Forecasting the Most Likely Status of Wild Salmon in the Central Valley of California in 2100

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Sierra E. Franks, Author

"No extinction comes in one fell swoop; instead, it occurs when the web of supporting relationships unravels." Salmonid Restoration Federation Plenary Talks, 2012

Abstract

Since the mid1800s the Central Valley of California has experienced a dramatic decline in the abundance of wild salmon. Wild salmon are defined here as Chinook salmon resulting from parents who spawned naturally in riverine habitat. The causes of their decline have been well studied and understood, however, despite restoration efforts spanning decades and billions of dollars, runs of wild salmon continue to decline over the long-term. Using the most probable policy and ecological scenarios (*i.e.* impacts of harvest, hatcheries, climate change, population growth and ensuing demands for scarce water resources) and based on expert opinion, I assessed the most likely future of wild salmon runs in the Central Valley of California in 2100. I posed seven questions to prominent salmon science and policy experts in federal and state agencies, local, regional and national organizations, non-governmental organizations, and universities. Respondents were assured complete anonymity to gain insight to their candid personal perspective and outlook on the future of wild salmon populations in the Central Valley of California. Twenty-six of the 33 contacted experts agreed to participate.

Based on these seven questions:

1) *Given current policies and trajectories, what is the most likely status of wild salmon in the Central Valley in 2100?*
2) *What would it take (be specific) to restore and sustain significant, sustainable (a third of historical) runs of wild salmon in the Central Valley through 2100?*

3) *What, exactly, does society need to do to change the downward trajectory and restore runs to significant, sustainable levels?*

4) *Is it possible to restore wild salmon in the CV while supplemental stocking from hatcheries continues?*

5) *Is it possible (realistically) to restore wild salmon in the CV while still harvesting adults?*

6) *How likely, in your opinion, is society to reverse these major policy drivers relative to wild salmon? This is not what anyone hopes will happen, but is your best guess.*

7) *Are current and likely planned recovery efforts likely to make much difference in the grand scheme of things?*

The key results were:

- Any action that will have a significantly positive effect on the recovery of wild salmon will be costly and politically controversial.
- Dramatic changes in hatchery practices would be needed to restore and sustain wild salmon in the Central Valley; about half the respondents concluded that supplemental stocking would need to be terminated.
- Respondents were skeptical about whether harvest could continue without hindering recovery of wild salmon.
- Respondents believed that society is unlikely to make the necessary policy shifts to restore wild salmon in the Central Valley.
- Respondents were of the opinion that current and likely planned recovery efforts would not greatly influence the overall, long-term downward trajectory of wild salmon in the Central Valley.
- By 2100 most experts concluded that wild salmon in the Central Valley of California would be extirpated or minimal in number if current trends continue.

Introduction

Chinook salmon (*Oncorhynchus tshawytscha*) is the only species of salmon that currently exists in the Central Valley (CV) of California (Figure 1). Hereafter, reference to "wild" salmon will be defined as those salmon resulting from parents who spawned naturally in natural habitat. This analysis covers the CV of California, but also briefly touches on the San Francisco Bay and Delta as these are the only route for salmon to migrate between the Pacific Ocean and the CV. Many dams (both large and small), numerous water diversions for agricultural, industrial, and municipal purposes, and a plethora of other factors have led to a precipitous decline in CV salmon since the mid-1800s (Yoshiyama *et al.* 1998).

The pre-1849 salmon runs in the CV most likely numbered in the several millions. Yoshiyama *et al.* (1998) conservatively put the number of historical Chinook salmon spawners in the CV at 1 to 2 million while (Gesh *et al.* 2000) estimated the number was closer to 2 to 4 million. With the draw of gold and the influx of settlers to the CV, the riparian habitat and naturally flowing waterways that wild salmon required, rapidly diminished. Fishing was also very intense. For example, by the 1850s, 60 boats fished the Sacramento River between Sutter's Fort and Suisan Bay. By 1882, the Sacramento River hosted 19 canneries producing 200,000 cases of salmon annually (Salmon Water Now 2012); nearly 4.3 million kilograms of salmon (Gesh *et al.* 2000).

Salmon have long played an important role for California's indigenous population and as a commercial and recreational fishery resource. In 2006, 489 California commercial fishermen landed 1.04-million pounds (dressed) of salmon on 477 vessels

and the revenue generated from this was approximately $5.3 million (Hackett & Hansen 2008). Although a majority of this catch was most likely from hatchery origin, it demonstrates the importance of salmon in California as a commercial and recreational resource. Ecologically, returning wild salmon whose carcasses decompose in their natal streams (unlike hatchery returners which are mostly used for eggs and milt upon return and whose bodies are then given to food banks or allowed to decompose on shore) allow for large influxes in nutrient composition and provide a food source for many different fauna. Merz and Moyle (2006) found that cultivated wine grapes adjacent to Mokelumne River (a tributary to the San Joaquin River) spawning sites received 18–25% of foliar nitrogen from marine sources. Their data suggest that "robust salmon runs continue to provide important ecological services with high economic value, even in impaired watersheds. Loss of Pacific salmon can not only affect stream and riparian ecosystem function, but can also affect local economies where agriculture and salmon streams coexist" (Merz & Moyle 2006).

