

Mark L. Botton and Robert E. Loveland

The Importance of Horseshoe Crabs in the Ecology of Delaware Bay: *More than Just Bird Food?*



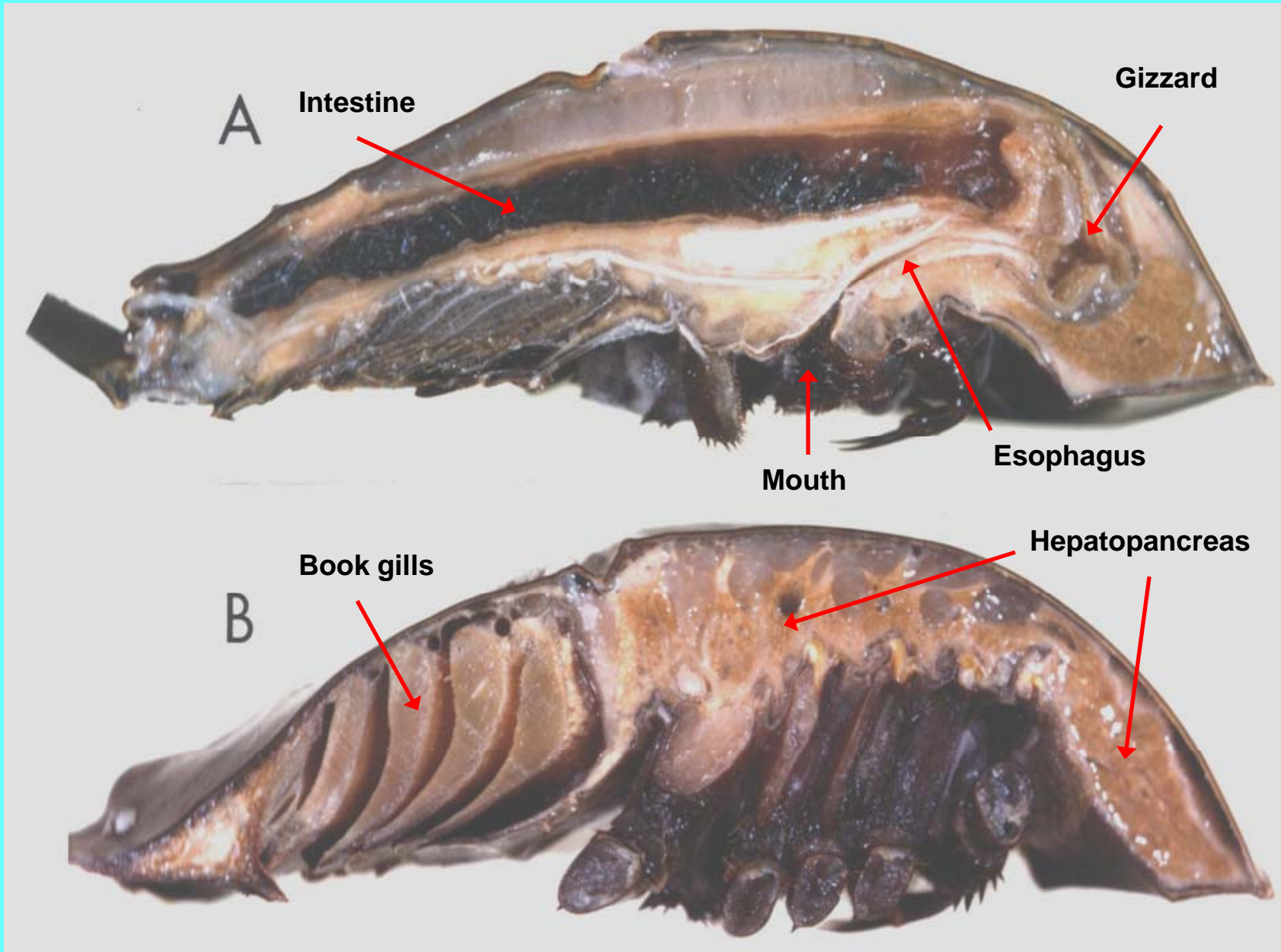
Getting Beyond the “Bird Food” Paradigm: Other Ecological Roles for HSC’s in the Ecosystem

