# Predicting American Oystercatcher Breeding Distribution in an Urbanized Coastal Ecosystem Using Maximum Entropy Modeling


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# *Research Objectives*

1. Evaluate the factors influencing AMOY nest success across a mosaic of habitats
2. Determine the extent of use of alternative breeding habitat by AMOYs in New Jersey
3. Identify the factors affecting AMOY distribution in a highly urbanized coastal ecosystem

# AMOY Breeding Habitat

Oystercatcher
Breeding Habitat

- Barrier Beach

# *AMOY Breeding Habitat*

Oystercatcher
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# *AMOY Breeding Habitat*

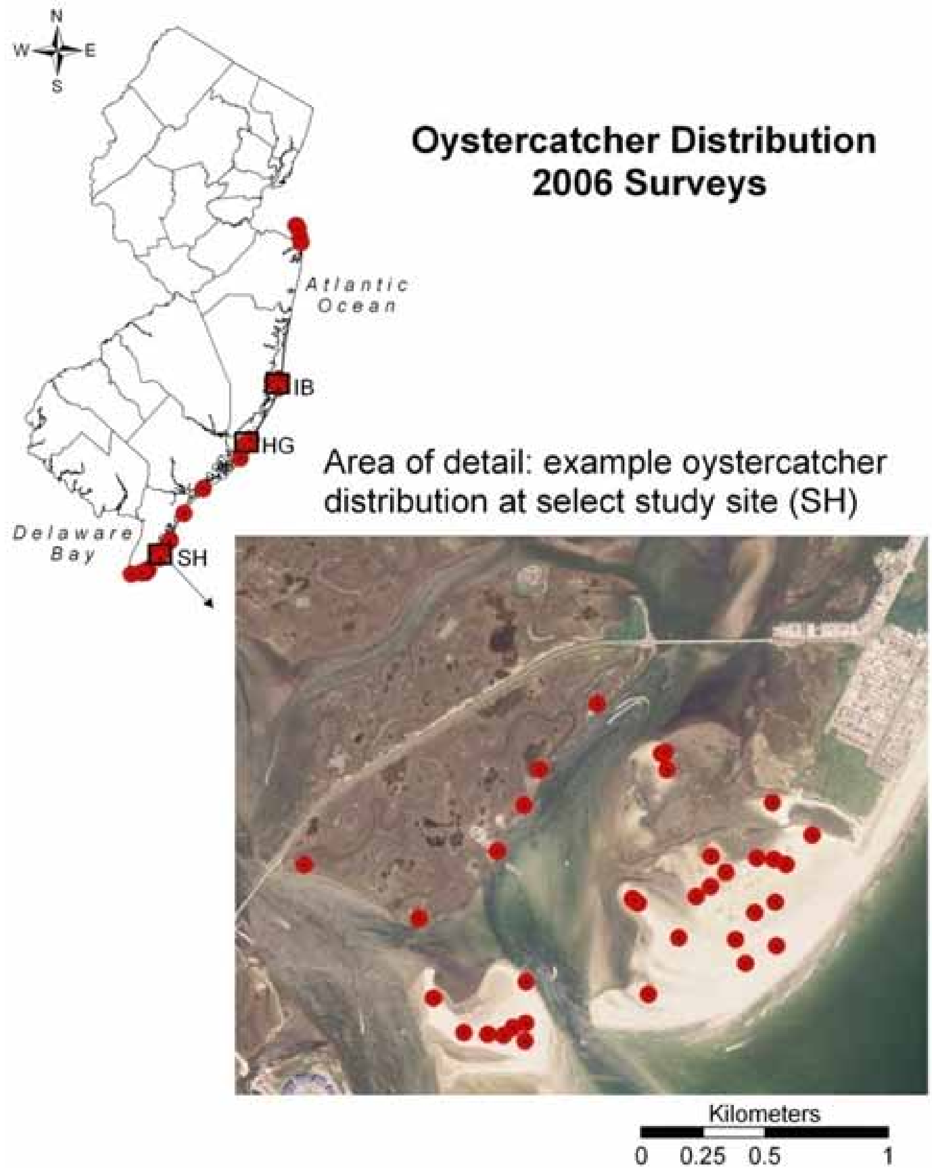
Oystercatcher
Breeding Habitat

- Barrier Beach
- Saltmarsh
- Natural/Artificial Islands

Alternative Habitat

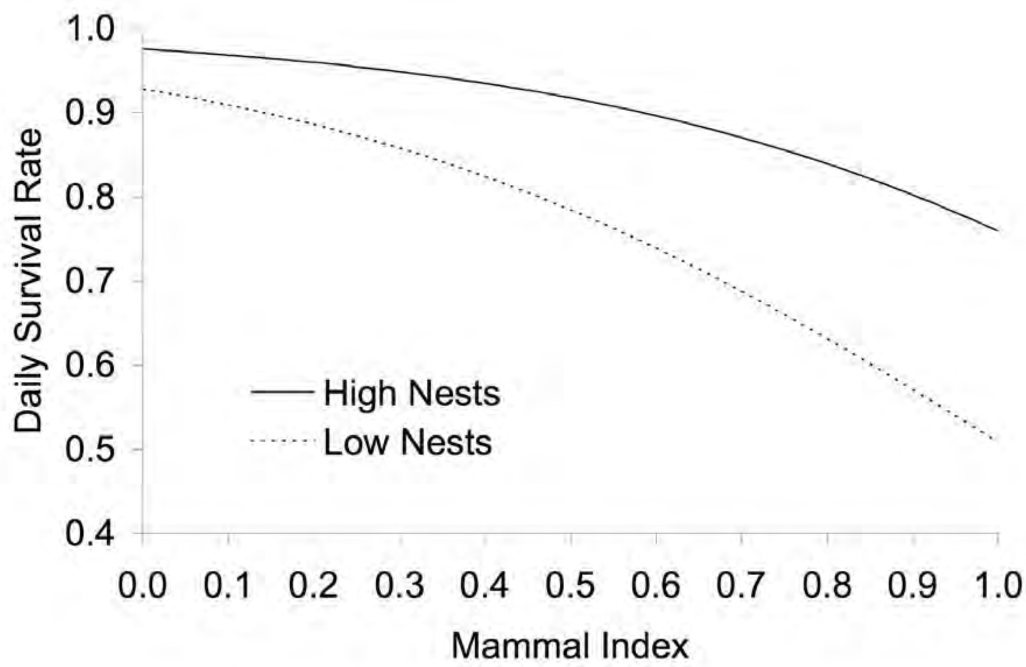
# *Nest Success Study - Summary*

- 2-Year Study (2005 – 2006)
- 3 Study Sites
- Sample Size
  - 205 Nests
  - 61 Broods
- Modeled Nest Survival in Response to:
  - Habitat Type
  - Nest Height
  - Mammal Activity
  - Gull Density
  - Human Disturbance



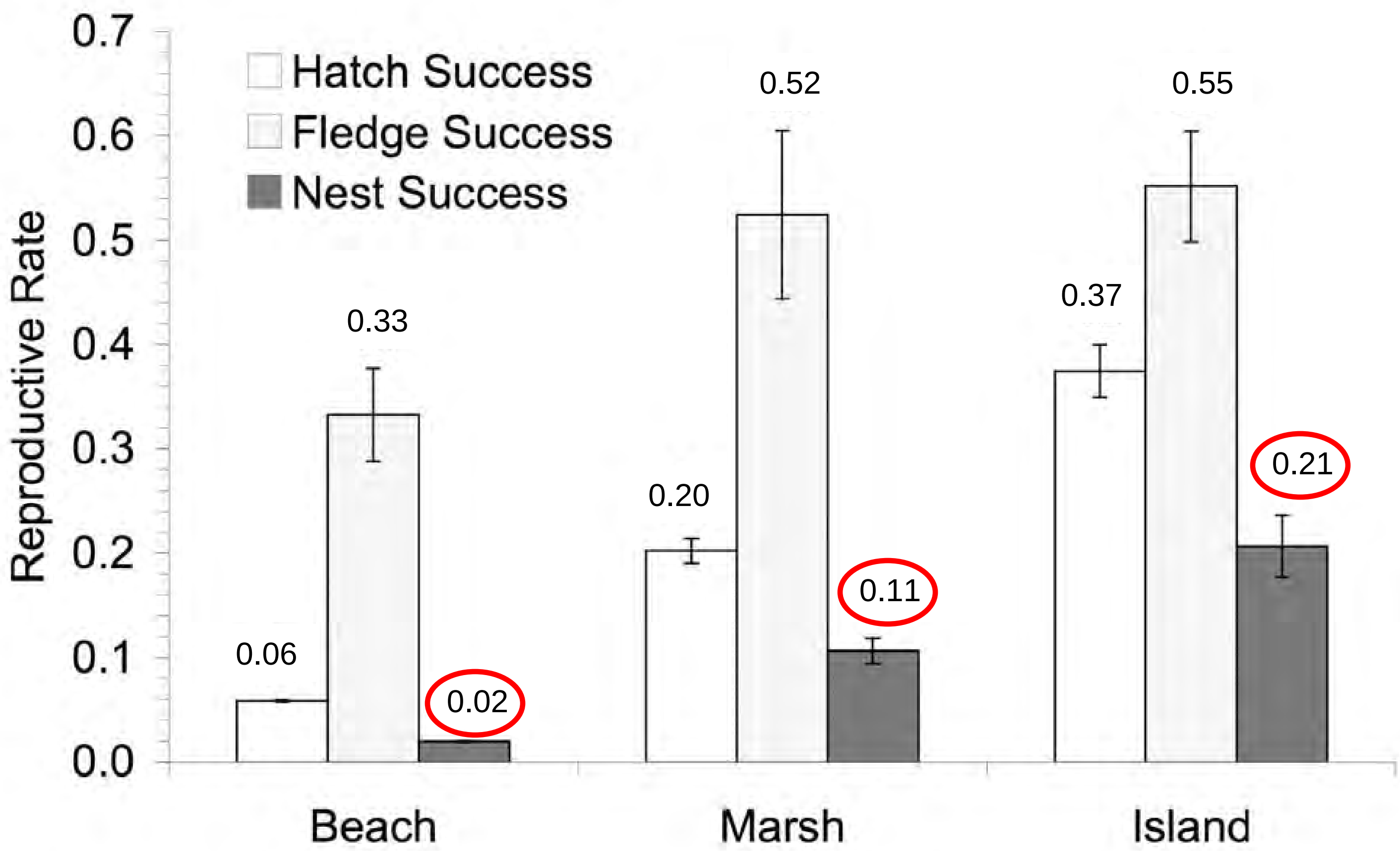
# Nest Success Study - Summary

Nest Survival Models




- DSR based on best model used to predict trends
- Nest success influenced most heavily by presence of mammalian predators (at both stages)

# Nest Success Study - Summary



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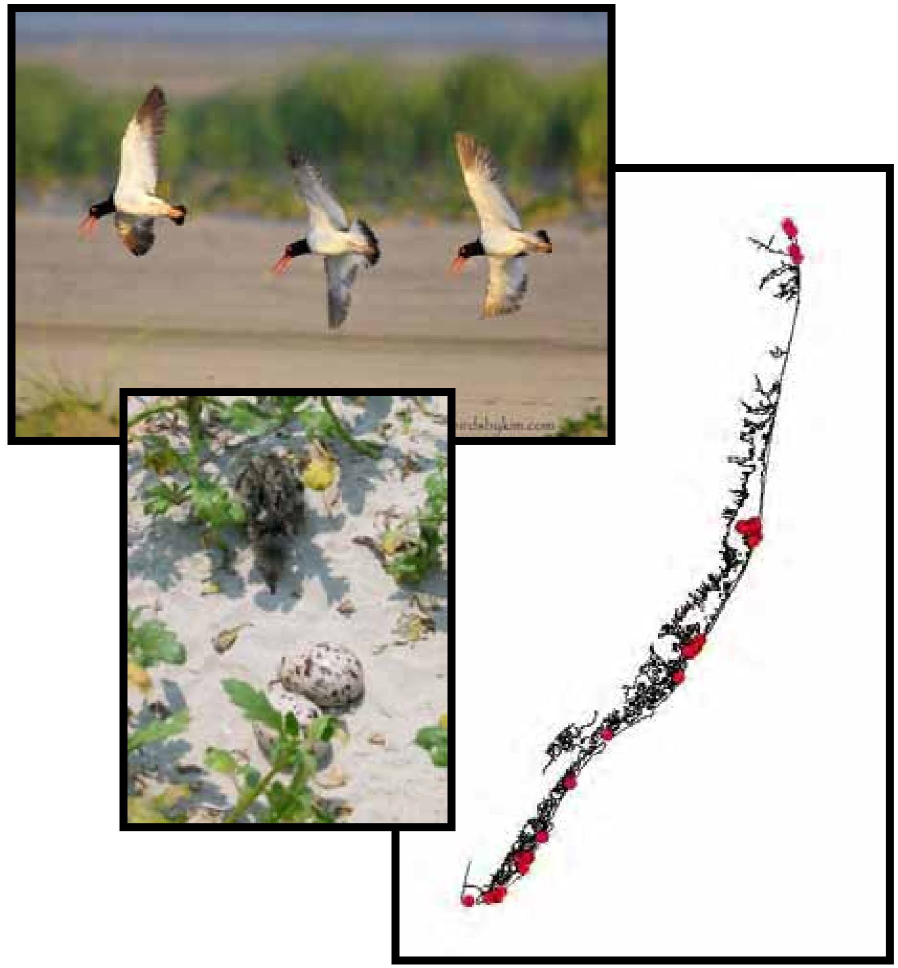
2. Determine the extent of use of alternative breeding habitat by AMOYs in New Jersey

3. Identify the factors affecting AMOY distribution in a highly urbanized coastal ecosystem

    - Coastal development
    - Recreational disturbance

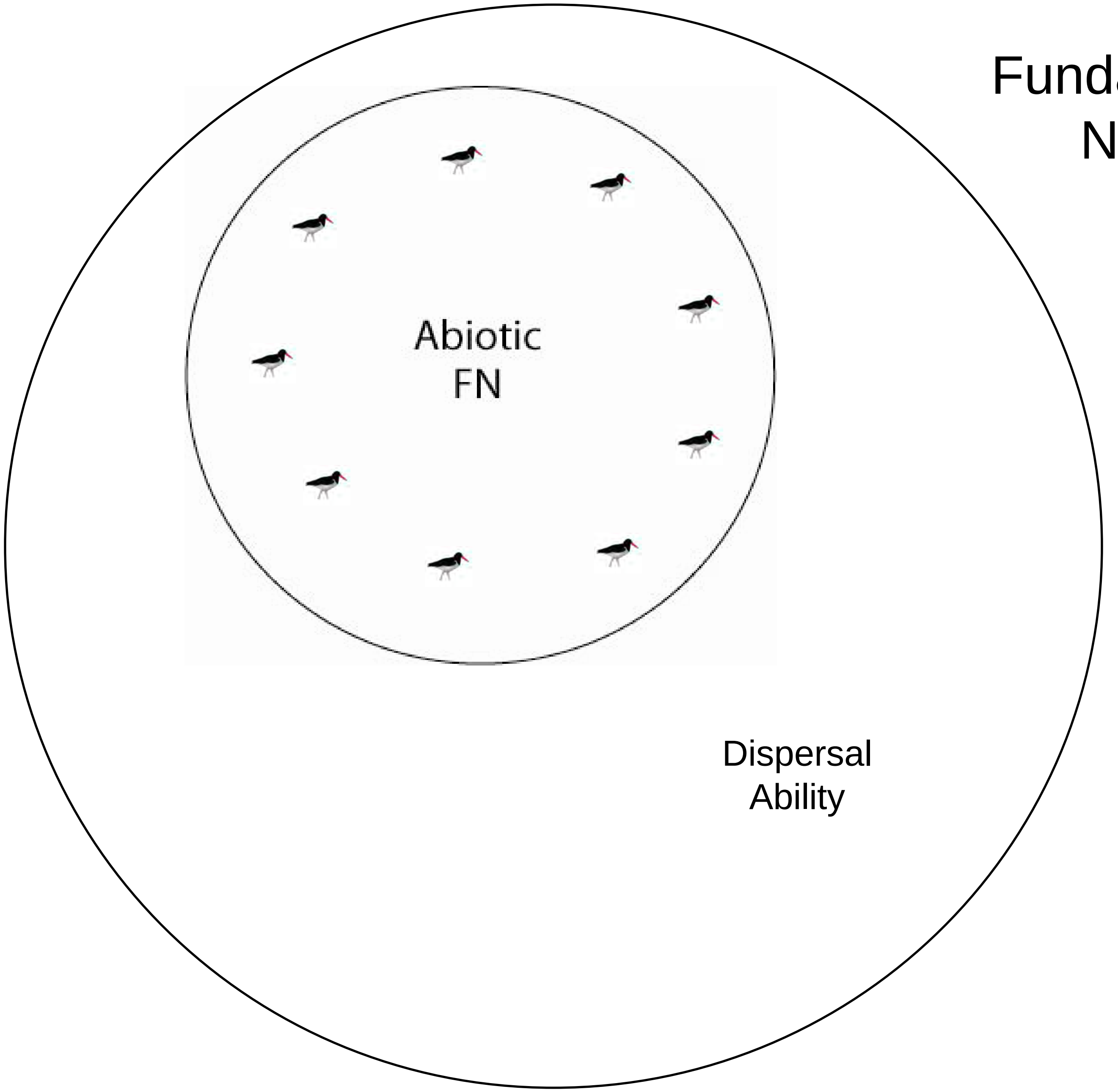
# Species Distribution Modeling

- Niche Modeling
- Explanatory Model
  - What factors lead to observed distribution of AMOYs in NJ?
- Predictive Model
  - Where else are AMOYs in NJ?