In 2009, total returns for all four Chinook runs (spring, winter, fall and late-fall) were just over 70,000 fish (natural and hatchery fish combined), around 5% of average historical abundance (Katz & Moyle 2012). A recent graph put out by the Natural Resource Defense Council and the Golden Gate Salmon Association shows how this looks in terms of the Central Valley Project Improvement Act (CVPIA) effort to have reached 990,000 wild salmon by 2002 (Figure 2).

Figure 1. The CV watershed includes the Sacramento and San Joaquin River and their major tributaries (Yoshiyama *et al.* 1998). The mainstem Sacramento and San Joaquin rivers and the vast majority of their tributaries have at least one dam, most have many more.

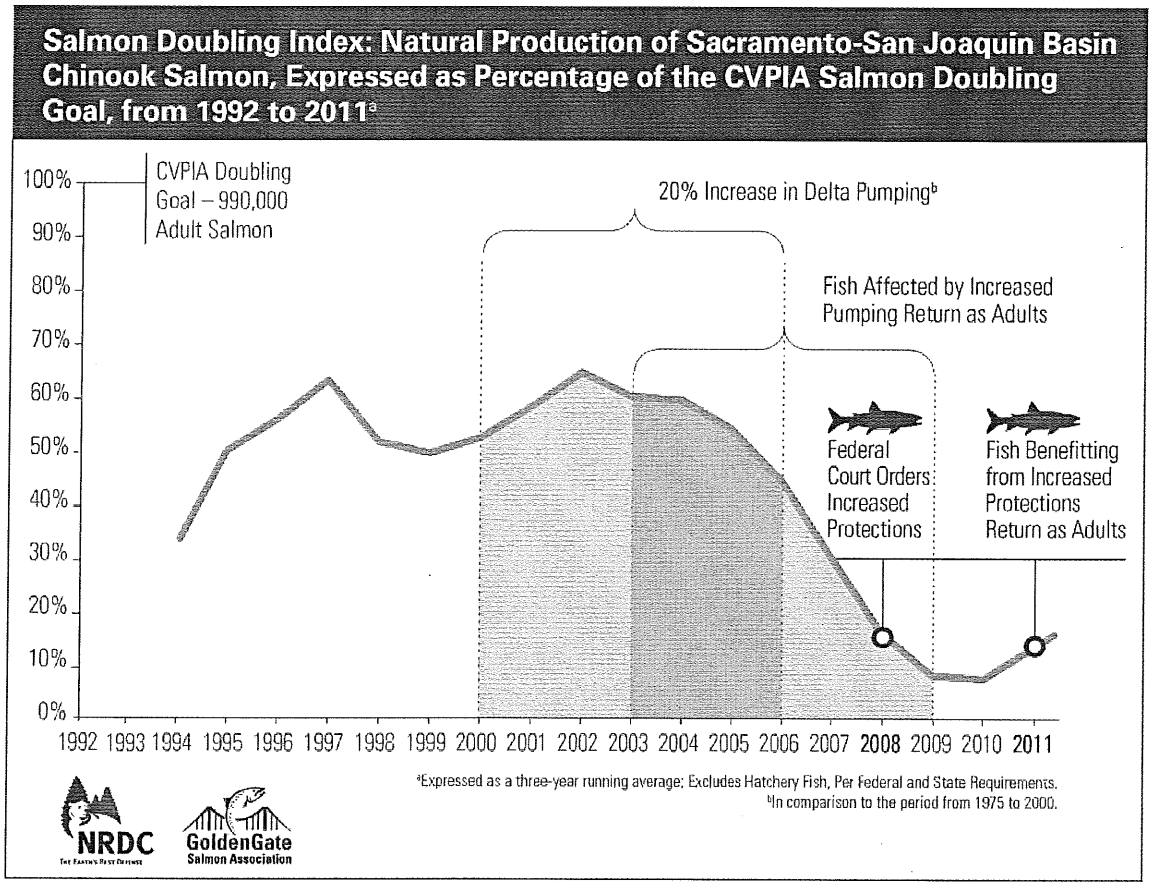

Figure 2. Former and current levels of naturally produced salmon the Sacramento – San Joaquin Basin 1992 - 2011 (NRDC & Golden Gate Salmon Association 2012).