- **Predators**
- **Prey**
- **Organic Carbon Inputs to Sandy Beaches**



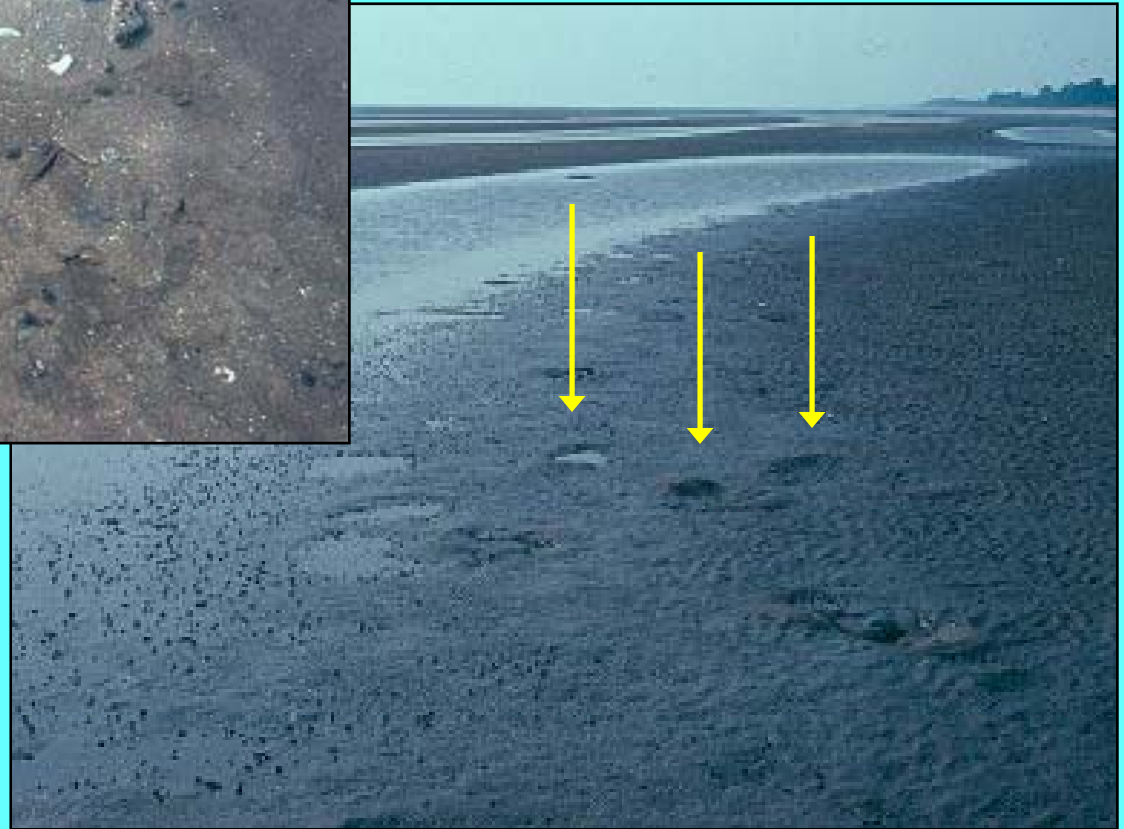
The Diet of Adult Horseshoe Crabs

- **Omnivorous but opportunistic: Feed on clams, polychaete worms, snails, crustaceans, and many other kinds of invertebrates.**
- **In Delaware Bay and adjacent shelf areas, they frequently consume small, thin-shelled clams such as *Mulinia*, *Spisula*, *Ensis*, *Mytilus*, and *Mya*.**



Photos courtesy of C. N. Shuster

At low tide, horseshoe crabs retreat to the intertidal flats, where they burrow and feed.



Predator exclusion studies: *Limulus* exclusion led to an increase in total prey density on Delaware Bay sand flats (from Botton, 1984)

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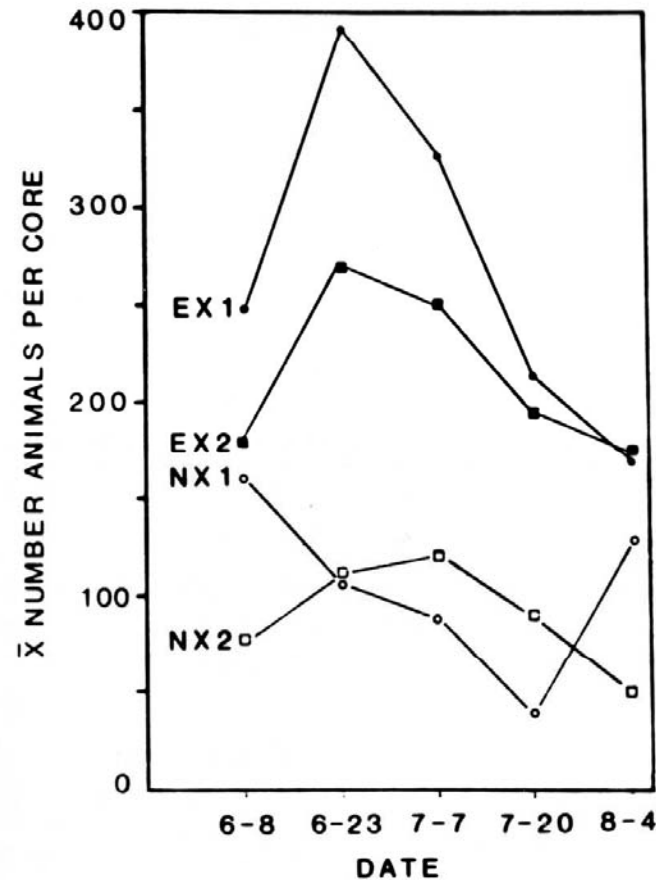


Figure 2. Mean number of animals per core versus time, 1978 predator exclusion experiment.
Legend: EX = within enclosures, NX = outside of enclosures; 1 and 2 are replicate sites.

