Chinook salmon – *Oncorhynchus tshawytscha*

Overall Vulnerability Rank = Low

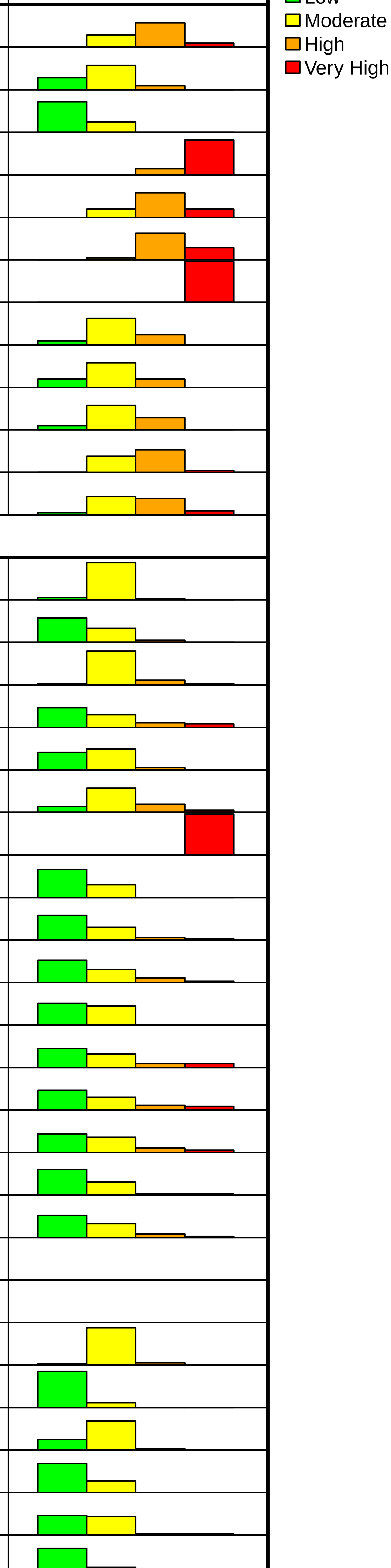
Biological Sensitivity = High

Climate Exposure = Low

Sensitivity Data Quality = 83% of scores ≥ 2

Exposure Data Quality = 64% of scores ≥ 2

	Oncorhynchus tshawytscha	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	2.8	2.5	
	Prey Specificity	1.8	2.8	
	Adult Mobility	1.2	2.5	
	Dispersal of Early Life Stages	3.8	2.2	
	Early Life History Survival and Settlement Requirements	3.0	2.0	
	Complexity in Reproductive Strategy	3.2	2.5	
	Spawning Cycle	4.0	2.8	
	Sensitivity to Temperature	2.1	2.5	
	Sensitivity to Ocean Acidification	2.0	1.8	
	Population Growth Rate	2.2	2.2	
	Stock Size/Status	2.6	2.0	
	Other Stressors	2.5	1.8	
	Sensitivity Score	High		
Exposure factors	Sea Surface Temperature	2.0	2.5	
	Sea Surface Temperature (variance)	1.5	2.5	
	Bottom Temperature	2.1	2.5	
	Bottom Temperature (variance)	1.8	2.5	
	Salinity	1.6	2.0	
	Salinity (variance)	2.2	2.0	
	Ocean Acidification	4.0	2.5	
	Ocean Acidification (variance)	1.3	2.5	
	Phytoplankton Biomass	1.5	1.2	
	Phytoplankton Biomass (variance)	1.6	1.2	
	Plankton Bloom Timing	1.5	1.0	
	Plankton Bloom Timing (variance)	1.8	1.0	
	Large Zooplankton Biomass	1.8	1.0	
	Large Zooplanton Biomass (variance)	1.8	1.0	
	Mixed Layer Depth	1.5	1.0	
	Mixed Layer Depth (variance)	1.6	1.0	
	Currents	NA	NA	
	Currents (variance)	NA	NA	
	Air Temperature	2.0	2.5	
	Air Temperature (variance)	1.1	2.5	
	Precipitation	1.8	2.0	
	Precipitation (variance)	1.3	2.0	
	Sea Surface Height	1.6	2.5	
	Sea Surface Height (variance)	1.3	2.5	
	Exposure Score	Low		
Overall Vulnerability Rank		Low		



