CENTRAL VALLEY LATE FALL-RUN CHINOOK SALMON
Oncorhynchus tshawytscha ESU

Status: High Concern. The Central Valley (CV) late fall-run Chinook salmon have been extirpated from the majority of their native spawning habitat, which now lies upstream of Shasta Dam. Although late fall-run Chinook salmon occur in tributary streams to the Sacramento River, most spawn in the main river. The primary population depends on dam operations for maintenance of suitable habitat. While affected to a lesser degree than fall-run Chinook salmon, this run remains of ongoing concern due to the strong influence of salmon hatchery stocks in the CV and associated potential ecological and genetic impacts to the sustainability of the run.

Description: Although morphologically similar to other Chinook salmon, Central Valley late fall-run Chinook tend to be larger than other Central Valley Chinook salmon, reaching 75-100 cm TL and weighing 9-10 kg or more. Like other Chinook salmon runs, thelate fall-run have numerous small black spots on the back, dorsal fin, and both lobes of the tail in both sexes. This spotting on the caudal fin and the black coloration of their lower jaw make them distinguishable from other sympatric salmonid species. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fins rays, and 10-11 pelvic fin rays. There are 130-165 scales along the lateral line. Branchiostegal rays number 13-19. They possess more than 100 pyloric caeca and have rough and widely spaced gill rakers, 6-10 on the lower half of the first gill arch.

Spawning adults are olive brown to dark maroon, without streaking or blotches on the sides. Males are often darker than females and develop a hooked jaw and slightly humped back during spawning. Juvenile Chinook have 6-12 parr marks, which often extend below the lateral line, and the marks are typically equal to or wider than the spaces between them. Parr (juveniles) can also be distinguished from other salmon species by the adipose fin, which is pigmented on the upper edge, but clear at the base and center. Some parr begin to show spots on the dorsal fin, but most fins are clear. There are no morphological features to separate the Evolutionary Significant Units (ESUs) of Chinook salmon in the CV, so separation is based on genetic data and life history characteristics.

Taxonomic Relationships: The four runs of Chinook salmon in the CV differ in life history characteristics, including maturity of fish entering fresh water, time of spawning migrations, spawning areas, incubation times, and migration timing of juveniles (Moyle 2002, Table 1). For management purposes, juvenile salmon are assigned to winter, spring, fall, and late fall-runs by size criteria, reflecting different spawning times and rearing conditions. While these criteria are useful, they are not very precise, given natural variability in lengths for any population and the presence of so many hatchery fish in the system (e.g., juvenile hatchery fish tend to be larger than wild members of the same run). The utility of the size criteria decreases rapidly downstream from Red Bluff Diversion Dam (RBDD).

All populations within the CV are more closely related to each other than they are to populations outside the valley. Because of their similar arrival time to fall-run Chinook, late fall-run Chinook were only recognized as a distinct run in 1966, after the construction of RBDD allowed careful observation of run timing for the first time. As salmon passed through the dam, two distinct peaks were observed. NMFS currently groups late fall-run with the fall-run ESU, though there are life history differences between the two runs. Yoshiyama et al. (1998), Moyle (2002), and Williams (2006) and others in recognizing the Central Valley late fall-run to be a distinct taxonomic entity with a unique evolutionary trajectory (as evidenced by a distinct life history strategy) and with specific management concerns of its own. It is still unclear if this is a unique ESU. Williams (2006) described genetic techniques being applied to late-fall-run Chinook salmon to investigate if late-fall run can be distinguished from the other runs. Currently, CDFW recognizes late-fall run as a unique life history strategy and, partnering with federal scientists, is further investigating the genetic relationship of this run with other runs in the Central Valley. Currently, late fall-run and fall-run are considered races under a single ESU.

	Migration period	*Peak migration*	*Spawning period*	*Peak spawning*	*Juvenile emergence period*	*Juvenile stream residency*
Sacramento River basin						
Late fall run	October–April	December	Early January–April	February–March	April–June	7–13 months
Winter run	December–July	March	Late April–early August	May–June	July–October	5–10 months
Spring run	March–September	May–June	Late August–October	Mid-September	November–March	3–15 months
Fall run	June–December	September–October	Late September–December	October–November	December–March	1–7 months

Table 1. Generalized life history timing of Central Valley Chinook complex. Source data from Yoshiyama et al. 1998.

