Chum salmon − *Oncorhynchus keta*

Overall Vulnerability Rank = Low

Biological Sensitivity = High

Climate Exposure = Low

Sensitivity Data Quality = 92% of scores ≥ 2

Exposure Data Quality = 64% of scores ≥ 2

	Oncorhynchus keta	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	2.8	2.2	
	Prey Specificity	1.5	2.8	
	Adult Mobility	1.2	2.2	
	Dispersal of Early Life Stages	3.8	2.5	
	Early Life History Survival and Settlement Requirements	3.2	2.0	
	Complexity in Reproductive Strategy	3.1	2.5	
	Spawning Cycle	4.0	2.8	
	Sensitivity to Temperature	2.1	2.2	
	Sensitivity to Ocean Acidification	2.1	2.0	
	Population Growth Rate	2.1	2.5	
	Stock Size/Status	2.2	2.0	
	Other Stressors	2.2	1.8	
	Sensitivity Score	High		
Exposure factors	Sea Surface Temperature	1.9	2.2	
	Sea Surface Temperature (variance)	1.3	2.2	
	Bottom Temperature	2.1	2.5	
	Bottom Temperature (variance)	1.8	2.5	
	Salinity	1.5	2.0	
	Salinity (variance)	2.3	2.0	
	Ocean Acidification	4.0	2.5	
	Ocean Acidification (variance)	1.3	2.5	
	Phytoplankton Biomass	1.8	1.2	
	Phytoplankton Biomass (variance)	1.9	1.2	
	Plankton Bloom Timing	1.5	1.0	
	Plankton Bloom Timing (variance)	1.9	1.0	
	Large Zooplankton Biomass	1.8	1.2	
	Large Zooplanton Biomass (variance)	1.7	1.2	
	Mixed Layer Depth	1.3	1.0	
	Mixed Layer Depth (variance)	1.8	1.0	
	Currents	NA	NA	
	Currents (variance)	NA	NA	
	Air Temperature	2.1	2.5	
	Air Temperature (variance)	1.1	2.5	
	Precipitation	1.8	2.0	
	Precipitation (variance)	1.3	2.0	
	Sea Surface Height	1.4	2.5	
	Sea Surface Height (variance)	1.4	2.5	
	Exposure Score	Low		
Overall Vulnerability Rank		Low		

Low
Moderate
High
Very High

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

Chum salmon (*Oncorhynchus keta*)

Overall Climate Vulnerability Rank: **Low**. (92% 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 (3.1) and early life history survival (3.2) were ranked as "high" sensitivity.

Potential for Distribution Change: **Low** (99% 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 chum salmon, with a 93% certainty in expert scores.

Data Quality: 92% 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 chum salmon is influenced by environmental conditions. Survival of western Alaska chum salmon was positively correlated to coastal surface water temperatures during the first year of residence at sea (Mueter et al. 2002). Abundance of juvenile chum salmon during late summer in the eastern Bering Sea increased with warming sea temperatures (2002-2016; Yasumiishi et al. 2017).

Body size at maturity of adult chum salmon determines fecundity and depends on factors regulating growth in the ocean (Helle 1979). For western Alaska stocks, warmer sea temperatures favored the growth in length of chum salmon, while cooler temperatures favored growth in weight of chum salmon (Agler et al. 2013; Farley and Moss 2009; Ruggerone and Agler 2008; Yasumiishi et al. 2015). Diets of juvenile chum salmon included more lipid-rich large zooplankton during cold years and prey with lower lipid such as pollock during warm years in the eastern Bering Sea (Coyle et al. 2011). Temperature-related reductions in body size can influence stock productivity through reduced fecundity (Helle 1989).

Timing of fry emergence from the gravel is a function of development rate, variation in activity, and environmental conditions (temperature, flow, oxygen) experienced by the egg and alevin. The timing of outmigration of fry from fresh water to salt water is triggered by temperature, flow rates, ice break-up, and light intensity (Koski 1975, Quinn and Groot 1984, Salo 1991, Martin et al. 1986). Survival rates from egg to fry emergence from the gravel was negatively correlated with the percent sand in the substrate (Koski 1975). Optimum freshwater temperature is 4.4-13.3 °C. Eggs develop at 1-10 °C, eggs hatch at 52-173 d, larvae emerge from gravel 146-325 d (NPFMC 2010).

Chum salmon distribute in a moderate range (< 15 °C) of water temperatures. In the eastern Bering Sea, sea temperature preferences were 6.9-15 °C (8.1 °C) for juveniles and 6.9-15.3 °C (8.4 °C range) during their second to final year at sea (Echave et al. 2012). During winter in the eastern North Pacific Ocean, the estimated temperature at the center of distribution was 6.13 °C ± 0.55 SD for age 0 - 1 chum salmon and 6.05 °C ± 0.64 SD for older chum salmon (Fukuwaka et al. 2007). Juvenile chum salmon expressed range expansions with warmer sea temperatures in the eastern Bering Sea (2002-2016; Yasumiishi et al. 2017). The known thermal and latitudinal ranges were larger for chum salmon than other salmon species.

