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

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INTRODUCTION

The vast expanse of the Central Valley region of California once encompassed numerous salmon-producing streams that drained the Sierra Nevada and Cascades mountains on the east and north and, to a lesser degree, the lower-elevation Coast Range on the west. The large areas that form the watersheds in the Sierra and Cascades, and the 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 25 Central Valley streams supported at least one annual chinook salmon run, with at least 18 of those streams supporting two or more runs each year. In the Sacramento drainage, constituting the northern half of the Central Valley system and covering 24,000 sq mi (Jacobs et al. 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 tributary 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 annual rainfall conditions allowed. In the San Joaquin drainage, composing much of the southern half of the Central Valley system and covering 13,540 sq mi (Jacobs et al. 1993), none of the westside streams draining the Coast Range had adequate streamflows to support salmon or any other anadromous fishes.

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. 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 utilized of the Central Valley anadromous fishes.

In this report, we consolidate historical and current information on the distribution and abundance of chinook salmon in the major tributary streams of the Central Valley in order to provide a comprehensive asssessment of the extent to which chinook salmon figured in the historical landscape of the Central Valley region.

THE FOUR RUNS OF CENTRAL VALLEY CHINOOK SALMON

Four runs of chinook salmon occur in the Central Valley system— 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 on the basis of the upstream migration season. The presence of four seasonal runs in the Sacramento River lends it the uncommon distinction of having some numbers of adult salmon in its waters throughout the year (Stone 1883, 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, CDFG 1993). Formerly, the runs also could be differentiated on the basis of their typical spawning habitats— spring-fed headwaters for the winter run, the higher streams for the spring run, upper mainstem rivers for the late-fall run, and the lower rivers and tributaries for the fall run (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. Fisher, unpubl. data).

Prior to the 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 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 foothill reaches (Rutter 1904)— below 500 ft elevation— and most likely were limited in their upstream migration by their egg-laden and somewhat 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). A California Fish Commission report (CFC 1890) 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." 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. The spring run, in fact, was generally required to utilize 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 in order to avoid the excessive summer and early-fall temperatures of the Valley floor and foothills— at least to ~1,500 ft in the Sacramento drainage and most likely correspondingly higher in the more southerly San Joaquin drainage.[1] If they spawned in early fall, they needed to ascend even higher— at least to ~2,500-3,000 ft in the Sacramento drainage— to be within the temperature range (35-58°F) required for successful egg incubation. Spring-run fish which 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 the fish could delay spawning— set by decreasing streamflows (before the fall rains began), ripening of the eggs, and the fish's deteriorating physical condition.

The spring run was originally most abundant in the San Joaquin system, ascending and occupying the high-elevation streams fed by snow-melt where they over-summered until the fall spawning season (Fry 1961). The heavy snow-pack 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. Fisher, unpubl. data). Their characteristic life-history timing and other adaptive features enabled spring-run salmon to utilize 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 more rain-driven Sacramento system was generally less suitable for the spring run due to lesser amounts of snow melt 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 (e.g., 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 snow melt 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 (Fisher, unpubl. data); there is no evidence that winter runs naturally occurred in any of the other major drainages prior to 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, seemingly the only areas where summer flow requirements were met. A similar 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 cold-water flows (Vogel and Marine 1991, Fisher 1994)— whether from springs or from late snow-melt. The late-fall run probably spawned originally in the mainstem Sacramento River and major tributary reaches now blocked by Shasta Dam and perhaps in the upper mainstem reaches of other Sacramento Valley streams (Fisher 1994) 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, Fisher 1994).

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

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— e.g., 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 (Fisher, unpubl. 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 Cascades 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 the late 1920s and later 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 also give limited qualitative information on salmon abundance. These reports provide a valuable “mid-term” view of what salmon distributions were like in the first half of the century, after major environmental alterations had occurred and populations were significantly depleted compared to earlier times, but the survival of the populations was not yet imperiled to the extent it presently is. 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 carried out by the California Department of Fish and Game and periodically summarized in the Department’s “Administrative Reports.”

In the following section we attempt to synthesize this 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.[2] The probable original distributions were determined by considering the presence of obvious natural barriers to upstream salmon migration together with historical information (e.g., accounts of gold miners and early settlers), and they apply to the salmon populations up to the period of intensive gold mining, ca. 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 during the early part of this century, who interviewed elder Native Americans from various groups. That information pertains to the life-experiences and traditions of the native informants during the period of their youth and early adulthood, and also to the mid-life periods of their parents and grandparents from whom they received information and instruction— spanning essentially much of the middle and latter parts of the 19th century (e.g., Beals 1933, Aginsky 1943, Gayton 1948a). For the mid-term distributions, we relied heavily on the papers of Clark (1929) and Hatton (1940) and retained much

[2] Unpublished documents are listed separately, following the References section, as are persons cited for personal communication (“pers. comm.”).

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.[3] 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.

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 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 utilize the mainstems and major forks of streams (Gerstung, pers. obs.). The migration timing 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 ~15 ft high— while chinook salmon in California appear to be stopped by falls greater than 10-12 ft high (Gerstung, pers. obs.), depending on the abruptness of the drop. Furthermore, steelhead do not require as much gravel for spawning; e.g., steelhead formerly used westside streams in the upper Sacramento drainage (near Shasta Lake) that had small patches of gravel interspersed among boulder substrate, which salmon generally shunned (Gerstung, pers. obs.). 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 squawfish (*Ptychochelis 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 which 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 further upstream. The presence of non-game native fish populations above obvious barriers in some streams indicates that at least some of the natural barriers were formed subsequent to the initial dispersal of those species into the upper drainages.

DISTRIBUTIONAL SYNOPSES OF SALMON STREAMS

Kings River (Fresno Co.) Chinook salmon are known to have occurred at least periodically in the Kings River, the southernmost Central Valley stream that supported salmon. The Kings River, in the past, 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 snow-melt period, so it is most likely that the spring run was the predominant or, perhaps, the only run to occur there. The spring-run fish would have had to

[3] Agency abbreviations are: California Department of Fish and Game (CDFG); California State Board of Fish Commissioners (CFC); United States Commission for Fish and Fisheries, or U.S. Fish Commission (USFC).

ascend to high enough elevations (probably >1,500 ft) to avoid excessive summer water temperatures, going past the area presently covered by Pine Flat Reservoir. The mainstem above Pine Flat Reservoir is of low gradient (Gerstung, pers. obs.) and free of obstructions for some distance (P. Bartholomew, pers. comm.), so the salmon probably were able to ascend ~10-12 mi beyond the present upper extent of the reservoir. The upper range of the bulk of salmon migration in the Kings River probably was near the confluence of the North Fork (Woodhull and Dill 1942). There is an undocumented note of "a few salmon" having occurred much further upstream at Cedar Grove (28 mi above present-day Pine Flat Reservoir) "in the past— before Pine Flat Dam was constructed" (CDFG unpubl. notes). However, it is not clear if salmon 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, pers. comm.).

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 subgroup of the Northern Foothills Yokuts) at the junction of Mill Creek (~2 mi below the present site of Pine Flat Dam). There, the "spring salmon run" was harvested and dried for later use (Gayton 1948b). Gayton (1946) wrote: "On the lower Kings River, the Choinimni (Y) [denoting Yokuts] and probably other tribes within the area of the spring salmon run (about May) held a simple riverside 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 would seem to indicate that salmon runs in the Kings River were not uncommon, even if they did not occur every year (e.g., in years of low precipitation). Drawing on testimony from one native informant, Gayton (1948a) also reported that salmon "were well known and greatly depended upon" by the Chunut people (a subgroup of 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) 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." It is evident, therefore, that salmon entered Tulare Lake at least on occasion, where they were taken by Chunut fishers. The different tribes of Yokuts people around Tulare Lake and the lower Kings River each had territorial limits (Gayton 1948a, Latta 1977), and transgressions apparently were vigorously repulsed (e.g., Gayton 1948a, Cook 1960). Furthermore, there would have been little reason for the Chunut to have made special 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 1970). It, therefore, does not seem likely 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.

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 ca. 1911, salmon began reappearing in the Kings River— "a few" in the spring of 1911, a "very considerable run" in 1912 which ascended to Trimmer Springs (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 CDFG biologist in the fall of 1942 near the town of Piedra on the mainstem Kings River (~2 mi downstream of the mouth of Mill Creek; W. Dill, pers. comm.); those fish were notable in that they were precociously mature males— i.e., running milt (W. Dill, pers. comm.). A single ~5-inch chinook salmon (with "very enlarged testes") was later captured in September 1946 in the mainstem "about 8 miles above the junction of the North Fork Kings River (W. Dill- CDFG letter). Moyle (1970) later collected juvenile chinook salmon (~4 in total length) in April 1970 from Mill Creek, shortly 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, pers. comm.). 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. The termination of natural streamflows down the channel of the San Joaquin River since 1946, 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 Co.) Spring and fall runs of salmon formerly existed in the upper San Joaquin River, and there may also have been a late-fall run present, but all salmon runs in the San Joaquin River above the confluence of the Merced River were extirpated by the late-1940s. The spring run historically ascended the river past the present site of Kerckhoff Power House in the Sierra foothills to spawning grounds in the higher reaches (CDFG 1921). A natural barrier shortly upstream of the mouth of Willow Creek, near present-day Redinger Lake, may have posed an obstruction to salmon (E. Vestal, pers. comm.). However, there is some evidence that salmon traveled further upstream to a point just below Mammoth Pool Reservoir (~3,300 ft elevation), where habitat suitable for spring-run salmon exists. The oral history of present-day Native American residents in the region includes references to salmon occurring there (P. Bartholomew, pers. comm. based on interviews with Native American informants). Suckers presently occur in the stream up to the location of a velocity barrier ~0.25-0.5 mi below Mammoth Pool Dam, suggesting that salmon likewise could have made the ascent to that point (P. Bartholomew, pers. comm.). Based on the absence of natural barriers, it is likely that salmon entered two tributaries of the upper San Joaquin River near Millerton Reservoir— Fine Gold Creek, possibly "as far upstream [~6 mi] as opposite Hildreth Mtn", and Cottonwood Creek, which they probably ascended as least 2 mi (E. Vestal, CDFG unpubl. notes and pers. comm.).

Native Americans belonging to Northern Foothill Yokuts groups, including the Chukchansi people from Coarse Gold Creek and the Fresno River, fished for salmon in the San Joaquin River near the area of Friant (Gayton 1948b). According to Gayton's (1948b) ethnographic account, the salmon were watched for "When the Pleiades were on the western horizon at dusk", and a first salmon ritual was held by several different Yokuts tribes 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). The areas further up the San Joaquin drainage, above the Yokuts, were occupied by Monache (Western Mono) groups. Gifford (1932) stated that the "Northfork Mono", who lived on the "North Fork" San Joaquin River (also called Northfork Creek or Willow Creek), Whiskey Creek and nearby areas, fished for and ate salmon as well as trout. The Northfork Mono also were said to have held first salmon rites (Aginsky 1943). However, it is not clear how far up Willow Creek salmon ascended.

