Report

Of

The Technical Review Panel

Compatibility of Coleman National Fish Hatchery Operations and Restoration of Anadromous Salmonids in Battle Creek

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Introduction

This is a report of the Technical Review Panel (Panel) convened by the CalFed Bay-Delta Program to review specific aspects of the Battle Creek Restoration Program. The Panel was formed at the request of the Battle Creek Working Group to provide an independent evaluation of scientific issues related to the restoration of Battle Creek and to assist in the decision-making process for the California Bay-Delta Authority Ecosystem Restoration Program. The Panel has five members:

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The Panel was charged with a review of the effects of Coleman National Fish Hatchery (CNFH) on the recovery of anadromous salmonids in the Battle Creek watershed. Panel members were given numerous documents (appendix A) several months prior to and also following a workshop held in Red Bluff, California on October 7 and 8, 2003. The workshop goals were to "Characterize the state of knowledge about the way Battle Creek works in terms of:

- Carrying capacity of the Battle Creek watershed for anadromous salmonids, including both spawning and rearing.
- Use of Battle Creek by salmon and steelhead returning to CNFH, in particular the percentage of instream spawners that are of direct hatchery origin
- Genetics of Central Valley Chinook salmon and steelhead as they apply to Battle Creek restoration
- Disease transmission from hatchery to natural spawning fish and other fish rearing facilities
- Instream flows and flow requirements — timing and magnitude — for spring and winter Chinook and steelhead" (Louma and Castleberry 2003).

The workshop met these goals with varying degrees of success.

The Panel was given seven questions to guide it in the preparation of this report. We reviewed those questions and made several revisions, which resulted in a new list of four general questions regarding the Battle Creek Recovery Plan and sixteen questions dealing specifically with the effects of CNFH. The sixteen hatchery questions were organized into four categories of risk: genetic, ecological, demographic and facility. These specific questions generally followed the approach used by the Washington Department of Fisheries and Wildlife to evaluate hatchery risks.
With one exception, the revised set of questions captures the intent of the original seven questions. The exception is an original question that dealt with the effects of CNFH on water quality in lower Battle Creek. Our panel did not have the expertise to address that concern and the topic was not covered at the workshop. Based on our collective experience, we believe that our answers to the revised questions lead to a more complete review of the potential effects of CNFH on the recovery of Battle Creek.

We organized the report into two parts. The first part is an Executive Summary of our most significant findings, conclusions and recommendations. In the second part, we provide a detailed response to each of the questions addressed by our Panel. Many readers may wish to read only the Executive Summary, but others may wish to examine our detailed responses to questions so as to determine the logical basis for statements made in the Executive Summary.

PART I: Executive Summary

Background Context and General Conclusions

Abundance of naturally-produced anadromous salmonids (coho and Chinook salmon; steelhead and cutthroat trout) has declined dramatically throughout the State of California and many individual stocks or stock groupings are listed as threatened or endangered under the California or Federal Endangered Species Acts. Central Valley steelhead are listed as threatened under the Federal act, Central Valley winter run Chinook salmon are listed as endangered under both the Federal and State acts, the Central Valley spring Chinook salmon ESU is listed as threatened under the Federal act and spring Chinook salmon are listed statewide as threatened under the State act.

Construction of Shasta and Keswick dams on the upper Sacramento River eliminated essentially all of the historic spawning habitat for the Sacramento's winter Chinook salmon and much of the spawning habitat for spring Chinook salmon. Today, remaining winter Chinook salmon may successfully spawn only in a short reach of the Sacramento River immediately below Keswick dam. In non-drought years, water temperatures immediately below Keswick Dam are kept cool by drawing cold water from the thermally stratified Shasta Reservoir. Remaining populations of naturally-spawning spring Chinook salmon in the Central Valley are restricted to a small number of modest-sized upper Sacramento tributaries and to the Feather River.

Battle Creek is a tributary to the upper Sacramento River that historically may have supported substantial numbers of anadromous salmonids, but since the early 1900s most of Battle Creek's flow has been diverted through an extensive network of diversions and power-generating facilities. Battle Creek was especially well suited for hydropower generation because of its uniquely high base flows that result from the volcanic nature of the watershed. The stream is also characterized by exceptionally cool water temperatures compared to other Sacramento River tributaries. Theoretically, if a substantial number of the existing diversions and barriers in Battle Creek were either removed or modified, and if the total magnitude of diversions were substantially reduced, a "restored" Battle Creek watershed might once again support sustainable populations of anadromous salmonids, in particular populations of the listed steelhead and winter and spring run Chinook salmon.

Over several years, substantial thought and cooperative effort have gone into the development of a Battle Creek Salmon and Steelhead Restoration Program (see, e.g., Battle Creek EIR, July 2003). Almost $30 million dollars have already been spent in plan development, including preliminary studies designed to determine flow regimes that might provide suitable spawning and rearing habitat but still allow a substantial degree of hydropower production. The recommended physical habitat actions called for in the restoration program include modification of five existing dams in Battle Creek, beginning in early 2004 and to be completed by 2006, at an estimated cost of approximately $30 million. With the exception of the Biological Assessment recently completed (2001) by the USFWS for operation of Coleman National Fish Hatchery (CNFH), however, the Battle Creek Restoration Program has focused primarily on habitat restoration and has not fully considered the implications and risks that operation of an extremely large-scale fish hatchery on lower Battle Creek might have on prospects of restoring sustainable populations of Chinook salmon and steelhead in a restored stream above the fish hatchery.

After having reviewed and considered workshop presentations, and various pertinent reports, our Panel has arrived at the unanimous conclusion that operation of CNFH may pose significant risk to the recovery of anadromous salmonids in Battle Creek and we urge modification of its operation to reduce those risks. In reaching this conclusion, the Panel is in substantial agreement with Appendix A, the AFRP position paper and part of the Central Valley Anadromous Fish Restoration Plan which states on Appendix page 9: "..... The adverse effects of interbreeding increase as hatchery-produced fish become more prevalent in the naturally spawning population.... In addition, large populations of hatchery-produced fish that are indistinguishable from naturally produced fish may intensify effects of harvest on naturally produced fish (Wright 1993). The simplest way to avoid adverse effects on naturally produced stocks is to minimize the opportunities for interactions between naturally and hatchery-produced fish. **The Program should be designed to avoid adverse effects of hatchery production on natural stocks."** **(**emphasis in the original**)**

The recovery of Battle Creek is an important and worthwhile goal, towards which a significant effort has already been expended. Improved habitat conditions in Battle Creek could lead to self-sustaining populations of winter and spring Chinook salmon and steelhead. The restoration of Battle Creek should be considered a viable and important project worthy of continuing. However, our review identified several shortcomings, uncertainties and risks to successful recovery. In the findings, conclusions and recommendations that follow we identify several steps that we believe should be completed before the recovery program continues. Those steps are:

- Prepare a single comprehensive plan with quantitative restoration objectives.
- Identify the priority species/runs targeted for restoration.
- Model the population dynamics for each species/runs over their entire life history.
- Review the role and locations of programs at CNFH in the context of the goals of the Battle Creek Restoration Program, including an immediate reassessment of the supplementation program for steelhead.
- Uncertainties identified in this report should be incorporated into the Adaptive Management and Monitoring programs.
- Provide detailed description of the reintroduction strategies for anadromous salmonids in Battle Creek.
- Consider dropping the restoration of fall and late fall Chinook salmon or delaying it for several generations.
- Design a marking program for the fall Chinook salmon at CNFH (complementing the marking programs for steelhead and late fall Chinook salmon) that contributes to the restoration of anadromous salmonids in Battle Creek.

The following section provides more information on the above steps and other recommendations that should be addressed. In part II of the report we provide even more technical detail in the responses to the questions.

Major Findings, Conclusions and Recommendations

1. **The Battle Creek restoration project should be described in its entirety in a single document so that all stakeholders have a shared understanding of the size, scope and objectives of the effort.**

   The Panel found pieces of the overall Battle Creek restoration program in several documents. These diverse sources of information on the program should be condensed and combined in a single document that covers all proposed restoration activities and considers the entire life histories of the species/runs targeted for recovery. The restoration plan should include specific, quantitative restoration objectives that describe measurable end points and explicit problem statements. An adaptive management plan is essential. Although the Battle Creek Restoration Program appears to have exciting potential for restoration of listed anadromous salmonids, we believe that f*unding for restoration activities and proposed removal of dams, etc., should not be granted and should not proceed until a comprehensive document has been produced.*

2. **The Restoration Program needs to clearly specify the species/runs of anadromous salmonids that are targeted for restoration.**

   For a variety of reasons, our Panel found that the most logical suite of species/races to be targeted for restoration would be, in priority order, winter Chinook salmon, spring run Chinook salmon, and steelhead. Each of these species/runs has been listed under Federal and/or State endangered species acts, and both winter and spring Chinook salmon require cool waters over summer that are extremely rare elsewhere in the Central Valley. Inclusion of fall and late-fall Chinook salmon in the mix of species/runs targeted for restoration might compromise the restoration effort for the primary target species and also greatly complicates the issues concerning compatibility of operation of CNFH with the restoration effort.

3. **In addition to the habitat analysis that has already been done, the population dynamics of each species/run targeted for restoration should be analyzed over their entire life cycle. This analysis should be used to assess the potential of a restored Battle Creek to support sustainable populations of anadromous salmonids.**

   Only if the underlying productivity of natural populations in Battle Creek exceeded a certain minimum value, would it be reasonable to infer that natural populations of steelhead, winter and spring Chinook salmon could sustain themselves over the long-term. Such basic population considerations are notably absent in documents related to the Battle Creek Restoration Program. Without consideration of these population dynamics issues, it is impossible to judge whether or not Battle Creek populations of winter and spring Chinook salmon or steelhead could be sustainable over the long term.

4. **Recommended strategies for reintroduction of anadromous salmonids into Battle Creek should be explicitly described and the advantages and disadvantages of these recommended strategies should be weighed against other alternatives.**

   Explicit consideration of reintroduction strategies will automatically generate consideration of the most appropriate role(s) of CNFH and possibly also LSNFH (winter Chinook) in the restoration of Battle Creek anadromous salmonids. The most conservative strategies, with respect to minimizing possible negative impacts of "domesticated" hatchery fish on naturally-spawning populations of Battle Creek salmonids, would be to restrict the hatchery's role to passing natural-origin fish upstream and keeping hatchery-origin fish out of the creek above the hatchery. This strategy, however, might be slowest to achieve long-term numerical goals for Battle Creek spawners above the hatchery. A strategy involving hatchery supplementation is more likely to boost the total number (hatchery + wild) of spawners more quickly, and is a strategy that has been initiated by the USFWS and CNFH for restoration of steelhead. But this accelerated strategy may threaten the integrity of a remnant Battle Creek population, increase uncertainties and risks with respect to the fitness and productivity of naturally-spawning steelhead, and preclude other important opportunities to learn about restoration (e.g., how quickly remnant wild populations can recover without supplementation after habitat is improved). We recommend that the current supplementation program for steelhead be revisited immediately in view of risk, uncertainties, alternative opportunities, and compatibility with the comprehensive recovery plan. We are not aware of any explicit reintroduction strategies having been proposed for winter or spring Chinook salmon.

5. **The success of the Battle Creek restoration project will depend a great deal on CNFH and possibly Livingston Stone National Hatchery (LSNFH) operations. Project planners and USFWS staff need to develop a detailed plan to ensure that hatchery operations are compatible with the recovery goals for Battle Creek.**

   The Panel identified several uncertainties regarding the possible effects of CNFH's operations on the recovery of anadromous salmonids in Battle Creek. As a consequence of this uncertainty the Panel cannot provide a direct answer to the question: *is the operation of a large harvest augmentation hatchery in lower Battle Creek compatible with the recovery of anadromous salmonids in the middle and upper watershed?* The role and location of the current programs at CNFH should be reviewed in the context of the Battle Creek Restoration Program once a coherent plan for the program has been completed (see recommendations 1, 2 and 4). If the current program is continued at CNFH, the uncertainties identified in this report should be incorporated into the Adaptive Management Program (AMP). CNFH has already begun a reintroduction program in Battle Creek. The existing CNFH supplementation programs in Battle Creek (steelhead, fall Chinook and late fall Chinook) should be reviewed for compatibility with the restoration goals and be modified as necessary to become compatible or be eliminated. The United States Fish and Wildlife Service's (USFWS) current efforts to improve the effectiveness of the barrier dam to prevent undesired passage of adults should continue.

6. **The restoration of anadromous salmonids in Battle Creek should be phased, with spring Chinook, winter Chinook and steelhead having the highest priority. Consideration should be given to dropping fall and late fall Chinook from the recovery program.**

   The Panel was concerned about the possibility of hybridization between winter and late fall Chinook salmon and between spring and fall Chinook salmon. Although the probability of hybridization is unknown, we recommend that the potential for hybridization be minimized by abandoning restoration of fall and late-fall Chinook salmon in Battle Creek or delaying it until after spring and winter Chinook salmon populations have become firmly established (i.e., delay for several generations). Passage of fall and late-fall Chinook salmon above the dam (through the ladder or by jumping) should be prevented or reduced to the lowest possible level during at least the initial period of restoration and on a long-term basis if the target species/runs are restricted to steelhead and winter and spring Chinook (see recommendation 2).

7. **Competition between hatchery and wild fish may pose a substantial risk to the restoration effort, and thus requires further evaluation.**

   Numbers of fall and late-fall Chinook salmon and of steelhead released into the upper Sacramento River seem to approach or exceed the numbers of wild conspecifics, substantially increasing the densities of these species and suggesting the possibility of competitive or other deleterious ecological effects on wild populations, including the incipient wild populations in Battle Creek. The Panel was not presented with adequate information to assess the possible importance of this issue. If analysts or stakeholders have not already tested the hypothesis that density-dependant effects in the Sacramento River, estuary, or marine waters caused by massive releases from CNFH or other hatcheries restrict natural production in the system, we recommend that they make the attempt. We also recommend that this topic receive special study in the lower six miles of Battle Creek where outmigrating naturally-produced salmon and steelhead would have to pass downstream through abnormally large numbers of returning hatchery spawners and possibly also juveniles released from CNFH or naturally produced in the lowest reach of Battle Creek.

8. **Handling wild fish in the hatchery before passage over the barrier weir may impose excessive stress and may encourage disease transfer to naturally-spawning fish.**

   Crowding, stress, and handling of wild fish in the hatchery prior to passing wild fish upstream may increase mortality of wild fish (due to stress and/or disease) and may pose a demographic threat[1] to restoration of anadromous salmonids in Battle Creek . These same factors may facilitate increased disease susceptibility and transmission of pathogens (see

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[1] Handling wild spring chinook salmon at Warm Springs National Fish Hatchery (Oregon) to separate them from hatchery fish and allow passage upstream seems to cause substantial prespawning mortality in the wild fish after they are passed upstream. This mortality was sufficient to cause the hatchery to install an automated fish separator to avoid handling the wild fish. Although we have no data from California to suggest a similar effect (and steelhead should be less susceptible than are salmon), we recommend that prespawning mortality be monitored.

conclusion no. 9). We encourage monitoring to evaluate prespawning mortality in Battle Creek, including a comparison of prespawning mortality between fish that are handled and those allowed upstream without delay, crowding or handling. Low prespawning mortality for handled fish would suggest no need for change in procedures; elevated mortality would call for a reduction of adult densities in holding ponds, retention time in the hatchery or handling, perhaps by employing an automated fish passage system.

9. **The impacts of pathogens resulting from CNFH operations on wild fish restoration efforts are unclear but disease control measures will be critical.**

   Crowding and stress associated with large numbers of returning hatchery adults results in optimal conditions for transmission of infectious hematopoietic necrosis virus (IHNV) and may also increase the presence of other primary or secondary pathogens. Wild adult salmon, including spring and winter Chinook, may thus encounter pathogens at doses and durations of exposure above those anticipated in a system without artificial impounding of adult salmon. Transmission of IHNV from late-fall Chinook adults to sac fry and fry (the most susceptible life stages) of natural-origin steelhead and spring Chinook salmon may represent a potential negative impact to Battle Creek restoration. Another potential source of pathogen amplification that could affect restoration efforts is hatchery effluent water from production lots of salmon and steelhead. Increased numbers of adult and juvenile salmon above the hatchery as part of the restoration effort, must be met with vigilance in disease control measures at the hatchery. Minimal down time of intake water treatments with ozone, vaccination of fish where practical, rapid diagnoses and treatments of production fish and the release of healthy smolts are all hatchery practices that can minimize disease impacts of hatchery effluent that contacts natural-origin fish. A more thorough understanding of the pathogen/disease dynamics among wild fish (salmonid and nonsalmonid) in Battle Creek and how these may differ or be impacted by the hatchery are needed. This information is critical to evaluating the potential sources of pathogens that might impact the restoration efforts over the long term and must be part of a monitoring program in the AMP.

10. **Marking programs at CNFH need to be designed so as to be consistent with and contribute to successful restoration of anadromous salmonids in Battle Creek.**

    Currently, all late-fall Chinook salmon released from CNFH are marked (AD+CWT), but no or only a small portion of fall Chinook salmon are marked. Marking all late-fall Chinook should allow passage of unmarked (wild) winter run Chinook when run timing overlaps with late-fall run Chinook. Late-entering unmarked (wild) spring Chinook salmon would, however, overlap with early returns of unmarked fall Chinook salmon. If genetic studies show that late-entering spring run Chinook cannot be reliably distinguished visually from unmarked fall Chinook salmon, then it may be essential to mark all or most fall run Chinook salmon released from CNFH. We therefore recommend an immediate (genetic) study to determine the reliability of separating unmarked spring and fall Chinook salmon at CNFH on the basis of visual methods.

11. CNFH water intakes must be screened to achieve NMFS "fail-safe" standards.

A large percentage (30-40%) of Battle Creek flow is diverted to CNFH during the months of September through November. This period of high diversion coincidences with the probable peak emigration period of juvenile winter run Chinook salmon in a restored Battle Creek watershed. This coincidence creates substantial concerns regarding entrainment or impingement of juvenile winter run Chinook in CNFH intakes. Therefore, all current and post-restoration intakes must be screened consistent with NMFS "fail-safe" standards.

PART II. Questions and Answers

The Executive Summary presented in the previous pages reflects the Panel's more important responses to four general questions concerning the Battle Creek Restoration Program and sixteen specific questions concerning the potential risks to restoration posed by operation of CNFH. The next section is a list of the questions and in the following section we provide our detailed responses to each question.

