Battle Creek Winter-Run Chinook Salmon Reintroduction Plan

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List of Acronyms and Abbreviations

Advisory Committee	interagency technical advisory committee
ACID	Anderson-Cottonwood Irrigation Dam
AMP	Adaptive Management Plan
AMPT	Adaptive Management Policy Team
AMTT	Adaptive Management Technical Team
BCRP	Battle Creek Salmon and Steelhead Restoration Project
BCRP AMP	*Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan*
CDFW	California Department of Fish and Wildlife
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CNFH	Coleman National Fish Hatchery
CNFH AMP	*Coleman National Fish Hatchery Adaptive Management Plan*
Coleman weir	barrier weir at Coleman National Fish Hatchery
CTWS	Confederated Tribes of the Warm Spring Reservation of Oregon
CWT	coded wire tag
Delta	Sacramento-San Joaquin River Delta
ESA	federal Endangered Species Act
ESU	evolutionarily significant unit
FGP	full genetic parentage
HGMP	Hatchery and Genetics Management Plan
ICF	ICF International
LSNFH	Livingston Stone National Fish Hatchery
LSNFH HGMP	*Livingston Stone National Fish Hatchery – Hatchery and Genetics Management Plan*
MOU	memorandum of understanding
N_e	Effective population size: defined as an ideal population that would have the same rate of genetic change as a natural population under consideration
NF Battle Creek	North Fork Battle Creek
NMFS	National Marine Fisheries Service

NMFS Recovery Plan	*Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon, and the Distinct Population Segment of California Central Valley Steelhead*
ODFW	Oregon Department of Fish and Wildlife
PG&E	Pacific Gas and Electric Company
pHOS	contribution of hatchery spawners in nature
PIT tag	passive integrated transponder tag
PNI	proportionate natural influence
RBDD	Red Bluff Diversion Dam
Reintroduction Plan	*Battle Creek Winter-Run Chinook Salmon Reintroduction Plan*
RM	river mile
RM&E	research, monitoring, and evaluation
SAR	smolt-to-adult return
SCARF	San Joaquin Conservation and Research Facility
SF Battle Creek	South Fork Battle Creek
SJRRP	San Joaquin River Restoration Program
TCD	temperature control device
TRT	Central Valley Technical Recovery Team
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population

Chapter 1
Introduction and Goals

1.1 Introduction

Expanding the spatial structure of the winter-run Chinook Salmon (*Oncorhynchus tshawytscha*) Evolutionarily Significant Unit (ESU) into vacant but historically occupied habitat is a high-priority action identified by the National Marine Fisheries Service (NMFS) in its recovery plan for threatened and endangered salmonids in the California Central Valley (NMFS 2014a). The restoration of Battle Creek pursuant to a memorandum of understanding (MOU) between several federal and state agencies and Pacific Gas & Electric Company (PG&E) presents an opportunity to implement an important recovery action for winter-run Chinook Salmon in Battle Creek.

The California Department of Fish and Wildlife (CDFW) contracted with ICF International (ICF) to work with an interagency technical advisory committee (Advisory Committee, Appendix A) to develop a *Battle Creek Winter-Run Chinook Salmon Reintroduction Plan* (Reintroduction Plan). The Advisory Committee comprised representation from CDFW, U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), NMFS, PG&E, and the Battle Creek Watershed Conservancy. This group, along with the ICF team, is referred to in this plan as the "workgroup."

The workgroup built upon the considerable work of a prior interagency effort involving the same entities. The prior team developed much of the background information and analyzed several options for reintroduction, but did not have the time or resources to finish a plan. The workgroup is thankful for their contribution to this effort.

At the time of drafting this plan, an implementing agency had not been identified to carry out the plan. Consequently, some of the content is less precise than it otherwise might have been. For example, we were unable to specify a location and precise design for alternative collection sites or facilities for producing and growing winter-run Chinook Salmon in Battle Creek.

The geographic areas referred to in this plan and the existing facilities important to implementation of the plan are shown in Figure 1.

1.2 Purpose and Content of This Reintroduction Plan

The purpose of the Reintroduction Plan is to describe the issues, considerations, and steps necessary to reestablish a population of Sacramento River winter-run Chinook Salmon in North Fork Battle Creek (NF Battle Creek), which will contribute to the recovery of the Sacramento River winter-run Chinook Salmon (NMFS 2014a).

The NMFS recovery strategy for California's Central Valley salmon and steelhead is to secure existing populations and reintroduce salmon to historically occupied or suitable habitats (NMFS 2014a). Specifically for winter-run Chinook Salmon, the strategy calls for the establishment of three populations at low risk of extinction. Battle Creek presents a reasonable option for reestablishment of an independent population because the Battle Creek Salmon and Steelhead Restoration Project (BCRP) (USBR 2008) is expected to restore unencumbered access to quality spring-fed spawning habitat in NF Battle Creek by 2017.[1] This document describes the process for reintroducing winter-run Chinook Salmon to its historical spawning and rearing habitat in NF Battle Creek, assuming successful implementation of the BCRP.

1.3 Historical and Present Status

The winter-run Chinook Salmon ESU is uniquely adapted to the basalt and porous lava geology of the upper Sacramento River Basin (Lindley et al. 2004). It is the only Chinook Salmon ESU that exhibits aspects of both stream-type and ocean-type life histories (Healy 1991).[2] Winter-run Chinook Salmon begin their migration from the ocean to their spawning grounds in late fall and winter. They leave the ocean in an immature condition (i.e., gametes are not sufficiently ripe for spawning) and migrate to coldwater habitats where they hold while their eggs mature (a stream-type strategy). Spawning occurs during late spring and summer months when air temperatures usually approach their yearly maxima. Juveniles rear in the river and Sacramento-San Joaquin River Delta (Delta) from summer into fall and winter, and migrate to sea in late winter and spring (ocean-type strategy) before water temperatures in the mainstem Sacramento River become too warm. Historically, these spawning and rearing habitats were found in the Little Sacramento, McCloud, and Pit Rivers and in Battle Creek (Yoshiyama et al. 1998), which are fed by glacial and snow melt from the flanks of Mt. Shasta and Mt. Lassen.

Winter-run Chinook Salmon are the only salmon ESU on the West Coast that has been entirely dislocated from its historical spawning and rearing habitat (Myers et al. 1998). Winter-run Chinook Salmon were excluded from their spawning and rearing habitat in Battle Creek in the early 1900s, in large part by hydroelectric development, and they were excluded from the remainder of their spawning and rearing habitat in the upper Sacramento River Basin by construction of Shasta and Keswick Dams in the 1940s (Reynolds et al. 1993).

Winter-run Chinook Salmon persist in the Sacramento River as a single population in habitat artificially maintained by the release of cold water from Shasta Dam on the upper Sacramento River.[3] This persistence is precarious, however, because limited supplies of cold water in Shasta Reservoir are sometimes insufficient to meet the needs of winter-run Chinook Salmon in critically dry or consecutively dry years (Reynolds et al. 1993; NMFS 2014a).

Releases of cold water from Shasta Reservoir created cold-water habitat downstream of Keswick Dam in a portion of the river that previously would have warmed to lethal temperatures (CDWR 1988) for incubating salmon eggs and fry during summer and early fall. For a period of time in the mid-1960s, prior to the construction of Red Bluff Diversion Dam (RBDD), winter-run Chinook Salmon thrived in this modified habitat.

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[1] Available at: http://www.usbr.gov/mp/battlecreek/status.html.

[2] Spring run-Chinook adults also enter the Sacrament River in an immature condition and hold in cool springs and pools until spawning in late summer and fall. Some juveniles, particularly those spawned in lower elevation streams such as Butte Creek, outmigrate as young of the year (ocean type). Others remain and outmigrate as yearlings (stream type) (CDFG 2004).

[3] For purposes of this document, the upper Sacramento River is defined as the reach between RBDD and Shasta Dam.

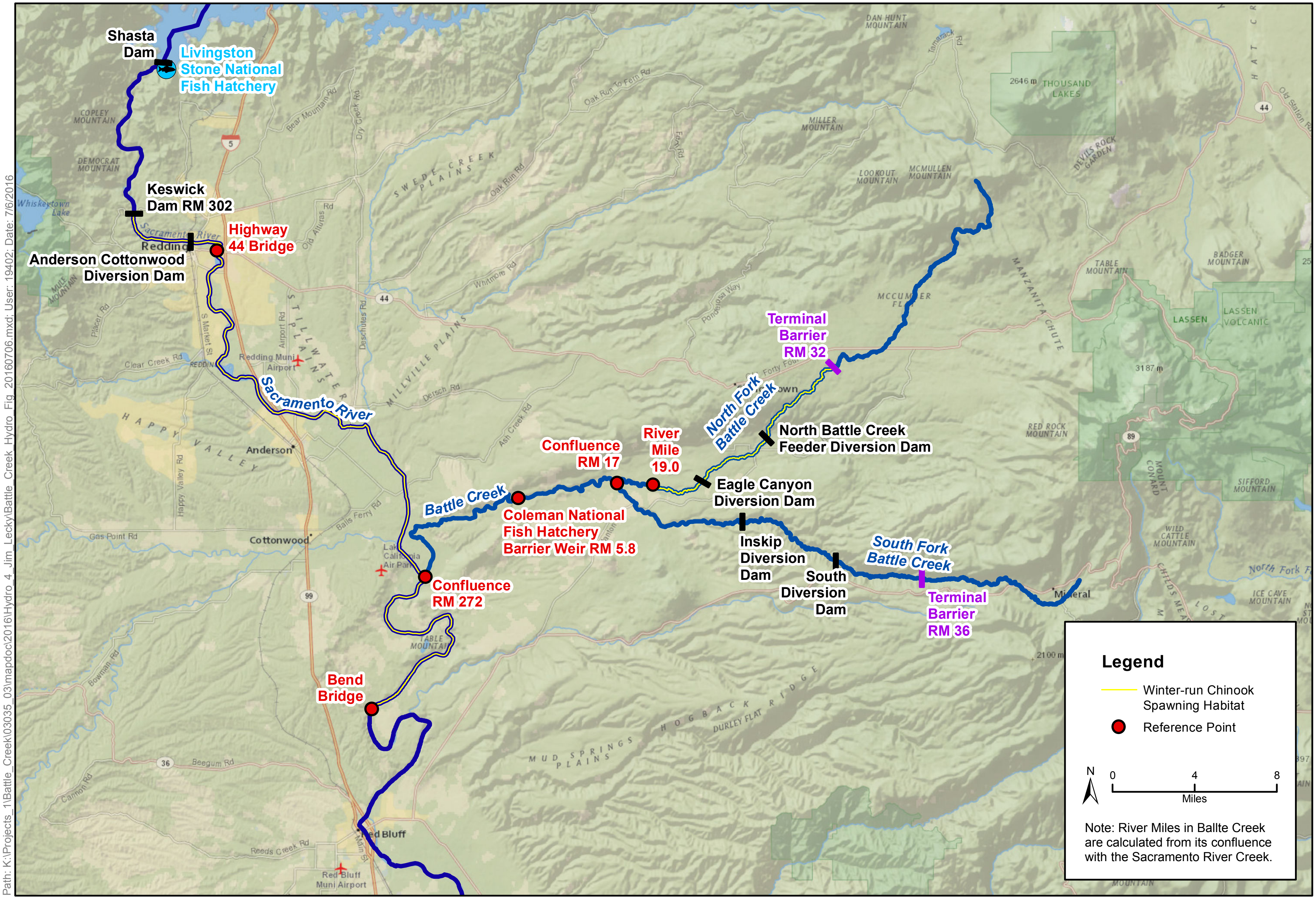

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Figure 1
Battle Creek Winter-Run Chinook Salmon Reintroduction Plan
Geographic Area and Relevant Facilities

Following construction of RBDD, the population began to decline. Although RBDD was constructed with fish passage facilities, the dam impeded passage and contributed to adults spawning downstream of the structure (Hallock et al. 1982). Spawning downstream of RBDD tends to be unsuccessful because that reach of the river is beyond the influence of the cold water released from Shasta Reservoir, and water temperatures above 56°F result in increased egg mortality (Gains and Martin 2002). RBDD also was a source of mortality for downstream migrant juveniles that were spawned above the dam. Turbulence created when the dam's gates were lowered into the river disoriented juvenile outmigrants, making them easy prey for predatory fish such as the Sacramento pikeminnow (*Ptychocheilus grandis*) that concentrated below the dam (Vogel and Marine 1991). Following closure of the dam gates in 1966, the year classes that were at sea returned strong, and then the population began a steady decline (Figure 2) attributable to the cumulative effects of habitat loss, fishing pressures, entrainment, and the added effects of the new barrier. (Myers et al. 1998). This decline ultimately led to their listing under the California Endangered Species Act (CESA) and federal Endangered Species Acts (ESA) in 1989 (NMFS 1989).

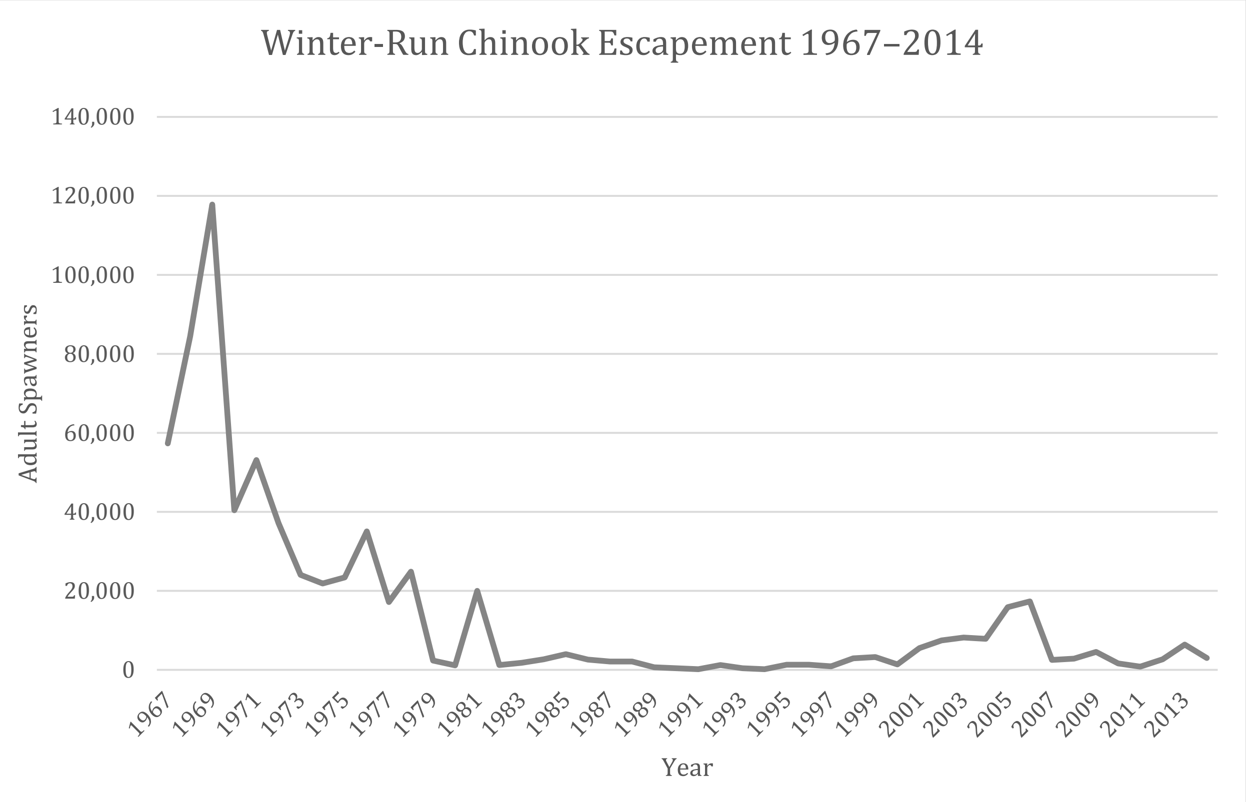

Figure 2
Estimated Escapement of Winter-Run Chinook Salmon in the Sacramento River
(Source: CDFW GrandTab 2015)

In 1989, USFWS initiated a hatchery supplementation program at Coleman National Fish Hatchery (CNFH) on Battle Creek to supplement the declining winter-run Chinook Salmon population in the Sacramento River. The program captured natural-origin spawners, spawned them in the hatchery, and reared them to pre-smolt stage for release on the spawning grounds in the Sacramento River. The expectation of the program was that adult returns from these releases would return to spawn in the Sacramento River; however, many of the adults returned instead to Battle Creek (Hedrick et al. 2000). In 1998, the supplementation program was transferred to the Livingston Stone National Fish Hatchery (LSNFH), a new hatchery facility at the foot of Shasta Dam on the Sacramento River. The program in this new location has been successful in returning spawners to the Sacramento River and contributing to the persistence of the population (NMFS 2014a).

In 1992, a captive broodstock program was initiated at Bodega Bay Marine Laboratory, University of California, and at Steinhart Aquarium, California Academy of Sciences, out of concern for the continued existence of the stock following the sever decline in 1989. This program was worked collaboratively with the winter-run Chinook Salmon supplementation program at CNFH and then at LSNFH by providing gametes for fertilization with wild winter-run Chinook Salmon collected for the supplementation program (Arkush et al. 1996). The captive broodstock program ended in 2004 based on signs that the population was recovering (Figure 2). In 2014, the captive broodstock program was revived at LSHFH due to concerns about low population levels and adverse temperature effects related to persistent drought conditions (Interagency Fish Passage Steering Committee 2015).

USBR also has contributed to the conservation of winter-run Chinook by enhancing its ability to manage and provide cold water to maintain spawning and rearing habitat below Keswick Dam. It installed a temperature control device (TCD) at Shasta Dam in 1997, with a low-level intake structure and a series of gates to access cold water from various depths, and it sequentially modified operations at RBDD to improve passage, culminating in construction of a new diversion facility and permanent suspension of the dam gate operations in 2012.[4] These actions, in combination with other conservation measures (e.g., reduction in ocean harvest, installation of fish screens at water diversions, constraints on Delta operations, and a supplementation program), led to a period of higher returns between 2001 and 2006 (NMFS 2010). In 2007, however, returns faltered, likely due to poor ocean conditions (NMFS 2010), and have remained low to date (Figure 2).

Even with a TCD to assist in management of the coldwater pool in Shasta Reservoir, the ability to influence temperatures in the Sacramento River is limited by water supply and ambient air temperature. In years of abundant snow pack and cool weather conditions, spawning habitat may be available as far downstream as RBDD. In low water years or years with hotter ambient air temperatures, spawning habitat may be extremely limited, as evidenced by the near reproductive failure of the 1976 and 1977 brood years (Nehlsen et al. 1991).

The winter-run Chinook Salmon ESU remains a single population, persisting in a high-risk, artificially maintained environment entirely, dependent on the availability of cold water in Shasta Reservoir and USBR's ability to manage and deliver it. This makes the ESU extremely vulnerable to catastrophic events (i.e., drought) and climate change (NMFS 2014a). The ongoing drought (2010–2016) has depleted reservoir storage, and the USBR is again challenged with lack of coldwater

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[4] The Fish Passage Improvement Project at the Red Bluff Diversion Dam: http://www.tccanal.com/RBDD-Bro-Sept2012-NoCrop.pdf.

reserves. In 2014, the winter-run Chinook Salmon egg-to-fry survival was exceptionally low as a result of depletion of cold water reserves that increased water temperatures in the spawning areas (USBR 2015). In 2015, the California State Water Resources Control Board (SWRCB 2015) approved a change in operations to retain water in Shasta Reservoir for summer temperature control. This situation is consistent with climate change models, which predict more frequent and prolonged droughts creating increasing challenges for management of the coldwater pool in Shasta Reservoir and adverse effects—particularly for winter and spring-runs of Chinook Salmon—as average atmospheric temperatures warm by 2°C or more (Yates et al. 2008). These conditions also emphasize the importance of increasing the spatial distribution of the winter-run ESU for long-term viability by establishing additional populations in secure locations within its historical range (e.g., NF Battle Creek).

1.4 Battle Creek Restoration Program – History, Current Status, and Future Direction

Reestablishing winter-run Chinook Salmon in Battle Creek has been under consideration for some time (see timeline in USBR 2008).The U.S. Bureau of Sportfish and Wildlife (1962, as cited in Kier Associates 1999) recognized the unique environmental conditions in Battle Creek and proposed that natural streamflow be restored to meet the needs of winter- and spring-run Chinook Salmon. However, the hydropower system within Battle Creek was an impediment to restoration due to blockages, depletion of flows, and conveyance of water from NF Battle Creek to South Fork Battle Creek (SF Battle Creek). In 1999, PG&E, the owner and operator of the hydropower facilities in Battle Creek; NMFS; USBR; USFWS; and the California Department of Fish and Game (now the California Department of Fish and Wildlife) entered into an MOU to facilitate development of the BCRP.

Following signing of the MOU, the signatories formed the Greater Battle Creek Watershed Working Group and, in cooperation with the Battle Creek Watershed Conservancy, undertook a period of investigation, project design, and environmental review. In 2008, USBR published a record of decision, identifying the preferred alternative for the restoration program to be implemented cooperatively by the signatories to the MOU and other interested parties. When completed, the BCRP will provide passage either by removing facilities or providing passage over manmade and natural barriers in the system, augmenting flows within the North and South Forks of Battle Creek, and disconnecting the conveyance of water from the North Fork to the South Fork of Battle Creek. Upon completion of the project, access to approximately 48 miles of spawning and rearing habitat is expected to be restored in the Battle Creek watershed for the assemblage of salmonids[5] that inhabited Battle Creek historically. Twenty-five miles of this habitat will be in the North Fork, of which 10 to 12 miles is expected to be suitable for winter-run Chinook Salmon spawning and incubation of winter-run Chinook Salmon eggs.[6]

Implementation of the BCRP was divided into three phases. Phase 1A, focuses on actions in NF Battle Creek, where cold spring-fed habitat most suitable for winter-run likely exists year round. Phases 1B

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[5] Historically, four runs of salmon (fall, late-fall, winter, and spring-runs) and steelhead trout occurred in Battle Creek.

[6] See Normandeau Associates report (Appendix B).

and 2 focus on SF Battle Creek, where spring-run and steelhead are likely to be the beneficiaries. Phase 1A is nearing completion, and final construction is expected to be completed by the end of 2017 (USBR, http://www.usbr.gov/mp/battlecreek/status.html). Completion of Phase 1A is essential to ensuring that winter-run Chinook Salmon have access to the quality spawning and rearing habitat expected to exist in the reaches above Eagle Canyon and North Battle Creek Feeder Diversion Dams.

The Reintroduction Plan described in this document is an outgrowth of the BCRP and is a key action in the NMFS *Recovery Plan for the Evolutionarily Significant Units of Sacrament River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon, and the Distinct Population Segment of California Central Valley Steelhead* (NMFS Recovery Plan) (NMFS 2014a). Reintroduction of winter-run Chinook Salmon into NF Battle Creek is part of a larger strategy in the NMFS Recovery Plan to restore some of the spatial structure of the ESU by reintroducing populations to habitats from which they have been extirpated.

1.5 Reintroduction Goals

NMFS has determined that a primary threat to the continued existence of winter-run Chinook Salmon is that the current naturally spawning component of the ESU consists of a single population in the mainstem Sacramento River, whose existence depends on the release of cold water from Shasta Reservoir (NMFS 2014a). As noted, the ESU is extremely vulnerable to catastrophic events that could lead to its extinction. Establishment of a separate, independent population of winter-run Chinook Salmon in Battle Creek is a goal of the BCRP and a key component of the NMFS *Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead* (NMFS Recovery Plan) (NMFS 2014a). This Reintroduction Plan describes the process for establishing an independent population of winter-run Chinook Salmon in Battle Creek to address this threat by increasing the spatial diversity of the ESU and increasing its resiliency.

1.5.1 Assumptions

This Reintroduction Plan is confined to actions leading to establishment of a population of winter-run Chinook Salmon in NF Battle Creek. A first principle of the NMFS recovery strategy is that functioning, diverse, and interconnected habitats are necessary for species recovery (NMFS 2014a). This Reintroduction Plan has been developed assuming that there is sufficient quantity and quality of habitat in NF Battle Creek to support a viable, independent, self-sustaining population of winter-run Chinook Salmon. It also assumes completion of the BCRP and implementation of its adaptive management plan (AMP) (Terraqua, Inc. 2004) to ensure that properly functioning habitat is available for a winter-run Chinook Salmon population.

The Reintroduction Plan assumes that supplementation will be necessary to speed the rate at which a population can be established in Battle Creek. The current rate of winter-run Chinook Salmon entering Battle Creek is small and variable (Brown and Newton 2002; Stafford and Newton 2010) and likely is insufficient to reestablish a natural run in a timely manner, given the vulnerability of the current population and ongoing environmental challenges. Consequently, natural straying is not included as a strategy in the plan for reestablishing a population of winter-run Chinook Salmon in Battle Creek.

Successful reintroduction of winter-run Chinook Salmon in Battle Creek depends on conditions in the Sacramento River, the Delta, and the eastern Pacific Ocean. Actions to improve conditions in these areas are addressed in a myriad of biological opinions and permit actions and in a number of restoration programs, including the Central Valley Project Improvement Act – Anadromous Fish Restoration Program, CDFW's Ecosystem Restoration Program, and the NMFS Recovery Plan. This Reintroduction Plan assumes that these actions will be successful in addressing limiting factors outside of Battle Creek so that winter-run Chinook Salmon spawned in NF Battle Creek can survive to live, grow, and return to NF Battle Creek as adults.

