Strategies for Salmon Recovery

This is the first post in a series on Tom Cannon's proposed salmon recovery plan. Cannon has degrees in fisheries and biostatistics from the University of Michigan.

• This paper focuses on proposed strategies for recovery of Central Valley salmon and steelhead populations.

Despite decades of effort and billions of invested dollars, there has been minimal improvement in the Valley's salmon and steelhead populations; indeed, some populations remain near or are nearer extinction. My proposed recovery plan if implemented to its fullest extend would reverse this trend. The proposed plan has six strategic approaches:

1. Restore native salmon and steelhead to upper watersheds above selected rim dams and other impassable barriers.
2. Maintain native salmon and steelhead populations in lower watersheds below selected rim dams and impassable barriers.
3. Improve the contribution of hatcheries to natural populations and to commercial and sport fisheries.
4. Restore native salmon and steelhead to streams without dams, streams where dams can be removed, or streams where effective passage can be provided.
5. Address habitat, hatcheries, and harvest in a *holistic framework* for salmon recovery.
6. Improve the viability of native wild salmon and steelhead populations by increasing their production through improved habitat, reducing competition with hatchery fish, and reducing harvest by focusing harvest on hatchery fish.

Restore Native Salmon and Steelhead Populations to Upper Watersheds Above Rim Dams and Other Impassable Barriers.

A primary focus of the proposed recovery plan is on the restoration of native salmon and steelhead stocks to targeted sanctuary areas in the upper watersheds above rim dams or other impassable barriers of the Central Valley's rivers that once supported or are capable of supporting salmon. Spring-run and winter-run salmon and steelhead once thrived in upper watersheds of many rivers now blocked by dams.

Our proposed plan will expand recent efforts to restore spring-run and winter-run salmon by transporting adult salmon to upper watersheds or transferring hatchery eggs and fry to historic spawning areas above the dams. In 2022, approximately 300 adult winter-run Chinook salmon were trucked to native habitat above Eagle Canyon Dam on the North Fork of Battle Creek, where they have been absent for more than 110 years. Some adult spring-run Chinook salmon that returned to Sacramento River traps below Keswick Dam were trucked to the upper reaches of Clear Creek in Shasta County, where cooler water increased chances of successful spawning. Winter-run eggs from the Livingston Stone Hatchery were injected into historic spawning riffles of the McCloud River above Shasta Reservoir in 2022. Spring-run eggs from the Feather River Hatchery were injected into historic spawning riffles of the North Yuba above Bullards Bar Reservoir in 2024.

Tens of thousands of winter-run salmon smolts from the Livingston Stone Hatchery have been trucked to upper Battle Creek and the McCloud River since 2018 to help reestablish winter-run salmon in the two streams. Smolts from these groups have been tracked to the Golden Gate. Some from the McCloud River release even traversed through Shasta Reservoir and negotiated Shasta Dam, reaching the lower Sacramento River. Small numbers of adults from Battle Creek tag-release groups began returning to Battle Creek in recent years.

Such successes bode well for extending such efforts to other Central Valley watersheds. The proposed plan proposes expansion of these efforts to historical salmon watersheds, including the upper Sacramento River, upper McCloud River, and upper Pit River above Shasta Lake; the upper Feather River above Lake Oroville and Lake Almanor; the upper American River above Folsom Lake; the upper Yuba River above Bullards Bar and Englebright Reservoirs; and the upper Butte Creek above diversion dams and falls. These proposed sanctuary areas encompass historic or previously inaccessible reaches with high quality habitat that have the necessary logistical characteristics for a program of this scope.

Tools employed for this strategy include selection of native stocks for propagation; transportation of adult fish or eggs/fry to upper watershed sites; habitat protection and enhancement of the upper watershed sites; and collection and transportation of produced juvenile fish to lower watersheds or Bay-Delta release sites. The subsequent return of adult spawners from these sanctuary stocks will be genetically identified, sorted, and collected in the lower rivers, then transported back to their natal upper watershed sites in the hope of building these natural stocks. Some of these returning fish may be selected as brood stock for a conservation hatchery or an existing production hatchery; some may naturally mix with lower river spawners. The strategy would acknowledge and reduce any negative effects or pitfalls of the "selection" approach[1].

Maintain Native Salmon and Steelhead Populations in Selected Lower Watersheds Below Rim Dams and Impassable Barriers

Lower watersheds selected are those areas of the Central Valley that presently sustain mixed stocks of salmon and steelhead, including hatchery stocks, natural tailwater stocks, and/or lower river spawning-and-rearing production fish resulting from mixed stock escapement. Some of these river reaches are designated as wild salmon sanctuaries, while others will support mixed stock salmon stocks.