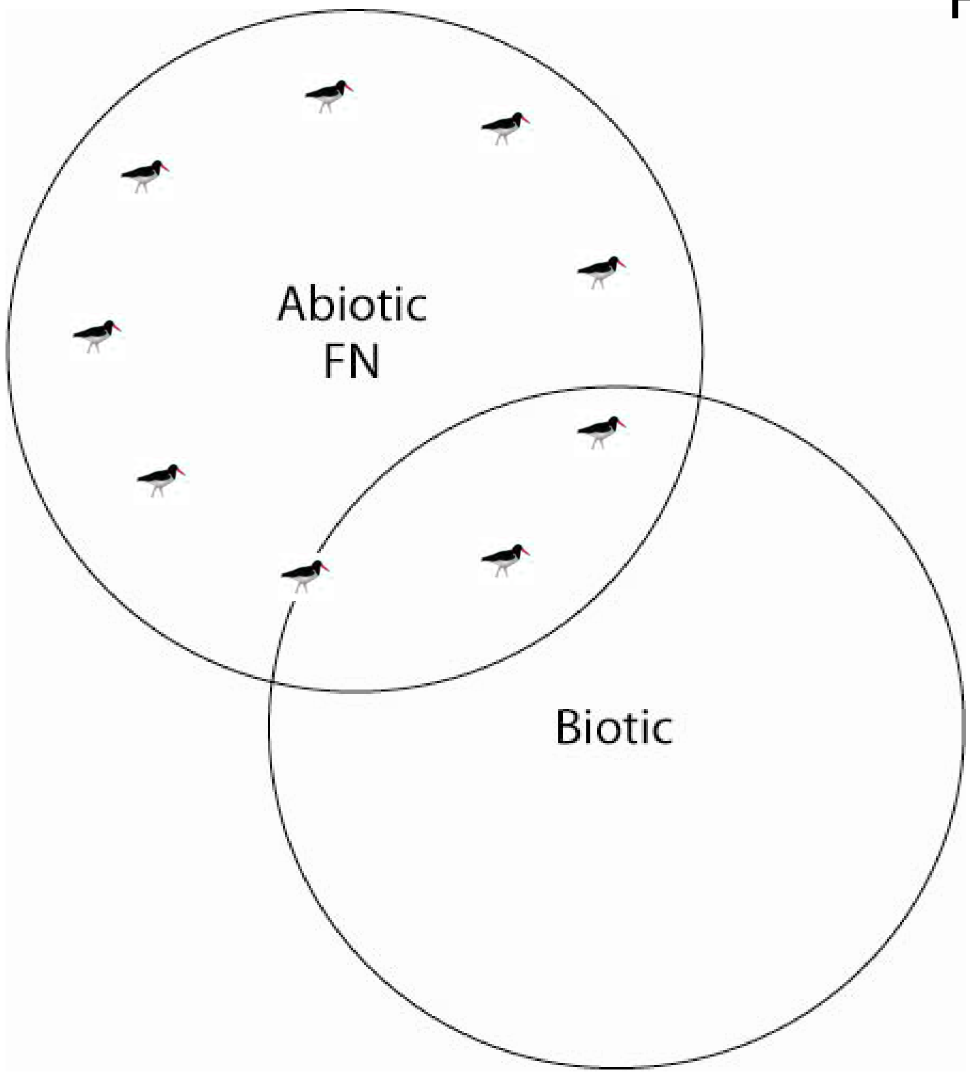
# *Niche Modeling*

Fundamental Niche



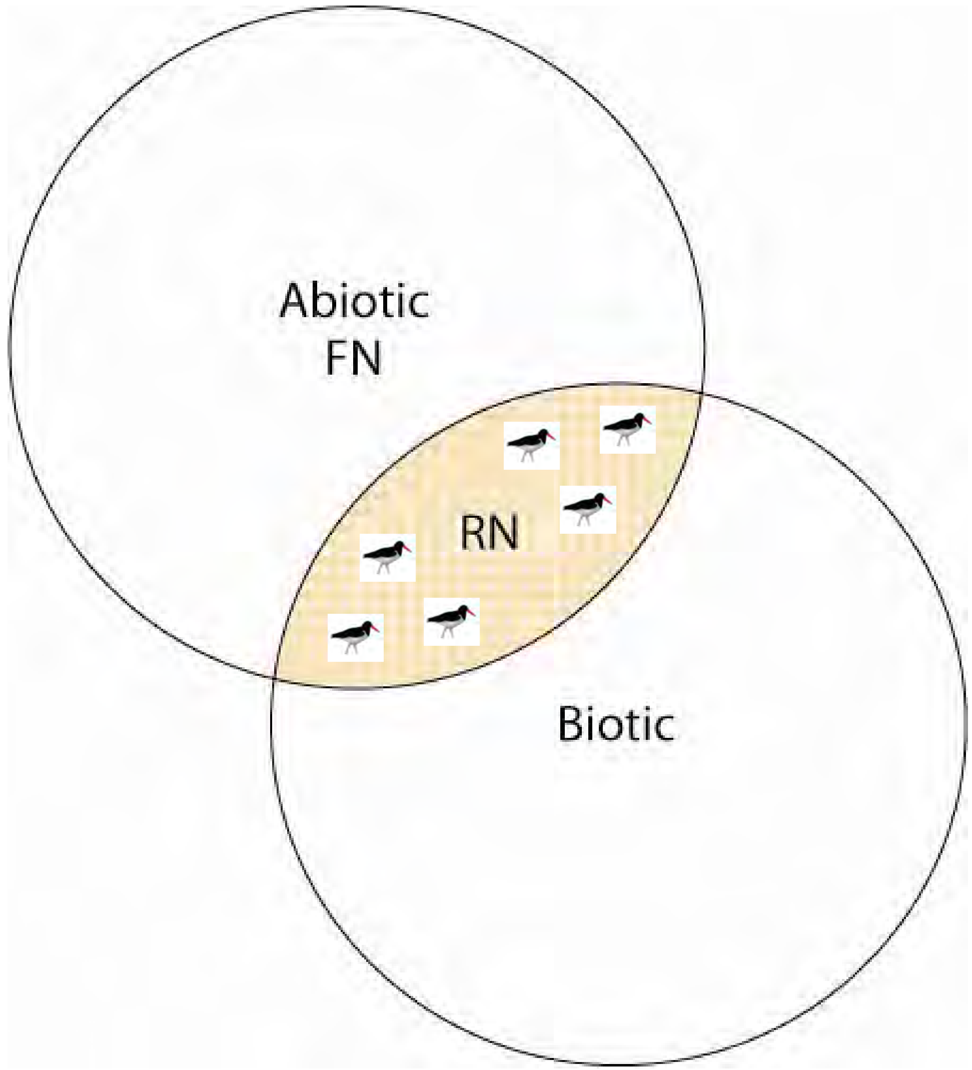
# *Niche Modeling*

Fundamental
Niche



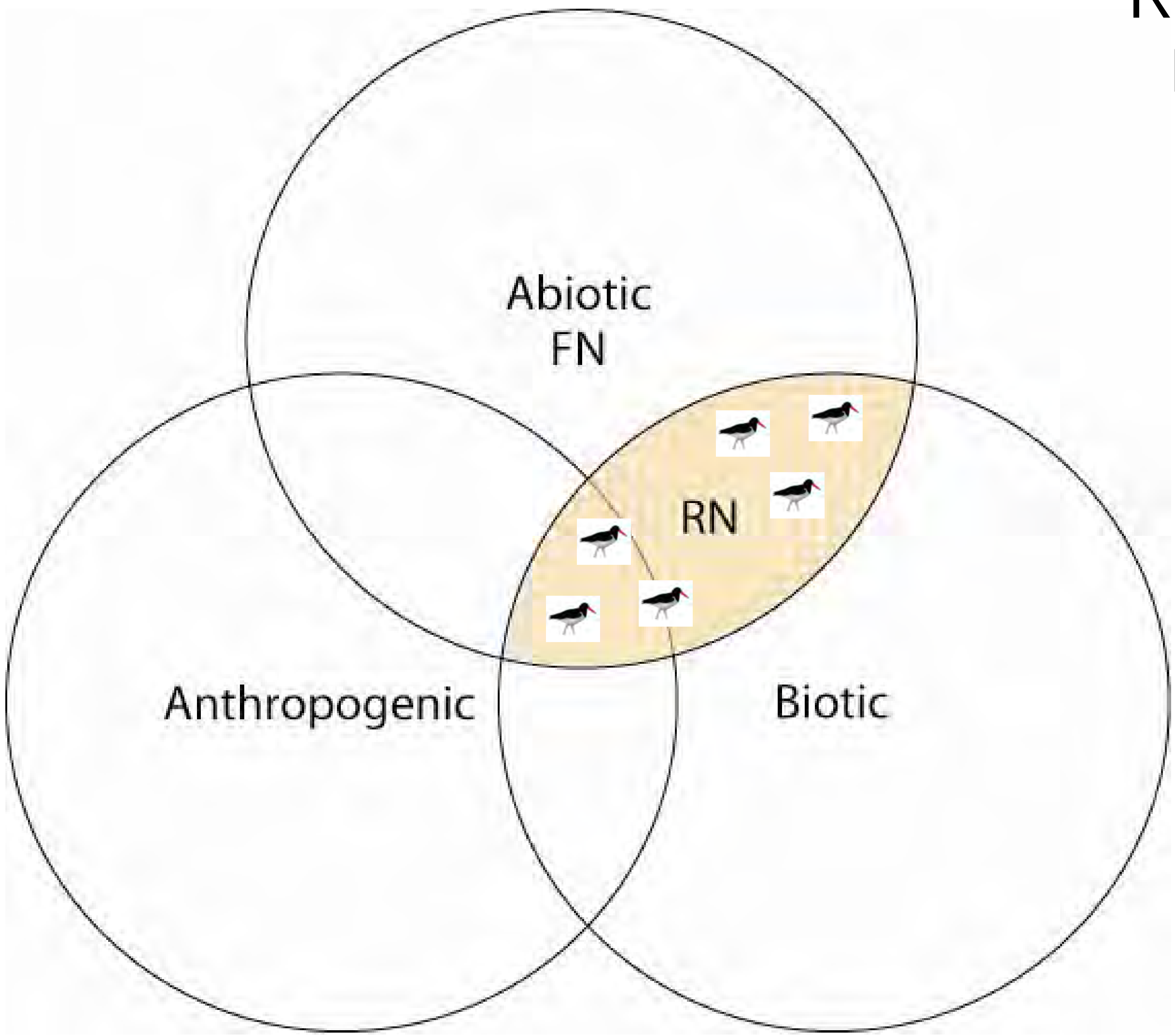
# *Niche Modeling*

Realized
Niche



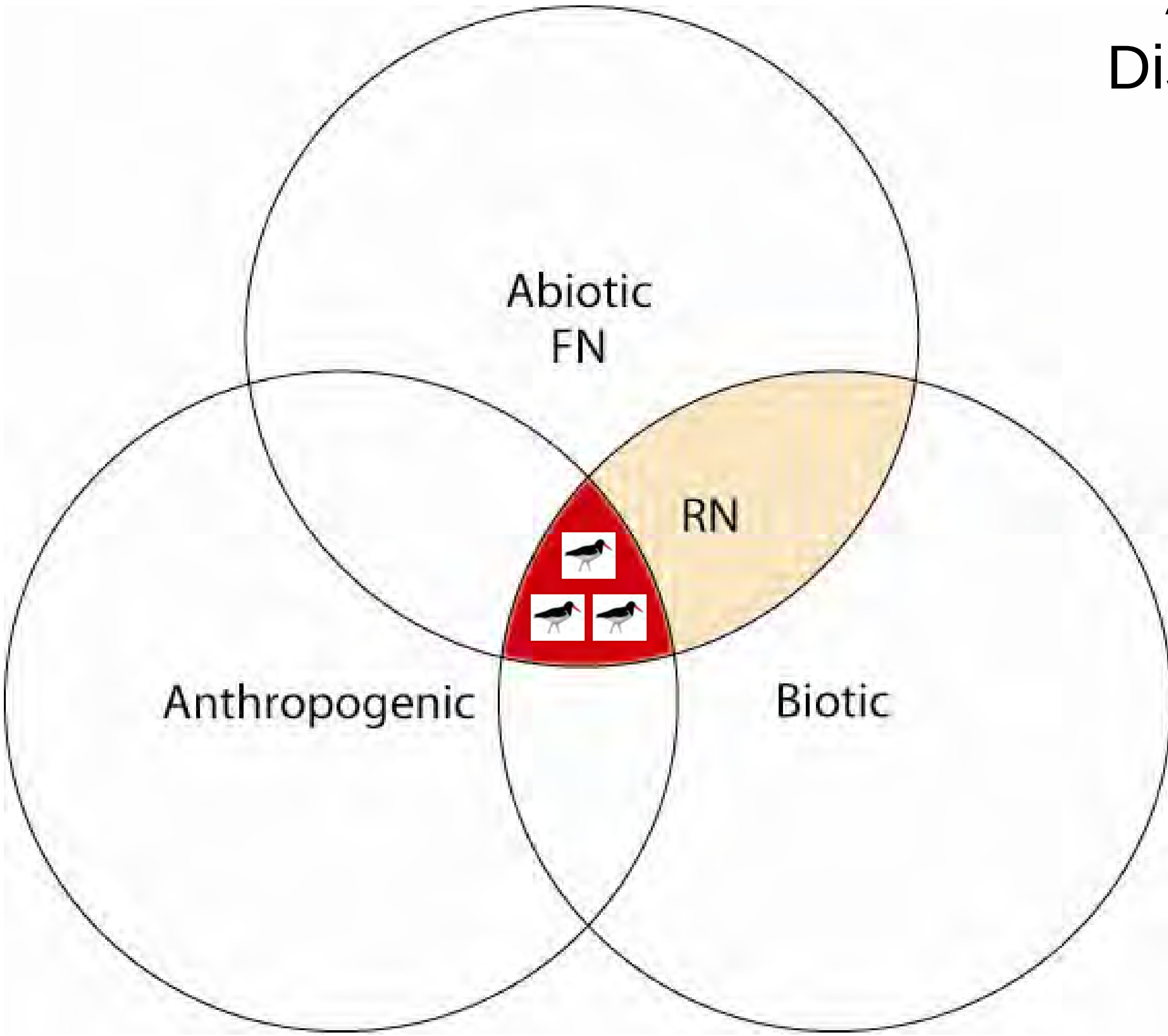
# *Niche Modeling*

Realized Niche



# Niche Modeling

Actual
Distibution



# MAXENT Model - Methods

## Maximum Entropy Modeling

- Model distribution based on known occurrences
- Distribution limited by some constraints
  - Habitat features
  - Urbanization
  - Prey Resources
  - Predation

# *MAXENT Model - Methods*

## Maximum Entropy Modeling

- In the absence of influences other than those included as constraints in the model, the geographic distribution of a species will tend toward the distribution of maximum entropy (Phillips et al. 2006)
  - Presence only modeling technique
  - Robust to small sample sizes
  - Better predictions than many other SDM techniques

# Maximum Entropy Modeling

- Estimate a target probability distribution by finding the probability distribution of MAXIMUM ENTROPY subject to a set of constraints
  - Entropy = measure of how much choice is involved in the selection of an event (Shannon 1948)
  - Maximum Entropy Distribution = most spread out or closest to uniform
  - 1st Law of Thermodynamics: In systems without outside influences, processes move in a direction that maximizes entropy

