Snow crab − *Chionoecetes opilio*

Overall Vulnerability Rank = Low

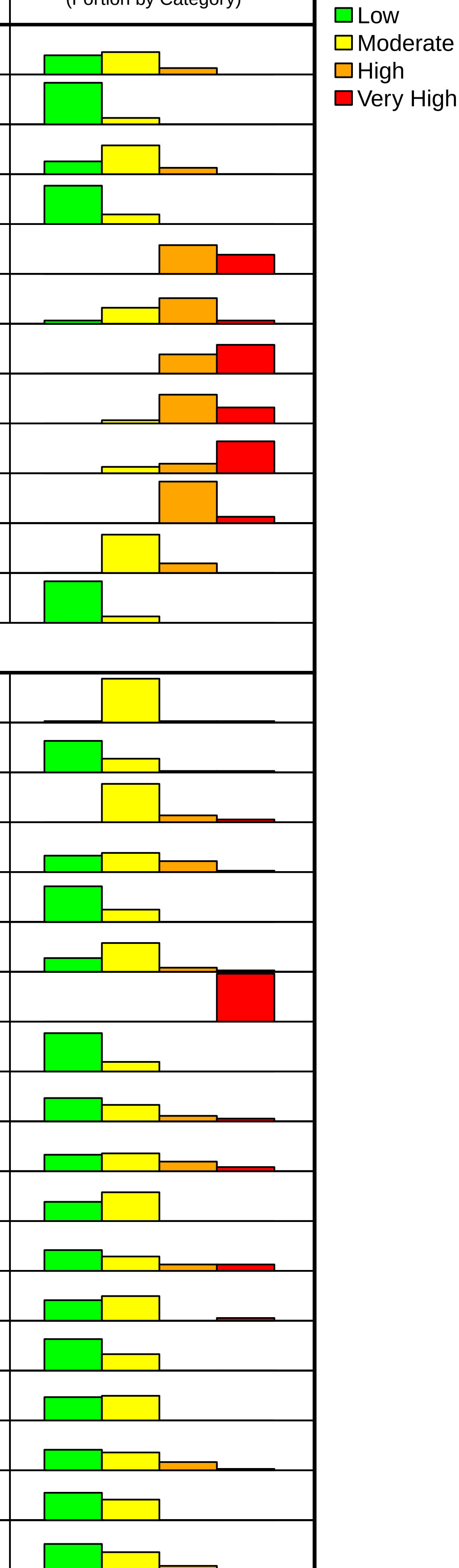
Biological Sensitivity = High

Climate Exposure = Low

Sensitivity Data Quality = 100% of scores ≥ 2

Exposure Data Quality = 56% of scores ≥ 2

	Chionoecetes opilio	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	1.7	3.0	
	Prey Specificity	1.1	3.0	
	Adult Mobility	1.9	2.7	
	Dispersal of Early Life Stages	1.2	3.0	
	Early Life History Survival and Settlement Requirements	3.4	3.0	
	Complexity in Reproductive Strategy	2.6	3.0	
	Spawning Cycle	3.6	3.0	
	Sensitivity to Temperature	3.3	3.0	
	Sensitivity to Ocean Acidification	3.5	2.7	
	Population Growth Rate	3.1	2.7	
	Stock Size/Status	2.2	3.0	
	Other Stressors	1.1	2.3	
	Sensitivity Score	High		
Exposure factors	Sea Surface Temperature	2.1	2.2	
	Sea Surface Temperature (variance)	1.4	2.2	
	Bottom Temperature	2.3	3.0	
	Bottom Temperature (variance)	1.9	3.0	
	Salinity	1.3	2.0	
	Salinity (variance)	1.9	2.0	
	Ocean Acidification	4.0	3.0	
	Ocean Acidification (variance)	1.2	3.0	
	Phytoplankton Biomass	1.7	1.2	
	Phytoplankton Biomass (variance)	2.0	1.2	
	Plankton Bloom Timing	1.6	1.0	
	Plankton Bloom Timing (variance)	2.0	1.0	
	Large Zooplankton Biomass	1.7	1.2	
	Large Zooplanton Biomass (variance)	1.3	1.2	
	Mixed Layer Depth	1.5	1.0	
	Mixed Layer Depth (variance)	1.8	1.0	
	Currents	1.4	2.0	
	Currents (variance)	1.5	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		



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Snow crab (*Chionoecetes opilio*)

Overall Climate Vulnerability Rank: **Low**. (86% 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: **High**. Spawning cycle (3.6) and sensitivity to ocean acidification (3.5) were ranked as "very high" sensitivity, and early life history survival (3.4), sensitivity to temperature (3.3), and population growth rate (3.1), were ranked as "high" sensitivity.

