Are Horseshoe Crab Eggs a Limiting Resource for Red Knots?

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Shorebirds and Horseshoe Crabs

Moore’s Beach, NJ 1987 2005

Moore’s Beach, NJ, 1987, crabs cover much of the beach. Since this picture was taken most of the beach has eroded away

CPUE Horseshoe Crabs DE 30-ft Trawl Survey, 1990-2004

From Niles et al. 2005
Red Knot, *Calidris canutus rufa*

# Red Knots in Tierra del Fuego
1986: 53,232 birds
2000: 52,255
2002: 27,242
2003: 29,915
2004: 30,778
2005: 17,653

Peak Counts Red Knot in DE and NJ
1982-2004

Niles et al. 2005
Declining *rufa* Red Knot population

- Fewer knots reaching necessary departure weight each year in Delaware Bay.

- Petitioned for Emergency Listing under the ESA in August 2005.
Is the red knot population limited by the availability of horseshoe crab eggs?

- Multi-year study

2004 Objective
Is Red Knot habitat selection in the Delaware Bay driven by
- horseshoe crab egg abundance?
- some other factor or combination of factors?
2004 Objectives

Landscape Level
• Do red knots preferentially select habitats with abundant crab eggs?
• Does red knot habitat selection differ before versus after a peak in crab-spawning activity?
• Aerial telemetry of 65 radio-tagged red knots in May-June 2004 over entire Delaware Bay estuary
• Use-Availability Analyses (Neu et al. 1974)
• Proportional Analysis of Habitat Use
• Explore effects of tide state, level of crab-spawning activity
2004 Objectives

Habitat Level

• Are knot-used areas richer in crab eggs than other areas?

• Is crab egg abundance a significant predictor of red knot presence?

• Ground telemetry of 65 radio-tagged red knots in May-June 2004

• Behavioral, habitat, prey sampling at knot-used and random, un-used sites within a habitat type

• Logistic regression, AIC model selection of knot-used versus un-used sites on Delaware Bay beaches

Foraging knot on Bay beach
## Landscape Level Habitat Selection

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Total Area</th>
<th>Proportion Total Area</th>
<th># Birds Observed</th>
<th># Birds Expected</th>
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<tbody>
<tr>
<td>Sandy Delaware Bay Beach</td>
<td>671</td>
<td>0.0126</td>
<td>172</td>
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<tr>
<td>Atlantic Coastal Emergent Marsh</td>
<td>12,716</td>
<td>0.2390</td>
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<td>Delaware Bay Emergent Marsh</td>
<td>39,793</td>
<td>0.7480</td>
<td>66</td>
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<td>Total</td>
<td>53,180</td>
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\[ df=2, \chi^2=9206, p<0.001 \]

Sandy Delaware Bay beach habitat significantly preferred over Atlantic coastal emergent marsh and Bay emergent marsh in all analyses by tide state and level of crab-spawning.
Proportion of telemetry locations by habitat and tide state

Habitat shift away from peat beach and marsh to sandy Delaware Bay beaches after the May 19th peak in crab-spawning activity.
Conclusions: Landscape-Level Habitat Selection

1. Do red knots preferentially select habitats with abundant crab eggs?
   - Birds exhibit significant preference for sandy beach habitat in comparison to coastal and emergent marsh.

2. Does red knot habitat selection differ before versus after a peak in crab-spawning activity?
   - Evidence of habitat shift before and after full moon spawning event with increased use of beach and decreased use of marsh.
Habitat-Level Selection: Delaware Bay Beach

1. Ground-based tracking of radio-tagged knots
   • Behavioral sampling: Flock Composition, Foraging Behavior, Disturbance Events
   • Habitat sampling: prey cores

2. Random points (no knots) paired with knot-sample habitats
### Selected Models: Bay Beaches
#### Probability of Red Knot Presence

