Are Horseshoe Crab Eggs a Limiting Resource for Red Knots?

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Shorebirds and Horseshoe Crabs

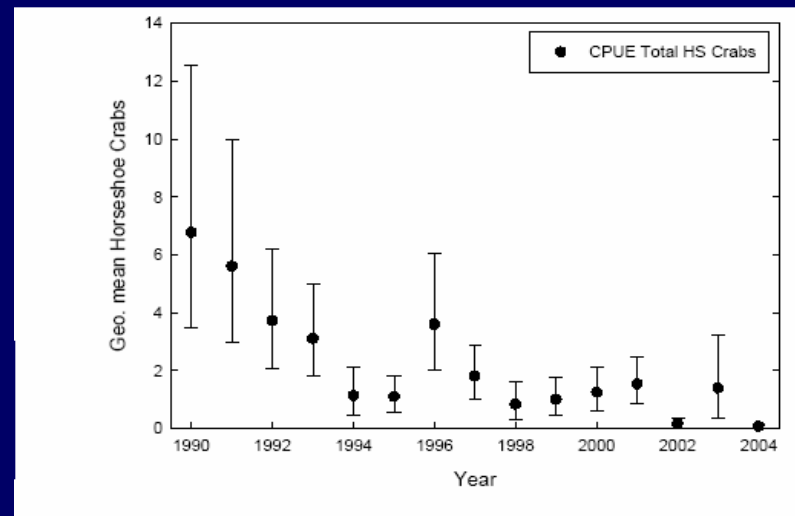Moore's Beach, NJ   1987   2005

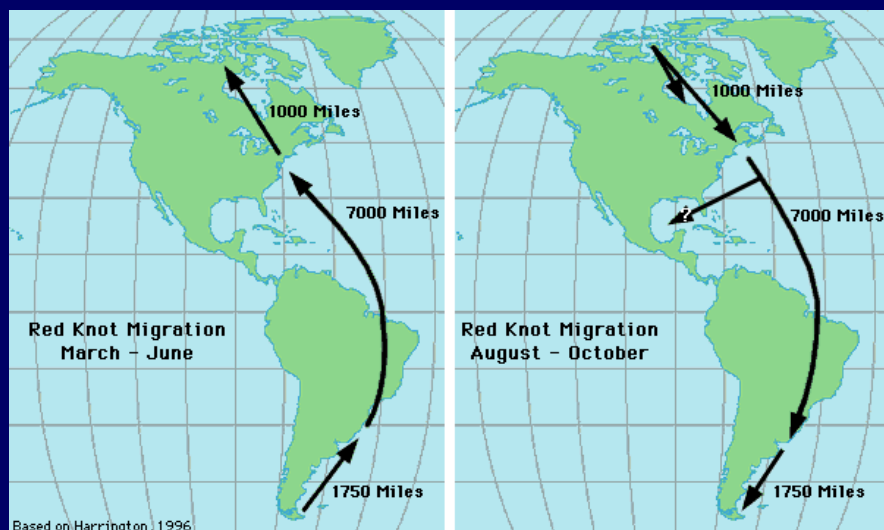*Moores Beach, NJ, 1987, crabs cover much of the beach. Since this picture was taken most the beach has eroded away*

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

From Niles
et al. 2005

Red Knot, *Calidris canutus rufa*

Red Knot Migration March – June

Red Knot Migration August – October

1000 Miles
7000 Miles
1750 Miles

Based on Harrington, 1996

Red Knots in Tierra del Fuego
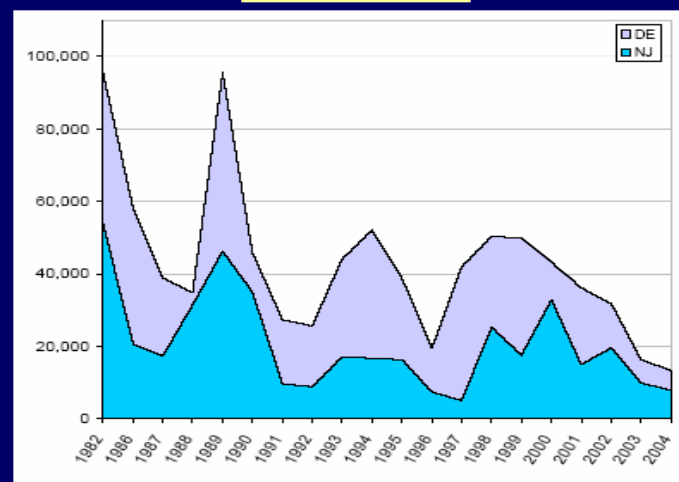
1986: 53,232 birds

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

Red Knots

Mixed flock

- 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?