General Questions about the Battle *Creek Recovery Program*

1. Does the Battle Creek Restoration Program have a set of goals and objectives that define success in unambiguous and measurable terms?

2. Has the problem been adequately defined?

3. Can Battle Creek support winter and spring Chinook salmon and steelhead?

4. How many individuals of the different races and species of anadromous fish can upper Battle Creek support? What are the major assumptions, challenges and uncertainties involved in answering such a question?

Specific Questions about the Relationship between CNFH (and possibly LSNFH) and the Battle Creek Recovery Program

Genetic Risks

A. What domestication risks are posed to juvenile Battle Creek salmon and steelhead populations by CNFH/LSNFH operations?
B. What are the risks posed to maintenance of appropriate effective population sizes in Battle Creek salmon and steelhead by CNFH/LSNFH operations?
C. What are the risks to adaptedness and genetic diversity of Battle Creek salmon and steelhead, beyond those from domestication, caused by operations at CNFH/LSNFH?
D. What additional genetic risks, other than the three categories already listed, are posed to Battle Creek salmon and steelhead by CNFH/LSNFH?

Ecological Risks

A. What risks are posed to Battle Creek salmon and steelhead populations through competition with fish released from CNFH/LSNFH at all life stages in Battle Creek, the Sacramento River, and the Sacramento-San Joaquin estuary?
B. What risks are posed to juvenile Battle Creek salmon and steelhead from predation by hatchery fish released from CNFH/LSNFH? Predation could occur in Battle Creek, the Sacramento River, or the estuary.
C. What risks are posed to juvenile Battle Creek salmon and steelhead by CNFH/LSNFH operations by indirect predation; i.e. the increased risk of predation to Battle Creek juveniles from other predators (e.g., pikeminnow, bass, birds, pinnipeds) caused by a numerical or functional response to fish released by CNFH/LSNFH?
D. What disease risks to Battle Creek salmon and steelhead populations are posed by contact with CNFH-origin fish or effluent waters from the hatchery? (Note: issues related to diseases as a result of passage through the hatchery on Battle Creek recovery are covered under Facility Risks.)

Demographic Risks

A. What is the risk to population sizes of Battle Creek salmon and steelhead from inclusion of wild fish in the hatchery broodstock at CNFH or LSNFH?
B. What risk to population size of Battle Creek salmon and steelhead populations is posed by potentially poor reproductive performance on the spawning ground of hatchery-origin fish?

Facility Risks

A. What risks are posed to Battle Creek salmon and steelhead from operation of the barrier dam and ladder at CNFH?
B. What risks are posed to Battle Creek salmon and steelhead populations from water withdrawals for CNFH use and by possible entrainment at intake screens?
C. What disease risks are posed to Battle Creek salmon and steelhead populations as fish pass through hatchery facilities?
D. What risks to Battle Creek salmon and steelhead populations by the large surpluses of CNFH fall Chinook returnees in the lower section of Battle Creek? (Risks likely include disease, mortality from BOD, and passage obstruction.)
E. What facility risks other than those mentioned above do CNFH operations pose to Battle Creek salmon and steelhead populations?

Answers to the Questions

General Questions about the Battle Creek Recovery Program

1. Does the Battle Creek Restoration Program have a set of goals and objectives that define success in unambiguous and measurable terms?

The short answer to this question is no.

Objectives of a restoration program such as the one proposed for Battle Creek should state as precisely and explicitly as possible what the program will accomplish, what the program will not address and describe the end point (success) in terms that make it possible to track progress (Phenicie and Lyons 1973). Objectives should describe the intended result and not just the process or task that must be completed to achieve the objective (Mager 1975).

After the workshop, the Panel met to discuss the presentations and its assignment. One of the first topics discussed at that meeting and in subsequent e-mails was the lack of clear, unambiguous goals and objectives for the program. To assist the Panel, Randall Brown (November 11, 2003 memo to the Panel) reviewed the documents containing goals and objectives related to the restoration of Battle Creek and confirmed that the objectives vary considerably from document to document. Variance in the goals and objectives stems in part from differences in the documents that provide guidance for recovery programs in the Sacramento Basin. For example:

- The CVPIA's Anadromous Fish Restoration Plan, where the goal is to double the populations of several naturally spawning anadromous fish, including Chinook salmon and steelhead.
- CalFed's ERP Strategic Plan emphasizes ecosystem (function and processes) goals in restoring Central Valley streams.
- CalFed ESA goals as, described in its Multi-species Conservation Plan, focus on listed species such as winter and spring Chinook and steelhead (Randall Brown, November 16, 2003 memo to the Panel).

Objectives related to the restoration of Battle Creek are found in several documents including the AMP, EIS/EIR, MOU and CVPIA's AFRP (Table 1). While all the statements might reasonably be included in some form in a restoration plan, none of them are adequate objective statements based on the criteria presented above. With one exception, CNFH is not mentioned in the objectives. The exception is the MOU. Neither are life stages outside Battle Creek mentioned. For example, the objectives are silent on commercial and sport harvest. Nearly all the objectives only describe a process or task and not what is to be accomplished, the end point. Some objectives have potential conflicts that are not resolved. For example, the three objectives listed below from the EIS/EIR imply tradeoffs between habitat restoration and other uses of the watershed that need more precise definition.

- Avoid impacts on other established water shed users/third parties.
- Minimize loss of clean and renewable energy produced by the Battle Creek Hydroelectric project.
- Restore self sustaining populations of Chinook salmon and steelhead by restoring their habitat in the Battle Creek watershed and access to it through a voluntary partnership with state and federal agencies, a third party donor(s) and PG&E.

The vague nature of the objectives found in the Battle Creek restoration documents is understandable. There are a large number of cooperators and stakeholders involved in the program. Their interests range from fish and wildlife conservation to ranching to hydroelectric production. It's easier to reach consensus among diverse stakeholders if the critical terms of the program such as objectives are kept vague. Each member of a disparate group of stakeholders can retain a separate vision of what is to be accomplished. However, this short-term advantage has the longer-term problems of impaired effectiveness in the implementation of the program. The adaptive management process and accountability are also diminished. In addition, review panels such as this one can provide better advice if they know specifically what is to be accomplished.

The Battle Creek watershed has unique attributes and could make an important contribution to the recovery of anadromous salmonids in the upper Sacramento Basin. Given the proposed cost of the Battle Creek restoration ($60 million) and the watershed's important role in the recovery of anadromous salmonids, the restoration program deserves a plan that provides guidance to the stakeholders and implementing agencies through a set of clear unambiguous objectives. The various pieces of the restoration program found in different documents should be pulled together into a single Battle Creek restoration plan.

Table 1. Objectives related to the restoration of Battle Creek from the Adaptive Management Plan, the Draft EIS/EIR, the MOU and CVPIA's AFRP.

Adaptive Management Plan	Draft EIS/EIR	MOU	CVPIA's AFRP
Population Level Objectives • Ensure successful salmon and steelhead spawning and juvenile production. • Restore and recover salmon and steelhead assemblage of naturally spawning anadromous salmonids (that is, winter-run, spring run and steelhead) that inhabit the stream's cooler reaches during the dry season. • Restore and recover the assemblage of anadromous salmonids (that is fall-run and late-fall run) that enter the stream as adults in the wet season and spawn upon arrival. • Ensure salmon and steelhead utilize available habitat in a manner that benefits all life stages, therefore maximizing natural production and full utilization of the ecosystem's carrying capacity. **Habitat Objectives** • Maximize habitat quality through changes in instream flow • Maximize habitat quality by ensuring safe water temperatures. • Minimize false attraction and harmful fluctuations in thermal and flow regimes resulting from planned outages or detectable leaks from the hydroelectric project. • Minimize the stranding and isolation of salmon and steelhead resulting from variations in flow regimes caused by hydroelectric project operations.	• Restore self-sustaining populations of Chinook salmon and steelhead by restoring their habitat in the Battle Creek watershed and access through to it through a voluntary partnership with state and federal agencies, a third party donor(s), and PG&E. • Establish instream flow releases that restore self-sustaining populations of Chinook salmon and steelhead. • Remove selected dams at key locations in the watershed where the hydroelectric values were marginal due to increased stream flow. • Dedicate water diversion rights for instream purposes at dam removal sites. • Construct tailrace connectors and install fail-safe fish screens and fish ladders to provide increased certainty about restoration components. • Restore stream function by structural improvements in the transbasin diversion to provide a stable habitat and guard against false attraction of anadromous fish away from their migratory destinations. • Avoid Restoration Project impacts on species of wildlife and native plants and animals and their habitats to the extent practicable, minimize impacts that are unavoidable, and restore or compensate for impacts. • Minimize the loss of clean and renewable energy produced by the Battle Creek Hydroelectric Project.	• Establish a transparent, balanced, collaborative, respectful and inclusive forum for communication that coordinates activities within the watershed, and that goals, objectives and evaluative processes of agencies and organizations are coordinated. • Take necessary steps to develop a comprehensive greater watershed strategy to ensure that fisheries, habitat restoration or watershed projects support and make important contributions to the recovery of, and has no long term adverse effect on, listed species (winter-run and spring-run Chinook salmon and steelhead), the restoration of non-listed naturally produced runs (fall-run and late fall-run Chinook salmon), production of Chinook salmon for sport and commercial uses, production of steelhead for in-river sport uses as well as continued health of the riparian and upland habitat. • Identify specific needs for new projects based on the comprehensive greater watershed strategy and current or planned activities within the watershed. • Adopt and apply principles of science and, as appropriate, adaptive management processes to actions considered and undertaken in the comprehensive greater watershed strategy. • Engage agencies, organizations and the public to provide information on the	Potential number of spawners Battle Creek could support Winter Chinook 2,500 Spring Chinook 2,500 Steelhead 5,700 Fall Chinook 4,500 Late fall Chinook 4,500

Adaptive Management Plan	Draft EIS/EIR	MOU	CVPIA's AFRP
	• Implement restoration projects in a timely manner. • Develop and implement a long term adaptive management plan with dedicated funding sources to ensure the continued success of restoration efforts. • Avoid impacts to other established water users/third parties.	comprehensive greater watershed strategy and adaptive management processes, identify and communicate issues and proposed projects, and maximize compatibility of activities of the CNFH, LSNFH, the Battle Creek Restoration Project and other agencies, private industries and nonprofit organizations operating within the Greater Battle Creek Watershed. • Establish and implement a review process for fisheries, restoration and watershed projects undertaken within the Greater Battle Creek Watershed that may result in endorsement by members of the Working Group. • Define and develop administrative processes to guide the Working Group in accomplishing its objectives effectively and efficiently. • Review and propose communication and education programs for the Battle Creek community.	

2. Has the problem been adequately defined?

For the purpose of this report, "the problem" is defined as the conditions of the habitat, the policies and human activities, which in aggregate, prevent realization of the restoration goals. Because the problem statement establishes the target for restoration activities, it is important to define it as precisely as possible. The problem statement is also an important part of the AMP (Healey 2001).

The problem statement should encompass the entire life history of the target populations. The salmon's life history can be described in the context of a chain of favorable habitats connected at the appropriate season to ensure the salmon's survival (Thompson 1959). Life history and the chain of habitats are inextricably linked. The Battle Creek problem must consider all the links in the life history-habitat chain, although not all the life history stages need receive the same level of evaluation. For example in the development of a problem statement for Battle Creek, that part of the life history carried out in the Battle Creek should receive the most intense evaluation, but all parts of the life history need some level of analysis.

The Panel could not find a problem statement for the Battle Creek Restoration Program that includes the elements described above. That is not to say that the problems facing anadromous salmonids were not discussed. They were, but those discussions are scattered among several documents and places within documents. Furthermore the focus is entirely on Battle Creek above the barrier weir and almost exclusively on the problems associated with the system of diversions and hydro power stations in the basin. The hydro power system is a major impediment to recovery and it deserves the priority it has received, but the Panel doubts that it is the only impediment to the recovery of anadromous salmonids in the Battle Creek Watershed. The focus of this Panel on the operations of CNFH shows that the broader nature of the problem confronting the recovery of anadromous salmonids in the Battle Creek Watershed has some recognition.

The recommendation under question 1 to prepare a single watershed restoration plan for Battle Creek applies here. That plan should include a precise description of the problem and should include consideration of the role and impact of CNFH operations on restoration of anadromous salmonids in Battle Creek.

3. Can Battle Creek support winter and spring Chinook salmon and steelhead?

Whether or not Battle Creek can support winter and spring Chinook salmon and steelhead depends on the quality of habitat attributes after restoration and the resulting survival in Battle Creek and the cumulative survival of targeted salmonids throughout their life histories. The definitive answer requires a model that evaluates the survival of winter and spring Chinook and steelhead/rainbow trout throughout their entire life histories and the entire chain of habitats they occupy while completing their life cycle. The analysis should take into account the effects on survival caused by the operation of CNFH, residence and downstream migration of juveniles, passage through the delta, climate fluctuations and changing ocean conditions and harvest. This model is a single species approach and has its drawbacks. For example, interactions among species are not considered. However, it would indicate whether the single species population dynamics lead to sustainable recovery. The Panel is not aware of such a model for Battle creek.

Information given to the Panel and the information presented at the October 8 and 9, 2003 workshop leads to the conclusion that Battle Creek has the potential to support winter and spring Chinook and steelhead rainbow trout. How many of each might be supported is the subject of the next question.

The Panel has another concern indirectly related to this question. Battle Creek is unique among streams in the northern Sacramento basin below Shasta dam. Two attributes in particular contribute to Battle Creek's uniqueness: high summer flows and cool temperatures. Anadromous salmonids may respond to habitat conditions in Battle Creek through unique or unusual life histories. Life history is the population's survival strategy and life history diversity ensures survival in fluctuating environments (Independent Science Group 2000; Thorpe 1994). It is critical that life history monitoring be capable of detecting emerging life histories. The adaptive process should be capable of changing management policies including those at CNFH to nurture those life histories.

4. How many individuals of the different races and species of anadromous fish can upper Battle Creek support? What are the major assumptions, challenges and uncertainties involved in answering such a question?

The EIR for the Battle Creek Restoration Plan is striking in its lack of numerical escapement or production goals for the races and species of anadromous fish for which the Restoration Plan is presumably designed. Indeed, the EIR is also vague with respect to the mix of naturally reproducing races and species that are desired to be present in upper Battle Creek. Throughout our report, we have assumed that the Restoration Plan is designed principally to allow long-term sustainable natural production of winter and spring run Chinook salmon and steelhead in Battle Creek.

Absence of explicitly identified and quantitatively justified escapement or production goals has been previously recognized. We share the position expressed in the September 2003 Technical Review Panel Report: "The restoration plan calls for sustaining viable populations, but does not set any expectations for numbers of adult returning salmon. The Panel believes this failure to clearly identify the expected number of returning adult salmon in the objectives is a fundamental flaw of the Battle Creek Restoration Project" (Technical Review Panel 2003).

Although the EIR itself presents no numerical goals for production of Chinook salmon and steelhead in a restored Battle Creek, there are several other pertinent documents that were provided to our Panel. Documents that, at least in part, could possibly be used as a basis for development of numerical escapement goals include: 1) Ward and Kier 1999; 2) Chapter 4 of the EIR; 3) Ward (2003) the draft Watershed Assessment report for upper Battle Creek; and 4) USFWS (1995), as reported at many points in our materials (e.g., at p.42 of Ward and Keir 1999) but not included among the materials supplied to us. The USFWS (1995) apparently provided predictions of adult population sizes in Battle Creek after restoration. These predictions were as follows:

Winter Chinook	2,500
Spring Chinook	2,500
Fall Chinook	4,500
Late-fall Chinook	4,500
Steelhead	5,700

Although we are unable to comment on the merits of the calculations used to arrive at these values, the reported values may possibly provide an order of magnitude guide to plausible restoration escapement goals. (Also, note that these calculations included fall and late-fall Chinook.)

Ward and Kier (1999) provided a useful visual description of habitat suitability at the reach level for steelhead and various races of Chinook salmon that might establish natural populations in Battle Creek (their Figures 15-19). On page 75 of the Ward and Kier (1999) report, illustrative calculations show how one might determine numbers of adult fish that might spawn in certain reaches of stream or the number of juveniles that might rear in certain reaches of stream. These calculations were used, however, to determine what habitat type would limit production in a given area (e.g., a shortage of suitable rearing habitat as compared to a shortage of suitable spawning habitat). All of these calculations were directly based on calculations of Weighted Usable Areas that resulted from Thomas R. Payne and Associates earlier IFIM studies of Battle Creek. Chapter 4 of the EIR might also be useful if there were some quantitative way to use the various fry and juvenile production indexes that are visually displayed in Figures 4.1-2 through 4.1-9. Finally, Ward's recent watershed assessment could conceivably be used to determine reaches of Battle Creek that might be suitable for summer holding of spring Chinook salmon prior to spawning. It seems possible that the relative absence of large, deep pools might severely limit the capacity of Battle Creek to support spring Chinook salmon, even if spawning and rearing areas seem otherwise adequate to support a substantial number of adults and juveniles.

The kinds of calculations described in the above paragraph are those that might allow estimation of the number of spawners that could successfully spawn in a certain reach of stream or the number of juveniles that could rear in a certain reach of stream given that the stream had been adequately "seeded" with juveniles. These kinds of calculations are premised on an assumption that weighted usable areas are valid metrics for spawning and rearing areas for anadromous salmonids, and they are also based on assumed fecundities and survival parameters from egg to juvenile. Although fecundities vary considerably among Chinook salmon and steelhead of different sizes and ages, it is still reasonable to calculate an expected egg deposition as the sum of the products of expected numbers of spawners at age and the expected stock-specific and age-specific fecundities. Guesses for survival rate from egg to juvenile typically rely on information collected elsewhere, however, and may or may not reflect survival rates actually achieved in Battle Creek. The USFWS' monitoring program, or an expansion of it, should be sufficient to provide these data for Battle Creek.

Even if one could calculate the number of spawning adults that could be accommodated by spawning gravels, and the numbers of juveniles that they could produce and that could successfully rear, a rigorous modeling effort must account for interactions among runs. Given the relatively limited total length of spawning stream in the two forks of Battle Creek and the relatively small physical size of the stream, it would seem critical to consider possible competition for spawning sites among runs of Chinook salmon for which spawning timing may overlap to a substantial degree (e.g., spring and fall Chinook, if fall run Chinook were to be passed above the barrier dam), and, perhaps more importantly, possible interspecies competition among juvenile fish for rearing space.

