Shasta Salmon Salvage Efforts: Coleman National Fish Hatchery on Battle Creek, 1895–1992

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Dedication

This paper is dedicated to the memory of wily fisherman and indefatigable salmon champion Nat Bingham. Named for a New London, Connecticut, whaling ship's captain, Nathaniel Shaw Bingham knew the best way to chart salmon futures was by peering unflinchingly into their and our own respective pasts.

I. The Early Years on Battle Creek

For well over a century, Californians have sought to compensate for depleted salmon runs in the upper Sacramento River Basin by creating fish hatcheries. Beginning in 1872, fish culturalist Livingstone Stone located the West's first fish hatchery on the lower McCloud River. Between 1870 and 1960, 169 significant public and private fish hatcheries and egg collecting stations were operated throughout the state (Leitritz 1970, p 11). The fifth hatchery to be owned and managed by the US Commission of Fish and Fisheries (later renamed the US Fish Commission), was the Battle Creek Station located near Anderson.

Originating on the western slopes of Mt. Lassen, Battle Creek flows some forty-two miles before emptying into the Sacramento River. Due largely to melting snow, Battle Creek enjoys a cold, year-round supply of filtered water. Porous volcanic rock acts as a sponge to absorb and gradually release stored underground waters. This Cascade stream also enjoys a reasonably steep gradient, falling some 5,000 feet, which made it a prime candidate for early hydroelectric development (Reynolds 1980, p 23). In 1901, five years after fish culturalists began harvesting Battle Creek's thriving populations of fall-, winter-, and spring-run chinook salmon, developers sought to cash in on its hydroelectric potential. The Volta plant would generate peak load power for a proposed copper smelter at Keswick, near Mountain Copper's Iron Mountain mine (Reynolds 1980, p 29).

Before this hydroelectric system went into effect, fish culturalists enjoyed an optimum five-year window for harvesting returning stocks of Battle Creek salmon. In 1893, J.P. Babcock (later named the station's Chief Deputy and director) recommended to California's Fish Commissioners that a new Sacramento River spawning station be established (Leitritz 1970, p 24). In September 1895, a hatchery was erected near the mouth of Battle Creek, in Tehama County (SBFC 1896, p 23). Investigators reported large numbers of salmon entering this stream during the months of October and November. Between October 21, and November 12, 1895, the hatchery's full capacity of 10 million eggs was easily reached (SBFC 1896, p 24). Hatchery personnel noted "...there [was] almost no limit to the numbers of eggs which can be secured there with proper apparatus" (SBFC 1896, p 24). John J. Brice, then US Commissioner of Fisheries, was approached about supplying that "proper apparatus" by erecting a much larger facility on Battle Creek.

In August, 1896, the US Fish Commission erected temporary structures at the Battle Creek site to handle any surplus spawn. During 1896 and 1897, the Battle Creek Station, as it was called, was jointly operated by the State of California and the US Fish Commission (SBFC 1898, p 35). In the 1896 season, the facility gathered twenty-six million eggs and in the following year, forty-eight million eggs (SBFC 1898, p 35). California's Fish Commissioners reported:

> *The location and operation of the Battle Creek station has been the most successful propagation work ever undertaken on this coast, and in its magnitude and importance equals any work of its kind in the world (SBFC 1898, p 35).*

During winter 1897, Congress set aside funding to purchase the State's interest in the Battle Creek facility, and it soon became the fifth federal breedery in the State (Biennial Report 1897–1898, p 35). Upon receipt of payment, California's Fish Commissioners shifted their investment to Mount Shasta City's Sisson hatchery.

In its early years, the Battle Creek facility was capable of producing as many as 60 million fertilized eggs (Leitritz 1970, p 24). In a letter dated December 5, 1904, G. H. Lambson, Superintendent of the US Bureau of Fisheries stations in California, remarks:

> *There is a large run of fish in both Battle and Mill creeks and there is hardly any limit to be placed on the number of eggs we could take if we had the room. We could have taken fully eighty to one hundred million at Battle Creek and about sixty million at Mill Creek if we could have fished daily (SBFC 1904, p 107).*

Recognizing the need to overcome "...the double odds of natural and human enemies," biologist Cloudsley Rutter pointed toward artificial propagation as the sole hope for the Sacramento River salmon (SBFC 1904, p 106). Believing that "the relative efficiency of natural versus artificial propagation is about one percent and eighty-five percent, respectively," (SBFC 1904, p 105) Rutter wrote:

> *Artificial propagation is keeping up the supply of salmon in the Sacramento River. With one exception, there are now no natural spawning beds in the Sacramento basin that amount to anything. All of the Feather, Upper Sacramento, and Pit rivers, with their tributaries have been practically abandoned, with the exception of the streams where the hatcheries are located. The only natural spawning beds still occupied are in the main river, between Redding and Tehama, which are yet visited by a considerable number of salmon (SBFC 1904, p 106).*

When Rutter assisted at the Battle Creek Station in August, 1897, he and his colleagues helped catch a record number of fall-run Sacramento salmon ascending Battle Creek (8,784 fish were spawned yielding 48,527,000 eggs). Between their weirs and nets, Schofield reports they "took almost every fish in the river," making artificial propagation the sole tool of choice for saving the Sacramento's beleaguered salmon (Jennings 1996, p 16; Schofield, as cited in SBFC 1898, 1900, p 69). Writing four years later, a confident Rutter concluded: "Artificial propagation of salmon has not yet reached such proportions as to entirely supplant natural propagation, with the exception of the work on the Sacramento River" (Rutter, as cited in SBFC 1904, p 105).

The Battle Creek Station remained in operation through 1945 when a new set of threats to fish and fisheries was felt throughout Western watersheds. From the Pacific Northwest's Columbia River to California's Sacramento River, federal agencies like the US Bureau of Reclamation (the Bureau) built pharaonic dams like Grand Coulee and Shasta. Attempts at reconciling anadromous fish losses with massive water development stemmed from the Grand Coulee Dam's construction. In rapid succession, experimental "fish salvage" efforts occurring on the Columbia River were attempted in the Sacramento River basin where the Coleman National Fish Station was erected[1].

1. As former DFG biologist Richard Hallock points out, the original Battle Creek Station site was essentially abandoned.

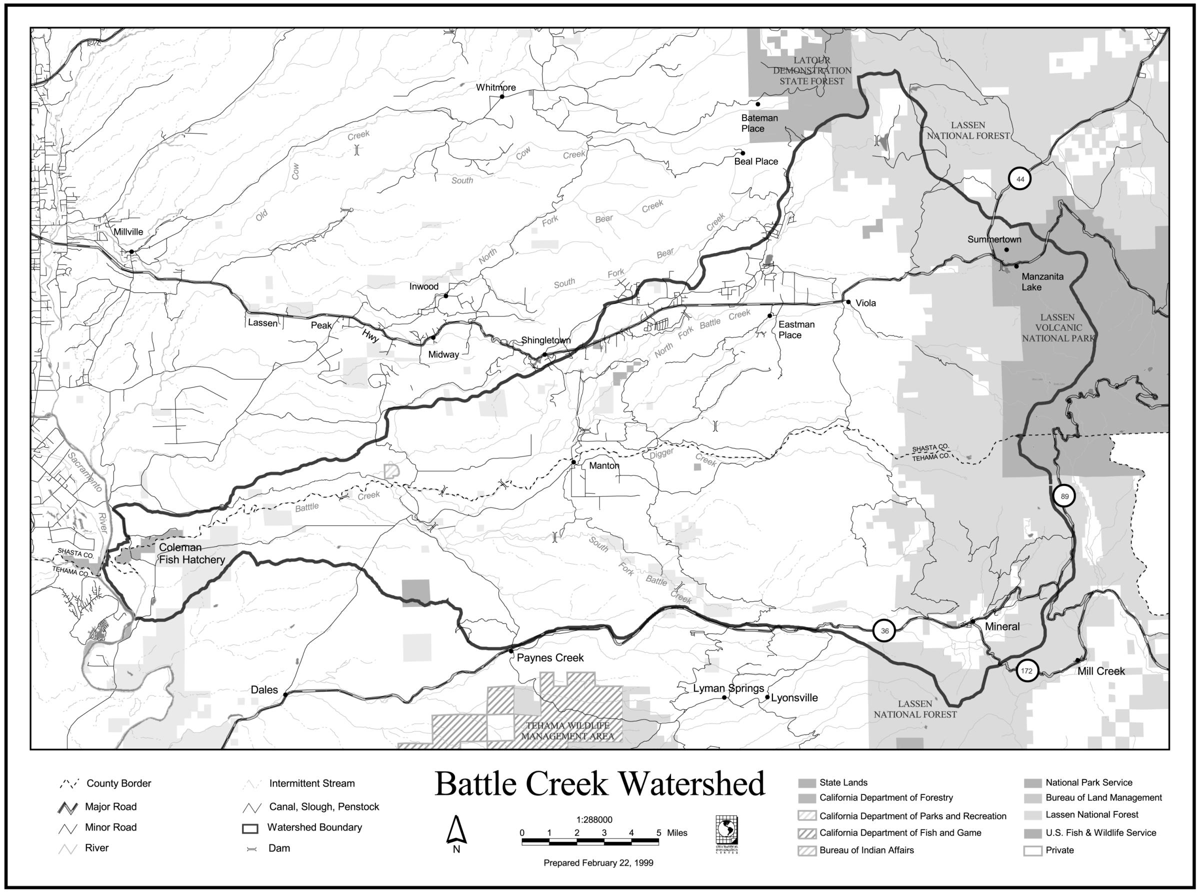

Figure 1 Battle Creek Watershed

II. Columbia River Antecedents

Upon its completion in 1941, the Columbia River's Grand Coulee Dam prevented roughly 100,000 chinook, sockeye, and steelhead from ascending 1040 miles of prime upstream habitat. Originally slated by the US Army Corps of Engineers to have been a "low dam" like Bonneville, the project had, by 1935, metamorphosed under Franklin D. Roosevelt's Public Works Administration and the Bureau, into the largest dam ever erected in North America (Reisner 1986, p 162–163). Impassable to migratory fish, it also became the proving grounds for subsequent, large-scale "fish salvage" efforts throughout the arid West. When it came to federal and State-level institutions, personnel, scientific, and technological precedents, fish rescue strategies at Grand Coulee foreshadowed what was later attempted on California's Sacramento River.

Willis H. Rich greeted the big dam era with trepidation (Rich 1939). The Stanford University professor (a classically educated biologist) was retained in 1938 by the Oregon Fish Commission to direct their new Research Division (Taylor 1996, p 355)[2]. Rich was dubious about excessive reliance on hatcheries as a means of mitigating fishery losses (Lichatowitch, personal communication, see "Notes"). In 1939, speaking before assembled ichthyologists at Stanford University, Rich concluded:

> *Biologists in general are skeptical of the claims made for artificial propagation...because these claims have often been extravagant and the proof is entirely inadequate. Indeed, many conservationists feel that the complacent confidence felt by fishermen, laymen, and administrators in the ability of artificial propagation to counterbalance any inroads that man may make...is a serious stumbling block in the way of the development of proper conservation programs (Rich as cited in Taylor 1996, p 354).*

Rich was more circumspect in his criticism of hatcheries. He recognized that enormous dams transformed hatcheries into self-fulfilling prophesies: dramatically shrinking natural habitats meant escalating hatchery programs (Taylor 1996, p 352). During the 1920s and 1930s, Alaska and British Columbia provided rare instances where hatchery-driven salmon production was deliberately scaled back due to excessive costs. Within these unique cases, however, artificial propagation could only be traded for intact spawning grounds (Taylor 1996, p 348; Calkins and others 1939b, p 6). Rich had no alternative but to accommodate himself to the big dam era, hoping that some day "general principles" might be discovered which reconciled massive water develop-

2. This account greatly benefits from Joseph E. Taylor's thoughtful synopsis of fish salvage efforts surrounding Grand Coulee Dam (Taylor 1996, p 350–360). The narrative that follows refers to the various roles Willis H. Rich played in his advisory capacity.

ment with the biological requirements of anadromous fish (Taylor 1996, p 355).

There was also the added matter of federal institutional precedents which had, for seventy years, informally mitigated for habitat losses by means of technological remedies like hatcheries (Black 1995). National fish mitigation policies accompanying dam construction finally became formalized under the Federal Power Act of 1920, spelling out compensatory obligations accompanying water projects. States, too, exhibited a strong predilection toward relying on hatcheries to rescue fisheries blocked by dams. Beginning roughly in 1906, Washington State shifted toward a policy of hatcheries "in lieu" of dams. Oregon began embracing the practice in 1909 (Taylor 1996, p 351).

The Mitchell Act[3] was passed by Congress in 1938 directing the Bureau and the Army Corps of Engineers to assist the US Bureau of Fisheries in saving salmon (Taylor 1996, p 357). The traditional mix of technological mitigations was amended by the desire to relocate, to downstream tributaries if possible, fish stocks displaced by massive dams. For example, the Grand Coulee Fish Maintenance Project (GCFMP) was designed to sustain the production of mid-Columbia River salmon and steelhead populations at levels comparable to those before dam construction. By restoring natural propagation within the downstream Wenatchee, Entiat, Methow, and Okanogan tributaries, biologists hoped to expand suitable substitute habitats for displaced wild fish (Mullan 1992, p iii; Hobart, personal communication, see "Notes"). Returning migratory species were trapped at downstream Rock Island Dam before being hauled and released upstream of temporary weirs, or transferred to the Leavenworth, Entiat, and Winthrop national fish hatcheries for artificial propagation (Mullan 1987, p iii).

As environmental historian Joseph Taylor observes, the Grand Coulee Fish Maintenance Project required that a century's accumulated managerial and technological precedents be systematically recombined and directed at relocating and producing fish on an undreamed of scale. Successful fish salvage efforts hinged upon: (1) identification and restoration of downstream tributaries suitable for fish transplantation and reproduction; (2) construction of a greatly expanded hatchery system; and (3) invention of a new means of moving fish around (Taylor 1996, p 358).

Several stages were required to achieve the objectives of the Grand Coulee Fish Maintenance Project. The initial task necessitated gathering a comprehensive inventory of downstream watersheds and their inhabitants. This included devising a means of measuring existing fish populations, evaluating their ecological suitability for fish habitats, and identifying adverse conditions

3. See Statute 345, 75th Congress, 3rd Session, May 11, 1938.

capable of undermining fish survival (like unscreened irrigation diversions and pollution). Works Projects Administrations' laborers cleared streams of obstacles like beaver dams, constructed fishways around instream blockages, and screened irrigation diversions.

Next came a program for significantly increasing hatchery production. Initially, Bureau policymakers presciently suggested setting aside "...some streams as fish refuges on which no conflicting water development would be made" (Bureau memorandum, as cited in Taylor 1996, p 358–359; ff. 76). However, Bureau leaders lacked sufficient power and political gumption to risk angering competing developmental interests, many of whom were agency supporters (Taylor 1996, p 358). Instead, they resorted to fine tuning and expanding existing hatcheries and constructing new facilities such as the Leavenworth plant on Icicle Creek.

As a tributary of the Wenatchee River, Icicle Creek proved to be a curious hatchery site. This facility, which anticipated handling 76.5 million eggs annually, sought to reproduce an annual run equivalent to 36,500 fish (Calkins and others 1939b, p 4)[4]. However, the creek's waters completely dried up the during late summer months. Bureau engineers nonetheless guaranteed Leavenworth a year-round supply of water by boring a two-thousand-five-hundred foot tunnel from nearby Upper Snow Lake. With sufficient engineering talent and money, even significant mitigation obstacles like these were retired with dispatch.

The project's final task lay with moving salmon around. By May, 1939, federal and State workers began trapping incoming salmon at Puget Sound Power and Light's Rock Island Dam. During the first year alone, eight Bureau-supplied tank trucks relocated 36,000 salmon to the Wenatchee, Methow, Okanogan, and Entiat rivers (Taylor 1996, p 359). In 1940, once holding ponds at the new Leavenworth hatchery had been completed, US Fish and Wildlife Service personnel began hauling fish to be ripened for artificial propagation. Finally there was the matter of sockeye (or "blueback") salmon, which had once migrated to reproduce in upper Columbia River nursery lakes. Most sockeyes were transported for rearing in Wenatchee and Osoyoos lakes, located on Wenatchee and Okanogan rivers (Mullan 1987, p 31).

Board of Consultants Recommendations: Round One

In 1938, Secretary of the Interior Harold L. Ickes appointed a "Board of Consultants" (Board) to review fish salvage proposals on the Columbia (and later the Sacramento) River. Consisting of two Stanford University professors and a

4. Consisting of 41 million chinook, 21.5 million sockeye, and 14 million steelhead eggs (Calkins and others 1939, p 4).

third faculty member from the University of California. (Stanford contributed W. F. Durand, Professor Emeritus of Mechanical Engineering and Willis H. Rich, Professor of Biology. Berkeley supplied R. D. Calkins, Professor of Economics). Their selection reflected the Department of the Interior's and the Bureau's predisposition toward finding cost-effective engineering solutions in significantly altered western watersheds. Doubtless these individuals were chosen for their particular areas of expertise, for their perceived autonomy as faculty members at prestigious universities, and for subtly distancing the sponsoring agency from any political repercussions arising from the Board's judgment.

Within their October 3, 1938 letter of appointment, Secretary of the Interior Ickes instructed Professors Calkins, Durand, and Rich that:

> *Your report should review all phases of the situation and the proposed plans of the state with a view to determining their feasibility from physical and biological standpoints, and whether the program as a whole, and the various features thereof, are economically justifiable...Your recommendation is also desired as to what proportion of the cost of such works...should be charged against the funds provided by the federal government for the construction of Grand Coulee Dam and what proportion should equitably be borne by other agencies such as the State of Washington and the US Bureau of Fisheries (Calkins and others 1939b, p i).*

Their Columbia River document was subdivided into two sections; the first of which addressed temporary means for salvaging some portion of the threatened 1939 and 1940 salmon runs. Washington State Department of Fisheries biologists counted a total of 28,000 chinook and sockeye salmon and steelhead passing upstream from Rock Island Dam. Of this total, biologists estimated that 10 percent entered the Wenatchee, Methow, Okanogan, and Entiat rivers, while 90 percent proceeded upstream from the Grand Coulee site into the upper Columbia River Basin (Calkins and others 1939, p 4). The Board of Consultants report recommended: (1) peak run fish trapped at Rock Island Dam be temporarily transported upstream of Grand Coulee Dam; (2) eight 1,000-gallon tank trucks be secured to experimentally transport anadromous fish; (3) during 1940 and 1941 Grand Coulee reservoir levels be maintained at an optimum level to facilitate downstream fish passage; and (4) a source of "eyed eggs" be secured for placement within the four tributaries between Grand Coulee and Rock Island dams (Calkins and others 1939a, p 14–15).

The blue ribbon panel instructed the Bureau to construct a hatchery for, among other species, steelhead trout, which they called "...one of the principal sport fish of the area" (Calkins and others 1939a, p 15). In 1937, Washington State authorities issued a total of 199,000 state and county hunting licenses. Hunters and sportsfishers expended some four million dollars a year on additional recreational goods and services, leading panelists to conclude: "...that a serious importance [be] attached to this form of recreation and to the game fish in the Upper Columbia River..."(Calkins and others 1939a, p 17). While a hatchery capable of propagating steelhead, chinook and sockeye was to be built at federal expense, its subsequent administration, operation and maintenance would fall to the State and remain entirely a State enterprise (Calkins and others 1939a, p 18)[5].

Part Two of "Fish Problems of the Upper Columbia River" responded to a detailed fish salvage plan submitted by the Washington State Department of Fisheries. The scheme sought to transfer fish once spawning above Grand Coulee Dam to the four tributaries immediately below (Calkins and others 1939b, p 65). Biologists proposed expanding the carrying capacity of the Wenatchee, Methow, Okanogan, and Entiat rivers to raise their fish populations to historic levels. Two hundred seventy-five thousand dollars in State monies were allotted to accomplish "stream rehabilitation." In addition, Board members ratified State recommendations calling for a combination of "...artificial spawning, hatching, feeding, rearing, and planting..."sufficient to compensate for 1,100 miles of blocked, upper river habitats. Up to one million chinook salmon fingerlings were also to be raised and released just before their seaward migration. (Calkins and others 1939b, p 1–2, 10, 77).

Under the guidance of Service biologists like Fred J. Foster, Regional Director of Seattle's Division of Fish Culture, artificial propagation figured prominently in the overall fish salvage effort[6]. Washington State's plan called for an initial expenditure of $2,760,000 at an annual operating cost of $184,000 (Calkins and others 1939b, p 65)[7]. In addition to the prominent Leavenworth facility, other "auxiliary hatcheries" capable of handling "eyed eggs" were called for on the Entiot, Methow, and Okanogan rivers (Calkins and others 1939b, p 3). Citing a "factor of safety" provided by hatcheries, Board members characterized the overall effort "...as an experiment in fish culture on a large scale..." (Calkins and others 1939b, p vi).

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5. The Board of Consultants recommended that the whole project be administered by "...the Federal Bureau of Fisheries, with the organization of a joint Advisory Board representing the states of Washington and Oregon and the US Bureau of Reclamation" (Calkins and others 1939b, p 8). State of Oregon resistance to federal interference in its fisheries are well documented by Taylor (1996).

6. See Fred J. Foster, "Outline of Artificial Propagation of Fish on the Lower Columbia River" (c. July 1937), box 611, fldr. 826.53, Entry 269; cited in Taylor 1996, p 357.

7. The document notes parenthetically that the Washington State Report of 1938 was "...later modified by some reduction in the size of proposed hatchery plants" (Calkins and others 1939b, p v).

Board members were candid in acknowledging the unpredictable nature of their proposed undertaking:

> *...[W]e recognize fully the experimental nature of the attempt to replace natural propagation above Grand Coulee by artificial propagation of the same fish populations at hatcheries located below the dam. We believe that no one can be assured of the success of such a venture but, on the other hand, this plan appears, in the present instance, to be the only feasible means to the desired end (Calkins and others 1939b, p 7).*

The hoped for gamble was twofold: artificial propagation could eventually be replaced by natural propagation within restored lower river tributaries, and, among intensely exploited fisheries, hatcheries could support much higher levels of fish productivity (Calkins and others 1939b, p 6–7).

By 1943, dam boosters (including the Bureau), touted the success of the Grand Coulee Fish Maintenance Project. Queried by a Reader's Digest editor, one representative of the US Fish and Wildlife Service (the Service) characterized the entire program as "highly satisfactory" (Taylor 1996, p 360). Assuaging a skittish public of their legitimate concerns about threatened sportfish may have invited an optimistic rush to judgment. Not all participants were as sanguine, however. Willis H. Rich wrote of artificial propagation:

> *...[that] actual accomplishment has seldom shown a sufficiently clear improvement over natural propagation to warrant the expenditure except in the case of a few small isolated runs (Rich, as cited in Calkins and others 1939b, p 6).*

Rich knew that this was no small project. Biologists like Rich, however, lacked the luxury of contemplation, as large dams continued being erected throughout the arid West. One such was at Kennett, on California's Sacramento River, where prior institutional precedents, personnel, techniques and rationale were recast in a renewed effort at salvaging salmon.