The construction and operation of Kerckhoff Dam (ca. 1920) for power generation blocked the spring-run salmon from their spawning areas upstream and seasonally dried up ~14 mi of stream, below the dam, where there were pools in which the fish would have held over the summer (CDFG 1921). Later in the 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 ~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 southest 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 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) 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." Hatton reported that 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 above Friant, where it entered a canyon was generally unsuitable, comprising mainly bedrock, "long, deep pools" and "short stretches of turbulent water." He also estimated that the planned Friant Dam would cut off 16 mi of stream where spawning occurred, which represented ~36 percent of the spawning beds with a spawner capacity of 7,416 salmon. At that time (1939), 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 elmination of spawning areas above the dam as the diversion of water from the stream channel downstream. Quoting Hatton (1940), it was "hoped that seepage from the dam and returned irrigation water will provide sufficient flow to make spawning possible." It would seem that the deleterious consequences of vestigial streamflows and polluted irrigation drainage on salmon were not yet fully appreciated at that time.

Hatton (1940) stated that the San Joaquin River where spawning occurred was "singularly free of obstructions and diversions", but there were obstructions further downstream. The lowermost barrier below the spawning beds was the Sack Dam of the Poso Irrigation District, "several miles below Firebaugh" (near Mendota), which in an average water year "destroys any possibility of a fall run up the San Joaquin" because its "compete diverson of water leaves the stream bed practically dry between that point and the mouth of the Merced River" (Hatton 1940). 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) stated that "Fifty or sixty years ago, the salmon in the San Joaquin were very numerous and came in great hordes." Indeed, it is recorded that ca. 1870 the residents of Millerton on the banks of the San Joaquin, were kept awake "by the 'myriads of salmon to be heard nightly splashing over the sand bars in the river'" (California State Historical Association 1929), the noise being "comparable to a large waterfall" (Northern California Historical Records Survey Project 1940). The site of Millerton presently lies covered by Millerton Reservoir. In reference to the fall run (and evidently steelhead), one early observer in correspondence with State Fish Commissioner B.B. Redding wrote: ..".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). The former spring 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 200,000-500,000 spawners annually" (CDFG 1990). Blake (1857) noted in reference to salmon in the vicinity of Fort Miller (just upstream of Millerton) in 1853: "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 salmon evidently was not accurate at the time, it foreshadowed events to come. Although Clark (1929) reported that a "very good run" of salmon was seen at Mendota in 1916-1917 and a "fairly good" one for 1920, "very few" fish were seen in 1928 and Clark considered the salmon in the San Joaquin River to be "fast decreasing." By then there was essentially only a spring run, the water being too low later in the year to support a fall run (Clark 1929). The decline of the salmon resource 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 2-3 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 businesss." (Frank Latta unpubl. papers, field notes). Coo-you-illik ("Sulphur Water") was a Dumna Yokuts village at the later site of Fort Miller (Latta 1977). The salmon were well-remembered by non-Native Americans also: "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).

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, both the spring run and the fall run managed to persist. Hatton (1940) reported that the fall run occurred in "some years", "making a hazardous and circuitous journey" through natural sloughs and irrigation canals, from near the mouth of the Merced River and "miraculously" entering the San Joaquin River again above Mendota weir. By 1942, the upper San Joaquin River was stated by Clark (1943) to have had "a fair-sized spring run of king [chinook] salmon for many years" and a fall run that had "been greatly reduced." In addition to those two runs, there were indications that a late-fall run formerly may have existed in the San Joaquin River (Van Cleve 1945). In 1941, a run apparently of appreciable size entered the river, starting about December 1 and continuing through at least December 10 (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). 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 more 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", clearly 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 (Fisher, unpubl. data), and the spawning migration period is known to include December in the San Joaquin basin tributaries (Hatton and Clark 1942, T. Ford, pers. comm.). Yet, an actual late-fall run may have 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 may have been suitable for supporting late-fall-run fish, which require cool-water flows during the summer juvenile-rearing period. Writing of the San Joaquin River near Fort Miller in late July, 1853, Blake (1857) noted: "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."

Fry (1961) reported that during the 1940s prior to the construction of Friant Dam, the San Joaquin River had "an excellent spring run and a small fall run." At that time the San Joaquin River spring run was considered probably "the most important" one in the Central Valley (Fry 1961), amounting to 30,000 or more fish in three years of that decade, with a high of 56,000 in 1945 (Fry 1961) and an annual value of "almost one million dollars" (Hallock and Van Woert 1959). In 1946, the sport catch in the San Joaquin Valley included an estimated 25,000 salmon produced by the upper San Joaquin River, with perhaps another 1,000 taken by the ocean sport fishery (CDFG 1955 unpubl. 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 (CDFG 1955 unpubl. document). The last substantial run (>1,900 fish) occurred in 1948 (Warner 1991). The salmon runs were extirpated from the upper San Joaquin drainage, above the confluence with the Merced River, as a direct result of the completion of Friant Dam (320 ft high) in 1942 and associated water distribution canals (viz., Madera and Friant-Kern canals) by 1949 (Skinner 1958). The 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 the ~60-mi stretch of river below Sack Dam to completely dry up (Skinner 1958, Hallock and Van Woert 1959, Fry 1961). While not attributing the collapse of the Sacramento-San Joaquin spring salmon fishery soley to Friant Dam, Skinner (1958) noted the "striking coincidence" that in the 1916-1949 (pre-Friant) period, the spring-run catch averaged 664,979 lbs (31% of the total Sacramento-San Joaquin commercial catch) and in 1950-1957 (post-Friant) it averaged 67,677 lbs (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 lbs in 1946 to a low of 14,900 lbs in 1953. Efforts by CDFG biologists to preserve the last cohorts of the upper San Joaquin spring-run salmon in 1948, 1949 and 1950— thwarted by insufficient streamflows and excessive poaching— ended in failure (Warner 1991). Since the closure of Friant Dam, highly 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 times have salmon occasionally been able to ascend to the upper San Joaquin River, the latest record being that of a single 30-in male (possibly spring-run) caught by an angler on July 1, 1969 below Friant Dam (Moyle 1970).

The 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 (CFC 1875, USFC 1876b) regarded the summertime migration of the fall 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." 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 72.1-80.7°F (considering both surface and bottom water) and maximal temperatures were 82-84°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,b). Quoting the California Fish Commission (CFC 1875): "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 to make their occasional, "miraculous" sojourns up the San Joaquin drainage mentioned by Hatton (1940). Nothing is known of the physiological and genetic basis of the seemingly remarkable temperature tolerances of upper San Joaquin River fall-run salmon, because that population has been long extinct. It is not known to what degree the remaining fall-run populations in the other tributaries of the San Joaquin basin possess the temperature tolerances and genetic characteristics of the original upper 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 upper San Joaquin River fall run. Similarly, the spring-run fish of the upper 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 utilize areas below the dam (Clark 1943). Approximately 5,000 spring-run fish were observed by Clark (1943) over-summering in pools below the dam during May-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). 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 (CDFG 1955 unpubl. document), although much lower temperatures (40-60°F) are necessary for successful incubation of the relatively temperature-sensitive eggs (Seymour 1956, Beacham and Murray 1990).

<u>Merced River</u> (Merced Co.) Both spring- and fall-run salmon historically occurred in the Merced River, although now only the fall run exists and is the most southerly occurring native chinook salmon run (CDFG 1993). According to one 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). Oral history obtained from local residents (Snyder unpubl. memorandum, 9 May 1993) indicates that salmon occurred in the area between Bagby and Briceburg near the branching of the North Fork. There is a 20-ft 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— probably approaching the vicinity of El Portal (~2,000 ft elevation). 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. Shebley (1927) stated that in 1892 "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", taking advantage of the high spring floods to surmount the low dams that were present in the river at that time. However, Shebley provided no evidence to support his statement, which was later discounted (Snyder 1993 unpubl. memo.). The absence of any clear reference to salmon in the early historical accounts of the Yosemite Valley (e.g., Muir 1902, 1938, 1961, Hutchings 1990), and the present lack of archeological and ethnographic evidence to show that native peoples subsisted on salmon in the higher elevation parts of the drainage (Snyder 1993 unpubl. memo.), seem to argue against the past occurrence of salmon there, at least in significant numbers. Snyder (unpubl. 1993 memo.), 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 (Gerstung, pers. obs.) 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, B.B. Redding of the California Fish Commission noted in 1875 that "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" (USFC 1876b). It appears, therefore, that salmon at one time and in unknown numbers had approached the vicinity of Yosemite Valley, even if they did not enter the Valley proper. For the present, the area around El Portal may be the best estimate of the historical upstream limit of salmon distribution in the mainstem Merced River, unless supporting evidence for Shebley's (1927) statement can be found.

Salmon most likely entered the South Fork Merced River at least as far as Peach Tree Bar, ~7 mi above the confluence with the mainstem, where a waterfall presents the first significant obstruction (P. Bartholomew, pers. comm.). Hardheads are limited in their upstream distribution by the waterfall, and Sacramento suckers occur even further upstream to the vicinity of Wawona (Toffoli 1965, P. Bartholomew, pers. comm.). Salmon, which often spawn in the same reaches frequented by those species (Moyle 1976, Gerstung, pers. obs.), undoubtedly reached as least as far as Peach Tree Bar. 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-ft waterfall located near the entry of Iron Creek, ~4 mi below Wawona (Gerstung, pers. obs.). The North Fork Merced River is a relatively low watershed (~1,300 ft elevation at the lower end), but there are substantial falls located ~1 mi above the mouth (T. Ford, pers. comm.; E. Vestal, CDFG unpubl. notes) which would have prevented further penetration into the drainage by salmon. This evidently 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 white-bait, not the smallest gudgeon" (Perlot 1985).

As early as 1853, a temporary dam was erected by fishermen ~10 mi below Merced Falls, thereby blocking the 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-ft high Benton Mills Dam at Bagby (built in 1859) and a later (1900) dam at Kittredge, 4 mi below Bagby (Snyder 1993 unpubl. memo). 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 (CDFG 1921). Clark (1929) stated that the existant 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 ~3 mi upriver, where there was a natural fall and the 20-ft 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 (1995), 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 (CDFG 1993). The Merced River Hatchery (operated by CDFG) is located by this dam. Fall-run spawners ascending to this point are captured at the dam's fish ladder, for use as hatchery brood stock, or are diverted into the adjacent artificial spawning channel where spawning can also occur.

Clark (1929) had reported both spring and fall runs of salmon present in the Merced River. He mentioned reports by early residents of the river who recalled great runs of migrating upriver to spawn in 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) 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; the fall-run fish 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; several hundred fish were reported in the Merced River in November 1928. According to Clark (1929), 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 now considered to be the early portion 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 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 refered 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 had 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" (CDFG 1993).

