LOWER SAN JOAQUIN RIVER SALMONID RESTORATION

Supplemental Report

Charles H. Hanson, Ph.D.
Hanson Environmental, Inc.
Walnut Creek, CA 94595

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ASSIGNMENT

One of the fundamental fishery restoration objectives for the San Joaquin River mainstem includes reestablishing a naturally reproducing self-sustaining population of salmonids. My assignment as a fishery expert knowledgeable about the life history and habitat requirements for Chinook salmon and current habitat conditions and limiting factors within the mainstem San Joaquin River was to address specific issues regarding restoration of one or more self-sustaining naturally reproducing populations of Chinook salmon, as well as enhancing habitat conditions for other resident and migratory fishes, within the San Joaquin River downstream of Friant Dam. This supplemental report specifically identifies and addresses issues raised in the expert report of Professor Peter B. Moyle, Ph.D.

CONCLUSIONS

Based on my review of the expert report of Dr. Moyle, and my knowledge of Chinook salmon life history requirements and limiting factors that currently exist on the San Joaquin River, it is my professional opinion that the restoration strategy proposed by Dr. Moyle has an unacceptably high risk that the actions proposed will not be successful in re-establishing the pre-Friant Dam community of Chinook salmon and native fishes. The proposed actions have a high degree of uncertainty and it is unlikely that they will achieve the biological objective of re-establishing a self-sustaining naturally reproducing population of one or two Chinook salmon species. Re-establishment of Chinook salmon populations on the San Joaquin River will require a significantly greater allocation of water resources than those proposed by Dr. Moyle. The reliance on short-duration pulse flows to provide successful upstream and downstream migration, synchrony of cues triggering migration during the limited time provided by the pulse flows, and the limitations that pulse flows constrain the seasonal timing of migration and the expression of life history diversity within a salmonid population, contribute to the high degree of uncertainty that the proposed hydrographs will be successful in meeting the resource objectives. Reliance on pulse flows alone for migration is, in my professional opinion, an experimental, unproven, high-risk approach to re-establishing a self-sustaining naturally reproducing Chinook salmon population on the San Joaquin River.

In addition, as described in my exert report, as well as the background reports (Jones & Stokes 2002; McBain and Thrush 2003) and restoration strategies report for the San Joaquin River (Stillwater Sciences 2003), there are many non-flow limiting factors on the San Joaquin River. Water alone will not provide suitable conditions to re-establish a Chinook salmon population. A significant commitment of financial resources will also be required to address critical limiting factors affecting the viability and population dynamics of Chinook salmon on the river. Key limiting factors include, but are not limited to, the following:

- Limited availability of suitable spawning gravels,
- Degraded spawning gravel quality by a high percentage of fine sediment and sand,
- Seasonal water temperatures that may adversely affect adult holding survival, spawning and egg incubation, hatching success, juvenile rearing, and successful migration,
- In-channel gravel pits that contribute to increased water temperatures, reduced water velocities, trap gravels, and increase vulnerability of juvenile salmon to predation by fish (largemouth bass, etc.) and birds,
- Changes in channel characteristics resulting from construction of flood control by-passes and flow routing that affect water temperatures, have poor habitat conditions for migrating salmon, and expose salmon to predation by birds and fish,
- Barriers and impediments to adult and juvenile migration under most hydrologic conditions, and
- Entrainment mortality resulting from operation of currently unscreened, large water diversions.

Although Dr. Moyle's expert report briefly identifies some of these critical non-flow related limiting factors, Dr. Moyle does not describe the specific non-flow actions, nor the costs associated with the proposed actions, that would be required in addition to the proposed hydrographs to achieve the objective of re-establishing a self-sustaining naturally reproducing population of Chinook salmon to the San Joaquin River.

Basis supporting each conclusion

The basis for each of my conclusions is summarized and documented below and in my expert report titled "Lower San Joaquin River Salmonid Restoration" dated August 22, 2005.

Data or other information you considered in forming each opinion

The data and information used in developing each of my conclusions are summarized and documented below and in my expert report titled "Lower San Joaquin River Salmonid Restoration" dated August 22, 2005.

Methodology used to analyze the data or information you considered

The methods of analysis used in developing each of my conclusions are summarized below and in my expert report titled "Lower San Joaquin River Salmonid Restoration" dated August 22, 2005, as are the analyses performed and used as the basis for each of my conclusions.

Key fishery issues are identified from Dr. Moyle's expert report followed by a brief discussion.

ISSUE 1

Dr. Moyle states:

"The first goal is to establish, as a minimum, the annual runs of salmon and Pacific lamprey that existed just prior to closure of Friant Dam, as well as to create permanent habitat for 10-14 species of native fishes in the reaches below the Dam. The number of salmon needed to satisfy this goal would probably be a minimum of around 500 fish of each run per year, based on the persistence of runs in the Stanislaus, Tuolumne, and Merced rivers." (Moyle, page 23, lines 8-13)

Response

Dr. Moyle provides very little justification regarding the proposed quantitative objective of re-establishing a Chinook salmon run of 500 adults. The references to models used to support the estimated minimum viable population size cited in Dr. Moyle's footnote number 8 are based on estimates of the minimum number of spawning adults necessary to maintain genetic integrity of a population given an assumed level of genetic variability. Adult Chinook salmon returning to the San Joaquin River tributaries have exhibited a high degree of variability in abundance from one year to the next (Figures 1a and 1b) with the average, minimum, and maximum estimated escapement for each of the three San Joaquin River tributaries summarized in Table 1. Dr. Moyle's restoration target number of 500 adult fish of each run is too small to accommodate the high degree of variability in abundance that would be expected in the mainstream of the San Joaquin River below Friant Dam.

Although a minimum salmonid population of 500 adults has been identified as a guideline based on simulation models of population genetics for species such a winter-run Chinook salmon on the Sacramento River, more rigorous analysis and consideration of population diversity, resilience, and ability to withstand environmental challenges (e.g., higher juvenile mortality during droughts) is warranted when establishing restoration targets. The resiliency of a population, for example, is in part a function of genetic variability and a diverse expression of life history characteristics. Larger naturally reproducing populations typically have a greater ability to express diverse life history characteristics and respond to a wider range of environmental challenges with a lower risk of extinction than a small population.