<u>Life History Synopsis:</u>

Chum salmon distribute from 36 °N to 72 °N latitude in the Pacific Ocean. North American chum salmon originate in rivers from as far south as the Sacramento and San Joaquin rivers that drain into San Francisco Bay, California, and in the north to the Mackenzie River into the Arctic Ocean from Canada's Northwest Territories (Groot and Margolis 1991). Asian chum salmon originate from as far north and west as the Yakutsk River in the Arctic, and along the eastern Eurasian coast to as far south as North Korea (Groot and Margolis 1991). The eastern Bering Sea is used as a rearing habitat for juvenile chum salmon and for feeding and migration by maturing chum salmon on their way back to fresh water to spawn (Farley et al. 2005). Chum salmon return to the eastern Bering Sea during their migration to fresh water to spawn (Farley et al. 2005).

Chum salmon is a short-lived (<10 years), anadromous, semelparous species. Adult salmon spawn and incubate eggs in fresh water. Chum salmon require slightly more specific habitat in that they seek upwelling groundwater for spawning (Salo 1991). After fry emerge from the gravel in spring, chum salmon head directly to salt water to rear. In the eastern Bering Sea, chum salmon fry outmigration from fresh water to salt water occurs during the period from ice break up through August, with peak outmigration during the latter part of June for chum salmon (Martin et al. 1987). During the first year at sea, juvenile salmon rear in pelagic waters above the continental shelf during the summer and then move off of the continental shelf during fall and return to the shelf to feed during the summer (Nagasawa and Azumaya 2009).

The peak timing of the upstream spawning migration and seasonal spawning occurs during July and November (June-December) for Arctic-Yukon-Kuskokwim chum salmon and July (June-August) for Bristol Bay chum salmon. Straying rates of salmon typically average 3%, but varies among salmon species and stocks and were higher than 34% for chum salmon (Keefer and Caudill 2014). Straying rates of hatchery salmon in Prince William Sound, Alaska, were 0-63% for chum salmon (Brenner et al. 2012).

Age at maturity is from 3 to 6 years for chum salmon, but commonly mature after 4 and 5 years (http://www.yukonriverpanel.com/about-us/yukon-river-panel/yukon-river-salmon/chum/). Recent trends of increasing age at maturity and decreasing size at maturity were attributed to an adaptive phenotypic response to a reduction in growth rate, which is probably caused by environmental changes (Morita et al. 2005).

Reproductive success of salmon depends on the size of females and offspring survival. Larger females dig deeper redds, produce larger and more eggs, larger fry, and fry with higher survival rates (Helle 1989). Larger males are more successful in fertilizing eggs than smaller males.

Chum salmon are micronectivores, zooplanktivores, and piscivores and consume the widest variety of prey than the other salmon species (Davis 2003, Davis et al. 2009). Juvenile chum salmon prey preferences include euphausiids, fish, and crab larvae (Davis et al. 2009). Adult chum salmon prey preferences include zooplankton, squid, and fish (Davis et al. 2009).

Natural mortality is highly variable. Marine mortality (fry to adult) is from 98.7% to 41.1% (Salo 1991).

Chum 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 chum salmon increased for Bristol Bay and Norton Sound, and was stable for Kuskokwim management areas (ADFG 2017, Poetter and Tiernan. 2017, Salomone et al. 2017). Total commercial harvest of chum salmon increased from 1996 to 2015.

Literature Cited:

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

Agler, B. A., G. T. Ruggerone, L. I. Wilson, and F. J. Mueter. 2013. Historical growth of Bristol Bay and Yukon River, Alaska chum salmon (*Oncorhynchus keta*) in relation to climate and inter-and intraspecific competition. Deep-sea Research Part II: Topical Studies in Oceanography 94: 165-177.

Brenner, R. E., S. D. Moffitt, and W. S. Grant. 2012. Straying of hatchery salmon in Prince William Sound, Alaska. Environmental Biology of Fishes 94(1): 179-195.

Coyle, K. O., L. B. Eisner, F. J. Mueter, A. I. Pinchuk, M. A. Janout, K. D. Cieciel, E. V. Farley, and A. G. Andrews. 2011. Climate change in the southeastern Bering Sea: Impacts on pollock stocks and implications for the oscillating control hypothesis. Fisheries Oceanography 20(2):139-156.

