Status of Chinook salmon, steelhead and green sturgeon in the Central Valley

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1 Legal status

California's Central Valley watershed hosts a diverse assemblage of anadromous fishes, including Chinook salmon populations, steelhead populations, and a population of green sturgeon. The distribution, abundance and diversity of these species has been greatly curtailed, however, by more than 160 years of human impacts, including the effects of gold mining, conversion of riparian and floodplain habitats to agriculture and urban use, and the development of the watershed for water storage and delivery, flood control and navigation.

The long decline of Chinook salmon in the Central Valley reached a crisis point in the 1980s when winter-run Chinook salmon declined to a few hundred individuals, down from more than 100,000 in the late 1960s. This, along with other declines in salmon along the west coast, initiated a series of status reviews and eventual listings of evolutionarily significant units (ESUs) [1] of salmon under the federal Endangered Species Act (summarized in Table 1).

The southern DPS of green sturgeon was listed as threatened in April 2006. Adams et al. (2007) provides a status review.

2 Viability of salmon populations

The original status reviews were motivated largely by declines in abundance. Low abundance is one risk factor for extinction, but as pointed out by McElhany et al. (2000), salmon populations also need adequate productivity, spatial structure and diversity to persist. High levels of abundance (such as might be achieved with hatchery production) may not mitigate extinction risk adequately if a population has limited spatial structure, low productivity, or little diversity. The so-called "viable salmon population" (VSP) parameters of abundance, productivity, spatial structure and diversity can be viewed hierarchically, with functional and diverse natural habitats providing the basis for viability (Fig. 1).

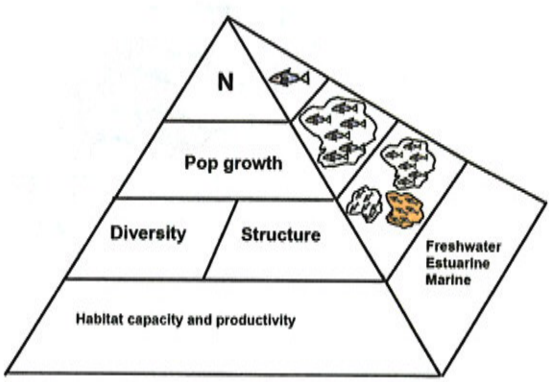

Figure 1: The viability of a salmon population depends ultimately upon functional habitats.

Table 1: ESA status of salmon ESUs in the Central Valley.

ESU	Status
Sacramento River winter-run Chinook	Endangered (Jan 1994)
Central Valley spring-run Chinook	Threatened (Sep 1999)
Central Valley fall-run Chinook	Candidate (Sep 1999)
Central Valley steelhead	Threatened (Mar 1998)

3 Viability criteria

Recovery plans require objective measureable criteria that can be used to determin when listed species can be removed from the list of endangered species. In 2003, NMFS formed the Central Valley Technical Recovery Team (CVTRT) to come up with viability criteria for listed salmonids in the Central Valley.

The CVTRT first described, as far as possible, the historical population structure of the listed ESUs. The historical ESU was presumed viable, so its structure offers a useful reference point for viability assessments. The CVTRT considered the dispersal capacity and spatial distribution of fish and habit to create lists historical populations grouped in diversity units that share similar environmental conditions, especially hydrologic regimes (Lindley et al. (2004, 2006); Fig. 2).

The CVTRT then developed simple criteria for assessing and specifying viability of individual populations, based on work by Allendorf et al. (1997) that is ultimately derived from IUCN Red List criteria. These are presented in Table 2. Based on ideas of representation and redundancy, the CVTRT reasoned that for an ESU to be viable, it needed to have at least two independent viable populations in each diversity unit (Lindley et al. (2007) describes the complete assessment framework).

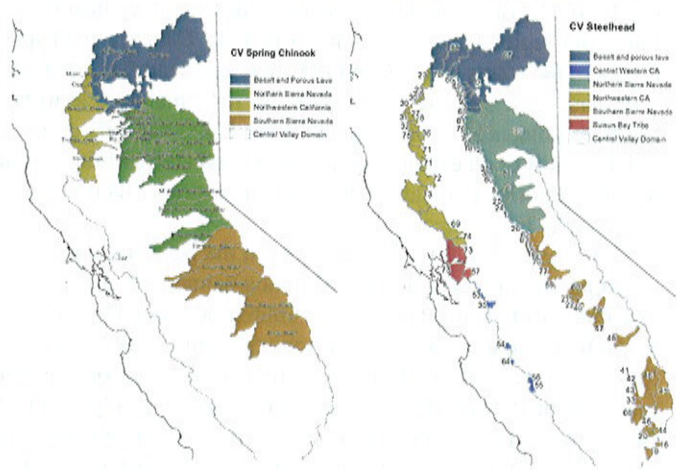

Figure 2: Population structure of spring-run Chinook (left) and steelhead (right). Winter-run Chinook salmon (not shown) occurred historically as four populations in the Basalt and Porous Lava region.