For assistance with this document, please contact NOAA Fisheries Office of Science and Technology at (301) 427-8100 or visit https://www.fisheries.noaa.gov/contact/office-science-and-technology

Chinook salmon (*Oncorhynchus tshawytscha*)

Overall Climate Vulnerability Rank: **Low**. (97% 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 (4.0) and dispersal of early life stages (3.9) were ranked as "very high" sensitivity, and complexity in reproductive strategy (3.3) and early life history survival (3.0) were ranked as "high" sensitivity.

Potential for Distribution Change: **Low** (98% certainty from bootstrap analysis). Adult mobility indicated a very high potential for distribution change, whereas the remaining three distribution attributes indicated low 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 Chinook salmon, with a 68% certainty in expert scores.

Data Quality: 83% of the sensitivity attributes, and 64% 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:

Stock productivity of western Alaska (primarily Yukon, Kuskokwim, and Nushagak rivers) Chinook salmon is influenced by environmental conditions. Mixed layer depth, latitude, and juvenile abundances are used to predict year-class strength in Canadian-origin juvenile Chinook salmon (Murphy et al. 2013). Since the early 2000s, juvenile Chinook salmon abundances in the northeastern Bering Sea were lower during cold years and higher during warm years (Murphy et al. 2013).

Adult Chinook salmon are the largest in size and highest in fecundity of all salmon species. In the last 30 years, declines in body size at maturity occurred for Chinook salmon from the Yukon, Kuskokwim, Kogrukluk, Nushagak, Kanektok, and Goodnews rivers in western Alaska (Lewis et al. 2015). The declines in size were linked to decreases in age at maturity and decreases in age-specific body size. Factors affecting size include size-selective fishing and sea temperature (Lewis et al. 2015). Annual scale growth trends were not significantly correlated with salmon abundance indices, sea surface temperature, or climate indices, although growth during the first year at sea changed during the 1977 and 1989 ocean regime shifts, for years 1965-2004 (Ruggerone et al. 2009). However, the back-calculated summer growth rates of these fish show increased growth rates during cooler summers and increased number of circuli on the scale during warm summers, a proxy for the length of the growing season, for juvenile growth years 1972-2010 (Yasumiishi, unpublished data.

Timing of adult spawning migration of Yukon River Chinook salmon are regulated by environmental conditions (Mundy and Evenson 2011). Spawning migration (June 10-30 range) of Yukon River Chinook salmon occurred earlier in years with less spring ice cover between St. Lawrence Island and the Yukon Delta, warmer April air temperatures in Nome (-14° - -4° C), and warmer marine surface temperatures just offshore of the delta in May (Mundy and Evenson 2011).

Chinook salmon distribute in 5-22 °C sea temperatures and freshwater temperatures from 0-22 °C (NPFMC 2010). In fresh water, days to emerge and days to hatch decrease with increasing water temperatures (2-14 °C) (Quinn 2005). At sea, Chinook salmon distribute in a 5.1-14.7 °C sea as juveniles, 6.5° – 15.5 °C sea temperatures from the second to penultimate year at sea, and 4.2° – 13.9 °C sea temperature as maturing fish (Echave et al. 2012). Juvenile Chinook salmon inhabit nearshore waters through the summer in the eastern Bering Sea (Farley et al. 2005). Juvenile Chinook salmon distribute over a large area but range farther south during warm years in the eastern Bering Sea (e.g., 2002-2016; Yasumiishi et al. 2017).