Life History: Chinook salmon life history strategies are differentiated by immigration timing, a fact implicit in the naming of the different “runs” according to the season of their spawning. However, movement between habitat types synchronized with changes in developmental life stage defines the entire life history, not simply adult spawning migration (Table 1). For instance, the fall-run has classic “ocean type” life history that minimizes time spent in freshwater. Because both fry and smolts out-migrate before water temperatures become too warm in summer, the fall-run can exploit extensive valley floor reaches of the CV where temperatures exceed thermal tolerances during summer and early fall. In contrast, spring and winter-run exhibit a “stream-type” life history that is dependent upon year-round, cool, freshwater habitat for both adults (which arrive in spring and mature while over-summering in foothill streams) and juveniles, which regularly spend more than a year in rivers before out-migration. Spring-run spawning and rearing habitat is, therefore, restricted to the higher elevation portions of the CV, where cool summer temperatures can be found in snow melt-fed rivers. The basic life history of late fall-run Chinook salmon is intermediate to the “ocean type” fall-run and the “stream type” spring-run, because adults arrive in fresh water already mature and spawn quickly after arriving (similar to fall-run) but juveniles regularly over-summer, out-migrating in their second year of life (similar to spring-run). The details of late fall-run life history, however, are much less well known than those of other CV runs because of the comparatively recent recognition of this run, coupled with its tendency to ascend and spawn at times when the Sacramento River is likely to be high, cold and turbid. This combination of factors makes this run particularly difficult to study.

Late fall-run Chinook salmon migrate upstream in December and January as mature fish, although their migration has been documented from November through April (Williams 2006). Historically, the spawning adults would have been comprised of a mixture of age classes, ranging from two to five years old. Currently, most of the run is composed of three-year olds. Spawning occurs primarily in late December and January, shortly after the fish arrive on spawning grounds, although it may extend into April in some years (Williams 2006). Emergence from the gravel begins in April and all fry have usually emerged by early June. Juveniles may hold in the river for 7-13 months before moving out to sea. Peak migration of smolts appears to be in October; however, there is evidence that many may out-migrate at younger ages and smaller sizes during most months of the year (Williams 2006).

Habitat Requirements: The specific habitat requirements of late fall-run Chinook salmon have not been determined but they are presumably similar to other CV Chinook salmon runs. It is believed that optimal conditions fall within the range of physical and chemical characteristics of the unimpaired Sacramento River above Shasta Dam. For a more detailed review of CV Chinook salmon requirements, see Williams (2006), Stillwater Sciences (2006), and Moyle (2002).

Distribution: The historic distribution of late fall-run Chinook salmon is not well documented, but they most likely spawned in the upper Sacramento and McCloud rivers, in reaches now blocked by Shasta Dam and flooded by Shasta Reservoir, as well as in portions of major tributaries that provided adequate cold water in summer. There is also some evidence they once spawned in the San Joaquin River in the Friant region and in other large San Joaquin tributaries (Yoshiyama et al. 1998).

Currently, late fall-run Chinook are found primarily in the Sacramento River, where most spawning and rearing of juveniles takes place in the reach between RBDD and Redding (Keswick Dam). Varying percentages of the total run spawn downstream of RBDD in some years. In 2003, for example, 3% of the late fall-run spawned below the dam, while, in 2004, no spawning occurred below the dam (Kano 2006a, b). R. Painter (CDFW, pers. comm. 1995) indicated that late fall-run Chinook have been observed spawning in Battle Creek, Cottonwood Creek, Clear Creek, Mill Creek, Yuba River and Feather River, but these are presumably a small fraction of the total population. The Battle Creek spawners are likely derived from fish that strayed from Coleman National Fish Hatchery.