Some Causes for the Decline of Wild Salmon

Hatcheries

Hatcheries have a long history in California. Intended to keep salmon populations high despite the dams and other habitat alterations (which they have done), they have in fact also contributed to a decline in wild salmon in the CV (Yoshiyama *et al.* 1998). California's earliest fish hatcheries were built over 135 years ago. As early as 1852, California passed its first salmon law, which forbade the obstruction of salmon runs in any of the rivers and streams that the fish used for breeding (CDFG 2010). In 1870, Governor Henry Haight signed legislation that established the Board of Commissioners

of Fisheries of California (Board). One of the Board's responsibilities was to establish "fish breederies"; to stock and supply streams, lakes, and bays with both foreign and domestic fish; to purchase and import spawn and ova; to employ fish culturists and other needed help; to construct fish ladders; and to distribute spawn and ova to fish breeders (CDFG 2010). This legislation was successful in that it has allowed for hatchery supported runs to do fairly well considering many habitat and fishing pressures, which in turn has a tendency to obscure the fact that wild salmonid runs in the CV were and are in decline. Some scientists argue that it will be impossible to restore wild salmon unless interbreeding with hatchery produced stock is eliminated (Katz *et al.* 2012). A recent study by Johnson *et al.* (2012) on the Mokelumne River (a tributary to the San Joaquin River) suggests that hatchery salmon alter population dynamics and the fitness of natural produced salmon in the CV. Furthermore, they estimated that 90.7 to 99.3% of returning adults (total fish in river and hatchery), were produced in a hatchery (Johnson *et al.* 2012). This information (assuming this is the case basin wide) suggests that management practices would need to be dramatically altered if the goals and strategies as outlined in the draft National Marine Fisheries Service (NMFS) recovery plan (2009) for ESA-listed CV salmonids or the United States Fish and Wildlife Service anadromous fish restoration program (AFRP) which aims to "make all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis" (USFWS 2011) are to be achieved.

Overfishing/Harvesting

Overfishing by commercial fisheries is one of the factors in the decline of wild salmon in the CV. The first people to harvest salmon in California were aboriginal people that lived throughout the CV and along the coast. By the early 1800s, the sustainable salmon harvest practices by Native Americans had been reduced substantially due to the drop in their population and the breakdown of their social structure (Lackey *et al.* 2006). The mid-1800s saw salmon abundance rapidly decline due to hydraulic mining activity, while the later 1800s saw the beginning of intensive commercial fishing. Subsequently with the development of different techniques to rapidly catch a large number of salmon, and the ability to pack salmon in cans for shipment anywhere, harvest hit an all-time high. Most salmon were taken by trolling in the ocean, but many were also fished in rivers and bays with gill nets until 1956; during World War II gill nets caught nearly half of the salmon landed (Fry 1949). Annual catches of Chinook salmon by the early Sacramento–San Joaquin in-river fishery commonly reached 4–10 million pounds and generally were higher than the total statewide catches made during the most recent several decades (Yoshiyama *et al.* 1998). Overharvesting by commercial fisheries is one factor in the decline of wild salmon in California. The collapse of the salmon runs was most dramatically noted by a wider audience in 2008 and 2009 when, for the first time, commercial fishing off of the coast of California was banned (LA Times 2009), impacting the livelihoods of thousands of fisherman.

Water Diversions & Agriculture Use

Water diversions are perhaps the most important factor currently affecting salmonid fisheries in the CV (Moyle *et al.* 2008). Demand for water continues to cause severe resource conflict. With a rapidly growing human population, the level of conflict is likely to remain severe. Currently, 27 million Californians receive water from the Delta (Delta Stewardship Council 2010). The Water Education Foundation (2008) points out that there are reservoirs where there once was desert, desert where there once was cropland, and cropland where there once was a swampy marsh. Some rivers have dried up; some rivers now flow beneath through mountains into another drainage basin; and some rivers even flow backwards at times. In 2011, 6.5 million acre feet for water usage was pumped for municipal and agricultural use south of the Delta (Leavenworth 2012). Most of this water is pumped through the federal and state pumping facilities. In 2011 it was estimated that the federal pumping facility salvaged 18,830 salmon while the state water pumping facility salvaged 18,135 salmon. 94% of the salvaged Chinook salmon at the federal facility was primarily wild spring-run and fall-run Chinook salmon. 95% of the salvaged Chinook salmon at the state facility were also primarily wild spring-run and fall-run fish (IEP 2012).

Almost every tributary to the Sacramento-San Joaquin Rivers has a major dam on it for diversion and/or water control purposes. The dams and water diversions alter the natural hydrology, salinity, turbidity, etc. to which wild salmon have adapted to over millions of years. These dams block nearly 80% of the historic spawning and rearing habitat that was formally available to salmon (American Rivers 2012). Herren and Kawasaki (2001) identified 3,356 diversions in the Sacramento and San Joaquin rivers

and the Delta, including the Stanislaus, Tuolumne and Merced Rivers as tributaries to the San Joaquin system. This number does not include diversions of any of the tributaries to the Sacramento River or on the Mokelumne, Cosumnes and Calaveras rivers which drain into the San Joaquin River/Delta. Of these 3,356 diversions, approximately 98.5% were either unscreened or screened insufficiently to prevent fish entrainment (Herren & Kawasaki 2001). This is a cause for major salmonid mortality annually as juvenile salmonids travel from these watersheds and emigrate to the Pacific Ocean.