# MAXENT Model - Methods

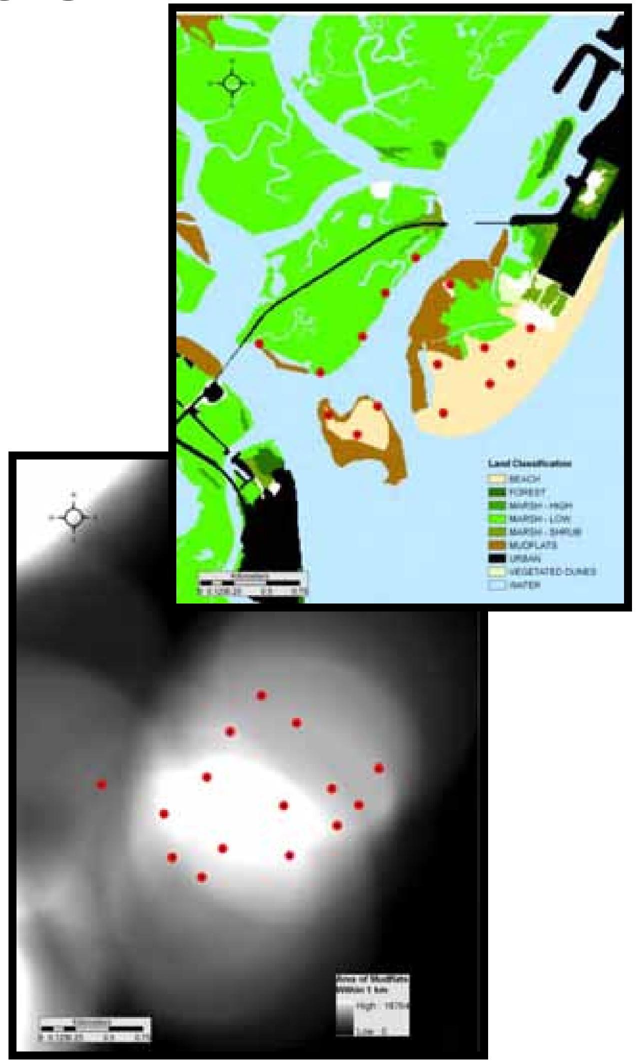
## Maximum Entropy Modeling

- Estimate a target probability distribution by finding the probability distribution of maximum entropy subject to a set of CONSTRAINTS
  - Constraints: The expected value of each feature should equal the average value of sample points
  - Features = Habitat Variables = Model Parameters
    - BACKGROUND DATA (random points)
    - Pixels of study area make up the space on which the Maxent probability distribution is defined
  - Sample Points = Occurrence Records
    - TRAINING DATA (actual occurrences)

# *MAXENT Model - Methods*

## Model Parameters

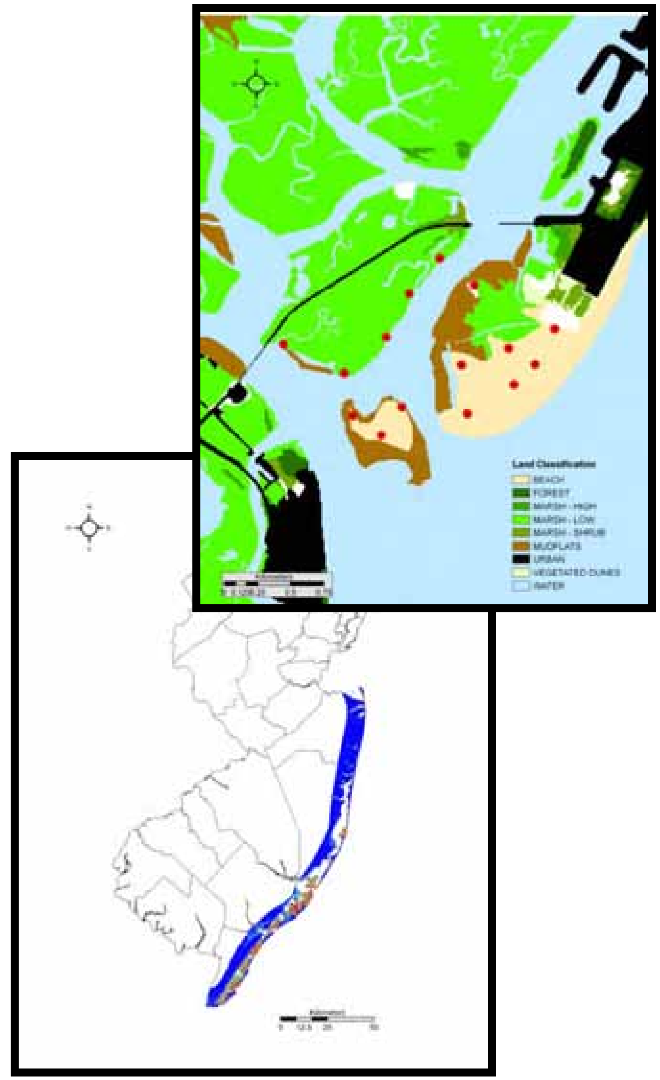
- Abiotic
  - Habitat classification
  - Area of habitat features
  - Distance from nearest inlet
  - Distance from tidal water
- Biotic
  - Prey availability measures
    - Area of low marsh
    - Area of tidal flats
- Anthropogenic
  - Area of urbanization
  - Distance from development



# *MAXENT Model - Methods*

## Model Training and Validation Data

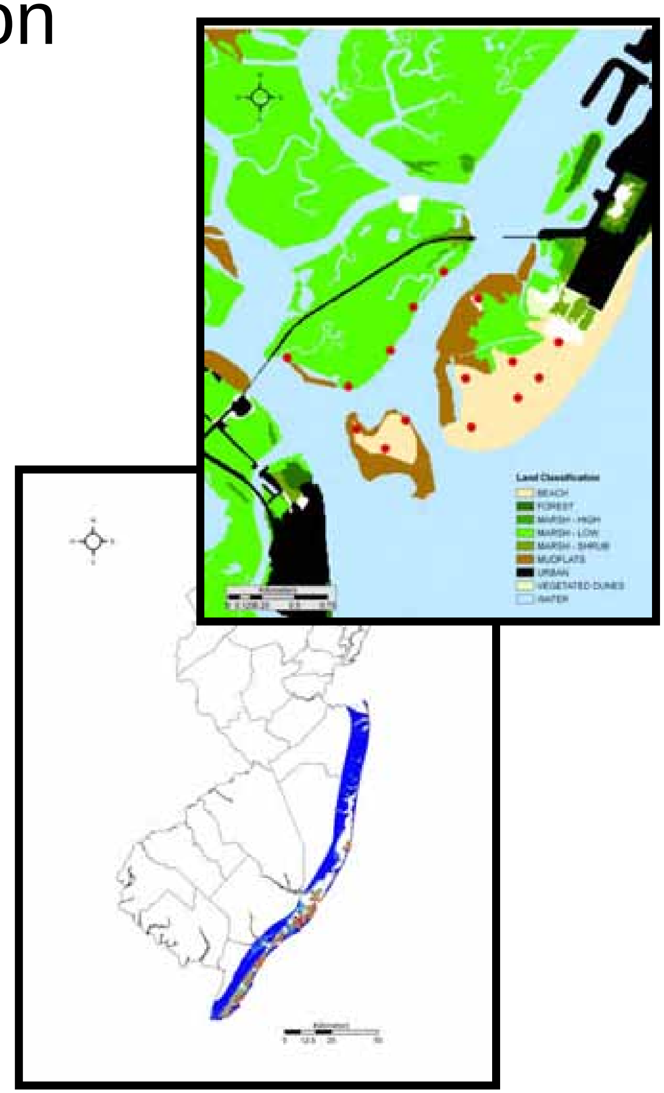
- Training Data
  - 67 occurrence records (breeding pairs)
  - Subset of data to reduce spatial autocorrelation
- Test Data
  - 25% of training data set aside to test models
- Validation Data
  - 283 randomly selected survey points
  - Independent dataset



# *MAXENT Model - Methods*

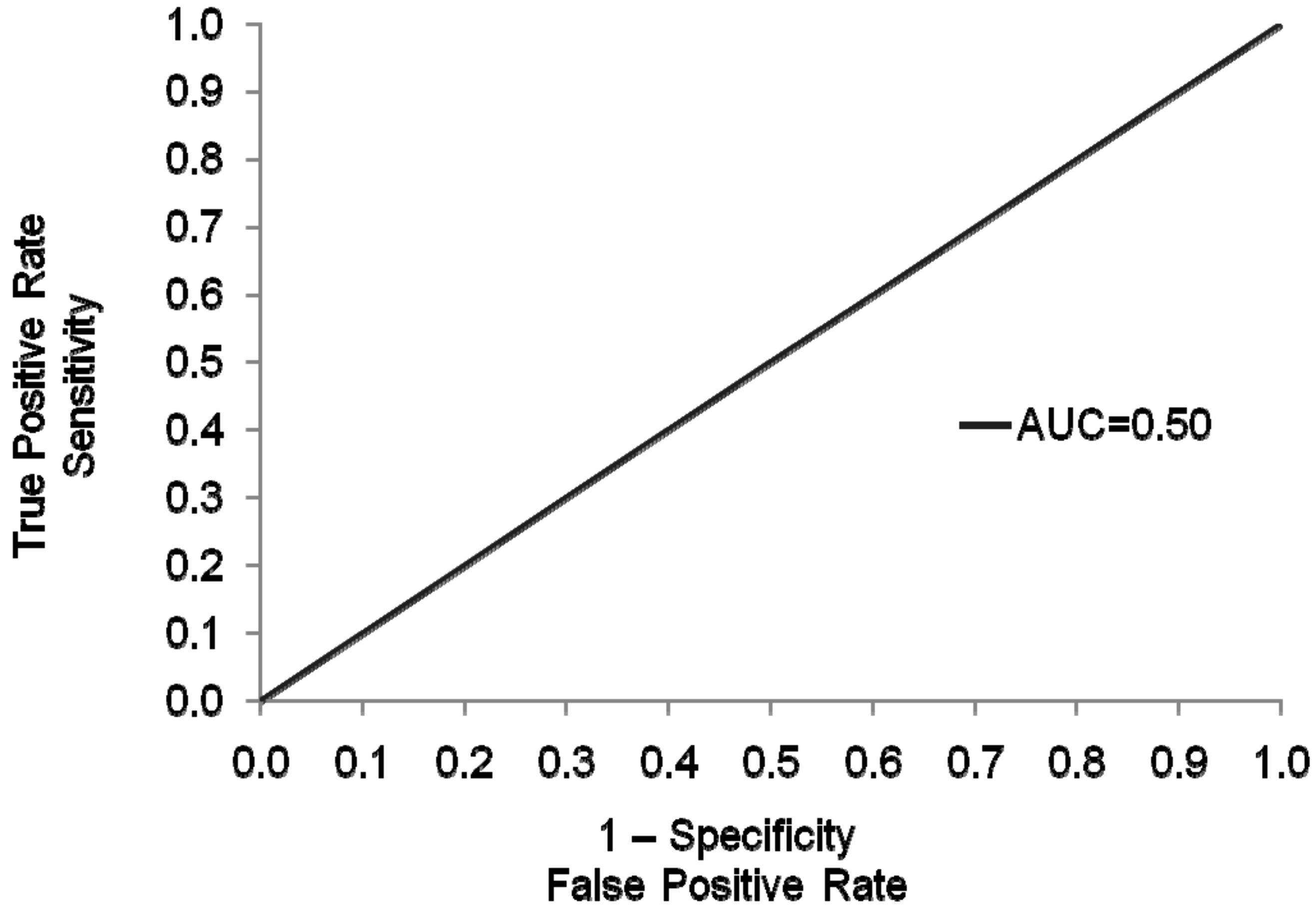
## Model Validation

- Evaluated using receiver operating characteristic (ROC) curves
  - Plots true positive rate against false positive rate
  - Area under the curve (AUC) values used to evaluate models



# MAXENT Model - Methods

Hypothetical ROC Curves



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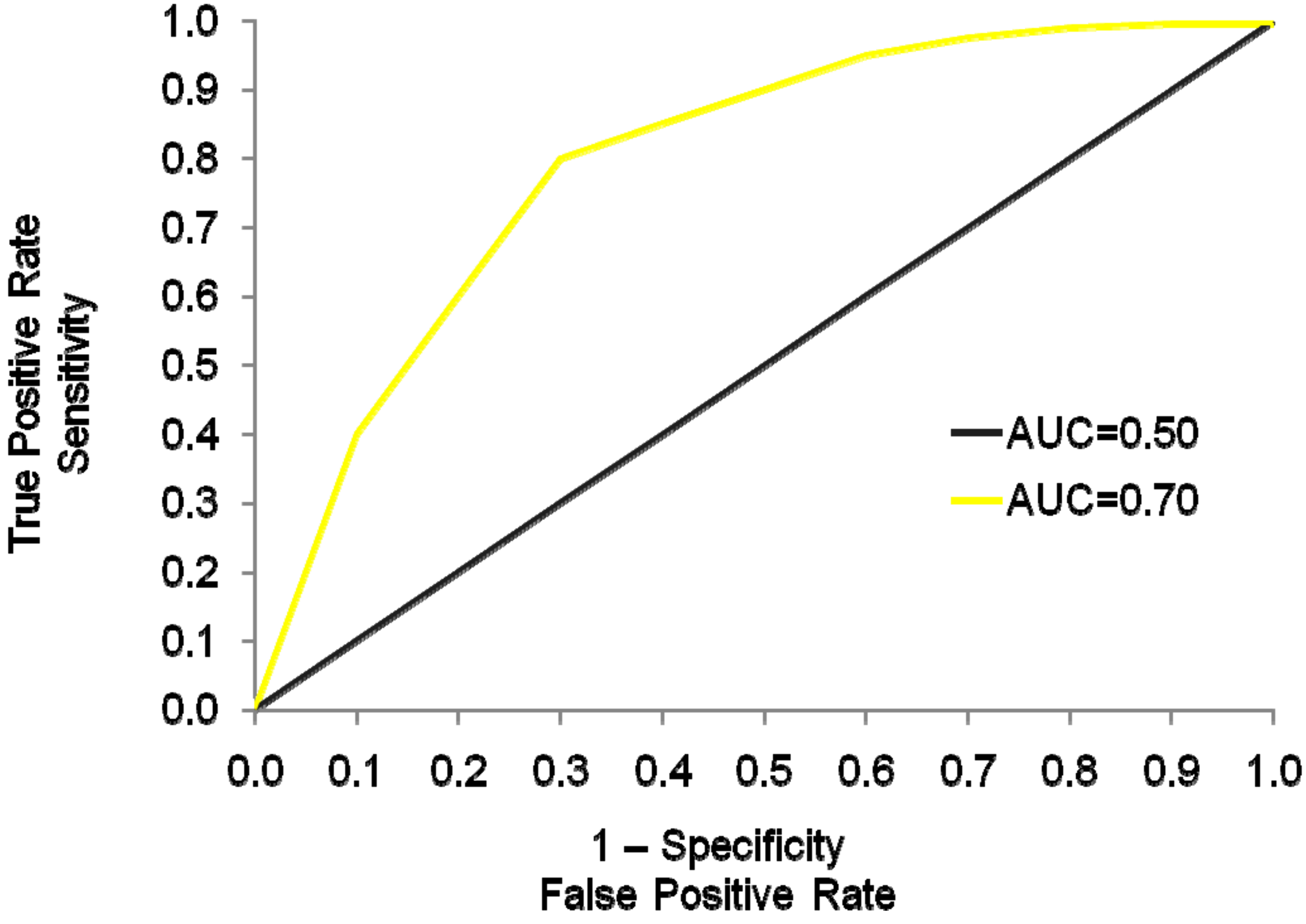