Finally, even if one could carry out a complex multi-species analysis designed to allow calculation of the total number of adult spawners and juveniles of steelhead and the various races of Chinook salmon that could be supported by the physical habitat, it would be impossible to specify an escapement goal in the absence of a population dynamics model for a given race of Chinook or steelhead. Key to specifying such population dynamics models would be age- and sex-specific maturation schedules, survival from emigration to age 2, age-specific ocean survival rates, and exploitation rates in ocean and freshwater fisheries (see, e.g., Hankin and Healey 1986). Only if the underlying productivity of natural populations in Battle Creek exceeded a certain minimum value, would it be reasonable to infer that natural populations of steelhead, winter and spring Chinook could sustain themselves over the long-term. Such basic population considerations are notably absent in the Battle Creek Restoration Program. Without consideration of these population dynamics issues, it is impossible to judge whether or not Battle Creek populations of winter and spring Chinook or steelhead could be sustainable over the long term.

Questions about the Relationship between CNFH (and possibly LSNFH) and the Battle Creek Recovery Program

Genetic Risks

A. What domestication risks are posed to juvenile Battle Creek salmon and steelhead populations by operations at CNFH/LSNFH?

We define domestication as genetic change resulting from adaptation of a population to artificial rearing or from accumulation of mutations that are selectively neutral under artificial rearing but deleterious for natural production. Adaptation and accumulation occur because artificial rearing imposes novel selective pressures on a population that are distinct from those for natural rearing, and relaxes other selective pressures such as predation. Hatchery and wild rearing environments are very different and seem to exert distinct selective pressures. Compared to their wild counterparts, hatchery juveniles experience much higher fish densities and a much less complex environment. Differences in spawning environment may also be important. Natural spawners must select redd sites, dig redds, attract and compete for mates, engage in courtship, deposit gametes, and guard them. Hatchery broodstock must only survive and produce viable gametes.

Theoretical considerations (e.g., Lynch and O’Hely 2001; Ford 2002) and empirical data from anadromous salmonids (reviewed by Reisenbichler and Rubin 1999) indicate that domestication reduces fitness for natural rearing and should be expected in hatchery programs for Pacific salmon and steelhead. Changes in a wide variety of traits have been noted, including reproductive success of males and females, body morphology, egg morphology, fecundity, juvenile survival, age at maturity, predator avoidance, and agonistic behavior. Although there is resistance to the idea that subjecting fish to the hatchery environment causes possible loss of fitness for natural production, a number of expert panels have considered it a risk, most recently the Independent Scientific Advisory Board for the Northwest Power Planning Council (ISAB 2003).

Domestication is an issue for wild (naturally reproducing) populations when hatchery fish interbreed with wild fish, whereupon the productivity and viability of the wild population are reduced. Unfortunately, data are insufficient to allow reliable predictions about the magnitude of those reductions. If the reductions are sufficient, they can preclude restoration[2] by preventing a population from becoming self-sustaining (Reisenbichler et al. 2003). A useful diagram of the relationship between the hatchery and wild components of a population was presented by Lynch and O'Hely (2001):

In the diagram r_c is the proportion of hatchery broodstock consisting of hatchery-origin fish, r_w is the proportion of natural spawners that are natural-origin fish, $1-r_c$ is the proportion of broodstock that are natural-origin fish, and $1-r_w$ is the proportion of natural spawners that are hatchery-origin fish. Any hatchery program that interacts genetically with a natural spawning population can be diagrammed in this way and characterized by the two parameters r_c and r_w. It is reasonable to assume that the strength of the domestication pressure depends on the proportion of time that genes spend in the hatchery or natural environments, respectively. The proportion of time genes spend in the natural environment is given by

$$\omega = \frac{1 - r_c}{2 - r_c - r_w}$$

[2] We define a restored or healthy population as one that is (i) genetically adapted to the local environment, (ii) self-sustaining at abundances consistent with the carrying capacity of the river system, (iii) genetically compatible with neighboring populations so that substantial outbreeding depression does not result from straying and interbreeding between populations, and (iv) sufficiently diverse genetically to accommodate environmental variability over many decades.

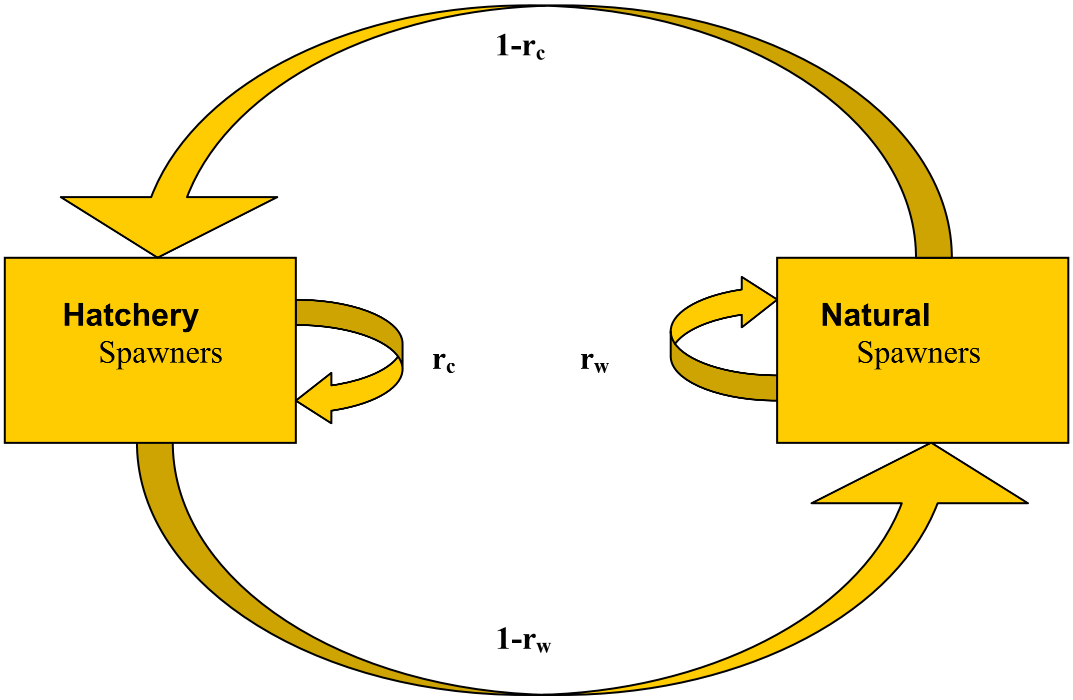

Figure 1. **Schematic of reproductive interactions between natural and hatchery subpopulations in an integrated production program (from Lynch and O'Hely, 2001).**

We commend the staff at CNFH/LSNFH for implementing progressive broodstock and rearing techniques to reduce domestication. Unfortunately, the efficacy of such techniques for reducing domestication may be limited. No matter what measures to reduce domestication are implemented, large differences between the two types of environment remain. One prominently mentioned technique that CNFH is using to reduce risk is the inclusion of a substantial number of wild fish in the broodstock, resulting in what is called an integrated program (HSRG 2003). Integration of natural-origin fish into the hatchery broodstocks is one basis for USFWS's assertion that hatchery and wild fish in the upper Sacramento River are genetically similar, and seems to be the primary basis for their corresponding dismissal of domestication as a risk (USFWS 2001).

The current similarity between hatchery and wild populations may more likely reflect substantial interbreeding (gene flow) than lack of domestication in the hatchery program. Returning to Figure 1 above and the accompanying equation, it can easily be seen that the level of domestication depends a great deal on the level of gene flow from the hatchery into the natural subcomponent of the population (1-r_w). The current situation is that about 95% of the late fall Chinook passed above the hatchery are of hatchery-origin and about 65% of the steelhead (in 2002) were hatchery-origin (S. Hamelberg, pers. comm.). It is clear that hatchery, and not wild production is dominating the system, a situation that should result in considerable domestication. We note, however, that the intent of the steelhead program is to reduce the proportion of hatchery-origin fish passed upstream as the population grows and eventually stop releasing hatchery-origin adults (D. Campton, pers. comm.). The winter Chinook program at LSFNH also has resulted in a high proportion of hatchery-origin fish on the spawning grounds, but the domestication risk has been accepted as a necessary cost of increasing fish numbers in a severely depleted population.

The similarity between hatchery and wild populations in the Sacramento River system has been documented for selectively neutral markers, not for survival or reproductive success. Neutral markers are more easily homogenized by gene flow than are traits related to fitness and can be misleading in this regard. Although gene flow reduces genetic differences, it has no effect on the magnitude of selection pressures for domestication. When domestication selection is strong and interbreeding of hatchery and wild fish is extensive, the result is two compromised populations: a wild population with reduced fitness for natural production and a hatchery population with reduced fitness for hatchery production (Ford 2002; Reisenbichler et al. 2003). Studies generally have low power to detect domestication unless they employ wild fish from a population that has been genetically isolated from hatchery fish, and a hatchery population that has been genetically isolated from wild fish. Such a situation prevents gene flow from masking the intensity of domestication. Stated another way, lack of detectable genetic differences between interbreeding hatchery and wild populations does not disprove that domestication is substantially reducing the viability of the wild population.

It is reasonable to assume that domestication has been occurring at CNFH over the entire 50+ years of the programs for fall Chinook and steelhead, and ~30 years for late-fall Chinook (USFWS 2001). Empirical data are lacking, but theoretical studies suggest that the rate of genetic change will decline and an equilibrium between domestication and adaptedness for natural production will be reached over time (Lynch and O'Hely 2001; Ford 2002). Thus, we propose three ways to look at domestication risk: 1) impacts to date; 2) current incremental impacts (under current practices); and 3) future impacts (under changed conditions).

Table 2 summarizes our sense of risk under current conditions. Actual data on domestication at CNFH and Battle Creek are nonexistent, so we base the table entries on our experience with domestication research, our knowledge of the literature, genetic/evolutionary theory, and concepts set forth in current risk assessment tools (e.g., Ford and Currens 2000; WDFW 2001).

The USFWS's current study comparing reproductive success of hatchery and wild steelhead above the dam should provide an improved basis for evaluating risk from the current hatchery population; however, the study may have low power to detect domestication. The results from the USFWS's analysis of DNA microsatellites (Campton's presentation) suggests that most wild fish, except from the latest portion of the run, may be only one generation removed from hatchery fish.

The Battle Creek plan currently lacks a reintroduction component. Such a component will require decisions about the role of CNFH and possibly LSNFH (in the case of winter Chinook). The most conservative strategy with respect to domestication would be to restrict the hatchery's role to passing natural-origin fish upstream and keeping hatchery-origin fish out of the creek above the hatchery. This strategy may be the slowest to achieve numerical goals for number of (hatchery + wild) spawners.

Table 2. Panel's assessment of the risk that domestication poses to restoration.

Run	Expected level of interbreeding	Risk	Comments
Fall	Very high	Intermediate to high	High uncertainty--no data on domestication for ocean-type life history.
Late-fall	Depends on effectiveness of the improved barrier dam	Intermediate if H[a] > 5% of W population; low otherwise	We anticipate greater domestication selection than for fall salmon because of the longer period of hatchery rearing.
Spring	None	None	No spring Chinook program at CNFH
Winter	Very low	None or low	Limited culture, now stopped, at CNFH
Steelhead	High unless W population nears 2000 adults/year and the dam blocks H throughout the run.	High	We expect substantial domestication due to the long history of propagation and the large difference between freshwater life histories for W & H. Effectiveness of improved dam to block H is uncertain.

[a] H = hatchery fish; W = wild

The conservation value of establishing wild populations in Battle Creek will be greatest if the wild populations are allowed to maximize their fitness (i.e., adapt to the local conditions), thereby maximizing their ability to persist during periods of adverse climatic or other conditions. For reasons given above, maximizing fitness (avoiding gene flow from the hatchery population) seems to conflict with maximizing numbers of fish by supplementing with hatchery fish (Reisenbichler et al. 2003). This conflict has been decided in favor of the latter for the current Battle Creek steelhead supplementation program, in which there is a stated intent to use large numbers of hatchery fish as necessary to fill the habitat (USFWS 2001).

New information, presented by Campton at the workshop, suggests that a wild population of steelhead may have persisted or reestablished itself in Battle Creek, and that hatchery steelhead are overwhelming the early portion of the population. The choice between supplementing with hatchery fish or not, or choices among levels and duration of supplementation should be made explicitly and articulated clearly to reflect the fundamental goals for restoration in light of domestication, the likelihood of compromising a remnant Battle Creek population, and other issues discussed in this report. It's not apparent to us that the current supplementation program for steelhead has met these criteria (in part because no overarching restoration plan exists) and we recommend that the supplementation be reconsidered immediately.

If maximizing numbers of fish (hatchery + wild spawners) is the goal for restoration, the current program for steelhead may be appropriate. We encourage the current efforts at CNFH to reduce domestication in the hatchery populations, and suggest that managers avoid supplementing the wild population with any more hatchery fish than necessary to achieve restoration goals. Additional hatchery fish are likely to reduce the reproductive success of wild fish through density-dependent effects as well as through increased gene flow. We foresee no circumstances where hatchery fish should be released if the number of naturally produced fish alone will approach carrying capacity.

If maximizing the number of naturally produced fish is the goal, uncertainty is greater. Adaptedness and perhaps numbers of naturally produced adult fish should be greater with fewer hatchery-origin spawners, even if the total population is considerably below capacity. If maximizing fitness is the predominant goal, we recommend that managers and stakeholders consider allowing the wild population to recover without supplementation from hatchery fish. This strategy would also provide better understanding of an important question throughout the West and elsewhere--how quickly can remnant wild populations recover (without supplementation) after habitat is removed. Another option may be appropriate if rate of recovery is critical--wild fish could be taken into the hatchery and their progeny exclusively used to supplement the wild population. Note that an increase in recovery rate for this last alternative has not been demonstrated, and this option should be considered only if the number of naturally spawning wild fish or effective population size (see Question 1B) is not reduced excessively.

B. What are the risks posed to maintenance of appropriate effective population sizes in Battle Creek salmon and steelhead by CNFH/LSNFH operations?

Probably the most widely discussed genetic topic in conservation biology is effective population size. Populations all lose genetic diversity through a random process called genetic drift. The smaller the population, the greater the rate of loss in diversity. Population size in this regard is not the census size, however, but the genetically effective size, which is the census size corrected for things such as differing numbers of males and females and non-random differences in reproductive success of individual fish. Typically, the effective size of a population is considerably lower than the census population size.

There is a large literature on effective population size, with numerous recommendations on how large this number should be for population health. While it is generally agreed that numbers as low as 50 should be avoided, it is less clear how large a population should be. Lande and Barrowclough (1987) suggested that at an effective size of 500, a population generates enough diversity by mutation to offset that lost by drift, but Lande (1995) proposed that this number should really be about 5000. This is a per-generation value, so assuming a 3:1 or 4:1 ratio of census to effective spawners, a generation length of 4 years, an effective size of 5000 equates to an average of 3750 to 5000 spawners per year. This is unrealistically large for many natural salmon and steelhead populations, and larger than many ever were thought to have been historically. Two additional factors need to be considered, that the numbers are theoretical values and that they are based on the concept of totally isolated populations, which is not true in the case of salmon and steelhead. The amount of natural gene flow from other populations serves to increase the effective size (Whitlock and Barton 1997). Considering all these factors, a population consisting of over a thousand spawners per year is probably in no danger of serious loss of diversity. Thus the “target” numbers for all five forms of salmon and steelhead thought to be achievable in Battle Creek (Ward and Kier 1999) should be large enough for genetic health in this respect.

Hatchery operations can potentially affect effective population size by two mechanisms. First, they can reduce fish numbers so low that unacceptable levels of genetic diversity are lost. This is essentially a facility effect on numbers. Speaking generally and not referring specifically to CNFH or LSNFH operations, any aspect of hatchery operations that reduces the numbers of fish in a natural population (e.g., passage impediments, broodstock collection) can depress effective size. Such an effect also manifests as a reduction in census size which is discussed under Demographic Risk. CNFH includes natural-origin steelhead and fall Chinook from Battle Creek returnees as broodstock for their programs, but in both cases return many times this number to the spawning grounds, so this does not pose a threat in terms of effective size. Our conclusion for Question 3 was that a significant demographic effect is unlikely. We also expect little or no risk for effective size. A key point for future operations is that severe reductions or wild fluctuations in population size can lead to reduced effective size and loss of genetic diversity.

The second mechanism by which hatchery operations can reduce effective population size is by exaggerating differences in reproductive success between the hatchery and natural components of a population in which hatchery fish contribute to the natural population (when $r_c < 1$; Figure 1, Question 1A), commonly called the Ryman-Laikre (R-L) effect (Ryman and Laikre 1991). A hatchery with a high survival rate to adulthood can magnify the genetic contribution of a relatively small number of fish if a large number of their progeny are allowed to spawn naturally. For example, if 100 hatchery adults that were the progeny of 10 pairs of hatchery parents were allowed to spawn with 100 wild adults that were the progeny of 50 pairs of wild parents, the 10 pairs of hatchery grandparents would contribute as much to the genetic makeup as would the 50 pairs of wild grandparents. This situation depresses effective size. The R-L effect is clearly most important in populations in which the hatchery operation is small relative to the wild population, the survival rate of hatchery fish is high relative to wild fish, and the proportion of natural spawners that are hatchery returnees is large. The effect can be reduced by increasing the number of fish used as broodstock, limiting hatchery survival rate by harvest, and by controlling the proportion of hatchery-origin fish on the spawning grounds.

It is important to consider both the current and the future situations in Battle Creek. Effective population size of any natural-origin population components of fall Chinook, late-fall Chinook , and steelhead in Battle Creek currently is dominated by CNFH operations. Because the hatchery spawns large numbers of fish relative to any natural population size, hatchery operations at present are probably enhancing effective size. CNFH spawns about 5000 fall Chinook, 400 steelhead (and this number will increase), and 540 late-fall Chinook (USFWS 2001). Even though the numbers of natural-origin spawners in Battle Creek are unknown except for steelhead, it is unlikely that they are large enough to cause a R-L effect. For example, it is likely that only about 5% of the late-fall Battle Creek spawners are natural-origin fish (S. Hamelberg, pers. comm.). Mass-marking was instituted for steelhead in 1998, allowing complete identification of hatchery and wild fish. Because few fish pass upstream that are not deliberately passed by the hatchery staff, the numbers passed up stream are almost the entire population. In 2002, this was 769 hatchery-origin and 428 natural-origin fish (S. Hamelberg, pers. comm.). With the 769 fish representing a spawning (parental) population of 400, it is extremely unlikely this ratio could result in a significant R-L effect. Natural-origin late-fall Chinook are taken from the Keswick trap (USFWS 2001), linking the Battle Creek population with the upper Sacramento population. This gene flow probably serves to increase effective size.

