Hierarchical modeling

Kemp's Ridley Sea Turtle

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BACKGROUND

Kemp's Ridley Sea Turtle

→ Once considered the most endangered sea turtle species

→ Survival, age to maturity, reproductive longevity, breeding rates, and fecundity can only be roughly estimated

→ Sea turtles do not nest every year and they occasionally move among nesting beaches within a region

→ the best opportunity for assessing population size is still on the nesting beach

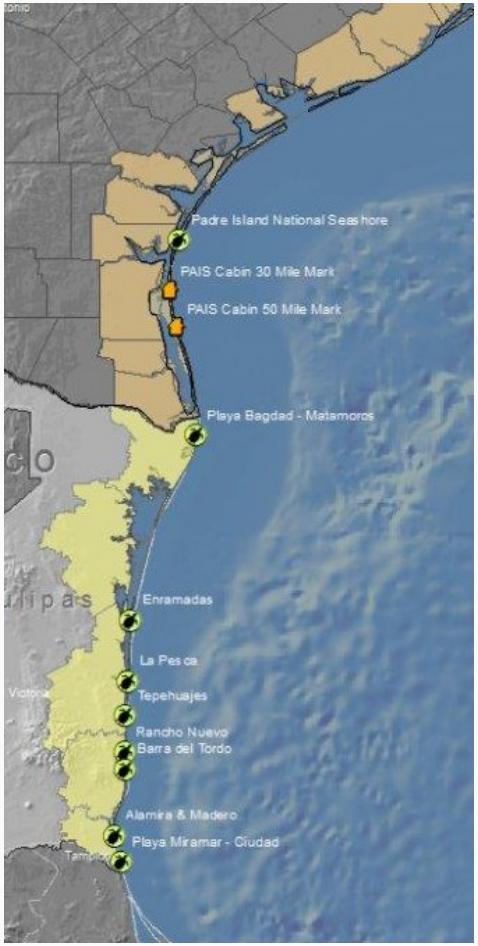
Nesting Background

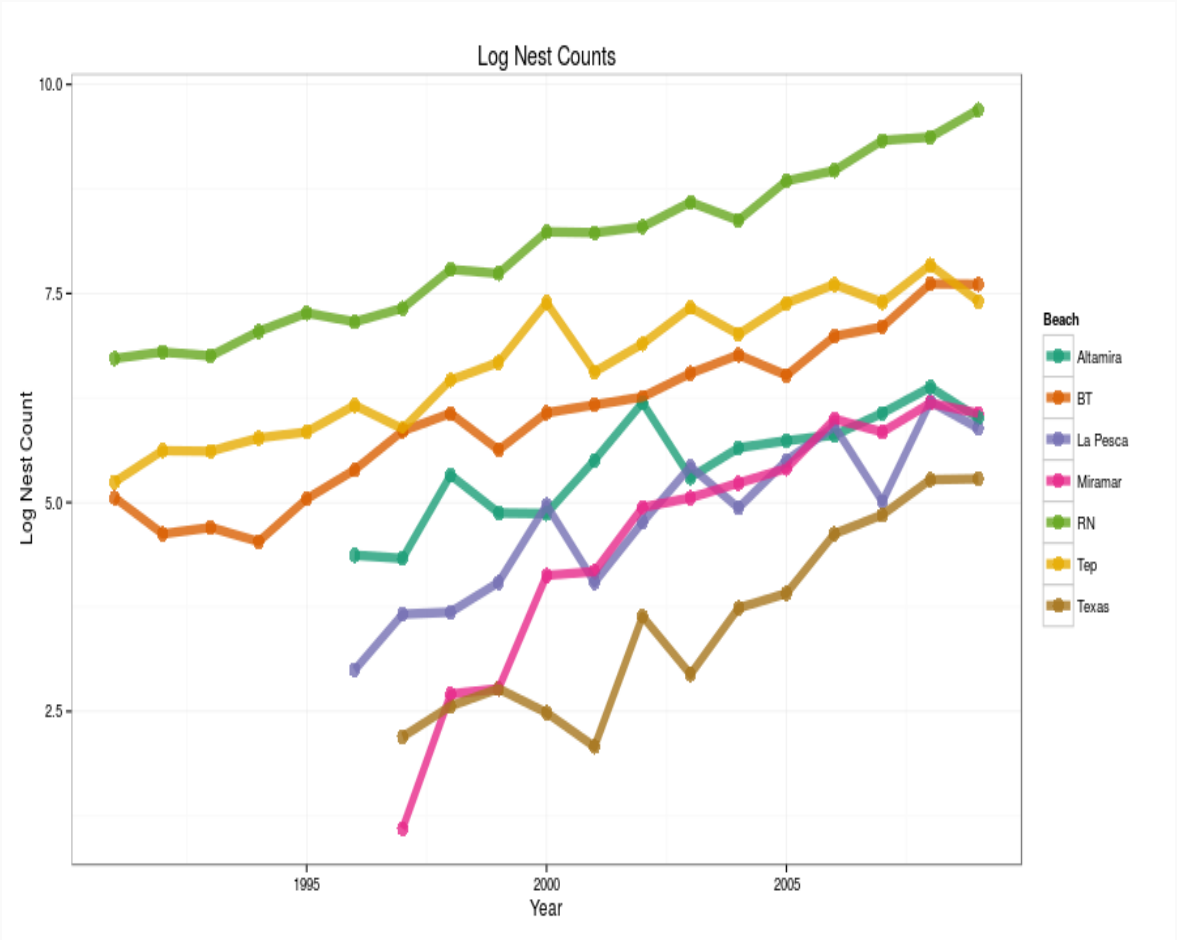
- Kemp's ridleys have synchronized nesting habits
  - Large groups gather off the shore of a beach
  - Wave of females come ashore to nest
  - This phenomenon is knows as "arribada", the Spanish word for arrival.
- The nesting period is from May to June
- Our data are of nesting counts from 7 beaches.
  - Texas
  - La Pesca
  - Tepehuajes
  - Rancho Nuevo
  - Barra del Tordo
  - Altamira
  - Playa Miramar


RESEARCH
QUESTION

Are the beaches part of one underlying population?

-- Do the beaches share the same growth rate?





MODEL DEVELOPMENT

General Approach

→ Set up hierarchical models with

→ process model : Exponential growth with constant rate b

→ observational model : Poisson

→ Compared observed nesting counts to the posterior predictive distribution to assess goodness of fit.

→ If good fit, then we have evidence that the trend is the same in all beaches.

