Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California

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Abstract

Chinook salmon (*Oncorhynchus tshawytscha*) formerly were highly abundant and widely distributed in virtually all the major streams of California's Central Valley drainage—encompassing the Sacramento River basin in the north and San Joaquin River basin in the south. We used information from historical narratives and ethnographic accounts, fishery records and locations of in-stream natural barriers to determine the historical distributional limits and, secondarily, to describe at least qualitatively the abundances of chinook salmon within the major salmon-producing Central Valley watersheds. Individual synopses are given for each of the larger streams that historically supported or currently support salmon runs.

In the concluding section, we compare the historical distributional limits of chinook salmon in Central Valley streams with present-day distributions to estimate the reduction of in-stream salmon habitat that has resulted from human activities—namely, primarily the construction of dams and other barriers and dewatering of stream reaches. We estimated that at least 1,057 mi (or 48%) of the stream lengths historically available to salmon have been lost from the original total of 2,183 mi in the Central Valley drainage. We included in these assessments all lengths of stream that were occupied by salmon, whether for spawning and holding or only as migration corridors. In considering only spawning and holding habitat (in other words, excluding migration corridors in the lower rivers), the proportionate reduction of the historical habitat range was far more than 48% and probably exceeded 72% because most of the former spawning and holding habitat was located in upstream reaches that are now inaccessible for salmon. Individual stream assessments revealed substantial differences among streams in the extent of salmon habitat lost. Some streams experienced little or no reduction (for example, Bear River, Mill Creek) while others were entirely eliminated from salmon production (for example, McCloud, Upper Sacramento, and Upper San Joaquin rivers.)

The river cañons, where the old bars were located, were romantic places previous to being disturbed and torn up by the gold-digger. The water was as clear as crystal, and above each ripple or rapid place was a long, deep pool, with water blue as turquoise, swarming with fish. Salmon at that time ran up all the streams as far as they could get, until some perpendicular barrier which they could not leap prevented further progress. (Angel 1882, p 402)

Introduction

The broad expanse of the Central Valley region of California once encompassed numerous salmon-producing streams that drained the Sierra Nevada and Cascade mountains on the east and north and, to a lesser degree, the lower-elevation Coast Range on the west. The large areal extent of the Sierra Nevada and Cascades watersheds, coupled with regular, heavy snowfalls in those regions, provided year-round streamflows for a number of large rivers which supported substantial—in some cases prodigious—runs of chinook salmon (*Oncorhynchus tshawytscha*). No less than 26 main Central Valley tributaries supported at least one annual chinook salmon run, with at least 23 of those streams supporting two or more runs each year.

In the Sacramento River basin, constituting the northern half of the Central Valley system (covering about 24,000 square miles; Jacobs and others 1993), most Coast Range streams historically supported regular salmon runs; however, those "westside" streams generally had streamflows limited in volume and seasonal availability due to the lesser amount of snowfall west of the valley, and their salmon runs were correspondingly limited by the duration of the rainy season. Some westside streams, such as Cache and Putah creeks, did not connect with the Sacramento River at all during dry years, and salmon runs only entered them opportunistically as hydrologic conditions allowed. In the San Joaquin River basin, composing much of the southern half of the Central Valley system (covering approximately 13,540 square miles; Jacobs and others 1993), a number of major streams such as the Merced, Tuolumne and upper San Joaquin rivers sustained very large salmon populations, while other streams with less regular streamflows (for example, Calaveras, Chowchilla and Fresno rivers) had intermittent salmon runs in years when rainfall provided sufficient flows. However, all of the westside San Joaquin basin streams, flowing from the Coast Range, were highly intermittent (Elliott 1882) and none are known to have supported salmon runs or any other anadromous fishes to any appreciable degree.

The great abundance of chinook salmon of the Central Valley was noted early in the history of colonization of the region by Euro-American people. The pioneer John Marsh, for example, wrote in 1844: "The magnificent valley through which flows the rivers San Joaquin and Sacramento is 500 miles long …. It is intersected laterally by many smaller rivers, abounding in salmon" (Elliott 1882, p 44). However, following the California Gold Rush of 1849, the massive influx of fortune seekers and settlers altered the salmon spawning rivers with such rapidity and so drastically that the historic distributions and abundances of anadromous fish can be determined only by inference from scattered records, ethnographic information, and analysis of the natural features of the streams. Probably the only species for which adequate information exists to develop a reasonably complete picture is the chinook salmon—the most abundant and most heavily used of the Central Valley anadromous fishes.

In this report, we consolidate historical and current information on the distribution of chinook salmon in the major streams of the Central Valley drainage to provide a comprehensive assessment of the extent to which salmon figured historically in the regional landscape. This paper is based and expands on an earlier work (Yoshiyama and others 1996) to include additional historical information as well as more recent data on chinook salmon abundances. Hereafter, references to "salmon" pertain to chinook salmon.

The Four Runs of Central Valley Chinook Salmon

Four seasonal runs of chinook salmon occur in the Central Valley system—or more precisely, in the Sacramento River drainage—with each run defined by a combination of adult migration timing, spawning period, and juvenile residency and smolt migration periods (Fisher 1994). The runs are named after the season of adult upstream migration—winter, spring, fall and late-fall. The presence of four runs in the Sacramento River lends it the uncommon distinction of having some numbers of adult salmon in its waters throughout the year (Stone 1883a; Rutter 1904; Healey 1991; Vogel and Marine 1991). The fall and late-fall runs spawn soon after entering the natal streams, while the spring and winter runs typically "hold" in their streams for up to several months before spawning (Rutter 1904; Reynolds and others 1993). Formerly, the runs also could be differentiated to various degrees on the basis of their typical spawning habitats—spring-fed headwaters for the winter run, the higher-elevation streams for the spring run, mainstem rivers for the late-fall run, and lower-elevation rivers and tributaries for the fall run (CFC 1900a, 1900b; Rutter 1904; Fisher 1994). Different runs often occurred in the same stream—temporarily staggered but broadly overlapping (Vogel and Marine 1991; Fisher 1994), and with each run utilizing the appropriate seasonal streamflow regime to which it had evolved. On the average, the spring-run and winter-run fish generally were smaller-bodied than the other Central Valley chinook salmon, and late-fall run fish were the largest (Stone 1874; F. W. Fisher unpublished data).

Before the (US) American settlement of California, most major tributaries of the Sacramento and San Joaquin rivers probably had both fall and spring runs of chinook salmon. The large streams that lacked either adequate summer flows or holding habitat to support spring-run salmon, which migrate upstream during the spring and hold over the summer in pools, had at least a fall run and in some cases perhaps a late-fall run. The fall run undoubtedly existed in all Central Valley streams that had adequate flows during the fall months, even if the streams were intermittent during other parts of the year. Generally, it appears that fall-run fish historically spawned in the valley floor and lower foothill reaches (Rutter 1904)—below 500 to 1,000 ft elevation, depending on location—and probably were limited in their upstream migration by their egg-laden and deteriorated physical condition.

The spring run, in contrast, ascended to higher-elevation reaches—judging from spawning distributions observed in recent years and the reports of early fishery workers (Stone 1874; Rutter 1904). The California Fish Commission noted, "It is a fact well known to the fish culturists that the winter and spring run of salmon, during the high, cold waters, go to the extreme headwaters of the rivers if no obstructions prevent, into the highest mountains" (CFC 1890, p 33). Spring-run salmon, entering the streams while in pre-reproductive and peak physical condition well before the spawning season, were understandably better able to penetrate the far upper reaches of the spawning streams than were fall-run fish. Their characteristic life-history timing and other adaptive features enabled spring-run salmon to use high spring-time flows to gain access to the upper stream reaches—the demanding ascent facilitated by high fat reserves, undeveloped (and less weighty) gonads, and a generally smaller body size. The spring run, in fact, was generally required to use higher-elevation habitats—the only biologically suitable places—given its life-history timing. Spring-run fish needed to ascend to high enough elevations for over-summering to avoid the excessive summer and early-fall temperatures of the valley floor and foothills—at least to about 1,500 ft elevation in the Sacramento drainage and most likely correspondingly higher in the more southerly San Joaquin drainage[1]. If the spring-run fish spawned in early fall, they needed to ascend even higher—at least to about 2,500 to 3,000 ft in the Sacramento drainage—to be within the temperature range (35 to 58 °F) required for successful egg incubation. Spring-run fish that spawned later in the season did not have to ascend quite so high because ambient temperatures would have started to drop as autumn progressed—but presumably there were constraints on how long they could delay spawning, set by decreasing stream-

1. English units of measurement for distances and elevations are used in this paper for ease of comparison with information quoted from earlier published work. Some locations are given by "river miles" (rm)—the distance from the mouth of the stream under discussion to the point of interest.

flows (before the onset of the fall rains), ripening of eggs, and deteriorating body condition.

The spring run probably was originally most abundant in the San Joaquin system, ascending and occupying the higher-elevation streams fed by snowmelt where they over-summered until the fall spawning season (Fry 1961). The heavy snowpack of the southern Sierra Nevada was a crucial feature in providing sufficient spring and early summer streamflows, which were the highest flows of the year (F. W. Fisher unpublished data). The more rain-driven Sacramento system was generally less suitable for the spring run due to lesser amounts of snowmelt and proportionately lower flows during the spring and early summer, but the spring run nonetheless was widely distributed and abundant in that system (Campbell and Moyle 1991). Some notable populations in the Sacramento drainage occurred in Cascades streams where coldwater springs provided adequate summer flows (for example, Upper Sacramento and McCloud rivers, Mill Creek). These coldwater springs emanated from the porous lava formations around Mount Shasta and Mount Lassen and were ultimately derived from snowmelt from around those peaks and also from glacial melt on Mount Shasta.

The winter run—unique to the Central Valley (Healey 1991)—originally existed in the upper Sacramento River system (Little Sacramento, Pit, McCloud and Fall rivers) and in nearby Battle Creek. There is no evidence that winter runs naturally occurred in any of the other major drainages before the era of watershed development for hydroelectric and irrigation projects. Like the spring run, the winter run typically ascended far up the drainages to the headwaters (CFC 1890). All streams in which populations of winter-run chinook salmon were known to exist were fed by cool, constant springs that provided the flows and low temperatures required for spawning, incubation, and rearing during the summer season (Slater 1963)—when most streams typically had low flows and elevated temperatures. The unusual life-history timing of the winter run, requiring cold summer flows, would argue against such a run occurring in other than the upper Sacramento system and Battle Creek, apparently the only areas where summer flow and water temperature requirements were met. A possible exception was the Big Meadows area (now Lake Almanor) on the North Fork Feather River where extensive cold-water springs provided year-round flows with "temperature[s] not higher than sixty degrees Fahrenheit" (CFC 1884, p 16), which theoretically might have been suitable for the winter run; however, we have seen no historical records or suggestions of winter-run salmon occurring in that drainage. A similar environmental constraint may apply to some extent to the late-fall run, of which the juveniles remain in freshwater at least over the summer and therefore require coldwater flows (Vogel and Marine 1991; Fisher 1994)—whether from springs or from late snowmelt. The late-fall run probably spawned originally in the mainstem Sacramento River and major tributary reaches now blocked by Shasta Dam (Fisher 1994) and perhaps in the upper mainstem reaches of other Sacramento Valley streams such as the American River (Clark 1929). There are indications that a late-fall run possibly occurred also in the San Joaquin River, upstream of its major tributaries at the southern end of that drainage (Hatton and Clark 1942; Van Cleve 1945; Fisher 1994).

Distributional Survey: General Background and Methods

As summarized by Clark (1929), makeshift barriers were built across Sierra Nevada streams as early as the Gold Rush period when mining activities significantly impacted salmon populations in a number of ways—for example, by stream diversions, blockages, and filling of streambeds with debris. Hydropower projects appeared in the 1890s and early 1900s, although most of the large irrigation and power dams were constructed after 1910 (F. W. Fisher unpublished data). The early hydropower dams of the early 1900s were numerous, however, and collectively they eliminated the major portion of spawning and holding habitat for spring-run salmon well before the completion of the major dams in later decades.

The early distributional limits of salmon populations within the Sierra Nevada and some Cascade drainages are poorly known, if at all, because of the paucity of accurate scientific or historical records pre-dating the heavy exploitation of populations and the destruction or degradation of stream habitats. It was not until after the late 1920s that reliable scientific surveys of salmon distributions in Central Valley drainages were conducted. Reports by Clark (1929) and Hatton (1940) give information on the accessibility of various streams to salmon and they identify the human-made barriers present at those times. They provide a valuable "mid-term" view of what salmon distributions were like in the first half of the 20th century after major environmental alterations had occurred and salmon populations were significantly depleted compared to earlier times. However, the survival of the runs was not yet imperiled to the extent it is presently. Those reports also give limited qualitative information on salmon abundance.

Fry (1961) provided the earliest comprehensive synopsis of chinook stock abundances in Central Valley streams, covering the period 1940–1959. Quantitative data were given by Fry (1961) for both spring and fall runs, but the fall-run estimates also included the winter and late-fall runs for the streams where those other runs occurred. Since then, fairly regular surveys of spawning runs in the various streams have been conducted by the California Department of Fish and Game and periodically summarized in the Department's "Administrative Reports."

In the following section we synthesize the earlier information with that available from more recent sources, with the aim of providing comprehensive descriptions for the major salmon-supporting streams of the Central Valley. For each of the major streams (excepting some tributaries in the upper Sacramento River system, for which little data exist) that are known to have had self-sustaining chinook salmon populations, we provide a narrative including their probable "original" distributions and later "mid-term" 1928-1940 distributions as indicated by published literature and unpublished documents. The probable original distributions were determined by considering the presence of obvious natural barriers to upstream salmon migration together with historical information (for example, accounts of gold miners and early settlers) and they apply to the salmon populations up to the period of intensive gold mining, around 1850–1890, when massive environmental degradation by hydraulic mining activities occurred. We also drew from ethnographic studies of Native American people. Much information on the material culture of the native peoples of California had been obtained by ethnographers who interviewed elder Native Americans of various tribal groups during the early part of the 20th century. That information pertains to the life-experiences and traditions of the native informants during the period of their youth and early adulthood and to the mid-life periods of their parents and grandparents from whom they received information and instruction-i.e., spanning essentially the middle and latter parts of the 19th century (Beals 1933; Aginsky 1943; Gayton 1948a). Generally, we quoted the original statements of earlier observers (both Native Americans and immigrants) on salmon and steelhead as fully as seemed informative so that readers may assess for themselves the meaning and credibility of those statements. The known or inferred historical upstream limits of salmon in Central Valley streams are compiled in Table 1.

Table 1 Historical upstream limits of chinook salmon in the California Central Valley drainage [a]

Stream	*Upstream distributional limit [b]*
Sacramento River Basin	
Pit River	Mouth of Fall River
Fall River	Source springs near Dana, about nine miles above mouth
McCloud River	Lower McCloud Falls
Upper (Little) Sacramento River	Vicinity of Box Canyon Dam (Mt. Shasta City) and Lake Siskiyou (that is, Box Canyon Reservoir)
Cow Creek	
North Fork (Little Cow)	Falls near Ditty Wells fire station
South Fork	Wagoner Canyon
Battle Creek	
North Fork	Falls three miles above Volta Powerhouse
Digger Creek	Vicinity of Manton, possibly higher
South Fork	Falls near Highway 36 crossing
Antelope Creek	Up North and South forks to present Ponderosa Way crossings
Mill Creek	Morgan Hot Spring
Deer Creek	Lower Deer Creek Falls
Big Chico Creek	Higgins Hole, about one mile above present Ponderosa Way crossing
Butte Creek	Centerville Head Dam (DeSabla)
Feather River	
West Branch	Vicinity of Stirling City
North Fork	Six miles above Lake Almanor, three miles up Hamilton Branch, and to Indian Falls on East Branch of North Fork
Middle Fork	Bald Rock Falls
South Fork	Upper limit of Lake Oroville (six miles above former mouth of South Fork)
Yuba River	
North Fork	Mouth of Salmon Creek, near present Sierra City
Middle Fork	Falls about one miles above juncture with North Fork
South Fork	Falls 0.5 mi below Humbug Creek
Bear River	Waterfall at vicinity of Camp Far West Reservoir

[a] Upper stream limits pertain to the farthest migrating seasonal run—meaning, either the spring run in most streams or the winter run where it occurred with the spring run, or the fall and late-fall runs in streams where spring and winter runs were absent.

[b] Sources are given in the text.

Table 1 Historical upstream limits of chinook salmon in the California Central Valley drainage [a] (Continued)

Stream	*Upstream distributional limit* [b]
American River	
North Fork	Mumford Bar
Middle Fork	Mouth of Rubicon River
South Fork	Waterfall near Eagle Rock
Clear Creek	French Gulch, above Whiskeytown Dam
Cottonwood Creek	
North Fork	Five miles above Ono
Middle Fork	Eight miles into Beegum Creek
South Fork	Maple Gulch
Stony Creek	Juncture of Little Stony Creek, five miles below Stonyford
Cache Creek	Vicinity of Capay Dam
Putah Creek	Vicinity of Monticello
San Joaquin River Basin and Sacramento-San Joaquin Delta	
Cosumnes River	Falls 0.5 mi below Latrobe Highway Bridge
Mokelumne River	Bald Rock Falls, seven miles upstream of Electra
Calaveras River	At least to site of New Hogan Dam
Stanislaus River	
North Fork	Makays Point, eight miles above juncture with Middle Fork
Middle Fork	Near Spring Gap Powerhouse, two miles below Beardsley Reservoir
South Fork	Presumably not used by salmon
Tuolumne River	
Mainstem	Preston Falls
North Fork	One mile above mouth
Middle and South forks	Presumably not used by salmon
Merced River	
Mainstem	Vicinity of El Portal
North Fork	Not used by salmon
South Fork	Peach Tree Bar
Upper San Joaquin River	Midway (3 mi) up length of Mammoth Pool Reservoir
Kings River	Mouth of North Fork

[a] Upper stream limits pertain to the farthest migrating seasonal run—meaning, either the spring run in most streams or the winter run where it occurred with the spring run, or the fall and late-fall runs in streams where spring and winter runs were absent.

[b] Sources are given in the text.

For the mid-term salmon distributions, we relied heavily on the papers of Clark (1929) and Hatton (1940) and retained much of their original wording to faithfully represent the situation they reported at those times. We also give more recent and current (1990s) salmon spawning distributions based on government agency reports, published papers, and interviews with agency biologists[2]. The stream accounts are presented starting with the southernmost Sierra streams and proceeding northward. We also include accounts for several streams on the west side of the Sacramento Valley which are known to have had chinook salmon runs. They are representative of other small westside or upper Sacramento Valley streams that formerly sustained salmon stocks, if only periodically, but lost them because of extensive stream diversions and placement of man-made barriers. More detailed physical descriptions of Central Valley salmon streams, factors limiting their salmon production, and management recommendations are given in Reynolds and others (1993) and USFWS (1995).

For each stream account, we attempted to identify which seasonal salmon runs were historically present, given the available information. Remember that the lack of historical documentation for certain runs in some watersheds does not necessarily mean that those runs were absent from those watersheds in past times. The late-fall run, for example, was not even recognized as a distinct run until the late-1960s after seasonal salmon counts were initiated at Red Bluff Diversion Dam on the mainstem Sacramento River. The presence of the late-fall run in several Sacramento River tributaries during recent decades (Reynolds and others 1993) might argue for its historical occurrence in some of those streams, assuming that streamflow conditions during the time of year when late-fall salmon were present were not substantially altered after the emplacement of dams and diversion projects. We also provide information on historical salmon abundances in individual streams where possible. While usually highly incomplete or anecdotal, the early statements and estimates on salmon abundances nonetheless indicate those watersheds which historically supported substantial, or in some cases enormous, salmon runs and also demonstrate that chinook salmon existed at viable population levels in streams through much of the Central Valley drainage. We have drawn particularly from Fry (1961) for earlier quantitative data.

We mention steelhead trout in several stream accounts, particularly where information on salmon is lacking. The intent is to show that certain stream reaches were accessible to at least steelhead and, hence, may have been reached also by chinook salmon—particularly spring-run fish, which typically

2. Agency abbreviations are as follows: California Department of Fish and Game (DFG); California State Board of Fish Commissioners (CFC); Federal Energy Regulatory Commission (FERC); United States Commission for Fish and Fisheries or U.S. Fish Commission (USFC); United States Fish and Wildlife Service (USFWS).

migrated far upstream. However, the correspondence between the occurrence of steelhead and spring-run salmon in stream reaches was by no means complete. Steelhead aggressively ascend even fairly small tributary streams, in contrast to chinook salmon which generally use the mainstems and major forks of streams (E.R. Gerstung, personal observation). The migration of steelhead during the peak of the rainy season (January-March) aided their ascent into the small tributaries. Steelhead also are able to surmount somewhat higher waterfalls—perhaps up to about 15 ft high—while chinook salmon in California appear to be stopped by falls greater than 10 to 12 ft high (E.R. Gerstung, personal observation), depending on the abruptness of the drop. Furthermore, steelhead do not require as much gravel for spawning. For example, steelhead formerly used streams in the upper Sacramento River drainage (near Shasta Reservoir) that had small patches of gravel interspersed among boulder substrate, which salmon generally shunned (E.R. Gerstung, personal observation). Yet, in terms of ascending the main stream reaches, it may be reasonably assumed that where steelhead were, spring-run salmon often were not far behind. Using the advantage of high spring flows, the salmon could have surmounted obstacles and reached upstream areas not much lower than the upper limits attained by steelhead in some streams.

Non-game fishes such as hardhead (*Mylopharodon conocephalus*), Sacramento pikeminnow (*Ptychocheilis grandis*) and Sacramento sucker (*Catostomus occidentalis*) also provide hints about salmon distribution. Those species are typical of valley floor and low- to mid-elevation foothill streams (Moyle 1976), and their recorded presence in stream reaches that are not blocked by obvious natural barriers is a good indication that anadromous salmonids likewise were able to ascend at least as far, and possibly even farther upstream. The presence of non-game native fish populations above obvious natural barriers in some streams suggests that at least some of the barriers were formed after the initial dispersal of those species into the upper watersheds.

Distributional Synopses of Salmon Streams

Kings River (Fresno County). Spring and fall runs of chinook salmon are known to have occurred at least periodically in the Kings River, the southernmost Central Valley stream that supported salmon. In the past, the Kings River flowed into the northeast part of Tulare Lake, and its waters occasionally ran into the San Joaquin River during wet periods when water levels became high enough in Tulare Lake to overflow and connect the two drainages (Carson 1852; Ferguson 1914). Streamflows would have been greatest during the spring snowmelt period, so it is most likely that the spring run was the predominant run to occur there. Spring-run salmon would have had to ascend to high enough elevations (probably >1,500 ft) to avoid excessive summer water temperatures, going above the area presently covered by Pine Flat Reservoir. The mainstem upstream of Pine Flat Reservoir is of low gradient (E.R. Gerstung, personal observation) and free of obstructions for some distance (P. Bartholomew, personal communication), so salmon probably were able to ascend about 10 to 12 mi beyond the present upper extent of the reservoir. The bulk of salmon migration in the Kings River probably ascended no farther than the confluence of the North Fork (Woodhull and Dill 1942), which we take as the upper limit. There is an undocumented note of "a few salmon" having occurred much farther upstream at Cedar Grove (28 mi above present-day Pine Flat Reservoir) in the past—"before Pine Flat Dam was constructed" (DFG unpublished notes). However, it is not clear if salmon actually could have reached that far, due to the presence of extensive rapids below around the area of Boyden Cave (3,300 ft elev.) and below Cedar Grove. The North Fork Kings River is very steep shortly above its mouth, and salmon most likely did not enter it to any significant distance (P. Bartholomew, personal communication, see "Notes").

Native American groups had several fishing camps on the mainstem Kings River downstream of Mill Flat Creek, including one used by the Choinimni people (a tribelet of the Northern Foothills Yokuts) at the junction of Mill Creek (about two miles below the present site of Pine Flat Dam). There, the "spring salmon run" was harvested and dried for later use (Gayton 1948b). Gayton (1946, p 256) wrote:

> *On the lower Kings River, the Choinimni (Y) [Y denoting Yokuts] and probably other tribes within the area of the spring salmon run (about May) held a simple river-side ritual at their principal fishing sites. The local chief ate the first salmon speared, after cooking it and praying to Salmon for a plentiful supply. Then others partook of a salmon feast, and the season, so to say, was officially open.*

The existence of a well-established salmon ritual among the native people seems to indicate that salmon runs in the Kings River were not uncommon, even if they did not occur every year (for example, in years of low precipitation). Furthermore, in regard to inter-tribelet relations among the Northern Foothills Yokuts, Gayton (1948b, p 143) stated: "While the Choinimni felt the north bank of Kings River to be theirs, … the Gashowa were welcome to occupy their fish camp … during the spring salmon run. These neighbors remained there while the fish dried, which they then took home to store." This statement indicates that there was a fairly regular granting of salmon-fishing privileges between some native groups around the Kings River.

The Tachi Yokuts, located on the Central Valley floor around the north shore of Tulare Lake and the lower reaches of the Kings River (Gayton 1948a; Cook 1955, 1960), also caught salmon as well as other fishes. The Spanish Lieutenant José Mariá Estudillo observed Tachi tribesmen catching fish by means of hand nets from the Kings River on 2 November 1819: "This they did before my very eyes, with great agility, diving quickly and staying under the water so long that I prayed …. After having caught sufficient large fish, salmon and others very palatable …" (translation by Gayton 1936, p 78). Given the date, those salmon were undoubtedly of the fall run. Steelhead also appear to have entered the Kings River drainage, at least to some extent. The pioneer Thomas Jefferson Mayfield, who was raised amongst the Choinimni people during the 1850s, recollected that "There were many pools of water in Sycamore creek, and in them we caught trout and speared a fish we called a steel head" (Latta 1929, p 15). Mayfield evidently was referring to the present Sycamore Creek which enters the Kings River above Trimmer (compare his description with map 2 of Gayton 1948a), at the upper part of Pine Flat Reservoir. Mayfield also stated that "Trout and other large fish were speared with a gig almost like a modern salmon gig" (Latta 1977, p 509). The ethnographer Frank Latta, a noted authority on the Yokuts nationality, added: "Many of the fish obtained in this manner were known as steelheads. They are a large fish resembling both salmon and trout. The meat of these, as well as others, was dried and smoked in large quantities" (Latta 1977, p 511).

Drawing on testimony from a Native American informant, Gayton (1948a) reported that "Salmon (*da'tu*) were well known and greatly depended upon" by the Chunut people (a subgroup of the Southern Valley Yokuts) who dwelt on the eastern shore of Tulare Lake—essentially the downstream terminus of the Kings River. A second Chunut informant interviewed by Latta (1977, p 722) similarly attested to the presence of salmon, and evidently steelhead, in the lake:

> *There were lots of fish in Tulare Lake. The one we liked best was a-pis, a bit [sic] lake trout. They were real big fish, as big as any salmon, and good meat …. Sometimes the steelheads came in the lake too; so did the salmon. We called the steelheads tah-wah-aht and the salmon ki-uh-khot. We dried lots of fish. When it was dried and smoked, the salmon was the best.*

The common "lake trout" of Tulare Lake was not a salmonid, but most likely the Sacramento pikeminnow. State Fish Commissioner B.B. Redding described it as "a fine large white-fleshed fish, about 2 feet 6 inches long, … It looks to me to be a carp, and of finer flavor than any I ate in Europe" (USFC 1876b, p 480). It is evident, however, that both salmon and steelhead entered Tulare Lake at least on occasion, where they were taken by Chunut fishers. It seems unlikely that the Chunut traveled out of their territory to the Kings River to obtain salmon, nor have we found any indication in the ethnographic literature that they did so. There would have been little reason for the Chunut to make regular fishing excursions to areas away from Tulare Lake, given that the lake contained an abundance and variety of high-quality fish resources (Gayton 1948a; Latta 1977), and in fact it was the Kings River Choinimni people (and perhaps others) who made seasonal trips downriver to Tulare Lake for fishing (Latta 1929; Gayton 1948b).

Furthermore, an early newspaper article mentioned the probable occurrence of salmon in Tulare Lake and its environs:

> *The abundance of fish of all kinds in these waters is absolutely astonishing. …Pike, perch, bass, salmon trout [probably steelhead or perhaps salmon grilse], eels [lampreys], suckers, and many other kinds, … are caught with the greatest of ease, and we have no doubt that the lordly salmon himself frequents the lakes in his proper season (San Francisco Picayune, 15 November 1851; reprinted in Heizer 1976, p 59).*

Diversions from the Kings River and other streams for agricultural irrigation occurred from the early years of American settlement and farming in the San Joaquin Valley. The reduced streamflows undoubtedly diminished the frequency of salmon runs—and perhaps extinguished them altogether—for a period spanning the late-19th to early-20th centuries. The California Fish and Game Commission reported that after a channel was dredged out between the Kings and San Joaquin rivers in about 1911, salmon began appearing in the Kings River—"a few" in the spring of 1911, a "very considerable run" in 1912, which ascended to Trimmer Springs (river mile [rm] 125) near the upper end of present-day Pine Flat Reservoir, and another "very considerable run" in June 1914 (Ferguson 1914). Several small chinook salmon were caught by a DFG biologist in the fall of 1942 near the town of Piedra on the mainstem Kings River (about two miles downstream of the mouth of Mill Creek; W. Dill, personal communication, see "Notes"); those fish were notable in that they were precociously mature males—in other words, running milt (W. Dill, personal communication, see "Notes"). A single, approximately five-inch chinook salmon (with "very enlarged testes") was later captured in September 1946 in the mainstem "about eight miles above the junction of the North Fork Kings River" (W. Dill DFG letter). Moyle (1970) later collected juvenile chinook salmon (about four inches total length) in April 1970 from Mill Creek, just above its mouth. Salmon that spawned in Mill Creek likely ascended the stream at least several miles to the vicinity of Wonder Valley (P. Bartholomew, personal communication, see "Notes"). Salmon runs in the Kings River were observed to occur more frequently after the construction of the Kings River Bypass in 1927, with "especially noticeable runs" in 1927, 1938, and 1940 (Woodhull and Dill 1942).

The Kings River salmon run was probably bolstered by, or perhaps even periodically reestablished from, the San Joaquin River population, particularly after series of dry years during which the run would have progressively diminished. After 1946, the termination of most natural streamflows down the channel of the San Joaquin River, except during exceptionally wet years, resulted in the extirpation of salmon runs in both the Kings and upper San Joaquin rivers.

San Joaquin River (Fresno County). Spring and fall runs of salmon formerly existed in the major San Joaquin River tributaries and in the upper San Joaquin River (Clark 1943; Fry 1961), and there also may have been a late-fall run present in the mainstem. However, all salmon runs in the San Joaquin River above the confluence of the Merced River were extirpated by the late-1940s.

The Spanish explorers and missionaries of Old California, probing the inner San Francisco Bay and Sacramento-San Joaquin Delta region, encountered evidence of salmon. In early April 1776, an expedition led by Captain Juan Bautista de Anza observed salmon (evidently spring-run) being harvested by the native people near present-day Antioch at the mouth of the San Joaquin River. De Anza wrote:

> *We have noted that the fish most abundant at present from the mouth of the bay to here are the salmon. They are very red in color, and are tender, and none of those we have seen is less than five quarters long [about 40 inches; based on Latta 1977, p 64]. … At the village which we passed there were so many that it seems impossible that its residents could eat them, … (Bolton 1930a, p 146).*

Father Pedro Font, diarest for that party, further noted that on April 2:

> *The soldiers purchased four fish somewhat more than a vara long [one Spanish vara equals about 33 inches; Cutter 1957, p 34] and about a third of a vara wide. At first we did not recognize it, but on opening it, and especially when we ate it, we saw that it was salmon, tenderer, fatter, and more savory than that which we ate at the mission of Carmelo [Carmel],… Bolton 1930b, p 377).*

Spanish exploration did not fully encompass the San Joaquin Valley until October 1806, when a party led by Ensign Gabriel Moraga traversed the eastern side of the San Joaquin River. Records of the expedition do not mention actual observations of salmon, but Father Pedro Muñoz noted that "Beaver abound and also salmon, according to what was told us by the Indians native to this country" (Diary of Father Pedro Muñoz, translation by Cook 1960, p 248). Moraga's expedition discovered and named the three major tributaries of the San Joaquin River—the River of Our Lady of Guadalupe (Stanislaus River), the River of Our Lady of Sorrows (Tuolumne River), and the River of Our Lady of Mercy (Merced River) (Cutter 1950; Cook 1960)—and those three streams now remain the southernmost streams supporting chinook salmon in North America.

