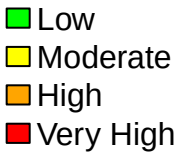
Horseshoe Crab − *Limulus polyphemus*

Overall Vulnerability Rank = Very High

Biological Sensitivity = High
Climate Exposure = Very High
Data Quality = 92% of scores ≥ 2

	Limulus polyphemus	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.0	2.8	
	Other Stressors	2.4	2.2	
	Population Growth Rate	3.4	2.6	
	Spawning Cycle	2.8	3.0	
	Complexity in Reproduction	3.1	2.8	
	Early Life History Requirements	2.0	3.0	
	Sensitivity to Ocean Acidification	2.1	2.6	
	Prey Specialization	2.2	2.4	
	Habitat Specialization	2.3	2.8	
	Sensitivity to Temperature	2.1	3.0	
	Adult Mobility	2.6	2.8	
	Dispersal & Early Life History	2.9	3.0	
	Sensitivity Score	High		
Exposure variables	Sea Surface Temperature	3.9	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	2.4	3.0	
	Variability Salinity	1.2	3.0	
	Air Temperature	3.1	3.0	
	Variability Air Temperature	1.0	3.0	
	Precipitation	1.3	3.0	
	Variability in Precipitation	1.4	3.0	
	Ocean Acidification	4.0	2.0	
	Variability in Ocean Acidification	1.0	2.2	
	Currents	2.0	1.0	
	Sea Level Rise	3.6	1.5	
	Exposure Score	Very High		
	Overall Vulnerability Rank	Very High		



Horseshoe Crab (*Limulus polyphemus*)

Overall Climate Vulnerability Rank: **Very High** (83% certainty from bootstrap analysis).

Climate Exposure: **Very High**. Three exposure factors contributed to this score: Ocean Surface Temperature (3.9), Ocean Acidification (4.0) and Sea Level Rise (3.6). Horseshoe Crabs use marine habitats, but spawn in intertidal areas that could be impacted by sea-level rise.

Biological Sensitivity: **High**. Two sensitivity attributes scored above 3.0: Population Growth Rate (3.4) and Complexity in Reproduction (3.1). Horseshoe Crabs are slow growing and long-lived. Their life cycle includes spawning on specific beaches on a lunar cycle.

Distributional Vulnerability Rank: **Low** (83% certainty from bootstrap analysis).

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Horseshoe Crab is likely to be negative (90-95% certainty in expert scores). Sea-level rise will reduce spawning habitat. Warming will negatively impact egg and larval survival and thereby reduce productivity. There is little information available regarding the effect of ocean acidification.

Data Quality: 92% of the data quality scores were 2 or greater indicate that data quality is moderate.

Climate Effects on Abundance and Distribution: Growth and larval development of larval Horseshoe Crab is temperature dependent, with maximum growth and development occurring at 30^{o}C (Laughlin, 1983). Vasquez et al. (2015) showed that the interaction of multiple stressors was important in determining the embryo development rate. Changes in temperature and salinity in the nearshore habitats could affect larval survival and ultimately recruitment and population productivity. Sea-level rise also poses a threat, and Galbraith et al. (2002) projected losses of intertidal habitat in Delaware Bay, which represents an important spawning area for Horseshoe Crabs. The effects of beach erosion and loss of spawning habitat may be more important to Horseshoe Crab dynamics than climate-related changes in temperature and salinity (Botton and Itow, 2009).

Life History Synopsis**:** Horseshoe Crab is a marine arthropod more closely related to spiders than to true crabs. Horseshoe Crabs can be found from northern Maine to the Yucatan Peninsula (ASMFC, 1998). Maturity is reached in 9-11 years (ASMFC, 1998). Adults migrate to protected, low-energy, intertidal sandy beaches between March and August to spawn (ASMFC, 1998). Multiple batch spawns occur during the season with peaks surrounding the full and new moons (ASMFC, 1998). Horseshoe Crabs are highly fecund with high egg and larval mortality (ASMFC, 1998). Eggs are deposited about 10 cm deep in moist sand nests at or near the water line (Laughlin, 1983; ASMFC, 1998), but waves or burrowing activity can wash eggs to the surface leaving them vulnerable to predation (ASMFC, 1998). Eggs hatch 2 -4 weeks post-fertilization depending on temperature, moisture, and oxygen content of the nest environment, but larvae can delay emergence to overwinter in the beach sediments until spring (ASMFC, 1998). Eggs are an important food source for shorebirds (ASMFC, 1998). The first larval stage is called the trilobite and is non-feeding and yolk-dependent until first molt into the first tailed stage (Laughlin, 1983). Trilobites remain close to shore and settle in shallow water to molt (ASMFC, 1998). Larvae eat polychaetes and nematodes and are prey to shorebirds and a variety of invertebrates and finfish including sharks (ASMFC, 1998). Juveniles spend the first two years on sand flats and in shallow waters of bays near the spawning beaches (ASMFC, 1998). Older juveniles either stay in coastal bays year-round or migrate to subtidal areas a few kilometers offshore with the adults of the population

(ASMFC, 1998). Horseshoe Crabs must molt to grow, and molt 16-17 times over the 9-11 years spent as a juvenile, molting more frequently during the early years (ASMFC, 1998). Adult Horseshoe Crabs are able to survive a wide range of conditions, but require salinities >7 and are generally found in 20 m or less water depths (although they have been found well offshore; ASMFC, 1998). Juveniles and adults consume a variety of molluscs, mainly bivalves, and benthic invertebrates such as arthropods, annelids, nemertean worms, and some vascular plants (ASMFC, 1998). Predation on adults of the species is likely low, but sea turtles and marine mammals may prey on Horseshoe Crabs, and the crabs are the preferred bait for American Eel, Channeled Whelk, and Knobbed Whelk fisheries (ASMFC, 1998). Adults are found in bay areas near spawning beaches during most of the year and can either remain there all winter or migrate in the fall to the continental shelf (ASMFC, 1998). Horseshoe Crabs are the primary bait for several commercial fisheries, and an important component of the biomedical industry, thus overfishing is a concern (ASMFC, 2013). Management of the Atlantic stock, from Maine to eastern Florida (with many subpopulations) is controlled by the Atlantic States Marine Fisheries Commission, but administered on state-by-state, multistate, and embayment levels (ASMFC, 2013). The Delaware Bay and southeast populations are stabilized and possibly rebuilding, but the New York and New England populations have declined (ASMFC, 2013). A ban on the import of Asian Horseshoe Crabs has been recommended to reduce importation of parasites and diseases (ASMFC, 2013).

Literature Cited:

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