[1] An ESU is a Pacific salmon population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species. ESUs are treated as distinct population segments by NMFS under the ESA.

Table 2: Criteria for assessing the level of risk of extinction for populations of Pacific salmonids. Overall risk is determined by the highest risk score for any category. Reproduced from Lindley et al. (2007) based on Allendorf et al. (1997).

	Risk of Extinction		
Criterion	High	Moderate	Low
Extinction risk from PVA	$> 20\%$ within 20 years	$> 5\%$ within 100 years	$< 5\%$ within 100 years
	– or any ONE of –	– or any ONE of –	– or ALL of –
Population size[a]	$N_e \leq 50$	$50 < N_e \leq 500$	$N_e > 500$
	–or–	–or–	–or–
	$N \leq 250$	$250 < N \leq 2500$	$N > 2500$
Population decline	Precipitous decline[b]	Chronic decline or depression[c]	No decline apparent or probable
Catastrophe, rate and effect[d]	Order of magnitude decline within one generation	Smaller but significant decline[e]	not apparent
Hatchery influence[f]	High	Moderate	Low

[a] Census size N can be used if direct estimates of effective size N_e are not available, assuming $N_e/N = 0.2$.
[b] Decline within last two generations to annual run size ≤ 500 spawners, or run size > 500 but declining at $\geq 10\%$ per year. Historically small but stable population not included.
[c] Run size has declined to ≤ 500, but now stable.
[d] Catastrophes occurring within the last 10 years.
[e] Decline $< 90\%$ but biologically significant.
[f] See Figure 1 of Lindley et al. (2007) for assessing hatchery impacts.

4 Application to ESUs

Application of the CVTRT viability assessment framework to listed ESUs confirms the tenuous status of these ESUs and clarifies the issues that need to be addressed to recover them. While the status of extant populations of winter-run and spring-run Chinook is generally acceptable, the ESUs are clearly at risk of extinction due to inadequate representation and redundancy (Fig. 3). Winter-run Chinook salmon are represented by a single population that spawns outside of its historical spawning range; all four historical populations have been extirpated. Spring-run Chinook salmon retain three low-to-moderate-risk populations, but they are all in the Northern Sierra Nevada region; populations in two other historically-important regions have all been extirpated. Data are inadequate to assess the status of the Central Valley steelhead ESU, but what little data exist indicate high extinction risk (mainly due to high hatchery influence). Conservation of the ESUs depends on securing the status of all extant populations immediately, while working towards restoring populations to a greater portion of their historical range in the longer term.

Lindley et al. (2007) also considered the potential impact of a warming climate on spring-run Chinook salmon. In summer, the distribution of spring Chinook is limited at lower elevations by warm temperatures; as climate warms this limit rises in elevation. Significant warming will greatly curtail the amount of oversummering habitat available to spring-run Chinook, possibly leading to further population losses (Fig. 4) . Mitigating climate warming will require restoring access to high-elevation refugia that are currently behind impassable dams.

5 What about green sturgeon?

Much less is known about the status of green sturgeon or the threats facing them than salmon. NMFS has begun developing a recovery plan for green sturgeon that will synthesize available information and prioritize conservation actions.

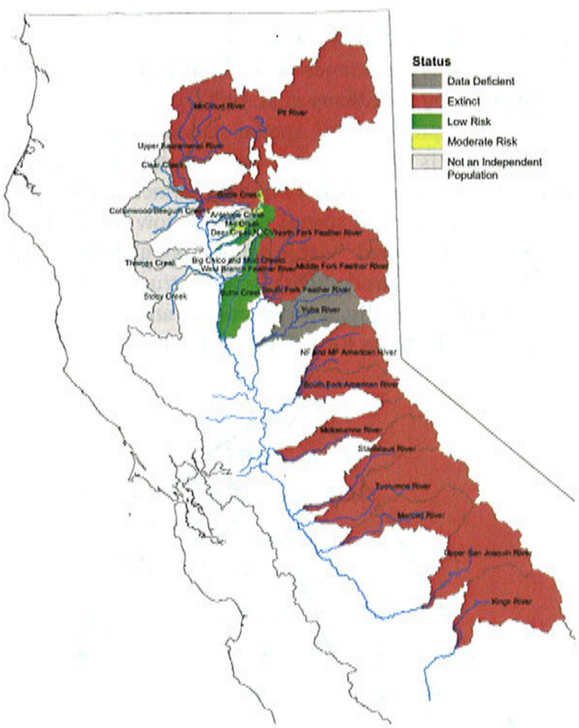

Figure 3: Status of spring-run Chinook populations. All four historical winter-run Chinook populations have been extirpated; data are insufficient to assess the status of steelhead populations, with the exception of populations associated with hatcheries, which are all likely at high risk of extinction.