Maintaining high production of ocean-emigrating smolts supports harvest goals in coastal and river fisheries and natural and hatchery escapement. But it's not simply a matter of numbers; a diversity of smolts from different stocks exploits the advantages of the variable river, Bay-Delta, and ocean habitats that manifest both within years and from year-to-year.

Optimal in-river and hatchery production requires both robust adult immigration and holding conditions that maintain the energy and strength required by adult salmon and steelhead prior to spawning. Low thiamine levels from poor ocean and fasting-period (pre-spawn holding) conditions reduce pre-spawn adult survival, spawning success, and egg viability[2]. Cold-water reservoir pool supply may be limited

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[1] McLaughlin et. al. 2013. Unintended consequences and trade-offs of fish passage. FISH and FISHERIES, 2013, 14, 580–604/

[2] Honeyfield, D.C., A.K. Peters, and M.L. Jones. 2016. Thiamine and lipid utilization in fasting Chinook salmon. N. Pac. Anadr. Fish Comm. Bull. 6: 13–19. doi:10.23849/npafcb6/13.19.

below dams in drier year types, resulting in high water temperatures that delay spawning, increase pre-spawn mortality, and/or reduced subsequent egg viability. Changes in streamflow conditions may cause redd scour or redd dewatering. Adequate quantities of gravel spawning habitat are necessary to ensure minimal egg superimposition and maximum egg-to-fry survival.

In sum, streamflow, cool water temperatures, and adequate spawning and rearing habitat are keys to good production below Central Valley rim dams.

Juvenile salmon and steelhead growth and survival conditions are also essential to lower river fry and smolt production. The young must have suitable growth and survival habitat to attain smolt size and reach the ocean before the lower rivers and Bay-Delta warm to lethal levels in late spring and summer. Streamflows must be sufficient to provide good feeding and refuge habitat conditions, as well as support downstream emigration to Bay. If lower river and Bay-Delta water temperatures are too warm, the number of smolts reaching the ocean will be lower. Under lower streamflows, young salmon may starve, demonstrate slow or truncated growth, perish from heat stroke or low dissolved oxygen, or be more vulnerable to predation.

Poor survival during emigration is also associated with the lower turbidities, reduced velocities, reduced cover, and higher water temperatures, conditions that are more prevalent in drier years.

Delayed spawning is a common management practice in Central Valley lower river tailwaters when necessary to conserve cold-water supply for salmon holding and spawning. Conserving cold-water pool supplies through the fall in drier years is important, but it may also delay spawning and subsequent emigration of young salmon in reaching the ocean.

Hatchery young often have an advantage over their wild counterparts because of earlier spawning, better water temperatures, greater food availability, less predation, and transportation via truck around low survival reaches of emigration routes. Many of these disadvantages that beleaguer natural salmon populations can be overcome with better habitat and water condition management. Strategic flow pulses from dam releases timed with natural fall-through-spring rainfall or snowmelt events will help improve natural in-river and hatchery production. In drier years, natural and hatchery production can be improved through trucking to lower watershed rearing and migratory habitats bypassing adverse conditions. For naturally produced fish, this would require effective low-flow collection weir or trapping systems coupled with transport to the Bay. Hatchery and natural fry can be transported to floodplain and lower watershed habitats, which provide better growth and survival conditions. Where possible, natural or hatchery produced smolts can be captured and trucked or barged to the Delta, Bay, and coast, especially in drier year types.

Producing and releasing more smolts to the ocean from hatchery and natural production is the central goal of this strategy. Essential to such production will be the effective management of reservoir storage, cold-water supply, and reservoir water releases to lower-river salmon and steelhead spawning, rearing, and migrating habitat.

Improve the Contribution of Hatcheries to Natural Populations and Fisheries

Production hatcheries release several tens of millions of salmon and steelhead smolts to Central Valley rivers, the Bay-Delta, and coastal bays each year. These production hatcheries were built below major federal and state water project dams decades ago for dam mitigation. The hatcheries contribute roughly three-quarters of the fish to coastal and river salmon and steelhead fisheries. The proposed plan would enhance the production and survival of hatchery smolts to increase the number of harvestable salmon in commercial and sport fisheries along the coast and in rivers. The number of smolts reaching the ocean can be increased through a wide range of actions, including trucking and barging smolts, better timing of smolt releases, providing pulse flows during and following releases, and reducing the predators that feed upon released smolts.