<table>
<thead>
<tr>
<th>Variables</th>
<th>K</th>
<th>AICc</th>
<th>Δ AICc</th>
<th>AICc (w_i)</th>
<th>Cumulative AICc (w_i)</th>
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<tbody>
<tr>
<td>Model 1</td>
<td>7</td>
<td>138.75</td>
<td>0</td>
<td>0.29</td>
<td>0.99</td>
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<tr>
<td># Crab Eggs</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td># Donax</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td># Mussel Spat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.94</td>
</tr>
<tr>
<td># Donax*#Crab Eggs</td>
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<td></td>
<td></td>
<td>0.87</td>
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<tr>
<td># Mussel Spat* # Crab Eggs</td>
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<td></td>
<td></td>
<td>0.85</td>
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<tr>
<td>Global Model:</td>
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<td>153.41</td>
<td>14.70</td>
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<tr>
<td>Null Model (Intercept only)</td>
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<td>147.59</td>
<td>8.84</td>
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<tr>
<td>Variables in Model</td>
<td>K</td>
<td>AICc</td>
<td>Δ AICc</td>
<td>AIC (w_i)</td>
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<tr>
<td># Donax,</td>
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</tr>
<tr>
<td># Mussel Spat* # Crab Eggs</td>
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<tr>
<td># Laughing Gulls</td>
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Selected Models: Bay Beaches Probability of Red Knot Presence

Laughing Gulls chasing shorebirds
### Selected Models: Bay Beaches

**Probability of Red Knot Presence**

<table>
<thead>
<tr>
<th>Variables in Model</th>
<th>K</th>
<th>AICc</th>
<th>ΔAICc</th>
<th>AICc (w_i)</th>
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<td># Donax,</td>
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<td># Potential Disturbance</td>
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# Crab Eggs, # Donax, # Mussel Spat, # Donax

<table>
<thead>
<tr>
<th>Variables in Model</th>
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<th>AICc</th>
<th>Δ</th>
<th>AICc</th>
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<td># Mussel Spat</td>
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<td></td>
<td>0.87</td>
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<tr>
<td># Donax * # Crab Eggs</td>
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<td></td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td># Mussel Spat * # Crab Eggs</td>
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<td>0.17</td>
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<td># Mussel Spat * # Donax</td>
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</tbody>
</table>

Selected Models: Bay Beaches

Probability of Red Knot Presence
Core Sample Biomass

Biomass (g) of core samples

- Nematodes
- Polychaetes
- Insect Larvae
- Crustaceans
- Crab Eggs
- Mussel Spat
- Donax

Species categories:
- Birds
- Random
Conclusions: Selection of Delaware Bay Beaches

1. Are knot-used areas richer in crab eggs than other areas?
2. Is crab egg abundance a significant predictor of red knot presence?
   - Red knot presence most strongly predicted by the abundance of crab eggs on Delaware Bay Beaches.
   - Knot-used areas had significantly more crab eggs than random points.
   - Interactions of prey are important
     --*Donax* and Mussel Spat low in biomass
   - Human disturbance
Are red knots limited by the availability of horseshoe crab eggs?

Multiple Lines of Evidence Needed:
1) Is red knot distribution in Delaware Bay driven by horseshoe crab eggs?
   • YES
2) Are there abundant available alternative food resources for red knots?
   • Probably Not, 2004 and 2006 Field Seasons
3) Are available egg resources being depleted by foraging birds during the migration season?
   • 2005 Field Season
2005 Field Methods: Exclosure Experiment

- Rack Line Control
- Rack Line Exclosure
- 10m
- Crab Nest Exclosure
- Crab Nest Control
- Random Beach Exclosure
- Swash 1
- Swash 2
- Water Line
- High Tide Line
48 Large, Permanent Exclosures Constructed on 8 Beaches in NJ and DE
The May Nor’Easter Strikes
Eggs are Patchily Distributed

25% of Core Samples, No Eggs
38% of Surface Samples, No Eggs
Exploratory Analyses
Proportion of Eggs Depleted

Core Samples-Control
Surface Eggs-Control
A Time Series of Surface Egg Depletion:
Ted Harvey Preserve, Delaware

Proportion of Surface Eggs Depleted

- Full Moon
Planned Depletion Analyses

How are egg depletion rates by foraging birds affected by:

• Diurnal Cycle
• Tidal Cycle
• Index of Bird Foraging Activity
• Index of Crab Spawning Activity
Acknowledgments

• National Marine Fisheries Service
• Delaware Fish and Wildlife
• Delaware Coastal Programs
• New Jersey Endangered and Non-Game Species Program
• British Trust for Ornithology
• Volunteers in DE and NJ
• Our Dedicated Field Crew