Models attempted

Assume: Constant growth rate over time

1. Same growth rate across all beaches.

2. Different growth rates for each beach.

3. Some beaches with same growth rate, some beaches with different growth rates.

   → growth rates for each beach indicated that some beaches have similar rates
   → clustered beaches geographically
   → attempted different clusters (will show best 3)

Model 1: Constant growth rate

→ PROCESS MODEL :

$\log N_i = \log N_{i-1} + b + \eta_i$

N_i = population of nesting turtles at time i

b = constant growth rate

$\eta_i \sim N(0, \sigma^2_{process})$

→ OBSERVATIONAL MODEL :

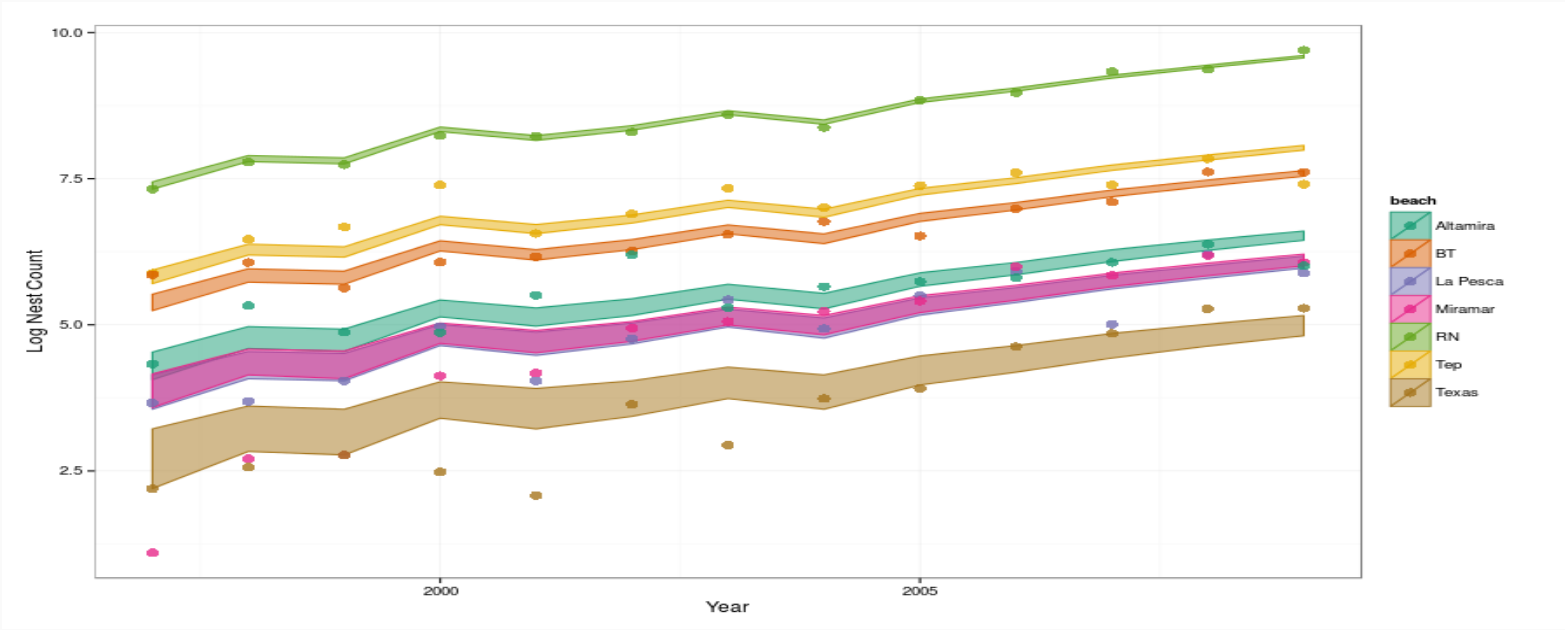
$Y_{ij} \sim \text{Poisson}(\, p_j * N_i \,)$

Y_{ij} = Nest count at time i at beach j

p_j = proportion of N_i that nests on beach j

Prior: $p_j \sim \text{Dir}(\alpha)$

Model 1: Constant growth rate



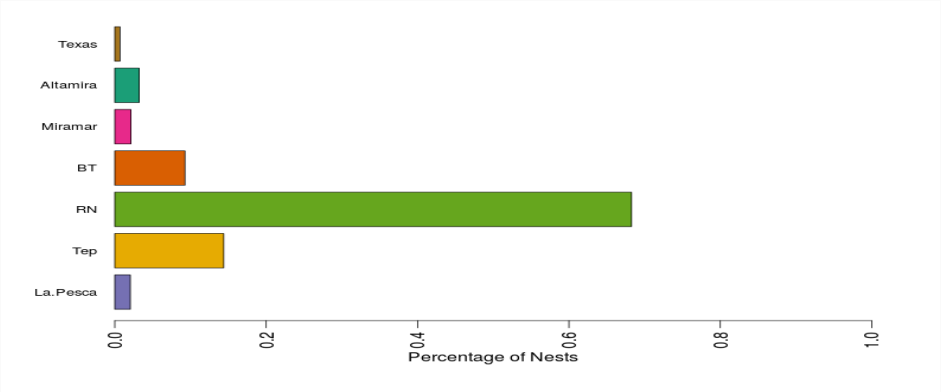


Figure: Proportion p_j of population in each beach

Model 2: Different growth rate per beach

→ PROCESS MODEL :