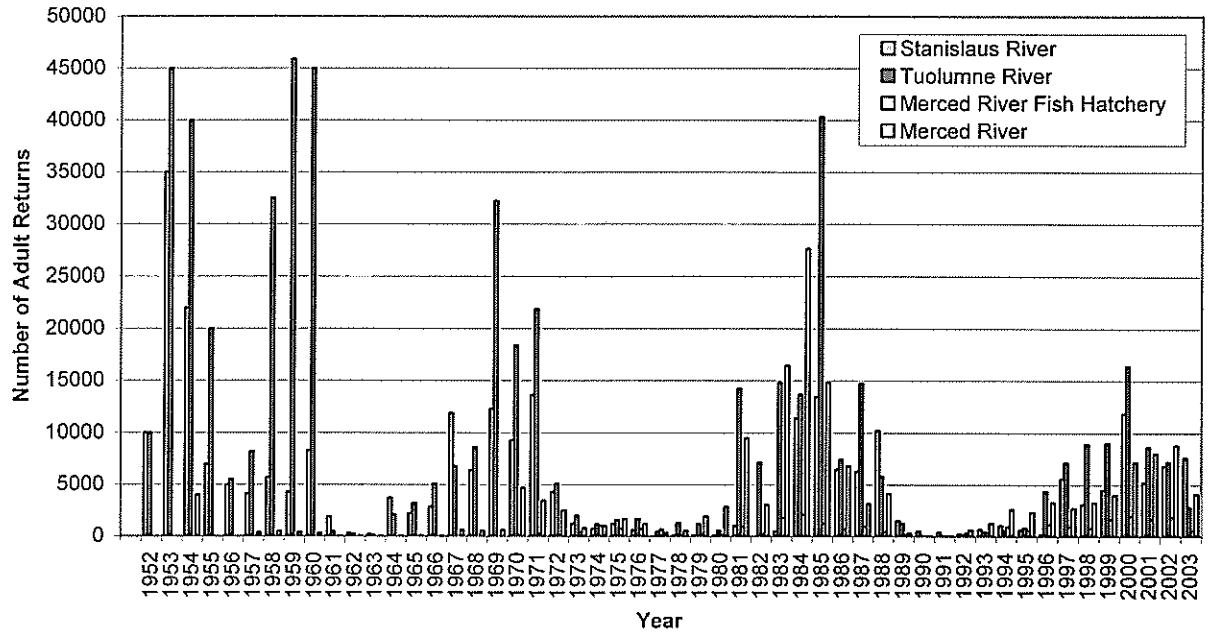

Figure 1a. Annual estimates of adult fall-run Chinook salmon escapement to the Tuolumne River, Stanislaus River, Merced Rivers, and Merced River Fish Hatchery, 1952-2003. (Source: GrandTab).

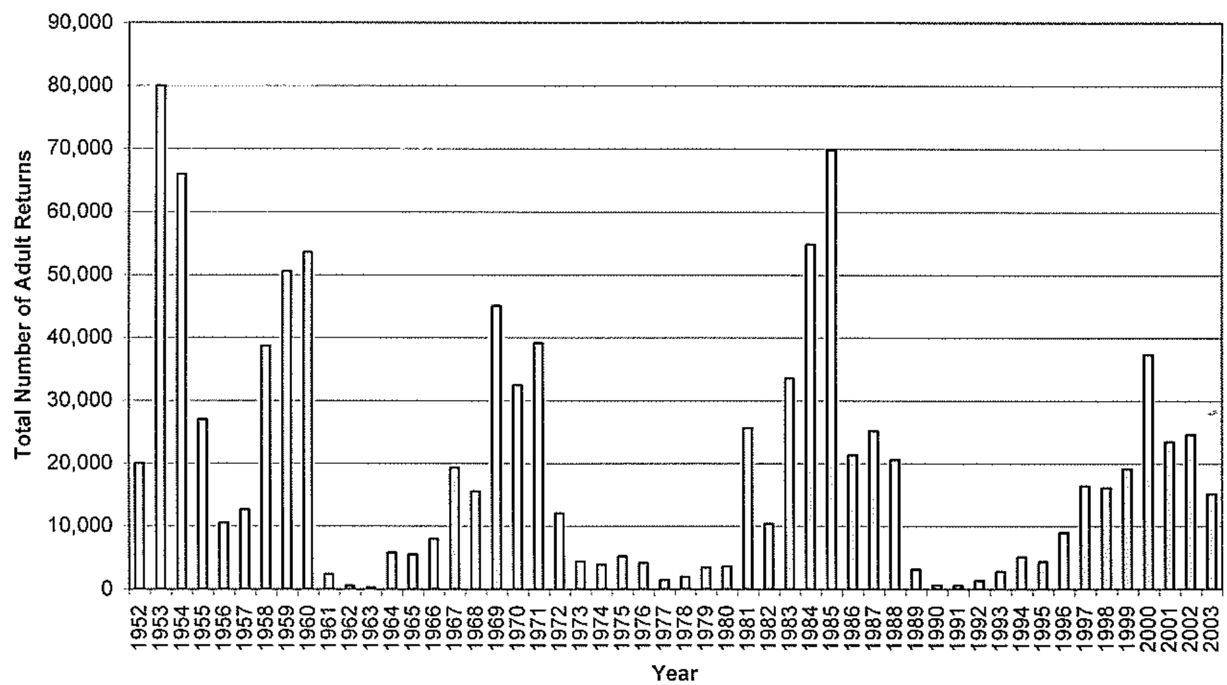

Figure 1b. Total annual estimates of adult fall-run Chinook salmon escapement to the San Joaquin River tributaries and Merced River Fish Hatchery, 1952-2003. (Source: GrandTab).

Table 1. Annual estimates of fall-run Chinook adult escapement to San Joaquin tributaries, 1952-2003. (Source: GrandTab).

YEAR	STANISLAUS RIVER	TUOLUMNE RIVER	MERCED RIVER FISH HATCHERY	MERCED RIVER	TOTAL
1952	10,000	10,000			20,000
1953	35,000	45,000			80,000
1954	22,000	40,000		4,000	66,000
1955	7,000	20,000			27,000
1956	5,000	5,500			10,500
1957	4,090	8,170		380	12,640
1958	5,700	32,500		500	38,700
1959	4,300	45,900		400	50,600
1960	8,300	45,000		350	53,650
1961	1,900	500		50	2,450
1962	315	250		60	625
1963	200	100		20	320
1964	3,700	2,100		35	5,835
1965	2,231	3,200		90	5,521
1966	2,872	5,100		45	8,017
1967	11,885	6,800		600	19,285
1968	6,385	8,600		550	15,535
1969	12,327	32,200		600	45,127
1970	9,297	18,400	100	4,700	32,497
1971	13,621	21,885	200	3,451	39,157
1972	4,298	5,100	120	2,528	12,046
1973	1,234	1,989	375	797	4,395
1974	750	1,150	1,000	1,000	3,900
1975	1,200	1,600	700	1,700	5,200
1976	600	1,700	700	1,200	4,200
1977	0	450	661	350	1,461
1978	50	1,300	100	525	1,975
1979	110	1,183	227	1,920	3,440
1980	100	559	157	2,849	3,665
1981	1,000	14,253	924	9,491	25,668
1982		7,126	189	3,074	10,389
1983	500	14,836	1,795	16,453	33,584
1984	11,439	13,689	2,109	27,640	54,877
1985	13,473	40,322	1,211	14,841	69,847
1986	6,497	7,404	650	6,789	21,340
1987	6,292	14,751	958	3,168	25,169
1988	10,212	5,779	457	4,135	20,583
1989	1,510	1,275	82	345	3,212
1990	480	96	46	36	658
1991	394	77	41	78	590
1992	255	132	368	618	1,373
1993	677	471	409	1,269	2,826

