Softshell Clam − *Mya arenaria*

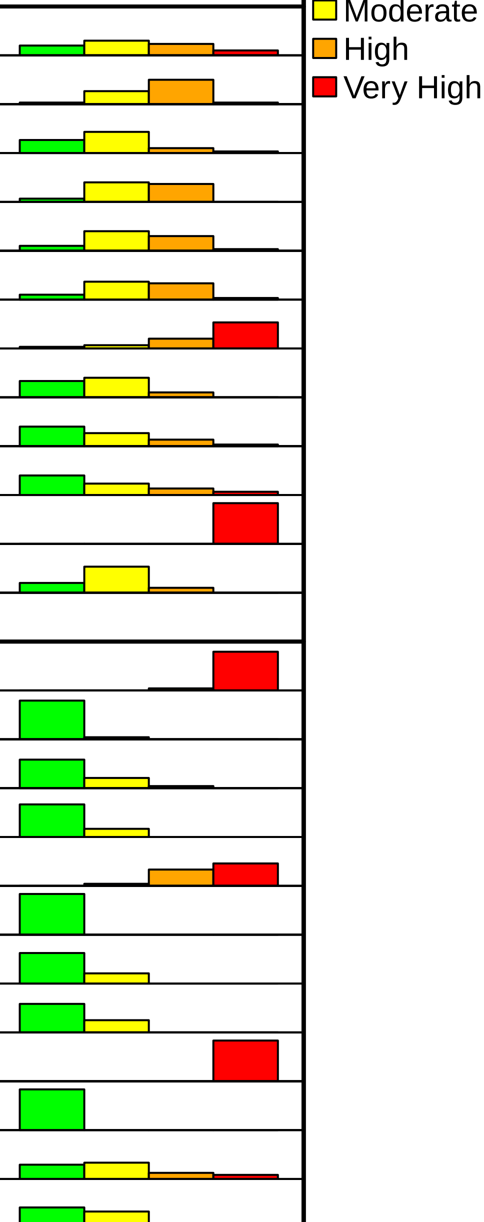
Overall Vulnerability Rank = Very High

Biological Sensitivity = High

Climate Exposure = Very High

Data Quality = 83% of scores ≥ 2

Mya arenaria		Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.3	0.4	
	Other Stressors	2.6	2.6	
	Population Growth Rate	1.9	2.8	
	Spawning Cycle	2.4	3.0	
	Complexity in Reproduction	2.3	2.6	
	Early Life History Requirements	2.4	2.6	
	Sensitivity to Ocean Acidification	3.5	1.8	
	Prey Specialization	1.7	2.8	
	Habitat Specialization	1.8	2.8	
	Sensitivity to Temperature	1.8	3.0	
	Adult Mobility	4.0	2.8	
	Dispersal & Early Life History	1.9	2.8	
	Sensitivity Score	High		
Exposure variables	Sea Surface Temperature	4.0	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	1.4	3.0	
	Variability Salinity	1.2	3.0	
	Air Temperature	3.5	3.0	
	Variability Air Temperature	1.0	3.0	
	Precipitation	1.2	3.0	
	Variability in Precipitation	1.3	3.0	
	Ocean Acidification	4.0	2.0	
	Variability in Ocean Acidification	1.0	2.2	
	Currents	2.0	1.0	
	Sea Level Rise	1.6	1.5	
	Exposure Score	Very High		
Overall Vulnerability Rank		Very High		



Softshell Clam (*Mya arenaria*)

Overall Climate Vulnerability Rank: **Very High** (58% certainty from bootstrap analysis).

Climate Exposure: **Very High**. Three exposure factors contributed to this score: Ocean Surface Temperature (4.0), Air Temperature (3.5), and Ocean Acidification (4.0). Softshell Clam utilize near coastal and intertidal habitats.

Biological Sensitivity: **High**. Two sensitivity attributes scored above 3.0: Sensitivity to Ocean Acidification (3.5) and Adult Mobility (4.0). Softshell Clams are sessile and have a calcium carbonate shell.

Distributional Vulnerability Rank: **High** (82% certainty from bootstrap analysis).

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Softshell Clam is likely to be negative (90-95% certainty in expert scores). Ocean acidification is likely to negatively impact Softshell Clams, but carbonate chemistry is complicated in coastal and intertidal systems. Warming temperatures may also lead to decreases in available habitat and may decrease productivity.

Data Quality: 83% of the data quality scores were 2 or greater indicate that data quality is moderate.

Climate Effects on Abundance and Distribution: Long-term decreases in recruitment of Softshell Clam in the Wadden Sea has been linked to an increase in predation pressure, with predators increases linked to climate change (Beukema and Dekker, 2005, Freitas et al., 2007). Laboratory studies found that calcification rates of Softshell Clam decreased as aragonite saturation state decreased from 2.5 to 1(ocean acidification) (Reis 2009). However, carbonate chemistry and ocean acidification are affected by many factors including atmospheric CO_2, making future aragonite saturation state in these systems difficult to project (Waldbusser and Salisbury, 2014). However, these studies suggest that productivity of Softshell Clam in the Northeast U.S. Shelf Ecosystem is likely to decrease as a result of direct (ocean acidification) and indirect (increases in predation) effects of climate change.

