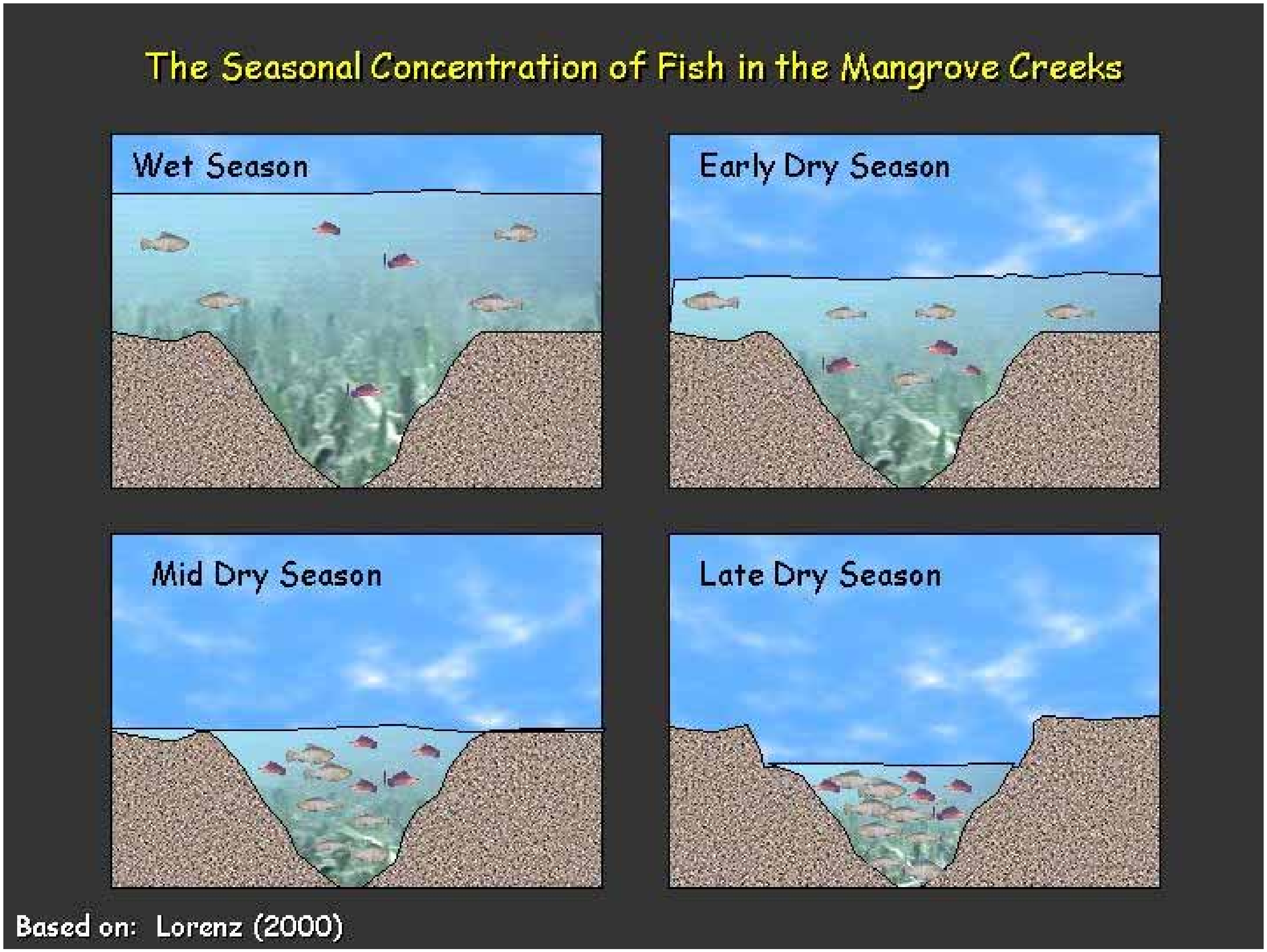
Step 1

The status of each 500-m cell, in terms of hydrology, is tracked daily during the breeding season. It is ‘active’ unless:

- Water depth is < MINDEPTH (currently 1 and 5 cm)
- Water depth is > MAXDEPTH (currently 20 and 35 cm)
- A 1-day rise in water depth is too large

The last of these refers to the occurrence of a ‘reversal’ in the decline of water depths. A ‘reversal’ occurs if there is rain during the dry season and water starts to rise again.

Fish populations grow rapidly during the wet season, and then are concentrated in ponds and creeks during the dry season, and available to wading birds.



Factor 2. Good Hydrologic Conditions Around Colony Pixel Must Have Sufficient Continuity

Step 2

The important thing is that we keep track of each of these conditions for all of the pixels surrounding the colony. Only if *enough* pixels are in the 'active' (usable) state almost each day can the colony continue.

If conditions are not good for a few days, then *Hydrologic Modification = 0* for those days and the colony will fail*,* because if the offspring are not fed for a few days they will die.

Total Wading Bird Habitat Suitability Index

The total Wading Bird Foraging Index is calculated as the product of the habitat suitability of pixels in the core area surrounding the colony pixel and the modification due to hydrologic conditions:

Wading Bird Foraging Index for Colony

= (*Neighborhood_HSI*)

(Hydrologic modification)

Applications of Wading Bird Suitability Index

The Wading Bird Habitat Suitability Index provides a tool for comparing the effects of different hydrologic 'scenarios' on potential colony sites for wading birds.

What do we mean by 'scenario'? A scenario is a 35-year 'run' of the model for either a particular restoration plan or the current situation (baseline case). We calculate the Wading Bird Suitability Index for each year.

Here we will compare a particular restoration plan, called AltD13r, with the baseline case.

Applications of Wading Bird Suitability Index

In the next slides, the results for AltD13r are on the left, the baseline case is on the right, and the difference is in the middle.

The cells are color coded:

‘white’ = not habitat

‘blue’ = poor habitat

‘red’ = excellent habitat

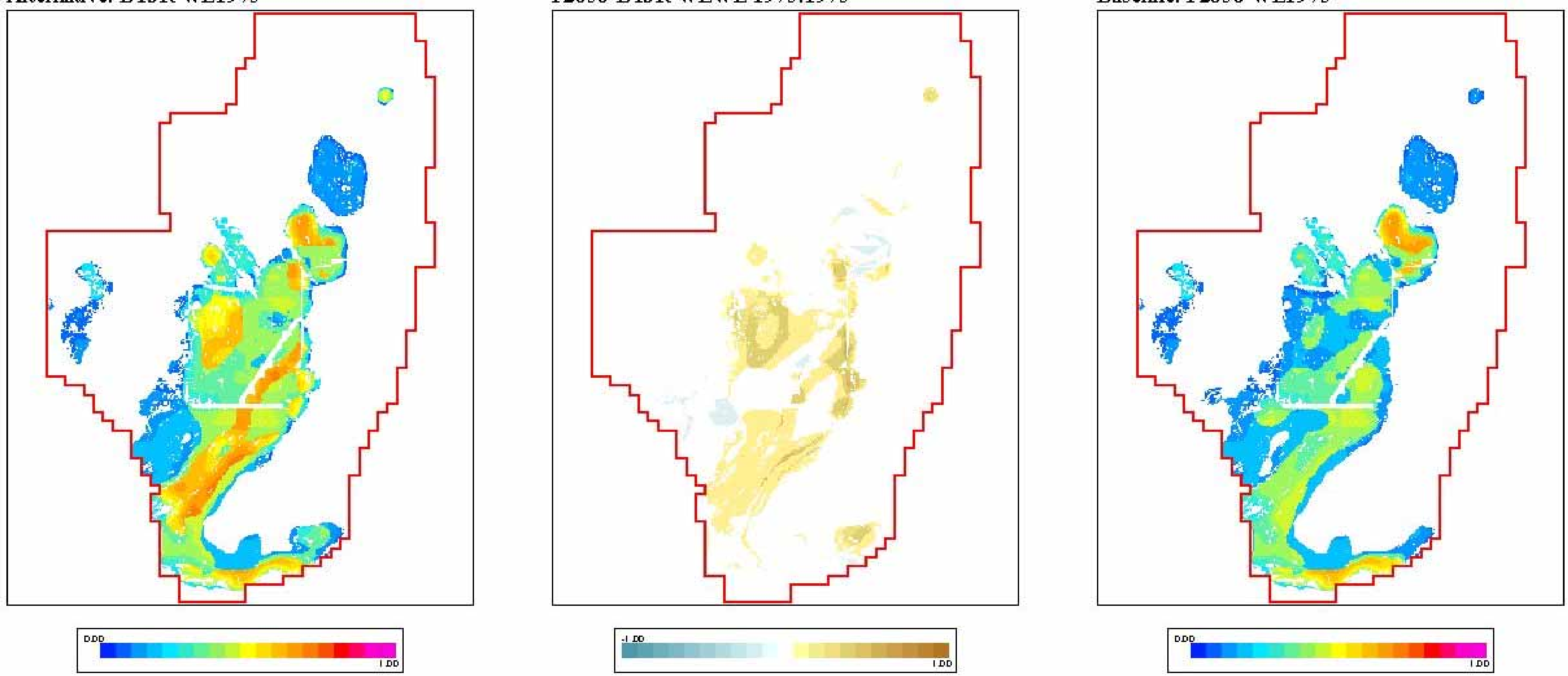
‘yellow’ or ‘green’ = fair habitat

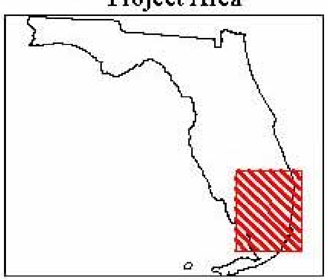
Each figure shows results for hydrology of a different year.

Assessment of the Effects of Proposed Water Regimes

Baseline: F2050 WL1975 versus Alternative: D13R WL1975

Map printed October 10, 2001





Scale: 1 : 4124008

20 0 20 40 60 80 Kilometers

N

Universal Transverse Mercator (UTM)
NAD83
Zone 17

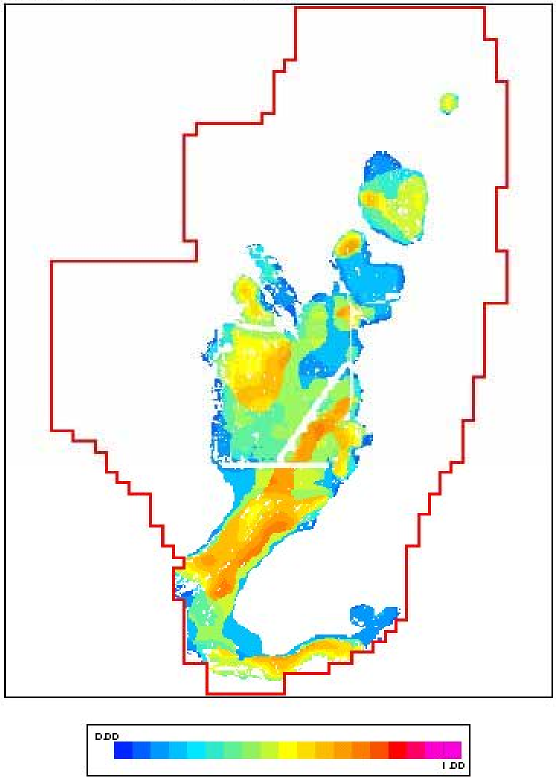
```
ANALYSIS TYPE:        - Comparison Analysis
AUTHOR:               - NWRC
DATE:                 - Wed Oct 10 15:53:59 2001

 >>> BASELINE SCENARIO
     TIME INTERVAL:        - 1975 (1 year)
     HYDROLOGIC REGIME:    - F2050
     ANALYSED MODEL:       - Long-legged Wading Bird FCI

 >>> ALTERNATIVE SCENARIO
     TIME INTERVAL:        - 1975 (1 year)
     HYDROLOGIC REGIME:    - D13R
     ANALYSED MODEL:       - Long-legged Wading Bird FCI

REGIONAL SUBDIVISIONS:     - ATLSS Subregions (poly)
```

Assessment of the Effects of Proposed Water Regimes

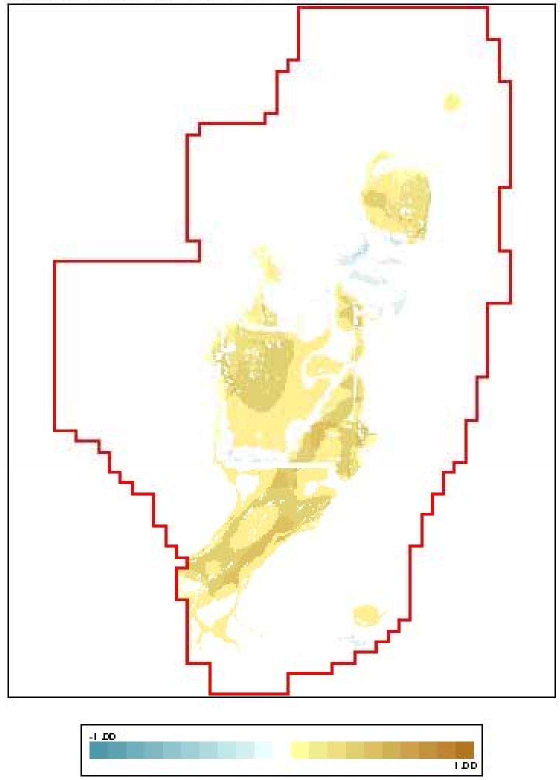
Baseline: F2050 WL1985 versus Alternative: D13R WL1985

Map printed October 10, 2001

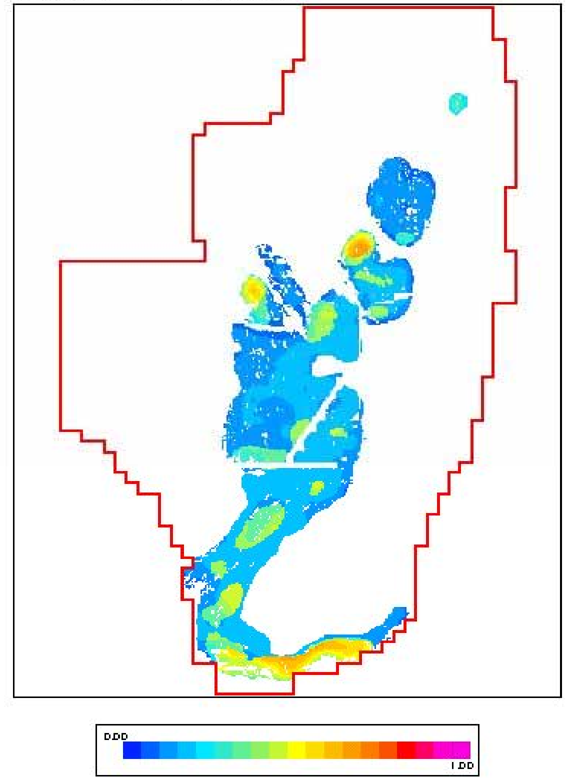
Alternative: D13R WL1985



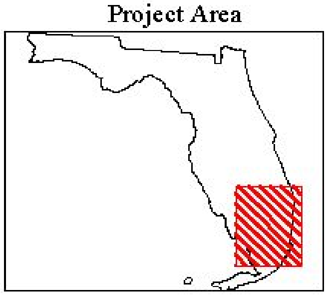
F2050-D13R WLWL 1985:1985



Baseline: F2050 WL1985



Project Area



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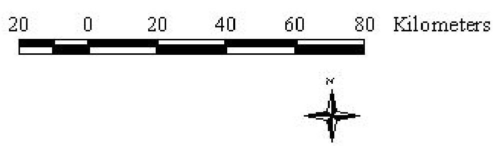

Universal Transverse Mercator (UTM)
NAD83
Zone 17

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ANALYSIS TYPE:          - Comparison Analysis
AUTHOR:                 - NWRC
DATE:                   - Wed Oct 10 16:06:08 2001

 >>> BASELINE SCENARIO
     TIME INTERVAL:          - 1985 (1 year)
     HYDROLOGIC REGIME:      - F2050
     ANALYSED MODEL:         - Long-legged Wading Bird FCI