1994	1,031	506	943	2,646	5,126
1995	619	827	602	2,320	4,368
1996	168	4,362	1,141	3,291	8,962
1997	5,588	7,146	946	2,714	16,394
1998	3,087	8,910	799	3,292	16,088
1999	4,500	9,000	1,626	4,000	19,126
2000	11,854	16,420	1,954	7,179	37,407
2001	5,194	8,600	1,660	8,000	23,454
2002	6,800	7,200	1,838	8,800	24,638
2003	7,596	2,854	549	4,110	15,109
Minimum	0	77	41	20	320
Average	5,365	10,621	754	3,396	19,510
Maximum	35,000	45,900	2,109	27,640	80,000

Dr. Moyle provides no justification for assuming that the return of 500 adult Chinook salmon to the San Joaquin River is consistent with estimates of adult salmon escapement prior to closure of Friant Dam. The best estimates available on adult escapement immediately prior to closure of Friant Dam were compiled by Cone (1973) as summarized below (Table 2):

Table 2. Salmon counts in the mainstem San Joaquin River upstream of Mendota Dam (Source: Cone 1973 [(4)])

YEAR	ADULT SALMON ESCAPEMENT
1939	5,000
1940	No Record
1941	3,000
1941[(1)]	6,000
1942[(2)]	7,000
1943	5,000
1944	56,000[(6)]
1945	No Record
1946	30,000[(6)]
1947	6,000
1948 [(3)]	2,000
1949	8,000
1950	Several hundred
Geometric Mean [(5)]	**7,423**

Notes

1. Count in large pool directly below Friant Dam
2. Count of spawning salmon seen in one trip from Friant to old Lane's Bridge
3. Salmon trapped and trucked to Outside Canal
4. State of California, Department of Fish and Game, 1958, Exhibit No. 32
5. Geometric mean excludes 1940, 1945, and 1950. The geometric mean is an accepted scientific method used to calculate a mean value for a highly variable or skewed population or set of measurements. The geometric mean is a measure of central tendency, similar to the median
6. The number of returning adult salmon far exceeds the carrying capacity of currently available spawning gravel as described below.

Dr. Moyle, citing Fry (1961) and Yoshiyama *et al.* (1998), presents similar estimates of adult Chinook salmon escapement on page 15 of his expert report as:

YEAR	ADULT SALMON ESCAPEMENT
1939	5,000
1940	No count
1941	5,000
1942	9,000
1943	35,000
1944	5,000
1945	56,000
1946	30,000
1947	6,000
1948	2,000
After 1949	Occasional small (<500) runs in wet years

The geometric mean of escapement between 1939 and 1948 (excluding 1940) reported by Dr. Moyle is 9,747 salmon. This estimate of adult returns is an order of magnitude greater than the minimum population size of 500 fish proposed by Dr. Moyle.

An adult salmon run of 500 adults is unlikely to be viable and is unlikely to restore the salmon population of the San Joaquin River below Friant Dam to the pre-Friant historical level. The following reasons support this conclusion:

- The water temperatures likely to occur in the spawning areas below Friant Dam during the incubation period, particularly for spring-run Chinook salmon are likely to cause substantial mortality of incubating eggs.

- The location and area of spawning gravels below Friant Dam limit the number of fish of each run that can spawn successfully. The number of returning adults, and the subsequent number of rearing juveniles, determine the spatial habitat requirements to meet the species' needs. For example, the amount of suitable spawning gravel required to support 100 female spawners, as suggested in footnote 8 of Dr. Moyle's expert report, is substantially less than the spawning gravel requirements to support a population having in excess of 1,000 spawning females. Similarly, the spatial habitat requirements necessary to support juvenile rearing produced by 100 spawning females is substantially less than the juvenile rearing habitat requirements for a larger population. There appear to be enough spawning gravels at the flows proposed by Drs. Moyle and Kondolf to accommodate 100 spawning females, but there is no evidence to indicate that 100 spawning females will produce enough offspring to result in the recruitment of enough returning adults in future years to establish a self-sustaining naturally reproducing salmon population in the river below Friant Dam.

- In addition to limitations on the availability of suitable spawning gravels, the quality of existing gravels on the San Joaquin River to support successful salmon spawning and egg incubation/fry emergence is degraded by a high percentage of fine sediments and sand. High concentrations of fine sediments and sand reduce egg hatching success and fry emergence.

- Dr. Moyle's restoration goal of re-establishing both the spring- and fall-runs is likely to result in superimposition of spring-run salmon redds, with resulting increased mortality, as well as hybridization if adults of both species were to be present in the San Joaquin River at the same time.

- Unless they are isolated, the gravel pits are likely to cause substantially increased mortality in juveniles by increasing water temperatures, slowing flows, and providing habitat for predators such as largemouth bass and various avian species.

- Unscreened major diversions at the Mendota Pool and downstream are likely to cause substantial mortality as a result of entrainment of out-migrating juveniles.

- At present there is no way under most hydrologic conditions for adult salmon to reach the spawning grounds. The Hills Ferry Fish barrier blocks the migration of returning fall run adults at the mouth of the Merced River. Mendota Dam generally presents an impassable barrier to migrating adult salmon.

- At low flows, Dr. Moyle's routing of emigrating juveniles into the bypass system from Sand Slough to Bear Creek exposes migrating juveniles to a higher than normal risk of loss because of avian predation, the absence of food and cover, and exposure to adverse water temperature conditions.

- Juvenile Chinook salmon emigrating from the San Joaquin River experience high rates of mortality during passage through the lower river and delta (SJRGA 2003, 2004). The high mortality of these juveniles is a significant factor affecting the overall population dynamics of San Joaquin River salmon.

- Although re-establishing an independent population of spring-run Chinook salmon on the San Joaquin River would be an important contribution to the recovery of Central Valley spring-run Chinook salmon, no analysis is provided in the expert witness report by Dr. Moyle to suggest that a population size of 500 fish would be sufficient to ensure the long-term viability of spring-run Chinook salmon or de-listing of the species.

- The ability of Dr. Moyle's target population of 500 adult fish to produce a sufficient number of juveniles necessary to maintain an adequate level of adult abundance to sustain the population is highly doubtful, given the high mortality rates and challenging physical conditions that exist on the San Joaquin River above the Merced River, as well as within the delta and ocean.

ISSUE 2

Dr. Moyle states:

"I consider possible constraints on the recovery of the river and its fishes in the following categories: (1) passage, (2) flows, (3) habitat, (4) temperature, (5) water

quality, (6) homing behavior, and (7) sources of salmon and other fish." (Moyle expert report, page 27, lines 11-13)

Response

The San Joaquin River downstream of Friant Dam has experienced over 50 years of habitat degradation and changes in land use that represent significant factors affecting the quality and availability of habitat needed to support various life history stages of Chinook salmon and other fish species. Although Dr. Moyle briefly acknowledges in his expert report the importance of flow and non-flow related limiting factors and constraints on successful re-establishment of a Chinook salmon population on the San Joaquin River, he presents no information regarding the specific actions he proposes to take to address the non-flow habitat constraints such as fish passage barriers, spawning gravels, flow routing, and the entrainment of juvenile migrating Chinook salmon into currently unscreened surface water diversions. These non-flow habitant constraints directly impact the viability of a Chinook salmon population and the ability to successfully re-establish a self-sustaining population.