Forecast/Projections

Here I transition from looking at some factors that have led to the decline of wild Chinook salmon in the CV, to factors that will most likely intensify and add to the stressors that have led to the downward trajectory. These most likely scenarios are important to consider when forecasting the most likely status of wild Chinook salmon in the CV in 2100.

Population Growth/Projections

Population growth and the associated human demands on already limited natural resources (*i.e.* water, land) will be one of the most determining factors in whether wild salmon can be expected in the CV in 2100. The inverse relationship between the increasing human population of California and declining salmon runs has long been recognized (Holmberg 1971). The population in California in 2010 was 37 million (United States Census Bureau 2011). The number of people residing in California in 2050 is projected to be more than 51 million (California Department of Finance 2012); projections for 2100 hover at around 90 million (Landis & Reilly 2003), almost triple the

current population in California. As new housing developments are built, more demand is placed on already scarce water resources. As Lund *et al.* points out, present-day water system operating rules and water allocation policies "...by 2100 should be seen as archaic" (Lund *et al.* 2003). As the population of California triples in size through this century and approaches 100 million in 2100, the options for sustaining, much less restoring wild salmon is extremely constrained.

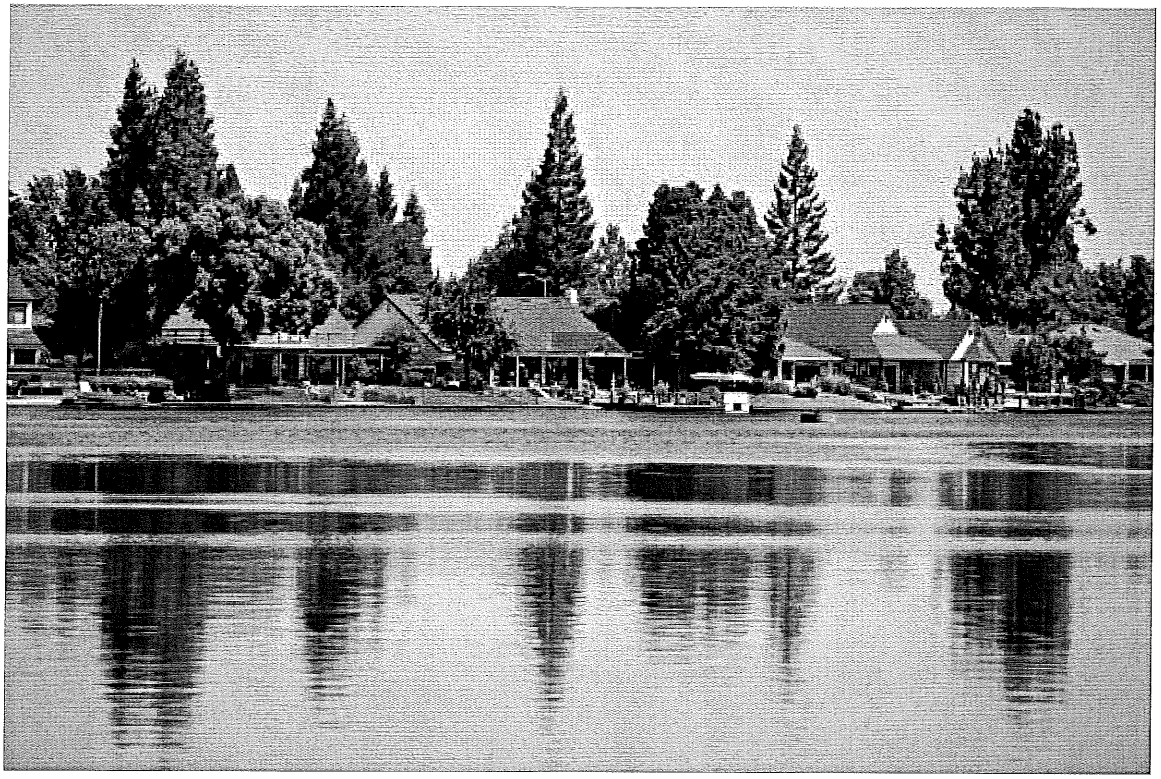

Figure 3. Homes along the San Joaquin River near Fresno, California (FresYes 2012). Providing homes, as well as roads, schools, stores, restaurants and businesses, for another 50 million Californians through this century will result in considerable loss of the remaining salmon habitat which is now less than 20% of the pre-1849 level.