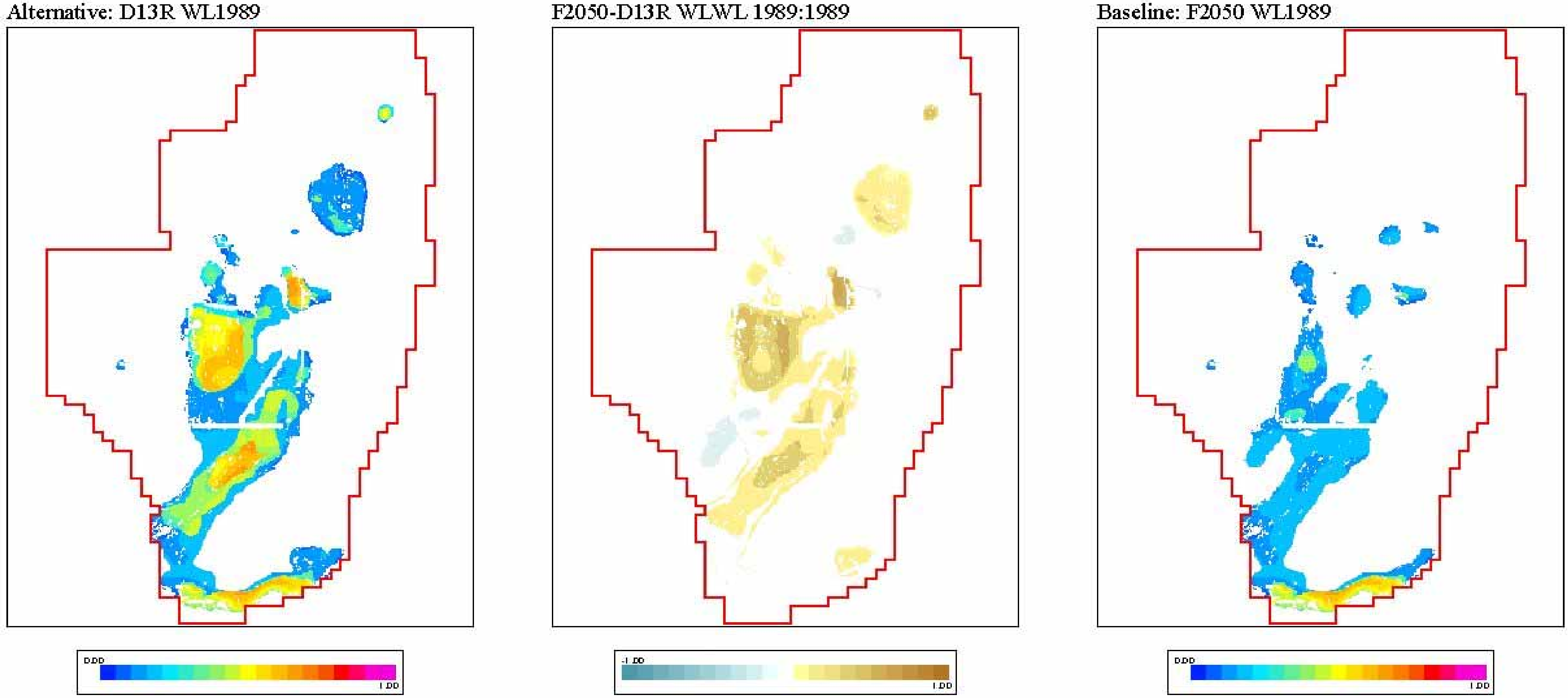
 >>> ALTERNATIVE SCENARIO
     TIME INTERVAL:          - 1985 (1 year)
     HYDROLOGIC REGIME:      - D13R
     ANALYSED MODEL:         - Long-legged Wading Bird FCI

REGIONAL SUBDIVISIONS:       - ATLSS Subregions (poly)
```

Assessment of the Effects of Proposed Water Regimes

Baseline: F2050 WL1989 versus Alternative: D13R WL1989

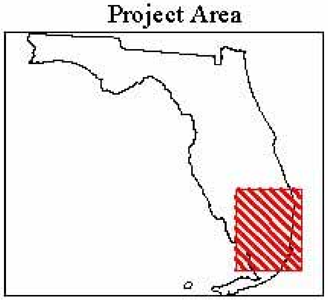
Map printed October 10, 2001



Scale: 1 : 4124008

20 0 20 40 60 80 Kilometers

Project Area



Universal Transverse Mercator (UTM)
NAD83
Zone 17

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ANALYSIS TYPE:        - Comparison Analysis
AUTHOR:               - NWRC
DATE:                 - Wed Oct 10 16:09:53 2001

 >>> BASELINE SCENARIO
     TIME INTERVAL:         - 1989 (1 year)
     HYDROLOGIC REGIME:     - F2050
     ANALYSED MODEL:        - Long-legged Wading Bird FCI

 >>> ALTERNATIVE SCENARIO
     TIME INTERVAL:         - 1989 (1 year)
     HYDROLOGIC REGIME:     - D13R
     ANALYSED MODEL:        - Long-legged Wading Bird FCI

REGIONAL SUBDIVISIONS:      - ATLSS Subregions (poly)
```
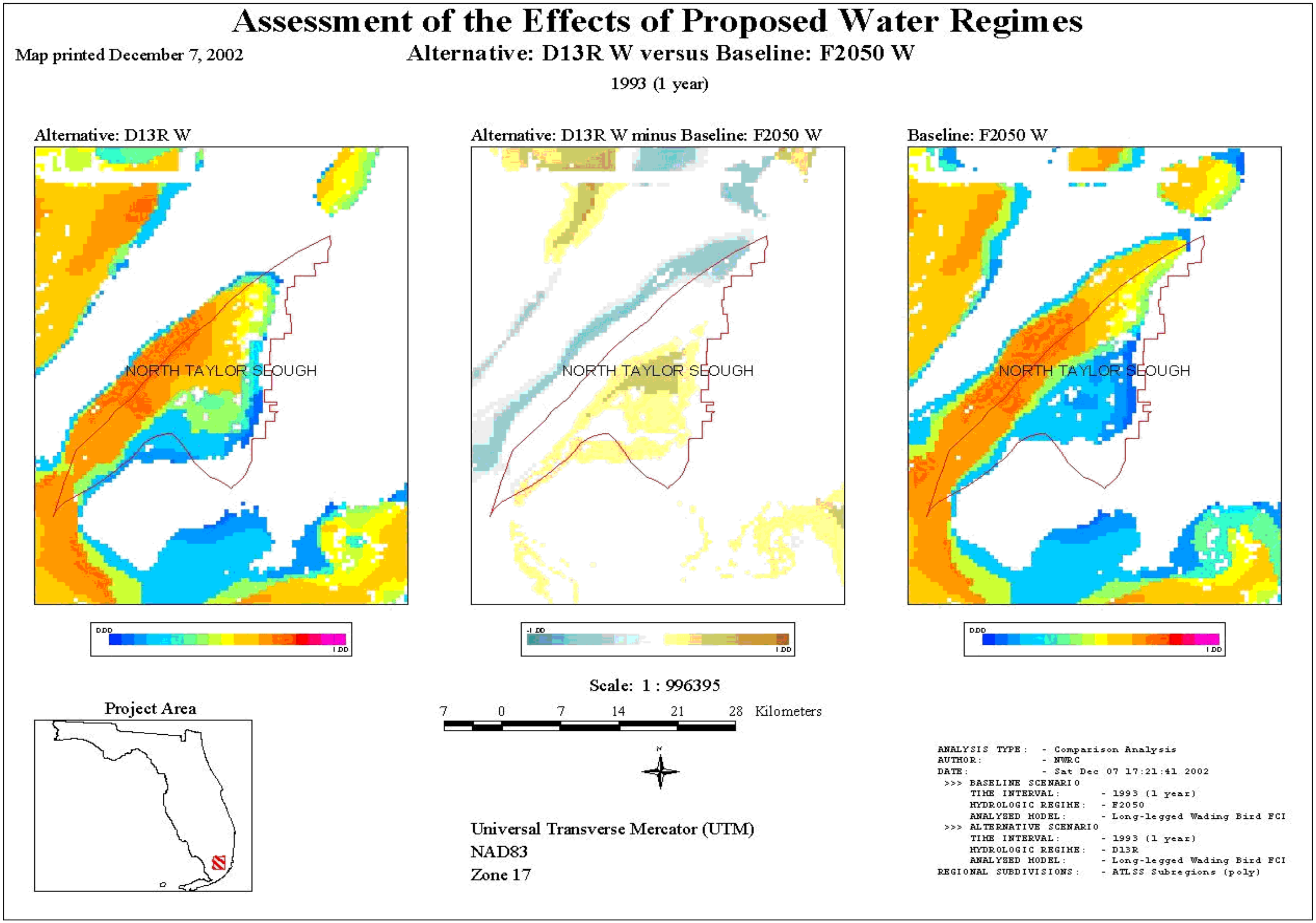
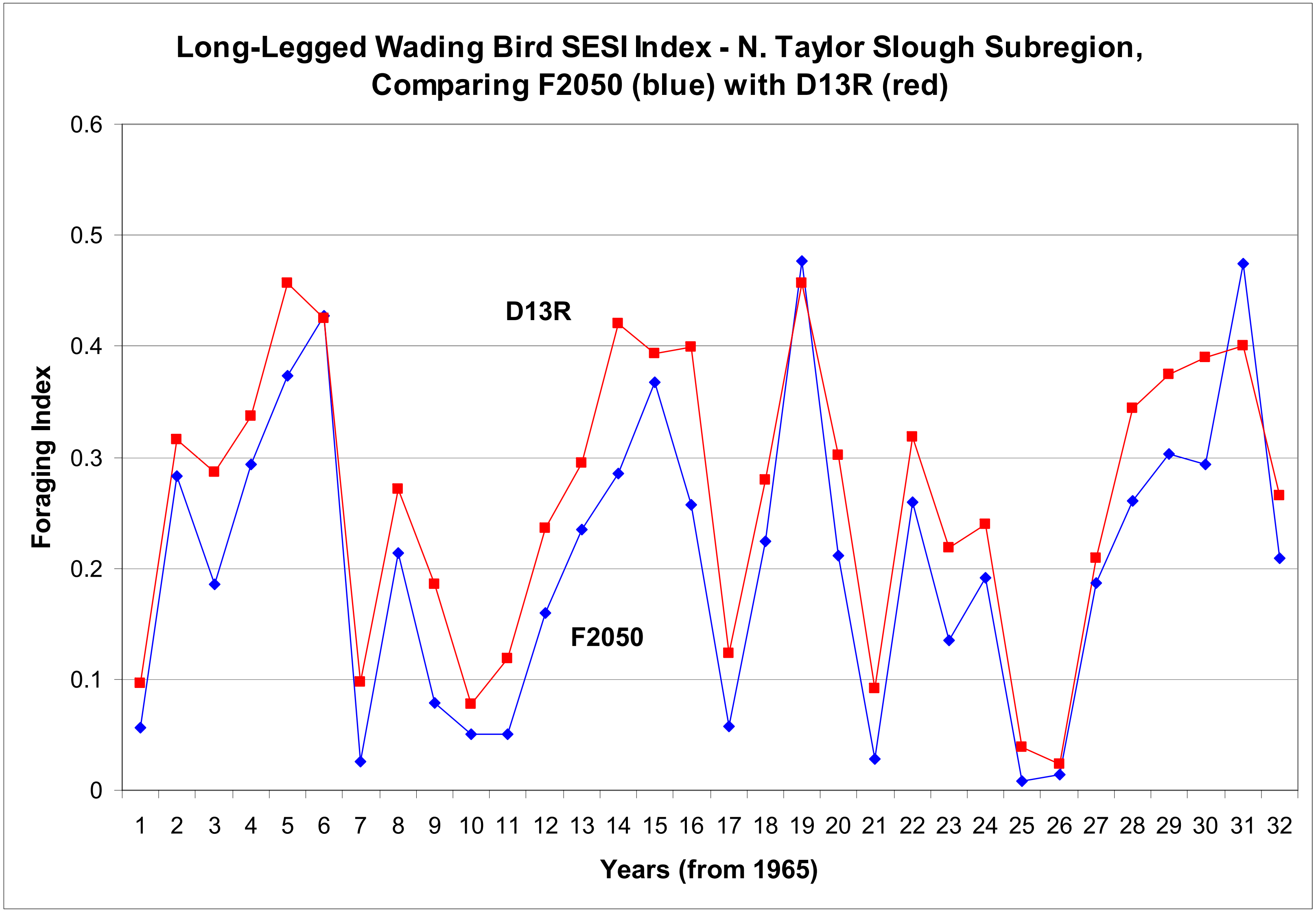
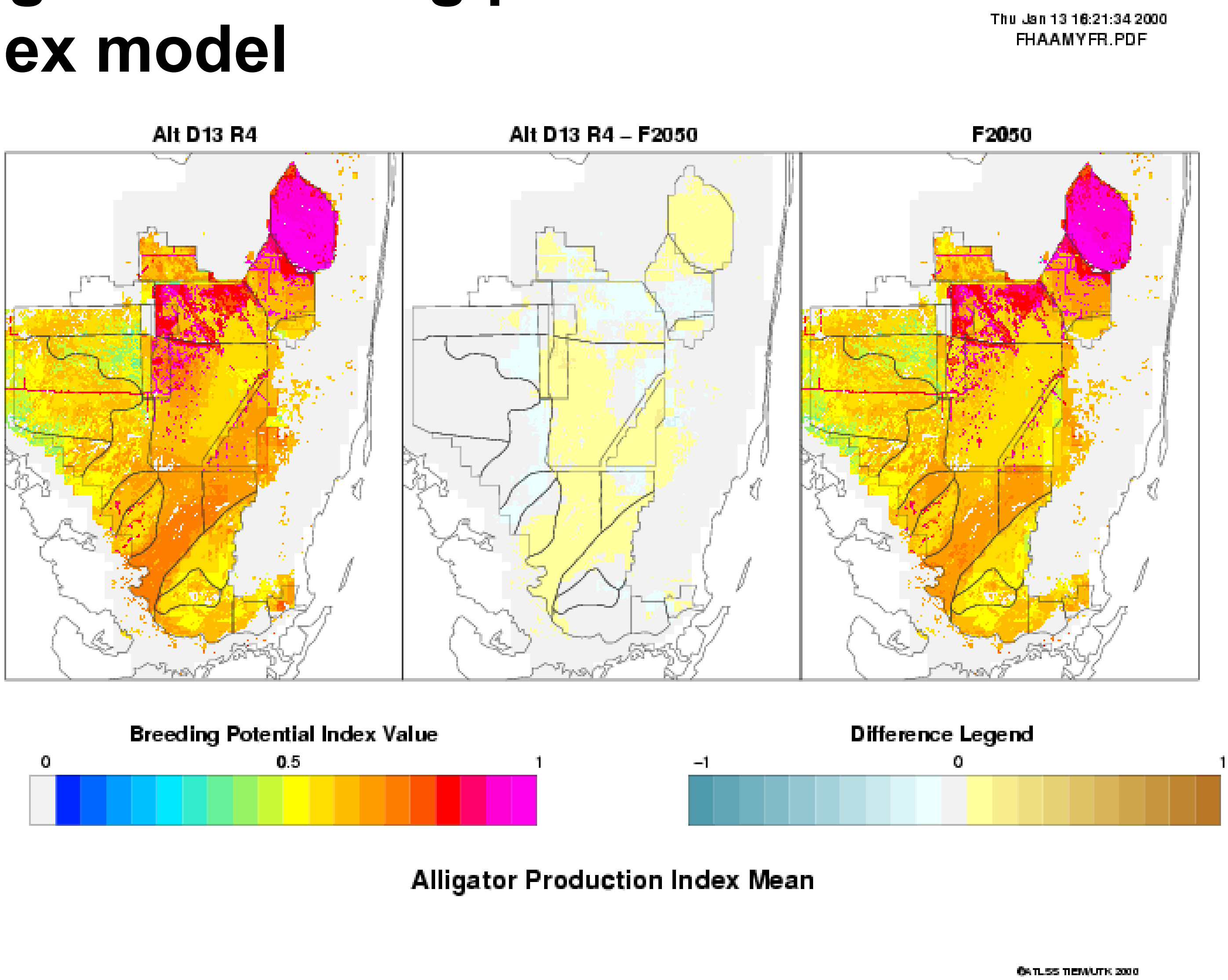

Output for Long-Legged Wading Birds in N. Taylor Slough: For 1993



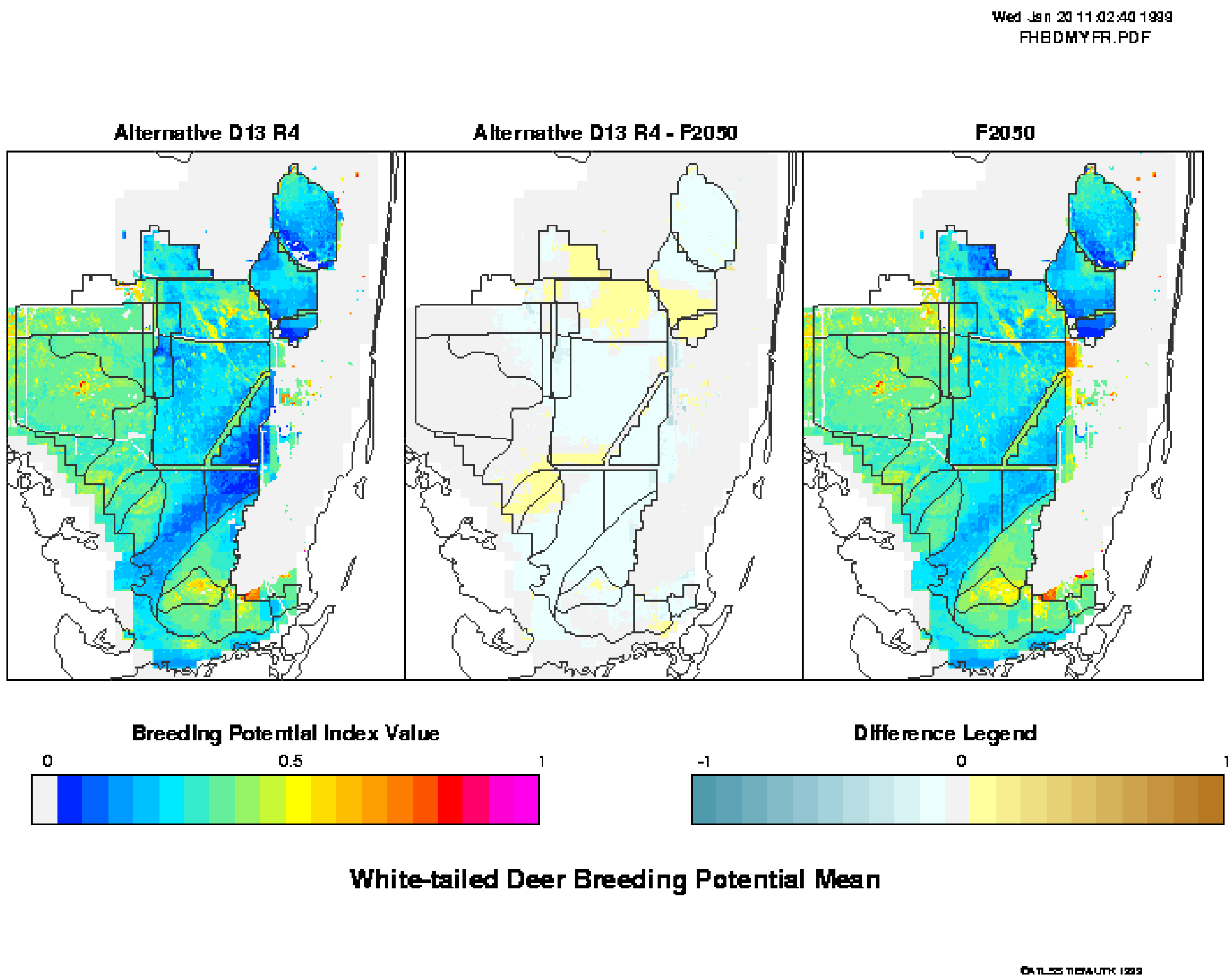

Long-Legged Wading Bird SESI Index - N. Taylor Slough Subregion,
Comparing F2050 (blue) with D13R (red)
Foraging Index
0
0.1
0.2
0.3
0.4
0.5
0.6
D13R
F2050
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Years (from 1965)

Such habitat suitability index models have been developed for a number of species.