Crab spawning depression with eggs

Crab eggs in rack line on beach

- 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?

Roosting red knots in Delaware Bay

• 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?

Foraging knot on Bay beach

• 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

Landscape Level Habitat Selection

| Habitat	Total Area	Proportion Total Area	# Birds Observed	# Birds Expected
Sandy Delaware Bay Beach	671	0.0126	172	3.14
Atlantic Coastal Emergent Marsh	12,716	0.2390	11	59.51
Delaware Bay Emergent Marsh	39,793	0.7480	66	186.25
Total	53,180	1		

df=2, X^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
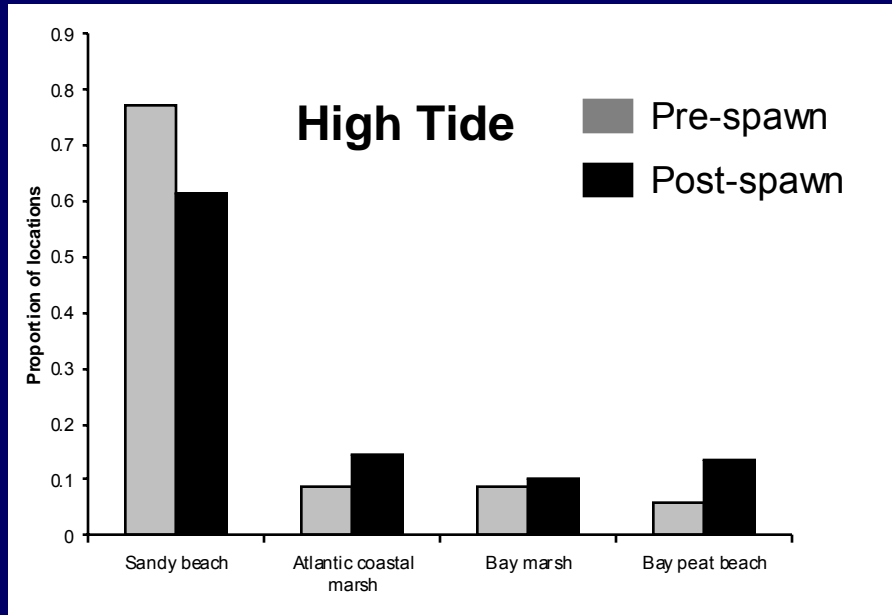
$\chi^3_2 = 3.14$, $P = 0.37$
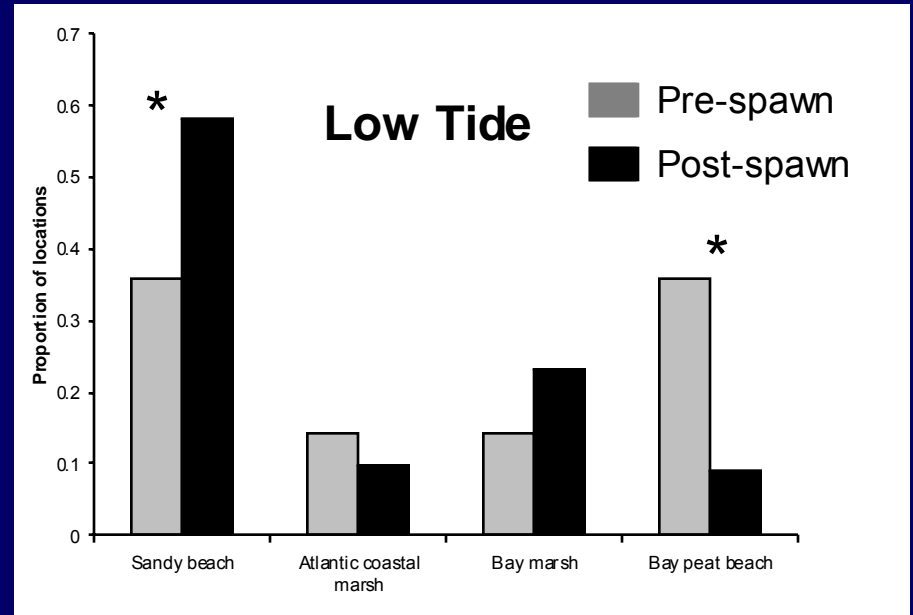
$\chi^3_2 = 9.30$, $P = 0.03$