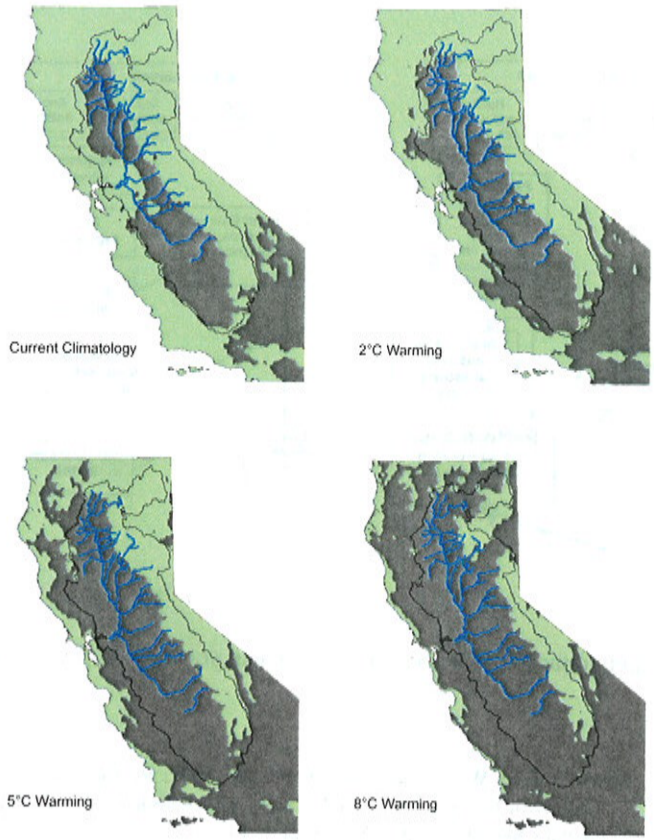

Figure 4: Effect of climate warming on the potential distribution of spring-run Chinook. Blue lines indicate historical range of spring-run Chinook. Gray areas indicate areas of excessive temperature.

6 What is needed to recover ESUs?

The glaring problem for all of the listed ESUs is the drastic curtailment of their spawning habitat by impassable dams, especially those of the state and federal water projects. The engineering and operations of the water projects also have negative effects on habitats that remain accessible below the dams, including on the timing, quantity and quality of water flows within the river network; on channel forms and the subsequent availability of shallow-water and floodplain rearing habitats and spawning habitats; and the distribution of nonnative species that prey upon or compete with native species. The net effect of these changes has been to reduce the complexity of habitats available to anadromous fish, extirpating many populations and undermining the viability of those that survive.

Improving the status of Central Valley salmonids (and sturgeon) therefore requires improving the function of habitats, including functions and locations that extant populations currently use, as well as functions and locations that were likely used historically (Fig. 5). From this perspective, actions that allow the river to create and maintain habitats for salmon through natural or semi-natural geomorphic processes (e.g., levee setbacks, more natural hydrographs) are more likely to be effective than engineering solutions that further constrain habitat diversification (e.g., bubble curtains, mechanical gates, hatcheries).

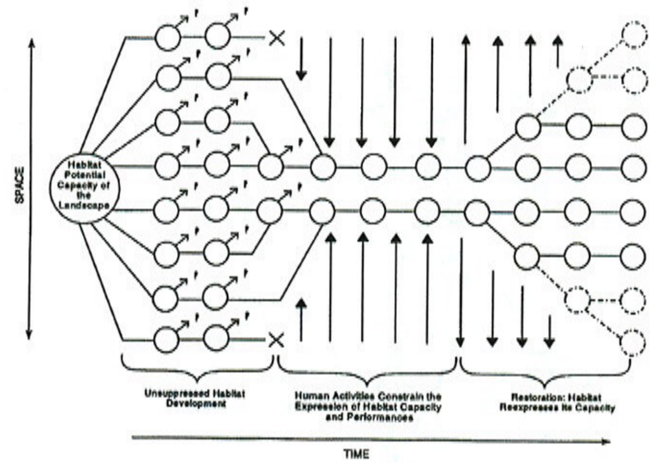

Figure 5: Human actions suppress habitat diversity and performance (inward arrows), which constrains diverse developmental pathways (circles). Restoration occurs when habitat capacity is re-expressed (outward arrows); less than full restoration may preclude re-expression of certain historic pathways (dashed lines). From Ebersole et al. (1997).