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 sizes 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 (CDFG 1993). As in other San Joaquin basin tributaries, spawning escapements in the Merced River have dropped to "seriously low levels" in recent years, numbering less than 200 fish in 1990 and 1991, including returns to the Merced River Hatchery (CDFG 1993, Fisher, unpubl. data). However, the fall run numbered over 1,000 spawners in both 1992 and 1993, and reached almost 5,000 fish in 1994 (Fisher, unpubl. data), perhaps auguring a partial recovery of the stock. The Merced River Hatchery, operated since 1971 by CDFG, has received a major fraction of the spawning run in the Merced River, accounting for 5-39% of the annual runs during the 1980s and 19-67% of the runs in 1990-1994 (Fisher, unpubl. data). Late-fall-run salmon are said to occur occasionally in the Merced River (CDFG 1993). The spring run of this river no longer exists.

<u>Tuolumne River</u> (Stanislaus, Tuolumne counties) At least spring and fall runs originally utilized the Tuolumne River. Clavey Falls (10-15 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 at the boundary of Yosemite National Park (~50 mi upstream of present New Don Pedro Dam), which is the upstream limit of native fish distribution (CDFG unpubl. 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 (CDFG unpubl. data; Moyle, unpubl. data), and spring-run salmon probably occurred throughout that reach as well. If they were present in the Tuolumne drainage, steelhead trout probably ascended several miles into Cherry Creek, a tributary to the mainstem ~1 mi 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, pers. comm.), although squawfish are found within the first mile of the Clavey River and suckers and roach occur up to 10-15 mi upstream (EA Engineering, Science and Technology 1990 unpubl. report). A large (25-30 ft) waterfall in the lower South Fork (Stanley and Holbek 1984) probably prevented further access up that fork. The North Fork, with a 12-ft waterfall ~1 mi above the mouth, likewise offered limited access. Overall, probably few, if any, salmon entered those upper reaches of the Tuolumne drainage (T. Ford, pers. comm.). The waterfalls just below present Hetch Hetchy Dam on the mainstem, ~10 mi above Preston Falls, evidently stopped all fish that might have ascended that far, for 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 further downstream (Snyder 1993 unpubl. memo.). Just as with the Merced River, there is no archeological 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 unpubl. memo.).

The first written record of salmon in the Tuolumne River is that of the Fremont Expedition of 1845-1846. Fremont's (1848) 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 Fremont's party caught the salmon or obtained them from the local native inhabitants. In any case, it would seem from the wording of the account that the fish were the beginning of a run (i.e., spring run) rather than the continuation of one which for some reason could not be procured earlier by the party. Although the bulk of the spring-run salmon migration occurs during April-June, at least in the Sacramento drainage (Fisher 1994), spring-run fish have occasionally appeared in their spawning streams in early February (e.g., in Butte Creek during 1995, F. Fisher, unpubl. data; they also were observed sometime in February 1946 in the American River, Gerstung 1971 unpubl. 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, the pioneer Edwin Bryant wrote in his journal, ."‥ 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).

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 unpubl. memo.) and undoubtedly had some impact. Wheaton Dam, built in 1871 at the site of present-day La Grange Dam, may have blocked the salmon to some degree (T. Ford, pers. comm.). La Grange Dam, 120 ft high and considered an engineering marvel when completed in 1894, cut off the former spring-run spawning areas. Mining and other activities that degraded the river habitat probably affected the salmon runs, but to an unknown degree. John Muir (1938) 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..."

Clark (1929) stated that the spawning grounds in 1928 extended from the town of Waterford to La Grange, over 20 mi 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 mi upriver, which 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 mi 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 (1995) occurs in the ~20-mi 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 (CDFG 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 sq ft (EA Engineering, Science and Technology 1992).

The California Fish Commission (CFC 1886) noted that the Tuolumne River "at one time was one of the best salmon streams in the State", but that salmon had not ascended that stream "for some years." At the time of Clark's (1929) writing, salmon generally still were "scarce" in the Tuolumne River. As of 1928, both spring and fall runs still occurred, but the spring run was inconsequential, "amounting almost to nothing" (Clark 1929). Clark reported, however, "a good run" (evidently the fall run) for 1925 that surpassed any of the runs seen in the several years prior to that. Presently, only the fall run exists in appreciable numbers in the Tuolumne River. In the past, fall-run sizes 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 (Fry 1961). Tuolumne River fall-run fish historically have comprised up to 12% of the total fall-run spawning escapement for the Central Valley (CDFG 1993). The average population estimate for the period 1971-1988 was 8,700 spawners (EA Engineering, Science and Technology 1991), but run sizes in most recent years have been extremely low— fewer than 130 spawners in each of the years 1990-1992 and <500 fish in both 1993 and 1994 (Fisher, unpubl. data).

It has been stated that "a small population" of late-fall-run fish exists in the Tuolumne River (CDFG 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-March) than is typical for fall-run fish (T. Ford, pers. comm.). 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 flows during the summer to support the juveniles (CDFG 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 belonging to fall-run fish, perhaps of hatchery origin, could also account for some of the juveniles that have been observed over-summering in the river.

<u>Stanislaus River</u> (Stanislaus, Calaveras counties). Both spring and fall runs originally occurred in the Stanislaus River. Salmon are known to have occurred in the vicinity of Duck Bar, 4.5 mi below the town of Stanislaus, which is now covered by the upper end of New Melones Reservoir. A long-time Native American resident named Indian Walker caught them there in fish traps to sell to the white community (Cassidy et al. 1981). Beals' (1933) ethnographic account states that salmon went up the Stanislaus River as far as Baker's Bridge— the location of which is unknown to us but very likely it was innundated by New Melones Reservoir. A more recent account (Maniery 1983) reports that Miwok residents of "Murphy's Rancheria", a village near the town of Murphy that was occupied ca. 1870-1920, caught salmon at Burns Ferry Bridge ("below the old road to Copperopolis") and at Camp Nine (~13 mi upstream of the town of Melones). Spring-run and perhaps some fall-run salmon probably went up the forks considerable distances because there are few natural obstacles (B. Loudermilk, pers. comm.). In the North Fork, suckers and hardhead occurred up to the confluence of Griswold Creek (Northern California Power Authority 1993 unpubl. report), so salmon may have ascended at least to that point. The North Fork Stanislaus River is accessible to salmon up to McKay's Point (~8 mi above the confluence with the Middle Fork), where the gradient steepens. Any salmon passing that point most likely were blocked 5 mi further upstream by a 15-ft waterfall, above Board's Crossing. Similarly, there are no substantial obstacles on the Middle Fork up to the reach above the present site of Beardsley Reservoir (3,400 ft elev.) (E. Vestal, pers. comm.), although the steep gradient may have deterred most salmon.

The South Fork 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 Stanislaus River, 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 (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 located in over 10 mi of stream, from the marshlands above Oakdale to Knight's Ferry. Dams on the river by that time included 20-ft 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-mi distance, the 9.3 mi between Goodwin Dam and the Power House was "only rarely accessible to salmon." Hatton 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 further than Goodwin Dam, which regulates streamflows from Tulloch Reservoir and diverts water for irrigation and power generation (CDFG 1993). Much of the spawning occurs on the extensive gravel beds in the 23-mi stretch from Riverbank upstream to Knights Ferry, which are essentially on the Valley floor (T. Ford, pers. comm.). Upstream of Knights Ferry, where the river flows throgh a canyon, spawning is concentrated at Two-mile Bar (~1 mi above Knights Ferry) but also occurs in scattered pockets of gravel (T. Ford, pers. comm.).

The California Fish Commission (1886) state that while the Stanislaus River in the past had been among the best salmon streams in the state, only occasionally was a salmon seen "trying to get over one of its numerous dams." Much later, Clark (1929) 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 these 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 the primary salmon run in the Stanislaus River, but after the construction of dams which regulated the streamflows (i.e., Goodwin Dam and, later, Melones and Tulloch dams), the fall run became predominant (CDFG 1972 unpubl. report). Fry (1961) described the Stanislaus River as "a good fall run stream for its size" but it had "almost no remaining spring run." Run-size estimates were 4,000-35,000 and averaged ~11,100 fall-run fish for the 1946-1959 period preceeding the construction of Tulloch Dam (in 1959); in the following 12-year period (1960-1971), the average run size was ~6,000 fish (Fry 1961, CDFG 1972 unpubl. report). Fall-run sizes since 1970 have ranged up to 13,621 (average ~3,600) spawners annually (Fisher, unpubl. data). The Stanislaus River fall run historically has contributed up to 7% of the total salmon spawning escapement in the Central Valley (CDFG 1993). Numbers of fall-run spawners returning to the Stanislaus River in recent years have been very low— <500 fish annually during the period 1990-1993 and 800 fish in 1994 (Fisher, unpubl. data).

Presently (1995) there is essentially only the fall run, although small numbers of late-fall-run fish are said to occur (CDFG 1993). A lesser run in the winter (most likely late-fall run fish) reportedly occurred in the Stanislaus River in earlier times (CDFG 1972 unpubl. report). One gold miner's account mentions a salmon, "which must have weighed twenty-five pounds", caught in the Stanislaus River during December 1849 (the exact date unknown, but suggested to have been just after December 19) (Morgan 1970)— a run time consistent with the peak migration period of the late-fall run, but also with the end of the fall run (Fisher 1994). As in the Tuolumne River, the occurrence of late-fall-run salmon in recent years could be due to strays moving in from the Sacramento River system.

Calaveras River (Calaveras Co.) The Calaveras River is a relatively small, low elevation drainage that receives runoff mainly from rainfall during November-April (CDFG 1993). This river was probably always marginal for salmon, and it lacks suitable habitat for spring-run fish (E. Gerstung, pers. obs.). Chinook salmon runs were known to have occurred on an "irregular basis" (CDFG 1993), although Clark (1929) reported that the Calaveras River was "dry most of the summer and fall" and so had no salmon. There was until recently an unusual salmon run in winter which spawned in late-winter and spring, but it is unknown if that run existed before the dams were built on the river. The presence of this "winter run" was documented for 6 years in the period 1972-1984 and it numbered 100-1,000 fish annually (CDFG 1993). The fish ascended to New Hogan Dam, and they held and spawned in the reach just below the dam (T. Ford, pers. comm.). Management of streamflows by the U.S. 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 (T. Ford, pers. comm.). 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 (CDFG 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 may be that the existence of salmon in this river during recent decades has been mainly the result of suitable conditions created by the dams, and perhaps their natural historical occurrence there was limited to exceptionally wet years. 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 (CDFG unpubl. data).

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). 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 seems 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]" (Sullivan 1934). Two decades later, the 49ner 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). That date is consistent with the peak migration time of the late-fall run, and although late stragglers of the fall run cannot be completely discounted, it is somewhat more likely that late-fall run fish would have been present in a physical condition that could be described as "fine."