Stock improvements through brood stock genetic selection may help improve smolt survival and production to the ocean, enhance the long-term viability of hatchery and wild stocks, and reduce negative hatchery impacts on salmon and steelhead along the Pacific Coast. Large numbers of hatchery fish in ocean fishing areas attract predators and fishermen that may jointly overexploit wild stocks. Indeed, hatcheries and associated harvest effects have been cited as the greatest factors in the demise of West Coast salmon and steelhead:[3]

"Large-scale hatchery programs for salmonids in the Pacific Northwest have largely failed to provide the anticipated benefits; rather than benefiting the salmon populations, these programs may pose the greatest single threat to the long-term maintenance of salmonids". [4]

Limiting hatchery effects on California's wild natural salmon populations is a foundational strategy of this plan. Keeping hatchery and wild stocks separate and employing genetic selection for brood stocks destined for upper and lower watersheds and hatcheries can minimize the detrimental effects of hatcheries. Focusing fishery harvest on hatchery stocks reduces hatchery fish escapement and straying, and minimizes harvest of wild stocks.

Marking all hatchery smolt releases (hatchery steelhead are presently all marked; hatchery salmon stocks have varying degrees of marking from 25% to 100%) will help minimize straying and the mixing of hatchery and wild stocks in hatcheries and sanctuaries. Selective harvest of marked hatchery fish in commercial and sport fisheries will help protect wild fish. The negative genetic effects production hatcheries impose on salmonid populations will be reduced by using better brood stocks in the hatcheries and preventing hatchery adults from entering sanctuary areas. Ultimately, these practices will reduce the influence of production hatchery stocks on natural wild populations.

Infrastructure improvements and operations management will help increase hatchery production and efficiency. Many facilities require upgrades and operations improvements. Funding is needed for marking all hatchery smolts and for needed transportation of smolts.

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[3] McMillan and Gayeski (2006). Historic Steelhead Abundance: Washington NW Coast and Puget Sound Prepared for the Wild Salmon Center. May 2006

[4] H**ilborn, R. (1992). Hatcheries and future of salmon in the northwest.** Fisheries 17(1): 5-8.

Conservation hatcheries are prescribed to support the stock selection and establishment of native natural-born (wild) fish in the proposed lower and upper watershed sanctuaries. Conservation hatcheries would support the initial establishment of native stocks in the sanctuaries, then work to sustain or expand both those stocks and the stocks of the production hatcheries and mixed stock natural spawning populations. The conservation hatcheries will base their brood stock selection on native genetics and produce eggs, fry, and smolts for the planned lower and upper watershed sanctuaries. An ultimate goal is to reduce the proportion of hatchery fish in salmon and steelhead populations.

California currently has two conservation hatcheries in operation. The Livingston Stone National Fish Hatchery near Redding is a federal conservation hatchery for the endangered winter-run salmon. The State of California maintains the spring-run Salmon Conservation and Research Facility in the San Joaquin River (SCARF) below Friant Dam. The state facility is founded on the following premise:

"*Even in a river system with an adequate number of adult salmon returning from the ocean to spawn, some river systems still need to rear hatchery juveniles to maintain healthy salmon populations. Climate change, drought, disease, predation, lack of habitat and other variables can impact returning salmon numbers. Fortunately, in most cases, with enough fish returning to the system, eggs/milt can be harvested from returners and used to supplement the next generation of fish…. However, a critical difference for the Program is that it is re-establishing a population of spring-run Chinook – in effect, creating a population from scratch. But, because there aren't enough adult spring-run Chinook salmon returning to the river yet to either propagate on their own or for a hatchery to harvest and supplement, the Program has two methods for creating a San Joaquin River-specific spring-run Chinook population: 1) get spring-run eggs from an existing population, in this case the Feather River, and, 2) grow spring-run to adults in a hatchery and harvest their eggs".*[5]

Hatchery programs require many precautions to minimize potential negative impacts on native wild populations;[6] such precautions have been incorporated into the proposed plan. These precautions include deliberate genetic selection and segregation actions, limiting harvest of wild stocks, and minimizing the introduction of hatchery diseases into wild populations.

Restore native salmon and steelhead to streams without dams, streams where dams can be removed, or streams where effective passage can be provided.