III. The Central Valley Project Era

When Shasta Dam construction began interfering with salmon passage on November 8, 1942, the Central Valley Project's centerpiece drastically affected an array of migratory salmon stocks. Sacramento River runs were once distinguishable by their many attributes including run-timing, size, and varying spawning habitats. Winter-run stocks once relied upon spring-fed headwaters like those provided by the Little Sacramento, the Pit, the McCloud, and Fall rivers, and in nearby Battle Creek (Yoshiyama and others 1998, p 490–491; Ward and Kier 1998, p 10–11; USFWS and Richardson 1987c; USFWS 1998)[8]. Spring-run stocks arrived in "pre-reproductive and peak physical condition" and frequented extreme elevations within mountainous streams fed by snowmelt. Late fall-run stocks spawned within the upper Sacramento's mainstem and those tributary reaches blocked by the Shasta-Keswick complex (and perhaps in upper tributaries like the American River). Fall-run stocks arrived about ready to spawn but the fish were often in a somewhat compromised physical state. They predominated within the lower river and its foothill reaches at elevations of 500 feet or less (Yoshiyama and others 1996, p 312–313; Rutter 1904; Fisher 1994)

Once erected, the Shasta-Keswick complex excluded now-endangered winter-run salmon from all of their historic spawning grounds (save for Battle Creek) (Hedgpeth 1941; Slater 1963). Spring-run salmon also lost access to their extreme headwater habitats. The late fall-run was cut off from most of its historic spawning beds. Least adversely affected were fall-run fish, whose lower river spawning gravels remained relatively intact. By one estimate, fall-run chinook salmon lost an estimated 15 percent of its upper river habitat due to the erection of Shasta-Keswick dams[9].

US Bureau of Fisheries biologists Harry A. Hanson, Osgood R. Smith, and Paul R. Needham, among others, were given barely three years to complete their Bureau sponsored investigation into the dam's full effects. Working at a breakneck pace, the investigating team made a number of recommendations

8. At the turn of the century, biologist Cloudsley Rutter captured newly emerged winter-run salmon fry in September and early October within Battle Creek's waters (Rutter 1902, 1903). As fisheries scientists Michael Ward and William Kier observe, the fish could not have originated within the downstream Sacramento River's mainstem due to lethal water temperatures (Kier and Ward 1998, p 10). Recently compiled Fish and Wildlife Service evidence documents existing Coleman hatchery-origin winter-run stocks in addition to "...a remnant population of wild winter-run [fish]" (USFWS 1998, as cited in Kier and Ward 1998, p 10).

9. See the accompanying historic run estimates provided by the California Department of Fish and Game within this document's appendix.

for "salvaging" some portion of the estimated 27,000 chinook salmon which passed the damsite in 1939[10]. Within their 1940 report, *An Investigation of Fish-Salvage Problems in Relation to Shasta Dam* (also called "Special Scientific Report Number 10"), Hanson, Smith and Needham proposed four competing mitigation plans for consideration by members of an advisory panel appointed by the Department of the Interior.

During winter 1940, discussions ensued between members of the Board of Consultants and the federal and State fisheries biologists charged with proposing possible salvage plans. As had occurred on the mid-Columbia River, the blue ribbon panel was again called upon to evaluate cost-effective salmon salvaging efforts on the soon-to-be-dammed Sacramento River. Professors Calkins, Durand and Rich reviewed reports submitted by the US Bureau of Fisheries and the California Department of Fish and Game (DFG).

In March 1940, additional meetings occurred at Stanford University with a broader representation of Bureau of Fisheries personnel. In attendance were Fred J. Foster, Regional Director of Seattle's Division of Fish Culture (within the Bureau of Fisheries), together with Seattle-based Harland B. Holmes, Director of the North Pacific Fishery Investigation. Foster provided specific knowledge about the potential role of artificial propagation in the project while Holmes advised Board members on the proper design of fish ladders, traps, and other fish engineering problems. At this session, informal draft copies of "Special Scientific Report Number 10" were circulated and "...discussions resulted in some suggestions for [its] modification" (Calkins and others 1940a, p 1).

In early April, 1940, the final version of Hanson, Needham and Smith's document was made available to all parties. It included three detailed plans for rescuing upper Sacramento River salmon and a fourth whimsical proposal for hauling displaced fish to the Trinity River. The detailed schemes included "The Stillwater Plan," "The Battle Creek Plan," and "The Sacramento River Natural Spawning Plan" (Hanson and others 1940, p 95)[11]. Before revealing

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10. Within a 1943 "Supplementary Report on Investigations of Fish-Salvage Problems in Relation to Shasta Dam," Paul Needham, Harry Hanson, and Lewis Parker concluded that 1940 and 1941 salmon populations "...could not have been less than 50,000...and were probably much greater than 60,000." They wrote that "...the salvage plan must be adjusted to great fluctuations in numbers of salmon and that no count to date has established the maximum numbers of salmon that may have to be handled" (Needham and others 1943, p 14).

11. The Trinity River strategy proposed relocating displaced Sacramento River fisheries into the Klamath Basin. That plan was soon dropped, however, due to costs, to probable competition with existing, indigenous Trinity River salmon stocks, and to pending dam construction on the lower Trinity.

particular aspects of each proposal, however, the document's general recommendations deserve some scrutiny.

Within their report, Hanson, Needham and Smith noted a number of critical problems dogging any kind of fish salvage effort. First and foremost was the issue of run-timing, for, as Shasta Dam neared completion, 1941's returning fish would already find themselves excluded from their ancestral spawning grounds. Second, in addition to fall- and spring-run fish, the report cited the "possible existence" of a separate "winter-" or "black" run of salmon on the McCloud River, which may be dispersed throughout the entire upper river basin (Hanson and others 1940, p 42–43)[12]. Third, and importantly, they warned of the dangers of releasing excessively warm Shasta reservoir waters to downstream salmonids. This was particularly threatening to spring-run fish which arrive "green" from the ocean and hold for long periods before spawning. Advising biologists urged the Bureau to significantly lower the dam's penstocks below the reservoir's warm water thermocline. Finally, there were the issues of dangerous levels of mining leachate in and around Shasta Reservoir, maintaining minimum instream flow requirements, and unscreened agricultural diversions. Aspects of their document remain prescient to this day.

Hanson, Needham, and Smith's fish salvage recommendations fell into three broad categories and reflected what had been attempted on the mid-Columbia River. These recommendations included (1) sustaining the runs by means of artificial propagation; (2) capturing and transferring the fish to suitable downstream tributaries for re-establishment in a new stream; and (3) some combination of artificial and natural propagation (Hanson and others 1940, p 14)[13]. After weighing these various options, the biologists dismissed reliance solely on artificial propagation as being too costly, too risky, and too fraught with unknowns. On the other hand, a paucity of year-round tributaries within the lower-middle Sacramento Basin (from the mouth of the Feather River to the proposed Keswick Dam site) ruled out exclusive confidence in natural habitat replacement for upper river fish[14]. Hanson and his colleagues settled on a combined natural and artificial strategy. They came to believe that a balanced combination of each would prove most biologically tenable and cost effective

12. The winter-run had been identified as early as 1882 by Livingston Stone in his reports on the McCloud River salmon. See Slater (1963) and Fisher (1994).

13. The Trinity River proposal was to be completely reliant on natural reproduction.

14. As will become clear, many promising downstream tributaries like Battle Creek were fraught with a multitude of competing water development interests. Members of the Bureau and the Service were loath to challenge those individuals and interests who long since held riparian or appropriative rights to California's precious water.

because each separate propagation path could serve as a "buffer" or a "safety factor" on the other (Hanson and others 1940, p 17).

Attending biologists reasoned that a hatchery-dominant path would require handling roughly 100 million eggs annually, and, in addition, there was the vexing problem of the spring-run salmon. This stream-type stock must be held in their natal streams for months before spawning. "Where would that be accomplished?" they asked. Hatchery sites required cold, pristine spring water, or so they believed. One location mentioned was Darrah Springs on upper Battle Creek, but its 35 cubic feet per second was no match for this scale of operation (Hanson and others 1940, p 14). In conclusion, they wrote:

> *The risk as well as the high initial and permanent costs of handling the entire run artificially at either Big Springs [on the upper McCloud] or Fall River Mills have made it necessary to omit these possibilities from further consideration. (Hanson and others 1940, p 15)*

Attending biologists were openly skeptical about using hatcheries to sustain incoming year-classes of spring-run fish.

As had been done on the Columbia River, an exhaustive stream survey to identify candidate streams for "naturally" transferring the upper Sacramento River salmon was conducted. Between the Shasta dam site and the Feather River, twelve tributaries entering the Sacramento from the east were counted. Of the twelve, eight showed no promise for housing displaced runs of fish. Only Churn Creek, Battle Creek, Deer Creek and Stillwater Creek exhibited attributes conducive to a potential salmon restoration effort[15]. Of the five streams emptying into the mainstem from the west, most were dry an appreciable part of the year. Larger tributaries like the American and the Yuba rivers were also evaluated but each was eliminated due to the century-old accumulation of mining debris. Finally, and perhaps in desperation, investigating biologists turned to the Klamath Basin's Trinity River as a potential transplant site. But it, too, was ruled out due to its excessive distance, to existing indigenous runs of fish, and to pending proposals for dams along its lower reaches.

Hanson, Needham and Smith developed alternative plans, a summary of which follows, along with discussion of the principal advantages and disadvantages of each.

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15. To date, I have discovered no mention by the Bureau of setting aside certain downstream tributaries as "refugia" for returning migratory fish. Apparently that idea was stillborn on the Columbia River in 1938.

"The Stillwater Creek Plan"

The aptly named Stillwater Creek is dry during the summer and early fall months before it enters the Sacramento River near Redding. It had several advantages over other candidate tributaries including prime potential salmon habitat, downstream proximity to proposed salmon trapping facilities at Keswick Reservoir, and excellent prospects for being "rewatered." Most significantly, due to its intermittent flow, Stillwater Creek was unencumbered when it came to competing water rights. Hanson, Needham and Smith recommended diverting and importing 150 cubic feet per second from the upper McCloud River (alternative sources included either the Pit River or the still less desirable water from Shasta Reservoir) via some combination of gravity-flow supply ditch (40 miles long) or tunnel (14 miles long) and a suspension bridge over the Pit River[16].

The Stillwater Plan called for constructing a separate "standby reservoir" at its highest point together with a hatchery and holding ponds suitable for rearing 50 million eggs. In the event a breakage interrupted their water source, biologists proposed a closed-loop watering and cooling system for all hatchery operations. The biologists calculated that a rewatered 24-mile-long stream had sufficient room for 5,000 redds. They set their total combined artificial and natural production objectives at 30,000 salmon.

Several of Stillwater's advantages stemmed from an assurance of the best upriver water available—fabled McCloud River water[17]. Secondly, and importantly, there were no conflicting interests with other water users. In addition, hauling distances from fish trapping sites at Keswick Dam to release points were the shortest of any proposed plan. Finally, since Stillwater Creek lay downstream from the proposed Keswick trapping operations, it was hoped that future returning migrants could reenter the creek on their own.

16. No doubt biologists also had winter-run chinook on their minds as they sought to import McCloud River water into the lower middle Sacramento River Basin.

17. Livingston Stone referred to the McCloud River "as the last best hope for the Sacramento River salmon," a sentiment subsequently echoed by biologist Joel Hedgpeth. See Hedgpeth (1941).

Stillwater's liabilities stemmed from its excessive construction and maintenance costs. Construction alone was apprised at $4.3 million dollars (Hanson and others 1940, p 102). Somewhat paradoxically, these same scientists faulted Stillwater Creek's limited areas for natural spawning and they cited downstream erection of the proposed Iron Canyon Dam (above Red Bluff) as deeply troubling[18]. Since the whole operation was contingent on a dependable upriver water supply, a break in the system remained an ever-present danger. Finally, diverted McCloud River water at Shasta Dam's turbines were calculated by Bureau engineers at an annual firm power loss of $62,500 (Hanson and others 1940, p 101).

"The [Combined] Battle Creek / Deer Creek Salvage Plan"

Due to its year-round flow and its existing US Bureau of Fisheries Hatchery, Battle Creek held promise in any fish recovery effort (Hanson and others 1940, p 102). This salvage plan revolved around establishing a large hatchery facility (or two hatcheries working cooperatively), while using lower Battle Creek for natural spawning. The trick would be to avoid jeopardizing Battle Creek's native fall and spring runs. In addition, a variation on the proposal called for transferring as many spring-run salmon into Deer Creek as possible.

This design required a permanent hatchery "salvage" program for a total of 16,000 fall-run and 6,000 spring-run fish. Biologists believed that fall-run migrants passing Shasta Dam would produce 50 million eggs annually, well beyond the modest capability of the long existing Battle Creek Hatchery (at 12 million eggs)[19]. Hanson, Needham, and Smith recommended building a sizable hatchery capable of handling 75 million eggs, inclusive of those already handled by the historic Battle Creek facility.

The report specifies Battle Creek's native runs as occupying a restricted space between the river's mouth and Pacific Gas and Electric's Coleman Power-

18. Citations about the proposed Iron Mountain and Table Mountain dams were scattered throughout the report. Should a lower river dam be built, biologists warned, all efforts to mitigate for the Shasta-Keswick complex would be "nullified." In 1944, federal and State biologists minced no words when they declared that "adequate protection should be provided [salmon] during [dam] construction periods: to [among many grounds,] prevent any man-made catastrophe which might eliminate for all time a portion of, or a whole, annual cycle of salmon." They urged a reexamination of the entire Table Mountain Dam project, for, "...as presently proposed, the dam will probably spell the doom of salmon and steelhead runs into the upper Sacramento River" (Rich and others 1944, p 7, 11).

19. In one year, peak production at the turn-of-the-century Battle Creek Hatchery produced 60 million eggs. However, substantial water development, aggressive broodstock harvesting, and intense fishing pressures reduced that number to a modest 12 million-egg capacity. (Leitritz 1970, p 25; USFWS and Richardson 1987a, p 4).

house. A stream survey cites room for 720 redds within a three mile reach between the upper racks and Coleman's tailrace (Hanson and others 1940, p 103). The two racks were installed to trap and hold fall-run chinook salmon. Additional spawning grounds above Coleman Powerhouse are dismissed as too limited "...to warrant the expense and difficulty of purchasing the power development on Battle Creek (Hanson and others 1940, p 103)." Biologists tailored their strategies so as not to disturb PG&E's existing operations and water rights[20].

Spring-run fish, the biologists specify throughout, require ripening and holding under tightly bounded conditions. Hanson, Needham and Smith believed Battle Creek to be excessively warm during the summer months (at one point a lower stretch reached 73 degrees Fahrenheit). Darrah Springs was suggested as one local source for cold, pure, spring water, where holding ponds might prove satisfactory. However, its modest 35 cubic feet per second (cfs) flow would be suitable for only a limited number of salmon. There was also the matter of a lengthy 32 mile commute from the trapping site near Redding. In addition, PG&E's consent would also be required before the facility could become fully functional to raise water some thirty feet to exit the hatchery (Hanson and others 1940, p 105).

Deer Creek is mentioned as the only other suitable lower Sacramento River tributary where spring-run salmon might also be transferred. In a Combination Battle Creek/Deer Creek Plan, Hanson and his colleagues record that the latter has sufficient spawning area for about 3,700 salmon between its mouth and the falls above Polk Springs (Hanson and others 1940, p 107). During summer months, however, irrigators pumped enough water out of Deer Creek to dry up its lower reaches. "Rewatering" Deer Creek required moving water around. Scientists urged that mainstem Sacramento River water be pumped to irrigators to compensate for Deer Creek's proposed restoration. This proposition was dismissed by members of the Board and others as being too costly.

20. For instance, they recommended supplying the proposed hatchery with water derived from Coleman Powerhouse's tailrace rather than from the creek itself. Service biologist Scott Hamelberg points out that "[e]ven though placing the [water] intake in Coleman Powerhouse's tailrace may have been "non-disruptive" to PG&E operations, we still recognize today there are major advantages to having the intake located at this site" (USFWS and Hamelberg 1999, p 1).

The formal Battle Creek proposal called for a 75 million-egg hatchery to be located below the Coleman Powerhouse for fall-run salmon. The Darrah Springs facility was to house at least 30 million spring-run eggs, or a second facility was to be located on or near Deer Creek[21]. Weirs, collecting systems, traps, and the like, would capture incoming fish. A fleet of 18 tanker trucks could haul fish the 60 miles required to their destinations. Interestingly, Hanson, Needham and Smith prepared no accompanying cost estimates for this plan. While they were operating under tight time constraints, evidence suggests they favored the much more costly Stillwater Plan.

The Combined Battle Creek/Deer Creek plan's advantages are "...its lower initial costs and the fact that it would not entail a power loss at Shasta Power Plant" (Hanson and others 1940, p 109). Biologists also believed they would find an "ample supply of cold water in Deer Creek" suitable for spring-run salmon to become reestablished. Liabilities included complete "[d]ependence upon artificial propagation as the sole salvage measure" (for the fall-run at least), total reliance upon Coleman Powerhouse's tailrace for incoming hatchery water, and excessive competition possibly culminating in overcrowding hatchery and native runs in both Battle and Deer creeks. They also lamented long hauling distances to Deer Creek, and, last but not least, the "necessity of replacing irrigation water with a permanent pumping plant if Deer Creek is to be used" (Hanson and others 1940, p 109).

"The Sacramento River Natural Spawning Plan"

Under the Sacramento River Natural Spawning Plan, most of the fall-run would be held within the river's mainstem where they could naturally reproduce. Two or more racks would be installed to disperse incoming fish to achieve their maximum sustained reproductive yields. Whatever remainder occurred, including all of the spring-run fish, were to be trapped and hauled to a Battle Creek hatchery situated at either Coleman or Darrah springs. Deer Creek was also specified as a possible holding area for naturally spawning spring-run fish.

The plan specified the building out of a hatchery facility capable of rearing 47 million eggs. Such a plant would supplant the existing Battle Creek operation as well as handle incoming fish from the Sacramento River. The plan called for building three removable racks in the mainstem Sacramento River, together with trapping and hauling facilities. The endeavor would cost an estimated $1.6 million with annual operating expenses of $40,000 (Hanson and others 1940, p 112).

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21. A spring-run hatchery on or near Deer Creek was called for in the event that the combined Battle Creek/Deer Creek Plan was embraced.

Advantages of a Sacramento mainstem holding plan included low initial capital costs, more natural spawning areas than were presented in other plans, and suitably cool water temperatures for 75 percent of the fall run. Disadvantages stemmed from uncertainty. How would fish behave behind in-river weirs? Would they tend to fall back, bunch up and overcrowd one another, or disperse downstream as hoped for? Biologists just didn't know. There was also the controversial matter of copper contamination from Iron Mountain and other upriver sites. Excessive water temperatures posed yet another hazard to incubating eggs and young salmon. Biologists were especially concerned with the mainstem Sacramento (below Redding) because stream temperatures reached well beyond 60 degrees Fahrenheit from May through October (Hanson and others 1940, p 113). Such elevated temperatures could be raised ever higher by drought conditions, potentially culminating in the loss of entire year-classes of fish. Finally, and perhaps most ominously, proposals loomed to construct either Table Mountain or Iron Canyon dams which would inundate mile upon mile of remaining prime spawning areas[22]. In closing their document, Hanson, Needham and Smith refer to fish salvage programs at both Grand Coulee and Shasta dams as little more than "large-scale experiments" (Hanson and others 1940, p 115).

Board of Consultant's Recommendations: Round Two

The Board of Consultants entrusted with selecting among the range of fish mitigation strategies presented by biologists Hanson, Needham and Smith eventually embraced a hybridized plan. Details of the "Sacramento River, Battle Creek, and Deer Creek Plan" (also called "The Foster Plan") were spelled out in a supplemental report prepared by Fred J. Foster. The report had several essential elements:

- Trapping and hauling an estimated 1,500 spring-run fish (about one quarter out of a total of 6,000 spring-run fish) to Deer Creek for natural spawning (Calkins and others 1940a, p 9–10).

- Trapping and hauling an additional quarter spring-run to a natural-type holding pool in Deer Creek.

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22. In a 1947 California Department of Fish and Game report, biologists stated that "Iron Canyon [D]am will destroy the entire salmon run now spawning between its site and Keswick Dam..." Members of the Statewide Water Committee of the California State Chamber of Commerce took issue with this assertion. Their research department argued that ample spawning gravel existed downstream from the proposed dam sites, that recent biological conclusions about the ill effects of Shasta-Keswick dams were contradictory, and that spiny rayed fishes had a significant place in the new West. See Blote 1946, p 175.

- Trapping and hauling the remaining spring-run to a holding pond at Darrah Springs on upper Battle Creek.

- Trapping and hauling about 4,000 early fall-run fish to planned holding ponds at Battle Creek's Coleman Hatchery site (to avoid potentially lethal Sacramento mainstem temperatures).

- Holding the remaining fall-run between racks within the mainstem Sacramento where they would spawn naturally.

- Construction of a hatchery at the Coleman site on Battle Creek suitable for 42 million eggs and/or advanced fry and 21 million fingerlings.

- Abandonment of the Bureau's historic Battle Creek Station but with retention of holding ponds for use by Battle Creek's fall-run salmon.

Low capital costs, extensive use of natural spawning areas, and suitably low mainstem water temperatures for perhaps three quarters of the fall-run were this plan's advantages. Its drawbacks included uncertainty of fish behavior when fish are caught behind racks, copper pollution from upriver mining leachate, high instream temperatures during summer and early fall months, and pending construction of Table Mountain and Iron Mountain dams (Calkins and others 1940a, p 10).

The Board of Consultants embraced Foster's Sacramento, Battle Creek, and Deer Creek Plan, but with a twist. They recommended deferring the Deer Creek portion until a better understanding of summer water temperatures was obtained. Once conditions looked sufficiently promising, they advised installing a Deer Creek natural-type pond which, they believed, should prove adequate for ripening and holding spring-run fish. Board members rejected outright a Sacramento River pumping station and means of conveyance to compensate irrigators for rewatering lower Deer Creek (Calkins and others 1940a, p 26).