The future situation is difficult to foresee, because the Battle Creek plan lacks any specific methods for reintroduction. If the reintroduction plans include hatchery supplementation, appropriate sizing of the hatchery and natural components of the population could be an issue. However, if the reintroduction programs include the use of hatchery fish from LSNFH (winter Chinook) and CNFH (all other populations) operating as they are now, there is no obvious risk of depressing effective population size. Indeed, using hatchery fish is likely to increase effective population size over that without hatchery assistance; however, many other factors must also be considered in deciding whether to use hatchery fish for supplementation.

C. What are the risks to adaptedness and genetic diversity of Battle Creek salmon and steelhead, beyond those from domestication, caused by operations at CNFH/LSNFH?

We see two basic issues here: exclusion of some genetic diversity from the population by the hatchery operation, and inclusion of genetic diversity from nonnative sources. The first problem is widely recognized. For a variety of reasons, hatcheries have intentionally or unintentionally excluded fish with certain characteristics from the broodstock. The desire to meet egg-take goals by taking eggs early in the season, for example, likely is responsible for a contraction of coho salmon spawning time in hatcheries (Flagg et al. 1995). CNFH practiced size selectivity for steelhead in the past by excluding small fish that were presumed to have remained in freshwater rather than migrating to sea (USFWS 2001). With increasing awareness of genetic risks in hatchery operations, especially in the last decade, CNFH has placed a much greater emphasis on random/representative broodstock collection. Currently, nonrandom sampling for broodstock is more likely to be caused by limitations imposed by hatchery facilities such as inability to avoid high mortality for early or late portions of a population.

In the case of CNFH and LSNFH we believe that risk from unrepresentative sampling is low for most of the propagated runs because large numbers of adults have been used as broodstock, hatchery personnel strive to sample over almost all of each run, and wild fish are regularly included in the broodstock[3]. We provide our sense of the risk for each run in Table 3.

The second concern mentioned above is the introduction of genes from nonnative sources. If fish are adapted to their environments, the effect from introduction of nonnative genes ranges from a simple decrease in adaptedness to a larger problem called outbreeding depression (Lynch 1991, Gharrett et al. 1999). Gene flow among salmon and steelhead populations occurs naturally, and is thought to be an important means of conserving diversity. Hatchery operations sometimes create situations where gene flow occurs at unnatural rates or comes from unusual sources. There are two primary mechanisms. The first is deliberately moving fish or eggs from one location to another. The second is inadvertent inclusion of nonnative fish into the broodstock. This can

[3] Although we accept that wild fish are included in the fall-run broodstock, we suspect that the USFWS's (2001) estimate is exaggerated because it does not account for a likely reduction in survival due to marking and an associated underestimation for numbers of (unmarked) hatchery fish

happen when fish wander into a hatchery trap in a location where they do not intend to spawn, or when a hatchery spawns multiple runs of the same species and the run timing overlaps. One frequent cause for such "wandering" is off-site release of hatchery fish, a practice that is widespread for Chinook salmon in the Central Valley.

Table 3. The assessment of risk to restoration in Battle Creek resulting from reductions in genetic diversity caused by hatchery operations.

Run	Risk	Comments
Fall	Low (possibly intermediate)	The earliest spawners may be excluded from the broodstock (the first 5% of the fall run returns when the ladder is open). We believe that substantially more exclusion of early or late fish occurred under previous hatchery managers.
Late-fall	Low	Substantial inclusion of wild fish in broodstock; however, the latest 5% of the run seems to be excluded because the ladder is opened.
Spring	NA	No hatchery population at CNFH/LSNFH.
Winter	Low	Wild fish compose 90% of the broodstock. at LSNFH
Steelhead	Low to intermediate	Some wild are included in the broodstock. The latest 5% of the run is excluded because the ladder is open; substantially more exclusion of late (or early) fish probably occurred under previous hatchery managers. Small fish have been excluded from the broodstock in the past.

In the case of salmon in Battle Creek and CNFH/LSNFH we consider interbreeding among conspecific populations of the same run timing to be a low risk for the salmon runs because the available genetic analyses suggest no stock structure within the upper Sacramento River, and strays from other rivers seem few. This lack of structure in large part may be a reflection of past management. If recovery efforts proceed to the point where populations in the upper Sacramento do become noticeably differentiated the concerns about "strays" in hatchery broodstock should increase. Currently our main concern is the possibility of interbreeding between fish from different temporal runs. There is currently a risk of spring Chinook being spawned as falls at CNFH (USFWS 2001)--a possibility likely to increase as the number of wild spring Chinook salmon in Battle Creek increases. A similar but reduced risk may also exist for interbreeding between fall and late-fall Chinook salmon. One means to avoid interbreeding would be for USFWS to mark a larger proportion of the juvenile fall fish and to use only marked fish as broodstock, at least during periods of overlap. Eggs from individual matings could be held separately until the CWT from each parent was read and confirmed run membership.

The genetic results presented at the workshop suggest that distinct stocks of steelhead exist in the Sacramento River; however, we have no information to indicate the consequences of interbreeding, and no data to indicate the frequency that fish from other streams (e. g. Mill and Deer creeks) enter (explore) Battle Creek before finally homing to their natal stream to spawn. We are concerned about the history of introductions of Kamloops rainbow trout and steelhead from coastal rivers, American River, and Feather River. As recently as 1990, ~1/3 of the fish released from CNFH had been transferred from Feather River Hatchery. Survival of steelhead released from CNFH seems low compared to survivals in the Pacific Northwest. Low survival in part could result from outbreeding depression due to previous stock transfers. We consider the risk from past conspecific interbreeding to be intermediate. It is important to development of a locally adapted steelhead population in Battle Creek that no additional non-local steelhead be cultured or released from CNFH. Thus we applaud and recommend the current policy of keeping the CNFH steelhead operation "closed" to importation of fish from other sources.

Although the focus of this review is CNFH operations, it is important to point out that there may also be genetic risks from hatchery rainbow trout. Evidence is growing that gene flow between steelhead and rainbow trout may be much more extensive than previously thought (Kostow 2003, Pearsons et al. 2003). If anadromous and resident fish are interbreeding in Battle Creek, hatchery rainbow trout could pose a threat to the genetic integrity of the Battle Creek steelhead/rainbow population. A thorough genetic analysis of steelhead and rainbow trout in the basin, comparing them to hatchery rainbow stocks, should be undertaken before the reintroduction begins so the genetic composition of this population can be properly managed. It could be that the wild rainbow trout in the basin are an important reservoir of native genetic material, in which case these fish should play a greater role in the reintroduction effort.

It is important to point out here that CNFH is not the only source of this type of genetic risk. Hybridization in natural systems is a general risk in any program that attempts to reintroduce several runs that are not completely discrete spatially or temporally. Hybridization seems to be facilitated when the match between a population's requirements and its habitat is compromised, as from human disturbance (e.g., Clarke et al. 2001), and may be more intense where hatchery fish are involved (Docker et al. 2003). Some level of mismatch should be expected during the early years of restoration because new populations will not be precisely adapted (genetically) to the specific environmental conditions of the restored system. Some mismatch seems particularly likely for salmon in Battle Creek because the environmental conditions are distinct from any others currently available to salmon in the Sacramento River. Of course, hybridization is only possible between runs that overlap in time of spawning. During the first several generations while populations adapt to the local conditions, spring Chinook salmon that spawn late in the run may be prone to hybridize with fall Chinook salmon that spawn early, and winter Chinook salmon that spawn early may be prone to hybridize with late-fall Chinook salmon that spawn late. This temporal overlap may be greater in Battle Creek than in the Sacramento River because of the distinct conditions in Battle Creek. We expect that the probability of hybridization will diminish over generations as the populations adapt genetically to the "new" conditions. During the interim, however, actions to avoid hybridization may be necessary. The obvious action is to reduce the numbers of fish that overlap in spawning time.

Although the probability for hybridization is unknown, the consequent loss of the genetic integrity could be disastrous so we highlight the issue. Of course the issue is not valid if the spawning locations for different runs don't overlap; however, we expect that overlap would be likely in Battle Creek. Accordingly, we recommend that the potential for hybridization be minimized by abandoning restoration for fall and late-fall salmon in Battle Creek or delaying it until after spring and winter Chinook salmon populations have become firmly established (i.e., delay for several generations). Passage of fall and late-fall Chinook salmon above the dam (through the ladder or by jumping) should be prevented or reduced to the lowest possible level during the initial period of restoration. The ladder should be closed to block the full extent of the fall and late-fall runs of Chinook salmon. This action would require that much larger proportions of the spring and winter Chinook salmon populations would be handled at CNFH, and intensifies the need to assess whether handling causes increased prespawning mortality (see Facility Risk, Question A). Because it seems impossible to block all fall and late-fall Chinook salmon, we also recommend intense genetic monitoring to detect any hybridization as early as possible so that managers can attempt to control the problem if it occurs. Such monitoring for hybridization between spring and fall Chinook salmon may require development of run-specific markers similar to those available for winter salmon.

D. What additional genetic risks, other than the three categories already listed, are posed to Battle Creek salmon and steelhead by CNFH/LSNFH?

Three possibilities exist for this category of risk: 1) inadvertent selection for resistance to novel pathogens; 2) inadvertent selection caused by enhanced conditions (flow releases, reduced diversions) for hatchery fish; and 3) inadvertent selection by fisheries or predators targeting hatchery fish. Selection due to any of these factors might reduce the productivity of a wild population by moving it away from otherwise optimal gene frequency and life history distributions. For example, selection due to the protective measures for hatchery fish might genetically alter the run timing for wild fish to better coincide (temporally) with these measures. We are not aware of data indicating the magnitude of these effects in the Sacramento River system. Our sense is that these risks are low.

Ecological Risks

A. What risks are posed to Battle Creek salmon and steelhead populations through competition with fish released from CNFH/LSNFH at all life stages in Battle Creek, the Sacramento River, and the estuary?

Juvenile hatchery fish released into a stream can affect wild fish in various ways. Effects include increased predation on wild fish by hatchery fish or other predators, premature emigration, competition between hatchery and wild fish during a brief period as the former migrate through a reach, and extended competition with hatchery fish that remain in the stream for a longer period. Both interspecific and intraspecific competition can occur, and both are concerns for restoration because they can reduce the productivity and viability of a naturally reproducing population. Such reductions can occur immediately, through reduced survival during the period of interaction, or later through decreased growth or increased stress. In reviewing this issue, we recognize that fish released from CNFH only traverse or occur in the lower 5.5 miles of Battle Creek before reaching the Sacramento River; and steelhead and winter Chinook salmon are released directly into the Sacramento River.

Competition can be indirect through a reduction in food supply. One or twelve million juvenile salmon moving through lower Battle Creek and the Sacramento River might significantly reduce the number of aquatic invertebrates, and thereby reduce the food and growth of wild fish. Of course, most of the aquatic invertebrates reside in the substrate and are unavailable to fish at any one time, and juvenile salmonids also feed on terrestrial invertebrates which should be unaffected by the number of juvenile salmon. We can only speculate about risk because the relative importance of these two food sources in Battle Creek and the Sacramento River are unknown to us, as are studies testing for depletion of aquatic invertebrates. Our sense is that this form of indirect competition is unlikely to have a serious effect on wild populations in Battle Creek or the Sacramento River but we strongly encourage evaluation. Sampling benthos for several years before and after hatchery releases, and evaluating the proportion of aquatic and terrestrial invertebrates in the stomachs of hatchery fish would provide a much stronger basis for assessing risk.

Allocation of conservation measures might be considered another form of indirect competition. For example, temporary increases in flow and reduced water diversions to benefit hatchery fish might provide a much greater benefit to wild fish if designed or timed for wild fish – e.g., if provided earlier, when more wild fish are present and able to benefit. Conservation measures designed for hatchery fish may promote otherwise less productive life histories (e.g., later emigration timing) in the wild populations. We mention this issue but a rigorous treatment is beyond the purview of this Panel. Clearly, the issue is attended by tremendous biological, physical, economic, and political complications.

Direct competition between juvenile hatchery and wild fish can result in reduced food and growth for wild fish, displacement of wild fish to marginal habitats, or premature emigration of wild fish. Competition between juvenile hatchery and wild salmonids occurring together, and deleterious effects on the latter have been shown or indicated in the Pacific Northwest (PNW) within species (e.g., coho salmon--Nickelson et al. 1986; steelhead—McMichael et al. 1999; spring Chinook salmon--Levin et al. 2001), and between species (e.g., spring Chinook salmon reduced steelhead production – Bjornn 1978; steelhead reduced spring Chinook salmon—Levin and Williams 2002). We recognize that competition may manifest differently for Sacramento River salmonids than for the species/runs evaluated in the PNW; nevertheless, deleterious effects from competition should be expected in Battle Creek and the Sacramento River to the extent that hatchery and wild fish overlap. The magnitude of effect will depend on innate aggressiveness, the duration of overlap, the proportional increase in density caused by hatchery fish and the total density of hatchery and wild fish. We caution that density-dependent effects such as reduced growth or survival can occur at densities below carrying capacity.

Direct competition requires that hatchery and wild fish occupy the same places at the same times. Information supplied to the Panel show that steelhead and all runs of salmon overlap with fish released from CNFH/LSNFH (Figure 2; Table 4). Overlap may result in competition although predation seems more likely when newly emerged fry overlap with hatchery parr or smolts. The extent of overlap between hatchery and wild fish is uncertain because (1) the spatial and temporal distributions for hatchery fish after release are not well documented, and (2) the spatial and temporal distributions for fully restored populations in Battle Creek are unknown.

Figure 2. Seasonal occurrence of selected life stages of anadromous salmonids in the upper Sacramento River. H indicates release times from CNFH/LSNFH. Hash marks indicate the additional rearing period surmised for winter salmon from the EIS/EIR or expected for spring Chinook that enter the ocean as yearlings. Data are primarily from Fig. 4.1-1 in Battle Creek Salmon and Steelhead Restoration Project Draft EIS/EIR.

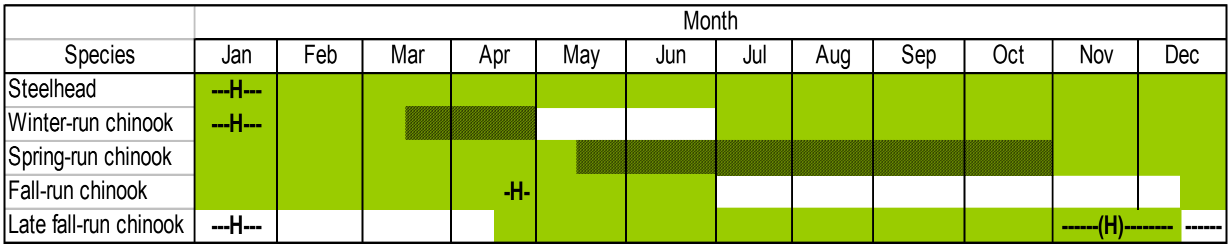

Table 4. Temporal overlap of hatchery releases from CNFH and LSNFH with naturally spawned Chinook salmon and steelhead is indicated by "X." "?" = uncertainty because we expect spring Chinook life history in Battle Creek to differ from that described for "the upper Sacramento River" due to differences in water temperature and other factors.

Run	Release Date	Number Released	Size (mm)	ST		WCS		SCS		LFS		FCS	
				Fry	juv	fry	juv	fry	Juv	fry	juv	fry	juv
FCS	Apr	$12*10^6$	75	X	X	--	--	--	X	X	--	--	X*
LFS	Nov/Dec	Variable	<135	--	X	--	X	X	X	--	X	X	--
LFS	Jan	10^6	135	--	X	--	X	?	X	--	--	X	X
WCS	Jan	200k	85	--	X	--	X	?	X	--	--	X	X
ST	Jan	600k	195	--	X	--	X	?	X	--	--	X	X

a) FCS = fall Chinook; LFS = late-fall Chinook; WCS = winter Chinook; SCS = spring Chinook; ST = steelhead

b) Fry = newly emerged fry. Juv = fingerling or parr. "*" = hatchery fish released after most wild fall Chinook have migrated downstream.

c) Gray shading indicates hatchery fish that are released into the Sacramento River, not Battle Creek.

Although "*most"* hatchery fish from CNFH appear to migrate downstream rapidly, even a modest proportion of 600,000-12,000,000 fish that might linger in Battle Creek or the upper Sacramento River could effect substantial competition with wild fish. Similarly, most wild fall Chinook salmon in the upper Sacramento emigrate before CNFH releases its fall Chinook; however, the USFWS's trapping data show a number of wild fish in lower Battle Creek and in the river during and after the hatchery release. Such "late" fish might be an important component of a restored Battle Creek population. Weber and Fausch (2003) provide data for fall Chinook salmon at two shallow, low-velocity sites in the Sacramento River indicating that few hatchery fish utilize such habitats. Unfortunately, deeper or higher-velocity habitats were not sampled. Near absence of information on the numbers of residual hatchery fish or the ratio of these fish to wild fish precludes a rigorous prediction for the consequences of competition.

The degree to which restored populations would rely on habitat below CNFH (in Battle Creek or the Sacramento River) for juvenile rearing also is a major uncertainty. Downstream movement and rearing in the lower reaches of tributaries and in mainstem habitats during fall and winter is common for Chinook salmon and steelhead in the PNW, has been observed in the Sacramento River system, and should be expected for Battle Creek populations of steelhead and late-fall, spring, and perhaps winter Chinook salmon. With the exception of fall Chinook salmon, we cannot predict the importance of life histories that are heavily dependent on rearing in lower Battle Creek or the Sacramento River.

The USFWS has taken measures to reduce competition between hatchery fish and wild fish by releasing fish at times (Figure 2), sizes, and conditions (high, turbid flows) so that *most* of the fish rapidly emigrate from the system. Under current conditions *most* wild late-fall, spring, and winter Chinook salmon and steelhead smolts have emigrated from the upper Sacramento River before fall Chinook salmon are released from the hatchery; however, newly emerged steelhead and late-fall Chinook salmon are present. As indicated above, relevant uncertainties include: 1) the proportion of hatchery fish that do not emigrate rapidly; 2) the number of wild parr present when hatchery fish are released and the importance of these fish to the wild populations; and 3) the level of competition between hatchery and wild fish and the effect of such competition on the wild populations.