Climate Change

Climate change is another factor that must be considered when looking at the most likely status of wild salmon in the CV in 2100. Global and localized climate

changes, such as El Nino ocean conditions and prolonged drought conditions, may affect the suitability of Chinook salmon habitat and, hence, viability – especially in the southern edge of the world-wide distribution, e.g. California. A current prediction is that the Sierra Nevada snow packs are expected to decrease with the long-term trend of increasing temperatures in California and that the majority of runoff in California will be from rainfall in the winter rather than from melting snow pack in the spring and early summer (CDWR 2006). This alteration of river runoff patterns will transform the tributaries that feed the Central Valley. The San Joaquin system particularly could change from a spring/summer snowmelt dominated system to a winter rain dominated system. It hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival (National Academy of Sciences 2012). The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This would truncate the time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without cold-water pools developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Shasta Lake and Lake Oroville, potentially could rise above thermal tolerances for juvenile and adult salmonids that must hold below the dam over the summer and fall periods. Increased winter precipitation and decreased snow pack could affect the flow and temperature of rivers and streams, with negative impacts on salmonid fish populations and the habitat that supports them (National Academy of Sciences 2012).

Current Recovery Efforts

There are currently many major and costly restoration efforts occurring in California aimed at increasing salmon numbers. Some notable projects include dam removal on Battle Creek, a major tributary to the Sacramento River, the permanent removal of the gates at the Red Bluff Diversion Dam (RBDD) which took effect this summer of 2012, the San Joaquin River Restoration Program (SJRRP), the Bay-Delta Conservation Plan (BDCP), and projects under the Central Valley Project Improvement Act (CVPIA) and actions in the Reasonable and Prudent Alternative of the NMFS biological and conference opinion on the long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) what is commonly referred to within NMFS as the Operations Criteria and Planning decision (OCAP). All of these efforts are seen as policy tools for recovery and should be considered when determining the most likely status of wild salmon in the CV in 2100.

- The Battle Creek project will remove 5 dams in upper Battle Creek (which also houses the largest federal fish hatchery in the country) and is estimated to cost near 80 million dollars (Darling 2010). This ongoing project should allow for increased passage into the upper watershed, which will allow access to cooler water and more spawning habitat, which in turn *should* increase salmon numbers.
- The removal of the gates at the RBDD, located near Red Bluff, California, allows for year-round passage of salmon and diminishes predation risk that used to occur in the back eddies that would form behind the dam gates. The new pumping station, located upstream of the dam, allows for

continued water service to residents in the southern part of the state, while providing "fish friendly" screening for passing juvenile salmonids. The cost to build the pumping plant is estimated at 200 million, which will be primarily funded by the Bureau of Reclamation (BOR) and the Tehama-Colusa Canal Authority (BOR 2009).

- The SJRRP is estimated to cost about $900 million dollars and will restore flows to the upper San Joaquin River and reintroduce CV spring-run Chinook salmon (currently listed as threatened under the federal Endangered Species Act (ESA). Funding comes from the Central Valley Project Improvement Act (CVPIA), the state of California and the San Joaquin River Restoration Fund. The SJRRP is a direct result of a Settlement reached in September 2006 and approved by the Federal Court in October 2006 after an 18-year lawsuit to provide sufficient fish habitat in the San Joaquin River below Friant Dam near Fresno, California. Settling parties included U.S. Departments of the Interior and Commerce, the Natural Resources Defense Council, and the Friant Water Users Authority (SJRRP 2011).
- BDCP is designed to achieve the co-equal goals of providing for the conservation and management of aquatic and terrestrial species, including the restoration and enhancement of ecological functions in the Sacramento-San Joaquin River Delta, and improving current water supplies and the reliability of water supply delivery conveyed through the State Water Project and the Central Valley Project (BDCP 2010).

Projected cost estimates are near 12.7 billion and would be financed by water users and the state of California (Lien-Mager 2010).

- The NMFS Biological Opinion issued June 2009 (now in remand) determined that the proposed project is likely to jeopardize the continued existence of threatened and endangered Central Valley anadromous fish species. As part of the opinion NMFS provided a number of ways Reclamation can operate the water system to benefit the species, including increasing the cold water storage and flow rates. Such methods will enhance egg incubation and juvenile fish rearing, as well as improve the spawning habitat and the downstream migration of juvenile fish. Changing water operations will impact an estimated five to seven percent of the available annual water on average moved by the federal and state pumps, or about 330,000 acre feet per year. In addition, the opinion calls for the bureau to develop a genetics management plan and an acoustic tagging program to evaluate the effectiveness of the actions and pilot passage programs at Folsom and Shasta reservoirs to reintroduce fish to historic habitat (NMFS Personal Comm. 2012).