On a later expedition in 1810, Father José Viader recorded that on October 20 at the village of Cholvones (or Pescadero) on Old River (the West Branch of the lower San Joaquin River), "…we rested here and passed time well with fresh salmon and wild grapes"; and, on October 23, "Indians …from the village of Cuyens, came out to meet us, bearing as a gift three very big, red, salmon" (Report of Father José Viader, translation by Cook 1960, p 259, 260). Cuyens (or Guyens) was located just downstream of the Stanislaus River mouth (Cook 1955; Bennyhoff 1977). The dates given in that report indicate that the salmon were of the fall run, which is perhaps the earliest explicit record of fall-run salmon for the San Joaquin River basin.

There are virtually no historical references to salmon occurring on the western side of the San Joaquin Valley, where the streams were seasonally prone to dry out. One enigmatic exception is the diary entry for 26 August 1810 by Father José Viader, when the expedition passed the area of San Luis Creek, just east of Pacheco Creek: "We stopped at the foot of the range along a creek which had no more water than a few scattered pools. In just one of these we caught forty fish including six trout or little salmon" (Cook 1960, p 259). Conceivably, those latter six fish might have been steelhead.

An American traveler, John Woodhouse Audubon, provided an early testimony of fall-run salmon in the San Joaquin River basin which he observed sometime after mid-November 1849 in a reach several days travel above the confluence of the Stanislaus River:

> *The water is beautifully clear now, and is full of fine-looking fish; the large salmon of these rivers is a very sharky-looking fellow and may be fine eating; but as yet we have not been fortunate enough to get one, though several have been shot by Hudson and Simson as they lay in the shallows (Audubon 1906, p 185).*

Likewise, the naturalist John Muir, while boating on the San Joaquin River just above the confluence of the Tuolumne river, observed on 18 November 1877 that "Salmon in great numbers are making their way up the river for the first time this season, low water having prevented their earlier appearance" (Muir 1938, p 244)—further attesting to a numerous fall salmon run. Muir found on that day a "salmon trout" carcass—possibly a steelhead—"new killed and dressed and laid out on the bank for me by fish hawks" (Muir 1938, p 243). Livingston Stone of the US Fish Commission stated, "…in regard to this [San Joaquin] river that it is much warmer than the Sacramento, but is frequented somewhat by salmon, especially in the fall, which are killed in considerable quantities on some of its tributaries" (Stone 1874, p 176). The California Fish Commission noted: "This [San Joaquin River] is a very good stream for the Fall run of salmon, the ascent being not very steep, and the current, especially the first seventy-five miles, not being very strong" (CFC 1884, p 15).

While the uppermost distribution of salmon in the San Joaquin River in earlier years is not known with certainty, the US Fish Commission (USFC 1876a, p xxviii) noted that salmon went up "…to the headwaters of the San Joaquin, about two hundred and fifty miles." The California Fish and Game Commission reported:

> *These [spring-run] salmon ascend the river during May, June and the first part of July. In the foot hills near Friants they congregate in the large pools and remain until such time in the fall as the temperature is right for them to spawn, then they ascend the river into the gorge of the San Joaquin River where they spawn in the fall. This is the result of our observations and data gathered from the residents and deputies who have lived in that vicinity for years (CFGC 1921a, p 21).*

It was reported that the spring run historically ascended the river past the present site of Kerckhoff Power House to spawning grounds in the higher reaches (CFGC 1921b). A natural barrier shortly upstream of Willow Creek near present-day Redinger Lake may have posed an obstruction to salmon (E. Vestal, personal communication, see "Notes"). However, there is evidence that salmon traveled considerably farther upstream at least to the vicinity of present-day Mammoth Pool Reservoir (about 3,300 ft elev.). The oral history of Native American residents in the region includes references to salmon occurring there (P. Bartholomew, personal communication, see "Notes" based on interviews with Native American informants). Lee (1998, p 87), drawing from family reminiscences, stated that salmon ascended to "their old spawning grounds upriver from *Cha:tiniu* [Logan Meadow, adjacent to Mammoth Pool Reservoir].…[where] our ancestors speared salmon only a few hundred yards from the meadow where they lived." Hence, we take the point about three miles up the length of Mammoth Pool Reservoir as the (minimal) upstream historical limit of salmon.

Based on the absence of natural barriers, it may be inferred that salmon probably entered two small tributaries of the upper San Joaquin River near Millerton Reservoir—Fine Gold Creek, perhaps "as far upstream [about six miles] as opposite Hildreth Mtn," and Cottonwood Creek probably at least two miles (E. Vestal unpublished notes and personal communication, see "Notes"). Also, salmon evidently entered two larger, intermittent tributaries farther downstream on the valley floor—the Chowchilla and Fresno rivers—which probably had only occasional runs during the wet years. The Fresno River arises "far back in the Sierra" and long ago was described as "carrying an immense body of water down toward the plains" (Elliott 1882, p 20), so the occasional past occurrence of salmon would not be surprising. In passing reference to those streams, B.B. Redding of the California Fish Commission wrote to US Fish Commissioner Spencer Baird in April 1875:

> *Formerly there was considerable work done in the catching of salmon in the San Joaquin, but of late years it has been abandoned, …I suppose that the fish are still going up the San Joaquin to spawn, but, if taken at all, are only now taken by Indians on the Merced, the Chowchilla, the Fresno, and the other branches of the San Joaquin, and I have no doubt they continue to do so (USFC 1876b, p 479).*

As recently as the 1980s, a few salmon—presumably strays from other streams—have been observed by anglers in the Chowchilla and Fresno rivers during years of high streamflows (R. Kelly, personal communication, see "Notes"). Because of the uncertainty of how far salmon formerly ascended the intermittent or small tributaries of the upper San Joaquin River, we exclude them from our tabulation of stream lengths historically used by salmon. Hence, our assessment of the distributional limits of salmon in the upper San Joaquin River drainage is conservative.

Native people of the Northern Foothill Yokuts groups, including the Chukchansi from Coarse Gold Creek and the Fresno River, traveled to and fished for salmon in the San Joaquin River near the area of Friant (Gayton 1948b). According to Gayton's (1948b, p 165) ethnographic account, the salmon were watched for "when the Pleiades were on the western horizon at dusk," and a first salmon ritual for the spring run was held by several different Yokuts groups when the first salmon of the season was caught. Large quantities of salmon were dried for storage: "They were put in a sack [skin?] and packed home with a tumpline. A man carried about two hundred pounds of fish" (Gayton 1948b, p 185). The zoologist-ethnographer C. Hart Merriam recorded in his field notes for 30 October 1903: "…a few Pit-kah'-te and Kosho'-o Indians [Yokuts groups] were fishing on a stretch of the river from Pullasky [later named Friant] upstream for a mile or so. They were spearing salmon and drying them for winter use" (Heizer 1967, Part III, p 416). Given the date, those salmon undoubtedly were the fall run. The ethnographer Frank Latta (1977, p 511) noted: "We are assured that along the San Joaquin River, many tons of salmon were taken during the annual 'run' and that the bushes and banks about the villages and camps were red with drying fish."

The areas farther up the upper San Joaquin River, above the Yokuts, were occupied by Western Mono groups. The "Northfork Mono" people (or Nüm), who lived on the "North Fork" San Joaquin River (also called Northfork Creek or Willow Creek), Whiskey Creek and nearby areas, caught "Steel-head trout (*Salmo rivularis*), rainbow trout, and the Sacramento salmon" which "were eaten with acorn mush" Gifford (1932, p 21). Fishing for salmon was done primarily in the mainstem upper San Joaquin River, rather than in the small tributaries. Lee (1998, p 89) identified the crossing at *Samhau* (just above present-day Redinger Lake) and *Pakapanit* (north of Italian Bar Road) as the preferred fishing spots in the old days, and he also noted that his grandfather and great-grandfather "speared salmon, suckers and trout" at "Pasagi, near *Chu:wani*" (on Ross Creek). Excursions also were made "to the river where Kerckhoff Dam is, to fish for salmon" (Lee 1998, p 87). We have found no references which indicate how far up Willow Creek salmon ascended, if at all, so we presently do not include it as a former salmon stream. The Northfork Mono people were said to have held first salmon rites (Aginsky 1943).

As early as 1884, the California Fish Commission noted that the salmon runs had been detrimentally affected because of "dams on the headwaters of the Stanislaus, Tuolumne, San Joaquin, and the upper Sacramento Rivers …a great drawback to the salmon interest, as the spawning grounds are, for the most part, above the dams" (CFC 1884, p 15). On the upper San Joaquin River, the construction and operation of Kerckhoff Dam (about 1920) for power generation permanently blocked the spring-run salmon from spawning areas upstream and seasonally dried up about 14 mi of stream below the dam, where pools formerly provided over-summering habitat for the salmon (CFGC 1921b). Later in that decade, Clark (1929) reported that the salmon spawning beds were located in the stretch between the mouth of Fine Gold Creek and Kerckhoff Dam and in the small tributary streams within that area, covering a stream length of about 36 mi; a few scattered beds also occurred below the town of Friant. At the time of Clark's (1929) writing, there were four dams on this river that impeded the upstream migration of salmon: the "Delta weir" (in a slough on the west side of the river, 14 mi southeast of Los Banos); Stevenson's weir (on the main river east of Delta weir); Mendota weir (1.5 mi from the town of Mendota); and the impassable Kerckhoff Dam, 35 mi above Friant. The first three dams were irrigation diversion projects. Friant Dam had not yet been constructed. In addition to the barriers themselves, reduced streamflows due to irrigation diversions impeded and disoriented uncounted numbers of migrating salmon which went astray in the dead-end drainage canals on the valley floor, where they abortively spawned in the mud (Clark 1930).

Hatton (1940, p 358) considered the upper San Joaquin River in 1939 to possess the "most suitable spawning beds of any stream in the San Joaquin system," and "even in the dry year of 1939, most of the suitable areas were adequately covered with water and the water level was satisfactorily constant." The spawning beds in the San Joaquin River were located along the 26 mi from Lane's Bridge up to the Kerckhoff Power House, all of which were accessible, and the "best and most frequently used areas" were between Lane's Bridge and Friant. The stream just above Friant, where it entered a canyon, was viewed as generally unsuitable, comprising mainly bedrock, "long, deep pools" and "short stretches of turbulent water" (Hatton 1940, but see

CFGC 1921a and above). The planned Friant Dam would cut off an estimated 16 mi of stream where spawning occurred, representing about 36% of the spawning beds, but at that time Hatton considered the spawning beds below Friant Dam to be "so underpopulated that even after the completion of the dam more than adequate areas will still be available, if water flows are adequate." The expected negative impact of Friant Dam was not so much the elimination of spawning areas above the dam as the diversion of water from the stream channel downstream. However, quoting Hatton (1940, p 359), it was "hoped that seepage from the dam and returned irrigation water will provide sufficient flow to make spawning possible." Evidently, the deleterious consequences of vestigial streamflows and polluted irrigation drainage on salmon were not yet fully appreciated at that time.

Hatton (1940) reported that the stretch of the San Joaquin River where spawning occurred was "singularly free of obstructions and diversions," but there were obstructions farther downstream. The lowermost barrier below the spawning beds was the "sack dam" of the Poso Irrigation District, "several miles below Firebaugh" (near Mendota). He stated: "In the average water year this dam destroys any possibility of a fall run up the San Joaquin. The compete diversion of water leaves the stream bed practically dry between that point and the mouth of the Merced River" (Hatton 1940, p 359). The sand bags constituting this dam were left in place until they were washed out by the winter floods. The only other obstruction below the spawning beds was the Mendota weir, which was equipped with a "satisfactory fishway"; however, there were eight unscreened diversions above the dam which Hatton viewed as "a serious menace to the downstream migrants."

The numbers of salmon that at one time existed in the San Joaquin River were, by some accounts, tremendous. Clark (1929, p 31) stated that, "Fifty or sixty years ago, the salmon in the San Joaquin were very numerous and came in great hordes." Indeed, the early residents of Millerton on the banks of the San Joaquin were kept awake by the migrating spring-run salmon (Vandor 1919; CSHA 1929), because "their leaping over the sandbars created a noise comparable to a large waterfall" (NCHRSP 1940, p 13). The historian Vandor (1919, p 106) wrote:

> *The San Joaquin was a stream of pure icy water, and clear as a crystal where not muddied by mining. Salmon ascended to the spawning grounds by the myriads, and, when the run was on, the fish were hunted with spear, pitchfork, shovel, even with shotgun and revolver. Salmon appeared in such shoals that as late as July, 1870, it was recorded that restful sleep was disturbed because 'myriads of them can be heard nightly splashing over the sand bars in the river opposite town as they make their way up.'*

The site of Millerton is now covered by Millerton Reservoir. In reference to the fall-run salmon (and perhaps steelhead), one correspondent wrote to State Fish Commissioner B.B. Redding: "…in the fall the salmon and salmon-trout find their way up here in large quantities. Last fall I helped to spear quite a number, as that is about the only way of fishing in this part of the county; but below the San Joaquin bridge I understand they were trapped in a wire corral by ranchers and fed to hogs; they were so plentiful" (USFC 1876b, p 480).

The former spring salmon run of the San Joaquin River has been described as "one of the largest chinook salmon runs anywhere on the Pacific Coast" and numbering "possibly in the range of 200,000 to 500,000 spawners annually" (DFG 1990). During a reconnaissance in late-July 1853 in the vicinity of Fort Miller (just upstream of Millerton), Blake (1857, p 20) observed, in reference to spring-run salmon: "During our stay at this camp we purchased fresh salmon of the Indians, who catch them in the river. It is probable, however, that they are not abundant, as the mining operations along the upper part of the stream and its tributaries sometimes load the water with impurities." While Blake's conjecture regarding the spring-run salmon evidently was not accurate at the time, it foreshadowed events to come.

By the end of the 19th century, the California Fish Commission observed:

> *Formerly there was a considerable run of salmon in the San Joaquin River, but as a result of mining and the diverting of water for irrigation, the run has decreased until now [1897-1898] it is confined to a short period in the fall. This fall run does not seek the extreme headwaters to spawn as formerly, and while a few enter the Stanislaus and Merced rivers, the majority seem to prefer the San Joaquin proper. …Why the spring run does not go up this stream [San Joaquin River] instead of preferring the Sacramento, while some of the fall run continue up this river…remains unresolved. That the condition described is well recognized by the net-fishermen is proved by the fact that none of them are to be found above Jersey Island in the spring, while a number of boats are used above that point in the fall (CFC 1900a, p 24).*

The Fish Commission of that time apparently did not fully realize that it was the spring run, rather than the fall run, that had formerly ascended to the headwaters and, hence, had been more drastically affected by the mining and the water diversions, although previous state fish commissioners were well aware of the detrimental impact of dams which had cut off the upper spawning grounds in the San Joaquin basin tributaries (for example, CFC 1884, p 15). Later, Clark (1929, p 31) reported that a "very good run" of salmon was seen at Mendota in 1916–1917 and a "fairly good" one for 1920, but thereafter the runs declined so that by 1928 "very few" fish were seen and the salmon of the San Joaquin River seemed to be "fast decreasing." By then there was essentially only a spring run, the water being too low to support any appreciable fall run (Clark 1929).

The decline of the salmon resource of the upper San Joaquin River was, of course, noted by the river inhabitants. Particularly affected were Native Americans who depended upon the runs for sustenance. In the words of a Yokuts man named Pahmit (William Wilson) in 1933:

> *Long time 'go lots salmon in San Joaquin River. My people—maybe two to three thousand come Coo-you-illik catch salmon—catch more salmon can haul in hundred freight wagons. Dry 'em—carry 'em home. …[Since 1909] no salmon in river. White man make dam at old Indian rancheria Käh-wäh-chu—stop fish—now Indian got no fish. Go river—water there, but no fish. White man got no fish. White man got no money. Injun got no fish—Injun got no money—everybody broke. That's bad business (F. Latta unpublished field notes).*

Coo-you-illik ("Sulphur Water") was a Dumna Yokuts village at the later site of Fort Miller (Latta 1977). The salmon were also well remembered by non-Native Americans in later decades: "The salmon fishing in the San Joaquin River was out of this world. It was one of the finest spawning rivers for salmon….There were hundreds and hundreds…. The salmon looked like silver torpedoes coming up the river" (Anthony Imperatice interview, 11 February 1988; in Rose 1992, p 119).

In spite of the general decline of salmon in the upper San Joaquin River due to increasingly inhospitable environmental conditions, particularly for the fall run, a substantial spring run and even a remnant fall run managed to persist for a time. Hatton (1940, p 359) reported that the fall run occurred in "some years…making a hazardous and circuitous journey through a series of natural sloughs and irrigation laterals [canals], beginning near the mouth of the Merced [River] and miraculously entering the [San Joaquin] river through the main canal above Mendota Weir." Clark (1943) stated that in 1942, the upper San Joaquin River had "a fair-sized spring run of king [chinook] salmon for many years" and a fall run that had "been greatly reduced."

Fry (1961) also reported that during the 1940s before the construction of Friant Dam, the San Joaquin River had "an excellent spring run and a small fall run" and that its spring run was probably "the most important" one in the Central Valley. The spring run amounted to 30,000 or more fish in each of three years of that decade and a minimum of 56,000 spawners which passed Mendota weir in 1945 (DFG 1946; Fry 1961), with an annual value of "almost one million dollars" (Hallock and Van Woert 1959, p 246). In 1946, the sport fishery in the San Joaquin Valley took an estimated 25,000 salmon produced by the upper San Joaquin River, with perhaps another 1,000 caught in the ocean sport fishery (DFG 1955 unpublished document). In addition, the commercial harvest (averaged for the period 1946–1952) accounted for another 714,000 pounds of salmon that originated from the San Joaquin River (DFG 1955 unpublished document). However, both the spring and fall salmon runs were extirpated from the upper San Joaquin River above the confluence with the Merced River as a direct result of the completion of Friant Dam (320 ft high) in 1942 and its associated water distribution canals (namely, Madera and Friant-Kern canals) by 1949 (Skinner 1958). Friant Dam itself cut off at least a third of the former spawning areas, but more importantly, the Friant Project essentially eliminated river flows below the dam, causing about 60 miles of river below "Sack Dam" to completely dry up (Skinner 1958; Hallock and Van Woert 1959; Fry 1961). During the relatively dry winter of 1946–1947, the US Bureau of Reclamation allowed no more than 15,000 acre-feet of water to be released from Friant Dam for the spring run, and only 6,000 salmon were counted passing Mendota weir in 1947 (DFG 1948). The last substantial spring-run spawning cohort (numbering >1,900 fish) occurred in 1948 (Warner 1991). While not attributing the collapse of the Sacramento-San Joaquin River spring-salmon fishery solely to Friant Dam, Skinner (1958) noted the "striking coincidence" that in the 1916–1949 (pre-Friant) period, the spring-run catch averaged 664,979 pounds (31% of the total Sacramento-San Joaquin River commercial catch) and in 1950–1957 (post-Friant) it averaged 67,677 pounds (6% of the total catch)—a 90% reduction in absolute poundage. Skinner (1958) further chronicled the telling correlation between events in the development of the Friant Project, their effects on year-classes of fish, and the rapid deflation of the spring in-river fishery—the latter falling from a high catch of 2,290,000 pounds in 1946 to a low of 14,900 pounds in 1953. "Last-ditch" efforts by DFG biologists to preserve the last cohorts of the upper San Joaquin River spring-run salmon in 1948, 1949, and 1950 were foiled by insufficient streamflows and excessive poaching, thereby resulting in the extinction of the run (DFG 1950; Warner 1991).

Since the closure of Friant Dam, polluted irrigation drainage during much of the year has comprised essentially all of the water flowing down the course of the San Joaquin River along the valley floor until it is joined by the first major tributary, the Merced River (San Joaquin Valley Drainage Program 1990). In only very wet years in recent decades have a few salmon occasionally ascended the San Joaquin River below Friant Dam, the latest record being that of a single 30-inch male (possibly spring-run) caught by an angler on 1 July 1969 below Friant Dam (Moyle 1970).

The former San Joaquin River salmon runs were the most southerly, regularly occurring large populations of chinook salmon in North America, and they possibly were distinctly adapted to the demanding environmental regime of the southern Central Valley. The California Fish Commission regarded the migration of the fall salmon run during the seasonally hot portion of the year as extraordinary:

> *Large numbers pass up the San Joaquin River for the purpose of spawning in July and August, swimming for one hundred and fifty miles through the hottest valley in the State, where the temperature of the air at noon is rarely less than eighty degrees, and often as high as one hundred and five degrees Fahrenheit, and where the average temperature of the river at the bottom is seventy-nine degrees and at the surface eighty degrees (CFC 1875, p 10; USFC 1876b, p xxv).*

The Commissioners noted that during August-September of 1875–1877, the average monthly water temperatures for the San Joaquin River where two bridges of the Central Pacific Railroad crossed (at 37°50'N, 121°22'W and 36°52'N, 119°54'W) were within 72.1 to 80.7 °F (considering both surface and bottom water) and maximal temperatures were 82 to 84 °F (CFC 1877). The high temperature tolerance of the San Joaquin River fall-run salmon inspired interest in introducing those salmon into the warm rivers of the eastern and southern United States (CFC 1875, 1877; USFC 1876a, 1876b). Quoting the California Fish Commission (CFC 1875, p 10):

> *Their passage to their spawning grounds at this season of the year, at so high a temperature of both air and water, would indicate that they will thrive in all the rivers of the Southern States, whose waters take their rise in mountainous or hilly regions, and in a few years, without doubt, the San Joaquin Salmon will be transplanted to all of those States.*

Perhaps it was this hardiness of the fall-run fish that enabled them to persist through years of depleted streamflows, "miraculously" negotiating the sloughs and irrigation ditches from about the mouth of the Merced River up the San Joaquin River drainage as mentioned by Hatton (1940, p 359). Yet, nothing is known of the physiological and genetic basis of the seemingly remarkable temperature tolerances of San Joaquin River fall-run salmon because that population was driven to extinction decades ago. It is not known to what degree the remaining fall-run populations in the major tributaries of the San Joaquin River possess the temperature tolerances and genetic characteristics of the original San Joaquin River fall run. Because of extreme fluctuations in year-to-year run sizes in recent times and the probable loss of genetic variation during population bottlenecks, it is likely that present-day fall-run salmon of the San Joaquin tributaries are genetically different from their forebears, or at least from the former San Joaquin River fall run. Similarly, the spring-run fish of the San Joaquin River perhaps also were physiologically and genetically distinctive due to their extreme southerly habitation. After completion of Friant Dam, spring-run fish began to use areas below the dam (Clark 1943). Approximately 5,000 spring-run fish were observed over-summering in pools below the dam during May through October 1942, where water temperatures had reached 72 °F by July. The fish remained in "good condition" through the summer, and large numbers were observed spawning in riffles below the dam during October and November (Clark 1943, p 90). A temperature of 80 °F has been regarded as the upper thermal limit for San Joaquin River spring-run fish, above which most of them would have died (DFG 1955 unpublished document), although much lower temperatures (40 to 60 °F) are necessary for successful incubation of the relatively temperature-sensitive eggs (Seymour 1956; Beacham and Murray 1990).

In addition to the spring and fall salmon runs, there were indications that a late-fall run possibly occurred in the San Joaquin River (Van Cleve 1945). In 1941, a run apparently of appreciable size entered the river, starting about 1 December and continuing through at least 10 December (Hatton and Clark 1942). The authors concluded that "a run of several thousand fish may enter the upper San Joaquin River during the winter months, in addition to the spring run during March, April and May" (Hatton and Clark 1942, p 123). This December run has been viewed as a possible late-fall run (Fisher 1994) because peak migration of late-fall-run fish characteristically occurs in December, at least in the Sacramento River system. A likely alternative, however, is that the migration observed by Hatton and Clark was simply the fall run, having been delayed by unfavorable conditions that evidently typified the river in the early fall months. Clark (1943) in fact stated that a "late-fall run of salmon occurs after this sand dam [the Sack Dam near Firebaugh] is washed or taken out in late November," indicating that the fall run was usually blocked from ascending past that point any earlier. Furthermore, spawning of Central Valley fall-run stocks tend to occur progressively later in the season in the more southerly located streams, at least at the present time (F. W. Fisher unpublished data), and the spawning migration period is known to include December in the San Joaquin basin tributaries (Hatton and Clark 1942; T. Ford, personal communication, see "Notes"). Nevertheless, a distinct late-fall run (sensu Fisher 1994; Yoshiyama and others 1998) may have actually existed in earlier times in the San Joaquin River. Historical environmental conditions in the mainstem reach of the San Joaquin River just above the valley floor were apparently suitable for supporting late-fall-run fish, which require cool water flows during the summer juvenile-rearing period. To wit, Blake (1857, p 20) noted of the San Joaquin River (near Fort Miller) in late July 1853:

> *The river was not at its highest stage at the time of our visit; but a large body of water was flowing in the channel, and it was evident that a considerable quantity of snow remained in the mountains at the sources of the river. A diurnal rise and fall of the water was constantly observed, and is, without doubt, produced by the melting of the snow during the day. The water was remarkably pure and clear, and very cold; its temperature seldom rising above 64° Fahrenheit while that of the air varied from 99° to 104° in the shade.*

Merced River (Merced County). Both spring and fall salmon runs, and evidently steelhead, historically occurred in the Merced River, but only the fall run has survived and is now the southernmost native chinook salmon run in existence (Reynolds and others 1993). According to a gold miner's account, Native Americans were observed harvesting salmon in the spring of 1852 at Merced Falls, where their "rancheria" (village) was located (Collins 1949). Another gold miner noted, during the first half of November 1849, "At the River Mercedes we saw some Indians, …These Indians were fishing for salmon, at which business they are very expert and successful" (Woods 1851, p 83)—in obvious reference to the fall run. Boating down the lower Merced River below Hopeton on 10 November 1877, John Muir observed, "Fish abundant in deep pools—salmon, trout, and suckers" (Muir 1938, p 241). Based on the date, the salmon he saw undoubtedly were fall-run salmon and the "trout" may have been steelhead. Spring-run salmon were also reported from the vicinity of "Horse Shoe Bend" (now covered by Exchequer Reservoir), near Coulterville (Mariposa Gazette, 24 June 1882 and 25 June 1887; J.B. Snyder, personal communication, see "Notes"). Oral history obtained from local residents (Snyder unpublished memorandum, 9 May 1993) indicates that salmon occurred in the mainstem Merced River in the area between Bagby and Briceburg near the branching of the North Fork. There is a 20-foot waterfall below Briceburg (Stanley and Holbek 1984), but it probably was not steep enough to have posed a substantial obstacle to salmon (see below). Another gold miner's journal (Perlot 1985) indicates that salmon were caught in abundance on the mainstem Merced River some unspecified distance above the confluence of the South Fork—possibly approaching the vicinity of El Portal (about 2,000 ft elev.). The section of river above El Portal is of high gradient and would have presented a rigorous challenge to migrating fish; thus, it is not clear if substantial numbers of salmon, if any, were able to ascend beyond that point.

There has been disagreement on whether any salmon reached Yosemite Valley. Dr. Lafayette Bunnell, writing of his service with the Mariposa Battalion which discovered the Yosemite Valley in 1851, noted:

> *Below the cañon of the Yosemite, young salmon were once abundant. The Indians used to catch fish in weirs made of brush and stones; but during the extensive mining operations on the Merced and other rivers, the salmon seemed to have almost abandoned their favorite haunts, for the mud-covered spawn would not hatch. Large salmon were speared by the Indians in all the rivers,…(Bunnell 1990, p 165).*

Shebley (1927, p 169) later stated: "At that time [1892] …the steelhead and salmon ascended the Merced River to Wawona [South Fork] and into Yosemite Valley [on the mainstem] as far as the rapids below the Vernal-Nevada Falls," and there "were a few low dams in the river, but they were not high enough to prevent the steelhead and salmon passing them during the spring floods." However, Shebley provided no evidence to support his statement, which was later discounted (Snyder 1993 unpublished memorandum). The absence of any clear reference to salmon in the early historical accounts of the Yosemite Valley (for example, Muir 1902, 1938, 1961, 1988; Hutchings 1990), and the present lack of archaeological and ethnographic evidence showing that native peoples subsisted on salmon in the higher elevation parts of the drainage (Snyder 1993 unpublished memorandum) seem to argue against the past occurrence of salmon there, at least in significant numbers. Snyder (unpublished 1993 memorandum), noted that there are no references to salmon in the native folklore of the Yosemite region, nor to terms related to the procedures of salmon fishing as there are in the cultural milieu of native inhabitants of the lower elevations. The paucity of suitable spawning gravels in Yosemite Valley (E.R. Gerstung, personal observation) also would indicate that few, if any, salmon ascended that far, although the presence of "speckled trout" (rainbow trout, *Oncorhynchus mykiss*) in Yosemite Valley was noted in some early accounts (Caton 1869; Lawrence 1884; Hutchings 1990). Yet, California Fish Commissioner B.B. Redding had noted even earlier, in 1875:

> *A few years since, they [salmon] spawned near the Yosemite Valley. A dam built for mining purposes, some four or five years since, prevented them from reaching this spawning ground. Last year the dam was removed and the fish have again free access to the headwaters of the Merced, but whether they have returned to their former spawning grounds on this river …I have not learned (USFC 1876b, p 481).*

It appears, therefore, that salmon at one time and in unknown numbers may have approached the vicinity of Yosemite Valley, even if they did not enter the valley proper. However, for the present, the area around El Portal or just downstream of it may be the best estimate of the historical upstream limit of salmon in the mainstem Merced River, unless supporting evidence for Shebley's (1927) statement that they ascended farther upstream can be found. Even the vicinity of El Portal may be higher than where most of the salmon historically ascended, considering the lack of archaeological evidence of salmon-fishing technology or salmon remains in excavations near El Portal (J. Snyder, personal communication, see "Notes").

Salmon most likely ascended the South Fork Merced River at least to Peach Tree Bar, about seven miles above the confluence with the mainstem, where a waterfall presents the first significant obstruction (P. Bartholomew, personal communication, see "Notes"). Hardheads are limited in their upstream distribution by the waterfall, and Sacramento suckers occur even farther upstream to the vicinity of Wawona (Toffoli 1965; P. Bartholomew, personal communication, see "Notes"). Salmon commonly spawn in the same reaches frequented by those species (Moyle 1976; E.R. Gerstung, personal observation), so they undoubtedly also reached Peach Tree Bar, if not further. It is possible that salmon surmounted the waterfall and ranged above Peach Tree Bar, but there is no confirmatory historical information available; if they did so, their upstream limit would have been a 20-foot waterfall located near the mouth of Iron Creek, about four miles below Wawona (E.R. Gerstung, personal observation). The North Fork Merced River is a relatively low watershed (about 1,300 ft elev. at the lower end), but there are substantial falls located about one mile above the mouth (T. Ford, personal communication, see "Notes"; E. Vestal unpublished notes) which would have prevented further penetration into the drainage by salmon. Rutter (1908) also mentioned "a 12-foot fall" that separated the North Fork from the "main Merced River." This perhaps was the cascade mentioned by the gold miner J.N. Perlot which "had at all times been an insurmountable obstacle for the fish," thus accounting for his observations that the North Fork "contained no kind of fish whatsoever, not the least whitebait, not the smallest gudgeon" (Perlot 1985, p 282).

As early as 1852, a temporary barrier was erected by fishermen about ten miles below Merced Falls which blocked the spring-run salmon from their upstream spawning areas (Collins 1949). In the following decades, a succession of dams was built at Merced Falls and at locations upstream up to the Yosemite National Park boundary—including the 120-foot high Benton Mills Dam at Bagby (built in 1859) and a later (1900) dam at Kittredge, four miles below Bagby (Snyder 1993 unpublished memorandum). Those dams had already impeded the upstream migration of salmon by the 1920s, but it was the construction of Exchequer Dam that permanently barred the salmon from their former spawning grounds (CFGC 1921b). Clark (1929) stated that the existent spawning beds were on "occasional gravel bars" located between the river mouth and Exchequer Dam, with "about 12 miles" of streambed available. These are in the lower river and therefore pertain to fall-run fish. As of 1928, there were three obstructions to migrating salmon: Crocker Huffman irrigation diversion dam near Snelling; Merced Falls about three miles upriver, where there was a natural fall and the 20-foot Merced Falls Dam with a defunct fishway; and Exchequer Dam, 20 mi above Merced Falls. A decade later, Hatton (1940) considered the spawning areas to occur between "a point half a mile downstream from a line due south of Balico" and Exchequer Dam. Of this 42.2-mi stretch, only 24.1 mi was accessible to salmon due to obstructions; there were four beaver dams, passable under "usual water conditions," and four impassable rock dams lacking fishways and allowing only "seepage" to pass downstream. Above these rock dams was the Merced Falls Dam, equipped with a fishway but inaccessible to the salmon because of the downstream obstructions and low water flows. Presently, natural spawning by fall-run fish principally occurs in the stretch above Highway 59 to the Crocker-Huffman diversion dam, the upstream limit of salmon migration (Reynolds and others 1993). The Merced River Hatchery (operated by DFG) is located by this dam. Fall-run spawners ascending to this point are captured at the dam's fish ladder, for use as hatchery broodstock.