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

Water Line

Beach-Marsh Boundary

Radio-tagged Red Knot
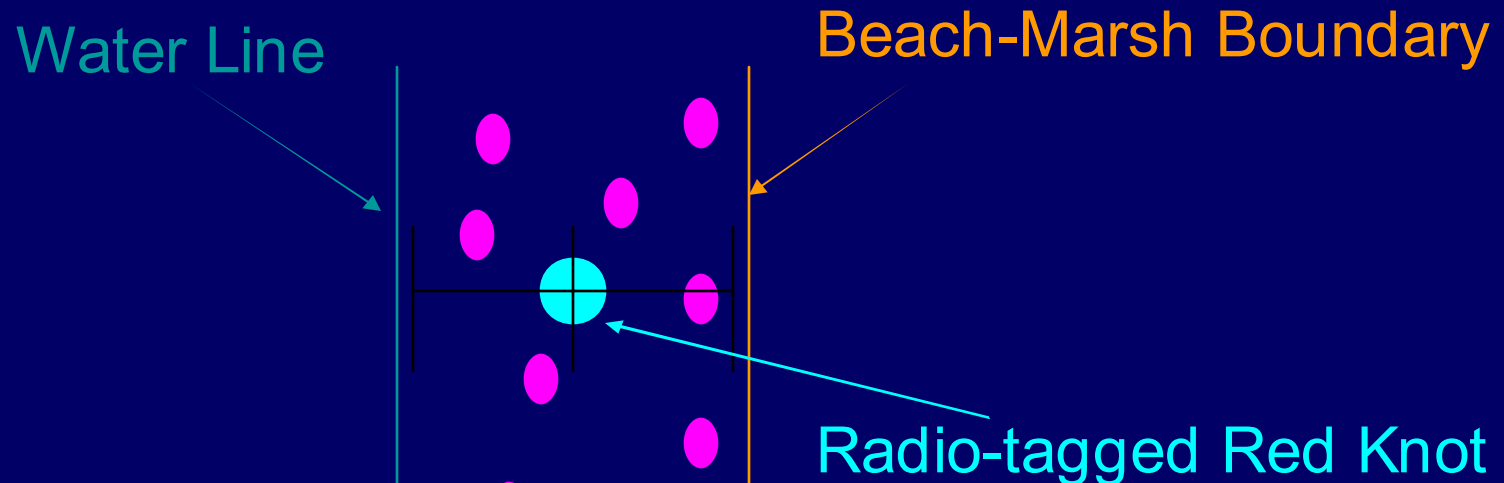
2. Random points (no knots) paired with knot-sample habitats

Selected Models: Bay Beaches Probability of Red Knot Presence

Variables	K	AICc	Δ AICc	AIC (w_i)	Cumulative AIC (w_i)
Model 1	7	138.75	0	0.29	
# Crab Eggs,					0.99
# Donax,					0.95
# Mussel Spat,					0.94
# Donax*#Crab Eggs,					0.87
# Mussel Spat* # Crab Eggs					0.85
Global Model:	18	153.41	14.70	0.0002	
Null Model (Intercept only)	2	147.59	8.84	0.004	

Selected Models: Bay Beaches Probability of Red Knot Presence

Variables in Model	K	AICc	Δ AICc	AIC (w_i)	Cumulative AIC (w_i)
Model 2	8	139.95	1.2	0.16	
# Crab Eggs,					0.99
# Donax,					0.95
# Mussel Spat,					0.94
# Donax*#Crab Eggs,					0.87
# Mussel Spat* # Crab Eggs					0.85
# Laughing Gulls					0.38