Research Questions/Methods

Methods

There are a relatively small number of experts who have been working on salmon science and policy for many years. I informally contacted colleagues to create a list of experts who were both knowledgeable about CV salmon recovery and had many years of

experience with this issue. From this list, I contacted as many of these as possible. Most of these experts work for organizations that are deeply engaged in salmon science and policy. Obtaining unbiased, honest answers to my questions was a concern because their employers are often active in political debates about the future of wild salmon; there may be overt or covert pressure to stick to the employers' policy goals. University employees who are experts on salmon science and policy often depend on grants from organizations with a vested interest in the outcome of salmon policy debates. The basic methodology that I used was to solicit input from such experts with the assurance that their identity would not be disclosed and their responses would be anonymous. Others have found that publicly stated opinions from such experts can differ substantially from opinions given when promised anonymity (Lackey *et al.* 2006). To assure that my survey questions would not put any respondents in jeopardy, my survey was reviewed and approved by OSU's Institutional Research Board #5257.

Questions

Seven questions were asked of these prominent professionals from federal, state and local agencies, non-governmental organizations (NGO's) and universities. Interviews were conducted in person, over the phone, or by e-mail. A majority of the participants chose to respond by e-mail. These professionals are deemed to be highly credible and well known for their understanding of salmon biology, ecology and policy. Most have published numerous peer reviewed literature articles and hold (or held) high level positions within their organizations. Respondents have 10-35 years, with most respondents falling somewhere in the middle. These individuals were chosen based on the reasoning that their experience far exceeds any one person's, and collectively they

would be the best to gauge what the future of wild salmon in the CV would most likely look like. A total of 33 people were questioned, 26 of whom provided responses. Of these, 13 held a doctorate degree (50%), 12 held a master's degree (46%) and 1 held a bachelor's degree (4%). Participants' backgrounds varied, with most having worked throughout the CV basin for many years, and were very familiar with the situation. Others have dealt with very similar issues in Oregon and Washington. The individuals will remain anonymous per internal review board (IRB) protocols established through Oregon State University and a commitment to participants as to how the information they provided will be disseminated. Providing anonymity was intended to allow respondents to be open, truthful, and not worry about possible repercussions from their current employer or possible feedback from colleagues or others if their personal viewpoint differs from the rest of their agency/university/organization. Questions were analyzed subjectively. Respondents were allowed to answer however they chose to the questions posed.

The questions asked were as follows:

1) *Given current policies and trajectories, what is the <u>most likely</u> status of wild salmon in the Central Valley in 2100?*

2) *What would it take (be specific) to restore and sustain significant, sustainable (a third of historical) runs of wild salmon in the Central Valley through 2100?*

3) *What, exactly, does society need to do to change the downward trajectory and restore runs to significant, sustainable levels?*

4) *Is it possible to restore wild salmon in the CV while supplemental stocking from hatcheries continues?*

5) *Is it possible (realistically) to restore wild salmon in the CV while still harvesting adults?*

6) *How likely, in your opinion, is society to reverse these major policy drivers relative to wild salmon? This is not what anyone hopes will happen, but what is your best guess.*

7) *Are current and likely planned recovery efforts likely to make much difference in the grand scheme of things?*

Results

Question 1- *Given current policies and trajectories, what is the most likely status of wild salmon in the Central Valley in 2100?*

Answer - As with all questions, it is important to stress that the focus was on *wild* salmon – those resulting from parents who spawned naturally in natural habitat. Salmon originating from hatcheries are not included. The nearly universal conclusion from the 26 experts was that few, if any, wild salmon populations will persist in the Central Valley in 2100. In short, current policies and trajectories are leading to the demise of wild salmon in the Central Valley. Specifically, 20 of the 26 respondents (77%) concluded that wild salmon will not be present in the CV by 2100. 1 of the 26 (4%) believed that wild populations would be larger than they are now, and 5 of the 26 (19%) believed that extirpation was possible, but still had some hope based on current recovery efforts.

The following is a sample selection of responses:

> *"Poor to non-existent. I think climate change will be the main determinant of whether remnant populations of wild salmon remain in the Central Valley."*

> *"Marginal at best, but also depends on our definition of 'wild'."*

"Complete extinction of individual stocks is more likely in the CV than in most places due the water demands, power demands, etc. that completely blocks access and/or dries up streams."

"Even among the agencies managing the Central Valley salmon there is no consensus on the value of historical or wild runs of fish. (California Department of Fish and Game is just as happy with hatchery fish, as wild fish----and what is really the difference?"

The one positive outlook was this:

"I would project the major salmon runs to be surviving and somewhat more robust by 2100. This projection assumes that the policies and practices of the past decade have been adjusted in light of increased scientific information, and that the social will to preserve and rebuild the runs will continue. I think the key question is whether we will soon identify and address the major factors limiting recovery."

Question 2 - *What would it take to restore and sustain significant, sustainable (a third of historical) runs of wild salmon in the Central Valley through 2100?*

Answer - Most respondents recognized that there were a multitude of causes of the historical decline and changes would have to take into account most, or perhaps all, of these in order to restore and sustain significant, sustainable runs of wild salmon in the Central Valley through 2100. Some were to eliminate harvest 4% (1/26), reform hatchery practices 12% (3/26), fix the Delta 4% (1/26), habitat issues 4% (1/26), remove dams 4% (1/26) and reduce population growth 8% (2/26). 73% (19/26) named multiple issues and could not point to any one in particular.