To protect Chinook salmon populations inhabiting virtually all of the Central Valley rivers and streams, it is recognized by state and federal resource agencies, local landowners, and others that concerns regarding fish passage and access, habitat quality and availability, gravel augmentation, and the installation of positive barrier fish screens on water diversions must be addressed before restoration will be successful.

Dr. Moyle's report is not specific on the importance of these factors and how they may affect his judgment regarding the adequacy of his proposed program for re-establishing Chinook salmon and other native fish to the San Joaquin River, nor the cost associated with such actions. The non-flow factors and associated costs are addressed in the Supplemental report of Dr. Hradilek. Their costs are conservatively estimated at over $500,000,000. Positive barrier fish screens and related measures have been previously estimated by Mr. Donahue at an additional $100,000,000. Because Dr. Moyle failed to identify specific non-flow actions required to implement his restoration strategy and because he failed to address non-flow related limiting factors, it is unlikely that Dr. Moyle's restoration hydrographs will succeed in re-establishing a self-sustaining Chinook salmon population.

ISSUE 3

Dr. Moyle states:

"The Arroyo Canal might have to be screened, blocked, or specially operated during times of juvenile salmon outmigration (which is mostly at times when demand for irrigation water is low) but this would be determined through studies (see Moyle and Israel 2005)." (Moyle expert report, page 28, lines 18-21)

Response

The Arroyo Canal has a diversion capacity of approximately 600 cfs and is currently unscreened. Operation of the Arroyo Canal diversion would result in a substantial probability that juvenile Chinook salmon would be entrained during downstream migration. Since the Arroyo Canal is operated to provide agricultural irrigation flows during the late winter and spring, coincident with the period identified for juvenile Chinook salmon emigration (February - May), the seasonal curtailment of diversion operations would result in significant disruption to local agricultural operations. Dr. Moyle presents no detail as to how the diversion operations and the risk of entrainment mortality will be addressed nor the capital, operating, or maintenance costs of these non-flow actions. The cost of providing positive barrier fish screen on the Arroyo Canal is presented in the expert report of Edward Donahue.

For discussion of other major unscreened diversions, see Issue 10 below.

ISSUE 4

Dr. Moyle states:

"Restoration of diverse fish communities in the San Joaquin River ultimately will require enough water to make a continuous living stream again from Friant Dam to its confluence with the Merced River." (Moyle expert report, page 30, lines 9-11)

Response

Dr. Moyle proposes that a base flow of 350 cfs released from Friant Dam will meet the requirements of surface water connectivity between Friant Dam and the confluence with the Merced River. Dr. Moyle, however, provides no information or analysis as to how the proposed base flow was established or assurances that the base flow will in fact meet the requirements of flow continuity throughout the lower San Joaquin River. Similarly, Dr. Moyle provides no discussion or analysis regarding the suitability of habitat conditions for various species and life history stages that would be met by the proposed base flow regime.

ISSUE 5

Dr. Moyle states:

"Except during critically dry years, flow regimes should have the following characteristics: (1) continuous flow from the Dam to the Merced River at all times of year to maintain habitat for fish in all reaches of the river, (2) flows from November through December for migration and spawning of fall-run Chinook salmon, (3) incubation and rearing flows for fall-run Chinook salmon (January – February), (4) flows in March through April for emigration of juvenile salmon of both runs, immigration of adult spring-run Chinook salmon, and spawning of native resident fishes, and (5) flows through the summer to maintain holding and rearing habitat for spring run Chinook salmon from Friant Dam down to somewhere above Highway 41, to maintain the diverse community of native fishes, and to support fisheries for

warm water game fishes." (Moyle expert report, page 30, line 28 through page 31 line 8)

Response

Fall-run Chinook salmon adults typically migrate upstream during the period from approximately mid-September through mid-December with juvenile fall-run Chinook salmon outmigration typically occurring during February – March (fry) and April – mid-June (smolts). The seasonal time periods proposed by Dr. Moyle to provide migration flows for fall-run Chinook salmon are inconsistent with the seasonal timing and requirements for egg incubation and juvenile rearing. By not allowing adult fall-run Chinook salmon to migrate upstream until November, spawning and the onset of egg incubation would be delayed until the latter part of their natural spawning period. The rate of egg development is dependent on seasonal water temperatures, as are the growth rates of rearing juvenile Chinook salmon.

Stillwater Sciences (2003) and others have provided life history models for Chinook salmon that suggest, based on the seasonal timing proposed by Dr. Moyle for migration, that fall-run Chinook salmon would not have a sufficient period of time to successfully migrate upstream, spawn, have their eggs develop, and their juveniles rear and grow to smolt stage before temperatures in the lower river become unsuitable for juvenile migration. Instead, any juveniles that manage to hatch would likely be subjected to a "thermal squeeze" with the onset of warm spring air temperatures. It may be possible for some proportion of the juvenile fall-run salmon to successfully migrate downstream during the window of opportunity proposed by Dr. Moyle as small fry (typically 30-40 mm in length). However, fry typically experience higher mortality rates than smolts. Despite this, there is no analysis presented by Dr. Moyle to suggest that a fall-run Chinook salmon population, dependent upon fry migration, would be able to successfully meet the targets of a self-sustaining naturally reproducing population.

Similarly, there are concerns that allowing fall-run Chinook salmon to migrate upstream and spawn during November and December, a period when spring-run Chinook salmon eggs would have been deposited and would be incubating in redds, would result in increased spring-run Chinook salmon egg mortality as a result of redd superimposition by fall-run Chinook salmon. The probability of redd superimposition of fall-run Chinook salmon on spring-run Chinook salmon redds is further increased by the limited availability of suitable spawning gravels currently within the mainstem San Joaquin River. In addition, if spring-run and fall-run adult salmon were to be present in the river at the same time there is a substantial risk of genetic hybridization between the two species. The risk of hybridization is reduced if adult fall-run Chinook salmon are only allowed access during November and December.

Although it may be desirable to re-establish fall-run Chinook salmon within the San Joaquin River, the life history and seasonal timing of migration and the suitability of water temperatures, particularly during the spring period of juvenile outmigration, represent significant constraints that will likely preclude the ability to successfully re-establish a self-sustaining fall-run Chinook salmon population in the San Joaquin River downstream of Friant Dam.