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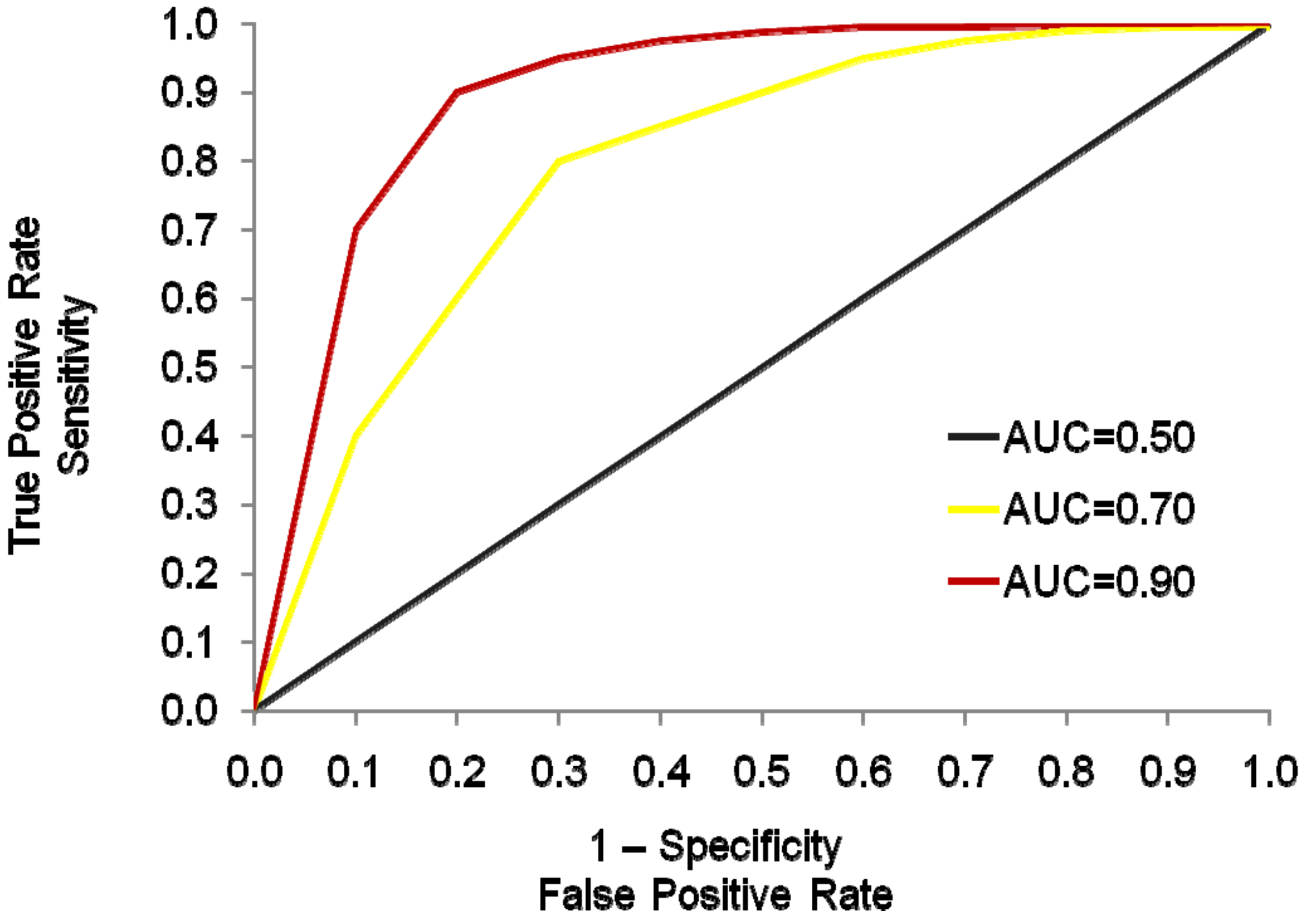
Hypothetical ROC Curves



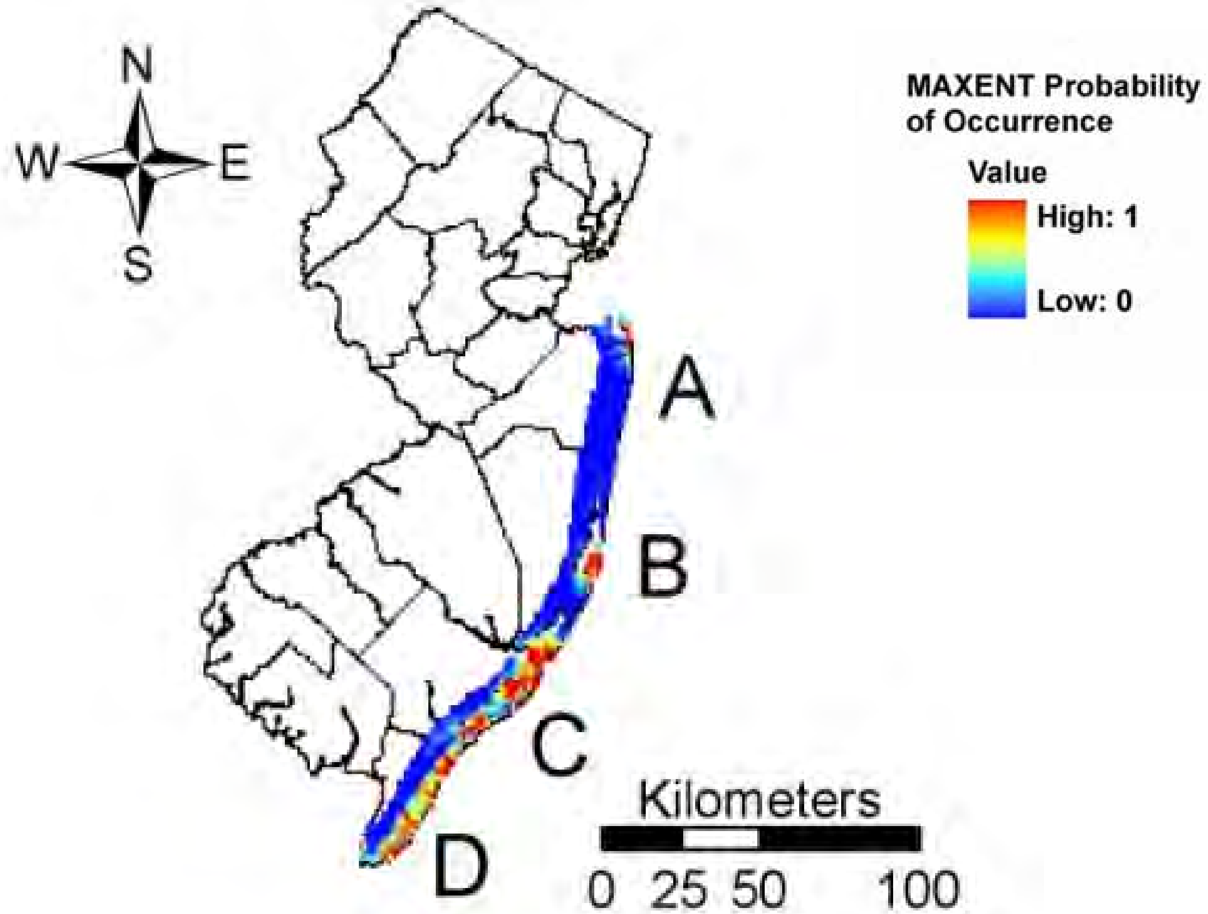
# MAXENT Model - Methods

## Model Validation

- Validated model with independent dataset
  - Compared ROC curve for validation data with MAXENT model results
  - Examined errors of omission and commission separately
    - Omission = prediction of absence when actually present (false negatives)
    - Commission = prediction of presence when actually absent (false positives)

# *MAXENT Model - Results*

Predicted Distribution



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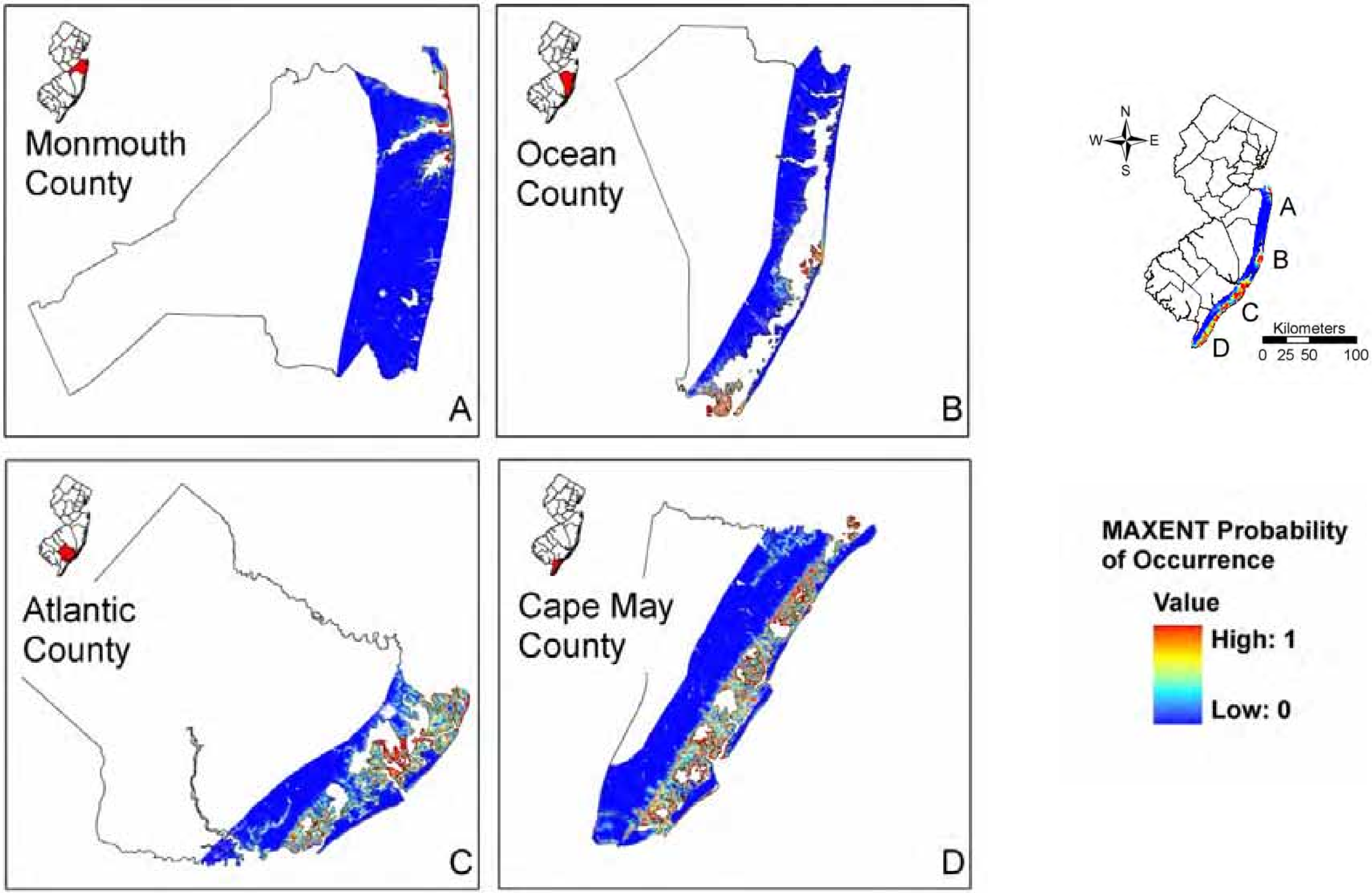
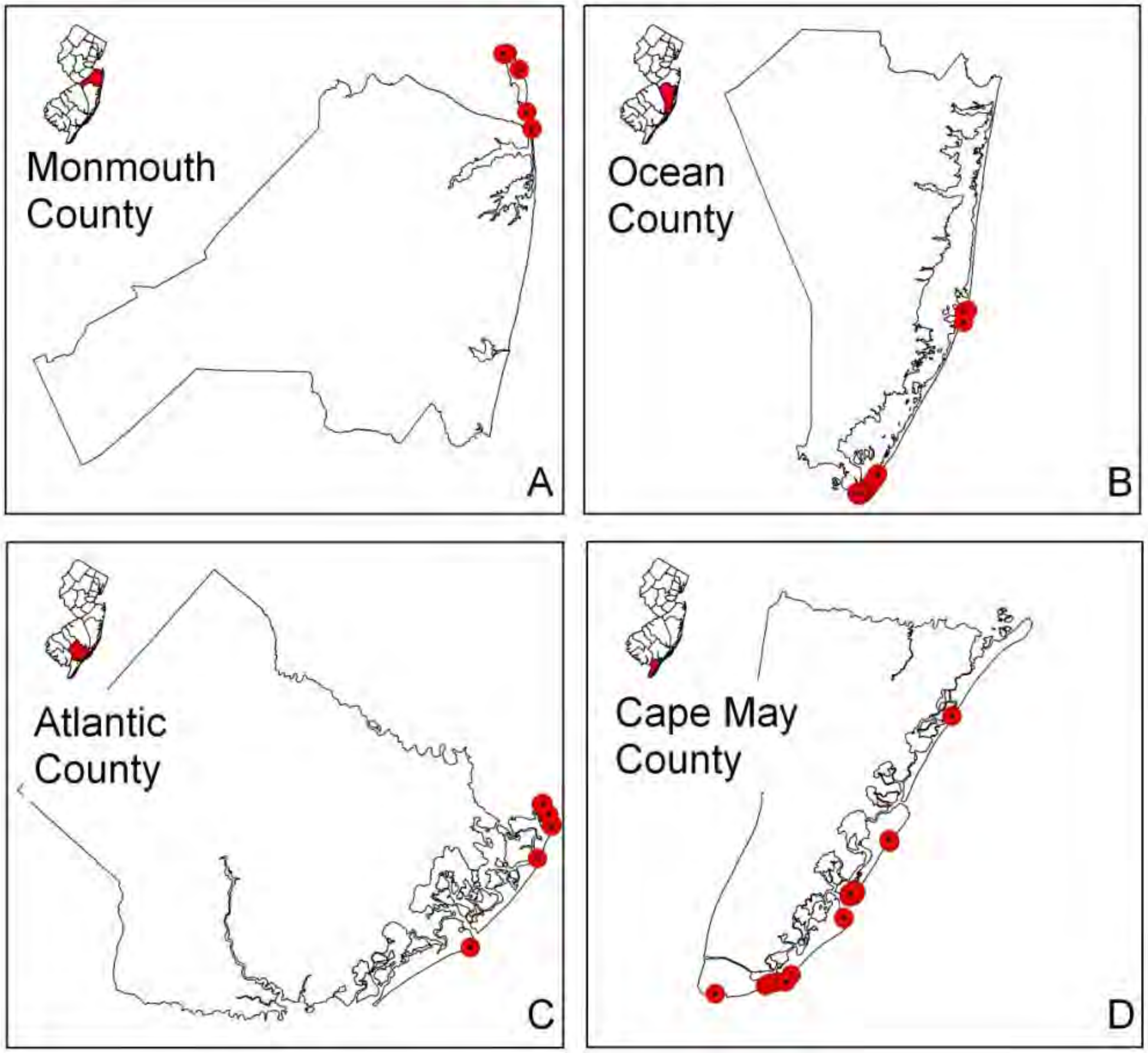
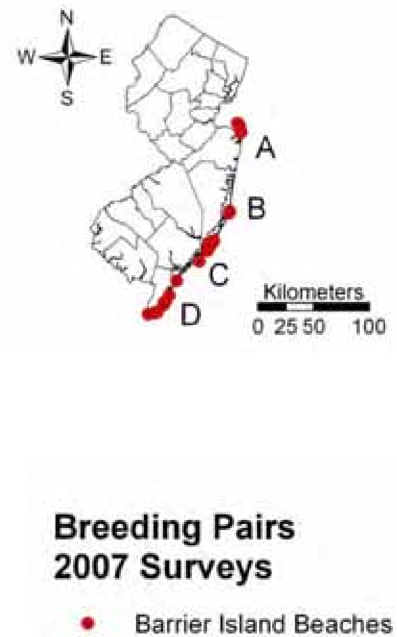


# MAXENT Model - Results

## Actual Distribution



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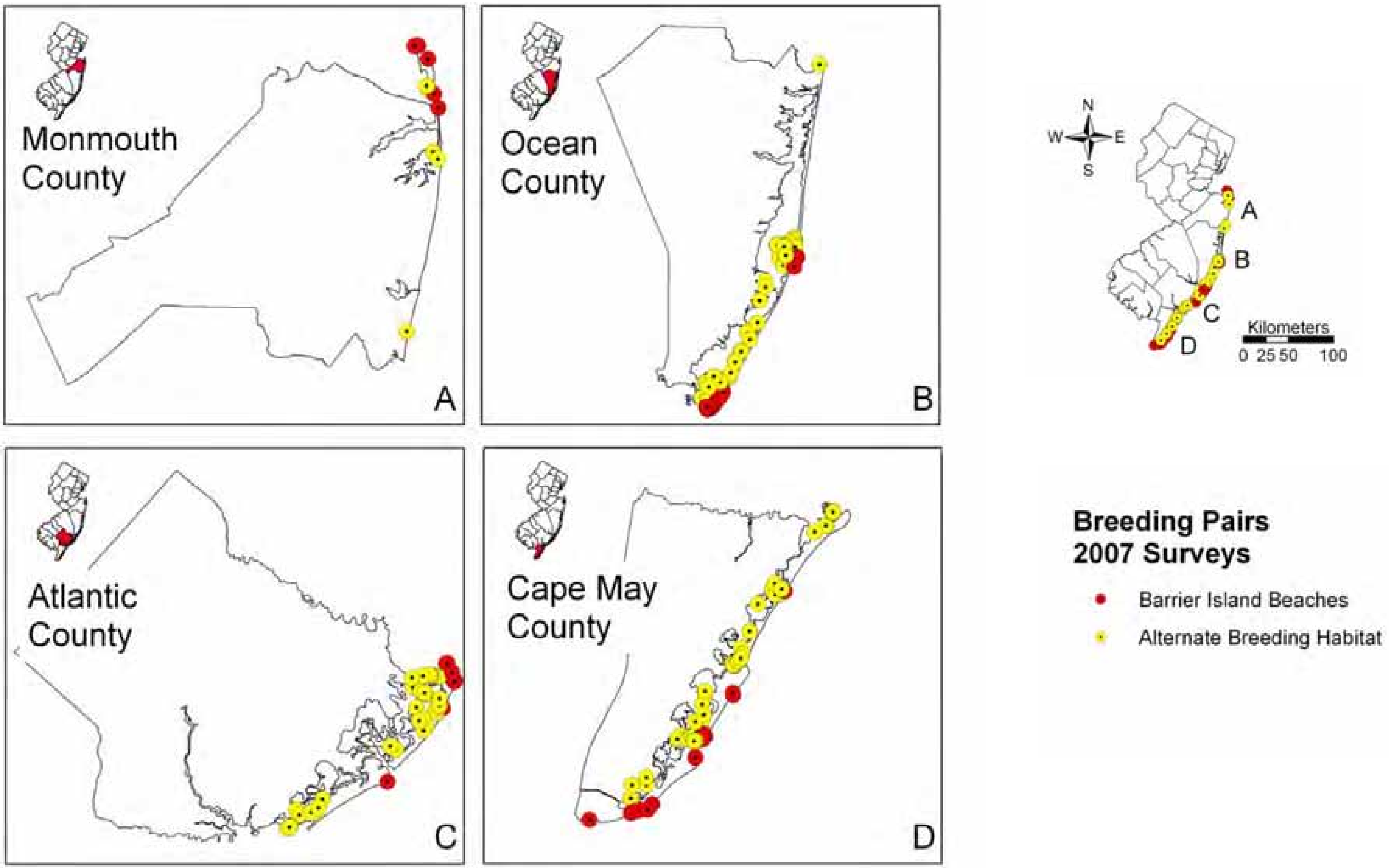

