Green Sea Urchin − *Strongylocentrotus droebachiensis*

Overall Vulnerability Rank = High

Biological Sensitivity = High
Climate Exposure = High
Data Quality = 83% of scores ≥ 2

Strongylocentrotus droebachiensis		Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.5	1.2	
	Other Stressors	1.8	2.1	
	Population Growth Rate	2.5	1.6	
	Spawning Cycle	3.4	3.0	
	Complexity in Reproduction	1.4	2.5	
	Early Life History Requirements	2.7	2.6	
	Sensitivity to Ocean Acidification	3.3	2.6	
	Prey Specialization	1.9	2.6	
	Habitat Specialization	2.4	2.7	
	Sensitivity to Temperature	1.7	2.8	
	Adult Mobility	3.2	3.0	
	Dispersal & Early Life History	1.9	2.4	
	Sensitivity Score	High		
Exposure variables	Sea Surface Temperature	3.9	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	1.1	3.0	
	Variability Salinity	1.2	3.0	
	Air Temperature	3.0	3.0	
	Variability Air Temperature	1.0	3.0	
	Precipitation	1.2	3.0	
	Variability in Precipitation	1.2	3.0	
	Ocean Acidification	4.0	2.0	
	Variability in Ocean Acidification	1.0	2.2	
	Currents	2.2	1.0	
	Sea Level Rise	1.1	1.5	
	Exposure Score	High		
Overall Vulnerability Rank		High		

Low
Moderate
High
Very High

Green Sea Urchin (*Strongylocentrotus droebachiensis*)

Overall Climate Vulnerability Rank: **High** (94% certainty from bootstrap analysis).

Climate Exposure: **High**. Three exposure factors contributed to this score: Ocean Surface Temperature (3.9), Air Temperature (3.0), and Ocean Acidification (4.0). All life stages of Green Sea Urchin use marine habitats and adults can be found in shallow waters.

Biological Sensitivity: **High**. Three sensitivity attributes scored above 3.0: Spawning Cycle (3.4), Sensitivity to Ocean Acidification (3.3), and Adult Mobility (3.2). Spawning occurs in a discrete season: early spring. Tests are made of calcium carbonate and adult mobility is limited.

Distributional Vulnerability Rank: **Moderate** (86% certainty from bootstrap analysis).

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Green Sea Urchin on the Northeast U.S. Shelf is very likely to be negative (>95% certainty in expert scores). Ocean acidification will likely negatively impact test forming echinoderms, including Green Sea Urchins. Warming will also likely reduce population productivity and may cause shifts out of the region.

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

Climate Effects on Abundance and Distribution: Juvenile growth and survivorship is related to temperature with maximum rates observed at 9-13^{o}C (Pearce et al., 2005). Warming above these temperatures would result in decreased growth and survivorship thereby reducing productivity. In addition, decreasing pH (i.e., ocean acidification) negatively affects many aspects of the life cycle including larval survival and settlement success (Dupont et al., 2013). However, there is evidence of plasticity and some ability to acclimate to lower levels of pH (Dupont and Thorndyke, 2013).

Life History Synopsis**:** Green Sea Urchin is a cold water echinoderm species found in the northern Pacific, western Baltic Sea, Korean coast, and from the Canadian Arctic to New Jersey in the western north Atlantic (CCIAP, 2007). Spawning is broadcast and external and predominantly occurs in spring with a smaller season in fall in Newfoundland (Meidel and Scheibling, 1998; CCIAP, 2007). Adults in barren grounds likely contribute fewer recruits than adults from kelp beds (Meidel and Scheibling, 1998; Meidel et al., 1999). Larvae are planktonic for 4-21 weeks (CCIAP, 2007). Settlement occurs in late spring and summer when larvae attach to suitable substrate and metamorphose into benthic juveniles (Lambert and Harris, 2000; CCIAP, 2007). Metamorphosis can be delayed until suitable substrate is found, usually calcareous algae although non-calcareous algae and microbial and algal films are also used (CCIAP, 2007). Juveniles are solitary, dispersed, and not associated with adults (Nishizaki and Ackerman, 2007). Adults are the dominant herbivore in shallow rocky subtidal zones of the northwest Atlantic, and also occur in sheltered and exposed kelp beds out to 1200 m (Meidel et al., 1999; CCIAP, 2007). Green Sea Urchins are cryptic and usually sparsely distributed in crevices and under boulders (Meidel and Scheibling, 1998). Green Sea Urchin consume detritus and drift algae when sparse, but when numbers increase, adults aggregate into fronts along the edge of kelp beds (Meidel et al., 1999). Population outbreaks lead to destruction of kelp beds and formation of sea urchin-dominated barren grounds (Meidel and Scheibling, 1998). Green Sea Urchin predominately consume perennial phaeophytes, but coralline algae and animals such as barnacles, gastropods, small shrimps, and occasionally dead fish are consumed in smaller amounts (Himmelman and Steele, 1971). American Lobsters, Rock Crabs, Purple Sea Stars, other urchins, and a variety of fishes and birds are common predators of the Green Sea Urchin