Exclusion led to an increase in prey species diversity (from Botton, 1984)

1984]

Botton: Importance of Limulus predation

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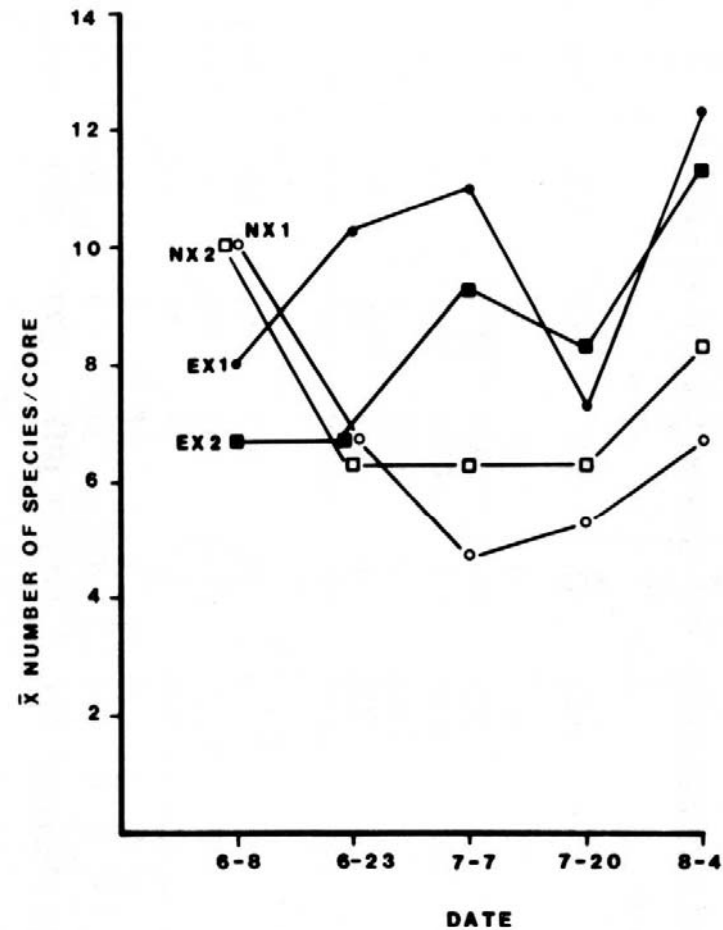
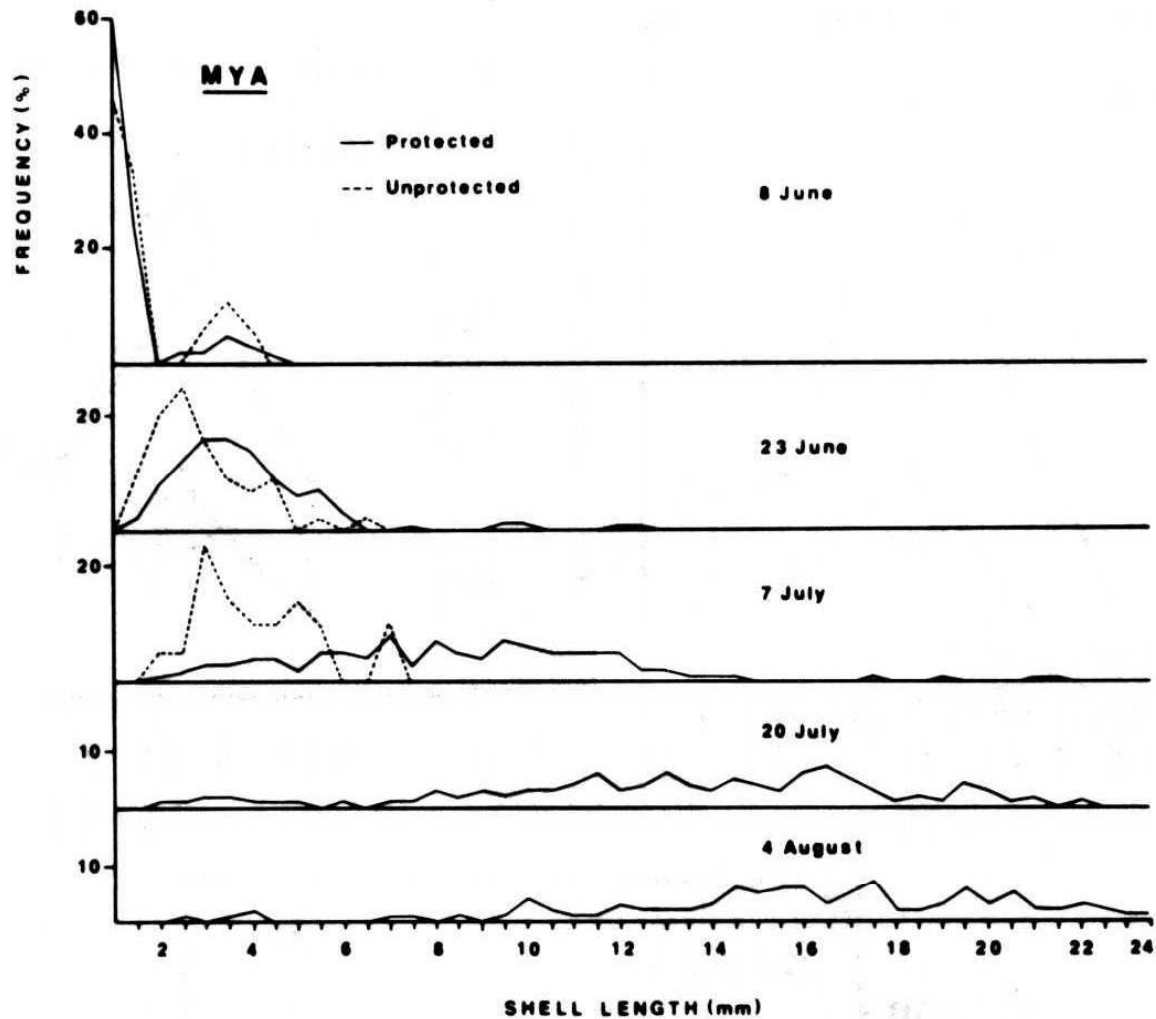


Figure 3. Mean number of species per core versus time, 1978 predator exclusion experiment.
Legend: EX = within enclosures, NX = outside of enclosures; 1 and 2 are replicate sites.