The Board of Consultants endorsed installing three racks in the Sacramento mainstem, the lowermost falling just upriver from Battle Creek's mouth (Calkins and others 1940a, p 28). They suggested locating a fish counting device on the lowest rack and keeping precise fish passage records. The Board advocated combining a trapping device with one of the instream weirs. Calkins, Durand, and Rich sanctioned a fleet of four trucks to ferry captured salmon to the proposed Coleman hatchery and to other holding ponds at Darrah Springs and within Battle Creek. Capital costs were placed at $1,064,500 (not including Deer Creek) with an annual operating expense of $35,000. Their justification for these expenditures invites a look at their calculations.

Board members believed they were compensating for a run of salmon from between 20,000 to 25,000 fish arriving at Redding in two well-marked peaks (Calkins and others 1940a, p 18). The spring run reached Redding between the middle of April and July, and consisted of 5,000 to 6,000 fish. The fall run arrived between mid-September and late-November and consisted of 15,000 to 20,000 fish. Any mention of a possibly existing winter-run went unacknowledged within their report.

Economist R. D. Calkins probably penned the Board's cost-benefit analysis on economic losses attributable to fish blockage at Shasta Dam. Any figures (he noted, and the Board ratified) depended on the "number, weight, and value of the fish taken in the commercial fishery" (Calkins and others 1940a, p 21). They recorded that one million pounds of fish were caught annually by an in-river net fishery while four million pounds of fish derived from ocean trolling. Since "...no more than half of the river catch is derived from above Redding," they reasoned that half of the Sacramento River District's current $57,000 fishery was in jeopardy. Board members concluded "...that no more than half, or $28,000, of this [in-river fishery] may be regarded as the value of fish derived from spawning above the Shasta Dam" (Calkins and others 1940a, p 22).

As for the more indeterminate ocean fishery, Board members reasoned that "...probably no more than one third to one half the California ocean catch is derived from the Sacramento [River]" (Calkins and others 1940a, p 23). Since between 1929 and 1938, ocean catches below the Mendocino County line averaged 1,781,000 pounds, their total assessed market value was $139,000. Assuming further that "...one third of these fish are from the Sacramento-San Joaquin river systems, and that one half of these are from above Redding, we reach a value of $23,000" (Calkins and others 1940a, p 24). By combining this figure with the in-river figure, the Board placed the gross value of upper Sacramento River salmon to commercial fishermen at $51,000, or possibly as high as $87,000 (Calkins and others 1940a, p 24).

The Board dismissed the value of salmon loss to California's sports catch as indeterminate. They stated that sports fishing losses, like steelhead, stemming from Shasta Dam, "...[were] of small or even negligible value" (Calkins and others 1940a, p 32–33). Calkins, Durand, and Rich echoed a sentiment expressed in their mid-Columbia River Report by questioning whether the Bureau had any role whatsoever in compensating for sports fisheries losses. Lester A. McMillan, Executive Officer of the State of California's Division of Fish and Game, took issue with this omission. In a letter to W. F. Durand dated August 12, 1940, McMillan concluded:

> *An additional economical value of the salmon run was brought to your attention in that a considerable sports catch of salmon occurs in California. Recent figures...[show] that 160,000 salmon were taken by sportsmen in 1939. This*

is between 1,600,000 and 2,000,000 pounds of fish. If one quarter of these fish, or 500,000 pounds, would have reached the Redding Dam, and represent a value of $1.00 per pound, which we have placed upon other sports fishes, the value of the run at Redding increases considerably (McMillan, as cited in Calkins and others 1940b, p 12).

DFG members did a far better job than federal representatives in defending the recreational interests of sportsmen loath to abandon prized sports fish as an inevitable price of progress. It would require another six years before steelhead achieved sufficient status to warrant artificial propagation at Coleman.

On October 5, 1940, the Board of Consultants formally responded to the State of California's concerns within a "Supplemental Report" (Calkins and others 1940b)[23]. Board members appeared responsive to a future enlargement of the Battle Creek Hatchery and to possible construction of another hatchery on Deer Creek. They raised from eight to fourteen the number of rearing ponds at the Battle Creek hatchery. Calkins, Durand and Rich concurred in using Battle Creek's natural holding ponds solely for adult fish. They increased the number of fish transport trucks from four to seven. Federal reviewers agreed that Keswick Dam should serve both as a river regulating structure and as a fish trapping site. Finally, on the sticky legal point of formalizing an agreement between the State of California and the Department of the Interior over fish salvage matters, Board members stated that it was not within their power to define the "...jurisdiction and responsibility of each agency" (Calkins and others 1940b; Moffett 1949, p 79)[24].

Implementing Fish Salvage Principles

The Board of Consultants 1940 recommendations were implemented with a few "minor revisions" (Needham and others 1943, p 7). By June 1, 1943, the

23. Recall that on the mid-Columbia River, Bureau of Fisheries biologists and members of the Board of Consultants responded to a fish salvage program prepared by the Washington State Department of Fisheries. On the Sacramento River, although one may have existed, I find no evidence of a separately existing, state-commissioned, fish salvage report. From the outset, it appears that state and federal regulators were in broad agreement about what needed to be done to save threatened Sacramento River salmon. Grand Coulee Dam's plan may have provided a compelling model for subsequent state and federal fish rescue efforts.

24. State fisheries regulators also proposed an experimental plan to ferry some salmon fingerlings above Shasta Dam to see what would become of them. Throughout the early 1950s, the US Army Corps of Engineers conducted experimental fish passage studies through Shasta Dam's turbines. Coleman's 1953 Annual Report makes mention of a lone, tagged salmon which managed to migrate from Shasta Reservoir and out to sea before returning to the Keswick trap. Board members dismissed the proposal as unworkable.

Bureau had placed in operation the following features of the "Sacramento River, Battle Creek, and Deer Creek Salvage Plan" (called by the Bureau "The Sacramento River Migratory Fish Control Program," or more generally known as "The Shasta Salmon Salvage Plan"):

- Fish ladder, traps and lifts in the Keswick Afterbay Dam and the Balls Ferry Rack for capturing and removing salmon under high and low water conditions, respectively (Needham 1943, p 8; Moffett 1949, p 79).
- Seven tank trucks for transferring salmon from the Balls Ferry and Keswick Dam traps to the Coleman National Fish Station on Battle Creek, and to Deer Creek;
- Construction of a Battle Creek hatchery infrastructure capable of handling 58 million eggs and approximately 29 million fingerlings. Twenty-eight outdoor rearing and holding ponds were constructed.
- Five racks in Battle Creek provide four holding and ripening areas for adult spring-run transferred from the Sacramento River (Needham 1943, p 8).
- Three removable Sacramento River racks, the lowermost at Balls Ferry. The Balls Ferry rack serves as a trap, as an aid in upstream spawner distribution, and as a barrier to incoming fish.
- One rack on Deer Creek for holding transferred fish upstream and for counting the native runs of fish.
- A fish ladder around Deer Creek's lower falls to open up five additional miles of spawning stream.

Within a 1943 supplemental report ("Special Scientific Report Number 26") issued on The Shasta Salmon Salvage Plan, Paul R. Needham, Harry A. Hanson, and Lewis P. Parker amended and updated efforts already underway to save threatened salmon. In it, scientists estimated at greater than 60,000 the actual number of salmon migrating past Redding, a sizable increase over 1939 and 1940s modest, drought-modulated estimates (numbering some 20,000 to 25,000 fish). The updated report warned that "...the [original] salvage plan must be adjusted to great fluctuations in numbers of salmon and that no count to date has established maximum numbers of salmon that may have to be handled" (Needham and others 1943, p 2). Biologists nevertheless recommended transferring 10,000 spring-run fish to Deer Creek with an additional 2,000 being held within Battle Creek for artificial propagation. Eighteen-thousand "summer" fish[25] (as they termed them) or early-fall-run fish would be

25. By "summer" fish, I can only assume that Needham and others meant fall-run fish which, they believed, were particularly vulnerable to high water temperatures during the late summer and early fall period (Needham and others 1943).

transferred to Battle Creek for artificial propagation, while 30,000 fall-run salmon would be distributed between Sacramento River mainstem racks for natural propagation (Needham and others 1943, p 7). The biologists reached the conclusion that only two Sacramento River tributaries, Battle and Deer creeks, held any promise for transplanting displaced upper river salmon.

"Special Scientific Report 26" also documents heavy losses occurring among the 1943 year-class of spring-run fish. Mortalities derived from:

> *A long delay in the completion of trapping facilities in Keswick Dam [which] resulted in serious losses to the 1943 spring-run. Many salmon confined below the dam during this delay were so badly bruised by jumping against the rocks and base of the dam that they died before the transfers began (Needham and others 1943, p 23).*

A 24.4 percent mortality occurred among spring-run salmon before successful spawning within Deer Creek[26].

Theories are often humbled by the acid tests of time and reality. Implementation of the aforementioned goals began disintegrating from the outset. Moreover, beginning in 1945, the leading institutional role being played by the Bureau (in tandem with the Central Valley Project beneficiaries), was being reevaluated and substantially rescinded. Piece by institutional piece, the Bureau abandoned to the Service (and indirectly, to the DFG) the responsibility for caring for, paying for, and operating ongoing fish salvage efforts.

Throughout the remainder of the 1940s, multiple components of the Shasta Salmon Salvage Plan broke down or were abandoned as unworkable. These fundamental features included (1) the failure of the Sacramento River's mainstem fish racks; (2) the Coleman National Fish Station's retreat from and abandonment of its attempts to ripen, hold, and propagate spring-run chinook salmon; (3) the Fish Transport System having higher than expected mortality rates, and (4) the spring-run transfer to Deer Creek being abandoned as unworkable. Finally, in June of 1950, the on-again, off-again Keswick Fishtrap and Loading Facilities were turned over to the Service by an exiting Bureau.

Sacramento River Fish Racks

Bids for the first of three proposed mainstem racks, at Balls Ferry, were received on August 15, 1941 (Needham and others 1943, p 11). This weir was

26. Mention was made of the winter-run fish which "...were very ripe and on several occasions deposited eggs in the truck while enroute from Keswick Dam" to [Deer Creek] (Needham and others 1943, p 23). Once transferred, winter-run salmon deposited their spawn almost immediately in Deer Creek.

the lowermost downstream and it contained a low-water salmon trapping and removing device. Construction began in September 1941 but was discontinued by December due to high water. Construction resumed the following May with the base of the rack completed by year's end. However, in January 1943, a modest flood (73,000 cfs) "...washed out four bents and damaged several more" (Needham and others 1943, p 12)[27]. The rack had been repaired and made fully operable by late spring. This on-again, off-again pattern continued until this rack was finally abandoned as unworkable in 1945 (Moffett 1949, p 86).

A middle rack was located about 12 miles upstream from the Balls Ferry structure. Substantially completed by September or October 1942, it could never be made "fish-tight" due to a combination of uneven bedrock and unstable gravels (Needham and others 1943, p 16). On November 14, 1942, a modest rainfall occurred, washing downstream great quantities of debris from construction at Shasta and Keswick dams. On the night of November 17, dam debris put sufficient pressure on the structure to "bend 8 by 8 inch stringers" (Needham and others 1943, p 16). The structure became increasingly unstable as workers were unable to clean out accumulating debris. Within a matter of days it washed out, save for an isolated segment near one bank. Engineers concluded that "...it may not be possible to maintain fish-tight racks without permanent sills on which to set tripods" (Needham and others 1943, p 16).

By early 1943, participants decided to abandon constructing a third rack. None of the weirs was ever made "fish-tight" and the units seldom survived longer than the next freshet. By 1946, any pretense of functioning instream racks was dropped as unworkable. Instead, the Bureau entered negotiations with the Anderson Cottonwood Irrigation District (ACID) to use its seasonal diversion dam at Redding as an upstream fish barrier (Moffett 1949, p 87). On November 6, 1950, the Fish and Wildlife Service suspended this weir practice due to excessive fish mortalities observed. The first element of the salvage plan was branded a failure.

The Keswick Fishtrap

Closely tied to the combination Balls Ferry rack and trap was the upstream Keswick Dam Fishtrap. If the former were operable under low water conditions, the latter remained functional at higher rates of flow[28]. Consisting of a fish ladder, sweep chamber, brail and trap, loading crane and elevator,

27. "Bents" were posts upon which the removable fish racks were held in place.

28. Controversy later erupted because the Keswick Fishtrap became inoperable at flows in excess of 16,000 cfs. The Service asked the Bureau for a significant redesign and negotiations ensued over making the facility functional during periods of high flow.

Keswick Dam's permanent fishtrap began at a slow pace. A temporary "stop-work order" issued by the War Production Board all but halted its construction. Alarmed Service biologists pointed to accumulating year-classes of salmon below and urged some sort of emergency measure. During spring 1942, Service and Bureau personnel improvised a solution from materials they had on hand. By June 1, 1942, the temporary fishtrap began operation (CAR 1943, p 7).

Construction by the Bureau of a permanent trap began during March 1943. However, once it was erected, improvisation was necessary to make it fully functional. The Keswick Fishtrap began operating on April 22, 1943 and continued through August 31, 1943. In the process, surprised biologists learned that "...although the Balls Ferry rack has been installed and closed for some time, fish continued to enter the trap at Keswick Dam" (CAR 1944, p 8). Passing migrating salmon continued defying the lowermost Balls Ferry rack and the upstream rack until both racks washed out altogether.

Considerable fine-tuning was required of Keswick's Fishtrap over the next two years for it to become dependable. During mid-February 1944, experimental trapping of winter-run fish was conducted at the Keswick Dam site. By the end of May, 145 fish were captured and hauled to Coleman Hatchery for "experimental holding purposes" (CAR 1945, p 4). By late August of that same year, 894 winter- and spring-run salmon were captured and moved to other locations.

Following a fairly routine year of trapping, the 1946 season turned things upside down. Failure and abandonment of both lower Sacramento River spawning racks raised fears about serious upstream overcrowding. The Bureau began negotiating with the ACID to use their dam near Redding as an upstream fish barrier. Consequently, the Keswick Fishtrap was "neither required nor in operation" throughout the entire year (CAR 1947, p 1). This would continue through 1950.

While the Bureau continued operating the Keswick Fishtrap, language shifting responsibility between the Bureau and the Service was contained within a September 21, 1948 Memorandum of Agreement. It read: This agreement "...does not specifically provide for the operation of the Keswick Fishtrap or for the transportation of fish therein to the Coleman Hatchery" (CAR 1949). The trap was used minimally during 1947 and the Bureau continued reimbursing the Service's transport costs.

On November 6, 1950, the ACID irrigation dam ceased operating as a fish barrier and the Keswick Fishtrap was again placed in operation. Fish and Wildlife Service personnel questioned the dam turned fish weir's "...value and the extreme probability that numbers of adult salmon were being injured and destroyed before they could spawn" (CAR 1950, p 3). The Bureau was amenable a discontinuance of ACID's lease as a fish blocking device. The continuing operation of the Keswick Fishtrap remained a cooperative effort between both agencies.

Fish Transport

During 1941, spring-run salmon were captured in a temporary loading and trapping facility located at the ACID dam near Redding. Fish left that site in a tanker truck loaned by the national hatchery at Leavenworth, Washington (CAR 1942, p 15). Fish were hauled to nearby Battle Creek where, lacking suitable unloading facilities, they were released in a way meant to prevent injury.

The following year, Service personnel learned from the Bureau that it had been unable to obtain seven new truck frames which were to be fitted with tanks. Trucks were critical to the ongoing war effort and fish salvage was deemed "nonessential". The Bureau arranged for and received seven semi-trailers upon which tanks were mounted. Describing the results as "very dissatisfactory," Service personnel launched their own campaign to secure new trucks. They eventually succeeded and took delivery of them in early May 1942 (CAR 1943, p 9).

Major difficulties subsequently encountered hinged upon the significant distances between Sacramento River trapping sites and Deer Creek.

Deer Creek was a distant 92 miles from Shasta Dam, thus creating a taxing ride for the fish. To make matters worse, salmon that were held before being transported began the journey in a weakened state. While there were subsequent improvements, the added stress of transporting fish may have influenced decision makers to abandon Deer Creek altogether.

By late 1950, the Service was poised to assume responsibility for the fish transport operation from the Bureau. Service personnel anticipated transferring fish from the Keswick Fishtrap to the Coleman Hatchery and other sites for years to come. Coleman's Director wrote:

> *It is contemplated to continue the transfer of the adults for an indefinite number of years in the future, or until the run in the Sacramento River so stabilizes itself as not to require further transfers (CAR 1950, p 3).*

The Deer Creek Natural Spawning Option

Stream surveys conducted throughout the 1940s concluded that Deer Creek had sufficient space for 15,000 salmon (Moffett 1949, p 93). Reconciling those high expectations with low native stock counts (ranging from 635 fish in 1941 to a high of 4,257 in 1946) was one of many puzzles facing biologists (Moffett 1949, p 89). Despite its obvious problems, Deer Creek still provided the best hope for transferring displaced spring-run salmon.

Experiments conducted during 1941 demonstrated that it was feasible to haul and establish fish in Deer Creek from upstream Sacramento River sites. However, early on, fish were left in a vulnerable state due to hauling delays before their arduous overland journey. Through the end of June 1943, the entire spring- and "summer" -run was trapped and hauled to Deer Creek. A total of 5,243 fish was transferred to Deer Creek with another 944 interned at Coleman Hatchery holding ponds (CAR 1943, p 8). By July 21, known mortalities reached 1,273 fish, almost a quarter of those transferred (Moffett 1949, p 90).

That following year, the spring-run was largely hauled to Deer Creek with the remainder moved to Battle Creek. Upon completion of the seasonal hauling, with 7,868 fish instream, Deer Creek's temperatures rose to 82 degrees Fahrenheit. Within three days, 1,135 fish perished, raising total observed mortalities to 16 percent (Moffett 1949, p 90). Excessive instream temperatures continued to erode efforts at establishing spring-run fish in Deer Creek.

During 1945, 1,606 spring-run salmon were hauled to Deer Creek while only 167 were transferred the following year (Moffett 1949, p 90). Numbers declined for several reasons. First, biologists theorized that significantly cooler water temperatures within the mainstem Sacramento River caused this race to hold and ripen farther downstream than ever before. Second, Deer Creek's status as a first-rate salmon stream fell prey to high agricultural diversions, unscreened irrigation diversions, and significant instream obstructions (like the Stanford-Vina Dam). A means of substituting Sacramento River water for Deer Creek's diversions was never created, thereby making the latter untenable for supporting large populations of fish. Despite the installation of fish ladders and other fish passage improvements, excessive losses "...cast doubt on the ultimate success of the transfer activities" (Moffett 1949, p 91). Serious spring-run transfers ceased by 1946.

Writing in 1948, Service biologists Cramer and Hammack summarized Deer Creek's potential this way: "The progeny of the transplanted salmon are doomed to a gradual or rapid extinction unless the conditions under which both populations are forced to live are changed enough to accommodate them" (Cramer and Hammack 1948, p 15). Without development of a substitute irrigation supply from the Sacramento River, "judicious channelization" at the creek's mouth, and removal of instream dams and obstructions, Deer Creek transfers would remain pointless.

Coleman National Fish Station

A hatchery on Battle Creek was always viewed as essential for perpetuation of the Sacramento River's spring-run fish and for a small segment of the early fall-run. Especially critical times were 1943 and 1944, "...when both Shasta and Keswick dams blockaded upstream passage but stored insufficient water to adequately lower downstream river temperatures" (Moffett 1949, p 79).

Recall that Professors Calkins, Durand and Rich had instructed that one half of what they believed constituted the spring run (or 3,000 out of 6,000 total spring-run fish) and about 4,000 early fall run (of 16,000 total fall-run fish) be transferred to the Coleman Hatchery site on Battle Creek. Coleman was designed to handle about 58 million eggs or advanced fry with any surplus space going to fingerlings.

Under the Bureau contract, hatchery construction began at Coleman in 1942 with the hatchery building completed in November of that year (Needham and others 1943, p 10). It was not until the early summer 1943, however, that Coleman's rearing ponds were capable of receiving spring-run salmon.

Some "experimental holding" of spring-run salmon on Battle Creek was attempted during the 1942 season (CAR 1942, p 15). In early July, a pond was created at an irrigation intake adjacent to Battle Creek. Forty percent of the fish held there died within 16 days of being transferred from the ACID dam. None of the 126 transplanted salmon were recovered for subsequent spawning at Coleman, signaling possible trouble ahead (CAR 1942, p 15–16). Simultaneously, 40 spring-run salmon were placed between racks within Battle Creek to commingle with its native fish. Transplanted and native fish mortalities were high, with 34 fish dying during July, 34 during August, and 27 during September. Thirty-six thousand five hundred eggs were eventually recovered but there was no way of identifying the parent stock (CAR 1942, p 16).

During 1945, Coleman's Annual Report estimated populations of Sacramento River spring- and fall-run chinook salmon to be in excess of those established during the previous year (while their formal counts were diminishing). Biologists resolved this paradox by arguing that spring-run salmon "...did not ascend the river due to the lower water temperatures" (CAR 1945, p 2). They speculated that prevailing cooler water temperatures "...may have caused these salmon to lay in the river until [becoming] near ripe instead of trying to get to the upper waters in the early summer" (CAR 1945, p 4). Whatever the cause, there would be fewer spring-run fish transferred either to Coleman Station, Battle Creek or to Deer Creek. Which fish stocks would take up the slack? The answer, as depicted in Table 1, was predominately lower river, fall-run fish.

Table 1 Annual egg production at Coleman Hatchery, 1943–1950[a]

Year	*Spring chinook salmon*	*Fall chinook salmon*	*Steelhead trout*
1943	1,053,665	8,320,853	
1944	4,040,650	11,298,880	
1945	1,281,272	20,759,463	
1946	2,763,000	25,178,000	
1947	165,000	10,875,000	31,250
1948		3,770,000	18,104
1949	206,513	13,221,464	178,052
1950	870,469	10,590,509	326,303

[a] Source: CAR 1950, p 17.

By 1945, Coleman raised 16 times the number of fall-run as spring-run fish, a ratio which generally climbed through 1950 (CAR 1946). In 1947, the hatchery raised roughly 66 times the number of fall-run as spring-run salmon. That following year, spring-run production plummeted to zero. The widening gap between spring- and fall-run production may have presented Coleman's Superintendent John Pelnar with an opportunity: he could substitute new species of sportfish—specifically steelhead—for diminishing spring-run fish and maximize production at his large hatchery facility.

In 1946, spring-run transfers to Deer Creek were rejected as unattainable. Beginning in 1947, hatchery production struck out in new directions with an experimental program involving steelhead. By 1950, Coleman accepted all of Keswick Fishtrap's spring-run transfers despite the hatchery's difficulty at holding and propagating these stream-type fish. In retrospect, we now know that it takes heroic measures and 1990s technologies to propagate winter-run salmon. It is no wonder Coleman failed fifty years earlier at replicating similar conditions to save diminishing spring-run fish. In late 1951, Service personnel concluded that perpetuation of the spring-run fish was best served by leaving them undisturbed within the mainstem Sacramento River (CAR 1952).

