OF HORSESHOE CRABS AND RED KNOTS.....

Stable Isotope Analysis Confirms Shorebird Dependence on Horseshoe Crab Eggs in Delaware Bay

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Spawning Horseshoe Crabs in Delaware Bay

Surplus Horseshoe Crab Eggs Feed Migrant Shorebirds

A Spring Spectacle of Crabs and Shorebirds.....

Delaware Bay is one of the North America's most important stopover points for spring migrant shorebirds as they make their annual flight from South America to the Arctic breeding grounds. Arrival of tens of thousands of shorebirds coincides with the May mass spawning event of the world's largest population of horseshoe crabs. These ancient creatures, perhaps several million strong, crowd the beaches of the Bay leaving vast quantities of surplus eggs as a feast for shorebirds. In a race against time, species like the red knot, gorge themselves on a rich diet of crab eggs in order to replenish fat and protein reserves to continue their 2 to 4 thousand-mile journey to the Arctic. As an apparent result of the quality and availability of crab eggs, red knots demonstrate one of the most remarkable "fattening" events known to nature: most birds make 50% to 80% weight gains and some even 100% gains in a short 2-3 week stopover. As their last major stopover before the breeding grounds, it seems clear that the shorebirds' migratory and perhaps reproductive fitness is critically linked to the horseshoe crab resource of Delaware Bay.

Red Knots and Dunlin Feeding on Horseshoe Crab Eggs, Mispillion Harbor, Delaware

THE PROBLEM.....

The age-old spectacle of spring-migrant shorebirds feeding on horseshoe crab eggs may be threatened by a renewed interest in the harvest of horseshoe crabs as bait for conch and eel, and food for catfish. A potential decline in numbers of horseshoe crabs might lead to a decline in shorebird populations that depend on their eggs to complete migration and breeding.

OBJECTIVES.....

1) Scientifically confirm the importance of horseshoe crab eggs in the diet of red knots.
2) Demonstrate by pen feeding trial that red knots feeding solely on crab eggs can make body mass gains comparable to those observed during spring stopover in Delaware Bay.

PROCEDURES.....

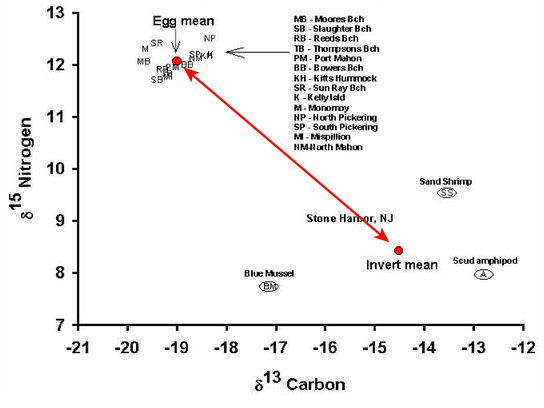
1) Apply stable isotope (SI) technology to establish the unique isotopic signature of horseshoe crab eggs and develop methods to track the signature in shorebird tissue.
   - use blood sampling as a noninvasive approach to track SI signature of red knots.....
   - use blood plasma as a rapid turnover tissue that potentially will track diet-related SI signature change over the short 2-3 week May stopover period.....
   - inventory crab eggs and alternative foods of red knots in Delaware Bay to establish that the crab egg SI signature can be discriminated from the signature of other available food resources...
2) Conduct a pen feeding trial with red knots to establish consumption rate, diet-tissue fractionation value, and body mass gains of birds fed only crab eggs.

RESULTS.....

Obtaining Blood Samples

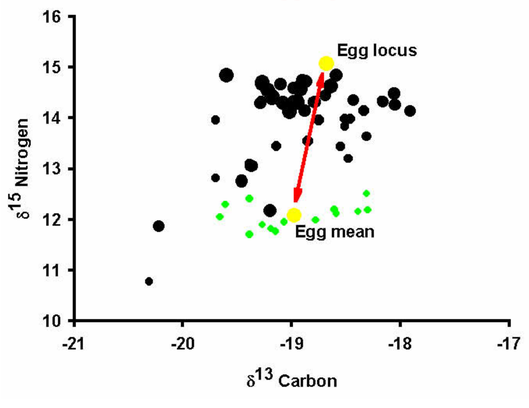
Small samples of blood in the 100-200 ul range successfully were obtained from the medial metatarsal vein of live-trapped shorebirds using a heparinized capillary tube. Tubes of blood were centrifuged to separate plasma and cellular fractions. Remarkably, minute quantities of freeze-dried plasma (fractions of milligrams) were found sufficient for stable isotope analysis.