Life History Synopsis**:** Softshell Clam, or softshell clam, is a coastal bivalve species found from Labrador to South Carolina, extending in low abundance south to Florida, throughout western Europe, and introduced to the eastern Pacific from Alaska to California (Newell and Hidu, 1986). Softshell Clams are typically dioecious (sepearte sexes) but can be hermaphroditic. They reach maturity within 5 years, at sizes typically >20 mm (Abraham and Dillon, 1986; Newell and Hidu, 1986). Spawning season is determined by temperature and food availability, occurs from late-spring through fall, and may occur as two spawning events (spring and fall) south of Cape Cod, Massachusetts, or a single event north of Cape Cod (Newell and Hidu, 1986). Males spawn first, inducing egg release in females, and fertilization is external (Newell and Hidu, 1986). Individual females are capable of producing millions of eggs each year, with larger females producing more eggs than smaller individuals (Newell and Hidu, 1986). The pelagic eggs hatch after 9-12 hours (Abraham and Dillon, 1986; Newell and Hidu, 1986). The ciliated embryo quickly develops into the planktonic trochophore larva, which is also ciliated and feeds on suspended particles (Abraham and Dillon, 1986). After 1-1.5 days, the first shell and swimming organ develop and the veliger stage begins (Abraham and Dillon, 1986; Newell and Hidu, 1986). The veliger larva uses the ciliated velum to remain suspended in the water column and drifts in estuarine and ocean currents (Abraham and Dillon, 1986; Newell and Hidu, 1986). Larval Softshell Clams feed on phytoplankton and are preyed on by fish larvae, jellyfish, and ctenophores (Abraham and Dillon, 1986; Newell and Hidu, 1986). This stage is often the most abundant plankton during late summer in inshore, subsurface waters, but is also characterized by very high mortality rates (Newell and Hidu, 1986). After 2-6 weeks (duration depends on water temperature) and at approximately 200 **μ**m, the shell thickens, a foot replaces the velum, the byssal gland develops, and the larva settles to the substrate, and becomes a bottom-dwelling spat (Abraham and Dillon, 1986; Newell and Hidu, 1986). The late-stage larva can delay metamorphosis until a suitable attachment site is found, but once found the spat anchors to the substrate with the byssal threads and can remain attached until 7 mm long (Abraham and Dillon, 1986; Newell and Hidu, 1986). The juvenile spat is generally attached to the substrate, but can crawl to a more favorable location with the foot (Abraham and Dillon, 1986). The floating and crawling stage can last 2-5 weeks, but the spat eventually burrow into the sediment, becoming sedentary (Abraham and Dillon, 1986; Newell and Hidu, 1986). The juvenile is shallowly buried in sandy substrate, so predation rates are high and movement due to hydrographic condition such as storms or eddies causes irregular settlement patterns (Abraham and Dillon, 1986; Newell and Hidu, 1986). Predators of juvenile Softshell Clam include: oyster drills, flatworms, blue, green, and mud crabs, Mummichog, Spot, Cownose Ray, American Eel, Winter Flounder, polychaetes, snails, and shrimp (Abraham and Dillon, 1986; Homer et al., 2011). Like juveniles, adults inhabit sand bottom, or a mix of sand and mud or clay, of intertidal bays and inlets out to 199m (Abraham and Dillon, 1986; Newell and Hidu, 1986). Burrowing depth increases with time, so adults can be as deep as 30 cm in the sediment with the siphons extended to the sediment surface (Abraham and Dillon, 1986). Softshell Clams can tolerate a wide range of temperature and salinities, but adults experience and tolerate a narrower range than juveniles due to their deep burrows (Abraham and Dillon, 1986; Newell and Hidu, 1986). Additionally, southern populations can tolerate lower salinities than northern populations (Newell and Hidu, 1986). Softshell Clams are filter feeders of microscopic particles of organic materials, especially planktonic flagellates and diatoms, but also organic detritus and bacteria (Newell and Hidu, 1986). Crabs, Spot, Atlantic Croaker, Cownose Ray, American Eel, Winter and Summer Flounder, moon snails, gulls, diving ducks, tundra swans, and raccoons are predators of the species, but the depth of burrows helps Softshell Clams avoid most predators (Abraham and Dillon, 1986; Newell and Hidu, 1986; Homer et al., 2011). Softshell Clams support important commercial and recreational fisheries throughout most of their range and are managed by each state. The Chesapeake Bay fishery collapsed and is slow to recover due to a combination of overharvesting, disease, and predation (Homer et al., 2011). Red tides do not harm the clams, but bioaccumulation of toxins can cause paralytic shellfish poisoning in humans (Abraham and Dillon, 1986).

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