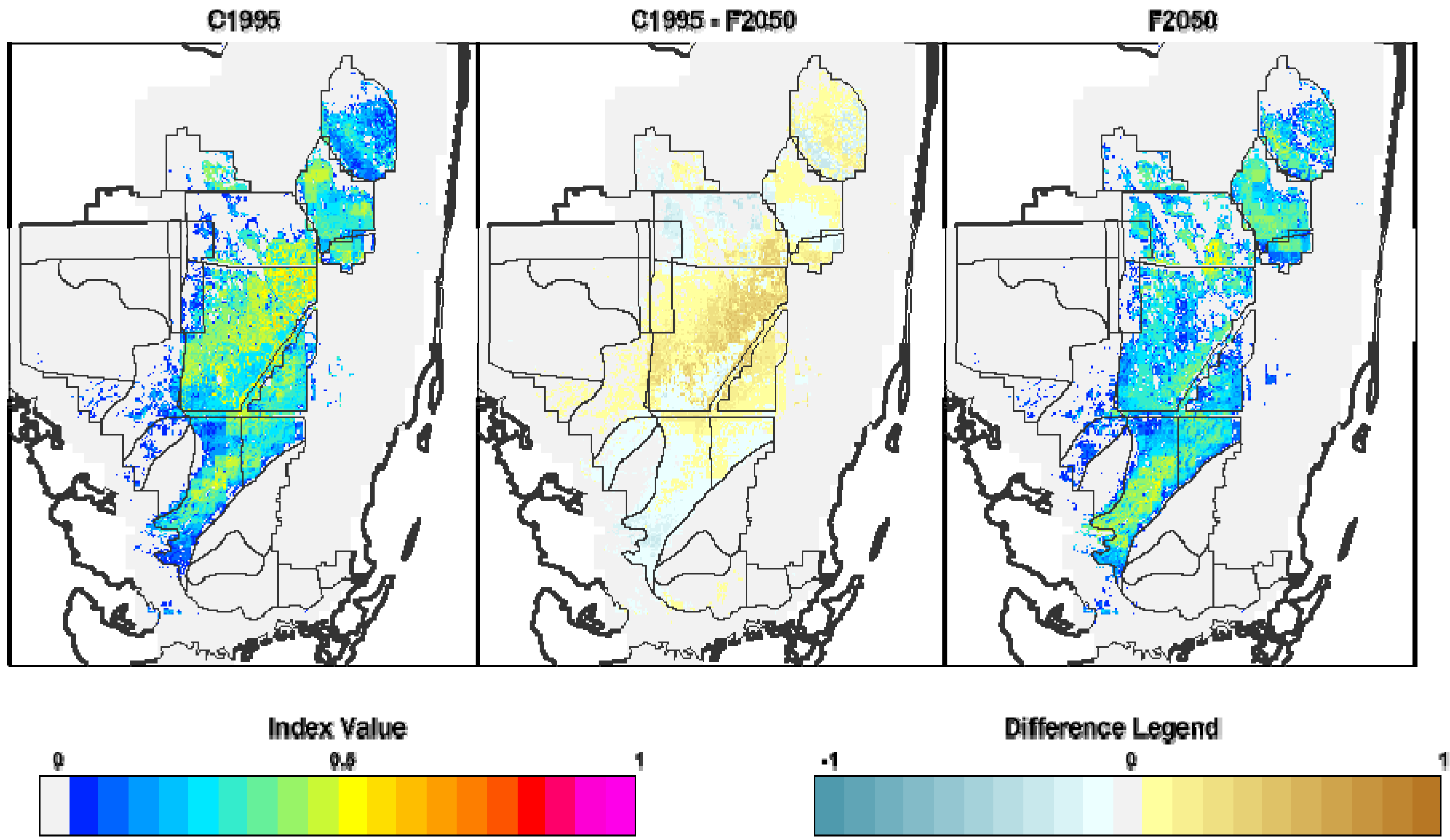
Alligator breeding potential index model



White-tailed Deer Habitat Suitability Index Model



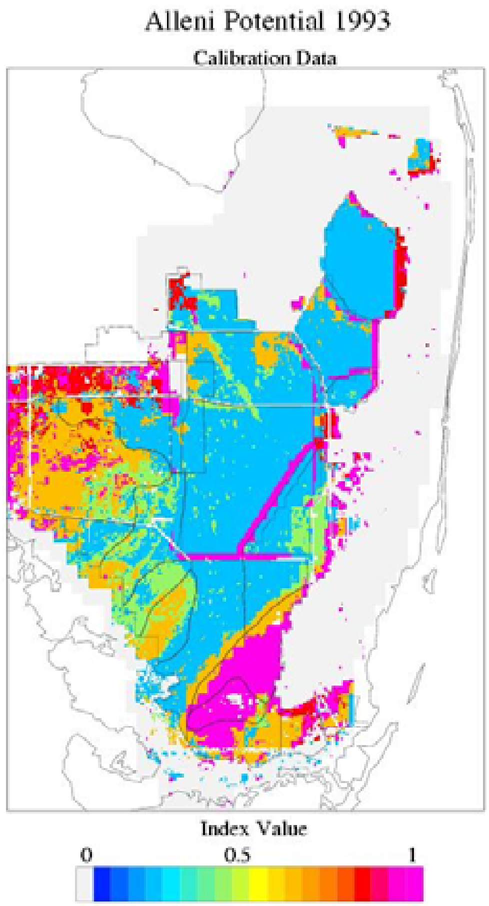
Tue May 5 12:57:03 1998
FESKMYFR.PDF

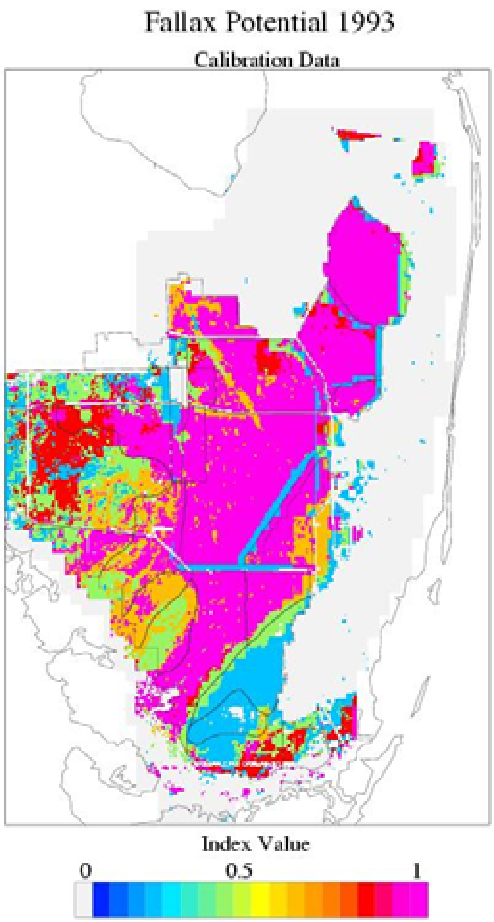


Snail Kite Index Mean

Snail Kite Habitat Suitability Model

Everglades and Slough Crayfish SESI Models





One further example…

… the Cape Sable Seaside Sparrow

ATLSS SESI MODEL: Cape Sable Seaside Sparrow Breeding Potential Index

Spatially explicit species index (SESI) model provides a relative estimate of quality of pixels as sites for nesting success

M. Philip Nott, Institute for Bird Populations

E. Jane Comiskey, University of Tennessee

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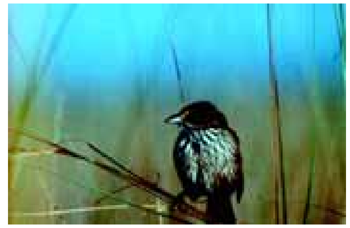
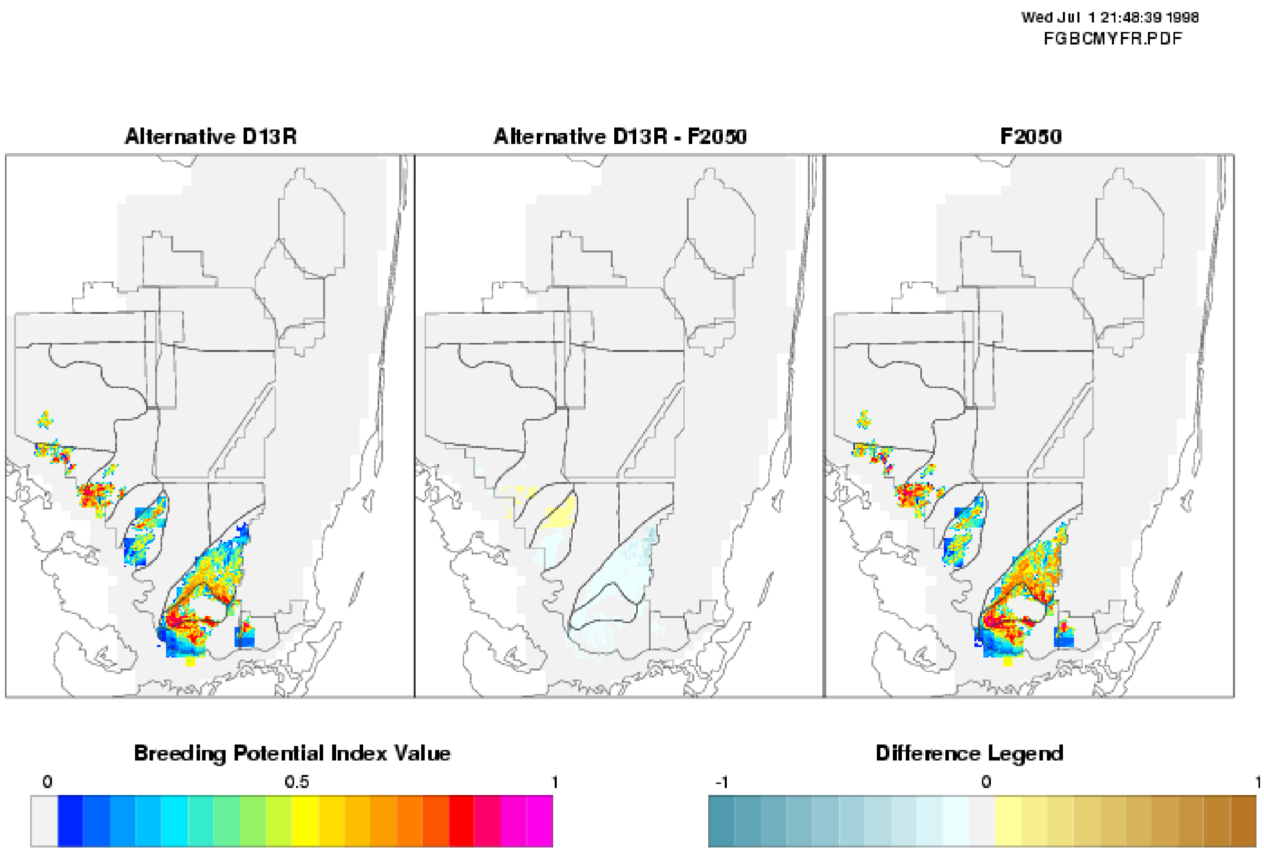
Ecological Knowledge Must Be Translated into Model Rules



Observations and historical data	Habitat/Model rules
Sparrows prefer dry marl prairie with sufficient fraction of Muhlenbergia or similar grass. Sparrows will not nest in areas near trees or woody vegetation.	Exclude spatial cells < 15% Muhlenbergia/sparse Cladium. Exclude spatial cells having woody vegetation.
Successful nesting cycle requires 45 days of dry conditions. Sparrows don’t start nest initiation until water depths are below a few centimeters and will abort nesting if water depth exceeds about 15 cm	Keep track of water depths between January 1 and June 30. Start a nesting cycle if depth < 5 cm. Abort cycle if water levels increase > 15 cm. Up to 3 nesting cycles are possible.

