

Modeling long-term changes, 1958-2011, in the reproduction and territory dynamics of Bald Eagles in Florida Bay, Southern Coastal Everglades



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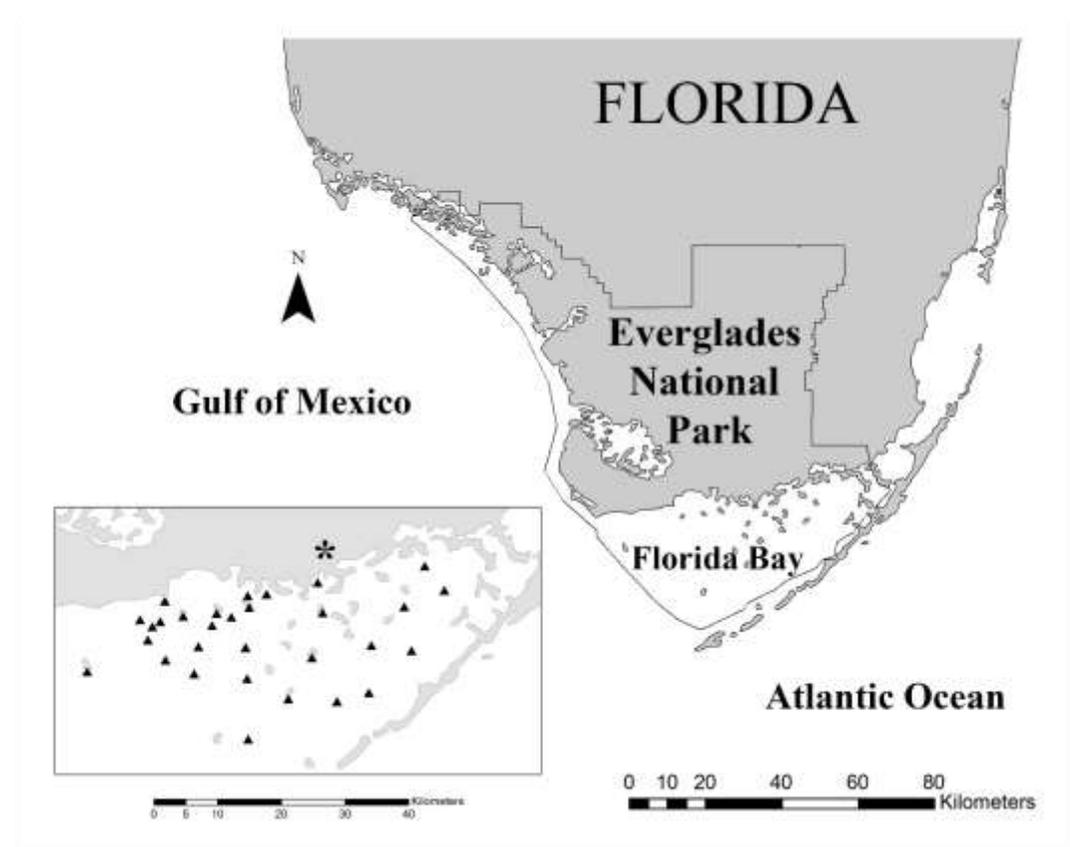
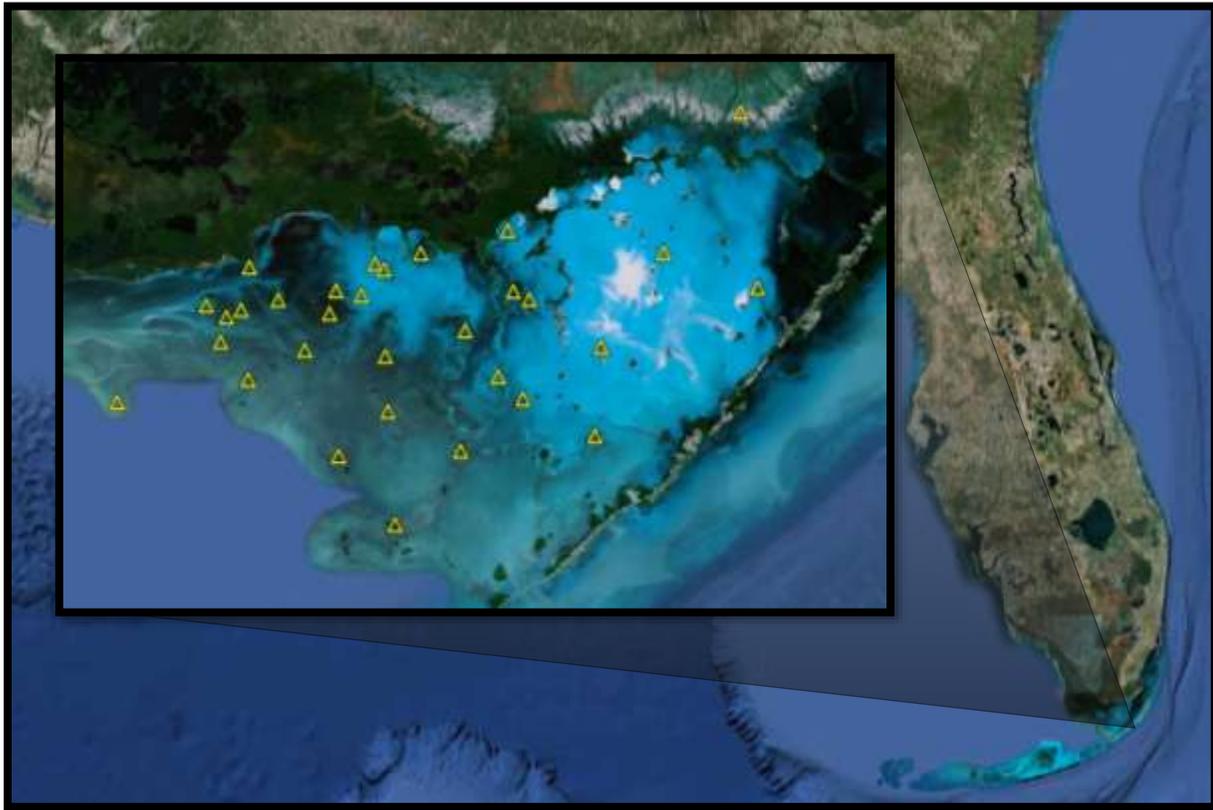
Raptors as candidates for modeling territory dynamics



- Conspicuous
- Mate and Site Fidelity
- Long-lived
- Ecosystem Quality

Study Area – Florida Bay

the previous pair. Individuals come and go, and nest sites change, but eagle nesting terns are virtually forever.











