Norton Sound red king crab − *Paralithodes camtschaticus*

Overall Vulnerability Rank = Low

Biological Sensitivity = High

Climate Exposure = Low

Sensitivity Data Quality = 83% of scores ≥ 2

Exposure Data Quality = 56% of scores ≥ 2

	Paralithodes camtschaticus	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	2.6	2.7	
	Prey Specificity	1.5	2.7	
	Adult Mobility	2.1	2.3	
	Dispersal of Early Life Stages	1.2	2.0	
	Early Life History Survival and Settlement Requirements	2.5	2.3	
	Complexity in Reproductive Strategy	2.5	2.3	
	Spawning Cycle	3.4	2.7	
	Sensitivity to Temperature	3.0	1.7	
	Sensitivity to Ocean Acidification	3.8	2.7	
	Population Growth Rate	3.8	2.0	
	Stock Size/Status	2.1	3.0	
	Other Stressors	1.3	1.7	
	Sensitivity Score	High		
Exposure factors	Sea Surface Temperature	2.1	2.5	
	Sea Surface Temperature (variance)	1.7	2.5	
	Bottom Temperature	2.0	3.0	
	Bottom Temperature (variance)	1.5	3.0	
	Salinity	2.1	2.0	
	Salinity (variance)	1.8	2.0	
	Ocean Acidification	4.0	3.0	
	Ocean Acidification (variance)	1.5	3.0	
	Phytoplankton Biomass	1.8	1.2	
	Phytoplankton Biomass (variance)	1.7	1.2	
	Plankton Bloom Timing	1.4	1.0	
	Plankton Bloom Timing (variance)	1.8	1.0	
	Large Zooplankton Biomass	2.1	1.0	
	Large Zooplanton Biomass (variance)	1.7	1.0	
	Mixed Layer Depth	1.5	1.0	
	Mixed Layer Depth (variance)	1.5	1.0	
	Currents	1.4	2.0	
	Currents (variance)	1.3	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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Norton Sound red king crab (*Paralithodes camtschaticus*)

Overall Climate Vulnerability Rank: **Low**. (67% 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**. Population growth rate (3.8) and sensitivity to ocean acidification (3.8) were ranked as "very high" sensitivity, and sensitivity to temperature (3.0) and spawning cycle (3.4) were ranked as "high" sensitivity.

Potential for distribution change: **High** (65% certainty from bootstrap analysis). Dispersal of early life stages indicated very high potential for distribution change, whereas sensitivity to temperature 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 Norton Sound red king crab, with 68% certainty in expert scores.

Data Quality: 83% 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: Different life stages of red king crab vary in their degree of thermal tolerance. Embryos are the most sensitive to higher temperatures, with mortality increasing at temperatures greater than 8°C (Nakanishi 1987). Mature females exhibit reduced, but sub-lethal, growth at 12°C (Shirley et al. 1989). In contrast, larvae and juveniles exhibit higher thermal tolerances and do not experience higher mortality (larvae, Kurata 1960) or reduced growth (juveniles, Rice et al. 1985, Stoner et al. 2010) until 15°C.

Red king crab are sensitive to changes in ocean acidification (Swiney et al. 2017). Larvae exhibited decreased time-to-starvation at a pH of 7.7 (Long et al. 2013a) while juveniles exhibited increased mortality and decreased growth at pH 7.8 (Long et al. 2013b). Swiney et al. (2017) found synergistic effects on mortality at pH 7.8 and temperature increased 4°C above ambient for early juveniles. Lower pH and increased temperatures also affected intermoult duration (Swiney et al., 2017).

Life History Synopsis: Red king crab inhabit intertidal waters to depths >200 m of the North Pacific Ocean from British Columbia, Canada, to the Bering Sea, and south to Hokkaido, Japan, and are found in several areas of the Aleutian Islands, eastern Bering Sea, and the Gulf of Alaska. Norton Sound red king crab is one of the northernmost red king crab populations that can support a commercial fishery (Powell et al. 1983). It is distributed throughout Norton Sound with a westward limit of 167-168^{o} W. longitude, depths less than 30 m, and summer bottom temperatures above 4°C. The Norton Sound red king crab management area consists of two units: the Norton Sound Section and the Kotzebue Section (Menard et al. 2011). The Norton Sound Section consists of all waters in Registration Area Q north of the latitude of Cape Romanzof, east of the International Dateline, and south of 66°N latitude. The Kotzebue Section lies immediately north of the Norton Sound Section and includes Kotzebue Sound. Commercial fisheries have not occurred regularly in the Kotzebue Section. For the purposes of fishery management, red king crab in the Norton Sound area are assumed to be a separate stock from red king crab outside of this area. The stock is currently not overfished nor is overfishing occurring (NPFMC, 2017).