Trends in Abundance: The historic abundance of Central Valley late fall-run Chinook is not known because it was recognized as distinct from fall-run Chinook only after RBDD was constructed in 1966. In order to pass the dam, salmon migrating up the Sacramento River ascended a fish ladder in which they could be counted with some accuracy for the first time. The four Chinook salmon runs present in the river (fall, late fall, winter, spring) were revealed as peaks in counts, although salmon passed over the dam during every month of the year. In the first 10 years of counting (1967-1976), the late fall-run averaged about 22,000 fish; in the next 10 years (1982-1991) the run averaged about 9,700 fish (Yoshiyama et al. 1998). Since 1991, when operation of the RBDD was changed, estimates of abundance have been less accurate but, from 1992-2007, total numbers were estimated to have averaged 20,777 fish, with a wide range in annual numbers, including a 1998 production total of over 80,000 fish. Reduced accuracy in fish counts resulted from the opening of RBDD gates to provide free passage of the listed winter-run Chinook salmon from September 15 to May 15 each year, starting in 1992. This made estimation of late fall-run Chinook spawner numbers more difficult because many late fall-run fish swam freely through the open gates and could not be counted as they had been previously while ascending the fish ladders. From 1992-1996, estimates were made by extrapolating from counts made on only part of the run. These numbers are extremely low and unreliable. In 1998, CDFW initiated surveys based on carcass and redd counts from airplanes and estimated that over 35,000 late fall-run Chinook had spawned above RBDD. Subsequent surveys have resulted in lower estimates (e.g. 5,000 in 2003), with variability from year to year. Spawner surveys and estimates seem to indicate that measures taken to benefit winter-run Chinook salmon have also benefited the late fall-run. Fish from Coleman National Fish Hatchery on Battle Creek are contributing at a low rate to the spawning population in the mainstem Sacramento River.

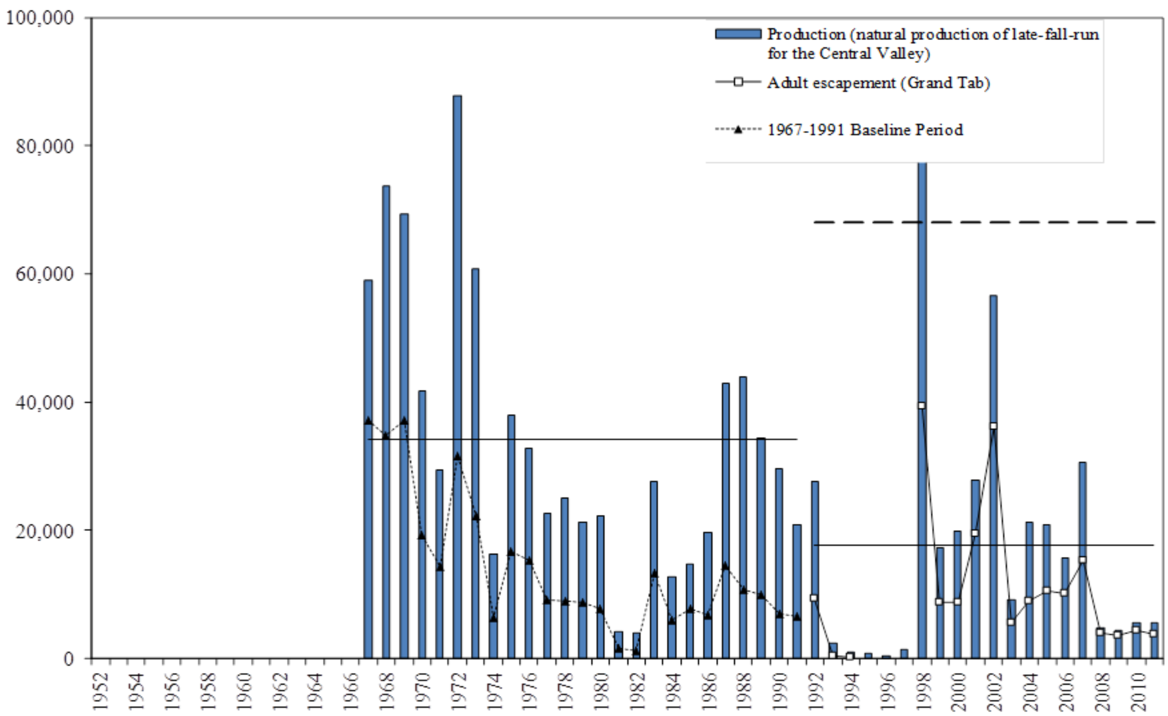

Figure 1. Estimated annual adult natural production and in-river adult escapement estimates for late fall-run Chinook salmon in the Central Valley. 1992 - 2011 numbers are from CDFW Grand Tab (Apr 24, 2012). 1967-1991 baseline period numbers are from Mills and Fisher (CDFG 1994).