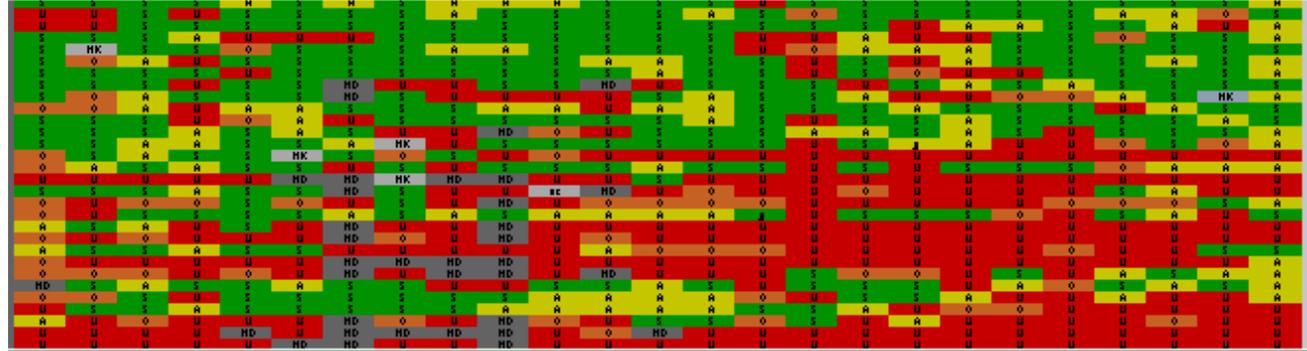
Reproductive Parameters



1958-1961 1962-1965 1966-1969 1970-1973 1974-1977 1978-1981 1982-1985 1986-1989 1990-1993 1994-1997 1998-2001 2002-2005 2006-2009 2010-2013 2014-2017 2018-2021 2022-2025



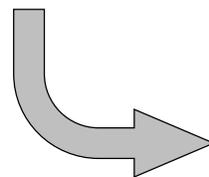
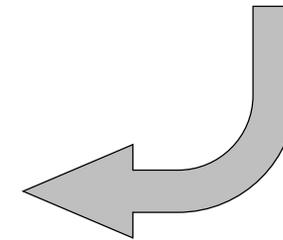
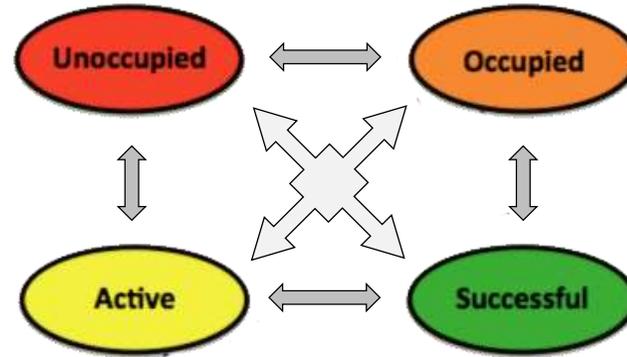
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What is a Markov Chain?

Transition Matrix

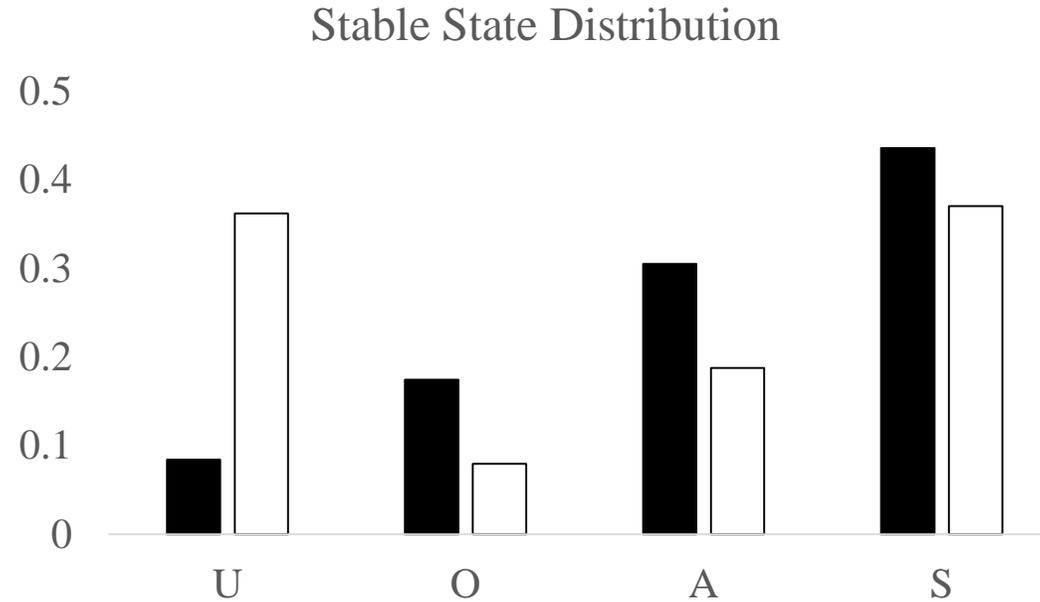
$$t \begin{matrix} & t + 1 \\ \begin{bmatrix} UU & UO & UA & US \\ OU & OO & OA & OS \\ AU & AO & AA & AS \\ SU & SO & SA & SS \end{bmatrix} \end{matrix}$$



Stable State Distribution (SSD)

