Greenland turbot − *Reinhardtius hippoglossoides*

Overall Vulnerability Rank = Low

Biological Sensitivity = Moderate

Climate Exposure = Low

Sensitivity Data Quality = 75% of scores ≥ 2

Exposure Data Quality = 56% of scores ≥ 2

	Reinhardtius hippoglossoides	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	2.1	3.0	
	Prey Specificity	1.8	2.8	
	Adult Mobility	1.8	2.2	
	Dispersal of Early Life Stages	1.1	2.0	
	Early Life History Survival and Settlement Requirements	2.4	2.4	
	Complexity in Reproductive Strategy	1.9	1.0	
	Spawning Cycle	2.6	1.8	
	Sensitivity to Temperature	2.9	2.6	
	Sensitivity to Ocean Acidification	2.0	2.8	
	Population Growth Rate	3.4	2.4	
	Stock Size/Status	2.8	2.4	
	Other Stressors	1.4	1.6	
	Sensitivity Score	Moderate		
Exposure factors	Sea Surface Temperature	2.0	2.5	
	Sea Surface Temperature (variance)	1.8	2.5	
	Bottom Temperature	2.1	3.0	
	Bottom Temperature (variance)	2.4	3.0	
	Salinity	1.1	2.0	
	Salinity (variance)	2.0	2.0	
	Ocean Acidification	4.0	3.0	
	Ocean Acidification (variance)	1.3	3.0	
	Phytoplankton Biomass	1.2	1.2	
	Phytoplankton Biomass (variance)	1.2	1.2	
	Plankton Bloom Timing	1.7	1.0	
	Plankton Bloom Timing (variance)	2.2	1.0	
	Large Zooplankton Biomass	1.2	1.0	
	Large Zooplanton Biomass (variance)	1.5	1.0	
	Mixed Layer Depth	1.6	1.0	
	Mixed Layer Depth (variance)	2.2	1.0	
	Currents	1.3	2.0	
	Currents (variance)	1.8	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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Greenland turbot (*Reinhardtius hippoglossoides*)

Overall Climate Vulnerability Rank: **Low**. (68% 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: **Moderate**. Population growth rate (3.4) was ranked as "high" sensitivity, and sensitivity to temperature (2.9), spawning cycle (2.6), and stock size/status (2.8) were ranked as "moderate" sensitivity.

Potential for distribution change: **High** (96% certainty from bootstrap analysis). Dispersal of early life stages 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 negative effect on Greenland turbot, with 90% certainty in expert scores.

Data Quality: 75% 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:

Juveniles settle in July and August in far northern middle shelf near St. Matthew Island, and area usually surrounded by a cold water pool with an average summer bottom temperature of <2°C. The size of the suitable habitat is dictated by the size of the cold pool which has been highly variable (Sohn 2010). This habitat would likely become increasingly rare with the current climate change trajectory. Additionally, the extent and duration of duration of the cold pool seems to be positively related to recruitment, which is likely due to increased cross-shelf larval drift in "cold" years, greater extent of suitable on-shelf settlement area, and perhaps reduced predation/ competition from more warm adapted predators such as arrowtooth flounder (Sohn 2010).

Life History Synopsis:

Greenland turbot are distributed in north Atlantic, Arctic, and north Pacific oceans. In the north Pacific, Greenland turbot have been found from the Sea of Japan to Baja California. In the Bering Sea, adult fish are found along the slope in depths of 100 m – 1200 m, with larger and mature fish occupying deeper water.

Information on diet in the eastern Bering Sea is available from the Alaska Fisheries Science Center Food Habits database. Smaller juvenile fish feed primarily on euphausiids, whereas the diet of larger juvenile fish includes juvenile walleye pollock and cephalopods. Adults on the eastern Bering Sea shelf feed on juvenile pollock, whereas adults off the shelf feed on squid. However, in the northwest Atlantic the diet of Greenland turbot is primarily cephalopods for turbot less than 60 cm, and a variety of fish species for turbot greater than 60 cm (Rodríguez-Marín et al. 1995).

Spawning likely occurs all along the continental slope south of the Pribilof Canyon in the winter between November and January, although fish may move slightly inshore for spawning. Tagging data has shown some seasonal migration from more offshore to inshore but again the distances have not been long. There is a slow ontogenetic migration from the shallow shelf to deeper slope waters as the fish mature which can take 8-10 years and covers ~100-200 km from settlement to maturation (Sohn et al. 2010).

Greenland turbot larvae have a long pelagic duration and are subject to extended drift pathways before settlement. The distance of probable drift to settlement location in the Bering Sea is approximately 1000 km over a six month period with vertical excursions of over 500m. They occupy a variety of habitats for spawning nursery and settlement and appear to utilize large swaths of the EBS shelf as nursery areas for immature stages. Larval stages can be categorized into pre- and post-flexion. With spawning in November to January, preflexion larvae are found over the outer continental shelf and the basin of the EBS and eastern AI from March to May. The highest abundance of preflextion larvae have been observed in March. These larvae have been collected throughout the water column to a depth of 530 m. Flexion and postflexion larvae have been found over the middle and outer continental shelves from July to September. (Sohn et al. 2010).

The natural mortality of Greenland turbot is estimated as 0.112 (Cooper et al. 2007). Greenland turbot have dimorphic growth, with females attaining larger sizes. The von Bertalanffy K parameter is estimated as 0.11 for females and 0.19 for males (Bryan et al. 2018). The length at which 50% of the females are is estimated as 60 cm (D'yakov 1982).

Greenland turbot is managed as a single stock throughout the Bering Sea/Aleutian Islands area, and is not being subjected to overfishing or overfished (Bryan et al. 2018).

Literature Cited:

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D'yakov, Yu. P. 1982. The fecundity of the Greenland turbot, *Reinhardtius hippoglossoides*, (Pleuronectidae), from the Bering Sea. J. Ichthyol. [Engl. Transl. Vopr. Ikhtiol] 22(5):59-64.

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Sohn, D., Cianelli, L. and Duffy-Anderson, J. 2010. Distribution and drift pathways of Greenland halibut (*Reinhardtius hippoglossoides*) during early life stages in the eastern Bering Sea and Aleutian Islands. Fish. Oceanogr. 19:339-353.