Salmon ascended the river at least as far as the vicinity of present-day Pardee Dam (completed in 1928). Reportedly, a large waterfall (30+ ft high) was present at Arkansas Ferry Crossing, 1 mi downstream of the Pardee Dam site in a narrow rocky gorge (R. Nuzum, pers. comm.), and it may have posed a serious, if not complete, 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, pers. comm.). Spring-run salmon undoubtedly would have ascended past that point in order to reach higher elevations where water temperatures were suitable for over summering. Steelhead were believed to have spawned mostly in the reaches above Pardee Dam (Dunham 1961 unpubl.). 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), 7 mi beyond Electra, is a complete fish barrier (Woodhull 1946); native fish such as hardhead and squawfish are known to have reached it (Woodhull 1946), so the falls can be reasonably taken as a likely upstream limit for salmon and steelhead as well.

However much the salmon runs had recovered from the habitat degradation of the gold mining era, the runs were believed to have started another decline after Woodbridge Dam (15 ft high) was constructed in 1910 at the town of Woodbridge (Dunham 1961 unpubl. report). Fry (1961) 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 extended from the river mouth above tidewater for ~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 only a fall run occurred, "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), 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.

The construction of Pardee Dam in 1928 presented an insurmountable obstacle, cutting off the upper spawning areas (Dunham 1961 unpubl. 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, ~10 mi below Pardee Dam. They spawn in the reach from Camanche Dam downstream to Elliott Road (J. Nelson, pers. comm.), and 95% of the suitable spawning habitat is within 3.5 mi of Camanche Dam (CDFG 1993). Prior to the completion of Camanche Reservoir (1964), the fall run also spawned upstream from Camanche Dam up to the canyon ~3 mi below Pardee Dam (CDFG 1993). The Mokelumne River Hatchery, operated by CDFG, was built in 1965 as mitigation specifically for that spawning stock component (CDFG 1993; J. Nelson, pers. comm.).

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. Fry also stated that the spring run appeared to be "practically extinct." Over the period 1940-1990, total annual run sizes ranged between 100-15,900 fish (CDFG 1993); the runs averaged 3,300 spawners during 1940-1963 (prior to impoundment of Camanche Reservoir) and 3,200 spawners during 1964-1990 (post-impoundment) (CDFG 1993). The most recent annual run-size estimates for the fall run have been 367-3,223 (average ~1,760) total spawners during 1990-1994, with hatchery returns composing

16-69% of the run; the number of natural spawners during this period ranged from 182 fish (in 1991) to 1,305 (in 1994) and averaged 756 fish (Fisher, unpubl. data).

Cosumnes River (El Dorado Co.) The Cosumnes River, a branch of the Mokelumne River, historically has been an intermittent stream and from earliest times offered limited access to salmon. Yet, the river derives its name from the Cosumne tribe of the Valley Yokuts— the "People of the Salmon Place" in the language of the neighboring Miwok people (Latta 1977). Only a fall run is definitely known to have occurred in this river. There is no indication that a spring run ever existed here (J. Nelson, pers. comm.) and the atypical streamflow regime and low elevation of the drainage make it unlikely that there was one. There is a 30-ft falls a half mile below Latrobe Highway Bridge which has been viewed as a barrier, although the salmon probably did not usually reach that far upriver. If any fish were able to surmount that obstacle, they would have been stopped by a second waterfall (50 ft high) at the Highway 49 crossing 8.5 mi further upstream. Because of the limited time available for migration into this stream, it is likely that few fish ascended past Michigan bar (rm 31).

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-ft 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, pers. comm.). 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 (Gerstung, per. obs.). The sole dam in the river— Granlees Diversion Dam (located 1 mi 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 (CDFG 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 ~1,000 fish, but recent runs have numbered no more than 100 individuals (CDFG 1993), when there was water in the streambed. 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 for at least the last four spawning seasons (1991-1994) (Fisher, unpubl. data).

American River (Sacramento, Placer counties) Spring, fall and posssibly late-fall runs of salmon ascended the American River and its branches and were blocked to varying degrees by a number of natural obstacles, at least one which no longer exists. In the North Fork, steelhead trout were observed during CDFG surveys in the 1930s at Humbug Bar, above where the North Fork of the North Fork enters (CDFG unpubl. data); because there are no substantial falls below that point, spring-run salmon no doubt also easily ascended that far. Mumford Bar, ~7 mi 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). If the salmon, like steelhead trout, were able to surmount the waterfall at Mumford Bar, they would have had clear passage ~4 mi further upstream to a 10-ft waterfall at Tadpole Creek (2,800 ft elevation), which is too steep for kayakers to boat over (Stanley and Holbek 1984). If salmon were able to jump that waterfall, their upper limit would have been another 7 mi upstream at the 60-ft falls at Royal Gorge (4,000 ft elev.), which likely was the uppermost barrier to steelhead (CDFG unpubl. data). That uppermost limit would accord with Beals' (1933) statement that salmon reportedly ranged above the elevational limit of permanent habitation (~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, ~3 mi above the confluence with the North Fork, obstructed the salmon at least to some degree (Angel 1882). 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." That scene was not exceptional, for the "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", and "During these times, the Indians supplied themselves with fish, which they dried in the sun" (Angel 1882). It is likely that the dense aggregations of salmon harvested by the native people below the natural obstacles were fall-run fish, impeded by the low fall-season streamflows. The spring run, ascending during the spring flood flows, presumably would have been able to transcend some of those same obstacles. 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 presently take as the historical upstream limit. Steelhead were observed in the Rubicon River during the early CDFG surveys, but a 15-ft waterfall ~4-5 mi 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, below which they concentrated; large numbers were harvested there by gold miners and Native Americans in 1850 and 1851 (CFC 1875). As recounted by Special Indian Agent E.A. Stevenson (31 December 1853 letter to Superintendant of Indian Affairs T.J. Henley; in Heizer 1993), "I 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." The site of Salmon Falls is now covered by Folsom Reservoir, and there has been disagreement on whether the 20-ft 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. 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 (CDFG unpubl. notes) and by another to allow the salmon to go further upstream, but the latter attempt was said to have ended in failure (Cassidy et al. 1981). The California Fish Commission report for 1888-1890 (CFC 1890) mentions "the removal of obstructions at Salmon Falls, in the American River." 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" (CDFG unpubl. notes). However, there is evidence that salmon did in fact ascend the South Fork past Salmon Falls in earlier times, prior to 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). Based on a review of that and other documents, Gay (1967) 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) states: "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" (Steele 1901). Also, Voegelin (1942) 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 (~5 mi 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 is that the fish were spring-run, becoming obtainable as streamflows dropped during the summer, and also that there was an annual first salmon ceremony— indicating that a regular run of salmon went up the South Fork American River. Furthermore, Beals (1933), 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— i.e., 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-ft waterfall, with an incline of 45° (Gerstung, pers. obs.) at Eagle Rock, ~12 mi 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. The vicinity of Eagle Rock (4,600 ft elev.), therefore, most likely was the approximate 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, ~257 million cubic yards of gravel, silt and debris from mining operations were washed into the American River (Sumner and Smith 1940, citing Gilbert 1917). Again quoting Indian Agent Stevenson (31 December 1853 letter, in Heizer 1993): "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, ~7 mi above the confluence with the South Fork, "and fried salmon was no uncommon dish" (Morgan 1970). By 1860 a sand bar had formed across the mouth of the American River on the Sacramento River (CDFG 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) 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 (1886) wrote: "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."

Somewhat later, the construction of dams that lacked adequate fish passage facilities caused the further diminishment of the runs (Gerstung 1989). The 68-ft 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-ft 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-ft high North Fork Debris Dam (completed in

1939), 2 mi 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) stated that the run of salmon in the American River had "always been a late-fall migration", although he provided no further details, and he also noted that this river "[had] known great runs." An early gold miner noted salmon migrating up the American River ~7 mi east of Sutter's Fort on 1 December 1848, of which "thirty-five splendid salmon" were procured by "well-directed rifle-ball" (Buffum 1959). 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-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, posssibly 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 unpubl. 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 ~1 mi 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 re-establish 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 unpubl. report). The spring-run count dropped to 42 fish in 1945, 16 in 1946, and 3 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 unpubl. 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 unpubl. report).

Fry (1961) noted the presence, at least through 1951, of "a small spring run" which became mixed with the "much larger fall run" during spawning. Total run sizes were 6,000-39,000 spawners annually during the period 1944-1959; these comprised mainly the fall run but included "a small but unknown proportion of spring run fish" in the years when the total counts exceeded 30,000 (Fry 1961). During 1944-1955, an estimated average of 26,500 salmon (range 12,000-38,652) spawned annually in the mainstem American River below the town of Folsom; ~73% of the spawners utilized the 5-mi stretch between Old Folsom Dam and the present site of Nimbus Dam, and the remainder spawned further downstream (Gerstung 1971 unpubl. report). In recent decades, spawning escapements of the fall run have ranged from 30,000 to 90,000 annually (Gerstung 1989); spawning escapements averaged 43,200 fish during 1980-1989 and 23,350 fish during 1990-1994 (range ~10,600-36,200 fish in the latter period) (Fisher, unpubl. data). The fall run formerly spawned not only above the site of Nimbus Dam but above Folsom Dam as well (J. Nelson, pers. comm.). 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, pers. comm.); the habitat downstream of Watt Avenue presently consists mainly of pools unsuitable for spawning (Gerstung, pers. obs.).

<u>Bear River</u> (Placer Co.) The Bear River, the second largest tributary to the Feather River, formerly contained salmon, but evidently only a fall run. The run reportedly was "substantial" (CDFG 1993) but has not occurred in its former numbers for decades (J. Nelson, pers. comm.) They 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, pers. comm.). 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, pers. comm.). 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) stated 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 ~9 mi 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 (CDFG 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). The impact on the salmon runs extant at that time would have been catastrophic, and undoubtedly accounts for the apparent historical scarcity of salmon prior to Clark's (1929) assessment. Indeed, it was written: "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). The change in the Bear River was so profound that the California Fish 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).

Presently, the fall run occurs only occasionally, when heavy rains and dam spillage provide adquate flows (CDFG 1993). At those times, the run may number in the "hundreds" (CDFG 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 ~6 mi to a point near Highway 65, although there are additional spawning gravels extending 4-5 mi further downstream to Pleasant Grove Road (J. Nelson, pers. comm.). There is no suitable upstream holding habitat for spring-run salmon in the Bear River (J. Nelson, pers. comm.).