$\log n_{ij} = \log n_{i-1,j} + b_j + \eta_{ij}$

n_{ij} = population at time i for beach j

b_j = growth rate for beach j

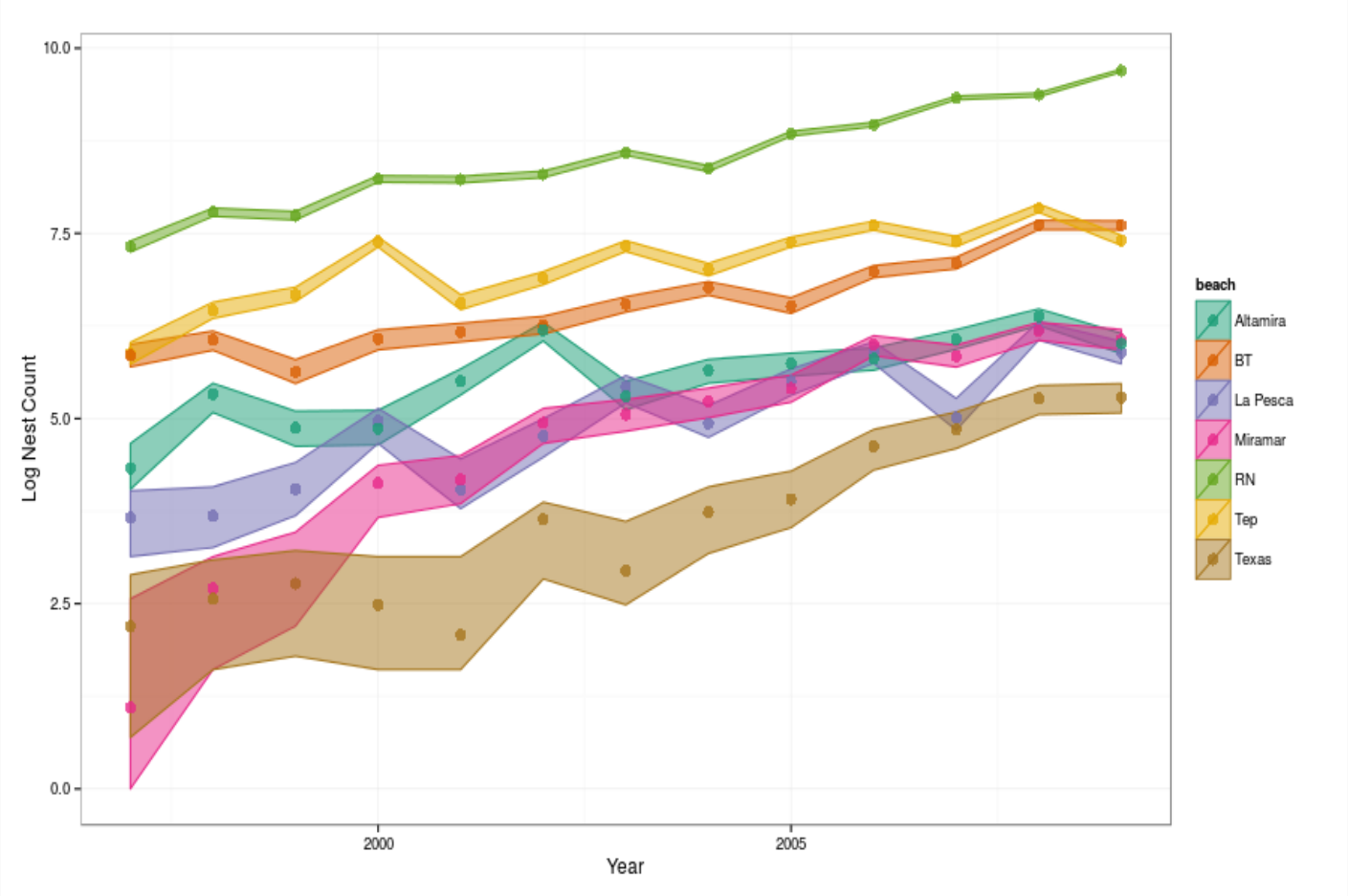
$\eta_{ij} \sim N(0, \sigma^2_{process})$

→ OBSERVATIONAL MODEL :

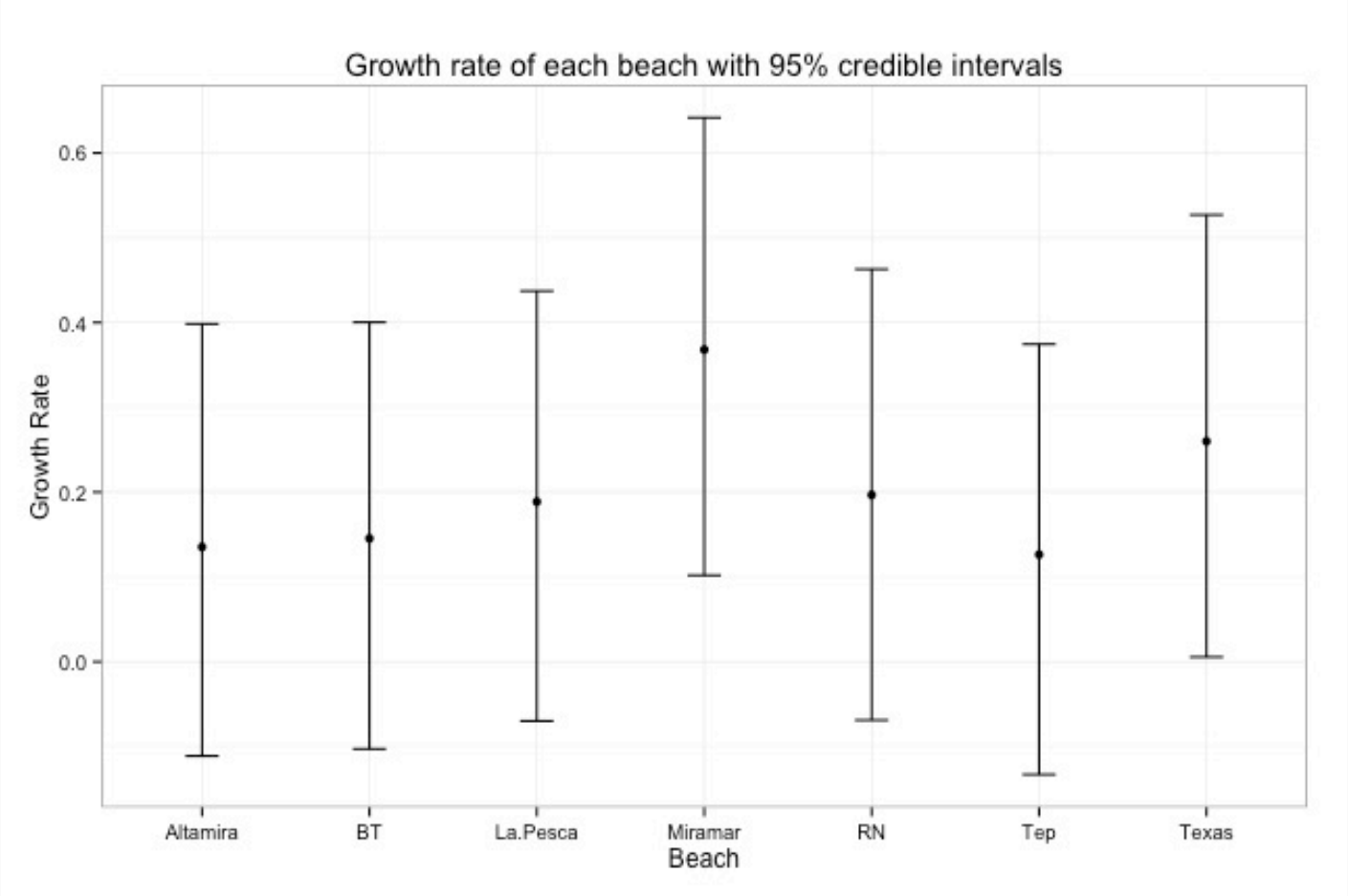
$Y_{ij} \sim$ Poisson(n_{ij})

Y_{ij} = Nest count at time i at beach j

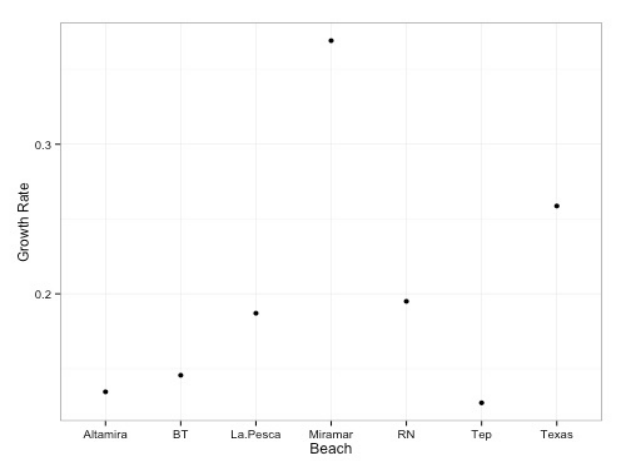
Model 2: Different growth rate per beach