Crab Egg - Invertebrate Signatures



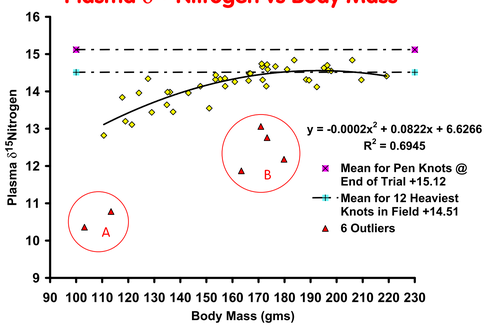
Stable isotope signatures of horseshoe crab eggs sampled from various beaches in Delaware Bay were clustered and well separated from abundantly available alternative food resources such as blue mussels, amphipods, and sand shrimp (pooled samples). This result establishes crab eggs as uniquely labeled and thus traceable in shorebird tissue.

Plasma - Crab Egg Signatures



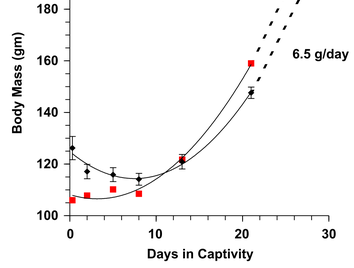
δ13carbon and δ15nitrogen plasma stable isotope signatures of red knots (n=48) were clustered near the crab egg value. The red arrow represents the diet-tissue fractionation as determined from pen feeding trial. The diameter of each data point varies directly with the body mass of each bird sampled.

Plasma δ^{15} Nitrogen vs Body Mass



Regression of plasma δ15nitrogen with body mass reveals close convergence to the crab egg signature. Remarkably, this relationship reveals body mass as a strong correlate of feeding time on crab eggs. Of the 6 outlying data points, the 2 at the left (circled A) most likely represent birds that have not begun to feed on crab eggs; the 4 birds at the right (circled B) most certainly have a different feeding history and therefore a different migratory history from the rest of the birds sampled (n=42).

Body Mass Gain of Captive Knots



After a 9-day period of adjusting to captivity, captive red knots (n=10) entered a period of hyperphagia and showed remarkable gain in body mass. During the last 13 days in captivity they increased body mass an average of 33.5 gms or 29.4%. Egg consumption during the last week averaged 104 ml/bird/day or a remarkable 18,000 eggs/bird/day. By chance, the lightest bird at capture (graph with red data points) was the heaviest at release. This bird gained 50% body mass from 106 to 159 gms. Extrapolation of regressions (shown dotted) reveal that rates of body mass gain would have exceeded 6 gms/bird/day, a rate comparable to that measured from live-trapped birds on the beaches of Delaware Bay.

CONCLUSIONS.....

- The finding that a grab sample of red knots captured at one point in time would reveal a strong asymptotic regression of body mass to the crab egg signature is irrefutable evidence of the importance of crab eggs in the diet. This relationship is very powerful because it confirms 4 *apriori* predictions about stable isotope signatures of red knots arriving from distant locations to feed on crab eggs in Delaware Bay:

  1) that the isotope signatures of the birds would show distinct convergence over time,
  2) that the observed convergence would be virtually to the predicted cab egg value,
  3) that the birds would gain considerable body mass, and
  4) that body mass gain would be correlated with feeding time on crab eggs.

- The small departure of the plasma mean from the egg locus likely suggests that the birds are ingesting a small proportion of invertebrate foods in the diet. This is predicted given the birds spend considerable time away from spawning beaches especially while roosting.

- The pen feeding trial with red knots demonstrated that the birds could not only survive on crab eggs alone, but could make body mass gains comparable to the maximum measured in the field over the same period of time. This clearly underscores the value and dependence of red knots and other shorebirds on this high quality food resource during stopover.