1.5.2 Vision and Goals for Reintroduction

The Reintroduction Plan is structured around a vision for the reintroduction program, a set of goals for each phase of the plan, and a number of measurable objectives that relate to specific decisions and steps in the reintroduction. The vision and goals for this plan were developed in consultation with the Advisory Committee. The vision describes the overall intent and desired endpoint for the plan with enough specificity to constrain the goals and objectives. It is a statement about the *future* that shapes actions in both the short and long term. Goals describe specific steps and strategies needed to achieve the vision. As discussed in subsequent chapters, the Reintroduction Plan is structured in three phases. Each phase has one or more goals that characterize strategies and conditions. Objectives provide specific, measurable conditions that are tied to key decisions in the Reintroduction Plan. Objectives relate to decisions in the Reintroduction Plan and provide the criteria for moving from one phase of reintroduction to another. For example, a goal for the first phase of reintroduction is to establish a return of winter-run Chinook Salmon to NF Battle Creek from releases of juvenile fish in the stream. A set of objectives would define a return goal in terms of numbers of adult fish over a time period.

Thus, the Reintroduction Plan has one overall vision, several goals, and numerous objectives—with an increasing level of quantitative specificity moving from vision to goals to objectives. This section describes the overall vision and goals that characterize each phase of reintroduction. Additional goals and all objectives are described in Chapters 2 and 3.

1.5.2.1 Vision

The vision for the Reintroduction Plan is as follows.

> *Establish a viable, self-sustaining and locally adapted population of winter-run Chinook Salmon in Battle Creek that adds to the spatial diversity and abundance of the Sacramento River winter-run Chinook Salmon ESU.*

A viable population of winter-run Chinook Salmon is defined by the criteria of the Viable Salmonid Population (VSP) concept used by NMFS to evaluate populations under the ESA (McElhany et al. 2000). The VSP concept assesses the status of populations in terms of abundance, productivity, biological diversity, and spatial structure. McElhany et al. (2000) define a viable salmonid population to be one "with a low extinction risk in the wild over time." The Central Valley Technical Recovery Team (TRT)(Lindley et al. 2007) provided specific criteria for viability that are incorporated into the NMFS Recovery Plan (e.g., <5 percent chance of extinction within 100 years). Lindley et al. (2007) also discuss guidelines for a minimum spawning population size for population viability based on demographic and genetic considerations.

A self-sustaining population is one that reproduces naturally in the environment with sufficient productivity and abundance to maintain a viable population without intervention from outside production, including hatcheries. However, this aspect of the vision does not preclude the use of artificial production, especially during the initial phases of reintroduction or as a future contingency measure. The Reintroduction Plan does envision a reduction in, and eventual elimination of, the use and influence of artificial production over time.

A locally adapted population is one that has been shaped by natural selection to be adapted to the characteristics of a specific environment—in this case, Battle Creek. Because selection operates at a genetic level, a locally adapted population will have some degree of reproductive isolation and genetic divergence from similar populations of the same species in other environments. Hence, a self-sustaining winter-run Chinook population in Battle Creek would be expected to diverge from the mainstem Sacramento River population due to selection and reproductive isolation of the Battle Creek population. However, the proximity of the Sacramento River and Battle Creek populations creates the likelihood that the two populations will be part of a meta-population with some degree of genetic exchange as the two populations act as sources and sinks, depending on relative productivity and abundance.

Spatial diversity and abundance are metrics of the VSP concept that apply to the Sacramento River winter-run Chinook Salmon ESU as a whole. The TRT (Lindley et al. 2007) has developed extinction risk criteria for listed salmon populations that are incorporated into the NMFS Recovery Plan. The rationale behind establishing a new population of winter-run Chinook Salmon in Battle Creek is to contribute to the viability of the ESU by increasing abundance, diversity, and spatial structure, which reduces risk from local events (e.g., a toxic spill, or loss of a cold-water pool) (NMFS 2014a).

1.5.2.2 Goals

The Reintroduction Plan is structured around a sequence of three phases of actions that lead to achievement of the vision articulated above. The contribution from artificial production is reduced over time in each phase, ultimately resulting in a self-sustaining population of winter-run Chinook Salmon. This section describes the goals that characterize the strategies and intent of each phase. Additional goals for each phase may be developed during implementation of the plan.

The three phases of reintroduction describe an ideal temporal sequence of actions. However, it is important to stress that the delineation between phases is not stark. Instead, the phases describe a continuum of actions, which may be punctuated by dramatic changes. Nor is reintroduction expected to be uni-directional across the three phases. It is entirely possible that environmental conditions, climate change, or other factors may “re-set” the continuum and require the reintroduction process to revert back to strategies more characteristic of a past phase. For example, it is possible that at some point in the future, catastrophic events or novel conditions, such as a prolonged drought, may require artificial production using locally adapted wild broodstock to stave off loss of the population. Such emergency measures do not negate the intent of the Reintroduction Plan to reduce the use of artificial production over time and achieve a self-sustaining population of winter-run Chinook Salmon in Battle Creek.

A general schematic of the three phases of reintroduction is shown in Figure 3. Phase 1 of reintroduction will establish a return of winter-run Chinook Salmon into Battle Creek with sufficient abundance to overcome founder effects and provide a basis for development of a self-sustaining, genetically diverse, and locally adapted population. Phase 1 will use a mix of artificial production and translocation of wild juveniles to build up population abundance based on the donor population. Phase 2 of reintroduction will develop a viable, self-sustaining and locally adapted population of winter-run Chinook Salmon in Battle Creek by reducing transfers from the donor population (creating a self-contained Battle Creek population) and reducing the use of artificial production. Hatchery production would be eliminated in Phase 3, and the focus would shift to management for long-term sustainability of the Battle Creek population, including monitoring to assess population productivity and health. Battle Creek has a relatively small expanse of habitat suitable for winter-run Chinook Salmon,[7] which will limit the capacity and maximum abundance of the winter-run Chinook Salmon population. This will make the population vulnerable to demographic constraints and catastrophic events, reinforcing the need for continual monitoring and management efforts.

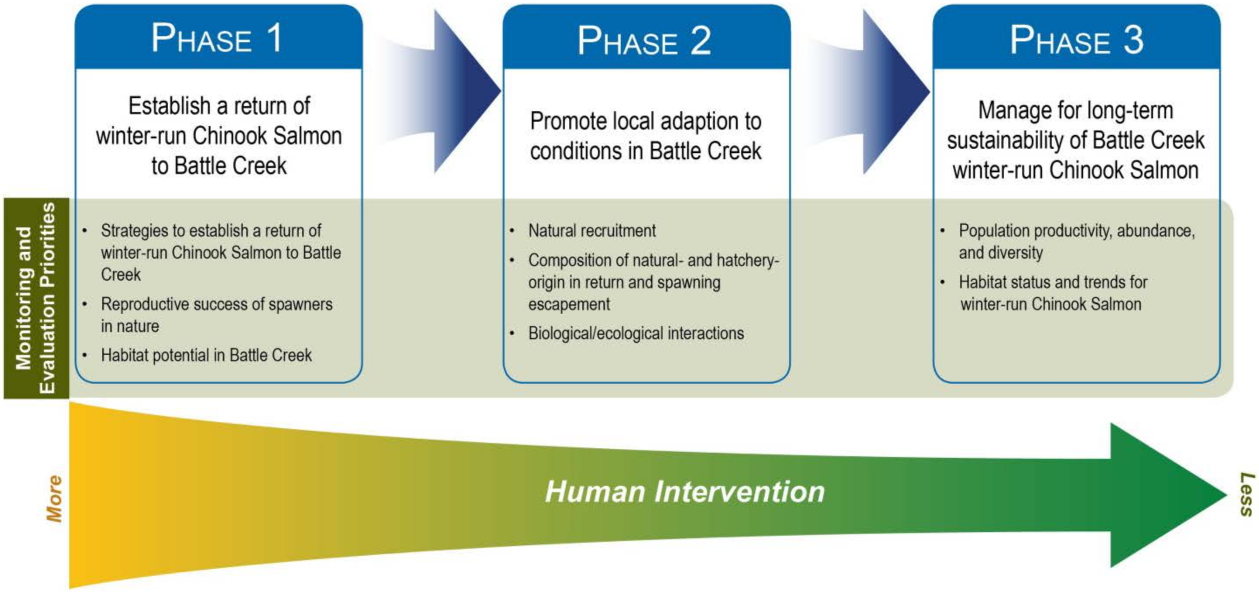

Figure 3
Phases of the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan

Goals describe the condition at the end of each phase; achievement of the goals marks the transition between phases.

Phase 1 Goal

> *Establish a population of winter-run Chinook Salmon in Battle Creek that meets abundance objectives, retains the genetic diversity of the Sacramento River population, and includes a substantial proportion of natural-origin fish.*

The goal of Phase 1 is to establish a return of winter-run Chinook Salmon to Battle Creek that can serve as the basis for establishment of a Battle Creek population. The abundance objectives are intended to establish sufficient abundance to overcome founder effects and provide the basis for development of a genetically diverse, self-sustaining population in Phase 2. The "substantial

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[7] Ibid.

proportion of natural-origin fish" phrase reflects the need for natural-origin fish to begin the process of recolonization, including setting the stage for development of local adaptation in Phase 2. It is necessarily qualitative, recognizing that during Phase 1, the number of natural-spawning winter-run Chinook Salmon in Battle Creek will range from zero to approximately 500 fish (Section 3.3.1). The TRT (Lindley et al. 2007) and the NMFS Recovery Plan (NMFS 2014a) provide abundance objectives that are appropriate to this goal. The expectation is that artificial production to support the Battle Creek winter-run Chinook Salmon reintroduction will be initiated from broodstock derived from the mainstem Sacramento River population and spawned at LSNFH. Artificial production to meet abundance objectives in Phase 1 will be based on contribution from the donor population.

Phase 2 Goal

> *Establish a self-sustaining, locally adapted population of winter-run Chinook Salmon in Battle Creek by encouraging local adaptation of the Battle Creek population, phasing out the contribution of artificial production, and eliminating the genetic contribution from the Sacramento River population into the artificial production program.*

The goal of Phase 2 is to promote development of a locally adapted population. Phase 2 is characterized by elimination of the contribution of brood stock from outside Battle Creek and development of a distinct, locally adapted population of winter-run Chinook Salmon in Battle Creek. The contribution of artificial production in general would be reduced throughout Phase 2, leading to development of a self-sustaining population of winter-run Chinook Salmon in Battle Creek.

Phase 3 Goal

> *Monitor the viability of the Battle Creek population and respond to concerns set by ESA recovery needs.*

The focus of Phase 3 is the long-term management of the restored Battle Creek winter-run Chinook Salmon population. In Phase 3, the vision of a viable, self-sustaining, and locally adapted population should be maintained through active management of the population and habitat, and monitoring of population abundance and productivity. As noted above, the limited extent of habitat in Battle Creek will likely result in a population with relatively low abundance and high vulnerability to catastrophic events or downturns in environmental conditions (e.g., more frequent and prolonged droughts). This vulnerability warrants continued monitoring and adaptive management to maintain the new population, which will contribute to meeting recovery criteria established under both the ESA and CESA.

Chapter 2
Background

2.1 Biological Setting

2.1.1 Overview of Fish Species in Battle Creek

Seventeen resident and anadromous fish species are known to occur in Battle Creek, four of which are introduced species (USBR 2005). Limited studies indicate that each of the Chinook Salmon runs in Battle Creek exhibit life history patterns and run timing similar to those derived from the studies at RBDD (CH2M Hill 1999). The actual timing of runs throughout the Sacramento River and its tributaries varies slightly from year to year as a function of weather, streamflow, and water temperature (Vogel and Marine 1991).

The distribution and abundance of resident fish in Battle Creek were examined in detail in 1989 (Thomas R. Payne and Associates 1998). Unlike anadromous species, the resident species in Battle Creek spend their entire lives in fresh water. Resident species include native and nonnative fishes. The assemblage of resident native fish that evolved in streams like Battle Creek transitions from warmwater species that occupy warmer, low-velocity reaches of the lower to mid-elevations to coldwater species that use colder, higher velocity reaches of the mid- to high elevations (Moyle and Cech 1988). Warmwater species such as non-native striped bass (*Morone saxatilis*), introduced centrachids (bass and sunfish), and native cyprinids (minnows) typically prefer slow-moving, low-velocity stream reaches in the low elevations of Battle Creek. Recreationally important coldwater resident species, such as Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) trout, generally prefer colder water and higher velocity water than warmwater fish; however, their occurrences overlap to varying degrees. The upper portions of Battle Creek and the hydroelectric project's canal system are both acknowledged to support a sport fishery for rainbow and brown trout (Kier Associates 1999).

Fall and late-fall runs of Chinook Salmon are relatively abundant in lower Battle Creek owing to their production at CNFH. There is also an isolated anadromous Steelhead Trout (steelhead) hatchery program at CNFH that mitigates steelhead production lost from the construction of Shasta and Keswick Dams (see Section 4.2.1.3 for a discussion of the CNFH Adaptive Management Plan). Natural-origin steelhead and spring-run and winter-run Chinook Salmon also occur in Battle Creek, but at much lower levels. Monitoring of adult Chinook Salmon passed through the CNFH barrier weir fish ladder into upper Battle Creek documents the passage of a few tens to several hundred spring-run Chinook; and since the winter-run Chinook Salmon hatchery supplementation program was transferred to LSNFH in 1997, escapement of winter-run Chinook Salmon to Battle Creek has varied between 0 and 6 adults (CDFW GrandTab 2015). Reports from screw trap monitoring in Battle Creek for the period from 1998 to 2010[1] also indicate regular production of a small number of spring-run Chinook Salmon and an occasional occurrence of a few winter-run Chinook Salmon in upper Battle Creek above the CNFH weir. The screw trap monitoring program has documented the

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[1] Available at: http://www.fws.gov/sacramento/fisheries/CAMP-Program/Documents-Reports/fisheries_camp-program_documents-reports.htm.

use of lower Battle Creek by juvenile winter-run Chinook, which are likely juveniles from the Sacramento River rearing in lower Battle Creek. While the current number of winter-run Chinook Salmon in Battle Creek is unknown, available evidence indicates that at least a few occasional winter-run Chinook Salmon stray into and spawn in Battle Creek. Thus, the current populations of winter-run Chinook Salmon appear to be severely depressed when compared to scant historical evidence (Brown and Newton 2002) and in need of supplementation to facilitate reestablishment of a viable population.

2.1.2 Battle Creek

Battle Creek enters the Sacramento River at River Mile (RM) 272 upstream of Red Bluff, California, and 30 miles downstream of Keswick Dam. Battle Creek includes the North and South Forks, which join to form the main stream channel at RM 17. The Battle Creek watershed encompasses about 357 square miles. NF Battle Creek, which is the focus of this Reintroduction Plan, has a watershed of 213 square miles, or about 60 percent of the Battle Creek watershed.

Battle Creek stands out from other Sacramento River tributaries because of its geology and hydrology. The watershed is characterized by a diverse array of relatively recent volcanic deposits originating from Mt. Lassen and other volcanic features. The region is geologically active—a series of eruptions at Mt. Lassen last occurred between 1914 and 1917, with a major eruption in 1915 (NPS 2016). Much of the stream cuts through basalt, breccia, and other volcanic deposits, which affect the topography and hydrology of the stream.

The hydrology of Battle Creek is unusual because of the large amount of groundwater and spring flow that contributes to streamflow. The porous basalts, characteristic of the North Fork, store large amounts of snowmelt from Mt. Lassen, which is released from springs primarily in the Eagle Canyon section of the North Fork. As a result, the stream has unusually high summer base flow and moderate temperature compared to nearby streams. NF Battle Creek is higher gradient, drains higher elevation areas, and has a greater contribution of flow from natural springs than SF Battle Creek. The South Fork experiences high-precipitation events with high peak flow. Under baseflow conditions, the majority of the flow in Battle Creek comes from the North Fork. The watershed hydrology is complicated by a system of dams, diversions, and canals that shunt water into several hydroelectric generating facilities operated by PG&E. Operation of these facilities has altered stream hydrology and the relative contribution of the two forks to total streamflow (USBR 2005).

NF Battle Creek cuts through porous basalt formations predominately in Eagle Canyon, a narrow, straight-walled canyon. These canyon walls are unstable and contribute large boulders to the stream that characterize habitat in the canyon and can obstruct adult fish passage (USBR 2005). Numerous springs emerge from the canyon walls. These springs create the unique flow and temperature regime that historically characterized habitat for winter-run Chinook Salmon in NF Battle Creek.

Historically, Battle Creek has had runs of fall, late-fall, winter, and spring-run Chinook, as well as steelhead. The natural upstream limit to passage of anadromous fish on NF Battle Creek is a falls located 13.2 miles upstream of the confluence of the North and South Forks. Presently, the largest returning runs of salmon are fall and late-fall run Chinook. However, a weir has been in place since 1950 at CNFH (RM 5.8) to control passage of fish into upper Battle Creek. The weir currently is operated to allow upstream passage of anadromous fish from March to July, including passage of spring- and winter-run Chinook, but is closed from August to the end of February to block passage of CNFH-origin fall and late-fall run Chinook Salmon (USBR 2011). This operation serves to prevent hybridization of spring-run and fall-run Chinook. Selective passage of natural-origin steelhead and late-fall Chinook Salmon is afforded by passing fish through CNFH from October through mid-March (natural steelhead) and December through mid-March (natural late-fall Chinook) to facilitate expansion of those populations in Battle Creek.

Winter-run Chinook Salmon were reported to be present in Battle Creek as early as 1898, and a spawning run of several hundred fish was reported in the 1940s and 1950s (Thomas Payne & Associates 2005). More recently, however, the return of winter-run Chinook Salmon to Battle Creek has been characterized as “remnant” to non-existent (USBR 2005).

2.1.2.1 Battle Creek Salmon and Steelhead Restoration Project

The BCRP is a collaborative effort between federal and state fishery managers, PG&E, and other interested parties (including the Greater Battle Creek Watershed Working Group) to restore habitat in the North and South Forks of Battle Creek and enhance production of salmon and steelhead. The project is focused on modifications to the PG&E dams and diversions on the North and South Forks. These structures block or impede fish passage and divert water from the North Fork to the South Fork. The BCRP has the following major features.

- Adjustments to hydroelectric project operations to allow cold spring water to reach natural stream channels, decreasing the amount of water diverted from streams, and decreasing the rate and manner in which water is withdrawn from the stream and returned to the canals and powerhouses following outages.
- Modification of facilities, such as construction of fish ladders, fish screens, and bypass facilities and removing diversion dams, canals, and powerhouse discharge facilities.
- Changes in the management approach for the hydroelectric project to balance hydroelectric energy production with habitat needs. Using ecosystem-based management that protects and enhances fish and wildlife resources and other environmental values, including adaptive management, more reliable facilities, and water rights transfers, among other strategies.
- An Adaptive Management Plan designed to monitor population, habitat, and fish passage objectives of the BCRP and determine whether changes to facilities or natural features of the BCRP are needed to address unforeseen circumstances consistent with the requirements of the Federal Energy Regulatory Commission license for Hydroelectric Project 1121 and the MOU.

These actions are expected to enhance conditions considerably for salmon and steelhead in Battle Creek, primarily through changes in flow and fish passage. The benefits of completing these actions were assumed as part of this Reintroduction Plan.

2.1.2.2 Habitat Potential for Winter-Run Chinook Salmon in Battle Creek

The vision for this Reintroduction Plan is to establish an independent, self-sustaining population of winter-run Chinook Salmon in Battle Creek. As discussed in Section 1.4.2.1, a viable self-sustaining population requires a sufficient number of spawners to prevent population extinction from demographic, stochastic, and genetic effects. A population size criterion for demographic and environmental variation will need to be developed as reintroduction progresses; this criterion will be based on population growth and decline metrics (Allendorf et al. 1997; Lindley et al. 2007). A population size criterion also needs to be developed to prevent the loss of genetic diversity through inbreeding depression and genetic drift, both of which contribute to decline in population fitness (Lindley et al. 2007).

The minimum population abundance needed to protect a viable population from genetic loss due to genetic drift and inbreeding is based on the concept of effective population size, referred to as $N_{e.}$ The notation N_e indicates the size of an ideal population (the number of effective spawners per generation) that satisfies the following criteria: random mating, an equal sex ratio, discrete (non-overlapping) generations, and random variation in reproductive success. It is essentially a measure of the number of individuals in a population who contribute offspring to the next generation. Departures from these criteria generally results in N_e being less than the census population size (N) (Waples 2002, 2004). Lindley et al. (2007), based in part on the work of Allendorf et al. (1997), suggest that salmon recovery plans should establish an effective population size of 500 individuals per generation as a criterion for assigning a population to a low risk of extinction.

However, N_e is difficult to calculate for wild salmon populations, because they do not adhere to the criteria that define an ideal population. For example, Waples (2004) concluded that, because of factors such as variation in reproductive success among individuals, degree of overlap between generations, and variability in sex ratio, N_e / N ratios likely range from 0.05 to 0.30 for Chinook Salmon. Lindley et al. 2007 suggest that, in the absence of information to estimate N_e, a reasonable approximation for Central Valley Chinook Salmon would be 0.2N; as a default (i.e., a census population size of 2,500 spawners per generation could be assumed to have an N_e of 500 individuals).

NMFS adopted the recommendations in Lindley et al. (2007) to define a population at a low risk of extinction in its Recovery Plan for California Central Valley salmonids, including winter-run Chinook Salmon. The NMFS Recovery Plan assumes that, in addition to other criteria, a low-risk population comprises 2,500 adult spawners per generation (NMFS 2014a). Lindley et al. (2007) also assume a mean generation time for winter-run Chinook Salmon of approximately 3 years; therefore, the annual run size for a low-risk population would be 2,500 adults divided by 3, or 833 fish, which was rounded to 850 fish for planning purposes.

To meet the goal of creating a viable, independent population of winter-run Chinook Salmon in Battle Creek, the quality and quantity of habitat must be sufficient through the life cycle of the species to support a census population of 2,500 adults (average annual run size of 850 adults) based on the guidance from the NMFS Recovery Plan. Evaluation of the full extent of habitat across the life cycle of winter-run Chinook Salmon is not the focus of this plan. However, evaluating the sufficiency of habitat for spawning winter-run Chinook Salmon in Battle Creek is possible.

The amount of habitat available in Battle Creek for winter-run Chinook Salmon has been estimated based on flow and measurements of habitat conditions (USBR 2005). Normandeau Associates (Appendix B) reviewed and reassessed the information on habitat expected to be restored by implementation of the BCRP with the specific consideration of winter-run Chinook Salmon habitat requirements, in particular temperature. They evaluated habitat availability with respect to four stages of the winter-run Chinook Salmon life cycle: adult migration and holding, spawning and incubation, juvenile rearing, and smolt migration. Their assessments of temperature-conditioned channel habitat under conditions provided by the Preferred (Five-Dam) Alternative (USBR 2005) consistently show a higher proportion of suitable habitat for winter-run in NF Battle Creek compared to the South Fork. Overall, the egg incubation life stage appears the most limiting to winter-run reintroduction, with no suitable (i.e., non-lethal) habitat in the mainstem reach. Fish straying into the South Fork may not result in loss of production, particularly if the fish migrate to the upper reaches of the South Fork during the cooler months—although the South Fork is likely to present challenges for rearing and outmigration of juveniles (Appendix B).

Table 1 displays the acres of winter-run Chinook Salmon spawning habitat in reaches of Battle Creek estimated to occur after completion of the BCRP. About 22 percent of the total spawning habitat is estimated to be in NF Battle Creek. Table 1 also shows the results of simple calculations of the potential number of spawners that could be supported by the available spawning areas without consideration of other factors such as temperature. These calculations indicate that, with improved flow and passage from the BCRP, estimated spawning habitat in the North Fork would be sufficient to accommodate escapement of 850 spawners per year. The capability of the habitat within and outside Battle Creek to support winter-run Chinook Salmon abundance also will be evaluated as part of the adaptive management plan for the BCRP.

Table 1. Estimated Number of Winter-Run Chinook Salmon Spawners That Could Be Supported in Battle Creek

Scenario Five-Dam Removal	Spawning Area (acres)	Spawning Area Distribution	Redds		Spawners	
			Low	High	Low	High
North Fork	1.41	66%	409	819	1,228	2,457
South Fork	0.71	34%	206	412	618	1236
Mainstem	0	0%	0	0	0	0
Total	**2.12**		**615**	**1,231**	**1,846**	**3,711**

Note: Estimated numbers are based on area of suitable spawning substrate accessible for winter-run Chinook Salmon upon completion of the Battle Creek Restoration Project (the Five Dam Removal Alternative). While Thomas R. Payne and Associates (2005) estimate that space will be available for winter-run Chinook Salmon spawners in the South Fork and mainstem of Battle Creek, temperatures in the South Fork may be challenging for egg incubation and juvenile survival. For this reason, the estimates in Table 1 for the South Fork and mainstem may be less relevant to this plan than the estimates for the North Fork.

Assumptions:

Redd size: Low = 150 sq. ft./redd, High = 75 sq. ft./redd

3 fish/redd

Source: USBR 2005.

2.1.3 Climate Change

Future climate change (IPCC 2013) will affect environmental conditions at regional and local scales in California (Hayhoe et al. 2004; Cayan et al. 2008). In general, future conditions in California and elsewhere are expected to be characterized by warmer conditions, less snow pack, and drier summers (Cayan et al. 2008; NMFS 2014a). A hotter, drier climate is expected to alter conditions in aquatic environments, with detrimental impacts on salmonids (Lindley et al. 2007; Mantua et al. 2010; NMFS 2014a).

Predicting climate change impacts at local scales, such as in Battle Creek, is problematic because of the high degree of variability in climate predictions and the influence of local factors (Dettinger 2005). Nevertheless, Lindley et al. (2007) analyzed the effects of several scenarios for increased mean summer temperatures (2°C, 5°C, and 8°C) on the distribution of usable salmon habitat. They estimated that, under the 5°C scenario, a substantial loss of habitat would occur, but remnants of useable habitat may persist in Battle Creek. Larger-scale predictions of future conditions in

California indicate the likelihood that climate change could alter conditions in the Battle Creek watershed, with implications to the success of species recovery programs (NMFS 2014a). In particular, higher summer air and water temperatures are likely to place additional stress on salmonid spawning and rearing habitat in the Sacramento River and may affect conditions in Battle Creek. Current drought conditions, which are placing strains on salmonid populations in California (Moyle et al. 2013), may be exacerbated by regional climate change and could become more frequent in the future (Moyle et al. 2013; Swain et al. 2014). The large contribution of spring flow in Battle Creek may provide winter-run Chinook Salmon with some protection from the effects of temperature rise and drought. However, changes in precipitation and decline in California snow pack also could affect the volume of spring flow into Battle Creek, contributing to a loss of cool water refugia in the future. Climate models predict an increase in wildfires, which can increase delivery of sediment to streams, increase stream temperatures as a result of lost vegetation cover, and otherwise diminish the quality of habitat for salmon. In short, while the specifics of climate change impacts on Battle Creek remain speculative, the likelihood of regional-scale climate change in California and the potential for negative impacts on salmonid habitat support the need to address climate change in the Reintroduction Plan and ensure that the plan is flexible enough to accommodate changes in future conditions.