7 Challenges

Biological and societal problems combine to inhibit progress towards conservation and recovery of anadromous fish in the Central Valley. Anadromous fish have complex life histories that exploit numerous habitats within several ecosystems, and the linkages between societal needs, impacts on habitats, and the response of the fish are complex (Fig. 6). The efficacy of any one conservation action may be contstrained by conditions elsewhere in the basin or by the lingering effects of previous actions, and it is difficult to determine the relative importance of the many causes for decline and to predict or detect the response of populations to management actions. This means resource managers struggle with enormous uncertainty.

The fragmentation of jurisdictions and authorities among agencies and regions with conflicting interests and constituencies makes a difficult management problem even harder. Not surprisingly, there are serious conflicts among interest groups, and currently these are mostly addressed in the legal arena. Lawsuits are unlikely to be the most efficient or effective way to manage ecosystems.

Ecosystem-based management and ecological risk assessment (EBM-ERA, *sensu* Gentile et al. (2001)) can guide restoration actions in the face of ecological uncertainty and competing interests. At the core of this approach are hierarchical conceptual models (such as Fig. 6) that depict the scientific understanding of the linkages between human actions and biological endpoints. These models help identify trade-offs, actions to take, and endpoints to measure, so that over time, agencies and stakeholders can reduce their uncertainties and move with increasing confidence towards their shared vision of an ecosystem that can reliably deliver the suite of services that society desires. Moving from lawsuit-driven ecosystem "management" to EBM-ERA will require stakeholders and agencies to work together rather than against each other, and this change may be the biggest challenge among many on the path to sustainable water and environmental management in the California Bay-Delta.

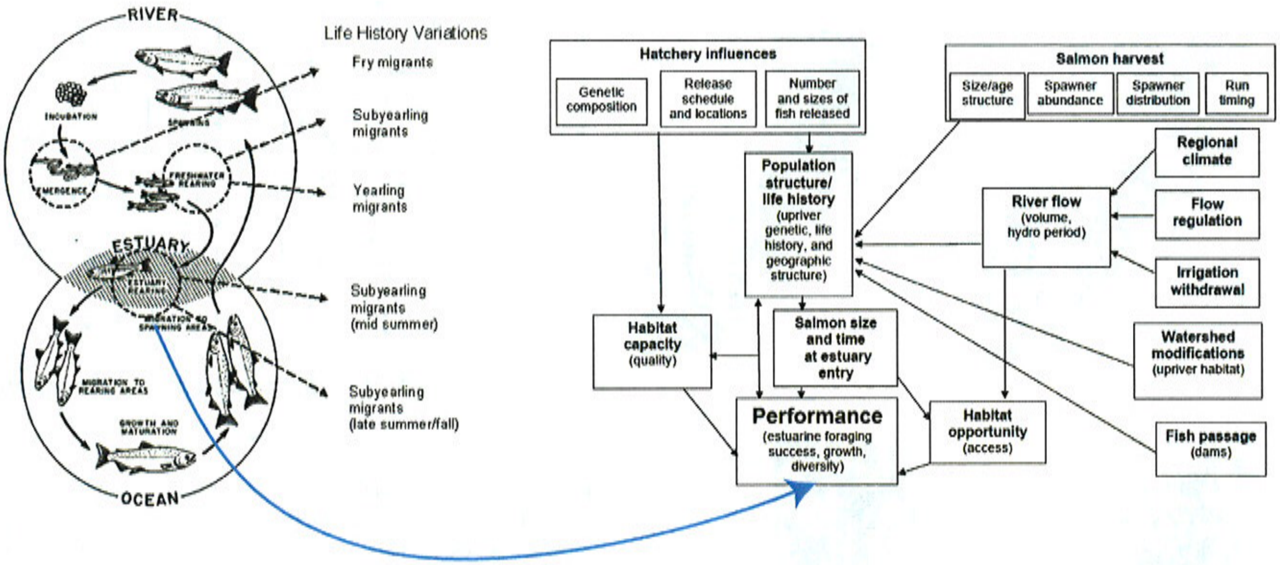

Figure 6: Conceptual model of how various human actions influence performance of juvenile salmon in an estuary. Redrawn from Bottom et al. (2009) and Bottom et al. (2005).

8 Summary

- Central Valley salmon ESUs are threatened with extinction.
- Water project facilities and operations have negative effects on fish habitat, with cascading effects on spatial structure, diversity, productivity and abundance of populations.
- Improving in-stream flows and curtailing exports may be necessary to conserve salmon, but will not be sufficient.
- An ecosystem perspective is needed to understand how human activities impact salmon.
- Adaptive management is needed to reduce risks.

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