(Himmelman and Steele, 1971). Green Sea Urchins are prized for their roe, particularly in Japanese markets. The U.S. fishery, which predominantly occurs in Maine and Massachusetts, is managed on a state-by-state basis.

Literature Cited:

Climate Change Impacts and Adaptation Program (CCIAP). Climate Change and Thermal Sensitivity of Canadian Atlantic Commercial Marine Species. 2007. Natural Resources Canada Project A515. Available: http://www.geog.mcgill.ca/climatechange/ReportsMap/sea_urchinRpt.pdf

Dupont S. Thorndyke M. Direct impacts of near-future ocean acidification on sea urchins. In Fernández-Palacios J. M., de Nascimento L., Hernández J. C., Clemente S., González A. & Díaz-González J. P., Climate change perspective from the Atlantic: past, present and future. 2013. Servicio de Publicaciones, Universidad de La Laguna. pp. 461-485.

Dupont S, Dorey N, Stumpp M, Melzner F, Thorndyke M. Long-term and trans-life-cycle effects of exposure to ocean acidification in the green sea urchin *Strongylocentrotus droebachiensis*. Mar. Bio. 2013; 160(8): 1835-1843. doi: 10.1007/s00227-012-1921-x

Himmelman JH, Steele DH. Foods and predators of the green sea urchin *Strongylocentroltus droebachiensis* in Newfoundland waters. Mar Biol. 1971; 9: 315-322. doi: 10.1007/BF00372825

Lambert DM, Harris LG. Larval settlement of the green sea urchin, Strongylocentrotus droebachiensis, in the southern Gulf of Maine. Invertebr Biol 2000; 119: 403-409. doi: 10.1111/j.1744-7410.2000.tb00110.x

Mann KH. Destruction of kelp beds by sea urchin: a cyclical phenomenon or irreversible degradation? Helgolander wiss Meeresunters. 1977; 30: 455-467.

Meidel SK, Scheibling RE, Metaxas A. Relative importance of parental and larval nutrition on larval development and metamorphosis of the sea urchin *Strongylocentrotus droebachiensis.* J Exper Mar Bio Ecol. 1999; 240: 161-178. doi:10.1016/S0022-0981(99)00046-5

Nishizaki MT, Ackerman JD. Juvenile-adults associations in sea urchins (*Strongylocentrotus franciscanus* and *S. droebachiensis*): protection from predation and hydrodynamics in *S. franciscanus*. Mar Biol. 2007; 151: 135-145.doi: 10.1007/s00227-006-0462-6

Pearce CM, Williams SW, Yuan F, Castell JD, Robinson S. Effect of temperature on somatic growth and survivorship of early post-settled green sea urchins, *Strongylocentrotus droebachiensis* (Müller). Aquacult Res. 2005; 36(6): 600-609. doi: 10.1111/j.1365-2109.2005.01264.x

Wharton WG, Mann KH. Relationship between destructive grazing by the sea urchin, *Strongylocentrotus droebachiensis,* and the abundance of American Lobster in the Atlantic coast of Nova Scotia. Can J Fish Aquat Sci. 1981; 38: 1339-1349. doi: 10.1139/f81-180

XChen Y, Hunter M. Assessing the green sea urchin (Strongylocentrotus drobachiensis) stock in Maine, USA. Fish Res 2003; 60: 527-537