<u>Yuba River</u> (Yuba Co.) Both spring and fall runs originally occurred in the Yuba River. 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). 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). 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 (also called "salmon-trout" in early writings) occurring further upstream at Downieville at the mouth of the Downie River (CDFG file records). In their historical account of Sierra County, Fariss and Smith (1882) related the following episode: "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). The California Fish Commission (CFC 1875) stated that in 1850 and 1851, "large quantities [of

salmon] were taken by the miners and by Indians … as far up as Downieville on the Yuba", as well as 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 steelhead and spring-run salmon most likely were able to traverse that stretch as well. The steelhead probably ascended the higher gradient reaches further up and their absolute upstream limit would have been Love Falls, but salmon most likely did not reach as far. Except for a 10-ft falls in the lower reach of the Middle Fork Yuba River, there are no significant natural obstructions and salmon therefore may have 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 CDFG survey in 1938 (CDFG unpubl. data). Steelhead were found as far upstream as the mouth of Bloody Run Creek near Moores Flat (CDFG unpubl. data). Whether salmon also were able to ascend that far remains conjectural because direct information on their distribution is lacking and it is uncertain if many of them were able to surmount the 10-ft falls on the lower river. 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 CDFG surveys were conducted in the 1930s. There are records of salmon occurring within 1-2 mi upstream of the mouth of the South Fork Yuba River (CDFG unpubl. data). A substantial cascade with at least a 12-ft drop, located 0.5 mi below the juncture of Humbug Creek (California Resources Agency 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 comformation to cascades on other streams which salmon are known to have surmounted (P. Lickwar, pers. comm.). Steelhead are known to have ascended further up the South Fork as far as the juncture of Poorman Creek near the present town of Washington (CDFG unpubl. data), and perhaps 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 5-6 mi in past decades (e.g., in the 1960s; Gerstung, pers. obs.), 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 (Gerstung, pers. obs.), 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 (1850-1885) (CDFG 1993), and the effects on the salmon runs were undoubtedly severe. Indeed, by 1876 the channel of the Yuba River reportedly had become completely filled and the adjoining agricultural lands covered with sand and gravel (CDFG 1993)— a marked deterioration of the river as salmon habitat. Chamberlain and Wells (1879) 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 basin (Sumner and Smith 1940, citing Gilbert 1917).

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 further 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 further 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 further upriver to spawn (Clark 1929). Daguerre Point Dam (15 ft high), located ~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"; 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 (Sumner and Smith 1940). Prior to 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). 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) 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, the low-water conditions remained as of 1959 (Fry 1961). Construction of Englebright Dam 12.5 mi further upstream (282 ft elev.) in the late-1930s eliminated much spring-run salmon habitat and "severely reduced the spring run" (CDFG 1990). Englebright Dam presently is the upstream limit of salmon distribution. Although most of the salmon spawning habitat occurs in the 7.8 mi of river on the open Valley floodplain downstream of Daguerre Point Dam (CDFG 1993), the greater part of the run now generally spawns above Daguerre Point (J. Nelson, pers. comm.). 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, pers. comm.). The spring run, when the fish were common in the recent past, spawned in the area between Engelbright Dam and Highway 20 (J. Nelson, pers. comm.).

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). At the time of Clark's (1929) report, a fall run occurred in late fall and there was an occasional, "slight" spring run. He 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." Fry (1961) reported fall-run sizes of 1,000-10,000 fish for the period 1953-1959. The assessment by the California Department of Fish and Game (CDFG 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 sizes during the period 1953-1989 ranged within 1,000-39,000 fish and averaged 13,050 annually (CDFG 1993). More recently (1990-1994), annual run-size estimates for the fall run have varied from 4,000 to ~36,200 spawners (Fisher, unpubl. data). Fry (1961) noted that the spring run had "virtually disappeared." A remnant spring run has managed to persist up to now (1995) in "minimal numbers" (J. Nelson, pers. comm.), but the run has been genetically mixed with the fall run due to spatial overlap of their spawning grounds, as has been the case also in the Feather and American rivers (J. Nelson, pers. comm.). These mixed spring-run fish are now present in "minimal numbers" (J. Nelson, pers. comm.).

<u>Feather River</u> (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. R.H. Buckingham, of the California Fish Commission, 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." 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, pers. comm.), 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.). Copies of early correspondence sent to the CDFG state that large numbers of spring-run fish ("thousands") entered the North Fork, most of which were stopped by Salmon Falls ~2-2.5 mi above the town of Seneca (CDFG letters no.1, no.2), although a few fish were able to surmount the falls and proceed further upstream (CDFG letter no.1). Flows from the many springs that fed the Lake Almanor area (formerly Big Meadows), together with streamflows from further up the North Fork, undoubtedly were sufficient for salmon to have ascended through the lakebed area and up the North Fork another 6 mi or more (J. Nelson, pers. comm.). 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, pers. comm.). Spring-run salmon are also known to have ascended Indian Creek, a tributary of the East Branch of the North Fork, at least as far as Indian Falls (near the junction of Highways 89 and 70); they concentrated there and were harvested by Native Americans, although the falls were not necessarily the upper limit of their distribution in that stream (J. Nelson, pers. comm.). In reference to two other North Fork tributaries, Hanson et al. (1940) stated that the quality of spawning habitat was good in Yellow Creek and excellent in Spanish Creek, although by that time salmon were blocked from reaching the streams by a diversion dam downstream. 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 above the mouth of Spanish Creek (R. Flint, pers. comm.) possibly barred salmon from ascending that stream. In the Middle Fork Feather River, the salmon were stopped shortly above Lake Oroville by Bald Rock Falls (18 ft high) and Curtain Falls (30 ft) immediately above. Spring-run salmon were observed spawning below Bald Rock Falls in the 1960s before Oroville Dam was built, and fishermen often caught large numbers of salmon from the pool below the falls (Gerstung, pers obs.). In Fall River, a tributary of the Middle Fork, the 640-ft Feather Falls ~1 mi above the mouth certainly was a barrier. The South Fork Feather River, according to Hanson et al. (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. Prior to 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 6 mi below Oroville was a 5-ft 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 8 ft 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) stated that both spring and fall runs were "very heavy in the Feather River previous to the building of obstructions." Clark asserted that early mining operations may have reduced the runs "somewhat", but that it was the building of dams that had "about destroyed the spring run." However, the impact of early mining operations on salmon habitat, while not quantifiable, nonetheless was undeniably substantial during their heyday. John Muir (1938), referring to water turbidity as he traveled along the Sacramento River wrote in November 1877:

.”..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 (1883) 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): “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 in 1904 Rutter 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” (Rutter 1904).

Clark described the fall run as “large, although not extremely abundant” and having “fallen off in the last few years.” He suggested that the salmon populations showed a 3- or 4-year cycle, based on statements by river residents. Fry (1961) reported run-size estimates for the fall run of 10,000-86,000 fish for the period 1940-1959, and of 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 prior to 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 orginal spring-run habitat (CDFG 1993). Currently, the fall run has its upstream limit at Oroville Dam fish barrier, spawning from there downstream to a point ~2 mi above the Gridley Road crossing (J. Nelson, pers. comm.). There is also a hatchery-sustained population of “spring-run” fish that has been genetically mixed with the fall run (Fisher 1994) and which spawns in the 0.5-mi stretch between the fish barrier immediately below Oroville Dam and downstream to Highway 7 (J. Nelson, pers. comm.). The hybrid spring-run fish hold over the summer in deep pools within the so-called “low-flow” section of the river between Thermolito Diversion Dam (5 mi below Oroville Dam) and the downstream Thermolito Afterbay Outlet (CDFG 1993). They are spawned artificially in the Feather River Hatchery and also spawn naturally in the river during late-September to late-October (CDFG 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 (Fisher, unpubl. data).

The Feather River Hatchery, located at the town of Oroville, was built by the California Department of Water Resources to mitigate for loss of upstream spawning habitat of salmon and steelhead due to the building of Oroville Dam (CDFG 1993). The California Department of Fish and Game began operation of the hatchery in 1967 (CDFG 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 (CDFG 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 prior to the construction of Oroville Dam (CDFG 1993). The hybrid spring-run stock has increased since the early 1980s and numbered >5,000 fish in 1989 (Campbell and Moyle 1991). The higher numbers for the more recent period are attributed to the consistent supply of cold water to the hatchery and to the "low-flow" section of the river (CDFG 1993). Fall-run fish also have increased since completion of Oroville Dam, averaging 39,100 spawners prior to the project and 51,400 fish afterwards (CDFG 1993). In addition, anglers are estimated to have harvested 10,000 fish (spring and fall runs combined) each year in the past decade (pre-1993) (CDFG 1993). Fall-run sizes in the most recent period 1990-1994 have averaged 40,390 fish annually (range ~31,100-51,400), including both hatchery and natural spawners, compared to an annual average of 50,390 fish (~30,500-69,000) during the 1980s (Fisher, unpubl. data).

The CDFG 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 (CDFG 1974). The Feather River Hatchery received returning age-3 and age-4 adults for two generations (during 1973-1978) following the plant, but the run subsequently failed to persist.

<u>Butte Creek</u> (Butte Co.) Spring and fall runs of salmon, and evidently a late-fall run, historically utilized Butte Creek. The spring run ascended at least as far as approximately the present site of Centerville Head Dam near DeSabla. PG&E company employees at one time had reported salmonids migrating past the site to areas upstream (J. Nelson, pers. comm.), but it is not known how much further upstream they went, or whether they were salmon or steelhead. A waterfall (25+ ft high) ~0.5-1 mi 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 CDFG spawning survey in early 1995 (J. Nelson, pers. comm.) indicates that some portion of the spring run historically may have spawned in reaches further upstream. Steelhead are believed to have ascended as far upstream as Butte Meadows (Flint and Meyer 1977 unpubl. report), but it is likely that the salmon did not reach that far (J. Nelson, pers. comm.). Clark (1929) 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 unpubl. 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-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. He 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. Presently, there are 10 diversion dams in Butte Creek above Butte Slough that divert water for various uses (e.g., power generation, irrigation, domestic supply), and all impair salmon migration— in some cases by dewatering sections of the stream (CDFG 1993). These barriers affect the upstream migration of the different runs to different degrees, because of seasonal variation in streamflows; e.g., fall-run fish are most affected, having to migrate when flows are inadequate to allow passage over the barriers.

According to Hanson et al. (1940), Butte Creek reportedly 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. Fry (1961) noted that Butte Creek had a spring run but "almost no fall run", 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 the period 1953-1959. As late as the 1960s, the spring run numbered >4,000 in Butte Creek, with smaller numbers of fall and late-fall fish (CDFG 1993). More recent annual estimates of spring-run numbers range from <200 to >1,000 adults (CDFG 1993). The fall run remains small, numbering "a few fish to as many as 1,000" (CDFG 1993) because of the very low late-summer and fall flows (Fisher, pers. obs.). There are also late-fall-run salmon in Butte Creek, but their numbers are unknown (CDFG 1993).

The fall-run salmon generally spawn below the Parrott-Phelan Dam (J. Nelson, pers. comm.). Unlike spring runs in other streams, spring-run fish in Butte Creek presently spawn in the lower part of the creek at relatively low elevation (~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 ~2000-ft elevation (Fisher, unpubl. data). Although the spring run in Butte Creek migrates and spawns 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 (CDFG 1993), and the remaining fraction remains in the stream until the following fall (1 yr after they had been spawned) (Fisher, pers. obs.). This is in contrast to the pattern seen in streams where spring-run fish spawn in the colder, high-elevation reaches (i.e., 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-October (Fisher, unpubl. data). Spring-run adults are present in Butte Creek in early February, March and April, in contrast to Feather River "spring-run" (hybrid) fish which do not enter that river until May or June.