Deleterious effects of late-fall Chinook salmon released from the hatchery on wild fish may be more likely than for fall Chinook salmon because the late-fall fish are released earlier in the year when more wild salmon of the same cohort are present in the system. Newly emerged fall and probably spring Chinook salmon are present in addition to larger winter, spring, and fall Chinook salmon and steelhead.

Hatchery winter Chinook salmon are released directly into the Sacramento River at Redding. The potential for competition with wild Battle Creek fish hinges on several unknowns including: 1) the extent that hatchery fish move up Battle Creek to continue rearing; and 2) the extent that juvenile Battle Creek fish move downstream to rear in lower Battle Creek or the Sacramento River.

Hatchery steelhead are released into the Sacramento River approximately 20 miles downstream from the mouth of Battle Creek and downstream from most of the salmon spawning areas. Steelhead are released at approximately the same time that winter and late-fall Chinook salmon are released. USFWS personnel sampled for residual steelhead during two years. In one year, no hatchery steelhead were found in Battle Creek two months after 150,000 fish were released directly from the hatchery; in the other year, no steelhead were found in the Sacramento River one month after ~600,000 hatchery fish were released (USFWS 2001). We recommend additional years of intense sampling in the Sacramento River and tributaries because migration/residualization and sampling efficiency vary from year to year. Low survivals for CNFH steelhead relative to survivals in the Pacific Northwest, and low emigration rates compared to coastal steelhead also reared at CNFH (USFWS, unpublished data from the late 1970's) suggest that CNFH steelhead may have a propensity to remain in freshwater. Regardless of whether such fish (residualized) survive to maturity or return to CNFH as adults, they might compete with or eat juvenile salmon and steelhead.

This discussion has focused on Battle Creek and nearby reaches of the Sacramento River; however, competition among juveniles also can occur further downstream in large rivers and estuaries. For example, in years of poor ocean conditions Levin et al. (2001) found a strong negative relation between survival of wild spring Chinook salmon and the number of hatchery spring Chinook salmon released in the Snake River system (Columbia River). These hatchery fish are released downstream from most spring Chinook rearing habitat. The numbers of fall and late-fall Chinook salmon and of steelhead released into the upper Sacramento River seem to approach or exceed the numbers of wild conspecifics, substantially increasing the densities of these species and suggesting the possibility of competitive or other deleterious ecological effects on wild populations, including the incipient wild populations in Battle Creek. The Panel was not presented with adequate information to judge this issue. If no one has rigorously tested the hypothesis that density-dependant effects in the Sacramento River, estuary, or marine waters caused by massive releases from CNFH or other hatcheries restrict natural production in the system, we recommend a serious attempt to do so.

Competition among adults for spawning sites is an obvious issue for fall and late-fall Chinook salmon and steelhead because hatchery fish return to Battle Creek in substantial or overwhelming numbers. We believe that the recent, excessive numbers of naturally spawning fall Chinook salmon would preclude a self-sustaining population in lower Battle Creek through competition for spawning sites and destruction of redds. The situation is less clear for late-fall Chinook salmon. Competition in upper Battle Creek is a concern for fall and late-fall Chinook salmon and for steelhead if large numbers of hatchery fish are able to pass the barrier weir. Lack of solid information on competition and carrying capacities for spawners and for juveniles precludes firm conclusions for upper Battle Creek; however, the large numbers of returning hatchery fish and the likelihood of deleterious effects from adult and juvenile competition warrant the current efforts to modify the barrier weir to deny or control passage of hatchery fish. Because density-dependent effects may occur at densities well below carrying capacity, we strongly recommend that hatchery adults be excluded when the total number of spawners will exceed one-half (or some other designated fraction) of the carrying capacity upstream of the weir.

In conclusion, the available information is insufficient to rigorously evaluate the level or consequences of competition between hatchery and wild fish in Battle Creek or the upper Sacramento River or the lower river and estuary. Our sense is that competition poses a low or intermediate risk to successful restoration of late-fall, spring, and winter Chinook salmon and steelhead in Battle Creek if the number of hatchery steelhead and late-fall Chinook salmon that pass the barrier weir is appropriately restricted; however, additional data are needed. Severe density-dependent effects and competition among adults below the weir, and the inability to prevent hatchery fish from passing above the dam (due in part to only partial marking of the hatchery population) seem to pose a high risk for fall Chinook salmon (and a threat to late-fall and spring Chinook populations – see Genetic Risks, Question D).

We recommend collection of additional information to reduce uncertainties and allow more rigorous conclusions about risk. Although rapid emigration of most juvenile hatchery fish has been reported, the numbers and distribution of slow or stationary (residualized) fish is unknown. Also unknown is the future importance of lower Battle Creek and the upper Sacramento River to restored salmon (excluding fall Chinook salmon which will be heavily dependent on these habitats) and steelhead populations in Battle Creek. The numbers, temporal and spatial distributions, and diet for slow or non-migrant hatchery salmon and steelhead should be monitored in lower Battle Creek and the Sacramento River. Monitoring downstream migration and other aspects of life history for wild fish in upper and lower Battle Creek should be continued, perhaps with additional effort to evaluate the use of lower Battle Creek and the Sacramento River by wild Battle Creek juveniles. Stakeholders should recognize that limited use of lower Battle Creek by juveniles may not be a good predictor of future conditions, and that monitoring must continue at least until restoration is achieved or abandoned. Use of lower Battle Creek during winter and other seasons may increase as restoration progresses and upstream rearing densities increase or as populations adapt to utilize the full range of habitats available in the creek. We also encourage work on competition between hatchery and wild fish ranging from the microcosm scale used by Weber and Fausch (2003) to the system-wide scale.

We list several actions that may reduce potential competition with wild Battle Creek populations. The efficacy or practicality of at least some of these actions is unclear, and should be further explored.

1. Mark all hatchery fish in the runs targeted for restoration and prevent marked fish from passing above the dam except as designated in the (forthcoming) restoration plan.
2. When not precluded by adverse water temperatures or diversions in the Sacramento River or estuary, release fall Chinook salmon later than currently scheduled to allow the emigration of more wild fish beforehand.
3. If fall Chinook salmon are to be restored, avoid overwhelming adult densities in Battle Creek by rearing and releasing fewer juvenile hatchery fish, by reducing adult densities in the holding ponds to entice more adult fish into the hatchery, or perhaps by releasing juveniles into an appropriately modified Gover's Ditch so that most of the adult salmon return through Gover's Ditch rather than Battle Creek. The merit for Gover's Ditch is particularly unclear, in part because of uncertainty about what proportion of returning adults would swim past the mouth of Battle Creek to ascend Gover’s Ditch.

B. What risks are posed to juvenile Battle Creek salmon and steelhead from predation by hatchery fish released from CNFH/LSNFH? Predation could occur in Battle Creek, the Sacramento River, or the estuary.

Substantial consumption of juvenile wild salmonids by juvenile hatchery salmon and steelhead has been observed in the Sacramento River system. Predation by steelhead has been observed in the Columbia River system (Flagg et al. 2000). Predation can occur for a brief period by the hatchery fish that emigrate promptly, and for an extended period by hatchery fish that emigrate more slowly or remain in the stream. Wild fish from Battle Creek will be vulnerable to predation from juvenile hatchery fish in the lower 5.5 miles of Battle Creek, or in the Sacramento River and seaward. Juvenile salmonids in upper Battle Creek may be vulnerable to predation by adult hatchery steelhead that move upstream past the barrier weir. The potential effect of adult steelhead is unclear because they may or may not actively feed in the river and tributaries. We found only one study that quantified the stomach contents of Sacramento River steelhead. Burns (1974 cited in Vander-Haegen et al. 1998) found mostly salmon eggs and invertebrates and a few juvenile salmonids in adult steelhead; however, no data were presented on relative availability of the different prey items.

Newly emerged steelhead and late-fall Chinook salmon occur in the Sacramento system when CNFH releases its fall Chinook; other wild salmonids are considered too large for significant predation by the fall Chinook salmon (USFWS 2001). Newly emerged fall and spring Chinook salmon occur in the system and are vulnerable to predation when CNFH/LSNFH releases late-fall and winter Chinook salmon and steelhead (Figure 2; Table 3). Wild steelhead and probably winter Chinook salmon should be large enough to avoid predation from hatchery fish of these two runs.

Uncertainties preclude firm judgment about the impact of predation on wild Battle Creek populations. These uncertainties include: 1) the spatial and temporal distributions for hatchery fish after release (e.g., What proportion of the 1,000,000 late-fall Chinook salmon and the 12,000,000 fall Chinook salmon do not emigrate promptly?); 2) the spatial and temporal distributions for fully restored populations in Battle Creek and the Sacramento River; 3) current or future predation rates by hatchery juveniles that rapidly emigrate, by those that remain in the stream longer, and by adult hatchery steelhead; and 4) the effect of any given amount of predation on the wild populations. USFWS personnel have adjusted their program to reduce predation on juvenile salmon by releasing steelhead in the Sacramento River downstream from the largest concentrations of salmon redds, generally releasing all runs during high flow and turbidity, and by striving to release fish as high quality smolts that rapidly emigrate (USFWS 2001). Nevertheless, we are not aware that current levels of predation have been evaluated.

We reiterate that the available information is insufficient for firm conclusions about risks to Battle Creek restoration from predation. Our sense is that the risk to Battle Creek steelhead and spring and winter Chinook salmon from predation by juvenile hatchery fish is low because of modest size differentials between wild and hatchery fish or modest if any overlap in spatial distributions with hatchery fish. Risks due to predation in Battle Creek on newly emerged fall-run fry (by hatchery late-fall Chinook salmon) and the late-fall Chinook (by hatchery fall Chinook salmon), or on spring or fall Chinook fry by adult steelhead may be intermediate (or high, particularly if substantial numbers of adult hatchery steelhead are allowed in upper Battle Creek). We encourage appropriate monitoring to reduce uncertainties and provide a more rigorous base for judging risk. In addition to the recommendations for monitoring competition (Ecological Risk Question A), we also recommend evaluating stomach contents of hatchery fish in areas of overlap with large numbers of wild fry.

C. What risks are posed to juvenile Battle Creek salmon and steelhead by CNFH/LSNFH operations by indirect predation; i.e. the increased risk of predation to Battle Creek juveniles from other predators (e.g., pikeminnow, bass, birds, pinnipeds) caused by a numerical or functional response to fish released by CNFH/LSNFH?

CNFH and LSNFH are two of six hatcheries releasing fish into the Sacramento basin. Some of the releases are low in the system in San Pablo Bay. At some point in the Sacramento River below Battle Creek predator attraction, if it occurs, will be the result of the combined presence of fish from several hatcheries and wild fish. The problem of untangling the effects of CNFH from the cumulative effects of all the hatcheries probably becomes insurmountable at some point downstream from the CNFH. To answer this question, the attraction of predators would have to be verified through extensive sampling in the Sacramento and Battle Creek below the points where hatchery fish are released. Monitoring combined with experimental variation in the location and number of fish released from CNFH will be needed to answer this question.

The information provided to the Panel suggests that little attention has been given to the problem of indirect predation. The Biological Assessment for CNFH and LSNFH (USFWS 2001) briefly mentions the problem on page 10-1 where it states: "Survival of hatchery origin fall Chinook may benefit form the en-masse release strategy by 'swamping' potential predators in the Sacramento River." The Panel could find no discussion of the potential impact on naturally produced salmonids resulting from increased predators attracted to the large releases of hatchery fish.

The lack of information provided to the Panel and the difficulty in obtaining information on indirect predation does not mean that it is not a real problem. Releases of hatchery fish can attract predators in the river (Collis et al. 1995) and in the near shore oceanic areas (Beamish et al. 1992). Reduced productivity of wild coho salmon over a broad geographical area was attributed to the attraction of predators by releases of hatchery fish (Nickelson 2003). Nickleson (2003) calculated an index of productivity for wild coho salmon in12 rivers and two lake systems on the Oregon coast. The index was negatively correlated with the average number of hatchery coho salmon smolts released in each basin. Nickelson evaluated various explanations for this observation and concluded "… evidence suggests that the mechanism reducing productivity of wild coho salmon was more likely predation, in this case the attraction of predators to concentrations of hatchery and wild juveniles in coastal estuaries."

Monitoring combined with experimental hatchery release strategies and numbers should be incorporated into the AMP to evaluate the mortality of wild salmon and steelhead caused by indirect predation. The advice by Beamish et al. (1992) would seem to apply to CNFH: "Hatchery practices must be at least as adaptive as the predators that await the hatchery-reared salmon at the river mouth." Nickelson (2003) cautioned that hatchery programs used for harvest augmentation should not be located in basins whose habitats have a high potential to produce wild salmonids (Nickelson 2003). At a minimum the Battle Creek restoration Program should include in its AMP a test of the hypothesis that releases of juveniles from CNFH will attract predators and negatively impact the program.

D. What disease risks to Battle Creek salmon and steelhead populations are posed by contact with CNFH-origin fish or effluent waters from the hatchery?

There is clearly a lack of specific data from both field and experimental work on the upper Sacramento and Battle Creek to make the best judgements on the ultimate outcome of the interactions of the hosts, pathogens and environment that will occur between the CNFH and the restoration project. However, insights from our studies of the relationships between salmonid hosts, pathogens and the environment (Hedrick 1998) do provide information not presently found in documents describing the restoration project or the hatchery operations.

In the following text the terms pathogens/diseases will be used frequently and at times seemingly interchangeably. They do represent quite different entities. Pathogens have the ability to infect fish and may even reproduce and be shed from their hosts without causing moribund changes (diseases). Most disease control strategies target pathogens and the conditions that foster their replication and spread (the conditions that are more apt to result in the occurrence of disease). Pathogens are defined as organisms that have the capability to cause disease. Thus a conservative approach to controlling diseases is based upon pathogens but must stipulate that pathogen presence does not necessarily equate to disease, just the potential for disease occurrence. An alternate but less conservative approach to disease control is to assume that pathogens are widely distributed so that the main effort should focus on ameliorating factors (host and environmental) that encourage disease to occur. In general and when the stakes are potentially high, the more conservative approach to disease control is utilized. This is true for most current disease control programs at the international, national and local levels.

Key points evaluating the potential disease risks to restoration of salmonids in Battle Creek by contact with CNFH-origin fish or effluent waters from the hatchery.

1. Pathogens/diseases present in salmonids/nonsalmonids in the restoration area

Our best information on this subject comes from published literature on historic accounts of the occurrence of diseases in the upper Sacramento River, recent pathogen surveys by U.S. Fish and Wildlife (USFWS) personnel as part of the Wild Fish Health Survey (True 2003) and personal communications with California Department of Fish and Game (CDFG) and USFWS (Dr. J. S. Foott, Fish Health Center Project Leader) fish health specialists working in this area. The principal category of diseases affecting fish populations fall into three general categories, those due to: 1) infectious agents or pathogens, 2) environmental factors, and 3) genetic/nutritional factors. Our focus in this review is the infectious diseases because their importance is increased when populations of fish are congregated as found in standard hatchery operations (Hedrick 1998). Pathogens present in Central Valley salmonids may be broadly classified into microbial and macroscopic in nature with the former being those known as significant causes of mortality. The major groups of microbial pathogens are viruses, bacteria, fungi, unicellular (protozoans) and multicellular (metazoans) parasites.

Viruses - Three viruses are known from salmonid fish in the upper Sacramento River: 1) the cutthroat trout virus (CTV) as isolated from rainbow trout and brown trout broodstocks from CDFG hatcheries at Darrah Springs or Mt. Shasta (Hedrick et al. 1990), 2) the salmonid herpesvirus type 1 (aka *Herpesvirus salmonis* or SalHV1) as found at the Feather River and Mt. Shasta hatcheries (Eaton et al.1989) and 3) infectious hematopoietic necrosis virus (IHNV) found in hatchery and wild salmon and trout (Wingfield and Chan 1970, Kurath et al. 2003). Both CTV and SalHV1 have been demonstrated to have no or low virulence (ability to cause disease) in salmonids, respectively. In contrast, IHNV has caused large-scale losses (epidemics) of juvenile Chinook salmon and steelhead trout at the Feather River Hatchery and CNFH (Wingfield and Chan 1970) and will receive the most attention in this review.

Bacteria- The bacterial pathogens found in the upper Sacramento and Battle Creek drainage are similar to those known from other salmonids in California. All have the ability to cause significant disease problems in hatchery and potentially wild fish. The following bacteria have been found among fish at the CNFH: *Flavobacterium*, *Aeromonas* and *Pseudomonas* spp., *Yersinia ruckeri*, and *Renibacterium salmoninarum* (Free and Foott 1998). Evidence for the presence of *R. salmoninarum* in rainbow trout and Sacramento sucker and hardhead in upper Battle Creek have been found by enzyme-linked immunosorbent assays conducted by USFWS personnel (True 2003).

Fungi- *Saprolegnia* and other oomycetes (water molds) are found on fish and eggs from CNFH and are presumed present in fish and other aquatic organisms in Battle Creek.

Protozoans- Flagellates present in the genera *Ichthyobodo* and *Hexamita* and ciliates in the genera *Ichthyophthirius* and *Tricodina* are present among salmon and steelhead trout at the CNFH and presumed present in fish in Battle Creek.

Metazoans- *Gyrodactylus* (Monogenea), *Nanophyetes salmonicola* (Digenea), *Ceratomyxa shasta, Parvacapsula* and *Chloromyxum* (Myxozoa) and *Sphaerothecum destruens* (Mesomycetozoa) are known from the CNFH (S. Foott, pers. comm.) and presumed to be present in fish in Battle Creek. *Myxobolus cerebralis* (Myxozoa) has been identified among rainbow trout found in the North and South forks of Battle Creek (Horsch 1987) in waters currently classified as both for anadromous and nonanadromous salmonids.

2. **Pathogens/diseases present in each run of salmon and steelhead trout during production (juvenile rearing and adult holding) at CNFH. The runs of Chinook salmon are fall (FCS), late-fall (LFS), winter (WCS), spring (SCS) and steelhead trout (ST). The SCS and WCS are no longer reared at CNFH.**

FCS

Virus- The prevalence of IHNV infection (% of infected fish) among the first returning Fall Chinook salmon (FCS) adults is generally low (<10%) but by the mid to end of the run (November, December) has risen to 50 to 95%. Despite the high prevalence among adult FCS, there have been no IHNV infections among juvenile FCS at the CNFH since 1999 as a result of egg sanitation procedures and ozone treatments of the hatchery water supply. Carcass examinations of adult FCS in Battle Creek indicate a prevalence of IHNV infection up to 70%.