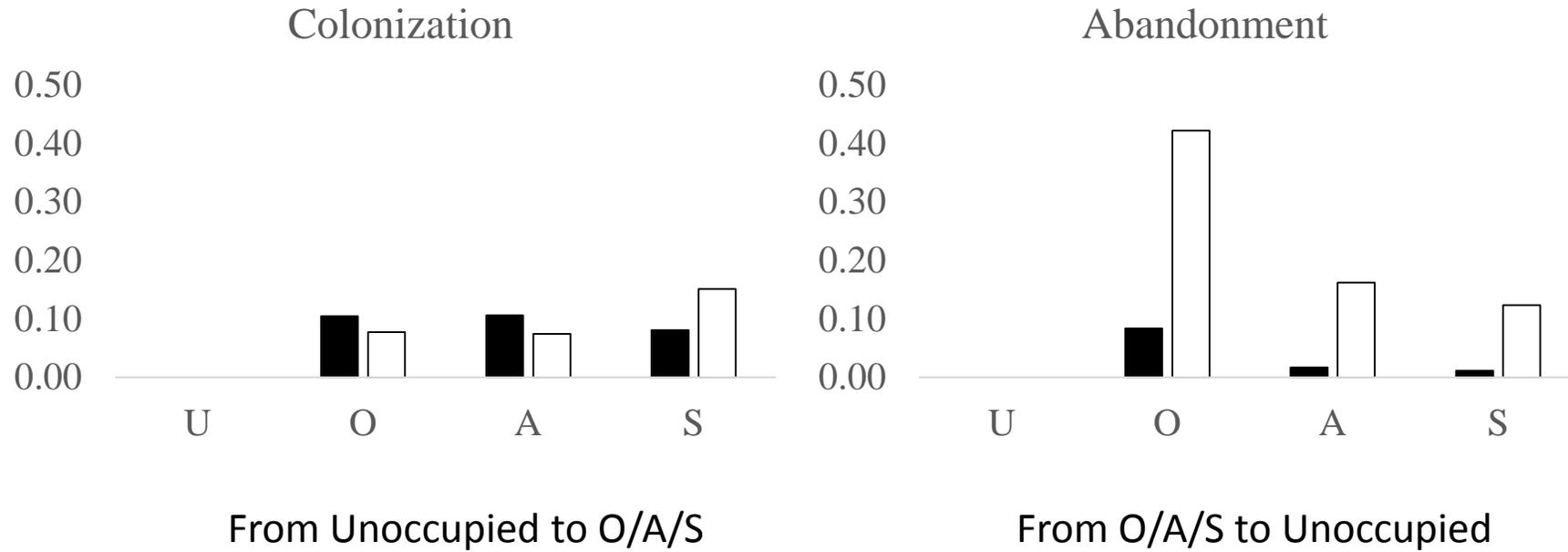
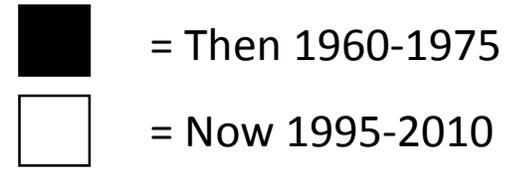
Then vs Now Comparison

■ = Then 1960-1975
□ = Now 1995-2010

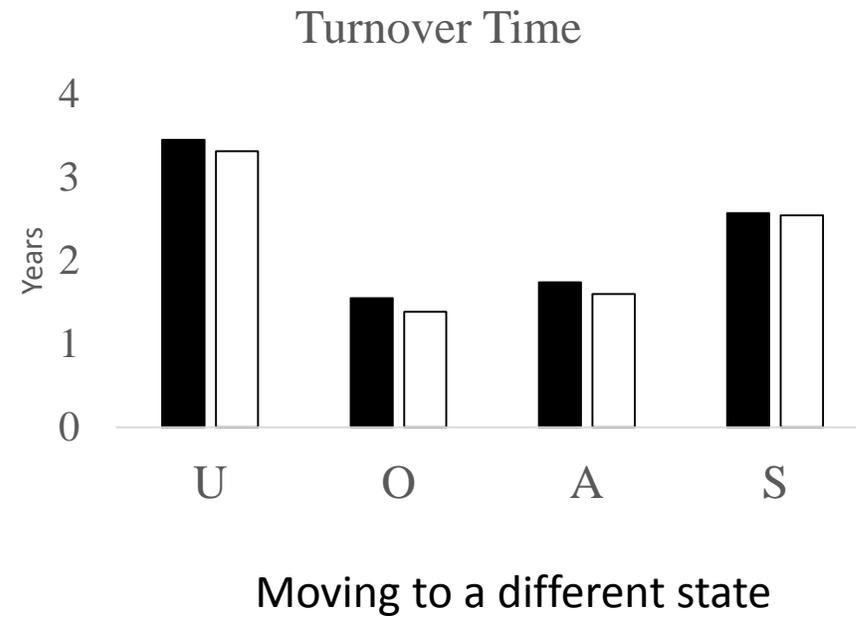
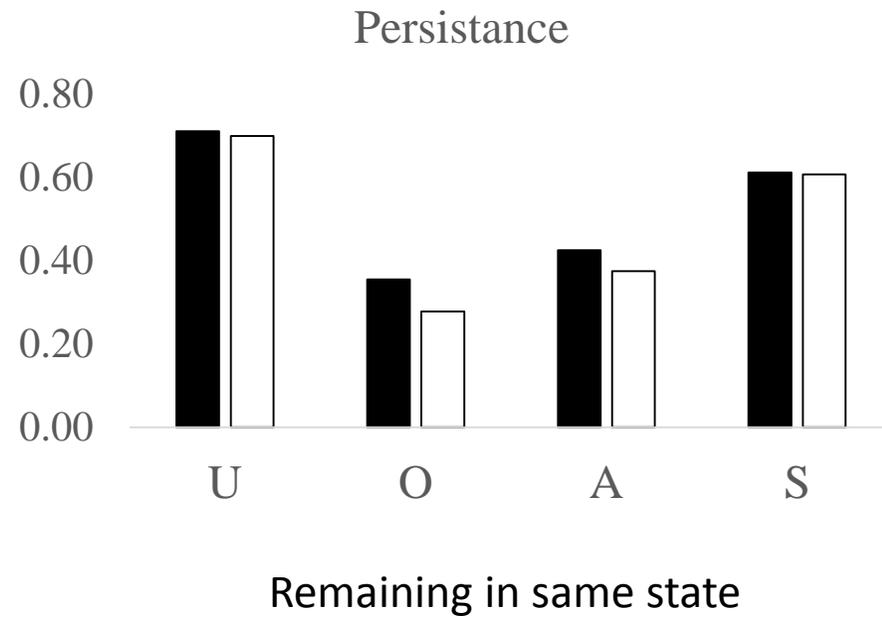
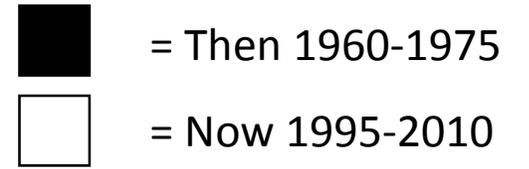


“Then”: 10% Unoccupied, 90% Occupancy
“Now”: 35% Unoccupied, 65% Occupancy

Then vs Now Comparison



Then vs Now Comparison



Sensitivity Analysis

$$t \begin{matrix} & & t + 1 \\ \begin{bmatrix} UU & UO & UA & US \\ OU & OO & OA & OS \\ AU & AO & AA & AS \\ SU & SO & SA & SS \end{bmatrix} \end{matrix}$$