Here is a representation of some of the replies:

> *"I don't believe it is feasible, either economically or socially, to contemplate restoration to a third of historical levels. One can forecast by hind casting. The problem and the issues are not new: we have known of them for decades."*
>
> *"Less (human) population growth, critical needs of salmon first"*
>
> *"Valley wide analysis of total water consumption and modeling to determine appropriate levels of water use for environmentally and economically sustainable agriculture"*
>
> *"Remove dams, decrease demands from human population".*
>
> *"If wild runs are preferred, the elimination of harvest will be required, salmon habitat will have to be preserved or restored, the role of hatcheries will need to be changed, and agricultural practice will have to change significantly."*
>
> *"Reformation of the hatchery system - not eradicating the hatchery system, but rather establishing best practices within the hatchery system to produce genetically diverse fish with the intention of re-establishing them as wild populations over time. Also, solving the Delta problem, it is a singular bottleneck for all Central Valley populations. Lastly, thinking way ahead about the impact of a changing Sierra snowpack on water supply, water supply reliability and the environment and then subsequently in solutions to these challenges."*

Question 3 - *What, exactly, does society need to do to change the downward trajectory and restore runs to significant, sustainable levels?*

Answer- All the suggested actions to change the long-term downward trajectory in wild salmon involved major modifications to current policies. These changes would be costly and politically divisive. Many responses came back to human population growth and the impacts this will have on the resource. Other responses noted society's unwillingness to make salmon recovery a social and economic priority. Californians have a lot less emphasis on the culture surrounding salmon than is typical of the Pacific Northwest. One respondent also suggested rewarding agricultural and municipalities for conserving, not overusing our water resources. Planning for climate change and the ability for policies to

aid in salmon recovery at all due to these assumed pressures also seemed to be a consistent theme.

Some specifics were as such:

> *"to give salmon the best chance of dealing with the effects of climate change I think society would need to: (1) curtail additional cumulative pressures on salmon (fisheries, agricultural demands on water, pumping), (2) invest in actions to improve / restore habitats (restore flows to San Joaquin, use technologies to cool river temperatures during migration)."*
>
> *"Make a concerted effort to save the species - and it will require difficult choices. To be effective at things like efficient water use, energy efficiency and improving water quality I think it will require potentially unpopular changes through fed, state and local legislation. People should be reward for conserving not overusing. We may need to make fundamental changes in the way we manage land - like not growing crops in areas that require excessive irrigation and requiring buildings to use the highest energy and water efficiency measures available. "*
>
> *"Maintain functional habitat, which will require human population control, reduction in the total footprint of each individual, reservation of watersheds to provide for human needs at the expense of other natural resources (triage)."*
>
> *"Stop growing water intensive crops, i.e. rice and cotton. Create a valley-wide land planning initiative."*

Question 4 - *Is it possible to restore wild salmon in the CV while supplemental stocking from hatcheries continues?*

Answer - The consensus was that current hatchery practices would have to be dramatically changed to even have a chance of restoring and sustaining wild salmon in the Central Valley. About half the respondents went further and concluded that supplemental stocking would have to be terminated if wild salmon were to be restored. It was clear from all respondents' answers that there are obvious deficiencies in the current way hatcheries are being managed in California in relation to restoring wild

salmon. Many thought that hatcheries need to at minimum implement 100% tagging of hatchery stock. Other suggestions were to relocate hatcheries to the mouth of river systems to reduce genetic mixing of hatchery stock with natural producing stock.

Here is a sample of some of the participants' responses to this question.

> *"I don't think so. Hatcheries support fisheries, which impose additional pressures on wild populations, thus making it more difficult for them to recover. Moreover, the genetic mixing between hatchery and wild salmon makes it more difficult for us to define / identify a truly wild salmon."*
>
> *"Yes, but hatcheries and harvest will need to be managed differently"*
>
> *"Yes. In fact, it may be the only way if one is going to allow for consumptive harvest of salmon. But, it will be necessary to design and operate the hatcheries in such a way that they do not damage the wild stocks."*
>
> *"No, salmon farming should produce salmon for consumption as a food and use hatcheries only to create brood stock for experiments in restoring lost runs to restored habitats."*
>
> *"...it matters a great deal whether the hatchery stock closely shares the genetics of any co-located or spatially overlapping ESUs. If it does not, and there is the nearly inevitable escapement of hatchery fish to the wild, then there is a high likelihood of genetic introgression. This obviously has an adverse impact on the fitness of the naturally spawning fish, likely resulting in maladaptation in the next generation. On the other hand, if the hatchery fish have identical genetics, there may be less of an issue, and potentially a restoration benefit in some supplementation. In general, I think there are good examples available of the beneficial use of hatchery fish, sometimes captive broodstocks, in rebuilding runs, and, on the other hand, examples of where the presence of hatchery fish with non-local genetics were devastating to local runs. The middle ground, use of closely-related hatchery fish as part of a continuing supplementation program, is still under study, with mixed results thus far."*