Exclusion of *Limulus* led to an increase in the size of surviving soft-shell clams (*Mya*)



Horseshoe crab also affect sediments and benthic infauna through bioturbation (source: Kraeuter and Fegley, 1994)

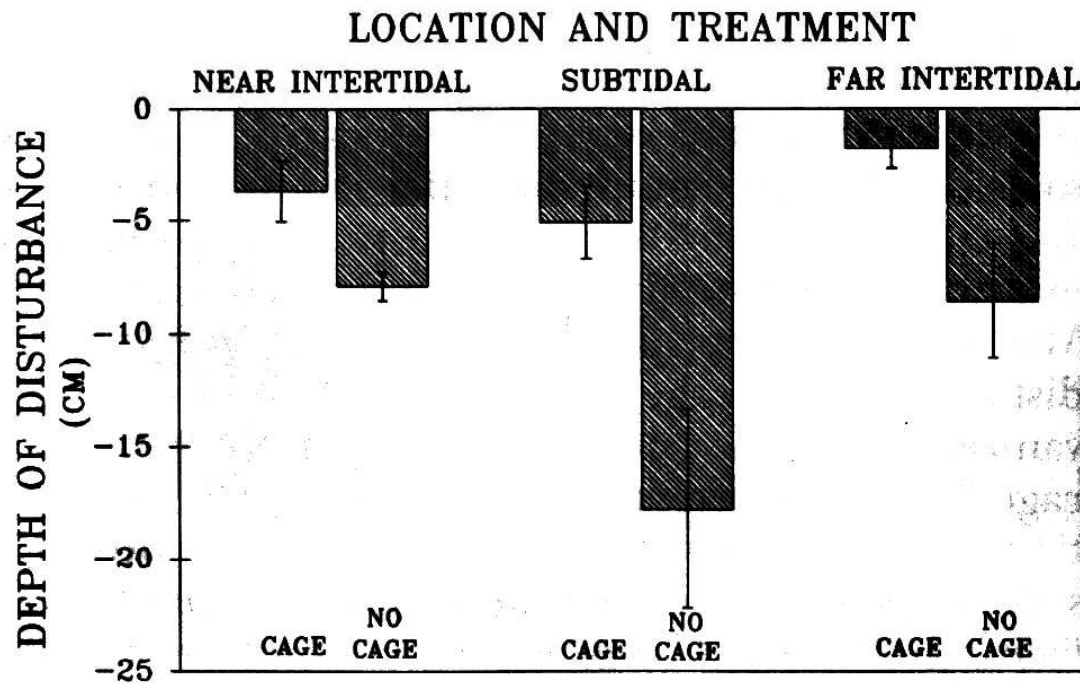


Fig. 2. Mean depth of sediment mixing in each treatment and site combination. Error bars indicate ± 1 standard deviation.

Horseshoe crab eggs/trilobites as prey for other species

- Obviously, most of the focus has been on the utilization of eggs by shorebirds and gulls, especially in Delaware Bay
- What other animals feed on *Limulus*?



Horseshoe crab juveniles as prey for other species



Predation by hermit crabs on larval and juvenile horseshoe crabs may be a significant cause of mortality

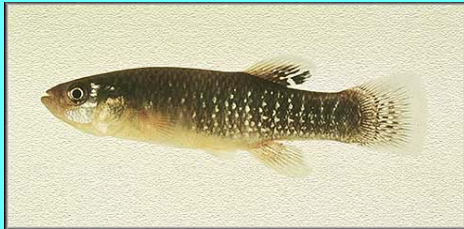


- **Hermit crab densities averaged about 3 to 5 ind.m⁻² on Cape Shore sand flats in mid-summer.**
- **In laboratory experiments, small hermit crabs ate an average of 8 trilobites or 10 second instars per day, while large hermit crabs ate an average of 26 trilobites or 22 second instars per day.**

(Source: Botton and Loveland, unpublished)