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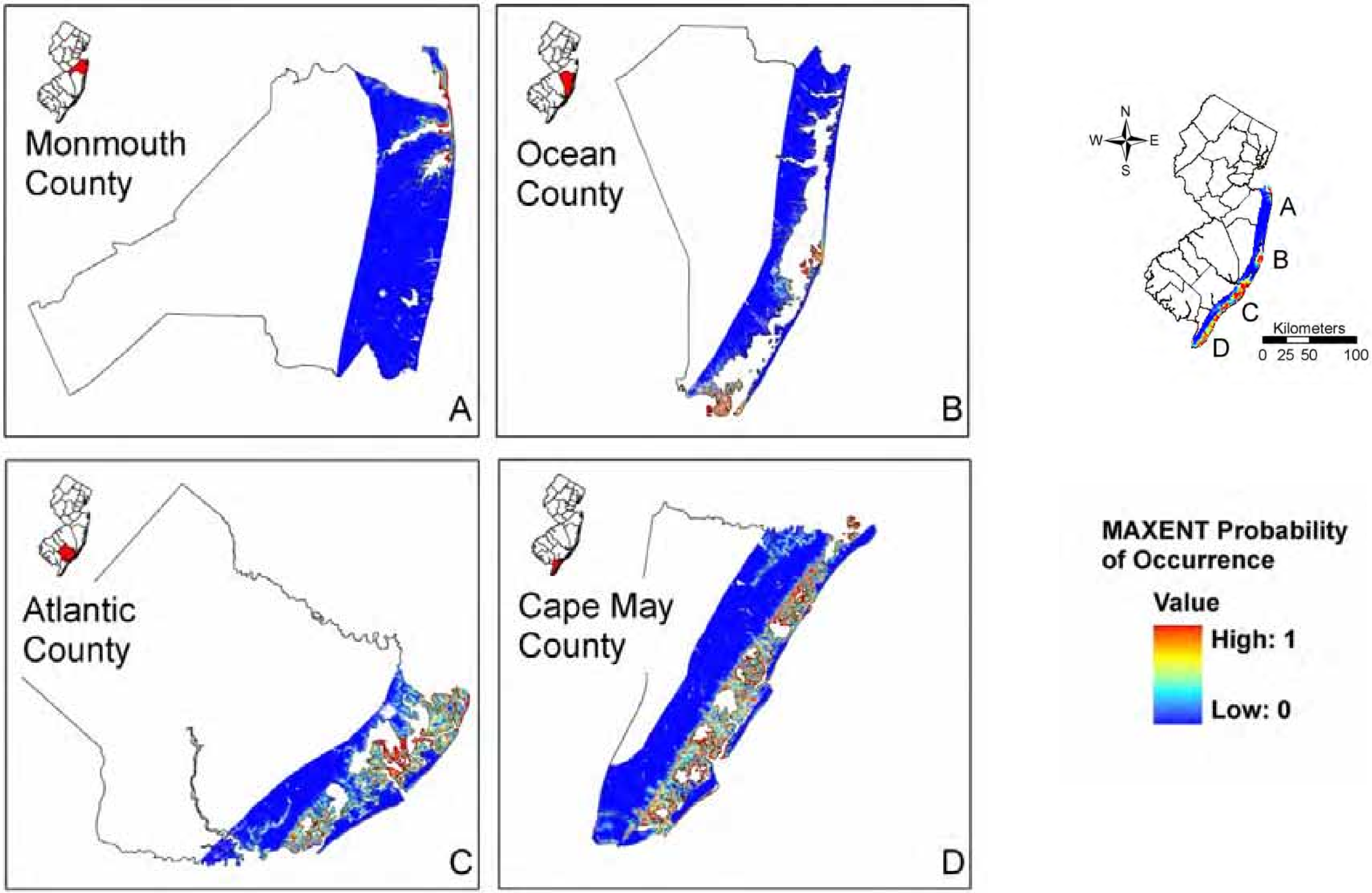
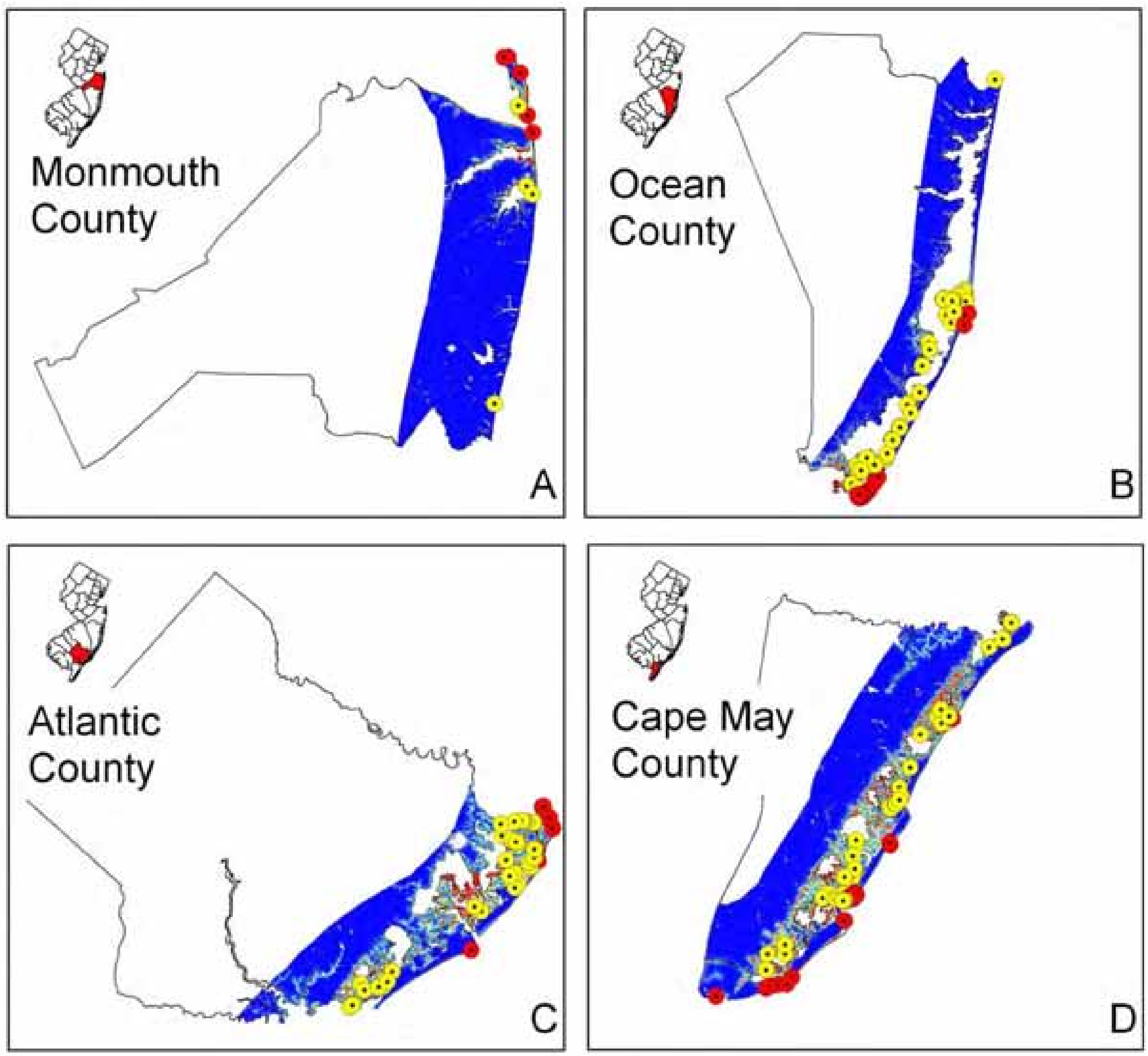


# *MAXENT Model - Results*

Predicted and Actual Distribution




| Habitat Type | No. Pairs | % Total |
|---|---|---|
| Barrier Beach | 60 | 19.4% |
| Saltmarsh | 213 | 69.0% |
| Inlet Islands | 10 | 3.2% |
| Dredge Islands | 26 | 8.4% |
| Total | 309 | 100.0% |

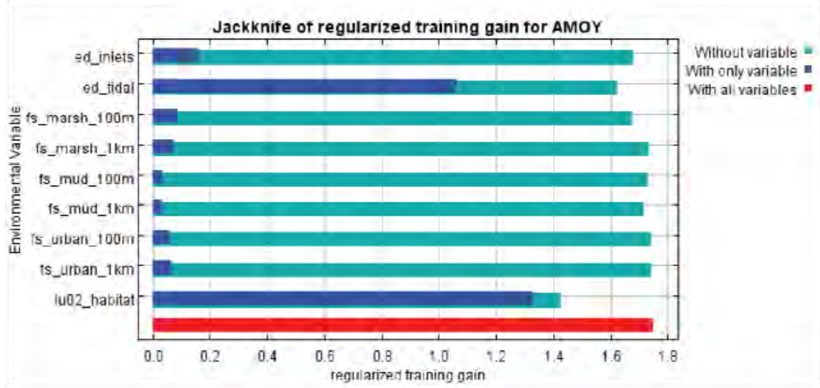
# MAXENT Model - Results

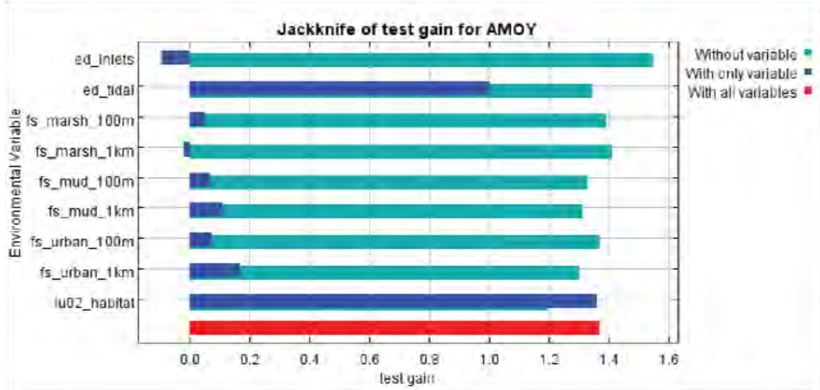
Variable Contributions (Heuristic Estimate)

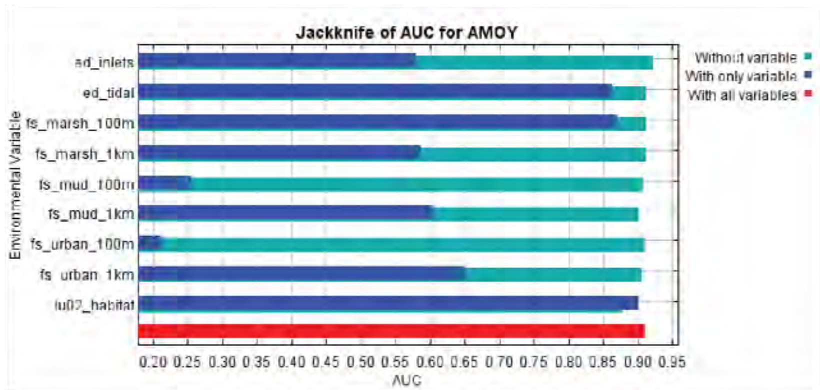
| Variable | % Contribution |
|---|---|
| Distance from nearest tidal waters | 46.8% |
| Habitat classification | 33.3% |
| Distance from nearest inlet | 10.9% |
| Area of low marsh edge within 100 m radius | 3.6% |
| Area of tidal flats within 1 km radius | 1.7% |
| Area of urbanization within 100 m radius | 1.6% |
| Area of tidal flats within 100 m radius | 1.6% |
| Area of low marsh edge within 1 km radius | 0.4% |
| Area of urbanization within 1 km radius | 0.1% |
| Total Contribution | 100.0% |

# MAXENT Model - Results

Variable Contributions
(Jackknife Tests)