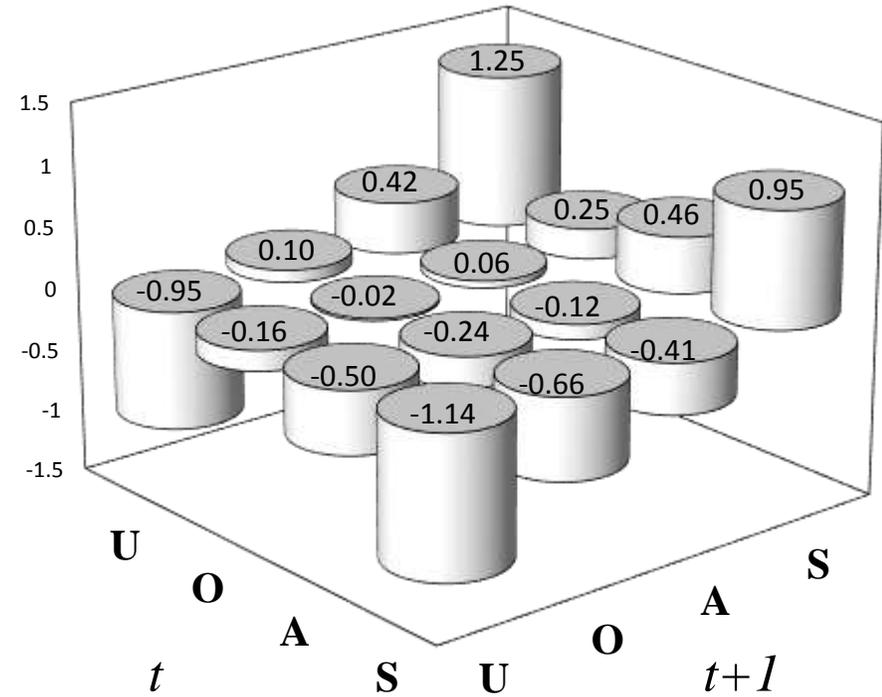
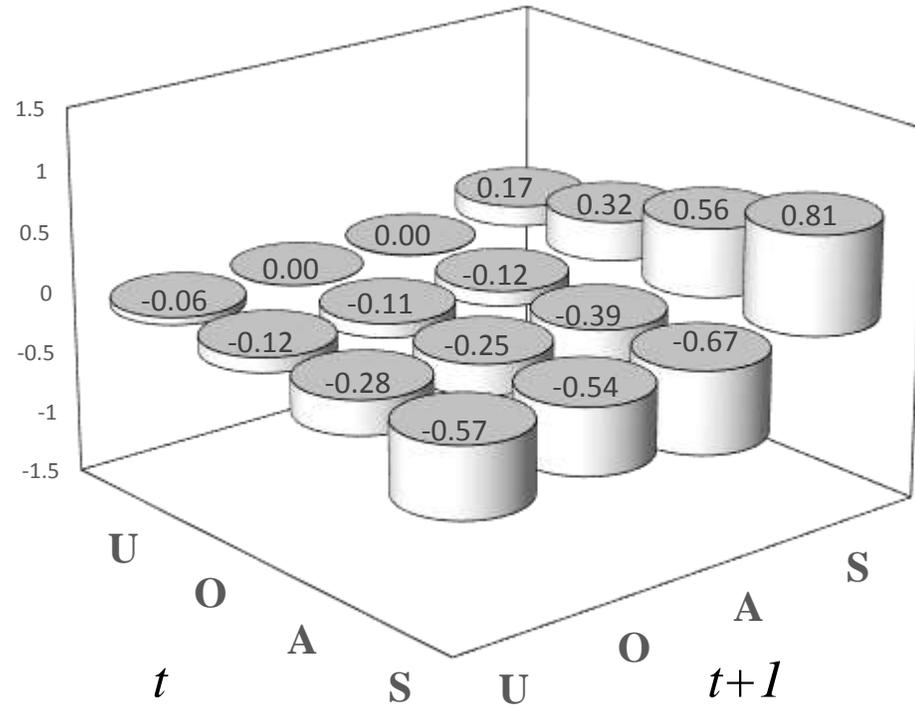
- Change in productivity relative to changes in individual transition elements
- Numerically perturb each element while maintaining the structure of the transition matrix
- Slopes/rate of change
- Sensitivities >1, greater effect
- Sensitivities <1, weaker effect