ISSUE 6

Dr. Moyle states:

"The amount and quality of gravel in many of the areas still needs careful evaluation to determine its suitability for spawning and incubation (along the lines of Sommer *et al.* 2000a) but there is clearly adequate gravel to support both spring-run Chinook (in the reach below Friant Dam) and fall-run Chinook (in the reach around Lanes Bridge and below)". (Moyle expert report, page 32, lines 25-29)

Response

The suitability of the existing gravels located within Reach 1, downstream of Friant Dam, to support a self-sustaining population of Chinook salmon is dependent upon several factors. These include the assumed number of female spawners (see comment above) and the expected level of successful egg hatching and fry emergence based upon spawning gravel quality (percentage fines and sand within the gravel matrix). Friant Dam, as well as other impoundments, have disrupted the recruitment of suitable gravels from upstream within the watershed. In addition, on-stream gravel mining pits and quarries trap and remove spawning gravels from suitable habitat areas within Reach 1. The quantity of existing gravels may be suitable to support an adult spawning population of 100 females; however spawning gravel availability becomes a significant limiting factor if higher abundance of spawning females is required to support a self-sustaining Chinook salmon population. Furthermore, the existing gravels have degraded quality based on both the occurrence of a high percentage of larger cobbles as well as a substantial amount of sand within the spawning gravels that exist within the river. A high proportion of sand within a spawning substrate has been demonstrated (Greig *et al.* 2005; Jong 1997; Magee *et al.* 1996; Merz and Setka 2004; Reiser and White 1988; and Wu 2000) to significantly adversely impact egg hatching success and fry emergence. Dr. Moyle presents no analysis to support his opinion that there "is clearly adequate gravel to support both spring-run Chinook (in the reach below Friant Dam) and fall-run Chinook (in the reach around Lanes Bridge)."

ISSUE 7

Dr. Moyle states:

"Generally, the ability of a juvenile or adult salmon to survive high temperatures is a function of the degree to which energy expended by dealing with stressful factors (i.e., avoiding predators, length of exposure to high temperatures) is balanced by energy gained from favorable factors (i.e., abundant food, daytime cool-water refuges). This bioenergetic approach to understanding temperature tolerances can explain why some populations that experience high (22 C [72 F] or more) temperatures thrive while others that experience the same temperatures die out." (Moyle expert report, pages 34, lines 26- page 35, line 3).

Response

Results of water temperature modeling presented by Jones & Stokes (2002), Stillwater Sciences (2003), and Deas (2005) all illustrate the risk that juvenile downstream migrating Chinook salmon and adult upstream migrating Chinook salmon would be exposed to substantially elevated water temperatures during the spring migration period. Many of the channels in the San Joaquin River below Friant Dam and above the Merced River, and particularly many of the bypass channels, are relatively wide and water depths within these channels under the hydrographs proposed by Dr. Moyle for migration would be relatively shallow (particularly in reaches such as Reaches 2 and 4). That would contribute to stressful conditions for upstream migrating adults, and downstream emigrating juveniles. These conditions would also increase the vulnerability of juvenile Chinook salmon to avian predation, as well as predation by resident and migratory warm-water fish colonizing the lower reaches of the river under conditions of surface water connectivity assumed by Dr. Moyle throughout the year. These additional stresses would exacerbate the exposure of both adult and juvenile Chinook salmon to seasonally elevated water temperatures and contribute directly and indirectly to increased mortality of both adults and juveniles as well as potentially reduced reproductive success of adult Chinook salmon. More detailed analyses of the hydrologic conditions that would occur within the channel of the San Joaquin River under the hydrographs presented by Dr. Moyle would be required to further assess and evaluate the potential significance of these and other stressors on the health and survival of Chinook salmon. Similarly, additional analyses are required to determine the probability of successfully meeting the goal of re-establishing a self-sustaining naturally reproducing population of Chinook salmon under the environmental conditions that would occur in response to the hydrographs and other habitat conditions proposed by Dr. Moyle.

Millerton Lake has a relatively small storage capacity and depletion of the cold-water pool as a result of instream flow releases to the river is a serious constraint on the potential success of salmonid re-establishment. Instream flows provided to meet the requirements of adult and juvenile migration during the spring and adult holding and juvenile rearing during the summer has the potential to deplete cold water within the lake and result in elevated temperatures during the September-October period of spring-run Chinook salmon spawning and egg incubation. Incubating eggs are extremely sensitive to exposure to elevated water temperatures and high egg mortality can result. Reducing the instream flow releases to conserve cold water may adversely impact quality and availability of suitable habitat for upstream and downstream migration, adult holding and juvenile rearing and therefore may reduce the productivity of the river as salmonid habitat. The alternative is to increase upstream storage capacity of cold water that can then be made available to meet spawning and egg incubation requirements during the fall.

ISSUE 8

Dr. Moyle states:

"Spring-run Chinook salmon would almost certainly have to be brought into the system from the Sacramento River drainage, although they most likely would re-colonize the system naturally if given enough time." (Moyle expert report, page 42, lines 5-7)

Response

Dr. Moyle proposes using spring-run Chinook salmon brood stock from Butte Creek as the founding population for re-establishing spring-run Chinook salmon on the San Joaquin River. Since spring-run Chinook salmon on Butte Creek have been listed under both the California Endangered Species Act and Federal Endangered Species Act as a threatened species, a number of potential regulatory issues as well as issues related to conservation biology, exist with the proposal to use Butte Creek as the founding population. At a minimum, regulatory approvals under the Endangered Species Acts would be required from both the National Marine Fisheries Service and California Department of Fish and Game/Fish and Game Commission to authorize the take of adult spring-run Chinook salmon from Butte Creek. In addition, concerns exist regarding genetic selection and integrity of a small population of spring-run Chinook salmon as a founding stock.

It is interesting to note that although Dr. Moyle's opinion is that spring-run Chinook salmon would naturally re-colonize the river system if given sufficient time, spring-run salmon populations have <u>not</u> re-colonized or been established within the Stanislaus, Tuolumne, Merced, Cosumnes, or Mokelumne rivers which are all tributary to the San Joaquin.

ISSUE 9

Dr. Moyle states:

"Regardless of origin, a population of spring-run Chinook salmon established in the San Joaquin River has the potential to nearly double the number of spring-run salmon returning to California streams, greatly increasing the probability of the fish being removed from the federal list of threatened species." (Moyle expert report, page 42, lines 23-26)

Response

The estimated number of adult spring-run Chinook salmon returning to Central Valley Rivers over the ten year period from 1994 to 2003 (recent period of reports) has averaged 14,086 fish, with a minimum of 6,187 fish (1994) and a maximum of 31,471 (1998) fish, based upon adult escapement estimates compiled by the resource agencies (Grand Tab data summary). Based on these adult escapement estimates, an average of 14,000 spring-run Chinook salmon would need to return to the San Joaquin River in order to double, on average, the Central Valley spring-run Chinook salmon population. There appears to be a conflict between the estimated number of salmon required to double the spring-run salmon population, as suggested in Dr. Moyle's expert report, and the earlier quantitative objective of re-establishing a minimum adult population size of 500 fish. Further, Dr. Moyle fails to provide any data to suggest that existing spawning grounds would support a population of 14,000 adult salmon or that such a population could be self-sustaining in view of the passage barriers, passage impediments, and limited habitat availability in the San Joaquin River above the Merced River.