Focusing recovery efforts on streams that are minimally affected by barriers will require less intervention to recover salmon and steelhead populations. Every effort should be made to make recovery as self-sustaining as possible. Interventions such as maintaining connectivity between upper and low watersheds are key objectives for these watersheds (e.g., Mill and Deer Creek). Otherwise, trap-and-haul, trucking, hatchery production, and fish passage at small diversion dams may be necessary for these streams. Natural habitats are more likely to produce natural fish – but keeping non-natural fish out of the best natural habitats is likely to be a challenge. The best natural areas should be designated and managed as Salmon Sanctuaries with special protections and resource priorities. Highly

[5] https://www.restoresjr.net/why-releasing-adult-spring-run-chinook-is-part-of-the-plan/

[6] Naish et al. (2008). An Evaluation of the Effects of Conservation and Fishery Enhancement Hatcheries on Wild Populations of Salmon. Advances in Marine Biology, Volume 53.

valued and functioning reaches in upper or lower rivers should be designated as sanctuaries. Maintaining such reaches for optimized salmon and steelhead production will require watershed protections focused on forest ecosystem and range management, and minimizing the effects of water diversions for agriculture, water supply, timber harvest, mining, power production, and other uses.

Address Habitat, Hatcheries, and Harvest in a Holistic Framework

The proposed strategy emphasizes a holistic approach to salmon and steelhead recovery:

"Addressing hatcheries, habitat and harvest independently would provide benefits to Central Valley Chinook but addressing them together within a holistic framework is likely to be much more successful"[7].

Such a strategy entails coordinating common goals and actions throughout the Central Valley. The key habitats in the Central Valley are spawning, rearing, and migratory river corridors and Bay-Delta tidal sloughs, marshes, and embayments. Salmon and steelhead are anadromous to varying degrees in that they migrate to and from spawning habitat and Bay-ocean adult habitats. In between are migratory habitats of lower rivers and Delta channels. Each habitat type or category has varying degrees of constraints on salmon and steelhead. Hatchery fish potentially interfere with natural production in spawning, rearing, and migratory habitat. Harvest can lead to over-fishing especially on natural-born (wild) stocks. Managing these functions in a holistic framework helps to maintain native wild stocks and harvest goals by focusing fishery harvest on hatchery stocks.

Improve the *Viability* of Native Salmon and Steelhead Populations

A central theme of this salmon and steelhead restoration plan is its focused strategy of improving the *viability* of populations listed under the U. S. Endangered Species Act (ESA):

To be viable an ESU needs more than simple persistence over time; it needs to be in an ecologically and evolutionarily functional state[8].

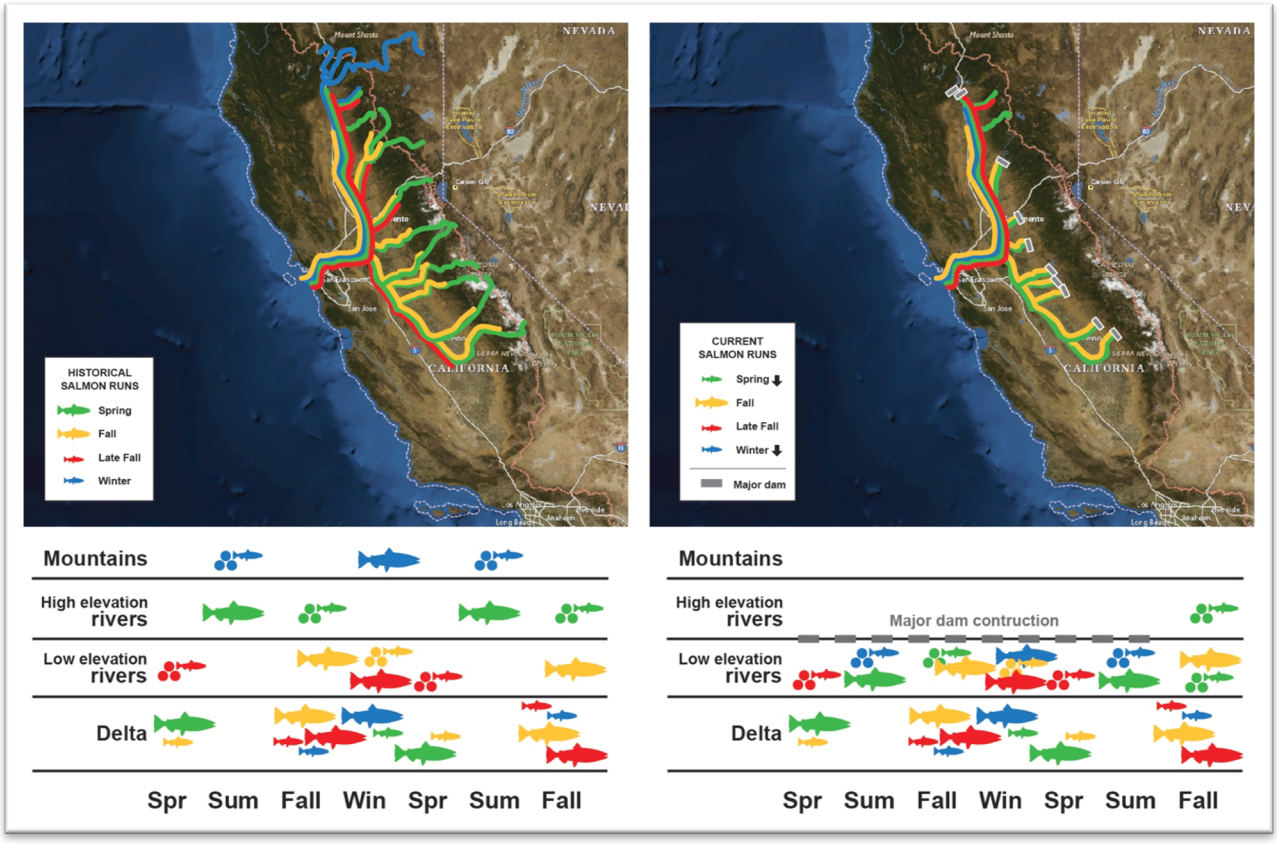
The listed populations relevant to the plan are Central Valley winter-run and spring-run Chinook salmon, and steelhead. Their *viability* in the context of the ESA incorporates the following characteristics:

- ***Abundance*** - The plan includes the development of hatchery and wild population abundance goals that emphasize natural or specifically supported sustainability.
- ***Productivity*** - Productivity assessment will include measurements of adult escapement, juvenile production, redd counts, or other factors related to population viability. All are incorporated into the plan's monitoring actions.
- ***Diversity*** - Diversity relates the extent and persistence of a population across its native area; the more widespread and entrenched a population, the more viable it is. The plan prescribes developing new populations in the lower and upper watersheds significant to each ESU.
- ***Spatial distribution of natural spawners*** - Increasing the spatial distribution of natural spawners is prescribed in each DPS and ESU.

[7] Lindley, et al. 2009.
[8] Bilby et. al. 2005.

- ***Fulfill key ecological functions that are attributable to the species, such as nutrient cycling and food web roles*** - Actions include transporting carcasses and their essential nutrients to upper river reaches targeted for restoration and natural stock recovery. Natural winter-run salmon stock transfers to the upper McCloud River will support native red-band trout food webs. Upper watershed spring-run salmon expansion will benefit natural steelhead stock expansion directly and indirectly through the steelhead food webs. Hatchery carcasses will be transferred to lower river mixed stock areas where production hatchery fish naturally spawn to increase natural mixed stock fish production.
- ***Provide for long-term evolutionary adaptability to changing environmental conditions*** – Increasing diversity among wild salmon and steelhead stocks in the Central Valley will provide enhanced genetic resilience among these populations, assuring greater adaptability to future environmental conditions.

In summary, overall viability will be achieved through reduced fishery harvest effects on wild stocks, reduced competition between hatchery stocks and wild stocks, reduced genetic influences of hatchery stocks on wild stocks, selective breeding of hatchery and wild stocks, improved habitat, reduced predation, improved fish passage, and reintroduction of wild stocks to historic habitats. Use of new technologies for stock identification, monitoring, and assessment will help ensure improvements in viability.



Historic and Current Range of Salmon Populations in California's Central Valley.

Tom Cannon is an fisheries population ecologist and biostatistician and has been involved in California fishery issues for more than 40 years. Over that period, Cannon has been a consultant to the California Department of Fish and Wildlife, U.S. Bureau of Reclamation, National Marine Fisheries Service, US Fish and Wildlife Service, US Army Corps of Engineers, US Forest Service, State Water Contractors, Metropolitan Water District, CalFed Bay-Delta Program, State Water Resources Control Board, PG&E, California Striped Bass Association, California Water Information Network (C-WIN), Fisheries Foundation of California, Cal Trout, Karuk Tribe, California Sportfishing Protection Alliance, and NCGASA.