Laughing Gulls chasing shorebirds

# Selected Models: Bay Beaches Probability of Red Knot Presence

Variables in Model	K	AICc	Δ AICc	AIC (w_i)	Cumulative AIC (w_i)
Model 3	8	140.34	1.59	0.13	
# Crab Eggs,					0.99
# Donax,					0.95
# Mussel Spat,					0.94
# Donax*#Crab Eggs,					0.87
# Mussel Spat* # Crab Eggs					0.80
# Potential Disturbance					0.38

Selected Models: Bay Beaches Probability of Red Knot Presence

Variables in Model	K	AICc	Δ AICc	AIC (w_i)	Cumulative AIC (w_i)
Model 4	8	140.75	1.99	0.11	
# Crab Eggs,					0.99
# Donax,					0.95
# Mussel Spat,					0.94
# Donax*#Crab Eggs,					0.87
# Mussel Spat* # Crab Eggs					0.85
# Mussel Spat* #Donax					0.17

Donax
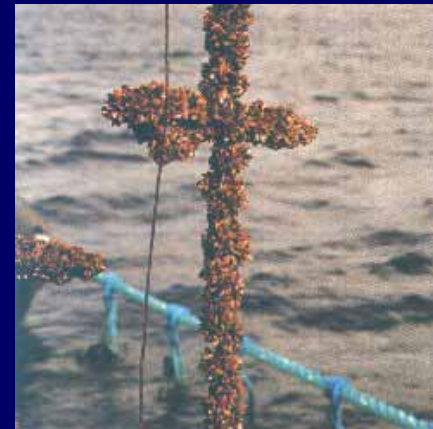
Mytilus

Core Sample Biomass
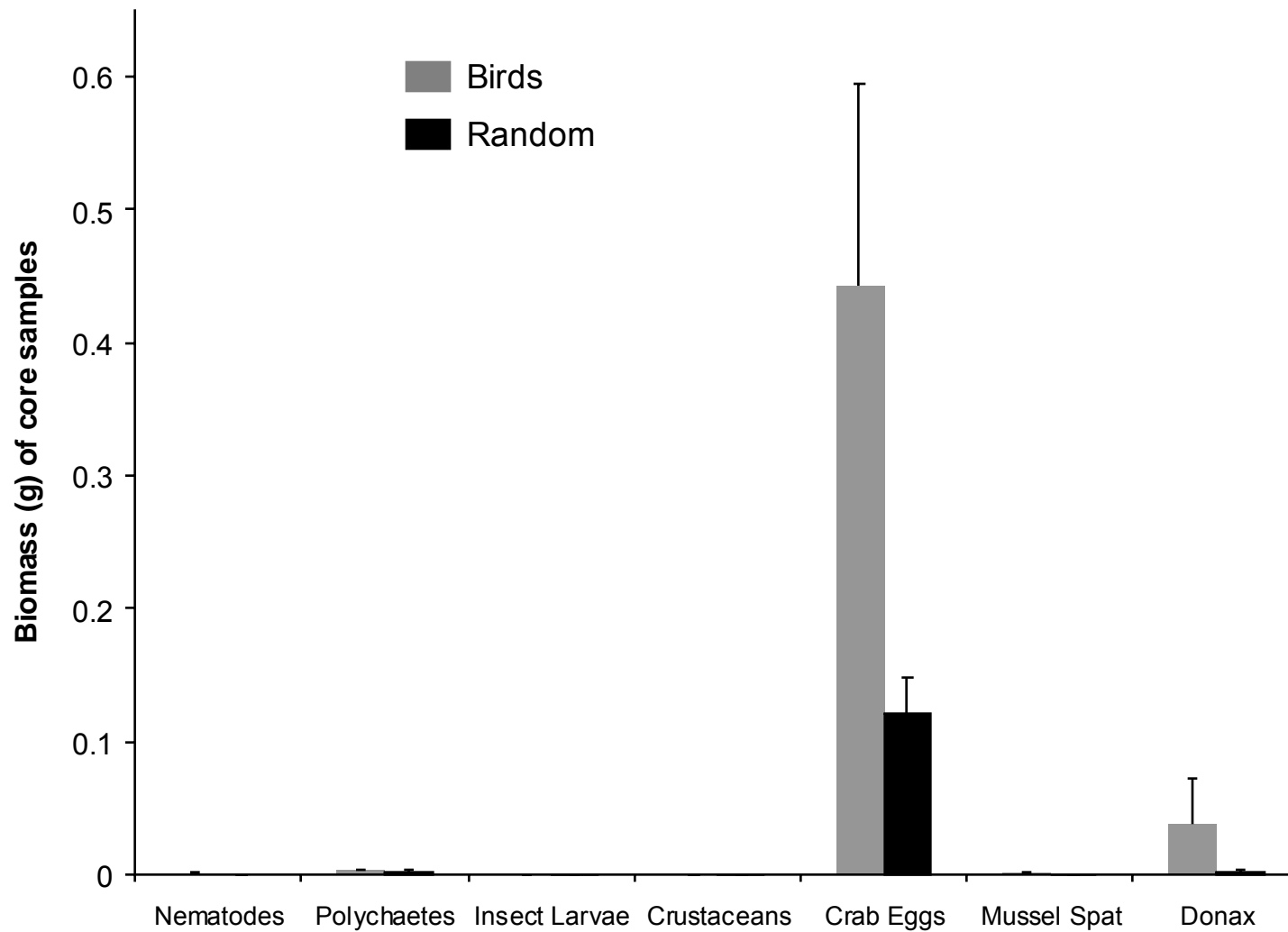
Conclusions: Selection of Delaware Bay Beaches