Breeding Potential Index Model

Output of Cape Sable Seaside Sparrow model - Averaged over all 31 years



Cape Sable Seaside Sparrow Breeding Potential Mean

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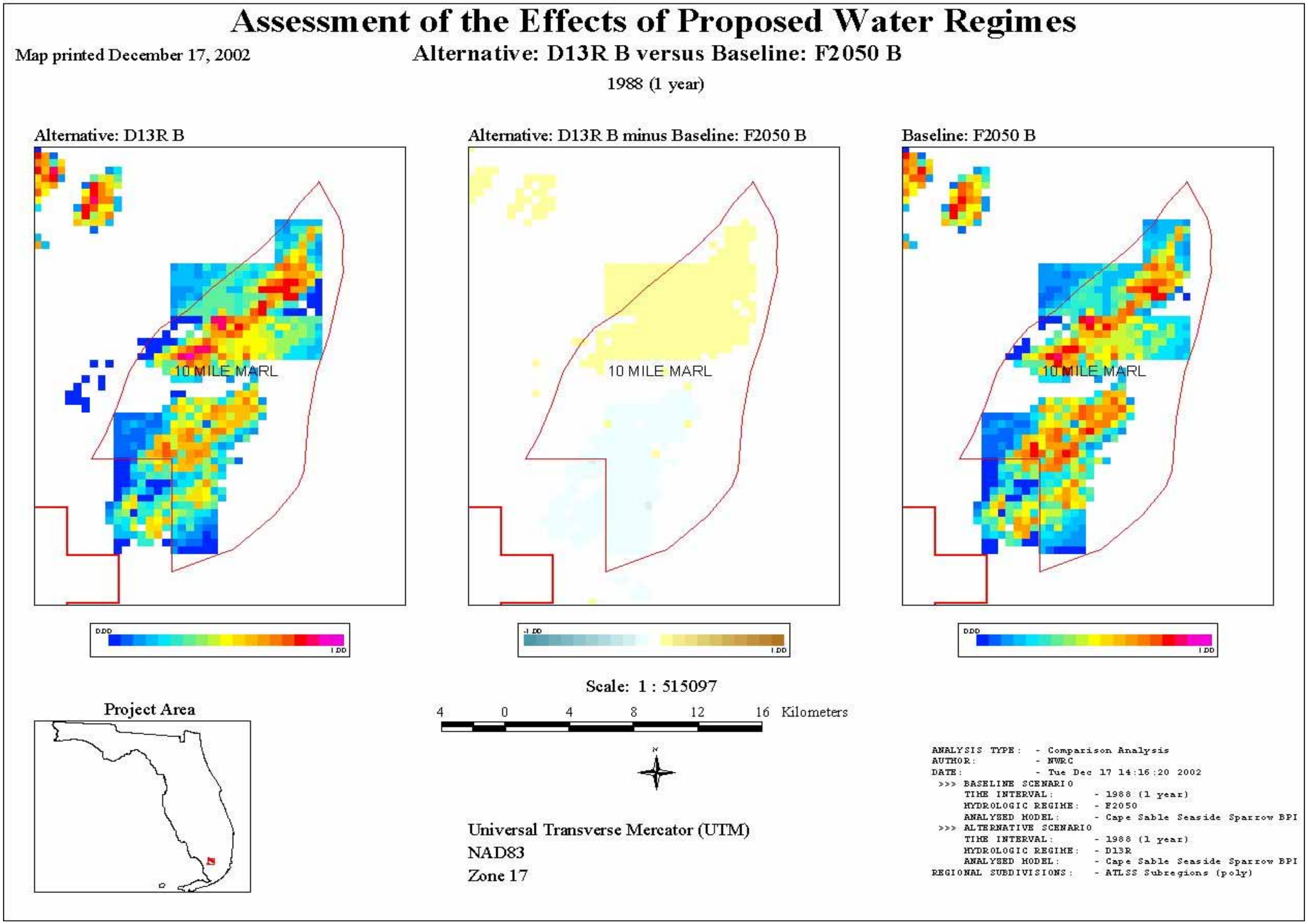
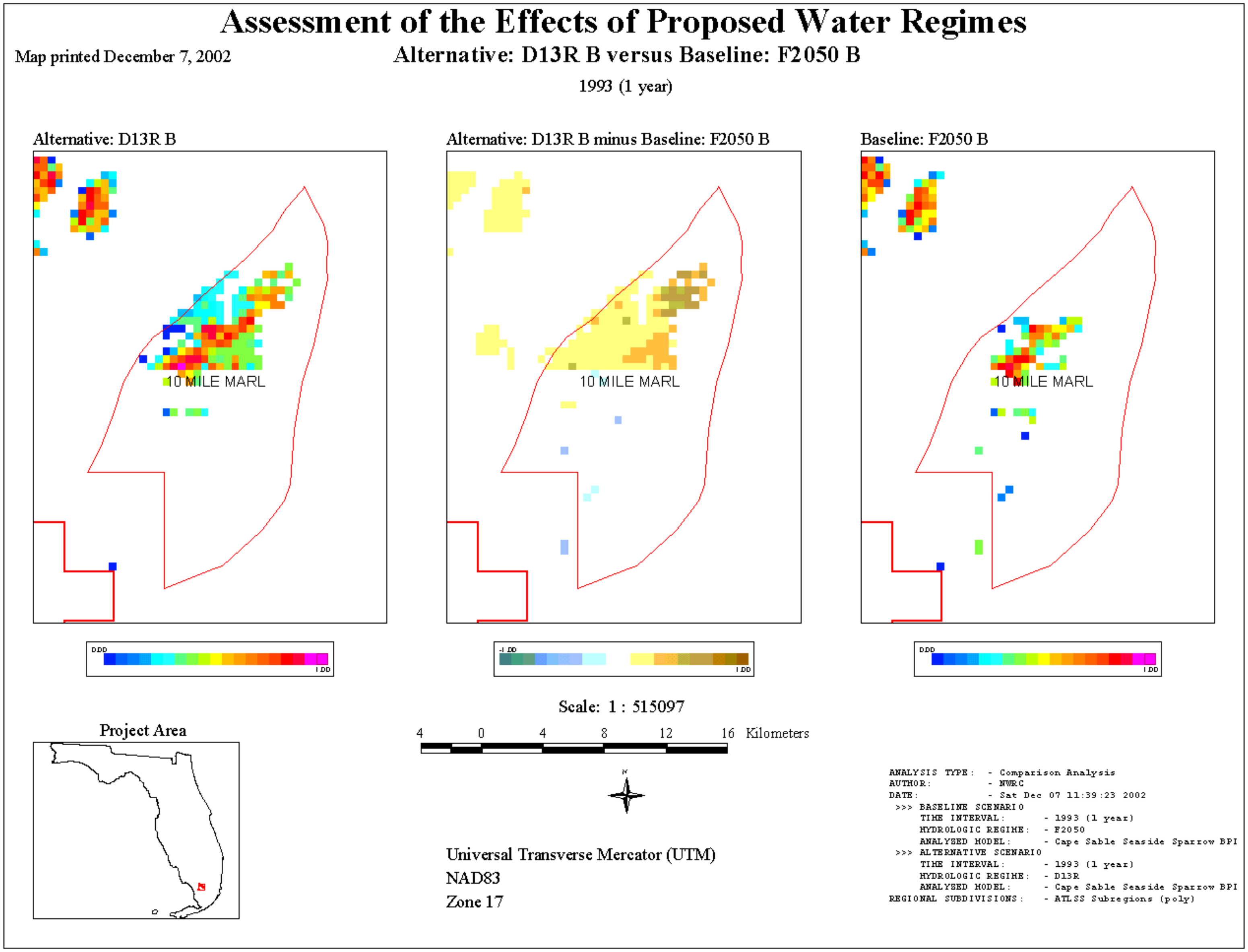
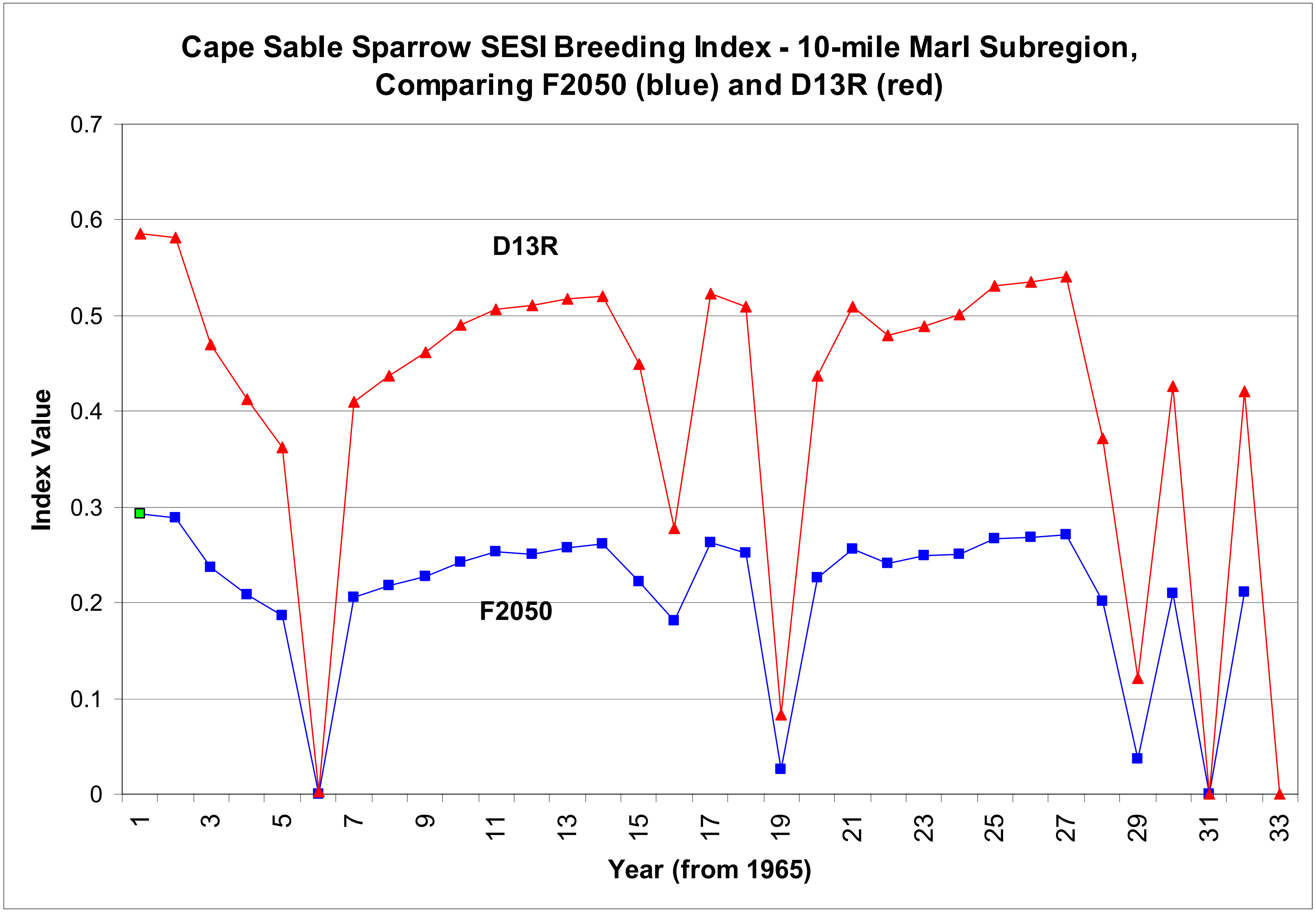
Cape Sable seaside sparrow SESI model output, 10-Mile Marl, 1988: Comparison of F2050 and D13R scenarios, with D13R - F2050 values in the center panel



Cape Sable seaside sparrow SESI model output, 10-Mile Marl, 1993: Comparison of F2050 and D13R scenarios, with D13R - F2050 values in the center panel




Cape Sable Sparrow SESI Breeding Index - 10-mile Marl Subregion,
Comparing F2050 (blue) and D13R (red)
Index Value
Year (from 1965)
D13R
F2050
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1
3
5
7
9
11
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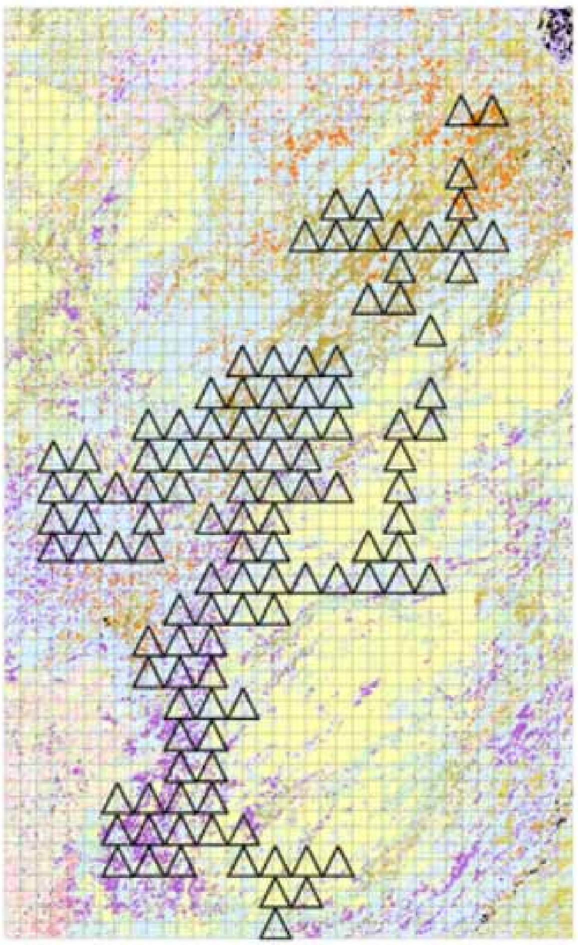
Testing of Model

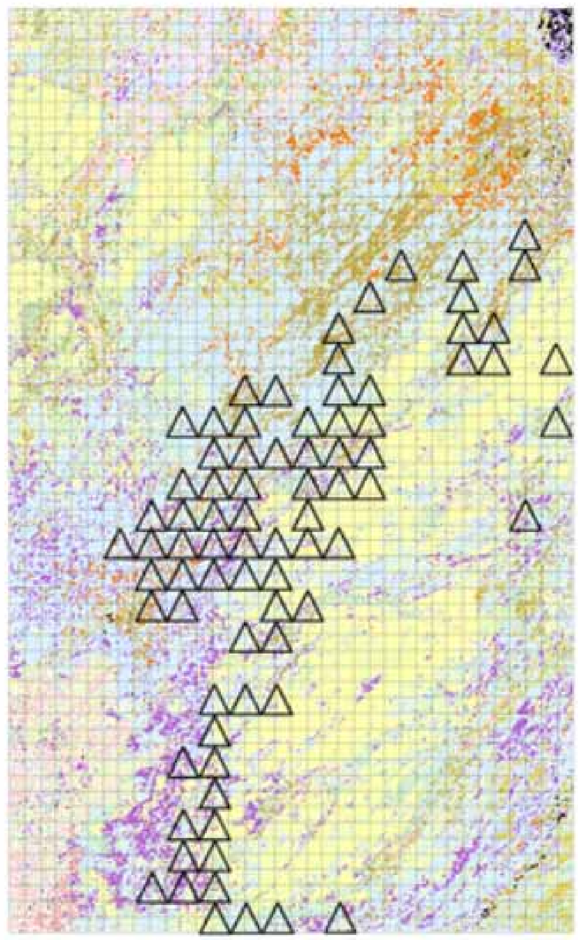
Both sensitivity analysis and preliminary testing of the model area actively being pursued at this time. The next slides show:

- **Output from some of the sensitivity analysis (rotated). Changes in mean value of SESI index in response to changes in mean water depths (to be expanded on later)**
- **Comparisons of SESI index values in Western area (Subpopulation A) and data on singing males for three years. Rigorous testing is awaits SFWMM2000 Calibration/Validation output.**

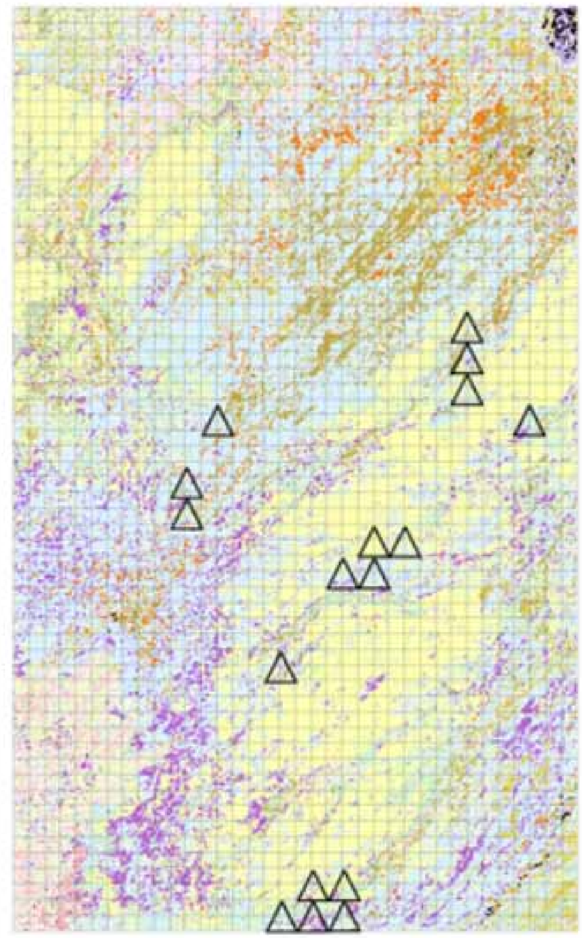
Singing Male Observations - 1981, 1992, 1993