2.2 Regulatory Setting

Certain authorizations and compliance with relevant environmental statutes and regulations will be required before this Reintroduction Plan can be implemented. Among these are the National Environmental Policy Act (NEPA), the California Environmental Quality Act (CEQA), the Clean Water Act (CWA), and ESA and CESA. In addition, local ordinances may apply to land use activities such as hatchery construction or modification.

NEPA is a federal statute that requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions. CEQA, is a California statute that requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible. Both statutes provide for a public review and comment process. When federal and state agencies cooperate on a proposed action, they may prepare a joint environmental document consistent with the requirements of both statutes to disclose the environmental consequences of the action. Because this reintroduction effort is consistent with and builds on the BCRP, the implementing agency may be able to rely in large part on the environmental review done for the BCRP, recognizing that some elements of this project (e.g., hatchery supplementation) were not considered in the BCRP joint NEPA/CEQA documents.

Depending on how the implementing agency chooses to go about collecting, spawning, and rearing fish for introduction to Battle Creek, authorizations may be required under the CWA and the State's Porter-Cologne Act for discharge of effluent to Battle Creek and/or modification of a streambank. Authorization for discharge of effluent to Battle Creek may require clean water certification (CWA Section 401) by the Central Valley Regional Water Quality Control Board; and to the extent construction of a hatchery or grow-out facility would require bank modification, a CWA Section 404 authorization for discharge of dredge or fill materials may be required by the U.S. Army Corps of Engineers.

Because winter-run Chinook Salmon are listed as endangered under both CESA and ESA, permit authorizations will be needed to collect, possess, and transport winter-run Chinook Salmon for release in Battle Creek. Federal authorizations are issued for scientific purposes or to enhance the propagation or survival of an endangered or threatened species via Section 10 (a)(1)(A) of the ESA and Title 50 Code of Federal Regulations (CFR) Section 222.308. CDFW may authorize the take of winter-run Chinook Salmon for scientific, educational, or management purposes via permit or MOU issued pursuant to California Fish and Game Code Section 2081(a). The implementing agency will need to apply to NMFS and CDFW for authorization of the direct take of winter-run Chinook Salmon for the purpose of reestablishing a population in Battle Creek.

As part of the review to take winter-run Chinook Salmon for establishment of a captive propagation program, NMFS and CDFW will likely request the implementing agency to prepare a Hatchery and Genetics Management Plan (HGMP). HGMPs are technical documents that thoroughly describe the composition and operation of individual hatchery programs. The primary goal of an HGMP is to describe biologically based artificial propagation management strategies that ensure the conservation and recovery of ESA-listed salmon and steelhead populations. HGMPs incorporate viable salmon population concepts and include, among other things, appropriate broodstock collection and mating protocols, mechanisms to protect the health and genetic integrity of populations involved, and an adequate monitoring program to evaluate the success of the hatchery program. The requirements for developing an HGMP are found at 50 CFR 223.203. A template for preparation of an HGMP is available at: http://www.westcoast.fisheries.noaa.gov/hatcheries/salmon_and_steelhead_hatcheries.html. To the extent that the reintroduction program uses LSNFH to initiate or maintain the hatchery component of this plan, the existing HGMP for LSNFH could be modified to address this need.

In addition, the implementing agency will need to comply with the interagency consultation requirements of both ESA and CESA to ensure that the program is not likely to result in jeopardy to the continued existence of winter-run Chinook, or any other listed species, which may be affected incidental to the winter-run Chinook Salmon reintroduction effort (e.g., California red-legged frog). The federal consultation process is conducted pursuant to Section 7 of the ESA and its implementing regulations at 50 CFR Section 402. Interagency consultation is initiated after the implementing agency prepares a biological assessment evaluating the effect of the action on any listed species present and any critical habitat designated in the action area. Depending on the species under consideration, NMFS or the USFWS will make a finding with respect to jeopardy and adverse modification standards of the ESA, for species under their respective jurisdictions. If a determination of no jeopardy and no adverse modification is supported by the assessment, NMFS and/or the USFWS will issue a biological opinion summarizing its findings and an incidental take statement authorizing the take of listed species that may occur incidental to the proposed action. CDFW may participate in these consultations and make a consistency determination pursuant to the California Fish and Game Code Section 2080.1(a). If CDFW makes a consistency finding, no other state authorization for the incidental take of listed species is required.

2.3 Scientific Knowledge and Synthesis of Experiences

Reintroduction is an effort to reestablish a species within an area that was once part of their historical range but where they are now no longer present (International Union for the Conservation of Nature 1980). Reintroduction can occur through transplanting wild individuals into vacant habitat and/or using artificial propagation and release of eggs, juveniles, or adults into vacant habitat. This Reintroduction Plan embraces the concept of a strategic and science-based approach to reintroduction in which research, monitoring, and evaluation (RM&E) address questions identified in the plan (Seddon and Armstrong 2007; Armstrong and Seddon 2008).

A strategic and science-based approach includes identification of goals, ecological purpose, and technical and biological limitations of reintroduction. It is characterized by a planning process that includes experimental and model approaches and a strong commitment to adaptive management, including the timely collection and analysis of relevant information to evaluate plan assumptions and track progress.

A reintroduction plan needs to identify key assumptions and associated indicators (e.g. survival rates, spawner abundance, natural production). Monitoring may be adequate to evaluate some key assumptions, but some questions may require active research to test alternative hypotheses and help adjust reintroduction strategies. Monitoring as part of the BCRP adaptive management plan will cover some indicators (Terraqua 2004). However, additional monitoring will be needed to address issues specific to winter-run Chinook Salmon reintroduction.

Carefully defined and quantitative indicators are key to the success of the plan and to help evaluate strategies, monitor progress through the reintroduction phases, and inform decisions regarding plan components. Multiple decisions will need to be made regarding the collection of donor fish from the Sacramento River population, the release of fish into Battle Creek, and the management of returning donor and natural-origin adults to Battle Creek. These decisions need to be consistent with the established guidelines developed in this plan and informed by reintroduction RM&E activities.

The reintroduction steps discussed below include preferred strategies along with contingent strategies to deal with changing circumstances. Planning for contingencies is complex, but important, to ensure that alternative strategies are clear and linked to specific criteria. Winter-run Chinook Salmon reintroduction is based on a set of logical key assumptions and associated strategies that together and in sequence describe a successful plan for reintroduction. However, multiple factors may affect the success of the plan.

The following sections are an overview of reintroduction concepts from the growing literature on reintroduction, a review of approaches and experiences used in other salmonid reintroduction plans, and a framework for winter-run Chinook Salmon reintroduction to help in the evaluation process during planning and implementation.

2.3.1 Considerations for Reintroduction

A variety of approaches to reintroduction have been applied to salmonids on the West Coast. Each reintroduction plan has unique circumstances, and each approach to reintroduction has unique risks and benefits that are influenced by the specific circumstances. Reintroduction can occur through the following methods: (1) natural colonization; (2) transplanting fish from a donor population; and (3) release of artificially propagated fish (Anderson et al. 2014).

2.3.1.1 Natural Colonization

Natural colonization is based on an assumption that enough adults will stray from the donor population to colonize vacant habitat. However, adults and their progeny must have the right characteristics to survive in the newly occupied habitat. A stray rate suitable for natural colonization of winter-run Chinook Salmon in Battle Creek involves a delicate balance of factors: it must be high enough to re-seed the available habitat but low enough to promote local adaptation and development of an independent population. The risk of relying on natural colonization is that the founding adults may be few and represent just a small component of the donor population diversity, resulting in a founder effect or genetic bottleneck. However, persistent straying of adults into the reintroduction site from the donor population could add diversity in successive generations to overcome a founder effect. Anderson et al. (2014) concluded that natural colonization was the lowest-risk approach "because it minimizes the interruption of natural biological processes." Anderson et al. (2014) cite several reintroduction efforts that relied entirely on natural colonization. However, many of these were following the removal of a migration barrier at the upstream extent of the donor population. In these examples, colonization entailed the extension of an existing population into the newly accessible habitat—for example, removal of Condit Dam on the White Salmon River in Washington.

Ideally in Battle Creek, colonizing adults from the mainstem Sacramento population would find preferred habitat for holding and spawning, thus maximizing survival and homing of offspring back to Battle Creek and minimizing the need for artificial production. The fact that winter-run Chinook Salmon returned to Battle Creek when the supplementation program was operated out of CNFH is encouraging for this effort because it demonstrated that winter-run adults will return to Battle Creek. However, since the transfer of the winter-run Chinook Salmon supplementation program from CNFH to LSNFH, winter-run Chinook Salmon from the mainstem Sacramento River population have not strayed into Battle Creek in numbers sufficient to support natural recolonization of Battle Creek. One hypotheses supported by the Normandeau Associates analysis (Appendix B) is that, under current operations, the flow and/or temperatures in the mainstem of Battle Creek may not be sufficient to attract winter-run Chinook Salmon into Battle Creek. That analysis, which was based in large part on the analysis in the environmental impact statement for the BCRP, did not account for return flows from the Coleman Diversion Dam that may provide cool water to this reach. Nevertheless, other forms of population supplementation are going to be needed to repopulate the habitat restored by the BCRP in a timely manner given the vulnerability of the current population and ongoing environmental challenges associated with drought and climate predictions.

2.3.1.2 Transplanting

Transplanting is the deliberate and facilitated movement of fish collected from the donor population. This reintroduction technique has the benefit of allowing selection of a variety of fish and life stages from the donor population to maximize diversity during reintroduction so that the potential for local adaption is not artificially diminished. Transplant strategies could include the collection of eggs, juveniles, or adults from the donor population for direct placement into vacant habitat. However, transplanting can disrupt the natural biological process, which introduces additional risks (Anderson et al. 2014). Transplant strategies may decrease survival, resulting in unintended divergence in survival among family groups, and may increase the risk of fish straying to non-target habitat.

2.3.1.3 Artificial Propagation

The use of artificial propagation can be an important component of reintroduction by increasing the contribution of donor fish to overcome survival bottlenecks prior to release (i.e., maximizing survival from spawning to release). Many salmonid reintroduction programs have used some form of hatchery release (Anderson et al. 2014). Fish may be collected from a donor hatchery population without the constraints imposed on a wild population, or fish may be collected from a wild donor population and reared in the hatchery to improve survival up to the point of release. Furthermore, ongoing artificial propagation is often a critical element to provide demographic support to the new population after initial reintroduction (Anderson et al. 2014). However, the use of a hatchery in reintroduction has the risk of domestication and artificial selection (Paquet et al. 2011), which must be managed. For example, broodstock used to develop the hatchery population may be few in number and possibly closely related; therefore, domestication selection from multiple generations in the hatchery is an additional risk. These factors may contribute to creation of a hatchery population with traits less suitable for survival in the natural environment. The use of hatchery releases also may increase straying and interbreeding with a nearby wild population (i.e., the Sacramento River population), negatively affecting the fitness of that population.

2.3.2 Review of Salmonid Reintroduction Programs

Four salmonid reintroduction plans on the West Coast were reviewed to help understand the issues, constraints, and approaches to reintroduction. Plans reviewed were mid-Columbia coho salmon (*Oncorhynchus kisutch*)(Yakama Nation 2012), upper Deschutes River (Columbia River) sockeye salmon (*Oncorhynchus nerka*), Chinook Salmon, and steelhead trout (ODFW and CTWS 2008), Idaho sockeye (Kline and Flagg 2014), and San Joaquin River spring-run Chinook Salmon (San Joaquin River Restoration Program 2011). All of these plans have a strong dependence on hatchery releases to support initial reintroduction and the continued persistence of the new populations.

This overview is intended to help explain how priorities, constraints, and perceived benefits and risks can inform development of a reintroduction plan for Battle Creek. However, the Battle Creek winter-run Chinook Salmon reintroduction is unique compared to most of these plans for several reasons. First, the Sacramento River winter-run Chinook Salmon ESU consists of a single population with a life history and a unique genome not found anywhere else. This results in a reintroduction effort that must focus on avoiding catastrophic loss of the entire ESU by preserving and expanding the remnant population. Many of the other plans involve reintroduction of a species or race with multiple natural populations within the ESU or species range. Second, many of the other reintroduction plans had multiple options for a donor population, including the option to source fish from multiple hatchery populations. For winter-run Chinook, there is only one option for donors from a natural population, as well as a single conservation hatchery program and a captive broodstock program. Third, the amount of habitat targeted for reintroduction in most other plans was much larger relative to the habitat available in Battle Creek. Reintroducing winter-run Chinook Salmon into Battle Creek is focused on a specific portion of the watershed with the unique flow and temperature characteristics required to support the winter-run Chinook Salmon life history.

2.3.2.1 Mid-Columbia River Coho Salmon Reintroduction

Coho salmon were essentially extirpated from the middle Columbia River tributaries in the early 1900s by impassable dams, degraded habitat, irrigation diversions, and high harvest rates. Coho continued to return to the middle Columbia area in small numbers until 1975 from hatchery releases in Wenatchee and Methow watersheds. However, few fish survived to return to spawn, and broodstock was not managed to preserve mid-Columbia populations. Once these programs were terminated, Coho disappeared from the middle Columbia tributaries.

The Yakama Nation developed a plan for coho reintroduction into the Wenatchee and Methow watersheds in the middle Columbia River (Yakama Nation 2012). The biggest challenge to reintroduction was establishing a coho population with the life history and survival characteristics needed to survive in these watersheds. The Wenatchee River enters the Columbia River at RM 470; the Methow River enters the Columbia River at RM 524. The nearest wild coho populations were downstream of Bonneville Dam at RM 146. The reintroduction plan relied heavily on hatchery propagation to get fish to return to the Wenatchee and Methow Rivers. The plan included a phased approach to develop a local hatchery population in the target watersheds by moving fish upriver through different watersheds to develop an upper Columbia River population. Once a hatchery return was established to the mid-Columbia, the strategy shifted to using natural-origin coho for the reintroduction program. The program is ongoing, with a strong hatchery release to augment runs as natural populations are established in the watersheds. As the natural runs build, the plan has decision rules regarding when to collect broodstock from natural-origin coho and numeric targets for inclusion of natural-origin broodstock and the number of fish to release. These decision rules and targets are intended to promote local adaptation to the natural environment and to scale back hatchery production. The plan recognizes the likely need for continued reliance on hatchery production to augment natural production in order to meet the harvest goals of the Yakama Nation. The use of a lower river hatchery population for reintroduction was an acceptable risk by the plan developers because (1) a suitable wild population of Coho Salmon was not available (i.e., one that would migrate to the mid-Columbia); and (2) hatchery-origin strays to critical wild populations of Coho Salmon was not a concern because there are no populations close enough to be affected. Strategies will change over time as a locally adapted hatchery and natural populations are established in these watersheds.

2.3.2.2 Deschutes River (Oregon) Salmonid Reintroduction above Pelton-Round Butte Dams

Salmonid migration in the Deschutes River in Oregon was blocked by construction of the Pelton-Round Butte Dam complex in the 1950s (ODFW and CTWS 2008). A hatchery was installed immediately below Pelton Dam to mitigate lost habitat. In 2005, a new license was issued for the project, which required fish passage at the projects and reintroduction of sockeye, Chinook, and steelhead above Round Butte Dam.

The Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Warm Spring Reservation (CTWS) developed a reintroduction plan for sockeye and Chinook Salmon, and steelhead trout in the Deschutes River upstream of the Pelton-Round Butte Project (ODFW and CTWS 2008). The biggest challenge for this reintroduction plan was to design and construct a facility in the reservoir above Round Butte Dam to collect downstream migrating juvenile salmonids for release below Pelton Dam.

Source populations of salmon and steelhead for reintroduction are native to the Deschutes River watershed. The plan identified wild fish returning to the Warm Springs River downstream of the project as a first-choice donor population for spring Chinook. The second choice was adults from an integrated hatchery program, which includes natural-origin adults in the broodstock, in the Warms Springs River, and the third choice was hatchery returns to the segregated mitigation hatchery at the dam. Anadromous sockeye were extirpated from the watershed above the dams. However, non-anadromous sockeye (kokanee) are present in the reservoir. The plan identified collection of the few anadromous adults collected at the dam fish ladder (assumed to be the progeny of kokanee that successfully completed an anadromous life history). These fish would be passed upstream to spawn naturally or spawned at the hatchery, and juveniles would be released into the reservoir. There are three populations of steelhead in the Deschutes River: two wild populations in tributaries to the lower river and a segregated hatchery population at the mitigation hatchery. The preferred approach was to use the two wild populations as donors, but the plan recognized that their low abundance likely would not allow collection of broodstock for reintroduction, leaving only the hatchery population. For all species, the preference in the plan is to source fish for reintroduction from wild populations. However, ODFW and CTWS were willing to accept the risk of using hatchery fish to move forward with reintroduction. They adopted a contingency plan to incorporate more natural-origin fish into the hatchery programs as they became available subsequent to natural populations being established. The lesson for the Battle Creek winter-run Chinook Salmon reintroduction from the Deschutes reintroduction is that identification of a preferred strategy, along with contingency plans that are triggered by changing circumstances and the availability of multiple donor populations, is likely to facilitate success.

2.3.2.3 Snake River (Idaho) Reintroduction of Sockeye Salmon

Historically, Snake River sockeye salmon returned in large numbers to a number of lakes in central Idaho. These fish represent the southernmost sockeye population and have the longest migration (900 miles) with the greatest elevation gain (6,500 feet) of any sockeye population (Kline and Flagg 2014). Abundance declined due in large part to water and hydropower development, and by the 1990s, their range was reduced to a single lake, Redfish Lake. Faced with extirpation, managers embarked on an ambitious reintroduction program. Reintroduction of sockeye salmon into lakes in Idaho began as a genetic conservation program to preserve the anadromous component of this species through a captive broodstock program (Kline and Flagg 2014). Long-term goals were set to rebuild populations through reintroduction using hatchery releases from the captive brood program and an anadromous hatchery program.

Once a hatchery return in Idaho has been well established, the plan identifies strategies for reintroduction of sockeye to multiple lakes. The program is ongoing with hatchery releases that bolster runs as natural populations establish in the lakes. As the natural runs build, the plan has decision rules on when to collect broodstock from natural-origin sockeye and numeric targets for inclusion of natural-origin broodstock and the number of fish to release. Much like the Oregon example, these decision rules and targets are intended to promote local adaptation to the natural environment and to scale back hatchery production. However, the plan recognizes that they will likely need to always include a hatchery component for supplementation if runs fall below critical levels due to environmental stochasticity.

The agencies engaged in developing and implementing the plan were very concerned about the loss of the unique population life history. The captive broodstock program used to preserve the population was truly a gene rescue plan. The captive broodstock population in 2014 was based on 16 anadromous adults, 26 residual Sockeye Salmon, and 886 outmigrating smolts (Kline and Flagg 2014). The reintroduction plan has multiple decision points to protect the diversity of the population and move from a “hatchery-based effort to a habitat-based effort” in order to promote recovery of the population (Kline and Flagg 2014). The Idaho sockeye reintroduction has relevance to the Battle Creek winter-run Chinook Salmon reintroduction because of its emphasis on preservation of a unique genetic resource and a goal to increase the viability of the population by reintroducing anadromous sockeye to multiple lakes in the Salmon River Basin.

2.3.2.4 San Joaquin River (California) Spring-Run Chinook Salmon Reintroduction

Spring-run Chinook Salmon were extirpated from the San Joaquin River by construction of Friant Dam and by water diversions and habitat degradation in the river below the dam. The San Joaquin River Restoration Program (SJRRP) has the goal of restoring habitat and reintroducing spring-run Chinook Salmon to the San Joaquin River below Friant Dam. The San Joaquin spring-run Chinook Salmon reintroduction plan identifies multiple strategies for reintroduction. These include development of a captive brood program using eggs or juveniles collected from natural-origin donor populations and release of juveniles from the captive broodstock program, direct release of hatchery-origin juvenile fish collected from a donor hatchery population (e.g., Feather River Hatchery), transplanting natural-origin fish (juveniles and adults) from donor stocks (e.g., Mill or Deer Creek) to the San Joaquin River, and development of a conservation hatchery program to support reintroduction (SJRRP 2011). Implementation of the reintroduction portion of the SJRRP began in 2015 with the release of 54,000 spring-run Chinook Salmon juveniles into the San Joaquin River near the confluence of the San Joaquin and Merced Rivers. For this initial release the program chose to use fish that were from the Feather River Hatchery. The program will transition to broodstock from hatchery-origin adults returning to the San Joaquin River and, as natural-origin abundance increases, will transition to an integrated program using hatchery- and natural-origin fish in the broodstock.

The plan calls for termination of the conservation hatchery program, pending the establishment of a self-sustaining population. The plan developers concluded that, although the preferred strategy included transplanting natural-origin fish from donor populations, it was likely not feasible—except in years of higher escapement in the donor populations, as it will require a large “harvest” of fish from the natural donor population. The plan developers concluded that a hatchery program for the San Joaquin River was needed to provide the high number of eggs to support the reintroduction plan. There was a concern that flow and habitat restoration may lag reintroduction efforts, requiring the support of hatchery returns to maintain levels of natural spawning in the river.

The transition of the San Joaquin hatchery program to an integrated program (inclusion of natural-origin adults in the broodstock) includes specific metrics to promote adaptation to the natural environment (Börk and Adelizi 2010). The HGMP identified maintaining a 4-year mean proportionate natural influence[2] (PNI) above 0.67 by including natural-origin fish from the San Joaquin River in the broodstock (pNOB) and managing escapement to keep the contribution of hatchery spawners in nature (pHOS) to less than 15 percent. *PNI* is a measure of the relative influence of the natural and hatchery environments on the mean phenotypic values of the integrated hatchery and natural population, and is based on the relative rates of gene flow between the two environments (Paquet et al. 2011). PNI is not a measure of fitness of the population but a measure of the strength of the natural environment on adaptation of the integrated hatchery-wild population. The San Joaquin program use of PNI as an index to evaluate progress toward local adaptation could be applied to the Battle Creek Reintroduction Plan to measure progress toward local adaptation to natural conditions in Battle Creek.

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[2] $PNI = pNOB/(pNOB + pHOS)$

2.3.3 Framework for Planning and Implementing Reintroduction

This Reintroduction Plan includes three phases for reintroduction, each with distinct steps, decisions, biological targets, and expected outcomes (see Figure 3). Each phase is an important step toward establishing a viable winter-run Chinook Salmon population in Battle Creek. The three phases are a continuum of actions intended to progressively lessen human intervention in sustaining the winter-run Chinook Salmon population. However, the success of reintroduction strategies and how the restored Battle Creek will function in subsequent years are unknown. Therefore, the plan framework includes an identification of the known issues most likely to affect reintroduction efforts and contingency strategies identified to improve the likelihood of success.

The Reintroduction Plan considers the following four key factors affecting its implementation and success.

- Status of the Sacramento River donor population and ability to collect winter-run Chinook Salmon for reintroduction into Battle Creek.
- Survival of donor winter-run Chinook Salmon in Battle Creek to contribute to natural spawning.
- Potential of the habitat in Battle Creek to support winter-run Chinook. The habitat potential includes biotic and abiotic factors affecting survival of winter-run Chinook Salmon in Battle Creek now and in the future, with long-term climatic changes likely to affect quality of habitat.
- Annual variability in survival and abundance of winter-run Chinook Salmon from environmental conditions in Battle Creek, the Sacramento River, the Delta, and the Pacific Ocean.

Figure 4 describes the framework for considering options and contingencies when developing the Reintroduction Plan. Factors that may affect success of the plan are in blue text, and contingency options are in black text. Vertical lines represent two hypothetical pathways or scenarios—red indicating a worst-case scenario and green, a best-case scenario. Conditions toward the red, or left side of the spectrum, will require more creative solutions, more human intervention, and more resources to move through the phases and achieve plan goals; they also will entail more risk. Conditions toward the green side are favorable, and the plan may proceed as anticipated with less risk. Chapter 3 *Planned Program Implementation* expands on these contingency decisions and strategy options specific to the plan phases.

Decisions in Response to Donor Source Status

Low Abundance Contingencies

- Adjust the number of natural-origin adults to use in plan
- Use hatchery-origin adults returning to Livingston Stone National Fish Hatchery
- Establish conventional hatchery program derived from donor population to support reintroduction

Decisions in Response to Donor Survival in Battle Creek

Low Survival Contingencies

- Consider alternative reintroduction strategies
- Establish a Battle Creek hatchery program using survivors
- Increase number of donor juveniles released into Battle Creek

Decisions in Response to Habitat Potential

Low Habitat Potential Contingencies

- Identify and remedy factors affecting habitat potential
- Maintain an integrated conservation hatchery program to supplement population demographics
- Reevaluate reintroduction goals

Decisions in Response to Variability

High Variability Contingencies

- Identify and remedy factors causing variation
- Maintain an integrated conservation hatchery program to provide a demographic safety net during periods of low survival

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Figure 4
Framework for Consideration of Contingent Actions

Chapter 3
Planned Program Implementation

3.1 Reintroduction Considerations

A range of options for reintroducing winter-run Chinook Salmon was considered while developing this plan, including options developed and analyzed by the Battle Creek Winter-Run Chinook Salmon Reintroduction Workgroup in 2014.

Natural colonization was dismissed as a viable option based on the low numbers of winter-run Chinook Salmon adults observed voluntarily entering Battle Creek, particularly in years of relative abundance when the Sacramento River population was increasing (2001–2007) (Figure 2).

