SACRAMENTO FALL-RUN CHINOOK SALMON ABUNDANCE

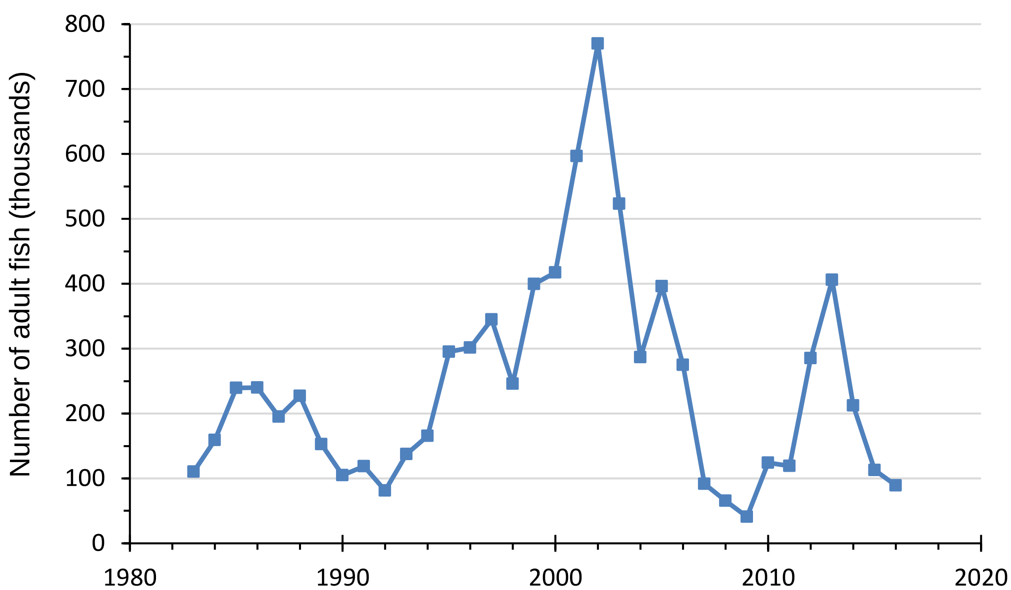
Salmon juvenile survival — and resultant adult abundance — has become more variable, with extreme juvenile mortality events occurring in the last two decades.


Photo: Allen Harthorn

Central Valley Chinook salmon (*Oncorhynchus tshawytscha*) rear in the fresh water of interior California, migrate as juveniles to feeding grounds in the Pacific Ocean, and return to fresh water from July to December to spawn. Four distinct runs of Chinook salmon spawn in the Sacramento-San Joaquin River system, named for the season when the majority of the run enters freshwater as adults.

The Sacramento River fall/late fall-run salmon comprise a large proportion of Chinook salmon spawners returning to Central Valley streams and hatcheries. This subpopulation is designated as the “indicator stock” for the Central Valley fall Chinook runs, and as a Species of Concern under the federal Endangered Species Act.

Figure 1. Sacramento Fall-Run Salmon Abundance



Source: PFMC, 2017

What does the indicator show?

Figure 1 shows annual escapement — the number of adult salmon returning to their freshwater spawning habitat — of Sacramento fall-run Chinook salmon, in thousands of fish. Fall-run Chinook salmon abundance fluctuated from 1983 to 2016. Relatively constant prior to 1995, the numbers peaked in 2002 before declining to near normal levels in 2006. The sudden drop in 2007 was followed by two years of record lows — 2008 and 2009, when only about 65,000 and 41,000 adults, respectively, returned to spawn. Extremely low escapement led to the closure of commercial and recreational fisheries in 2008 and 2009 and opened for only a few days in 2010.

Salmon abundance increased to levels above the long-term average in 2012 and 2013 before declining again in 2014 and 2015. In 2016 the number of returning fall-run dropped to values similar to those witnessed in 2007.

Why is the indicator important?