Life History Synopsis:

Chinook salmon originate in rivers from as far south as the Sacramento River, California, north to the Kotzebue Sound, Alaska (Stephenson 2006, Irvine et al. 2009). Western Alaska Chinook salmon distribute as far west as 172 ºE (Myers et al. 2010). Juvenile Chinook salmon in the eastern Bering Sea tend to be nearshore, move to the central Bering Sea during fall, and return to the eastern Bering Sea during their migration to fresh water to spawn (Myers et al. 2001, Farley et al. 2005).

Chinook salmon is a short-lived (<10 years), anadromous, and semelparous species. Adult salmon spawn and eggs incubate in fresh water. During the first year at sea, juvenile salmon rear in pelagic waters nearshore during the summer and then move off of the continental shelf during fall and return to the shelf to feed during the summer (Farley et al. 2005).

The peak timing of the upstream spawning migration and seasonal spawning is June-August (April-August) for Bristol Bay Chinook salmon and July (June-August) for Arctic-Yukon-Kuskokwim Chinook salmon (ADFG). Straying rates of Alaska Chinook salmon following transplant to hatcheries were 1.2% (Hard and Heard 1989).

Age at maturity of western Alaska Chinook salmon ranges from 4 to 8 years, but they commonly mature after 4-6 years (ADFG 2013). Ages range from < 1 to 2 years in fresh water and 1-6 years at sea (ADFG 2013). Western Alaska Chinook salmon primarily spend 2 winters in fresh water and 2 to 4 winters in the ocean.

Chinook salmon primarily consume fish and squid in the eastern Bering Sea (Davis et al. 2009a, b). On the eastern Bering Sea slope, Chinook salmon consumed a larger proportion of squid during the winter and more fish during the summer (Davis et al. 2009a). Juvenile Chinook salmon prey preferences include fish and crab larvae (Davis et al. 2009). Adult Chinook salmon prey preferences include squid and fish (Davis et al. 2009).

Natural mortality is largely unknown for Bering Sea Chinook salmon stocks. For the Canadian-origin Chinook salmon returning to the Yukon River, Murphy et al. (2013) found a positive correlation between the relative abundance of juvenile Chinook salmon during late summer and returns of adult Chinook salmon from the same brood year, indicating that natural mortality was more variable prior to late summer during the first year at sea and relatively stable thereafter (Murphy et al. 2013).

Chinook salmon are managed in-season at local area levels by the Alaska Department of Fish and
Game. http://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercialByArea.main&_ga=2.207693394.172348407.1523379747-1353484536.1523379747 .

From 1996 to 2015, commercial harvest of Chinook salmon declined for Bristol Bay, Norton Sound, and Kuskokwim management areas (ADFG 2017, Poetter, A. D., and A. Tiernan. 2017, Salomone et al. 2017). Total commercial harvest of Chinook salmon decreased from 1996 to 2015.

Literature Cited:

ADFG. 2018. http://www.adfg.alaska.gov/index.cfm?adfg=fishingsportfishinginforuntiming.main .

ADFG 2017 http://www.adfg.alaska.gov/static/applications/dcfnewsrelease/780062021.pdf

ADFG (Alaska Department of Fish and Game). 2013. Chinook salmon stock assessment and research plan, 2013. Alaska Department of Fish and Game, Chinook salmon research team, Anchorage. Special publication No. 13-01.

Davis, N.D., K.W. Myers, and W.J. Fournier. 2009a. Winter food habits of Chinook salmon in the eastern Bering Sea. North Pacific Anadromous Fish Commission Bulletin 5:243–253.

Davis, N.D., A.V. Volkov, A. Ya. Efimkin, N. A. Kuznetsova, J. L. Armstrong, and O. Sakai. 2009b. Review of BASIS salmon food habits studies. North Pacific Anadromous Fish Commission Bulletin 5: 197–208.

Echave, K., M. Eagleton, E. Farley, and J. Orsi. 2012. A refined description of essential fish habitat for Pacific salmon within the U.S. Exclusive Economic Zone in Alaska. U.S Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-236, 104 p.