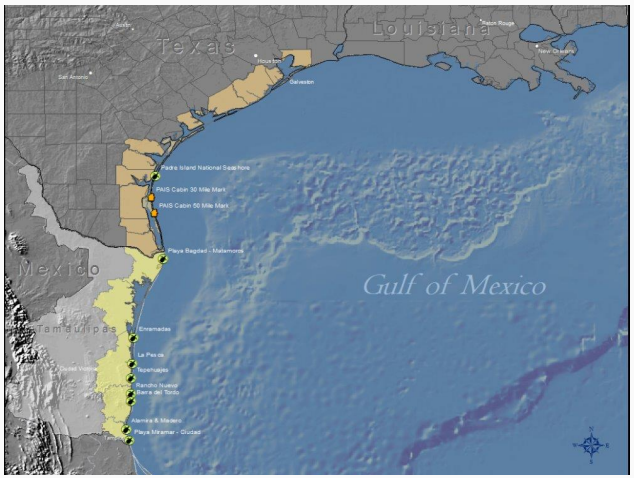


Model 2: Different growth rate per beach



Model 3: Clustering of Trends





Grouping 1:

- La Pesca + Tep
- RN + BT
- Altamira
- Texas
- Miramar

Grouping 2:

- La Pesca + Tep + RN + BT
- Altamira
- Texas
- Miramar

Grouping 3:

- La Pesca + Tep + RN + BT + Altamira
- Texas
- Miramar

Model 3: Clustering of Trends

For j^{th} beach in cluster:

PROCESS MODEL:

$$\log N_i = \log N_{i-1} + b + \eta_i$$
$$\eta_i \sim N(0, \sigma^2_{process})$$

OBSERVATIONAL MODEL:

$$Y_{ij} \sim \text{Poisson}(p_j * N_i)$$

Prior: $p_j \sim \text{Dir}(\alpha)$

Y_{ij} = nest count at time i on beach j

N_i = population of nests at time i

p_j = proportion of nests on beach j

For j^{th} beach not in cluster:

PROCESS MODEL:

$$\log n_{ij} = \log n_{i-1,j} + b_j + \epsilon_{ik}$$
$$\epsilon_{ij} \sim N(0, \sigma^2_{process})$$

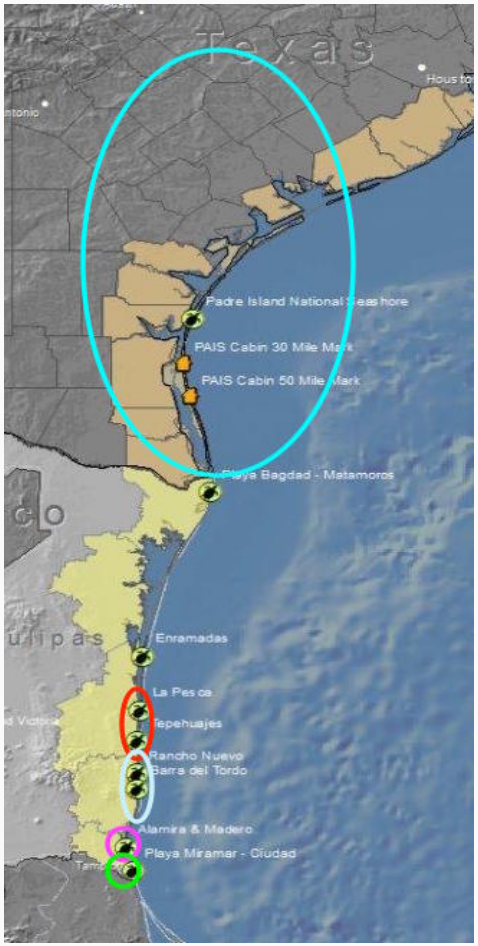
OBSERVATIONAL MODEL:

