Arrowtooth flounder − *Atheresthes stomias*

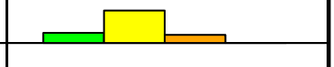
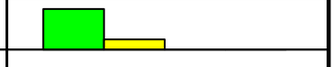
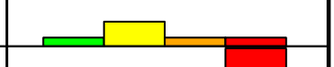
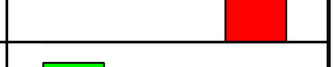
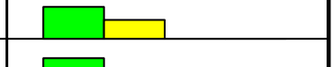
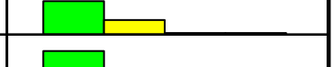
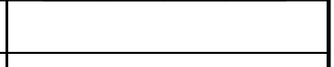
Overall Vulnerability Rank = Low

Biological Sensitivity = Low

Climate Exposure = Low

Sensitivity Data Quality = 92% of scores ≥ 2

Exposure Data Quality = 56% of scores ≥ 2

	Atheresthes stomias	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	1.1	3.0	
	Prey Specificity	1.6	2.6	
	Adult Mobility	1.7	2.0	
	Dispersal of Early Life Stages	1.4	2.0	
	Early Life History Survival and Settlement Requirements	2.0	2.0	
	Complexity in Reproductive Strategy	1.8	1.8	
	Spawning Cycle	2.3	2.0	
	Sensitivity to Temperature	1.7	2.8	
	Sensitivity to Ocean Acidification	2.0	2.8	
	Population Growth Rate	3.0	3.0	
	Stock Size/Status	1.0	3.0	
	Other Stressors	1.1	2.8	
	Sensitivity Score	Low		
Exposure factors	Sea Surface Temperature	2.0	2.5	
	Sea Surface Temperature (variance)	1.6	2.5	
	Bottom Temperature	2.1	3.0	
	Bottom Temperature (variance)	2.1	3.0	
	Salinity	1.2	2.0	
	Salinity (variance)	2.3	2.0	
	Ocean Acidification	4.0	3.0	
	Ocean Acidification (variance)	1.4	3.0	
	Phytoplankton Biomass	1.4	1.2	
	Phytoplankton Biomass (variance)	1.3	1.2	
	Plankton Bloom Timing	1.5	1.0	
	Plankton Bloom Timing (variance)	2.2	1.0	
	Large Zooplankton Biomass	1.2	1.0	
	Large Zooplanton Biomass (variance)	1.3	1.0	
	Mixed Layer Depth	1.5	1.0	
	Mixed Layer Depth (variance)	2.3	1.0	
	Currents	1.4	2.0	
	Currents (variance)	1.6	2.0	
	Air Temperature	NA	NA	
	Air Temperature (variance)	NA	NA	
	Precipitation	NA	NA	
	Precipitation (variance)	NA	NA	
	Sea Surface Height	NA	NA	
	Sea Surface Height (variance)	NA	NA	
	Exposure Score	Low		
Overall Vulnerability Rank		Low		

Low
Moderate
High
Very High

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Arrowtooth Flounder (*Astheresthes stomias*)

Overall Climate Vulnerability Rank: **Low**. (99% certainty from bootstrap analysis).

Climate Exposure: **Low**. With the exception of ocean acidification (4.0), all exposure factors had scores less than 2.5.

Biological Sensitivity: **Low**. Population growth rate (3.0) was ranked as "high" sensitivity, whereas all other attributes were ranked as "low" sensitivity.

Potential for distribution change: **High** (97% certainty from bootstrap analysis). Dispersal of early life stages and habitat specificity indicated very high potential for distribution change, whereas adult mobility indicated a high potential for distribution change.

Directional Effect in the Eastern Bering Sea: Projected climate change in the eastern Bering Sea is expected to have a neutral effect on Arrowtooth Flounder, with 94% certainty in expert scores.

Data Quality: 92% of the sensitivity attributes, and 56% of the exposure factors, had average data quality scores of 2 or greater (indicating at least "moderate" data quality).