With respect to facilitated reintroduction into Battle Creek, there are three considerations to address: (1) the source of fish from the Sacramento River mainstem winter-run Chinook Salmon population during initial reintroduction efforts and from Battle Creek as the program progresses; (2) strategies for transfer and release of fish into Battle Creek; and (3) physical features of proposed fish collection and hatchery facilities to support the plan.

Sequence of Preferred Program Reintroduction Strategies

- Initiate hatchery spawning and rearing to release with broodstock from Sacramento River natural-origin adults
- Develop facilities for rearing from eyed-egg to release on NF Battle Creek
- Develop Battle Creek hatchery program for spawning adults
- Begin collection and translocation of naturally produced juveniles from Sacramento River
- Transition to an integrated hatchery program using natural-origin adult returns from Battle Creek
- Reduce hatchery augmentation and translocation of Sacramento River-origin juveniles as natural population abundance increases
- Eventual termination of hatchery program

3.1.1 Sources of Fish for Reintroduction

Even though the only source of fish for reintroduction is the Sacramento River mainstem population, there are multiple options of using that population for reintroduction. Strategies could include the following.

- Direct translocation of natural-origin (Chinook Salmon progeny from natural spawning) eggs, juveniles, or adults from the mainstem population into Battle Creek.
- Using the Sacramento River hatchery program at LSNFH to produce fish for introduction into Battle Creek.
- Using the Sacramento River population to initiate a hatchery program in Battle Creek to produce fish for introduction into Battle Creek.

- A combination of all three options above.

Options were evaluated based on their potential impact on the Sacramento River natural population and the premise that successful reintroduction would require approximately 500 natural spawners annually over several years to overcome likely demographic hurdles[1] in order to successfully establish natural production and avoid diminishing genetic diversity during reintroduction.

3.1.1.1 Translocation Options

Translocating natural-origin fish from the Sacramento River to Battle Creek would avoid potential artificial selection inherent in a hatchery-dependent strategy. However, collecting enough winter-run Chinook Salmon from the Sacramento River mainstem to establish a population in Battle Creek could be difficult. Annual collection and release of several hundred adults would be necessary for several generations to ensure enough natural spawners in Battle Creek in order to establish a natural, genetically diverse population. The impact of removing natural-origin adults from the mainstem population for translocation to Battle Creek would likely be too great, given recent counts of adults returning to the mainstem of less than 6,000 fish and their importance to maintenance of the Sacramento River population. This option would be feasible only if adult counts in the mainstem were to rebound to the numbers seen in 2005 and 2006, when respectively over 15,000 and 17,000 winter-run Chinook Salmon were estimated to have spawned in the Sacramento River (see Figure 2).

Winter-run Chinook Salmon eggs could be mined from redds in the Sacramento River and transplanted to Battle Creek for injection into artificial redds or streamside incubators for incubation. Given optimistic survival rates from egg to smolt of 20 percent and smolt to adult of 0.3 percent, producing the number of returning adults needed to establish a population from transplanted eggs would require collection of approximately 1 million eggs from the wild annually until a regular return was established in Battle Creek. Mining and handling that number of eggs during late spring and summer months (April to August) when winter-run Chinook Salmon are spawning and water temperatures are increasing would likely not be feasible due to a high risk of egg mortality and impacts on the Sacramento River population.

While juveniles may be the optimal life stage to work with because they are more temperature tolerant than eggs and less important to the Sacramento River population individually than adults, it is also unfeasible to rely entirely on collecting and transplanting juveniles to establish a population in Battle Creek. Assuming the fry-to-adult survival rates would be comparable to those observed at LSNFH, the number of juveniles needed from the Sacramento River mainstem to provide the number of adults returning to Battle Creek in order to establish a population would require hundreds of thousands of juveniles for over several generations. Collecting that many juveniles is infeasible, particularly in warm months of July and August when fish will need to be handled and transported. In addition, it is highly probable that adult returns from transplanted juveniles would return to the Sacramento River because homing may already have been established prior to capture, further reducing the number of adults entering Battle Creek to establish a population.

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[1] The demographic characteristics of a future winter-run Chinook population are unknown. They include population size, growth rate, variation in growth rate, and carrying capacity. All are dependent on the quality and quantity of habitat in Battle Creek used by winter-run Chinook. Furthermore, stray rates, suboptimal selection of spawning habitat, and variable reproductive success of reintroduced Chinook may impede progress toward reintroduction.

3.1.1.2 Hatchery-Dependent Options

Given the diminished state of the Sacramento River population and the apparent high risk to that population from relying entirely on a transplant-only strategy, the workgroup considered hatchery options for producing enough fish to establish a population in NF Battle Creek. A hatchery release in Battle Creek could be developed by expanding the number of Sacramento River winter-run Chinook Salmon brought into LSNFH for spawning and egg incubation. While the LSNFH is managed under an HGMP (USFWS 2013a) to meet current standards for operation of conservation hatcheries, the risk of some level of domestication appears unavoidable (Ford 2002; Christie et al. 2012). While this strategy could achieve producing approximately 500 adult returns to Battle Creek, a strategy of repeated release of hatchery fish from LSNFH of mainstem origin would limit opportunities for Chinook Salmon to adapt to environmental conditions unique to Battle Creek.

The workgroup considered an option of immediately establishing a separate hatchery program in Battle Creek that also could achieve production levels for reintroduction. A Battle Creek hatchery program could be initiated using natural-origin adults collected from the mainstem Sacramento River or from hatchery returns to LSNFH. This option has a greater dependence on hatchery returns for broodstock, as it would take several generations for natural production to be established in Battle Creek for use in the broodstock. Consequently, this option presents the concern of a greater risk of domestication and a loss of genetic diversity. In addition, establishing a separate hatchery program in Battle Creek may not be a practical option. The BCRP has not yet been completed. Although the performance of the habitat vis-à-vis natural production of winter-run Chinook Salmon was assumed, it has not yet been demonstrated. Relying on LSNFH in the early phases of the reintroduction program while performance of the restored habitat is being evaluated would avoid sunk costs associated with building a new hatchery in the event that the habitat performance falls below expectations.

3.1.1.3 Preferred Option

The workgroup determined that a combination of translocation and hatchery-dependent options would have the best chance of success. A translocation-only option would not provide enough fish to overcome demographic hurdles, and a hatchery-only option raise concerns about domestication and constraint of genetic diversity relative to the source population in the Sacramento River. The workgroup thought that the success of the program was dependent on maximizing the genetic diversity available in the population trying to reestablish itself in Battle Creek. Therefore, the workgroup chose a hybrid approach in which (1) a hatchery program would be used to overcome the demographic challenge of having enough fish to establish a population in NF Battle Creek; and (2) the hatchery program would be supplemented with collection and translocation of naturally produced juveniles from the Sacramento River to NF Battle Creek to enhance the genetic diversity of the population reestablishing in NF Battle Creek.

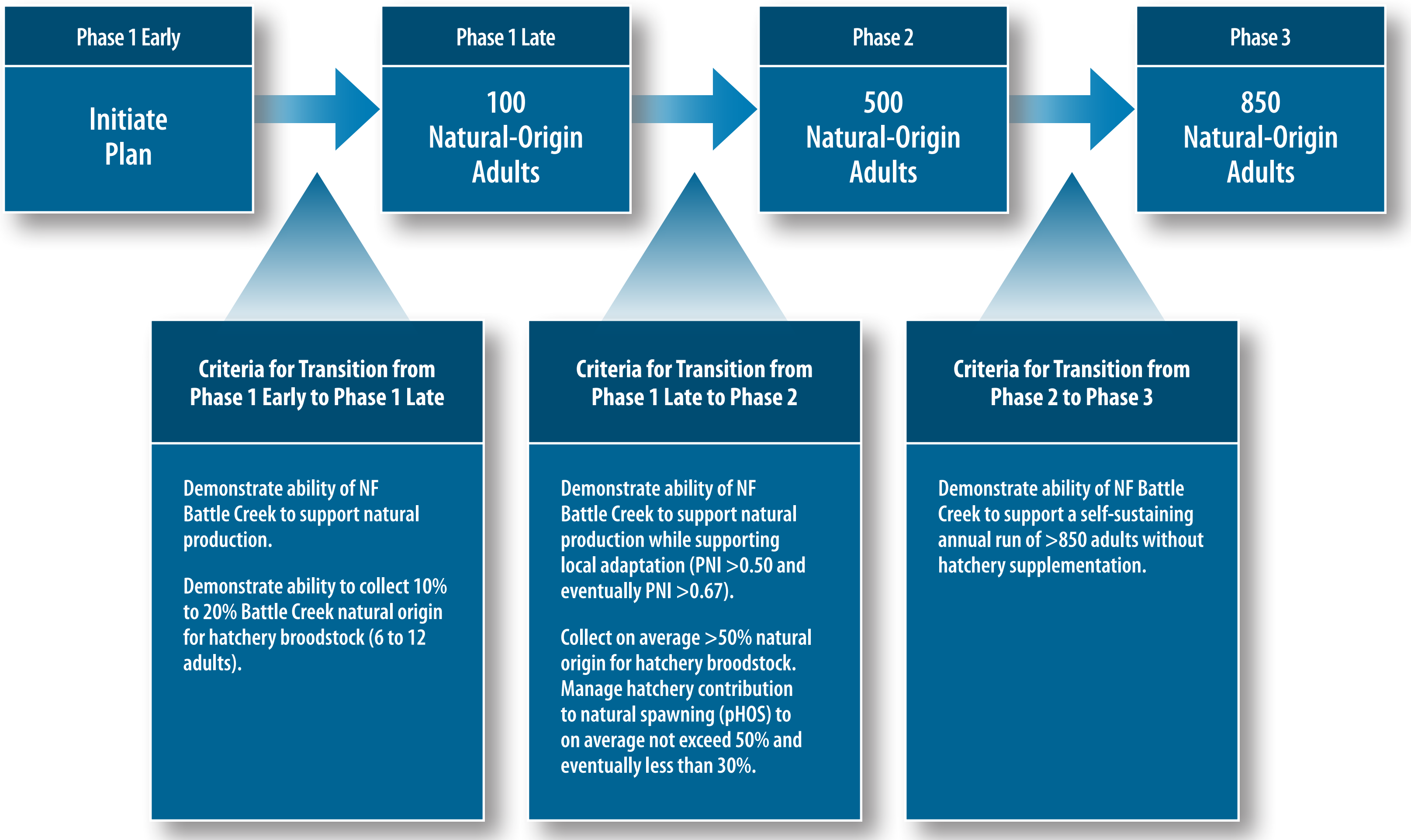
Important considerations for the more hatchery-dependent strategies are risks of reduced genetic diversity of fish introduced into Battle Creek and reduced fitness due to potential domestication selection in the hatchery. These factors may affect long-term reintroduction success in Battle Creek. They also have the potential to affect the Sacramento River mainstem population if high numbers of returning adults from releases in Battle Creek stray to the Sacramento River mainstem to spawn, thus affecting the fitness and possibly the genetic diversity of that population. Another consideration is a concern by the California Hatchery Scientific Review Group (2012) that adult broodstock collected at Keswick Dam may not fully represent the genetic diversity of the Sacramento River mainstem population.

Multiple measures were identified to address these concerns. To address domestication concerns, the preferred option includes measures to incorporate natural-origin adults from the Sacramento River mainstem population and eventually from Battle Creek into the broodstock to the maximum extent possible. With respect to concerns over reduced genetic diversity from overrepresentation from a subset of adults collected at Keswick Dam, two strategies were identified: (1) develop alternative sites for collection of adult broodstock in the mainstem—nearer the lower end of the primary spawning area (e.g., at the Anderson-Cottonwood Irrigation District [ACID] dam; and (2) collect natural-origin fry and pre-smolts from the mainstem population at a location downstream of spawning areas to transplant to Battle Creek for acclimation and release. The transplant option also could address concerns about domestication selection associated with strategies dependent on hatchery production, but depending on how well they acclimate to Battle Creek their stray rates back the upper Sacramento River may be higher than hatchery fish produced and released in Battle Creek.

Broodstock collection from the Sacramento River mainstem to support reintroduction would need to be above what is already required for the ongoing mainstem conservation hatchery program and would need to be managed to avoid jeopardizing the sustainability of the mainstem population. The strategy requires a mainstem natural population large enough to support collection of an additional 120 natural-origin adults for broodstock (i.e., a total return of 1,600 to 2,400 adults, assuming that collection would be limited to between 10 and 15 percent of the natural-spawning returns in the Sacramento River).

Several alternative broodstock strategies were considered in the event that the natural population in the Sacramento River mainstem was insufficient to supply fish for reintroduction. Foremost was the use of hatchery-origin adults produced by the conservation hatchery program at LSNFH for broodstock. Additional strategies considered to support reintroduction of winter-run Chinook Salmon in Battle Creek included early development of an independent hatchery population in Battle Creek and the use of progeny from a recently reestablished captive broodstock program at LSNFH; however, these two alternatives were dismissed due to concerns over genetic constraints and domestication or reduced fitness.

The workgroup determined that a phased approach to reintroduction was most feasible, with biological triggers using a 5-year geometric mean of natural-origin run (NOR) sizes returning to Battle Creek to “trigger” management decisions (Figure 5). This approach was chosen to manage the risks of domestication and loss of genetic diversity, and to ensure progress toward reintroduction goals. Management decisions include reducing/eliminating the use of mainstem adults in the broodstock, collecting and transplanting mainstem juveniles, using Battle Creek hatchery and natural-origin fish in the broodstock, and reducing (and eventually eliminating) hatchery production. The following is an overview of these decisions. Details of the reintroduction phases, including the number of winter-run Chinook Salmon needed for release, expected survival rates in-hatchery and post-release, and expected return rates to Battle Creek, are discussed in Section 3.3. Additional rationale for the numbers of broodstock and transplanted juveniles to be collected, the targets for juvenile releases, and triggers for transitioning between phases is presented in Appendix C.



Phase 1 Early

Initiate Plan

Phase 1 Late

100 Natural-Origin Adults

Phase 2

500 Natural-Origin Adults

Phase 3

850 Natural-Origin Adults

Criteria for Transition from Phase 1 Early to Phase 1 Late

Demonstrate ability of NF Battle Creek to support natural production.

Demonstrate ability to collect 10% to 20% Battle Creek natural origin for hatchery broodstock (6 to 12 adults).

Criteria for Transition from Phase 1 Late to Phase 2

Demonstrate ability of NF Battle Creek to support natural production while supporting local adaptation (PNI >0.50 and eventually PNI >0.67).

Collect on average >50% natural origin for hatchery broodstock. Manage hatchery contribution to natural spawning (pHOS) to on average not exceed 50% and eventually less than 30%.

Criteria for Transition from Phase 2 to Phase 3

Demonstrate ability of NF Battle Creek to support a self-sustaining annual run of >850 adults without hatchery supplementation.

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Figure 5

Biological Triggers for Transitioning Between Phases

The preferred initial strategy for reintroduction in Phase 1 is a release of presmolts or smolts from hatchery production using natural-origin broodstock from the Sacramento River mainstem population and supplementing the hatchery releases with presmolts produced from natural-spawning adults in the Sacramento River. This strategy was selected as the most feasible way to return a sufficient number of natural-spawning adults to Battle Creek and overcome demographic hurdles during the reintroduction process, while conserving the genetic diversity of the reintroduced population.

As reintroduction progresses out of the initial reintroduction of winter-run Chinook Salmon in Phase 1, the preferred strategies for hatchery broodstock source change to support objectives for local adaptation to conditions in Battle Creek, while maintaining diversity in the newly established population (Figure 5). Early adult returns to Battle Creek in Phase 1 will be hatchery-origin winter-run Chinook Salmon from Sacramento River mainstem parents. These adults would have survived emigration from Battle Creek as juveniles, completed their migration and oceanic phases of their life cycle, and voluntarily entered Battle Creek as adults. This experience may have provided an opportunity for some degree of adaptation to juvenile and adult migration conditions in Battle Creek beyond simply imprinting to the Battle Creek watershed. To the extent adaptations to Battle Creek are developed, strategies were designed to retain and enhance them through incorporation of those adults returning to Battle Creek into the hatchery broodstock.

However, one consequence of transitioning to use of Battle Creek returns in the hatchery broodstock too quickly could be lost genetic diversity compared to the source population from the Sacramento River and limited genetic variation for development of local adaption to Battle Creek. Phase 1 broodstock management strategies should avoid a potential diversity bottleneck by including hatchery production from adults from the Sacramento River mainstem population with hatchery production from Battle Creek's returning adults. In addition, transplants of natural-origin juveniles collected from the Sacramento River would serve as another source of genetic diversity.

Options for the initial use of hatchery-origin adults returning to Battle Creek (these are adults from broodstock collected from the Sacramento River mainstem) include: (1) collecting a portion of the returns for broodstock to establish a Battle Creek hatchery program in order to support subsequent reintroduction efforts; or (2) passing the returning adults upstream to spawn naturally in Battle Creek to establish natural production as quickly as possible. Option 2 also would facilitate assessment of the potential for habitat to support natural reproduction of winter-run Chinook Salmon. Given that the early objectives in Phase 1 are to overcome a demographic threshold (i.e., providing enough fish to achieve a return to Battle Creek) and to determine the potential for Battle Creek to produce winter-run Chinook Salmon, option 2 was chosen because it establishes natural spawning.

As a breeding population begins to establish in Battle Creek, returning hatchery- and natural-origin adults will become more readily available as a source for a Battle Creek broodstock. Collecting adults from Battle Creek for hatchery production would increase the number of winter-run Chinook Salmon available for release into Battle Creek and reduce impacts on the Sacramento River mainstem population. It would facilitate local adaptation by sourcing progeny from adults that had completed their life cycle in Battle Creek. Battle Creek broodstock also could be used to test alternative propagation techniques (e.g., using eggs or fry), provided that spawners are available and marking strategies can be applied to accurately identify those Chinook Salmon when they return.

In summary, the risks of domestication, loss of genetic diversity, and limited availability of fish were important factors to consider during Phase 1. These risks were weighed against a need to return enough adults to Battle Creek to establish a stable population (i.e., resilient to demographic and environmental stochasticity). The preferred strategies are intended to achieve a return of approximately 500 natural-spawning winter-run Chinook Salmon needed to seed initial stages of reintroduction.

In Phase 2, options for broodstock source are more limited in order to promote objectives for local adaptation that support a self-sustaining Battle Creek population. The preferred strategy is to transition to a broodstock comprising hatchery-origin to natural-origin adults returning to Battle Creek (an integrated hatchery program[2]) and manage for a PNI greater than 0.50 early in Phase 2 and 0.67 as confidence increases that the natural population can persist without hatchery supplementation. This strategy recognizes the need to avoid isolating Battle Creek winter-run Chinook Salmon from the larger Sacramento River population when still releasing hatchery-origin Chinook Salmon into Battle Creek. Ideally, natural stray rates from Battle Creek to the mainstem and from the mainstem to Battle Creek would be sufficient to meet diversity goals and provide the basis for natural variation in Battle Creek Chinook Salmon from which selection, leading to local adaptation, can occur. However, hatchery propagation can easily result in a disproportionate contribution of hatchery broodstock to the spawning population compared to natural propagation because of large differences in survival. Therefore, managing for a small fraction of the Sacramento River winter-run Chinook Salmon to be included in the hatchery release in Phase 2 is intended to simulate a natural stray rate of from 5 to 20 percent from the Sacramento River.

By Phase 3, reintroduction strategies and broodstock decisions are no longer relevant because the population is assumed to be self-sustaining. However, as in the other phases, contingency strategies will provide a safety-net should the population decline. Such a decline in population abundance may necessitate reverting to Phase 2 with hatchery supplementation to bolster run size.

3.1.2 Transfer and Release Strategies

Options for transferring winter-run Chinook Salmon progeny from hatchery production to Battle Creek include (1) transferring prespawning adults; (2) planting eggs using Vibert boxes or direct gravel injection; and (3) releasing fry, presmolts, or smolts. Options considered for releasing hatchery juvenile Chinook Salmon include their direct transfer and release into NF Battle Creek, or releasing them after transfer to short-term rearing/acclimation ponds in NF Battle Creek water so they more likely to imprint on Battle Creek.

Release strategies involve trade-offs between minimizing the time in a hatchery environment with potential domestication selection and achieving the post-release survival abundance metrics necessary to return enough adults back to Battle Creek to establish a population. Release strategies that include more time in a hatchery outside of Battle Creek have the potential to increase stray rates to the mainstem Sacramento River or to non-target spawning habitat in Battle Creek. High

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[2] An integrated program is when hatchery and natural production are two components of a single population. This is accomplished by using natural-origin Chinook for a portion of the broodstock and limiting the proportion of hatchery-origin Chinook spawning in the wild. The objective is to minimize genetic divergence between the hatchery and natural populations, and for the natural environment to drive the adaptation of the combined population (HSRG 2015).

stray rates to non-target spawning areas reduces the number of adults returning to target spawning areas in NF Battle Creek.

The preferred initial strategy therefore is to maximize survival by releasing hatchery-origin Chinook Salmon at presmolt or smolt stages that will adapt to NF Battle Creek as returning adults. This involves establishing hatchery facilities on NF Battle Creek that can accept eyed-eggs and rear them to release as presmolts. If facilities for rearing fish from the eyed-egg stage to presmolts are not available on NF Battle Creek early in implementation of the plan, transferring juveniles and holding them in rearing ponds in upper NF Battle Creek from 1 to 2 months for acclimation and imprinting is a contingency. The workgroup also discussed and dismissed as not likely to achieve survival and homing objectives defined in the plan, the direct transfer and release of juveniles from facilities outside of Battle Creek. The workgroup concluded that long-term success of the plan would require a facility on NF Battle Creek that can rear Chinook Salmon from eyed-egg to release.

Transplanted natural-origin juvenile Chinook Salmon collected from the Sacramento River as fry also would need to be reared in a NF Battle Creek hatchery to a presmolt or smolt stage before release in order to maximize their survival and improve homing to Battle Creek.

Release times that maximize survival and reduce potential ecological interactions with other salmonid populations likely will be similar to the LSNFH program, late January to early February (USFWS 2013). However, the workgroup noted that it is important to evaluate alternative release times during implementation of the reintroduction plan that could maximize local survival because streamflow and other habitat characteristics in Battle Creek may suggest a different release strategy.

3.1.3 Physical Components and Hatchery Facility Needs

The LSNFH, the adult trap at Keswick, and the barrier weir on Battle Creek at CNFH (Coleman weir) are important components of the Reintroduction Plan. Nonetheless, hatchery programs perform best when they are located near the population they are supplementing (Mobrand et al. 2005; HSRG 2012). Therefore, use of LSNFH is considered an interim step until hatchery facilities can be constructed on NF Battle Creek. The workgroup concluded that a facility on NF Battle Creek would have biological benefits (e.g., improved imprinting because of the use of NF Battle Creek water from incubation to release and rearing of fish on water temperatures consistent with the natural environment) and operational benefits (e.g., not needing to complete multiple transfers of eggs or fish and not needing to compete with other programs for hatchery space at LSNFH). A significant factor in this decision was the workgroup's anticipation that supplementation of natural production in Battle Creek with hatchery fish will need to occur for multiple generations as this reintroduction plan is implemented.

In summary, the reintroduction strategies described in planned program implementation assume the following physical components.

1. The adult fish collection facility at Keswick Dam on the Sacramento River will continue to serve as a primary collection point for natural-origin and hatchery-origin winter-run Chinook Salmon. Adult collection at Keswick Dam should be supplemented with an improved collection facility at ACID or an additional, yet to be developed trapping facility at some other location downstream of the primary spawning areas on the mainstem Sacramento River.
2. A new hatchery on NF Battle Creek will be used to incubate eggs from eyed-egg stage to tanking and subsequent rearing to release sizes.

3. The LSNFH facility will hold and spawn adults and will be used to incubate eggs to the eyed-egg stage. The LSNFH is designed and managed to facilitate propagation of winter-run Chinook Salmon, and husbandry practices are in place to ensure high survival of adults to spawning. Furthermore, it has the spawning and incubation infrastructure needed to achieve the maximum effective population size of the hatchery broodstock. For these reasons, the workgroup concluded that it is not necessary to develop additional adult holding and spawning capabilities at this facility.
4. The weir at CNFH will be used to monitor escapement of adult fish into upper Battle Creek and collect adult winter-run Chinook Salmon for broodstock. Additional tanks, plumbing, and water chillers will be needed to temporarily hold adults at the weir for sorting and to hold fish while genetic samples are processed.
5. Rotary screw traps and holding facilities on the Sacramento River will be used to collect and temporarily hold natural-origin winter-run Chinook Salmon fry from the mainstem population for subsequent transfer to rearing ponds on NF Battle Creek.

The hatchery facilities on NF Battle Creek are described in general terms at this stage of plan development to allow flexibility for further discussion of a preferred course of action for developing the facility. Facilities currently exist in the NF Battle Creek watershed that could be adapted to support the reintroduction program. Privately owned facilities developed for aquaculture operations that exist within Battle Creek could serve as rearing ponds for the reintroduction.

The CNFH on Battle Creek is a mitigation hatchery for fall-run and late-fall-run Chinook Salmon and steelhead. This facility is not preferred because it is downstream of the target spawning habitat in NF Battle Creek; water temperatures are too warm in summer and require chillers for holding adults and for egg incubation; and its water source includes SF Battle Creek water, which may confound homing to NF Battle Creek.

3.2 Marking Strategies

The ability to distinguish winter-run Chinook Salmon from other runs of Chinook Salmon at Coleman weir is an essential component of this plan (see Section 3.3). However, there is considerable overlap in the timing of adult runs to the upper Sacramento River, which presents a challenge in assigning individuals to a particular run. For example, the timing of late-fall run Chinook Salmon and winter-run Chinook Salmon adult returns overlap during December, January, February, and March; and spring-run Chinook Salmon and winter-run Chinook Salmon adult returns overlap from late March into July (Vogel and Marine 1991). Physical characteristics (e.g., the presence of fungus, fish coloration and condition, and degree of maturity) can be used to distinguish between these runs, but these characteristics are not completely reliable throughout the duration of the run. Late-fall and winter-run Chinook Salmon are generally differentiable based on phenotype during February and March, when late-fall Chinook Salmon tend to appear dark in coloration and may exhibit excessive fungus. However, differences between individuals of these same stocks may be obscured during December and January, when either stock may exhibit firm body composition and bright coloration.

