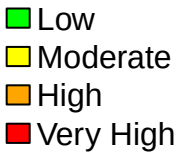
Atlantic Menhaden − *Brevoortia tyrannus*

Overall Vulnerability Rank = Moderate

Biological Sensitivity = Low
Climate Exposure = Very High
Data Quality = 88% of scores ≥ 2

	Brevoortia tyrannus	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.4	1.4	
	Other Stressors	2.1	2.4	
	Population Growth Rate	1.2	2.8	
	Spawning Cycle	1.8	2.8	
	Complexity in Reproduction	1.9	3.0	
	Early Life History Requirements	2.9	2.9	
	Sensitivity to Ocean Acidification	1.8	2.4	
	Prey Specialization	1.5	3.0	
	Habitat Specialization	2.0	3.0	
	Sensitivity to Temperature	1.5	3.0	
	Adult Mobility	1.6	3.0	
	Dispersal & Early Life History	1.8	3.0	
	Sensitivity Score	Low		
Exposure variables	Sea Surface Temperature	4.0	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	2.4	3.0	
	Variability Salinity	1.2	3.0	
	Air Temperature	4.0	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	1.5	1.5	
	Exposure Score	Very High		
	Overall Vulnerability Rank	Moderate		



Atlantic Menhaden (*Brevoortia tyrannus*)

Overall Climate Vulnerability Rank: **Moderate** (64% certainty from bootstrap analysis).

Climate Exposure: **Very High**. Three exposure factors contributed to this score: Ocean Surface Temperature (4.0), Ocean Acidification (4.0) and Air Temperature (4.0). Exposure to all three factors occur during all life stages. Atlantic Menhaden spawn on the shelf, juveniles use estuarine nurseries, and adults make seasonal migrations feeding in estuarine and coastal areas.

Biological Sensitivity: **Low**. Only one sensitivity attribute scored above 2.5: Early Life History Requirements (2.9). Atlantic Menhaden exhibit an obligate estuarine-dependent life cycle, using estuaries during the late larval and juvenile stages (Able, 2005).

Distributional Vulnerability Rank: **High** (99% certainty from bootstrap analysis). Two attributes indicated vulnerability to distribution shift. Atlantic Menhaden larvae are widely dispersed after spawning and adults make large seasonal migrations along the East Coast of the United States.

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Atlantic Menhaden on the Northeast U.S. Shelf is very likely to be positive (90-95% certainty in expert scores). Recruitment will likely increase as temperature warm and more spawning occurs in the region. Adult distribution will likely extend northwards and the species may re-occupy the Gulf of Maine during summertime. The effect of ocean acidification over the next 30 years is likely to be minimal.

Data Quality: 88% of the data quality scores were 2 or greater.

Climate Effects on Abundance and Distribution: Wood and Austin (2009) described synchrony in recruitment of three coastal spawning species in Chesapeake Bay: Atlantic Menhaden, Spot, and Summer Flounder. The generalized recruitment pattern was asynchronous with recruitment of diadromous species in the Bay and the authors suggest large-scale climate forcing is responsible for the patterns in recruitment. This study suggests that Atlantic Menhaden productivity may change with changes in precipitation and temperature. Atlantic Menhaden distribution may also change. Dow (1977) reported that Atlantic Menhaden catches in the Gulf of Maine increased in the 1950s coincident with a warm period suggesting that distribution expands northward during warmer periods. Walsh et al. (2015) documented that the time of spawning of Atlantic Menhaden in the Northeast U.S. Shelf has also changed with more spawning in the spring in recent years.

Life History Synopsis**:** Atlantic Menhaden is a schooling, migratory, pelagic, estuarine-dependent, marine species that ranges seasonally from Nova Scotia to northern Florida (Rogers and van den Avyle, 1989). Menhaden mature after 2-3 years (ASMFC, 2011). Spawning occurs year round with a latitudinal gradient in occurrence, but peaks in spring and fall in the north and mid-Atlantic regions (Rogers and van den Avyle, 1989; Able and Fahay, 2010). All ages and size classes accumulate off the Carolinas in winter near the shelf break and spawn. They then migrate inshore and to the north, continuing to spawn on the inner continental shelf and into estuaries. Spawning continues through the fall during the southward and offshore migration (Rogers and van den Avyle, 1989; Able and Fahay, 2010). Spawning north of Long Island, New York may not result in many surviving larvae (Munroe, 2002). Eggs are pelagic and hatch after 2-3 days depending on temperature (Rogers and van den Avyle, 1989; Able and Fahay, 2010). Larval menhaden spend 1-3 months in the upper water column on the continental shelf and make diel vertical migrations to the surface (Rogers and can den Avyle, 1989; Munroe, 2002; Able and Fahay,