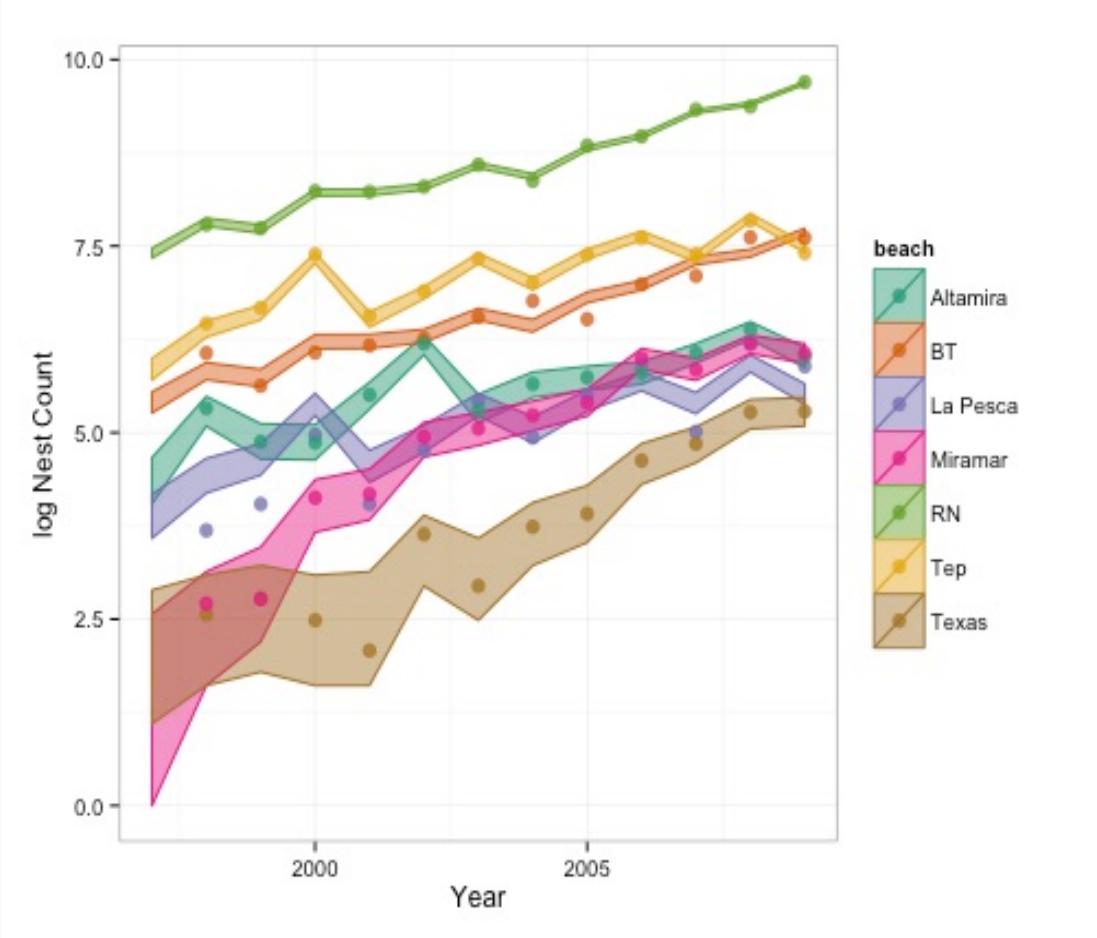
$$Y_{ij} \sim \text{Poisson}(n_{ij})$$

Y_{ij} = nest count at time i on beach j

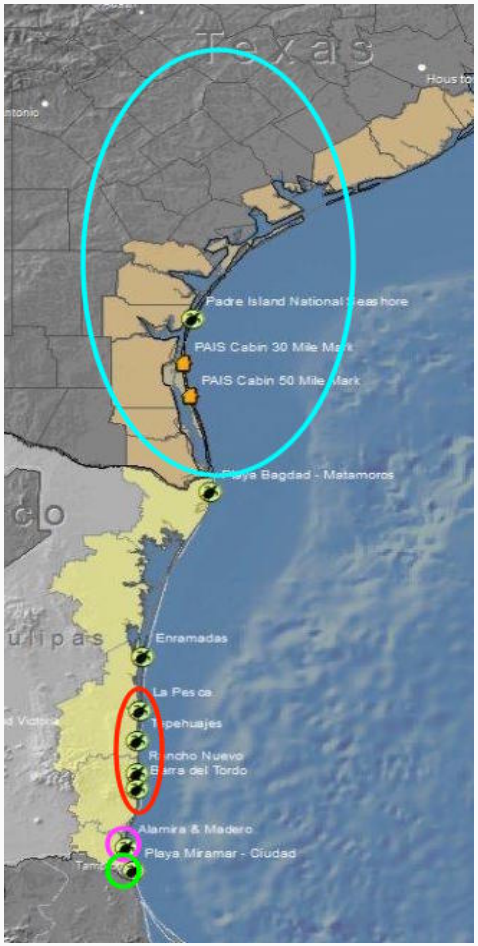
n_{ij} = population of nests at time i on beach j

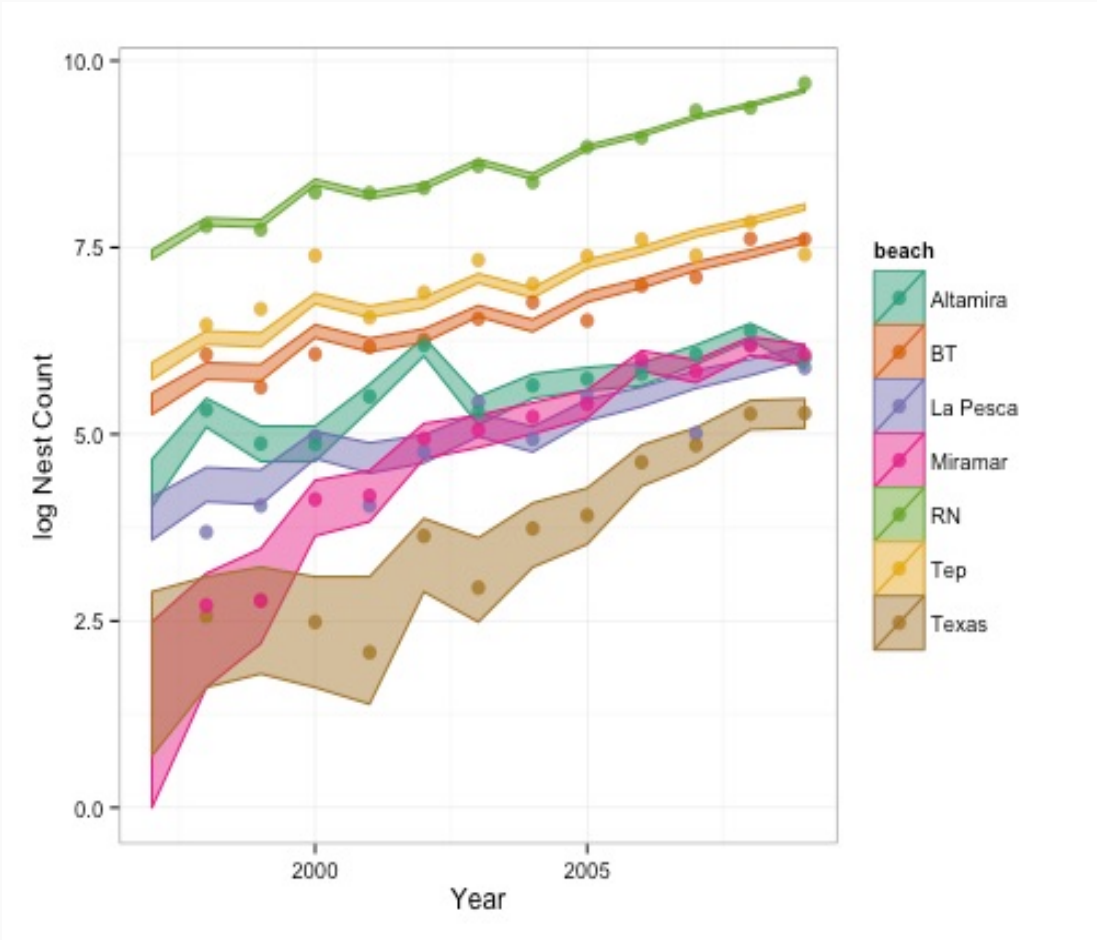
Model 3: Clustering of trends using grouping 1