Early Steelhead Production at Coleman

It is ironic that steelhead were included among sportfish rescued under The Grand Coulee Fish Maintenance Program while they were dropped, initially at least, from consideration under The Shasta Salmon Salvage Plan. How can we account for this historic omission? There are biological, cultural, economic, institutional, and political factors that underscored an exclusive focus on Sacramento River salmon mitigation.

Recall that members of the Washington State Department of Fisheries wrote the initial draft of the Grand Coulee Fish Maintenance Program. From the outset, that state agency placed a significantly higher economic and political value on the role played by tens of thousands of sportsfishers than did their federal counterparts.[29] In addition, they argued that the economic "multiplier effects" arising from a vigorous recreational industry made steelhead integral to the region's economy. Lose steelhead production, so the argument went, and whole communities dependent upon outdoor recreational sports would miss out on a substantial part of their yearly incomes.[30]

Within their March, 1939 report, members of the Board of Consultants portrayed steelhead in a much less flattering light. They dismissed steelhead production in the mid-Columbia Basin as "not of great commercial importance." Even worse, however, the Board cautioned that "steelhead are predatory on the salmon." Hence, to boost the value of commercial fisheries, Rich and his colleagues urged,

> *...it would seem far better to center attention upon the production of Chinook salmon in the streams of this region and to eliminate rather than attempt to increase the steelhead (Calkins and others 1939b, p 10).*

Leavenworth Hatchery's eventual annual production of 14 million steelhead eggs is more a compromise between the states of Oregon and Washington and federal authorities than a reflection of the Board's actual preference of exclusively focusing on salmon restoration.

In their 1940 Bureau of Fisheries report, federal biologists Hanson, Needham, and Smith placed steelhead in their "coarse" fish category, together with various species of native eels, Sacramento pike minnow, and the like. Members of the Board of Consultants reiterated that, in addition to being salmon predators, steelhead had little to no commercial value. The Board of Consultants also dismissed the numbers of steelhead passing the Shasta Dam site as "negligible" (Calkins and others 1940a). Steelhead advocacy eventually fell to Service personnel like Coleman Superintendent John Pelnar, members of the DFG, and inland recreational fisheries advocates like Henry Clineschmidt.

29. The same can be said for the California Department of Fish and Game. See Executive Director Lester A. McMillan's letter to W. F. Durand, dated August 12, 1940 (Calkins and others 1940b, p 11–13).

30. Additional pressure may have been exerted by sportsmen organized to protect their threatened major resources. For a general treatment of sportsmen and the conservation movement, see Reiger (1986).

Clineschmidt was a close friend of John Pelnar and a "very active" Commissioner with the DFG (Hallock, personal communication, see "Notes"). The fact that "Steelhead Unlimited" and "Kamloops, Incorporated" were the same organization went a long way toward explaining the more or less simultaneous introduction of kokanee, Kamloops, and steelhead production at Coleman National Fish Station.[31] Beginning in 1947, the hatchery experimentally undertook steelhead propagation, a program which continues to this day.[32]

The Myth of a Successful CVP Mitigation

Throughout the 1940s, Coleman National Fish Station gradually abandoned its first objective of producing sufficient spring-run fish to perpetuate one-half of the upriver race. The Coleman facility did succeed at the propagation of lower-river, fall-run fish, thereby meeting its 1940 goal of reproducing one-quarter of the fall run among early migrants.[33] Beginning mid-February 1944, the facility experimentally held and attempted rearing winter-run salmon. No evidence pointed to any degree of success. Three years later, Coleman undertook producing steelhead for the first time. Immediately following the decade's close, Coleman's hatchery production objectives were broadened as hatchery personnel began stocking Shasta and later Whiskeytown reservoirs with "put-and-take" Kamloops trout and kokanee salmon from British Columbia. Coleman hatchery production objectives diversified from exclusive focus on salmon production to a broader range of recreational fisheries.

31. Under Clineschmidt's leadership, "Steelhead Unlimited" would later channel money to Coleman via The California Department of Fish and Game and "California Kamloops." California Kamloops issued the checks for steelhead propagation on behalf of Steelhead Unlimited (USFWS 1956).

32. A recent U. S. Fish and Wildlife Service Draft Report argues that "[construction of Shasta and Keswick dams] potentially denied [steelhead] access to large areas of natural spawning and rearing habitat" (USFWS 1997; USFWS and Hamelberg 1997, p 4).

33. It would take over two decades to recognize that late fall-run chinook salmon constituted a genetically unique stock. During the early years, mixing sometimes occurred at Coleman Hatchery of fall- and late fall-run stocks (Hallock, personal communication, see "Notes").

This significant transition began during July 1944, in a series of yearly Memoranda of Understanding (MOUs). Bureau administrators began making clear that they wanted to remove themselves from the fish salvage business. It is important to remember that the Bureau consisted of dam builders who moved rivers around as opposed to fish tenders. Fish maintenance, they insisted, was the business of the Service.[34] Why not let the Service tend to fishery affairs while the Bureau stuck to what it did best? There was also the contentious issue of signing over to the Service, mitigation budgets over which the Bureau had little or no control. Ron Brockman, Fisheries Program Manager with the Bureau's Sacramento office, believes the Service, via Coleman, sought an autonomous foothold in their California salmon restoration efforts (Brockman, personal communication, see "Notes"). Brockman observes a kind of historic tug-of-war occurring between the Bureau and the Service over who did what, when, (and for how much) at the hatchery facility. From Brockman's point of view, there was always reluctance to have the Bureau involved in shaping operations at Coleman Station.

If precedents on the Columbia River were any guide, Bureau administrators also sought—as soon as practicable—to declare victory and get out of the fish mitigation business (Taylor 1996, p 360). Nor was it the Bureau's intent to remain saddled with costly, long-term mitigation expenditures (Calkins and others 1939b, 1940a). On both the Columbia and Sacramento rivers, or so the theory held, hatcheries constituted capital-intensive means for artificially augmenting fish production within downstream tributaries until natural propagation might take hold. Bureau-supported hatchery mitigations were never intended to be an open-ended proposition with no end in sight (Calkins and others 1939b).

Such views were reflected within successive MOUs as each generation contained more and more equivocal language about the Bureau's responsibilities and obligations to the Service under the original "Sacramento River Migratory Fish Control Program." By mid-year 1948, an institutional mitosis ensued whereby both agencies inventoried, then cleaved, their separate properties and holdings. Initially at least, the Service enjoyed a cost-free, lease-back arrangement. However, that external support did not last for long.

Negotiations discussing Coleman's fate continued to intensify. In June 1947, Coleman Station's Superintendent John Pelnar reported that the station was

34. Roy Wingate, archivist at the Bureau of Reclamation's Denver Regional headquarters, advised me that comprehensive Bureau records ceased being assembled in 1945. That means that events like these occurring subsequent to that year would be difficult to track and were perhaps better retrievable at the regional office level. My trip to the Service's Portland Regional Office was due, in part, to his advice (Wingate, personal communication, see "Notes").

being "...contemplated for abandonment and closure" (CAR 1947, p 50). One month later, the MOU dated July 5 specified the withholding of Bureau funds for fish culture. In addition, the 1948 MOU did "...not specifically provide for the operation of the Keswick fishtrap or for the transportation therein to the Coleman Hatchery" (CAR 1948).

Within the September 21, 1948 Memorandum of Agreement (MOA), the Bureau of Reclamation formally launched the process of a hatchery transfer to the Fish and Wildlife Service. In retrospect, there appears to have been a simultaneous "push" and "pull" to this transaction. Significant numbers of returning mainstem spawners (above and below Red Bluff, and within Battle Creek) left many to argue that the Bureau-funded salvage program had indeed succeeded. For example, biologist James Moffett cites rough estimates of fish spawning above Red Bluff (144,000 in 1944, 106,000 in 1945, and 96,900 in 1946) and concludes that "Natural spawning in the Sacramento River was remarkably successful as is indicated by examinations of dead salmon and the hourly rate of catch in fyke nets of young salmon" (Moffett 1949, p 101). Indeed, a clause within the 1948 MOA stated:

> *WHEREAS, the Bureau and the Service are agreed that as a result of the salmon maintenance program and the operation of Shasta Dam with a regard for the welfare of the fishery, the salmon runs above Shasta Dam appear to have become established below the dam in numbers equal to the numbers existing before the dam was built...(Engle 1957, Part II, p 421).*

Negotiations transferring Coleman from the Bureau to the Service did, however, require the resolution of one final stumbling block. A September 8, 1948 memorandum stated the Service sought to compel the Bureau to underwrite "...the excessive cost of replacing the present Balls Ferry Fish Rack with a good fish-tight structure" (USFWS 1948b). The memorandum concluded that responsibility for the fish rack was "...the only matter upon which there had been a difference in interpretation of the terms of the proposed agreement..." (USFWS 1948b). Acting Service Director Johnson clearly wanted to take possession of a functional Balls Ferry Fish Rack. In a memorandum dated August 11, 1948, he complained the rack "...has not resulted in a fish-tight barrier and because of this, has never been a satisfactory facility for use in connection with operation at the Coleman Fish Hatchery (USFWS 1948a).

Bureau Commissioner Michael B. Straus countered that replacing the structure "would run into seven figures" and, instead, proposed to maintain the temporary structure "...as long as it [stood]" (USFWS and USBR 1948). The Coleman facility enjoyed Bureau funding during the first half of 1949 after which the Service assumed full funding responsibility (CAR 1949, p 1). In addition, the July 1, 1949 MOA declared Coleman Station to be separate from the Bureau's Central Valley Project obligations.[35]

The US Fish and Wildlife Service was eager to assume control of the Coleman facility. As former Coleman Superintendent Jerry Grover explained, by seeking a direct appropriation from Congress, the Service could run the facility and pocket a ten percent administrative overhead charge (which once reverted to the Bureau). Absorption of the Coleman facility also "built up" the national hatchery budget by approximately four percent, while the Service picked up added national and regional stature (Grover, personal communication, see "Notes"). A Service-run Coleman was also freed up to operate in a fundamentally new way. In something resembling a paradigm shift, Superintendent Pelnar could diversify Coleman's production objectives in accordance with a broader, nonreimbursable set of "recreational" criteria, and forego haggling with the Bureau over funding. Since the upstream reservoirs were created by a federal project, federal obligations existed to "...provide and maintain a sports fishery..." (USFWS 1963, p 33; USFWS and Richardson 1985). No longer exclusively tied to CVP mitigation objectives, the Service saw new opportunities in stocking Shasta (and later Whiskeytown) reservoirs with exotic game fish like Kamloops trout and kokanee salmon, in folding in steelhead production, and in achieving additional recreational objectives.[36] A heightened federal interest in sports fisheries surely drew applause from California's senators and congressmen, as well as from California's Department of Fish and Game.

In the end, elevated egg takes and salmon populations persuaded many State and federal biologists that the Shasta Salmon Salvage Plan had succeeded. Citing State Bureau of Marine Fisheries reports, Martin Blote of the California Chamber of Commerce recounts that catch records were broken in 1945 when salmon landings in California totaled 13,367,523 pounds. This commercial peak was exceeded in 1946 with a total catch of 13,649,673 pounds of fish

35. The Bureau and the Service's 1948 MOA did contain one fragmentary reminder about CVP fishery responsibility. "WHEREAS, the continued maintenance of the Sacramento River salmon runs is recognized as one of the purposes of the Central Valley Project in operating Shasta Dam,..." This clause reappeared 35 years later as a reminder that the Bureau was responsible for Coleman's attempts at mitigating for disappearing salmon (and steelhead). See Forbes (1983, p 4).

36. Concomitant to the Service's takeover at Coleman, Kamloops trout eggs were introduced into California from British Columbia in June of 1948 (CAR 1949, p 43).

(Blote 1948, p 7). Salmon landings in the upper San Francisco Bay, the Sacramento-San Joaquin Delta, and the Sacramento and San Joaquin rivers, totaled 5,467,960 pounds in 1945 and 6,642,050 pounds in 1946 (Blote 1948, p 7). Egg takes at Coleman were also invoked as grounds for optimism. Counts from 1945 (22,040,735 eggs) were surpassed by Coleman's 28,297,100 eggs captured in 1946 (Blote 1948, p 32). In 1947, Superintendent John Pelnar summarized Coleman's artificial propagation and fingerling rearing activities:

> *...the station, being one of the most efficient and producing units in the world, planned to attain a record undreamed of by fisheries workers. We successfully held and reared 25,794,652 chinook salmon fingerling, all of which had been fed for considerable time before being released....[T]he weight of the fish reared at Coleman during 1947, totaled 109,799 pounds, which is a record for other fisheries workers to look at with wonder and admiration (CAR 1947, p 1).*

The temperature regime within the lower river had been so improved by the Shasta-Keswick complex, or so argued Blote, that spring-run salmon "spawned themselves" within the lower mainstem Sacramento River (Blote 1948, p 32). Blote also pondered how continuing reservations about the success or failure of the Shasta Salmon Salvage Plan could be reconciled with record numbers of returning fish (Blote 1948). Although clearly impressed by these and subsequent high abundance figures, biologist James Moffett withheld final judgment, cautioning, in a paper's closing remarks, that "Experience has been insufficient to establish definitely the success or failure of the [Sacramento River] salmon maintenance work..." (Moffett 1949, p 102). What was held as true among many, however, was the belief that a sizable salmon fishery had become reestablished on yet another dramatically altered western river.

A Failed Mitigation Program Confronts Historic Salmon Populations

In retrospect, we can forgive those caught up in events for having made the best judgments possible at a given historic moment. History is sometimes less forgiving, however, as cumulative choices and events often give rise to a cascading series of institutional, economic, and ecological backlashes. Unanswered is how does Coleman's primary failure to mitigate for upstream losses (like spring-run fish) affect the achievement of other key 1940s Bureau of Reclamation "Sacramento River Migratory Fish Control Program" objectives? A reflection on what occurred among other key features of the Shasta mitigation program may answer the query. To reiterate:

- The Sacramento River fish racks essentially failed before being used.
- The Keswick Fish Trap operated on an on-again/off-again basis, and it became inoperative at moderate flows exceeding 16,000 cfs.

- The Fish Transport service often delivered weakened fish to inferior waters.

- Coleman National Fish Station was never able to propagate one half of the threatened spring run.

- The Deer Creek fish transfer was completely abandoned as unworkable by 1946.

In the end, what is concluded is that the mitigation failed.

The two surviving pieces of the original Shasta Salmon Salvage Plan were the Coleman Station itself and the Bureau-run Keswick Fishtrap. From the Service's point of view, Coleman Station did succeed at producing significant numbers of fall-run chinook salmon.

Although perhaps not in direct alignment with the [originally] proposed mitigation responsibility, the contribution of Coleman NFH in maintaining the ocean and sport fishery and upper river escapement of fall chinook salmon, while the quality of the Central Valley watershed was continually degraded, (Yoshiyama and others, this volume; USFWS and Hamelberg 1997, p 7).[37]

Within ensuing years, the Bureau's Keswick Fishtrap also continued being called upon to capture incoming cohorts of salmon. Most of the time the fishtrap functioned satisfactorily. However, even under moderate flow conditions of 16,000 cfs or greater, the fish trapping apparatus became inoperative (Hallock 1987, p 32).

What was lost with the building of the Central Valley Project's keystone Shasta-Keswick complex? Based upon initial 1940 run-estimates, the answer is roughly:

- 15% of the fall-run's upriver habitat.[38]

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37. An earlier version of this document was reviewed by unnamed Service biologist(s) stationed at Red Bluff's Northern Central Valley Fish and Wildlife Office. Subsequent correspondence attributed those comments to biologist Scott Hamelberg. This final version is clearly stronger for Hamelberg's efforts (USFWS and Hamelberg 1997, 1999).

38. Late fall-run fish would require years before being identified as a separate phenotype. Their upriver spawning habitats were more adversely affected than those of the fall-run salmon. DFG biologist Richard Hallock observes that late fall salmon eggs taken at Keswick Trap (between January and March) sometimes made up one-half to one-third of the total Coleman egg take. He adds that Coleman stopped taking late fall eggs when too many "green" salmon (winter-run) were being hauled back to Coleman hatchery (Hallock, personal communication, see "Notes").

- Save for upper Battle Creek, 100% of the winter-run's historic habitat.
- 100% of the spring-run's habitat in the watershed above Keswick.
- 90% of the steelhead's habitat.[39]

However, this was not all. Within their supplemental report to the original 1940 Shasta salmon salvage estimates, biologists Needham, Hanson, and Parker concluded that 1940 and 1941s runs were "...near 60,000 salmon by early December" (Needham and others 1943, p 14). Admitting that total runs "...might actually have been far greater than 60,000..." these scientists concluded that 1940 and 1941s combined runs

> *...could not have been less than 50,000 in either season "...and that the salvage plan must be adjusted to great fluctuations in numbers of salmon and that no account to date has established the maximum numbers of salmon that may have to be handled (Needham and others 1943, p 14).*

The salmon abundance estimates of 1943 roughly doubled previous drought-moderated figures under the Shasta Salmon Salvage Plan. Their new benchmarks included:

- 12,000 spring-run salmon (captured between January 1 and June 30).
- 18,000 summer and early-fall salmon (captured between June 16 and October 10 for artificial propagation).
- 30,000 fall-run (captured between October 1 and December 31 for natural propagation within the mainstem Sacramento River) (Needham and others 1943, p 7).

39. Recall from earlier discussions that steelhead propagation was folded into Coleman's operations in 1947. We have scant evidence of historic steelhead populations. I assume that historically, steelhead may have used spawning beds as far as 10 miles below Keswick Dam, hence the approximation of a 90 percent loss. If one assumes steelhead never spawned within the Sacramento River's mainstem, then estimates for what is missing climb upwards toward 100 percent.

More sobering still are recently prepared DFG spawning habitat estimates of historic salmon and steelhead populations above Keswick and Shasta dams (see Appendix A)[40]. Using recent and early spawning gravel surveys[41], biologists computed the number of nesting sites lost above Keswick and Shasta dams as a percentage of the entire Sacramento River run. These calculations assumed that each redd was 40 square feet above Shasta Dam (Hanson and others 1940) and 50 square feet downriver (Rieser and Bjorn 1979). In 1939, roughly 15 percent of the total fall run's estimated spawning areas occurred above Keswick Dam. Computations were based on 24,847 salmon spawning sites upriver from Shasta Dam and 5,945 salmon spawning sites occupying the stretch between Shasta and Keswick dams. The recommended space for spawning pairs during the mating process is 145 square feet for spring run and 215 square feet for fall-run salmon (Rieser and Bjorn 1979).

The most critical feature of the lost spawning grounds above Shasta and Keswick dams was not the absolute number of fish excluded but rather the quality of that drought-proof habitat. The McCloud River, the Little Sacramento River, and the Pit River were resistant to drought and the mortality caused by elevated water temperatures. These upper watersheds produced high quality habitats because of their higher elevations and their volcanic geomorphology. These rivers absorbed much of the wet seasonal runoff, then gradually released it in abundant cold spring flows throughout the dry season. The respectable counts of salmon and steelhead returning to the areas above Shasta Dam at the close of 1939's drought cycle attested to the drought-resistant character of these stream reaches. The habitat above Shasta Dam also provided for the natural spatial separation of the different races of salmon; especially spring-run and winter-run chinook.

Estimates of usable spawning habitat available in the first 130 river miles below Keswick Dam varied greatly among the four available studies. The pre-Shasta Dam estimates of 1939 occurred immediately following one of the worst droughts in recent history. That makes redd counts extremely low compared to the post-Shasta Dam era where estimates climbed due to higher and cooler river flows. The 1939 estimate for the 60-mile reach between Keswick and Red Bluff was placed at 18,413 spawning sites, while figures for this same

40. Within an unpublished paper, H. D. Radtke and S. W. Davis use Northwest Power Planning Council methodologies to estimate historic Central Valley salmon abundance. They reconstruct populations at between 2 million to 4 million fish (as cited in Gresh and others 1998, p 7). Using commercial catch figures, DFG biologist Frank Fisher estimated historic Central Valley salmon populations to have been 2 million fish (Fisher 1994). By drawing on USFWS derived run-size estimates, Thomas Richardson estimates pre-1915 peak Sacramento River salmon runs to have been between 800,000 to one million fish, with a yearly average of 600,000 (Richardson 1987, p 6; USFWS 1984).

41. Historic survey data derive from Hanson and others (1940, p 25, 31, 48).

reach after Shasta Dam averaged 120,588 sites. There was no comparable 1939 estimate for the 70-mile reach below Red Bluff Diversion Dam because it appeared to observers to be of excessively poor quality. However, if it is assumed that in 1939 there were the same numbers of sites above as below Red Bluff (18,413), this was significantly lower than the estimate of 70,908 sites determined in a 1976 mapping.

The spawning habitats below Shasta Dam were apparently increased during periods when there were cold high volume water releases from Shasta Dam. There is a danger, however, in counting on these conditions if they were transitory (as described in Moffett 1944). Even if there were assurances of making the lower elevation habitats below reservoirs reliable, they certainly did not possess quality conditions comparable to those found above Shasta Dam. The below-dam habitats remained drought-prone and they did not provide spatial isolation between overlapping stocks of spring- and fall-run salmon. Currently, below Shasta Dam, the winter-run salmon have 40 miles of river with suitable spawning habitat available during 90 percent of the water years with no available habitat under the worst drought conditions (USBR 1991; DFG 1992; NMFS 1992). To make matters worse, DFG biologist Richard Hallock demonstrated that over a 17-year period, Red Bluff Diversion Dam greatly undermined downstream reproductive conditions where lower river water temperatures were suitable for winter-run spawning and incubation 22 percent of the time (Hallock 1987, p 55).

Above-Shasta populations of winter-run salmon once had an estimated 34,634 spawning sites available in the Little Sacramento, the McCloud, and the Pit river systems. Save for Battle Creek, 100 percent of the winter-run race spawned upriver from the Shasta-Keswick complex (Hallock and Rectenwald 1989).

Pre-Shasta populations of spring-run salmon once had at least 51,377 spawning sites dispersed throughout the Little Sacramento, the McCloud, and Pit rivers. In the 1920s, Pacific Gas and Electric's Pit River dams cut off an additional 7,444 upriver spawning sites without benefit of mitigation.[42]

Despite substantial evidence of widespread failure, the Bureau, the Service, the DFG, and many interested observers, convinced themselves that the "Sacramento River Migratory Fish Control Program" had succeeded. In the end,

42. This figure is based upon DFG computations. For insights into the proposed damming of the lower Pit River, see Hopson and Means (1915). G. H. Clark observes that Pit Dam No. 4, PG&E's lowermost dam on the Pit River, blocked upstream passage of salmon. The structure was completed in May 1927, and, as biologist Clark observes, "...is impassable with no provisions to take care of the fish." Pit No. 3 is located nine miles upriver. Also impassable, it was completed in 1925 (Clark 1929, p 42–43).

the spectacle of considerable fish in the Sacramento River provided the screen to hide the salvage program's cumulative failures. A myth had been created and it would require considerable time before the Shasta Dam's full effects came into plain view.