2010). Late stage larvae ingress into estuaries from spring to fall in the North Atlantic and winter through spring off the coast of the southeastern United States (Rogers and van den Avyle, 1989). These pre-juveniles inhabit shallow, low-salinity areas of vegetated tidal marshes for 4 months or up to a year (Rogers and van den Avyle, 1989; Able and Fahay, 2010). Early juvenile survival is linked to low salinity, temperatures above 5 ^{o}C, and slow rates of cooling (Able and Fahay, 2010). As the young menhaden mature, they move from the upper estuary to more saline parts of the estuary (Able and Fahay, 2010). Young menhaden are very selective feeders on specific zooplankton, particularly copepods, but as they mature, become increasingly reliant on filter feeding of phytoplankton and detritus (Rogers and van den Avyle, 1989; Able and Fahay, 2010). While a few Atlantic Menhaden have been observed to overwinter in the estuary, most leave the shallow habitat for the open ocean in fall, when temperatures begin to fall more quickly, and migrate south and offshore with the adults (Able and Fahay, 2010). At this same time, the schooling behavior begins (Able and Fahay, 2010). Large schools of similarly sized and aged adult menhaden make long migrations both along- and cross-shelf, with larger fish migrating larger distances (Rogers and van den Avyle, 1989; Able and Fahay, 2010). Atlantic Menhaden are a very important prey species, particularly for Bluefish, Striped Bass, Bluefin Tuna, and sharks (Rogers and van den Avyle, 1989; Able and Fahay, 2010). The Atlantic States Marine Fishery Commission under Amendment 2 to the Interstate Fishery Management Plan for Atlantic Menhaden manages Atlantic Menhaden. As of the most recent assessment, menhaden are not overfished, and overfishing is not occurring (SEDAR, 2015).

Literature Cited:

Able KW. A re-examination of fish estuarine dependence: evidence for connectivity between estuarine and ocean habitats. Estuar Coast Shelf Sci. 2005; 64(1), 5-17. doi:10.1016/j.ecss.2005.02.002

Able KW, Fahay MP. Ecology of estuarine fishes: temperate waters of the western North Atlantic. Baltimore: The Johns Hopkins University Press; 2010. 566p.

Atlantic States Marine Fisheries Commission (ASMFC). 2011. Atlantic menhaden stock assessment and review panel reports. Stock Assessment Report No. 10-02. 326p. Accessed online (June 2014): http://www.asmfc.org/uploads/file/2010AtlanticMenhadenStockAssessmentAndReviewPanelReport.pdf

SEDAR. 2015. SEDAR 40 – Atlantic Menhaden Stock Assessment Report. SEDAR, North Charleston SC. 643 pp. Available: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=40.

Dow RL. Effects of climatic cycles on the relative abundance and availability of commercial marine and estuarine species. ICES J Mar Sci. 1977; 37(3): 274-280. doi: 10.1093/icesjms/37.3.274

Munroe T. 2002. Herring and herring-like fishes: Order Clupeiformes. In: B.B. Collette BB, Klein-MacPhee G, editors, Fishes of the Gulf of Maine, 3rd ed. Washington: Smithsonian Institution Press; 2002. pp. 104-158.

Rogers SG, Van Den Avyle MJ. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic)--Atlantic menhaden. U.S. Fish Wildl. Serv. Biol. Rep.82 (11.108). U.S. Army Corps of Engineers TR EL-82-4. 23 pp. Accessed online (June 2014): http://www.nwrc.usgs.gov/wdb/pub/species_profiles/82_11-108.pdf

Walsh HJ, Richardson DE, Marancik KE, Hare JA. 2015. Long-term changes in the distributions of larval and adult fish in the Northeast U.S. Shelf Ecosystem. PLOS ONE. doi: 10.1371/journal.pone.0137382

Wood RJ, Austin HM. Synchronous multidecadal fish recruitment patterns in Chesapeake Bay, USA. Can J Fish Aquat Sci. 2009; 66(3): 496-508. doi: 10.1139/F09-013