ISSUE 10

Dr. Moyle states:

"The pool behind the [Mendota] dam is about 1200 acres and today it receives most of its water from the Delta-Mendota Canal, which delivers, on average, 2500 - 2800 cfs. This water in turn is mostly diverted into 5 canals to various irrigation districts, replacing the San Joaquin River water, which the irrigators used before construction of Friant Dam. The remaining 500 - 600 cfs flows downstream for 22 miles before being diverted into the Arroyo Canal at Sack Dam." (Moyle expert report pages 20, line 25 through page 29, line 1).

Response

As noted by Dr. Moyle, there are five currently unscreened water diversions located within Mendota Pool that divert, on average, approximately 2,000 cfs during the late winter and spring migration period. Juvenile Chinook salmon migrating downstream in the mainstem San Joaquin River would be vulnerable to direct entrainment mortality as a result of operation of these unscreened water diversions. Entrainment mortality within Mendota Pool has the potential to be a significant factor affecting the overall population dynamics of Chinook salmon on the San Joaquin River. Dr. Moyle correctly identifies the entrainment of juvenile salmon within Mendota Pool as a potential constraint that can be reduced through a combination of either positive barrier fish screens or modifications to diversion operations. Dr. Moyle, however, does not report the capital or operating and maintenance costs associated with construction of positive barrier fish screens within the Mendota Pool to accommodate the five existing diversion canals and to provide adequate protections for juvenile Chinook salmon.

An additional alternative to providing positive barrier fish screens within Mendota Pool would be the construction of a bypass channel circumventing Mendota Pool and allowing juvenile Chinook salmon the opportunity to migrate downstream without encountering the unscreened diversions within Mendota Pool. The estimated engineering costs for constructing a bypass channel to avoid entrainment mortality within Mendota Pool have been developed and are presented in the expert reports of Edward Donahue and Peter Hradilek. The capital costs for constructing a bypass channel around Mendota Pool are estimated to be in excess of $50,000,000. The Mendota Pool bypass channel was estimated to have a lower cost than constructing and operating positive barrier fish screens on the existing water diversions.

The capacity of the unscreened canals diverting from Mendota Pool is comparable to or larger (averaging 2500-2800 cfs during the spring irrigation season), than the bulk of the restoration hydrograph proposed by Dr. Moyle. In addition to contributing to direct mortality as a result of entrainment, operation of these diversion canals would also have a significant effect on instream flows and resulting habitat conditions, both upstream and downstream of the diversion points, that would affect habitat quality and availability for various species and lifestages of fish.

Successfully addressing the mortality that would result from entrainment of juvenile Chinook salmon into the currently unscreened water diversions within Mendota Pool is one of the key elements of a potentially successful reestablishment of a Chinook salmon population on the San Joaquin River. In the absence of addressing these and other significant limiting factors and constraints, it is my opinion that there would be a high degree of uncertainty regarding the ability to reestablish a Chinook salmon population on the river.

ISSUE 11

Dr. Moyle states:

"Data on various species of salmon in Groot and Margolis (1991) indicate that adult Chinook salmon are capable of migrating up-river at a rate of 20-40 miles/day. Once they enter the San Joaquin River above its confluence with the Merced River, they could reach their spawning grounds in 4-8 days if there are no delays. This rapid migration time would minimize risks to developing eggs by exposure to high temperatures" (Moyle expert report page 36 lines 14-18).

Response

Keefer *et al.* (2004) conducted a study of adult spring-summer run Chinook salmon within unimpounded reaches of the Columbia River system. The study tracked movement of 1801 radio tagged adult salmon from 1997 to 2002. Median migration rates within reaches having a mean river flow of less than 30,000 cfs during the migration period ranged from approximately 6 to 17 miles/day. Mitchell (pers. comm.) reported that estimated adult fall-run Chinook salmon upstream migration rates ranging from 3.1 to 9 miles/day. Assuming a migration rate of 6 miles/day transit through a 150 mile reach would require 25 days. At a migration rate of 17 miles/day transit would require approximately 9 days. The range of transit times based on results of these studies is substantially greater than the range reported by Dr. Moyle. Migration within the lower San Joaquin River may be slower than that reported by Keefer *et al.* (2004) as a result of the challenging conditions posed_by shallow water depths and impediments to migration.

Demko *et al.* (1998) reported migration rates for radio tagged salmon in the Stanislaus River in which five tagged salmon migrated 37.9 miles in under three days (approximately 12.6 miles/day with fish moving an average of 7.1 miles the first night after release. Demko *et al.* (1999) report migration rates for a small number of juvenile Chinook salmon released and recaptured in the Stanislaus River. Migration rates for these marked juvenile salmon ranged from 1.3 to 15.8 miles/day in 1999 and are reported to be comparable to results from previous years. Based on these estimates of juvenile migration rates transit through a reach 150 miles in length would range from approximately 9 to 115 days.

Zabel and Anderson (1997) analyzed downstream migration rates for PIT tagged juvenile spring-run Chinook salmon on the Snake River and found migration rates ranged from 1.9 to 7.7 miles/day. Based on these estimates of juvenile migration rates transit through a reach 150 miles in length would range from approximately 19.5 to 79 days.

ISSUE 12

Dr. Moyle states:

"Salmon from the San Joaquin run could once again colonize the Kings River by migrating through Fresno Slough. Given the year-round coldwater in the Kings River report it is reasonable to expect that a regular run could develop there as well" (Moyle expert report, page 44, lines 19-21).

Response

Dr. Moyle provides no substantiation of his opinion that a regular run of Chinook salmon can be established on the Kings River (Dr. Moyle provides no data to suggest that a regular run of Chinook salmon ever existed on the Kings River). Based on the life history requirements of Chinook salmon, the ability to successfully migrate upstream and downstream between spawning and juvenile rearing areas and coastal marine waters is required virtually every year. Chinook salmon have the ability to withstand, on an occasional basis (such as a critically dry water year), a rare occurrence when adult and/or juvenile migration is not possible for one or possibly two years; however, a self-sustaining population could not be developed on the Kings River without the ability to successfully migrate upstream and downstream in virtually every year.

Dr. Moyle provides no hydrologic information to suggest that opportunities for successful migration exist between the Kings River through Fresno Slough and the lower San Joaquin River with sufficient frequency to support a self-sustaining Chinook salmon population on the Kings River. Although water from the Kings River periodically flows through Fresno Slough, as reflected in flows in the James by-pass, into the lower San Joaquin River, the frequency of occurrence of these flow events is limited to wet years when flood control releases are required from Pine Flat Dam as well as from other tributaries. Examination of the hydrologic records demonstrates that flows in James by-pass that would provide continuity between the Kings River and the lower San Joaquin River have occurred in approximately 5 years out of 49 years (water years 1955-56 through 2003-04) during the fall migration period (September 15-December 15). During the spring migration period connectivity has occurred in 17 out of 49 years. During both the fall and spring migration periods there are many occasions when connectivity did not occur over a period of three or more consecutive years. This frequency of occurrence of potentially suitable migration conditions would not be adequate to support a self-sustaining population of Chinook salmon on the Kings River. Historically there may have been occasions when Chinook salmon opportunistically strayed into the Kings River drainage, however Dr. Moyle presents no information to suggest that a self-sustaining population of Chinook salmon ever inhabited the Kings River.