Sensitivity Analysis

■ = Then 1960-1975

□ = Now 1995-2010

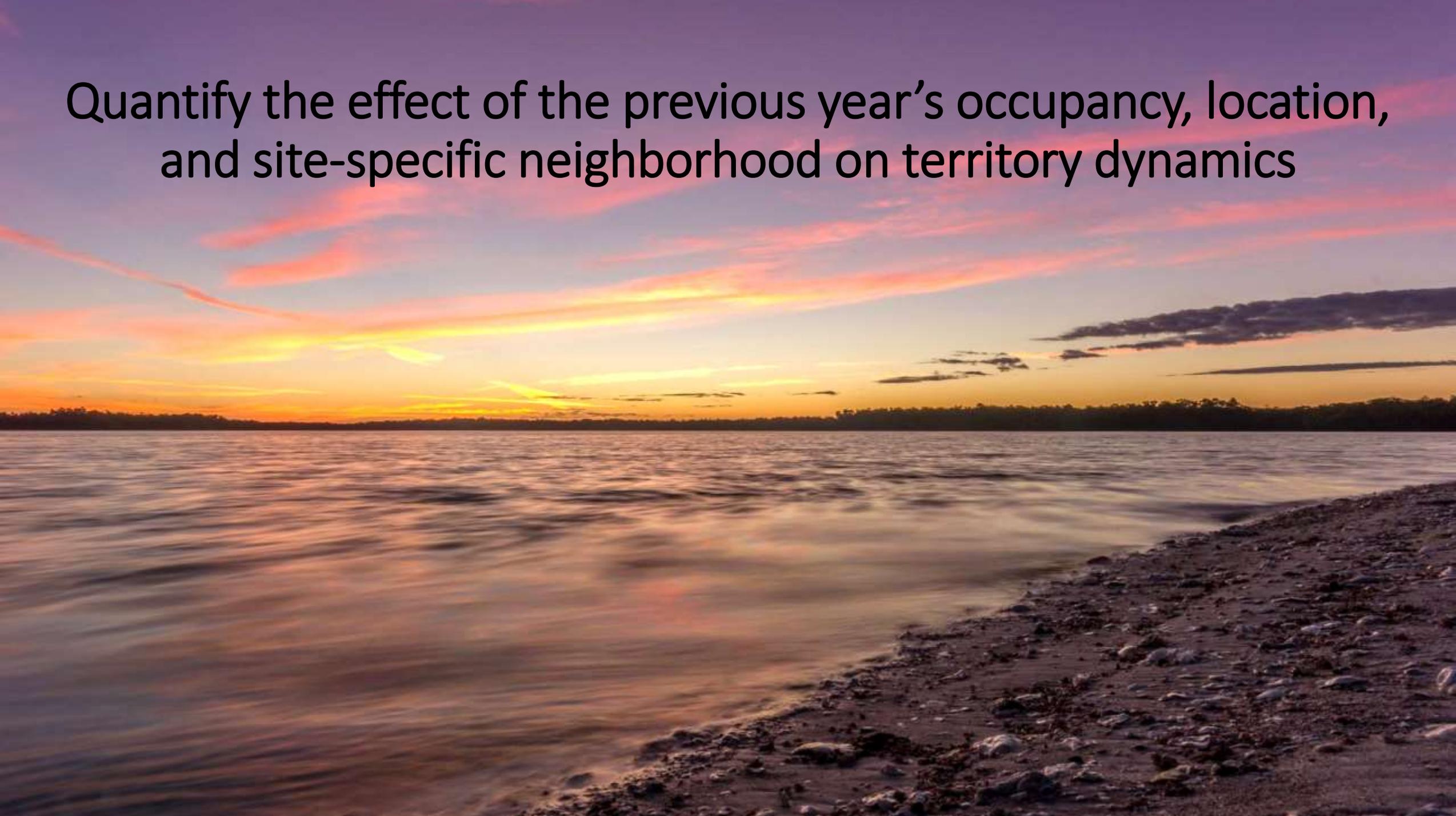


Multistate Markov Chain

- Yearly transition matrix for each territory
- Short and long-term probabilities
- Failure to breed vs breeding failure
- Fewer transitions, longer vacancy periods
- Key transitions relative to proportion of Successful territories



Quantify the effect of the previous year's occupancy, location, and site-specific neighborhood on territory dynamics



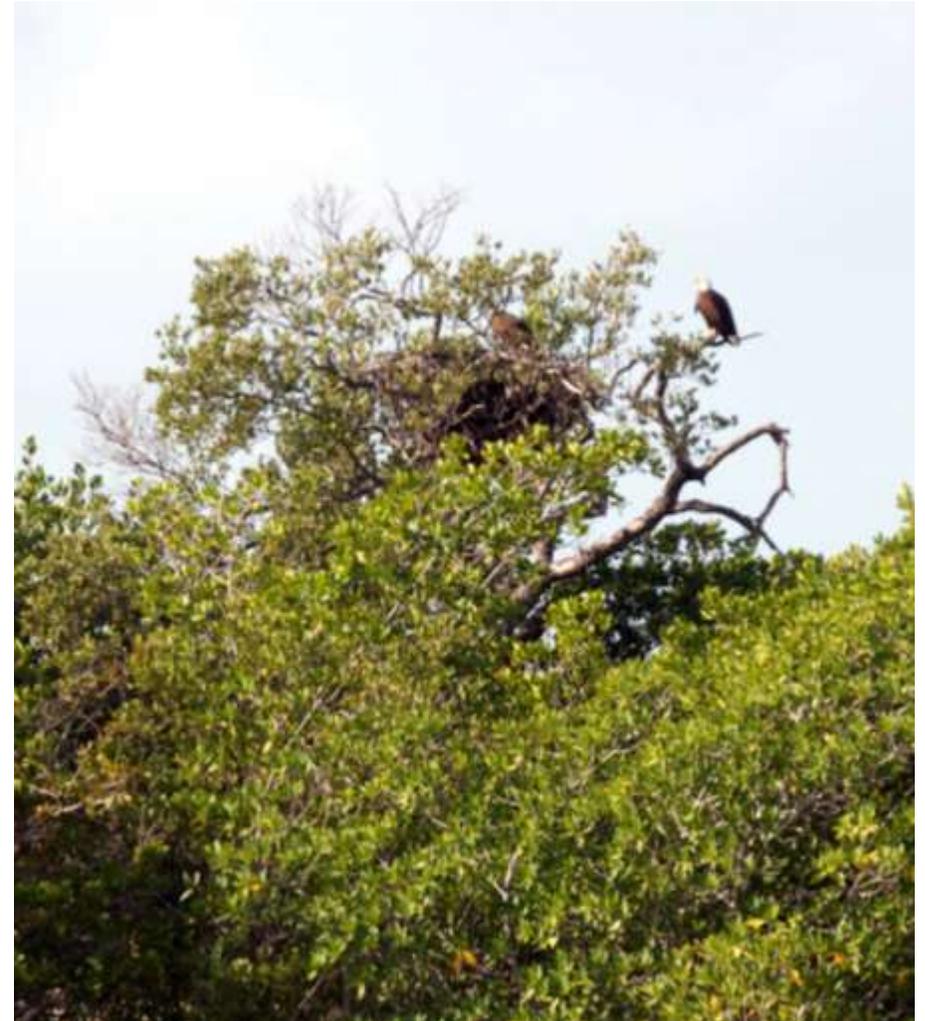
Using occupancy as a measure of habitat quality

Site-selection:

- Return
- Try somewhere better (perceived fitness)

Assumptions:

- Habitat quality is variable
- Success is repeatable
- Individuals are capable of evaluating territory quality before breeding