Salmon are among California's most valued natural resources (CDFW, 2013). The Chinook salmon is the largest of the salmon species. This iconic fish is legendary for its migration from the streams in which it is hatched to the Pacific Ocean, where it can travel as far as a thousand miles, only to return to its natal stream to spawn and die. California marks the southern end of the range of all salmon on the Pacific coast (Moyle et al., 2017; UC Davis, 2017). In addition to their important role in the aquatic ecosystem, Sacramento fall-run Chinook salmon have been the largest contributor to ocean salmon harvest off California and Oregon for decades (O'Farrell et al., 2008). They provide a highly nutritious food source and an important source of income for the commercial salmon industry. Salmon fishing also supports a large recreational fishing community and Native Americans depend on and celebrate them in many aspects of their culture.

Salmon play a key role in marine and inland ecosystems and thus can serve as an indicator of the health of both ecosystems. They are both top predator and prey, and their carcasses contribute to nutrient cycling of riparian systems (CDFW, 2013). In combination with an understanding of the processes underlying salmon abundance, scientists can use the conditions of the ocean ecosystem to allow for rough estimates of the future abundance of adult Chinook salmon.

Both climate change and other factors described below will likely put the salmon population at risk of extirpation and/or extinction. Experts suggest that nearly all of California's salmon face extinction within 50 to 100 years, with about 45 percent of the population at risk of extinction within 50 years, if current trends in climate change and other anthropogenic stressors persist. Management strategies that protect and restore habitats and promote salmon diversity and abundance will greatly help salmon in the years to come (Moyle et al., 2017; UC Davis, 2017).

What factors influence this indicator?

California salmon abundance is influenced by dynamic interactions between natural landscape features (such as climate and topography) and commercial activities. Much of the information concerning anthropogenic impacts on salmon populations has focused on activities such as urban and agricultural runoff as well as mining. Scientists have recently started to look more critically at climate change influences on the health and survival of salmon (Moyle et al., 2013; Wells et al., 2014).

Climate change can alter freshwater, estuarine, and marine habitats, putting salmon populations at risk (Wells et al., 2014). As air temperatures rise, river and stream temperatures have increased in California and will likely continue to increase. With warming temperatures, more precipitation falls as rain instead of snow in the mountains (see *Precipitation* indicator), reducing the amount of snowmelt that provides cold water year-round to rivers and streams. Significant reductions in cold-water river and stream flows in summer will likely affect juvenile and adult migration, spawning, egg viability, and rearing conditions.

For fall-run Chinook salmon, warming freshwater temperatures delay adults' migration to streams later in the season and could cause juveniles to leave freshwater earlier in the spring, narrowing the window of time for successful reproduction and rearing. Snowpack losses are expected to be increasingly significant, especially at elevations below 3,000 meters. The lower abundance of fall-run salmon in the years 2014 and 2015 were likely influenced by a significant reduction in snowpack during those years (see *Snow-water content* indicator). Future changes in stream flow and temperature are expected to be much greater in the Sacramento River and its tributaries, which are fed by the relatively lower northern Sierra Nevada. The practice of maintaining a large pool of cold water behind reservoirs allows for controlled releases to compensate for the warmer water temperatures in the fall. A decline in snowmelt volume could threaten this pool of cold water, thus threatening successful spawning (Moyle et al., 2017).

Winter- and spring-run Chinook salmon also inhabit the complex Sacramento-San Joaquin River system. These subpopulations may respond differently to changing climate conditions due to differing life history patterns and area-specific environmental conditions. For example, while fall-run Sacramento River Chinook migrate upstream and spawn in the river during the cooler months, spring- and winter-run Sacramento River Chinook enter the river and spawn during the warmer months and for longer periods of time (CDFW, 2013), making them more vulnerable to warming freshwater temperatures associated with climate change.