Western Sparrow Breeding Area – 1981

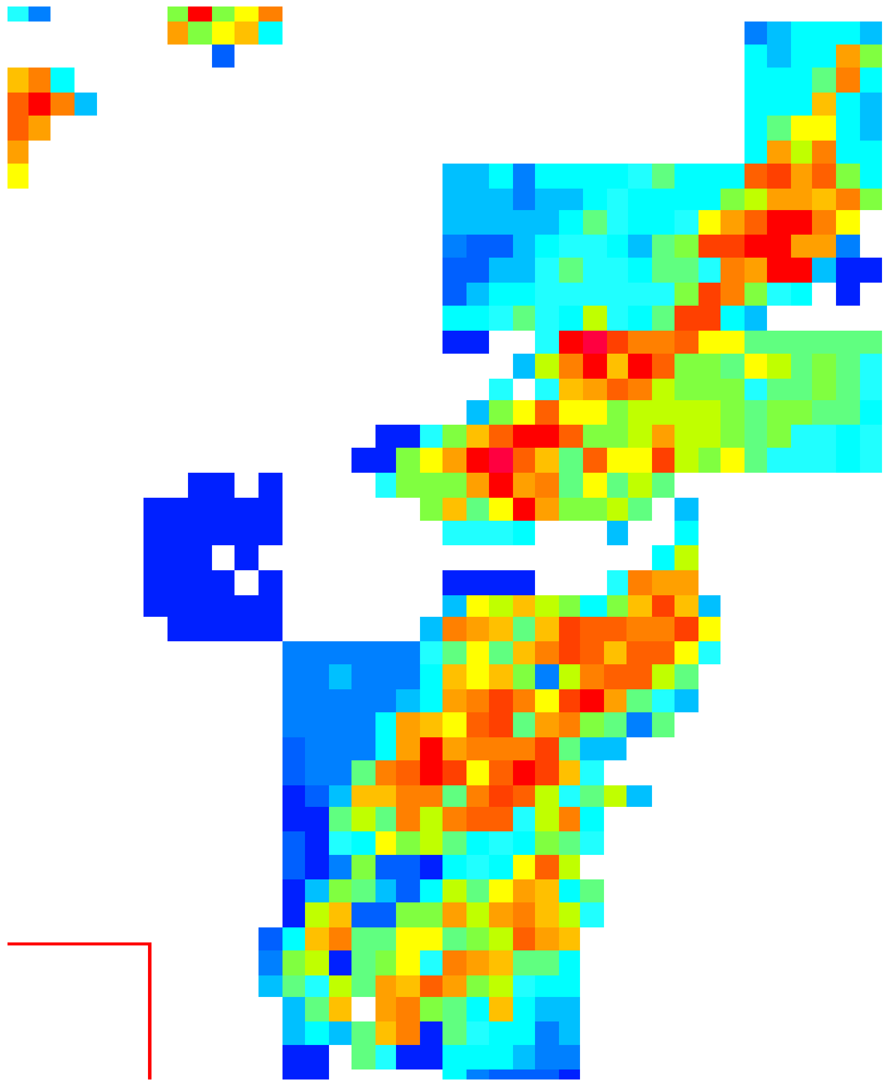


Western Sparrow Breeding Area – 1992



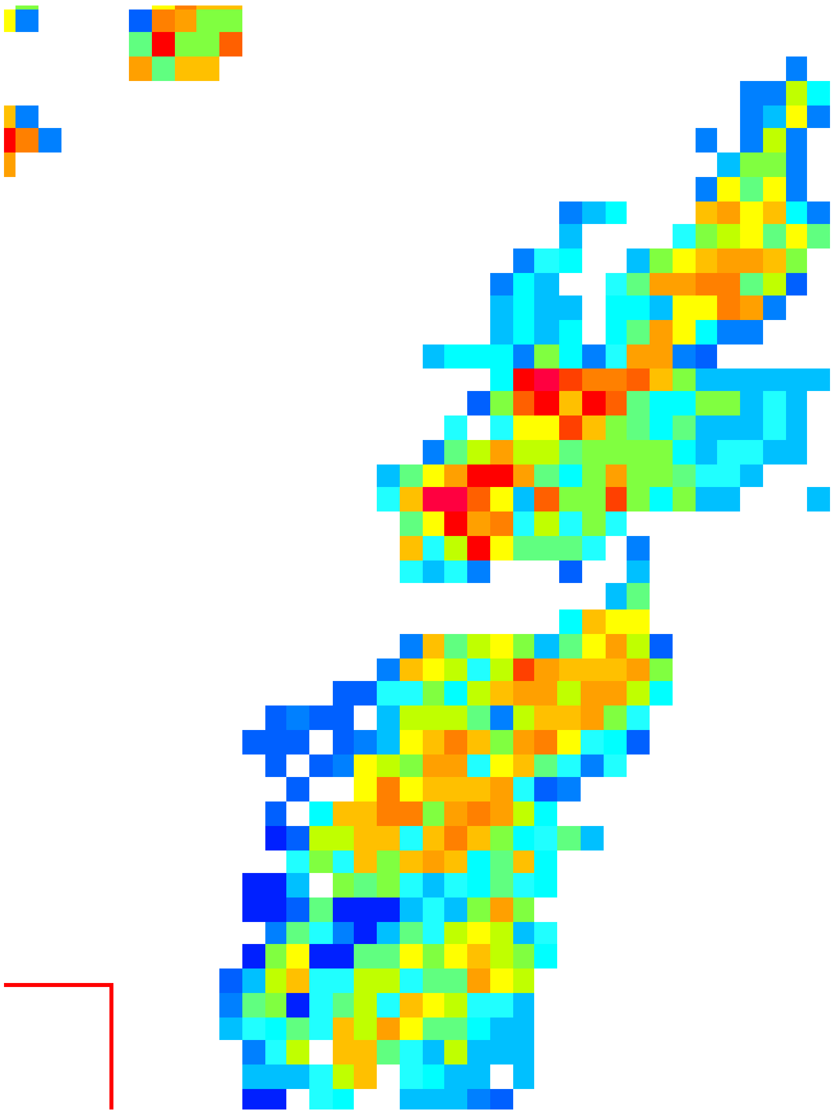
Western Sparrow Breeding Area – 1993

Cape Sable Sparrow SESI Values: 1981



USGS

Cape Sable Sparrow SESI Values: 1992



USGS

Cape Sable Sparrow SESI Values: 1993

There are two other types of spatially explicit population models

Spatially explicit individual-based demographic population models

- Individual-by-individual population dynamics on the landscape

Spatially-explicit demographic models of age- and size-structure of populations or functional groups

- Age- and size-class dynamics on the landscape

Model Type 2: Spatially Explicit Demographic Models

Habitat suitability models indicate differences in habitat suitability, but do not project how the populations in question actually may change.

Demographic models are necessary for that.

•**Cape sable seaside sparrow** individual-based demographic model (SIMSPAR - Version 1.3). Developed by field ecologists: Phil Nott, with Julie Lockwood (See also, Elderd and Nott, *J. of Applied Ecology*, 2007

•**Snail kite** individual-based demographic model (EVERKITE - Version 5.05). Developed by Wolf Mooij, working with Rob Bennetts, snail kite field ecologist

•**American alligator** age-structured demographic model (Version 1.1). Developed by Dan Slone, working with Ken Rice, alligator field ecologist

USGS
science for a changing world

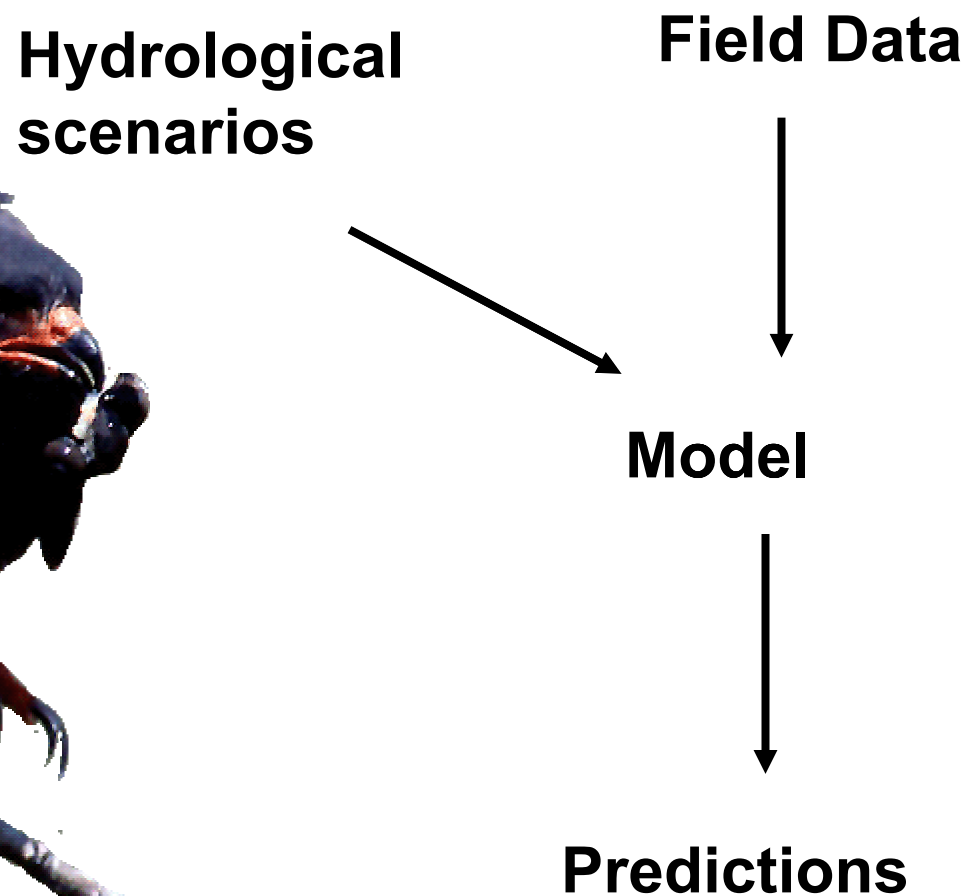
EVERKITE: A spatially explicit individual-based snail kite model

Wolf Mooij (mooij@cl.nioo.knaw.nl)

Netherlands Institute of Ecology, Centre for Limnology

Program website: atlss.org

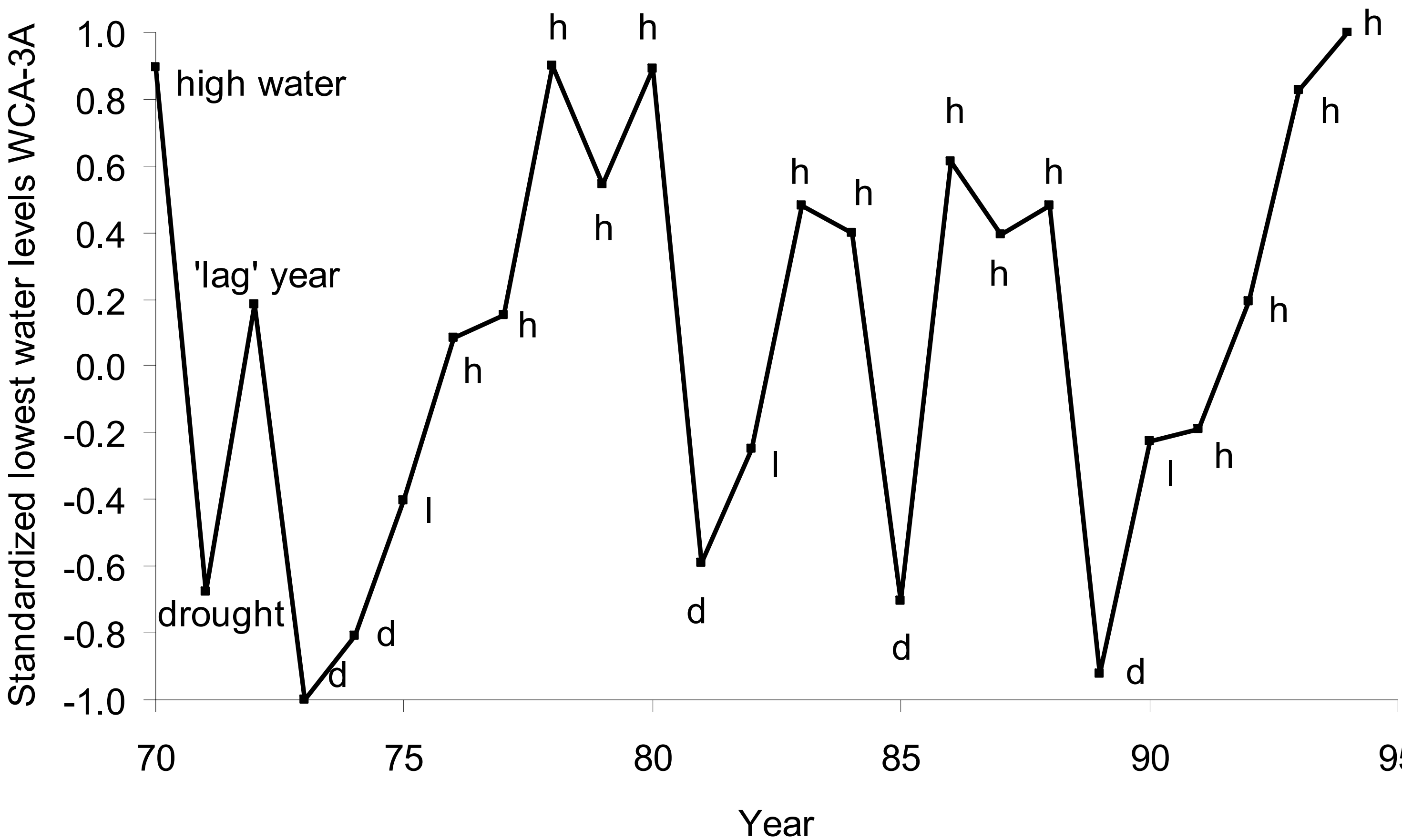
The model incorporates field data on the snail kite to allow examination of its population dynamics under different hydrologic scenarios



Connection with Hydrology

- The specific objective of the model is to predict the response of the snail kite population to different hydrologic scenarios.
- There are year to-year variations in the minimum depths of water in various snail kite breeding areas (see next slide).
- These are known to have an effect on snail kite breeding success, and also on the behavioral response of the snail kite through movement.

Water Level



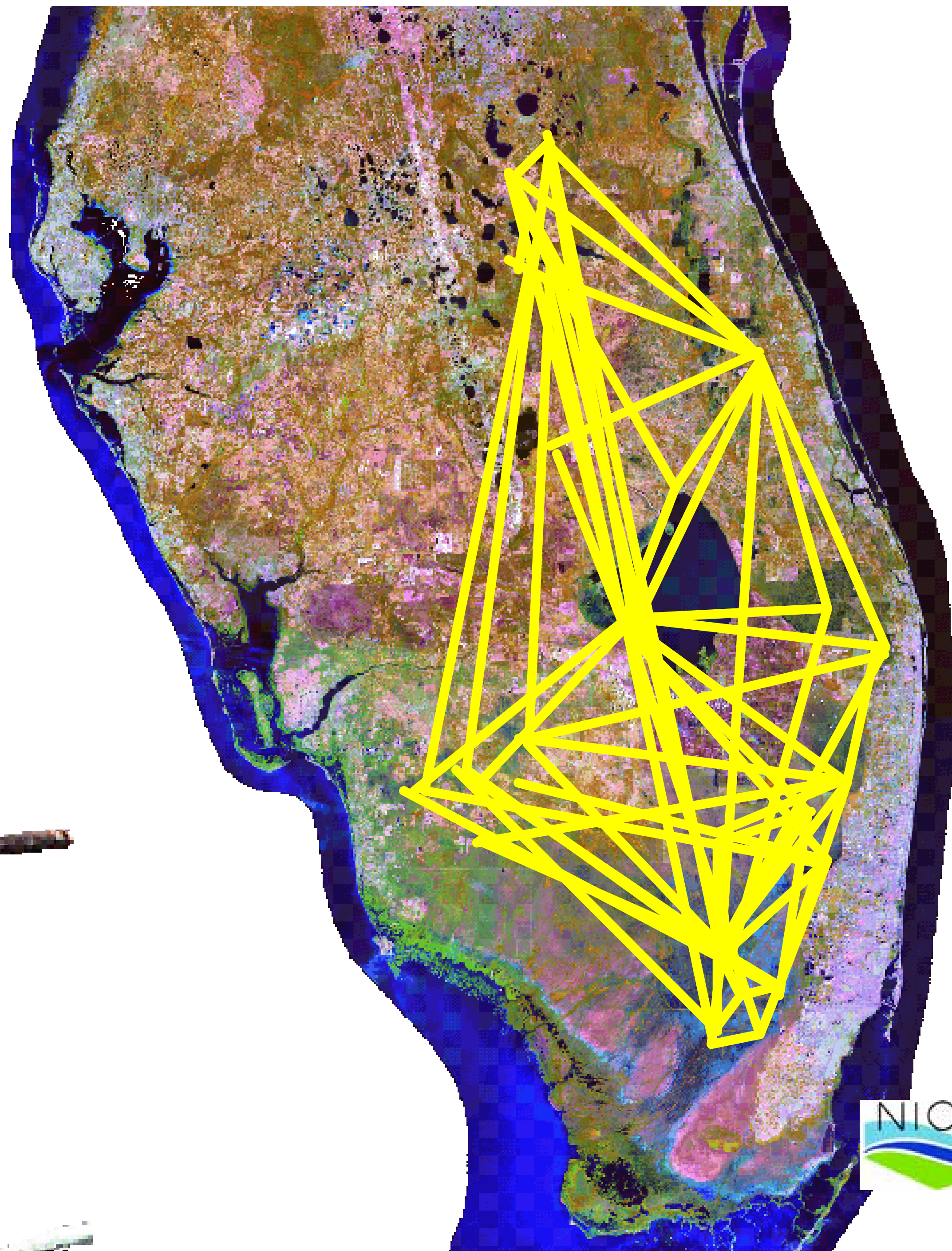
Modified after Beissinger 1995

Behavioral characteristics of snail kite

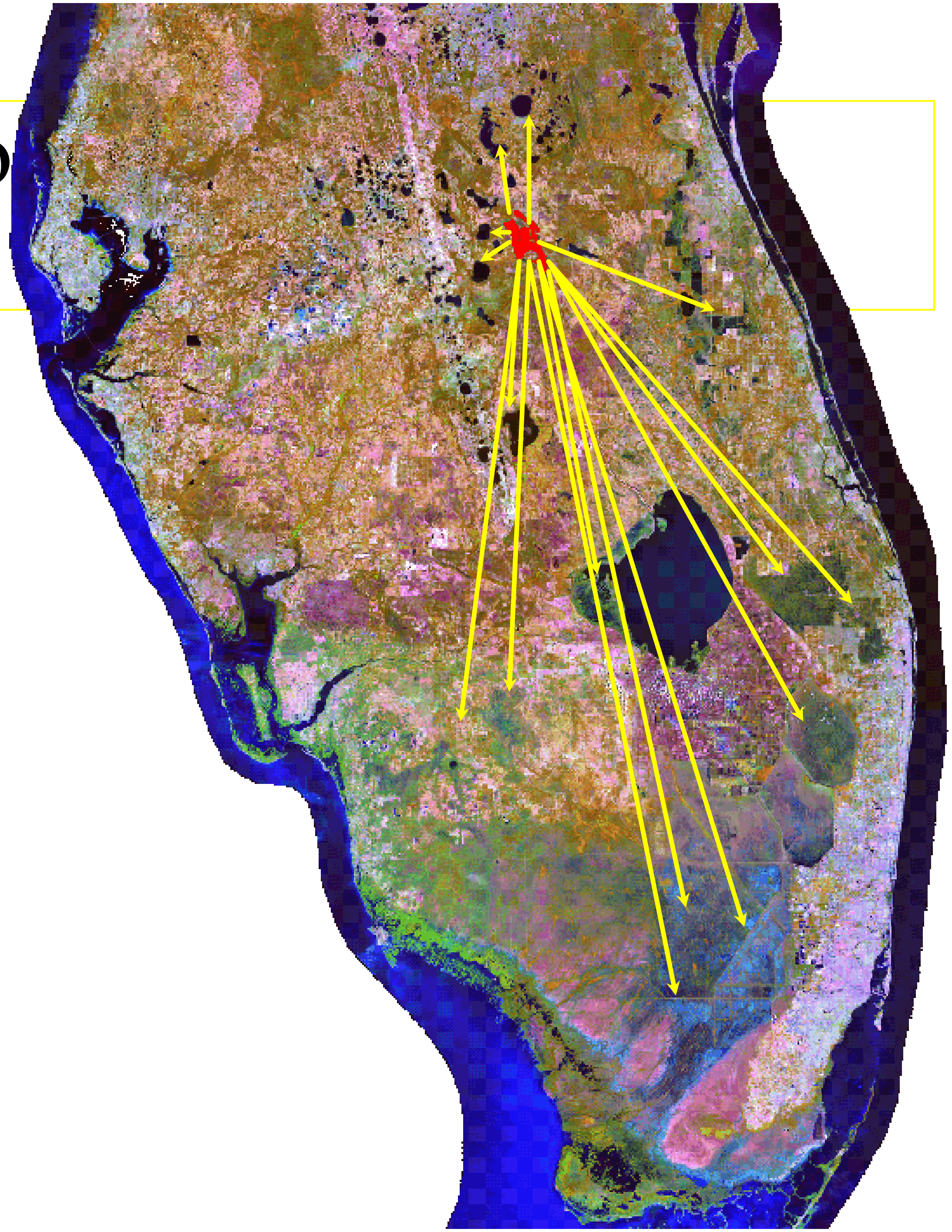
- **The spatial as well as temporal variation in water depths, and hence breeding conditions, is important to snail kite population dynamics, since ...**