<u>Big Chico Creek</u> (Butte Co.) 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 (CDFG 1993). 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 9 mi 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-ft falls in the Iron Canyon area created by rocky debris from a rock slide that occurred around the time of the San Francisco earthquake of 1906— 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 further 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, ~0.5-1 mi above the crossing of Ponderosa Way, although with high enough streamflows the fish can ascend a half mile further upstream (J. Nelson, pers. comm.). 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, pers. comm.).

The average annual run-size of the spring run is believed to have been <500 fish during the 1950s-1960s, but is now considered to be only a remnant (CDFG 1993). The fall and late-fall runs recently have been highly variable, and presently the fall run occurs in very low numbers due to the lack of water in late summer and fall (CDFG 1993). The Iron Canyon fish ladder was damaged by high flows during the winter of 1994-95, thereby blocking the spring salmon run in

1995; in that year, ~100 salmon were captured below the obstruction and transported further upstream (J. Nelson, pers. comm.) 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 (Fisher, unpubl. data). Intensive pumping of water from lower Big Chico Creek for irrigation takes a heavy toll of young salmon migrants during all but very high streamflow conditions and is likely responsible for the recent population declines in this stream.

<u>Deer Creek</u> (Tehama Co.) 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 Ishi himself was said to have "used a salmon spear most expertly" (Pope 1918).

Prior to the 1940s, the spring-run salmon salmon ascended Deer Creek for ~40 mi from its mouth up to the 16-ft high Lower Deer Creek Falls (Hanson et al. 1940), located ~1 mi below the mouth of Panther Creek. According to Hanson et al. (1940), salmon were never known to have passed Lower Deer Creek Falls. Clark (1929) stated that spawning beds extended from the creek mouth (near the town of Vina) to about 10 mi into the foothills, which he described as "a good spawning ground when there is water"; he was, however, evidently referring only to the fall run.

Clark (1929) reported the presence of two irrigation diversion dams on the creek: Stanford Vina Dam, ~3 mi east of Vina, 5 ft high but with a fish ladder and screens installed on the irrigation ditches, and Deer Creek Irrigation District Dam, 8 mi 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), there was a "small spring run" but "quite a large fall run" and salmon had been "very numerous" in Deer Creek "until the diversion dams removed 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 (e.g., Needham et al. 1943; Fisher, pers. obs.). 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 et al. 1943, Moffett 1949). By the end of 1943, salmon were able to ascend ~5 mi further upstream to Upper Deer Creek Falls, a "sheer drop" of ~20 ft (Hanson et al. 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 (Moyle, pers. obs.). 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 et al. 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 (CDFG 1993). In recent years, most of the flow in the lower 10 mi 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 (CDFG 1993). Although all of the diversion structures have fish screens and fish ladders, inadequate flows sometimes impede or prevent the upstream passage of salmon (CDFG 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 ~2,900 ft elevation), which lies between Lower Deer Creek Falls and the U.S. Forest Service (Potato Patch) Campground further 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 (Fisher, pers. obs.).

Fry (1961) reported spring-run population estimates of <500 to 4,000 fish for the period 1940-1956, and fall run estimates ranging from <500 to 12,000 fish for the period 1947-1959. From 1950 onward, the number of fall-run spawners has ranged over 10-12,348 fish annually, averaging ~600, but since 1985 has numbered 16-900 fish, averaging ~300 (Fisher, unpubl. data). The spring run has varied within 77-3,500 fish (average ~1,360) annually since 1950, and within 77-1,500 fish (average ~550) since 1980 (Fisher, unpubl. data). The spring-run population in Deer Creek is one of only four remaining naturally spawning spring-run chinook populations in California considered to be genetically pure and demographically viable (CDFG 1990)— the only other Central Valley population being the one in nearby Mill Creek.

<u>Mill Creek</u> (Tehama Co.) Both spring and fall are present in Mill Creek, and occasionally late-fall run fish also occur (CDFG 1993). Clark (1929) described Mill Creek as “a celebrated salmon stream” that had “some very large runs.” Clark (1929) stated that the spawning beds extended from the U.S. Bureau of Fisheries egg station and hatchery (located ~1 mi above the creek mouth) for a distance of 2 mi to Clough Dam. Most habitat for salmon, either for holding or spawning, is currently viewed as extending from the mouth of Little Mill Creek (~1,500 ft elevation) up to the area around Morgan Hot Spring (~5,000 ft) (Fisher, pers. obs.). Some spring-run salmon in Mill Creek reportedly spawn in stream reaches well in excess of 5,000 ft elevation (CDFG 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 (Fisher, pers. obs.).

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 further downstream the lateral influx from coldwater springs results in cooler temperatures (Fisher, pers. obs.). 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 (CDFG 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-ft high 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 7-ft high dam further 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. Presently, there are three dams in the lower eight miles of the creek which divert most of the natural flow (CDFG 1993). All three dams have fish screens, and the lowermost and uppermost dams have operative fish ladders (CDFG 1993). However, the fish ladder on Clough Dam (the middle and tallest dam) functions poorly during certain flow conditions (CDFG 1993) and may therefore impede upstream migration.

Clark (1929) noted that salmon abundance in this creek was reflected by the egg takes at the U.S. 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 (CDFG 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" (i.e., 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) 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 underestimated their presence. Fry (1961) reported spring-run numbers of <500 to about 3,000 fish in the 1947-1959 period, while the fall run ranged between 1,000-16,000 spawners. Fry stated that most of the fall run spawned below Clough Dam, while "for all practical purposes the entire spring run" went upstream past the dam.

In recent decades, the spring-run population size has varied from zero fish, during the severe drought in 1977, to 3,500 fish in 1975 (CDFG 1993, Fisher, unpubl. data), but the trend has been downward from an annual average of 2,000 fish in the 1940s to ~300 in the 1980s (CDFG 1990). Since 1983, the spring run has ranged between 73 and 844 spawners annually, averaging ~300 (Fisher, unpubl. data). Fall-run sizes have ranged between 0 and 16,000 spawners since 1952, usually hovering near 1,500 fish (Fisher, unpubl. data). The CDFG (1993) reported an average annual fall-run size of 2,200 fish for the 38 years of record. In the last decade (1985-1994), the fall run has numbered from the hundreds up to ~4,200 fish, but the run has been absent during some years due to low seasonal streamflows (Fisher, unpubl. data). As in Deer Creek, the spring and fall runs are separated temporally, the fall run ascending the creek during fall flows well after the spring-run fish have finished spawning (Fisher, pers. obs.). 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 posssibility of hybridization (CDFG 1990). Late-fall run salmon have been occasionally observed spawning in the lower reaches of the creek (CDFG 1993).

<u>Antelope Creek</u> (Tehama Co.) 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 ~5-6 mi to the vicinity of the Ponderosa Way crossings— their probable historical upper limit— beyond which there is little suitable habitat (Fisher, pers. obs.).

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

The spring run formerly numbered 200-300 fish annually, with lows down to 50 fish (Fisher, unpubl. data). The CDFG (1993) gave an estimated historical run size of 500 fish No regular estimates of run size 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; 2-3 individuals at most have been seen in the last few years. The fall run in Antelope Creek generally has been small. During the period 1953-1984, the fall run ranged in size between 50-4,000 fish, with an annual average of ~467 fish (CDFG 1993). Population estimates have not been made in recent years due to the scarcity of the salmon, and the run may be extirpated (CDFG 1993).

Battle Creek (Tehama Co.) Both spring and fall runs of salmon originally occurred in Battle Creek, and there is evidence that a winter-run was also present. Rutter (1904) reported the capture in September and early October of newly emerged fry of a size that could only have been the winter run, and in 1939 Needham et al. (1941) observed salmon spawning in Battle Creek during May and June— 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 cold-water flows required for the summertime spawning and rearing of the winter run, despite Slater's (1963) assertion that the winter run would not normally spawn successfully in Battle Creek, or in Deer and Mill creeks, because of high (>70°F) water temperatures during the summer. However, the winter run was largely eliminated after hydroelectric development of the creek in 1910-1911, which cut off the spawning habitat. A 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 CDFG (1990). However, spring-run fish have been observed in more recent times (including 1995) passing the Coleman National Fish Hatchery at the fish barrier dam (T. Healey, pers. comm.). 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, pers. comm.).

Surveys conducted prior to the construction of Shasta Dam indicated that the reaches above Coleman National Fish Hatchery could support >1,800 spawning pairs of salmon (CDFG 1993). The North Fork of Battle Creek, especially Eagle Canyon, contains deep, cold pools— ideal summer holding habitat for spring-run salmon (CDFG 1993), and significant areas of spawning gravel have been determined to exist from Coleman Powerhouse on the mainstem up to Macumber Dam on the North Fork and on the South Fork between South Powerhouse and South Diversion Dam (CDFG 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 upstream as Volta Powerhouse above Manton (T. Healey, pers. comm.). Hanson et al. (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) reported that Battle Creek had a fall run and a "small" spring run. As of 1928, there was a U.S. Bureau of Fisheries egg-collecting station and hatchery (Battle Creek Hatchery) located about 1.5 mi above the creek mouth. The station collected eggs from the fall run but allowed the spring run to pass upstream (Hanson et al. 1940). Spawning by spring run occurred in the 5-mi 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 6 mi 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 ~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.

Natural spawning of salmon in Battle Creek presently occurs in the stretch between the creek mouth and the Coleman National Fish Hatchery weir 6 mi above the mouth, and is "still significant" (CDFG 1993). The salmon for the most part are blocked at the hatchery, and natural spawning that formerly occured upstream has been largely eliminated by this blockage and by low flows due to hydropower operations of Pacific Gas and Electric (CDFG 1993). There are presently 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 (CDFG 1993).

The records for egg takes (for the fall run) at the U.S. Bureau of Fisheries egg station indicated peak spawner abundances generally occurring in the period 1896-1907; 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), the spring run, which was allowed to spawn naturally in the creek, amounted to "almost nothing"; only six or seven spring-run salmon were seen in 1928. The old Battle Creek Hatchery, which took fall-run spawners from the creek, operated through 1945 (Fry 1961). The larger Colemen 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 Hatchery received most of its fish (both spring- 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). Coleman Hatchery started taking fall-run fish locally from Battle Creek in 1946 (Moffett 1949, Fry 1961).

During the period 1946-1956, the spring run numbered ~2,000 fish in most years (Fry 1961, Campbell and Moyle 1990). The spring run has since been either extirpated or is nearly so (Campbell and Moyle 1990). 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 2-mi stretch below Coleman Hatchery. Numbers of fall spawners ranged over 3,000-30,000 fish and averaged 15,000 during 1946-1959 (Fry 1961). In 1995, approximately 1,000-4,000 fall-run salmon ascended past the Coleman Fish Hatchery Dam (CDFG unpubl. data).