Davis, N. C. D. 2003. Feeding ecology of Pacific salmon (*Oncorhynchus* spp.) in the central North Pacific Ocean and Central Bering Sea, 1991-2000. Ph. D. dissertation. Hokkaido University, Hokkaido, Japan. http://eprints.lib.hokudai.ac.jp/dspace/bitstream/2115/58189/1/DavisDissertation.pdf.

Davis, N. D., A. V. Volkov, A. Y. Efimkin, N. A. Kuznetsova, J. L. Armstrong, and O. Sakai. 2009. 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 Fisheries Research Bulletin 11:15–26.

Farley, E. V. Jr., and J. H. Moss. 2009. Growth rate potential of juvenile chum salmon on the eastern Bering Sea shelf: an Assessment of salmon carrying capacity. North Pacific Anadromous Fish Commission Bulletin 5:265-277.

Fukuwaka, M., S. Sato, S. Takahashi, T. Onuma, O. Sakai, N. Tanimata, K. Makino, N. D. Davis, A. F. Volkov, K. B. Seong, and J. H. Moss. Winter distribution of chum salmon related to environmental variables in the North Pacific. North Pacific Anadromous Fish Commission. Technical Report No. 7: 29-30.

Groot, C., and L. Margolis (eds.). 1991. Pacific salmon life histories. University of British Columbia Press. Vancouver, B. C.

Helle, J. H. 1979. Influence of the marine environment on age and size at maturity, growth, and abundance of chum salmon, *Oncorhynchus* keta (Walbaum), from Olsen Creek, Prince William Sound, Alaska. Ph. D. thesis, Oregon State University, Corvallis, Oregon. 118 p.

Helle, J. H., 1989. Relation between size-at-maturity and survival of progeny in chum salmon, *Oncorhynchus keta* (Walbaum). Journal of Fish Biology 35(sA):99-107.

Keefer, M. L., and C. C. Caudill. 2014. Homing and straying by anadromous salmonids: a Review of mechanisms and rates. Reviews in Fish Biology and Fisheries 24(1):333-368.

Koski, K. V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled stream environment at Big Beef Creek. Ph.D. thesis. University of Washington, Seattle, WA. 212 p.

Koski, K. V., 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. Rapport et Proces-Verbaux des Reunions du Conseil International pour l'Exploration de la Mer (ICES) 178:330-333.

Martin, D. J., D. R. Glass, C. J. Whitmus, C. A. Simenstad, D. A. Milward, E. C. Volk, M. L. Stevenson, P. Nunes, M. Savoie, and R. A. Grotefendt. 1986. Distribution, seasonal abundance, and feeding dependencies of juvenile salmon and nonsalmonid fishes in the Yukon River Delta. NOAA OCSEAP Final Report 55(1998):381-770.

Morita, K., S. H. Morita, M. Fukuwaka, and H. Matsuda. 2005. Rule of age and size at maturity of chum salmon (*Oncorhynchus keta*): implications of recent trends among *Oncorhynchus* spp. Canadian Journal of Fisheries and Aquatic Sciences 62:2752-2759.

Mueter, F. J., R. M. Peterman, and B. J. Pyper. 2002. Opposite effects of ocean temperature on survival rates of 120 stocks of Pacific salmon (*Oncorhynchus* spp.) in northern and southern areas. Canadian Journal of Fisheries and Aquatic Sciences 59(3):456-463.

Nagasawa, T. and T. Azumaya. 2009. Distribution and CPUE trends in Pacific salmon, especially sockeye salmon in the Bering Sea and adjacent waters from 1972 to the mid 2000s. North Pacific Anadromous Fish Commission Bulletin 5:1-13.

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., and C. Groot. 1984. The effect of water flow rate on bimodal orientation of juvenile chum salmon, *Oncorhynchus keta*. Animal Behaviour 32(2):628-629.

Quinn, T. P., 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18(1-2):29-44.

Ruggerone, G. T., and B. A. Agler. 2008. Retrospective analysis of AYK chum and coho salmon. Prepared for the 2008 Arctic Yukon Kuskokwim Sustainable Salmon Initiative Project Product, Anchorage, Alaska. 57 p.

Salo, E. O. 1991. Life history of chum salmon (*Oncorhynchus keta*). Pacific salmon life histories, p. 231-309. *In* C. Groot and L. Margolis (eds.), Pacific salmon life histories. University of British Columbia Press. Vancouver, B. C.

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.

Yasumiishi, E. M., K. R. Criddle, N. Hillgruber, F. J. Mueter, and J. H. Helle. 2015. Chum salmon (*Oncorhynchus keta*) growth and temperature indices as indicators of the year–class strength of age-1 walleye pollock (*Gadus chalcogrammus*) in the eastern Bering Sea. Fisheries Oceanography 24(3):242-256.

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.