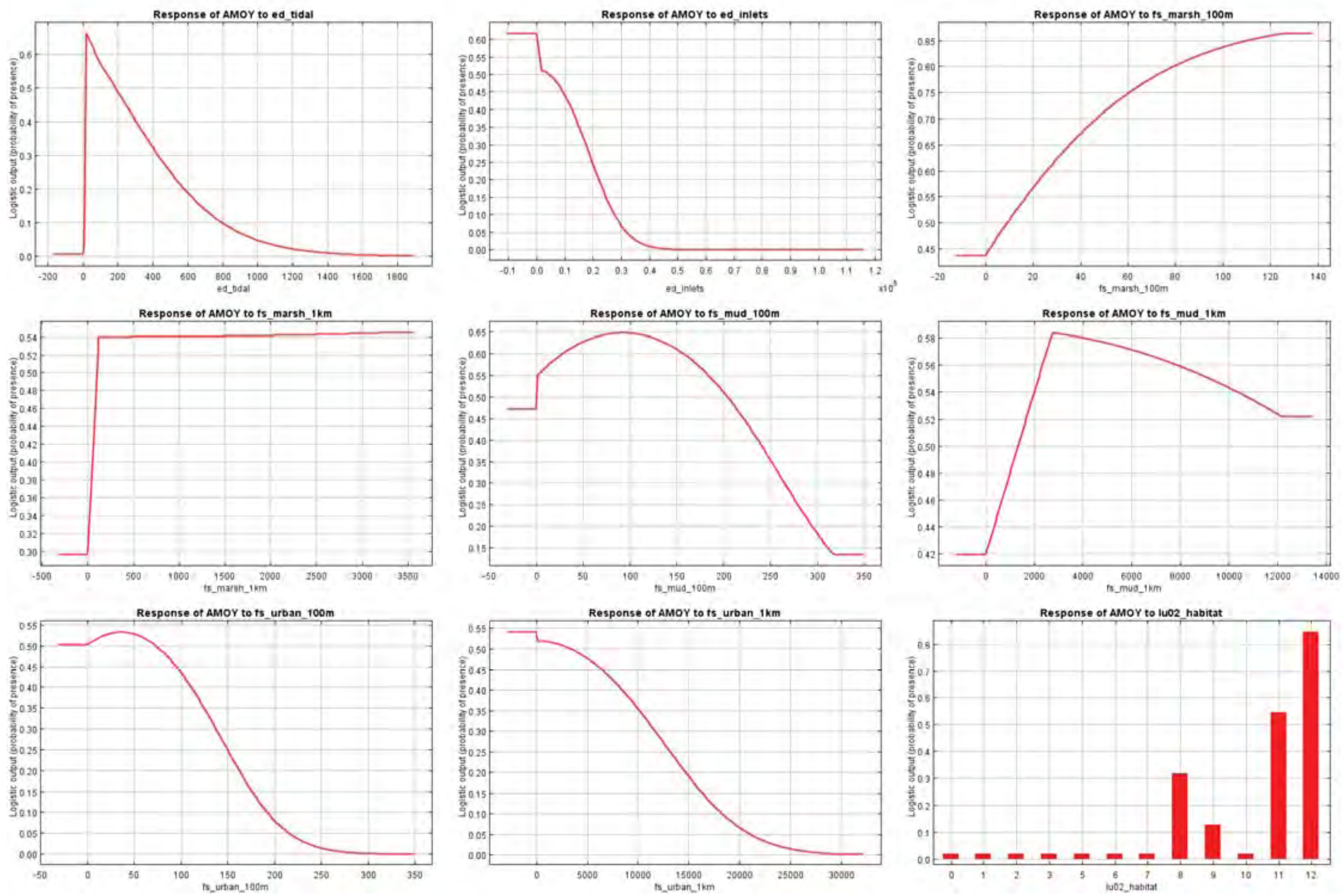


# MAXENT Model - Results

## Variable Response Curves



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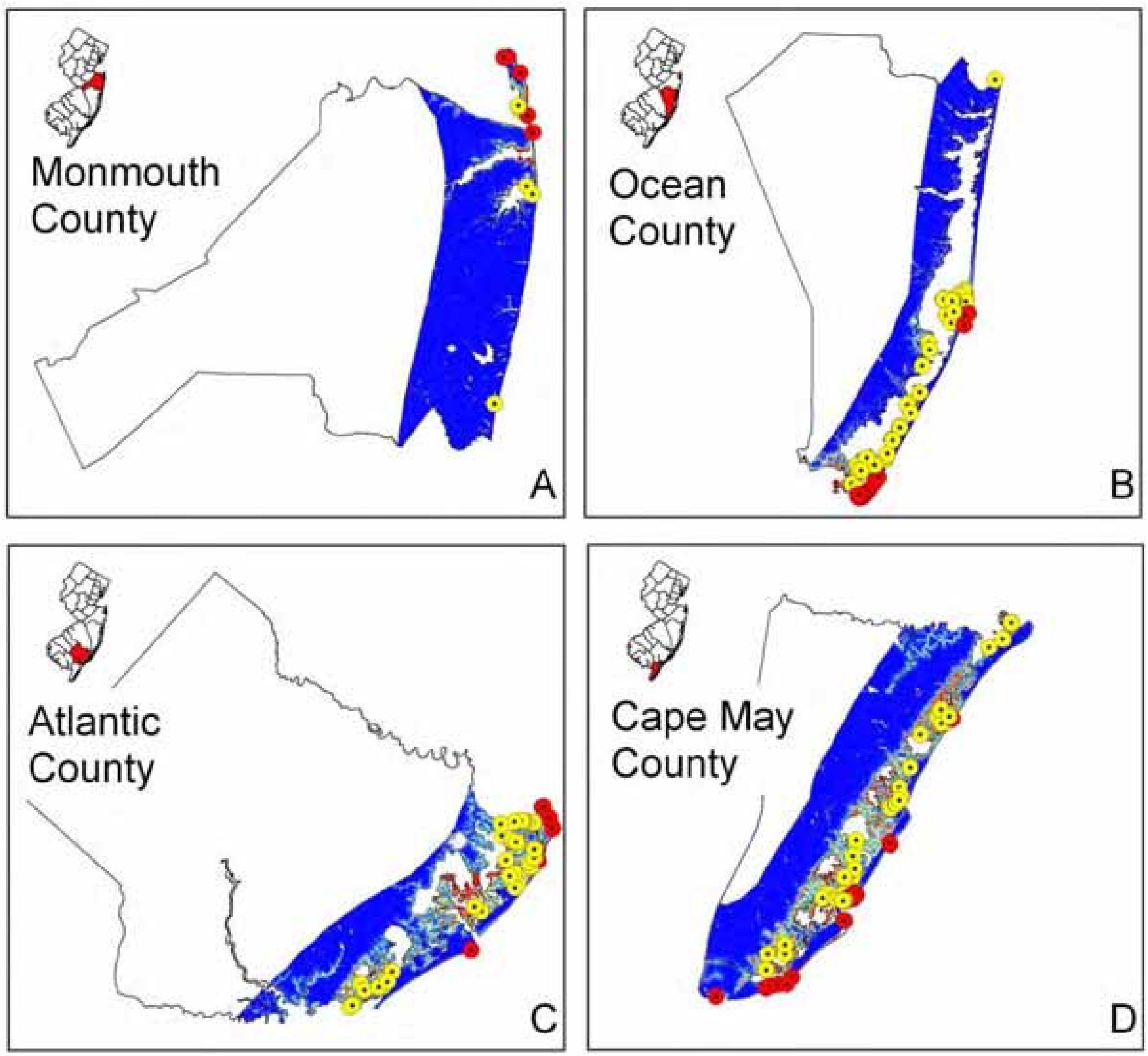
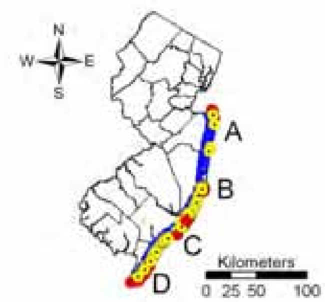
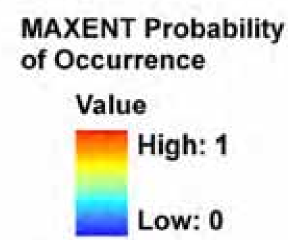
## Model Validation

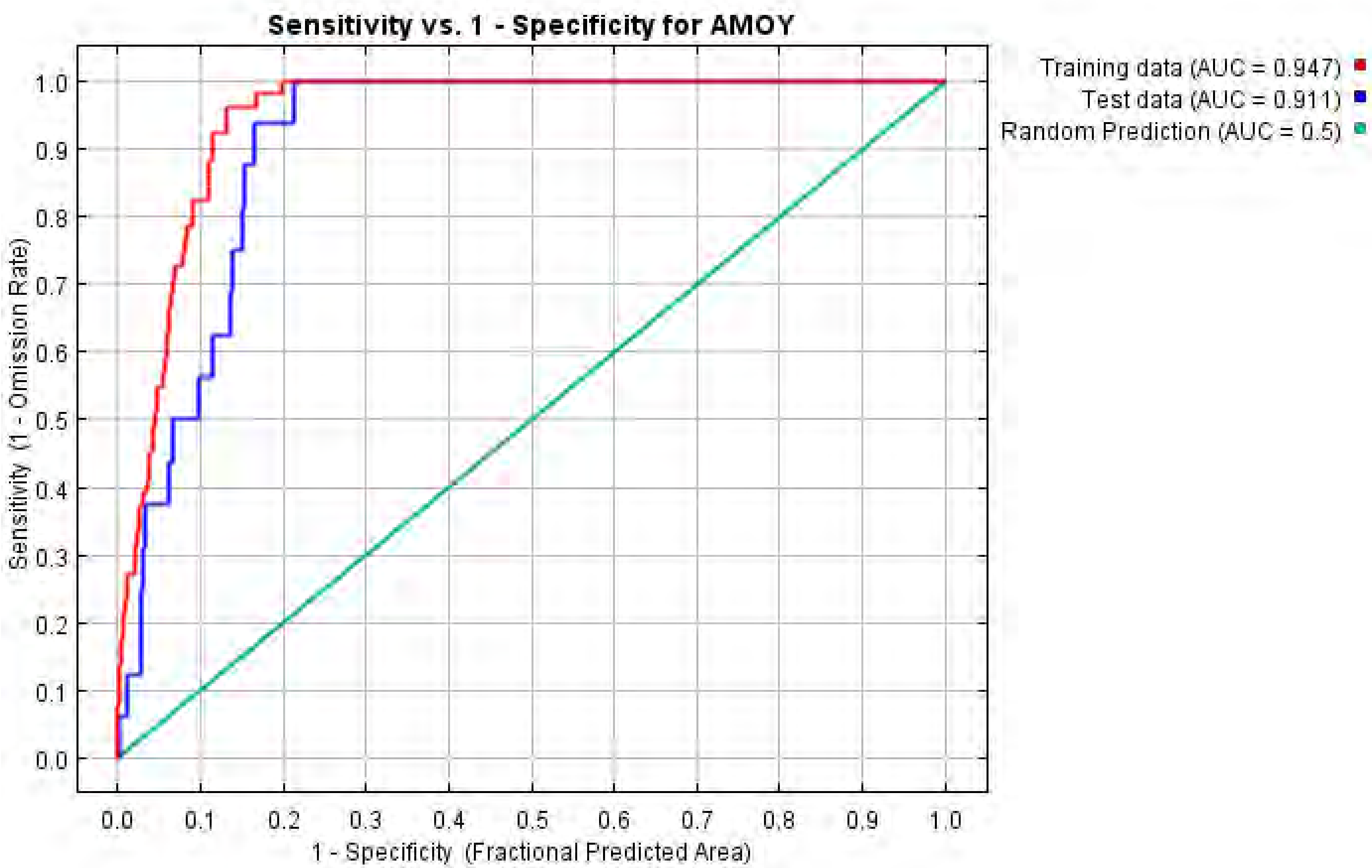


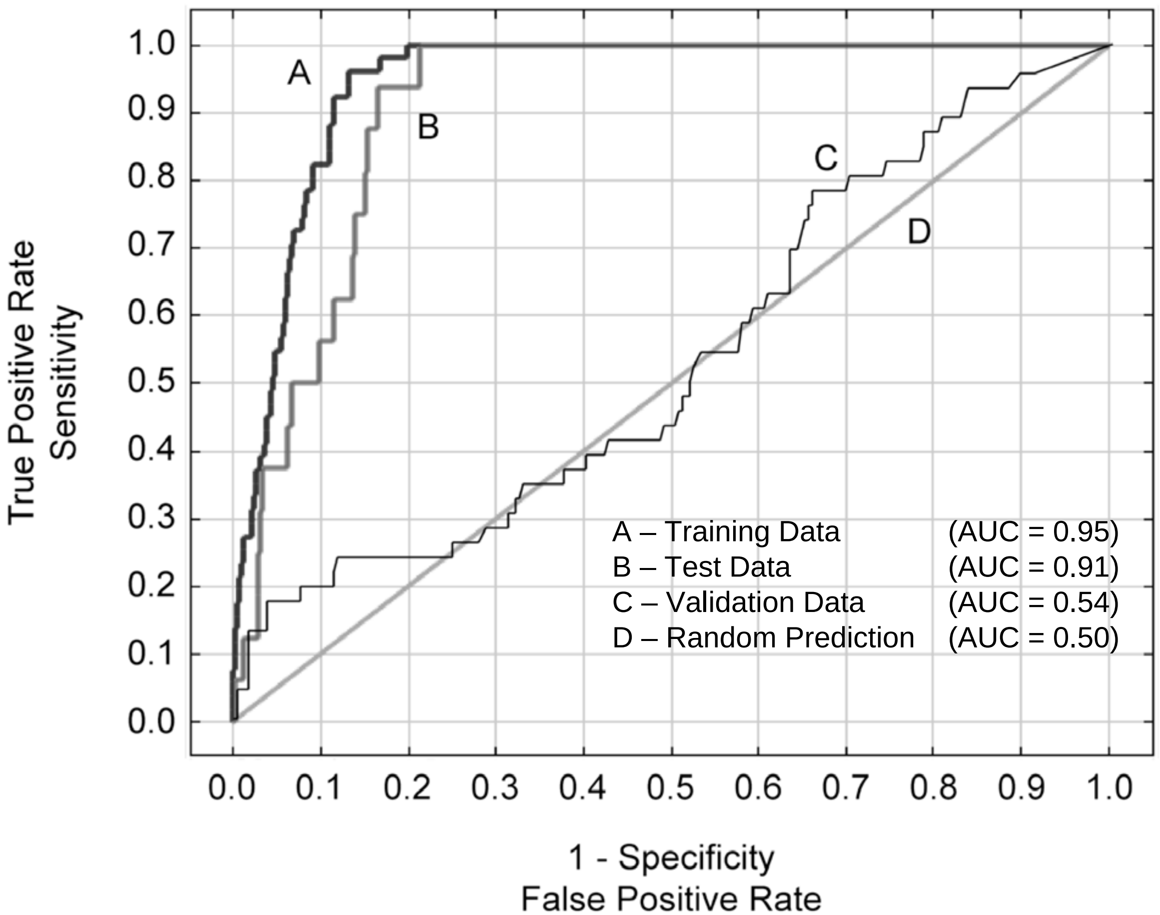
# *MAXENT Model - Results*

## MAXENT ROC Curves (Internal Validation)



# *MAXENT Model - Results*

ROC Curves
(MAXENT vs. Independent Validation)



# MAXENT Model - Results

- Omission Error Rate
  - High false negative rate
  - There are a large number of AMOYs in habitat that is predicted to be unsuitable
- Commission Error Rate
  - High false positive rate
  - There are many areas predicted to be suitable that do not have AMOYs

| | | Validation Data $AUC_{max} = 0.54$ | | | | | |
|---|---|---|---|---|---|---|---|
| Measure | Threshold | TP | FN | TN | FP | OE | CE |
| Point | 0.50 | 9 | 37 | 203 | 34 | 0.80 | 0.79 |
| Mean | 0.50 | 6 | 40 | 220 | 17 | 0.87 | 0.74 |
| Max | 0.50 | 11 | 35 | 185 | 52 | 0.76 | 0.83 |
| Point | 0.70 | 6 | 40 | 230 | 7 | 0.87 | 0.54 |
| Mean | 0.70 | 3 | 43 | 235 | 2 | 0.93 | 0.40 |
| Max | 0.70 | 8 | 38 | 219 | 18 | 0.83 | 0.69 |

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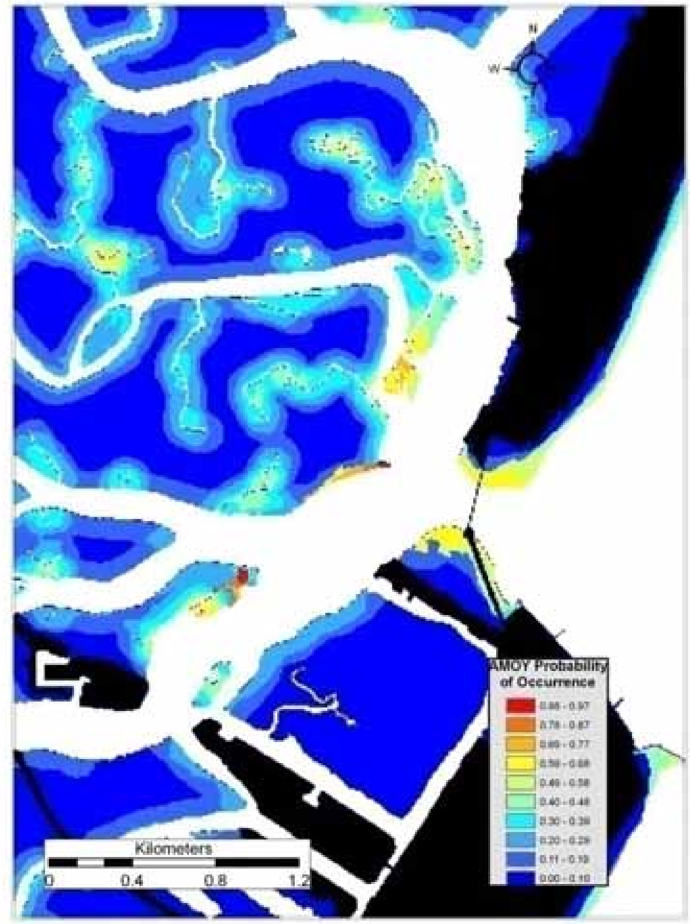

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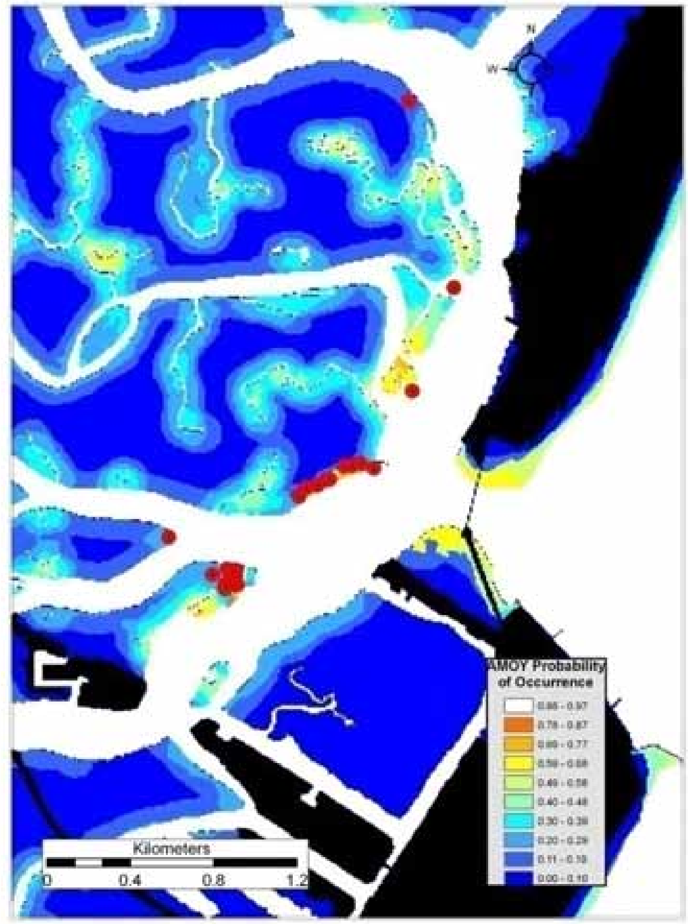