Clark (1929, p 31) reported both spring and fall salmon runs present in the Merced River and mentioned recollections by early residents of "great quantities of fish coming up the river to spawn in the summer and fall…so numerous that it looked as if one could walk across the stream on their backs." An early newspaper account (Mariposa Gazette, 26 August 1882, J.B. Snyder, personal communication, see "Notes") reported "…the water in the Merced river has become so hot that it has caused all the salmon to die. Tons upon tons of dead fish are daily drifting down the river, which is creating a terrible stench, and the like was never known before." Judging from the date, the reference was to spring-run salmon; fall-run salmon would not have entered the tributaries so early, assuming they behaved similarly to the Sacramento River fall run. By 1928, the runs were greatly depleted, with only several hundred fish reported in the Merced River during the fall (before 12 November) of that year (Clark 1929, p 31). According to Clark (1929, p 32), very low flow conditions due to irrigation diversions during the spring, summer and early fall had "just about killed off the spring and summer runs" (the "summer" run evidently was the latter part of the spring run or perhaps an early fraction of the fall run), and only fish arriving in late fall after the rains were able to enter the river. These fish were probably a late-running component of the fall run, rather than a true late-fall run (sensu Fisher 1994) because there was no explicit mention by Clark (1929) of early residents referring to salmon runs in December or later that would have been more characteristic of the late-fall run. Clark also referred to late fall as including November in his account for the Mokelumne River, which is a somewhat earlier run time than is characteristic of most late-fall-run fish. Even in recent years when drought conditions and extensive irrigation diversions reduced streamflows to very low levels, the salmon did not spawn in the Merced River "until after the first week of November when water temperatures [had] become tolerable" (Reynolds and others 1993, p VII.96).

Fry (1961) considered the Merced River to be "a marginal salmon stream" due to the removal of water by irrigation diversions, and he stated that there was "a poor fall run and poor spring run." Run-size estimates for the fall run were 4,000 fish for 1954 and <500 fish for every other year during the period 1953–1959 (Fry 1961). No numerical estimates were available for the spring run at that time. After 1970, fall-run spawning escapements increased to an annual average of 5,800 fish, reaching 23,000 spawners in 1985, due to increased streamflows released by the Merced Irrigation District and operation of the Merced River Hatchery (Reynolds and others 1993). As in other San Joaquin basin tributaries, spawning escapements in the Merced River, including returns to the Merced River Hatchery, dropped to "seriously low levels" during the early 1990s—numbering <100 fish in 1990 and <200 in 1991 (DFG 1996 unpublished data). The fall run increased from about 1,000 to 2,000 spawners in 1992–1993 to 4,000 to 6,000 spawners in 1996–1998 (DFG 1996 unpublished data), perhaps auguring a partial recovery of the stock. The Merced River

Hatchery, operated since 1971 by DFG, has received a major fraction of the spawning run in this stream, accounting for 5% to 39% of the annual runs during the 1980s, 19% to 67% in 1990–1994, and 17% to 30% in 1995–1998 (DFG unpublished data). Late-fall-run salmon are said to occur occasionally (Reynolds and others 1993), but the spring run no longer exists in the Merced River.

Tuolumne River (Stanislaus and Tuolumne counties). At least spring and fall salmon runs historically used the Tuolumne River. Clavey Falls (10 to 15 ft high), at the confluence of the Clavey River, may have obstructed the salmon at certain flows, but spring-run salmon in some numbers undoubtedly ascended the mainstem a considerable distance. The spring-run salmon were most likely stopped by the formidable Preston Falls four miles above Early Intake Dam near the boundary of Yosemite National Park (about 50 mi upstream of present New Don Pedro Dam), which is the upstream limit of native fish distribution (DFG unpublished data). Sacramento suckers (*Catostomus occidentalis*), riffle sculpins (*Cottus gulosus*) and California roach (*Lavinia symmetricus*) were observed during stream surveys between Early Intake and Preston Falls (DFG unpublished data; P. B. Moyle unpublished data), and spring-run salmon probably formerly occurred throughout that reach as well. If they were present in the Tuolumne drainage, steelhead probably ascended several miles into Cherry Creek, a tributary to the mainstem about one mile below Early Intake, and perhaps spring-run salmon also entered that stream. Steep sections of stream in the Clavey River and the South and Middle forks of the Tuolumne shortly above their mouths most likely obstructed the salmon (T. Ford, personal communication, see "Notes"), although Sacramento pikeminnow are found within the first mile of the Clavey River and suckers and roach occur up to 10 to 15 miles upstream (EA Engineering, Science and Technology 1990). In the lower South Fork, a large waterfall (25 to 30 ft high, Stanley and Holbek 1984) probably prevented further access up that fork. The North Fork, with a 12-foot waterfall about one mile above the mouth, likewise offered limited access. Probably few, if any, salmon entered those upper reaches of the Tuolumne drainage (T. Ford, personal communication, see "Notes"). The waterfalls just below present Hetch Hetchy Dam on the mainstem, about ten miles above Preston Falls, evidently stopped all fish that might have ascended that far, and John Muir wrote that the river was barren of fish above the falls (Muir 1902). There are no indications that salmon ever reached Hetch Hetchy Valley, or Poopenaut Valley farther downstream (Snyder 1993 unpublished memorandum). Just as with the Merced River, there is no archaeological or ethnographic evidence indicating that salmon were part of the subsistence economics of the native inhabitants of the higher elevations along the upper Tuolumne River (Snyder 1993 unpublished memorandum).

The first written record of salmon in the Tuolumne River is that of the Frémont Expedition of 1845–1846. Frémont's (1848, p 18) journal entry for 4 February 1846 reads: "Salmon was first obtained on the 4th February in the To-wal-um-né river, which, according to the Indians, is the most southerly stream in the valley in which this fish is found." It is not clear whether Frémont's party caught the salmon or obtained them from the local native inhabitants, but in any case, it is likely that the fish were early arrivals of the spring run. Although the bulk of the spring-run salmon migration occurs during April through June, at least in the Sacramento drainage (Fisher 1994), spring-run fish have occasionally appeared in their spawning streams in early February, as in Butte Creek during 1995 (F. W. Fisher unpublished data), and sometime during February in the American River (in 1946) (Gerstung 1971 unpublished report). The occurrence of salmon in the Tuolumne River in those early years was also noted by John Marsh, who had arrived in California in the mid-1830s. Quoting Marsh, Edwin Bryant wrote, "…the river of the Towalomes; it is about the size of the Stanislaus, which it greatly resembles,…and it particularly abounds with salmon" (Bryant 1849, p 277). Furthermore, in his memoirs of the Gold Rush, the entrepreneur Samuel Ward recollected enjoying "a plenteous fish supper" of fresh salmon, caught by rifle shot in the lower Tuolumne River at Dickensons Ferry (located roughly halfway between the river mouth and the Sierra foothills (Collins 1949, p 104). That occasion was "late in the autumn [1851], just after winter's first premonitory showers" (Collins 1949, p 100)—coincident with the timing of the fall run. A later historical account also noted of the local native people: "Every spring, when the salmon were running up the river, enough were caught and dried to last nearly all the year"; "The waters of the Tuolumne, Stanislaus, Merced and San Joaquin generally furnish them with good fishing. They spear the salmon with spears made of some kind of tough wood,…"(Elliott 1882, p 162, 166).

Significant blockage of salmon runs in the Tuolumne River began in the 1870s when various dams and irrigation diversion projects were constructed, although dams and water diversions associated with mining had been present as early as 1852 (Snyder 1993 unpublished memorandum) and undoubtedly had some effect. Wheaton Dam, built in 1871 at the site of present-day La Grange Dam, may have blocked the salmon to some degree (T. Ford, personal communication, see "Notes"). By 1884, the Tuolumne and Stanislaus rivers were "dammed in such a way to prevent the fish from ascending" (CFC 1884, p 16). La Grange Dam, a 120-foot-high engineering marvel when completed in 1894, permanently cut off the former spring-run spawning areas. In 1896, the California Fish Commission stated, "The number of salmon that enter this stream [Tuolumne River] to spawn is small, and after its waters are taken out for irrigating purposes, will probably decrease," and the proposed fish ladder for La Grange Dam was viewed by the Fish Commission to be "not warranted, and would be of little or no benefit to the people or the fish" (CFC 1896, p 18). However, mining and other activities that degraded the river habitat undoubtedly also affected the salmon runs even before the early period of dam construction on the Tuolumne River. John Muir recorded in his journal in

November, 1877: "Passed the mouth of the Tuolumne…. It is not wide but has a rapid current. The waters are brown with mining mud. Above the confluence the San Joaquin is clear…" (Muir 1838, p 244).

Clark (1929) stated that the spawning grounds in 1928 extended from the town of Waterford to La Grange, over 20 miles of "good gravel river." At the time, there were two dams of major significance: La Grange Dam and Don Pedro Dam (built in 1923) 13 miles upriver; the latter was 300 ft high and formed a large irrigation reservoir (Clark 1929). Hatton (1940) later stated that the spawning beds in the Tuolumne River lay between a point 2.2 miles below the Waterford railroad bridge and the La Grange Power House. As of 1939, the Modesto Weir (a low structure) had no water diversion and was passable to salmon because the flash boards were removed "several weeks in advance of the fall run" (Hatton 1940). The rest of the Tuolumne River was clear of obstructions up to the impassable La Grange Dam. Spawning now occurs in the approximately 20-mile stretch from the town of Waterford (rm 31) upstream to La Grange Dam (EA Engineering, Science and Technology 1992). La Grange Dam remains a complete barrier to salmon and thus defines the present upstream limit of their spawning distribution (Reynolds and others 1993). The total area of spawning gravel presently considered available to salmon in the lower Tuolumne River (below La Grange Dam) is 2.9 million square feet (EA Engineering, Science and Technology 1992).

The California Fish Commission (CFC 1886, p 20) noted of the Tuolumne River: "[it] at one time was one of the best salmon streams in the State; Salmon have not ascended the stream for some years." Clark (1929) also reported that salmon generally were "scarce" in the Tuolumne River; at that time, both spring and fall runs still occurred at low levels, but the spring run was inconsequential, amounting "to almost nothing," and the fall run comprised "some fish" (Clark 1929, p 32). Clark noted, however, that "a good run" (evidently the fall run) had been reported in 1925 which "surpassed anything that had appeared in several years." Two decades later, only "a bare remnant of a spring run" was reported to exist during 1944–1946 (DFG 1946).

Only the fall run presently occurs in appreciable numbers in the Tuolumne River. In the past, fall-run spawning escapements in the Tuolumne River during some years were larger than in any other Central Valley streams except for the mainstem Sacramento River, reaching as high as 122,000 spawners in 1940 and 130,000 in 1944 (DFG 1946; Fry 1961). In fact, over the past half-century the Tuolumne River has supported one of the largest natural populations of salmon in the Central Valley tributaries (DFG unpublished data; USFWS 1995). Tuolumne River fall-run salmon at times comprised up to 12% of the total fall-run spawning escapement for the Central Valley (Reynolds and others 1993), but run sizes during the early 1990s fell to extremely low levels—specifically, fewer than about 130 spawners in each of the years 1990–1992 and about 400 to 500 fish in 1993 and 1994 (DFG 1996 unpublished data). The fall run recently rebounded to at least 3,600 to 5,500 spawners in 1996–1997 and 7,900 spawners in 1998 (DFG unpublished data). The fall run historically has been a naturally sustained population because there is no hatchery on the Tuolumne River, unlike most other major salmon streams in the Central Valley (Reynolds and others 1993). However, increasing numbers of hatchery-derived spawners have ascended the Tuolumne River in recent years, mainly due to large releases of hatchery juveniles (from Merced River Hatchery) for study purposes into this stream and elsewhere in the San Joaquin River basin and Sacramento-San Joaquin Delta (DFG unpublished data; FERC 1999).

It has been stated that "a small population" of late-fall-run fish exists in the Tuolumne River (Reynolds and others 1993), but the existence of such a run appears to be based mainly on the occurrence of juveniles in the river during the summer and on observations of occasional spawning in later months (January through March) than is typical for fall-run fish (T. Ford, personal communication, see "Notes"). However, hydrological conditions in the Tuolumne River during the past few decades have not been conducive to the maintenance of a late-fall run—notably the lack of consistent, cool streamflows during the summer to support the juveniles (Reynolds and others 1993). It is possible that the infrequent observations of fish with late-fall-run timing characteristics have been strays from the Sacramento River system and their progeny. Late-emerging or slow-growing fry produced by fall-run fish, perhaps of hatchery origin, also could account for some of the juveniles observed over-summering in the river.

Stanislaus River (Stanislaus, Calaveras counties). Both spring and fall runs historically occurred in the Stanislaus River. The forty-niner Alfred Doten wrote in his journal for 4 November 1850: "At sunset we crossed the Stanislaw river and camped on the opposite side—Beautiful river—forded it at a shallow place where the natives were shooting and spearing salmon" (Clark 1973, p 59)—obviously the fall run. Another gold miner, Howard C. Gardiner, made note of salmon in the Stanislaus River at Knights Ferry, in mid-December 1848 (the exact date unknown, but probably soon after December 19): "…we reached the ferry…the others went over, leaving me to dicker with an Indian for the purchase of a salmon which we had seen him capture a few minutes previous. The native soon came with the fish which must have weighed twenty-five pounds…. I bought the salmon for eight dollars…" (Morgan 1970, p 109). The approximate date is consistent with the peak migration period of the late-fall run, but also with the end of the fall run (Fisher 1994). The California Department of Fish and Game reported that besides the spring salmon run, "lesser runs occurred in fall and winter due to the natural, unaltered regime of the river" (DFG 1972, p 2–3), but the later-running fish were most likely late-fall-run salmon or perhaps a segment of the fall run.

Steelhead evidently also were seen by the gold miners, as attested by Alfred Doten:

> *The Salmon Trout of the mountain streams is a most beautiful and delicious fish, and not to be beaten for good eating by any other freshwater fish; at least I used to think so when I was a gold digger. They generally weigh from two to four pounds, and are abundant in most of the upper streams and rivers of the Sierra Nevada (Clark 1973, p 311).*

The native Central Sierra Miwok people, located near the Tuolumne and Stanislaus rivers, were said to have "fished in the Le Grange [sic] and Knights Ferry Area for two kinds of salmon: The summer salmon which were small and also called 'red salmon,' and winter salmon or 'dog salmon' which were larger, 'they were all the big ones'" (Theodoratus 1976, p 486)—the two kinds apparently corresponding to spring-run (summer or red) and fall-run (winter or dog) salmon. In an interview conducted in 1975, an elder (90+ years old) Miwok informant stated that the "red salmon" (spring run) were speared in the Stanislaus River above a bridge near Knights Ferry, and some numbers also were taken at "Burns Ferry" (now covered by Tulloch Reservoir) and farther upstream at a "dam" near Columbia (perhaps at a mining diversion) (Theodoratus 1976). The "winter salmon" (fall-run) fishing spots were at Knights Ferry and, when the water was high, at "Wild Cat Canyon." Other Miwok and non-Indian informants reported that salmon were taken below the "old Camp Nine bridge" (near the town of Stanislaus), "under the bridge at Parrotts Ferry" and "in the Melones area…in the early 1900s" (Theodoratus 1976, p 487; Maniery 1983). The latter two sites are now covered by upper New Melones Reservoir. According to one Miwok informant, his father caught salmon in six-foot long basketry fish traps: "…he use[d] to haul fish out of the canyon with ten of his mules up from Camp Nine [Stanislaus] to Tablerock Mountain up to Murphys…to sell the salmon for 50¢ a piece"—some of which "weighed up to twenty-five pounds or so" (Theodoratus 1976, p 398). The large size of those fish suggests they were of the fall run. Salmon also were taken near Duck Bar (4.5 mi below Stanislaus, now inundated), where a long-time Miwok resident named Indian Walker caught them in fish traps to sell to the white community (Cassidy and others 1981). Barrett and Giifford (1933, p 189) reported that "salmon were caught in the late spring"—in obvious reference to the spring run.

Spring-run and perhaps some fall-run salmon probably went considerable distances up the forks because there were few natural obstacles (W. Loudermilk, personal communication, see "Notes"). Before the filling of New Melones Reservoir, there were no natural barriers to salmon in the reach from Old Melones Reservoir upstream to the mouth of the Middle Fork Stanislaus River (which was a popular rafting reach; E.R. Gerstung, personal observation), or on the Middle Fork from its mouth up to Sand Bar Flat located just below the

Spring Gap Powerhouse (E. Vestal, personal communication, see "Notes"). One ethnographic account stated, "On the Stanislaus river, salmon (*kosimo*) went as far as Baker's bridge where there is a waterfall" (Barrett and Gifford 1933, p 189). Baker's Bridge was located near Spring Gap Powerhouse on the Middle Fork, about two miles below present-day Beardsley Reservoir, according to an old-time rancher in that area (personal communication to E.R. Gerstung, see "Notes"). That same location was designated as "Baker's Crossing" on an old US Geological Survey map, drawn in 1901 by Thomas R. Hanna (Map of Stanislaus Forest Reserve, Alpine Count Library Archives, Markleyville). Apparently, there were no impassable natural obstacles on the Middle Fork to just above present-day Beardsley Reservoir (3,400 ft elev.) (E. Vestal, personal communication, see "Notes"), although the increasingly steep gradient up to that point may have deterred most salmon.

In the North Fork Stanislaus River, suckers and hardhead occurred in the first several miles up to the confluence of Griswold Creek (Northern California Power Authority 1993 unpublished report), so salmon undoubtedly would have ascended at least to that point. The North Fork was probably accessible to salmon as far as McKay's Point (about eight miles above the confluence with the Middle Fork), where the gradient steepens and which we take as the practical upstream limit. Presumably few, if any, salmon passed that point and they probably were blocked five miles farther upstream by a 15-foot waterfall above Board's Crossing. The South Fork Stanislaus River is a small drainage and is unlikely to have supported more than a few, if any, salmon because of the paucity of habitat. We have seen no suggestions of salmon having occurred in the South Fork, and for the present we do not include it as a former salmon stream.

Damming and diversion of water on the Stanislaus River, for both mining and irrigation, began soon after the Gold Rush. The earliest "permanent" dam on the river was the original Tulloch Dam, constructed in 1858 just downstream of the present Tulloch Dam (Tudor-Goodenough Engineers 1959). The original Tulloch Dam was a relatively low structure and evidently had an opening at one end (photograph in Tudor-Goodenough Engineers 1959), and its impact on the salmon runs, therefore, may not necessarily have been significant. Clark (1929) stated that the salmon spawning beds were distributed over ten miles of stream, from the marshlands above Oakdale to Knight's Ferry. Dams on the river by that time included 20-foot Goodwin Dam (completed in 1913) 18 mi above Oakdale, which had a fishway and was at times negotiable to salmon, and the 210-ft impassable Melones Dam (completed in 1926) above the town of Melones. The spawning beds in 1939 were reported by Hatton (1940) to extend from Riverbank Bridge to the Malone Power House, although of this 32.7-mile distance, the 9.3 miles between Goodwin Dam and the Power House was "only rarely accessible to salmon." Hatton (1940, p 355) stated that the fishway over Goodwin Dam was "seldom passable" and that the fluctuating water level caused by hydroelectric operations above Goodwin Dam and the "almost complete diversion of water at the dam" made it "very nearly an impassable barrier." Fry (1961) also mentioned the blockage of migration by Goodwin Dam, the operation of which also caused low and warm flows downstream during the summer and "violent" water fluctuations (due to power-generation releases) during the fall and winter. Presently, the salmon do not ascend the Stanislaus River farther than Goodwin Dam, which regulates streamflows from Tulloch Reservoir and diverts water for irrigation and power generation (Reynolds and others 1993). Much of the spawning occurs on the extensive gravel beds in the 23-mile stretch from Riverbank upstream to Knights Ferry, which are essentially on the valley floor (T. Ford, personal communication, see "Notes"). Upstream of Knights Ferry, where the river flows through a canyon, spawning is concentrated at Two Mile Bar (about one mile above Knights Ferry) but also occurs in scattered pockets of gravel (T. Ford, personal communication, see "Notes").

The California Fish Commission reported that while the Stanislaus River had once mirrored the Tuolumne River as a preeminent salmon stream, by 1886 only an occasional salmon was seen "trying to get over one of its numerous dams" (CFC 1886, p 20) Much later, Clark (1929, p 32) reported that the Stanislaus River "has a good spring and fall run of salmon," but he also stated that their abundance was "about the same as in the Tuolumne" where he had described them to be "scarce." Given Clark's contradictory statements, it is not clear how abundant, even qualitatively, the salmon were in the Stanislaus at the time of Clark's survey (late 1920s). Historically, the spring run was said to have been the primary salmon run in the Stanislaus River, but after the construction of dams which regulated the streamflows (namely, Goodwin Dam and, later, Melones and Tulloch dams), the fall run became predominant (DFG 1972). Fry (1961, p 64) described the Stanislaus River as "a good fall run stream for its size" but it had "almost no remaining spring run."

The Stanislaus River fall run, in recent historical times, has contributed up to 7% of the total salmon spawning escapement in the Central Valley (Reynolds and others 1993). Annual escapements for the fall run were minimally estimated at 4,000 to 35,000 spawners (average about 11,100) during 1946–1959 (Fry 1961), before the construction of Tulloch Dam (in 1959). In the following 12-year period (1960–1971), the average run size was about 6,000 fish (DFG 1972). Fall-run abundances during the 1970s and 1980s ranged up to 13,600 (average about 4,300) spawners annually (DFG unpublished data). The numbers of spawners returning to the Stanislaus River have been especially low during most of the 1990s—<500 fish annually in 1990–1993, 600 to 800 fish in 1994–1995, and <200 fish in 1996—but there was a modest increase to 1,500 spawners in 1997 and 2,200 spawners in 1998 (DFG unpublished data).

Presently (1999) only the fall run has sustained itself in the Stanislaus River, although small numbers of late-fall-run fish have been reported to occur (Reynolds and others 1993). As in the Tuolumne River, the recent occurrence of late-fall-run salmon in the Stanislaus River could be due to strays from the Sacramento River system.

Calaveras River (Calaveras County). The Calaveras River is a relatively small, low-elevation drainage that receives runoff mainly from rainfall during November through April (Reynolds and others 1993), and its lower reaches historically were dry during part of the year (Carson 1852). This river was probably always marginal for salmon, and it lacks suitable habitat for spring-run fish (E.R. Gerstung, personal observation). Chinook salmon runs reportedly occurred on an "irregular basis" (Reynolds and others 1993), although Clark (1929, p 235) had stated that the Calaveras River was "dry most of the summer and fall and so it has no run of salmon." Yet, the name of the river itself represents, in a way, a salmon legacy. Quoting the historian Sanchez (1932, p 291):

> *In his diary Moraga says that the river tribes fought against those of the Sierra for possession of the salmon in the stream, and that in one battle many were said to have been killed and left on the field. A great number of skulls, relics of this bloody conflict, were found by Moraga scattered along the creek bed, and for that reason he called it Las Calaveras [The Skulls].*

O'Brien (1951, p 33) further elaborated:

> *Moraga followed them…and there halted in amazement. Skulls and bones littered an acre and more. An Indian of a nearby ranchería explained that the field was an ancient battleground. A long time before, he said, invading warriors swarmed down from the Sierra to drive the tribes of the Sacramento and San Joaquin Valleys from their river fishing preserves…and these skulls and bones were the remains of those who had fallen.*

The Calaveras River had, in recent times, an unusual "winter" salmon run which spawned during late-winter and spring, but it is unknown if the run had existed before the dams were built on the river. This run has been referred to as a "winter run," but perhaps it was more like a late-fall run, given that the spawning period was relatively early compared to the Sacramento winter run. The presence of this run was documented for six years within the period 1972–1984 and it numbered 100 to 1,000 fish annually (Reynolds and others 1993). The fish ascended to New Hogan Dam, and they held and spawned in the reach just below the dam (T. Ford, personal communication, see "Notes"). Management of streamflows by the US Army Corps of Engineers entailed high-flow releases from New Hogan Dam interspersed with periods of very low flow, which undoubtedly contributed to the apparent demise of this run since 1987 (T. Ford, personal communication, see "Notes"; USFWS 1995). Bellota Dam, 15 mi below New Hogan Dam, and at least two other diversion dams are known to have blocked upstream salmon migration during periods of low streamflow (Reynolds and others 1993). The run's extirpation may also have been hastened, if not guaranteed, by persistently low streamflows due to the 1987–1992 drought and to irrigation diversions.

It is possible that the existence of salmon—particularly the supposed "winter run"—in this river during recent decades has been mainly the result of suitable conditions created by the dams. Historically, the natural occurrence of salmon there was most likely limited to wet years. Currently, fall-run salmon—perhaps those destined for other San Joaquin River tributaries—occasionally enter the Calaveras River when suitable fall streamflows occur. For example, several hundred fall-run fish were observed during the fall of 1995 at Bellota Dam, where they were temporarily blocked (DFG unpublished data). We have no information on the historical upstream range of salmon in the Calaveras River, so we consider the site of New Hogan Dam (the upper limit in recent times) as a minimal approximation of the historical limit.

Mokelumne River (San Joaquin, Amador counties). The Mokelumne River, in its original state, apparently supported at least fall and spring salmon runs. Some evidence suggests that a late-fall run also occurred at one time. In what is probably the earliest record of salmon in the Mokelumne River, the fur trapper Jedediah Smith, having encamped on "Rock River" (Mokelumne River), wrote in his journal for 22 January 1828: "Several indians came to camp and I gave them some tobacco. They brought with them some fine salmon some of which would weigh 15 or 20 lbs. I bought three of them and one of the men killed a deer…" (Sullivan 1934, p 56). The salmon that would have been present during that part of January in "fine" condition most likely were late-fall-run or perhaps spring-run, although the timing is extraordinarily early for the latter. Smith's party evidently was on the lower Mokelumne River on the marshy valley floor, for "…although the ground was rolling the horses sank at every step nearly to the nees [sic]." Two decades later, Alfred Doten similarly recorded (for 22 December 1851): "Saw three fine salmon, which were brought from the Moqueleme—they averaged about 20 lbs a piece" (Clark 1973, p 80). That date is consistent with the peak migration time of the late-fall run, and although later-arriving spawners of the fall run cannot be completely discounted, it is more likely that late-fall run fish would have been present in "fine" physical condition. Ethnographic information attests that native Northern Sierra Miwok people on the Mokelumne River in the past had at least a simplified "first-salmon" rite (Aginsky 1943)—suggesting the historical presence of the spring salmon run, given that such rites characteristically were associated with the onset of the spring-run harvest in other Central Valley streams (for example, Gayton 1946 [p 256], 1948b [p 166]; Voegelin 1942, [p 57, 175]) and on the northern California coast (Swezey and Heizer 1977).

Salmon ascended the river at least as far as the vicinity of present-day Pardee Dam (rm 73). Reportedly, a large waterfall (30+ ft high) was present at Arkansas Ferry Crossing, one mile downstream of the Pardee Dam site in a narrow rocky gorge (R. Nuzum, personal communication, see "Notes"), and it may have posed a significant barrier to the fall run. The site of the waterfall was inundated by Camanche Reservoir, and no natural obstructions presently exist between Camanche Reservoir and Pardee Dam (S. Boyd, personal communication, see "Notes"). Spring-run salmon undoubtedly would have ascended past that former waterfall to reach higher elevations where water temperatures were suitable for over-summering. It has been stated that, "An unknown number of chinook salmon" spawned upstream of the Pardee Dam site in earlier times (FERC 1993). Steelhead were believed to have spawned mostly in the reaches above Pardee Dam (Dunham 1961 unpublished report). Because there are no impassable falls between Pardee and the Electra powerhouse 12 mi upstream, spring-run salmon undoubtedly also reached the latter point. Bald Rock Falls (30 ft high), seven miles beyond Electra, is a complete fish barrier (Woodhull 1946). Native fish species such as hardhead and pikeminnow are known to have reached the falls (Woodhull 1946), so Bald Rock Falls can be reasonably taken as a likely upstream limit for both salmon and steelhead.

The California Fish Commission reported in 1884 that the Mokelumne River was the "only stream emptying into the San Joaquin not dammed" (CFC 1884, p 16). Collins (1892, p 163) also asserted: "Salmon do not run into the San Joaquin in large numbers. In the fall, when the fishery is at its best, fishermen go a few miles up the Mokolumne …[sic]" Yet, the salmon runs into the Mokelumne River already had been largely eradicated by 1877 due to gold mining activities (CFC 1877, p 5). However much the salmon runs subsequently recovered from the habitat degradation of the gold mining era, the runs were believed to have started another decline after the construction of Woodbridge Dam (15 ft high) in 1910, at the town of Woodbridge (rm 39) (Dunham 1961 unpublished report). Fry (1961, p 64) cited Woodbridge Dam as having been "a serious fish block" for many years, as well as providing "often too little water for the passage of salmon," and he mentioned industrial and mining pollution as having been "very serious" at times. As of 1928 the salmon spawning grounds reportedly extended from the river mouth above tidewater for about 15 mi to above Woodbridge Dam (Clark 1929). There was a small fishway at this dam which had very little water flowing down it during summer and fall (Clark 1929). Clark reported that the Mokelumne River at that time had "only a fall run," "usually quite late." He stated that a "considerable run" migrated upriver each year, although not as large as in former years, and that the flashboards in Woodbridge Dam were taken out in late fall (November) to allow passage of the salmon. Although this is possibly an indication of a late-fall run, it seems more likely that the fish for the most part were a late-running fall run, delayed by the lack of water. The true late-fall run, as currently recognized (Fisher 1994; Yoshiyama and others 1998), probably would not have been present in the Mokelumne River or other tributaries in significant numbers until December at the earliest. However, the earliest historical references to salmon (noted above) seem to indicate that late-fall run salmon actually occurred in the Mokelumne River at least until the mid-19th century.

Despite Clark's (1929) statement to the contrary, spring-run salmon evidently still entered the lower Mokelumne River during the early 1930s. Salmon and other fish were landed in the small fishing port of Lockeford, about nine miles upstream of Woodbridge. Scofield (1954, p 78) reported that in the period 1931–1935, "an average of 2,000 pounds per year of mixed fish were credited to this town" and that "During May, June and July salmon predominated." The salmon in that season almost certainly would have been spring-run fish. Scofield (1954, p 78) also reported "only the record of 3,800 pounds of salmon in August and September of 1931" associated with the town of Acampo three miles north of Lodi on the east side of the Mokelumne River. If the fall run in this river usually ran late, as Clark (1929) stated for that historical period, then perhaps those salmon recorded in August-September at Acampo were a component of the spring run that had been blocked from ascending farther upstream, presumably by Woodbridge Dam.

The construction of Pardee Dam in 1928 presented an insurmountable obstacle, cutting off the upper spawning areas (Dunham 1961 unpublished report). Hatton (1940) stated that spawning beds on the Mokelumne River occurred in the 22.5 mi between Lockeford Bridge and Pardee Dam. At that time (1939), the irrigation dam at Woodbridge had a fishway but was impassable at times due to "fluctuating water levels," and Hatton was of the opinion that probably most of the migrating spawners did not ascend to the spawning beds until the dam's weir boards were removed, usually "around the first week in November."

Fall-run salmon are now stopped at the lower end of Camanche Reservoir, about nine miles below Pardee Dam. They spawn in the reach from Camanche Dam (rm 64) downstream to Elliott Road (rm 54) (J. Nelson, personal communication, see "Notes"), and 95% of the suitable spawning habitat is within 3.5 miles of Camanche Dam (Reynolds and others 1993). Before the completion of Camanche Reservoir (1964), the fall run also spawned upstream from Camanche Dam to the canyon about three miles below Pardee Dam (Reynolds and others 1993). The Mokelumne River Hatchery, operated by DFG, was built in 1965 as mitigation specifically for that spawning stock component (Reynolds and others 1993; J. Nelson, personal communication, see "Notes").