The Coleman 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 relies on obtaining late-fall spawners from the Keswick fish trap below Keswick Dam on the Sacramento River.

<u>Mainstem Sacramento River</u> and <u>Upper (Little) Sacramento River</u> (Solano, Yolo, Sacramento, Sutter, Colusa, Glenn, Butte, Tehama, Shasta counties) The Sacramento River, regarded by Clark (1929) as "the most important salmon stream in the state" and by Fry (1961) 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.

Salmon originally ascended the Sacramento drainage into the Upper, or Little, Sacramento River (called the Destruction River in some early accounts) in large numbers at least to the falls near the town of Sims, ~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), 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." 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) reported that in July 1871 “hundreds of salmon, averaging 15 pounds apiece”, were caught by anglers 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) upriver of Sims, between Castle Crag depot 5 mi south of Dunsmuir and Shasta Retreat ~1 mi above Dunsmuir (Voegelin 1942). According to one Wintu informant, the salmon fishing activities involved “200-300 people” and lasted 2-3 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, where several spring-fed streams enter the Upper Sacramento River from the east (Mt. Shasta). Rutter (1904) 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 plantings of salmon fry into the Upper Sacramento from Sisson (Mount Shasta) Hatchery, a practice started in 1888 (CFC 1890, Shebley 1922). However, salmon were abundant enough in the remote reaches of the Upper Sacramento River prior to any hatchery plantings to gain notice in the first report of the California Fish Commission (CFC 1871): “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.” 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); this statement likewise antedates any possible results from plantings of young salmon in the Upper Sacramento River in 1888 and later, due to the minimum generation time of three years for chinook salmon.

Both fall and spring runs occurred in the Upper Sacramento River, and the winter run was reported to have spawned in the headwaters near Mt Shasta (Stone 1874). The late-fall run, with its requirement of cool summer flows for fry and juvenile rearing, also can be inferred to have ascended at least the lower reaches of the Upper Sacramento where such flows existed. Stone (1874) stated that the 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 exception being the McCloud River). Clark (1929) described the Upper Sacramento River as an “ideal spawning stream” with “wonderful spawning beds” along its entire length. He stated that “the salmon were extremely abundant” prior to construction of the Southern Pacific Railroad through the Sacramento Canyon, and that “the run was almost destroyed” by the construction work ca. 1884-1887. 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), 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.” 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-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 et al. (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 et al. (1940) for other streams generally are lower than the run sizes that subsequently have been observed for those streams (Fisher, unpubl. data).

On the mainstem Sacramento River on the Valley floor, the Anderson-Cottonwood Irrigation District (ACID) diversion dam (built 1917) at Redding was an almost complete barrier to salmon during the irrigation season (April-October) for about 10 yrs (1917-1927) (Hanson et al.

1940). Despite the contention by the ACID authorities that an open section of the dam was adequate to allow the passage of salmon (CFGC 1921), it was 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). Clark (1929) 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, probably was not significantly affected. After installation of a new fish ladder on the dam, reportedly "quite a number of salmon" passed over, "but nothing to compare with conditions before the dam was constructed" (Clark 1929). The ACID dam continues to pose some fish-passage problems (CDFG 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, CDFG 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. Shasta Dam barred the salmon entirely from their former spawning grounds in the Upper Sacramento, McCloud and Pit River drainages, thus removing those areas from salmon production. In addition, ~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 9 mi below Shasta Dam. Fall-run salmon spawn in the mainstem Sacramento River where spawning gravels occur from Keswick Dam dowstream to below the town of Tehama (Clark 1929, Gerstung, pers. obs.)— a distance of ~67 mi. Fall-run spawning escapements in the mainstem Sacramento River averaged 252,000 fish annually during the period 1952-1959, 159,200 fish in the 1960s, 88,400 in the 1970s, 108,300 in the 1980s, and 65,700 fish in the period 1990-1994 (Fisher, unpubl. data).

<u>McCloud River</u> (Shasta Co.). The McCloud River, once denoted by the California Fish Commission as "the best salmon-breeding river in the world" (CFC 1890), originally supported both spring and fall runs of salmon, as well as a winter run (Stone 1874, Hanson et al. 1940, Needham et al. 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 (DuBois 1935). The winter run appears to have been the least abundant of the three runs, with small numbers of of spawners reported by various workers (Stone 1874, Schofield 1900, Rutter 1904, Hanson et al. 1940). Salmon ascended the McCloud River up to the impassable Lower Falls (20 ft high), ~6 mi above present Lake McCloud (Rutter 1904, Wales 1939, Hanson et al. 1940). Hanson et al. (1940) reported observations of salmon (evidently winter-run) spawning during May and June, 1939, in the McCloud River between Big Springs and Lower Falls (~1.5-mi distance). However, the reach from Big Springs to Lower Falls was ecologically less suitable than areas downstream for salmon because of relatively low streamflows. Big Springs (rm 49) is where two large springs feed the McCloud River and which, in the past, contributed well over half the minimum streamflow measured near the mouth of the river; Big Springs, therefore, 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 32, 1 mi below Lake McCloud: the "salmon got no further, just got there" (Guilford-Kardell and Dotta 1980). That point was the location of a Wintu village named Nurumwitipom ("salmon come back") or Nurunwititeke ("falls back where the salmon turn back") (Guilford-Kardell 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. It would seem that if salmon had ascended in large numbers to the uppermost limit,

Lower Falls, that point most likely would have been a major fishing site, just as other barrier falls on other streams had been (e.g., Burney Falls in the Pit drainage and Salmon Falls on the South Fork American River). 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 (e.g., Star City, Claiborne and Caluchi creeks) (Wales 1939).

Clark (1929) described the McCloud as "a good spawning stream" throughout its length. As of 1928 there were no dams or other artificial obstructions on the river except for the racks of the U.S. Fish Commission egg station (Clark 1929). Hanson et al. (1940) 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 5 mi of Squaw Valley Creek, a tributary entering the McCloud River ~29 mi upstream of the mouth, could support ~830 redds (Hanson et al. 1940).

After its establishment on the McCloud River in 1872 by the noted fish culturist Livingston Stone, the U.S. Fish Commission egg-collecting station (Baird Station) soon was taking the spawn from almost all of the returning 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). Production of salmon in the McCloud itself could not be sustained. A precipitous drop in salmon numbers entering the McCloud River occurred in 1883, caused by railroad construction along the Sacramento River (Stone 1885a,b). In 1884 the scarcity of salmon led to the temporary closure of the egg station (Stone 1885a, 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 ~1 million to over 12 million eggs during the period 1873-1883, the first phase of operation prior to its temporary closure (Clark 1929). Eggs were taken from spring-run fish in that period, but the demise of that run led to cessation of operations in 1884-1887. The egg station resumed activities in 1888 and continued to 1924, but taking eggs primarily from the fall run; the spring run was still decimated (CFC 1890, Stone 1893), nor would it ever fully recover. In recognition of the depleted condition of the Sacramento River salmon stocks, Baird Station was reactivated for the expressed purpose of "aiding in the maintenance of the salmon fisheries of the Sacramento River" (USFC 1892). During that latter period of operation (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). From about 1907 onward, the egg takes showed a fairly steady decline down to about 1-1.5 million eggs per year. By 1924, there were only "about 260 fish at the racks", which produced 1.2 million eggs (Clark 1929).

Stone (1876b) 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 the nearer the truth" passed upstream before the weir was finished, and "thousands more" were blocked after its completion. After the hiatus in the mid-1880s, the salmon (fall run) 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). Clark (1929) reported both spring and fall 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. 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 (Clark 1929) and ultimately by Shasta Dam (starting in 1943; Slater 1963). The latter completely blocked access upriver and thereby extirpated all runs of salmon and other anadromous fishes into the McCloud River and other upper Sacramento tributaries.

Pit River (Shasta Co.). The Pit River system covers an extensive area, according to Clark (1929) comprising "at least half of the main Sacramento River." The Achumawi people (referred to in the past as the "Pit River Indians") are reported to have controlled ~50 mi of salmon streams in their territory (Olmsted and Steward 1978). The salmon ascended in large numbers at least to Pit River Falls (rm 75). Voegelin's (1942) ethnographic account states that "Salmon ascend Pit River as far as falls at site of Pit 1 power house, in Achomawi area." The presence of spring-run salmon in Hat Creek, a tributary of the Pit River below Pit River Falls, was reported by Rutter (1904), and the occurrence of a winter run (spawning in "the headwaters") was indicated by Stone (1874). Despite their occurrences in Hat Creek observed by early fishery workers, salmon evidently were not present there in significant numbers during the latter part of the 19th century, but they supposedly had been abundant in earlier times. One ethnographic account states that among the Atsuwegi people, who controlled most of the Hat Creek drainage, "salmon were obtained only by invitation of the western Achumawi on Pit River" (Garth 1978) to where the Atsuwegi made salmon-fishing expeditions in the fall, and giving the Achumawi part of the catch as payment to trespass (Garth 1953). Garth's (1953) survey of Atsuwegi informants indicated that salmon were "rarely seen in Hat Creek", and Voegelin (1942), drawing from an interview in 1936 with a 79-year-old Atsuwegi informant, recorded: "Not many salmon in Hat Creek; occasionally a good run." However, Kniffen's (1928) earlier ethnographic summary, in describing the Hat Creek Valley, states that "Formerly the streams contained an abundance of salmon, pike, trout, and suckers." Garth (1953) reported that a waterfall located "about a mile below Caasel [Cassel] on Rising River", was a favorite fishing place of the Atsuwegi people, who called it "ani" [salmon] "wecéici" [jumping]. This reference is evidently to a stretch of Hat Creek which contains cascades and was sometimes called "Rising River"; it 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 (Gerstung, pers. obs.). Shebley (1922) stated that although salmon abundance in Hat Creek was so low in 1886 and 1887 as to cause abandonment of the newly constructed (1885) Hat Creek Hatchery, a "large run" of salmon formerly entered Hat Creek and the spawning beds only "a few years before had been covered with thousands of spawning fish." Rutter (1908) also reported that Hat Creek was "a salmon stream of some importance", but with "a number of rapids that make its ascent difficult." Available spawning habitat and suitable conditions also occur in Kosk and Burney creeks, two other 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-ft double waterfall located ~1 mi above the mouth of Burney Creek, was an obvious historical barrier to salmon.