ISSUE 13

Dr. Moyle states:

"A 400-500 cfs pulse flow, measured at the Merced River for 10 days, including two days of ramping up and down at each end, in November. This flow is to bring adult

fall-run Chinook salmon upstream to spawn" (Moyle expert report page 47, lines 25-26).

"A1500 cfs pulse flow for two weeks in March plus an additional two weeks of ca. 500 cfs for ramping up gradually." (Moyle expert report page 48, lines 9-10)

"March pulse flow for spring-run Chinook salmon immigration and juvenile salmon emigration, as for Dry years. In addition, I recommend a 2500 cfs flow for the first two weeks of April. The increase in length and volume of the flow would ensure that all salmon would be able to move up or down the river, that juvenile salmon would be able to rear in productive edge habitat . . ." (Moyle expert report page48 line 26 through page 49, line 1)

"Same as for Normal-Dry but providing an additional 4000 cfs pulse for two weeks at the end of April." (Moyle expert report page 49, lines 18-19)

Response

The hydrographs proposed by Dr. Moyle in his expert report for both fall-run and spring-run migration rely on short-duration pulsed flow events. In the example cited above, a 10-day pulsed flow would be available in November for adult Chinook salmon migration. Other pulses provided in the hydrographs developed by Dr. Moyle similarly provide a short duration of surface water connectivity to allow for upstream migration of adult fall-run and spring-run Chinook salmon, as well as downstream migration of juvenile Chinook salmon. Dr. Moyle provides no examples or references supporting the contention that short-duration pulse flows, as proposed in his expert report, would be effective in providing sufficient migration opportunities to support a self-sustaining Chinook salmon population. In fact, experiments conducted on the Mokelumne River (and other California rivers), have not shown that adult or juvenile Chinook salmon will consistently migrate in response to a pulsed flow event.

The seasonal timing of upstream and downstream migration by Chinook salmon occurs in response to a variety of environmental and physiological factors. Pulsed flows are only one of the environmental factors that cue salmon migration. Other factors such as changes in seasonal water temperature, day length, the physiological rate of development and smoltification, and juvenile growth rates, also affect the behavioral patterns and seasonal periods of migration of Chinook salmon. Dr. Moyle provides no scientific reference or support for his opinion that a sufficient synchrony would exist between the behavior and physiological conditioning of Chinook salmon and the prescribed short-duration pulsed flows proposed in his hydrographs. In fact, short-duration pulse flows are not used as a routine management tool downstream of reservoirs and impoundments to provide either behavioral cues or hydraulic opportunities for Chinook salmon upstream or downstream migration.

Demko *et al.* (1998) report on an evaluation of the effects of pulse flows on juvenile Chinook salmon migration in the Stanislaus River. Results of the 1998 investigation showed an apparent relationship between fry (< 45 mm in length) migration and flow. Results of this investigation, however, did not show a clear or consistent pattern of migration response between migration of smolt sized salmon (45-80 mm in length) and flow changes. Demko *et al.* (1999) found a similar pattern in the response of salmon to flow. Demko *et al.* (1999) reported that peak fry migration in January coincided with increased flows, however, peak fry passage in February occurred during periods of increasing and decreasing flows. Flows appeared to have less correlation with smolt migration although the variation in spring flows on the Stanislaus River in 1999 were relatively stable and did not produce a pronounced spring pulse flow to test.

A second significant concern regarding reliance on short-duration pulse flow events to allow successful upstream and downstream migration of Chinook salmon, as proposed by Dr. Moyle, relates to the expression of a range of life-history attributes for Chinook salmon. Chinook salmon, like many other species, exhibit a range of behavioral patterns, rates of development, behavioral responses to environmental cues, and evolutionary strategies in response to variable environmental conditions. For example, Chinook salmon exhibit a range of juvenile rearing behaviors with juvenile emigration occurring over a range of seasonal periods - fry (30-45 mm in length), smolts (80-100 mm in length), and yearlings (typically greater than 150 mm in length) all exhibit different seasonal periods of downstream migration. Current thinking in conservation biology supports management options that allow for the greatest expression of behavioral, genetic variability, and life history strategies within a species. The expression of a range of life history characteristics provides a species greater stability in response to a range of environmental conditions as well as greater genetic integrity within a population.

Jager and Rose (2003) used a simulation model to design optimal flow patterns for Chinook salmon using the Tuolumne River as an example. The simulation model included seasonal flows intended to maximize recruitment as well as maximizing spawning time variation. The resulting optimal flow regimes predicted by the model varied in response to water supply conditions and were characterized by an increasing flow beginning in the winter (December-January) and continuing to increase throughout the spring months followed by ramping down to baseflow conditions in June. The model hydrographs were designed to provide a range of opportunities for the various lifestages of Chinook salmon to express a range of expressions while also considering the effects of factors such as seasonal water temperature and other environmental conditions on reproductive success and juvenile survival.

In fact, current hatchery management practices within the Central Valley are being modified in response to concerns by the California Department of Fish and Game and National Marine Fisheries Service that hatchery practices support a wider range of life-history characteristics and genetic characteristics within a population. One of the principal criticisms of past hatchery management practices concerned the selection of adult Chinook salmon from a very narrow window of time for use as brood stock. In response, brood stock selection at Central Valley hatcheries is being modified to assure that adults reflecting the entire range of seasonal timing and genetic characteristics are included as part of the hatchery spawning population to improve the overall genetic integrity of the population. The use of short-duration pulse flows to provide opportunities for adult upstream migration and juvenile downstream migration, although an attractive water conservation measure, would be expected to directly limit and constrain the expression of a wide range of life-history strategies. Only those adults and juveniles that are capable of migrating upstream or downstream during the short-duration pulsed flow event would be represented in the population. These constraints on the expression of life history variability, similar to the past hatchery management practices that were criticized, is a serious consideration affecting the ability to re-establish a self-sustaining Chinook salmon population on the San Joaquin River that would have sufficient genetic diversity and integrity and characteristics to insure long-term sustainability of the population and contribute to spring-run Chinook salmon recovery efforts.

No other Chinook salmon population in California or within the Pacific Northwest is managed solely using short-duration pulsed flow events to support upstream and downstream migration. Nor am I aware that any such strategy has been successful in maintaining a self-sustaining population that would meet Dr. Moyle's definition of a population in good condition. Dr. Moyle cites no data or scientific studies that support the use of short-duration pulse flow events as the sole method of achieving suitable migration conditions that support a self-sustaining population of Chinook salmon.