In general, red king crab have a complex life history. One unique aspect of Norton Sound red king crab biology is that they spend their entire lives in shallow water, since Norton Sound is generally less than 40 m in depth, although they migrate seasonally and ontogenetically between (relatively) deeper offshore and shallow inshore waters (NPFMC, 2017). However, the distribution and migration patterns of Norton Sound red king crab have not been well studied. Based on trawl surveys (1976-2006), red king crab in Norton Sound are found in areas with a mean depth range of 19 ± 6 (SD) m and bottom temperatures of 7.4 ± 2.5 (SD)° C during summer (NPFMC, 2017). Timing of the inshore mating migration is unknown, but is assumed to be during late fall to winter (Powell et al. 1983). Offshore migration occurs in late May-July (NPFMC, 2017). Older/large crab (> 104mm CL) probably stay offshore in winter, based on findings that large crab are not found nearshore during spring offshore migration periods. Timing of molting is unknown but is considered to occur in late August‑September, based on increased catches of fresh-molted crab later in the fishing season; blood hormonal studies, however, suggest an April-May molting season consistent with Powell et al. (1983). Recent observations indicate biennial mating (NPFMC, 2017). Trawl surveys show that crab distribution is dynamic. Recent surveys show high abundance on the southeast side of the sound, offshore of Stebbins and Saint Michael.

Fecundity is a function of female size, ranging from several tens of thousands to a few hundreds of thousands (Haynes 1968; Swiney et al. 2012). The eggs are extruded by females, fertilized in the spring, and held by females for about 11 months (Powell and Nickerson 1965). Fertilized eggs are hatched in the spring, most during April-June (Weber 1967). Primiparous (first clutch) females are bred a few weeks earlier in the season than multiparous females.

Larval duration and juvenile crab growth depend on temperature (Stevens 1990; Stevens and Swiney 2007). Red king crab spend 2- 3 months in larval stages before settling to the benthic life stage. Young-of-the-year crab occur at depths of 50 m or less. They are solitary and need high relief habitat or coarse substrate such as boulders, cobble, shell hash, and living substrates such as bryozoans and stalked ascidians. King crab molt multiple times per year through age 3 after which molting is annual. At larger sizes, king crab may skip molting as growth slows. Females grow slower and do not get as large as males. Between the ages of two and four years, there is a decreasing reliance on habitat and a tendency for the crab to form pods consisting of thousands of crabs. Podding generally continues until four years of age (about 65 mm), when the crab move to deeper water and join adults in the spring migration to shallow water for spawning and deep water for the remainder of the year. Male and female RKC mature at 5–12 years old, depending on stock and temperature (Loher et al. 2001; Stevens 1990) and may live >20 years (Matsuura and Takeshita 1990). In the eastern Bering Sea, males and females can attain maximum sizes of 227 and 195 mm carapace length (CL), respectively (Powell and Nickerson 1965), but probably do not reach these sizes in Norton Sound (large males in Norton Sound are typically < 140 mm

CL; NPFMC, 2017). Female maturity is evaluated by the size at which females are observed to carry egg clutches. Male maturity can be defined by multiple criteria including spermataphore production and size, chelae vs. carapace allometry, and participation in mating in situ (reviewed by Webb 2014). For management purposes, males in Norton Sound are assumed to be functionally mature at sizes >94 mm CL (NPFMC, 2017), reflecting the slower growth and smaller size for Norton Sound red king crab relative to the Bristol Bay red king crab stock (> 119 mm CL).

Pacific cod is the main predator on red king crabs. Walleye pollock, yellowfin sole, and Pacific halibut are minor consumers of pelagic larvae, settling larvae, and larger crabs, respectively. Juvenile crab may be cannibalistic during molting.

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