	Rating	Explanation
Major dams	High	Dams block access to the majority of historic spawning grounds; however, current operation of Shasta Dam creates some replacement habitat
Agriculture	Medium	Levees reduce access to floodplains and other important habitats; diversions and agricultural return water decrease water quantity and quality
Grazing	Low	Little grazing on valley floor
Rural residential	Low	Source of minor changes to river banks and pollution
Urbanization	Low	Urban areas along Sacramento River and tributaries may restrict habitat and decrease water quantity and quality
Instream mining	Low	Gravel mining and legacy effects of placer mining may continue to impair habitats
Mining	Low	Discharge from Iron Mountain Mine has been attenuated, now posing only a slight risk to water quality in the upper Sacramento River
Transportation	Low	Roads line banks and cross rivers, contributing to habitat simplification and sediment or pollutant input
Logging	Low	Generally low impact; occurs at higher elevations
Fire	Low	Few impacts on mainstem river likely
Estuary alteration	High	San Francisco Estuary is a highly altered system; fall-run Chinook salmon, however, have short residence periods in the estuary; the Sacramento-San Joaquin rivers Delta is greatly altered and current physical and water habitat conditions impact effective migration of adults and juveniles in both river basins
Recreation	Low	Recreation (boating, wading, angling) can disturb spawners and migrants
Harvest	Medium	Ocean and inland fisheries may harvest natural-origin (wild spawned) fish at unsustainable rates
Hatcheries	Medium	Based on recent coded-wire tag recoveries, a small proportion of the spawning population is of hatchery-origin but still of concern
Alien species	Low	Predation and competition from introduced fishes is a growing concern

Table 2. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Central Valley late fall-run Chinook salmon. Factors were rated on a five-level ordinal scale where a factor rated “critical” could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated “high” could push the species to extinction in 10 generations or 50 years whichever is less; a factor rated “medium” is unlikely to drive a species to extinction by itself but contributes to increased extinction risk; a factor rated “low” may reduce populations but extinction is unlikely as a result. A factor rated “n/a” has no known negative impact. Certainty of these judgments is moderate. See methods section for descriptions of the factors and explanation of the rating protocol.

Nature and Degree of Threats: The causes of population decline from pre-dam numbers for late fall-run Chinook salmon are poorly documented, compared to the other three runs. Some of principal factors specifically affecting late fall-run Chinook salmon status and abundance, past and present, are: (1) dams, (2) loss of habitat, (3) fisheries, (4) outmigrant mortality, (5) water management, and (6) hatcheries (Table 2).

Dams. When Shasta and Keswick dams were built in the 1940s, they blocked late fall-run Chinook access to upstream spawning areas, where spring water originating from Mt. Shasta, as well as extended snow-melt, kept water temperatures cool enough for successful spawning, egg incubation and survival of juvenile salmon year-round. At present, late fall-run Chinook salmon are largely dependent on cold-water releases from Shasta Reservoir. Large dams on the Sacramento River and its tributaries have not only blocked salmon access to historic spawning grounds, but they have reduced or eliminated recruitment of spawning gravels into the river beds below dams and altered temperature regimes. Loss of spawning gravels in the Sacramento River below Keswick Dam is regarded as a serious problem; large quantities of gravel are now trucked and placed in the river. Warm water temperatures are potentially a problem in this reach during drought years, when the cold-water pool in Shasta Reservoir is reduced. However, modification of Shasta Dam to provide cooler water in summer for winter-run Chinook has presumably also benefited late fall-run Chinook.

The effects of RBDD were more subtle. This dam apparently delayed passage to upstream spawning areas and also concentrated predators, increasing mortality on out-migrating smolts. Kope and Botsford (1990) documented that the overall decline of Sacramento River salmon was closely tied to the construction of RBDD. Raising the dam's gates for much of the year to allow salmon passage apparently alleviated much of this problem. The gates are now open year-round, allowing uninhibited passage of adult and juvenile late fall-run Chinook salmon.

Agriculture. Outmigrant mortality of both fry and smolts is a factor affecting late fall-run Chinook abundance, as it is for all runs of salmon in the Sacramento-San Joaquin drainage. Small numbers of outmigrants are presumably entrained at larger irrigation diversions along the Sacramento River that are operating during the migration period. At the same time, extensive bank alteration to benefit agricultural operations has reduced the amount of cover available to protect outmigrants from striped bass, terns, herons and other predators. Given the extensive agricultural land use in the CV, it is likely that return waters negatively affect water quality, even in systems as large as the Sacramento River. Levees to protect agricultural fields from flooding have substantially degraded riparian habitats and eliminated connectivity of main stem river channels to historically widespread (and ecologically important) floodplain habitats.