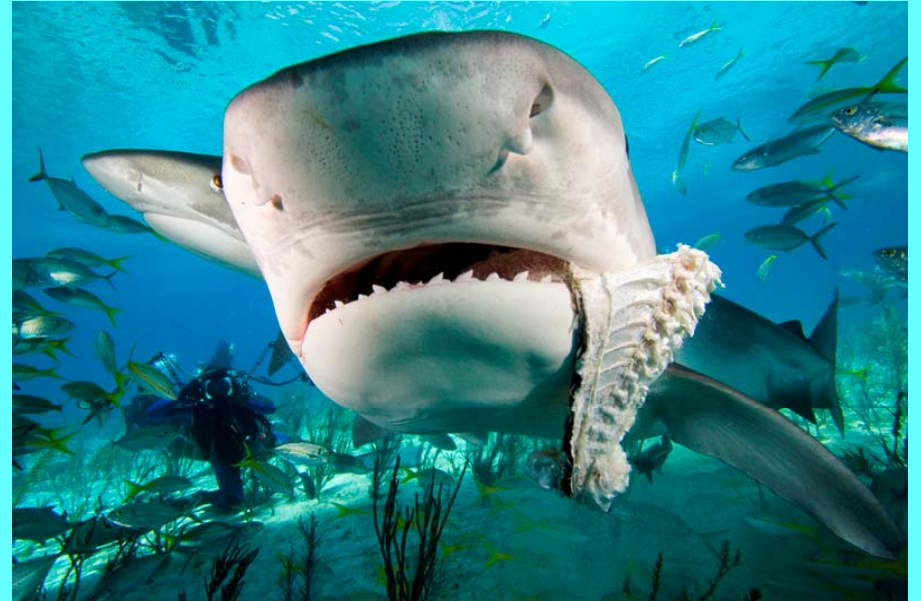
Fish predation on trilobite larvae and second instar juveniles

(source: *Botton and Loveland, unpublished*)



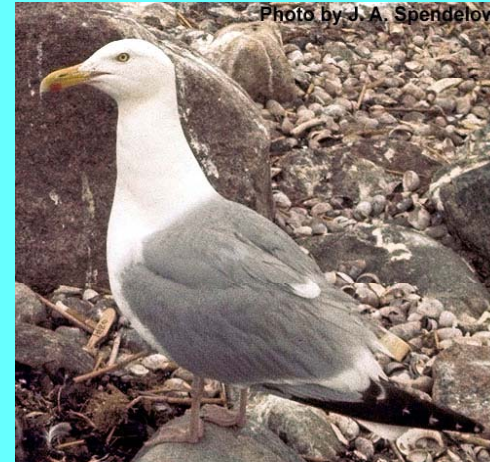
Species	Frequency of occurrence	Mean number of horseshoe crab stages per gut (\pm SD)
Killifish (n = 20)	95%	16.9 (\pm 15.1)
Atlantic Silversides (n = 25)	96%	11.5 (\pm 11.0)

Predation on adult horseshoe crabs



Predation by birds on adult HSC's

- Stranded adult *Limulus* may be eaten by Great Black-backed Gulls and Herring Gulls (*Botton and Loveland, 1993*).



- Juvenile loggerhead turtles (*Caretta caretta*) are abundant in Chesapeake Bay and feed extensively on adult *Limulus* (Keinath et al., 1987).
- Spotila et al. [2007 Delaware Estuary Conference] reported that the density of loggerheads in lower Delaware Bay was comparable to the Chesapeake.



Horseshoe crabs, sediment organic carbon, and possible links to higher trophic levels

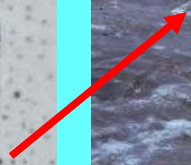
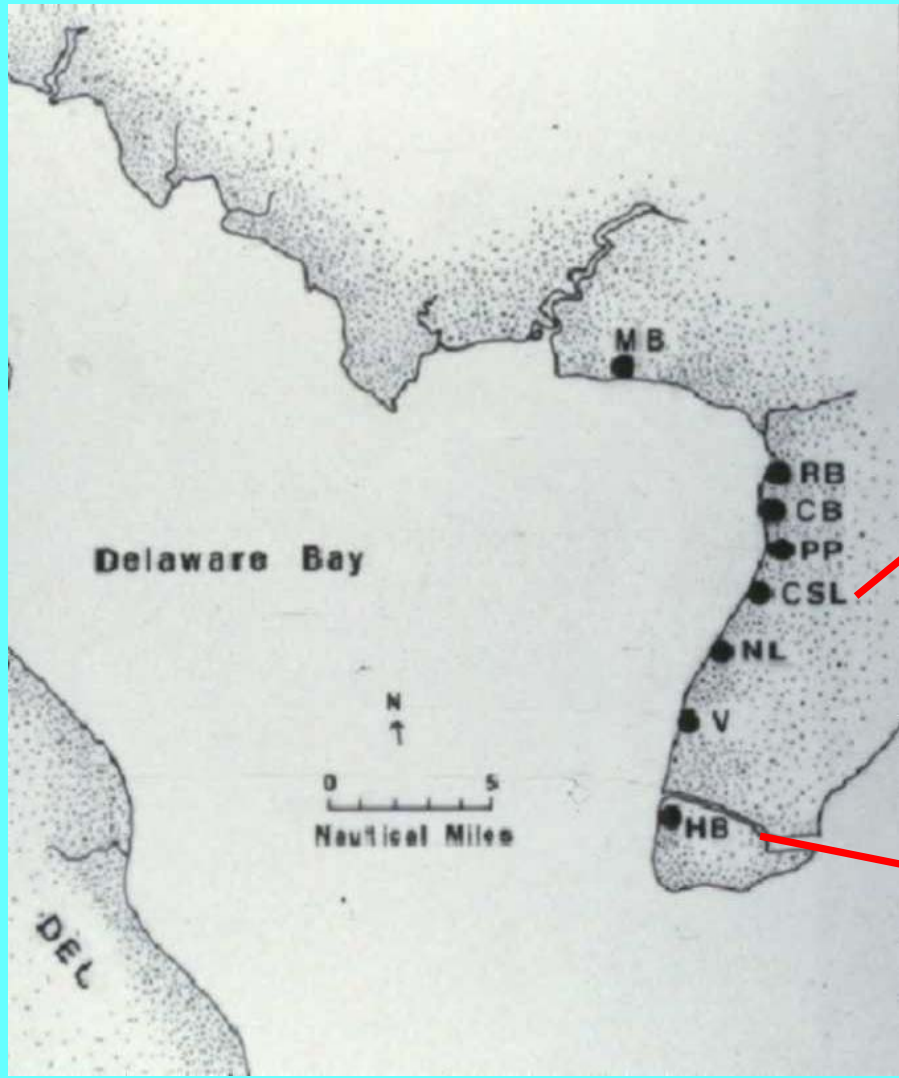
- **Horseshoe crab eggs are deposited on sandy beaches that typically have fairly coarse sediments with low organic carbon.**