IV. Coleman Hatchery Production: The 1950s

Throughout the 1950s, a Service-directed Coleman Station produced a wider assortment of fish species reared for a greater number of northern California destinations and clients. In addition to fall-, winter- and spring-run chinook salmon, Coleman produced or handled coho salmon, steelhead, rainbow trout (mostly provided by the State of California), Kamloops trout, kokanee salmon, and even a few warm water fishes. Specific clients came to include "Kamloops, Incorporated" and "Steelhead Unlimited" of Redding, Beale Air Force Base (near Marysville), and Stead Air Force Base.

Between 1949 and June, 1957, the Bureau of Reclamation sponsored cooperative state and federal research consisting of life cycle assessments and data accumulation on the continuing fish maintenance program. Writing within their summary report, Service biologists Robert L. Azevedo and Zell E. Parkhurst observed that:

> *...during the 1943–1949 period [the upper Sacramento River changed]...from primarily [being] a salmon salvage program to a program of maintenance and evaluation. The Bureau of Reclamation continued to finance the fishery program beyond the salmon salvage stage because evaluation studies, as well as hatchery operations, were considered an integral and necessary part of the conservation of natural resources associated with the Central Valley Project (Azevedo and Parkhurst 1957, p 3–4).*

The ensuing eight-year program principally consisted of:

- Spring-run chinook salmon being left to spawn naturally within the Sacramento mainstem and other accessible tributaries.
- Fall- and some winter-run chinook salmon being taken at Keswick Fishtrap and hauled to Coleman Hatchery for artificial propagation.
- Fall-run chinook spawners being diverted from Battle Creek into the Coleman facility.
- Data gathering to determine annual fluctuations in populations, fishing pressures, adverse effects of mining leachate, and so forth (Azevedo and Parkhurst 1957, p 4–5).

Within what Kai Lee has subsequently called an "industrialized ecosystem," riverine studies such as these were useful in determining how best to coordinate Coleman's migratory releases coincident with natural fish migrations and other identifiable windows of opportunity (Lee 1993; Azevedo and Parkhurst 1957, p 6). For instance, water temperature records aided in determining optimal periods for releasing salmon fingerlings. In addition, by carefully tracking upriver pollution deriving from sites like Iron Mountain mine, Coleman Hatchery's personnel even sought to avoid excessive fishkills.

These and other similar data provided Coleman Superintendent John Pelnar with means of maximizing fish escapement. Within a dramatically altered ecosystem, Coleman-reared fish arguably possessed certain advantages never enjoyed by their wild counterparts. For instance, Superintendent Pelnar knew the best times of the year to avoid hatchery releases due to excessive downstream irrigation (Hallock, personal communication, see "Notes"). It was certainly helpful knowing about mainstem Sacramento River water exports considering the "...335 separate diversions, utilizing a total of 448 pumps, along the Sacramento River between Redding and Sacramento" (Hallock and Van Woert 1959, p 263). Coleman also provided State and federal biologists with increasingly sophisticated means of marking outgoing and incoming cohorts of anadromous fish (Cope and Slater 1957). DFG biologists, in particular, conducted elaborate marking experiments for tracking the whereabouts, perils, and life cycle patterns exhibited by anadromous fish.

Fall-run chinook salmon and steelhead production predominated at Coleman with a small but steady supply of imported Kamloops trout and kokanee salmon for Shasta Reservoir. The hatchery's last major attempt at spring-run production occurred in 1951 (after which it was begrudgingly abandoned).[43] In 1955, an experimental trapping of winter-run salmon occurred in which only two females out of 184 total fish spawned (CAR 1955, p 20). Experimentation with winter-run stocks reoccurred during 1958 when they stripped eggs and milt from a total of 191 fish (CAR 1958, p 20). Attempted propagation of winter-run fish ceased during the following year, only to occur again in 1962.

In 1952, British Columbia- and Montana-derived Kamloops trout and kokanee salmon were obtained by Coleman Hatchery for a recreational fishery in Shasta Reservoir.[44] Henry Clineschmidt's Redding-based group(s), "Kam-

43. Well, almost. During 1954 they propagated a total of four spring-run chinook (CAR 1955).

44. Richard Hallock observes that during the 1950s, marked yearling Kamloops trout were also released in the Sacramento River to produce a resident trout fishery near Redding. The fish, however, took an unexpected turn and headed out to sea, only to return with incoming steelhead. Hallock also points to evidence of hybridization between Kamloops and steelhead (Hallock, personal communication, see "Notes").

loops, Incorporated," (and "Steelhead Unlimited") forged several funded, cooperative agreements with the Bureau of Sports Fisheries and Wildlife and the DFG, to propagate specific game fish. Clineschmidt, like Pelnar, was a significant force in northern California fisheries circles, and together, they made formidable advocates. Clineschmidt and Pelnar's plan was simply to introduce Kamloops trout into Shasta (and later Whiskeytown) reservoirs, to be followed by kokanee salmon (Hallock, personal communication, see "Notes"). They hoped to mirror ecological conditions found in Idaho's lake Pend Oreille, in which legendary forty pound Kamloops trout fed off an established kokanee population. Anticipation of landing a forty pound Kamloops trout on light tackle went a long way toward explaining why "Kamloops, Incorporated" and "Steelhead, Unlimited" were founded by the same individual and consisted of complimentary memberships.

In 1955, Coleman's production was drafted by the US Air Force. The Commander at Beale Air Force Base (near Marysville) sought advice and assistance in stocking waters adjacent to his geographically-isolated personnel. Beale's base population would soon swell to over 15,000 individuals as it became a Strategic Air Command base.[45] Rainbow trout as well as some warm water fishes were planted. A subsequent agreement signed between the Service and the Air Force directed Coleman to stock waters near two northern California bases (CAR 1955, p 5). Some rainbow trout were reared at Coleman while the majority came from State of California hatcheries.

In March 1956, 43,025 yearling coho salmon were introduced into the Sacramento River basin from Washington's Lewis River (Hallock and Fry 1967, p 15). In late September 1957, Coleman Hatchery trapped 910 coho salmon for the continuing experiment in artificial propagation (CAR 1957, p 5).[46] Cohos were promoted by Jim Baucum, President of the Sacramento River Resort Owners Association. Baucum, himself a resort owner (in Los Molinos), saw an opportunity in introducing these prized sports fish into the Sacramento's mainstem. Resort owners sought to convince biologists that cohos might fill a seasonal recreational fishing "gap" without unfairly competing with other anadromous fish.[47] The Resort Owner's Association promised to foot the bill

45. In 1960, Congress passed the Sikes Act which institutionalized cooperative arrangements between the US Fish and Wildlife Service and other federal agencies which were interested in stocking and managing, among others holdings, Indian and military reservations (USFWS and Hamelberg 1997, p 7).

46. Of this total, 125 were females, yielding a total of 386,971 eggs (CAR 1957, p 5).

47. Richard Hallock, personal communication, see "Notes." DFG biologists presumed that coho would come upriver after steelhead and remain within the mainstem Sacramento rather than proceed on into upriver tributaries and compete with other salmon.

if Leo Shapovalov of DFG and John Pelnar of Coleman Hatchery were agreeable. Coho salmon trapped at Coleman were part of a three year study conducted by Richard Hallock of the DFG (Hallock, personal communication, see "Notes"; Hallock and Fry 1967, p 15–16).

Over the next three years, Coleman and Darrah Springs hatcheries sought to establish a run of coho in the Sacramento River basin. Hatchery personnel later discovered that eggs taken from returning fish were unsuitable for artificial propagation. The eggs themselves were soft and failed to fertilize properly. The experiment seemed to have been quietly discontinued in 1960 when 63 coho were released into Battle Creek (CAR 1960, p 6). Superintendent John Pelnar was pleased to be rid of the project because, in the words of biologist Richard Hallock, "it made his numbers look bad" (Hallock, personal communication, see "Notes"). By the fall of 1963, Hallock and Fry reported that cohos were as scarce in the Sacramento River as they had been before this recreational experiment (Fry and Hallock 1967, p 16).

Throughout the 1950s, the DFG reported a general increase in steelhead populations throughout the remaining mainstem Sacramento River. By 1958, artificial propagation of steelhead at Coleman Hatchery shifted from its prior experimental status to becoming a more fully established program. Collaboration with members of Steelhead Unlimited and the DFG helped solidify Coleman's steelhead production objectives. Azevedo and Parkhurst reported that roughly 5,000 chinook salmon and 2,500 steelhead were caught by sportsfishers in the upper Sacramento River between 1952 and 1954 (Azevedo and Parkhurst 1958, p 70). These biologists also noted that Sacramento River fishing resorts "...increased from eight in 1951 to twenty in 1954" (Azevedo and Parkhurst 1958, p 70). Kamloops, kokanee and steelhead production at Coleman was bolstered by outside recreational interests who shared a sizable economic stake in the hatchery's recreational production.

Throughout the 1950s, disease remained a serious problem at Coleman Hatchery. In 1953 through 1955, biologists believed a filterable virus of unknown origin hit hatchery salmon stocks.[48] Heaviest losses occurred during March, April, and May of 1955 when almost 17 percent of the salmon stock affected died (CAR 1955, p 5). Biologists observed the disease outbreak diminishing when water temperatures rose in late Spring. Again during 1958 and 1959, the station was hit by considerable losses among salmon fingerlings, prompting personnel to write: "Since the advent of this station's fish operations a steadily increasing loss was suffered by all age groups of chinook salmon, various

48. Biologists believed that with sufficient filtration, they could prevent the onset of this disease. The disease was probably Infectious Hematopoietic Necrosis (IHN) which was finally identified in 1962 after several years of study.

remedies were made use of but to no avail" (CAR 1959, p 7). Scientists from Seattle's Western Fish Disease Laboratory were called in to study the problem.

As hatchery personnel busily contained disease outbreaks, Coleman's director observed there was growing public interest in hatchery activities and production. A steady stream of visitors prompted Superintendent Pelnar to write:

> *Considerable interest has been shown by commercial and sport fishermen in the station's work, due to the general down trend of the chinook run in California. Many feel that the natural reproduction is no longer practical and far too much loss occurs from natural spawning (CAR 1957, p 3).*

Throughout the 1950s, Coleman National Fish Station's diversification strategy appears to have been opportunistically motivated. Saddled as it was with running a very expensive facility, the Service had little choice but to continually seek sympathetic outside constituencies, external funding, and broad-based public support. By 1960, the sole remaining formal piece of the Bureau's original "Sacramento River Migratory Fish Control Program" was booming production of predominantly lower-river, fall-run chinook salmon. In 1960, Coleman hatchery combined the stripped eggs of 6,849 female salmon with the milt of 2,225 males to yield 41,612,640 fertilized eggs. Of this total, 96 percent survived to become fingerlings (CAR 1960, p 26). Although not originally part of the Bureau's upriver mitigation efforts, steelhead production continued at Coleman where 357 females and 207 males were stripped yielding a total of 791,000 fertilized eggs. Almost 79 percent survived to the fingerling stage (CAR 1960, p 26). Meanwhile, due to increasing habitat degradation, water exports, and stock hybridization, among other causes, naturally-reproducing Sacramento River salmon and steelhead populations continued their long, steady decline.

V. Coleman Hatchery Production: The 1960s

Well established production patterns originating in the late 1940s and early 1950s continued at Coleman National Fish Hatchery through the 1960s with a few notable exceptions. In 1961, a small number of Kamloops trout was produced for stocking Shasta reservoir and fall-run chinook salmon and steelhead trout remained the primary fish reared at Coleman.[49] The DFG supplied Coleman with catchable rainbow trout for stocking Beale Air Force Base (CAR 1962, p 3) and the following year, brown trout were imported from Massachu-

49. In 1961, Donald Fry identified a separate late fall-run of chinook salmon on the Sacramento River when substantial numbers of spawning fish were captured at Keswick Fishtrap and hauled to the Coleman National Fish Hatchery (Fisher 1994, p 871; Fry 1961).

setts to stock California sites (CAR 1962). Twelve coho salmon made their way back upstream to the Battle Creek hatchery while the Keswick Fishtrap was used to trap 2,625 winter-run salmon for re-release below the ACID dam.[50] One hundred fifty-five winter-run salmon were also trapped and hauled to Coleman's ponds for ongoing experimentation.

Biologists at the DFG cooperatively marked one half million hatchery chinook salmon fingerlings for the third year in a row. A third of the fish was released into adjacent Battle Creek and a third was trucked to Rio Vista. The final third was hauled to Rio Vista and then transported downstream by boat for eventual release at 50 percent salinity (CAR 1961, p 13). By planting fingerlings within different parts of the river basin, scientists sought to understand issues like optimal escapement size, straying effects, and eventual upriver recruitment of mature fish. Those fish released at Rio Vista "contributed significantly more [1.5 times]...to the fisheries than those released at the hatchery," while downstream transplants "strayed considerably [more] from the parent stream when returning to spawn" (Hallock and Reisenbichler 1979, p 3). DFG also conducted a jointly run Kamloops marking program.

Outbreaks of the "Sacramento River Chinook Salmon Disease" (Infectious Hematopoietic Necrosis) continued at Coleman Hatchery. During 1960, fish disease specialist Tom Parisot substantiated prior observations that a subtle increase in hatchery water temperatures to between 54 and 56 degrees "rendered the virus agent inactive" (CAR 1961, p 13). Biologists constructed a system capable of blending, then re-using, warmer temperature well water with cooler Battle Creek waters to obtain the desired 54 degree temperature. Unfortunately, the experimental system easily clogged up with mud, silt, or debris, causing high mortalities among fry. Various parasitic and bacterial invasions continued to dog production efforts at Coleman National Fish Hatchery as it had throughout the 1950s.

In 1966, Coleman's disease specialist Elmo Barney prescribed "antibiotic therapy" to nullify the ill effects of disease on Coleman's fish stocks (CAR 1966, p 9).[51] It was not until February 1967, that an experimental water rehabilitation system existed for regulating water temperatures. Hatchery personnel pinned high hopes on temperature stabilization, calling it "The first real breakthrough in the control of the Sacramento River Chinook Salmon Disease..." (CAR 1968, p 4). That optimism was dashed the following season

50. Biologists believed that winter-run below Keswick Dam could become entrained in irrigation canals upstream from ACID (CAR 1961, p 11).

51. To quote from the annual report, "Healthy and diseased fish were challenged with new parasiticides and bactericides for fish toxicity and biological control. Satisfactory control of Myxobacterial infections in juvenile fish populations has been attained through antibiotic therapy" (CAR 1966, p 9).

when three times the normal precipitation fell upon the Battle Creek watershed, keeping water temperatures well below normal for over six weeks. Sacramento River Chinook Salmon Disease "ran rampant" through the chinook salmon stocks, save for those few enjoying elevated temperatures within a Burrows water re-use system (CAR 1969, p 6).

Throughout the early 1960s, Coleman Hatchery personnel continued cooperating with other federal agencies including the US Bureau of Reclamation and the US Army Corps of Engineers. The Bureau continued operating the Keswick Fishtrap and attempted to control, as best they could, for toxic mining leachate harmful to anadromous fish (CAR 1962, p 8).[52] When pulses of heavy metal contamination exited Spring Creek, Bureau personnel trapped, then hauled, downstream winter-run salmon for re-release below the ACID dam. Members of the Army Corps of Engineers used Coleman fish in a lengthy series of elaborate studies of fish passage through Shasta Dam's turbines.

Winter-run Salmon

During 1962, 140 winter-run chinook were hauled to Coleman for experimental holding and propagation. The first full length report on the occurrence of the Sacramento River winter run occurred the following year, when Service biologist Dan Slater published a seminal article on the salmon. Slater observed that, historically, winter-run were "...uniquely adapted to streams fed largely by the flow of constant-temperature springs arising from the lavas around Mount Shasta and Mount Lassen" (Slater 1963, p 8). In 1884, Livingston Stone identified the winter run (he also called them "black salmon") as one of three major stocks inhabiting the upper Sacramento River (Stone 1874; Fisher 1994, p 871). In its 1888–1889 Biennial Report, the State Board of Fish Commissioners records that, "it is a fact well known to fish culturalists that winter and spring run salmon, during the high cold winters, go to the extreme headwaters of the rivers if no obstructions prevent, into the highest mountains" (SBFC 1890, p 33; Hallock and Rectenwald 1989, p 4) Ironically, mention of the winter run also occurred among early biological investigators charged with creating Shasta Salmon Mitigation Plan proposals (Hanson and others 1940). Although never included among the Board of Consultants mitigation obligations, the winter-run waited until the late 1960s before its life history details were fully understood.

Combining life history traits common to both "stream-" and "ocean-type-" salmon, the winter-run was something of a behavioral anomaly (Healey, as cited in Groot and Margolis 1991, p 319). Mike Healey observes,

52. Bureau personnel sought to remove mature fish from the river when Spring Creek's pollution was present (CAR 1962, p 8).

[winter-run fish] enter the river green and migrate far upstream. Spawning is delayed for some time after river entry. Young winter-run chinook, however, migrate to sea in November or December, after only four to seven months of river life (Healey, as cited in Groot and Margolis 1991, p 319).

Biologists Slater and Richard Hallock combined their talents to estimate inland catch and population. Concomitantly, Slater approached Pacific Coast fisheries agencies to determine if there were other similar stocks. When that answer came back "no," it became clear winter-run were uniquely adapted to the Sacramento River (Hallock, personal communication, see "Notes").

Independently of Slater's work, questions about the winter run continued to pique Hallock's interest. Hallock questioned whether the winter-run constituted a truly distinctive population. Over the course of three years, and working together with five assistants, Hallock seined, fin-clipped, and released several hundred thousand juveniles along the shores formed by Red Bluff Diversion Dam. Seining occurred "almost entirely in September" when the juveniles were 35 to 45 mm in length (Hallock, personal communication, see "Notes"). Adult returns allowed Hallock and his colleagues to construct the first life history profile on where the fish went in the ocean, age at spawning, eggs per female, catch to escapement ratio, and migration timing (Hallock, personal communication, see "Notes"; Hallock and Reisenbichler 1980; Hallock and Fisher 1985).

Red Bluff Diversion Dam

In 1987, Richard Hallock identified the Bureau of Reclamation's Red Bluff Diversion Dam (RBDD) as "One of the major causes, and perhaps the single most important recent cause of the decline of salmon and steelhead in the Sacramento River..." (Hallock 1987, p 33). Originally promoted as a "fish-enhancer," the structure was located two miles downstream from Red Bluff and it diverted water into the Tehama-Colusa Canal and to the Corning Canal Pumping Plant. During average water years, each canal shunted 700,000 and 50,000 acre feet, respectively (Hallock 1987, p 33).

Completed in 1964 (it became fully operational in 1966), the dam included elaborate fish protection measures. Closed circuit television monitored fish passage through separate fishways. A built-in trap assured biologists access to incoming adult fish. Louver-type fish screens sought to limit fish losses within canals while a (never-used) Service hatchery was eventually constructed on site to harvest roe and milt from excessively ripe fish.[53] The 3,000 salmon which once occupied RBDD's immediate upstream spawning riffles were to be more than compensated by newly engineered downstream spawning channels suitable for holding 30,000 fish (Hallock 1987, p 58).[54] Jack Savage of the Fish and Wildlife Service promoted the idea of spawning channel enhancements (Hallock, personal communication, see "Notes"). The mitigation strategy partially stemmed from Washington State and British Columbia precedents with considerable help provided by Columbia River-based engineering and hatchery staffs (Grover, personal communication, see "Notes").[55] There were just two problems: it never worked, and, to make matters worse, it required 20 years to discover that fact.[56]

Richard Hallock observes that the Red Bluff Diversion Dam radically altered the existing distribution of fish within the lower and remaining reaches of the Sacramento River. Before its full operation, 90 percent of the fall-run spawned upriver from the damsite. After operating for a decade, less than 40 percent of the fall-run chinook salmon spawned above and greater than 60 percent were distributed below the dam site (Hallock, as cited in Lufkin 1991, p 100).

53. Female salmon were considered ripe upon losing eggs when handled. The Service constructed the temporary 3 million-egg incubation station near the dam's left bank fishway. Fish were released back into the river in the hope that they would spawn naturally. The facility became fully operational in 1979, but due to a "...lack of personnel and management interest," the 7 million egg hatchery was never used (Hallock 1987, p 33). Within a subsequent cooperative study, biologists demonstrated that "...an average of almost 2,500 (3.4%) of those [fish] passing the dam were ready to spawn immediately..." (Hallock and others 1982, p 17).

54. Tehama-Colusa Fish Facilities enhancements were calculated at 27,000 fish, a hypothetical number which "...made the entire [diversion dam] water project much more feasible" (Hallock 1987, p 58).

55. In 1950, Harold Gangmark operated a federally sponsored artificial spawning channel in Mill Creek at the site of the old abandoned hatchery at Los Molinas (Hallock, personal communication, see "Notes"). Dale Schoeneman was brought in to manage the newly constructed RBDD spawning channels from Washington State where he oversaw a similar spawning channel venture.

56. Cost for building the Tehama-Colusa Canal "salmon enhancement facilities" was $23 million dollars. Engineers originally called for building a "dual-purpose" irrigation-spawning canal, including water turn-outs, for spawning fish at Thomes and Stony creeks. For a particularly biting assessment, read Zeke Grader's commentary (Grader 1988a).

Although historical information was lacking, declines among other races of anadromous fish followed these same disturbing trend lines. Hallock reported:

> *Between 1969 and 1982,...RBDD has caused an estimated loss in the upper Sacramento River system's adult salmon population of 114,000 fish: 57,000 fall run, 17,000 late fall run, and 40,000 winter run. These losses have deprived the fisheries of about 228,000 salmon a year at a catch-to-escapement ratio of two-to-one...In addition, an estimated decline of 6,000 sea-run steelhead...has been attributed to RBDD (Hallock, as cited in Lufkin 1991, p 101).*

Biological investigations document upstream salmon passage delays of one to forty days, while an additional 26 percent never even made it past the dam (Hallock 1987, p 36). Particularly hard hit were winter-run salmon which remained ill-suited to spawning within the warmer lower river. Downstream from Red Bluff Diversion Dam, Hallock reports that "...water temperatures were suitable for winter-run spawning and incubation...only four out of eighteen years (only 22 percent of the time) between 1967 and 1984" (Hallock 1987, p 55). By comparing the 1967–1969 average salmon counts passing RBDD with those between 1970–1982, Hallock and Fisher demonstrated a decline of 58 percent (or 40,364) among winter-run salmon. If records from the three drought years of 1979–1980 and 1982 were included, the percent winter-run decline was 79 percent (79,289 fish), or a 52 percent decline in each successive generation (Hallock and Fisher 1984, p 9).