Urbanization. Urbanization simplifies and pollutes Chinook salmon habitats. By diverting water and denying access to floodplain areas, the simplification process is similar to that discussed above for agriculture.

Mining. Existing gravel mining operations and legacy effects of past gravel mining, as well as placer and hydraulic mining, may continue to affect late fall-run Chinook salmon; however, the effects are largely unknown. Lasting impacts may be especially acute in the middle to upper portions of watersheds (preferred late fall-run spawning areas), where hydraulic mining was most prevalent and caused dramatic changes to river geomorphology and hydrology and severely degraded aquatic habitats.

In the past, Iron Mountain Mine, northwest of Redding, drained highly acidic water laden with heavy metals into the Sacramento River, resulting in acute mortality to Chinook salmon. Although the discharge is now highly controlled, failure of the Spring Creek retention reservoir could result in impacts to aquatic life in the entire Sacramento River.

Estuary alteration. There is growing appreciation of the importance of "biocomplexity" for the persistence of salmon in a variable environment (Hilborn et al. 2003), including those in the CV (Carlson and Satterthwaite 2011). Biocomplexity is defined as multiple variations in life history that improve the ability of populations to persist in changing environmental conditions. Loss of diverse habitats in the San Francisco Estuary has essentially eliminated aspects of life history diversity and the best strategy for juvenile salmon, today, appears to be to move through the estuary as quickly as possible. Large pumping stations in the southern Sacramento-San Joaquin Rivers Delta (Delta) divert approximately 40% of the historic Delta flows, resulting in substantial modifications in flow direction (Nichols et al. 1986). Pumping also increases the likelihood of out-migrating smolts entering the interior delta, where longer migration routes, impaired water quality, increased predation, and entrainment result in higher mortality rates (Perry et al. 2010).

Despite long-term monitoring, causes of apparent high mortality rates as fish pass through the estuary are poorly understood. General observations suggest that rearing conditions in the estuary are often poor; highest survival occurs during wet years, when passage through the estuary is likely most rapid and water quality is higher (Brandes and McLain 2001, Baker and Mohrhardt 2001). Flooding in wet years also increases rearing habitat in the Delta and Yolo Bypass, which may also have a positive effect. Additionally, recent studies documented that the further downstream a group of late fall-run smolts is released, the longer the group takes to reach the ocean. These finding suggest that environmental cues that trigger migration in the upper watershed may be subdued or absent in the lower river (Michel et al. 2013).

The Delta ecosystem is as, if not more, altered than the estuary. Land and water management practices have altered the delta's landscape and ecological processes such that fall-run Chinook salmon and other native fishes encounter poor to extremely poor habitat conditions when migrating through the Delta's waters.

Harvest. The effects of harvest on CV salmon, in general, are discussed by Williams (2006). The actual harvest rates of late fall-run Chinook salmon are not known, but it is highly likely that they are harvested at similar rates as fall-run Chinook salmon. Although hatcheries are operated to sustain fisheries and hatchery fish can sustain higher harvest rates than wild fish, fisheries do not discriminate between them. Fisheries may, therefore, be taking a disproportionate number of natural-origin late fall-run Chinook salmon. Other effects are discussed in the 2015 fall-run Chinook salmon account.

Hatcheries. Late fall-run Chinook salmon have been reared at Coleman National Fish Hatchery on Battle Creek since the 1950s, even though the run was not formally recognized until 1973 (Williams 2006). The current production goal is one million smolts per year, which are released into Battle Creek from November through January (Williams 2006). Hatchery broodstock selection for late fall-run fish includes both fish returning to Coleman National Fish Hatchery and those trapped below Keswick Dam. Large numbers are needed because survival rates are low (0.78% at Coleman). Hatchery production may have impacts to the naturally-spawning population, although a low proportion of hatchery-origin fish have been found in the in-river spawning surveys (Kormos et al. 2010).

Alien species. Over the past 150 years, numerous fish species have been introduced to the Bay-Delta system. Several species of introduced fishes prey upon Chinook salmon, including striped bass, largemouth bass, smallmouth bass, and spotted bass. Striped bass can consume large numbers of juvenile salmon, particularly at diversion structures, or where hatcheries release large numbers of juvenile fish.