Fry (1961) reported that counts of fall-run spawners passing Woodbridge Dam ranged from <500 (in two separate years) to 7,000 fish during the period

1945–1958, and there were partial counts of 12,000 fish each in 1941 and 1942 (DFG 1944; Fry 1961). Fry also stated that the spring run appeared to be "practically extinct." During the period 1940–1990, total annual run sizes ranged between 100 and 15,900 fish (Reynolds and others 1993); the runs averaged 3,300 spawners during 1940–1963 (before impoundment of Camanche Reservoir) and 3,200 spawners during 1964–1990 (post-impoundment) (Reynolds and others 1993). More recent annual run-size estimates for the fall run have been 400 to 3,200 (average about 1,800) total spawners during 1990–1994, increasing to 5,400 to 7,800 fish in 1995–1996 and perhaps 16,700 fish in 1997 (DFG unpublished data). The latter DFG estimate for 1997 may be inflated; a lower escapement of about 10,180 spawners was reported by the East Bay Municipal Utility District (J. Miyamoto, personal communication, see "Notes"). Hatchery returns have composed 14% to 69% of the fall run during the 1990s. Estimated numbers of natural spawners during this period ranged from 180 (in 1991) to 10,160 fish (in 1997), averaging 2,500 fish (DFG unpublished data).

Cosumnes River (El Dorado County). The Cosumnes River, a branch of the Mokelumne River, historically has been an intermittent stream and therefore offered limited access to salmon. Yet, the river derives its name from the Cosumne triblet of the Valley Yokuts—the "People of the Salmon Place" in the language of the neighboring Miwok people (Latta 1977, p 99)—or, alternatively, from Southern-Central Miwok words for salmon (*kos'-sum*, *kos'-sum-mi*) (Powers 1877, p 347; Bennyhoff 1977, p 101). Latta (1977, p 100) noted that the Cosumne village of "*Musu* (moo-soo, probably a variant of *Cosu* and meaning Salmon Place) was…located two miles northeast of present Bruceville"—about nine miles above the mouth of the Cosumnes River.

Only a fall salmon run is definitely known to have occurred in this river. Hallock and Van Woert (1959) reported that the Cosumnes River had a "notoriously late" fall run, probably due to insufficient streamflows until well into the fall rainy season. There is no indication that a spring run ever existed here (J. Nelson, personal communication, see "Notes") and the atypical streamflow regime and low elevation of the drainage make it unlikely that there was one. There is a 30-foot falls a half mile below Latrobe Highway Bridge which has been viewed as a barrier, and which we take as the historical upstream limit. However, salmon probably did not usually reach that far upriver because of the limited time available for migration in this stream, and most likely only a few fish ascended past Michigan Bar (rm 31). If any fish were able to surmount that obstacle, they undoubtedly were stopped by a second waterfall (50 ft high) 8.5 mi farther upstream at the Highway 49 crossing.

Clark (1929) reported the presence of "a considerable run" (fall run), which he stated to be equal in abundance to that in the Mokelumne River. At that time the spawning grounds extended from the river mouth above tidewater to the irrigation diversion dam near the town of Sloughhouse, which was a barrier to the salmon. In 1939, the spawning grounds on the Cosumnes River extended along the 15.2 mi stretch from Sloughhouse Bridge up to the falls below Latrobe Highway Bridge (Hatton 1940). Hatton (1940) reported that the best spawning areas were between the Sloughhouse and Bridgehouse bridges; just above Bridgehouse the river passed through a canyon where bedrock largely replaced the gravel beds. At that time (1939), the 18-foot high Bridgehouse Dam was the only permanent dam on the river, having two "apparently satisfactory fishways" but an unscreened diversion. The lower end of the stream was dry during the months when irrigation diversions were taken, but in late fall "a run of undetermined size" took place (Hatton 1940). The fall run presently spawns in the reach from downstream of the Highway 16 crossing (Bridgehouse Bridge) up to the falls below Latrobe Road (J. Nelson, personal communication, see "Notes"). Additional spawning habitat occurs downstream of the Highway 16 crossing to Sloughhouse Bridge, but below that point the substrate is largely sand and unsuitable for spawning (E.R. Gerstung, personal observation). The sole dam in the river—Granlees Diversion Dam (located one mile upstream of the Highway 16 crossing)—presently may pose an obstacle to salmon migration because its fish ladders are sometimes inoperative. The salmon generally cannot ascend the river until late October to November, when adequate flows from rainfall occur (Reynolds and others 1993).

Fry (1961) reported run-size estimates for the fall run of <500 to 5,000 fish for the period 1953–1959. Historically, the run size has averaged about 1,000 fish, but more recent runs, when there was water in the streambed, numbered no more than 100 individuals (Reynolds and others 1993). In many years there has been insufficient streamflow to maintain connection with the San Joaquin River. No salmon have been observed in the Cosumnes River since 1988 (DFG unpublished data).

American River (Sacramento, Placer counties). Spring, fall and possibly late-fall runs of salmon, as well as steelhead, ascended the American River and its branches and were impeded to varying degrees by a number of natural obstacles, at least one which no longer exists. According to a Native American (Nisenan) informant, salmon and steelhead were said to have formerly entered all the small, lower-elevation streams around Auburn (at the juncture of the North and Middle forks) and Colfax (about 16 mi farther up the North Fork) (Wilson 1972). In the North Fork American River, steelhead were observed during DFG surveys in the 1930s at Humbug Bar, above where the North Fork of the North Fork enters (DFG unpublished data); because there are no substantial falls below that point, spring-run salmon no doubt also easily ascended that far. Mumford Bar, about seven miles above Humbug Bar, was one of several salmon fishing spots for the native Nisenan people, at which "salmon [were] taken with bare hands during heavy runs" (Beals 1933, p 347). For the present, given the lack of more definite information, we take Mumford Bar as the minimal upstream point reached by salmon. However, if the salmon, like steelhead, were able to surmount the waterfall at Mumford Bar, they would have had clear passage about four miles farther upstream to a 10-foot waterfall at Tadpole Creek (2,800 ft elev.), which is too steep for kayakers to boat over (Stanley and Holbek 1984). And if salmon were able to jump that waterfall, their upper limit would have been another seven miles upstream at the 60-foot falls at Royal Gorge (4,000 ft elev.), which likely was the uppermost barrier to steelhead (DFG unpublished data). That uppermost limit would accord with Beals' (1933) general statement that salmon reportedly ranged above the elevational limit of permanent habitation (3,000 to 4,000 ft) of the Nisenan people of the area.

On the Middle Fork American River, falls that had existed before the gold mining era at Murderer's Bar, about three miles above the confluence with the North Fork, obstructed the salmon at least to some degree. The pioneer Myron Angel wrote:

> *Before the falls at Murderer's Bar was cut down, during spawning time, the salmon would accumulate so thickly in a large pool just below, that they were taken in great numbers by merely attaching large iron hooks to a pole, running it down in the water, and suddenly jerking it up through the mass. And that place was not an exceptional one; it was so at all places where there was any obstruction to free running. During these times, the Indians supplied themselves with fish, which they dried in the sun. (Angel 1882, p 402)*

It is likely that the dense aggregations of salmon harvested by the native people below the natural obstacles were more often fall-run fish, impeded by the low fall-season streamflows. The earlier-migrating spring run, ascending mainly during the spring flood flows, would have been able to transcend some of those same obstacles (CFC 1900a, p 25, 1900b, p 13). Spring-run salmon probably were able to ascend the Middle Fork a fair distance due to the absence of natural barriers above Murderer's Bar. In 1938, the spawning area for salmon was reported to extend up the Middle Fork to below the mouth of Volcano Creek (1,300 ft elev.) (Sumner and Smith 1940); salmon likely reached the confluence with the Rubicon River (1,640 ft elev.), which we view as the historical upstream limit. Steelhead were observed in the Rubicon River during the early DFG surveys, but a 15-foot waterfall about four to five miles upstream from the mouth was a likely barrier to them and to any salmon that ascended that far.

In the South Fork American River, a major part of the salmon runs went at least as far as Salmon Falls, and "large quantities" were harvested there in 1850 and 1851 by gold miners and Native Americans (CFC 1875, p 14). As recounted by Special Indian Agent E.A. Stevenson: "…saw them at Salmon

Falls on the American river in the year 1851, and also the Indians taking barrels of these beautiful fish and drying them for winter" (31 December 1853 letter to Superintendent of Indian Affairs T. J. Henley, as cited in Heizer 1993, p 16). The forty-niner Daniel Woods also noted in his journal entry for 4 July 1849, at Salmon Falls: "They [the "Indians"] have brought us in some salmon, one of which weighs twenty-nine pounds. These they spear with great dexterity, and exchange for provisions, or clothing, and ornaments of bright colors" (Woods 1851, p 49). The site of Salmon Falls is now covered by Folsom Reservoir, and there has been disagreement on whether the 20-foot falls originally were a complete barrier to migrating salmon. It seems likely that it was the fall run—egg-laden and migrating during low streamflows—that would have been largely blocked, especially before the major fall rains had swelled the streams (CFC 1900a, p 25). But even the fall run may not have been completely barred by the falls—their dense concentration there and at other places perhaps being bottlenecks where some fraction of the run rested or was stalled until streamflows increased before ascending further. Salmon Falls was blasted sometime near the turn of the century, by one account to create passage for log drives down the river (DFG unpublished notes) and by another to allow the salmon to go farther upstream, but the latter attempt was said to have ended in failure (Cassidy and others 1981). The California Fish Commission reported "the removal of obstructions at Salmon Falls, in the American River" sometime during 1888–1890, for which the State Legislature appropriated $500 (CFC 1890, p 4). The falls were also later blasted in 1935 by the California Division of Fish and Game "to make them more passable for steelhead trout and salmon" (DFG unpublished notes). However, there is evidence that salmon did in fact ascend the South Fork past Salmon Falls in earlier times, before the attempts to modify the falls. Henry W. Bigler, one of the Mormon workmen at Sutter's Sawmill at Coloma during the fateful winter of 1847–1848, wrote in his diary, "Our grub was mainly unbolted flour, pork, mutton, salmon, peas, tea, coffee and sugar" (Gudde 1962, p 84). Based on a review of that and other documents, Gay (1967, p 138) added: "Beef and beans also formed part of the diet…the pork, mutton and beef was freshly killed on the spot; while the river rewarded anyone who had piscatorial inclinations with a nice catch of salmon." A gold miner's account (Steele 1901, p 275) stated: "In the latter part of August [1852] a band of forty or fifty Indians camped on the opposite bank of the river, spending about two weeks mining and fishing.…Here, with long spears, they caught many fine salmon"; the location was "Texas Bar on the south fork of the American River," one-half mile upstream of Chili Bar and "about two miles from Placerville." Also, Voegelin (1942, p 174) reported the following ethnographic information given in 1936 by a 65-year-old Nisenan informant who had lived all her life in the vicinity of Camino (about five miles east of Placerville and due south of present Slab Creek Reservoir on the South Fork): "Salmon obtainable within area, in American River. No salmon caught until certain time in summer; first fish cooked, divided and eaten by all members of community, for 'good luck'." The implication of the last statement is that those were spring-run salmon which became obtainable as streamflows dropped during the summer; also, there was an annual first salmon ceremony of sorts, indicating that a regular run of salmon in the South Fork American River. Beals (1933, p 347), based upon his ethnographic survey of elder Nisenan informants in 1929, reported that salmon "Ascended S. fork American r. to Strawberry near summit." However, we view Beals' statement broadly—that is, that salmon went up to the general area approaching the present town of Strawberry—because it is less specific than other ethnographic references to salmon that we have included. There is a 30-foot waterfall with an incline of 45° (E.R. Gerstung, personal observation) at Eagle Rock, about eight miles downstream of Strawberry, which kayakers portage around (Stanley and Holbek 1984). There are also several steep stretches above Eagle Rock up to Strawberry, and very little suitable habitat (pools and gravel beds), so salmon probably did not ascend past Eagle Rock in significant numbers, if at all. We take the vicinity of Eagle Rock (4,300 ft elev.), therefore, as the most likely upper limit for salmon in the South Fork.

Hydraulic mining during the 1850–1885 period caused the deposition of large quantities of sediments into the American River, as was true for many other Sierra streams. By one estimate, about 257 million cubic yards of gravel, silt, and debris from mining operations were washed into the American River (Gilbert 1917). Again quoting Indian Agent Stevenson (31 December 1853 letter, in Heizer 1993, p 16):

> *The rivers or tributaries of the Sacramento formerly were clear as crystal and abounded with the finest salmon and other fish…. But the miners have turned the streams from their beds and conveyed the water to the dry diggings and after being used until it is so thick with mud that it will scarcely run it returns to its natural channel and with it the soil from a thousand hills, which has driven almost every kind of fish to seek new places of resort where they can enjoy a purer and more natural element.*

According to one gold miner's account, in the summer of 1851, "Salmon were then caught in the river" at Horseshoe Bar on the North Fork American River about seven miles above the confluence with the South Fork, "and fried salmon was no uncommon dish" (Morgan 1970, p 165). By 1860 a sand bar had formed across the mouth of the American River on the Sacramento River (Reynolds and others 1993). The silting over of the spawning beds in the mainstem and forks due to mining activities nearly exterminated the salmon runs in the American River (Gerstung 1989). Stone (1874, p 176) wrote, "The American Fork was formerly a prolific salmon river, but the mining operations on its banks have rendered it so muddy that the salmon have abandoned it altogether, and none ascend it now." Similarly, the California Fish Commission reported: "The American is a shallow, muddy stream…. But few fish are found in the lower part of the stream…. This river, prior to placer mining, was one of the best salmon streams in the State. Of late years no salmon have ascended it" (CFC 1886, p 20).

Somewhat later, the construction of dams that lacked adequate fish passage facilities caused the further diminishment of the runs (Gerstung 1989). The 68-foot high Old Folsom Dam (completed in 1895), 27 mi upstream from the mouth, initially was an impassable barrier to salmon and blocked them from reaching the forks of the American River for about 36 years (Sumner and Smith 1940). A fish ladder was built for Old Folsom Dam in 1919, but Clark (1929) stated that salmon were never known to have passed above it, although steelhead probably did; an effective fish ladder for salmon was later constructed in 1931 (Sumner and Smith 1940). Another potential barrier to salmon was a 16-foot high dam built in 1899 by the North Fork Ditch Company on the North Fork American River near Auburn, a few miles downstream of the confluence with the Middle Fork; a rock chute fishway was provided in 1912, but it allowed difficult passage and few salmon used it (Sumner and Smith 1940). The 140-foot high North Fork Debris Dam (completed in 1939), two miles above the confluence with the Middle Fork, posed yet another impassable barrier and assured the extirpation of the salmon run in the North Fork (Sumner and Smith 1940).

Clark (1929, p 36) stated that the salmon run in the American River had "always been a late-fall migration," although he provided no further details, and also that this river "[had] known great runs." An early gold miner noted salmon migrating up the American River about seven miles east of Sutter's Fort on 1 December 1848, of which "thirty-five splendid salmon" were procured by "well-directed rifle-ball" (Buffum 1959, p 41). Early December coincides with the upriver migration periods of both fall and late-fall runs; however, it is appreciably later than the peak migration presently observed for the Sacramento Valley fall run (September through October) but within the peak migration period for the late-fall run (December) (Fisher 1994). The implication seems to be that a late-fall run occurred in the American River, possibly in substantial numbers. However, it is more likely that the run was a fall run that had a relatively late or extended migration season, combined perhaps with some unknown numbers of true late-fall-run fish. The spring run is known to have entered the American River as early as February, as occurred in 1946 (Gerstung 1971 unpublished report).

Clark (1929) described the 1927–1928 salmon run as "very good" and noted that residents on the river had seen no noticeable decrease in the run size over the previous 20 years, although the run reportedly had been devastated by early mining operations. Spawning occurred from the river mouth to Old Folsom Dam about one mile above the town of Folsom, "a distance of 30 mi of good gravel river." In the 1940s, both the spring and fall runs began to reestablish themselves in the American River above Old Folsom Dam. Counts at the fishway at Old Folsom Dam showed that the spring run reached a maximum of 1,138 fish in 1944 and the fall run reached 2,246 fish in 1945 (Gerstung 1971 unpublished report). The spring-run count dropped to 42 fish in 1945, 16 in 1946, and three fish in 1947; both the spring and fall runs reportedly were decimated after the fish ladder on Old Folsom Dam was destroyed by flood waters in 1950 (Gerstung 1971 unpublished report). The spring run was finally extirpated during the period of construction of present-day Folsom Dam and Nimbus Dam (the latter completed in 1955) (Gerstung 1971 unpublished report).

Fry (1961, p 64) noted the presence of "a small spring run," at least through 1951, which became mixed with the "much larger fall run" during spawning. Combined run sizes were 6,000 to 39,000 spawners annually during the period 1944–1959, with estimates exceeding 30,000 fish during 1944–1946; these fish comprised mainly the fall run but included "a small but unknown proportion of spring run fish" in the first three years of the period (Fry 1961). During 1944–1955, an estimated average of 26,500 salmon (range 12,000 to 38,652) spawned annually in the mainstem American River below the town of Folsom; about 73% of the spawners used the five-mile stretch between Old Folsom Dam and the present site of Nimbus Dam, and the remainder spawned farther downstream (Gerstung 1971 unpublished report). In recent decades, spawning escapements of the fall run have ranged from about 10,000 to 95,000 fish annually (Gerstung 1989, DFG unpublished data). Spawning escapements were about 10,200 to 75,000 fish (average: 41,000) during 1990–1997, with Nimbus Hatchery accounting for an estimated 9% to 59% of the spawning runs during this period (DFG unpublished data). The fall run formerly spawned not only above the site of Nimbus Dam but above Folsom Dam as well (J. Nelson, personal communication, see "Notes"). Completion of Nimbus Dam is said to have inundated half of the then-existent spawning gravels in the American River (Holmberg 1972). Fall-run salmon presently are limited in their upstream migration by Nimbus Dam and spawn mainly downstream from the dam to just above the Watt Avenue crossing (J. Nelson, personal communication, see "Notes"); the habitat downstream of Watt Avenue presently consists mainly of pools unsuitable for spawning (E.R. Gerstung, personal observation).

Bear River (Placer County). The Bear River, the second largest tributary to the Feather River, historically contained salmon, but evidently only a fall run. The run reportedly was "substantial" (Reynolds and others 1993) but has not occurred in its former numbers for decades (J. Nelson, personal communication, see "Notes"). Adult salmon ascended as far as present day Camp Far West Reservoir, where a waterfall in that vicinity probably barred their further passage. No waterfall exists there now, so it evidently was submerged or built upon during the construction of Camp Far West Reservoir and Dam (J. Hiskox, personal communication, see "Notes"). There are no natural barriers above Camp

Far West Reservoir at least to Rollins Reservoir 24 mi upstream, next to present-day Chicago Park (J. Hiskox, personal communication, see "Notes"). According to one native Nisenan informant who had resided most of her life around Chicago Park, there were no salmon in that area (Voegelin 1942), so the salmon evidently were completely blocked by the waterfall near Camp Far West.

Clark (1929, p 36) stated, erroneously, that the Bear River "has never been known to be a salmon stream," with only an occasional salmon observed there. Clark reported the presence of an impassable dam near the town of Lincoln (which is not on the river but lies about nine miles south of Camp Far West Reservoir). As with other Sierra streams, hydraulic mining activities caused substantial sedimentation problems in the Bear River such that by 1876 its channel had become completely filled (Reynolds and others 1993). According to early historians,

> *Near Wheatland the river has altered its course for several miles, making a new channel half a mile south of the old bed. The banks of this stream were once twenty-five to thirty feet high. Its channel has been filled up, and the water is so thick and heavy with sediment that in summer there is scarcely any stream at all. From 1866 to 1869, the stream almost ceased to run except on Sundays, the water on other days being used by the miners (Chamberlain and Wells 1879, p 86).*

The effect on the salmon runs at that time would have been catastrophic and undoubtedly accounts for the apparent historical scarcity of salmon immediately before Clark's (1929) assessment. Indeed, it was written by early historians:

> *Bear, Yuba and Feather rivers were full of salmon, and the Indians speared them by the hundred in the clear water. When the river began to be muddy, the fish became scarce. The Indians even then speared them, and although unable to see the fish, they could tell their position with unerring precision by the ripples made in their passage through the water (Chamberlain and Wells 1879, p 15).*

The abundance of salmon in the Bear River long ago was also attested in an old newspaper account (Marysville Daily Appeal, 24 July 1889):

> *J. M. C. Jasper, of Wheatland, says that the generation now growing up in that vicinity are altogether too incredulous, because they wont [sic] believe that thirty years ago he used to stand on the banks of Bear river and with a pitchfork catch salmon weighing thirty pounds and over, to feed to the hogs. Many other old-timers tell the same thing.*

And, according to the California Fish Commission, "It is the testimony of all the pioneer miners that every tributary of the Sacramento, at the commencement of mining, was, in the season, filled with this fish, …A few salmon continued to enter the Feather, Yuba, Bear, and American Rivers until the floods of the Winter of 1860–1, which covered the gravel bottoms of all those streams with mining sediment…" (CFC 1880, p 3). The change in the Bear River was so profound that the Commission would later write, "Bear has lost all claim to the name of river… It never was noted as a fish stream, although a few salmon and perch were taken from its waters in early days" (CFC 1886, p 20).

Within the present decade or so, the fall run has occurred only occasionally, when heavy rains and dam spillage provide adequate flows (Reynolds and others 1993). At those times, the run may number in the "hundreds" (Reynolds and others 1993). The spawning distribution has its upper limit at the South Sutter Irrigation District (SSID) diversion dam, 15 mi above the confluence with the Feather River and 0.5 mi below Camp Far West Reservoir. The spawning areas extend from the SSID dam downstream about six miles to a point near Highway 65, although there are additional spawning gravels extending four to five miles farther downstream to Pleasant Grove Road (J. Nelson, personal communication, see "Notes"). There is no suitable upstream holding habitat for spring-run salmon in the Bear River (J. Nelson, personal communication, see "Notes").

Yuba River (Yuba County). Both spring and fall runs originally occurred in the Yuba River. A pioneer missionary's wife, writing of the Marysville area in 1851, noted:

> *The rivers abound in excellent salmon, which the Indians spear in great numbers, and dispose of in the towns. They are the finest I ever tasted. Some of them are three and four feet long, and weigh fifty pounds or more. It is amusing to see the Indians spearing them…. Their aim is unerring (Bates 1857, p 156).*

In the North Fork Yuba River, salmon were caught by PG&E workers in the Bullards Bar area during the 1898–1911 period of operation of the Yuba Powerhouse Project; the ditch tenders at the diversion dam "would nail two or three salmon on boards, place them body down in the ice-cold ditch stream, and ten hours later the night's dinner would come floating down" to the powerhouse on the valley floor (Coleman 1952, p 139). In later years, the salmon ascended in "considerable numbers" up to Bullards Bar Dam during its period of construction (1921–1924)—"so many salmon congregated and died below it that they had to be burned" (Sumner and Smith 1940, p 8). There are no natural barriers above the Bullards Bar Dam site, so salmon presumably had been able to ascend a considerable distance up the North Fork. There is photographic evidence of steelhead (called "salmon-trout" in early writings) occurring farther upstream at Downieville at the mouth of the Downie River (DFG file records). In their historical account of Sierra County, Fariss and Smith (1882, p 422) related the following episode from 1849: "While encamped on Jersey flat Jim Crow one day killed with a small crow bar a salmon-trout which weighed fourteen pounds. It was boiled in the camp kettle … afterwards gold was found in the bottom of the kettle." Jersey Flat (formerly Murraysville) was located across the river from Downieville (Fariss and Smith 1882). That incident may have been a reference to salmon because the latest spring-run spawners possibly were present at that date (shortly after October 5). Also, native Central Valley steelhead typically weighed three to eight pounds and rarely exceeded 13 lbs (Eigenmann 1890; Hallock and others 1957, 1961), at least in the present century, although steelhead in coastal streams may reach about 20 lbs (Hubbs 1946; Barnhart 1986). On the other hand, the term "salmon-trout" suggests the fish was distinguished from salmon so it could have been an uncommonly large steelhead, possibly of a now extinct summer run. In fact, there is evidence that "summer" steelhead formerly occurred in parts of the Sacramento River system as late as the 1930s and 1940s (Needham and others 1941; McEwan and Jackson 1996), and a few large steelhead (for example, up to 15.5 lbs) were observed in a DFG study of Sacramento River steelhead during the 1950s (Hallock and others 1961). Referring to the salmon runs in 1850 and 1851, the California Fish Commission (CFC 1875, p 14) stated that "large quantities were taken by the miners and by Indians … as far up as Downieville on the Yuba," and at other points on the American and Feather rivers. There are no natural obstructions from Downieville upstream to Sierra City, where Salmon Creek enters, so spring-run salmon and steelhead most likely were able to traverse that distance. Deep pools are present throughout the North Fork Yuba River from its mouth up to Sierra City (E.R. Gerstung, personal observation) and would have provided prime holding habitat for spring-run salmon. Spring-run salmon and steelhead probably ascended the higher-gradient reaches up to about two miles above the juncture of Salmon Creek and their absolute upstream limit on the North Fork would have been Loves Falls.

In the Middle Fork Yuba River, there are no significant natural obstructions except for a 10-foot falls in the lower reach, and salmon possibly had access to a considerable portion of the Middle Fork. Both salmon and steelhead were observed in the lower part of the Middle Fork, near where the North Fork joins, during a DFG survey in 1938 (DFG unpublished data). Steelhead were found as far upstream as the mouth of Bloody Run Creek (DFG unpublished data). Whether salmon also reached that far remains conjectural, although it is likely that salmon ascended some unknown distance up the Middle Fork because other native fishes such as pikeminnow have been observed as far upstream as Box Canyon, several miles below Milton Reservoir (R. Cutter, personal communication to E.R. Gerstung, see "Notes"). However, direct information is lacking and it is uncertain if many salmon were able to surmount the 10-foot falls on the lower river; therefore, we conservatively consider the falls 1.5 mi above the mouth as the effective upstream limit of salmon in the Middle Fork. Similarly, little is known of the original distribution of salmon in the South Fork Yuba River—the salmon population was severely depressed and access up the stream long since obstructed by dams by the time the DFG surveys were conducted in the 1930s. There are records of salmon occurring within one to two miles upstream of the mouth of the South Fork Yuba River (DFG unpublished data). A substantial cascade with at least a 12-foot drop, located one-half mile below the juncture of Humbug Creek (CRA 1972; Stanley and Holbek 1984), may have posed a significant obstruction to salmon migration, but it was not necessarily a complete barrier. This cascade, or "step-falls," is similar in dimensions and conformation to cascades on other streams, which salmon are known to have surmounted (P. Lickwar, personal communication, see "Notes"). However, we presently take that cascade below Humbug Creek as essentially the historical upstream limit of salmon during most years of natural streamflows. Steelhead are known to have ascended the South Fork as far as the juncture of Poorman Creek near the present town of Washington (DFG unpublished data), and perhaps some spring-run salmon historically also reached that point. Among the tributary streams of the lower Yuba River, salmon and steelhead were observed to ascend Dry Creek at least five to six miles in past decades (for example, in the 1960s; E.R. Gerstung, personal observation), and they occasionally still do when streamflows are high. Steelhead also went up Deer Creek a quarter of a mile where they were stopped by impassable falls (E.R. Gerstung, personal observation), but we have no records of salmon in that stream.

The Yuba River, along with the Feather and Bear rivers, sustained some of the most intensive hydraulic mining carried out during the gold mining years (1853–1885) (Kelley 1989; Reynolds and others 1993), and the effects on the salmon runs were undoubtedly severe. The Yuba in its pristine state, in 1849, was described by a forty-niner thusly:

> *Juba River is a fine stream, deep enough for navigable purposes for a considerable distance up its course to where it widens out at the ford, passing over a broad, level, gravell bed. Its waters in the stream appear of a greenish hue, but when taken into a glass are perfectly colourless, clear, and well-tasted (Kelly 1950, p 50).*

With banks rising about fifteen to twenty feet above the original channel at low water, the Yuba River was rapidly degraded by the immense influx of hydraulic mining debris. In March 1860, the Marysville Appeal remarked that the "yellow Yuba…that turgid vehicle of sediment takes a vulgar pride in spreading out its dirty face" (Kelley 1989, p 69). The great flood of 1861–1862 buried much of the "lower" bottomlands along the Yuba under sand deposits averaging two to seven feet deep (Kelley 1989). By 1876 the channel of the

Yuba River reportedly had become completely filled, and what remained of the adjoining agricultural lands was covered with sand and gravel (Kelley 1989; Reynolds and others 1993)—a marked deterioration of the river as salmon habitat. Chamberlain and Wells (1879, p 86) wrote:

> *At Timbuctoo ravine it is claimed that the Yuba river has been filled with a deposit, eighty feet in depth…. At Marysville, the depth of the deposit is about twenty-two feet. At a point, in front of the city, the river was considerably deeper than at any point above or below; this has been filled up to the regular line of the bottom, the deposit being over thirty feet in thickness. The bottom-lands along the Yuba and Bear rivers have been covered to a depth of five to ten feet, extending, in some places, one and one-half miles back from the streams.*

It was estimated that during the period 1849–1909, 684 million cubic yards of gravel and debris due to hydraulic mining were washed into the Yuba River system (Gilbert 1917)—more than triple the volume of earth excavated during construction of the Panama Canal. The California Fish Commission described the Yuba River as "a shallow stream, except during the rainy season … and its water is muddy" due to the mining that was still being carried on along the river (CFC 1886, p 20).

Clark (1929) reported that the salmon spawning grounds extended from the river mouth up to the town of Smartsville, but that very few salmon (evidently spring run) went past that point farther upstream. As of 1928, there was the "Government barrier" dam (Daguerre Point Dam) near the town of Hammond below Smartsville which served to catch sediments washed down the river from mining and dredging operations farther upriver. Although fishways had been provided at this dam, they were destroyed by floods in winter 1927–1928, but in any event few salmon reportedly went farther upriver to spawn (Clark 1929). Daguerre Point Dam (15 ft high), located about 11 mi east of Marysville on the valley floor (at 120 ft elev.), was said to have "almost completely blocked king salmon runs since its construction in 1910" (Sumner and Smith 1940, p 7); but salmon did surmount that dam in occasional years because they were observed in large numbers in the North Fork Yuba River during the early 1920s at Bullards Bar. Before the construction of Daguerre Point Dam, "heavy runs of salmon" reportedly occurred in Dry Creek and Deer Creek upstream of the dam site, but "few, if any," were present in 1938 (Sumner and Smith 1940, p 8). An even earlier structure, Barrier No. 1 (built in 1904–1905), was 4.5 mi above the later site of Daguerre Point Dam and probably hindered salmon until floods destroyed it in 1907 (Sumner and Smith 1940). Clark (1929) also reported that located on the South Fork Yuba north of Nevada City was Edison Dam, a power project dam that had a "good fish ladder and screens." There evidently were other dams on the Yuba River which were washed out or damaged during the winter of 1927–1928. Fry (1961, p 63) later stated that the Yuba River "was seriously handicapped" for many years by a diversion dam (evidently Daguerre Point Dam) which lacked a functional fish ladder and below which there "was often very little water." Although adequate fish ladders were later provided about 1950–1952 (DFG 1953), the low-water conditions remained as of 1959 (Fry 1961). Construction of Englebright Dam 12.5 mi farther upstream (282 ft elev.) in the late 1930s eliminated much spring-run salmon habitat and "severely reduced the spring run" (DFG 1990). Englebright Dam presently is the upstream limit of salmon distribution. Although most of the salmon spawning habitat occurs in the 7.8 miles of river on the open valley floodplain downstream of Daguerre Point Dam (Reynolds and others 1993), the greater part of the run now generally spawns above Daguerre Point (J. Nelson, personal communication, see "Notes"). The fall run previously spawned in the entire stretch from Englebright Dam downstream to Simpson Lane (Marysville), below which the substrate is too sandy (J. Nelson, personal communication, see "Notes"). The spring run, when the fish were common in the recent past, spawned in the area between Englebright Dam and Highway 20 (J. Nelson, personal communication, see "Notes").