Hallock observes that upstream dam passage delays increased with river flow, for mature fish experienced greater difficulty finding fishways under higher than lower water conditions (Hallock, as cited in Lufkin 1991, p 100). Downstream passage by juvenile fish was equally problematic, as excessive downstream dam turbulence disoriented emigrating fish and forced them toward the river's surface. Whereas adult fish held their own against predators like Sacramento pike minnow, striped bass, steelhead and shad, younger fish often were eaten. Among juvenile salmon, 1974 Service studies estimated downstream migratory salmon losses at between 55 to 60 percent during daylight hours (Hallock, as cited in Lufkin 1991, p 100). Within another document, ocean sampling data among marked Coleman salmon indicated that fingerlings freed below RBDD "...survived better than those released upstream from the dam...Losses among those released upstream from the dam ranged between 29 percent and 77 percent (Hallock 1983, p 5). To this day, many fish conservationists still consider the Bureau's Red Bluff Diversion Dam to be a "fish killer."

Quite unlike the once proposed Iron Canyon or Table Mountain dams, however, the Red Bluff Diversion Dam did not "nullify" the attempted Shasta Salmon Salvage Plan of the 1940s. Serious delays in upstream fish passage did render remaining spawning grounds inaccessible to a quarter of the fall run alone. Excessive dangers accompanying downstream fish passage further undermined escapement, and, among Coleman managers at least, raised the size, distribution and age of fish at release. If the original "Foster Plan" sought to balance natural propagation within the mainstem Sacramento with artificial propagation at Coleman National Fish Hatchery, then RBDD hurt the former while selecting for the latter. Coleman's personnel could plan rearing fish to larger sizes, and release these same cohorts below the offending structure. Naturally spawning spring- and winter-run salmon did not enjoy these same artificial advantages and were left as they were to fend for themselves within the river's mainstem. Yearling steelhead, which were released below Red Bluff Diversion Dam enjoyed twice the rate of return to the Coleman Hatchery as those released directly into Battle Creek (Hallock 1976, p 2). Declining numbers of returning migratory fish began to worry biologists who became aware of a troubling portrait of irreversible declines.

Diminishing Anadromous Fisheries

Within a July 11, 1968 memorandum, Walter T. Shannon, Director of the DFG, called for severe cutbacks in commercial and recreational salmon harvests (Shannon July 1968). King salmon populations, he noted, were at historically "low levels," as reflected by falling ocean harvests and depleted Central Valley spawning populations. Department of Fish and Game biologists singled out "...a reduced survival rate of young fish" as the primary factor in the crisis. Shannon said that the "emergency situation" nevertheless warranted "...placing some restrictions on both the river and ocean sports fisheries" (Shannon July 1968).

DFG biologists observed in an accompanying report that ocean caught king salmon dropped from about 800,000 in 1964 to a low of 400,000 in 1967 (Fry and others 1968, p 1). The report noted that ocean harvested fall-run chinook had diminished since 1959 while, for the moment at least, record numbers of returning winter-run fish masked the severity of the crisis. Propelling the emergency was

> *Increased predation, partly from a larger steelhead population, losses in unscreened irrigation diversions, water quality and quantity problems in the San Joaquin and its tributaries, diseases, or unknown changes in the ocean environment (Fry and others 1968, p 1).*

No specific mention was made of the Central Valley Project Tracy pumps, nor of the Bureau's Red Bluff Diversion Dam. The report highlighted (and quite literally underlined) that, *The Fishermen are not to blame for the decline, but the survival rates of young fish have become so low that the adult population has been unable to support both good catches and a good spawning population returning to the rivers (Fry and others 1968, p 2).*

DFG sought to bolster escapement and adult salmon recruitment by implementing a "small reduction" in the size of the sports and commercial catches between 1969 and 1972 (Fry and others 1968, p 5).

On the evening of July 23, 1968, DFG Director Walter Shannon and Fish and Game Commission President Henry Clineschmidt convened a public meeting to discuss matters (Kier 1998). Clineschmidt had already solicited support for the shut-down among sympathetic sportsmen. What DFG required was a buy-in by commercial fishermen. Fishermen appeared grudgingly compliant with a fishing ban except for Fort Bragg fishbuyer Bill Grader who staunchly opposed any reduced catch (Kier 1998). Grader's fervent opposition, together with that of many others, marked a watershed point in the fisheries debate: simply shutting down the fisheries was no longer deemed sufficient to save salmon.

The following day Bill Grader visited Senate aide William M. Kier in his Sacramento office with proposals for at least fifteen separate pieces of fisheries legislation. In Kier's words,

One created the Citizen's Advisory [Committee] on Salmon and Steelhead; another attempted State fish protections at federal water projects; another sought tightening of fish screen laws; another [an] extension of the spawning gravel protections (Kier 1998).

Subsequently, Grader became chair of the Advisory Committee and he funded the entire project himself. DFG provided clerical and biological assistance to the committee.

It would require a full decade to attribute serious migratory fish declines to a largely-impassable Red Bluff Diversion Dam. In addition, the full impact of the Delta's combined federal and State water projects constituted, in the words of retired DFG biologist Frank Fisher, a literal "black hole" (Fisher, personal communication, see "Notes"). Between 1967 and 1983, members of the Upper Sacramento River Salmon and Steelhead Advisory Committee wrote that fish counts past RBDD "...indicate[d] substantial declines in the fall and late fall runs, a serious decline in the spring run and the almost complete loss of the unique winter run." (Frost and others 1984, p 5), The report also singled out steelhead as having all but "disappeared," save for Coleman Hatchery's Battle Creek production.

The man-made origins of the fishery collapse were eerily reminiscent of conclusions reached in 1944 by Willis Rich, Paul Needham, A. C. Taft, and Richard Van Cleve, who wrote:

> *It has been relatively recent that recognition has been given to the importance of dams and diversions to the continued existence of the salmon runs in many of our western rivers. As the ultimate plan for water development is approached, the effect is cumulative and the present proposed postwar projects bring the problem to the acute stage (Rich and others 1944, p 5).*

What was more, many of these water projects hinged upon massive and continuing governmental intervention. In 1962, a Bureau of Sports Fisheries and Wildlife report complained that it was man's activities in California which have,

> *...generally proceeded counter to the best interests of the anadromous salmon and trout resources. In fact, they have destroyed substantial segments of these resources while employing only token efforts to ameliorate the damage. Activities conducted, sanctioned, sponsored and supported by the Federal Government have been prominent in the history. The [following] dam list...documents the major harmful results of direct federal activity (USFWS 1962, p 5).*

No wonder this unattributed Fish and Wildlife Service document bore this prominent stamp on its cover: "Official Use Only: Not for Public Release."

Coleman Summary

Throughout the 1960s, several "limiting factors" were identified at the Coleman National Fish Hatchery including an insufficient availability of fresh water necessary to sustain high levels of production (USFWS 1963, p 33). While new rearing ponds constructed in 1962 did boost capabilities, concerns about excessive crowding among fish and disease limited production to about 250,000 pounds a year (USFWS 1963, p 33).[57] The Coleman Master Plan of 1963 explicitly called for a new hatchery facility to be constructed near Keswick to accommodate incoming fall- and winter-run fish. Diversification would permit the Coleman Hatchery to focus on rearing Battle Creek chinooks to a larger size while concentrating on producing incoming winter-run fish (USFWS 1963, p 34).

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57. Within Coleman's 1963 Master Plan, annual production objectives were reassessed at 40 million chinook salmon, steelhead trout and Kamloops trout eggs, fingerlings, and yearling fish weighing 250,000 pounds" (USFWS 1963).

Throughout the 1960s, hatchery personnel continued experimenting with new fish foods. Rather than grinding up spawned out salmon carcasses, Sidney Campbell constructed an automatic fish feeder for delivering moist pellets into several raceways in 1962 (CAR 1963, p 3). Additional mechanical fish feeders followed, coincident with an ongoing debate over which pelleted fish foods to use: Abernathy dry diet versus Oregon Moist Pellets (CAR 1967). During 1967, chinook salmon eating the Abernathy pellets "...suffered a severe mortality" and, during that year at least, the tests were halted (CAR 1968, p 7). Refinements in feeding strategies continued throughout the ensuing decade.

Additional experimentation occurred as Coleman Hatchery sought to produce other kinds of fish. In addition to their Kamloops, rainbow and brown trout stocking programs, coho salmon were again brought into the Sacramento River Basin. In 1967, 550,000 eggs were imported to Coleman Hatchery from Eagle Creek, Oregon. Of these numbers, 390,000 coho salmon were released into the Sacramento River during July, 1968, at a weight of 25 fish per pound (CAR 1971, p 24). During 1970, 81 coho returned to the hatchery. As had occurred during the previous decade, poor quality eggs deposited by returning adults were deemed a total loss before the eyed stage. Consulting DFG found evidence of Sacramento River virus (CAR 1970, p 9). The following year, the coho stocking program was discontinued as 226 unspawned coho were transported and released into an upriver Shasta Reservoir (CAR 1971, p 7).

VI. Coleman Hatchery Production: The 1970s

Throughout the 1970s, fish production at Coleman National Fish Hatchery followed 1950s and 1960s precedents. Fall chinook salmon and steelhead production remained Coleman's bread and butter objectives. In 1969, the Service co-signed a "Salmon-Steelhead Accelerated Production Program" with the DFG. The agreement paved the way for Coleman to accept more fall-run chinook salmon and steelhead eggs (or stocks) from state hatcheries like Nimbus on the American River. The program was designed to maximize primary production at Coleman in exchange for fulfilling certain state restoration priorities (in other words, stocking steelhead on the Yuba river). A second, continuing, cooperative federal-State stocking and fish exchange program required Coleman to produce, rear and/or stock Kamloops trout, brown trout, rainbow trout, coho salmon, and hybridized Kamloops and rainbow trout in designated state waters. In 1978, trout production was suspended and much of the federal-State exchange program was discontinued or substantially renegotiated.

Late in the decade, severe drought exacerbated an established pattern of anadromous fisheries decline. A 1978 drought reduced salmon and steelhead returns to Coleman Hatchery to one of their lowest on record. In 1977, William Sweeney, Area Manager for the Fish and Wildlife Service, became increasingly alarmed by steadily diminishing numbers of returning fall-, winter- and spring-run chinook salmon and steelhead (Sweeney, personal communication, see "Notes"). Sweeney sought, and obtained, DFG's cooperation in redirecting Coleman's activities back to its original 1940s mandate—salmon and steelhead production. Coleman's trout production was curtailed in fiscal year 1978, but not before the epizootic IHN infected the hatchery's state-supplied Kamloops population. As Coleman responded to the growing anadromous fisheries problem, 795,000 Kamloops were buried (CAR 1978, p 2).

Coleman Hatchery began with a series of crises in the 1970s. The initial fall chinook salmon harvest on Battle Creek looked promising until January freshets flooded out many of Coleman's holding ponds (CAR 1970, p 8). High water not only made Battle Creek's winter harvests difficult, it also wreaked havoc on the Keswick Fishtrap. In addition, the previous year's stream "rehabilitation" along lower Battle Creek by the US Army Corps of Engineers had transformed a natural stream into "an ideal spawning channel." Unfortunately, the paltry numbers of incoming fish belied this ideal. The remains of lower Battle Creek were no exception. Biologists believed that homogenization of the stream bed significantly undermined returning spring steelhead and chinook salmon stocks to Coleman Hatchery (CAR 1970, p 8 and 13).

During 1970, Coleman's steelhead and trout rearing programs suffered a 50 percent reduction in funding. Concomitantly, poor quality Kamloops eggs were "...believed to be the result of accidental introduction of steelhead and rainbow trout into the brood lot over the past years" (CAR 1970, p 9). New, "pure," disease-free Kamloops broodstock would be obtained from Idaho's Clark's Fork Hatchery. While Sacramento River Chinook Salmon virus remained the most serious disease at Coleman, coagulated yolk, columnaris, bacterial gill, and external parasites also caused considerable headaches. William Waldsdorf, the hatchery's Supervisory Fishery Biologist, was also assigned to Nevada's Lahontan National Fish Hatchery. That hatchery's discovery of "Whirling Disease" required emergency measures and Coleman[58] was called upon to provide diagnostic expertise for several years to come (CAR 1970, p 11).[59] For a matter of months, biologist Waldsdorf would even

58. Concern over Nevada's nearly extinct Lahontan trout is Coleman's first attempt at returning a threatened fish species from altogether disappearing.

59. The Environmental Protection Agency also cited Coleman for being in violation of its pollution discharge permits. Emergency pollution abatements measures were taken until longer term abatement facilities could be constructed.

relocate his family to Nevada as he dedicated his time to resolving Lahontan fisheries emergency.

Within the 1970s, ongoing cooperative agreements between the Service and the DFG bore real benefits. Coleman relied on the State to stock southern California reservations and military bases in exchange for rearing rainbow trout for Whiskeytown and Shasta reservoirs. A 76-mile commute in a tank truck beat a 1400 mile round trip to stocking sites east of San Diego (CAR 1970, p 12). Previously cited cooperative marking programs for salmon and steelhead also paid biological dividends as scientists could better track what became of ocean-bound and incoming fish.

In 1973, Keswick Fishtrap's fall-run chinook never materialized. Since Keswick contributed 50 percent of the spawn to Coleman's production, what accounted for the lowest return of adult fish on record? (403 adults were taken). Biologists attributed the loss to December 1969's deadly overflow from Spring Creek's Debris Dam (CAR 1973, p 4). Scientists believed that copper, zinc, cadmium, and other heavy metal contaminants killed eggs and young fish immediately downstream from Keswick Dam. Other possible contributors included downriver plants at Rio Vista in which 30 percent of the salmon fingerlings returned to stray up the American or Feather rivers (CAR 1973, p 6). DFG biologists also speculated that "unknown changes in the ocean environment" may have further undermined returning numbers of fish (CAR 1973, p 6).

Throughout the 1970s, Coleman Hatchery constructed more and more temperature-controlled rearing ponds to contain Sacramento River Chinook Salmon virus. In February 1974, five new temperature-controlled raceways were added bringing the total available to 20 (CAR 1974, p 6). These ponds, however, were only as reliable as the technological systems serving them. In 1975, the station's water recirculation system failed on two occasions, causing mortalities among greater than six million fish (CAR 1975, p 4). That year unusually cool winter and spring water temperatures compounded the virus problem and Coleman Hatchery suffered heavy fingerling salmon losses. Fish losses also stemmed from high ammonia and nitrite levels in holding ponds.[60] Coleman simply lacked an efficient water reuse and filtration system capable of keeping pace with the high levels of production being sought (CAR 1976, p 6).

Between 1976 and 1978, chronic disease among trout populations, persistent drought, and declining salmon populations, forced a reconsideration of Coleman's fundamental mission. The combination of poor rainfall (below 50 per-

60. Concern over Nevada's nearly extinct Lahontan trouth is Coleman's first attempt at returning a threatened fish species from altogether disappearing.

cent of normal), poor instream flows, and dangerously elevated water temperatures, spelled trouble ahead. By 1977, 18,000 fall-run salmon were blocked at the Red Bluff Diversion Dam and hauled "...to tributaries above and below Red Bluff and to Coleman and the Tehama-Colusa [S]pawning Channel" (CAR 1977, p 3).[61] That year's fall steelhead populations also stood at one-quarter their normal size, casting doubt on even achieving the coming year's propagation requirements. To bolster escapement, all of Coleman's salmon and steelhead plants occurred below Red Bluff Diversion Dam.

Watching the crisis unfold was recently arrived USFWS Area Manager, William Sweeney. In a letter dated March 28, 1978, Sweeney wrote DFG Director E. C. Fullerton that the Service wanted to substantially renegotiate its long standing joint stocking agreement with the State (USFWS 1978, p 1). Sweeney identified producing fall- and spring-run chinook salmon at Coleman Hatchery as his highest priority and he expected that water chillers would be "online" within the year. Sweeney proposed that during summer 1978, Coleman start harvesting incoming spring-run fish for an artificial propagation program. Due to space limitations, Sweeney suggested replacing Coleman's entire Kamloops rearing program by focusing instead on spring-run production. He wanted to eliminate any disparities in the federal-State exchange agreement "...by rearing 55,000 pounds of 10–15 [per pound] spring chinook salmon instead of Kamloops trout (USFWS 1978, p 1). Sweeney asked that as part of the exchange, DFG consider picking up Coleman's military program obligations.[62] (Footnote on next page.)

61. By June 1975, members of the DFG's Sacramento River Task Force had reported that "...the numbers of fall-run king salmon spawning above Red Bluff [Diversion Dam] have declined from an average of about 118,000 per year (1964–69) to an average of 51,000 per year (1970–74)" (Burns and others 1975, p 8). Speculations as to why ranged from the design and operation of the Bureau's Red Bluff Diversion Dam to the deterioration of spawning beds below Keswick Dam.

In 1978, Coleman's disease plagued Kamloops "...was discontinued and the production program redirected to include Winter and Spring Chinook salmon rearing" (CAR 1978, p 1). Winter-run salmon were dry-spawned at the Keswick Fishtrap and transferred to Coleman hatchery. Eighty-four percent of the eggs "eyed-up" yielding 102,000 eggs: but all but 12,500 perished when Coleman's water chiller broke down (CAR 1978, p 2). The same season that Sweeney advocated a return to spring-run production, no spring-run fish entered the Keswick Fishtrap.

During 1978–1979, migration of salmon and steelhead into Coleman Hatchery was one of the lowest on record. Slightly over 2.1 million Battle Creek fall chinook salmon eggs and just under a million steelhead eggs were harvested at Coleman Hatchery (CAR 1979, p 1). To bolster its flagging salmon production, Coleman obtained an additional 3.7 million fall chinook salmon eggs from the State's Nimbus hatchery and 816,000 fingerlings arrived from the Mad River Fish Hatchery (CAR 1979, p 1). The first season that Coleman consciously separated out late fall-run chinook salmon stocks (1.7 million eggs were harvested) arriving at the Keswick Fishtrap from those of the earlier Battle Creek run occurred in 1979.

In late spring 1979, IHN virus was finally isolated from coastal fall chinook salmon stocks at the Mad River Fish Hatchery. Due to their lengthy struggle with the disease, Coleman's superintendent was comfortable importing diseased fish from the Mad River Hatchery for rearing within Coleman's temperature-regulated 58 degree waters (CAR 1979, p 2). Unbeknownst to Coleman's

62. William Sweeney also closed his letter with a significant managerial shift. Sweeney proposed that ever hereafter, all DFG "...requests received for stocking and/or transfer of fish and eggs..." be referred through the Service's Sacramento Area Office (USFWS, Coleman files, Sweeney, March 1978, p 1). Historically, Coleman Hatchery enjoyed an unusually high degree of managerial autonomy. John Pelnar's long and distinguished tenure as Coleman's Superintendent greatly insulated the hatchery from excessive meddling, either by the State of California or by Washington, D.C. As many have observed, Pelnar's colleagues deferentially treated him as something of a "God" when it came to California's fisheries matters (Kier, personal communication, see "Notes"; Black, personal communication, see "Notes"). Lou Garlic, the Service's former Washington Hatcheries Program Administrator confirmed that historically, the Service had never dictated fish policies among its various hatcheries. Specific programs, Garlic insisted, derived from hatchery superintendents making decisions on site in accordance with budgetary constraints. "Whatever gave [Michael Black] the idea," Garlic wondered, "[that hatchery] policy was dictated from Washington" (Garlic interview conducted by George Black, see "Notes"). Occasional exceptions, like the Sikes Act, simply formalized what had once been handled informally among discrete hatcheries and other federal agencies. Former Coleman Hatchery Superintendent Jerry Grover remarked that it was not until 1984, when Donald Hodel was President Ronald Reagan's Secretary of the Interior, that a comprehensive policy on hatchery programs was finally spelled out (Grover, personal communication, see "Notes"). It was at this point that modern management substantially reshaped policy formulation at the hatchery level.

personnel, however, Mad River's cohort of fall-run salmon bore Enteric Red Mouth Disease (ERM). In early August of 1979, mortality among transferred fish increased sharply and during 1981–1982, ERM again infected Coleman juvenile steelhead and late fall chinook salmon. As an anonymous Coleman memorandum explained, "This was the first recorded outbreak of ERM in either species" (USFWS 1988, p 1).

Coleman National Fish Hatchery continued its production of fall-run chinook salmon and steelhead rainbow trout throughout the 1970s. A cooperative rearing arrangement with the DFG assured maximizing production at Coleman even as disease and overcrowding plagued the hatchery. While a substantially modified water reuse system was completed in December 1979, the hatchery remained saddled with inadequate funding, a decaying infrastructure, soaring power charges for new equipment (like chillers), and remained marginally able to tackle new artificial propagation objectives like spring- and winter-run salmon. Plummeting numbers of salmon reminded some that a long awaited reckoning had come due.

VII. Coleman Hatchery Production: The 1980s and The Richardson Reports

Coleman Hatchery returns of 1980 marked a significant improvement over the previous several years. Over 15.5 million fall chinook salmon eggs were harvested at Coleman and a record number of steelhead arrived during fall 1979, culminating in a 3.2 million egg harvest (CAR 1980, p 1). One hundred fifty-thousand late fall chinook salmon were held over for spring stocking in 1981, but no mention is made of attempts to rear either winter- or spring-run chinook salmon (CAR 1980, p 1).

Throughout the early 1980s, Coleman continued focusing on fall and late fall salmon and steelhead production. In 1982, experimentation resumed with 57 winter-run salmon which were captured at Keswick Fishtrap and hauled to Coleman Hatchery. A total of seven females was spawned. By the close of the spawning cycle, however, water temperatures peaked at 60 degrees. Two power outages interfered with the hatchery's water chilling systems. Coleman's Superintendent wrote that: "The eggs from two females were no good. The rest of the winter chinook salmon adults died before spawning." By the late September 1982, 14,700 of the 15,000 surviving eggs hatched successfully (CAR 1982, p 1).

Nineteen eighty-three's fall chinook salmon run was the largest in Coleman's history. Just shy of 20,000 fish made the upriver journey, yielding a total of 26,624,000 green eggs (21,137,000 eyed-up). Of this total, in October 1982, 4,856 fish died due to low dissolved oxygen in Coleman's ponds. Mortalities were blamed on PG&E's water operations just upriver from Coleman's water intakes (CAR 1983, p 2). A total of 11,548 winter-run salmon was released into the Sacramento River Basin. In addition to the fall run, 958 late fall fish yielded 1,888,000 green eggs, 1,629,000 of which eyed-up. Steelhead numbered 958 this year, yielding 1.4 million eggs (a half million of these were imported from the State's Feather River Hatchery).