Question 5 - *Is it possible (realistically) to restore wild salmon in the CV while still harvesting adults?*

Answer - Overall, the respondents were skeptical about whether harvest of hatchery-bred fish could continue without hindering recovery of wild salmon. The continuing harvest of hatchery bred adult salmon was recognized to be a major stumbling block to recovering wild salmon.

Some of the respondents pointed out the irony that salmon are still being allowed for commercial, recreational and/or tribal harvest purposes at all, since they are in such dire conditions and they are the only species listed under the ESA that is still being caught for consumption purposes. A reoccurring theme of creating a terminal fishery (moving fisheries usually to the mouth of rivers or bays where the targeted species is returning to spawn) came up often in responses to this question.

Specific comments included:

> *"In the near term I do not think it possible to have both harvest and recovery of wild salmon."*
>
> *"It is often possible to rebuild naturally-spawning runs where there is slight harvest pressure, and very difficult to do so where there is intensive harvest pressure. First, where tribal treaty rights are involved, maintenance of some level of harvest may be essential to partially fulfill the expectations of the treaty, and maintain tribal culture. Secondly, and often overlooked, is the fact that the opportunity for some level of harvest, especially, sport harvest, may help sustain and support the recovery efforts needed to rebuild naturally-spawning runs."*
>
> *"No. We cannot continue harvest rates AND restore the species. It would be a good experiment to quit harvesting for an entire generation (3-5 years) and see what happens. This is one of those arguments where folks are typically in favor of restoring salmon but not of cutting of harvest."*

Question 6 - *How likely, in your opinion, is society to reverse these major policy drivers relative to wild salmon?*

Answer – Nearly universally, the respondents answered that society is unlikely to make the shifts in policy necessary to restore wild salmon in the Central Valley.

Participants had this to say about it.

> *"I believe it very unlikely that society can / will take sufficient action to restore wild salmon in the Central Valley.*
>
> *"Society will reverse the policy drivers when they see the benefits of restoring wild salmon as greater than the costs. Currently, the commercial focus on salmon harvest produces very pricey fish for a very narrow set of consumers."*
>
> *"Since this issue is entangled with political and economic pressures I don't think any major policy drivers are likely to change soon. And by the time they do change, it will likely be too late for salmon."*

Question 7 – *Are current and likely planned recovery efforts likely to make much difference in the grand scheme of things?*

Answer: The majority of the respondents (most of whom were aware of the current ongoing efforts) were of the opinion that current and likely planned recovery efforts would not make much difference in the overall, long-term trajectory of wild salmon in the Central Valley.

> *"Based on a goal of restoring salmon to 1/3 of historical abundance, I do not believe that the current recovery efforts related to habitat manipulations, hatchery, and harvest will make much of a difference to the long term status of wild salmon in the Central Valley."*
>
> *"No. Society will not take out key dams; it will need increasingly more water; it will generate more impervious surfaces and alter more of the landscape...*

"No. The current efforts are more of a holding action until the next election or until one retires"

"I think the problems are difficult, but I'm optimistic that they will be sufficiently addressed for most, if not all, of the runs to be sustained and recover to some degree."

"Recovery efforts will make a difference. The difference probably will not be what the designers of these recovery efforts expect."

Conclusion

After carefully analyzing the confidential responses from 26 nationally recognized experts on salmon science and policy, I conclude that wild salmon in the Central Valley will be largely eliminated by 2100 unless drastic and pervasive changes in current policies are implemented soon. Salmon must have the cold water, clean gravel, estuaries, and so on. Even then, the future of Central Valley wild salmon is tenuous. Salmon have been subject to altered hydrographs, habitat loss, genetic stress, fishing pressures, compromised water quality, competition with introduced species, *etc.* and this outlook has no foreseeable change except to become ever-increasing due to an escalating human population and their associated resource demands as well as the additional stressors climate change will create. The respondents were nearly uniform in their conclusion that current policy projections through this century show no indication that the current course will lead to recovery of wild salmon runs.

Effective policy choices are based on a candid assessment of reality. Based on a cross section of expert opinion, I have provided such a candid assessment of the future of wild salmon in the Central Valley of California, given the current situation and factoring in the most likely future choices. If society wishes to alter this most likely continued

downward trajectory for wild salmon, the path forward has been identified. It would require making policy choices that are not easy, quick, or cheap, but something dramatically different needs to be done if society wishes to have significant, sustainable runs of wild salmon in the Central Valley in 2100.

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