Multiple Causes of Central Valley Chinook Salmon Decline

Peter B. Moyle

Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, 1 Shields Ave., Davis, CA 95616, pbmoyle@ucdavis.edu

Ed. note—Earlier this year, fisheries managers in California reported that the Central Valley's most abundant run of salmon had suffered an "unprecedented collapse," eventually forcing a shutdown of all recreational and commercial Chinook fishing on the ocean in California and most of Oregon. In addition, recreational fishing for Chinook in all 14 Central Valley Rivers and streams has been closed (except for a one-salmon bag limit in one part of the Sacramento River from November 1 to December 31). The anticipated economic loss to California of the closure of the recreational ocean fishery will be around $167 million, while the economic loss of the commercial fishery will be approximately $63 million. State and federal government officials claim that "ocean conditions" are the likely culprit for the collapse. But as explained in this essay by Peter B. Moyle, author of Inland Fishes of California *and the leading authority on the biology and conservation of California fishes, the causes of the Central Valley Chinook Salmon collapse are much more complex.*

Ever since EuroAmericans arrived in the Central Valley, Chinook Salmon populations have been in decline. Historic populations probably averaged 1.5-2.0 million (or more) adult fish per year. Such high populations resulted from four distinct runs of Chinook Salmon (fall, late-fall, winter and spring runs) taking advantage of the diverse and productive freshwater habitats created by cold rivers flowing from the Sierra Nevada. When the juveniles moved seaward, they found abundant food and good growing conditions in the wide valley floodplains and complex San Francisco Estuary, including the Delta. The sleek salmon smolts then reached the ocean, where the southward flowing, cold, California Current and coastal upwelling together created one of the richest marine ecosystems in the world, full of the small shrimp and fish that salmon require to grow rapidly to large size. In the past, salmon populations no doubt varied as droughts reduced stream habitats and as the ocean varied in its productivity, but it is highly unlikely the numbers ever approached the low numbers we are seeing now.

Unregulated fisheries, hydraulic mining, logging, levees, dams, and other factors caused precipitous population declines in the 19th century, to the point where salmon canneries were forced to shut down (all were gone by 1919). Minimal regulation of fisheries and the end of hydraulic mining allowed some recovery to occur in the early 20th century but the numbers of harvest salmon steadily declined through the 1930s. There was a brief resurgence in the 1940s but then the effects of the large rim dams on major tributaries began to be severely felt. The dams cut off access to 70% or more of historic spawning areas and basically drove the spring and winter runs to near-extinction. In the late 20th century, thanks to hatcheries, special flow releases from dams and other improvements, salmon numbers (mainly fall-run Chinook) averaged nearly 500,000 fish per year, with wide fluctuations from year to year, but only about 10-25% of historic abundance. In 2006, numbers of spawners dropped to about 200,000, despite closure of the fishery. In 2007, the number of spawners fell further to about 90,000 fish, among the lowest numbers experienced in the past 60 years, with expectations of even lower numbers in fall 2008 (probably <64,000 fish). The evidence suggests that these runs are largely supported by hatchery production, so numbers of fish from natural spawning are much lower.

So, what caused this apparently precipitous decline in salmon? Unfortunately, the causes are historic, multiple and interacting. The first thing to recognize is that Chinook

Salmon are beautifully adapted to living in a region where conditions in both fresh water and salt water can alternate between being highly favorable for growth and survival and being comparatively unfavorable. Usually, conditions in both environments are not overwhelmingly bad together, so when survival of juveniles in fresh water is low, those that make it to salt water do exceptionally well. And vice versa. This ability of the two environments to compensate for one another's failings, combined with the ability of adult salmon to swim long distances to find suitable ocean habitat, historically meant that salmon populations fluctuated around some high number. Unfortunately, when conditions are bad in both environments, populations crash, especially when the heavy hand of humans is involved.

The recent crash has been blamed largely on "ocean conditions." Generally what this means is that the upwelling of cold, nutrient-rich water has slowed or ceased, so less food is available, causing the salmon to starve or move away. Upwelling is the result of strong, steady alongshore winds that cause surface waters to move off shore, allowing cold, nutrient-rich, deep waters to rise to the surface. The winds rise and fall in response to movements of the Jet Stream and other factors, with both seasonal and longer-term variation. El Niño events can affect local productivity as well, as can other "anomalies" in weather patterns. Chinook Salmon populations fluctuate accordingly.

The 2006 and 2007 year classes of returning salmon mostly entered the ocean in the spring of 2004 and 2005, respectively (most spawn at age 3). Although upwelling should have been steady in this period, conditions unexpectedly changed and ocean upwelling declined in the spring months, so there were fewer shrimp and small fish for salmon to feed on. According to an analysis by an interdisciplinary group of scientists, conditions were particularly bad for a few weeks in spring 2005 in the ocean off central California, resulting in abnormally warm water and low concentrations of zooplankton, which form the basis for the food webs, which include salmon. All this *could* have caused wide scale starvation of the salmon. Note the emphasis on *could*. While the negative impact of ocean anomalies is likely, monitoring programs in ocean are too limited to make direct links between salmon and local ocean conditions.