Coleman Hatchery's Operational Plan (1981)

In 1981, Coleman Hatchery manager Thomas B. Luken co-authored (with Terrence Merkel and Richard Navarre) an "Operational Plan" for rebuilding and greatly expanding Coleman National Fish Hatchery (Luken and others 1981). A subheading titled "Authorization and History" trails its brief introduction. As though to remind readers, the subsection's opening lines read:

> *The Coleman hatchery was built under the authority of the Federal Reclamation Laws-Act of June 17, 1902, 32 state. 388, and acts amendatory thereof or supplementary thereto. The Coleman station and its many associated facilities were included in the reimbursable costs of the Central Valley Project (Luken and others 1981, p 1).*

A two-page history underscores that the Service assumed the "operational costs" and "responsibility" for Coleman during fiscal year 1950. A detailed description of Coleman's infrastructure comes next, followed by a summary of current and proposed production capabilities. Winter- and spring-run salmon receive passing mention as do Coleman's water chilling capabilities. "At this time [the reports authors concede, Coleman's] production program does not include the [winter and spring] runs" (Luken and others 1981, p 16). The authors also attribute 40 percent of the Sacramento River's steelhead production to Coleman's "hatchery sustained run" (Luken and others 1981, p 16).

Coleman's production objectives include rearing chinook salmon for sport and commercial fisheries and steelhead for sport fisheries (Luken and others 1981, p 21). Under the draft Central Valley Strategy Plan, targeted current and long-term salmon hatchery objectives (catch plus escapement) are 68,000 and 314,000 adults, respectively. Short- and long-term steelhead production is pinned at 13,000 and 19,000 adults, respectively (Luken and others 1981, p 21). With sufficient help from DFG hatcheries, a substantially expanded Coleman Hatchery should be able to meet various proposed long-term goals.

Ambitious future objectives, however, contrast sharply with 1982's declining abundance figures. Based upon a ten year cycle (adjusted) of fish counts at Red Bluff Diversion Dam, we learn that "...the relative abundance of the various runs since 1971 have been approximately 53 percent, 15 percent, 23 percent, and 9 percent for the fall, late-fall, winter, and spring runs, respectively" (Luken and others 1981, p 22). During the 1953–1960 period, fall chinook salmon averaged 257,000 spawners. Between 1961 and 1976, that number fell by greater than 50 percent to stabilize near 121,000 adult spawners (Luken and others 1981, p 22). Between 1953 and 1976, spring-run chinook salmon averaged 9,000 spawners. Throughout the 1970s, late fall- and winter-run salmon averaged roughly 50,000 fish. The winter-run returns were profoundly affected by the drought of 1976–1977, however, and 1978–1979 counts past Red Bluff Diversion Dam numbered a mere 2,242 fish, dropping to 1,156 fish in 1979–1980 (Luken and others 1981, p 22–23). Steelhead counts in 1977–1978 were approximately 13 percent of those counted in 1967 (Luken and others 1981, p 25).

Coleman's "Operational Plan" closes by identifying hatchery strategies to arrest and reverse serious anadromous fisheries declines. Specific problems cited include finding sources for obtaining sufficient milt and eggs for winter- and spring-run salmon. Holding facilities for these stream-type fish must also be constructed, necessitating running chillers 24 hours a day. In 1981 dollars, power costs to operate Coleman's existing chillers would be $27,000 per month (Luken and others 1981, p 26). For some spring-run salmon, this would require continuously operating chillers for four months or more, resulting in very expensive power bills. Studies would identify Coleman's optimal fish release timing, escapement sizes, and release sites, for steelhead and all four salmon runs. Specific tagging studies would determine the percentage of hatchery contributions to commercial and sports fisheries.

Luken, Merkel and Navarre argue that achieving Coleman's future operational objectives required an infusion of roughly $5.5 million. Under the subheading of "Future Development," a four-phase program prioritizes strategies for substantially rebuilding and expanding the hatchery's production capacities. Personnel services, utilities, and fish food are singled out as the hatchery's three main expenditures. In view of the high cost of running chillers, means of reducing power costs required immediate consideration (Luken and others 1981, p 26). The Coleman Hatchery could either generate its own power on site or seek to obtain Department of Energy Central Valley Project power at "preferred rates." It was up to USFWS policy makers to select among four production options, thereby bolstering the Sacramento River's plummeting anadromous fish populations (Luken and others 1981, p 29–30).

USFWS Report on Problem A–6 (1982)

In May 1982, a second Service report built from Coleman's previous "Operational Plan" to argue for a substantial expansion and rehabilitation of the Sacramento River's salmon and steelhead mitigation program. This sophisticated document (entitled *Report of the US Fish and Wildlife Service on Problem A–6 of the Central Valley Fish and Wildlife Management Study*, or referred to simply as "A–6")[63] embeds activities and future expansion at Coleman Hatchery and the

Keswick Fishtrap within a historical narrative and a comprehensive policy framework (USFWS 1982).

The document notes that hatchery objectives at Coleman have been recently expanded to increase chinook salmon contributions to commercial fisheries (USFWS 1982, p 3). Improved hatchery escapement is to be bolstered by "...increasing survival of juveniles by releasing them at size;" releasing smolts at optimum time and location (while assuring proper imprinting); and making certain hatchery production reinforces these prior objectives (USFWS 1982, p 2–3). Primary production of winter- and spring-run chinook salmon are made pivotal among Coleman's formal objectives.

The A–6 document argued that expansion and modernization of the Coleman National Fish Hatchery required the implementation of a five year development program initiated in 1977 (Luken and others 1981). Construction priorities necessitated investigating additional sources for groundwater, increasing fish rearing capacity, and, for disease-containment, achieving effective temperature control (by completing the partially constructed water reuse systems) (USFWS 1982, p 4). For an additional $5.487 million, Coleman Hatchery could rear 12 million chinook salmon fingerlings annually, weighing 115,000 pounds (USFWS 1982, p 4). The report further specified that, due to severe spawning gravel losses below Keswick dam, the Keswick Fishtrap must capture as many incoming salmon as possible for relocation to suitable substitute habitats or for artificial propagation at Coleman Hatchery.

Following this general statement of objectives, the document circled back to the historic 1949 MOA between the US Bureau of Reclamation and the US Fish and Wildlife Service. A precedent-setting disclaimer followed a general restatement of that document:

> *This agreement, while recognizing that salmon were successfully spawning in the Sacramento River downstream from Shasta Dam, should not be construed as a concession on behalf of the Service that the Bureau had satisfied its mitigation obligation for the Shasta Dam Project (USFWS 1982, p 6).*

This may have been the first time in 33 years that Service personnel sought to consciously extricate themselves from the myth of a successful Shasta Salmon Salvage Plan. For heightened dramatic effect, Service biologists took language from the 1949 MOA and inverted its originally intended meaning:

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63. "A–6" referred to an anadromous fisheries team assigned to "Determine the need for additional support for ongoing evaluation of Coleman National Fish Hatchery and Keswick Fishtrap operations, and providing this support if necessary" (USBR 1985, p 8).

Despite the now obvious failure of the Sacramento River-Butte Creek-Deer Creek Plan...to fully mitigate for pre-project salmon resources, and the inability of the Central Valley Project to maintain salmon runs below Shasta Dam in numbers equal to the numbers existing before the dam was built, operation of the Coleman NFH is still funded entirely by the Service (USFWS 1982, p 7).

In spite of substantial Service improvements made at Coleman National Fish Hatchery over the previous four decades, the A–6 document repeats that runs of chinook salmon and steelhead continue to decline. It noted that gravel degradation, heavy metal toxicity, unfavorable flow patterns, the Red Bluff Diversion Dam, predation, increased Delta pumping, unscreened diversions, and over-fishing, were all factors contributing to overall fisheries decline (USFWS 1982, p 27). Despite these problems, Coleman nevertheless continued producing 10 percent of the fall chinook salmon run and 70 percent of the steelhead run left below Keswick Dam (USFWS 1979; Hallock as cited in USFWS 1982, p 32). "Because of declining runs of all four races of chinook and steelhead trout to the upper Sacramento River," the document concludes that "the Service is committed to improving efficiency of the Coleman NFH" (USFWS 1982, p 32).

Before a summary statement of "problems" and "recommendations" was made, biologists identified the winter- and spring-runs as being particularly deserving of study for artificial propagation. Additional loss of natural habitats (for example, suitable spawning gravel, favorable seasonal flows, and suitable water temperatures), "may eventually necessitate" artificially propagating winter- and spring-run stocks (USFWS 1982, p 33). The report concluded that heightened hatchery efficiency is the best means of sustaining these badly depleted populations of fish.

Redefining Coleman Hatchery's mission, the report asserts, departs from these two fundamental premises. First the Bureau and the Service must:

Assess the need for revising the 1949 Memorandum of Agreement...pertaining to the operation and maintenance of Coleman National Fish Hatchery in view of the deterioration of salmon and steelhead runs resulting from long-term impacts of Keswick and Shasta Dams (USFWS 1982, p 35).

Second, redefining Coleman's mission hinges upon successfully receiving Central Valley Project electrical power at preferred rates.

Electrical water chiller operation is necessary to initiate production of and [to] provide protection [for]...the depressed run of winter chinook salmon in the Sacramento River. Estimated annual cost of operating chillers on [the] existing rate schedule is $129,600 (USFWS 1982, p 35).

The Service basically invites the Bureau of Reclamation to reexamine that agency's historic and future salmon mitigation obligations by using the precarious status of winter-run salmon.

Coleman Station Development Plan (1984)

During October 1984, a second Coleman report was issued by the Service on the status of Battle Creek's antiquated Coleman National Fish Hatchery (USFWS 1984). The Coleman Station Development Plan called for a significant hatchery upgrade

> *To restore chinook salmon stocks of the upper Sacramento drainage to levels of the 1950s (adult contribution 673,000 fall chinook, 50,000 late fall chinook, 80,000 winter chinook and 130,000 spring chinook (USFWS 1984, p 9).*[64]

Hatchery goals ranged from energy-efficient means of controlling disease to increased hatchery size to accommodate winter-run chinook. A historical subsection underscores that "Construction of the facility was authorized as an integral part of the Central Valley Project" (USFWS 1984, p 5). Within yet another subsection on water rights, Coleman Hatchery's legal entitlement to Battle Creek's waters "...are [called] the lowest priority known on Battle Creek" (USFWS 1984, p 15).

Coleman's Station Development Plan specifies a three phase development program in which the term "rehabilitate" figures prominently. Initial priorities included rebuilding the hatchery's badly undercut diversion dam, expansion of pollution abatement facilities, installation of an ozone generator for water treatment, installation of emergency power generators, and the digging of several wells (USFWS 1984, p 26–28). Intermediate priorities included replacing the original redwood incubation troughs installed in 1942, replacing the deteriorating hatchery building's badly leaking roof, repairing chillers for water temperature control, and constructing new broodstock holding ponds for adult winter- and spring-run salmon (USFWS 1984, p 30–32). Costs for accomplishing the whole development program (in extrapolated 1986 dollars) are $6,524,800 (USFWS 1984, p 25).

Petitions to List the Winter-run Chinook Salmon

Driving this latest Coleman document was a litany of woes contained in 1981's Coleman Report. Also disturbing were winter-run stocks which had plunged from 1969's estimated high of 117,808 to a 1983 figure of 1,381 fish (USBR and Richardson 1985, p 13). Within the same time frame, spring-run

64. This objective was taken verbatim from the Regional Resource Plan. Hoped for production figures included catch plus escapement.

chinooks also fared poorly, falling from 26,471 to 3,491 fish (USBR and Richardson 1985, p 13). Similarly, steelhead diminished from 10,995 to 1,968 fish (USBR and Richardson 1985, p 13). With the sole exception of hatchery-driven fall- and late fall-run stocks, the Sacramento River's anadromous fisheries were in trouble and the Service, the National Marine Fisheries Service (NMFS), and the DFG needed to formulate credible responses.

Tension was heightened by the potential listing of winter-run chinook salmon under the State and federal endangered species acts. The threats of a "listing" carried significant political muscle, as it focused statewide and national political attention-desired or not-on a regulatory agency's rationales and performance. Considerable opposition would be triggered by this State and federal action and the DFG, the Service, and NMFS exhibited reluctance to act. Meanwhile, independent advocates concerned with diminishing anadromous fisheries were clamoring to have the fish listed.

Partial justification for both State and federal ESA winter-run listings derived from the status report prepared by Richard Hallock and Frank Fisher and by subsequent counts (Hallock and Fisher 1985). The Tehama Fly Fishers (the Sacramento River Preservation Trust later joined them) petitioned the State of California for a listing, while, in October 1985, the California-Nevada Chapter of the American Fisheries Society (AFS) petitioned NMFS to list the winter-run as "threatened" under the federal Endangered Species Act (16, USC 1531, et. seq.). The Sierra Club Legal Defense Fund handled court proceedings against the federal government (Hallock, personal communication, see "Notes"). Annual winter-run counts between 1982 and 1988 averaged 2,334 fish, a 97 percent decline from prior levels (Williams and Williams, as cited in Lufkin 1991, p 107).

In 1986, NMFS responded with a non-binding, ten point action plan:

1. Resolving the fish passage problems at Red Bluff Diversion Dam.

2. Instituting a hatchery program for winter-run at the Coleman Hatchery.

3. Restoring spawning habitat in the Redding Area.

4. Developing measures to control Sacramento pike minnow at Red Bluff Diversion Dam.

5. Restricting in-river sport fishing.

6. Developing water temperature control for drought years.

7. Correcting Spring Creek pollution problems.

8. Correcting the problem at the Anderson-Cottonwood Irrigation District Dam (due to flow fluctuations and an inadequate fish ladder).

9. Correcting the spilling basin problem at the Keswick Fishtrap.

10. Continuing to expand studies on winter-run chinook salmon (after Grader 1988, p 2).[65]

Pacific Coast Federation of Fishermens' Associations General Manager Zeke Grader observed that AFS and NMFS staff were in agreement that "...the problem facing the winter run [was] from water temperature and diversions and not fishery pressure..." (Grader 1988, p 2).[66] The sole permanent step taken was a restriction of the in-river sport fishery. The Bureau of Reclamation did open the gates at Red Bluff Diversion Dam but closed them again without notifying NMFS (Grader 1988, p 2). Without a "threatened" listing, many, including Grader himself, believed it "...may be impossible to force agencies such as the Bureau of Reclamation to make the necessary changes in their [water] operations to protect the winter run" (Grader 1988, p 3).

With their ten point recovery plan in place, NMFS determined in February 1987 that a winter-run listing was "not warranted" (Williams and Williams, as cited in Lufkin 1991, p 110). A year later, the Sierra Club Legal Defense Fund filed suit on behalf of AFS and others against the federal government, arguing that under the Endangered Species Act, the federal government had a "non-discretionary obligation" to list the nearly extinct fish (Williams and Williams, as cited in Lufkin 1991, p 111). All it would take were additional droughts or accelerated habitat losses accompanying new water projects to undermine the precarious status quo. "Threatened" ESA status for the winter-run fish would not be forthcoming until August 4, 1989 (Williams and Williams, as cited in Lufkin 1991, p 113).

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65. Wally Steucke asked the Service's FAO-Red Bluff Project Leader to develop the preceding "Suggested Management Actions" which were intended to benefit the beleaguered winter-run salmon. On June 16, 1986, DFG's John Hayes participated in formulating these recommendations. Tellingly, a final eleventh suggestion was dropped from the list. It called for "Oppos[ing] any new [water] projects that would adversely impact winter-run chinook. With current severely depressed run sizes, winter-run cannot sustain additional adverse impacts." (USFWS 1986).

66. Grader clearly spelled out the PCFFA's interest in the winter-run case. "If listed as a threatened species," Grader wrote, "NMFS would be required to declare critical habitat, and to develop, adopt and implement a [fish] recovery plan. All federal agencies would be obligated, by law, to assure that their actions would not jeopardize the winter run. A threatened listing would not require restrictions on [ocean] fisheries, [however] an "endangered" listing would..." (Grader 1988, p 2)

Initially, the DFG withheld listing the winter-run under the state's ESA. Managers at DFG believed that the non-binding NMFS ten point conservation program would prove sufficient to reverse winter-run declines. Legal wrangling, mounting political pressures and declining numbers of fish eventually overwhelmed opposition to a listing. On August 7, 1986, the petition to list the winter-run as endangered was submitted to the California Fish and Game Commission (pursuant to subdivision (a) (2) of Section 2074.2 of the Fish and Game Code, as a candidate species defined in Section 2068 of the Fish and Game Code). The State Commission eventually accepted the petition at their February 4, 1988 meeting (Grader 1988, p 2). Implementation, however, still required a written report by DFG indicating that the petitioned action was warranted. In February 1989 the DFG had not yet completed its recommendation on winter run listing, so the Fish and Game Commission delayed action until its March 1989 meeting. At the March meeting the Commission accepted the DFG recommended to not list winter run but required the DFG to provide 60-day updates on the status of the resource and adherence to the 10-point plan. At the May 1989 meeting, the DFG changed its recommendation in favor of listing the winter run and the Commission made a finding at that meeting to list the species as Endangered. At its August 3-4, 1989 meeting, the Commission added winter-run chinook salmon to Section 670.5, Title 14, California Code of Regulations as an Endangered Species (Robert R. Treanor, Executive Director, Fish and Game Commission, personal communication).

Problem A–6 and the Bureau's Coleman Hatchery Action Plan (1984)

As State and federal fisheries agencies mobilized to stave off diminution of winter-run salmon stocks, the Bureau of Reclamation began responding with new programs of their own. Throughout the 1970s and into the 1980s, the Bureau funded collaborative, coded-wire tagging studies to determine optimal fish size at release and solve fish passage problems stemming from Red Bluff Diversion Dam. The Bureau also pumped resources into resurrecting the ill-fated Tehama-Colusa Fish Facilities. It also sought to overcome long-standing problems surrounding the Keswick Fishtrap. Resolution of issues arising from Red Bluff Diversion Dam and its compensatory spawning channels fell under a Bureau program termed "Interim Action Measures" (USBR and Richardson 1985, p 32). In November, 1984, the Bureau initiated the Coleman Hatchery Action Plan (CHAP) which was intended to "...assist the US Fish and Wildlife Service...in the fishery mitigation effort at the Keswick Dam fishtrap and the Coleman [National Fish Hatchery]" (USBR and Richardson 1985, p 32).

CHAP's objectives included identifying problems at Coleman Hatchery and Keswick Fishtrap, selecting cost-effective alternative solutions, determining which agencies had the ultimate authority and responsibility to implement solutions, prioritizing effective solutions by using cost/benefit analysis, and setting a reasonable timetable for achieving desired results (USBR, Richardson 1985, p 32–33). As Service biologist Thomas Richardson stated, CHAP's main goal was for the Bureau "...to offer the technical expertise, resources, and equipment which could provide immediate solutions to ongoing problems that [adversely] affected hatchery production (CHAP, as cited in USBR and Richardson 1985, p 33).

CHAP's recommendations derived from a steering committee composed of representatives from the Bureau, the Service, NMFS, DFG, and the Department of Water Resources. While most of Coleman's and Keswick Fishtrap's problems and resolutions lay well beyond CHAP's scope, interagency participants insisted that their entire priorities list be presented to the Bureau's Regional Director for identification and eventual funding consideration (USBR and Richardson 1985, p 34). At the top of their wish list was new broodstock facilities capable of handling the beleaguered winter-run chinook salmon. There was also the matter of legally obtaining Central Valley Project power at "preferred rates" to run Coleman's power-hungry chillers (USBR and Richardson 1985, p 35).[67]

CHAP suggestions included increasing Bureau water releases from the Shasta-Keswick complex "...to 14,000 cubic feet per second for a 3-day period from May 13–16, 1985" (USBR and Richardson 1985, p 34). This pulse of water would help flush Coleman's 6 million salmon smolts downstream into the Delta and Suisun and San Pablo bays. To help Sacramento River fish migration, the Bureau also agreed to operate its Red Bluff Diversion Dam to minimize fish losses due to irrigation. CHAP's steering committee also recommended that the Keswick Fishtrap be modified to remain usable at flows between 16,000 and 20,000 cubic feet per second, when not yet higher water conditions (USBR and Richardson 1985, p 56).

CHAP recommendations were imbedded within two subsequent, Bureau-commissioned versions of 1992's A–6 Service document which sought to identify and resolve nagging problems at Coleman Hatchery and Keswick Fishtrap (USBR and Richardson 1985; USBR 1985). Within the first report, Richardson wrote that Sacramento River salmon declines stemmed from a variety of factors

67. As to Coleman Hatchery's eligibility for CVP power at "preferred rates," the Service sought out the Solicitor General's legal determination. On the issue of "...free mitigation water with respect to the FWS facilities in the Grasslands area, one part of the overall Central Valley Project," Donald J. Barry, the Department of the Interior's Assistant Solicitor wrote: "Agreement was reached in the Solicitor's Office among the Divisions of Conservation and Wildlife and Energy and Resources that, with respect to the Coleman National Fish Hatchery, there was ample legal authority for the Bureau of Reclamation to provide water and power to operate the Hatchery, the cost for which must be borne by the project users" (USDI and Barry 1985, p 2).

...including gravel degradation, heavy metal toxicity, unfavorable flow patterns, the Red Bluff Diversion Dam, predation, increased delta pumping, unscreened diversions and over-fishing (USBR and Richardson 1985, p 52).

From the Service's point of view, insufficient returning broodstock simply underscored the importance of improving efficiency at Coleman and the Keswick Fishtrap. A second Bureau-funded report concluded:

The [Bureau] should endorse the efforts of the [Service] and assist in securing funding for facilities modifications required to meet mitigation responsibilities at both Coleman NFH and the Keswick Fishtrap (USBR 1985, p 84).

Achieving these ends would be best obtained by revisiting the 1949 MOA between the Bureau and the Service. The report continues:

...operation and maintenance of Coleman NFH should be assessed in view of the deterioration of salmon and steelhead runs resulting from long-term impacts of Keswick and Shasta dams (USBR 1985, p 84).

The three phase resurrection of a dilapidated Coleman National Fish Hatchery carried a projected price tag of $6,524,800 (USBR 1985, p 58).

Whirling Disease (*Myxosoma cerebralis*) at Coleman Hatchery

Coleman Hatchery's propagation activities followed somewhat predictable patterns during most of fiscal year 1985. A total of 21,543 fall chinook salmon was spawned yielding 27,814,636 green eggs (25,430,879 eyed up). A total of over 24.1 million fall-run chinook salmon was stocked. A total of 388 late fall-run chinook salmon was harvested, yielding 597,378 eggs (492,029 eyed up). Over 374,000 late fall-run salmon were stocked (CAR 1985, p 3).

