American Horseshoe Crabs in the Subtropics: Genetics, Phenotype, Populations, and Marine-Life Harvest

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Most horseshoe crabs are found in the subtropics or tropics.
Most research on horseshoe crabs is from temperate regions.

Comparison with Asian species requires an understanding of subtropical and tropical *Limulus*.
Subtropical and tropical *Limulus* are genetically different from temperate populations

Neighbor-joining phenogram depicting genetic distances among 35 collections using 13 highly variable microsatellite markers (nuclear DNA)
Outline: *Limulus* in the Subtropics

- Florida and SE *Limulus*
  - Genetic structure
  - Phenotypic patterns
  - Life history
  - Seasonality
  - Factors affecting spawning

- Management
  - Population status
  - Florida harvest
Florida has at least 5 genetically distinct populations of horseshoe crabs

- Based on neighboring joining trees using 13 highly variable microsatellites and analyses using STRUCTURE
- No migration between populations
- Boundaries between populations are not known (in progress)

From King et al. 2015

Numbers indicate collection sites
Population structure of northeast Florida horseshoe crabs

- Based on the distinctive phenotype of the Southeast Atlantic population, they extend to New Smyrna Beach.
- Where they overlap with the Florida East population, which is in the northern Indian River Lagoon.
- Populations overlap, do they interbreed? (genetic analysis underway)

From King et al. 2015

Numbers indicate collection sites
## Life-history Patterns

<table>
<thead>
<tr>
<th>Instar</th>
<th>MA (field)</th>
<th>GA (lab)</th>
<th>SK (field)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3</td>
<td></td>
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<tr>
<td>2</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
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<td>3</td>
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<td>4</td>
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<td>0.85</td>
<td>0.84</td>
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<tr>
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<td>1.3</td>
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<tr>
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<td>1.7</td>
<td>1.4</td>
<td>1.5</td>
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<tr>
<td>7</td>
<td>2.2</td>
<td>1.8</td>
<td>1.85</td>
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<tr>
<td>8</td>
<td>3.0</td>
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<td>9</td>
<td>4.1</td>
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<td>3.07</td>
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<td>10</td>
<td>4.9</td>
<td>3.8</td>
<td>3.91</td>
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<tr>
<td>11</td>
<td>6.3</td>
<td>5</td>
<td>5.12</td>
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</tbody>
</table>

**Adult Male Size (mean):**
- MA: 18 cm
- GA: 23 cm
- SK: 16 cm

**Total Instars:**
- MA: 19
- GA: 24+?
- SK: 17?

**Total years:**
- MA: 9
- GA: 
- SK: 

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Preliminary data from GA and SK compared with data from Cape Cod, MA (Carmichael et al. 2003):

- Similar rates of development despite very different adult sizes
- Suggests that molt number is variable, i.e. different numbers of molts in different populations
- They may molt more often (e.g. 2x/yr?) where they are active (feeding) all year
Horseshoe crabs are active throughout the year in GA and FL.

Data from FIM trawl surveys by GA DNR and FL FWCC.
### Seasonality

**Northern Sites:**
- No spawning in Dec and Jan, heavy spring spawning and a smaller peak in autumn

**Southern Sites:**
- Spawning throughout the year with no obvious peaks

From on-line database with sightings from the public.
Effect of Tidal Fluctuations on Spawning

Spring Tides:
High tide height
– CUIS: 2.5m
– NSB: 1m
– IRL: 0 (microtidal)
– SK: 1.3m
Effect of Tides: More spawning when actual high tides are higher

From Brockmann & Johnson 2011
All sites are strongly affected by tidal inundation and/or wind surge. Highest spawning densities are during spring high tides.
Cars driving on the beach are a serious threat to nesting *Limulus*.

Alligators eat horseshoe crabs.

Horse conchs eat horseshoe crabs.

Status of Florida populations?
Only data available are monthly Florida FIM trawl surveys where horseshoe crabs are bycatch (only a few caught per 100 trawls).
Indian River power plant kills *Limulus*

Horseshoe crabs follow currents into plant intake

Horseshoe crabs trapped by one power plant in Feb-March 2015 were deposited in a landfill (many still alive)

Florida Power and Light Canaveral Plant in Indian River protects turtles and manatees

Two Indian River power plants trapped
- 173,662 HSC/year in 1975
- 92,218 HSC/year in 1979

No data since then
Population Status at SK

Breeding Survey
Spring 1992-2014

- Seahorse Key long-term breeding beach survey. Mean number of pairs on 1 km beach during 35-45 spring tides
- Population is not harvested
- Population is stable or increasing
Harvesting horseshoe crabs in Florida

- Biomedical – none
- Bait for eel and whelk
  - hand harvest only
  - 25 hsc/person/day
  - annual total for FL below 9,455 limit set by ASMFC

- Marine-life fishery
  - hand harvest only
  - 100/person/day
  - no total annual limit
  - harvesters report with “trip tickets”
  - mostly juveniles

Bait harvest is for the eel fishery
Horseshoe crabs are fun to watch
Florida Aquarium, Tampa

Horseshoe crabs are harvested for the home aquarium trade

“Horseshoe Crabs: Sand Stirrer, Detritus Eater. The Horseshoe Crab ...can be a unique specimen for any aquarium... Very hardy, a good choice for beginners.... An excellent reef aquarium species because it will not bother invertebrates...Level of Care: Easy...”