The ability to distinguish late-fall Chinook Salmon from winter-run Chinook Salmon is particularly important because of the relatively high numbers of hatchery-origin late-fall run Chinook Salmon returning to Coleman weir and CNFH. Late-fall run Chinook Salmon hatchery fish returning to CNFH must be correctly identified by run so that broodstock collection goals can be achieved (USFWS 2011). The USFWS minimum spawning target for late-fall Chinook Salmon at CNFH is 540 adults to meet a production target of 1 million late-fall run smolts for release (USFWS 2011). However, the number of late-fall Chinook Salmon spawned at CNFH frequently exceeds 1,000 fish (USFWS 2011). Currently, all late-fall Chinook Salmon produced at CNFH are marked with an adipose fin clip and coded wire tag (CWT).

Relatively fewer spring-run Chinook Salmon than late-fall run Chinook Salmon return to Battle Creek. During the last decade (2006–2015), between 105 and 799 spring-run Chinook Salmon are estimated to have returned to Battle Creek (CDFW GrandTab 2016) compared to between 3,183 and 6,436 hatchery-origin late-fall run Chinook Salmon returning to CNFH (USFWS 2011). These runs also will need to be distinguished from winter-run Chinook Salmon. Given that spring-run Chinook Salmon are not currently produced at CNFH, spring-run Chinook Salmon returning to Battle Creek are likely of natural origin and will not be tagged or adipose fin clipped. This will make it difficult to distinguish natural-origin spring-run Chinook Salmon from naturally produced winter-run Chinook Salmon that will be used as hatchery broodstock. Phenotypic differentiation of natural-origin spring-run and winter-run Chinook Salmon will be most confounded in March, when both enter Battle Creek in an immature state. After March, they become distinguishable because winter-run Chinook Salmon begin showing physical signs of maturing. Occasionally, hatchery-origin spring Chinook Salmon from the Feather River Fish Hatchery, which are marked with a CWT and adipose fin clip, stray into Battle Creek. These fish will need to be identified so they are not mixed with either the late-fall run Chinook Salmon broodstock or the winter-run Chinook Salmon broodstock. Differentiation of spring-run and potential winter-run Chinook Salmon broodstock in Battle Creek will be best accomplished using short-term quarantine and genetic analysis, which is feasible because of lower numbers of spring-run and winter-run Chinook Salmon relative to late-fall Chinook Salmon.

Data stemming from adipose fin clips and CWTs are useful for assessing ocean distribution of salmon stocks and for cohort reconstruction, which is used to manage ocean fisheries (PSC 2008). NMFS and CDFW rely on CWT data to monitor the commercial and recreational fishery impacts on winter-run Chinook Salmon (NMFS 2010). These data also can be used to identify winter-run Chinook Salmon mortalities during their migration downstream and through the Delta (NMFS 2009). Given the importance of CWTs, the hatchery marking protocols for the winter-run Chinook Salmon hatchery program will likely require an adipose fin clip and a CWT. This requirement will compromise the ability of the CNFH weir operators to distinguish the winter-run Chinook Salmon from hatchery-origin late-fall-run Chinook Salmon, potentially resulting in the inadvertent removal of winter-run Chinook Salmon during broodstock collection for the late-fall-run Chinook Salmon hatchery program. The increased handling associated with this collection will likely result in delay, stress, injury, and mortality, which may cause reduced reproductive success when these fish are released into Battle Creek. To avoid this problem, the implementing agency will need to work with the other agencies, experts in the field of marking salmon, and CNFH staff to develop a strategy for distinguishing between these runs that is both reasonable and practical.

While the workgroup chose not to recommend a particular method in this plan, it recommended that the various methods be discussed. Options include genetic testing of all adipose fin-clipped adults, implanting passive integrated transponder (PIT) tags in winter-run Chinook Salmon, applying a secondary external mark to either winter-run Chinook Salmon or late-fall run Chinook Salmon prior to release, or applying a secondary CWT on the body of winter-run Chinook Salmon or late-fall run Chinook Salmon prior to release.

3.2.1 Genetic Testing

Genetic testing requires collecting all adipose fin-clipped adults returning to Coleman weir (potentially several hundred fish daily during the peak of the late-fall run) and holding them for several days while testing is conducted to distinguish winter-run Chinook Salmon from late-fall run Chinook Salmon. While genetic testing could be completed in a few days, all of these fish would need to be quarantined at CNFH. This presents a number of concerns and logistic issues. A mechanism for identifying individual fish tested would need to be developed (e.g., application of an external tag or tattoo, or injection of a visible elastomer) so that fish identified as winter-run Chinook Salmon could be located in the holding pool and collected either for release above Coleman weir to spawn naturally or as broodstock for the winter-run hatchery program. Quarantined fish at LSNFH are floy tagged, to allow genetic results to be matched with individual fish (USFWS 2013a), but that approach may not be appropriate at CNFH given the number of late-fall-run Chinook Salmon handled and the intent to let the winter-run Chinook Salmon pass upstream to spawn naturally or be collected for the winter-run Chinook Salmon broodstock. Increased handling associated with these procedures could affect the fitness of fish returned to Battle Creek.

One advantage of genetic testing, particularly in a novel hatchery program, is that it can be used to develop a full genetic parentage (FGP) program (Anderson and Garza 2005). Because this is a new program, establishing a parentage database (genotyping all broodstock and including their genotypes in a database) would provide the advantages of an FGP program, such as analysis of cohort replacement rates and smolt-to-adult return (SAR) rates. It also would allow evaluation of a host of life history, ecological, and quantitative genetic questions, such as the heritability of age at reproduction and disease resistance/susceptibility, as well as an evaluation of hatchery domestication, estimation of effective population size, and many other biological topics. An FGP program would not replace the use of CWTs, however, and it would still require holding fish at CNFH while the genetic tests are completed, unless the program was conducted in concert with another marking effort that allowed ”real-time” differentiation between winter-run Chinook Salmon and late-fall run Chinook Salmon.

3.2.2 PIT Tags and Coded Wire Tags

The USFWS is considering developing an automated fish sorting facility at Coleman weir to enable some of the sorting and trapping to be implemented continually and without manual handling. Automated sorting would allow fish to be sorted based on internal tags or external marks without exposing them to delay and additional handling stress. The technology for automated sorting and data collection is still under development, but the methods being considered at Coleman weir are currently technologically feasible and available (USBR 2016).

If these facilities are constructed and operate as anticipated, the utility of PIT tag technology is another option that can be incorporated to identify winter-run Chinook Salmon. PIT tag detectors are being designed into the new facility at Coleman weir in anticipation of future research and monitoring needs. The PIT tag technology may be a good fit for winter-run Chinook Salmon in Battle Creek because tags are relatively cheap; they allow identification of individual fish; and the technology is established, effective, and easy to automate. However, there are still some challenges and drawbacks to PIT tagging winter-run Chinook Salmon. PIT tags are expensive (several hundred thousand dollars annually for tags and labor at the scale of the anticipated reintroduction plan), there is a small window of time for tagging 200,000 smolts between when they reach sufficient size for tagging and when they need to be released, and releases of some late-spawned juveniles may need to be delayed for the fish to reach a size sufficient for tagging.

As with other tagging methodologies, the results of studies on the effects of PIT tags on survival and growth of tagged salmon are mixed. A recent study by Knudsen et al. (2009) found that dual-tagged (CWT and PIT tag) hatchery spring-run Chinook Salmon smolts released in the Yakima River had lower SAR rates compared to smolts tagged with only CWTs, indicating that PIT tags may impart a survival bias relative to smolts tagged only with CWTs. The study reported, after correcting for tag loss, that SAR rates of PIT-tagged fish were 10 percent lower than those of non-PIT-tagged fish and that PIT-tagged adults were smaller in length and body weight than the non-PIT-tagged fish, thus reducing per capita productivity by 4 percent through decreased fecundity. Although not directly comparable to Knudsen et al. 2009 because of their limited time frame, Prentice et al. (1984, 1986) reported no significant difference in survival between tagged groups and control groups for 102 days post tagging. In later studies, however, Prentice et al. (1993) concluded that any type of tagging, either PIT tags or CWTs, is likely to reduce survival compared to untagged fish, and speculated that PIT tags and CWTs would probably reduce survival to adulthood by 5 to 10 percent.

The Northwest Power and Conservation Council's Columbia Basin Fish and Wildlife Program is conducting a long term comparative survival study of PIT-tagged spring/summer/fall Chinook Salmon, summer steelhead, and sockeye (McCann et al. 2014). Preliminary SARs for the 2011 releases have been calculated and show similar SAR rates for the CWT-only, PIT tag-only, and untagged groups. Although these are preliminary results in an ongoing study, they suggest that PIT tags and CWTs provide similar estimates of SAR rates, and these SAR rates appear consistent with SAR rates estimated for untagged individuals (McCann et al. 2014). These preliminary results also suggest that dual-tagged fish may have lower SAR rates than singular-tagged fish (McCann et al. 2014). Of note, Prentice et al. (1989) determined that double-tagged coho salmon exhibited significantly ($P = 0.001$) lower survival (46 percent) than fish tagged with PITs (66 percent) or CWTs (71 percent).

3.2.3 Secondary Marks

Secondary marks, such as clipping an additional fin (e.g., one of the pelvic fins, which are often referred to as ventral fins), could be used to distinguish the two runs. As with tags, investigation of the effects of fin clips has produced mixed results. Eriksen et al. (2011) reviewed the literature on the use of fin clips to identify fish and reported such mixed results. For example, Nicola and Cordone (1973) studied the long-term survival of fin-clipped and unmarked rainbow trout in Castle Lake, California and reported that fin removal significantly decreases survival of fingerling salmonids, including the adipose fin. They found that removal of the adipose fin may reduce survival by as much as 50 percent, removal of a ventral fin may reduce survival by as much as 60 to 70 percent, and removal of a pectoral or dorsal fin may reduce survival by as much as 70 to 80 percent. Mears and Hatch (1976) evaluated the overwinter survival of fin-clipped and unmarked brook trout (*Salvelinus fontinalis*) in a reclaimed pond in Maine. While they reported that overwinter survival for all groups was poor, they found that survival of unmarked, unanesthetized trout was significantly higher than survival of marked, anesthetized fish. Survival of trout with multiple fin excisions was lower than that of fish with single fin excisions. They also reported, contrary to Nicola and Cordone (1973), that removal of the adipose fin had little or no effect on survival and that removal of a pectoral fin was no more detrimental than removal of a ventral fin.

Other investigations have reported no deleterious effects associated with fin clipping. For example Bumgarner et al. (2009) investigated the practice of clipping the left ventral fin as a routine method of visually identifying the presence of a CWT in steelhead (*Oncorhynchus mykiss*) in the Columbia River Basin. They reported a slight, non-significant difference in return rates between fish with adipose fin clips and those with both adipose and left ventral fin clips. Overall, fish with adipose and left ventral fin clips had return rates at Lyons Ferry Hatchery that were 5 percent greater than those of fish with only adipose fin clips. Jones et al. (1997) found no significant differences in pre-release or post-release mortality or in migration rates from Kooskia National Fish Hatchery to Lower Granite, Little Goose, or McNary Dams for groups of juvenile spring-run Chinook Salmon marked with a left ventral fin clip versus an adipose fin clip. During their investigation, numbers of returning adults were not sufficient to evaluate survival, and they did not evaluate the effect of marking with both an adipose and left ventral fin clip. Wertheimer et al. (2002) investigated the survival and adult size of pink salmon (*Oncorhynchus gorbuscha*) marked as recently emigrating fry with adipose fin clips and CWTs and compared them with sibling groups that were either unmarked or marked by removing the adipose fin and a ventral (pelvic) fin. While they found that the unmarked group survived better than either marked group, survival of both adipose and ventral fin-clipped fish was equal to or greater than the adipose fin clip only and CWT only group.

If a second mark is applied to differentiate winter-run from late-fall run Chinook salmon, a decision will need to be made regarding which group would receive the secondary mark. Based on the size of the release groups (200,000 to 300,000 winter-run Chinook Salmon versus 1 million late-fall run Chinook Salmon), marking the smaller number of winter-run would be easier and more cost effective. However, because winter-run Chinook Salmon are an endangered species and an additional mark might reduce survival, marking the late-fall run Chinook Salmon, which are not currently listed as threatened or endangered, might be preferable.

An additional form of secondary mark, which would not require clipping an additional fin, would be inserting a second CWT somewhere on the body apart from the snout, which is the location used in the coast-wide CWT assessment of fishery impacts. Goulette and Lipski (in press) investigated whether CWTs could be implanted into various body locations of Atlantic salmon (*Salmo salar*) parr as a non-lethal batch identifier after recapture. Because Atlantic salmon are iteroparous (characterized by multiple reproductive cycles), they were interested in non-lethal mechanisms for identifying batches of fish upon their return to a hatchery. They evaluated placement of CWTs at four different body locations (left and right sides 2 millimeters below the dorsal fin, and left and right sides 2 millimeters below the adipose fin) and monitored growth and survival for 28 months. They achieved a 94.7 percent tag recovery rate, and found no differences in specific growth rates among the control group and the groups of tagged fish. Adding a second CWT below the dorsal fin, in addition to the CWT traditionally placed in the snout, may be an effective way to identify winter-run adults returning to Coleman weir. A secondary CWT also would be less expensive and easier to implement than a PIT tagging program. But automated interrogation with a tunnel-type CWT detector, anticipated for use at Coleman weir, would not differentiate between a fish with a single CWT (e.g., late-fall-run Chinook Salmon) and a fish with a double body-marked CWT (e.g., winter-run Chinook Salmon). All fish would be diverted into holding pools and would be anaesthetized and interrogated with a wand-type tag detector. This method is challenged with the same risks associated with other programs that require holding and handling fish.

Handling and marking effects are recognized with all types of tagging; these include tag loss and effects on behavior, growth, and survival. However, the severity of the effects are uncertain; the severity varies depending on the tagging method and the handling process. Whatever method is selected to identify the run of adult salmon returning to Coleman weir should be evaluated with a well-designed study to determine its effectiveness in distinguishing among runs and its effect on the reintroduction plan.

3.3 Reintroduction Phases

As described previously, the Reintroduction Plan is a continuum of actions described in three phases (see Figure 5). Each phase has one or more goals and objectives. Goals help to define the strategies and desired outcomes at the end of each phase. Objectives provide specific, measurable conditions that are tied to key decisions in the Reintroduction Plan. Some of the objectives trigger management decisions, such as reducing the number of Sacramento River winter-run Chinook Salmon released in Battle Creek, increasing the number of natural-origin fish in the hatchery broodstock, or reducing hatchery production. The following sections describe the strategies and biological triggers specific to each phase.

3.3.1 Phase 1 – Recolonization

Phase 1 Goal

> *Establish a population of winter-run Chinook Salmon in Battle Creek that meets abundance objectives, retains the genetic diversity of the Sacramento population, and includes a substantial proportion of natural-origin fish.*

In Phase 1, a recolonization of winter-run Chinook Salmon in NF Battle Creek will be achieved based on hatchery production initially using broodstock collected from the mainstem Sacramento River. Over time, the broodstock will transition to a mix of Sacramento River and Battle Creek adults. Hatchery production is an important element of Phase 1 to provide approximately 500 adult returns to Battle Creek in order to colonize habitat and avoid demographic and genetic bottlenecks as the new population is established.

Phase 1 is described in two steps: Phase 1 Initial and Phase 1 Late. The workgroup decided that, based on the present vulnerability of winter Chinook Salmon, the plan should establish a return of winter-run Chinook Salmon to Battle Creek as soon as feasible and that returning adults should be passed upstream to spawn in order to evaluate the capability of Battle Creek in supporting winter-run Chinook Salmon natural production. Phase 1 Initial objectives are to develop a return of hatchery-origin winter-run Chinook Salmon to Battle Creek and to colonize natural spawning areas in NF Battle Creek (Figure 6).

The transition to Phase 1 Late occurs once natural production has been established in NF Battle Creek and hatchery returns are sufficient to collect broodstock and pass adults upstream to natural spawning areas (Figure 7). Phase 1 Late objectives are to (1) expand natural production in Battle Creek through continued hatchery supplementation, with strategies intended to return from 500 to 1,000 adults (including natural origin) to natural spawning areas; and (2) maximize diversity of Chinook Salmon colonizing habitat in NF Battle Creek through the use of a combination of Sacramento River and Battle Creek hatchery- and natural-origin-sourced broodstock.

The workgroup also decided that transplanting of wild-caught juveniles (fry) will be an important strategy to maximize genetic diversity in the Battle Creek population in Phase 1 Late. However, they decided wild-caught juveniles should not be incorporated into the Reintroduction Plan until there is evidence that the restored habitat in NF Battle Creek is functioning sufficiently to support a winter-run Chinook Salmon population. They thought naturally produced juveniles in the Sacramento River were valuable for sustaining the Sacrament River population and should not be used to test the suitability of newly available habitat in NF Battle Creek.

Multiple broodstock sources and implementation strategies will produce returning adults from four potential sources: returns from hatchery matings of broodstock collected from the Sacramento River, returns from hatchery matings of broodstock collected from Battle Creek, returns from fry transplanted to Battle Creek, and returns from natural spawning in Battle Creek. Tracking the contribution from each of these sources will be accomplished with a combination of marking methods and genetic parentage analysis.

3.3.1.2 Phase 1 Strategies

The operational components and preferred strategies in Phase 1 Initial presented in Figure 6 include the following.

1. The preference is to collect natural-origin returns to the mainstem Sacramento River winter-run Chinook Salmon population from the Keswick Dam fish trap (or ACID trap) and to spawn and hold to eyed-egg stage at LSNFH, through the existing LSNFH conservation hatchery program.
2. Chinook Salmon for reintroduction would come from expanding the LSNFH program to provide the additional fish for release into Battle Creek. The genetic diversity of the Sacramento River mainstem population would be retained by collecting a portion of the eggs across the entire LSNFH spawning period for use in the Battle Creek reintroduction program.
3. If the number of natural-origin adults collected at the Keswick Dam fish trap or another adult trap on the Sacramento River mainstem cannot meet broodstock needs for the combined programs, broodstock would include hatchery-origin fish from the Sacramento River conservation program at LSNFH.
4. The LSNFH would be used for adult holding, spawning, and incubation to the eyed-egg stage. At that stage, eggs would be transferred to the new facility on NF Battle Creek to complete their incubation and rearing to release stage.

The operational components and preferred strategies in Phase 1 Late presented in Figure 7 (solid lines) include the following:

1. The preference is to collect broodstock from two locations: (1) natural-origin returns to the mainstem Sacramento River winter-run Chinook Salmon population collected at the Keswick Dam fish trap (or ACID trap); and (2) hatchery- and natural-origin returns to Battle Creek collected at Coleman weir at CNFH. Sacramento River and Battle Creek broodstock will be spawned and reared separately to a size to allow placement of unique CWTs.
2. Sacramento River-sourced Chinook Salmon for reintroduction would come from expanding the LSNFH program. The genetic diversity of the Sacramento River mainstem population would be retained by collecting a portion of the eggs across the entire LSNFH spawning period for use in the Battle Creek reintroduction program. Although not preferred, the use of hatchery-origin adults in the broodstock is a contingency strategy (dashed line).
3. Battle Creek-sourced Chinook Salmon for reintroduction would come from broodstock collected at Coleman weir. The priority is to include at least 10 percent of the broodstock from natural-

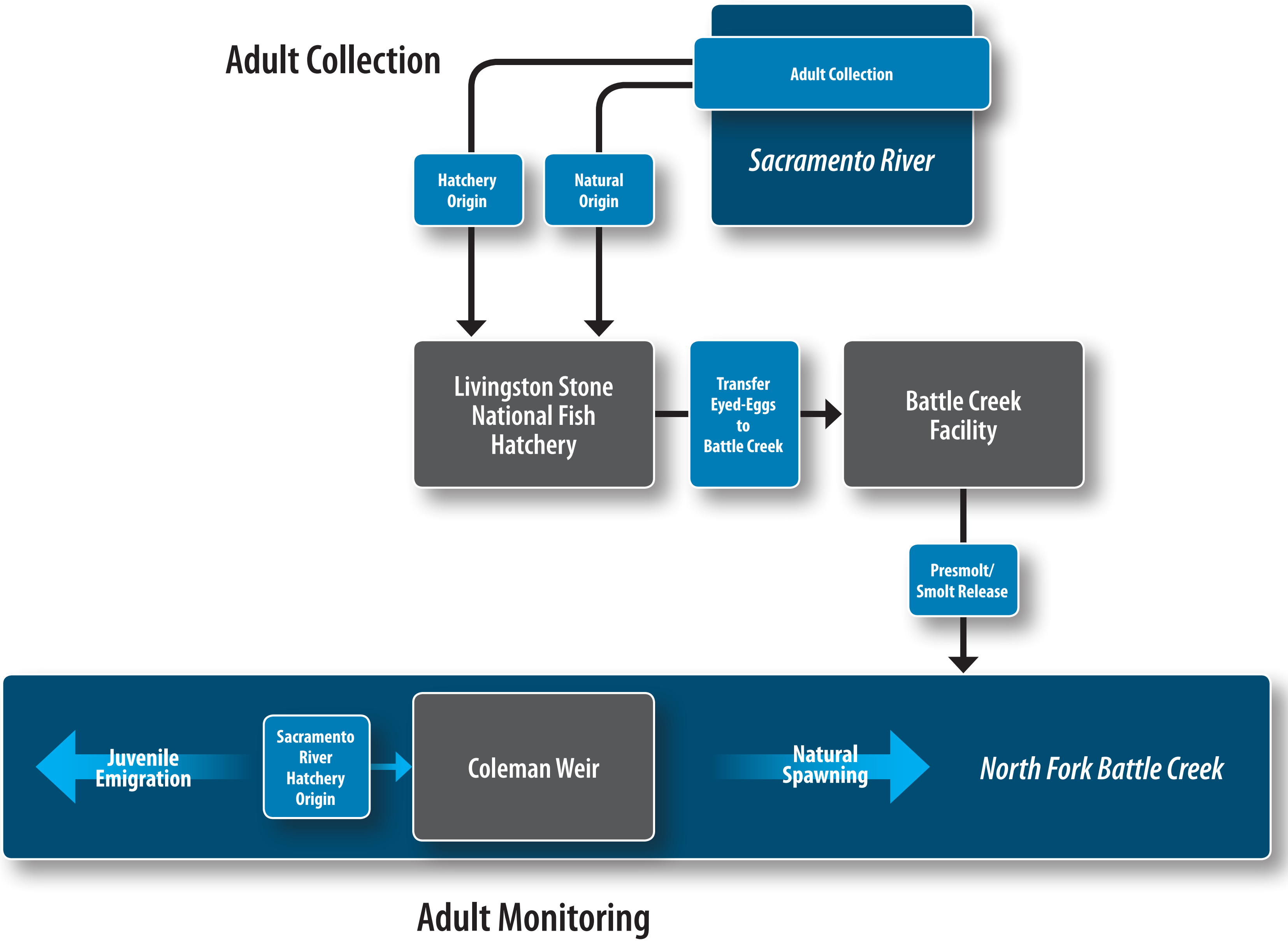

Figure 6
Reintroduction: Phase 1 Initial Actions

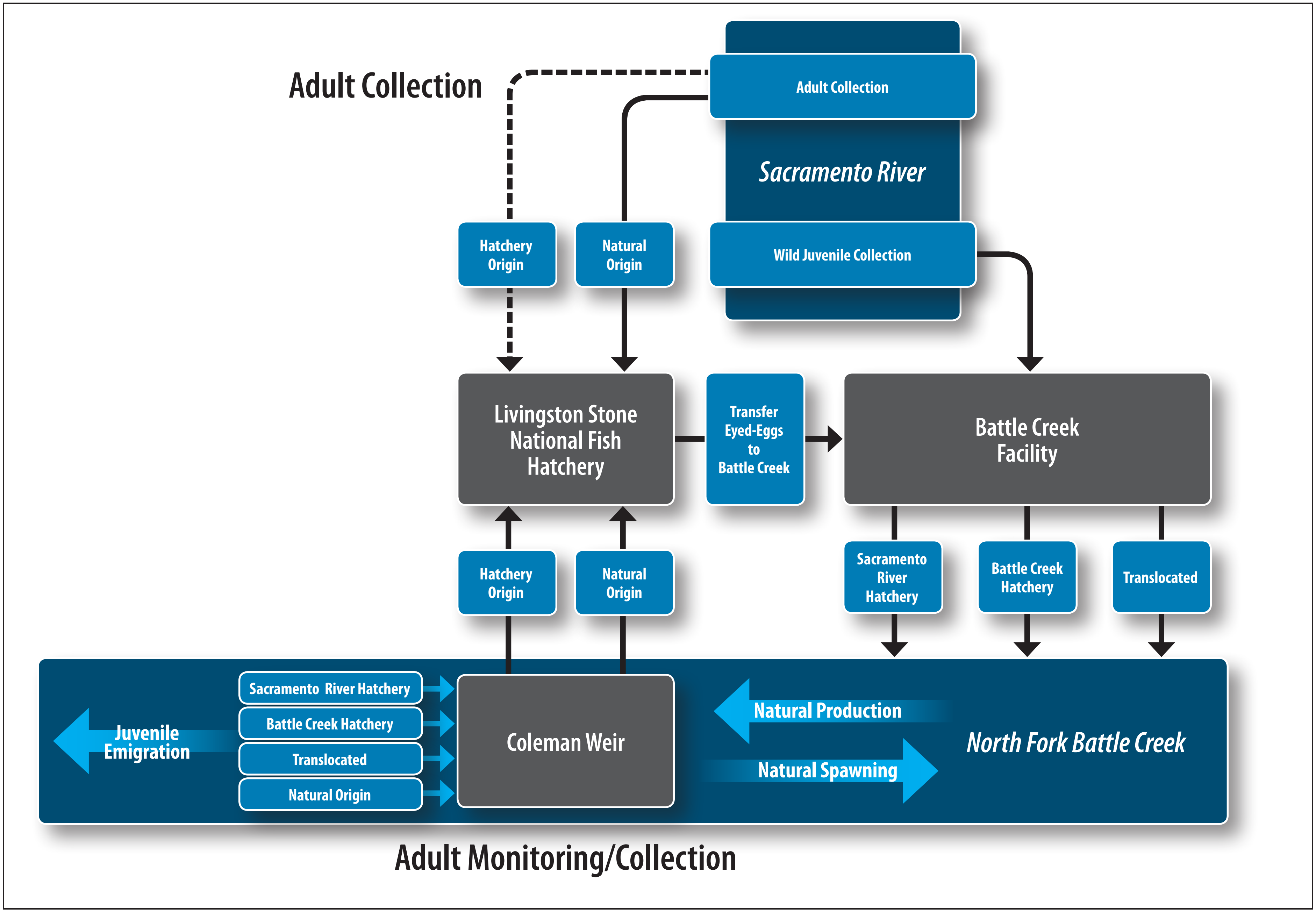

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Figure 7
Reintroduction: Phase 1 Late Actions

origin returns to maintain genetic continuity between hatchery and natural production. Broodstock would be collected from a portion of the run across the entire adult migration period (the migration timing established during monitoring in Phase 1 Initial). Early on, hatchery-origin adults would be returns from progeny of the Sacramento River broodstock; but over time, this would transition to also include Chinook Salmon whose parents were returns to Battle Creek (i.e., independent of the Sacramento River mainstem population).