Salmon originally migrated into the Yuba River in large numbers to spawn. The California Fish Commission reported that in 1850 "the salmon resorted in vast numbers to the Feather, Yuba, American, Mokolumne [sic], and Tuolumne Rivers," and on the Yuba River as late as 1853 "the miners obtained a large supply of food from this source"; however, by 1876 the salmon no longer entered those streams (CFC 1877, p 5). At the time of Clark's survey in 1927–1928, a fall run occurred in late fall and there was an occasional, "slight" spring run. Clark (1929, p 37) stated that "very little could be learned" about past salmon abundances in this river, but at that time (1928) the salmon (essentially the fall run) were "holding their own and not decreasing." By the late 1950s, Fry (1961, p 63) noted that the spring salmon run had "virtually disappeared." A remnant spring run managed to persist at least up to 1995 in "minimal numbers" (J. Nelson, personal communication, see "Notes"), but the run has been genetically mixed with the fall run due to spatial overlap of their spawning areas, as is the case also in the Feather and American rivers (J. Nelson, personal communication, see "Notes"). Fry (1961) reported fall-run spawning escapements of 1,000 to 10,000 fish during 1953–1959. The assessment by the California Department of Fish and Game (Reynolds and others 1993) was that the Yuba River "historically supported up to 15% of the annual run of fall-run chinook salmon in the Sacramento River system." Fall-run escapements during the period 1953–1989 ranged within 1,000 to 39,000 fish and averaged 13,050 annually (Reynolds and others 1993). More recently (1990–1997), fall-run estimates have varied from 5,900 to 25,800 spawners annually (DFG unpublished data).

Feather River (Yuba, Butte, Plumas counties). The Feather River, noted by one early traveler in 1843 as "tributary to the Sacramento and still richer in salmon" (Van Sicklen 1945), was renowned as one of the major salmon-producing streams of the Sacramento Valley. California Fish Commissioner R.H. Buckingham wrote in the Sacramento Bee (31 December 1885), "In years gone by, some of the fishermen of Sacramento would ascend the Feather river as far as Yuba City, to fish for salmon, which were very plentiful at times, Indians catching as many as two hundred in a single night with spears." Regarding the native fishing for salmon, an early historical account stated,

> *The Feather River was partially closed by piles extending nearly to the middle of the stream. These piles were interwoven with brush so as to prevent the passage of the fish. They were thus compelled to pass through the opening, where the Indians on platforms, captured them with their spears in their ascent of the stream (Chamberlain and Wells 1879, p 15).*

Salmon originally ascended a considerable distance into the Feather River system, particularly the spring run which spawned in the higher streams and headwaters. They went up the West Branch at least to the site of Stirling City (F. Meyer, personal communication, see "Notes"), and also up along the entire length of the North Fork Feather River through the area now covered by Lake Almanor and into the surrounding tributary streams (>4,200 ft elev.). Early correspondence sent to the DFG state that large numbers of spring-run fish ("in the thousands") entered the North Fork, most of which were stopped by Salmon Falls (about ten feet high) approximately 2 to 2.5 miles above the town of Seneca (DFG letters no. 1, no. 2). One writer stated, "There was an old indian couple known as Caribou Bill and his wife who used to net them at the Falls, smoking and drying them for use during the winter…. The spring run usually reached the Falls about the first of July" (DFG letter no. 1). A few fish were able to surmount the falls and proceed farther upstream to the area of present Lake Almanor (DFG letter no. 1). Flows from the many springs that fed the Lake Almanor area (formerly "Big Meadows"), together with streamflows from farther up the North Fork, undoubtedly were sufficient for salmon to have ascended through the lakebed area and up the North Fork another six miles or more (J. Nelson, personal communication, see "Notes"). In a newspaper article more than a century ago, a Dr. J.H.C. Bonte wrote of salmon angling: "They are caught with hook and bait now along the Sacramento river above Knight's Landing, and in the Feather river not far below Lassen's peak…. Young salmon are frequently caught in Big Meadows, Plumas county, and older ones weighing eight and ten pounds, are also taken though not very often" (Sacramento Union, 24 December 1881).

Judging from streamflows that occur in the Hamilton Branch of the North Fork above Lake Almanor, salmon most likely ascended that branch for several miles, possibly to within a very short distance of present-day Mountain

Meadows Reservoir (J. Nelson, personal communication, see "Notes"). Spring-run salmon are also said to have ascended Indian Creek, a tributary of the East Branch of the North Fork (DFG letter no. 2), at least as far as Indian Falls (near the junction of Highways 89 and 70). They concentrated and were harvested there by Native Americans, although the falls were not necessarily their upper limit in that stream (J. Nelson, personal communication, see "Notes"). In reference to two North Fork tributaries, Hanson and others (1940) stated that the quality of spawning habitat was good in Yellow Creek and excellent in Spanish Creek (a tributary of the East Branch of the North Fork), although by that time salmon reportedly were blocked farther downstream by a diversion dam. The previous distribution of salmon in those two streams is unknown, but Yellow Creek probably was used at least to some extent. A substantial waterfall occurs above the mouth of Spanish Creek (R. Flint, personal communication, see "Notes") and possibly barred salmon from ascending any appreciable distance, although DFG correspondence indicates salmon may have entered "Clear Creek" (a tributary of Spanish Creek) for spawning (DFG letter no. 2).

In the Middle Fork Feather River, the salmon were stopped near Bald Rock Dome shortly above Lake Oroville by Bald Rock Falls (18 ft high) and Curtain Falls (30 ft) immediately upstream. Spring-run salmon were observed spawning below Bald Rock Falls in the 1960s before Oroville Dam was built, and sport fishermen often caught large numbers of salmon from the pool below the falls (E.R. Gerstung, personal observation). Testimonies of Native American (Concow Maidu) residents also identify the waterfall below Bald Rock Dome as having "marked the upper limits of salmon migration" which "made it a desirable fishing spot for the Indians" during earlier times (Jewell 1987, p 19). In Fall River, a tributary of the Middle Fork, the 640-foot Feather Falls about one mile above the mouth certainly was a barrier.

The South Fork Feather River, according to Hanson and others (1940), had "much more spawning gravel per mile of stream than either the Middle or North Fork," but at that time nearly all of the streamflow was diverted for irrigation into the Forbestown and Palermo canals. Before the diversion of the stream, spring-run salmon may have ascended to the vicinity of Forbestown, near the present upper limit of the South Fork arm of Lake Oroville.

Clark (1929) reported both spring and fall runs present in the Feather River. The main spawning beds extended for 30 mi from the river mouth up to Oroville. At that time (1928), the spring-run fish evidently still went up all four branches above Oroville, which were all suitable as spawning habitat, up to points where they were blocked by dams. Several dams in the Feather River drainage presented obstacles to salmon in 1928. The Sutter-Butte Dam six miles below Oroville was a five-foot high irrigation diversion dam with a reportedly ineffective fishway and lacking fish screens on the intake ditches, although the salmon nonetheless surmounted it (Clark 1929). Miocene Dam near the town of Magalia on the West Fork was 12.5 ft high power project with no fishway or fish screens. Stirling City Dam, also on the West Fork, was eight feet high and supplied a powerhouse; it had a fish ladder but Clark stated that salmon never reached this far upriver. On the North Fork was the Great Western Power Company dam equipped with a fish ladder, although water diversions to the powerhouse dried up the river for "a number of miles" when streamflow was low (Clark 1929). Clark was not aware of any barriers to salmon on the Middle Fork Feather River, but he noted that the South Fork had two irrigation diversion dams: Dam No. 1 on Lost Creek, which took "nearly all the water from the South Fork during the summer months," and Dam No. 2 located on the main fork and lacking a fishway.

Clark (1929, p 38) stated: "The runs of salmon, both spring and fall, used to be very heavy in the Feather River previous to the building of obstructions. It is true that the mining operations in the early years may have reduced the amount of fish somewhat, but the building of dams has almost destroyed the spring run." However, the effect of early mining operations on salmon habitat, while not quantifiable, nonetheless was undeniably substantial during their heyday. The California Fish Commission noted that mining sediments which washed into the Feather, Yuba and American rivers during the winter floods of 1860–1861 smothered the spawning grounds of the few salmon returning to those streams up to that time (CFC 1880). John Muir (1938, p 244), referring to the turbidity of the Sacramento River in October 1877, stated, "…the Sacramento is clear above the confluence of the Feather." Somewhat earlier, Stone (1874) noted that poor water quality resulting from intense mining activity was the reason for the absence of salmon from the Feather, Yuba, and American rivers. A decade later, Stone (1883a, p 221) again observed:

> *…the Feather River, the Yuba, the American Fork, have long ago been completely ruined as spawning grounds, in consequence of the immense deposit of mud in them, caused by the hydraulic mining operations on these rivers. Not a salmon ever enters these streams now. Except possibly at a time of very high water, these streams are so thick with mud that it would kill any fish attempting to ascend them.*

A graphic account was given by Chamberlain and Wells (1879, p 85):

> *A detailed statement of the loss by mining debris it is impossible to make, but its ravages can be seen on every hand. The surface of the country has undergone a change; the streams diverted from their obstructed channels, have been compelled to seek new courses and outlets for their mud-burdened waters. The banks of Feather, Yuba, and Bear rivers, were, formerly, several feet above the ordinary level of the water, and the steamers and sailing vessels were enabled to make easy and convenient landings. The streams were as clear as crystal, at*

all seasons of the year, and thousands of salmon and other fishes sported in the rippling waters, their capture being a favorite amusement of both the white man and the native. But now the channels have become choked with sediment, the waters heavy and black with its burden of mud, and the fish been compelled to seek other localities… The bed of the Feather river, from Oroville to the mouth of Yuba river has been raised six or eight feet.

Even two decades later Rutter (1904, p 71) would write: "The water of the upper part of the Sacramento River and the upper tributaries is quite clear, and continues so until the mouth of the Feather River is reached, from which point to the mouth it is very muddy. It is in the muddy water between the mouth of Feather River and Vallejo that the salmon for the markets are taken." An estimated minimum of 40 million cubic yards of mining debris from the lower river and up to 186 million cubic yards from the entire watershed were produced in the Feather River basin during the period of hydraulic mining before 1909 (Gilbert 1917).

Clark (1929, p 38) described the fall salmon run as "large, although not extremely abundant" and having "fallen off in the last few years" and suggested that the populations showed a three- or four-year cycle, based on statements by river residents. Fry (1961) reported run-size estimates for the fall run of 10,000 to 86,000 fish during the period 1940–1959, and about 1,000 to 4,000 fish for the spring run. The fall run spawned mainly in the mainstem, while most of the spring run spawned in the Middle Fork, with a few spring run entering the North Fork, South Fork and West Branch (Fry 1961). Just before the completion of Oroville Dam (in 1967), a small naturally-spawning spring run still existed in the Feather River, but the Oroville project cut off all the original spring-run habitat (Reynolds and others 1993). Currently, the fall run has its upstream limit at Oroville Dam fish barrier, spawning from there downstream to a point about two miles above the Gridley Road crossing (J. Nelson, personal communication, see "Notes"). There is also a hatchery-sustained population of "spring-run" fish that has been genetically mixed with the fall run (Fisher 1994; DFG 1998) and which spawns in the one-half-mile stretch between the fish barrier immediately below Oroville Dam and downstream to Highway 7 (J. Nelson, personal communication, see "Notes"). The hybrid spring-run fish hold over the summer in deep pools within the so-called "low-flow" section of the river between Thermalito Diversion Dam (five miles below Oroville Dam) and the downstream Thermalito Afterbay Outlet (Reynolds and others 1993). They are spawned artificially in the Feather River Hatchery and also spawn naturally in the river during late September to late October (Reynolds and others 1993). The "spring run" thus overlaps temporally as well as spatially with the fall run—which is the cause of the hybridization between the runs. The hybrids consistently enter the hatchery as the early component of the spawning run, but infusion of fall-run genetic material into the hybrid population by artificial hatchery selection continues to dilute the genetic integrity of the putative (hybrid) spring-run fish (F.W. Fisher unpublished data).

The Feather River Hatchery, located at the town of Oroville, was built by the California Department of Water Resources to mitigate for the loss of upstream spawning habitat of salmon and steelhead due to the building of Oroville Dam (Reynolds and others 1993). The California Department of Fish and Game began operating the hatchery in 1967 (Reynolds and others 1993). The Feather River Hatchery presently is the only source of eggs from "spring-run" chinook salmon in the Central Valley and is viewed as a key component in plans for restoration of spring-run populations (Reynolds and others 1993). Population estimates for the period 1982–1991 indicated an average of 2,800 "spring-run" fish, compared to the average of 1,700 fish before the construction of Oroville Dam (Reynolds and others 1993). The hybrid spring-run stock increased since the early 1980s and numbered >5,000 fish in 1989 (Campbell and Moyle 1991; DFG 1998). More recently (1990–1996), the spring run has ranged between 1,500 and 6,000 fish (average: 3,800; DFG 1998). The increase in numbers is attributed to the consistent supply of cold water to both the hatchery and "low-flow" section of the river (Reynolds and others 1993) but probably also reflects the extension of the seasonal period ("perhaps arbitrarily") in which spawners entering the Feather River Hatchery are defined as spring-run fish (DFG 1998, p VII-6). See Hedgecock and others (this volume) for a discussion of the genetic attributes of Feather River spring run.

Fall-run salmon also increased after completion of the Oroville Dam complex in 1968, averaging 39,100 spawners before the project and 51,400 fish afterwards (Reynolds and others 1993). In addition, anglers are estimated to have harvested 10,000 fish (spring and fall runs combined) each year in the ten-year period before 1993 (Reynolds and others 1993). Fall-run escapements more recently (1991–1997) have averaged 53,600 fish annually (range: 32,200 to 71,800), including both hatchery and natural spawners, compared to an annual average of 51,200 fish (range: 30,500 to 77,800) during the 1980s (DFG unpublished data). The hatchery component of the fall spawning escapements composed 13% to 41% of the annual runs during 1991–1997 (DFG unpublished data). The fall run may be considered to be genetically introgressed by hybridization with the spring run due to hatchery practices (DFG 1998).

The DFG attempted to introduce a late-fall run into the Feather River in the fall of 1970 by planting over one million eyed eggs from Coleman National Fish Hatchery (DFG 1974). The Feather River Hatchery received returning age-3 and age-4 adults for two generations following the plant, during 1973–1978, but this introduced run failed to persist.

Butte Creek (Butte County). Butte Creek, described by John C. Frémont (1848, p 21) as "a beautiful stream of clear water about fifty yards wide, with a bold current running all the year," historically supported spring and fall salmon runs and evidently a late-fall run (Hallock and Van Woert 1959). The spring run probably ascended at least as far as the present vicinity of Centerville Head Dam near DeSabla, which we consider here as the upstream limit. Pacific Gas & Electric Company employees at one time had reported salmonids migrating past the site to areas upstream (J. Nelson, personal communication, see "Notes"), but it is not known how much farther upstream they went, or whether they were salmon or steelhead. A waterfall (25+ ft high) about one-half to one mile below Centerville Head Dam previously had been viewed as a barrier to salmon migration, but the presence of one salmon carcass above the waterfall during a DFG spawning survey in early 1995 (J. Nelson, personal communication, see "Notes") indicates that some portion of the spring run historically ascended above the waterfall. Steelhead are believed to have ascended as far upstream as Butte Meadows (Flint and Meyer, 1977 unpublished report), but salmon most likely did not reach that far (J. Nelson, personal communication, see "Notes").

Clark (1929, p 38) described Butte Creek has having been known as "a very fine salmon stream" and "a good spawning ground." He stated that there was only a fall run present, "as the water is very low and warm in the summer." At that time (1928) so much water was being diverted from the stream during most of the summer and fall that the fall run was stated by Clark to have been "almost destroyed." However, it appears that Clark did not fully recognize that the flow conditions he observed in the summer and fall, while detrimental to the fall run or to any salmon that might be present in the lower creek, did not preclude the existence of the spring run. Spring-run fish, migrating during the time of high flows, would have been well upstream during the summer-fall period when Clark evidently made his observations. Flint and Meyer (1977 unpublished report) stated that the spring run "historically provided a good fishery in Butte Creek"; they also mentioned the presence of a late-fall run which "migrates up Butte Creek in January and February and spawns immediately after arriving at the spawning beds."

Clark (1929) reported the presence of two duck club weirs and three irrigation dams on the creek, but all were low enough to be surmounted by salmon if there was enough water. Clark specifically mentioned a drainage canal ("833") which carried "considerable water" and in which adult salmon became stranded, to "die in the mud." There were a few spawning beds in the lower creek, but he noted that the few fish that entered the creek spawned in the upper reaches, if they were able to surmount the irrigation dams and ditches. As late as 1958–1960, adult spring-run salmon in Butte Creek were being lost to unscreened irrigation diversions (DFG 1960). In recent years there have been as many as ten diversion dams on Butte Creek above Butte Slough that divert water for various uses (for example, power generation, irrigation, domestic supply) and all impair salmon migration, in some cases by dewatering sections of the stream (Reynolds and others 1993). However, several dams have been dismantled or are scheduled for removal from Butte Creek to aid in wildlife and fisheries restoration (Sacramento Bee, 5 November 1997). These barriers have affected the upstream migration of the different salmon runs to different degrees because of seasonal variation in streamflows; for example, fall-run fish are most affected, having to migrate when flows are inadequate to allow passage over the barriers.

Hanson and others (1940, p 78) stated that Butte Creek was "a very fine salmon stream in the past" but was no longer suitable for salmon due to extensive mining and hydroelectric development that had occurred in the watershed. Yet, Hallock and Van Woert (1959, p 260) reported the presence of "an early spring run," a fall run, and the "remnants of a late fall run" in Butte Creek during the mid-1950s. In reference to the fall run, they noted that "occasionally considerable numbers of fish" surmounted the numerous diversions on the lower creek to reach the spawning beds (Hallock and Van Woert 1959, p 260). Fry (1961) shortly thereafter noted that Butte Creek had a spring run but "almost no fall run," thus setting it apart from most small streams in the northern Sacramento Valley which had mainly, or only, a fall run. The many removable dams on the creek blocked or reduced flows late into the fall, and the fall run could not surmount them. Fry (1961) reported that the spring run ranged from <500 to 3,000 fish during 1953–1959. During the 1960s, the spring run at times numbered >4,000 fish in Butte Creek (DFG 1998), with smaller numbers of fall-run and late-fall-run fish (Reynolds and others 1993). More recently, estimated spring-run numbers were 100 to 700 fish during the 1990s and rose to 7,500 fish in 1995 and 20,000 fish in 1998 (DFG 1998 unpublished data). The source of the surprisingly numerous spring-run spawners that entered Butte Creek in 1998 is not known, but they presumably were largely due to the strong escapement in 1995. The Butte Creek fall run remains small, numbering "a few fish to as many as 1,000" (Reynolds and others 1993, p VII-42), because of the very low late-summer and fall flows (F.W. Fisher, personal observation). There are also late-fall-run salmon in Butte Creek, but their numbers are unknown (Reynolds and others 1993).

The fall-run salmon generally spawn below the Parrott-Phelan Dam (J. Nelson, personal communication, see "Notes"). The spring-run fish in Butte Creek, unlike spring runs in other streams, presently spawn in the lower part of the creek at relatively low elevation (about 1,000 ft), where they are blocked by the Centerville Head Dam. However, the water there is unusually cold, comparable in temperature to that typically found at about 2,000-foot elevation (F. W. Fisher unpublished data). Although spring-run adults in Butte Creek migrate and spawn at the same times as spring-run fish in other streams, it appears to be a somewhat different "breed" in that the fry emerge in December; some of these fry migrate out immediately while others migrate out in the spring (Reynolds and others 1993), and the remaining fraction remains in the stream until the following fall (one year after they had been spawned) (F.W. Fisher, personal observation). This is in contrast to the pattern seen in streams where spring-run fish spawn in the colder, high-elevation reaches (Mill and Deer creeks). There the fry do not emerge from the gravel until March, and they remain in the streams over the summer to migrate out in September and October (F. W. Fisher unpublished data). Spring-run adults are present in Butte Creek in early February, March, and April, in contrast to Feather River "spring-run" fish (that is, spring-fall hybrids), which do not enter that river until May or June.

Big Chico Creek (Butte County). Big Chico Creek contains marginally suitable habitat for salmon and probably was opportunistically used in the past. Spring, fall and late-fall runs have occurred in this creek (Reynolds and others 1993). In apparent reference to the fall run, Mrs. Annie Bidwell, wife of the pioneer John Bidwell, noted: "In the fall of the year the first run (being the fish in the streams after the first rains) of salmon were considered the best, as later in the season they had more or less germs in them and were consequently not so good to eat" (Bidwell 1980, p 56).

Fry (1961) gave estimates of 50 fall-run (including late-fall-run) fish in 1957, 1,000 spring-run fish in 1958, and 200 spring-run in 1959. Fry (1961) also reported that a barrier had been removed from the creek in summer 1958, thus providing an additional nine miles of habitat for salmon up to Higgins Hole (a deep pool), above which is another natural barrier (Outdoor California 1958; Travanti 1990). The lower barrier—a 14-foot falls in the Iron Canyon area created by rock-slide debris around the time of the 1906 San Francisco earthquake—blocked upstream access for what had previously been a "sizable" salmon run (Outdoor California 1958). The present distribution of salmon in Big Chico Creek thus is probably not much different from what it had been originally. The spring run has been able to ascend farther upstream during spring flows than is reached by the fall run, and thus is both spatially and temporally isolated from the fall run, as is true in some other streams. The current upper limit of the spring run and steelhead is essentially Higgins Hole, about one-half to one mile above the crossing of Ponderosa Way, although with high enough streamflows the fish can ascend a half mile farther upstream (J. Nelson, personal communication, see "Notes"). The fall run typically spawns below the Iron Canyon Fish Ladder in Bidwell Park, in the lower one-third or one-fourth of the creek (J. Nelson, personal communication, see "Notes").

The average annual run size of the spring-run is believed to have been <500 fish during the 1950s to 1960s and more recently has been considered to be only a remnant (Reynolds and others 1993). Big Chico Creek has been heavily planted with Feather River "spring-run" fish, which evidently had been genetically mixed with fall-run fish. In the last decade or so, very few, if any, of these hybrid spring-run spawners have returned to the creek (F. W. Fisher unpublished data). During the 1990s, estimated spring-run escapements have ranged from zero to 200 fish, averaging 35 fish (DFG 1998). The Iron Canyon fish ladder was damaged by high flows during the winter of 1994–1995, thereby blocking the spring salmon run in 1995. In that year, about 100 salmon were captured below the obstruction and transported farther upstream and another 100 salmon were observed in the stream (J. Nelson, personal communication, see "Notes"; DFG 1998). A relatively large spring-run escapement (about 400 fish) was observed in 1998 (DFG unpublished data), but the source of these fish is unknown. The fall and late-fall runs in recent times have been highly variable, and the fall run occurs in very low numbers due to lack of water in late summer and fall (Reynolds and others 1993). Intensive pumping of water from lower Big Chico Creek for irrigation takes a heavy toll of young salmon migrating downstream and juveniles that enter the stream for rearing, except during very high streamflow conditions (Reynolds and others 1993; USFWS 1995).

Deer Creek (Tehama County). Both spring- and fall-run salmon occurred in Deer Creek, which is a cold, spring-fed stream. The Yahi branch of the Yana people occupied both the Deer and Mill creek drainages, and for whom salmon and other fishes were an important secondary food source (Johnson 1978). The celebrated Ishi, last of the Yahi, demonstrated to anthropologists the Yahi methods of procuring fish, and he was said to have "used a salmon spear most expertly" (Pope 1918, p 199).

Before the 1940s, the spring-run salmon ascended Deer Creek for about 40 miles from its mouth up to 16-foot-high Lower Deer Creek Falls (Hanson and others 1940), located about one mile below the mouth of Panther Creek. According to Hanson and others (1940), salmon were never known to have passed Lower Deer Creek Falls. Clark (1929, p 39) stated that spawning beds extended from the creek mouth (near the town of Vina) to about ten miles into the foothills, which he described as "a good spawning ground when there is water." Clark, however, was evidently referring only to the fall run.

Clark (1929) reported the presence of two irrigation diversion dams on the creek: Stanford Vina Dam, about three miles east of Vina, five feet high but with a fish ladder and screens installed on the irrigation ditches, and Deer Creek Irrigation District Dam, eight miles east of Vina. The latter dam had no fish ladder, because it was not considered to be an obstruction to salmon, but it also lacked fish screens at that time (Clark 1929). According to Clark (1929, p 39), there was "a small spring run and quite a large fall run" and salmon previously had been "very numerous in Deer Creek until dams were built which took most of the water from the creek." Clark furthermore stated that "the spring run has never been successful as the fish come up in the spring and summer and lay in the holes until fall before spawning," and "The water becomes too warm for them and they die before they can spawn." Clark may have made this latter statement based on limited observations on fish relatively low in the drainage or during years of low streamflows; spring-run fish are presently known to be capable of over-summering in the pools in Deer Creek (for example, Needham and others 1943; F.W. Fisher, personal observation). Clark stated that the fall run was more successful, when there was "sometimes enough water in late fall," but even the fall run was "very small" at that time (1928) due to irrigation diversions from the creek. Decreased streamflows and consequently high water temperatures in the early summer caused mortalities of up to several hundred late-migrating adult salmon in the years 1945–1947 (Moffett 1949).

As part of the Shasta Fish Salvage Plan (to mitigate for construction of Shasta Dam), a fish ladder was constructed around Lower Deer Creek Falls in 1942–1943 (Needham and others 1943; Moffett 1949). By the end of 1943, salmon were able to ascend about five miles farther upstream to Upper Deer Creek Falls, a "sheer drop" of about 20 feet (Hanson and others 1940), which is the present major upstream barrier. There is, however, a fish ladder at the Upper Falls that is occasionally used by a few salmon (P.B. Moyle, personal observation). Hence, the amount of stream available for over-summer holding and for spawning (particularly for the spring run) has been increased. To compensate for the loss of spawning habitat in the upper Sacramento drainage caused by construction of Shasta and Keswick dams, Sacramento River spring-run salmon were caught at Keswick and transported to Deer Creek during the 1940s to mid-1950s (Needham and others 1943; Moffett 1949; Fry 1961), but those transfers had no noticeable effect on the spring run in Deer Creek (Fry 1961). Deer Creek is currently believed to have sufficient habitat to support "sustainable populations" of 4,000 spring-run and 6,500 fall-run salmon (Reynolds and others 1993). In recent years, most of the flow in the lower ten miles of the creek on the valley floor has been diverted, and in "many years" all of the natural flow from mid-spring to fall is depleted by the three diversion dams and four diversion ditches (Reynolds and others 1993). Although all of the diversion structures have fish screens and fish ladders, inadequate flows sometimes impede or prevent the upstream passage of salmon (Reynolds and others 1993).

The fall run presently still exists, spawning at lower elevations than the spring run and later in the fall, after ambient temperatures have become cooler. The two runs thus are both spatially and temporally isolated for spawning. The center of the present summer-holding and spawning areas for the spring run is the A-line Bridge (at about 2,900 ft elev.), which lies between Lower Deer Creek Falls and the US Forest Service (Potato Patch) Campground farther upstream. The spring run spawns from late August to early October (having held over the summer in the upstream reaches), while the fall run cannot enter the lower creek to spawn until stream flows increase in late October (F.W. Fisher, personal observation).

Fry (1961) reported spring-run population estimates of <500 to 4,000 fish for 1940–1956 and fall-run estimates of <500 to 12,000 fish for 1947–1959. From the 1960s through 1980s, the number of fall-run spawners in Deer Creek ranged from 60 to 2,000 fish (average: 500), and in the present decade (1990–1997) the run has numbered 70 to 1,200 fish (average: 400 from DFG unpublished data). Estimates for the spring run were 400 to 3,500 fish (average: 2,200) annually during 1950–1979 and 80 to 2,000 fish (average: 660) during 1980–1998 (DFG unpublished data). Although spring-run estimates for most years during the 1990s have been in the low- to mid-hundreds, estimated escapements reached 1,300 in 1995 and 2,000 fish in 1998 (DFG 1998 unpublished data). The spring-run population in Deer Creek is one of only three or four remaining naturally spawning spring-run chinook populations in California that can be considered genetically intact and demographically viable (DFG 1990)—two other such populations within the Central Valley drainage being in nearby Mill and Butte creeks.

Mill Creek (Tehama County). Both spring and fall salmon runs are present in Mill Creek, and occasionally late-fall run fish also occur (Reynolds and others 1993). Stone (1874, p 208) mentioned "Mill-brook, near Tehama, …a small stream, where the salmon rush up to spawn in great numbers, in October and November. They also come up this brook in April, May, and June." The presence of a large "summer" (that is, spring) run in 1901 was reported by the US Fish Commission (USFC 1904). The "summer" run in 1902 was blocked by newly constructed racks and the fish all died due to excessively high temperature, while the fall run of that year was small due to low streamflows (USFC 1904). Clark (1929, p 39) later described Mill Creek as "a celebrated salmon stream" that had "some very large runs" and he stated that the spawning beds extended from the US Bureau of Fisheries egg station and hatchery (located about one mile above the creek mouth) for a distance of two miles to Clough Dam. Most habitat for salmon, either for holding or spawning, is currently viewed as extending from the mouth of Little Mill Creek (about 1,500 ft elev.) up to the area around Morgan Hot Spring (about 5,000 ft) (F.W. Fisher, personal observation). Some spring-run salmon in Mill Creek reportedly spawn in stream reaches well in excess of 5,000 ft elevation (Reynolds and others 1993) near the boundary of Lassen National Park—among the highest altitudes known for salmon spawning in North America. All the original upstream habitat suitable for spring-run salmon is still intact, and no major changes have been made on this stream (F.W. Fisher, personal observation).

Mill Creek is spring-fed and generally cold enough to sustain a spring run. However, it is unusual in that there is an elevational temperature inversion. The upper creek is fed by water from Lassen National Park, where there are many hot springs, but farther downstream the lateral influx from coldwater springs results in cooler temperatures (F.W. Fisher, personal observation). Mill Creek also differs from other streams of the eastside Central Valley drainage in having high silt load and turbidity during the spring snow-melt, the silt originating naturally from volcanic and glacial materials in Lassen Volcanic National Park (Reynolds and others 1993).

Clark (1929) reported three dams on Mill Creek: the Molinas Water Company dam with fish screens on its diversion ditches and "not considered an obstruction"; 16-foot Clough Dam, an irrigation diversion project equipped with fish screens but with a poor fishway, which was seldom passable due to low water; and a third, unnamed seven-foot dam farther upstream with screened diversion ditches. However, these dams were in the lower reaches of the creek, essentially on the valley floor, and they probably posed no real obstruction to spring-run fish during the spring flows. In the early 1990s, there were three dams in the lower eight miles of the creek which diverted most of the natural flow (Reynolds and others 1993). All three dams were equipped with fish screens and the lowermost and uppermost dams had operative fish ladders (Reynolds and others 1993). However, the fish ladder on Clough Dam (the middle, tallest dam) functioned poorly during certain flow conditions (Reynolds and others 1993) and therefore may have impeded upstream migration. Clough Dam was breached by flood flows in January 1997 and since then has not obstructed salmon migration (C. Harvey-Arrison, personal communication, see "Notes").

Clark (1929) noted that salmon abundance in this creek was reflected by the egg takes at the US Bureau of Fisheries egg station, which collected eggs from fall-run fish but not from the spring run. The station operated during 1902–1945, closing down after completion in 1945 of the Coleman National Fish Hatchery on Battle Creek (Reynolds and others 1993). The egg takes peaked during 1904–1906 but were generally high from 1903 to 1918, dropping substantially during the later years 1919–1924. Clark stated that female salmon in this system produced about 5,000 eggs each, thus allowing estimates to be made of female spawner abundance from the total egg takes by the station; he also stated that there were "at least half again the number of males" (in other words, males were 50% or more as abundant as females). Thus, at the peak productivity in 1905 (30 million eggs taken), there were an estimated 9,000 spawners present (including 6,000 females). In 1924, one of the years of lowest egg production, 2.3 million eggs were taken, which translated to 450 female and 675 total spawners in the creek.

Clark (1929, p 41) mentioned the presence of both fall and spring runs, but he described the spring run as "very small and decreasing each year." It is possible, however, that Clark did not realize that spring run fish ascended far upstream and held there over the summer, and he therefore may have under-estimated their presence. Fry (1961) reported spring-run numbers of <500 to about 3,000 fish during 1947–1959, while the fall run ranged between 1,000 to 16,000 spawners. Fry (1961, p 61) stated that most of the fall run spawned below Clough Dam, while "for all practical purposes the entire spring run goes upstream past the dam."