Effects of Climate Change. The effects of climate change on late fall-run Chinook salmon are similar to those of other runs of Chinook salmon. However, particularly critical for late fall-run Chinook salmon, is maintaining a cold water pool in Shasta Reservoir to keep water in the Sacramento River cold enough to support late fall-run habitat requirements year-round. Maintaining the cold water pool will be increasingly difficult during periods of extended drought and in the face of predicted increasing air and water temperatures. Thus, spring-fed Battle Creek may be crucial as a refuge during periods of drought. Moyle et al. (2013) found late fall-run Chinook salmon to be "critically vulnerable" to extinction from the effects of climate change because of the run's dependence on cold water released from dams.

Status Determination Score = 2.6 – High Concern (see Methods section Table 2). Late fall-run Chinook have been extirpated from a considerable portion of their historic spawning grounds. In the past 10 years, numbers of CV late fall-run Chinook salmon have fluctuated but appear to be comparable to numbers in the 1970s and 1980s. According to NMFS, they "continue to have low, but perhaps stable, numbers." (pdf http://www.fisheries.noaa.gov/pr/species/fish/chinook-salmon.html). Nevertheless, CV late fall-run Chinook may be vulnerable because of their relatively small population size and limited spawning distribution (Figure 1). Lack of access to (and degradation of) spawning and rearing habitats may make this population exceptionally vulnerable to changes in water quality and flow in the Sacramento River, as in the case of an extended drought, changes in water management, or a major spill of toxic materials. Their persistence depends on operation of water projects (Shasta Dam) and hatchery operations. The late fall-run Chinook salmon is considered a Species of Concern by the National Marine Fisheries Service (combined, single ESU with two races, late fall-run and fall-run Chinook salmon).

Metric	Score	Justification
Area occupied	2	Only one primary population concentrated in the upper Sacramento River; some tributary spawning and rearing
Estimated adult population	3	Total escapement has averaged approximately 10,000 spawners in recent years; hatchery contribution is low
Intervention dependence	3	Primary population is dependent on dam operation for flows and gravel injection for spawning habitat improvement
Tolerance	4	Moderate physiological tolerance, multiple age classes
Genetic risk	2	Hybridization with other runs may occur

Anthropogenic threats	2	See Table 2
Climate change	2	Snow pack or cold spring-fed flow dependent
Average	2.6	18/7
Certainty (1-4)	2	Least studied of CV Chinook runs

Table 3. Metrics for determining the status of Central Valley late fall-run Chinook salmon, where 1 is a major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. See methods section for further explanation.

Management Recommendations: Currently, less management is directed to benefit late fall-run Chinook salmon than for any other run in the Sacramento River, because little is known about the run and it is considered a race within the fall-run Chinook ESU. A key to conserving late fall-run Chinook is to develop and implement specific measures tailored to its unique life history.

This run should benefit considerably from measures being taken to enhance winter and spring-run Chinook salmon populations in the upper Sacramento River. However, specific studies should be undertaken to better understand the environmental requirements specific to the late fall-run, because this population needs protection at all stages of its life cycle. The Anadromous Fish Restoration Program has set a goal in their final restoration plan of an average production (escapement plus catch in fishery) of 44,000 fish per year, although the official doubling goal (required in the Central Valley Project Improvement Act) is 68,000 natural-origin fish (http://www.delta.dfg.ca.gov/afrp/). Whether or not existing habitat is adequate to sustain a population at either level is uncertain. Spawning and rearing ground monitoring specific to the run as well as additional genetic studies should be conducted for late fall-run Chinook salmon.

Restoration will require: (1) continuing to provide improved passage of adults to holding and spawning areas, (2) protecting adults in spawning areas, (3) establishing additional spawning populations (e.g., Battle Creek), (4) providing passage flows for out-migrating juveniles to move through the Delta as rapidly as possible, (5) maintaining and expanding rearing habitats for juvenile fish in the mainstem river and floodplains, and (6) ensuring ocean and inland fisheries regulations minimize impacts. Most of these require continuous, adaptive management as well as improved monitoring and population evaluation programs for both hatchery and naturally-produced fish (Williams 2006). Recent oversight by the California Hatchery Scientific Review Group (2010), improving hatchery practices, and the release of a comprehensive monitoring plan for Central Valley salmon are promising signs that efforts are being made to focus on better understanding and protecting salmon stocks, minimizing impacts of hatchery stocks to wild-spawned stocks across all runs of Chinook salmon in the CV and elsewhere, and strengthening regulatory protection of at-risk stocks.

Figure 2. Distribution of Central Valley late fall-run Chinook, *Oncorhynchus tshawytscha*, in the Sacramento River and tributaries of California.