- **... snail kites are nomadic and can move frequently on a regional scale.**

- **This allows snail kites to escape locally unfavorable conditions.**



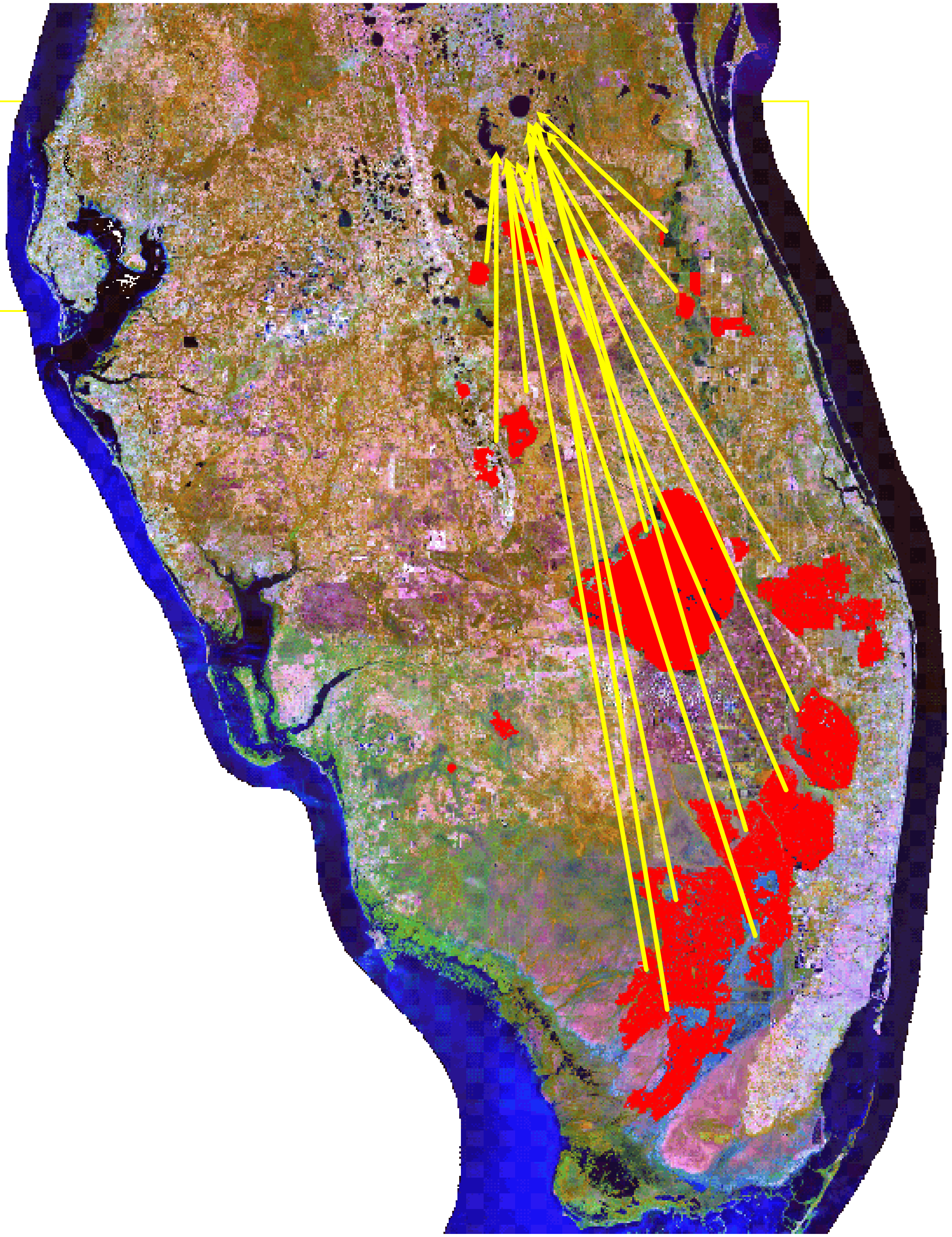
Network o
Wetlands



- Local drying event

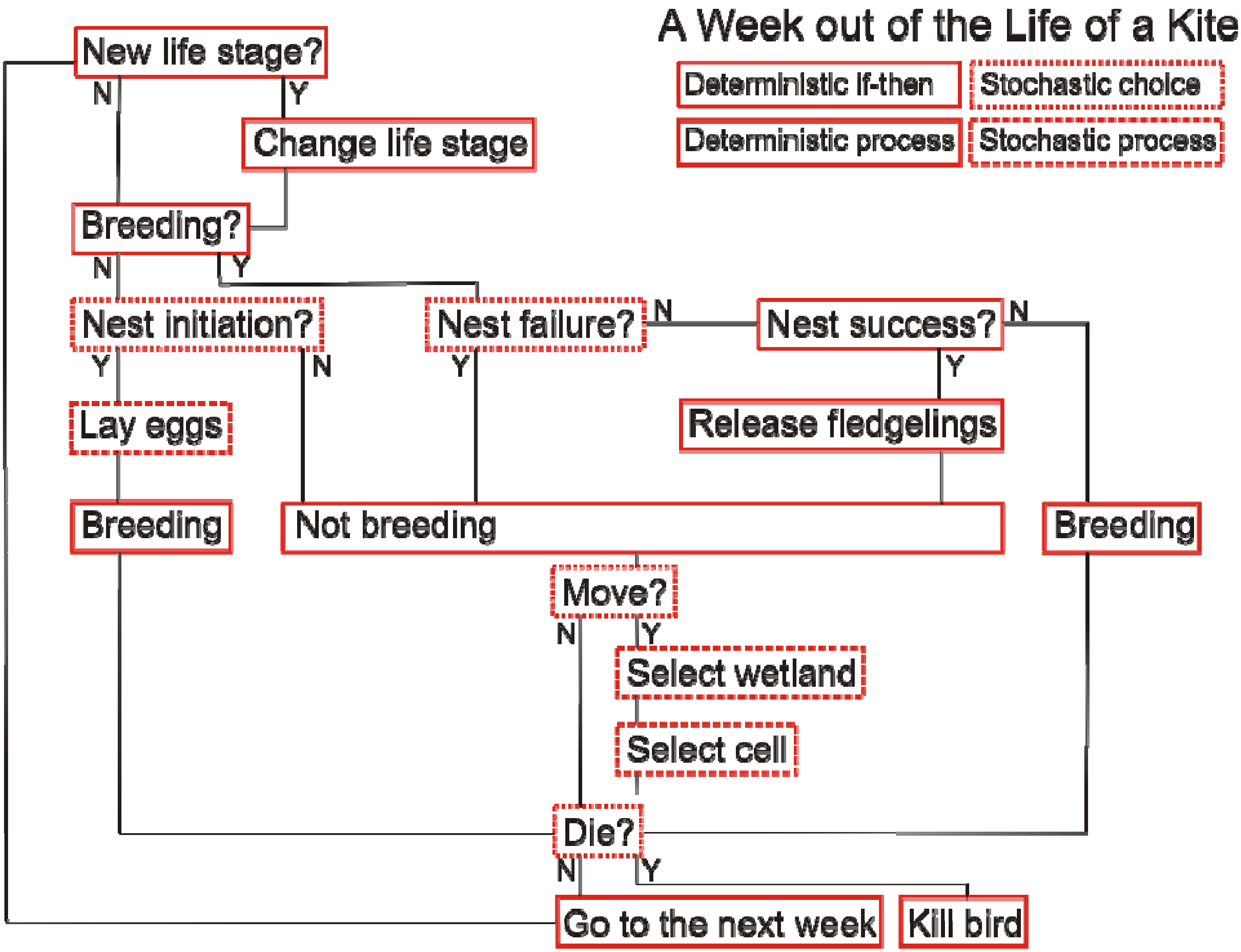
Network of Wetlands

- Widespread drying event



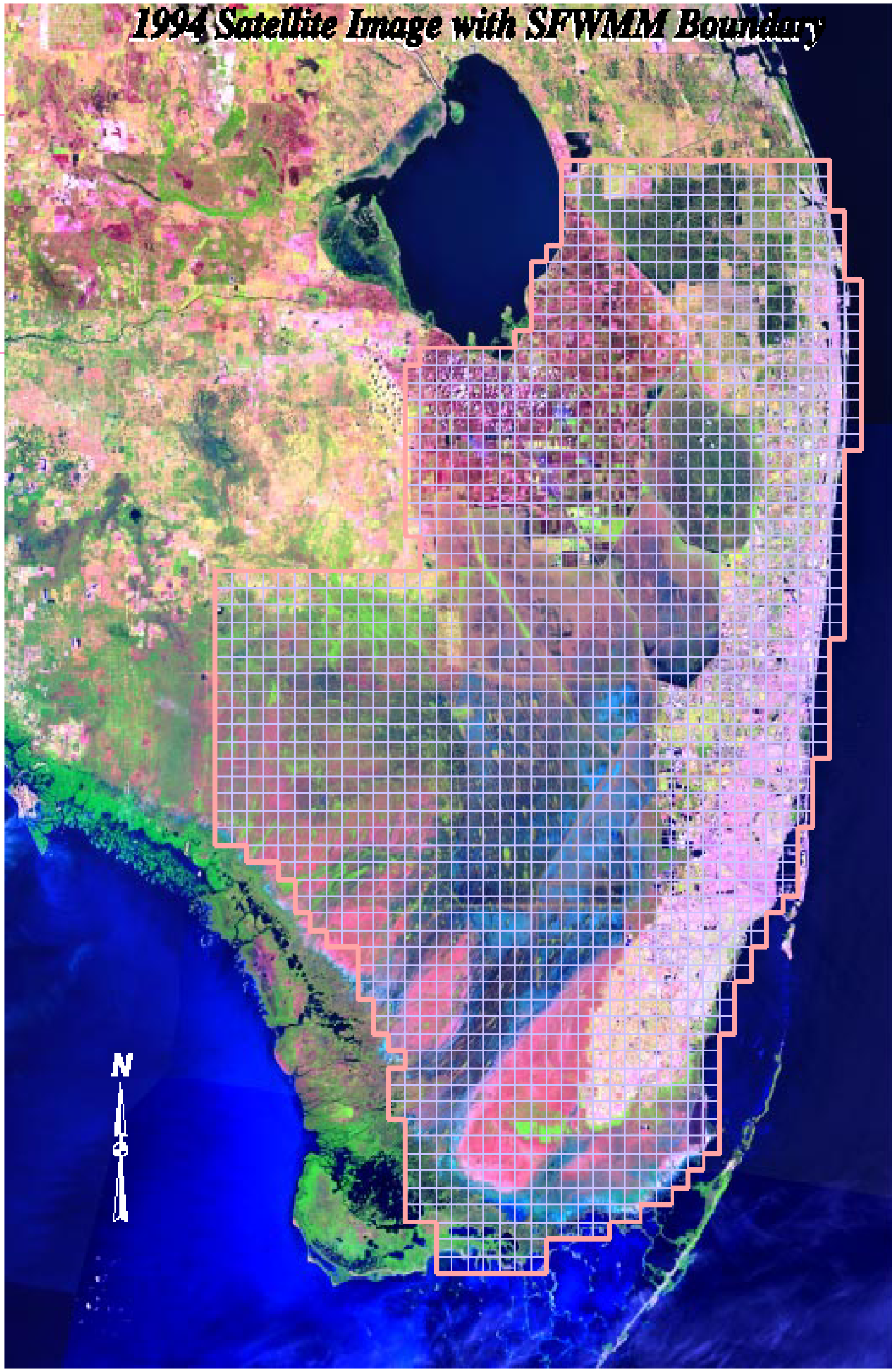
Main Components and Mechanisms of EVERKITE

- Individual-based
- Spatial resolution currently limited to the wetland level (14 wetlands plus peripheral habitat)
- Weekly time steps
- Includes four major processes: aging, breeding, movement and mortality
- Breeding, movement and mortality are modeled in relation to hydrological conditions
- Density dependence currently not included
- Produces all demographic parameters of the kite populations (lambda, densities per wetland, etc).


A Week out of the Life of a Kite
Deterministic if-then
Stochastic choice
Deterministic process
Stochastic process
New life stage?
N
Y
Change life stage
Breeding?
N
Y
Nest initiation?
Y
N
Nest failure?
Y
N
Nest success?
Y
N
Lay eggs
Release fledgelings
Breeding
Not breeding
Breeding
Move?
N
Y
Select wetland
Select cell
Die?
N
Y
Go to the next week
Kill bird

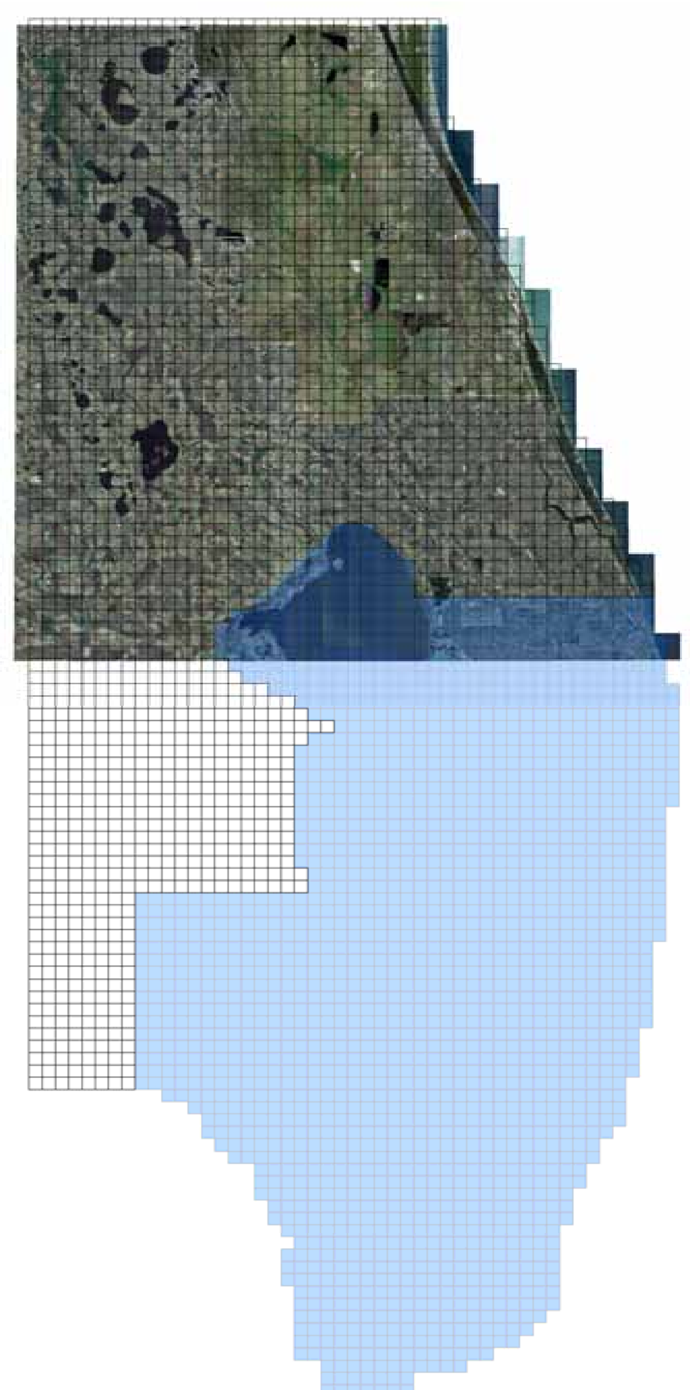
Hydrology

The SFWMM 2 x 2 mile grid is limited to South Florida.



