Ecosystem Restoration: Fall-Run Chinook Salmon in the Tuolumne River

What is this Indicator and Why is it Important?

This indicator reports the escapement (the estimated number of adult salmon escaping ocean harvest and inland recreational fishing and successfully returning each year to spawn) of adult fall-run Chinook salmon in the Tuolumne River. Central Valley fall-run Chinook is a candidate species for listing under the federal Endangered Species Act. Because of concerns about its status, it was targeted for restoration efforts, with the same doubling targets applied to other runs (see Technical Note and Systemwide Central Valley Chinook Salmon indicator). As with other runs, this indicator focuses specifically on the instream conditions that are the locus of restoration efforts and that may influence the success of four key phases of the species' survival and reproduction in the Tuolumne River (see conceptual model in Figure 1). This indicator alone is clearly not sufficient to evaluate progress toward the AFRP doubling targets. Any such evaluation would necessarily include a broader range of indicators and information (see Technical Note). However, measures of instream conditions are a valuable part of this broader portfolio of indicators and can provide important insight into the progress of specific restoration actions and the effect of instream conditions on salmon populations.

What Has Happened to Affect the Indicator?

The Tuolumne fall run has been affected by a combination of factors related to habitat degradation and water quality and supply. Historic instream and floodplain mining, encroachment on the riparian zone, and increased water temperatures due to drought and water diversions have combined to degrade habitat for both adult and juvenile salmon. The La Grange Dam, one of the oldest dams in California, greatly restricted flows needed for upstream adult and downstream juvenile migrations and prevented the movement through the system of the larger sediment necessary for riffle formation (i.e., spawning gravel). In addition, the creation of the dam blocked salmon from a major portion of its spawning habitat. The construction of the New Don Pedro Dam (upstream of the La Grange Dam) in the late 1960s for hydroelectric production, irrigation storage, and flood control complied with conditions in a Federal Energy Regulatory Commission (FERC) settlement agreement that defined minimum flows as well as pulse flows for spawning and rearing purposes below both dams. These flows were intended to minimize the impacts of dam construction and operation on salmon habitat.

Despite these flow requirements, there are times when rapid changes in flows, or conflicting demands for water during dry years, cause reduced flows that both restrict salmon movement and lead to occasional temperature increases that are hazardous to salmon. In addition, water management actions have shifted peak spring flows needed for juvenile emigration from the historical June-July period to the current April-May period. This means that only very early spawners will spawn successfully, with potential (but unknown) consequences for the genetic structure of the stock. In addition to these factors that operate within the Tuolumne River, the run has been affected by significant losses at the Delta water export facilities. Like all runs from the south (or San Joaquin River) side of the Central Valley, the Toulumne fall run has a higher juvenile mortality during passage through the Delta than do runs entering the Delta from the north (or Sacramento River side). Finally, past gravel- and gold-mining left a legacy of large pits that have altered the river's morphology and flow and that harbor populations of predators (such as large mouth black bass) that may reduce juvenile survival during their spring emigration.

Restoration actions in the Tuolumne River (Figure 2) have therefore focused on managing flows to ensure suitable water temperatures during critical periods, adding spawning gravel at several locations, constructing and maintaining the levees that isolate the large mining pits from the river, filling in these pits, and restoring a more natural morphology to the river, particularly in terms of functional floodplains.

What Do the Data Show?

The data show (Figure 2) that adult fall-run Chinook escapement has fluctuated widely, alternating between periods of high escapement and periods of low escapement, with no trend readily apparent. However, the data do show that the lowest escapement on record occurred in the early 1990s and escapement numbers have increased steadily since then. Many of the recent years have been relatively wet, which may have contributed to higher instream escapement during following years, given the strong relationship between spring flow in the San Joaquin basin and subsequent adult escapement two years later. Further, changes in ocean harvest regulations since 1995, developed to protect listed stocks, have also resulted in lower ocean harvest rates on fall-run Chinook, which may have contributed to the higher instream escapements observed since that time. Temperature stresses increased in 2001, due primarily to a drop in flows to levels more characteristic of the early 1990s.

The data show (Figure 2) that the increased escapement in the latter half of the 1990s followed restoration actions, beginning in the early 1990s, that improved flows and temperatures in most years during critical migration periods, provided additional floodplain habitat for juveniles, and reduced predation on juveniles during the spring emigration. However, this simple correlation does not amount to clear evidence of the effects of these restoration actions. As the preceding paragraph, as well as the Discussion and the Technical Note, make clear, it will take between 10 and 25 years, to begin to reliably assess the longer-term success of restoration efforts.