Horseshoe crabs, sediment organic carbon, and possible links to higher trophic levels

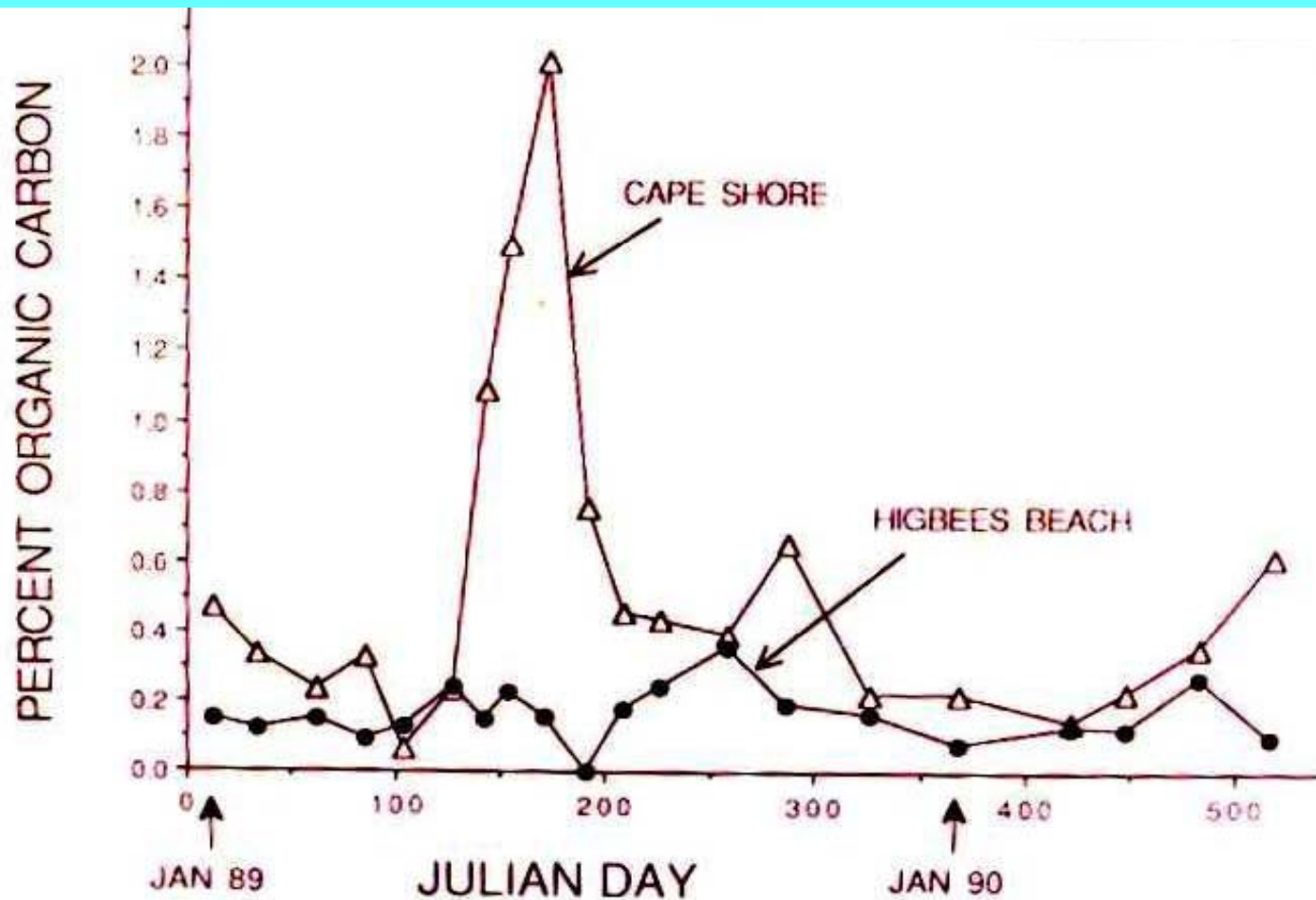
- Horseshoe crab eggs are deposited on sandy beaches that typically have fairly coarse sediments with low organic carbon.
- **We hypothesized that the seasonal input of horseshoe crab eggs to the beach provides a significant “pulsing” of organic carbon to the sandy beach ecosystem.**

Horseshoe crabs, sediment organic carbon, and possible links to higher trophic levels