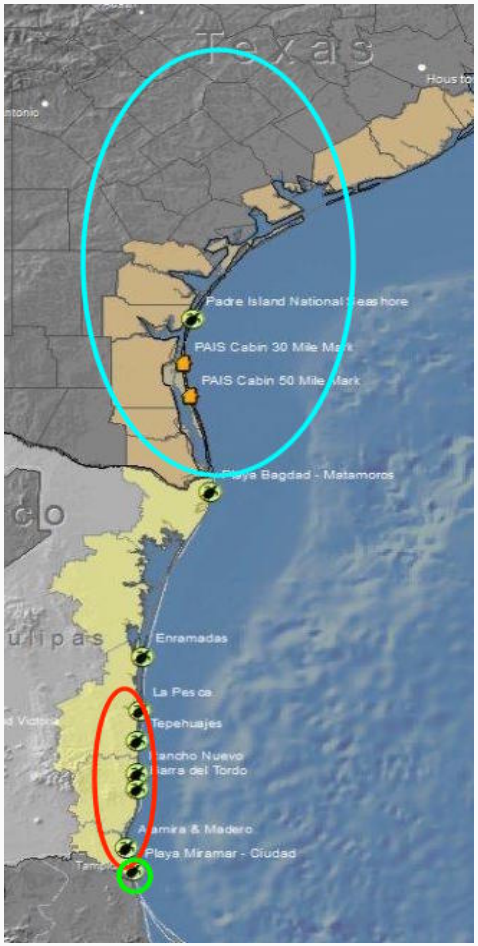


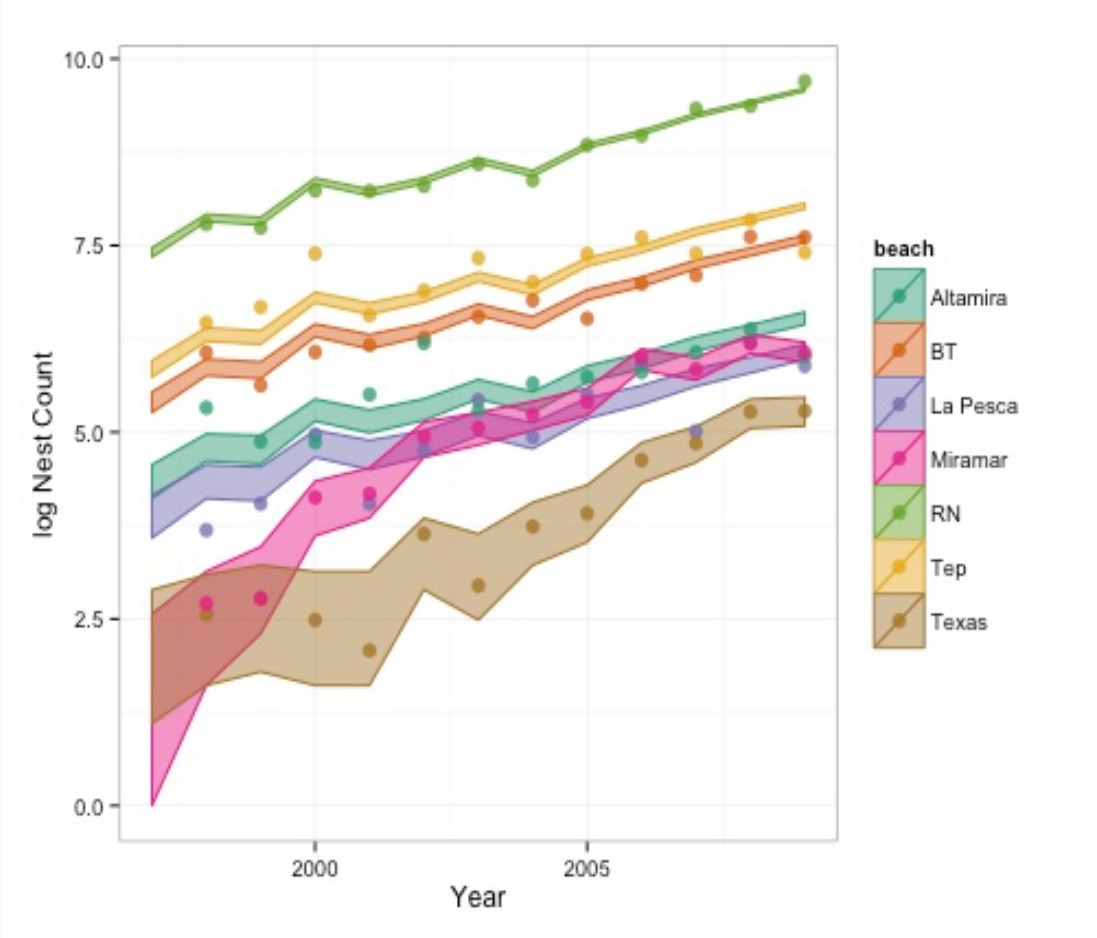
Model 3: Clustering of trends using grouping 2