4. Hatchery production would be augmented with a release of natural-origin juveniles collected from the mainstem Sacramento River. These Chinook Salmon would be collected from the Sacramento River from July to September as recently emerged fry, immediately transferred to raceways in NF Battle Creek, and reared to presmolt or smolt size for release.
5. The LSNFH would be used for adult holding, spawning, and incubation to the eyed-egg stage. At that stage, eggs would be transferred to the new facility on NF Battle Creek to complete their incubation and rearing to release stage.

The preferred marking strategy for all released juveniles (hatchery production and transplanted fry) is an adipose fin clip with a CWT. An additional mark will be identified by the implementing agency to distinguish winter-run Chinook Salmon from late-fall-run Chinook Salmon at Coleman weir (see Section 3.2). Each release group (Sacramento River, Battle Creek, and transplanted fry sourced) would have unique tag codes for post-spawning recovery and run reconstruction. The adult return would have two external mark groups: (1) adipose fin-clipped hatchery-origin or transplanted survivors mostly from Battle Creek releases that may include strays from the mainstem conservation program; and (2) unclipped natural-origin adults that would mostly be from Battle Creek but could include some Sacramento River strays.

Genetic parentage analysis will be important to distinguish between Sacramento River and Battle Creek hatchery-origin fish at Coleman weir and in a spawning matrix. In Phase 1 Initial (Figure 5), it will not be possible to distinguish between Sacramento hatchery-origin releases in the mainstem and releases from Battle Creek because they will have the same parentage. Phase 1 Late (Figure 6) will include separate hatchery broodstocks, and returning adults from Battle Creek-sourced broodstock can be identified. Genetic samples will not be collected from transplanted fry prior to release. Adult returns from transplanted fry can be identified by the adipose fin clip but not assigned to one of the hatchery groups.

Run timing, marking, tagging, and parentage analysis allow differential processing (spawning and passing upstream) of adults at Coleman weir and monitoring of strays to and from the Sacramento River mainstem population.

3.3.1.3 Phase 1 Program Size, Decision Rules, and Biological Triggers

Program size, decision rules, and biological triggers for Phase 1 Initial and Late are presented in Table 2.

The planned program size is an additional 120 adults in the LSNFH broodstock. This would produce approximately 207,000 Chinook Salmon for release into Battle Creek, assuming the fecundity and in-hatchery survival rates reported for the LSNFH conservation program (USFWS 2013a). The median post-release survival rate back to the upper Sacramento River for the LSNFH program (excluding release from captive broodstock) is 0.28 percent (Table 3). Release of 207,000 Chinook Salmon is expected to return 580 adults to the upper Sacramento River assuming the LSNFH median return rate.

Not all Battle Creek-origin adults returning to the upper Sacramento River are expected to enter Battle Creek. However, an annual return of slightly more than 500 hatchery-origin adults to Coleman weir is expected, assuming that 90 percent of Battle Creek-origin adults return to the upper Sacramento River and home to Battle Creek (Table 2).

Table 2. Planned Program Broodstock Collection and Juvenile Release – Phase 1

	Stage	Parameter	Phase 1 Initial Assumptions	Phase 1 Late Assumptions
Hatchery Program	Broodstock	Broodstock priorities by source population and composition		
		Sacramento River source	100%	50%
		Natural origin	100% Preferred	100% Preferred
		Hatchery origin	*Contingency to achieve juvenile release target*	*Contingency to achieve juvenile release target*
		Battle Creek source	0%	50%
		Natural origin	NA	10% to 20%
		Hatchery origin	NA	80% to 90%
		Total broodstock	120	120
	Eggs	Percent female	50%	50%
		Fecundity	5,000	5,000
		Egg take	300,000	300,000
	Juveniles	Survival egg to release	69%	69%
		Number released	207,000	207,000
Sacramento River Natural-Origin Juvenile Collection Strategy				
Number juveniles collected			0	Up to 88,000
Survival to release			---	85%
Number released			---	Up to 75,000
Hatchery and Transplanted Fry Return to Upper Sacramento River				
Post-release survival to upper Sacramento (median)			0.28%	0.28%
Adult return to upper Sacramento (hatchery production)			580	580
Adult return to upper Sacramento (juvenile transplant)			---	Up to 210
Adults to Battle Creek				
Return rate to Coleman weir (hatchery)			90%	90%
Return rate to Coleman weir (juvenile transplant)			---	75%
Number encountered at Coleman weir (hatchery)			522	522
Number encountered at Coleman weir (juvenile)			---	Up to 158
Escapement Management at Coleman Weir				
Hatchery origin removed for broodstock			0	60
Hatchery origin passed upstream			522	462
Juvenile transplant origin passed upstream			0	Up to 158
Natural origin removed for broodstock			0	6 to 12
Percent hatchery origin in natural spawning			NA	No limit

Table 3. Observed Post-Release Survival Rates for LSNFH Winter-Run Chinook Salmon

Brood Year	Number Released	Return Year	Number Adults	Return Rate (%)
2000	166,206	2003	474	0.29
2001	190,732	2004	633	0.33
2002	165,015	2005	3,092	1.87
2003	152,011	2006	2,382	1.57
2004	148,385	2007	189	0.13
2005	160,274	2008	170	0.11
2006	196,288	2009	467	0.24
2007	71,883	2010	199	0.28
2008	146,211	2011	80	0.06
	Median return rate to upper Sacramento			0.28

Source: Table 1.12 in Livingston Stone National Fish Hatchery: Hatchery and Genetics Management Plan (USFWS 2013a).

As noted earlier, a significant potential barrier to plan implementation is the availability of natural-origin Chinook Salmon from the Keswick Dam trap to support the combined LSNFH conservation program and the Battle Creek reintroduction program (combined 240 adults). The total number of natural-origin fish captured at Keswick Dam has been less than 240 adults in past years (Table 4). The workgroup noted that alternative capture sites (such as the ACID dam) are being explored and reconfirmed that an alternative adult collection site is a priority to meet reintroduction goals and continue to support the Sacramento River mainstem conservation program. An additional constraint to initiating the plan is that management guidelines for LSNFH limit the number of broodstock collected to no more than 15 percent of the upper Sacramento River natural-origin run. This limit has not been a problem in past years but may be constraining in future years with anticipated depressed returns following drought years.

The combined number of natural-origin and hatchery-origin fish at the Keswick Dam trap has exceeded 240 adults in past years, suggesting that a combination of natural-origin and hatchery-origin fish could meet broodstock objectives for both programs. Because of the urgent need to establish a second population of winter-run Chinook Salmon spawning in Battle Creek to preserve the run, the workgroup decided to include hatchery-origin fish in the broodstock at LSNFH. The workgroup recognized that this decision would temporarily affect the PNI in the Sacramento River mainstem population by providing a pNOB less than 100 percent, possibly resulting in a PNI less than recommended (PNI >0.50) for integrated hatchery programs (HSRG 2012). The workgroup encourages the USFWS, NMFS, and CDFW to develop guidelines and monitoring that reflect these changes in PNI for the Sacramento River mainstem population.

In Phase 1 Initial, all winter-run adults at Coleman weir would be passed upstream to test habitat conditions for adult upstream migration and spawning in NF Battle Creek, with the goal to establish natural production.

Table 4. Sacramento River Winter-Run Chinook Salmon Estimated Run Size by Origin and Number of Adults Counted at Keswick Dam Fish Trap

	Sacramento River Run Size			Number Observed at Keswick Trap (% of Run)		
Return Year	Natural Origin	Hatchery Origin	Total	Natural Origin	Hatchery Origin	Total
2001	7,711	513	8,224	102 (1%)	103 (20%)	205 (2%)
2002	6,871	570	7,441	125 (2%)	71 (12%)	196 (3%)
2003	7,795	423	8,218	98 (1%)	138 (33%)	236 (3%)
2004	7,233	636	7,869	122 (2%)	224 (35%)	346 (4%)
2005	12,783	3,056	15,839	164 (1%)	227 (7%)	391 (2%)
2006	14,916	2,380	17,296	132 (1%	180 (8%)	312 (2%)
2007	2,401	140	2,541	71 (3%)	86 (61%)	157 (6%)
2008	2,660	170	2,830	142 (5%)	56 (33%)	198 (7%)
2009	4,070	467	4,537	168 (4%)	111 (24%)	279 (6%)
2010	1,397	199	1,596	118 (8%)	302 (152%)[a]	420 (26%)
2011	744	80	824	116 (16%)	262 (328%)[a]	378 (46%)
2012	1,867	809	2,676	146 (8%)	659 (81%)	805 (30%)
2013			6,404	183	130	313 (5%)
2014			3,015	154	275	429 (14%)
2015			3,400 (approx.)	204	229	433 (13%)

[a] In 2010 and 2011, the estimate of hatchery-origin fish in the run was less than the reported Keswick Dam trap hatchery-origin catch.

Sources: Trap catch unpublished data provided by K. Niemela, USFWS on November 13, 2015. Multiple recaptures have been removed from counts. Run size from Table 1, Upper Sacramento River Winter Carcass Survey 2012 Annual Report (USFWS 2013b).

Evidence of successful natural production (juvenile outmigrants and returning adults) based on the abundance of natural-origin adults at Coleman weir will trigger the transition from Phase 1 Initial to Phase 1 Late. The trigger is as follows.

> *When the 5-year running geometric mean of natural-origin adult returns to Coleman weir exceeds 100 Chinook Salmon, the program will transition to Phase 1 Late.*

The rationale for this trigger is that a 5-year running geometric mean of 100 adults would be adequate evidence that restored habitat in Battle Creek is functioning to support a winter-run Chinook Salmon population and is ready for collection of a portion for hatchery broodstock (from 10 to 20 percent) in Phase 1 Late.

The plan is to pass most natural-origin adults upstream to contribute to natural production. Hatchery returns are expected to contribute another 500 adults, based on the median post-release survival rate assumed from the LSNFH program. The total number of naturally spawning adults in NF Battle Creek is expected to exceed 500 Chinook Salmon after removing a portion of the natural-origin and hatchery-origin fish for broodstock.

The transition to Phase 1 Late is largely a change in broodstock rules (Table 2). Approximately half of the broodstock would still come from the Sacramento River population. The workgroup preferred that this broodstock be 100 percent natural origin but also recognized the importance of the contingency that hatchery-origin fish may still be used for broodstock (dashed line in Figure 7). The remaining broodstock for the full program release of 207,000 Chinook Salmon would come from hatchery-origin and natural-origin adults collected at Coleman weir.

Decision rules for implementing the fry transplant strategy were based on evidence that Battle Creek can support natural production and fry can be removed from the Sacramento River population without affecting the population. Up to 75,000 Chinook Salmon fry are prioritized for collection and release into Battle Creek as presmolt or smolts (Table 2). The workgroup also concluded that this strategy should not be attempted if projected natural abundance or trap efficiency might mean the number released would be less than 33,700 (half of 75,000).

Survival of fry from capture to release is not known. For planning purposes, 85 percent survival resulting in 75,000 Chinook Salmon would require collecting a little over 88,000 fry from the Sacramento River. Post-release survival of transplanted Chinook Salmon released at presmolt or smolt stage was assumed to be the same as for hatchery release (0.28 percent). Fry would be treated the same as hatchery production—transferred to rearing ponds in NF Battle Creek, reared to release stage, and released.

A release of 75,000 transplanted Chinook Salmon is anticipated to result in a return of 210 adults to the upper Sacramento River (Table 2). These adults were assumed to have a lower homing rate to Battle Creek based on their incubation and early rearing experience in the Sacramento River. Assuming a 75-percent return to Battle Creek, a median annual run to Coleman weir of 158 Chinook Salmon is anticipated. A release of 33,700 Chinook Salmon would result in a return of 80 adults to Coleman weir. This range would provide a sufficient portion of natural-origin returns to ensure genetic diversity representative of the Sacrament River population in Phase 1. Adults from the fry transplant are expected to contribute to approximately 25 percent of the spawners in NF Battle Creek. These Chinook Salmon likely will have the highest genetic diversity of the release groups, assuming that fry collection can occur throughout the juvenile migration period. They will be incorporated into the hatchery broodstock collected at Coleman weir in proportion to their contribution to the annual run.

The abundance of natural-origin adults at Coleman weir will be the trigger to transition from Phase 1 Late (Recolonization) to Phase 2 (Local Adaptation). The trigger is as follows.

> *When the 5-year running geometric mean of natural-origin adult returns to Coleman weir exceeds 500 Chinook Salmon, the program will transition to Phase 2.*

The rationale for this trigger is that 500 Chinook Salmon will provide sufficient natural-origin adults to actively manage hatchery broodstock composition to achieve on average 50 percent of natural origin broodstock (pNOB) in Phase 2 while still achieving an annual minimum natural-origin objective of 400 Chinook Salmon spawning in NF Battle Creek. The minimum spawner criterion for natural origin is to ensure a combined natural- and hatchery-origin escapement of approximately 800 adults, while limiting the hatchery-origin contribution to less than 50 percent (pHOS).

3.3.2 Phase 2 – Local Adaptation

Phase 2 Goal

> *Establish a self-sustaining, locally adapted population of winter-run Chinook Salmon in Battle Creek by encouraging local adaptation of the Battle Creek population, phasing out the contribution of artificial production, and eliminating the genetic contribution from the Sacramento River population into the artificial production program.*

The goal of Phase 2 is to promote a locally adapted and self-sustaining natural population in Battle Creek using returns of winter-run Chinook Salmon to Battle Creek and natural production established in Phase 1. Hatchery production is an important element early in Phase 2, but over time, the hatchery contribution would be phased out as natural production expands enough to facilitate a transition to Phase 3, when hatchery supplementation is no longer needed to support the population.

Initially, Phase 2 of the reintroduction program will comprise a moderately strong natural production component, with an average run size exceeding 500 adults. Under Phase 2 assumptions, natural-origin returns to Battle Creek exceeding this estimate will be sufficient to transition the Battle Creek hatchery program developed in Phase 1 to an integrated program. Phase 2 objectives are to include at least 50 percent natural origin (pNOB) in hatchery broodstock and a hatchery contribution to natural spawning of less than 50 percent (pHOS). The result is a PNI in Battle Creek greater than 0.50 in all years and, over time, a PNI running average greater than 0.67.

Phase 2 moves natural production toward biological targets consistent with a self-sustaining natural population. Phase 2 transitions to Phase 3 when biological targets are achieved, and Phase 3 ensures persistence of a self-sustaining natural population in Battle Creek.

3.3.2.1 Phase 2 Strategies

Operational components and preferred strategies in Phase 2 presented in Figure 8 (solid lines) are as follows.

1. The preference is to collect most broodstock from Battle Creek at Coleman weir at CNFH.
2. The workgroup thought that some contribution of Sacramento River fish (from LSNFH and/or fry transplants) should be included in the releases to Battle Creek during hatchery supplementation of natural production. The proportion of Sacramento River-origin fish would remain at a low level in Phase 2 to mimic a natural stray rate (between 5 and 20 percent contribution to natural spawning). The preference is that broodstock for the Sacramento River contribution would be natural origin, and genetic diversity of the Sacramento River mainstem population would be retained by collecting a portion of the eggs across the entire LSNFH spawning period for use in the Battle Creek reintroduction program.
3. Sacramento River and Battle Creek broodstock will be spawned and reared separately to a size large enough to receive unique CWTs and other marks determined necessary by the implementing agency to distinguish among the runs at Coleman weir.
4. The LSNFH will continue to be used for adult holding, spawning, and incubation to the eyed-egg stage. At that stage, eggs would be transferred to the new facility on NF Battle Creek to complete their incubation and rearing to release stage. Other release strategies may be used if they are proven to result in better imprinting to NF Battle Creek.

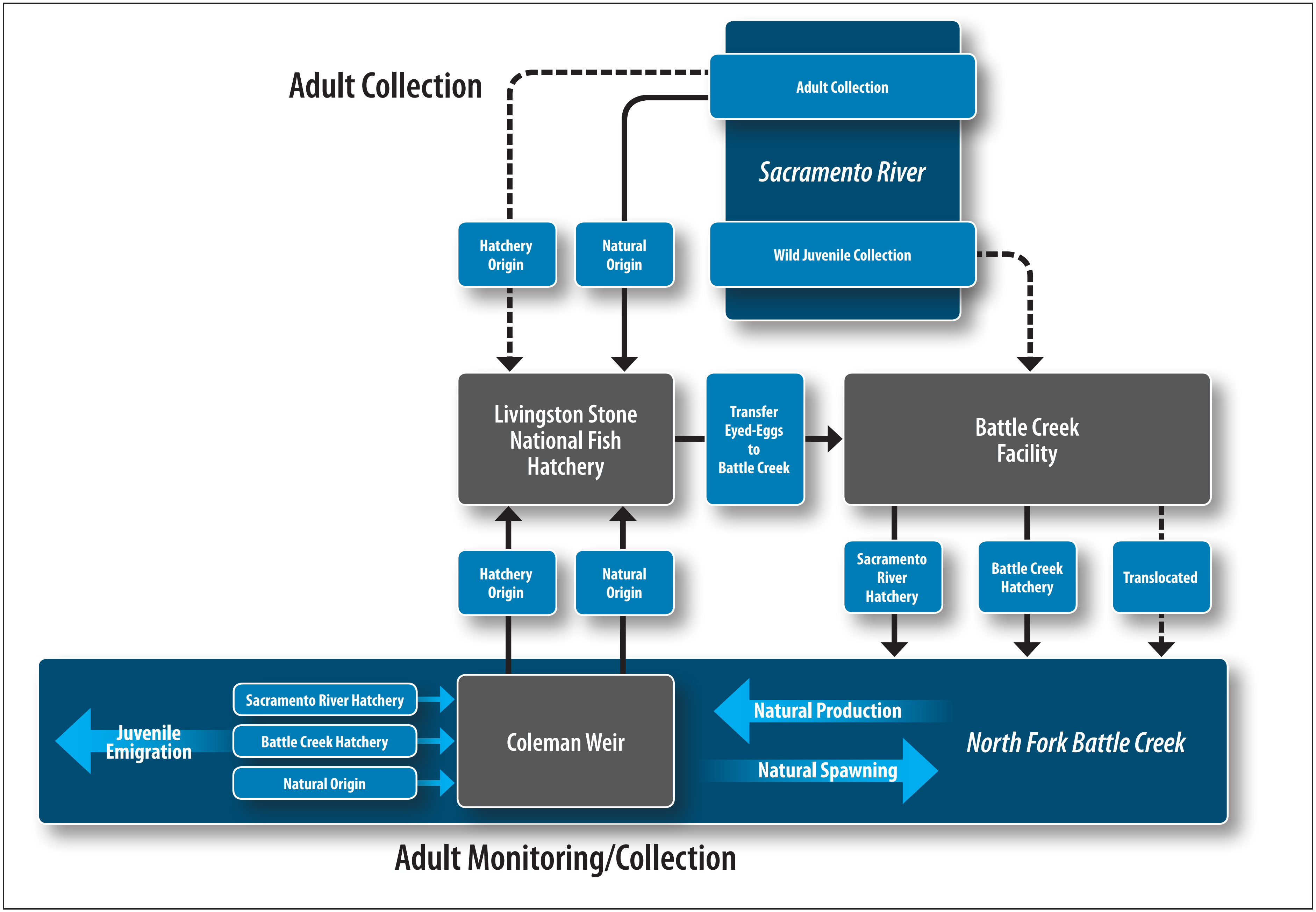

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Figure 8
Reintroduction: Phase 2 Actions

5. Returns to Battle Creek in Phase 2 are planned to be sufficient enough to pass most hatchery-origin adults upstream to supplement natural production. The workgroup acknowledged that this may result in a hatchery contribution to natural spawning that exceeds the 50-percent pHOS objective in some years. Repeated years with contribution of hatchery-origin adults exceeding the pHOS objective would indicate that the number of hatchery-origin Chinook Salmon released in Battle Creek can be reduced and the natural production potential of NF Battle Creek can be evaluated.

The preferred marking strategy for released juveniles is to adipose fin clip and implant CWTs unique to each release group (Sacramento River and Battle Creek sourced). Adult returns would include two groups: (1) hatchery-origin adults and possibly adults from transplanted juveniles with an adipose fin clip (and possibly a secondary mark or tag [e.g., a fin clip or PIT tag]); and (2) natural-origin fish with no external mark that would mostly be from Battle Creek, but could include some Sacramento River strays. Genetic parentage analysis will be important to distinguish between Sacramento River and Battle Creek hatchery origin. It will not be possible to distinguish between Sacramento River hatchery-origin release in the Sacramento River mainstem and in NF Battle Creek because they will have the same parentage.

The marking, tagging, and parentage analysis are intended to allow differential processing (spawning and passing upstream) of adults at Coleman weir and to monitor strays to and from the Sacramento River mainstem population.

3.3.2.2 Phase 2 Program Size, Decision Rules, and Biological Triggers

Program size, decision rules, and biological triggers for Phase 1 Initial and Late are presented in Table 5.The program size remains at 207,000 Chinook Salmon smolts/presmolts released in Phase 2 with an integrated broodstock of at least 50 percent natural origin adults (Table 5).

Total broodstock collected at Coleman weir would vary from 100 to 110 adults. Production from another 10 to 20 adults from the Sacramento River would round out the release to 207,000 Chinook Salmon smolts/presmolts. For planning purposes, the survival rate from release-to-adult return to the upper Sacramento River was assumed to be 0.28 percent, based on rates at LSNFH, to provide an annual return of 580 hatchery-origin adults to Battle Creek. However, in-hatchery survival and fecundity may differ with adults sourced from Battle Creek natural-origin returns and broodstock numbers may need to be adjusted based on the results of the monitoring programs.

As noted for Phase 1, not all adults returning to the upper Sacramento River are expected enter Battle Creek. A median annual return of slightly more than 500 hatchery-origin adults to Coleman weir is expected, assuming that 90 percent of adults returning to the upper Sacramento River home to Battle Creek (Table 5).

At the beginning of Phase 2, PNI for the integrated hatchery and natural population is expected to average 0.50 (50 percent pNOB and 50 percent pHOS). As program success becomes evident and natural production increases in Phase 2, the population PNI is expected to exceed 0.67, with a pNOB objective of 100 percent and a pHOS objective of less than 30 percent. It may be necessary to manage the contribution of hatchery fish to natural spawning if repeated years with hatchery-origin percentages exceed the objectives for pHOS.

In Phase 2, contingency strategies will be used to achieve a total broodstock objective of from 100 to 110 adults at a cost of reducing the number of natural-origin fish used to a floor of 50 percent.

The second contingency is to reduce program size by 25 percent (155,000 total release), and the third contingency is to increase the contribution of Sacramento River natural-origin broodstock if the Battle Creek hatchery return is not able to support the program. In other words, revert back to Phase 1 strategies if the first two options are not viable.

The abundance of natural-origin adults at Coleman weir will be the trigger to transition from Phase 2 (Local Adaptation) to Phase 3 (Long-Term Management). The trigger is as follows.

> *When the 5-year running geometric mean of natural-origin adult returns to Coleman weir exceeds 850 Chinook Salmon, the program will transition to Phase 3.*

The rationale for this trigger is that an annual run of 850 Chinook Salmon will ensure the per-generation census minimum spawner abundance of 2,500 adults described in Section 2.1.2.2 to achieve a viable population that protects against genetic loss based on the concept of effective population size (Ne).

Table 5. Planned Program Broodstock Collection and Juvenile Release – Phase 2

	Stage	Parameter	Phase 2 Assumption
Hatchery Program	Broodstock	Broodstock priorities by source population and composition	
		Sacramento River source	5% to 20%
		Natural origin	100% preferred
		Hatchery origin	*Dependent on LSNFH composition*
		Battle Creek source	80% to 95%
		Natural origin	Greater than 50%
		Hatchery origin	Less than 50%
		Total broodstock	120
	Eggs	Percent female	50%
		Fecundity	5,000
		Egg take	300,000
	Juveniles	Survival egg to release	69%
		Number released	207,000
Hatchery Return to Upper Sacramento River			
Post-release survival to upper Sacramento (median)			0.28%
Adult return to upper Sacramento (hatchery production)			580
Adults to Battle Creek			
Return rate to Coleman weir (hatchery)			90%
Number encountered at Coleman weir (hatchery)			522
Escapement Management at Coleman Weir			
Hatchery origin removed for broodstock			50
Hatchery origin passed upstream			472
Natural origin removed for broodstock			50
Percent hatchery origin in natural spawning			Less than 50% and eventually less than 30%

3.3.3 Phase 3 – Long-Term Management

Phase 3 Goal

> *Monitor the viability of the Battle Creek population and respond to concerns set by ESA recovery needs.*

Phase 3 is characterized by termination of hatchery supplementation in Battle Creek (Figure 9). At this point, a naturally spawning, locally adapted population of winter-run Chinook Salmon will have been established in Battle Creek that achieves the numeric objectives described in Section 2.1.2.2 for a long-term, viable population—a census population of 2,500 spawners per generation or 850 adults annually.