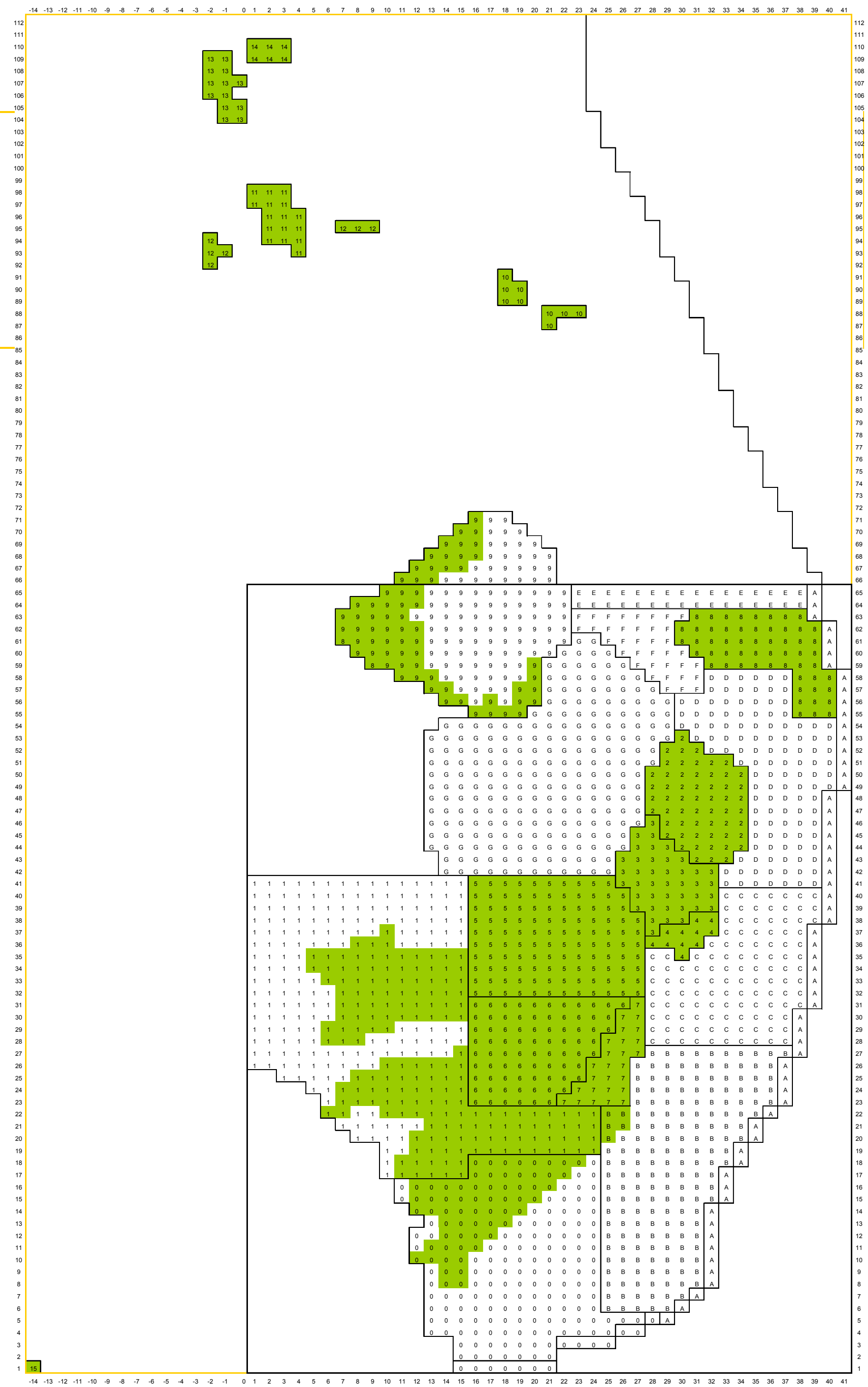
Grid Extension

An extension of the 2 x 2 mile grid has been made to includes Central Florida



Habitat map

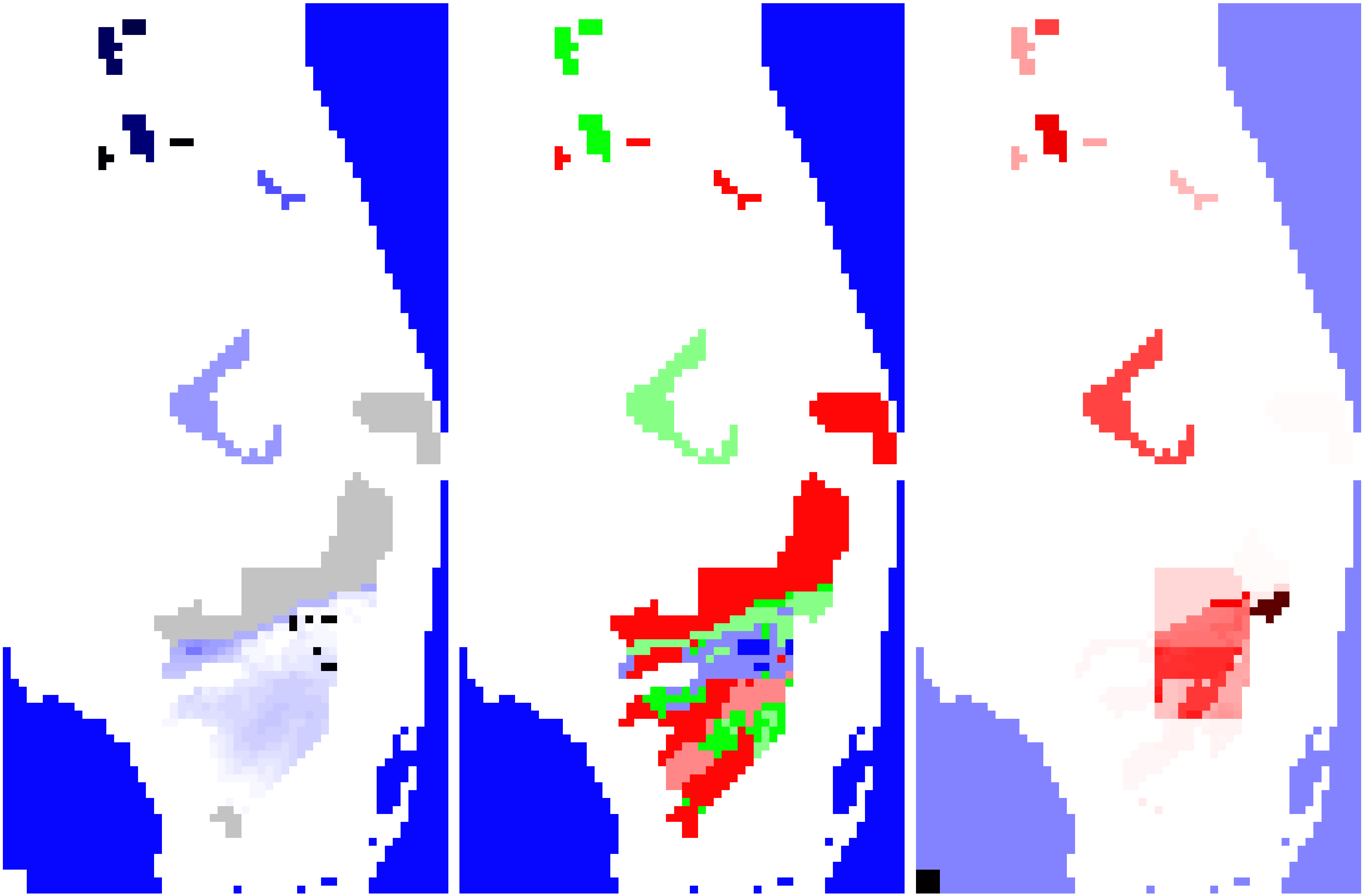
Habitat map
for use in
Everkite 5.05



Preliminary Results CSOP

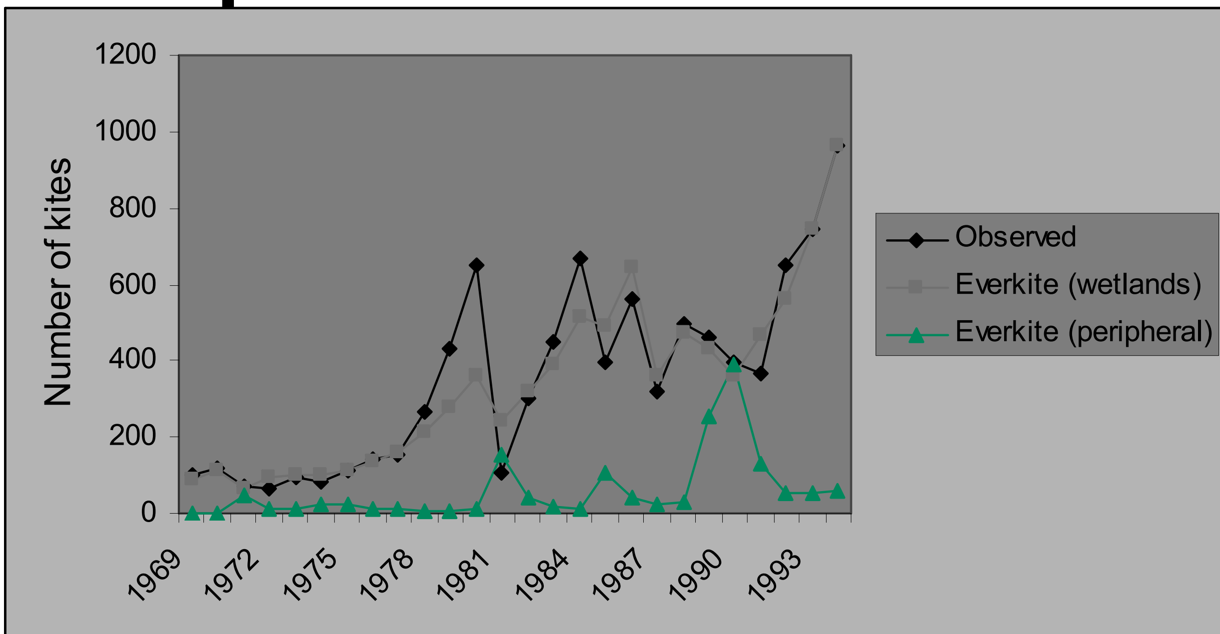
Maps

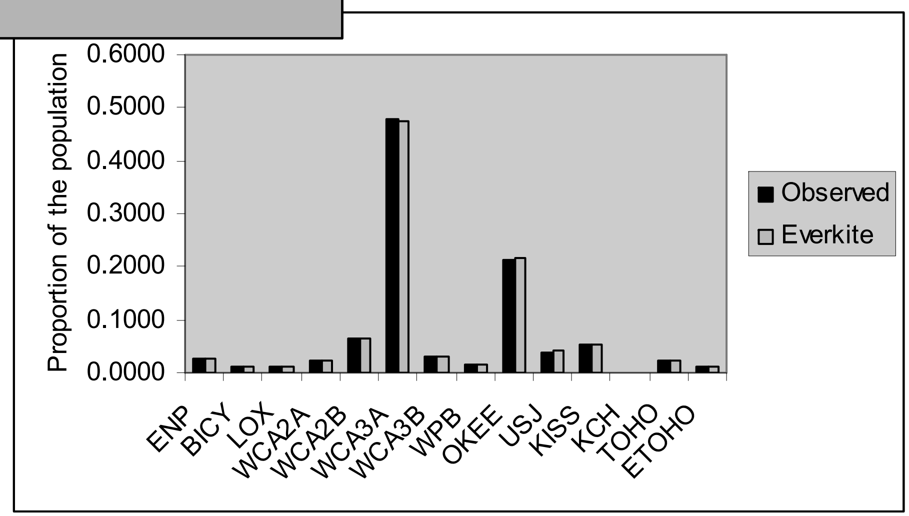
- Stage
- Environmental State
- Distribution of the snail kites



1967 Stage State Kite

EVERKITE provides a very good fit to empirical data





Other ATLSS Modeling Projects

Everglades Small Mammals

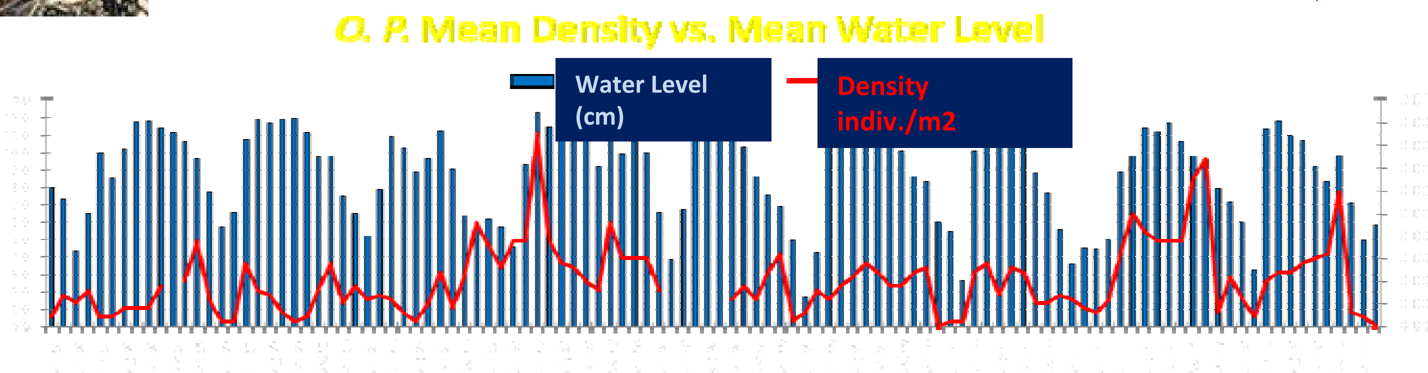
– Gaines, Fernandes, DeAngelis

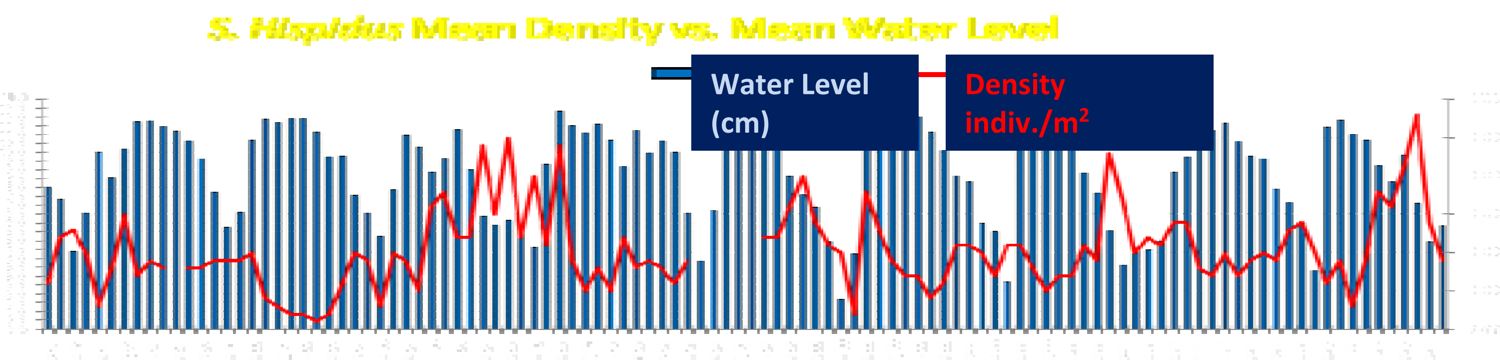
Hispid cotton rat

Marsh rice rat

Small mammal mark-recaptured data collected between February 1994 to December 2005.
16 trees islands.
Rock Reef Pass, Everglades National Park, Homestead FL.

The objective is to develop relationships between density, survival, and fecundity of cotton rats and rice rats and hydrology





ATLSS Small Fish Community Model

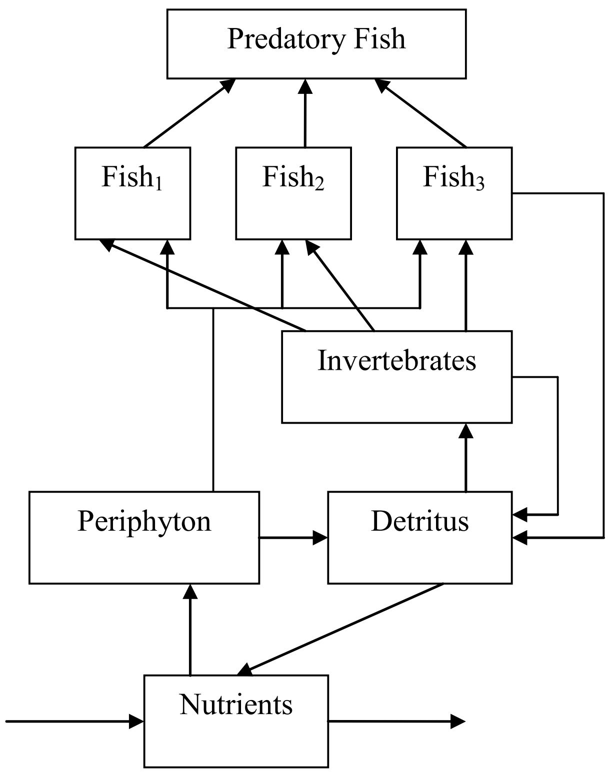
DeAngelis, Trexler, Donalson, Jopp

Purpose:

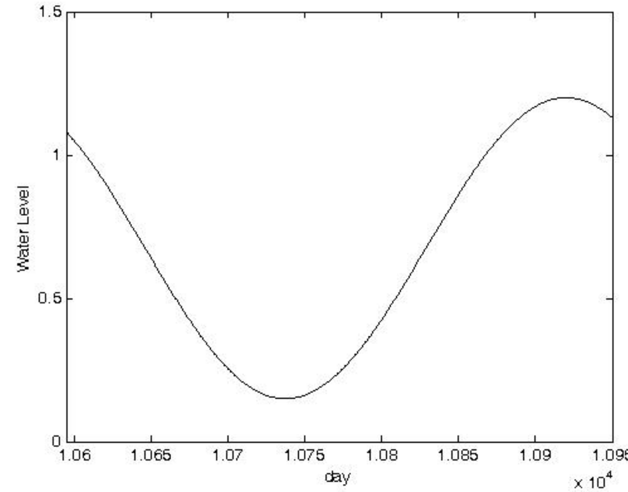
Determine the effects of water level fluctuations and spatial heterogeneity on:

- fish biomass productivity
- small fish standing stock through time
- trophic cascades
- species coexistences