Success at propagating winter-run salmon remained as elusive a goal as ever. Lack of fish prevented obtaining adequate broodstock at Keswick Fishtrap and insufficient State and federal fish personnel precluded much fish capture at Red Bluff Diversion Dam. Only one of the 32 winter-run salmon obtained survived. That lone fish was released into Battle Creek. As Coleman's Superintendent wrote: "The bottom line is that with current Coleman facilities and funding, [winter chinook salmon] holding and spawning at CNFH is impossible" (CAR 1985, p 3).

This same year 1078 steelhead were spawned yielding 2,723,830 eggs (2,281,269 eyed up). However, in June 1985, an outbreak of Whirling Disease (*Myxosoma cerebralis*) was detected among steelhead trout fingerlings. In compliance with the Service's Fish Health Protection Plan, the "Class A" infected fish were destroyed in February 1986 (CAR 1985, p 2–3; USFWS, Coleman

Files, “Whirling Disease,” Decision Paper, 1987). The destruction of 1.3 million juvenile steelhead was hardly welcome news in any quarters. However, since the DFG classified the *Myxosoma cerebralis* organism as a far less catastrophic affliction than did the Service, State biologists pleaded that the fish be released into Battle Creek. The Service’s Class A designation held sway, however, and Coleman Hatchery destroyed its entire steelhead production for one year, amounting to a 70 percent in-river decline among returning 1988–1989 Sacramento River runs.

Amidst a hail of criticism, Service personnel responded that Coleman’s history of disease and parasitism necessitated significant facilities upgrades. The previous year, members of the Upper Sacramento River Salmon and Steelhead Advisory Committee had argued that chronic underfunding and inefficiencies produced a substandard Coleman Hatchery rife with disease problems (Payton and Coakley 1985; Frost and others 1984). Writing in August 1984, that Committee’s members argued that Coleman’s operation should be increased to $1.5 million a year and “recommended operating the hatchery as part of the federal Central Valley Project, with funding from the US Bureau of Reclamation instead of [the Fish and Wildlife Service] (Payton and Coakley 1985).

Service spokesman Bill Meyer of the Portland Regional Office believed that significant Coleman funding should derive from the Bureau of Reclamation. Bureau officials, however, were more circumspect. They responded that Coleman remains the sole responsibility of the Service.

> *‘They’ve assumed full jurisdiction and we’ve been out of it for years,’ said David Houston, mid-Pacific regional director for the Bureau. Still, Houston said his agency is committed to doing what it can to rehabilitate Coleman (Payton and Coakley 1985, p A–14).*

The discovery of whirling disease at Coleman Hatchery intensified discussions as to the ultimate responsibility for salmon and steelhead mitigations throughout the Sacramento River Basin. For some it was only a dress rehearsal before the Bureau accepted full financial responsibility for a failed Shasta Salmon Salvage Plan.

Coleman Hatchery’s Revised Station Development Plan (1987)

In 1987, a new Coleman Station Development Plan was released “...to upgrade or develop sound, practical station development plans for future budget requests” (USFWS 1987b, p 1). The major addition to this proposal was a comprehensive, nine phase construction program which bore a total price tag of $22,104,800 (USFWS 1987b, p 27–28). An ozone generator for water treatment topped priorities while visitor facilities closed out the list. One nagging question remained. Who would provide the funding for such an ambitious anadromous fish recovery effort? The agency or agencies willing to fund that dramatically increased budget remained unspecified. However, it appears as though the Service pinned their hopes on the Bureau of Reclamation and a failed Shasta Salmon Salvage Plan.

It would require an additional five years before the issue of agency responsibility was resolved by an Inspector General's inquiry. Numbers of Sacramento River salmon populations requiring formal mitigation derived from Needham and others' (1943) study, which argued that a minimum of 60,000 (but probably many more) Sacramento River salmon required mitigation. Recall that Needham had called for 10,000 spring-run chinook to be hauled to Deer Creek for natural propagation; 2,000 spring-run fish to be transferred to Battle Creek for artificial propagation; 18,000 summer and early fall-chinook to be transferred for artificial propagation; and distribution of 30,000 fall-run chinook by means of instream racks (Needham and others 1943).

In a series of Service- and Bureau- commissioned reports, Thomas H. Richardson best argued that the Bureau had an outstanding unmet mitigation obligation. Time and time again he returned to historic themes to build his case (USBR and Richardson 1985). In blunt language, Richardson wrote:

> *...It appears that the proper [Bureau of Reclamation] mitigation goals [of the Sacramento River Migratory Fish Control Program] were not established for the loss of habitat and fish runs upstream from Keswick and Shasta Dams (USFWS and Richardson 1987a p, 32).*

Using original spawning survey data, Richardson calculated that 118,048 salmon were cut off as a result of Shasta Dam (USFWS and Richardson 1987, p 12). Particularly hard hit were the spring-run for access to 187 miles of their upriver spawning habitat (consisting of 2,360,000 square feet of spawning beds) were blocked while below-dam, spring-run mitigations failed entirely (Hanson and others 1940). Richardson cited Needham's 1943 revised population estimates of 60,000 salmon as being much closer to true population size lost as a result of Shasta and Keswick dams (Needham and others 1943).

As one crude measure of what was missing, Richardson suggested the Service (and the Bureau) take current production goals and subtract them from Needham's far more plausible estimate of 60,000 fish. Since Coleman's 1984 production goals specified 18,650 return spawners, Richardson deducted this figure from Needham's preceding estimate to arrive at an unmet mitigation of 41,350 fish (USFWS and Richardson 1987, p 32). The Service biologist concluded that "...any hoped for [Bureau sponsored post-Shasta enhancement] was never realized" (USFWS and Richardson 1987, p 33). [68]Richardson advised the Bureau of Reclamation that "...the loss of anadromous fish runs (but not habitat) may be compensated by artificial propagation" (USFWS and Richardson 1987, p 31).

VIII. The Inspector General's Report and the CVPIA

Initially the Bureau of Reclamation resisted accepting Richardson's invitation to reimburse the Service for ongoing unmet mitigation obligations. Sometimes the Service funded mitigation costs which agency personnel believed "...were properly assessable to water project beneficiaries," and Coleman Hatchery was no exception (Audit Report 1991, p 3). Service policy sought to promote "cost assumption," a term connoting recovery from water project beneficiaries of unmet mitigation costs. Discussions on this and other points continued between the two agencies and culminated in a November 1988 interagency agreement (Audit Report 1991, p 3). However that MOA failed to resolve the controversial cost-assumption issue. Additional progress was also hampered by interagency bickering over who retained formal "operational control" over mitigation facilities like hatcheries. Tiring of the impasse, Service directors eventually sought and obtained a formal audit by the Office of the Inspector General. If the Service could not resolve this by means of direct negotiations with the Bureau, then they would try another approach.[69]

The Auditor General's report concluded that the Service continued "...to underwrite almost $1.5 million a year in [hatchery] mitigation costs on behalf of the beneficiaries of the two Bureau water projects [Coleman was specifically singled out]" (Audit Report 1991, p 4). Throughout the 1950–1989 period,

68. In a separate 1987 report, biologist Richard J. Hallock summarized the results of the "Shasta Salvage Plan" this way: "The plan included only mitigation for fall- and spring-run salmon, none for late fall and winter-run salmon or steelhead. Only part of the plan was ever implemented. As each element of the salvage plan failed, it was simply abandoned and those particular groups of fish to be salvaged were just "written off" (Hallock 1987, p 30).

69. Service eligibility for project power was the first in several legal steps taken to force the Bureau's hand at reinstating funding to achieve mitigation compliance.

the Service spent $8 million in operating costs for Coleman National Fish Hatchery which should have been properly assumed by project beneficiaries.[70] Auditors also observed that a 1949 MOA between the Bureau and the Service omitted a critical "...provision for cost recovery or user assumption" as part of the project's reimbursable costs (USDI 1991, p 4). Auditors found no justification for omitting this provision upon transfer of the facility (Audit Report 1991, p 4).

The Inspector General's report helped break though an interagency logjam. The Bureau generally agreed that "...mitigation costs were legally assessable to project beneficiaries" and that they could logically recover these mitigation costs through its water service contracts (USDI 1991, p 5). The final point rested on "operation control," over who would actually run these facilities and receive assessed costs. As the chief protector and conservator of the nation's fish and wildlife resources, the Service continued insisting it was best suited to run the nation's hatcheries.

On January 11, 1991, Harold Bloom of the Inspector General's office ordered the Service to negotiate with the Bureau to establish procedures for recovering costs stemming from future CVP and other mitigations. He also advised that the Service seek a separate opinion from the Solicitor "...concerning recoverability [from the Bureau and CVP beneficiaries] of [historic] mitigation expenditures" at the Coleman Hatchery. Although Service compensation on this point was never forthcoming, a new institutional arrangement meant funding for CVP salmon and steelhead mitigations was back on track as never before.

The Central Valley Project Improvement Act (1992)

A second institutional transformation in attitudes and policies toward Western water politics, development, and its beneficiaries began in 1992. Passage of the Central Valley Project Improvement Act (CVPIA) assured that for the first time, fish and wildlife resources would have legitimate standing as a serious "beneficial use" (CVPIA 1992). The act provided specifically for the protection, restoration, and enhancement of fish, wildlife habitats in California's Central Valley and Trinity River basins (CVPIA 1992, p 1). The CVPIA included protection of both the Sacramento-San Joaquin Delta Estuary and downstream San Francisco Bay. CVPIA specified achieving a

> *...reasonable balance among competing demands for use of Central Valley Project water, including the requirements of fish and wildlife, agricultural, municipal and industrial and power contractors (CVPIA 1992, p 1).*

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70. The Service had spent $11 million dollars funding operations at Coleman since 1950. Of this total, the Bureau advised as 76.4 percent of this total cost was reimbursable from agricultural, industrial, and municipal water users (USDI 1991, p 5).

Section 3406 of the CVPIA focuses on fish, wildlife and habitat restoration. It specifies that environmental "... mitigation, protection, and restoration of fish and wildlife" are its top priorities. This section specifies:

> *The mitigation for fish and wildlife losses incurred as a result of construction, operation, or maintenance of the Central Valley Project shall be based on the replacement of ecologically equivalent habitat and shall take place in accordance with the provisions of this title and concurrent with any future actions which adversely affect fish and wildlife populations or their habitat but shall have no priority over them (CVPIA 1992, p 11).*

The CVPIA proposes by the year 2002, that "...natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967–1991" (CVPIA 1992, p 12). The legislation also directs the Secretary of the Interior to "...address other identified adverse environmental impacts of the Central Valley Project..."without exactly specifying what they are (CVPIA 1992, p 12). First priority goes to "...measures which protect and restore natural channel and riparian habitat values..." through ecological restoration. To achieve this objective Central Valley Project operations like insufficient instream flows can be modified to benefit anadromous fish (CVPIA 1992, p 12).

Implementing Coleman National Fish Hatchery's Development Plan received special mention as did the Keswick Fishtrap. Additional hatchery production may mitigate for fish losses provided that it is only used to "...supplement or to re-establish natural production while avoiding adverse effects on remaining wild stocks" (CVPIA 1992, p 24). The act also calls for "...eliminating barriers to upstream and downstream migration of salmonids in the Central Valley..." including other measures deemed appropriate to "...protect, restore, and enhance natural production of salmon and steelhead trout in tributary streams of the Sacramento [River] (like Battle, Butte, Deer and Mill creeks)" (CVPIA 1992, p 25).

The intent of Central Valley Project Improvement Act legislation regarding anadromous fisheries is clear. With the recognition of fish as a legitimate interest, the act favors:

- Natural spawning over artificial propagation as a reproductive strategy.

- Restoration of certain "critical habitats" capable of supporting threatened or endangered anadromous fish stocks. (Battle, Butte, Deer and Mill creeks are singled out for their restoration promise).

- Elimination of instream fish barriers which hamper passage of returning migratory fish stocks (including Coleman Hatchery).[71]

Under the CVPIA's legislative umbrella, artificial propagation was relegated to last on the list of priorities. First-order priorities included restoration of riparian stream corridors capable of supporting regenerative stocks of (remaining) wild salmon. The satisfaction of "public trust" values were best accomplished by allowing nature to heal itself with minimal human interference.

Concluding Remarks

Several conclusions stem from the historical review presented within this paper.

Coleman Hatchery should seek a more balanced role in attempting to mitigate anadromous fish losses incurred above the Shasta-Keswick complex. Hanson, Needham, and Smith originally argued that a combination of artificial and natural propagation was required to achieve a balanced fish rescue strategy on the Sacramento River. These Bureau of Fisheries biologists sought a combination of reproductive paths so that each could serve as a "buffer" for the other (Hanson and others 1940, p 17). Neither Coleman Hatchery nor the Keswick Fishtrap should be faulted for becoming the sole surviving pieces of the Bureau's original fish salvage plan. Nor should we forget the hatchery's decisive failure to raise spring-run salmon. Almost by default, Coleman produced predominantly lower river fall-run chinook.

Today's CVPIA legislation calls for natural propagation within restored rivers and streams. Battle, Butte, Deer and Mill creeks, among others, should be set aside, to the greatest extent possible, as refugia for naturally propagating salmonids. Historically, spring-run and winter-run fish also spawned within some east-side Sacramento River tributaries like Battle Creek. Good faith negotiations must occur among all those affected to remove instream obstacles and "rewater" critical habitats like Battle Creek. Given the opportunity, resilient fish should be able to hold their own within surviving, remnant watersheds.

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71. I recognize that Coleman's wider barrier is essential to the hatchery's broodstock collection operations (USFWS and Hamelberg 1999, p 2). However, a seasonally removable structure would provide the hatchery with their broodstock requirements while eliminating yet another obstacle for upmigrating Battle Creek stocks during most months of the year. Technologies such as wiers should be redesigned to suit the biological requirements of naturally spawning fish within restored river basins.

The idea of using tributaries as salmon refugia is hardly a recent one. In 1938, the Bureau considered designating four tributaries below Grand Coulee Dam as protected anadromous fish corridors. The Bureau sponsored considerable stream restoration on the Wenatchee, Methow, Okanogan, and Entiat rivers in the hopes of bringing newly transplanted salmon populations back up to their historic levels. The Bureau, however, soon abandoned the idea of reining-in (or buying out) competing and often harmful water development. Within the intervening decades, we have paid dearly for the Bureau's understandable but regrettable failure to set aside tributaries located downstream from dams as experimental refugia.

Water for fish is a "beneficial use". Some argue that fish conservationists can have anything they want in California, as long as it is not water. Competing riparian and appropriative water claims make salmon and steelhead restoration within their southernmost ranges all the more difficult. Salmon salvage efforts in the Sacramento River Basin are fraught with examples where biologists were required to place competing water claims above fish and wildlife habitat requirements. Under the Stillwater plan of 1940, Bureau of Fisheries biologists sought to export McCloud River water (by flume, suspended pipeline and tunnel) to a stream which was typically dry nine months of the year. There were no other competing water claims along Stillwater's dry streambed. In a second example, biologists sought to import water from the mainstem Sacramento River to supply riparian and appropriative users who seasonally dewatered Deer Creek. Money for the water substitution scheme never materialized, however, and, by 1946, the spring-run transplants to Deer Creek were abandoned. The history of fish rescue in California contains similar stories of biologists attempting to cobble together fish restoration plans with insufficient water. Sufficient, guaranteed instream flows are required to have suitable habitats for healthy runs of anadromous fish. In the end, there is no substitution for enough, clean, fresh water dedicated for fisheries.

Mitigating for salmon biodiversity on the Sacramento River. The Sacramento River (including Battle Creek) is North America's only river basin with four phenotypically unique stocks of chinook salmon. Dispersed, both temporally and spatially, one race of salmon was vacating a stretch of river just as their mature replacements (given suitable conditions) were headed upstream to spawn. This co-evolutionary example is all the more eloquent because emigrating fry and smolts feed along their downriver journey while migrating upriver salmon cease eating long before moving upstream to their natal spawning waters.

Sacramento River salmon still constitute an unequaled biodiversity treasure. With the loss of their upriver habitats, gone, too, was the opportunity for fish to mature in the upper river's high canyons. Also missing was the possibility of over-wintering or summering in protective, upper riverine pools. After construction of the Shasta-Keswick complex, salmon stocks headed for the few remaining spawning grounds along the mainstem Sacramento. This included a stretch of river extending from Red Bluff to Keswick Reservoir. Upriver stocks remain casualties of a historically failed mitigation effort. Thus far, we have failed to mitigate for salmon biodiversity loss on a dramatically altered river, thereby placing at risk a national biodiversity treasure.

Acknowledgments

Many individuals have given freely of their time, knowledge and advice to strengthen this document. My thanks extend to: Laurie Aumack, Nat Bingham, George Black, Michael Borrus, Ron Brockman, Jim Buell, Bill Davoren, Frank Fisher, Ed Forner, Dan Free, Lou Garlic, Jerry Grover, Dick Hallock, Scott Hamelberg, Colleen Harvey-Arrison, Joel Hedgpeth, Patrick Higgins, Will Hobart, Buford Holt, Mark Jennings, Bill Kier, Susan Kitchell, Jim Lichatowitch, Tom Luken, Erik Merrill, Barry Mortimeyer, Peter Moyle, Willa Nehlsen, Tom Nelson, Kevin Niemela, Patricia Parker, Roger Patterson, Paula Peterson, Harry Rectenwald, Felix Smith, Jim Smith, Gary Stern, Ted Steinberg, Bill Sweeney, Joseph Taylor, Paul Ward, Ed Whitsel, Rick Worthington, Ronald Yoshiyama, and members of the Battle Creek Technical Advisory/Work Group. I would also like to thank the many archivists or fish historians (and their assistants) who have provided invaluable materials necessary to complete this study. Specific thanks go to Roy Wingate of the Bureau of Reclamation's Denver Regional Office; archivists located at the Bureau's Sacramento Office; Gretta Siegel at "Streamnet," of the Columbia River Inter-Tribal Fish Commission in Portland; Frank Fisher and Zeral Twitchell of the DFG's Red Bluff office; Scott Hamelberg, Patricia Parker, and Kevin Niemela of the Service's Red Bluff Northern Central Valley Fish and Wildlife Office; Ed Forner and Mary Brubaker of the Service's Portland Regional Office; Linda Vida at UC Berkeley's Water Resources Center Archives, archivists at UC Berkeley's Science Library, and cartographers Brian Lasagna and Chuck Nelson at Chico State University's Geographical Information Center.

Contractual Statement

This document was prepared under contract for the Battle Creek Technical Advisory/Work Group by William M. Kier Associates, 207 Second Street, Suite B, Sausalito, California 94965. Original funding stemmed from a subcontract with Kier Associates as part of a Metropolitan Water District of Southern California Category III, Agreement No. 14532, "Battle Creek Chinook Salmon and Steelhead Restoration Plan Development," with additional funding provided by the US Department of the Interior, Bureau of Reclamation, Shasta Lake, CA; Contract No. 1425–98–PG–23–00840.

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Notes

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Appendix A: Spawning Habitat Analysis for the Sacramento River System Affected by the Keswick Dam and Shasta Dam Projects

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Introduction

This document was prepared for the Battle Creek Technical Advisory/Work Group in an effort to understand the historic role of Coleman Hatchery.[72]

Methods

Spawning Habitat Inventories. Spawning habitat estimates were made in 1939 as part of the Shasta Salmon Salvage Program (Hanson and others 1940). The surveyed habitat was divided into habitat considered suitable for spring-run, winter-run, or fall-run chinook salmon. The divisions were made according to recorded occurrence of spawners and available information on the suitability of temperatures in the various spawning zones. The 1939 spawning habitat surveys were compared with modern day surveys on the South Fork of Battle Creek where there have not been any habitat changes since 1939. The modern survey completed by Coots and Healey (Coots and Healey 1966) and Kondolf (Thomas R. Payne & Associates 1989) are within 10% of the 1939 surveys within this reach.

The number of available nest sites or redds available above Shasta Dam was estimated by dividing the average redd size measured in 1939 in to the available habitat. The average redd size for the reaches above Shasta Dam was 40 square feet. Reaches below Shasta Dam used a value of 50 square feet per redd (Rieser and Bjorn 1979). It was assumed the distribution of spawning efforts

72. This "Spawning Habitat Analysis" was discussed in October 1997 at a Santa Rosa meeting of the Battle Creek Technical Advisory/Work Group. The methodology of extrapolating from spawning gravel surveys to arrive at historic Sacramento River salmon populations still requires additional work.

over the three month spawning period allowed the necessary space; especially during the first and last quarter of the spawning period.

It is possible to extrapolate the available nest sites into an estimated population size. A habitat-based method may be as justified as the fish counting effort used during the late 1930s and early 1940s. The counting effort at that time was a partial count and the returning adults were from juveniles produced during the worst drought in recent recorded history. This habitat-based estimate of the population represents carrying capacity of the river system only if spawning habitat is limiting and the long-term average population is stable (1:1 spawner replacement). Each redd is assumed to represent two adults and some jacks. The percentage of jacks in 1939 was reported by the U.S. Bureau of Fisheries in 1940.

Results

Spawning sites available above Shasta Dam:

- Fall run: 24,847 nest sites representing 64,602 salmon at 2 adults per redd and 30% jacks.
- Spring run: 51,377 nest sites representing 133,580 salmon at 2 adults per nest and 30% jacks. In addition, the Pit River habitat lost to PG&E dams is estimated at 7,444 redds representing 19,354 salmon at 2 adults per redd and 30% jacks.
- Winter-run: 34,634 nest sites (including habitat lost to PG&E dams), representing 90,048 salmon at 2 adults per redd and 30% jacks.

Spawning sites available between Keswick and Shasta dams:

- Fall run: 2,286 nest sites representing 5,945 salmon at 2 adults per redd and 30% jacks.
- Spring run and winter run: None—the temperatures were too warm.

Spawning sites available between Keswick Dam and Red Bluff Dam:

- 1939 Ground Survey: 18,413 sites.
- 1964 Generalized Aerial Survey: 145,000 sites.
- 1980 Extensive Ground and Aerial Survey: 96,000 sites.

Significant differences within these surveys are attributable to the following:

- The 1939 survey was conducted during the worst drought in recent history.
- The 1964 survey was not as extensive as the 1980 survey because it only used aerial survey techniques without ground surveys.
- The 1964 and 1980 surveys incorporated aerial observations of spawning fish. The 1980 population was only one-third of the 1964 survey.
- There was less spawning gravel available in 1980 than in 1964 within the upper 15 miles of those reaches due to lost gravel recruitment caused by Shasta Dam.

Spawning sites available between Red Bluff Dam and Woodson Bridge:

- 1939—No survey was conducted. Biologists characterized the additional 70 miles of spawning habitat to be in a "broad, slow..." and warm river.
- 1964—Generalize Aerial Survey: 70,906 sites.