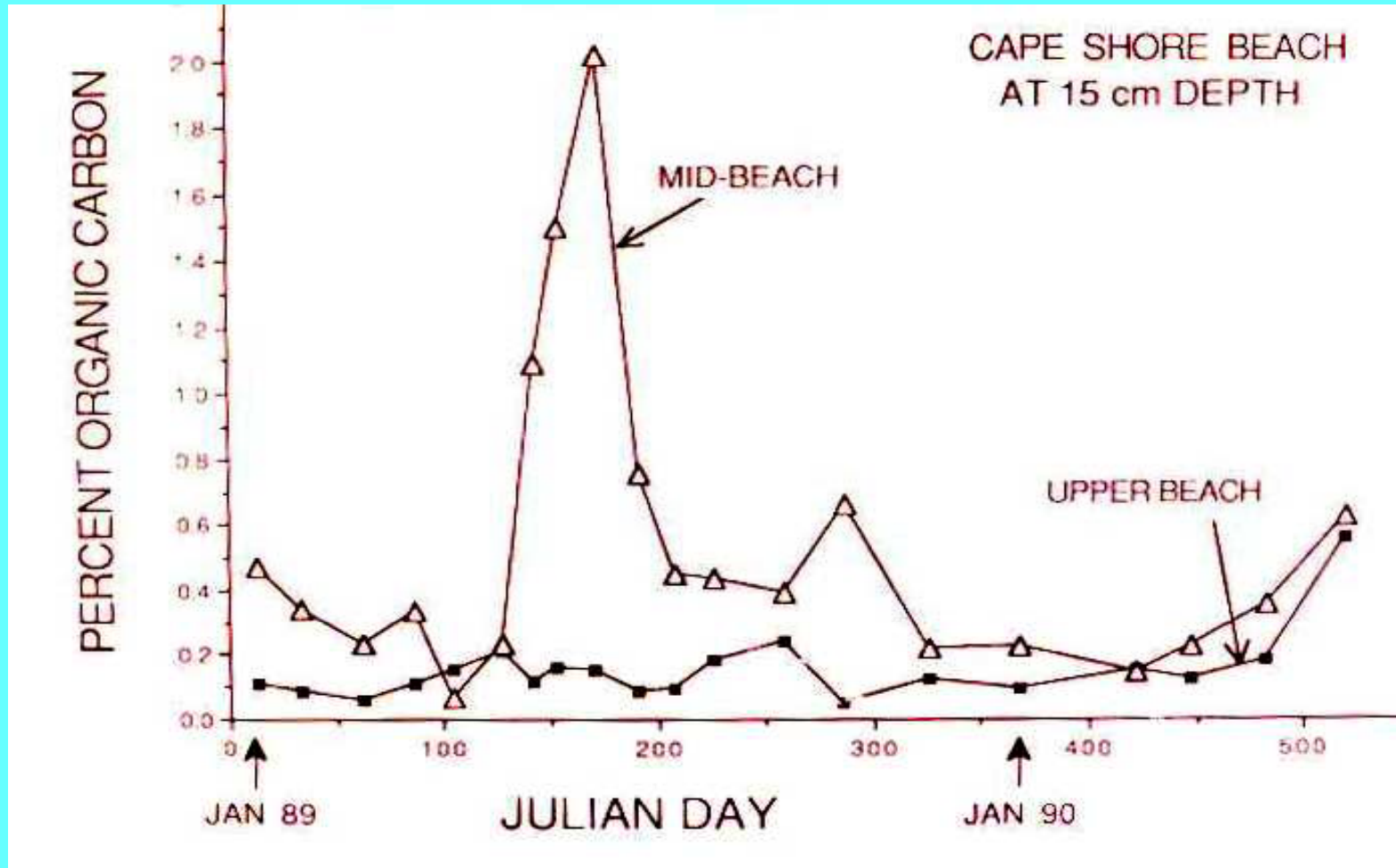
- Horseshoe crab eggs are deposited on sandy beaches that typically have fairly coarse sediments with low organic carbon.
- We hypothesized that the seasonal input of horseshoe crab eggs to the beach provides a significant “pulsing” of organic carbon to the sandy beach ecosystem.
- **We tested this hypothesis through seasonal sampling of beach sediments at Higbees Beach (near Cape May Canal w/few crabs) and Cape Shore Beach (mid-peninsula w/many crabs).**