Dr. Moyle reports, "the length of the release presented here is based, in part, on estimated travel times of the adults to potential spawning areas (3- 7 days)" (Moyle expert report, page 47, line 29; and page 40, lines 1-2). The migration corridor extending from the confluence of the Merced River upstream to Friant Dam is approximately 150 river miles which, under Dr. Moyle's assumed migration rates, would require that adults Chinook salmon migrate at a rate 21 to 50 miles per day. Although adult Chinook salmon may have the capability to migrate at relatively high rates in some rivers where water depths, velocities, temperatures, and the absence of passage barriers and impediments are all optimal, these conditions do not occur on the San Joaquin River. The hydrographs proposed by Dr. Moyle would be expected to result in relatively shallow waters (less than several feet deep) over a number of miles of the river (e.g., over approximately 24 miles within Reach 2 as well as in Reach 4). Similarly, upstream migrating adult Chinook salmon would encounter a number of passage barriers and impediments that would further contribute to delays in upstream migration. Although during February and March water temperatures would be expected to be suitable for adult upstream migration, seasonal increases in water temperatures during April would be a factor affecting adult Chinook salmon migration rates, adult health and condition, and potentially egg viability.

All of these factors contribute to a substantial degree of uncertainty and lack of confidence that the passage flows provided by Dr. Moyle would provide suitable conditions to allow for successful upstream and downstream migration of an adequate number of Chinook salmon to support a self-sustaining population on the San Joaquin River.

The potential constraints of providing short-duration pulsed flows as the sole method for allowing upstream and downstream migration of adult and juvenile Chinook salmon on the San Joaquin River is acknowledged by Dr. Moyle. Dr. Moyle has proposed hydrographs with an increasing duration and magnitude of pulsed flow events in response to wetter year-types to "insure that all salmon would be able to move up or down the river, that juvenile salmon would be able to rear in productive edge habitat or side channels for 2-3 weeks (growing faster and larger as a consequence), and that the native fishes would have adequate time to spawn (on riffles) and have their young rear in flooded edge habitat" (Moyle expert report page 48,line 28 through page 49, line 3). Although the increase in the magnitude of proposed streamflows and the duration that pulsed flows would be maintained increases in response to water-year-type in the proposed hydrographs presented by Dr. Moyle, the duration and limited frequency of migration opportunities remains short and would not provide the opportunities for successful expression of a wide range of life-history characteristics.

ISSUE 14

Dr. Moyle states:

"In cases like this, trap-and-truck operations could be instituted, where humans capture the fish and move them in both directions as a temporary experiment. Some of these fish could be brought into hatcheries to create a backup source for fish if wild populations fail or are greatly reduced, using the experience gained in managing winter run Chinook salmon in the Sacramento River. The Friant hatchery could be converted to a rescue hatchery or the fish could be moved to hatcheries with cold water supplies on the Sacramento system (e.g., Coleman Hatchery on Battle Creek)" (Moyle expert report page 50, line 27 through page 51 line 4).

Response

Reliance on a trap-and truck-operation and the use of hatchery production, either the Friant Hatchery or other out of basin hatcheries, is inconsistent with the objective of re-establishing a <u>self-sustaining</u> population of Chinook salmon. Human intervention is inconsistent with the basic objectives identified for the restoration of San Joaquin River Chinook salmon. Although human intervention, such as truck-and-trap operations or use of a conservation oriented hatchery, have been used in other river systems, the application of these tools as part of the San Joaquin River restoration program should be limited to very infrequent catastrophic emergency circumstances if the goal of maintaining a self-sustaining naturally reproducing Chinook salmon population is to be maintained. Given the low population abundance proposed as a target by Dr. Moyle, the loss of one or two consecutive year classes, as a result of factors such as unsuitable conditions for adult or juvenile migration during a critical drought or other factors, would be sufficient to significantly impact the viability of a San Joaquin River Chinook salmon population and potentially would lead to the extirpation of a re-established run.

Despite the criticism above, the use of tools such as trap-and-truck and juvenile production and out-planting from a conservation hatchery have merit in the event that a fundamental change were to be made in the resource management objectives underlying the re-establishment of Chinook salmon on the San Joaquin. A number of additional fishery management tools such as the use of streamside egg incubators, conservation hatchery production, isolation weirs to segregate spring-run from fall-run Chinook salmon and reduce the risk of hybridization, and transport of adults and/or juveniles to suitable release sites may be applied to provide greater certainty and confidence that a population could be maintained on the river in the future. These actions, however, would not be consistent with re-establishing the historic, self-sustaining fishery that existed prior to Friant Dam.

ISSUE 15

Dr. Moyle states:

"It is important to remember that Chinook salmon populations have great resiliency, with 3-4 year classes from each year's run present in the ocean. Thus, even after 2-3 years of no salmon returns to the river, some adult fish could still come back to spawn" (Moyle expert report page 51, lines 4-7).

Response

Dr. Moyle's assertion that a viable self-sustaining naturally reproducing Chinook salmon population could be maintained after 2-3 years of no adult returns is inconsistent with (1) the low minimum population size presented in Dr. Moyle's expert report (returns of 500 adult fish per year); and (2) the age class distribution of Chinook salmon currently inhabiting coastal marine waters. The complete loss of two to three consecutive years of adult escapement when adult returns are expected to be in the hundreds, rather than thousands or tens of thousands, would potentially result in returns of so few effectively spawning females that the returning population of adults would not be sufficient to continue production of an adequate number of juveniles to perpetuate the run.

In addition, although historically there was a relatively wide age distribution of adults inhabiting the ocean (e.g., two -five year olds) factors such as recreational angler harvest, commercial harvest, and hatchery management for brood stock selection, all appear to have contributed to a reduction in the age class distribution of adult Chinook salmon. The predominant age classes of returning adult Chinook salmon to the Central Valley streams are three-year-olds with grilse (age 2 fish) being common in many river systems. The number of four and five-year-old Chinook salmon returning to Central Valley rivers has substantially declined from historic conditions. As a result of the change in age-class distribution, the population resiliency described by Dr. Moyle has been substantially reduced.

Given these two factors and given the assumptions identified in his report, I disagree with Dr. Moyle's opinion that the complete loss of two - three consecutive years of returning adults would allow the continuation of a self-sustaining naturally reproducing population of Chinook salmon on the San Joaquin River. It is also my opinion that a population of Chinook salmon, particularly spring-run Chinook salmon, that was in jeopardy of losing two - three consecutive years of adult returns would not be considered a viable contribution to the recovery and delisting of the species.

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PUBLICATIONS

A list of my scientific publications was attached to my August 22, 2005 expert report.

A LIST OF ANY OTHER CASE IN WHICH YOU HAVE TESTIFIED AS AN EXPERT WITHIN THE LAST FOUR YEARS

I have submitted written declarations and an expert report in NRDC v. Rogers regarding fishery issues on the San Joaquin River. I have not participated in any other case in the past four years.

COMPENSATION

Financial compensation for preparing and presenting results of my expert report is provided on an hourly basis at a rate of $130 per hour for my professional services.

RESUME

A copy of my resume has been provided as an attachment to my expert report dated August 22, 2005.

Charles H. Hanson Ph.D.

September 19, 2005