Potential for distribution change: **High** (99% certainty from bootstrap analysis). Three attributes (adult mobility, habitat specificity, and sensitivity to temperature) indicated 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 snow crab, with 97% certainty in expert scores.

Data Quality: 100% 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: Snow crab are stenothermic organisms, and temperature affects their biology throughout their life history, from embryo to adult. Small changes in temperature (< 2 °C) can increase the duration of egg incubation from one year to two years (Comeau et al., 1999; Moriyasu and Lanteigne, 1998; Sainte-Marie, 1993; Watson, 1970). The proportion of crabs on a two-year cycle of embryo incubation relative to those on a one-year cycle is unknown and may fluctuate with changes in environmental temperature (Moriyasu and Lanteigne, 1998). The two-year cycle from extrusion to hatch is one of the longest known durations of embryonic development for marine invertebrates (Petersen, 1995; Strathmann, 1987). In the eastern Bering Sea, primiparous (first-brood) and multiparous (second +-brood) females have been observed on a two-year reproductive cycle at temperatures below 1 °C (L. Rugulo, NOAA/NMFS, unpublished). Juvenile snow crab are cold-limited and are found at highest densities in the wild in 0 to 1 °C water (Dionne et al., 2003). Temperature is more important than substrate in determining juvenile distribution, and temperature preferences vary ontogenetically in early benthic instars, with instar III's preferring 0–1.5 °C temperatures, and instar V's preferring slightly warmer temperatures of 1.5–2.5 °C (Dionne et al., 2003). Adult snow crab are energetically confined to waters below 7 °C; above this temperature energetic demands exceed metabolic capability. Peak activity (movement) occurs at 0 °C and decreases with increasing temperature (Foyle et al., 1989). As they approach maturity, females undergo an ontogenetic migration following gradients in near bottom temperature or depth from northeast to southwest in the eastern Bering Sea (Ernst et al., 2005; Zheng et al., 2001).

The effects of climate change on snow crab in the eastern Bering Sea may already be evident. The geographic distribution of mature female snow crab has changed in the past two decades, moving northward with a six year lag after the northward contraction of the 2 °C near bottom temperature isotherm during the 1975–1979 warming period (Orensanz et al., 2004). Expected future changes in the distribution of bottom water temperatures will probably continue this trend toward northward contraction of the geographic range for the stock in the eastern Bering Sea.

Little is known regarding the potential effects of increased ocean acidification on snow crab.

Life History Synopsis: Snow crab are distributed on the continental shelf of the Bering Sea, the Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. In the Bering Sea, snow crab are distributed widely over the shelf and are common at depths less than about 200 meters (NPFMC, 2017). Smaller crabs tend to occupy more inshore northern regions and mature crabs occupy deeper areas to the south of the juveniles (Zheng et al. 2001). The eastern Bering Sea population within U.S. waters is managed as a single stock; however, the distribution of the population may extend into Russian waters to an unknown degree (NPFMC, 2011).

The mean size of mature females varies annually over a range of 63 mm to 72 mm carapace width (CW), with 50% of females mature at 50 mm CW. The median size of maturity for males is 65 mm CW (approximately 4 years old). Both sexes stop growing with a terminal molt upon reaching maturity; females rarely exceed 80 mm CW. Male snow crab are sperm conservers, using less than 4% of their sperm at each mating; females will also mate with more than one male. Females are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores. The amount of stored sperm and clutch fullness varies with sex ratio (Sainte-Marie et al., 2002).

As noted above, snow crab are stenothermic organisms, and temperature affects their biology throughout their life history, from embryo to adult.

Snow crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, crustaceans (including other snow crabs), polychaetes and other worms, gastropods, and fish. In turn, they are consumed by a wide variety of predators including bearded seals, Pacific cod, halibut and other flatfish, eel pouts, sculpins, and skates (NPFMC, 2011).

Snow crab are managed as a unit stock in the eastern Bering Sea. Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. After the closure to foreign fleets, retained catches increased from relatively low levels in the early 1980s (e.g. retained catch of 11.85 kt during 1982) to historical highs in the early and mid-nineties (retained catch during 1991, 1992, and 1998 were 143.02, 104.68, and 88.09 kt, respectively). The stock was declared overfished in 1999 at which time retained catches dropped to levels similar to the early 1980s. Retained catches have slowly increased since 1999 as the stock has rebuilt. The stock is currently not overfished and overfishing is not occurring (NPFMC, 2017).

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