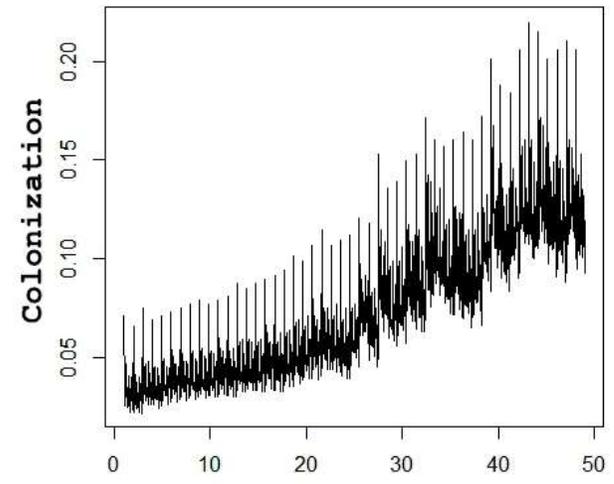
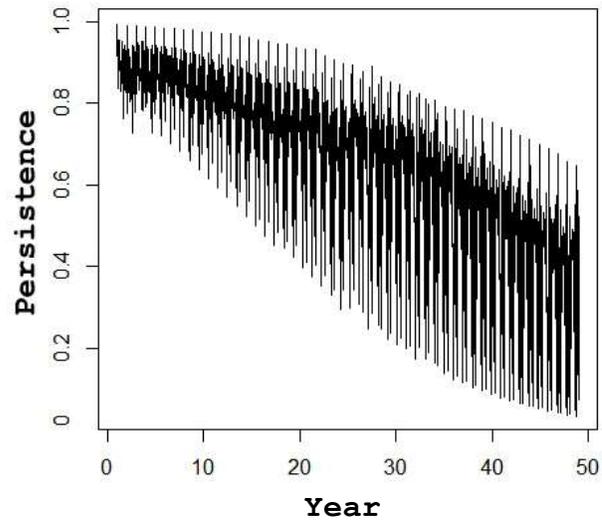
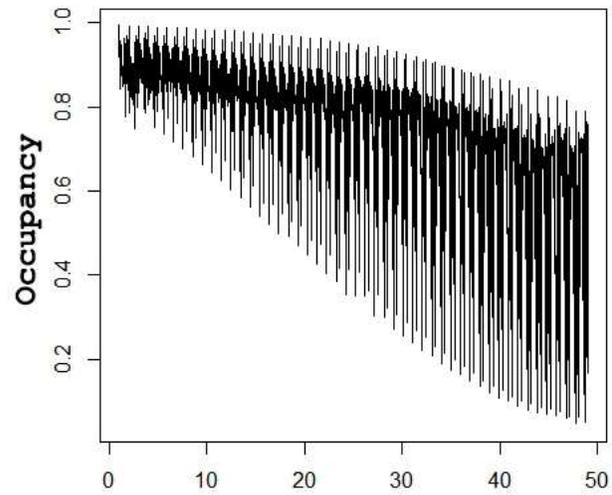


Spatial Network

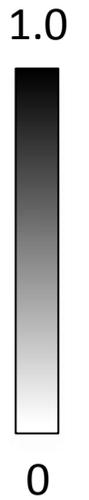
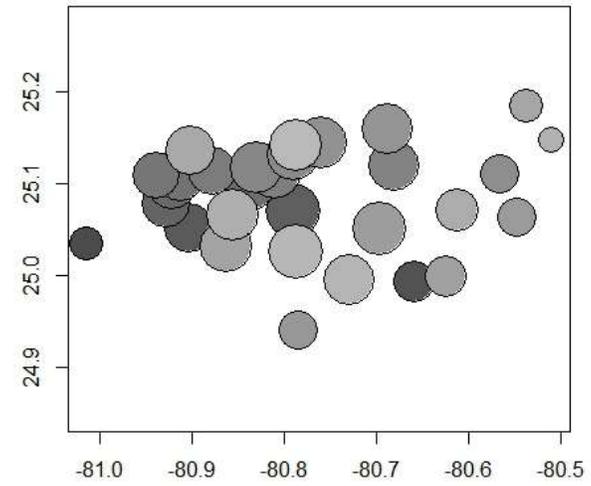
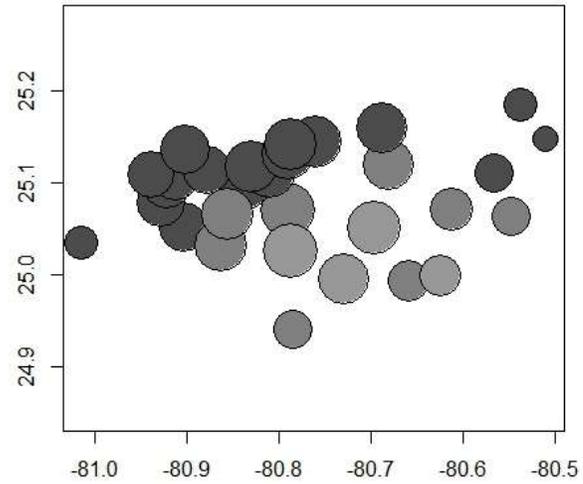
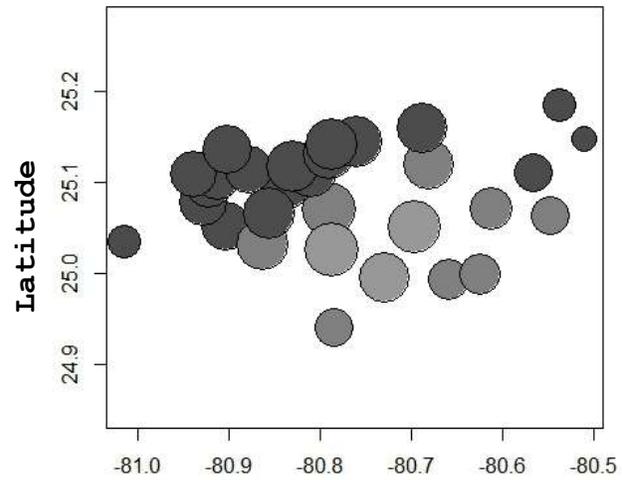
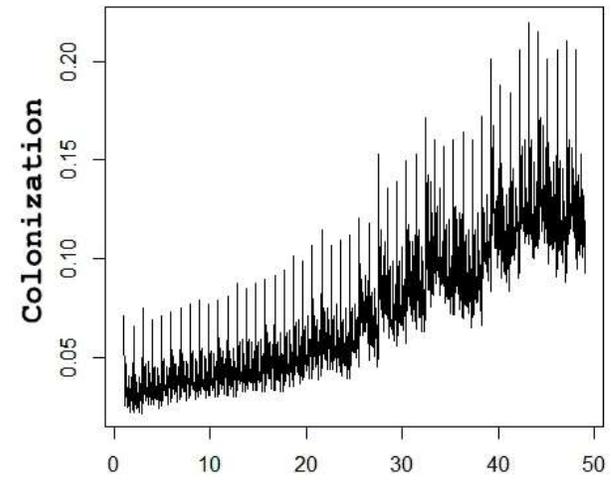
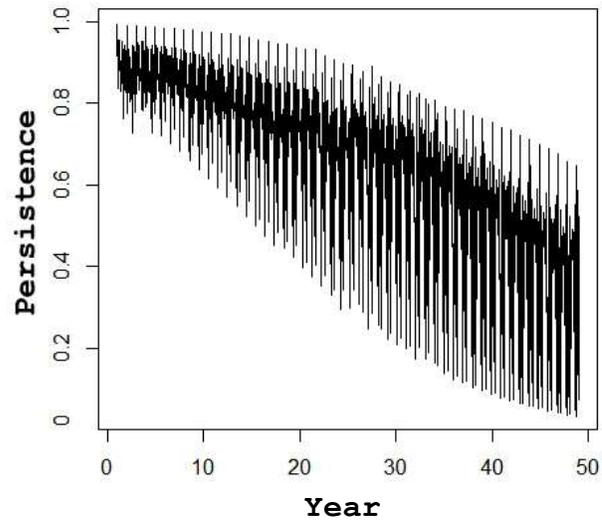
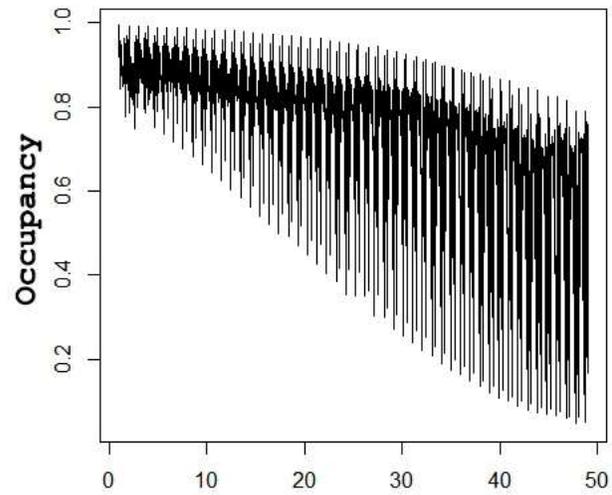