In recent decades, the spring-run spawning escapement varied from zero fish, during the severe drought in 1977, to 3,500 fish in 1975 (Reynolds and others 1993; DFG unpublished data), but the trend has been downward from an annual average of 2,000 fish in the 1940s to about 300 in the 1980s (DFG 1990). During 1980–1998, the spring run ranged from about 60 to 840 spawners annually (average: 380) (DFG 1998 unpublished data). Fall-run escapements have been zero to 16,000 spawners since 1952, generally hovering near 1,500 fish (DFG unpublished data). The DFG (1993) reported an average annual fall-run escapement of 2,200 fish for the 38 years of record up to that time. In the present decade (1990s), the fall run has numbered about 600 to 2,100 fish but was absent in some years due to low seasonal streamflows. As in Deer Creek, the spring and fall runs in Mill Creek are separated temporally, the fall run ascending the creek during fall flows after the spring-run fish have finished spawning (F.W. Fisher, personal observation). There is also spatial separation of the spring and fall runs in both Mill and Deer creeks, with spring-run fish spawning well upstream from the fall-run fish and thus further minimizing the possibility of hybridization (DFG 1990). Late-fall run salmon have been occasionally observed spawning in the lower reaches of the creek (Reynolds and others 1993).

Antelope Creek (Tehama County). Both spring and fall runs, and probably a late-fall run, originally occurred in Antelope Creek. Spring-run salmon ascended the creek at least to where the North and South forks join (where several salmon were observed a few years ago by Lassen National Forest biologists), and they probably held there over the summer. The few spring-run fish that now enter the creek ascend the North and South forks about five to six miles to the vicinity of the Ponderosa Way crossings, their probable historical upper limit, beyond which there is little suitable habitat (F.W. Fisher, personal observation).

As in Mill and Deer creeks, the low, late summer and fall streamflows limit the accessibility of the creek to fall-run fish. Until at least 1993 there were two water diversions on Antelope Creek, operated by the Edwards Ranch (50 cfs) and by the Los Molinos Mutual Water Company (70 cfs) (Reynolds and others 1993). During the typical flow-diversion season (1 April to 31 October), operation of both diversions usually dried out the lower reach of the stream (Reynolds and others 1993), thus impeding or preventing the upstream migration of both spring and fall runs.

The spring run formerly numbered 200 to 300 fish annually, with lows down to 50 fish (DFG unpublished data). Reynolds and others (1993) gave an estimated historical spring-run size of 500 fish. No regular escapement estimates have been made recently, but occasional checks indicate that Antelope Creek currently has no more than a remnant spring run which probably is not self-sustaining; for example, two to three individuals at most have been seen through much of the 1990s. However, in 1998 about 150 spring-run fish were observed in Antelope Creek (DFG 1998). The fall run in Antelope Creek generally has been small. During 1953–1984, the fall run numbered 50 to 4,000 fish annually (average: about 470 fish) (Reynolds and others 1993; DFG unpublished data.). Population estimates have not been made in more recent years due to the scarcity of the salmon, and the fall run may be extirpated (Reynolds and others 1993).

Battle Creek (Tehama County). Both spring and fall runs of salmon originally occurred in Battle Creek, and there is evidence that a winter-run was also present. The California Fish Commission noted that, "Salmon enter this stream in large numbers during the months of October and November" (CFC 1896, p 23) and averred, "…there being almost no limit to the number of eggs which can be secured there with proper apparatus" (CFC 1896, p 24). Curiously, Stone (1897, p 218) stated:

> *This Battle Creek is the most extraordinary and prolific place for collecting salmon eggs yet known, though the eggs are limited to the fall run of salmon, as none worth mentioning of the summer run [the current spring run] of fish ascend Battle Creek. The first salmon make their appearance early in the fall, and before November and during that month they are found in almost incredible numbers in the wide lagoon extending about 2 1/2 miles up the creek from its mouth.*

It appears that even at that time fishery biologists had not yet fully explored the upper reaches of the stream where the spring-run salmon over-summered. In April 1902, the US Fish Commission emplaced racks in Battle Creek and observed large numbers of salmon during "late spring and early summer," thus proving the existence of "a large summer run of fish in the creek" (USFC 1904, p 73). A US Fish Commission Report also noted a "site suitable for a branch hatchery for the summer run of salmon …on Battle Creek, opposite the mouth of Baldwin Creek" (Smith 1905, p 81) Rutter (1904) then reported capturing in Battle Creek (during October 1898 and early October 1900) recently emerged fry (1.5 inches long) that could only have been of the winter run. In 1939, salmon were observed spawning in Battle Creek during May and June (Needham and others 1941), the typical winter-run spawning time (Slater 1963; Fisher 1994). The North Fork of Battle Creek contains a series of springs near the town of Manton which would have provided coldwater flows required for the summertime spawning and rearing of the winter run, despite

Slater's (1963, p 4) assertion that the winter run would not normally spawn successfully in Battle Creek or in Deer and Mill creeks because of high (>70 °F) summer water temperatures. However, the winter run was largely eliminated after hydroelectric development of the creek in 1910–1911, which cut off the spawning habitat. The formerly large spring run also was significantly reduced by the loss of habitat at that time and it may have been completely eliminated for a period thereafter, as indicated in DFG (1990).

Surveys conducted before the construction of Shasta Dam indicated that the reaches above Coleman National Fish Hatchery could support >1,800 spawning pairs of salmon (Reynolds and others 1993). The North Fork of Battle Creek, especially Eagle Canyon, contains deep, cold pools—ideal summer holding habitat for spring-run salmon (Reynolds and others 1993), and significant areas of spawning gravel have been determined to exist from Coleman Powerhouse on the mainstem up to above the Volta Powerhouse (extending to Macumber Dam) on the North Fork and on the South Fork between South Powerhouse and South Diversion Dam (Reynolds and others 1993). It is likely that much of those areas had been previously used by salmon before blockage of migration and the alteration of the streamflow regime. In the North Fork, salmon have been observed as far as Volta Powerhouse above Manton (T. Healey, personal communication, see "Notes"), but the upper distributional limit would have been a waterfall three miles farther upstream (H. Rectenwald, personal communication, see "Notes"). Hanson and others (1940) reported the presence of a waterfall on the South Fork near the Highway 36 crossing, which evidently was a natural barrier to salmon.

Clark (1929) noted that Battle Creek had a fall run and a "small" spring run. As of 1928, there was a US Bureau of Fisheries egg-collecting station and hatchery (Battle Creek Hatchery) located about 1.5 mi above the creek mouth. The station, first established in September 1895 (CFC 1896), collected eggs from the fall run but allowed the spring run to pass upstream (Hanson and others 1940). Spawning by spring-run fish occurred in the five-mile stretch between the egg station and the upstream dams (Clark 1929). Clark (1929) reported the presence of three power dams and plants: the Coleman plant six miles above the mouth, with an operative fish ladder and screens on the diversion canals; a second dam, 30 ft high and equipped with "a good fish ladder and ditch screens," on the South Fork about 20 mi above the Coleman plant; and the Volta plant on the North Fork. Clark stated that despite the presence of fish ladders, the water was often so low that the dams were impassable to fish.

Presently, natural spawning of salmon in Battle Creek is by far heavily concentrated in the stretch between the creek mouth and the Coleman National Fish Hatchery weir six miles upstream, and instream spawning has been said to be "still significant" (Reynolds and others 1993). The predominant fall-run salmon are blocked at the hatchery weir, and whatever natural spawning that formerly occurred upstream has been largely eliminated by that blockage and low flows due to hydropower operations of Pacific Gas and Electric Company (PG&E) (Reynolds and others 1993). It is not known how much farther fall-run salmon ascended Battle Creek, and we conservatively assume that they were constrained to the vicinity of the hatchery weir. During recent years when streamflows were adequate, small numbers of spring-run and winter-run salmon have been able to ascend past the weir and spawn in upstream reaches (T. Healey, personal communication, see "Notes"). Spring-run and a few winter-run salmon were observed in the Eagle Canyon area of the North Fork Battle Creek during summer 1995 (T. Healey, personal communication, see "Notes"). As of 1993, there were four unscreened hydropower diversions on the North Fork, three unscreened hydropower diversions on the South Fork, two storage reservoirs and a system of canals and forebays in the drainage, as well as two "significant" agricultural diversions (one unscreened) on the main stem (Reynolds and others 1993). Current negotiations to reconfigure the PG&E hydropower system on Battle Creek, including dismantling several dams, will considerably improve access for salmon to the upper reaches (Sacramento Bee, 4 May 1999).

The records for egg takes (for the fall run) at the US Bureau of Fisheries egg-collecting station indicated peak spawner abundances generally occurring in the period 1896–1907, and the egg takes remained fairly high until 1916, after which there seemed to be an overall decline until 1924 (Clark 1929). Translating the egg takes to numbers of females (assuming 5,000 eggs per female, after Clark [1929]) gives a peak of 10,000 females for 1904 and a low of 200 females for 1924. According to Clark (1929, p 41), the spring run, which was allowed to spawn naturally in the creek, amounted to "almost nothing," and only six or seven spring-run salmon were seen in 1928. The old Battle Creek Hatchery, which took fall-run spawners from the creek, continued to operate through 1945 (Fry 1961). The larger Coleman National Fish Hatchery began operations in 1943 and took small numbers (<1,200) of spring-run fish from Battle Creek in 1943-1946, but during that period Coleman National Fish Hatchery received most of its fish (both spring-run and fall-run) from fish salvage efforts at Keswick Dam and from the Balls Ferry Racks on the mainstem Sacramento River (Moffett 1949, Fry 1961). In 1946, Coleman National Fish Hatchery started taking fall-run fish locally from Battle Creek (Moffett 1949; Fry 1961). (See also Black, this volume, for a thorough review of the history of Battle Creek hatchery operations.)

During the period 1946–1956, the spring run numbered about 2,000 fish in most years (Fry 1961; Campbell and Moyle 1990). By the late 1980s, the spring run in Battle Creek was either extirpated or close to it (Campbell and Moyle 1990). Small numbers of spring-run fish have returned in recent years, ranging from 40 to 100 fish (average: 70) in 1995–1997 (DFG 1998). The escapement for

1998 was about 50 to 100 fish (USFWS 1998 unpublished report). Historical abundance data for the winter run in Battle Creek are almost nonexistent, although Slater (1963) reported that on 22 May 1962, 457 winter-run fish were counted and a population size of 2,687 fish was estimated for the two-mile stretch below Coleman National Fish Hatchery. Small numbers of winter-run fish have been observed in recent years, with about 100 spawners estimated for 1998 (USFWS 1998 unpublished report). Numbers of fall-run spawners in Battle Creek were about 3,000 to 30,000 (average: 15,000) during 1946–1959 (Fry 1961). Annual fall-run escapements during the 1980s and 1990s have ranged between 12,700 and 83,900 fish, with averages of 29,600 (in the 1980s) and 46,400 fish (1990–1997) (DFG unpublished data). Hatchery spawners composed 20% to 73% (average: 51%) of the annual runs during 1980–1997 (DFG unpublished data).

The Coleman National Fish Hatchery also has maintained a late-fall run, but returns of adults have not been consistently strong enough to sustain the run and the hatchery has relied on obtaining late-fall-run spawners from the Keswick fish trap below Keswick Dam on the Sacramento River. During 1995–1997, however, numbers of the late-fall run returning to Coleman National Fish Hatchery were 1,300 to 4,600 fish (average: 3,000) (USFWS 1998 unpublished report).

Mainstem Sacramento River and Upper (Little) Sacramento River (Solano, Yolo, Sacramento, Sutter, Colusa, Glenn, Butte, Tehama, and Shasta counties). The Sacramento River, regarded by Clark (1929, p 34) as "the most important salmon stream in the state" and by Fry (1961, p 59) as "the largest and best salmon stream of the Central Valley," has the sole distinction among the salmon-producing rivers of western North America of supporting four runs of chinook salmon—spring, fall, late-fall and winter runs.

One of the earliest references to salmon of the Sacramento River was by the fur trapper Colonel J. J. Warner who traveled the Central Valley in 1832: "The banks of the Sacramento river, in its whole course through its valley, were studded with Indian villages, the houses of which, in the spring, during the daytime, were red with the salmon the aborigines were curing" (Chamberlain and Wells 1879, p 12; Gilbert 1879, p 12; Elliott 1882, p 161). John Work, of the Hudson's Bay Company, reported that his party of fur trappers, while moving down the Sacramento Valley (near Putah Creek) on 16 March 1833, obtained "some fine[?] Salmon" (spring-run, or perhaps winter-run) from the native people (Maloney 1943, p 339). Lieutenant Charles Wilkes, reporting on the United States Exploring Expedition of 1838–1842, later described "a substantially-built fish-weir"—undoubtedly for catching salmon (see Curtis 1924b)—which was observed on 31 August 1841 near the present town of Colusa on the lower mainstem Sacramento River (Wilkes 1845, p 187). Another party of the US Exploring Expedition encountered Native American people (probably

Wintu) farther north in the Sacramento Valley and traded with them for salmon—caught by the natives by means of weirs and long, forked fish spears (Dillon 1975). Perhaps the last published record of the intact native fishery on the Sacramento Valley floor was that of a forty-niner who observed in 1849, near "a very large settlement of Indians" on the lower Sacramento River, "a scrap of beach, on which a vast number of miserable spent salmon of enormous size, split, were hung along on poles to dry in the sun" (Kelly 1950, p 73). Unpublished notes by the pioneer H.C. Bailey also alluded to "Sacramento Valley Indians" taking salmon in the springtime before 1853: "During the salmon run (March and April) they caught them in abundance and some times sturgeon. We could buy a 25 pound salmon for a quart of flour. They were the finest fish I ever tasted." (Latta 1930–1931).

Salmon fishing as a commercial enterprise on the Sacramento River had been initiated by John A. Sutter near his New Helvetia settlement (present-day Sacramento) by about 1842–1843, if not earlier (Wright 1880; Van Sicklen 1945; Bennyhoff 1977). Another fishing entrepreneur was a Mr. Schwartz, whose fishing operation was located six miles downstream of New Helvetia. Concerning Schwartz's fishery, the pioneer Edwin Bryant noted in his journal for 26 October 1846:

> *Mr. Schwartz provided us with a breakfast of fried salmon and some fresh milk…. Near the house was a shed containing some forty or fifty barrels of pickled salmon… The salmon are taken with seines dragged across the channel of the river by Indians in canoes. On the bank of the river the Indians were eating their breakfast, which consisted of a large fresh salmon, roasted in the ashes or embers, and a kettle of atóle, made of acorn-meal. The salmon was four or five feet in length, and when taken out of the fire and cut open, presented a most tempting appearance (Bryant 1849, p 345).*

The date of the narrative indicates that the salmon were of the fall run. The lower mainstem Sacramento River later became the center of the bustling commercial salmon fishery carried out by immigrant European and Euro-American fishers drawn to California during the Gold Rush and following period (Clark 1929; Skinner 1962). As noted by a gold-miner, "In 1851…the Sacramento river was full of splendid salmon, equal in flavour to those of the Scottish rivers, though in appearance note quite such a highly finished fish, being rather clumsy about the tail" (Borthwick 1857, p 48).

Unquestionably the spring chinook salmon run, and probably lesser numbers of the winter run, occurred in the Upper (Little) Sacramento River (also called the Destruction River in early accounts). In 1841, a detachment of the US Exploring Expedition reconnoitered the Siskiyou Trail from Oregon to the Sacramento Valley. Traveling southward along the Upper Sacramento River, the party passed downstream of "Soda Springs" and Castle Crags and observed evidence of the spring run during the latter part of the spawning period (early October) (Poesch 1961; Dillon 1975). Titian Ramsey Peale, a member of that party, recorded in his journal for 6 October 1841:

> *Passed several old Indian camps, at one there were several new graves, over which were bundles of provisions and near by on a stump a bundle of Salmon… One of our hunters saw several more ["Indians"] on the river below our camp fishing for Salmon, which must have been numerous earlier in the season, as quantities of dead ones now lay along the rocky Shores. We saw the remains of fences and weirs for catching them (Poesch 1961, p 194).*

A later historical account of Shasta County noted that the sudden influx of gold miners into the Upper Sacramento River valley in the spring of 1855 drove the native people from their usual haunts (near Castle Crags) and prevented them from obtaining "the salmon they were wont to spear," thus precipitating hostilities (Southern 1942, p 66). Salmon normally present at that time of year would have been either the winter or spring runs (or both). Curtis (1924b, p 87) stated that the Wintu people on the Upper Sacramento River caught (spring-run) salmon in midsummer, "with spears fifteen to twenty feet long, in deep quiet pools"; "In the autumn salmon were speared while spawning in the riffles, and in spring spearing was carried on at night by torchlight…" Furthermore, the winter salmon run was said to have spawned in the headwaters near Mt. Shasta (Stone 1874). Stone (1879, p 234) noted that "in July the summer run [currently termed winter run] are spawning at the headwaters of the McCloud and Little Sacramento; in August and September [the spring run spawn] farther down these rivers…" Scofield (1900, p 68) also reported: "In Hazel Creek, a tributary of the Sacramento near Sims, I found, on November 6, 1897, two sizes of young salmon…. Of the smaller size [average length 2.87 inches] only four were taken….they must have hatched from the egg early in August, and allowing three months for hatching, they were spawned early in May." The timing of those smaller fish is indicative of the winter run. The late-fall run, with its requirement of cool summer flows for fry and juvenile rearing, also possibly entered at least the lower reaches of the Upper Sacramento where such flows existed.

Salmon at one time ascended the Upper Sacramento River in large numbers at least to the falls near the town of Sims, about 31 mi upstream of the site of Shasta Dam. Large numbers of juvenile salmon were observed in the vicinity of Sims during the summer of 1898 by Rutter (1904, p 105), who estimated a probable density of "as many as 10,000 young salmon to the mile in the Upper Sacramento…or between a half and three quarters of a million in all the headwaters of that stream" (see also Rutter 1902). Juveniles were also captured in Hazel Creek, "a favorite spawning stream both for salmon and trout," which joins the Sacramento River near Sims (Rutter 1904). Clark (1929) stated that the falls at Sims stopped most of the salmon, although "a few fish" were able to surmount them. However, Stone (1874, p 180) reported: "Last July [1871] hundreds of salmon, averaging 15 pounds apiece, were caught in the Little Sacramento with a hook and line, near Frye's Hotel, at Upper Soda Springs," upriver of Sims and just below the town of Dunsmuir. Furthermore, the native Wintu people were said to have fished for salmon (during July) above Sims in the reach from Castle Crag depot (five miles below Dunsmuir) to Shasta Retreat (about one mile above Dunsmuir) (Voegelin 1942). According to one Wintu informant, the salmon fishing activities involved "200 to 300 people" and lasted two to three weeks (Voegelin 1942), indicating that substantial numbers of salmon were able to ascend the falls past Sims. Once over the falls, salmon would have had clear access up to the present site of Mt. Shasta City, and it appears that they were able to ascend almost the entire length of the river to the site of present-day Box Canyon Dam and Lake Siskiyou (also called Box Canyon Reservoir), where several spring-fed streams enter the Upper Sacramento River from the east (Mt. Shasta).

Rutter (1904, p 96) reported netting "nearly 500" juvenile salmon in a single seine haul from a pool at the head of Box Canyon, near Sisson in August 1897, and he stated that it was not uncommon "to catch over a hundred at a time in many of the pools of the headwaters." It is possible that the large numbers of young salmon observed by Rutter were to some extent due to large-scale plantings of salmon fry into the Upper Sacramento from Sisson (Mt. Shasta) Hatchery, a practice started in 1888 when that hatchery was built (CFC 1890; USFC 1892; Shebley 1922), and some numbers of juvenile salmon from Baird egg-collecting station on the McCloud River were transferred to the Upper Sacramento River as early as 1880 and 1881 (Stone 1883b; Green 1887). However, salmon evidently were abundant enough in the remote reaches of the Upper Sacramento River before any hatchery plantings to gain notice in the first report of the California Fish Commission (CFC 1871, p 44): "Salmon are caught by the Indians in the small streams that empty into the Sacramento from the sides of Mount Shasta, at an elevation of more than four thousand feet above the level of the sea; to reach which they must have passed through at least fifty miles of almost continuous rapids." The US Fish Commission (USFC 1876a, p xxviii) likewise stated that the salmon "traverse the Sacramento Valley to the headwaters of the Little Sacramento and the McCloud Rivers, about four hundred miles…" A similar quote was attributed to Dr. David Starr Jordan: "They are known to ascend the Sacramento as far as the base of Mount Shasta, or to its extreme headwaters—about four hundred miles" (CFC 1890, p 59). Jordan's statement (probably made before 1890) antedates any possible results (specifically, returning adults) from regular plantings of young salmon into the Upper Sacramento River from Sisson Hatchery in 1888 and later—given the minimum generation time of three years for chinook salmon.

Stone (1874, p 176) stated that salmon ascended the Upper Sacramento River "in great numbers, and make the clear waters of this stream the principal spawning-ground of the salmon of the Great Sacramento River, with one exception"—the McCloud River. Clark (1929) described the Upper Sacramento River as an "ideal spawning stream" with "wonderful spawning beds" along its entire length; "the salmon were extremely abundant" before construction of the Southern Pacific Railroad through the Sacramento Canyon, but "the run was almost destroyed" by construction work in 1883–1884. Erosion of rocks and sediments into the river blocked and muddied the water, and the railroad workers reportedly blasted areas holding the salmon to catch the fish (Clark 1929). As noted by Shebley (1922, p 64), many fish were used to feed the 9,000 laborers camped along the Sacramento River, but "there was wanton destruction in the way they were killed." Again in 1886, blasting for the railroad along the Upper Sacramento River prevented the salmon from entering that stream very far; "quite a number" attempted the ascent but turned back after a few days and entered the McCloud River instead (Green 1887). Furthermore, a mining tunnel, located just above the confluence with the Pit River, essentially prevented the migration of the fall run when flows were low in August and September during the 1880s. The tunnel's diversion of water from a short stretch of the Upper Sacramento River evidently accounted for the greatly depressed fall run "for a long while past," until the tunnel was closed in 1890 (CFC 1890). In the only quantitative assessment of salmon abundance for this stream, Hanson and others (1940) estimated that the Upper Sacramento River in 1938 had a "potential spawning capacity" of 14,303 redds. This should be viewed as a minimal estimate because the spawning capacity estimates given by Hanson and others (1940) for other streams generally are lower than the run sizes that subsequently have been observed for those streams (F. W. Fisher unpublished data).

On the mainstem Sacramento River on the valley floor, the Anderson-Cottonwood Irrigation District (ACID) diversion dam at Redding was an almost complete barrier to salmon during the irrigation season (April through October) for about ten years (1917–1927) (CFGC 1927; Hanson and others 1940). This blockage occurred despite an initial "understanding" during the construction of the dam in 1916–1917 between the California Fish and Game Commission and the Irrigation District's chief engineer "that the dam was not to be raised above a certain level" and "would allow all the salmon to pass the dam and proceed on their way up the McCloud and Pit rivers" (CFGC 1921a, p 20). The ACID authorities contended that an open section of the dam was adequate to allow the passage of salmon (CFGC 1921c), although McGregor (1922, p 149) noted that "With no little humor, they speak of it as a fishway." It was subsequently determined that salmon did not use that spillway and that very few fish surmounted the dam at any point along it (McGregor 1922). Further testimony regarding the ineffectiveness of the original "fishway" was given by upstream residents who reported that salmon had become "extremely scarce since the erection of the dam"; as one pioneer fisherman of the area noted, "Why would we journey miles down the river from our homes to fish at the dam if we could get fish up where we belong?" (McGregor 1922, p 153). Clark (1929, p 35) stated that the dam "nearly exterminated the salmon run at that point of the river." Clark presumably was referring to the winter and spring runs because the dam routinely was dismantled during October; the fall run for the most part had clear access up the river and, therefore, was not significantly affected. After installation of a new fish ladder on the dam, it was reported that "quite a number of salmon" passed over, "but nothing to compare with conditions before the dam was constructed" (Clark 1929, p 35). The ACID dam has continued to pose fish passage problems (Reynolds and others 1993).

The Glenn-Colusa Irrigation District (GCID) diversion facility has been another significant obstacle to salmon, but mainly for downstream-migrating juveniles which are destroyed in large numbers by the pumping operations (Phillips 1931; Reynolds and others 1993). However, by far the greatest factor to affect the salmon runs of the Sacramento River in recent times has been Shasta Dam (completed in 1943). With its closure in November 1942, Shasta Dam barred the salmon entirely from their former spawning grounds in the Upper Sacramento, McCloud and Pit River drainages (DFG 1944), thus removing those areas from salmon production. In addition, about 13 mi of salmon habitat in the mainstem Sacramento River above Shasta and Keswick dams up to the confluence of the Upper Sacramento and Pit rivers were no longer accessible. Operation of the Coleman National Fish Hatchery in Battle Creek was intended to compensate for the habitat loss. Presently, the upstream distribution of salmon in the Sacramento River is delimited by Keswick Dam, a flow-regulating dam nine miles below Shasta Dam. Fall-run salmon spawn in the mainstem Sacramento River where spawning gravels occur from Keswick Dam downstream to below the town of Tehama (Clark 1929; E. R. Gerstung, personal observation)—a distance of about 67 miles. Fall-run spawning escapements in the mainstem Sacramento River averaged 217,100 fish annually during 1952–1959; 136,600 fish in the 1960s; 77,300 in the 1970s; 72,200 in the 1980s; and 48,000 fish from 1990 to 1997 (DFG unpublished data).

McCloud River (Shasta County). The McCloud River, once denoted by the California Fish Commission as "the best salmon-breeding river in the world" (CFC 1890, p 33), originally supported both spring and fall runs of salmon, as well as the winter run (Stone 1874; USFC 1900; Hanson and others 1940; Needham and others 1941). According to native Wintu informants, the spring run was "heavier" than the fall run in both the McCloud and Sacramento rivers, and the average size was "approximately twenty pounds," with occasional fish weighing as much as 65 and 70 pounds (Du Bois 1935, p 15). The winter run appears to have been the least abundant of the three runs, with small numbers of spawners reported by various workers (Stone 1874; Scofield 1900; USFC 1900, 1904; Rutter 1904, 1907; Hanson and others 1940). Yet, Stone (1876, p 446) reported that during the egg-collecting season (August and September for the spring run) in 1874 "Young salmon a few inches long were very plentiful"—those evidently being winter-run juveniles. Scofield (1900, p 69) noted that salmon had been observed "spawning in considerable numbers in the [McCloud] river above Baird early in May," again corresponding to the winter run. The observation of one or two salmon spawning in the McCloud River near the hatchery around 20–24 April 1902 (USFC 1904; Rutter 1907) is indicative of early-spawning winter-run fish or perhaps late spawners of the late-fall run (based on life stage timing given in Vogel and Marine 1991; USFWS 1995). In June 1898, two size groups of young salmon were observed in the McCloud River "in large numbers" (USFC 1899)—one group corresponding in size (three to four inches) to fall-run juveniles and a second group of smaller fish (1.5 inches long) of a size indicative of newly emerged late-fall-run progeny.

Salmon ascended the McCloud River up to the impassable Lower Falls (20 ft high), about six miles above present Lake McCloud (Rutter 1904; Wales 1939; Hanson and others 1940). Hanson and others (1940) reported observations of salmon (evidently winter-run) spawning during May and June, 1939, in the McCloud River between Big Springs and Lower Falls (about 1.5 miles). However, the reach from Big Springs up to Lower Falls was ecologically less suitable than areas downstream for salmon because of relatively low streamflows. Big Springs (rm 49) is the location of two large springs which in the past contributed well over half the minimum streamflow of the McCloud River, and Big Springs thus was somewhat of an "ecological barrier" to salmon (Wales 1939). Ethnographic information similarly indicates that salmon did not ascend in significant numbers past a bend in the river at rm 41, one mile below Lake McCloud; according to a Native American informant, the "salmon got no further, just got there" (Guilford-Kardell and Dotta 1980, p 76). That point was the location of a Wintu village named *Nurumwitipom* ("salmon come back") or *Nurunwitititeke* ("falls back where the salmon turn back") (Guilford-Kardell and Dotta 1980). The native people, primarily interested in harvesting the salmon in quantity, evidently paid little heed to the presumably small numbers of salmon that ascended past the main fishing sites into the less suitable upper reaches. A few salmon reportedly were observed in Squaw Valley Creek, the largest tributary to the McCloud, in September 1938, and they probably also entered the lower reaches of several other tributary streams (for example, Star City, Claiborne, and Caluchi creeks) (Wales 1939).

Clark (1929, p 43) described the McCloud as "a good spawning stream" from its mouth to the falls near its source. As of 1928 there were no dams or other artificial obstructions on the river except for the racks of the US Fish Commission egg station (Clark 1929). Hanson and others (1940, p 47) estimated that the McCloud River potentially could support 25,097 redds, and they reported salmon spawning in 1939 near the mouth, at Big Springs, and at "several other places below the Lower Falls." They also estimated that the lower five miles of Squaw Valley Creek, a tributary entering the McCloud River about 29 mi upstream of the mouth, could support approximately 830 redds (Hanson and others 1940).

After its establishment on the McCloud River in 1872 by the noted fish culturist Livingston Stone, the US Fish Commission egg-collecting station (Baird Station) soon was taking the spawn from almost all of the returning spring-run salmon (Clark 1929). During the early years of its operation (1872–1883), most of the eggs collected were shipped out of California for the main purpose of establishing runs in East Coast rivers, which in almost all attempts were failures (USFC 1892; Clark 1929; Towle 1987). However, production of salmon in the McCloud itself could not be sustained and in 1884 the scarcity of salmon led to the temporary closure of the egg station (Stone 1885a, 1897; Clark 1929).

Clark (1929) presented a tabulation of egg takes by the Baird Station in the years 1872-1924, which illustrated the decline in salmon abundance during the later years compared with earlier years. Aside from the first year operation (1872) in which 50,000 eggs were collected, the egg takes ranged from about 1 million to over 12 million eggs during the period 1873–1883, the first phase of operation before its temporary closure (Clark 1929). Eggs were taken from spring-run fish in that early period, but railroad construction along the Sacramento River during 1883 and 1884 blocked the salmon runs (Stone 1885b), and the paucity of the spring run forced the cessation of egg-collecting operations during 1884–1887 (Stone 1885a). In response to the depleted state of the Sacramento River salmon stocks, Baird Station was reactivated in 1888 for the expressed purpose of "aiding in the maintenance of the salmon fisheries of the Sacramento River" (USFC 1892, p 35). The egg station continued activities until 1935 (Hedgpeth 1941), but taking eggs during some years from the fall run to supplement the temporarily depleted spring run (see CFC 1890, 1907). During that later period of productive operation (mainly 1888–1924), between 1 million and 29.9 million eggs were taken annually, and the peak production (in 1903) was from about 5,600 females (Clark 1929). After 1907, the egg takes showed a fairly steady decline down to about 1 million to 1.5 million eggs per year (Clark 1929). By 1924 there were "only about 260 fish at the racks" which produced 1.2 million eggs (Clark 1929, p 43), and in 1935 only 5,200 eggs were collected, "probably from a single female" (Hedgpeth 1941, p 145).

Stone (1876, p 446) had estimated that in 1874, the first year in which a weir was set across the McCloud River for capturing the salmon, "Tens of thousands, not to say hundreds of thousands, which would perhaps be nearer the truth" passed upstream before the weir was finished, and "thousands more" were blocked after its completion. Stone (1897, p 213) noted that in 1878, there was "an immense gathering of salmon in the McCloud." He averred:

> *I have never seen anything like it anywhere, not even on the tributaries of the Columbia. On the afternoon of the 15th of August there was a space in the river below the rack about 50 feet wide and 80 feet long, where, if a person could have balanced himself, he could actually have walked anywhere on the backs of the salmon, they were so thick" (Stone 1880, p 749).*

Stone (1880, p 763) also stated that during the 40 days before 5 October 1878, the egg-collecting crew "caught and examined, one by one, nearly 200,000 salmon"—all of which were of the spring run, as eggs were taken from only that run (in other words, "the first or August run") at Baird Station during the period before 1888 (CFC 1890, p 17; USFC 1892, p xxxv). After the hiatus in the mid-1880s, the salmon (both spring and fall runs) returned in large numbers to the McCloud River in the 1890s and early 1900s—according to elder Wintu informants, "So thick on the McCloud it looked like you could walk across them" (Guilford-Kardell and Dotta 1980, p 82). The runs again declined, and in 1922 there was "no run of salmon whatever in the McCloud River," due at least partly to abnormally low stream flows (Leach 1923). Clark (1929, p 43) reported spring and fall salmon runs still present in the McCloud River as of 1928, with the fall run "not as heavy as the spring," but by that time both runs were greatly depleted.