Small: 2-4 cm @$14.99 (1-3 yrs)
Medium: 5-7 cm @ $18.99 (4-6 yrs)

Some specimens are used for research and education
Marine-life harvest landings

From State of Florida, Marine Fisheries Information System

- CPUE has declined
- CPUE remains strong

18,593 – 55,460 juveniles harvested annually in Florida
- Impact of juvenile removal
- Release sites
Conclusions: *Limulus* in the Subtropics

### Patterns
- Population structure: 5 genetically distinct populations
- Phenotypic differences between populations: large size variation
- Life history: possibly variable number of instars
- Seasonality: active all year; north: breeding spring & fall; south: breeding at any time
- Factors affecting spawning: tide height and wind surge

### Management
- Population structure: distinct populations may require different management strategies
- Population status: unknown in most areas; probably declining in Indian River, stable in the northern Gulf population (long-term surveys needed)
- What is the impact of the marine-life fishery that harvests mostly juveniles? Limits are needed; controls on release needed
Many thanks to:

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many have helped us over the years

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Animal Behavior Program

Facilities
UF Marine Lab at
Seahorse Key

Permits
US Fish & Wildlife (Cedar Keys National Wildlife Refuge)
Cumberland Island National Seashore
Marine Discovery Center, New Smyrna Beach
The Southeast Atlantic population is phenotypically different from all others. 40-60% have these extra spines. Juvenile from Wassaw Sound, Georgia (near Savannah, GA).
Citizen Science efforts starting: New Smyrna Beach and Indian River Breeding Surveys

Tagging studies to understand movements
Status at SK

Despite variation in breeding numbers, the breeding sex ratio has remained at about 60% male.

The proportion of males and females that are newly molted, i.e. adult recruitment varies markedly from year to year.
Developmental rates are similar
5 genetically distinct populations of horseshoe crabs in Florida

What traits differ among populations?

(From Brockmann, Black and King 2015)
Differences in Spawning activity:
- timing of breeding
- population density
- breeding sex ratio (few satellites)

(Spring breeding)

(Spring and fall breeding: Feb-May & Aug-Oct)

(Mid-Atlantic (Apr-May))

(South east: SC, GA & N. FL (Feb-Apr))

(Maine (Jun-Jul))

(May-Jun)

(Feb - May & Aug - Oct)

(C. & S. FL)

(Yucatan, Continuous opportunistic breeding)

(Gulf Coast)

(No horseshoe crabs)
Data Sources Used

- Genetic analysis
- On-line database from sightings by the public
- State fin-fish trawl surveys (otter trawl)
- SK spawning surveys
- Size measurements from various sites
- State harvest data (trip tickets)
Are these horseshoe crabs active throughout the year?

Water temperature °C

<table>
<thead>
<tr>
<th>Location</th>
<th>Winter</th>
<th>Summer</th>
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<tbody>
<tr>
<td>CUIS</td>
<td>10-18°</td>
<td>20-30°</td>
</tr>
<tr>
<td>NSB</td>
<td>19-24°</td>
<td>24-30°</td>
</tr>
<tr>
<td>IRL</td>
<td>13-24°</td>
<td>24-35°</td>
</tr>
<tr>
<td>SK</td>
<td>10-20°</td>
<td>28-33°</td>
</tr>
</tbody>
</table>

At SK horseshoe crabs spawn when water temperatures are between 11°C and 33°C.
Population Status: biological challenges

75,220 loggerhead sea turtles nested along Florida’s east coast in 2014.

Alligators eat horseshoe crabs.

Stomach contents from one alligator: remains from 17 horseshoe crabs.

Horse conchs feed on horseshoe crabs.
Spawning densities are lower but birds feed on eggs & juveniles when available

Willets feeding on eggs excavated by nesting horseshoe crabs at Seahorse Key

White ibis feeding on juvenile horseshoe crab
In FL breeding occurs in all coastal counties.

From Florida FWCC website on-line, voluntary reporting from the public.


E36
Proportion in each size category
Females

Indian River Lagoon
(N=45)

New Smyrna Beach
(N=78)

Cumberland Island
(N=68)