- Proximity relative to neighboring territories
 - Connection matrix
 - Exogenous Spatial Dependence

Territory Dynamics Models



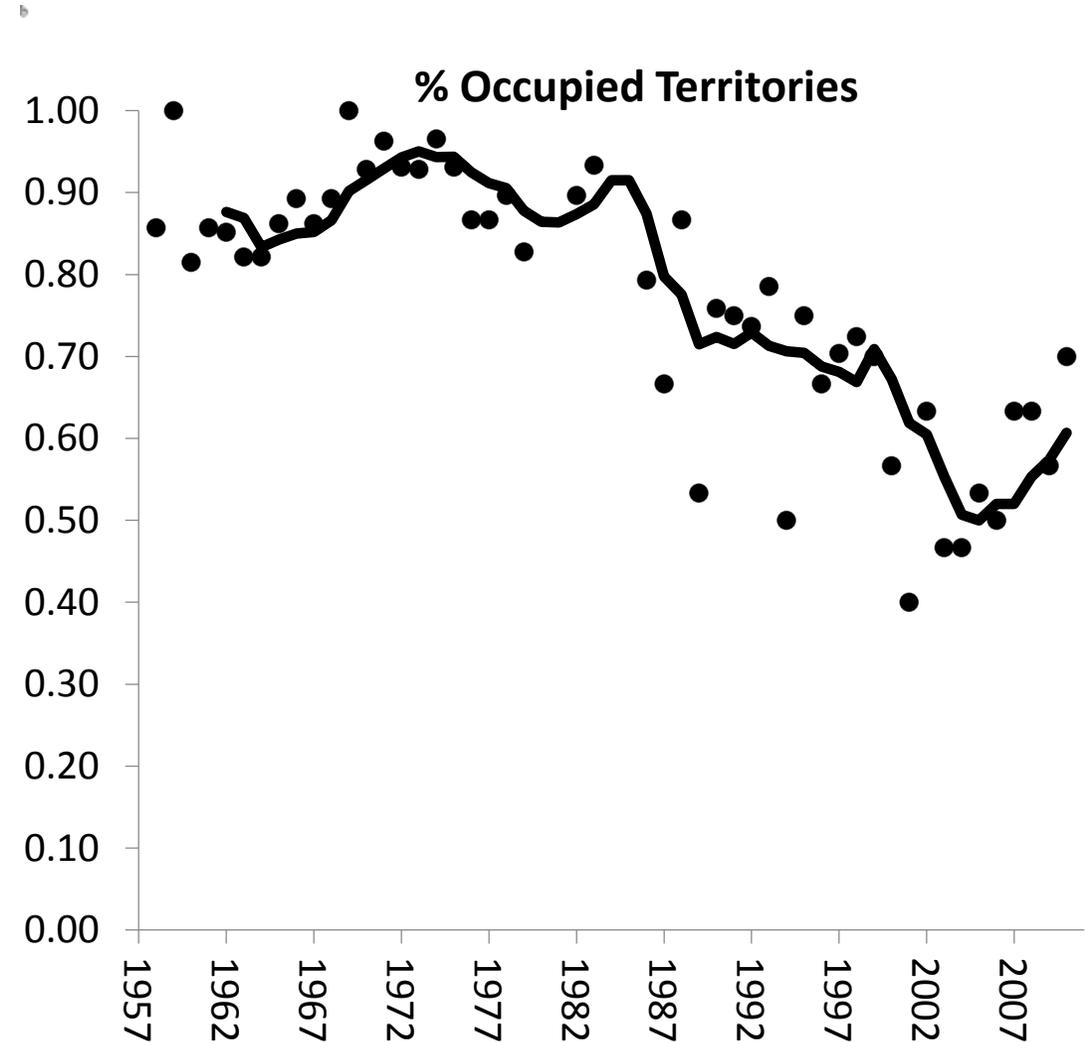
Territory Dynamics



Habitat Heterogeneity Hypothesis



- Density dependence pushes subordinates into marginal habitat
- Poor quality habitat vulnerable
- No longer supports juvenile/sub-adult populations
- Misleading reproductive parameters
- Difficult to assess effects on high quality habitat



Summary

- Territory loss has increased and is likely ongoing
- Changes in territory dynamics are greatest in southeast Florida Bay
- Despite this, productivity and breeding success meet criteria for population maintenance
- Suggests importance of early breeding activity (occupied terr.)
- Possess tools to assess individual territory fates when current state is known





Then vs Now Comparison

Year $t+1$	Year t			
	Unoccupied	Occupied	Active	Successful
1960-1975				
Unoccupied	0.710	0.086	0.017	0.012
Occupied	0.104	0.350	0.163	0.128
Active	0.106	0.321	0.432	0.263
Successful	0.081	0.242	0.388	0.597
1995-2010				
Unoccupied	0.681	0.421	0.162	0.118
Occupied	0.083	0.277	0.061	0.050
Active	0.080	0.109	0.373	0.223
Successful	0.156	0.192	0.404	0.609
Difference				
Unoccupied	-0.029 (-4.04%)	0.336 (390.76%)	0.145 (852.92%)	0.106 (888.21%)
Occupied	-0.021 (-20.26%)	-0.073 (-20.78%)	-0.103 (-77.25%)	-0.078 (-61.21%)
Active	-0.026 (-24.33%)	-0.212 (-65.96%)	-0.059 (-16.11%)	-0.04 (-15.22%)
Successful	0.076 (93.74%)	-0.051 (-20.92%)	0.016 (4.11%)	0.013 (2.16%)