Climate Effects on Abundance and Distribution:

A large proportion (>60%) of the juvenile arrowtooth flounder diet consists of organisms with calcium carbonate shells/exoskeletons, including shrimp, euphausiids, and polychaete worms (Spies et al. 2014). If these species declined under the effects of ocean acidification, the degree to which juvenile arrowtooth flounder could switch to other prey items is unknown.

In the laboratory, eggs and larvae survived the longest at 3°C with minimal water changes, eggs survived for over 26 days, and larvae lived for an additional 6 days (Blood et al. 2007). However, sensitivity to temperatures has not been specifically tested. Larvae are dependent on tidal currents and steep bathymetry to move them onto the continental shelf where they settle as juveniles (Blood et al. 2007).

Life History Synopsis:

Arrowtooth flounder is the more common of two species of the genus *Atheresthes* in the eastern Bering Sea. They range from the eastern Bering Sea to southern California, and off the Alaska Peninsula and Aleutian Islands. Catch per unit effort (CPUE) from survey data is highest between 100m and 300m (Spies et al. 2014). The maximum age observed in arrowtooth flounder is 29 for females and 34 for males. Arrowtooth flounder are considered benthic, although their prey are primarily walleye pollock, which are pelagic, and they move between the bottom and mid-water for feeding.

They are believed to reside in deeper waters in the winter, 300-500m, and spawn during winter months in the eastern Bering Sea (Blood et al. 2007). However, spawning adults have been observed during almost all months of the year except April in different locations; March, May-September in the GOA (Hirshberger and Smith 1983), December off the Washington coast (Rickey 1995), September - March in the Bering Sea (Pertseva-Ostroumova 1961), January-

February in the Gulf of Alaska (Blood et al. 2007). Spawning takes place between 400-500m and eggs incubate 15-20 days at 3-6C (Blood et al. 2007).

As larvae mature to early juveniles, they passively advect onto the shallower shelf regions of the Bering Sea and Gulf of Alaska and eventually settle from pelagic to demersal habitat (DeForest et al. 2014). In the Bering Sea, larvae as old as 2-3 months have been found at 300-400m near the southern Bering Sea slope from April - September (DeForest et al. 2014). In the GOA, larvae have been found at depths greater than 200m beginning in late February (Blood et al. 2007).

Diets of juvenile arrowtooth flounder are more similar to other Bering Sea shelf flatfish species than to arrowtooth flounder adults. Nonpandalid shrimp compose 42% of the total consumption, euphausiids 25%, juvenile pollock 22% and then polychaetes, sculpins and mysids accounting for another 10%; thus, a large proportion (>60%) of the juvenile arrowtooth flounder diet consists of organisms with calcium carbonate shells/exoskeletons, including shrimp, euphausiids, and polychaete worms (Spies et al. 2014). Nearly half of the adult diet is comprised of juvenile pollock (47%) followed by adult pollock (19%) and euphausiids (9%) (Spies et al. 2014). The adult diet composition appeared to shift from euphausiids to capelin from May to August, based on a study from 2002-2004 (Knoth and Foy 2008). In 2002 and 2003 walleye pollock were the dominant prey for arrowtooth flounder, but diet shifted to euphausiids and capelin. Arrowtooth flounder only compose approximately 2% of the diet of Bering Sea pollock, 3% of Alaska skate and 12% of the sleeper shark diet. Juveniles are also consumed by Pacific cod, but are a small portion of their diet.

Arrowtooth flounder are considered to be subject to different levels of instantaneous natural mortality for males (0.2 $year^{-1}$) and females (0.35 $year^{-1}$). Males and females exhibit differential growth by sex, with females reaching a maximum size of 1 m and age of 23, and males growing to 54 cm and 20 years. Age at 50% maturity was estimated at age 7 (Stark 2008). Arrowtooth flounder are managed as a single stock in the eastern Bering Sea and Aleutian Islands, with the majority of the stock occurring in the eastern Bering Sea. Genetic population structure has not been examined in Arrowtooth flounder. The stock has increased 25-50% since the late 1980s. The stock is not overfished or subject to overfishing; biomass measured in 2015 is 261% of B_{40}%.

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