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:

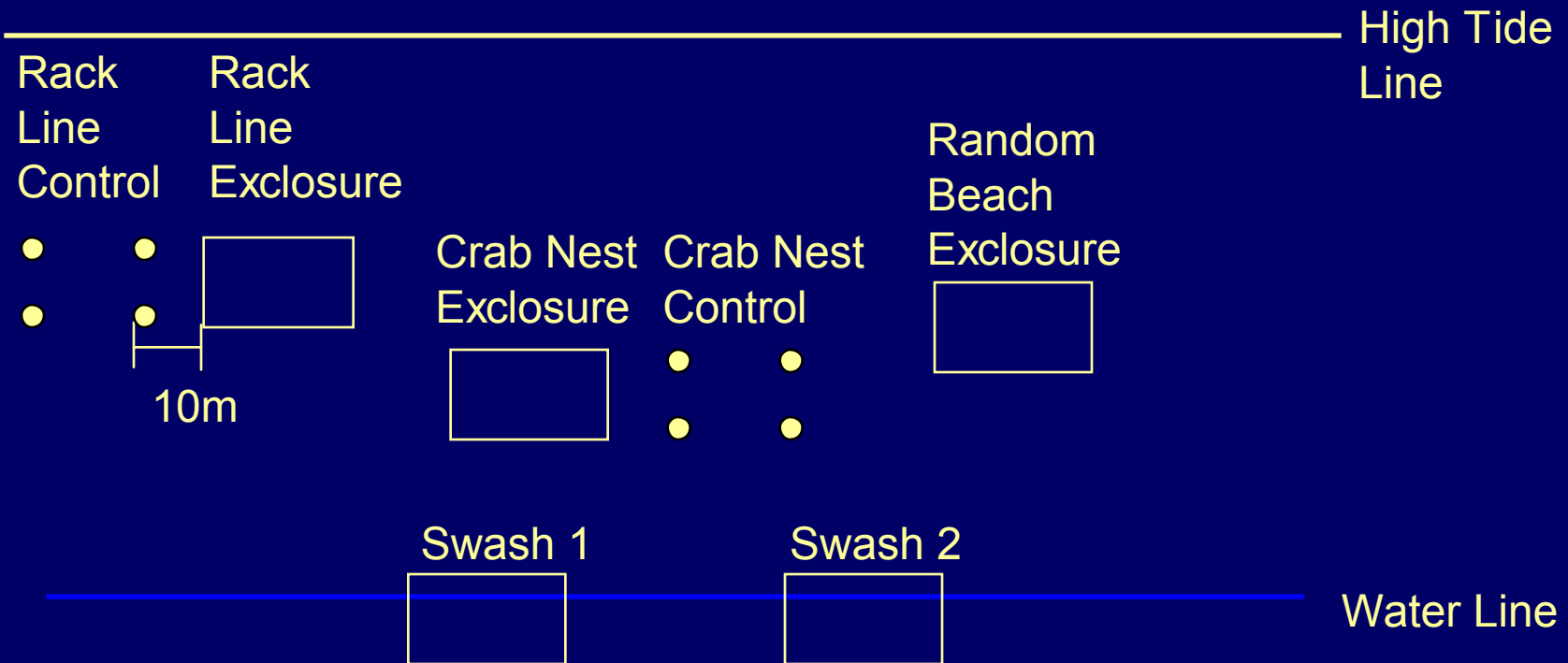1) Is red knot distribution in Delaware Bay driven by horseshoe crab eggs?