Discussion

The reduction of spawning habitat in the system and the interruption of required migration flows (due to the construction of the La Grange dam) reduced the long-term sustainability of the population by decreasing the overall reproductive potential of the system. Similarly, the large mining pits and the increased predator populations they harbor may have increased the mortality rate of the juveniles produced in the remaining spawning habitat. The amount of floodplain habitat also affects juvenile growth and survival by providing refuges from predators and flow, as well as increased food sources and habitat diversity. Restoring adequate ecosystem functions is important for this run, which, because it is near the southern extent of the Chinook's range, is particularly sensitive to inreased temperature and other stresses.

Returns of adult fall-run Chinook salmon are influenced by factors within the Tuolumne River watershed, in the San Joaquin River and its delta/estuary, and in the Pacific Ocean (see Figure 1). During the adult upstream migration, in the spawning areas, and during the juvenile emigration phase, temperature—which is influenced by water releases from the New Don Pedro and La Grange Dams—is a key factor that can affect reproduction and survival. In the larger San Joaquin River-bay-delta system, the timing and extent of high temperatures, the availability of food (in the river), the presence of sufficient transport flows (e.g., enhanced in the Delta by the Vernalis Adaptive Management Plan (VAMP)), predation, and entrainment by export pumps (managed bo somem extent by the VAMP and the barrier across the Head of Old River) all combine to affect the success of outmigration. In the Pacific Ocean, conditions related to shorter-term events (such as El Niños) and to longer-term shifts in ocean climate (such as the Pacific Decadal Oscillation) also affect overall patterns of salmon abundance. Changes in ocean harvest regulations since 1995 have also significantly changed harvest rates on fall-run Chinook. These factors can interact in

complex ways and the degree to which they become limiting, either individually or in combination, depends on their relative severity and on the state of the population at any given time.

This wide range of influences contributes to year-to-year variability in escapement and to longer-term fluctuations in population levels. Because of these sources of variability, it will take some time to determine whether the increase in escapement in the 1990s is part of a long-term increasing trend or merely the upward-trending portion of another cycle of abundance such as those that have occurred since the 1950s.