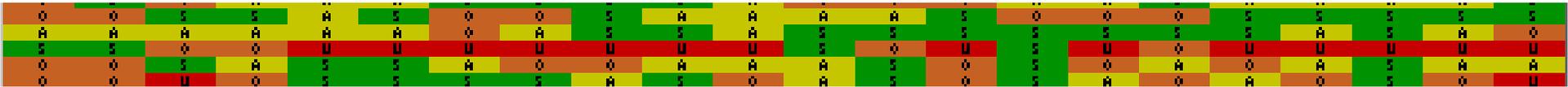
Territory Dynamics Models

Table 3-1. Coefficient estimates (and 95% CIs) from the best-approximating models using AIC selection from the analysis examining factors related to territory dynamics of Bald Eagles in Florida Bay, EVER. Estimates in bold indicate strong support ($p < 0.05$).

Parameter	Occupancy probability	Persistence probability	Colonization probability
intercept	-427.46 (-598.24,-258.34)	405.62 (-565.40,-246.76)	-165.71 (-351.29,19.38)
latitude	2.343 (-2.83, 7.47)	2.066 (-2.875, 6.957)	0.421 (-3.178, 4.119)
longitude	-4.615 (-5.97, -3.32)	-4.427 (-5.667, -3.223)	-1.887 (-3.611, -0.109)
year	-7.285 (-11.63, -3.04)	-7.591 (-11.917, -3.377)	0.0277 (0.012, 0.044)
connectivity, D_{it}	-0.139 (-0.207, -0.071)	-0.116 (-0.181, -0.051)	-0.055 (-0.111, 0.000)
D_{it} X year	0.003 (0.001, 0.005)	0.002 (-0.000, 0.004)	-
latitude X year	0.287 (0.118, 0.460)	0.299 (0.131, 0.471)	-

Territory Dynamics

Four state categorization binned into presence (1) and absence (0) data



example $h = 01100$

Colonized -> Persisted -> Abandoned -> Vacant

$$\Pr(Z=h) = \gamma \times \phi \times (1-\phi) \times (1-\gamma)$$

Territory Dynamics

Occupancy. Presence/absence on a territory for a given year.

Persistence. Presence on a territory given that territory was occupied in the previous year.

$$\phi = \Pr(Z_{i,t}=1 | Z_{i,t-1}=1)$$

Colonization. Presence on a territory given that territory was not occupied in the previous year.

$$\gamma = \Pr(Z_{i,t}=1 | Z_{i,t-1}=0)$$

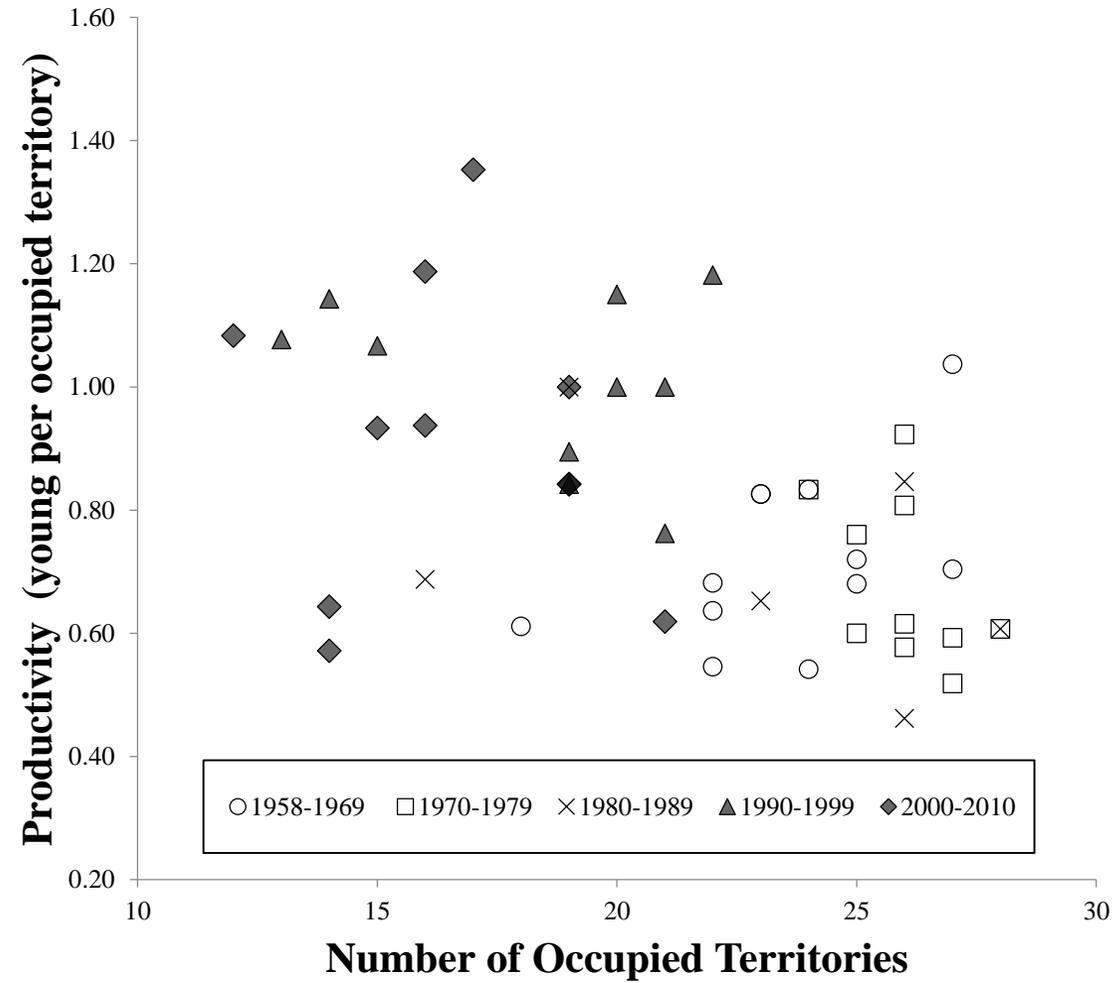
Abandonment. Absence at a territory given that territory was occupied in the previous year.

$$(1-\phi)$$

Vacant. Absence at a territory given that territory was not occupied in the previous year.

$$(1-\gamma)$$

Shifting Territory Use



Shifting Territory Use

