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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

[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.

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).

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 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

[2] Unpublished documents are listed separately, following the References section, as are persons cited for personal communication ("pers.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

[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).

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 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 *Kăh-wăh-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).

Merced River (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

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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.

Tuolumne River (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.

Stanislaus River (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.

<u>Calaveras River</u> (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).

<u>Cosumnes River</u> (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

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