Excessive fishing pressure by commercial gillnetters in the Sacramento River undoubtedly depressed the spawning runs into the McCloud River; for example, illegal fishing in the 1877 season reduced the "unusually large number" of salmon running in the Sacramento River so completely that only "extremely small numbers" reached the McCloud River (Stone 1879, p 799). In the early 1880s, the fishermen reportedly had the Sacramento River completely blocked with their gill nets (CFC 1884; McEvoy 1986). The McCloud River runs were also significantly affected by downstream obstructions in the Sacramento River—first by the Anderson-Cottonwood Dam in the period 1917–1927 (Leach 1922; CFGC 1923, 1927; Clark 1929) and ultimately by Shasta Dam, starting in 1942–1943 (Slater 1963; Reynolds and others 1993). Shasta Dam, about 560 ft high and then the second largest dam in the world, completely blocked access upriver and thereby extirpated all runs of salmon and other anadromous fishes into the McCloud River and other upper Sacramento tributaries (Needham and others 1941).

Pit River (Shasta County). The Pit River formerly was recognized as "a noted salmon stream" (CFC 1886). The Pit River system covers an extensive area, according to Clark (1929) comprising "at least half of the main Sacramento River." The Achumawi people, historically referred to as "Pit River Indians," are reported to have controlled about 50 mi of salmon streams in their territory (Olmsted and Stewart 1978), primarily the mainstem Pit River. They harvested "vast quantities of suckers" by diverting streams as well as salmon "which were taken in great numbers by net and spear" and dried for winter consumption (Curtis 1924a, p 141). The Achumawi fished for a variety of other fishes, including steelhead: "The weir known as *tatsítschi* was set in the main stream for catching *allís* (steelhead trout) on their return to the sea in the autumn" (Curtis 1924a, p 137). The salmon ascended in large numbers at least to Pit River Falls (rm 75), but the falls evidently were not a complete barrier. Voegelin's (1942, p 175) ethnographic account states that "Salmon ascend Pit River as far as falls at site of Pit 1 power house, in Achomawi area." The Pit 1 powerhouse was located at the mouth of Fall River (Clark 1929), a major tributary of the Pit River about four miles above Pit River Falls.

The presence of spring-run salmon in Hat Creek, a tributary of the Pit River below Pit River Falls, was noted by Rutter (1902, 1904), and they were also reported to have ascended the Pit River in the spring of 1926 (DFG 1929). The occurrence of a winter run in the Pit River drainage, spawning in "the headwaters," was indicated by Stone (1874). One ethnographic account stated that among the Atsugewi people ("Hat Creek Indians"), who controlled most of the Hat Creek drainage, "salmon were obtained only by invitation of the western Achumawi on Pit River" (Garth 1978, p 242) to where the Atsugewi made salmon-fishing expeditions in the fall, giving the Achumawi part of the catch as payment to trespass (Garth 1953). Garth's (1953, p 136) survey of Atsugewi informants indicated that salmon were "rarely seen in Hat Creek," and Voegelin (1942, p 175), drawing from an interview in 1936 with a 79-year-old Atsugewi informant, recorded: "Not many salmon in Hat Creek; occasionally a good run." However, Kniffen's (1928, p 315) earlier ethnographic summary, in describing the Hat Creek Valley, stated that "Formerly the streams contained an abundance of salmon, pike, trout, and suckers." Garth (1953, p 136) reported that a waterfall located "about a mile below Caasel [Cassel] on Rising River," was a favorite fishing place of the Atsugewi people, who called it "*ani*" [salmon] "*wecéici*" [jump up]. This reference is evidently to a stretch of Hat Creek which contains cascades and was sometimes called "Rising River"; that stretch is located just downstream of the mouth of the true Rising River. The latter is a wide, slow-flowing tributary to Hat Creek which lacks salmon habitat (E. R. Gerstung, personal observation). Hat Creek was said to have been "where salmon formerly abounded by the thousands during the spawning season," and the California Fish Commission established a salmon hatchery there in 1885 (CFGC 1914, p 63). However, so few salmon ascended to that point in 1886 and 1887 that the hatchery was abandoned in 1888 (CFC 1888; CFGC 1914; Shebley 1922). Rutter (1908, p 110) described Hat Creek as "a salmon stream of some importance, but it has a number of rapids that make its ascent difficult." Available spawning habitat and suitable conditions also occur in Kosk and Burney creeks, two other Pit River tributaries where it is likely that winter-run salmon spawned. The Achumawi people owned fish weirs situated at Burney Falls, where they evidently caught salmon (Garth 1953). Burney Falls, a 129-foot double waterfall located about one mile above the mouth of Burney Creek, was an obvious historical barrier to salmon.

Rutter (1904), in reference to the spring run, stated that "some of the earlier ones even pass Pit River Falls and ascend Fall River to its source." Those "earlier ones" he referred to probably comprised some number of winter-run fish. Rutter also stated that "they are not found in Pit River above the mouth of Fall River," indicating that the salmon runs entered the cool and partially spring-fed Fall River for spawning—"mainly in August"— rather than continuing up the relatively warm Pit River. Garth's (1953) ethnographic account similarly reported that salmon seldom ascended the Pit River above Fall River Mills, located at the mouth of Fall River, and Kroeber (1925, p 309) also noted, "Salmon hardly ascended beyond Fall River…"

Before Rutter's (1904) report, the California Fish Commission (1880, p 13) wrote of Pit River Falls, located below the Fall River confluence: "The salmon in vast numbers reach the foot of this fall, and are now unable to pass." The Commission arranged to have a fishway excavated out of the rock formation on the south side of Pit River Falls, in 1881, to enable the salmon to reach suitable spawning gravels above the falls (Throckmorton 1882). A new fishway was later constructed in 1902 (CFC 1904). Pit River Falls (65 ft high, according to Rutter) was "thought by many to rival in beauty any to be seen in the Yosemite Valley" (Rutter 1908, p 110), and which Rutter, in his 1904 paper, also stated had been impassable for salmon before the modification. Yet Rutter (1908, p 110) later noted that "each side is broken by ledges, so that it is possible in high water for fish to pass"— perhaps suggesting that salmon also could have surmounted the falls on the side opposite where the fishway was constructed. In fact, Powers (1874, p 413 and 1877, p 269), in discussing the first salmon ritual (probably for the spring run) of the Achumawi people on the Pit River, wrote: "After the vast crystal volume of Fall River enters and overcomes the swampiness of the snaky Pit, then salmon are caught, the Indians say, though the whites assert that they do not ascend above a certain tremendous cataract which is said to exist on the lower river." That "tremendous cataract" undoubtedly was Pit River Falls and which may not have posed a complete barrier to the salmon, if the above statement is taken literally. Powers had made his observations on the Achumawi and other native groups during the early 1870s (primarily in the summers of 1870 and 1871; Heizer 1976), well before any attempt to modify Pit River Falls. However, Powers (1874, p 413) also stated in regard to salmon that, "they do not ascend the Pit to the mouth of Fall River," and it is puzzling why salmon reputedly would not have ascended farther upstream to the Fall River once they had passed Pit River Falls. Overall, it seems likely that spring-run and perhaps winter-run salmon, if only in limited numbers, originally surmounted Pit River Falls and entered the Fall River some distance up its length—probably nine miles up to the source springs near Dana. Kniffen (1928, p 312) correspondingly noted that the Fall River delimited the easternmost area where salmon were an important component of the native people's food economy in that region, and "Fall River also marked the upper limit of the salmon run." Likewise, Davis (1974, p 19) stated that the Achomawi and Atsugewi met "annually in the autumn in Fall River Valley when the winter supply of salmon was being laid in."

The historical abundance of salmon in the Fall River cannot be clearly determined. Young salmon were reportedly "common" in the Fall River in August 1898 (Rutter 1902). After construction of the new fishway in 1902, salmon were said to have passed over Pit River Falls "in considerable numbers" (Rutter 1908, p 110). It was reported that within two weeks of the opening of the new fishway (on 1 November 1902), "large numbers of salmon were found in Fall River…which was the first time they were seen in any numbers in those waters" (CFC 1904, p 52). Those fish were clearly fall-run salmon, and their newly observed occurrence in the Fall River indicates that the fall run previously had ascended only as far as Pit River Falls which barred their passage.

Clark (1929) stated that the spawning beds extended from the river mouth (where the river joins the McCloud and Little Sacramento rivers) to the Pit 4 dam, and there were suitable beds also in Squaw Creek and two or three smaller creeks. Access up the river was completely cut off by several power projects dams constructed during 1922–1927. Proceeding from the lowest to highest upriver, they were: Pit 4, seven miles below Burney and Burney Falls, 60 feet high and without fish passage facilities; Pit 3, nine miles above Pit 4, impassable to salmon; and Pit 1, near the town of Fall River Mills on the Fall River and also impassable (Clark 1929).

Stone (1874, p 176) stated that the salmon "come up Pit River in great numbers in the spring," but as the weather became warmer in late June or early July the salmon reportedly all "left Pit River for the colder waters of the McCloud." Stone thought it "probable that they ascend[ed] the upper waters of the Pit River also to a limited extent." Clark (1929) later noted both a spring run and a fall run occurring in the Pit River. Comparing with the earlier years of Stone's time, Clark described the salmon population in the Pit River in 1928 as "very small"; he mentioned statements from long-time residents of the river indicating that the Pit River formerly "was one of the best for salmon" but that the salmon had "decreased considerably" (Clark 1929, p 43). Based on observations made in July 1923, Clark estimated that "at the most" 150 to 200 salmon were stopped at the base of Pit 4 dam, and that they probably comprised the entire spring run (Clark 1929). As with the Little Sacramento and McCloud rivers, construction of Shasta Dam eliminated salmon runs into the Pit River drainage.

Cottonwood Creek (Tehama County). Cottonwood Creek, a tributary on the westside upper Sacramento Valley, historically supported both spring and fall runs and, presumably, also a late-fall run. The spring-run fish formerly migrated to the headwaters of the South and Middle forks of Cottonwood Creek—above Maple Gulch on the South Fork (Reynolds and others 1993) and about eight miles into Beegum Creek on the Middle Fork (DFG unpublished data). According to Hanson and others (1940), the North Fork has a two-part falls (15 ft and 10 ft high) that forms a natural barrier about five miles upstream of Ono; below the falls, the stream has only a limited amount of suitable pools and spawning gravel to support salmon.

The past abundance of salmon in Cottonwood Creek reportedly had been "considerable," but by 1928 there was only "a very slight fall run" (Clark 1929, p 43). Clark stated that the salmon spawned near the mouth of the creek because low water flows did not allow them to ascend farther upstream. He reported the presence of an irrigation diversion (which lacked a fishway) 25 mi above the mouth on the South Fork, although salmon rarely reached that point, and several other smaller ditches for irrigation diversions. Holmberg (1972) also cited low streamflows as the primary factor limiting the salmon population in Cottonwood Creek, despite the presence of "excellent spawning grounds."

In recent years before 1993, the fall, late-fall and hybrid fall-spring runs occurred in Cottonwood Creek (Reynolds and others 1993). Annual fall-run escapements ranged between "a few hundred" to >8,000 fish, averaging 1,000 to 1,500 (Reynolds and others 1993), and the latest escapements were about 700 fish in 1991 and 1,600 fish in 1992 (Kano 1998a, 1998b). The late-fall run numbered <500 fish, spawning in the mainstem and the lower reaches of the North, Middle, and South forks (Reynolds and others 1993). The spring run is believed to have averaged about 500 fish historically (Reynolds and others 1993), but there are no recent escapement estimates except for about 480 fish in 1998 (DFG 1998 unpublished data). Eight adult spring-run salmon were observed by DFG personnel during summer 1995 near the North and South forks (T. Healey, personal communication, see "Notes"). Low spring flows and high water temperatures may prevent the upstream migration of the spring run during some years (Reynolds and others 1993). In most recent years there has been only the bare remnants of a salmon run in Cottonwood Creek.

Stony Creek (Tehama County). Stony Creek is a west side tributary in the Sacramento drainage and formerly supported spring run and fall runs (Clark 1929). Stony Creek was said to have been "a very good salmon stream" before the placement of the irrigations dams (Clark 1929, p 45). Kroeber (1932, p 295), drawing from ethnographic data, stated that "Salmon, for instance, ran up Stony creek through Wintun as far as Salt Pomo territory." The downstream (eastern) border of the Salt Pomo (Northeastern Pomo) tribe has been placed at the confluence of Stony Creek and Little Stony Creek, about five miles below Stonyford (Kroeber 1925, p 224, McLendon and Oswalt 1978), so that point would have been the minimal upstream range of salmon. By 1928, both spring and fall runs were nonexistent due to irrigation diversions that kept the stream dry except during the rainy season (Clark 1929). At that time, there were two permanent dams on the creek: the Orland Project Dam (20 ft high, built about 1914) four miles west of Stonyford, and a dam on Big Stony Creek (90 ft high, "too high for a fish ladder") (Clark 1929). There was also a dam across Stony Creek where an irrigation canal built by the Glenn Colusa Irrigation District (GCID) crossed the creek about three miles upstream of its mouth. This dam was usually washed out in high water, but most of the time it would have been a barrier to salmon, had there been any water in the creek (Clark 1929). Presently there are three storage reservoirs on the creek (Reynolds and others 1993). There is "excellent" spawning gravel within the about 20 miles of stream between the creek mouth and the lowermost dam, Black Butte Dam, which would be a barrier to salmon (Reynolds and others 1993). However, the GCID canal, which crosses Stony Creek downstream of Black Butte Dam, completely bars salmon migration any farther upstream (Reynolds and others 1993; USFWS 1995). This cross-stream barrier is now seldom washed out except when flood control releases are made from Black Butte Reservoir.

Miscellaneous Small Sacramento Valley Tributaries. In addition to Antelope, Cottonwood, and Stony creeks, more than a dozen other small tributaries in the northern Sacramento Valley occasionally supported fall-run salmon spawning stocks during the period 1940–1959 in years of early and heavy rains, and a few of those streams also had spring runs (Fry 1961). In Clear Creek, spring-run salmon were observed in 1949 and 1956 (Azevedo and Parkhurst 1958 unpublished report); they most likely ascended past the present site of Whiskeytown Reservoir to somewhere above the French Gulch area (about 1,400 ft elev.). Clear Creek in some years still supports a substantial fall run, which was estimated to have numbered up to 10,000 spawners in 1995 (DFG unpublished data). Thomes Creek supported a small spring run. Murphy (1946) observed three adult salmon in early August 1946 in a pool situated within The Gorge area below Lake Hollow, eight miles upstream from the town of Paskenta; however, no salmon were observed in that stream during a later survey in the 1960s (T. Healey, personal communication, see "Notes"). In contrast, spring-run salmon probably did not use the Cow Creek drainage to any significant extent either because there is no suitable over-summering habitat (specifically, deep bedrock pools), particularly lacking in the South Fork, or because natural barriers prevented access to the headwaters, as in the other forks. Fall-run salmon presently occur in the mainstem Cow Creek up to where the South Fork joins, and they ascend the South Fork up to Wagoner Canyon. In the North Fork Cow Creek, fall-run fish are stopped by falls near the Ditty Wells fire station of the California Department of Forestry. Occasionally, late-fall run salmon also occur in Cow Creek. Fall-run salmon reportedly migrated 20 mi up Stillwater Creek to spawn in 1938, when the fall rains began early (Hanson and others 1940). Cache and Putah creeks, two intermittent streams on the westside lower Sacramento drainage, have supported fall salmon runs only during wet years within historical times (Shapovalov 1947). Decades ago, salmon were observed as far upstream as Capay Dam in Cache Creek (Hanson and others 1940, Shapovalov 1947) and near the town of Monticello in Putah Creek (Shapovalov 1947). Based on archaeological remains from earlier times (about AD 1450–1650), Putah Creek long ago provided salmon to the local Native Americans in at least some minor quantity (Schulz 1994 unpublished manuscript). Fry (1961) reported that the combined fall runs (including late-fall) for the miscellaneous Sacramento tributary streams totaled 1,000 to 13,000 fish annually during 1940–1959. The spring-run totals, available for only three years in that period, were <500 fish in both 1944 and 1945 and 1,000 fish in 1956 (Fry 1961). During 1953–1969, the Cow Creek drainage alone supported a fall run that averaged 2,800 fish (Reynolds and others 1993). In most recent years, the combined fall run in these miscellaneous streams, if existent, has been inconsequential and the spring run essentially has not occurred (Reynolds and others 1993).

Conclusion: Quantitative Assessment of Distributional Changes

It has been estimated that before the placement of man-made obstructions in the streams of the Sacramento and San Joaquin drainages there were "at least 6000 linear miles of streambed suitable and available to spawning salmon" (Clark 1929), although the process by which that figure was determined was not explained. Given the sheer magnitude of that estimate, it is evident that not only spawning habitat but all lengths of stream traversed or occupied by salmon (migration corridors and holding areas) were included. The actual amount of spawning habitat that was originally used by, or available to, Central Valley salmon is not clearly known but as early as 1918 the California Fish and Game Commission (CFGC) acknowledged that "Fully 80 per cent of the natural spawning grounds of the Sacramento River basin have been destroyed by the mines, and dams constructed for the purpose of generating electricity, and by the diverting of water for irrigation purposes" (CFGC 1921a, p 20). For the period 1924–1926, the CFGC reported that "approximately 90 per cent of the spawning areas in these two river systems [Sacramento and San Joaquin rivers] have been cut off from the salmon or destroyed" (CFGC 1927, p 35). By 1928, the amount of spawning stream habitat in the entire Central Valley drainage had been reduced to an estimated 510 linear miles with reportedly "At least 80 per cent of the spawning grounds…cut off by obstructions"—which included 11 dams in the San Joaquin system and 35 dams in the Sacramento system that posed partial or complete barriers to salmon (Clark 1929, p 28). Van Cleve (1945) later estimated a somewhat lesser loss of 75% of the original spawning habitat due to all causes. In 1993, the total amount of existent spawning habitat for salmon and steelhead in the Central Valley drainage was estimated by the California Department of Fish and Game to be less than 300 miles (Reynolds and others 1993).

We estimated from map distances the stream lengths that have been lost as salmon habitat in each of the major Central Valley watersheds due to installation of barriers or the reduction of streamflows that made passage of salmon impossible under usual conditions (Table 2). We included reaches of streams which salmon are known or can be inferred to have had access to, whether for holding or spawning purposes. These estimated stream lengths are minimal estimates because we have considered only the mainstems and the major forks and tributaries as salmon habitat. Numerous small third- and fourth-order streams very likely were used to some degree by spawning salmon, for which records do not exist, although the numbers of salmon using those smaller streams would have been relatively small. In fact, the full extent of the historical distribution of salmon even in the major stream reaches is not clearly known for some watersheds (for example, Middle Fork American River, mainstem and South Fork Merced River). Furthermore, recent studies have shown that juvenile salmon in large numbers, and some steelhead, enter small temporary streams for rearing (for example, Rock, Mud, Pine, and Toomes creeks in the northern Sacramento Valley) even though spawning by salmon may not necessarily occur in those streams (Maslin and McKinney 1994 unpublished report). Undoubtedly, salmon historically used those and other non-natal "nursery" streams, as probably did steelhead (IEP 1998 unpublished report), but we have no way of accurately assessing the distributional extent of such usage.

Based on the available information, our estimates indicate that the amount of habitat that was lost differs greatly from watershed to watershed. In the Bear River, for example, the length of stream accessible to salmon has changed very little, while in Deer Creek it actually has increased by several miles due to artificially improved fish passage over natural barriers. In lower Battle Creek, the salmon were blocked for many years by the Coleman National Fish Hatchery weir, but in recent years access to upstream reaches has been reopened for the winter- and spring-run fish so that much of the historical range is again available to those runs. However, in most watersheds considerable portions of the former salmon-supporting reaches are no longer accessible to salmon, and some watersheds have been entirely removed from salmon production—namely, McCloud, Pit, Upper (Little) Sacramento, and upper San Joaquin rivers. The general pattern has been the elimination of the higher foothill and mountain reaches in the Sierra Nevada and Cascades from the distributional range of chinook salmon.

Summing the stream-by-stream estimates of accessible salmon habitat (for streams tabulated in Table 2) yields a total of 1,126 mi of main stream lengths presently remaining of the more than 2,183 mi of Central Valley streams that we estimate were originally available to chinook salmon—indicating an overall loss of at least 1,057 mi or 48% of the original total. Our estimate of 1,126 mi is remarkably similar to the figure of 1,075 mi of "chinook habitat" in the Central Valley given by Holmberg (1972) almost three decades ago. Our calculations did not include the Sacramento-San Joaquin Delta, comprising about 700 mi of river channels and sloughs (USFWS 1995), available to various degrees as migration corridors or rearing areas for salmon. In contrast to most previously cited estimates specifying only spawning habitat, our figures include the lengths of stream used by salmon mainly as migration corridors (for example, the lower Sacramento and San Joaquin rivers) in addition to holding and spawning habitat. Our figures include about 200 mi in the lower Sacramento River (below Tehama), about 50 mi in the lower San Joaquin River (below the confluence of the Merced River), and the lower reaches of several tributaries which contain no spawning habitat. It is likely that those lower Sacramento and San Joaquin reaches historically were used as rearing areas (at least during some flow regimes) as the juveniles moved downstream, but in recently they have been less suitable for rearing due to alterations in channel morphology and other degraded environmental conditions. In terms of only spawning and holding habitat, the proportionate loss far exceeds 48% because a relatively large portion of the original spawning habitat was located in upper stream reaches that have been cut off by dams. In contrast, much of the remaining lengths of stream in the lower drainages now traversed by salmon cannot be used for spawning. Of the total length of stream courses presently accessible, less than one-third in the San Joaquin River drainage and probably less than a half in the Sacramento River drainage are suitable as spawning habitat. Excluding the lower stream courses that were used only as adult migration corridors (and only minimally for juvenile rearing)—by our estimate amounting to 709 stream miles—we roughly calculate that at least 72% of the original spawning and holding habitat for salmon in the Central Valley drainage is no longer available. Thus, the DFG's most recent assessment that about 95% of the original spawning habitat has been lost is perhaps somewhat high but probably roughly accurate (Reynolds and others 1993). However, the earlier estimate by Clark (1929, p 28) that there were "at least 6,000 linear miles of stream bed suitable and available to spawning salmon" probably is overly high by a factor of three.

The amount of habitat loss for steelhead most likely was much higher than that for salmon because steelhead were undoubtedly more extensively distributed. Due to their superior leaping and swimming ability, the timing of their upstream migration which coincided with the winter rainy season, and their less restrictive preferences for spawning gravels, steelhead could have used at least hundreds of miles of smaller tributaries not accessible to even the highest migrating winter-run and spring-run salmon.

Table 2 Estimated changes in lengths of stream available to chinook salmon in the major salmon-supporting watersheds of the California Central Valley [a]

Watershed	*Length (mi) of stream historically available [b]*	*Length (mi) of stream presently accessible [c]*	*Length (mi) of stream lost (or gained) [d]*	*Percent lost (or gained)*
Sacramento River Basin				
Mainstem Sacramento R. [e]	299	286	13	4
Pit River	99	0	99	100
McCloud River	50	0	50	100
Upper (Little) Sacramento R.	52	0	52	100
Eastside Streams				
Battle Creek	43	6 [43] [f]	0	0
Antelope Creek	32	32	0	0
Mill Creek	44	44	0	0
Deer Creek	34	38	(4)	(12)
Big Chico Creek	24	24	0	0
Butte Creek	>53	53	>0	>0
Feather River	211	64	147	70
Yuba River	80	24	56	70
Bear River	16	16	0	0
American River	161	28	133	83

[a] The estimates for stream lengths originally available and subsequently lost are in most cases minimal values because the full extent of the former salmon distributions in individual streams is incompletely known. Additional minor streams such as Thomes, Paynes, Cache, and Putah creeks (and perhaps a dozen others in the Sacramento Valley) historically supported salmon (Fry 1961)—probably only the fall run and only during wet years. The historical upstream limits of salmon in those streams is too poorly known to allow inclusion in this table. Current salmon production in those streams is limited because of a number of factors, including low streamflows, habitat degradation and obstruction by irrigation canal crossings (DFG 1993).

[b] Lengths of all stream reaches known or presumed to have been traversed or used by salmon in the drainage are included.

[c] Length between the mouth of the stream and the current upstream limit.

[d] Length of stream gained is given in parentheses; this situation applies only to Deer Creek.

[e] From Rio Vista in the north Sacramento-San Joaquin Delta upstream to the confluence of the Upper (Little) Sacramento and Pit rivers.

[f] First number pertains to the fall run; second number [in brackets] pertains to the spring and winter runs. The fall run in Battle Creek is stopped by the Coleman National Fish Hatchery weir, six miles above the mouth; the fall run's historical upper limit is not known, but we presume it was not much further upstream of the current limit at the hatchery weir. Spring-run and winter-run salmon currently are allowed to pass upstream and probably ascend to much of the historical range (that is, an additional 37 stream miles above the hatchery weir).

[g] From Mossdale in the south Sacramento-San Joaquin Delta upstream to the confluence of the Merced River. This stretch lacks spawning gravels and serves primarily as a migration corridor.

[h] Includes the mainstem San Joaquin River above the confluence of the Merced River.

Table 2 Estimated changes in lengths of stream available to chinook salmon in the major salmon-supporting watersheds of the California Central Valley [a] (Continued)

Watershed	*Length (mi) of stream historically available [b]*	*Length (mi) of stream presently accessible [c]*	*Length (mi) of stream lost (or gained) [d]*	*Percent lost (or gained)*
Westside Streams				
Clear Creek	25	16	9	36
Cottonwood Creek	79	79	0	0
Stony Creek	54	3	51	94
Cow Creek	32	32	0	0
San Joaquin River Basin and Sacramento-San Joaquin Delta				
Lower San Joaquin R. [g]	50	50	0	0
Cosumnes River	31	31	0	0
Mokelumne River	92	64	28	30
Calaveras River	approx. 38	38	0?	0?
Stanislaus River	124	58	66	53
Tuolumne River	104	52	52	50
Merced River	107	51	56	52
Upper San Joaquin R. [h]	173	0	173	100
Kings River	76	0	76	100
Central Valley Total	**2183**	**1126**	**1057**	**48**

[a] The estimates for stream lengths originally available and subsequently lost are in most cases minimal values because the full extent of the former salmon distributions in individual streams is incompletely known. Additional minor streams such as Thomes, Paynes, Cache, and Putah creeks (and perhaps a dozen others in the Sacramento Valley) historically supported salmon (Fry 1961)—probably only the fall run and only during wet years. The historical upstream limits of salmon in those streams is too poorly known to allow inclusion in this table. Current salmon production in those streams is limited because of a number of factors, including low streamflows, habitat degradation and obstruction by irrigation canal crossings (DFG 1993).

[b] Lengths of all stream reaches known or presumed to have been traversed or used by salmon in the drainage are included.

[c] Length between the mouth of the stream and the current upstream limit.

[d] Length of stream gained is given in parentheses; this situation applies only to Deer Creek.

[e] From Rio Vista in the north Sacramento-San Joaquin Delta upstream to the confluence of the Upper (Little) Sacramento and Pit rivers.

[f] First number pertains to the fall run; second number [in brackets] pertains to the spring and winter runs. The fall run in Battle Creek is stopped by the Coleman National Fish Hatchery weir, six miles above the mouth; the fall run's historical upper limit is not known, but we presume it was not much further upstream of the current limit at the hatchery weir. Spring-run and winter-run salmon currently are allowed to pass upstream and probably ascend to much of the historical range (that is, an additional 37 stream miles above the hatchery weir).

[g] From Mossdale in the south Sacramento-San Joaquin Delta upstream to the confluence of the Merced River. This stretch lacks spawning gravels and serves primarily as a migration corridor.

[h] Includes the mainstem San Joaquin River above the confluence of the Merced River.

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References

Aginsky BW. 1943. Culture element distributions: XXIV Central Sierra. Univ Calif Publ Anthropol Rec 8(4):390–468.

Angel M. 1882. History of Placer County, California, with illustrations and biographical sketches of its prominent men and pioneers. Oakland (CA): Thompson & West. 416 p.

Audubon JW. 1906. Audubon's western journal: 1849–1850. Being the MS record of a trip from New York to Texas, and an overland journey through Mexico and Arizona to the gold-fields of California. Cleveland (OH): Arthur H. Clark. 243 p.

Barnhart RA. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest). Steelhead. US Fish Wildl Ser Biol Rep 82(11.60), US Army Corps of Engineers, TR EL–82–4. Washington, DC. 21 p.

Barrett SA, Giifford EW. 1933. Miwok material culture. Bull Milwaukee Public Mus 2(4):125–277.

Bates DB. 1857. Incidents on land and water, or four years on the Pacific Coast. Boston (MA): James French. 336 p.

Beacham TD, Murray CD. 1990. Temperature, egg sizes, and development of embryos and alevins of five species of Pacific salmon: a comparative analysis. Trans Am Fish Soc 119(6):927–45.

Beals RL. 1933. Ethnology of the Nisenan. Univ Calif Publ Am Archaeol Ethnol 31:335–410.

Bennyhoff JA. 1977. Ethnogeography of the Plains Miwok. Center for Archaeological Research at Davis, Publ. nr. 5. Davis (CA): University of California. 181 p.

Bidwell AEK. 1980. Rancho Chico indians. Hill DJ, editor. Chico (CA): Bidwell Mansion Cooperating Assoc. 72 p.

Black M. 2001. Shasta salmon salvage efforts: Coleman National Fish Hatchery on Battle Creek, 1895–1992. In: Brown RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 1. Sacramento (CA): California Department of Fish and Game.

Blake WP. 1857. Geological report nr. 1. Itinerary, or notes and general observations upon the geology of the route. Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean. Volume 5, Part II. Washington, DC: War Department.

Bolton HE. 1930a. Anza's California expeditions. Volume III. The San Francisco Colony. Diaries of Anza, Font, and Eixarch, and narratives by Palóu and Moraga. Berkeley (CA): Univ Calif Pr. 436 p.

Bolton HE. 1930b. Anza's California expeditions. Vol. IV. Font's complete diary of the second Anza expedition. Berkeley (CA): Univ Calif Pr. 552 p.

Borthwick JD. 1857. Three years in California. Edinburgh: William Blackwood & Sons. 318 p.

Bryant E. 1849. What I saw in California: being the journal of a tour, in the years 1846, 1847. New York (NY): D Appleton. 480 p.

Buffum EG. 1959. Six months in the gold mines: from a journal of three years' residence in upper and lower California 1847–8–9. Caughey JW, editor. Los Angeles (CA): Ward Ritchie Pr. 145 p.

Bunnell LH. 1990. Discovery of the Yosemite and the Indian War of 1851 which led to that event. Yosemite National Park (CA): Yosemite Assoc. 315 p.

[DFG] California Department of Fish and Game. 1929. Division of Fish and Game thirtieth biennial report for 1926–1928. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1944. Division of Fish and Game thirty-eighth biennial report for 1942–1944. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1946. Division of Fish and Game thirty-ninth biennial report for 1944–1946. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1948. Division of Fish and Game fortieth biennial report for 1946–1948. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1950. Division of Fish and Game forty-first biennial report for 1948–1950. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1953. Division of Fish and Game forty-second biennial report for 1950–1952. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1960. Division of Fish and Game forty-sixth biennial report, July 1, 1958 through June 30, 1960. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1972. Report to the California State Water Resources Control Board on effects of the New Melones Project on fish and wildlife resources of the Stanislaus River and Sacramento-San Joaquin Delta. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1974. Feather River Hatchery administrative report 74–5. Sacramento (CA): California Department of Fish and Game.

[DFG] California Department of Fish and Game. 1990. Status and management of spring-run chinook salmon. Report by Inland Fisheries Division to California Fish and Game Commission. Sacramento (CA): California Department of Fish and Game. 33 p.

[DFG] California Department of Fish and Game. 1996. San Joaquin River chinook salmon enhancement. Annual report, fiscal year 1994–1995. Sacramento (CA): California Department of Fish and Game, Region 4. February 1996.

[DFG] California Department of Fish and Game. 1998. A status review of the spring-run chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Report to California Fish and Game Commission. Candidate species status report 98–1. June 1998. Sacramento (CA): California Department of Fish and Game. 378 p.

Campbell EA, Moyle PB. 1991. Historical and recent population sizes of spring-run chinook salmon in California. In: American Fisheries Society Proceedings, 1990 Northwest Pacific chinook and coho salmon workshop. Arcata (CA): Humboldt State University. p 155–216.