Phase 3 involves monitoring the status of the Battle Creek population relative to the demographic and genetic objectives of the previous phases. Hatchery production and supplementation of natural production are terminated in Phase 3 and now becomes a contingency strategy should the population experience a downturn (dashed lines in Figure 9).

In transition to Phase 3, terminating hatchery production will require careful consideration. If the population exhibits high inter-annual variability or an indication of a possible downward trend in abundance in Phase 2, it may be necessary to delay terminating hatchery production and remain in Phase 2. Monitoring and testing the resiliency of the population in Phase 2 will be important to understand the sensitivity of the population to environmental events and predict the likelihood of a downward trend. This is possible only in Phase 3 because hatchery augmentation in Phase 2 may mask this variability.

Contingency options require moving back to Phase 2 of the Reintroduction Plan. They include collecting broodstock from the Sacramento River population (dashed lines in Figure 9) or from Battle Creek, or transplanting juveniles from the Sacramento River. Strategies that include moving Chinook Salmon from the Sacramento River population should be carefully evaluated because of the potential consequences to local adaptation of fish in Battle Creek. On the other hand, indication of low genetic diversity in the Battle Creek population may necessitate reinitiating transfers of Chinook Salmon from the Sacramento River mainstem to add diversity to the Battle Creek population.

3.4 Implementation Schedule

Reintroduction strategies and progress are contingent on successful hatchery production to produce adult returns to Battle Creek, restored capacity of Battle Creek to produce winter-run Chinook Salmon, and abundance triggers for natural-origin adult returns. Implementation of the Reintroduction Plan does not refer to specific time-dependent milestones.

However, it is important to understand the timescale these kinds of efforts require. Altogether, reintroduction is likely at least a 40-year effort. Phase 1 Initial will last approximately 6 years and encompass two brood cycles and subsequent adult returns to Battle Creek. Progress in Phase 1 Late may be slower, as it depends on establishing natural production and growing the population to meet the natural-origin trigger of 500 adults for transition to Phase 2. Phase 1 Late may require another 10 years of passing adults and monitoring natural-origin returns. Phase 2 assumes that natural selection and a locally adapted population in Battle Creek will increase the productivity and abundance of the population to achieve the natural-origin trigger to Phase 3 of 850 adults absent hatchery supplementation. Progress in Phase 2 also depends on the potential of the habitat in Battle Creek to support winter-run Chinook Salmon, and environmental trends affecting life cycle productivity of the population. Therefore, it may take another 20 years to transition from Phase 2 to Phase 3 and achieve the vision of a viable, self-sustaining, and locally adapted population of winter-run Chinook Salmon in Battle Creek.

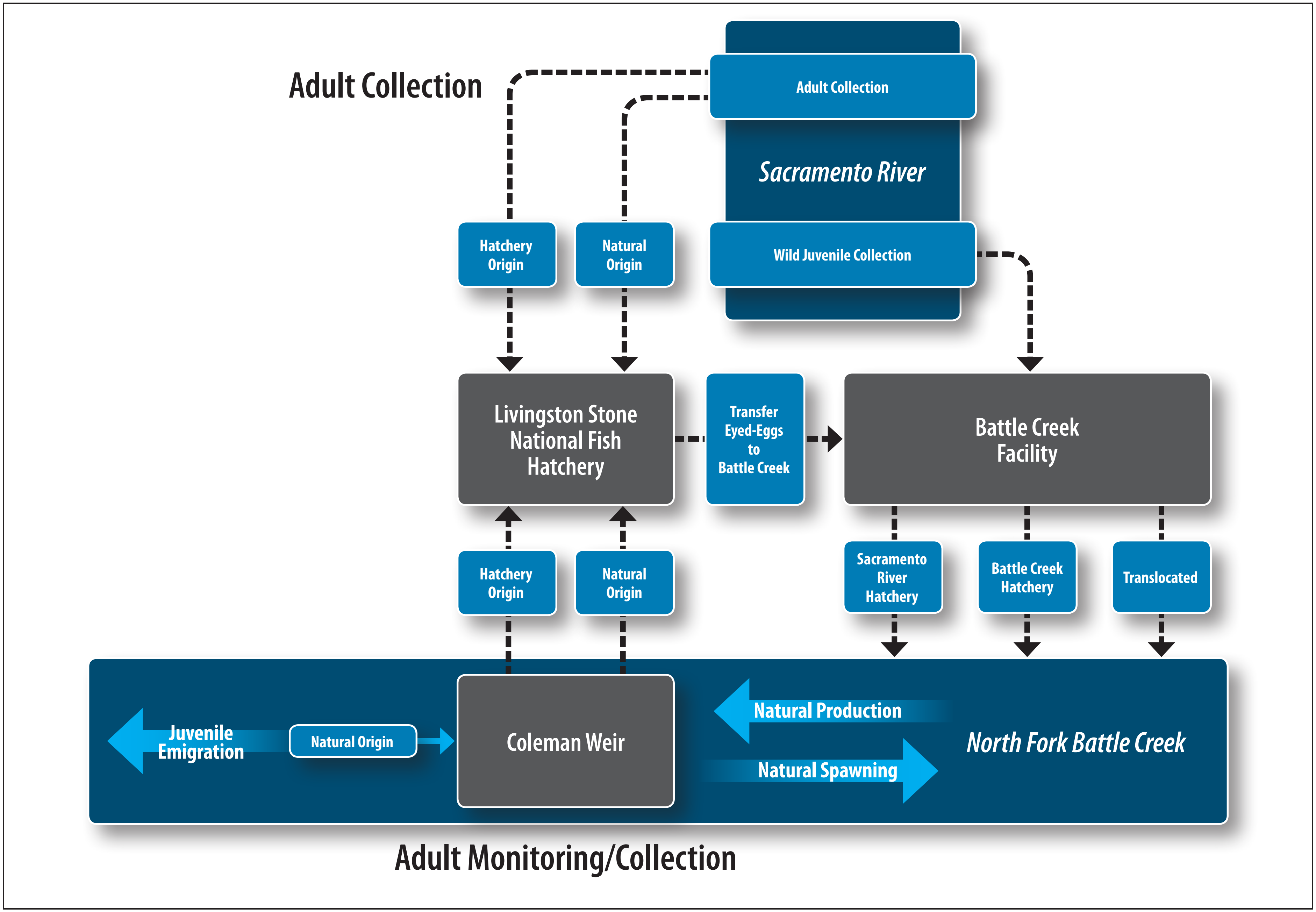

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Figure 9
Reintroduction: Phase 3 Actions

Chapter 4
Program Evaluation – Adaptive Management

4.1 Introduction

In general, reintroductions have not been particularly successful for rare or threatened species, particularly when "success" has been defined as the establishment of a self-sustaining population (Fischer and Lindenmayer 2000). The few programs that are succeeding have developed unique strategies adapted to local circumstances and constraints (see Chapter 2). In short, there is no manual that prescribes the guidelines for successful reintroduction of winter-run Chinook Salmon in Battle Creek. The success of this Reintroduction Plan will be tied to the effectiveness and speed of learning about the relative efficiency of different strategies and actions, and the ability to adapt to changing circumstances, including climate change. Making timely decisions and adjusting management actions based on new information and circumstances obtained through the monitoring program are essential to the success of the plan.

This Reintroduction Plan lays out a framework for reintroduction of winter-run Chinook Salmon in Battle Creek and describes several of the conditions necessary for its success. However, many uncertainties exist in key areas. Its success also will depend to a large degree on factors outside its purview—factors influencing salmon survival in the Sacramento River, the Delta, and the eastern Pacific Ocean. The looming effect of regional climate change also will create challenges, which are difficult to reliably predict at this time. Consequently, implementation of the Reintroduction Plan will need to take place within an adaptive management framework, in which key assumptions can be tested and management actions adjusted to accommodate changing circumstances.

The management framework will be grounded in a scientific approach of hypothesis testing and informed decision making. The adaptive management process will evaluate indicators of progress, the need for exercising contingencies or other adaptive responses to revise strategies and schedules for reintroduction, and define the end points at which goals are attained (Figure 10). The implementation and adaptive management framework therefore will allow decision makers to review information related to the Reintroduction Plan, make decisions regarding management policies, and update components of the Reintroduction Plan as needed.

4.2 Adaptive Management Framework

The following elements of the monitoring program will guide adaptive implementation of this Reintroduction Plan.

- Hypothesis testing
- Status and trends in key indicators
- Application of decision rules
- Assessment of biological goals

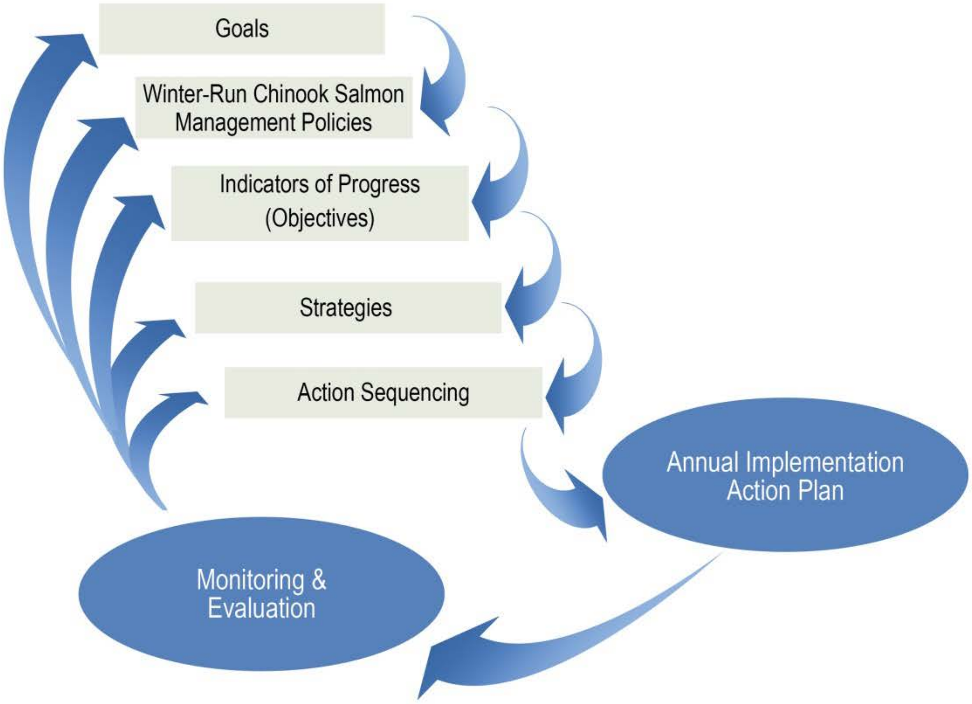

Figure 10
Adaptive Management Process

Hypothesis Testing. The Reintroduction Plan has been developed based on a set of assumptions or hypotheses reflecting the best information available prior to implementation of the plan. These hypotheses are key to the structure and success of the plan, and should be tested through monitoring and evaluation. Where hypotheses are not supported, the need for revisions to strategies or schedules will be identified and considered.

Status and Trends in Key Indicators. Key indicators relate to the decision rules and ultimately indicate the progress and success of reintroduction or a need to consider a contingency or shift in strategy. Trends in these indicators, rather than episodic events, are especially important because trends allow characterizing sustained conditions of the reintroduction program (e.g., returns of winter-run Chinook Salmon to Coleman weir), which allows clear evaluation of decision rules. Episodic events are difficult to relate to decision rules and may not be a good basis for implementing a change, except in rare events, such as when a catastrophe alters conditions sufficiently to warrant an adaptive response.

Application of Decision Rules. Movement across the continuum described by the three phases of reintroduction (Figure 3) is governed by decision rules, which relate to the potential for Battle Creek to support winter-run Chinook Salmon and the objectives for each phase. For example, movement from Phase 1 (which has a demographic emphasis on establishing a return of winter-run Chinook Salmon to Battle Creek for natural production) to Phase 2 (which emphasizes local adaptation of the population established in Battle Creek) would occur based on key indicators, such as adult returns to Coleman weir, counts of spawning fish in Battle Creek, or the number of natural-origin adults in the return. These decision rules are articulated as part of this Reintroduction Plan but should be regularly reviewed by the management agencies and updated or revised as appropriate (the process and procedures for implementation of the plan are discussed below in Section 4.4).

Assessment of Biological Goals. The biological goals of this Reintroduction Plan relate to the overall goals for management of the Sacramento River winter-run Chinook Salmon ESU and the need to augment its spatial structure. These biological goals need to be reviewed and updated in the context of the performance of this plan; management of the ESU; and larger scale issues affecting the status of the ESU, such as changes in water management policy and climate change.

4.2.1 Related Adaptive Management Programs

The value of adaptive management in overall efforts to restore Battle Creek in general and winter-run Chinook Salmon in particular is well recognized within the array of related ongoing programs. These programs are addressed in the following documents and planning efforts.[1]

- *Battle Creek Salmon and Steelhead Restoration Project Adaptive Management Plan* (BCRP AMP) (Terraqua, Inc. 2004).
- *Livingston Stone National Fish Hatchery – Hatchery and Genetics Management Plan* (LSNFH HGMP) (USFWS 2013a).
- *Coleman National Fish Hatchery Adaptive Management Plan* (CNFH AMP) (USFWS in progress).
- *Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead* (NMFS Recovery Plan) (NMFS 2014a).
- CDFW recovery planning under the CESA for winter-run Chinook Salmon.

To a large degree, the adaptive management needs related to winter-run Chinook Salmon reintroduction can be addressed through coordination with these other programs. The BCRP AMP, in particular, lays out a program to address many habitat and fish population questions related to winter-run Chinook Salmon reintroduction. The CNFH AMP describes management of Coleman weir, which will play a key role in managing winter-run Chinook Salmon in Battle Creek and monitoring the success of reintroduction. Issues related to fish culture are largely addressed in the LSNFH HGMP, which could be expanded to include this plan. Finally, all aspects of reintroduction will be coordinated with the NMFS Recovery Plan. This chapter describes the major adaptive management needs of the reintroduction program and the intersection with related programs.

4.2.1.1 Battle Creek Restoration Project Adaptive Management Plan

The goal of the BCRP is to restore habitat in Battle Creek by eliminating or minimizing natural and manmade impediments to passage, restoring a more natural hydrology, and reestablishing the native salmonid community that existed prior to development of barriers preventing passage and associated habitat alterations.[2] The success of the BCRP in restoring properly functioning habitat for winter-run Chinook Salmon is prerequisite to this Reintroduction Plan. However, a number of

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[1] See BCRP AMP Table 27 for a complete list of related programs monitoring production and survival of salmonids in the Central Valley, Delta, and marine environments.

[2] The BCRP assumes that all four runs (winter, spring, fall, and late-fall), of Chinook Salmon used some portion of Battle Creek to complete their life cycles in the past.

uncertainties remain regarding how well restored habitat in Battle Creek will perform and whether it will be capable of supporting the historical assemblage of steelhead and Chinook Salmon runs. These uncertainties are being addressed in the implementation of a comprehensive AMP (Terraqua, Inc. 2004, referred to as the BCRP AMP) developed by the parties to the MOU. With a few additions and clarifications, the BCRP AMP will address most of the monitoring needed within Battle Creek to adaptively manage the winter-run Chinook Salmon reintroduction effort.

The BCRP AMP uses a “passive adaptive management” approach, in which a Best Management Policy (in this case, the Five Dam Removal Alternative [USBR 2005]) is implemented, given current understanding of the system, and then monitored to ensure that performance is within expected limitations (Healey 2001). Implementation of the AMP will involve learning more about the system under management (i.e., address uncertainties) and making adjustments toward achieving the goals of the program. For this Reintroduction Plan, the Best Management Policy is defined as the reintroduction program described in the previous chapters.

The BCRP AMP identifies 11 objectives (Table 6) for monitoring and adapting implementation of the BCRP and restoring self-sustaining populations of Chinook Salmon and steelhead in the Battle Creek watershed. BCRP AMP objectives relate to:

- Population response of salmon and steelhead to changes in habitat
- Changes in habitat conditions in response to management actions
- Improvements to passage over dams and natural barriers and past diversions to provide for full use of the restored habitat

For each objective in Table 6, the adaptive management approach for the BCRP follows a stepwise scientific process in which the objective is restated as a testable hypotheses. A monitoring and data assessment approach is described to test these hypotheses, consistent with contemporary standard methods and reporting practices that are adopted by CALFED and Resource Agencies. Trigger events are described, indicating when an adaptive response should be taken; and end points are described, indicating when an objective has been attained. This framework has been adopted for adaptive management of this Reintroduction Plan.

Population Objective 2 in Table 6 relates directly to the restoration of winter-run Chinook Salmon in Battle Creek as part of a native fish assemblage. The measures anticipated in the BCRP AMP needed to achieve that objective are laid out in Table 7. They include monitoring adult returns at Coleman weir and other fish passage facilities, instream surveys to confirm distribution of adults and location of holding and spawning areas, carcass surveys, and operation of fish traps to confirm and estimate juvenile fish production. These efforts will be useful for collecting the information necessary to evaluate the acclimation and survival of winter-run Chinook Salmon to the restored habitat in Battle Creek. Population Objective 2 also is linked to the habitat and fish passage objectives in Table 6; in the event that winter-run Chinook Salmon do not reach viable population levels, information on habitat performance can be used to isolate the cause(s) and to identify appropriate adaptive management responses that move the population toward sustainability.

The BCRP did not anticipate the use of hatchery supplementation as a mechanism for reestablishing winter-run Chinook Salmon in Battle Creek; therefore, the BCRP AMP does not include provisions for monitoring the effect of hatchery production on the population or on the diversity and fitness of the population as it reestablishes in Battle Creek. However, the LSNFH HGMP does address these issues for the Sacramento River population of winter-run Chinook Salmon and could be modified to address relevant genetic issues in this plan.

Program evaluation and adaptive management measures described in this Reintroduction Plan are designed to fit into the structure and decision-making process described in the BCRP AMP (see Section 4.4).

Table 6. Adaptive Management Objectives in the Battle Creek Restoration Project Adaptive Management Plan

Salmon and Steelhead Population Objectives

1. Ensure successful salmon and steelhead spawning and juvenile production.
2. Restore and recover the assemblage of anadromous salmonids (i.e., winter-run Chinook, spring-run Chinook, steelhead) that inhabit the stream's cooler reaches during the dry season.
3. Restore and recover the assemblage of anadromous salmonids (i.e., fall-run Chinook, late fall-run Chinook) that enter the stream as adults in the wet season and spawn upon arrival.
4. Ensure salmon and steelhead fully utilize available habitat in a manner that benefits all life stages thereby maximizing natural production and full utilization of ecosystem carrying capacity.

Salmon and Steelhead Habitat Objectives

1. Maximize usable habitat quantity – volume.
2. Maximize usable habitat quantity – water temperature.
3. Minimize false attraction and harmful fluctuation in thermal and flow regimes due to planned outages or detectable leaks from the hydroelectric project.
4. Minimize stranding or isolation of salmon and steelhead due to variations in flow regimes caused by hydroelectric project operations.

Salmon and Steelhead Passage Objectives

1. Provide reliable upstream passage of salmon and steelhead adults at North Battle Creek Feeder, Eagle Canyon, and Inskip Diversion Dams per contemporary engineering criteria or standards/guidelines.
2. Provide reliable downstream passage of juveniles at North Battle Creek Feeder, Eagle Canyon, and Inskip Diversion Dams per contemporary criteria after the transfer of facilities to Licensee.
3. Provide reliable upstream passage of adult salmon and steelhead to their appropriate habitat over natural obstacles within the Restoration Project Area while maintaining an appropriate level of spatial separation among the runs.

Source: BCRP AMP (Terraqua, Inc. 2004).

Table 7. Hypothesis Testing for Population Objectives in the Battle Creek Restoration Project Adaptive Management Plan

Population Objective
Restore and recover the assemblage of anadromous salmonids (i.e., winter-run Chinook, spring-run Chinook, steelhead) that inhabit the stream's cooler reaches during the dry season
HYPOTHESIS: Implementation of instream flow levels and facilities modifications specified in the description of the Restoration Project, implementation of the Facilities Monitoring Plan, and implementation of any adaptive responses affecting instream flows or hydroelectric project facilities, will ensure that populations of spring-run Chinook, winter-run Chinook and steelhead are at viable population levels.
MONITORING AND DATA ASSESSMENT APPROACH: (1) Estimate adult and jack population sizes using adult counts at fish ladders, carcass counts, snorkel surveys, or redd surveys; (2) Estimate juvenile production using outmigrant traps within the Restoration Project Area; (3) Calculate, analyze, and monitor Chinook Return Rates (CRR) according to protocols; (4) After population levels are sufficient to reliably calculate CRR, compare 3-year running average CRR with expected CRR; (5) Compare trends in CRR with limiting factors from outside the Restoration Project Area using the linked monitoring in the Sacramento River system; (6) Compare trends in CRR with Reference Watersheds.
TIMELINE: (1) Each monitoring and data assessment approach applies separately for each run of salmon and steelhead to reflect the diversity of life histories; (2) Estimates of adult population size and juvenile production will be made throughout the term of the AMP or until this Objective is met; (3) CRR protocols suggest that calculation and analysis of CRR will continue for a minimum of 13 years plus 3 years and will likely extend for at least the term of the AMP
TRIGGER EVENT: The three-year running average CRR falls below 1.0 after CRR can be reliably calculated according to CRR protocols above, and trends in CRR differ from CRR trends in Reference Watersheds.
RESPONSE: (1) If the limiting factor is flow-related, the response would be that set forth in Habitat Objective 1; (2) If the limiting factor is water temperature-related, the response would be that set forth in Habitat Objective 2; (3) If the limiting factor is unidentifiable after testing hypotheses from all habitat and passage objectives, identify unanticipated limiting factors and work to eliminate those factors that are controllable and related to the Restoration Project.31
RESPONSE LIMITS: (1) If the limiting factor is identified by testing hypotheses from any of the habitat and passage objectives, the response limits would be based on the appropriate objective; (2) If the limiting factor is not associated with any of the objectives, but is controllable and related to the Restoration Project, the response limit will be any action deemed feasible, practical, reasonable, prudent, acceptable to the local community, and consistent with MOU and FERC protocols, provided that Consensus has been reached among the Parties.
RESPONSE EVALUATION: Per standard response evaluation described above.
END POINT: Continue these monitoring and data assessment approaches, separately for each run of salmon and steelhead, until populations reach viable population levels.
REPORTING: Per standard data management and reporting procedures described in sections III.D.7 and III.D.8.b
RESPONSIBILITY/FUNDING: (1) Licensee will conduct or fund, up to the Licensee's Commitment, adult counts at fish ladders in the initial three-year period of operation. Pursuant to Adaptive Management protocols, if salmon and steelhead populations are insufficient to affirm ladder effectiveness under continuous duty, Licensee will conduct or fund adult counts at fish ladders for a longer period of time to be determined by mutual agreement per protocols. (2) Resource Agencies will, subject to available funds, conduct or fund or seek funding for other monitoring and data assessments. (3) NOAA Fisheries will define recovery goals for anadromous salmonid species in Battle Creek listed under the ESA at any time during the term of the AMP.

Source: BCRP AMP (Terraqua, Inc. 2004).

4.2.1.2 Livingston Stone National Fish Hatchery – Hatchery and Genetics Monitoring Plan

As discussed above (Section 2.2), HGMPs are technical documents that describe the composition and operation of individual hatchery programs. They also include rather extensive monitoring and adaptive management components to manage hatchery influence on naturally producing populations. For example, the LSNFH HGMP for winter-run Chinook Salmon describes a program designed to maintain stock integrity, conserve genetic and life history diversity, and reduce divergence from the naturally reproducing stock.

Prior to being used as broodstock, adult salmon captures at the Keswick Dam fish trap are evaluated for phenotypic criteria (run/spawn timing, collection location, intact adipose fin, and physical appearance) and genetic criteria (based on 96 single nucleotide polymorphism [SNP] markers). In combination, the genetic and phenotypic criteria enable accurate and precise identification of winter-run Chinook Salmon for use in the supplementation program and ensures that they are not unintentionally hybridized with fish from overlapping runs (e.g., spring-run Chinook Salmon).

Spawning protocols (i.e., random selection of broodstock and factorial mating) are designed to conserve genetic variability, reduce genetic drift, increase effective population size, and minimize divergence from naturally reproducing stocks. All hatchery production are tagged with CWTs and an adipose fin clip in order to monitor the success of the hatchery fish and their interaction with the wild population.

This Reintroduction Plan will begin with expansion of the LSNFH winter-run Chinook Salmon program to accommodate both the Sacramento River supplementation program and to produce eyed eggs for transport to and rearing in Battle Creek. The monitoring protocols contained in the LSNFH HGMP are expected to be applied to this initial phase of the Reintroduction Plan and to form the basis for either an expanded HGMP or a separate HGMP for a new hatchery program and facilities on Battle Creek.

4.2.1.3 Coleman National Fish Hatchery Adaptive Management Plan

The overall aim of the CNFH AMP is to maximize compatibility of CNFH with the BCRP, thereby contributing to the reconciliation of ecological functions and human services in the Battle Creek watershed. The plan is designed to minimize actions—through the process of producing fall-run and late-fall run Chinook Salmon to support commercial and recreational fisheries— that adversely affect efforts to restore viable populations of winter-run and spring-run Chinook Salmon and steelhead trout in Battle Creek.

Part of the CNFH AMP will address operation of Coleman weir to monitor adult returns. The weir provides a tool for controlling fish access to upper Battle Creek, which can be used to minimize opportunities for hybridization between runs. In addition, the weir provides an opportunity to handle fish for collection of broodstock and collection of samples for genetic tests. These tests can evaluate the diversity of the returning winter-run Chinook Salmon for comparison to the Sacramento River population, in order to evaluate the relative success of each of the release groups and to investigate signs of local adaptation.