Farley, E.V. Jr., J.M. Murphy, B.W. Wing, J. H. Moss, and A. Middleton. 2005. Distribution, migration pathways, and size of western Alaska juvenile salmon along the eastern Bering Sea shelf. Alaska Fishery Research Bulletin 11(1):15-26.

Hard J., and W.R. Heard 1989. Analysis of straying variation in Alaskan hatchery Chinook salmon (*Oncorhynchus tshawytscha*) following transplantation. Canadian Journal of Fisheries and Aquatic Sciences 56(4):578-589.

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*), p. 313-393. *In* C. Groot and L. Margolis (eds.), Pacific salmon life histories. University of British Columbia Press, Vancouver, B. C.

Irvine, J.R., R.W. Macdonald, R.J. Brown, L. Godbout, J. D. Reist, and E. C. Carmack. 2009. Salmon in the Arctic and how they avoid lethal low temperatures. North Pacific Anadromous Fish Commission Bulletin 5:39-50.

Lewis, B., W.S. Grant, R.E. Brenner, and T. Hamazaki. 2015. Changes in size and age of Chinook salmon *Oncorhynchus tshawytscha* returning to Alaska. PLOS ONE 10(7): e0132872. https://doi.org/10.1371/journal.pone.0132872.

Mundy, P.R., and D.F. Evenson. 2011. Environmental controls of phenology of high-latitude Chinook salmon populations of the Yukon River, North America, with application to fishery management, ICES Journal of Marine Science 68:1155-1164.

Murphy J.M., K. Howard, A. Andrews, W. Templin, C. Guthrie, K. Cox, and E. Farley. 2013. Linking abundance, distribution, and size of juvenile Yukon River Chinook salmon to survival in the northern Bering Sea. North Pacific Anadromous Fish Commission. Technical Report No. 9:25-30.

Myers, K.W., R.V. Walker, and N. Davis 2001. Ocean distribution and migration patterns of Yukon River Chinook salmon. School of Aquatic and Fishery Sciences, University of Washington, Seattle. SAFS-UW-0109.

Myers, K.W., R.V. Walker, N.D. Davis, J.A. Armstrong, W.J. Fournier, N.J. Mantua, and J. Raymond-Yakoubian. 2010. Climate-ocean effects on Chinook salmon. AYK SSI, Project Final Product. School of Aquatic and Fishery Sciences, University of Washington, Seattle. SAFS-UW-1003.

NPFMC (North Pacific Fishery Management Council). 2010. Essential Fish Habitat (EFH): 5-year review for 2010, Summary Report. North Pacific Fishery Management Council, 605 W. 4th Ave, Suite 306. Anchorage, AK 99501.

Poetter, A.D., and A. Tiernan. 2017. 2016 Kuskokwim area management report. Alaska Department of Fish and Game, Fishery Management Report No. 17-50, Anchorage, Alaska.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle WA. 320 p.

Ruggerone, G.T., J.L. Nielsen, and B.A. Agler 2009. Climate, growth and population dynamics of Yukon River Chinook salmon. North Pacific Anadromous Fish Commission Bulletin 5: 279–285.

Salomone P., T. Elison, T. Sands, G. Buck, T. Lemons, F. West, and T. Krieg. 2017. 2016 Bristol Bay area annual management report. Alaska Department of Fish and Game, Fishery Management Report No. 17-27, Anchorage, Alaska.

Stephenson, S.A. 2006. A review of the occurrence of Pacific salmon (*Oncorhynchus* spp.) in the Canadian western Arctic. Arctic 59:37-46.

Yasumiishi, E., Cieciel, K., Murphy, M., Andrews, A., and E. Siddon. 2017. Spatial and temporal trends in the abundance and distribution of juvenile Pacific salmon in the eastern Bering Sea during late summer, 2002–2016, p. 120-124. *In* E. Siddon and S. Zador (eds.), Ecosystem Considerations 2017: Status of the Eastern Bering Sea Marine

Ecosystem, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W. 4th Ave, Suite 306, Anchorage, AK 99501.