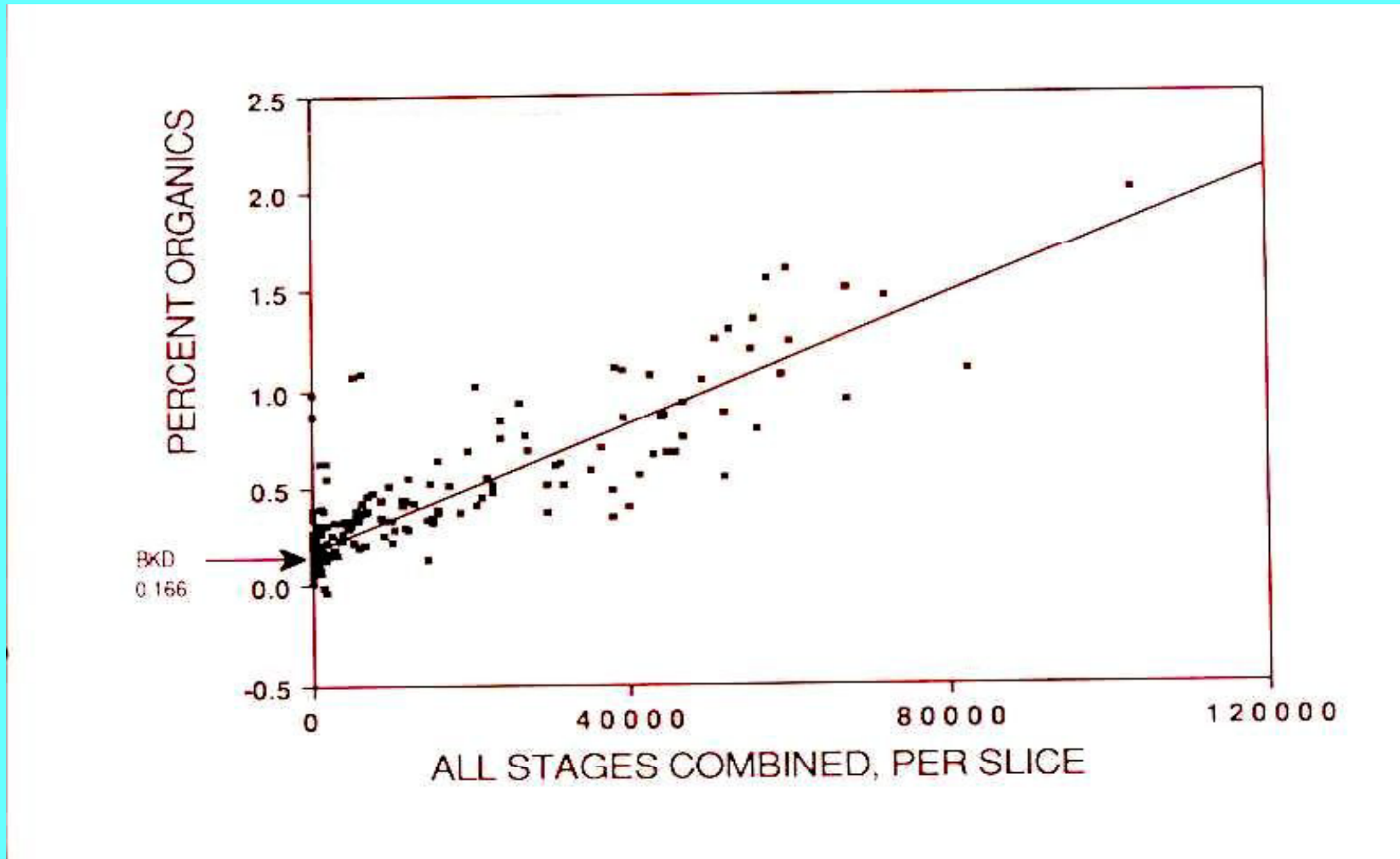
The seasonal pattern of % organic carbon shows a strong seasonal pulsing at Cape Shore Beach coinciding with the peak of horseshoe crab spawning. This pattern was not seen at Higbees Beach, where there was little spawning activity.



At Cape Shore, the seasonal pulsing of organic carbon is evident at mid-beach (high HSC egg input) but not at upper beach



There is a strong positive relationship between the % organic carbon in beach sediments and the number of horseshoe crab stages ($r^2 = 0.754$, 269 df)



Sources of organic carbon for sandy beach ecosystems

- Carbon inputs are generally attributed to decomposing beach wrack (macrophytes) and phytoplankton
- Previous studies have found that mats of herring eggs on beaches or shallow subtidal may be a significant input of organic carbon (e.g. Hay and Fulton 1983; Napier 1993)
- We suggest that the input of *Limulus* eggs may be significant to the sandy beaches in Delaware Bay

How does the presence of *Limulus* eggs affect beach meiofauna?
(from Hummon et al. 1976)

Component	<i>Limulus</i> eggs absent 18 June	<i>Limulus</i> eggs present 18 June	<i>Limulus</i> eggs absent 29 June	<i>Limulus</i> eggs present 29 June
Total meiofauna	125.5	574.2*	378.4	896.5*
Nematoda	57.3	386.4*	178.0	537.8*

Conclusions: Horseshoe Crabs as Predators and Prey in the Delaware Estuary

Adults:

Are dietary generalists; they can be ecologically important as predators and/or sediment disturbers when and where they are abundant.

Exclusion of horseshoe crabs from a tidal flat led to increases in prey abundance and species diversity, and clams protected from horseshoe crabs grew substantially larger than clams outside cages.

Adult horseshoe crabs form a significant part of the diet of loggerhead sea turtles in the Chesapeake Bay area, and possibly in Delaware Bay and other locations.

Juveniles:

We know little about what they eat in Delaware Bay (or elsewhere), or about their importance in the food web.

Conclusions: Ecological Importance of HSC Eggs and Larvae in the Delaware Estuary

***Limulus* eggs sustain migratory shorebirds in Delaware Bay.**

Shore zone fishes and hermit crabs prey on horseshoe crab larvae and juveniles, but more work needs to be done to understand the causes and magnitude of natural mortality to YOY and older juvenile HSC's.

HSC eggs and larvae are a significant source of organic carbon to sandy beaches in Delaware Bay, and the possible relationships linking horseshoe crabs to beach meiofauna and macrofauna is deserving of further investigation.

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