- 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

48 Large, Permanent Exclosures Constructed on 8 Beaches in NJ and DE
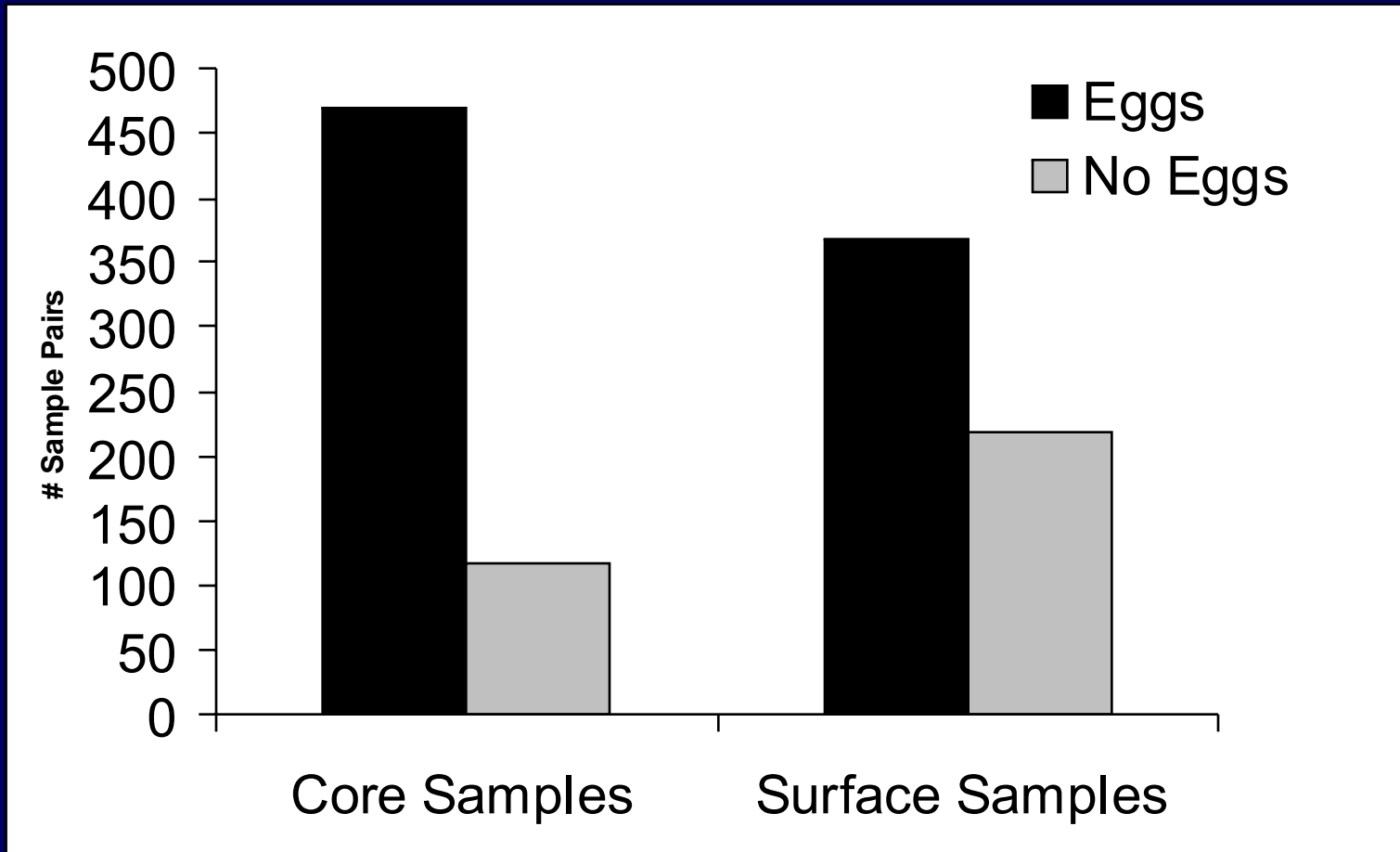
The May Nor'Easter Strikes

