Coho Salmon (*Oncorhynchus kisutch*)

Central California Coast coho

Overall vulnerability—Very high (100% Very high)
Biological sensitivity—Very high (100% Very high)
Climate exposure—High (86% High, 14% Very high)
Adaptive capacity—Low (1.3)
Data quality—79% of scores ≥ 2

	Central California Coast Coho	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Early life history	3	1.5	
	Juvenile freshwater stage	3.8	2.8	
	Estuary stage	3.2	1.5	
	Marine stage	3.4	2.5	
	Adult freshwater stage	1.9	2.8	
	Cumulative life-cycle effects	3.6	1.5	
	Hatchery influence	2.1	2.8	
	Other stressors	3	2	
	Population viability	3.7	3	
	Ocean acidification sensitivity	1.8	1.8	
	Sensitivity Score	Very High		
Exposure variables	Stream temperature	3.2	2	
	Summer water deficit	2.4	1.8	
	Flooding	3.7	1.3	
	Hydrologic regime	1.1	2.5	
	Sea level rise	3.3	2	
	Sea surface temperature	3.4	2	
	Ocean acidification exposure	4	2.5	
	Upwelling	2.9	1	
	Ocean currents	1.8	1	
	Exposure Score	High		
	Overall Vulnerability Rank	Very High		

Life History Synopsis

Central California Coast coho adults typically enter rivers from November through mid February (Shapovalov and Taft 1954, Weitkamp et al. 1995). Because many central California estuaries are seasonally closed by sandbars, migration timing can depend on bar-breaching dynamics. Freshwater migration distances range from a few to 50 km or more in larger watersheds such as the Russian River. Egg incubation generally takes place between December and late April or early May (Shapovalov and Taft 1954, Weitkamp et al. 1995).

Juveniles exhibit a range of behaviors, life histories, and habitat associations. The majority reside about one year in fresh water before migrating to sea. Some age-0 juveniles migrate only as far as the ecotone between the stream and estuaries, which are often seasonally closed due to sandbar dynamics. These juveniles reside in estuaries for variable periods depending on temperature, dissolved oxygen, and salinity levels, and they subsequently move back upstream (Miller and Sadro 2003, Koski 2009, Jones et al. 2014, Wallace et al. 2015). A small-to-modest fraction may spend a second year in fresh water before migrating to sea (Bell 2001, Gallagher et al. 2014). Downstream migrants typically enter the ocean between April and May (Spence and Hall 2010).

Marine movements of Central California Coast coho are unclear, but tag recovery data from hatchery populations to the north suggest these fish inhabit marine regions fairly near their natal rivers (Pearcy and Fisher 1988, Weitkamp and Neely 2002, Quinn and Myers 2005). The majority of adults return to spawn at age 3, though 2-year-old males (jacks) can be a significant proportion of the run (Shapovalov and Taft 1954, Weitkamp et al. 1995). Fish residing for 2 years in fresh water appear to return for spawning at age 3 or 4 (E. Ettlinger, Marin Municipal Water District, pers. comm.).

Climate Effects on Abundance and Distribution

The Central California Coast coho DPS comprises the southern distributional limit of its species, and thus already faces numerous limiting factors stemming from climate change. No formal studies were reported on the effects of climate change on Central California Coast coho, but the vulnerability assessment suggested four important threats:

1) Estuary breaching dynamics and water-quality are important for coho ecology and are likely sensitive to rising sea-level, rising air temperatures, and changes in stream flow. To reflect this threat, sensitivity in the *estuary stage* was ranked ***high***, as was exposure to *sea level rise* and *stream temperature*, making this a ***highly vulnerable life stage***. Exposure to *flooding* ranked ***very high***. It is important to note that flooding can have positive effects on bar-breaching, despite negative effects on eggs in the gravel. During dry periods, California estuaries naturally develop sand bars that close the estuary, block fish passage, and alter hydrological functioning. In many streams, recent drought has delayed and sometimes prevented the winter breaching of sand bars that allows migrating adults to enter fresh water to spawn. Some juveniles use estuaries during the closed phase, but these fish are impacted and can even be killed by poor water quality during this phase (high temperature, low dissolved oxygen, high salinity (Smith 2009). In closed estuaries, water quality depends on complex interactions between stream flow, over-bar exchange of marine waters, breaching dynamics of sand bars, wind, and other factors. Changes in sea-level, air temperature, and the amount and timing of precipitation are likely to alter these interactions in ways that further impact coho.
2) For coho eggs and juveniles, the interaction between hydrologic change and warming will likely have sub-lethal effects that propagate through the life cycle. Warmer water temperatures accelerate development and hatching of eggs (Murray and McPhail 1988), as well as affecting metabolism, growth, and development of juveniles in complicated ways

that involve both costs and benefits to fitness (Spence 1995). Streambed scour may increase due to more extreme winter flows, which may in turn increase the deposition of fine sediments, thereby increasing egg mortality (Shapovalov and Taft 1954, Stillwater Sciences and EA Engineering 1997). Fine sediments may obstruct the emergence of alevins. However, the relationship might not be entirely predictable (Ward et al. 2015). Sensitivity in the *early life history* stage was ranked ***moderate***.