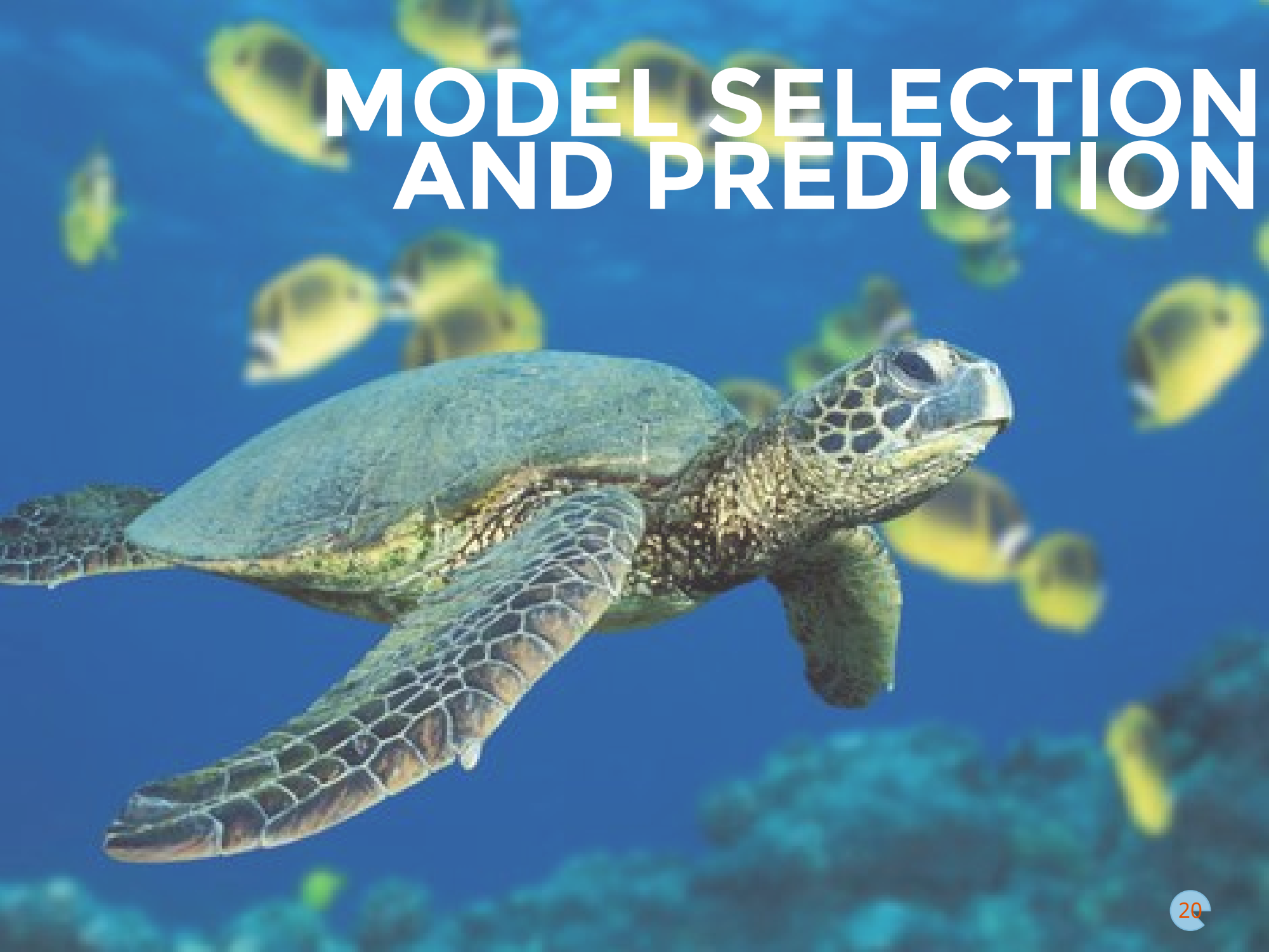


Model 3 :Clustering of trends using grouping 3

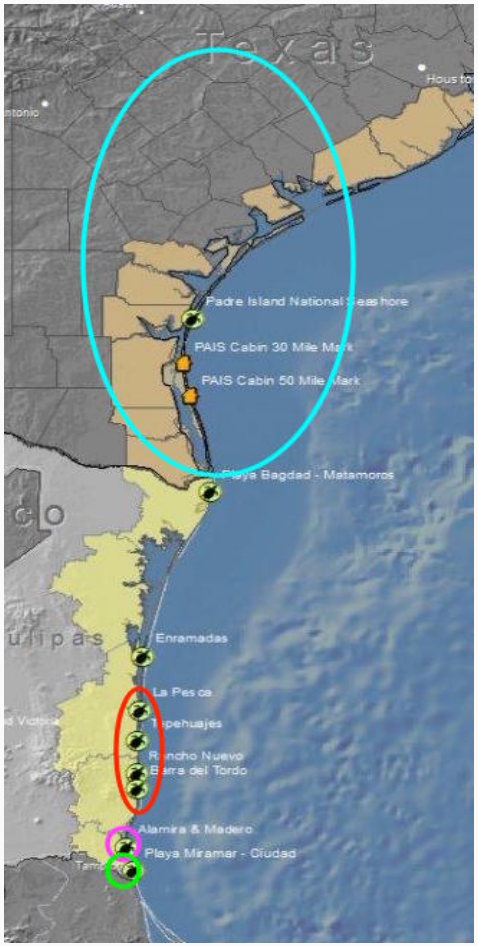


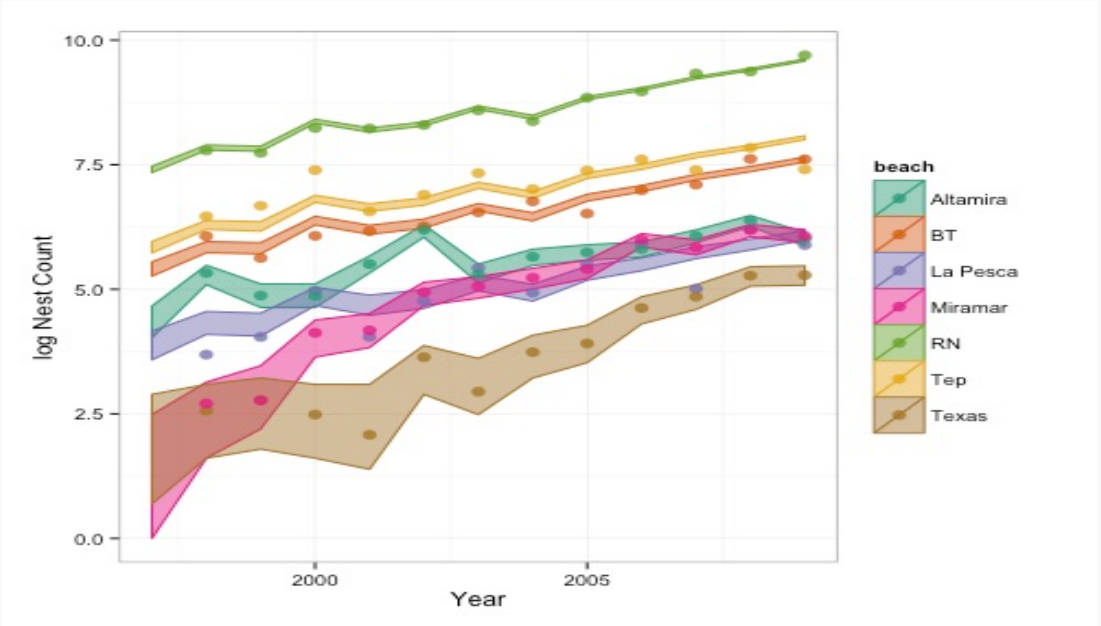


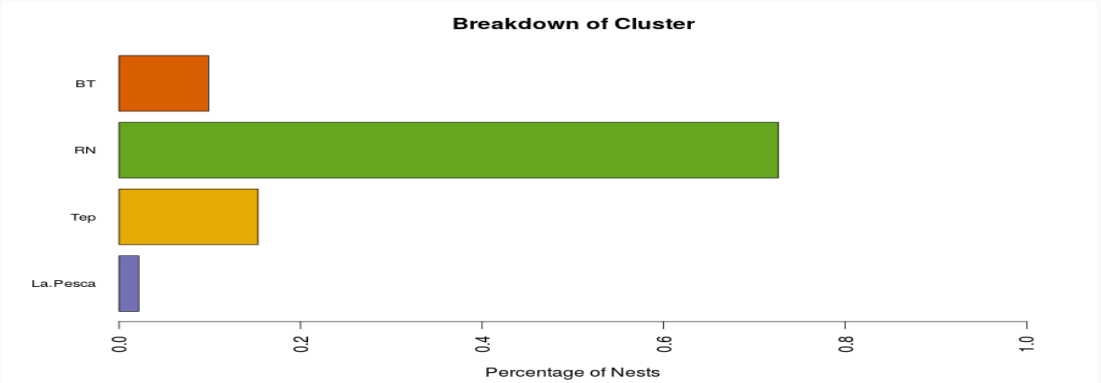
MODEL SELECTION AND PREDICTION



Model Selection

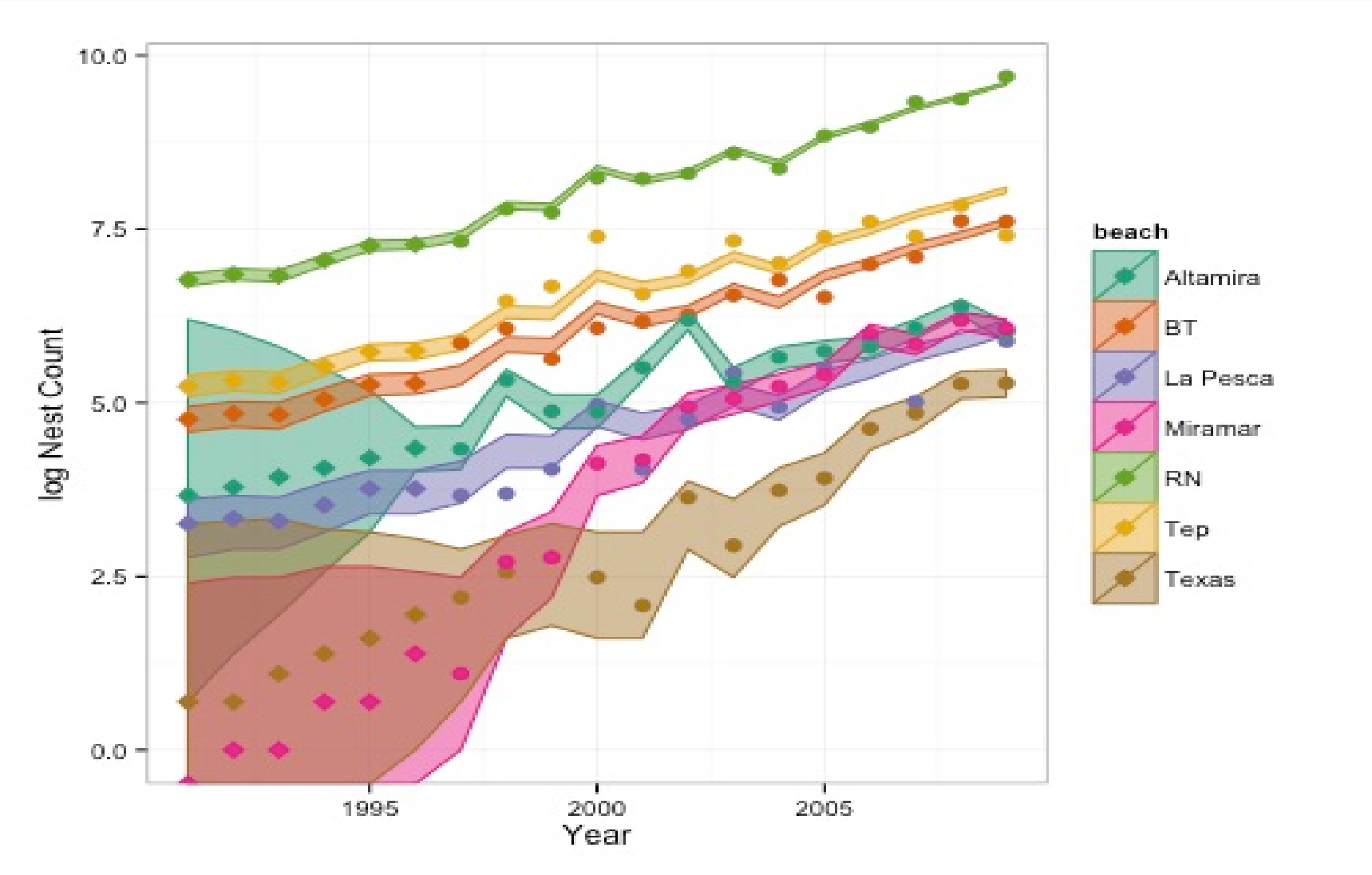




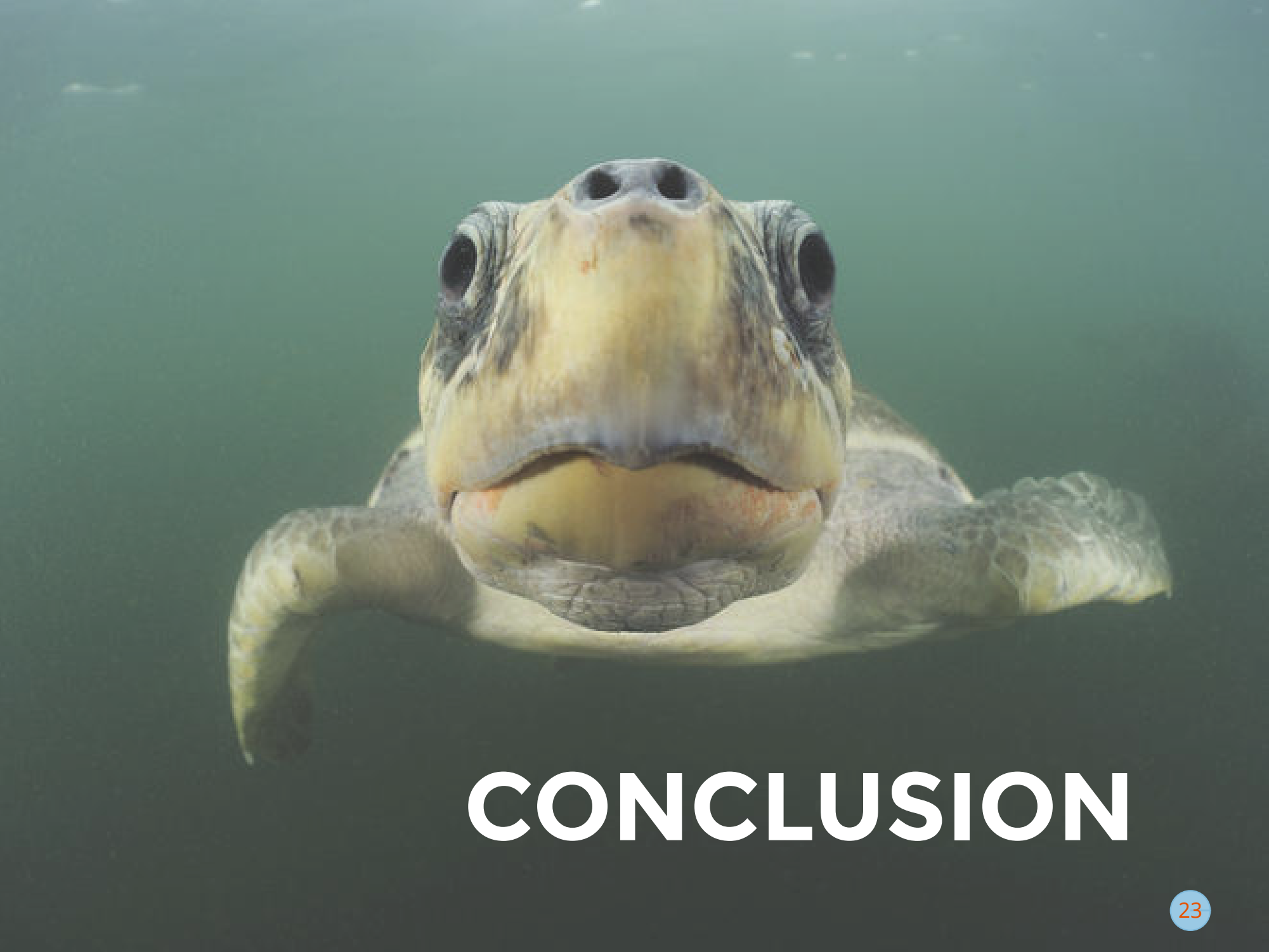


Model 3: Clustering of Trends using Grouping 2

Prediction backwards



Model 3: Clustering of Trends using Grouping 2



CONCLUSION

Conclusion & Future Work

Conclusions:

→ Findings suggest that nesting counts on the 7 beaches are not all part of the same underlying population.

→ Texas and Miramar have distinct trends and are likely 2 different populations.

→ There is some evidence that ”middle 4” beaches geographically (La Pesca, Tepehuajes, Rancho Nuevo, Barra del Tordo) may belong to same population.

Future work:

→ Consider varying the proportion of nesting population in each beach by year.