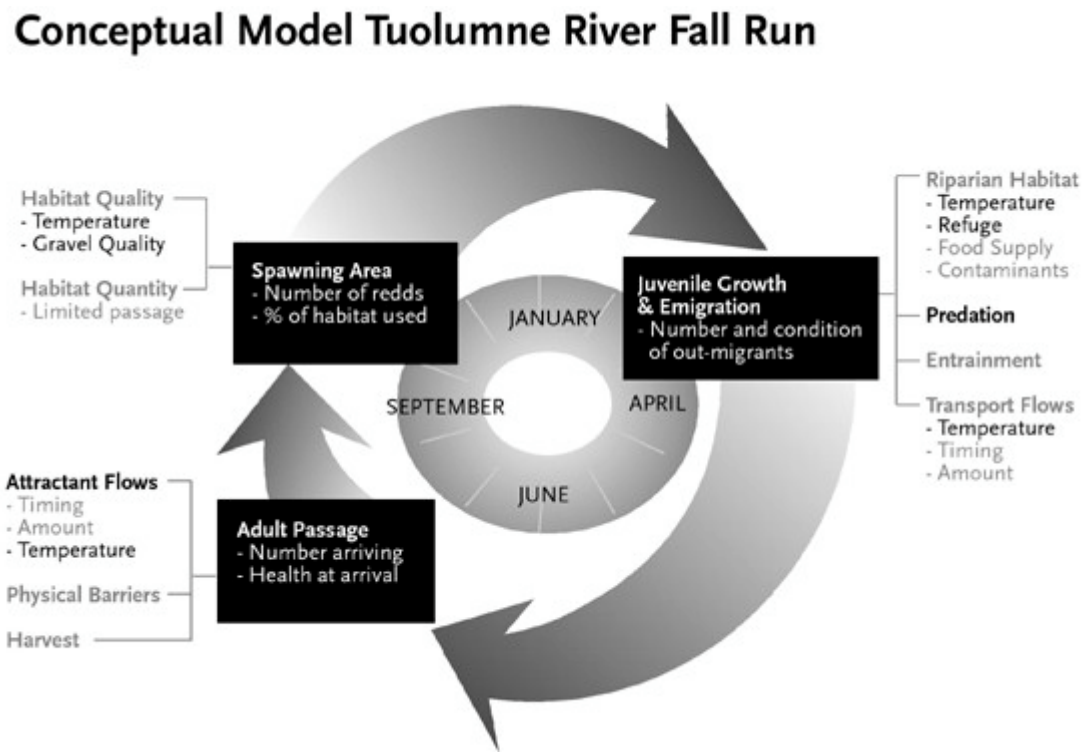

Figure 1. Conceptual model of the Tuolumne River fall run, emphasizing factors and processes that operate within the Tuolumne River itself. Elements in bold text have a larger influence on overall success of the run. The ocean life-history phase is not included, and processes in the delta are subsumed under juvenile growth and emigration.

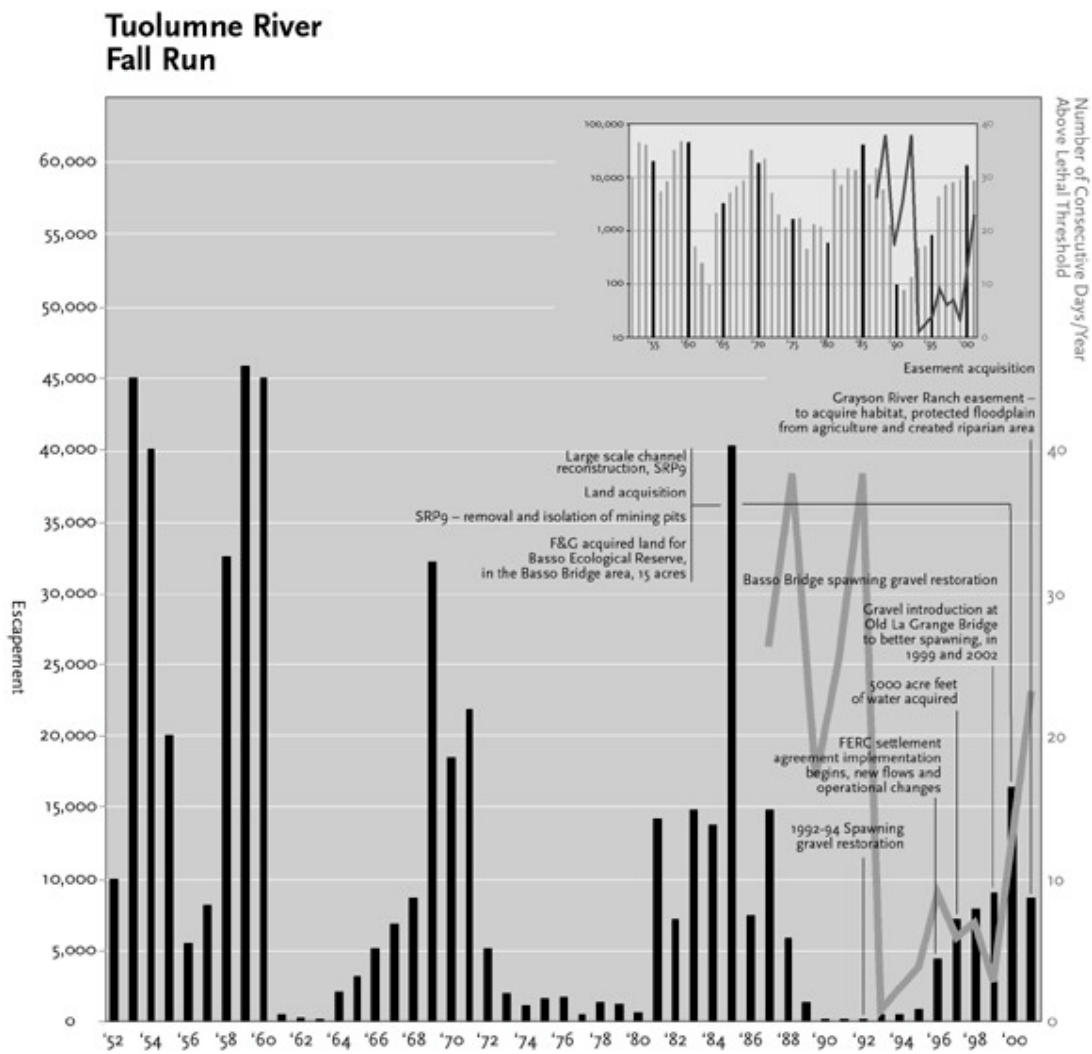

Figure 2. Long-term trend in escapement (vertical bars) shown in the context of key restoration actions and the number of consecutive days in each year's migration periods that temperatures were above the 65° F thresholds (continuous line).