Bacteria- *Flavobacterium* and *Y. ruckeri* have been observed as primary pathogens among juvenile FCS and *Aeromonas* and *Pseudomonas* spp. as secondary pathogens (opportunistic pathogens that colonize a deteriorating host) among both juvenile and adult FCS. *Renibacterium salmoninarum* is seldom detected in adults and has never been detected in juvenile FCS at the CNFH.

Fungi – Saprolegnia and other oomycetes are found on eggs, juveniles and adult FCS at the CNFH. It is presumed to be present but at perhaps lower levels in natural-origin fish and among fish spawning or dying in Battle Creek.

Protozoans- Flagellates present in the genera *Ichthyobodo* and the ciliate *Ichthyophthirius* have been detected in juvenile FCS at the CNFH and on occasion associated with mortality.

Metazoans- *Gyrodactylus* and *N. salmonicola* are found among juvenile FCS at the CNFH. Levels of the latter have decreased significantly following ozonation of the water supply. The myxozoans *C. shasta* and *Chloromyxum* have been found in returning adult salmon to the CNFH but not in juveniles. Both myxozoan parasite infections are presumed to be contracted while migrating through the lower Sacramento River (Hendrickson et al. 1989).

LFS

Virus- The overlap of the late FCS with early arriving LFS adults results in a high prevalence (near 100%) of IHNV at the onset and throughout the LFS run at the CNFH. No infections in juveniles since 1999 have been observed in the hatchery. The virus is presumed present in natural-origin LFS adults as well.

Bacteria- *Flavobacterium* and *Y. ruckeri* have been observed as primary pathogens among LFS juveniles and *Aeromonas* and *Pseudomonas* spp. as secondary pathogens among both juvenile and adult LFS. *Renibacterium salmoninarum* has been seen rarely in adults with no clinical signs. *Renibacterium salmoninarum* has never been detected in juvenile LFS at the CNFH. Infections with *Y. ruckeri* are minimized by vaccination of LFS juveniles in June when fish are 500 – 600/lb.

Fungi – Saprolegnia and other oomycetes are found on eggs, juveniles and adult LFS at the CNFH.

Protozoans- The flagellates *Ichthyobodo* and *Hexamita* and ciliates in the genera *Ichthyophthirius* and *Tricodina* have been detected in juvenile LFS. *Ichthyophthirius* is more common in LFS than FCS or ST juveniles.

Metazoans- *Gyrodactylus* and *N. salmonicola* are found among juvenile LFS at the CNFH. Levels of the latter have decreased significantly following ozonation of the water supply. The myxozoans *C. shasta*, *Chloromyxum* and *Parvacapsula* have been found in returning adult LFS to the CNFH but not in juveniles. These myxozoan parasite infections are presumably contracted when adults migrate through the lower Sacramento River. The mesomycetozoan parasite *Sphaerothecum destruens* (Rosette Agent) is found in adult LFS. The prevalence of infection among LFS adults returning to CNFH ranged from 20 – 32% over several years of testing but since 1998 has dropped below 1%%. *Sphaerothecum destruens* is presumed to be present in Battle Creek.

ST

Virus- Steelhead trout (ST) adults returning from August through March to Battle Creek, even during the peak IHNV prevalence of FCS and LFS, have considerably lower prevalence of IHNV infection (<10%) than the salmon. No infections have been observed among juveniles at the CNFH.

Bacteria- *Flavobacterium* and *Y. ruckeri* have been observed as primary pathogens among juvenile ST and *Aeromonas* and *Pseudomonas* spp. as secondary pathogens among both juvenile and adult ST. *Renibacterium salmoninarum* has not been observed in adult or juvenile ST. As with LFS juveniles, infections with *Y. ruckeri* are minimized by vaccination in late June.

Fungi – Saprolegnia and other oomycetes are found on eggs, juveniles and adult ST at the CNFH and are presumed to be present but at perhaps lower levels in natural-origin fish.

Protozoans- The flagellate *Ichthyobodo* is found among juvenile ST at the CNFH and on occasion associated with losses. The flagellate *Hexamita* and the ciliate *Ichthyophthirius* are also present in juveniles but not associated with significant losses. The protozoan *Tricodina* is rarely detected in juvenile ST at the CNFH. All of these parasites are presumed to be present in natural origin salmonids or nonsalmonids present in Battle Creek.

Metazoans- *Gyrodactylus* and *Nanophyetes salmonicola* are found among juvenile ST at CNFH. Levels of the latter have decreased significantly following ozonation of the water supply. The myxozoans *Ceratomyxa shasta*, *Chloromyxum* and *Parvacapsula* have been found in returning adult ST to the CNFH but not in juveniles. All three myxozoan parasite infections are presumed to be contracted while adults are migrating through the lower Sacramento River (Foott pers comm). *Myxobolus cerebralis* was found among juvenile ST at CNFH in 1995 (Horsch 1987) but not since, although a potential reservoir of infection resides in upper Battle Creek rainbow trout (True 2003).

SCS

There have not been ample opportunities to examine pathogens present in juvenile or adult SCS nor are they currently reared at CNFH.

WCS (Reared at LSNFH not CNFH)

Virus- Infections with IHNV have been observed among WCS adults returning to the Keswick trap or transported to LNFH with a prevalence of IHNV infection from 15 – 90% at the time of spawning. There have been no infections in captive-reared juveniles at LNFH, the Bodega Marine Laboratory or Steinhardt Aquarium. All captive WCS adults spawned to date have been free of IHNV.

Bacteria- All of the above mentioned bacteria are potentially present in WCS adults or juveniles. *Renibacterium salmoninarum* has been detected in adults and juveniles and clinical disease has been observed in juveniles reared at the Bodega Marine Laboratory and Steinhardt Aquarium.

Fungi – Saprolegnia and other oomycetes are found on eggs, juveniles and adult WCS.

Protozoans- Protozoan pathogens are rare among fish reared at LSNFH.

Metazoans- Few parasites, with the exception of the copepod *Salmincola*, have been found among captive juvenile WCS at LSNFH. Adult infections with the myxozoans *C. shasta*, *Chloromyxum* and *Parvacapsula* have been reported. The mesomyceteazoan *S. destruens* has been associated with mortality in captive WCS at the Bodega Marine Laboratory and Steinhardt Aquarium (Arkush et al. 2003) during seawater rearing and is detected among returning adult WCS to the Keswick trap.

3. The temporal patterns of the occurrences of diseases/pathogens at CNFH

Adults - Pathogens associated with adult salmon will peak with each run of salmon or steelhead trout. Thus IHNV will begin to be present as shed from FCS adults beginning in October and November and will be high through holding and spawning of LFS adults from January to March. The low prevalence in ST adults suggests they contribute little to virus present at the CNFH. Prior to ozone treatment of the water supply, outbreaks due to IHNV began with FCS fry in March, presumably due to contact with virus in the water from adult LFS above the hatchery. Since outbreaks due to IHNV at CNFH have not occurred since 1999, the CNFH contributions of IHNV into Battle Creek are restricted to hatchery effluents from adult holding ponds. Infections with *R. salmoninarum* in Chinook salmon and ST have been extremely low or undetectable recently. Adult salmon and steelhead trout are potential sources of numerous other bacteria that might be considered opportunistic or secondary pathogens (e.g. *Micrococcus, Staphylococcus, Aeromonas, Pseudomonas*). These bacteria would be similar to those found in dead or dying adult salmon in Battle Creek. Thus the temporal pattern of occurrence for these bacteria would correspond to peak adult returns from October to March with a peak in November/December corresponding with the numbers of adult FCS the most abundant run. Adult LFS are also the potential source of *S. destruens* spores that would be present from January to March although the parasite has not been detected in surveys of fish in the last two years. The concentrations of infective stages or zoospores for *Saprolegnia* or other water molds should show a pattern similar to that of opportunistic bacteria in adults with a peak corresponding to the adult run/holding period among fish that had been held or worked the most.

Fry/Juveniles – A second potential source of pathogens from the CNFH in addition to those from adult impoundment would come from effluent waters from the >12 million FCS fry and juveniles reared at the hatchery from January until April when the fish are released directly into Battle Creek. Bacterial infections with *Flavobacterium* or *Y. ruckeri* and protozoan parasites *Ichthyophthirius and Ichthyobodo* would be potentially present and associated with disease episodes during this period. Both LFS and ST juveniles are present for up to 1 year on site and represent a second source of pathogen discharge although numbers of fish are greatly reduced compared to FCS juveniles. The occurrence of *Hexamita* is most frequent in June in both LFS and ST juveniles although no specific mortality is attributed to infection. *Ichthyophthirius* is most frequently observed in LFS but also found in STand is present from March to July at which time it is infrequently observed. *Ichthyobodo* is found during juvenile rearing of both ST and LFS but more commonly found among ST. The WCS are reared and released off site and currently there is no production of SCS at the CNFH and thus neither would currently contribute to any pathogen discharge from CNFH.

4. The prevalence of infection and doses of pathogens released during such occurrences

Adults- The initial prevalence of IHNV in early returning FCS adults to CNFH may be near 0%. By November however, prevalence has jumped to 50 – 70% and stays at this level throughout the spawning period. The first arriving LFS adults will have a high prevlance (near 100%) and stay at this level throughout spawning. ST have a prevalence of IHNV infection of 10% or less throughout the spawning period. Concentrations of IHNV in adult FCS and LFS may approach 10^8 plaque forming units or pfu (this is an indirect measure of the number of virus particles) per gram of tissue or ml of fluid (e.g. ovarian) (Mulcahy et al. 1983). Precise measurements of IHNV present in the water during peak times of adult holding (e.g. when FCS are stacked from the CNFH holding ponds downstream into Battle Creek) have not been obtained but are presumed to be sufficient to facilitate adult to adult transmission such that virus prevalence reaches 100% in spawning LFS or 80% in FCS adult carcasses found in Lower Battle Creek. Actual concentrations of virus discharged into or present in Battle Creek from salmon are unknown but are suspected to be in the range of 10^1 pfu per ml of water or less and present in pulses rather than a constant level as a result of asynchronous releases from fluids of live adults or deteriorating tissues of dead adults. Attempts to demonstrate transmission of IHNV to caged Chinook fry held in the adult holding ponds have been unsuccessful (S. Foott, pers comm.).

The concentrations of bacteria, particularly opportunistic pathogens, would be high among the most debilitated fish but no prevalence data are available. The prevalence of infection with water molds would be similar to that of opportunistic bacteria, reaching the greatest prevalence among the adult fish held for the longest period. In LFS and ST adults, prevalence may approach 10 – 15% and a 5% prespawning loss may occur. The concentrations of bacteria and fungi released from these adults have not been determined.

The myxozoan *C. shasta* is found causing adult infections in FCS, LFS, ST and WCS. Infections of the intestine may be severe with a prevalence of 50%. Some prespawning loss is presumed to result from severe infections. Releases of spores of *C. shasta* may occur from such infections but the polychaete worm *Manayukina speciosa* necessary for the further development of the parasite (Bartholomew et al. 1997) is not currently known fromthe Battle Creek drainage and thus the life cycle is terminated. *Parvacapsula* is a recently described myxozoan parasite in adult FCS and LFS but not ST. Little is known of the shedding potential or alternate host (e.g. oligochaete, polychaete, etc.) for this myxozoan. *Chloromyxum* is a myxozoan detected in the kidney of adult FCS and LFS at a prevalence of less than 1%. The life cycle of the parasite remains unknown as does potential shedding of spores from infected fish.

The mesomycetozoan parasite *S. destruens* (Rosette Agent) is found in LFS adults. The prevalence of infection ranged from 20 – 32% over several years of testing but since 1998 has dropped below 1%. The concentrations of spores released from such fish are unknown but would be greatest from the carcasses of dead fish and thus levels should be lower in the hatchery effluent compared to Battle Creek where carcasses would accumulate. Stages of the life cycle have just recently been described and involve a motile zoospore that emerges from spore stages found in fish tissues (Arkush et al. 2003). Spores may be shed from live fish but presumably most shedding and zoospore formation occurs from dead fish.

Fry/Juveniles – No IHNV has been found in fry or juveniles of any fish held at CNFH since ozone treatment of the hatchery water supply began. *Flavobacterium* is present principally in LFS and STjuveniles from late May through July. Prevalence of infection may reach 10 – 15% with cumulative mortality up to 1%. *Aeromonas* and *Pseudomonas* spp. appear as opportunistic pathogens throughout juvenile rearing but at extremely low levels. *Yersinia ruckeri* outbreaks and losses occur occasionally in FCS during March (3 outbreaks in past 10 years). Prevalence of *Y. ruckeri* infection overall in FCS juveniles is at most 1 – 2% and mortality never exceeds 0.1 %. During active disease episodes (e.g. mortality occurring) bacterial concentrations may reach 10^4 or greater per ml or g of fish fluid (urine) or tissues, respectively. The actual concentrations of bacteria present in the water at the time of discharge are unknown. The prevalence of *Ichthyobodo* is greatest among ST juveniles and may reach 10% with a lower prevalence among LFS and FCS. Prevalence of *Ichthyophthirius* is greater among LFS compared to FCS or ST juveniles and may reach 20 – 30% but mortality is rare. The prevalence of *Hexamita* may reach 50% in LFS and ST juveniles but mortality attributed to this flagellate is less than 0.1%. The concentrations of the motile infective stages released into hatchery effluent from these parasites is unknown but would be greatest during periods of active disease outbreaks in the hatchery. *Gyrodactylus* are found principally in juvenile ST with a prevalence up to 50% throughout the rearing period without losses if treatments keep trematode numbers low. Intermittent and low level shedding of trematodes could occur throughout the rearing period for ST but the concentrations released are unknown. *Nanophyetes salmonicola* is found in LFS at a prevalence of up to 70% but numbers of metacercariae are low. Prevalence is lower in ST and metacercariae are not observed in FCS (perhaps because there is insufficient time for them to develop prior to release). Because metacerariae are not released nor will they develop until the fish is eaten by the next host (a mammal), there should be no release of infective stages for either the snail or fish hosts with hatchery effluent.

5. Temporal patterns in the presence of susceptible life stages of naturally reproducing salmon and steelhead trout present in Battle Creek

In general anadromous semelparous salmonids are most susceptible to diseases at the two extremes of their life cycle, as newly emergent fry or as physiologically compromised adults approaching death. At both extremes of the life cycle the immune response has either not fully developed or has begun a progressive collapse. This results in increased susceptibility to pathogens encountered in the environment by these life stages.

Considering current/proposed restoration, lower Battle Creek would support FCS and LFS life stages and upper portions of the North and South Forks of Battle Creek would support WCS, SCS and ST. Thus effluent from CNFH would most influence naturally reproducing FCS and LFS adult, fry and juvenile stages present below the effluents from the adult holding (fish ladder) or production ponds (a total of 3 potential discharge points with the primary being the waste water ditch). The lower 5 miles of Battle Creek from CNFH to the Sacramento River also serve as the main access of adult salmon and steelhead migration to and the emigration of juveniles from the upper reaches of Battle Creek. Thus potentially impacted stages could include all 4 runs of Chinook salmon and steelhead trout.

Virus - The most susceptible life stages of Chinook salmon and steelhead trout to IHNV would be sac fry and fry. Older fish can become infected but are less apt to undergo severe infections and mortality. Sac fry and fry of ST are present from February to June with a peak in April. These stages for SCS are present from October to December with a peak in November. For WCS these stages would be expected to be present from June to October with a peak in July and August. Naturally reproducing FCS sac fry and fry would be present from December to February with a peak in January.

Bacteria - Juveniles and potentially adults would be susceptible to all of the bacterial pathogens listed above. Most susceptible juvenile stages would be those subject to any environmental or other concurrent stressors (e.g. high water temperature).

Fungi – Predisposed adult salmon and potentially salmon or ST eggs would be susceptible to *Saprolegnia* or related water molds. Fish that had compromised external barriers (e.g. skin or gill damage) would also be most susceptible.

Protozoans- Juveniles and perhaps adults would be susceptible to all protozoan pathogens listed above. The most susceptible juvenile stages are those subject to any environmental or other concurrent stressors (e.g. high water temperature).

Metazoans- Salmon and ST would be susceptible to *Gyrodactylus* but this would likely be only a concern for juveniles. There should be little or no hatchery source and therefore no effect on susceptible life stages of salmon or steelhead trout for either *Nanophyetes salmonicola* or *C. shasta*. The infection cycle of *Parvacapsula* is currently unknown and thus the susceptible salmonid life stages, other than returning adults are unknown. C*hloromyxum* is not found in CNFH juveniles and any releases from adult salmon should be minimal in hatchery effluent. Juvenile chinook salmon and to a lesser extent steelhead trout would be susceptible to infections with *S. destruens* (Rosette Agent) that might be released from adult LFS.

6. Doses of pathogens and environmental conditions needed for transmission of pathogens from hatchery sources to natural populations in Battle Creek

This is an area for which little direct evidence is available. Most studies on the dose of pathogen and the environmental conditions conducive to infection have been conducted in the laboratory. Exposures to pathogens in these laboratory trials tend to be at high doses for a relatively short period rather than at low doses and over extended periods of time or in pulses as suspected for natural fish populations (Foott et al. 2000). In addition, one of the few environmental factors that has been investigated in any detail is water temperature and again primarily in the context of controlled pathogen exposure studies in the laboratory (Hetrick et al. 1979). Thus, the information provided below suffers from significant information gaps and contains instead estimations of the potential doses and environmental conditions that would most likely lead to the transmission of pathogens present as a result of CNFH operations to susceptible life stages residing or passing through lower Battle Creek.

Virus - Doses of IHNV required to infect various life stages of Chinook and steelhead trout may be less than 10 pfu/ml of water on a single or potentially multiple short exposures.

Adults - Most FCS and LFS adults returning to CNFH are presumed to become infected by coming in contact with virus as released from infected adults held or present in close proximity. This explains why the prevalence of infection increases over the duration of the run and why the overlap of late FCS results in a high prevalence of infection in early LFS adults. Virus concentrations directly in water samples from rearing units with disease outbreaks in juveniles or in effluent from adult holding ponds ranges from 0.2 – 7 pfu/ml of water. Although the effects of cumulative dose remain unknown, sustained concentrations of 0.2 – 7 pfu/ml appear to be sufficient to initiate productive infections in FCS, LFS, SCS and LFS adults. Adult ST appear to have a greater resistance than Chinook salmon to virus strains found in the upper Sacramento River and this may explain the lower prevalence observed in adults.