"Ocean conditions" can also refer to other factors, which can be directly affected by human actions, especially fisheries. For example, fisheries for rockfish and anchovies can directly or indirectly affect salmon food supplies (salmon eat small fish). Likewise, fisheries for sharks and large predators may have allowed Humboldt squid (which grow to 1-2 m long) to become extremely abundant and move north into cool water, where they conceivably prey on salmon. These kinds of effects, however, are largely unstudied.

Meanwhile, what has been going on in the Sacramento and San Joaquin rivers? On the plus side, dozens of stream and flow improvement projects have increased habitat for spawning and rearing salmon. Removal of small dams on Butte Creek and Clear Creek, for example, has increased upstream run sizes dramatically. Salmon hatcheries also continue to produce millions of fry and smolts to go to the ocean. On the contrary side:

- The giant pumps in the South Delta have diverted increasingly large amounts of water in past decades, altering hydraulic and temperature patterns in the Delta as well as capturing fish directly.
- The Delta continues to be an unfavorable habitat for salmon, especially on the San Joaquin side, where the inflowing river water is warm and polluted with salt and toxic materials. Most of the rest of the Delta lacks the edge habitat juvenile salmon need for refuge and foraging.
- Hatchery fry and smolts are released in large numbers but their survivorship is poor compared to wild fish, although they contribute significantly to the fishery. Nevertheless, they may be competitors with better-adapted wild fish under conditions of low supply in the ocean. Most of the hatchery fish are planted below the Delta to avoid the heavy mortality there.
- Numbers of salmon produced by tributaries to the San Joaquin River (Merced, Tuolumne, Stanislaus) continue to be exceptionally low, in the hundreds, and the promised restoration of the San Joaquin River appears to be stalled for lack of federal funds.

Thus reduced survival of wild fish in fresh water, especially in the Delta, combined with the naturally low survival rates of hatchery fish, most likely contribute to the plummeting numbers of adult spawners. This is especially likely to happen if young salmon also hit adverse conditions in the ocean, especially as they enter the Gulf of the Farrallones. The growing salmon can also hit other periods when food is scarce in the ocean, along with abundant predators and stressful temperatures, at any time in the ocean phase of their life cycle.

The overall message here is that indeed "ocean conditions" have had a lot to do with the recent crash of salmon populations in the Central Valley. However, they are superimposed on a population that has been declining in the long run (with some apparent stabilization in recent decades). The salmon still face severe problems before they reach the ocean, especially in the Delta. In the short run, there are only a few "levers" we can pull to improve things for Central Valley salmon. These include shutting down the commercial and recreational fisheries, reducing the impact of the big pumps in the South Delta, changing the operation of dams (increasing outflows at critical times), regulating hatchery output, and reducing other ocean fisheries. In the longer run (10-20 years) we need to be engaged in improving the Delta and San Francisco Estuary as a habitat for salmon, reducing the input of toxic materials into the estuary, continuing with improvements of upstream habitats, managing floodplain areas such as the Yolo Bypass for salmon, restoring the San Joaquin River, and generally addressing the multiplicity of factors that affect salmon populations. There is also a huge need to improve salmon monitoring in the ocean as well as the coastal ocean ecosystem off California. Right now, our understanding of how ocean conditions affect salmon is largely educated guesswork with guesses made long (sometimes years) after an event affecting the fish has happened. An investment in better knowledge should have large pay-offs for better salmon management.

Overall, blaming "ocean conditions" for salmon declines is a lot like blaming Hurricane Katrina for flooding New Orleans, while ignoring the many human errors that made the disaster inevitable, such as poor levee construction and the loss of protective salt marshes. Managers have optimistically thought that salmon populations were well managed, needing only occasional policy modifications (such as hatcheries or removal of small dams) to continue going upward. The listings of the winter and spring runs of Central Valley Chinook as endangered species were warnings of likely declines on an even larger scale. "Ocean conditions" may seem like a destructive hurricane to those wanting to avoid responsibility but we humans are in fact regulating salmon populations, directly or indirectly. Continuing on our present course will result in the permanent loss of a valuable and iconic fishery unless we start taking corrective action soon.

On a final more optimistic note, there is a reasonable chance that Chinook Salmon populations will once again return to higher levels, as they have in the past, although not quickly. However, the lower the population goes and the more the environment changes in unfavorable ways, the more difficult recovery becomes.

Recovery is officially defined by the goals set by the Anadromous Fish Restoration Program under the Central Valley Project Improvement Act, which has pledged to use "all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis." The final doubling goal is 990,000 fish for all four runs combined. We have a long way to go and some major course modifications to make if we are to reach anything close to that goal.