Minimal food web model on a spatial grid with fluctuating water conditions

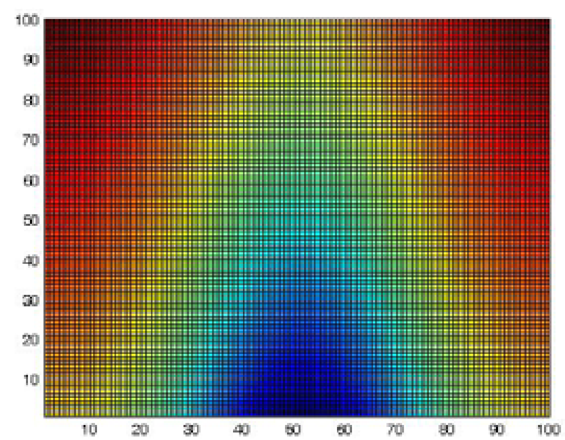


Seasonal water level changes



Spatial grid: 100 x 100

Red = high elevation



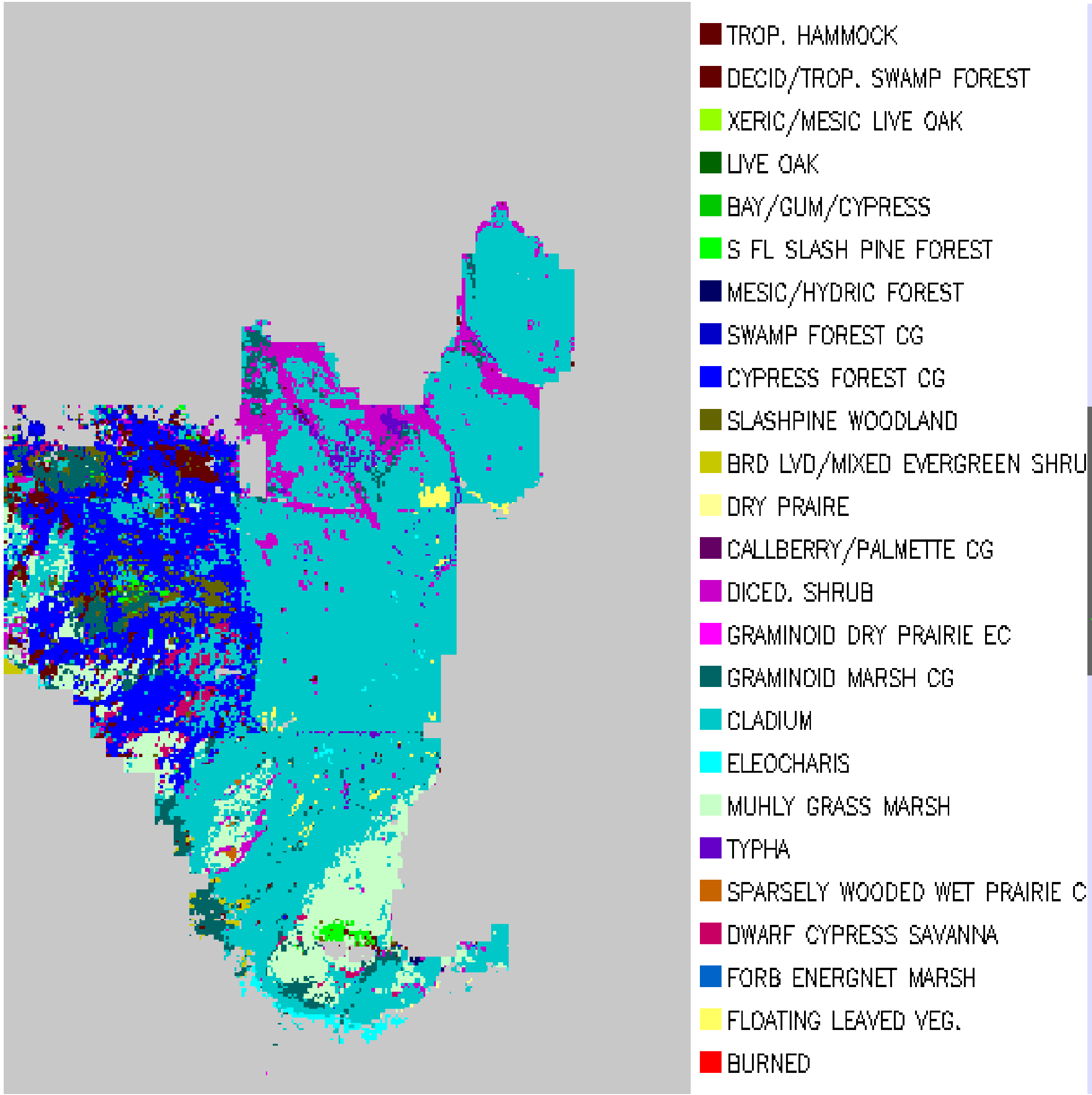
Vegetation Change

Models of allogenic vegetation succession due to

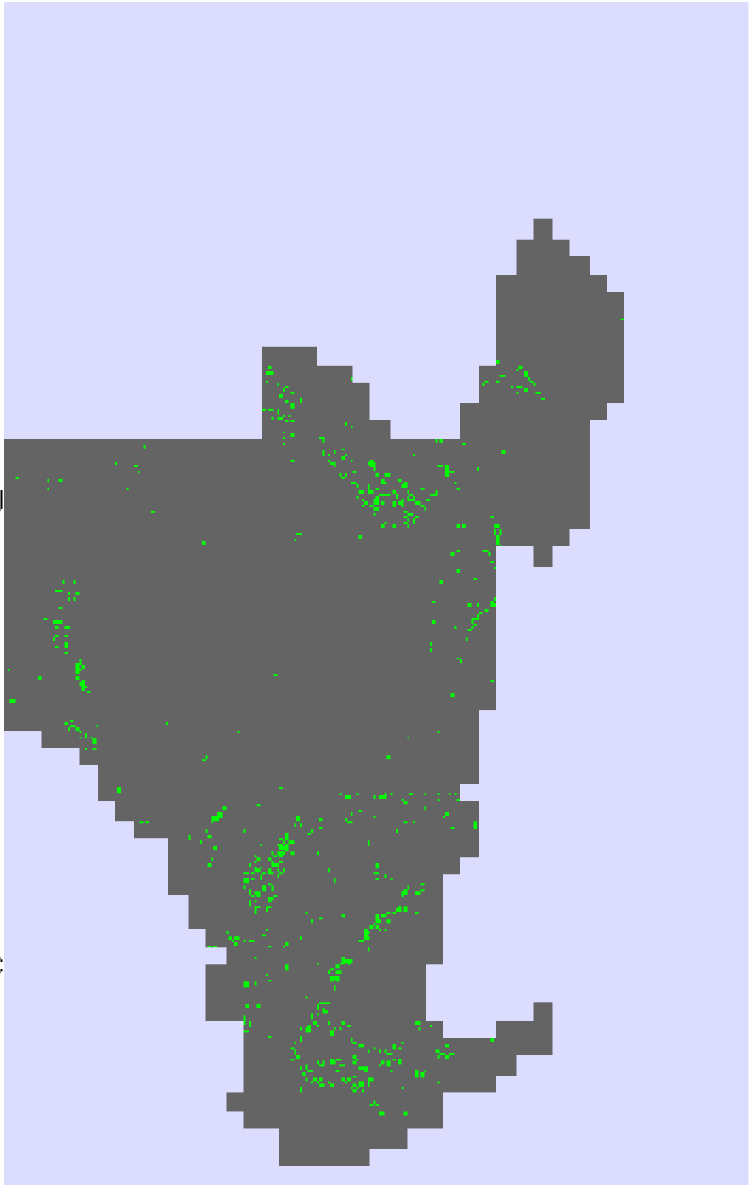
- changes in freshwater hydroperiods
- sea-level rise

Allogenic Succession

1981



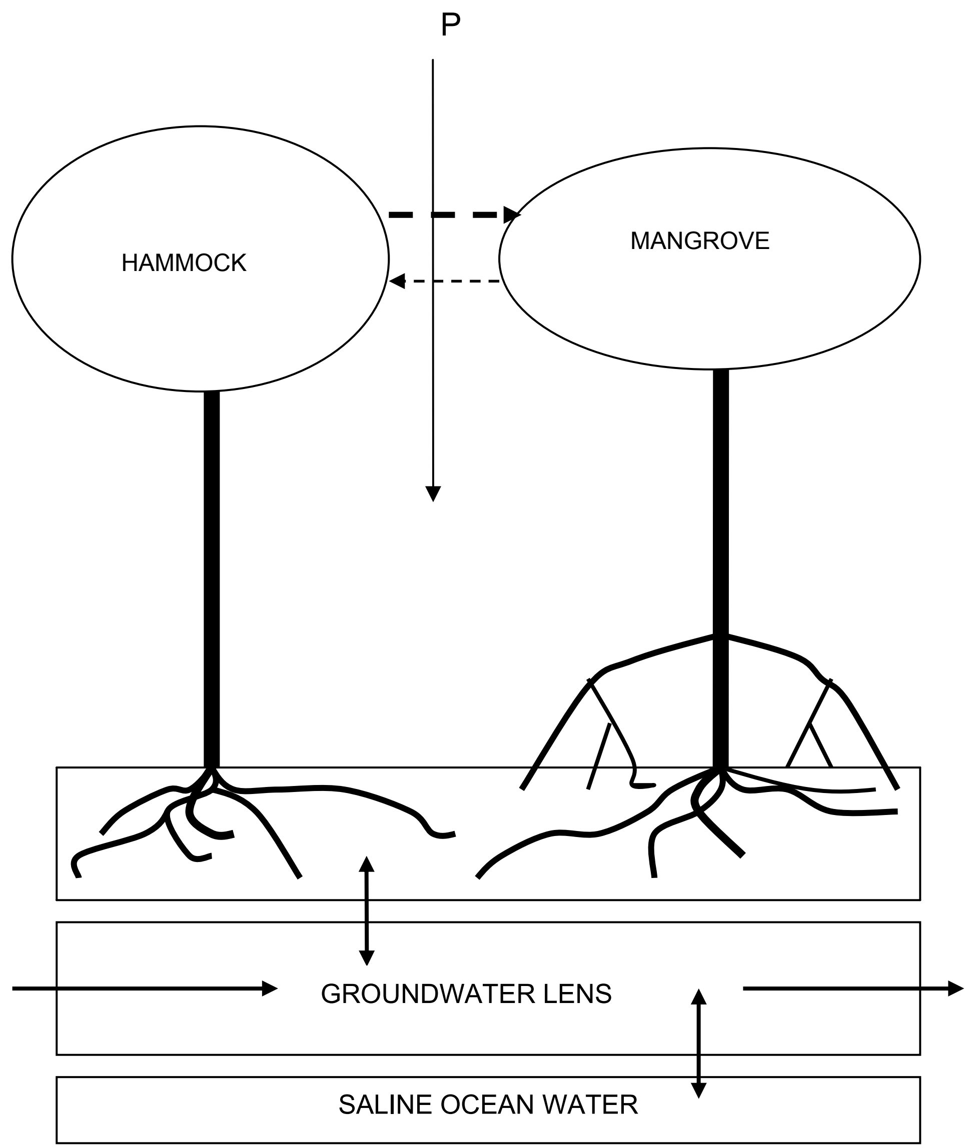
Change from 1980



Vegetation Change:

The Effects of Storm Surge Disturbance Events on the Spatial Interactions Between Hardwood Hammocks and Mangroves in Coastal South Florida:

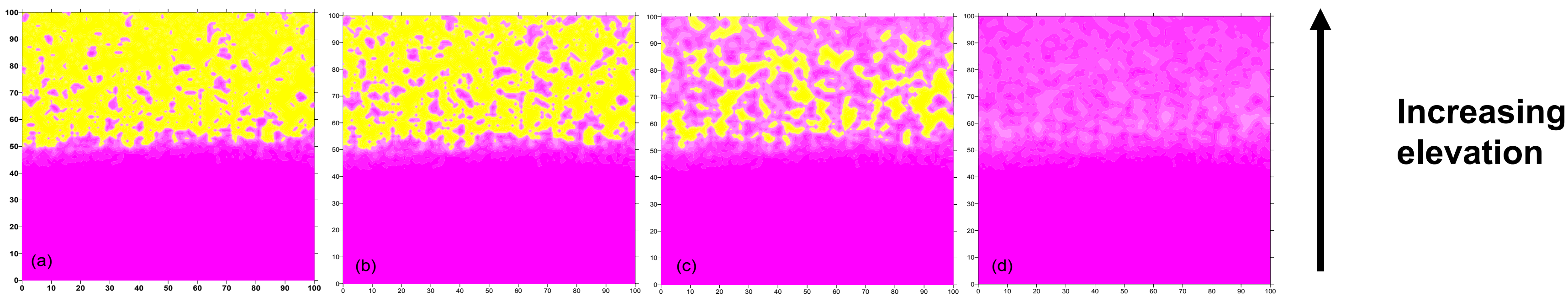
Pulse of salinity from storm surge might change the balance from hammock trees to mangroves over a broad area



Schematic of Hammock-Mangrove Interaction

Model simulation results indicated that a heavy storm surge that completely saturated the vadose zone at 30 ppt for one day could lead to the eventual domination by mangroves of areas previously dominated by hardwood hammocks.

Yellow = hammock   Magenta = mangrove



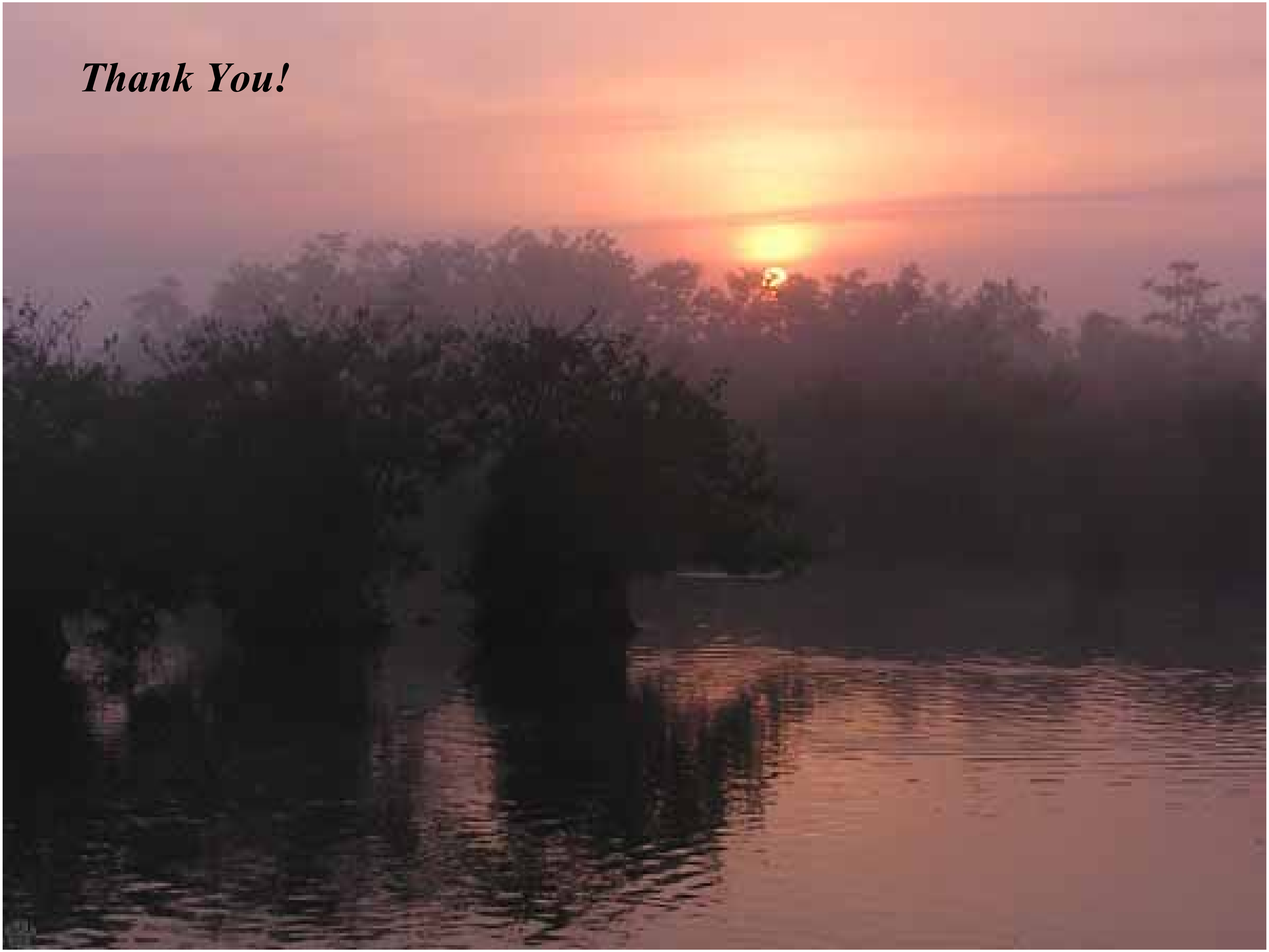
Distribution of mangroves and hammocks at the end of a 50-year simulation

(a) without a storm surge, and subject to storm surges that saturate the vadose zone homogeneously to the following levels of salinity for one day during year 27:

(b) 7.5 ppt,

(c) 15 ppt

(d) 30 ppt.


Thank You!