3) Fog dynamics in summer, associated with coastal upwelling in the nearby ocean, can have a significant influence on maximum temperature and evaporation in local streams. Exposure was ranked ***moderate*** for *upwelling* but ***high*** for *sea surface temperature* and *stream temperature*. For juveniles, summer and fall are high-stress periods characterized by low flows, diminished food production, and high metabolic demands caused by warm temperatures. Sensitivity in the *juvenile freshwater stage* was thus ranked ***very high.*** Changes in the fog regime would further directly affect the juvenile freshwater stage, which is already a stressful period. However, the future fog regime is highly uncertain: fog may intensify, diminish, or change in seasonality or year-to-year consistency (Johnstone and Dawson 2010).

4) Depending on the balance of these factors in the adult, early life history and juvenile freshwater stages, fish may or may not transform to smolts during the historical juvenile migration period, which in turn has further fitness consequences due to mismatch with favorable ocean conditions or migration corridors closed by sandbar formation (Osterback et al. 2018). Owing to the combination of very high scores for adult and juvenile freshwater stages and the potential for lost access between freshwater and ocean habitats, *cumulative life-cycle effects* was ranked ***very high***.

Broadly, marine survival of coho salmon across Oregon and California populations appears to be sensitive to certain aspects the Pacific Decadal Oscillation, such as the timing of spring transition, strength of upwelling in spring, and sea-surface temperatures, although relationships are complex (Lawson 1997, Mantua et al. 1997, Ryding and Skalski 1999, Beamish et al. 2000, Koslow et al. 2002, Logerwell et al. 2003). Movements of coho salmon in response to ocean regimes is not well understood, but the first few months at sea appear to be critical to marine survival (Pearcy 1992). Thus, overall sensitivity in the *marine stage* was ranked ***moderate***.

Extrinsic Factors

The Central California Coast coho DPS is listed as endangered under the U.S. Endangered Species Act, resulting in a score of ***very high*** for *population viability*. In the most recent viability assessment, 8 of 12 independent populations were extant in this DPS, but none of these populations were at low-risk (Spence 2016). Assessing the viability of coho populations in this DPS is challenging due to the scarcity of long-term datasets for most populations. Available data indicated that all independent and dependent populations were well below recovery targets, and in some cases, exceeded high-risk thresholds. An area of particular concern was the downward trends in abundance of virtually all dependent populations throughout the DPS. Downward trends in dependent populations may indicate that they are less able to maintain connectivity or act as buffers against declines in neighboring independent populations. Independent populations might therefore become more isolated with time (Spence 2016).

Stressors that limit viability in this DPS include pollution and poor water quality, especially in areas of heavy agricultural and urban development (NMFS 2012), as well as modest bycatch in Chinook and coho fisheries off California and Oregon (Williams et al. 2016). Many stream and estuarine habitats used by this DPS have been significantly reduced in extent, quality or complexity due to flood-plain alteration, lack of large woody debris, water diversions, and other stressors. These historic habitat alterations will likely reduce the resilience of coho to climate change, but an ongoing, long-term effort to improve habitat conditions would aid resilience over time. For these reasons, sensitivity to other stressors was ranked ***high***.

For populations in this DPS, persistence is supported by two conservation hatcheries involving captive rearing of adults. Conservation hatcheries scored lower in this risk assessment than production hatcheries, so overall sensitivity to *hatchery influence* was ranked ***low*** for this DPS . However, these hatcheries present risks from loss of genetic diversity (Satterthwaite et al. 2015) and possible inbreeding depression, in addition to fungal infection at the southernmost hatchery. Furthermore, marine survival of conservation hatchery fish has generally been poor compared to that of fish from other hatcheries.

Adaptive Capacity

Adaptive capacity ranked ***low*** for this DPS. The Central California Coast coho DPS comprises the southern distributional limit of the species, apparently having maximized its ability to modify its life history. No further compensation was anticipated.

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