Rutter (1904), referring 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" most likely comprised some number of winter-run fish. He 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, rather than continue 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. Prior to the time of Rutter's (1904) report, a fishway had been excavated out of the rock formation on the southern side of Pit River Falls, in 1881 (Throckmorton 1882). Pit River Falls (65 ft high) was "thought by many to rival in beauty any to be seen in the Yosemite Valley" (Rutter 1908), and which Rutter, in his 1904 paper, stated had been impassable for salmon prior to the modification. Yet Rutter (1908) 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 situated. In any event, Powers (1877), in discussing the first-salmon ritual (probably for the spring run) of the Achumawi 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." The "tremendous cataract" undoubtedly was Pit River Falls— which, it seems, did not actually pose a complete barrier to the salmon, as the Achumawi evidently knew. 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 the falls. Thus, it is probable that spring-run salmon, and perhaps winter-run, originally surmounted the Pit River Falls and entered the Fall River some distance up its 15-mi length. Kniffen (1928) similarly 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 it "also marked the upper limit of the salmon run." Salmon historical abundance in the Fall River cannot be clearly determined, but after construction of the fishway, they reportedly passed over Pit River Falls "in considerable numbers" (Rutter 1908).

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 the period 1922-1927. Proceeding from the lowest to highest upriver, they were: Pit 4, 7 mi below Burney and Burney Falls, 60 ft high and without fish passage facilities; Pit 3, 9 mi 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) 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." Based on his observations made in July 1923, Clark estimated that "at the most" 150-200 salmon were stopped at the base of Pit 4 dam, and that they probably comprised the entire spring run (Clark 1929). Hanson et al. (1940) estimated that the lower 28 mi of the Pit River, "from the mouth to Fender's Ferry", potentially could support 14,402 salmon nests. As with the Little Sacramento and McCloud rivers, construction of Shasta Dam eliminated salmon runs into the Pit River drainage.

<u>Cottonwood Creek</u> (Tehama Co.) 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 (CDFG 1993) and ~8 mi into Beegum Creek on the Middle Fork (CDFG unpubl. data and notes). According to Hanson et al. (1940), the North Fork has a two-part falls (15 ft and 10 ft high) that forms a natural barrier ~5 mi 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 it had only "a very slight fall run" (Clark 1929). Clark stated that the salmon spawned near the mouth of the creek because low water flows did not allow them to ascend further. He reported the presence of an irrigation diversion (lacking 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.

In recent years prior to 1993, fall, late-fall and hybrid fall-spring runs occurred in Cottonwood Creek (CDFG 1993). The fall-run size ranged between "a few hundred" to >8,000 fish, with an annual average of 1,000-1,500 (CDFG 1993). The late-fall run numbered <500 fish, spawning in the mainstem and the lower reaches of the North, Middle and South forks (CDFG 1993). The spring run is believed to have averaged ~500 fish historically (CDFG 1993), but there are no recent run-size estimates. Low spring flows and high water temperatures may prevent the upstream migration of the spring run during some years (CDFG 1993). Presently, there are only the bare remnants of a salmon run in Cottonwood Creek. Individuals appear only occasionally and do not constitute a self-sustaining population. Eight adult spring-run salmon were observed by CDFG personnel during the summer of 1995 in the vicinity of the North and South forks (T. Healey, pers. comm.).

Stony Creek (Tehama Co.) Stony Creek is a west-side tributary in the Sacramento drainage and formerly supported spring run and fall runs. Stony Creek reportedly was "a very good salmon stream" prior to the placement of the irrigations dams (Clark 1929). Kroeber (1932), 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 latter has been placed at the confluence of Stony Creek and Little Stony Creek, ~5 mi below Stonyford (McLendon and Oswalt 1978), so that point would have been the upstream range of the salmon. By 1928, both spring and fall runs were nonexistant 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 ca. 1914) 4 mi 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 ~3-4 mi 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 (CDFG 1993). There is "excellent" spawning gravel within the ~20 mi of stream between the creek mouth and the lowermost dam, Black Butte Dam, which would be a barrier to salmon (CDFG 1993). However, the GCID canal, downstream of Black Butte Dam, continues to completely bar salmon migration any further upstream (CDFG 1993); this canal-crossing 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 upper Sacramento Valley occasionally supported fall-run salmon 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 unpubl. report); they most likely ascended past the present site of Whiskeytown Reservoir to somewhere above the French Gulch area (~1,400 ft elevation). Clear Creek in some years still supports a substantial fall run; in 1995, the fall run was estimated to have numbered up to 10,000 spawners (CDFG unpubl. data). Thomes Creek supported a small spring run. Murphy (1946) observed 3 adult salmon in early August 1946 in a pool situated within The Gorge area below Lake Hollow, 8 mi upstream from the town of Paskenta; however, no salmon were observed in that stream during a later survey in the 1960s (T. Healey, pers. comm.). In contrast, spring-run salmon probably did not utilize the Cow Creek drainage to any significant extent either because there is no suitable over-summering habitat (i.e., deep bedrock pools), as 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 et al. 1940). Cache and Putah creeks, two intermittent streams on the west side of the lower Sacramento drainage, have supported fall salmon runs only during wet years within historical times (Shapovalov 1947). Salmon have been observed as far upstream as Capay Dam in Cache Creek (Hanson et al. 1940, Shapovalov 1947) and near the town of Monticello in Putah Creek (Shapovalov 1947). In even earlier times (ca. A.D. 1450-1650), Putah Creek provided salmon to the local Native Americans in at least some minor quantity (Schulz 1994, unpubl. manuscript). Fry (1961) reported that the combined fall runs (including late-fall) for the miscellaneous Sacramento tributary streams totaled 1,000-13,000 fish annually during 1940-1959. The spring-run totals, available for only three years in that period, were <500 fish in two years and 1,000 fish in the third (1956). During the period 1953-1969, the Cow Creek drainage alone supported a fall run that averaged 2,800 fish (CDFG 1993). Currently (1994), the combined fall runs in these miscellaneous streams, if existant, are inconsequential and the spring runs essentially no longer occur (CDFG 1993).

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It has been estimated that prior to the placement of man-made obstructions in the salmon 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. However, 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 (i.e., migration corridors and holding areas) were included. The actual amount of spawning habitat origninally used by, or available to, Central Valley salmon, therefore, is not clearly known. By 1928, the amount of spawning stream habitat had been reduced to an estimated 510 linear mi and reportedly at least 80 percent of the spawning grounds were cut off by obstructions— which include 11 dams in the San Joaquin system and 35 dams in the Sacramento system that posed partial or complete barriers to salmon (Clark 1929). Van Cleve (1945) later estimated a somewhat lesser loss of 75% of the original spawning habitat due to all causes. In 1993, the amount of existant spawning habitat for salmon and steelhead in the Central Valley system was estimated by the California Department of Fish and Game to total less than 300 mi (CDFG 1993).

We estimated from map distances the lengths of stream that have been lost as salmon habitat in each of the major Central Valley drainages due to installation of barriers or reduction of streamflows that made passage of salmon impossible under usual conditions (Table 1, Map). We included lengths of stream that salmon are known or can be inferred to have had access to, whether for holding or spawning purposes. These estimated stream lengths are minimum estimates because we have considered only the mainstems and the major forks and tributaries as salmon habitat. Numerous small 3rd- and 4th-order streams undoubtedly were utilized to some degree by salmon, for which records do not exist, although the numbers of salmon using those smaller streams would have been small. Furthermore, the full extent of the historical distribution of salmon even in the major stream reaches is not clearly known for some drainages (e.g., Middle Fork American River, mainstem and South Fork Merced River). Based on the available information, our estimates indicate that the amount of habitat that was lost differs greatly from drainage to drainage. In the Bear River, for example, the length of stream accessible to salmon has changed very little, while in Deer Creek it has actually increased by several miles due to artificially improved fish passage over natural barriers. In most drainages, considerable portions of the former salmon-supporting reaches are no longer accessible to salmon, and some drainages have been entirely removed from salmon production (i.e., McCloud, Pit, Upper (Little) Sacramento, 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 1), we obtain a total of 1,014 mi of main stream lengths remaining of the 2,113 mi of Central Valley streams originally available to chinook salmon— indicating an overall loss of 52%. We did not include Sacramento-San Joaquin Delta in our calculations, where ~700 mi of river channels and sloughs were available to salmon, to various degrees, as migration corridors or rearing areas. In contrast to previously cited estimates which specified only spawning habitat, our figures include the lengths of stream available to salmon as migration corridors (e.g., the lower Sacramento and San Joaquin rivers) as well as holding and spawning habitat. We note that our figures include ~220 mi in the lower Sacramento River (below Tehama), ~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 certain flow regimes) as the juveniles moved downstream, but in recent times they have become less suitable for rearing due to alterations in channel morphology and other environmental conditions. In terms of spawning habitat only, the proportionate loss from the amount originally available far exceeds the value of 52% because the upper stream reaches that have been cut off contained a relatively large proportion of the available spawning habitat. In contrast, much of the remaining lengths of stream in the lower drainages now traversed or occupied by salmon cannot be used for spawning. Of the total length of stream courses presently accessible, less than one-third in the San Joaquin drainage and probably less than a half in the Sacramento drainage are suitable as spawning habitat. Excluding stream courses that were used only as migration corridors (and only minimally for juvenile rearing), we roughly estimate that ~82% of the original spawning and holding habitat for salmon in the Central Valley drainage is no longer available. Thus, the CDFG's (CDFG 1993) earlier assessment that ~95% of the chinook salmon spawning habitat that was originally available has been lost seems reasonably accurate; however, the frequently cited estimate that over 6,000 mi of habitat were once available for spawning (Clark 1929) is probably overly high by a factor of three.

The extent 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 jumping 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 utilized at least hundreds of miles of smaller tributaries not accessible to the earlier-spawning salmon.

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Table 1. Estimated changes in lengths of stream available to chinook salmon in the major salmon-supporting drainages of the Central Valley. The values for stream lengths originally available and subsequently lost are in most cases minimum estimates because the full extent of the former salmon distributions is incompletely known.[1]

Drainage	Length (mi) of stream historically available[2]	Length (mi) of stream presently accessible[3]	Length (mi) of stream lost (or gained)[4]	Percent lost (or gained)
Sacramento Valley				
Mainstem Sacramento River[5]	299	286	13	4
Pit River	99	0	99	100
McCloud River	43	0	43	100
Upper (Little) Sacramento River	52	0	52	100
Battle Creek	53	6	47	89
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	77	21	56	73
Bear River	16	16	0	0
American River	161	28	133	83
Clear Creek	25	16	4	16
Cottonwood Creek	79	79	0	0
Stony Creek	54	~3	51	94
San Joaquin Valley				
Mainstem San Joaquin River[6]	50	50	0	0
Cosumnes River	34	34	0	0
Mokelumne River	69	46	23	33
Calaveras River	~38	38	0?	0?
Stanislaus River	113	46	67	59
Tuolumne River	99	47	52	53
Merced River	99	43	56	57
Upper San Joaquin River[7]	171	0	171	100
Kings River	84	0	84	100

[1] Additional, minor streams such as Thomes, Paynes, Cache and Putah creeks and perhaps a dozen others in the Sacramento Valley historically supported salmon runs (Fry 1961)— probably only the fall run and only during wet years when streamflows were adequate. The historical upstream distribution of salmon in those streams is too poorly known to allow inclusion in this table. Futhermore, 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 (CDFG 1993).

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

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

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

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

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

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