Carson JH. 1852. Recollections of the California mines. An account of the early discoveries of gold, with anecdotes and sketches of California and miners' life, and a description of the Great Tulare Valley. Reprinted in 1950. Oakland (CA): Biobooks. 113 p.

Cassidy J, Daley-Hutter M, Nelson C, Shepherd L. 1981. Guide to three rivers. The Stanislaus, Tuolumne and South Fork of the American. San Francisco (CA): Friends of the River Books. 295 p.

Caton JD. 1869. Trout fishing in the Yosemite Valley. American Naturalist 3:519–22.

[CFGC] California Fish and Game Commission. 1914. Twenty-third Biennial Report for 1912–1914. Sacramento (CA): California Fish and Game Commission.

[CFGC] California Fish and Game Commission. 1921a. Report of the Department of Fish Culture. Twenty-sixth Biennial Report for 1918–1920. Sacramento (CA): California Fish and Game Commission. p 19–22.

[CFGC] California Fish and Game Commission. 1921b. San Joaquin River salmon. In: Shebley WH, editor. Hatchery notes. California Fish and Game 7(1):51–2.

[CFGC] California Fish and Game Commission. 1921c. An important decision on the fishway law. California Fish and Game 7(3):154–6.

[CFGC] California Fish and Game Commission. 1923. Twenty-seventh biennial report for 1920–1922. Sacramento, Calif.

[CFGC] California Fish and Game Commission. 1927. Report of the Department of Fish Culture. Twenty-ninth biennial report for 1924–1926. Sacramento, Calif. p 33–8.

[CFC] California State Board of Fish Commissioners. 1871. (1st) Rep. Comm. Fish. State of California for 1870 and 1871. Reprinted in January 1933. California Fish and Game 19(1):41–56.

[CFC] California State Board of Fish Commissioners. 1875. (3rd) Rep. Comm. Fish. of the State of California for 1874 and 1875. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1877. (4th) Rep. Comm. Fish. of the State of California for 1876 and 1877. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1880. (6th) Rep. Comm. Fish. of the State of California for 1880. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1884. (8th) Biennial Rep. Comm. Fish. of the State of California for 1883–4. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1886. (9th) Biennial Rep. Comm. Fish. of the State of California for 1885–1886. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1888. (10th) Biennial Rep. Comm. Fish. of the State of California for 1886–1888. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1890. (11th) Biennial Rep. Comm. Fish. of the State of California for 1888–1890. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1896. Fourteenth Biennial Rep. Comm. Fish. of the State of California for 1895–1896. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1900a. Fifteenth Biennial Rep. Comm. Fish. of the State of California for 1897–1898. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1900b. Sixteenth Biennial Rep. Comm. Fish. of the State of California for 1899–1900. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1904. Eighteenth Biennial Rep. Comm. Fish. of the State of California for 1903–1904. Sacramento, Calif.

[CFC] California State Board of Fish Commissioners. 1907. Nineteenth Biennial Rep. Comm. Fish. of the State of California for 1905–1906. Sacramento, Calif.

Chamberlain WH, Wells HL. 1879. History of Sutter County, California. Oakland (CA): Thompson & West. 127 p. Reprinted in 1974. Berkeley (CA): Howell-North.

Clark GH. 1929. Sacramento-San Joaquin salmon (*Oncorhynchus tshawytscha*) fishery of California Division of Fish and Game. Fish Bulletin 17. p 1–73.

Clark GH. 1930. Salmon spawning in drainage canals in the San Joaquin Valley. California Fish and Game 16(3):270.

Clark GH. 1943. Salmon at Friant Dam—1942. California Fish and Game 29(3):89–91.

Clark WVT. 1973. The journals of Alfred Doten 1849–1903. Volume 1. Reno (CA): Univ Nevada Pr. 808 p.

Coleman CM. 1952. PG and E of California. The centennial story of Pacific Gas and Electric Company 1852–1952. New York (NY): McGraw-Hill. 385 p.

Collins C. 1949. Sam Ward in the gold rush. Stanford (CA): Stanford Univ Pr. 189 p.

Collins JW. 1892. Report on the fisheries of the Pacific coast of the United States. US Comm. Fish and Fish., Rep. Comm. for 1888. Appendix 1:3–269.

Cook SF. 1955. The aboriginal population of the San Joaquin Valley, California. Univ Calif Publ Anthropol Rec 16:31–80.

Cook SF. 1960. Colonial expeditions to the interior of California. Central Valley, 1800–1820. Univ Calif Publ Anthropol Rec 16:239–92.

[CRA] California Resources Agency. 1972. California protective waterway plan, 1972. Appendix by C. Trost. Sacramento, Calif.

[CSHA] California State Historical Association. 1929. Millerton, landmark of a vanished frontier. California History Nugget 2:114–7.

Curtis ES. 1924a. The North American Indian. Volume 13. Reprinted in 1970. New York (NY): Johnson Reprint. 316 p.

Curtis ES. 1924b. The North American Indian. Volume 14. Reprinted in 1970. New York (NY): Johnson Reprint. 284 p.

Cutter DC. 1950. Spanish exploration of California's Central Valley [PhD dissertation]. Berkeley (CA): Univ Calif Pr. 275 p.

Cutter DC. 1957. Diary of Ensign Gabriel Moraga's expedition of discovery in the Sacramento Valley 1808. Los Angeles (CA): Glen Dawson Pr. 37 p.

Davis WN, Jr. 1974. California Indians 5. Sagebrush corner. The opening of California's northeast. New York (NY): Garland Publishing. 553 p.

Dillon R. 1975. Siskiyou Trail. The Hudson's Bay Company route to California. New York (NY): McGraw-Hill. 381 p.

Du Bois C. 1935. Wintu ethnography. Univ Calif Publ Am Archaeol Ethnol 36:1–148.

EA Engineering, Science and Technology. 1990. Report to the Federal Regulatory Commission. Application for license—major unconstructed project. Clavey River Project Nr. 100181. Exhibit E, report 3: fish, wildlife, and botanical resources. Submitted by Tuolumne County and Turlock Irrigation District.

EA Engineering, Science and Technology. 1992. Lower Tuolumne River spawning gravel availability and superimposition report. EA Engineering Fishery Report, Appendix 6. February 1992.

Eigenmann CH. 1890. The food fishes of the California fresh waters. (11th) Biennial report of the State Board Fish Comm. of the State of California for 1888–1890. Sacramento, Calif. p 53–65.

Elliott WW. 1882. History of Fresno County, California, with illustrations. San Francisco (CA): W Elliott & Co. 258 p. Reprinted in 1973. Fresno (CA): Valley Publishers.

Fariss [no initials], Smith CL. 1882. Fariss and Smith's History of Plumas, Lassen and Sierra counties, California, and biographical sketches of their prominent men and pioneers. Reprinted in 1971. Berkeley (CA): Howell-North. 507 p.

[FERC] Federal Energy Regulatory Commission. 1993. Final Environmental Impact Statement. Proposed modifications to the lower Mokelumne River Project, California. FERC project nr. 2916–004. November 1993. 624 p.

Ferguson AD. 1914. General conditions and some important problems. State of California Fish and Game Comm. In: Twenty-third biennial report for 1912–1914. Sacramento, Calif. p 27–9.

Fisher FW. 1994. Past and present status of Central Valley chinook salmon. Conserv Biol 8(3):870–3.

Frémont JC. 1848. Geographical memoir upon Upper California, in illustration of his map of Oregon and California. Report to the US Senate, 30th Congress, 1st Session, Misc. nr. 148. Washington, DC. 64 p.

Fry DH, Jr. 1961. King salmon spawning stocks of the California Central Valley, 1940–1959. California Fish and Game 47(1):55–71.

Garth TR. 1953. Atsugewi ethnography. Univ Calif Anthropol Rec 14(2):129–212.

Garth TR. 1978. Atsugewi. In: Heizer RF, editor. Handbook of North American Indians. Volume 8. California. Washington, DC: Smithsonian Inst. p 236–248.

Gay T. 1967. James W. Marshall. The discoverer of California gold. A biography. Georgetown (CA): Talisman Pr. 558 p.

Gayton AH. 1936. Estudillo among the Yokuts: 1819. In: Essays in anthropology present to A.L. Kroeber in celebration of his sixtieth birthday June 11, 1936. Berkeley (CA): Univ Calif Pr. p 67–85.

Gayton AH. 1946. Culture-environment integration: external references in Yokuts life. Southwestern J Anthropol 2:252–68.

Gayton AH. 1948a. Yokuts and Western Mono ethnography I: Tulare Lake, Southern Valley, and Central Foothill Yokuts. Univ Calif Publ Anthropol Rec 10:1–142.

Gayton AH. 1948b. Yokuts and Western Mono ethnography II: Northern Foothill Yokuts and Western Mono. Univ Calif Publ Anthropol Rec 10:143–302.

Gerstung ER. 1989. Fishes and fishing in the forks of the American River: then and now. In: The American River. North, Middle and South forks. Auburn (CA): Wilderness Conservancy. Protect American River Canyons. 320 p.

Gifford EW. 1932. The Northfork Mono. Univ Calif Publ Am Archaeol Ethnol 31:15–65.

Gilbert FT. 1879. History of San Joaquin County, California. Oakland (CA): Thompson & West. Reprinted in 1968. Berkeley (CA): Howell-North. 142 p.

Gilbert GK. 1917. Hydraulic-mining débris in the Sierra Nevada. US Geological Survey professional paper nr. 105. Washington, DC.

Green LW. 1887. Salmon in the McCloud River during the season of 1886. Bull US Fish Comm 6(1886):334–6.

Gudde EG. 1962. Bigler's chronicle of the West. The conquest of California, discovery of gold, and Mormon settlement as reflected in Henry William Bigler's diaries. Berkeley (CA): Univ Calif Pr. 145 p.

Guilford-Kardell M, Dotta J. 1980. Papers on Wintu ethnography: 239 Wintu villages in Shasta County circa 1850. Occasional papers of the Redding Museum nr. 1. Redding (CA): Redding Mus Art Center. 131 p.

Hallock RJ, Fry DH Jr., LaFaunce DA. 1957. The use of wire fyke traps to estimate the runs of adult salmon and steelhead in the Sacramento River. California Fish and Game 43(4):271–98.

Hallock RJ, Van Woert WF. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin Rivers. California Fish and Game 45(4):227–96.

Hallock RJ, Van Woert WF, Shapovalov L. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system. Fish Bulletin 114. p 1–74.

Hanson HA, Smith OR, Needham PR. 1940. An investigation of fish-salvage problems in relation to Shasta Dam. US Bur Fish Spec Sci Rep nr. 10. Washington, DC. 202 p.

Hatton SR. 1940. Progress report on the Central Valley fisheries investigations. California Fish and Game 26(4):334–73.

Hatton SR, Clark GH. 1942. A second progress report on the Central Valley fisheries investigations. California Fish and Game 28(2):116–23.

Healey MC. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). In: Groot C, Margolis L, editors. Pacific salmon life histories. Vancouver, BC: Univ British Columbia Pr. p 313–393.

Hedgpeth JW. 1941. Livingston Stone and fish culture in California. California Fish and Game 27(3):126–48.

Heizer RF, editor. 1967. Ethnographic notes on California Indian Tribes III. Ethnological notes on central California Indian tribes, by C. Hart Merriam. Reports of the Univ Calif Archaeol Surv nr. 68. Part III. p 257–448.

Heizer RF, editor. 1976. A collection of ethnographic articles on the California Indians. Ramona (CA): Ballena Pr. 103 p.

Heizer RF. 1993. The destruction of California Indians. Lincoln (NE): Univ Nebraska Pr. 321 p.

Holmberg JJ. 1972. Salmon in California. Report for the US Bureau of Reclamation, Division of Planning. March 1972. Sacramento, Calif. 91 p.

Hubbs CL. 1946. Wandering pink salmon and other salmonid fishes into Southern California. California Fish and Game 32(2):81–6.

Hutchings JM. 1990. Yosemite Valley and the Big Tree Groves. In: Browning P, editor. The heart of the Sierras. Lafayette (CA): Great West. 505 p.

Jacobs D, Chatfield E, Kiley L, Kondolf GM, Loyd L, Smith F, Walker D, Walker K. 1993. California's rivers. A public trust report. Sacramento (CA): California State Lands Commission. 334 p.

Jewell DP. 1987. Indians of the Feather River. Tales and legends of the Concow Maidu of California. Menlo Park (CA): Ballena Pr. 184 p.

Johnson JJ. 1978. The Yana. In: Heizer RF, editor. Handbook of North American Indians. Volume 8. California. Washington, DC: Smithsonian Inst. p 361–369.

Kano RM. 1998a. Annual report. Chinook salmon spawner stocks in California's Central Valley, 1991. Inland Fisheries administrative report nr. 98–8. Sacramento (CA): California Department of Fish and Game. 40 p.

Kano RM. 1998b. Annual report. Chinook salmon spawner stocks in California's Central Valley, 1992. Inland Fisheries administrative report nr. 98–10. Sacramento (CA): California Department of Fish and Game. 40 p.

Kelley R. 1989. Battling the inland sea. American political culture, public policy, and the Sacramento Valley 1850–1986. Berkeley (CA): Univ Calif Pr. 395 p.

Kelly W. 1950. A stroll through the diggings of California. Oakland (CA): Biobooks. 206 p.

Kniffen F. 1928. Achomawi geography. Univ Calif Publ Am Archaeol Ethnol 23:297–332.

Kroeber AL. 1925. Handbook of the Indians of California. Bur Am Ethnol Smithsonian Inst Bull 78:1–995. Reprinted in 1976. New York (NY): Dover.

Kroeber AL. 1932. The Patwin and their neighbors. Univ Calif Publ Am Archaeol Ethnol 29:253–423.

Latta FF. 1929. Uncle Jeff's story. A tale of a San Joaquin Valley pioneer and his life with the Yokuts Indians. Tulare (CA): Pr Tulare Times. 88 p.

Latta FF. 1977. Handbook of Yokuts Indians. Santa Cruz (CA): Bear State. 765 p.

Lawrence JH. 1884. Discovery of the Nevada Fall. October 1884, second series. Overland Monthly 4(22):360–71.

Leach GC. 1922. Propagation and distribution of food fishes, 1921. Report of the US Commission of Fisheries for 1921. Appendix IX. p 26–7.

Leach GC. 1923. Propagation and distribution of food fishes, 1922. Report of the US Commission of Fisheries for 1922. Appendix XVII. p 39–40.

Lee GD. 1998. Walking where we lived. Memoirs of a Mono Indian family. Norman (OK): Univ Oklahoma Pr. 208 p.

Maloney AB, editor. 1943. Fur brigade to the Bonaventura. John Work's California expedition of 1832–1833 for the Hudson's Bay Company. Calif Hist Soc Quart 22:193–222, 323–48.

Maniery JG. 1983. A chronicle of Murphys Rancheria (Mol-Pee-So): an historic Central Sierra Miwok village. J Calif Great Basin Anthropol 5(1 and 2):176–98.

McEvoy AF. 1986. The fisherman's problem. Ecology and law in the California fisheries, 1850–1980. New York (NY): Cambridge Univ Pr. 368 p.

McEwan D, Jackson TA. 1996. Steelhead restoration and management plan for California. Sacramento (CA): California Department of Fish and Game. 234 p.

McGregor EA. 1922. Migrating salmon at Redding Dam. Calif Fish and Game 8(3): 141–54.

McLendon S, Oswalt RL. 1978. Pomo: introduction. In: Heizer RF, editor. Handbook of North American Indians. Volume 8. California. Washington, DC: Smithsonian Inst. p 274–88.

Moffett JW. 1949. The first four years of king salmon maintenance below Shasta Dam, Sacramento River, California. California Fish and Game 35(2):77–102.

Morgan DL. 1970. In pursuit of the golden dream. Reminiscences of San Francisco and the northern and southern mines, 1849–1857, by Howard C. Gardiner. Stoughton (MA): Western Hemisphere. 390 p.

Moyle PB. 1970. Occurrence of king (chinook) salmon in the Kings River, Fresno County. California Fish and Game 56(4):314–5.

Moyle PB. 1976. Inland fishes of California. Berkeley (CA): Univ Calif Pr. 405 p.

Muir J. 1902. Our National Parks. Boston (MA): Houghton Mifflin. 370 p.

Muir J. 1938. John of the Mountains. In: Wolfe LM, editor. The unpublished journals of John Muir. Boston (MA): Houghton Mifflin. 459 p.

Muir J. 1961. The mountains of California. Garden City (NY): Doubleday. 300 p.

Muir J. 1988. The Yosemite. San Francisco (CA): Sierra Club. 215 p.

Murphy GI. 1946. A survey of Stony Creek, Grindstone Creek and Thomes Creek drainages in Glenn, Colusa and Tehama counties, California. Inland Fisheries Branch administrative report nr. 46–14. Sacramento (CA): California Department of Fish and Game.

[NCHRSP] Northern California Historical Records Survey Project. 1940. Inventory of the county archives of California. No. 10. Fresno County (Fresno). Division of Professional and Science Projects, Work Projects Administration. July 1940.

Needham PR, Hanson HA, Parker LP. 1943. Supplementary report on investigations of fish-salvage problems in relation to Shasta Dam. US Fish Wildl Serv Spec Sci Rep 26. 30 June 1943. 52 p.

Needham PR, Smith OR, Hanson HA. 1941. Salmon salvage problems in relation to Shasta Dam, California, and notes on the biology of Sacramento River salmon. Trans Am Fish Soc 70:55–69.

O'Brien R. 1951. California called them. A saga of golden days and roaring camps. New York (NY): McGraw-Hill. 251 p.

Olmsted DL, Stewart OC. 1978. Achumawi. In: Heizer RF, editor. Handbook of North American Indians. Vol. 8. California. Washington, DC: Smithsonian Inst. p 225–35.

Outdoor California. 1958. Salmon get a freeway up a rugged canyon. August 1958. p 4–5.

Perlot JN. 1985. Gold seeker. Adventures of a Belgian argonaut during the Gold Rush years. Bretnor HH, translator. Lamar HR, editor. New Haven (CT): Yale Univ Pr. 451 p.

Phillips JB. 1931. Netting operations on an irrigation canal. California Fish and Game 17(1):45–52.

Poesch J. 1961. Titian Ramsay Peale and his journals of the Wilkes Expedition. Philadelphia (PA): Am Philos Soc. 206 p.

Pope ST. 1918. Yahi archery. In: Heizer RF, Kroeber T, editors. Ishi, the last Yahi. A documentary history. Berkeley (CA): Univ Calif Pr. p 172–201. Reprinted in 1979.

Powers S. 1874. The California Indians. Nr. XI.—various tribes. The Overland Monthly XII:412–24.

Powers S. 1877. Tribes of California. In: Heizer RF, editor. Contributions to North American Ethnology, Volume III. Washington, DC: Department of the Interior, US Geographical and Geological Survey of the Rocky Mountain Region. Reprinted in 1976. Berkeley (CA): Univ Calif Pr. 480 p.

Reynolds FL, Mills TJ, Benthin R, Low A. 1993. Restoring Central Valley streams; a plan for action. Sacramento (CA): California Department of Fish and Game. 129 p.

Rose G. 1992. San Joaquin. A river betrayed. Fresno (CA): Linrose. 151 p.

Rutter C. 1902. Studies in the natural history of the Sacramento Salmon. Seventeenth biennial report of the State Board of Fish Commission of the State of California for 1901–1902. p 64–76.

Rutter C. 1904. Natural history of the quinnat salmon. A report of investigations in the Sacramento River, 1896–1901. Bull US Fish Comm 22(1902):66–141.

Rutter C. 1907. Do quinnat salmon return to their native streams? Nineteenth biennial report of the State Board of Fish Commission of the State of California for 1905–1906. Appendix. p 93–7.

Rutter C. 1908. The fishes of the Sacramento-San Joaquin Basin, with a study of their distribution and variation. Bull US Bur Fish 27(1907):103–52.

San Joaquin Valley Drainage Program. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California. Volume 1. October 1990. Sacramento, Calif. 166 p.

Sanchez HVG. 1932. California and Californians. Volume I. The Spanish period. San Francisco (CA): Lewis Publishing. 569 p.

Scofield NB. 1900. Notes on an investigation of the movement and rate of growth of the quinnat salmon fry in the Sacramento River. Fifteenth biennial report of the State Board of Fish Commission of the State of California for 1897–1898. p 66–71.

Scofield WL. 1954. California fishing ports. California Department of Fish and Game. Fish Bulletin 96. p 1–159.

Seymour AH. 1956. Effects of temperature upon young chinook salmon [PhD dissertation]. Seattle (WA): Univ Washington.

Shapovalov L. 1947. Report on fisheries resources in connection with the proposed Yolo-Solano development of the United States Bureau of Reclamation. California Fish and Game 33:61–88.

Shebley WH. 1922. A history of fish cultural operations in California. California Fish and Game 8(2):62–99.

Shebley WH. 1927. History of fish planting in California. California Fish and Game 13(3):163–73.

Skinner JE. 1958. Some observations regarding the king salmon runs of the Central Valley. Water projects miscellaneous report nr. 1. California Department of Fish and Game. 14 October 1958. 14 p.

Skinner JE. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay area. Water projects branch report nr. 1. California Department of Fish and Game. June 1962. Sacramento, Calif. 225 p.

Slater DW. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements at spawning. US Fish Wildl Serv Spec Sci Rep. Fisheries nr. 461. November 1963. 9 p.

Smith HM. 1905. Report on inquiry respecting food fishes and the fishing grounds. US Commission on Fish and Fisheries report for the year ending June 30, 1903. p 75–100.

Southern MH. 1942. Our stories landmarks. Shasta County, California. Redding (CA): Shasta Hist Soc. 100 p.

Stanley C, Holbek L. 1984. A guide to the best whitewater in the state of California. Palo Alto (CA): Friends of the River. 281 p.

Steele J. 1901. Camp and cabin. Mining life and adventure, in California during 1850 and later. Chicago (IL): RR Donnelley & Sons. 377 p. Reprinted in 1928 by The Lakeside Press.

Stone L. 1874. Report of operations during 1872 at the United States salmon-hatching establishment on the M'Cloud River and the California Salmonidae generally; with a list of specimens collected. US Commission on Fish and Fisheries report for 1872 and 1873. Appendix B. p 168–215. Washington, DC.

Stone L. 1876. Report of operations during 1874 at the United States salmon-hatching establishment on the M'Cloud River, California. US Commission on Fish and Fisheries report for 1873–4 and 1874–5. Appendix. p 437–78. Washington, DC.

Stone L. 1879. Report of operations at the United States salmon-hatching station on the M'Cloud River, California, in 1877. US Commission on Fish and Fisheries report for 1877. Appendix. p 741–70. Washington, DC.

Stone L. 1880. Report of operations at the United States salmon-hatching station on the M'Cloud River, California, in 1878. US Commission on Fish and Fisheries report for 1878. Appendix. p 741–70. Washington, DC.

Stone L. 1883a. Account of operations at the McCloud River fish-breeding stations of the United States Fish Commission, from 1872 to 1882 inclusive. Bull US Fish Comm 2(1882):217–236.

Stone L. 1883b. Report of operations at the United States salmon-hatching station on the M'Cloud River, California, during the season of 1880. US Commission on Fish and Fisheries report for 1880. Appendix, Part XXI p 597–612. Washington, DC.

Stone L. 1885a. History of operations at the fish hatching stations on the McCloud River, California, from the beginning, August 1872, to October 1884. Bull US Fish Comm 5(1885):28–31.

Stone L. 1885b. Report of operations at the United States salmon-breeding station on the McCloud River, California, during the year 1883. US Commission on Fish and Fisheries report for 1883. Appendix, Part XI. p 989–1000. Washington, DC.

Stone L. 1897. The artificial propagation of salmon on the Pacific Coast of the United States, with notes on the natural history of the quinnat salmon. Bull US Fish Comm 16(1896):203–235.

Sullivan MS. 1934. The travels of Jedediah Smith. A documentary outline including the journal of the great American pathfinder. Santa Ana (CA): Fine Arts Pr. 195 p.

Sumner FH, Smith OR. 1940. Hydraulic mining and debris dams in relation to fish life in the American and Yuba rivers of California. California Fish and Game 26(1):2–22.

Swezey SL, Heizer RF. 1977. Ritual management of salmonid fish resources in California. Calif J Anthropol 4:6–29.

Theodoratus DJ, editor. 1976. An ethnographic study of the New Melones Lake Project. New Melones Ethnographic Research Project. Report to the US Army Corps of Engineers, Contract nr. DACW05–76–0033. July 1976. Sacramento, Calif. 529 p.

Throckmorton SR. 1882. Description of the fish-way in Pitt River, California. Bull US Fish Comm 1:202–3.

Toffoli EV. 1965. Chemical treatment of the Merced River, Mariposa County. California Department of Fish and Game Inland Fisheries Branch administrative report nr. 65–14. Sacramento, Calif. 12 p.

Towle JC. 1987. The great failure: nineteenth-century dispersals of the Pacific Salmon. Calif Geograph Soc 27:75–96.

Travanti L. 1990. The effects of piscicidal treatment on the fish community of a northern California stream [MS thesis]. California State University, Chico. 67 p.

Tudor-Goondenough Engineers. 1959. Summary report on the Tri-Dam Project. Stanislaus River, California. January 1959. San Francisco, Calif. 99 p.

[USFC] US Commission of Fish and Fisheries. 1876a. The propagation of food-fishes in the waters of the United States. US Commission of Fish and Fisheries report for 1873–4 and 1874–5. Washington, DC.

[USFC] US Commission of Fish and Fisheries. 1876b. Correspondence relating to the San Joaquin River and its fishes. US Commission of Fish and Fisheries report for 1873–4 and 1874–5. Part XXIII. p 479–483. Washington, DC.

[USFC] US Commission of Fish and Fisheries. 1892. Rep. Comm. for 1888. US Commission of Fish and Fisheries report for July 1, 1888 to June 30, 1889. p xxxv–xxxvi. Washington, DC.

[USFC] US Commission of Fish and Fisheries. 1899. US Commission of Fish and Fisheries report for the year ending June 30, 1898. p xciii–xcvii. Washington, DC.

[USFC] US Commission of Fish and Fisheries. 1900. US Commission of Fish and Fisheries report for the year ending June 30, 1899. p xcvi–c. Washington, DC.

[USFC] US Commission of Fish and Fisheries. 1904. US Commission of Fish and Fisheries report for the year ending June 30, 1902. p 71–74. Washington, DC.

[USFWS] US Fish and Wildlife Service. 1995. Working Paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volumes 1, 2, and 3. 9 May 1995. Prepared for the US Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, Calif.

Van Cleve R. 1945. Program of the Bureau of Marine Fisheries. California Fish and Game 31(3):80–138.

Vandor PE. 1919. History of Fresno County, California. Volume 1. Los Angeles (CA): Historic Record. 2,603 p.

Van Sicklen HP. 1945. A sojourn in California by the King's orphan. The travels and sketches of G. M. Waseurtz af Sandels, a Swedish gentleman who visited California in 1842–1843. San Francisco (CA): Book Club Calif. 95 p.

Voegelin E. 1942. Culture element distributions: XX. Northeast California. Univ Calif Pub Anthropol Rec 7:47–252.

Vogel DA, Marine KR. 1991. Guide to upper Sacramento chinook salmon life history. Report to US Bureau of Reclamation, Central Valley Project. Redding (CA): CH2M Hill. 55 p.

Wales JH. 1939. General report of investigations on the McCloud River drainage in 1938. California Fish and Game 25(4):272–309.

Warner G. 1991. Remember the San Joaquin. In: Lufkin A, editor. California's salmon and steelhead. The struggle to restore an imperiled resource. Berkeley (CA): Univ Calif Pr. p 61–9.

Wilkes C. 1845. Narrative of the United States Exploring Expedition during the years 1838, 1839, 1840, 1841, 1842. Volume V. Philadelphia (PA): Lea & Blanchard.

Wilson NL. 1972. Notes on traditional Foothill Nisenan food technology. In: Papers on Nisenan environment and subsistence. Center for Archaeological Research Publication nr 3. Davis (CA): Univ Calif Davis. p 32–8.

Woodhull C. 1946. A preliminary investigation of the Mokelumne River from Tiger Creek to Pardee Reservoir. California Division of Fish and Game, Bureau of Fish Conservation administrative report nr. 46–16. 28 p.

Woodhull C, Dill W. 1942. The possibilities of increasing and maintaining a run of salmon (*Oncorhynchus tshawytscha*) in the Kings River, California. California Division of Fish and Game, Bureau of Fish Conservation administrative report nr. 42–26. 32 p. + figures.

Woods DB. 1851. Sixteen months at the gold diggings. New York (NY): Harper Bros. 199 p.

Wright GF. 1880. History of Sacramento County, California. Oakland (CA): Thompson & West. Reprinted in 1960 by Howell-North. 294 p.

Yoshiyama RM, Fisher FW, Moyle PB. 1998. Historical abundance and decline of chinook salmon in the Central Valley region of California. N Am J Fish Manage 18:487–521.

Yoshiyama RM, Gerstung ER, Fisher FW, Moyle PB. 1996. Historical and present distribution of chinook salmon in the Central Valley drainage of California. Sierra Nevada Ecosystem Project: Final report to US Congress. Volume III, assessments, commissioned reports, and background information. p 309–62.

Unpublished Documents

Azevedo RL, Parkhurst ZE. 1958. The upper Sacramento River salmon and steelhead maintenance program, 1949–1956. US Fish and Wildlife Service. 96 p.

[DFG] California Department of Fish and Game. 1955. Fish and game water problems of the Upper San Joaquin River. Potential values and needs. Statement submitted to the Division of Water Resources at hearings on the San Joaquin River water applications. 5 April 1955. Fresno, Calif. 51 p.

DFG letter no.1. Letter dated 23 April 1941 from H.A. Kloppenburg, US Forest Service District Ranger, to R. Van Cleve, DFG.

DFG letter no. 2. Letter dated 29 April 1941 from R. Belden to the California Fish and Game Commission.

DFG unpublished field data and notes. Stream survey data, fish counts at dam fishways, notes and photographs on file at DFG offices, Red Bluff, Sacramento and Rancho Cordova.

Dill W. Letter dated 24 September 1946 to Donald H. Fry, Jr., California Department of Fish and Game, Fresno.

Dunham R. 1961. Report on the pollution of the Mokelumne River. California Department of Fish and Game. 27 June 1961. Sacramento, Calif.

Flint RA, Meyer FA. 1977. The De Sabla-Centerville Project (FERC No. 803) and its impact on fish and wildlife. California Department of Fish and Game report. October 1977. Sacramento, Calif.

Gerstung ER. 1971. A report to the California State Water Resources Control Board on the fish and wildlife resources of the American River to be affected by the Auburn Dam and Reservoir and the Folsom South Canal and measures proposed to maintain these resources. California Department of Fish and Game. June 1971. Sacramento, Calif.

Hedgecock D, Banks MA, Rashbrook VK, Dean CA, Blankenship SM. 2001. Applications of population genetics to conservation of chinook salmon diversity in the Central Valley. In: Brown RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 1. Sacramento (CA): California Department of Fish and Game.

[IEP] Interagency Ecological Program-Steelhead Project Work Team. 1998. Monitoring, assessment, and research on Central Valley steelhead: status of knowledge, review of existing programs, and assessment of needs. Draft report. 2 November 1998. Sacramento, Calif. 37 p.

Latta R, editor. 1930–1931. Papers, publications: H.C. Bailey, pioneer California sketches. Yosemite Research Library Archives, Yosemite National Park.

Latta F. Unpublished papers, field notes. Frank Latta interview with Pahmit (William Wilson), 1 July 1933. Yosemite Research Library Archives, Yosemite National Park.

Maslin PE, McKinney WR. 1994. Tributary rearing by Sacramento River salmon and steelhead. 30 October 1994. Department of Biology, California State University, Chico. 46 p.

Northern California Power Authority. 1993. Griswold Creek Diversion Project application for license for major unconstructed project. Submitted to US Federal Energy Regulatory Commission. December 1993.

Schulz PD. 1994. Fish remains from YOL–182: a prehistoric village in the lower Sacramento Valley, October 10, 1994. Brienes, West and Schulz, P.O. Box 184, Davis, CA 95617. 18 p.

Snyder JB. 1993 Memorandum to Park Superintendent Mike Finley. Did salmon reach Yosemite Valley or Hetch Hetchy? 9 May 1993 manuscript. P.O. Box 577, Yosemite National Park. 8 p.

[USFWS] US Fish and Wildlife Service. 1998 unpublished report. Status of key Fish and Wildlife Service activities in the Battle Creek watershed. July 1998. Redding, Calif. 2 p.

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