Fry/Juveniles - Experimental trials conducted by USFWS and UC Davis suggest that infections but not disease results from bath exposures to $\geq$10 pfu/ml of IHNV in FCS juveniles (70 mm FL). The effects of multiple low dose exposures of sac fry and fry would more likely results in more serious infections and disease but this is currently under investigation. Doses of 10^{3-4} pfu of IHNV/ml with these younger life stages is known to result in virus-induced mortality ranging from 70% to 90% under experimental conditions. Most infections of fry and juveniles may be at lower virus doses and thus occurring in the absence of clinical disease. What environmental factors might be encountered that might cause these asymptomatic infections to progress to clinical disease is not known but this a potential concern for survival of outmigrant juveniles.

Environmental conditions that might favor virus transmission are poorly understood. Water temperatures near 10 – 11^{o}C are most likely optimal for virus infections in both adults and juveniles based upon limited laboratory studies and field observations. However, infections and disease might be anticipated at higher and lower water temperatures (e.g. 8 – 15^{o}C or greater) as known from rainbow trout (Hetrick et al. 1979). Similar experimental trials with strains of IHNV from the upper Sacramento River with juvenile Chinook salmon or steelhead trout have not been conducted.

Bacteria – The *Flavobacterium* found among salmonids at the CNFH has not been fully characterized but does not appear to be typical *F. columnare* nor *F. psychrophilum* which are the most common salmonid pathogens found in this group. Doses of *F. columnare* and *F. psychrophilum* known to infect salmonids by bath exposures are not well known as artificial challenge methods most often involve a need for scarification, or skin insult as part of the exposure protocol. Under those conditions, concentrations of 10^{3-4} colony forming units (cfu) of the bacterium will initiate infections and mortality. Doses of *Aeromonas* or *Pseudomonas* spp. required for transmission are unknown for the specific isolates from fish at CNFH but are presumed to be in a range similar to or perhaps slightly less than that for *Flavobacterium*. The doses of *Yersinia ruckeri* necessary to induce infections and mortality by experimental bath exposures is higher (e.g. 10^{7-8} cfu/ml).

Environmental conditions can greatly influence transmission of bacterial fish pathogens. Warmer water temperatures (>15°C) would be expected to favor transmission of *F. columnare* and *Y. ruckeri*, while cooler temperatures (<15°C) would be more suitable for *F. psychrophilum*. Stress due to water quality or other factors is often associated with *Y. ruckeri* infections in salmonids and this would presumably be true for the opportunistic pathogens *Aeromonas* and *Pseudomonas*.

Fungi – The doses of zoospores of *Saprolegnia* (or other water molds) required to initiate infections is not well defined but may be as low as 200/L of water (Willoughby and Pickering 1977). Concentrations of zoospores present in holding ponds with infected adult salmonids may increase up to 220,000 zoospores/L. Most zoospores coming in contact with the mucus on the skin are removed and do not invade. If the skin is injured through trauma the progress of infection is facilitated. Infections and zoospore production occurs over a wide range of temperatures (e.g. 3 - >20°C). Thus, environmental factors including water temperature and quality combined with damage to the skin of the fish will be conducive to fungal infections at lower concentrations of zoospores in the water (Pickering and Willoughby 1982).

Protozoans – The dose of free swimming forms of *Ichthyobodo* needed for transmission is unknown but infections spread rapidly among susceptible salmonids in close proximity. Fry and young fish are considered the most susceptible stages and if left untreated mortality to 25% can occur (Lom and Dykova 1992). Infections occur over a wide temperature range (3 – 16°C). Doses of *Hexamita* required for transmission are not known and the flagellate may be more of a commensal than a pathogen with ill effects only under conditions in which the fish are subject to other stressors (e.g. among "pin heads"). Low doses of the theront or infective stage of *Ichthyophthirius* for salmonids can initiate infections but more massive doses are required to cause disease signs and death. The progress and severity of the disease is accelerated in salmonids as water temperatures increase (Lom and Dykova 1992).

Metazoans – Concentrations of the trematode *Gyrodactylus* and mesomycetazoan *S. destruens* needed to initiate infections are unknown and the environmental conditions conducive to transmission are unclear. Crowding and poor water quality would facilitate greater problems with both metazoan parasites.

Assessments of Risks from Pathogens Found among Fish at CNFH to Restoration Efforts in Battle Creek.

1. **Which pathogens would be present and or thrive in a hatchery environment that would not be expected to do so in natural populations in Battle Creek?**

Juvenile rearing - In general, infectious agents (pathogens) spread most rapidly and have the potential for the most severe consequences (disease and mortality) among animals at high population densities whether they are captive or free-living. In a hatchery environment, stressors associated with standard practices can further increase the probability of infections and outbreaks due to pathogens. Thus, despite a reasonable level of protection of the water supply by ozone treatments, pathogens are still present during production of FCS, LFS and ST at the CNFH. Pathogens that can escape inactivation by ozone treatment or that are able to establish in pipes or resident escaped fish in the hatchery water delivery system will continue to infect and amplify in numbers during production of juvenile fish (there may be protective or therapeutic procedures to reduce this effect – see section "d" below). Pathogens in this category would include the protozoans *Ichthyobodo*, *Ichthyophthirius*, *Hexamita*, and the bacteria *Flavobacterium* and *Y. ruckeri*. Ozone treatments appear to be effective in reducing or eliminating IHNV and *S. destruens* present in the water supply whose source may have been adult LFS above the barrier dam. Whether ozone treatments will continue to provide protection if restoration results in significantly more IHNV infected adults above hatchery intakes is uncertain. This will in part depend on prevalence of infection and number of adults present in these areas of Battle Creek when susceptible stages of fish are present at the CNFH.

Adult holding – Large numbers of adult FCS in Battle Creek and CNFH holding ponds is a second situation in which fish densities are conducive to pathogen amplification and transmission. This is not strictly a hatchery phenomenon as the amplification and spread of IHNV in wild sockeye salmon adults can lead to a high prevalence of infection (up to 100%) late in the run (Mulcahy et al 1982). These high adult densities facilitate adult to adult infections with IHNV within and between successive runs of Chinook salmon and to a much lesser extent to adult ST. Adult holding most likely increases zoospore production of *Saprolegnia* or other related water molds found on captive adult salmon or ST. The potential disease impacts of hatchery adults dying or spawning in Battle Creek is addressed under Facilities Risk part B.

2. **Does pathogen amplification in the hatchery result in doses sufficient to infect susceptible life stages exposed to hatchery effluent?**

The lack of actual data on levels of pathogens in the hatchery effluent makes these assessments difficult. Clearly, all of the pathogens mentioned in this review have the capability to spread via the water either directly or via some other host. With low doses of IHNV found in the water from a few initial adult salmon the virus can rapidly spread to infect other salmon in proximity. In fact, the spread of IHNV from adult to adult salmon may be one principal means by which the virus maintains itself in the upper Sacramento River. With respect to adult to fry transmission of the virus, adult LFS may be a potential source of virus that would infect sac fry and fry of SCS or ST that might be present or potentially moving in lower Battle Creek. Laboratory research at the Cal-Nev Fish Health Center (CA-NV FHC) and UC Davis are investigating this possibility using FCS and rainbow trout as surrogates for SCS and STT fry. That transmission of virus from adult to fry is not easily accomplished in lower Battle Creek has been demonstrated by CA-NV FHC personnel who found no evidence of virus in FCS sac fry captured below spawned out IHNV-positive adult FCS carcasses.

Pulses of other pathogens including *Flavobacterium, Yersinia,* the protozoans and the monogenetic trematodes present in hatchery effluent would have the potential to infect juvenile salmon or in some cases resident nonsalmonids in lower Battle Creek. It is not known how pathogens present in hatchery effluent influence the prevalence and carrier rates among resident nonsalmonids (this would not apply to host specific pathogens like IHNV but would apply to bacterial, protozoan and potentially some metazoan parasites). To date no systematic surveys of pathogens among lower Battle Creek salmonids or nonsalmonids have been undertaken. When large numbers of juvenile fish (up to 14 million) are present at CNFH and when disease outbreaks do occur it is likely that pathogen discharge does influence pathogen prevalence in susceptible stages of salmonids or nonsalmonids resident in Lower Battle Creek. This is based solely upon the potential volume/dose that would be present in the effluent when disease episodes are experienced in large hatchery populations.

3. **What is the interaction/effective contact between hatchery-origin and natural-origin populations in Battle Creek upon release or as they return to the hatchery?**

Adults – The increased probability of IHNV infection among co-mingled adults has been previously mentioned. Passage through the hatchery or temporary holding of natural-origin adults would most likely increase their probability of becoming infected with IHNV and *Saprolegnia* or other related water molds. It is also probable that in a fully restored Battle Creek that the temporally spaced runs of all four Chinook and steelhead trout could be conducive to maintenance of IHNV through adult to adult infections independent of CNFH operations.

Juveniles – Approximately 12 million FCS juveniles (in two en masse episodes) are released directly into lower Battle Creek. Most of these fish appear to migrate rapidly downstream and therefore minimize the potential transmission of pathogens they might carry to natural-origin FCS migrating with them (Foott and Williamson 1996). Studies by CA-NV FHC personnel with IHNV have shown the virus is not easily transmitted between infected juvenile salmon held at the low densities expected in out migrating fish (Free and Foott 1998, Foott et al. 2000). This is most likely the case with other pathogens present in low numbers on healthy fish released from the hatchery. This is one important reason, in addition to improved survival, to avoid releasing fish with disease signs. Many fewer hatchery-origin LFS and ST are released into lower Battle Creek. Potential disease transmission between healthy hatchery-origin fish and natural-origin fish present should be minimal for at least three reasons: 1) numbers of pathogens present should be low at the time of release (if only healthy fish are released), 2) densities following release are not conducive to transmission and 3) hatchery-origin and natural-origin fish older in age have potentially developed some immunity to more commonly encountered pathogens and this immunity would interfere with fish to fish transmission of these pathogens.

4. **What hatchery practices contribute to increasing/decreasing the potential for disease transmission between hatchery and natural fish populations?**

   a. Hatchery practices decreasing potential transmission.

Water treatment – Treatment of the water supply at CNFH that began in 1999 has reduced or eliminated the occurrences of certain pathogens. Most notably, IHNV has not appeared in any production lots at the hatchery since 1999. In addition, bacterial, protozoan and metazoan infections have been decreased in frequency and severity.

Prophylactic measures – All eggs are treated with standard iodophor procedures to reduce vertical transmission of viral, bacterial or other egg-associated pathogens. In addition, all LFS and ST juveniles are vaccinated to prevent *Y. ruckeri* infections. The young FCS are too small to effectively vaccinate and thus occasional outbreaks due to *Y. ruckeri* are still encountered and antibiotic therapy is utilized for control.

Rapid diagnosis and treatment – CNFH has the distinct advantage of having highly trained fish health expertise on site. The CA-NV FHC is located on the hatchery grounds and is staffed by personnel able to diagnose and prescribe control approaches that include the use of approved drugs or chemicals. Hatchery practices that routinely alert or seek CA-NV FHC support or advice will help to minimize disease episodes and thus potential pathogen discharges in effluent or with fish at release.

b. Hatchery practices increasing potential transmission.

Adult holding – The standard hatchery practice of confinement and amassing of large numbers of adults as a result of the barrier dam increases the potential for fish to fish transmission of pathogens and also the potential from hatchery-origin to natural-origin adults or fry.

Tagging – Tagging of juvenile fish involves direct trauma and greatly increases the potential for local infections with a number of opportunistic pathogens. Care in the process and appropriate follow up treatments when necessary can help to minimize infections that would be a potential source of pathogen release from the hatchery.

Demographic Risks

A. What is the risk to population sizes of Battle Creek salmon and steelhead from inclusion of wild fish in the hatchery broodstock at CNFH or LSNFH?

Steelhead seem to be the only fish for which a broodstock management plan intentionally uses wild Battle Creek fish in the hatchery. That plan calls for integration of the hatchery and wild populations by taking 40-80 wild adults into the hatchery each year (when the total number of wild fish is at least 200), and allowing enough hatchery adults above the weir to achieve a total population size of 2000 each year. This plan should not pose a demographic threat to the naturally spawning component of the integrated population unless the hatchery fish prove to be almost incapable of natural reproduction. The latter situation, however, is unlikely because USFWS's genetic analysis (Campton's presentation) has shown that the hatchery steelhead are capable of natural reproduction; indeed hatchery steelhead seem to have overwhelmed the early portion of the preexisting wild population. Crowding, stress, and handling in the hatchery as wild fish are passed upstream may increase mortality of wild fish and might pose a demographic threat[4]. We encourage monitoring to evaluate prespawning mortality.

Little if any depletion of Battle Creek winter Chinook salmon should result from collections of hatchery broodstock. No more than 120 wild adults are collected each year for hatchery broodstock, and the broodstock is collected well upstream from Battle Creek, near Redding. Homing of most Battle Creek fish to Battle Creek, and much larger numbers of Sacramento River fish should result in few Battle Creek fish in the broodstock. We suggest work to evaluate homing/straying of wild Battle Creek fish once a population is established. Otolith microchemistry may provide the best tool if the chemical signature left on the otoliths of fish rearing in Battle Creek can be readily distinguished from that of fish rearing in the Sacramento River.

Spring Chinook salmon are not intentionally taken for broodstock, and only the latest 5% of the Battle Creek run is diverted into CNFH when the ladder is closed after August for collection of fall Chinook salmon. Spring Chinook salmon that enter the hatchery are visually identified during the regular sorting operations and are then released to continue upstream migration. Even if the late fish experience increased (prespawning) mortality resulting from crowding, delay, and handling in the hatchery, the demographic effect on the overall population should be minor because only 5% of the population is involved; however, the effect on the late component might be substantial. Inasmuch as this late portion of the run might be important to a Battle Creek population and a greater proportion of the run may be handled in the future (see Genetic Risk, Question D.), we encourage monitoring to determine whether the prespawning mortality of spring Chinook salmon handled at the hatchery is greater than for those passing upstream when the ladder is open. If mortality of handled fish is greater, additional work should ensue to separate the effect of handling from the effect of return time.

Wild (i.e., unmarked) fish for the late-fall Chinook broodstock are collected from the Sacramento River above Redding and therefore should include few if any Battle Creek fish. Almost all of the late-fall Chinook salmon in Battle Creek are diverted into the hatchery, and the wild fish are released above the dam. Misidentification of late-fall Chinook salmon that enter CNFH and retention for the fall Chinook broodstock is a potential risk; however, hatchery personnel take care to avoid this mistake and the demographic risk is small. For this run also, crowding, stress, and handling in the hatchery as wild fish are passed upstream may increase mortality of wild fish. Although we expect any such mortality to be minor; monitoring should be conducted to evaluate prespawning mortality[1].

[4] Handling wild spring chinook salmon at Warm Springs National Fish Hatchery (Oregon) to separate them from hatchery fish and allow passage upstream seems to cause substantial prespawning mortality in the wild fish after they are passed upstream. This mortality was sufficient to cause the hatchery to install an automated fish separator to avoid handling the wild fish. Although we have no data from California to suggest a similar effect (and steelhead should be less susceptible than are salmon), we recommend that prespawning mortality be monitored.

Collection of fall Chinook salmon for broodstock would pose high risk for a wild population of fall Chinook salmon; however, we lack essential information for a firm conclusion. We have not seen a plan for how wild fall Chinook salmon that enter the hatchery could be separated from unmarked hatchery fall Chinook salmon fish and passed upstream to spawn. Nor do we know the spawning distribution (percent above and percent below the dam) for a restored population. Competition with overwhelming numbers of hatchery fish would seem to preclude a (self-sustaining) wild population below the barrier dam (see Ecological risk, Question A.), and we have no data to indicate the proportion of recruits from above the dam that would ascend the ladder to spawn upstream – i.e., we have no information on whether homing to the upper creek would be sufficient to allow a viable population above the dam. Currently the ladder at the barrier dam is open when the earliest (~5%) of the fall Chinook returns, so these fish will not be vulnerable to collection unless they delay in the lower creek and then move upstream after the ladder is closed. Unless all hatchery fall Chinook were marked, we see no way to segregate the wild fish that return when the ladder is closed and pass them above the dam so that they can maintain a self-sustaining population. Along with complete marking of hatchery fish, the hatchery may need to enhance their facilities or procedures for handling adult fall Chinook salmon to avoid excessive delay or stress to wild fish. Of course, this requirement to mark all hatchery fall Chinook salmon is conditioned on an assumption that restoration objectives included development of a self-sustaining population of fall Chinook salmon in upper Battle Creek. If restoration objectives did not call for development of a fall run of wild Chinook salmon in Battle Creek, then 100% marking of CNFH fall Chinook releases might not be necessary.

B. What risk to population size of Battle Creek salmon and steelhead populations is posed by potential poor reproductive performance on the spawning ground of hatchery-origin fish?

A growing body of scientific literature reports that hatchery-origin fish are less successful at reproduction than natural-origin fish (e.g, Chilcote et al. 1986; Fleming and Gross 1992; Lura et al. 1993; Petersson and Jarvi 1997). It is unclear to what extent it is a reflection of domestication and to what extent it is a reflection merely of being reared in a hatchery, but the general observation has been made so many times that this phenomenon should be considered a risk wherever a large proportion of the naturally spawning fish are from a hatchery.

The concern is that low relative fitness of hatchery-origin fish might reduce the effective population size of a naturally spawning population because of low fitness (see genetic Risk, Question A) or competition for spawning sites. Extremely low reproductive success for hatchery fish could mean that they add nothing to the effective population size, and actually reduce it in the current generation by drastically reducing the contribution of wild fish that interbreed with hatchery fish. Low reproductive success for hatchery fish could result in fewer adults the following generation. Thus, tracking the relative reproductive success of hatchery-origin spawners is an important monitoring measure in a supplementation program.

This concern relates to Battle Creek only if supplementation is or will be used in restoration. Currently a steelhead supplementation program is in place. The goal is to increase the population size to about 2000 fish, which is thought to be the basin's current capacity, by passing a mix of natural-origin and hatchery-origin fish in Battle Creek above CNFH. Currently the ratio of hatchery-origin to natural-origin is about 2:1 (S. Hamelberg, pers. comm.). Because the number of spawners will be at or above (the estimated) capacity, we are concerned that hatchery-origin spawners may be less successful that natural-origin spawners. If supplementation continues, the reproductive success of hatchery fish should be monitored relative to that for natural-origin fish – e.g., as currently proposed by USFWS in Campton's presentation to the Panel. Similar monitoring should be an integral part of any supplementation program to restore Battle Creek populations.

