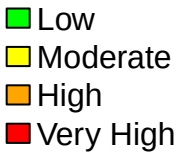
Rainbow Smelt − *Osmerus mordax*

Overall Vulnerability Rank = Very High

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

	Osmerus mordax	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Stock Status	2.9	1.2	
	Other Stressors	3.3	2.1	
	Population Growth Rate	1.4	1.8	
	Spawning Cycle	3.3	2.6	
	Complexity in Reproduction	2.8	2.8	
	Early Life History Requirements	3.2	2.2	
	Sensitivity to Ocean Acidification	1.6	2.2	
	Prey Specialization	1.5	3.0	
	Habitat Specialization	2.8	3.0	
	Sensitivity to Temperature	2.7	3.0	
	Adult Mobility	1.9	2.9	
	Dispersal & Early Life History	2.9	2.6	
	Sensitivity Score	High		
Exposure variables	Sea Surface Temperature	4.0	3.0	
	Variability in Sea Surface Temperature	1.0	3.0	
	Salinity	1.1	3.0	
	Variability Salinity	1.2	3.0	
	Air Temperature	4.0	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	3.1	1.5	
	Exposure Score	Very High		
	Overall Vulnerability Rank	Very High		



Rainbow Smelt (*Osmerus mordax*)

Overall Climate Vulnerability Rank: **High** (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). Rainbow Smelt are anadromous, spawning in freshwater, developing in freshwater and estuarine habitats, feeding as adults in estuarine, coastal, and marine habitats.

Biological Sensitivity: **High**. Three sensitivity attributes scored above 3.0: Other Stressors (3.3), Spawning Cycle (3.3), and Early Life History Requirements (3.2). Rainbow Smelt are diadromous and exposed to a number of other stressors including habitat destruction, blockage to spawning habitats, and contaminants (Limburg and Waldman, 2009). Spawning is in the spring as temperatures warm (Murawski et al., 1980) and eggs and larvae develop in fresh and brackish water (Laprise and Dodson, 1989).

Distributional Vulnerability Rank: **Moderate** (89% certainty from bootstrap analysis). Several attributes indicate limited vulnerability to distribution shifts. Adults are small and not highly mobile. Eggs and larvae remain near spawning sites and use selective tidal-stream transport to enhance retention (Laprise and Dodson, 1989). Spawning sites are relatively specific and the proportion of natal homing is high (Bradbury et al., 2008).

Directional Effect in the Northeast U.S. Shelf: The effect of climate change on Rainbow Smelt is very likely to be negative (>95% certainty in expert scores). Rainbow Smelt are found in the colder coastal habitats in the region. As these habitats warm, productivity may decrease and distributions may shift northwards. Increased precipitation and sea-level rise may also negatively impact Rainbow Smelt through changes in their coastal habitats. The effect of ocean acidification over the next 30 years is likely to be minimal.

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

Climate Effects on Abundance and Distribution: There is relatively little information on the effect of climate on anadromous Rainbow Smelt. In one study, Mingelbier et al. (2001) found that catch of Rainbow Smelt in the St. Lawrence estuary was linked to air temperature and water level. Population-scale differences in the effect of climate variables were explained by the interaction between climate factors and adult habitat – shallow shoals and deep channels.

Life History Synopsis**:** Rainbow Smelt is a pelagic, anadromous species from the Arctic Ocean, the northern Pacific Ocean, and from southern Labrador to New Jersey in the North Atlantic Ocean (Able and Fahay, 2010). While generally an anadromous species, Rainbow Smelt also occur as several land-locked populations. Most of the population reaches maturing at age 2, but maturity is related to size and may occur earlier in the faster growing southern portion (Klein-MacPhee, 2002). Adults move from near-shore and estuarine waters to freshwater streams to spawn in late winter through spring (Klein-MacPhee, 2002). Males arrive at spawning sites first and remain there longer than females (Klein-MacPhee, 2002). Spawning occurs at night over rock, rubble, sand, or gravel in fast flowing freshwater streams and individuals may spawn in several streams during the season (Klein-MacPhee, 2002). The semi-adhesive eggs are deposited on the bottom and form clusters, sticking to anything they touch (Klein-MacPhee, 2002; Able and Fahay, 2010). Adults return to saltwater by mid to late spring (Klein-

MacPhee, 2002). Eggs require a fairly long incubation time of 2 weeks to 2 months, determined by temperature, and exposure to even low-salinity water can be fatal (Klein-MacPhee, 2002). Larvae drift passively downstream to brackish water or larger lakes and maintain their position in more turbid parts of the estuary using tidal currents and vertical migrations (Able and Fahay, 2010). Larvae are planktivorous, consuming rotifers, copepods, and other planktonic invertebrates (Klein-MacPhee, 2002). The dominant predators of eggs and early larvae are sticklebacks and trout (Able and Fahay, 2010). Juveniles are found on sea grass beds in shallow near-shore areas (Able and Fahay, 2010). By their first winter, juveniles mix with the estuarine adult population and move to salt water during their first year of life (Klein-MacPhee, 2002). Adults occur in bays, estuaries, coastal waters, and freshwater lakes (Able and Fahay, 2010). Juveniles and adults can produce antifreeze chemicals to withstand freezing water temperatures without migrations, but seek deeper, cooler waters in summer (Able and Fahay, 2010). Adults also aggregate in estuaries in autumn in preparation for the spawning run to freshwater (Klein-MacPhee, 2002). Rainbow Smelt consume many invertebrates (e.g., amphipods, euphausiids, mysids, shrimps, and marine worms; Klein-MacPhee, 2002) and small fish (e.g., Atlantic Herring, Bay Anchovy, Cunner, Sand Lance, Atlantic Silversides, Three-spine Sticklebacks, and river herring; Able and Fahay, 2010). Atlantic Cod, Atlantic Salmon, Lake Trout, Striped Bass, Bluefish, Burbot, Walleye, Yellow Perch, mergansers, cormorants, gulls, and terns are common predators of the species (Klein-MacPhee, 2002; Able and Fahay, 2010). Rainbow Smelt were made a federal species of concern after construction of dams, blocking entrance to suitable spawning habitat, and habitat degradation, mostly due to development, severely reduced anadromous population abundances (Klein-MacPhee, 2002). Smelt are managed on a state-by-state basis to rebuild the anadromous population (Enterline et al., 2012) and as an invasive species in several mid-western United States systems (USGS, 2014).

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