Summer Flounder − *Paralichthys dentatus*

Overall Vulnerability Rank = Moderate

Biological Sensitivity = Low

Climate Exposure = Very High

Data Quality = 92% of scores ≥ 2

Paralichthys dentatus		Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.0	3.0	
	Other Stressors	2.3	2.6	
	Population Growth Rate	2.0	2.6	
	Spawning Cycle	2.0	3.0	
	Complexity in Reproduction	1.3	2.8	
	Early Life History Requirements	2.2	2.7	
	Sensitivity to Ocean Acidification	1.3	2.4	
	Prey Specialization	1.2	3.0	
	Habitat Specialization	1.4	3.0	
	Sensitivity to Temperature	1.2	3.0	
	Adult Mobility	1.5	3.0	
	Dispersal & Early Life History	1.9	2.8	
	Sensitivity Score	Low		
Exposure variables	Sea Surface Temperature	4.0	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	2.6	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	2.4	1.5	
	Exposure Score	Very High		
Overall Vulnerability Rank		Moderate		

Low
Moderate
High
Very High

Summer Flounder (*Paralichthys dentatus*)

Overall Climate Vulnerability Rank: **Moderate** (100% 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). Summer Flounder is an obligate estuarine-dependent species (Able, 2005), spawns on the shelf and juveniles develop in estuaries. Adults make seasonal north-south migrations exposing them to changing condition inshore and offshore.

Biological Sensitivity: **Low**. No sensitivity attributes scored above 2.5.

Distributional Vulnerability Rank: **High** (100% certainty from bootstrap analysis). Three attributes indicated vulnerability to distribution shift. Summer flounder spawning in shelf waters and eggs and larvae are broadly dispersed. Adults make regional-scale north-south migrations seasonally. Adults use a range of habitats including estuarine, coastal, and shelf. The life history of the species has a strong potential to enable shifts in distribution.

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Summer Flounder on the Northeast U.S. Shelf is estimated to be neutral but with high uncertainty (<66% certainty in expert scores). Adult distribution have shifted northward, but this is linked to changes in fishing. Also, productivity of the stock has remained fairly constant over the past 3 decades, during which temperatures in the ecosystem have increased. The effect of ocean acidification over the next 30 years is likely to be minimal. However, there are many aspects of the life history which could result in a positive effect resulting from climate change and these lead to the expert uncertainty.

Data Quality: 92% of the data quality scores were 2 or greater.

Climate Effects on Abundance and Distribution: Wood and Austin (2009) described synchrony in the 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 Summer Flounder productivity may change with changing climate. Recent changes in Summer Flounder distribution also have been identified and linked to climate (Pinsky et al 2013), but Bell et al. (2014) presented evidence that changes in Summer Flounder distribution were linked to reductions in fishing and expanding population rather than changes in temperature. Murawski (1993) also documented changes in Summer Flounder distribution related to abundance and not temperature. These results do not mean that climate does not affect distribution, but rather changes in abundance have a much greater effect, pointing to the important role of fishing in determining fish abundance and distribution. Chambers et al. (2014) found that survival of Summer Flounder eggs and larvae decreased with increasing CO_2 concentrations. However, the experimental conditions were extreme relative to the expected changes in CO_2 concentrations in the next several decades, thus the effects of ocean acidification in the near-term remain unclear.

Life History Synopsis**:** Summer Flounder is an estuarine-dependent, marine, benthic flatfish species that is found from Nova Scotia to Florida, but mostly occurs from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Packer et al., 1999). Most Summer Flounder are sexually mature by age 2, and females reach larger sizes than males (Packer et al., 1999). North of Cape Hatteras, spawning occurs from September through January or as late as early March (peaking October to November) beginning inshore and continuing as the adults migrate to offshore winter habitats (Packer et al., 1999; Able and Fahay, 2010). Summer Flounder are highly fecund serial spawners producing thousands to millions of pelagic eggs (Packer et al., 1999). Eggs hatch after 2-9 days depending on water temperature (Packer et al., 1999; Able and Fahay, 2010). Larvae are planktonic and are transported inshore eventually reaching estuaries (Packer et al., 1999; Able and Fahay, 2010). While offshore, survival is influenced by temperature, salinity, and the availability of prey as the yolk runs out (Packer et al., 1999). Larvae feed during the day on copepod nauplii, copepodites, and tintinnids, changing to larger prey including calanoid copepods, and appendicularians as they approach the coast (Klein-MacPhee, 2002; Able and Fahay, 2010). Beginning while still at sea, Summer Flounder larvae undergo a significant metamorphosis where the right eye migrates over the head to the left side (Packer et al., 1999). The duration of this stage depends on temperature and can last 3 weeks to 3 months (Klein-MacPhee, 2002; Able and Fahay, 2010). Larvae ingress to estuaries during late fall to early spring at approximately 13 mm standard length (Able and Fahay, 2010). The diet of post-larvae in estuaries relies heavily on the calanoid copepod, *Temora longicornis* (Able and Fahay, 2010). After completing metamorphosis, juveniles settle on estuarine soft sediments and begin exhibiting burying behavior (Packer et al., 1999). Recently settled juveniles occur in a variety of estuarine habitats including: marsh creeks, seagrass beds, mud flats, open bays, and shallow coves with mud, sand, and shell hash substrates, and remain in the same area for several months (Packer et al., 1999; Able and Fahay, 2010). Juveniles are most abundant in estuaries from Virginia to South Carolina (Able and Fahay, 2010). Many juveniles from southern estuaries remain in the estuary for up to 20 months, while northern estuary inhabitants often move to just outside the estuary in winter and return to the same estuary the next spring (Packer et al., 1999; Klein-MacPhee, 2002). The juvenile diet shifts from invertebrates, such as mysids, shrimp, polychaetes, copepods, and crabs, to a diet dominated by blue crabs and small fishes such as juvenile Winter Flounder, silversides, mummichogs, and Spot (Klein-MacPhee, 2002; Able and Fahay, 2010). Crangon shrimp and blue crabs are also common predators of juvenile flounder (Able and Fahay, 2010). Adults are common in estuarine and coastal waters from spring through fall near eelgrass beds and salt marshes in muddy or silty sediments (Klein-MacPhee, 2002; Able and Fahay, 2010). In fall, starting with the oldest and largest individuals, adults and large juveniles migrate offshore to sand or mud bottom on the outer continental shelf to overwinter (Klein-MacPhee, 2002; Able and Fahay, 2010). By late spring the adults migrate back to coastal waters, often to the same estuaries year after year; although, some large individuals stay offshore even during summer (Able and Fahay, 2010). Bony fish, such as sand lance, anchovies, hakes, and other flatfish are the dominant prey of these active hunters (Klein-MacPhee, 2002; Able and Fahay, 2010). Squid, decapod shrimp, and small crustaceans are also important prey (NEFSC, 2013). Spiny Dogfish, Blue Shark, Little Skate, Winter Skate, Atlantic Cod, Silver Hake, Monkfish (Goosefish), Northern Sea Robin, Spot, Bluefish, and Winter Flounder are all predators of Summer Flounder (Klein-MacPhee, 2002; NEFSC, 2013). The Atlantic States Marine Fisheries Commission (state waters) and Mid-Atlantic Fishery Management Council (federal waters) cooperatively manage Summer Flounder as a single stock from the Canadian border to the southern border of North Carolina (NEFSC, 2013). Summer Flounder are not overfished nor is overfishing occurring and the stock was declared rebuilt in 2010 (NEFSC, 2013).

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