A Time Series of Surface Egg Depletion:
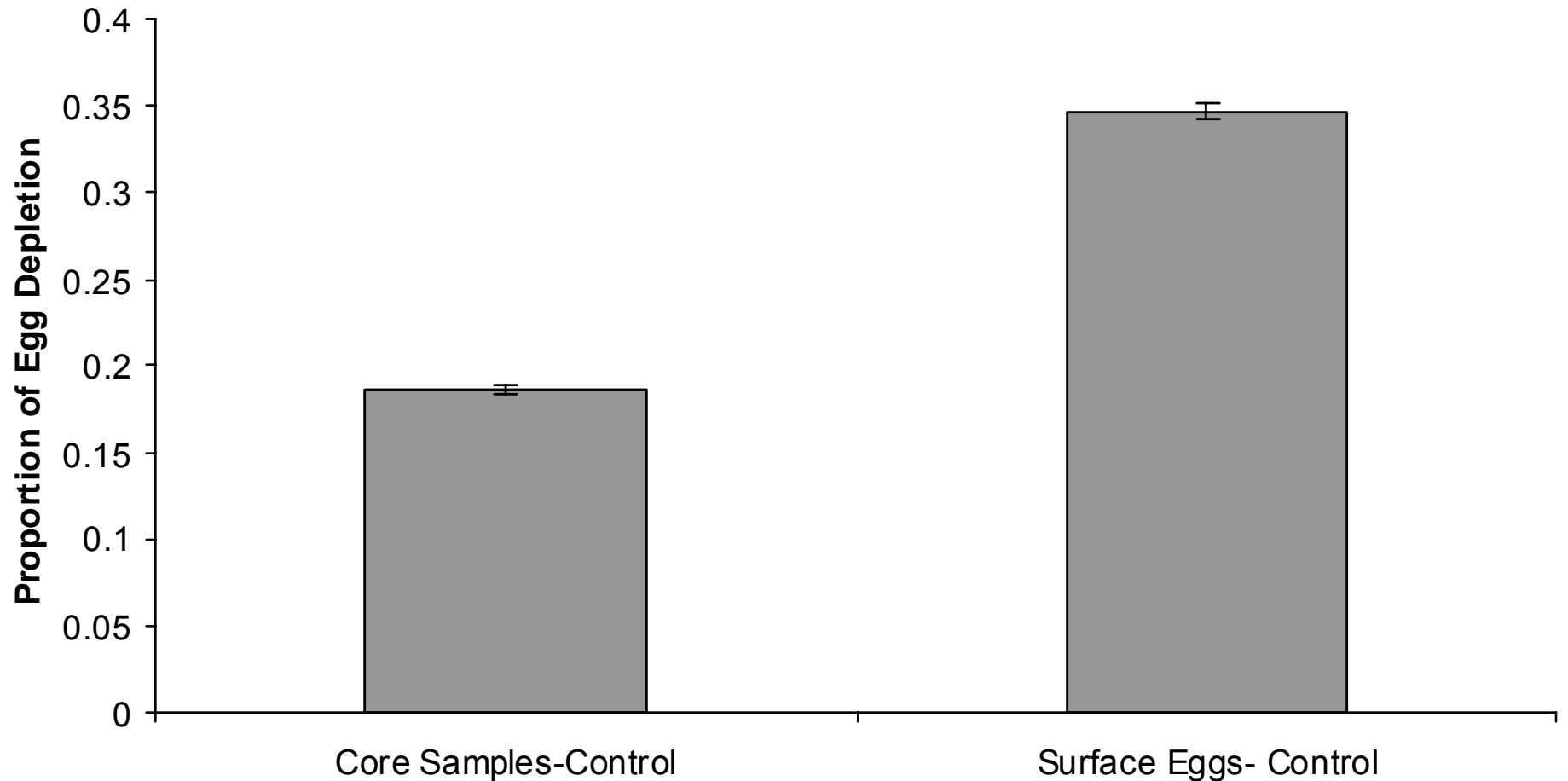Ted Harvey Preserve, Delaware
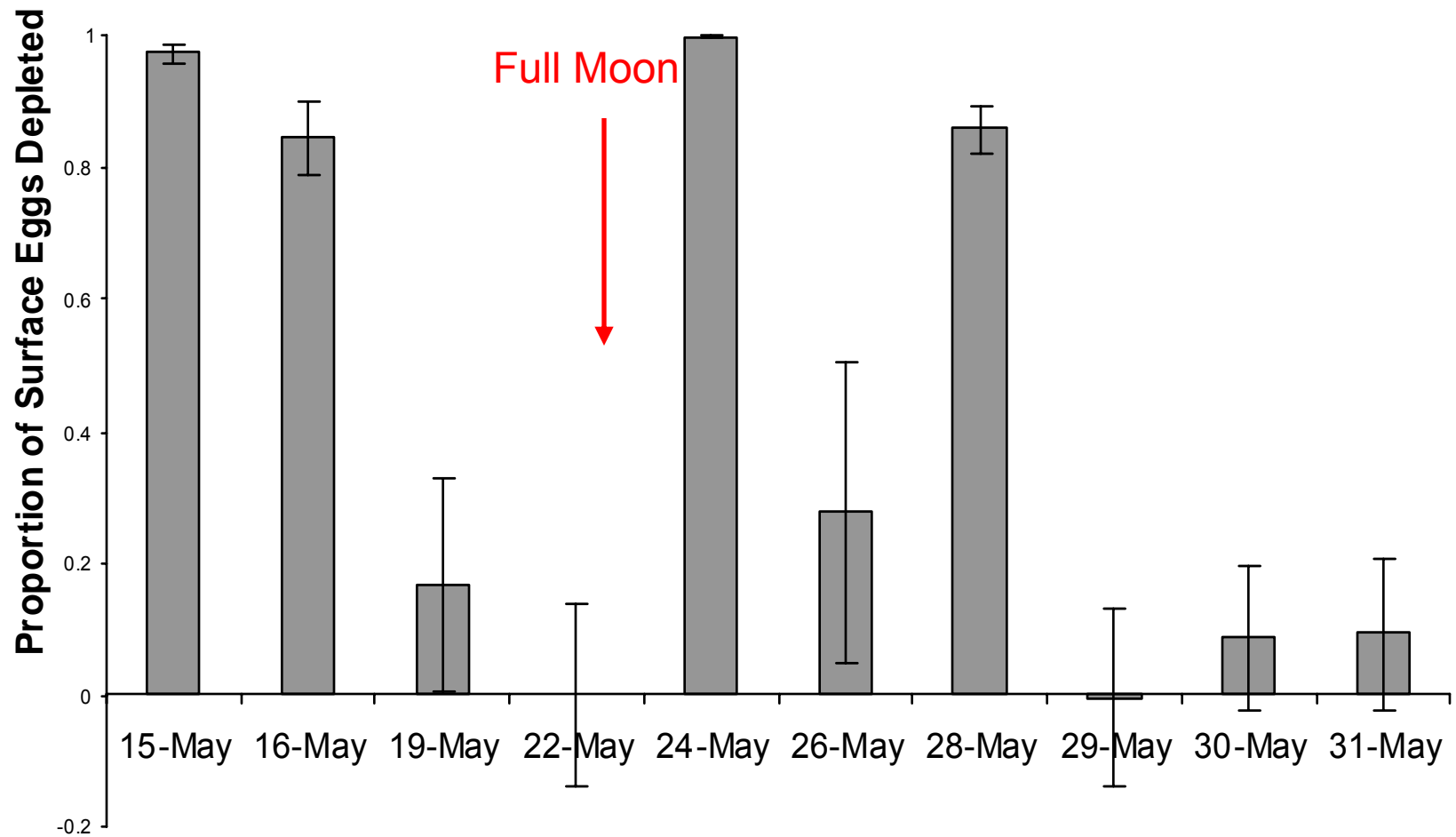
Planned Depletion Analyses

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
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- New Jersey Endangered and Non-Game Species Program
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- Our Dedicated Field Crew