Changes in physical, chemical and biological components and processes in the marine environment also affect salmon (Wells et al., 2014). Water temperature affects fish metabolism, development, behavior, and distribution. Salmon survival during the initial months of ocean life depends on available prey (largely krill, forage fish and crab larvae). Increasing ocean temperatures can negatively alter the food web on which salmon depend, changing the range of predators, competitors, and prey species. Overall, warming ocean temperatures are expected to result in range changes for California salmon, a phenomenon that is already occurring with other fishes.

In 2014-2015, the west coast of North America experienced unusually warm sea surface temperatures (see C*oastal ocean temperature* indicator). This marine heat wave first appeared as a large area of exceptionally high sea surface temperatures, informally known as the "warm blob", in the Gulf of Alaska in November 2013. It later extended southward along the entire Pacific coast of the contiguous US, where surface temperatures reached unprecedented levels in many locations. Although not yet well understood, these unusually warm conditions were influenced by periods of weaker upwelling, the absence of winter storms, and El Niño-Southern Oscillation (ENSO) conditions.

The timing and intensity of coastal upwelling — a wind-driven motion of dense, cooler, and usually nutrient-rich water towards the surface — also impacts salmon. Salmon feed on krill and other phytoplankton in upwelled waters and have suffered population declines during years of weak upwelling conditions. As surface waters warm, an increase in water column thermal stratification is expected to increase, reducing upwelling of cold nutrient-rich water. For example, the rapid decline in krill in the juvenile salmon feeding area between 2001 and 2007 paralleled a sharp decline in salmon abundance in the Gulf of Farallones and in the central northern California region (Lindley et al., 2009). Another coastal phenomenon, rising sea levels, can lead to inundation of low-lying lands and increases in salinity, transforming estuary habitats for migrating salmon.

Another factor that may threaten salmon is the acidification of coastal waters as a consequence of increasing atmospheric carbon dioxide (Wells et al., 2014). Although acidification will likely have little direct effect on salmon, it may have a significant impact on invertebrate species that are important to the salmon diet.

Taken together, threats from climate change and historical stressors such as habitat loss and urban/agricultural runoff place salmon in a precarious condition.

Technical Considerations

Data Characteristics

Total spawning escapement values were taken from Table II-1 of the Pacific Fisheries Management Council's Preseason Report (PFMC, 2017). Natural-area escapement estimates are made using methods such as carcass surveys, aerial red counts, ladder counts, weir counts and video monitoring (O'Farrell et al., 2013).

Strengths and Limitations of the Data

Estimates of spawning escapement are extremely important to salmon management as an indication of the actual reproductive population size. The number of reproducing adults is important in defining population viability, as a measure of both demographic and genetic risks. It is equally important to harvest management, which typically aims at meeting escapement goals such that the population remains viable (for Endangered Species Act-listed populations) or near the biomass that produces maximum recruitment (for stocks covered by a fisheries management plan). Spawning escapement is the most widely available measure of abundance for West Coast salmon, although these data are often limited to the most commercially important stocks.

Spawning escapement, as an indicator of salmon abundance, differs from metrics used by fishery managers (such as the Sacramento Index). The former focuses on trends relevant for evaluating salmon populations from an ecosystem perspective.

Estimates of the number of Chinook salmon returning to spawn have been made since the early 1950s, and in some cases since the 1940s. Programs have evolved over the years, and vary in methods used, intensity of sampling effort, and reliability of estimates. Mark-recapture carcass surveys are now widely used as the standard method to estimate in-river spawning escapement. Despite their widespread use in the Central Valley, models to estimate in-river spawning escapement based on mark-recapture carcass survey data require a number of assumptions which may not be met in the surveys. Field and data analysis methods used in the existing escapement surveys have not been reviewed for adequacy of statistical power or potential bias. In addition, data management and reporting in the Central Valley is not standardized; escapement data and reports are not readily accessible in a timely way by other researchers, stakeholders, or the public.

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