The possibilities for risk containment are fairly straightforward. Monitor the relative reproductive success of hatchery-origin and natural-origin spawners and reevaluate the supplementation strategy if the reproductive differential is large. Low reproductive success can be a problem when large numbers of hatchery-origin fish occur on the spawning grounds regardless of whether the event results from intentional supplementation or failure of the barrier system.

Facilities Risk

A. What risks are posed to Battle Creek salmon and steelhead from operation of the barrier dam and ladder at CNFH.

Background

A barrier dam is located on Battle Creek adjacent to CNFH. The dam is used to divert returning hatchery fish into the hatchery and to block fish from further ascending Battle Creek. Access to the upper creek is provided from the hatchery holding ponds and by a fish ladder at the North end of the dam. Prior to 2000, the fish ladder was closed from July through early March for collection of hatchery steelhead and salmon. Since 2000, the ladder has been closed from September 1 through early March. When the ladder is closed and wild Chinook salmon or steelhead encounter the dam, they are diverted into CNFH or remain in the creek. Some fish are able to jump and pass the dam. Wild fish diverted into the hatchery must be physically separated from returning hatchery fish and relocated above the barrier dam.

Issues of Concern

Our discussion below assumes that the upstream ladder at the barrier weir is open from early March through August, but is closed from September 1 through early March (CNFH Bio. Assess., 2001, p. 7-3). Given this current schedule of operation, we identified four related and potentially serious risks associated with operation of the barrier dam and fish ladder on Battle Creek:

1. Possible (selective) handling (or hatchery holding) mortality on components of the spawning runs of steelhead, winter and spring Chinook salmon that migrate when the barrier dam ladder is closed;
2. Possible delays in spawning migrations of the same stock components identified in (a), again due to migration timing that coincides with closure of the barrier dam ladder;
3. A substantial likelihood that large numbers (often exceeding 20,000) of hatchery fall Chinook salmon might pass through the barrier dam ladder when the barrier dam ladder is open. Hatchery fall Chinook might interbreed with spring Chinook, compete for spawning areas, or superimpose nests on earlier-spawning spring Chinook. Fall Chinook juveniles surviving from natural spawning of hatchery fall Chinook might compete with wild juvenile Chinook, especially spring run; and
4. For fall Chinook salmon, existing marking programs (low marking rates for hatchery fall-run Chinook) compromises reliable separation of hatchery fall Chinook from wild Chinook salmon (spring, late-fall, or fall).

Below we address each of the above risks in greater detail.

1. All but the late portion (mid-February through March) of the steelhead run encounter the barrier dam fish ladder when the ladder is closed for collection of hatchery salmon and steelhead (September through early March). The early portion (mid-December through early March) of the winter Chinook population would be similarly affected. Immediate or delayed mortality of wild adult steelhead or winter Chinook that enter the hatchery might result from disease transmission or increased stress due to handling or the high densities of salmon in the holding ponds at CNFH (See footnote 4). We suggest monitoring to evaluate whether prespawning mortality of wild steelhead or winter Chinook within CHFH, or on spawning grounds, is substantial. If prespawning mortality is substantial, then research should be initiated to evaluate the role of crowding and handling in the hatchery.

2. In addition to possible immediate or delayed mortality associated with hatchery handling of the late portion of the wild steelhead run and the early portion of the winter Chinook run, both run components might also experience delayed migration and a possible shift in eventual locations of spawning as a consequence of delay or handling at CNFH.

   The barrier dam ladder is open during almost the full duration of the adult spring Chinook migration, and we anticipate no dam-related problems for these fish. The ladder will be closed for the latest segment (<5%) of the run. Neither the effect of delay and handling on this segment, nor the importance of this segment to a Battle Creek population are known. We anticipate no significant problem for the wild population but recognize this as an uncertainty and recommend appropriate monitoring.

   Almost all of the late-fall Chinook salmon in Battle Creek are diverted into the hatchery; wild (unmarked) late-fall Chinook could be released above the dam. Wild late-fall Chinook might also experience some handling mortality and delayed migration, but effects might be less on this stock than on the earlier runs because water temperatures should be lower when the late-fall Chinook migrate up Battle Creek.

3. Current operation of the barrier dam ladder appears to allow passage of all fall Chinook salmon, regardless of origin, during the earliest part of the run (August), and substantial numbers can pass later if flows exceed 350 cfs. Therefore, as many as 20,000 (~5% of the hatchery fall Chinook run) or more adult hatchery fish may pass above the barrier dam and spawn in Battle Creek. Such a large number of hatchery fall Chinook salmon may pose competitive risks for a wild population of fall Chinook salmon if a wild fall Chinook population is desired in Battle Creek.

4. Unless the fall Chinook program at CNFH is changed so that all hatchery salmon are marked, we see no way to segregate wild and hatchery fall Chinook or to allow *only* wild fall Chinook to pass above the dam so that they can maintain a self-sustaining population. Foregoing restoration (i.e., development of a self-sustaining population) of fall Chinook salmon would alleviate this problem and several others (see Genetic Risk, Question D.).

Recommendations

1. Physical or human failures that block fish when they should have free passage, or pass fish when they should be blocked at the barrier dam, were not covered at the workshop but should be considered. A system of checks and balances probably already exists. Such a system should be reviewed and maintained to minimize human failure (e.g., ladder open when it should be closed; and vice versa) and to provide daily records of dam and ladder operations. Hatchery personnel have considered physical failures and have plans to avoid them. We support and encourage such planning, and the associated monitoring of successful jumping (and passage during high flows) and fall-back (fish failing to remain above the dam once they have passed it). We also recommend contingency plans (which may exist already) to ensure that catastrophic failure of the barrier dam, due to floods or other events, can be corrected as quickly as possible.

2. We suggest continuation and perhaps expansion of carcass surveys to assess prespawning mortality in wild fish for each run. We also suggest using radio or other appropriate tags on some of the wild steelhead, and spring and winter Chinook salmon as they enter CNFH to assess possible delays in spawning migration and handling-induced shifts in spawning locations.

3. We believe that CNFH should close the barrier dam during July and August, as was apparently practiced prior to 2000 (CNFH Bio Assess. 2001, at 7-5) unless this change would harm spring Chinook salmon. Such a closure should prevent large numbers of hatchery fall Chinook from passing the barrier dam. Although this change should affect only a small proportion of the spring Chinook, the effect should be assessed (see [2] above). We support the USFWS proposal to improve the effectiveness of the barrier dam and the facilities for passing fish upstream.

4. For reasons given here and elsewhere in this review, we believe the barrier dam should be used to deliberately prevent upstream passage of hatchery *and* wild fall Chinook salmon. Given the relatively small amount of upstream spawning and rearing habitat for fall

Chinook in Battle Creek, its relatively poor quality for fall Chinook as compared to winter or spring Chinook (see, e.g., Figures 15-19 in Kier Associates 1999, Battle Creek Salmon and Steelhead Restoration Plan), and the clear potential for fall Chinook adults or juveniles to compete for spawning or rearing space with winter and spring Chinook and possibly also steelhead, it seems risky to encourage development of a substantial fall Chinook run above the barrier weir.

5. We recommend that a combination of genetic and visual methods be used to ensure that, to the maximum extent feasible, only spring Chinook are passed above the weir during periods when the barrier weir ladder is closed and both unmarked hatchery fall Chinook and unmarked wild spring Chinook may be entering CNFH.

B. What risks are posed to Battle Creek salmon and steelhead populations from water withdrawals for CNFH use and by possible entrainment at intake screens?

Background

Chapter 4 of the 2001 CNFH Biological Assessment provides a summary of the water rights and water diversions at CNFH as well as a discussion of intake screening.

The hatchery's primary intake (Intake 1) is located at the Coleman Powerhouse about 1.6 miles upstream of the hatchery property boundary. Water entering Intake 1 actually originates from the Inskip Powerhouse on the South Fork of Battle Creek, above the Coleman diversion dam. Therefore, under current conditions, no anadromous fish would be entrained at this intake. The Coleman Diversion Dam is scheduled for removal, however, so anadromous fish could be entrained in the future. Water from Intake 1 travels to the hatchery via a 46" diameter conveyance pipe.

Intake 2 is located on the south bank of Battle Creek, immediately opposite Intake 1. This intake is used as an emergency backup to Intake 1 in the event of canal failure or powerhouse maintenance that prevents use of Intake 1. Over the past ten years, Intake 2 has been used an average of about 17 days annually. Water from Intake 2 travels to the hatchery via the same 46" diameter conveyance pipe used to deliver water from Intake 1. This intake also appears to be unscreened although a flap gate blocks entrance of fish when the intake is not in use.

Intake 3 draws water directly from Battle Creek, approximately 0.4 miles downstream of Intake 2, and about 1.2 miles upstream of the hatchery property boundary. Water is delivered to the hatchery via a 48" diameter pipeline. This intake was screened in 1998 although the method of screening has apparently not met NMFS "fail-safe" screening criteria.

Intakes 1 and 2 are used primarily to supply 28 15'x150' raceways, whereas Intake 3 is used primarily to supply 30 8'x80' raceways and the hatchery's incubation and early-rearing building. A detailed description of the CNRH water delivery system apparently can be found in Sverdrup and Tetra Tech/KCM 1999), but our Panel was not given that document.

CNFH has water rights (with priority diversion dates ranging from 1950 through 1965) on Battle Creek that allow diversion of up to 122 cfs. Of this total flow, about 50 cfs are usually taken through Intake 1 and up to 50 cfs additional flow may be taken via Intake 3. As Intakes 1 and 2 cannot be simultaneously operated, it does not appear that the full 122 cfs water right can be diverted given current intake design. However, monthly water requirements are reported to range from 34 to 119 cfs, and an additional 23 cfs must be delivered to downstream users below the hatchery. Presumably, these obligatory downstream deliveries carry with them priority permits that allow CNFH to at times take close to its full 122 cfs total water right.

Table 4-5 in the 2001 CNFH Biological Assessment displays average monthly discharge for Battle Creek and compares these to recommended minimum monthly discharge and average CNFH diversions. Average monthly flows in Battle Creek have been measured at USGS gaging station 11376550 (location unspecified, but presumably below the Coleman Powerhouse tailrace or near the points of diversion at Intakes 2 and 3). Average monthly flows from 1961-1996 ranged from a low of 255 cfs during September to a high of about 725 cfs during January. CNFH water requirements range from about 25 cfs during May to about 119 cfs during January. Percentage of total Battle Creek flows diverted by CNFH ranged from about 6% of total flow during May to nearly 35% of total flow during September.

There are no direct estimates of the total number of juvenile anadromous salmonids that are entrained or impinged as a consequence of diverting water for operation of CNFH. Table 4-3 in the 2001 CNFH Biological Assessment provides estimates of possible take (losses) resulting from CNFH water diversions. These range from a low of 933 juvenile spring Chinook to a high of 19,556 juvenile fall Chinook. Appendix 4A of that document presents a detailed accounting of how these values were calculated. Assumed numbers of naturally spawning adults that produced the hypothetical numbers of juveniles that might be vulnerable to entrainment or impingement were 100 each for winter and spring Chinook, and 1,500 each for fall and late fall Chinook.

Issues of Concern

1. From approximately September 1 through November 30, average CNFH diversions of water range from about 30% - 40% of total creek flows at the points of diversion in lower Battle Creek. According to Table 4A-2 of the CNFH Biological Assessment, and p. 4-10 of this same document, this period of largest percentage diversion of water from Battle Creek coincides with the peak emigration timing of winter Chinook salmon. The CNFH Biological Assessment assumes that the emigration of juvenile winter Chinook would be 13.5% during August, 68% during September, 13.5% during October, and 2.5% during November. Average August diversion percentage is about 25%. The large percentage of Battle Creek flows that is diverted during the months of August through November, and the coincidence of this high percentage diversion with the majority of probable emigration of juvenile winter run Chinook creates substantial concerns regarding entrainment or impingement.

2. Intakes 1 and 2 are unscreened. Although Intake 2 is rarely used, Intake 1 could possibly create a substantial future entrainment/impingement problem once the Coleman Diversion Dam is removed according to the restoration plan's preferred alternative. Intake

3 appears to have been screened since 1998, but screen design apparently does not yet achieve the NMFS "fail-safe" standards.

3. During periods of drought and/or emergency situations (e.g., hydropower facilities failures), CNFH diversions may be sufficiently large compared to total Battle Creek flows that flow in the hatchery-affected reach (i.e., below the three hatchery Intakes) might drop below proposed minimum flows.

Recommendations

Inadequate or nonexistent screening of the hatchery intakes to CNFH poses a significant risk to salmon and steelhead in the restoration project. Inadequate screening results in diversion, entrainment or impingement of natural-origin salmon and steelhead trout from upper Battle Creek. As indicated in the CNFH Biological Assessment, the proper “fail-safe” screening of these intakes is required to prevent the current “salvage” operations that are of limited value. We recommend the following specific actions:

1. Prior to the restoration activities, CNFH should ensure that Intakes 2 and 3 are fitted with fish screens that meet or exceed NMFS standards for "fail-safe" design.

2. When the Coleman Diversion Dam has been removed as part of the restoration plan, the furthest upstream diversion of water (Inskip diversion dam) that feeds the Coleman Canal, and eventually feeds Intake 1, should also be fitted with a "fail-safe" fish screen.

3. To the maximum extent possible, CNFH operations should attempt to minimize use of Battle Creek water, especially during the relatively low flow period of August through November when juvenile winter run Chinook would be expected to emigrate to the mainstem Sacramento. Entrainment/impingement impacts would seem to be a function of (a) screen effectiveness and (b) percent of flow diverted. Impacts could be reduced by (a) improving effectiveness of screens and/or (b) reducing percent of flow diverted.

4. Currently available data and hypothetical calculations do not allow an empirical assessment of actual entrainment/impingement related to CNFH water diversions. Routine monitoring of entrainment/impingement at all three intakes should be an obligatory CNFH responsibility after Coleman Diversion Dam is removed and revised flow regimes have been implemented.

B. What disease risks are posed to Battle Creek salmon and steelhead populations as fish pass through hatchery facilities or hatchery effluent waters?

This question has been addressed in previous sections that cover the holding and handling of adult salmon and steelhead that would be passed above the barrier dam (see Ecological Risk Question D. keypoints no. 5, assessments no. 4 and Facility Risks Question A). The inherent stress and trauma associated with holding and handling of adult salmon and steelhead will increase the opportunity for disease and potential for prespawning mortality due to water molds (*Saprolegnia*) or other opportunistic pathogens. Holding adults bound for placement above the barrier dam will also increase the opportunity for adult to adult transmission of IHNV. Whether this would increase the prevalence of IHNV in upper Battle Creek salmon and steelhead trout compared to fish that had not been artificially impounded is unknown. The contact of natural-origin fish at all life stages with effluents from hatchery waters are of concern and covered in detail in Ecological Risk Question D.

Recommendations

1. Reduce to as minimal as possible holding and handling of fish destined to be passed above the barrier dam.

2. Minimize all potential for hatchery effluent waters to contain pathogens by strict attention to intake water safeguards, health care procedures and preventative protocols, and release of only healthy fish.

C. What risks to Battle Creek salmon and steelhead populations by the large surpluses of CNFH fall Chinook returnees in the lower section of Battle Creek?

Disease transmission issues associated with the large surpluses of adult hatchery-origin FCS have been addressed in prior sections (See Ecological Risks D keypoints no. 3 and 4, assessment no. 2). Surpluses (> 8,000) have occurred routinely since 1990 with minimum surpluses in 1992 (3,500) and maximum (455,000) in 2002. With such large excesses, water quality is severely compromised by low dissolved oxygen and high organic loads associated with decaying carcasses. Pre-spawning losses of both hatchery and natural-origin adult FCS have been observed at these fish densities. Losses of adult SCS making their way through this environment might also occur. Lastly, early rearing of natural-origin FCS would be compromised as a result of this environment. The carcasses have gone and water quality improves significantly by late December and January when flows in Battle Creek begin to increase and this risk is reduced.

Current hatchery practices attempt to move as many surplus FCS adults into the holding ponds as possible. The fish are killed and trucked out but only a fraction of the surplus can be handled with the current procedures.

Recommendations

1. Consider reducing juvenile releases to lessen numbers of adult FCS returning to CNFH. Lower numbers of FCS adults would also lessen the stress associated with handling/sorting or holding of LCS and late segment SCS adults present during the same period.

2. Explore improved methods to remove excess adults from adult holding ponds

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Appendix

List of documents given to Panel members.

- The 2001 USFWS biological assessment of effects of operation of CNFH
- A Conservancy report, " Maximizing compatibility between Coleman National Fish Hatchery Operations, Management of Lower Battle Creek, and Salmon and Steelhead Restoration" . 1999, Kier Associates.
- A proposal, " Managing Risk to Facilitate the Success of the Battle Creek Salmon and Steelhead Restoration Project" . 2001 A proposal to the Packard Foundation by the Battle Creek Watershed Conservancy.
- CDs of the Battle Creek Salmon and Steelhead Restoration Project – Draft EIR/EIS – Main report (Disc 1) and Appendices (Disc 2).
- Descriptions of alternate actions and operations at CNFH being considered by the USFWS and other interested parties
- Volume 1 of California Department of Fish and Game Fish Bulletin 179. The Panel was particularly encouraged to consider material in the papers on Central Valley salmon genetics, history of the CNFH and historical abundance of Chinook salmon in the Central Valley.
- A report, " Coleman National Fish Hatchery Barrier Weir – Preliminary Concept Study Report" – 2002 by the USBR
- A report, " Battle Creek Salmon and Steelhead Restoration Plan" 1999, by Kier Associates
- Technical Review Panel – Battle Creek Salmon and Steelhead Restoration Project. A September 2003 Panel report to CALFED.

- Page from AFRP Working Paper on Restoration Needs – Volume 3 – describing salmonid goals for Battle Creek.
- 12/16/94 memo from Steve Croci (USFWS) to Dave Hoopaugh (DFG) on the Battle Creek plan.
- Thorpe, JE. 1994. Salmonid Flexibility : Response to Environmental Extremes. Trans. Amer. Fish Society:123:606-612
- Microsoft power point slides from presentations
- Draft of Michael Ward's watershed assessment
- Williamson and May (20030 report to CALFED about genetics of Central Valley fall run Chinook salmon
- Weber and Fausch 2003a -- a report on competition between hatchery and naturally spawned juvenile salmon on the upper Sacramento River
- Weber and Fausch 2003b -- a paper on the above project published in the *Canadian Journal of Fisheries and Aquatic Sciences*