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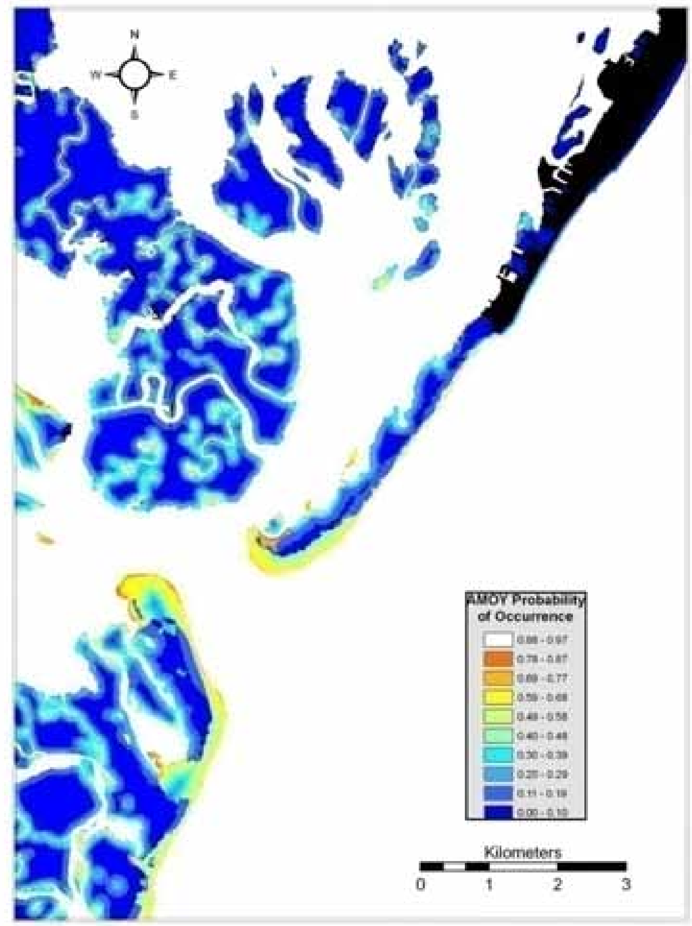

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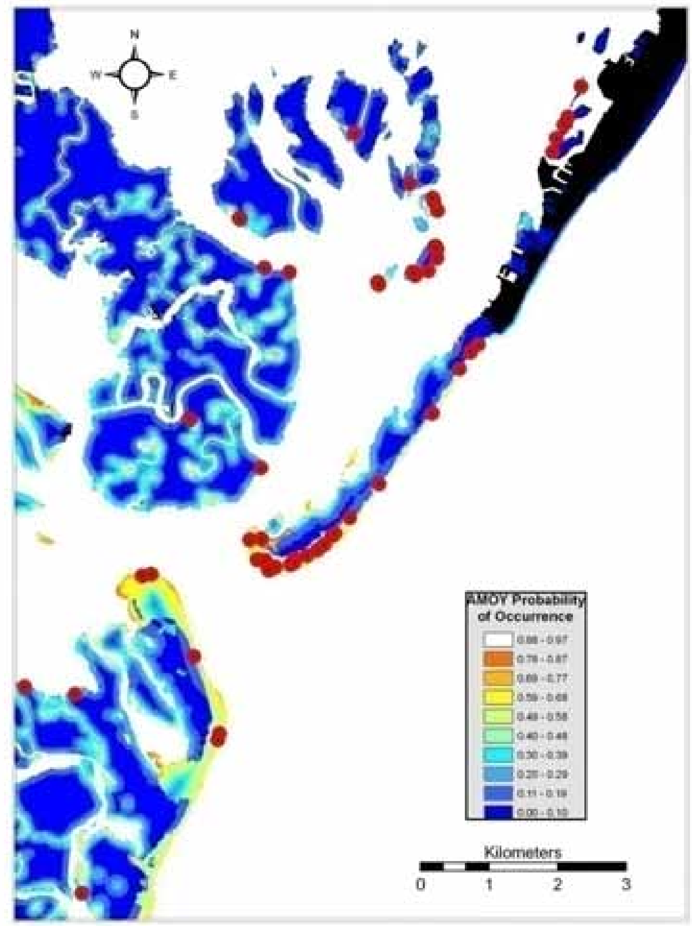

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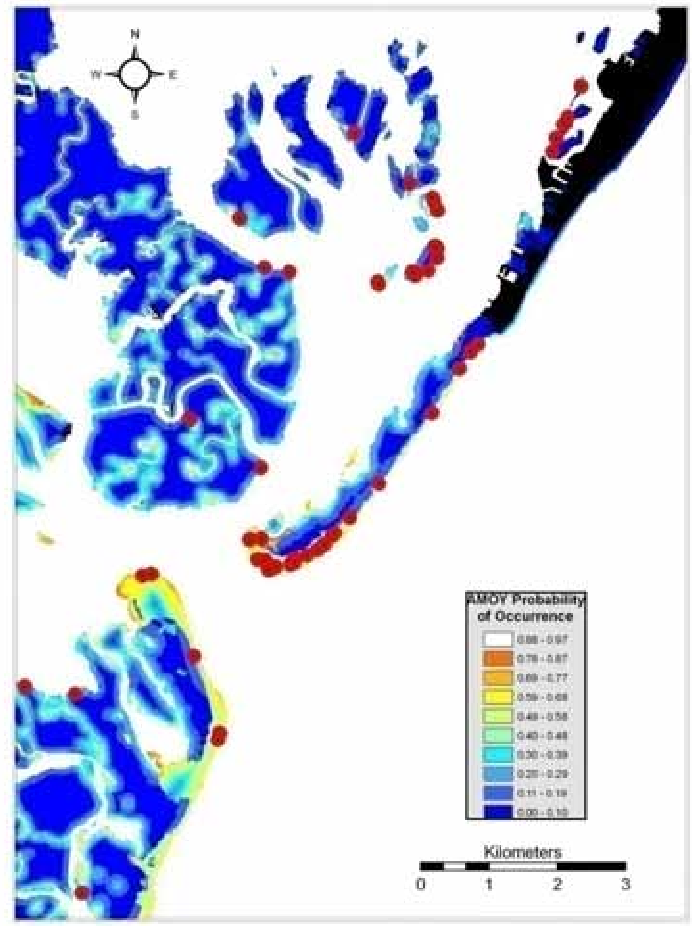
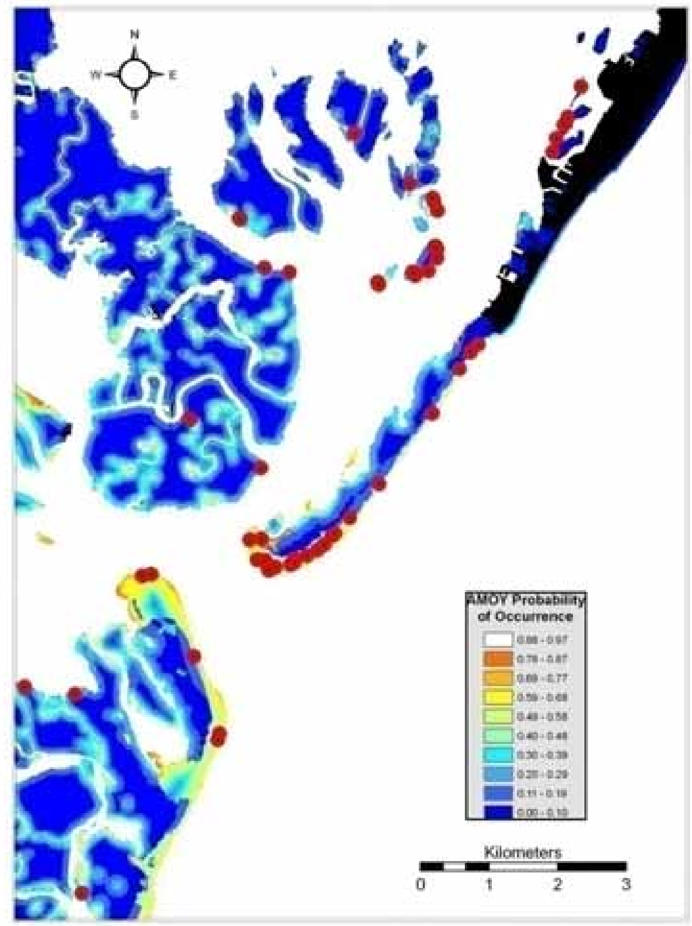
- Why are so many AMOYs occurring in unsuitable habitat?



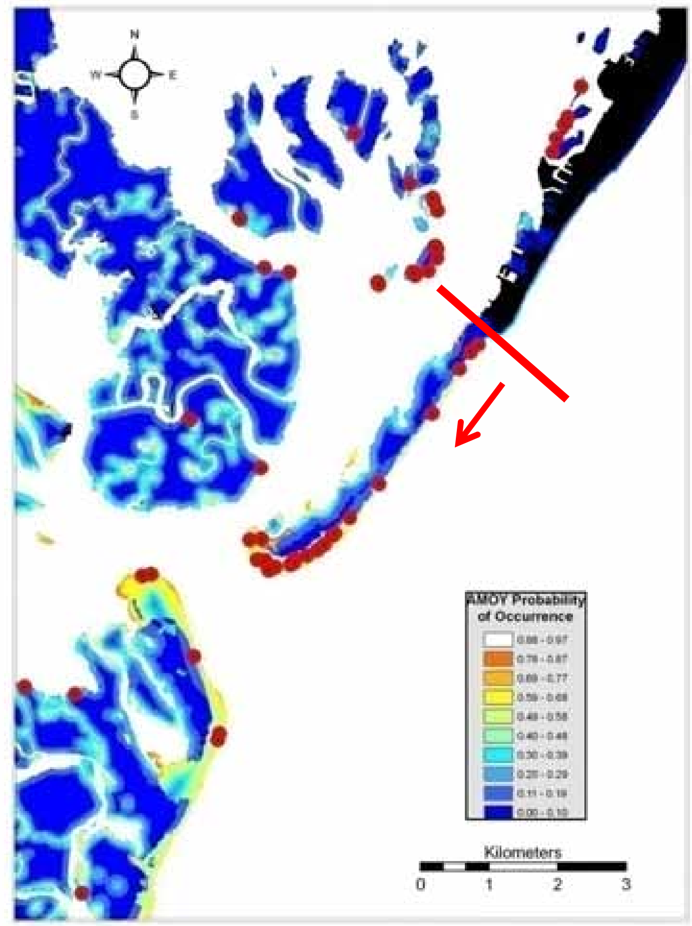
# *MAXENT Model - Discussion*

- Why are so many AMOYs occurring in unsuitable habitat?
  - Modeling errors:
    - Spatial autocorrelation of training data
    - Excessive number of model parameters
  - Data errors:
    - Missing variables that influence distribution (e.g. wrack deposits)
    - Misclassifications in GIS layers (e.g. small sand patches)



# *MAXENT Model - Discussion*

- Why are so many AMOYs occurring in unsuitable habitat?
    - Source-sink dynamics
    - Despotic distribution (Ens 1992)
    - Severe lack of highly suitable habitat in New Jersey
    - Human disturbance displacing oystercatchers from highly suitable habitat



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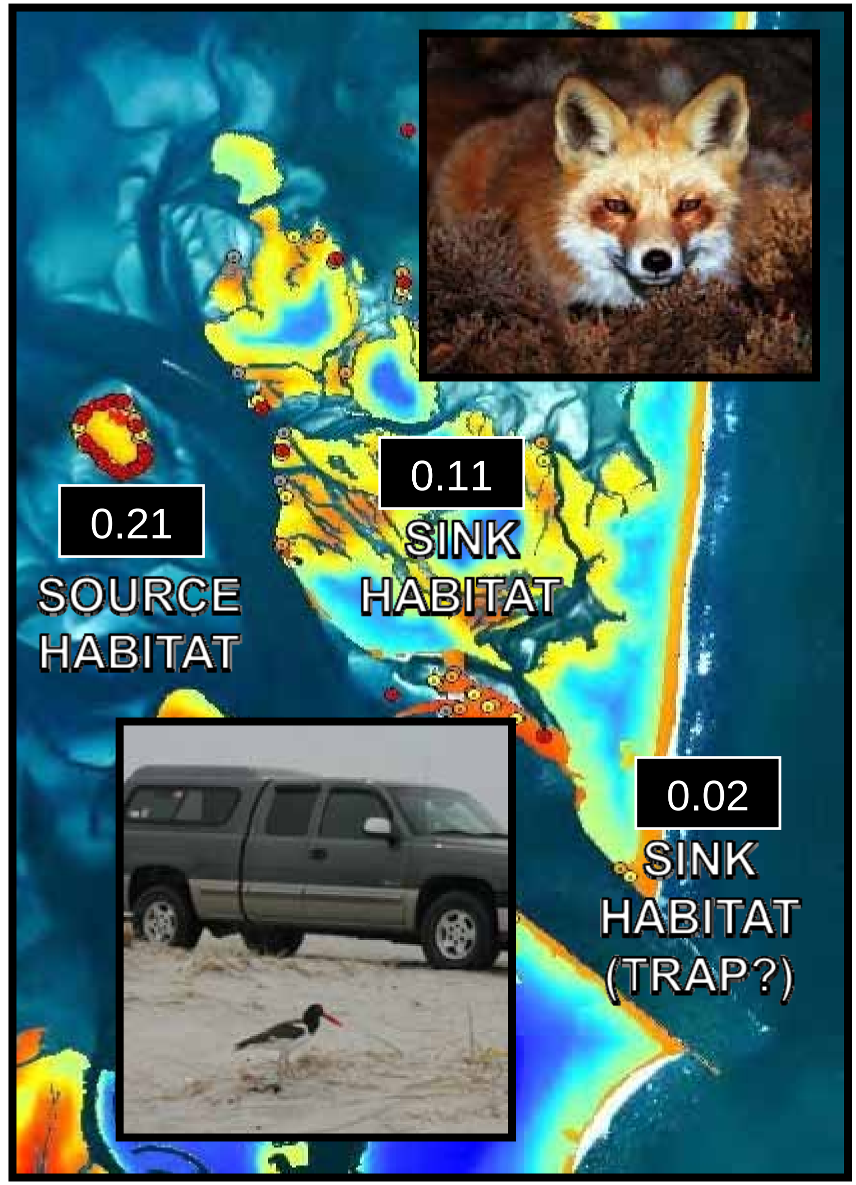

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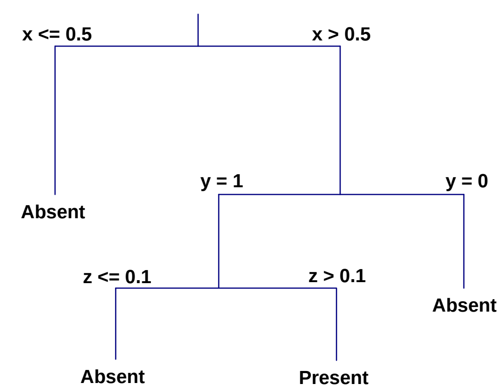
# CART Models - Methods

- Classification and regression tree (CART) models explain the variation of a single response variable by repeatedly splitting the data into more homogeneous groups based on multiple explanatory variables (De'Ath & Fabricius 2000)