Technical Note: Fall-Run Chinook Salmon on the Tuolumne River

The Indicator

Goal: See Technical Note for the Systemwide Central Valley Chinook Salmon indicator.

Response Time: See Technical Note for the Systemwide Central Valley Chinook Salmon indicator.

The Data

Data Collection: Escapement data on the Tuolumne River extend back to 1940. Data represent a combination of visual counts at the Modesto Dam fish ladder, visual counts of spawning salmon and carcasses, and, beginning in 1973, mark-recapture sampling on carcasses. The Turlock Irrigation District gathers temperature data at several points along the river.

See Technical Note for the Systemwide Central Valley Chinook Salmon indicator for further discussion of methods of estimating escapement and gathering flow and temperature data.

In general, elevated temperatures are considered to be harmful if they persist for three consecutive days or more. Thus, the temperature metric shows the number of periods during which temperatures remained above the harmful (e.g., 65° F) thresholds for three days or longer at key locations in the River.

Data Quality / Limitations: See Technical Note for the Systemwide Central Valley Chinook Salmon indicator for further discussion of data quality issues related to escapement estimates.

In terms of estimates of juvenile production, there are substantial amounts of data from rotary screwtraps and seines and the utility of these data depend on the questions being asked. For example, production estimates from rotary screwtraps (RSTs) have large confidence intervals which hamper rigorous statistical comparisons. However, the RST data may be useful as an index for tracking relative changes in juvenile production. Seine data is considered useful as a measure of fry distribution but there is disagreement over its suitability as a useful index of abundance.

With regard to estimates of predation on juvenile salmon, while the mining pits are thought to harbor increased populations of predators that prey on juvenile salmon, the data on this issue are not definitive. Electroshocking surveys have documented the presence of populations of largemouth black bass in the mining pits, but the limitations of this technique reduce its effectiveness for more mobile predators such as striped bass and squawfish. As a result, data on the numbers of predators in the Tuolumne is incomplete and uncertain. In addition, the largemouth black bass resident in the large mining pits are warm-water fish. The relatively low temperatures in the Tuolumne during the spring juvenile emigration period may therefore lower their digestion and feeding rates and reduce their impact on Chinook juveniles. The lack of reliable population estimates for potentially significant predators, combined with the absence of rigorous feeding studies, means that suppositions about predator impact and about the effect of the removal of mining pits on the salmon population are only partially substantiated (see Longer-Term Science Needs).

Longer-Term Science Needs

See Technical Note for the Systemwide Central Valley Chinook Salmon indicator for a discussion of science needs related to improving estimates of escapement and juvenile production and to developing improved, quantitative recovery goals.

Better estimates of the proportion of hatchery fish in the Tuolumne River fall run (see Technical Note for Systemwide Salmon for more detail on this issue) would improve understanding of the effectiveness of restoration actions. Because the fall run in the Tuolumne includes an unquantified proportion of fish from several hatcheries (including the Merced, Mokulumne, and Feather River hatcheries), it is not currently possible to separate the effects of instream restoration actions on production from those of the hatcheries.

Improved population estimates of predatory fish species, along with studies of their feeding habits and feeding rates, would help clarify the impact of these populations on the spring juvenile salmon emigration in the Tuolumne River. A key question is whether mortality rates due to predation are in excess of what would normally be expected in a healthy salmon stream. This information is needed to more accurately predict and measure the effectiveness of restoration actions targeting the mining pits. Any research on predator impacts should also include an evaluation of how broadly applicable predation studies elsewhere (e.g., on the Stanislaus River) are to the Tuolumne and to other rivers.

Research on patterns and trends in the long-term relationship between flow at critical periods of the year and salmon population levels would furnish information about whether this relationship is changing in ways that make the Tuolumne River fall run more vulnerable. Because the Tuolumne is near the southern extent of the Chinook's range, this run may be especially susceptible to long-term increases in temperature, for example, from global climate change.