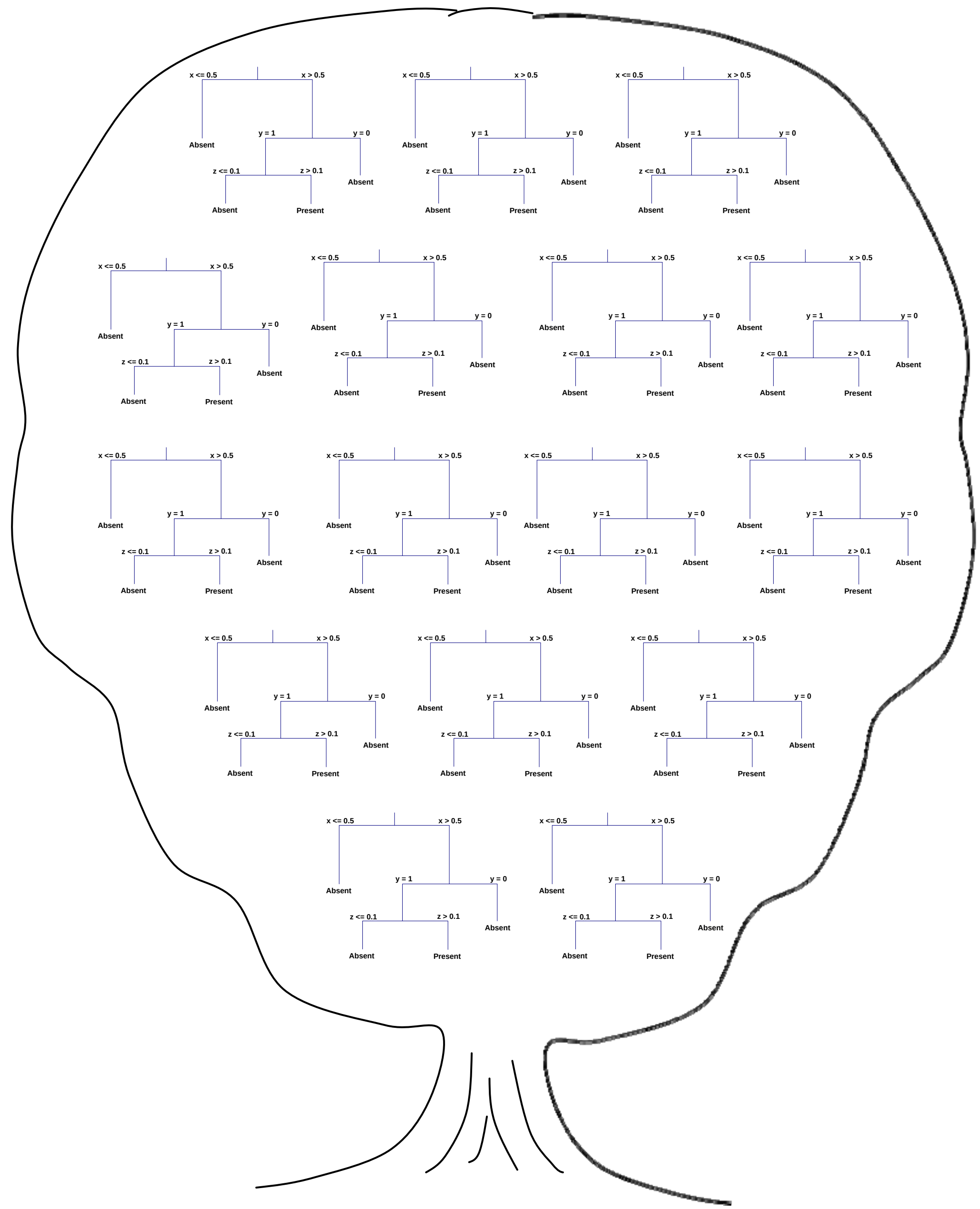
- Classification Models – Presence or Absence
- Regression Models – Density

- Compared with other techniques
  - Random Forests
  - MAXENT



# *CART Models - Methods*

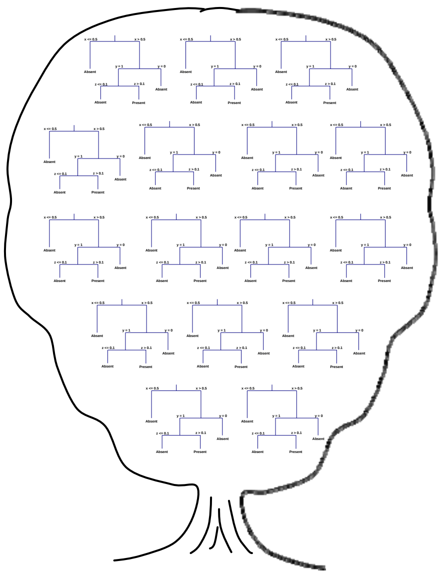
- Grow an overlarge tree by splitting data into homogeneous groups
- Prune by 10-fold cross validation process (run 50 times)
- Goal – find the most parsimonious tree that explains the most variance



# *CART Models - Methods*

- Training Data
  - 68 presence and 68 absence records
  - Data from 2007 surveys on barrier beaches
  - AMOY abundance recorded at all survey points

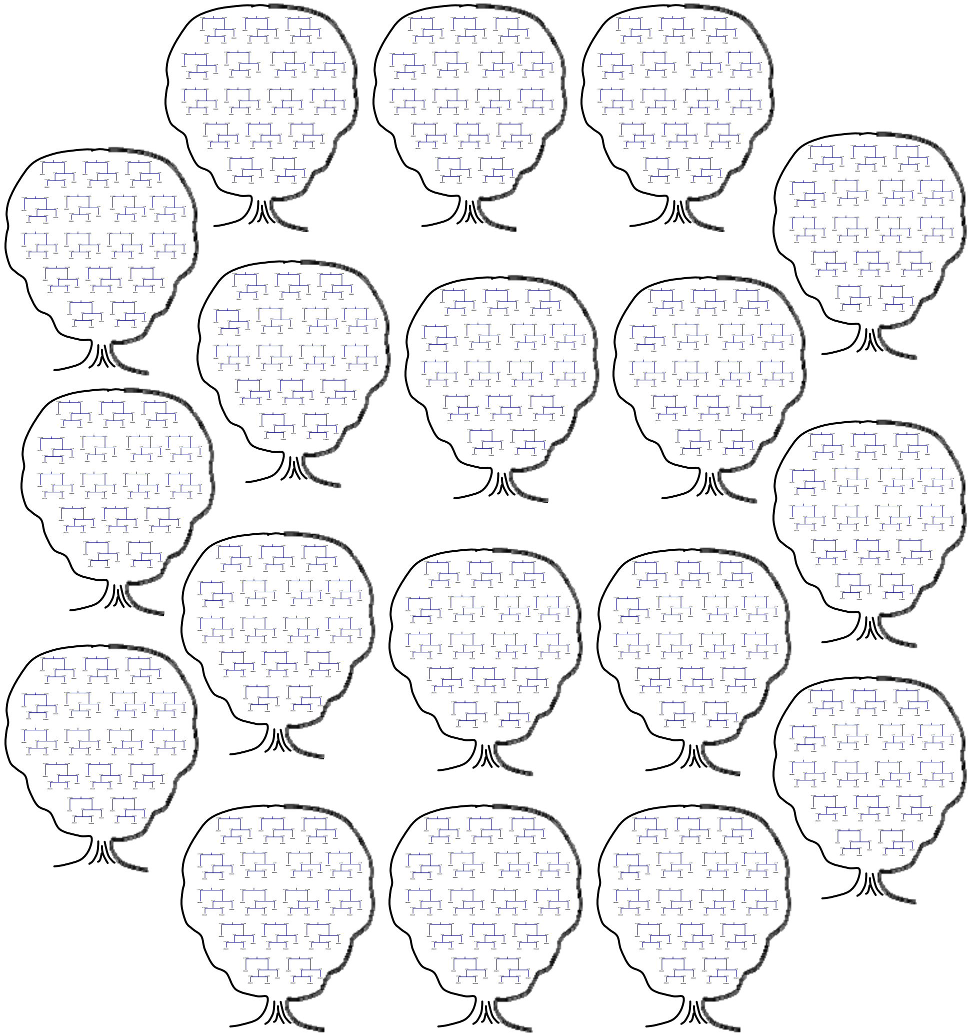
- Explanatory Variables
  - Habitat suitability (based on MAXENT model)
  - Beach disturbance level (rank)
  - Distance from nearest public beach access point
  - Driving on beach permitted during March, April, May or June (separate variables)



# *CART Models - Methods*

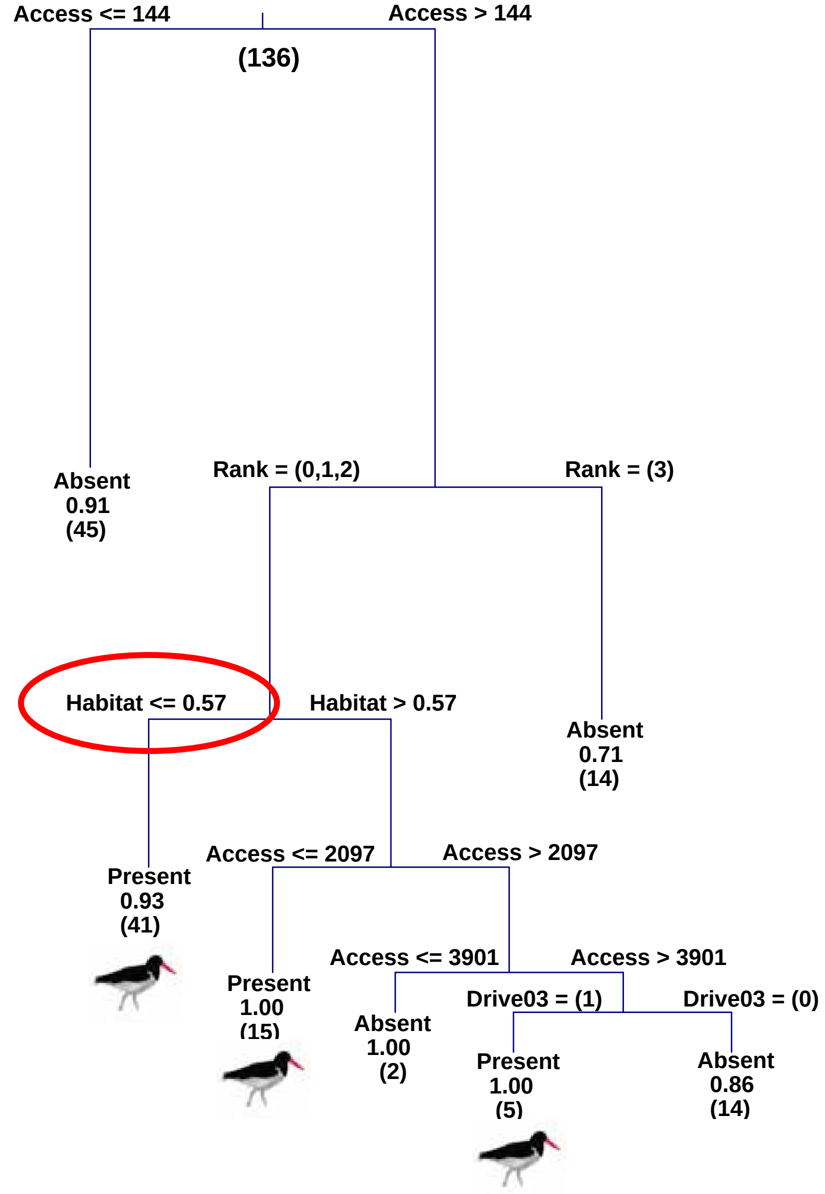
Random Forests Model

- Grow a forest of trees (500 trees)
- Randomization introduced into each tree
  - Bootstrap training data
  - Randomly select variables



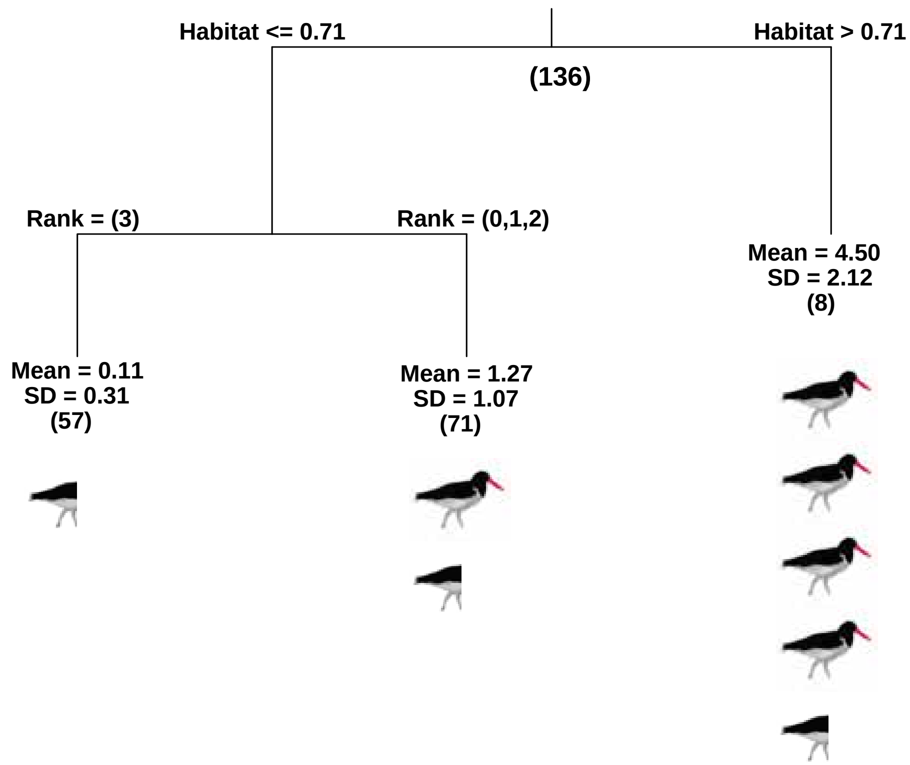
# CART Models - Results

- Classification Tree
  - Length of branches proportional to variance explained at each split
  - Habitat less important variable than expected
  - Most occurrences on less disturbed beaches distant from access points



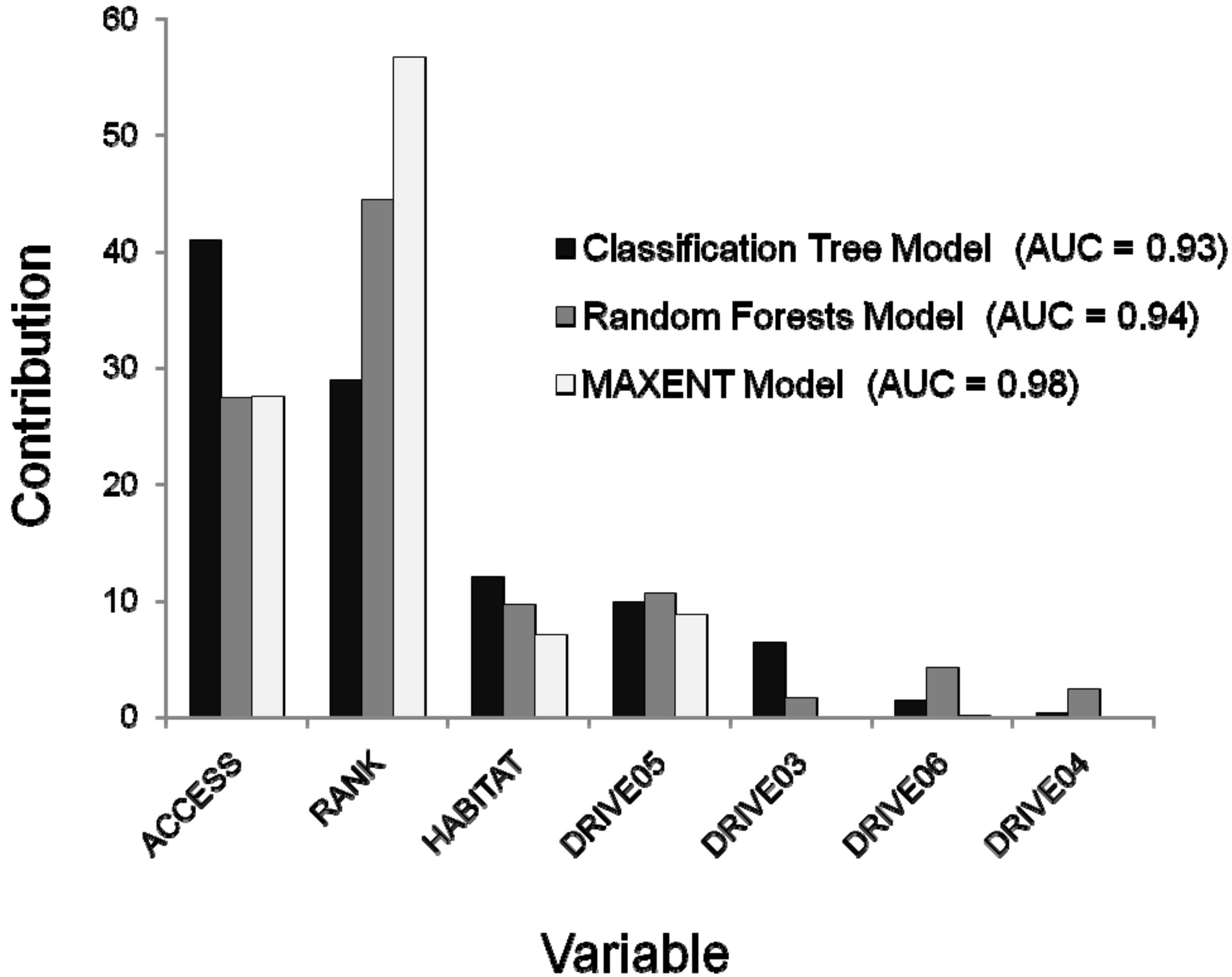
# *CART Models - Results*

- Regression Tree
  - Density highest in most highly suitable habitat
  - However, most training points are in less suitable habitat (128 of 136)
  - Density lowest on most highly disturbed beaches



# CART Models - Results

## Comparison of Techniques: Variable Contributions



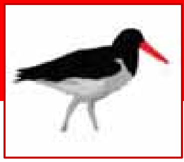
# Conclusions

- Most oystercatchers (~80%) breed in alternative habitats in New Jersey

- Important factors influencing local distribution include: proximity to inlets and presence of sand substrate for nesting

- Recreational activity influences local distribution, excluding AMOYs from highly suitable habitat

- Saltmarsh and barrier beach habitats may be acting as sinks



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