4.2.1.4 National Marine Fisheries Service Recovery Plan for Winter-Run Chinook Salmon

The NMFS Recovery Plan defines a goal of establishing three populations in the Basalt and Porous Lava Diversity group at low risk of extinction, and it describes site-specific management actions necessary for reaching that goal (NMFS 2014a). Like other recovery plans, it is an advisory document that is broad in scope and addresses all identified threats and limiting factors but does not assign accountability for implementation to any particular agency or interest. Nevertheless, the plan provides guidance regarding the definition of independent and sustainable populations, which has been incorporated into this Reintroduction Plan as targets for population size and performance in Battle Creek (see Section 3.3 *Reintroduction Phases*). Implementation of the NMFS Recovery Plan may affect implementation of this Reintroduction Plan as elements of the Recovery Plan outside of Battle Creek are implemented, and implementation of the Reintroduction Plan may influence refinement of the NMFS Recovery Plan as assumptions regarding Battle Creek are confirmed or revised. For example, although Battle Creek may not operate as an independent population, maintaining fish there would still provide spatial diversity for the ESU.

4.2.1.5 California Department of Fish and Wildlife Recovery Planning for Winter-Run Chinook Salmon

In 1989, California listed winter-run Chinook Salmon as endangered under the CESA. Since that time, CDFW has collaborated with federal, regional, and local partners in recovery efforts in general and specifically in restoration of Battle Creek. CDFW's Status Review, reports to the California Fish and Game Commission, and past reports to the State Legislature on the status and trend of winter-run Chinook Salmon have detailed recovery efforts and environmental conditions. The objectives and results of the BCRP AMP and this reintroduction plan will be integrated into and inform CDFW's efforts for recovery of Winter-Run Chinook Salmon and progress reports to the Director of CDFW, California Fish and Game Commission, and State Legislature.

4.3 Information Needs for Winter-Run Chinook Salmon Reintroduction Plan

Although the BCRP AMP is comprehensive in monitoring habitat performance, effectiveness of fish passage facilities, and fish population response to the modifications of the hydropower system, it does not anticipate a supplementation program to accelerate recolonization of the watershed. The decision to boost the reestablishment of a winter-run Chinook Salmon population through supplementation and translocation adds elements not considered in the BCRP AMP and will accelerate the need for fielding survey crews to monitor fish passage, habitat use, and habitat quality. Those elements not covered in the BCRP AMP are addressed in this chapter and are intended to be integrated into the BCRP AMP decision-making framework for efficiency.

Within this chapter, monitoring activities are identified to address specific components of the Reintroduction Plan and to track progress through the three phases of reintroduction described in Chapter 1 (Figure 3). The monitoring needs of this reintroduction program are organized around two major topics: (1) monitoring to evaluate reintroduction strategies (i.e., the effectiveness of hatchery and translocation programs, including demographic and genetic expectations) to inform adjustments if needed; and (2) monitoring natural production to evaluate progress through each of the three phases of the Reintroduction Plan.

4.3.1 Monitoring to Evaluate Reintroduction Strategies

The working hypotheses underlying the Reintroduction Plan and run-size triggers for transition between phases are shown in Table 8. The following assumptions underlie these hypotheses.

1. The Sacramento River population is sufficiently large to support collection of target numbers of broodstock for the hatchery and juveniles for transplant, and those fish are representative of the genetic diversity of the natural population.
2. The average release-to-adult return survival rates are as anticipated and will produce the average adult returns from hatchery production and transplanted juveniles described in Section 3.3.
3. Return rates to Battle Creek and upstream survival in Battle Creek are as described in Section 3.3 and anticipated in the BCRP AMP.
4. Natural production run-size triggers in Phase 3 are sufficient to maintain a population in Battle Creek at a low risk of extinction (i.e., a population of 2,500 adults with a 5-year geometric mean of 850 spawners per year).

The monitoring and evaluation elements of this Reintroduction Plan are organized to address monitoring priorities for hatchery broodstock targets, production targets, diversity targets, survival of released fish-to-adult returns, and adult return rates to Battle Creek including natural production. The BCRP AMP already anticipates the need to estimate adult and jack returns using adult counts at Coleman weir and fish ladders, carcass counts, or redd surveys in addition to the need to estimate juvenile production using outmigrant traps within the restoration project area. These efforts will provide much of the information needed for evaluating the survival of juveniles-to-adult returns at Coleman weir, as well as the success of adults in passing Coleman weir, fish ladders, and other barriers to reach suitable holding and spawning habitat. The outmigrant trapping anticipated in the BCRP AMP will allow assessment of juvenile survival from release to the sampling stations at the lower end of the project area. The survey protocols will need to be adjusted to account for the various marked groups, and additional monitoring elements will be needed for evaluation of hatchery and translocation programs not anticipated in the BCRP AMP.

4.3.1.1 Annual Hatchery Production Monitoring Activities

The success of the Reintroduction Plan relies in part on the ability to meet hatchery production targets and targets for capturing juveniles for translocation (Table 9). Production targets differ as reintroduction strategies change through each of the plan’s phases. The hatchery broodstock and release targets used to support the Reintroduction Plan are based in part on past experience from the propagation and monitoring of winter-run Chinook Salmon returns from Coleman and Livingston Stone National Fish Hatcheries and other supporting documents specific to recovery of winter-run Chinook Salmon.

Table 8. Expected Average Outcomes for Each Phase of Reintroduction and Run-Size Triggers for Phase Transitions

	Stage	Phase 1 Initial	Phase 1 Late	Phase 2	Phase 3
Hatchery/Transplanted Production	**Sacramento River Broodstock**				
	Broodstock target	120	60	5% to 20% of release	0
	Adult return to Coleman weir	0	260	25 – 100	0
	Passed upstream for natural spawning	0	260	25 – 100	0
	Sacramento River Source Translocated Juveniles				
	Juveniles released (Sacramento River)	0	75,000	0	0
	Adult returns to Coleman weir	0	210	0	0
	Removed for broodstock	0	10	0	0
	Passed upstream for natural spawning	0	200	0	0
	Battle Creek Broodstock				
	Broodstock target (Battle Creek)	NA	60	100 to 110	0
	Adult returns to Coleman weir	0	260	580	0
	Removed for broodstock	0	60	100 to 110	0
	Passed upstream for natural spawning	0	200	470 to 480	0
Natural Production	Adult return (biological triggers for transition to next phase)	100	500	500	850
	Natural spawning escapement pHOS	NA	NA	Initial <50% and moving toward <30%	0%
	PNI	NA	NA	Initial >0.50 and moving toward >0.67	1.00

All hatchery-produced fish will be externally marked with an adipose fin clip and implanted with a unique CWT to identify a production group (i.e., Sacramento River broodstock or Battle Creek-origin broodstock). Transplanted fry also would have an adipose fin clip and a unique CWT to identify that group, and natural-origin returns would have an intact adipose fin and no CWT. In some years, up to four groups of fish could return to Coleman weir: (1) Sacramento River-sourced hatchery adults (adipose fin-clipped and CWT); (2) Battle Creek-sourced hatchery adults (adipose fin-clipped and CWT); (3) adult returns from Sacramento River transplanted juvenile (adipose fin-clipped with CWT); and (4) Battle Creek natural-origin adults (intact adipose fin and no CWT). The carcass surveys in Battle Creek and the Sacramento River will be important for collecting CWT returns that will provide information for analyzing the success of each of these groups and investigating stray rates between Battle Creek and the Sacramento River. Carcass surveys also will provide data for run reconstruction. As discussed in Section 3.2, a decision is needed regarding the strategy for distinguishing among late-fall-run, winter-run, and spring-run Chinook Salmon at Coleman weir. That strategy may include the application of an additional mark or tag to winter-run Chinook Salmon.

Table 9. Key Hatchery Production and Translocation Monitoring Elements

Program Element	Plan Assumption	Monitoring Activity	Objective	Alternative Strategy	Data Source
Broodstock (Sacramento River source)	240 natural-origin adults at Keswick trap to support Sacramento River supplementation and Battle Creek reintroduction	Keswick trap counts (natural and hatchery origin)	Broodstock collection targets achieved (number of males and females necessary to meet LSNFH and Battle Creek production targets)	Implement contingency strategy to include hatchery origin in broodstock Develop alternative/additional collection points for broodstock Adjust program target if consistent with reintroduction objectives	USFWS annual reports and HGMP reports
Broodstock (Battle Creek source)	100 to 110 adults at Coleman weir and up to 100% pNOB to transition to an integrated Battle Creek program	Coleman weir adult counts by origin	Broodstock collection targets achieved (number of males and females necessary to meet Battle Creek production targets)	Adjust program release target if consistent with reintroduction objectives Implement contingency strategy to include broodstock from Sacramento River	Population Objective 1 in BCRP AMP
In-hatchery survival to release	Fecundity ~5,000 eggs, 50% sex ratio, survival to release of 69%	Hatchery records	Program release targets achieved (number of juveniles consistent with production targets)	Identify cause for low survival and can it be attributed to an operational failure that can be fixed? Adjust program broodstock target if consistent with reintroduction objectives	LSNFH HGMP or Battle Creek HGMP (to be developed)

Program Element	Plan Assumption	Monitoring Activity	Objective	Alternative Strategy	Data Source
Transplanted juveniles	Collect juveniles to 75,000 fry for release into Battle Creek, survival to release of 95%	Juvenile counts at Sacramento River Rotary Screw Trap, count of number of juveniles surviving to release in Battle Creek	Juvenile capture targets (number of fry less than <50 mm over entire juvenile migration period) and survival to release achieved	Adjust program target if consistent with reintroduction objectives Develop alternative collection points Identify cause for low survival and can it be attributed to an operational failure that can be fixed? Abandon strategy for another to achieve same objective (maximize diversity during reintroduction)	CDFW Central Valley Salmon and Steelhead Monitoring Plan USFWS Comprehensive Assessment and Monitoring Program (CAMP)
Diversity	Diversity of hatchery production is representative of the Sacramento River natural population	Compare diversity with Sacramento River population	Diversity of hatchery production is representative of the Sacramento River population	Increase pNOB Increase fraction of Sacramento River naturally produced fry in the out-plants Develop alternative adult capture sites	HGMP reports

Hatchery objectives and production targets can be reduced to a series of monitoring questions (hypotheses) that, if appropriately addressed, could change hatchery practices to better achieve the reintroduction goals. For example, if broodstock requirements are not routinely met, monitoring should identify the reason, giving the agencies the information they would need to meet targets in subsequent years or to identify alternative strategies to meet the targets. In this case, the indicators for success are largely implicit in the questions of interest and generally focus on testing assumptions in the monitoring protocols identified in the LSNFH HGMP (e.g., egg-to-release and release-to-adult survival rates) used to develop the Reintroduction Plan. Table 9 details key program elements for hatchery operations, release targets, and capture of fry for release into Battle Creek. Plan assumptions are identified and restated as an objective, and alternative strategies are identified for circumstances in which the objective was not met. Linkages to monitoring activities from existing monitoring programs are identified in the column labeled “Data Source.”

4.3.1.2 Annual Hatchery Performance Monitoring

The monitoring plan requires an annual accounting of the hatchery and translocated adult returns through run reconstruction. The performance indicators listed in Table 10 will be estimated each year. The precision of adult counts at Coleman weir is expected be high (a coefficient of variation of 5 percent is a goal). Estimates of return rates, post-release survival, and total recruitment will depend on the ability to estimate adults not recovered at Coleman weir (i.e., strays to the Sacramento River and those that did not enter Coleman weir fish ladder).

4.3.1.3 Genetics Monitoring

Hatchery supplementation can reduce short-term extinction risk by conserving genetic resources and increasing the number and spatial distribution of natural-origin spawners. It can also be a risk to productivity and genetic diversity (NMFS 2014b). In this case, the risk is low because the habitat in Battle Creek that would be “supplemented” is currently devoid of winter-run Chinook Salmon. Nevertheless, genetic aspects of small populations must be considered at the outset in order to maximize the probability of long-term survival and continued adaptability (Meffe 1986). Recent studies have shown that selection pressures in hatcheries can produce heritable traits that optimize survival in the hatchery but diminish fitness in the wild, even in a single generation in the hatchery (Christe et al. 2016; Ford et al. 2008; Ford 2002). Through integration of the wild and hatchery stocks, adherence to mating protocols, and monitoring variability, hatchery managers can minimize the risk of these adverse effects. NMFS has addressed many of the issues associated with hatcheries through its encouragement for development of HGMPs (50 CFR 223.203[b][5]).

Table 10. Key Hatchery Production Performance Indicators

Performance Indicator	Definition	Relationship to Plan	Potential Methods
Adult abundance at Coleman weir (ColeReturn)	Total number of returns at Coleman weir each year estimated by release group (SacHat, BCHat, and SacFry)	Evaluate effectiveness of strategies to return adults to Battle Creek and recover at Coleman weir	Counts at Coleman weir fish ladder, differentiate fish by marking, PIT tags, and genetic parentage analysis
Spawner abundance (NatSp)	Total number of natural spawners each year estimated by release group (SacHat, BCHat, SacFry)	Evaluate plan assumption to place spawners into targeted spawning habitat in Battle Creek	Mark recapture adult carcasses on spawning grounds
Total recruitment (TotRecs)	Annual number of adult recruits (catch plus strays plus count at Coleman weir) estimated by release group (SacHat, BCHat, and SacFry)	Estimate total survival rates by release group to compare to plan assumptions	Hatchery CWT recoveries in fisheries, CWT and PIT tag recoveries in strays to Sacramento River and Battle Creek downstream of Coleman weir
Recruits per spawner (HatRS)	Number of adult recruits per hatchery broodstock spawner by hatchery release group	Evaluate trends in recruitment rates for hatchery release groups	Total recruitment divided by broodstock count
pNOB (BC)	Proportion of Battle Creek hatchery broodstock of natural origin collected at Coleman weir	Monitor trends relative to plan assumptions for local adaptation; this management control variable helps to achieve the PNI target (see Table 8 for plan assumptions).	Count of adults in Battle Creek broodstock of natural origin
pNOB (SacR)	Proportion of Sacramento River hatchery broodstock of natural origin collected from Sacramento River population	Evaluate plan strategy to use natural-origin adults for reintroduction	Count of adults in Sacramento River broodstock of natural origin

Among other requirements, HGMPs state the goals, objectives, and purpose for a hatchery program. They are intended to ensure the health and viability of the affected salmon population, and minimize the genetic and ecological effects of the hatchery program on wild populations. They describe monitoring provisions aimed at detecting and evaluating success, and provisions to address any risks potentially impairing recovery of a listed ESU. In 2013, the USFWS developed an HGMP for the winter-run Chinook Salmon supplementation program at LSNFH, which includes the following fish culture practices (USFWS 2013a).

- Rear fish using the water where the fish are intended to imprint in order to facilitate strong homing and promote integration of hatchery fish with the natural population(s) they are intended to supplement.
- Develop a hatchery facility designed specifically for supplementing Sacramento River winter Chinook Salmon.
- Constrain the collection of natural broodstock (maximum of 15 percent of estimated total run) to lower the demographic and genetic risks to the naturally spawning population.
- Develop and use genetic discrimination techniques to effectively identify and spawn only target broodstock.
- Use factorial-type mating strategy to maximize effective population size.
- Mark 100 percent of hatchery production.

The LSNFH HGMP also includes a robust monitoring and evaluation program, which addresses the following performance indicators (USFWS 2013a).

- Conduct field surveys to generate adult run-size estimates and evaluate survival, spawning success, and integration of hatchery-propagated winter-run Chinook Salmon with the natural population.
- Monitor and evaluate the genetic risks of the winter-run Chinook Salmon propagation program to measure potential genetic effects on the natural population.
- Conduct a parentage-type analysis to confirm reproductive success of the winter-run Chinook Salmon from the propagation program at LSNFH.

The implementing agency (if it is not USFWS) should work with USFWS to amend the existing LSNFH HGMP to accommodate the Battle Creek reintroduction program or to develop a separate HGMP for the Battle Creek program. The HGMP should include the relevant provisions for the ongoing Sacramento River supplementation program and augment them with provisions to ensure that (1) the hatchery program is expanded to include an additonal120 additional spawners (some of which may be hatchery-origin spawners); (2) it maintains spawning protocols to conserve the genetic diversity of spawning population relative to the wild population; and (3) it minimizes hatchery influence on the wild Sacramento River population. While the initial population (Phase 1) will be heavily influenced by hatchery fish, as the program transitions to Phase 2, the proportionate natural influence (PNI) should be monitored and managed to be greater than 0.5.

With respect to the Battle Creek hatchery program, the initial goal is demographic (i.e., release enough winter-run Chinook Salmon to create a reasonable probability of a return [207,000 presmolts/ smolts]). Released fish should be evaluated to ensure that they represent the diversity present in the wild population. Likewise, the genetic diversity of transplanted juveniles from the Sacramento River should be evaluated to ensure that there is no bias in the collection protocol that would reduce the diversity of the transplanted release group relative to that of the wild population. Ensuring that the genetic diversity within the hatchery and transplanted release groups is representative of the wild population will maximize genetic resources upon which selective forces in Battle Creek can operate to produce a locally adapted population.

Run reconstruction from collection and analysis of CWTs will be used to monitor the survival rates of hatchery releases and translocated juveniles. Parentage analysis of these groups also can be used to determine the relative rates of survival for each group. As a population becomes established in Battle Creek, the PNI will become important in facilitating local adaptation. The composition of broodstock and information derived from Coleman weir monitoring of returns and spawning ground/carcass surveys should be used to monitor PNI targets for transitioning through Phase 2 and to refine stocking strategies as appropriate.

4.3.2 Monitoring Natural Production to Evaluate Progress

The transition between the three phases of this Reintroduction Plan and the ultimate goal of the plan is defined in terms of natural-origin returning adult winter-run Chinook Salmon to Battle Creek (Table 7). This section describes the information needed for deciding when to transition to the next phase or, if necessary, to return to a prior phase. Much of the information for monitoring natural production in Battle Creek will come from other programs that are already in place or will be in place as the BCRP AMP is implemented. The information needs for natural production include the following (linkages to other monitoring programs are noted in parentheses).

- Survival of emigrating juveniles reared and released in Battle Creek will be monitored as a measure of habitat performance (BCRP AMP Population Objective 2 and Habitat Objectives 1–4).
- Habitat potential of Battle Creek for winter-run Chinook Salmon will be evaluated to determine whether the habitat response expected from the BCRP is achieved and managers are confident that wild-produced juveniles from the Sacramento River are likely to survive before proceeding with translocation (BCRP AMP Population Objective 4 and Habitat Objectives 1–4).
- Inter-annual environmental variability of habitat in Battle Creek will help define variability in return rates and inform decisions regarding when the population is robust enough to proceed to the next phase (BCRP AMP Habitat Objectives 1–4).
- Survival of donor winter-run Chinook Salmon in Battle Creek to contribute to natural spawning will be monitored via counts of adults returning to Coleman weir, fish ladders, and surveys of the stream channel (BCRP AMP Population Objective 2).
- Future conditions for survival of winter-run Chinook Salmon in the Sacramento River, Delta, and eastern Pacific Ocean, and long-term climatic patterns and trends will inform decisions regarding whether the Battle Creek population is resilient enough to endure outside influences without support (Interagency Ecology Program, Anadromous Fish Restoration Program, and CALFED Ecosystem Restoration Program).

4.3.2.1 Natural Production Monitoring Elements

The success of this Reintroduction Plan relies on the ability of hatchery-propagated and transplanted winter-run Chinook Salmon to survive and emigrate from Battle Creek, grow to adulthood, return to Battle Creek, get correctly identified at Coleman weir, successfully migrate to spawning habitats in Battle Creek, spawn with other winter-run Chinook Salmon, and successfully produce natural offspring. Therefore, tracking performance of the natural population over time is a primary objective of this monitoring plan, as it is in the BCRP AMP.

Post-release survival and return rates to Battle Creek are critical assumptions related to early reintroduction efforts in Phase 1 and to support local adaptation in Phase 2. Low survival or low return rates to Battle Creek will affect the numeric objectives necessary to maintain an integrated Battle Creek hatchery program and adult returns to utilize spawning habitat in Battle Creek. Low hatchery return rates to Battle Creek will be more critical as reintroduction progresses to Phase 2 because low return rates could indicate failure to develop a Battle Creek population.

As discussed above, the future production potential of Battle Creek habitat for winter-run Chinook Salmon is uncertain. The BCRP is expected to provide suitable habitat for winter-run Chinook Salmon. The success of this plan relies on how quickly habitat capacity develops in Battle Creek to support winter-run Chinook Salmon and how quickly natural production is established in Battle Creek. Natural production potential is a function of the population dynamics affected by habitat in Battle Creek during that portion of their life cycle. Battle Creek winter-run Chinook Salmon population dynamics will likely track the Sacramento River population for factors affecting survival through the Sacramento River, in the Delta, and in marine areas. However, Battle Creek may present selective pressures that differ from the Sacramento River mainstem in some significant ways. Habitat quality (e.g., temperature, sediment load, and flow), habitat quantity (pools for adult holding, the amount and distribution of spawning riffles, and habitat available for early juvenile rearing), and the capacity of restored habitat for winter-run Chinook Salmon (juvenile and adult abundance) affect the productivity of winter-run Chinook Salmon (spawner to juvenile and spawner to spawner). All of these factors influence the numeric expectations and resiliency of a new population in Battle Creek. Long-term climatic patterns and trends are another layer of complexity that may exert different selective forces on a winter-run Chinook Salmon population in Battle Creek. The BCRP AMP addresses the specific monitoring and evaluation needs to analyze habitat performance in Battle Creek and identifies responses to various outcomes.

With the expectation that the BCRP will address habitat needs, the following discussion focuses on the specific needs of the reintroduction program to monitor key indicators of population performance, and status and trends of the population in order to track progress and adjust program strategies over time based on run-size triggers (Table 7). The triggers determine when to adjust or terminate strategies not consistent with the goals of a phase and when contingency strategies should be implemented. The triggers also determine when a program transition to the next phase of implementation can occur without compromising success. Because mean run size defines when actions are to be taken, the timeframe for implementing major milestones is uncertain. However, accuracy of run-size triggers is certain because of the ability to accurately quantify adult returns at Coleman weir. The challenge will be to accurately identify adult returns by brood source (e.g., Sacramento River and Battle Creek hatchery origin, transplanted juveniles, Battle Creek natural origin) and the relative success of each group passed upstream to produce natural-origin recruits.

The plan was developed assuming a release-to-return rate of 0.28 percent. This survival rate to the upper Sacramento River is the median of observed rates, which ranged from 0.05 to 1.87 percent for fish released from LSNFH from 2000 through 2008 (USFWS 2013a). The Reintroduction Plan assumes that 95 percent of hatchery-origin adults reaching the upper Sacramento River will return to the fish ladder at Coleman weir, where they will be collected for broodstock or passed upstream to utilize upstream spawning habitat. The plan recognizes that return rates to Battle Creek may be lower for adults returning from translocated fry/pre-smolts, as they were exposed to Sacramento River water for longer periods of time and may exhibit higher stray rates to the upper Sacramento River than the hatchery returns. The plan assumes a 75-percent return rate to Battle Creek for returns for transplanted Chinook Salmon.

A key operational assumption of this monitoring component is that winter-run Chinook Salmon will enter the fish ladder at Coleman weir. Carcass surveys and collection of CWTs in the mainstem Battle Creek below the weir and in the Sacramento River will be necessary to verify this assumption. Operations at the weir will include sampling all adults across the entire run for a variety of information needs (e.g., external marks, CWTs, PIT tags, and biological samples to determine age at return and adult size, and to provide tissue for genetic analysis for run identification). The Reintroduction Plan assumes that adult handling protocols and sampling measures at Coleman weir will be addressed in the CNFH AMP.

The BCRP will enable upstream fish passage in Battle Creek by providing more water in the stream, providing fish ladders for safe upstream passage of dams, and separating NF Battle Creek water from SF Battle Creek water to reduce the potential for false attraction flows into the South Fork. The BCRP also provides for passage around natural barriers in the project area. This Reintroduction Plan assumes that these measures will be effective and that 95 percent of the fish entering Battle Creek and passed upstream of Coleman weir will migrate to target spawning habitat in NF Battle Creek.

The previously described assumptions for post-release survival, return rates, and upstream migration success lead to a series of monitoring questions (hypotheses) that, if appropriately addressed, can influence changes in production targets, release strategies, and handling of adults to obtain the desired results during reintroduction (Table 10). For example, if post-release survival rates are not routinely met, monitoring may provide information to determine the cause, thereby giving the agencies the information necessary to modify practices to improve survival, via the BCRP AMP. Alternately, if the monitoring does not suggest a change in practices, the agencies may decide to adjust production targets to meet adult return objectives via this monitoring program.

Table 11 details key program elements for monitoring natural production in Battle Creek. Plan assumptions are identified and restated as objectives, and alternative strategies are identified for circumstances in which the objective was not met. These alternative strategies will assist in achieving the expected outcome. Linkages to monitoring activities from existing monitoring programs are identified in the column labeled "Data Source."

Table 11. Key Natural Production Monitoring Elements

Program Element	Plan Assumption	Objective	Monitoring Activity	Alternative Strategy	Data Source
Timing of entry to Battle Creek	Winter-run Chinook Salmon will enter Battle Creek and continue upstream migration to favorable holding habitat in NF Battle Creek	Adult timing patterns are consistent with assumption of adults encountering favorable pre-spawn holding habitat in NF Battle Creek	Accurate counts of adults entering fish ladder at Coleman weir and in-river surveys of adults occupying holding habitats in Battle Creek	Identify cause for behavior and can it be attributed to an aspect of Battle Creek flow management that can be fixed? Identify capture sites and implement a trap-and-haul strategy to move fish upstream past migration barriers	BCRP AMP Population Objectives 1 and 3
Productivity of population (recruits per spawner) consistent with goal of a self-sustaining population in Battle Creek	Reintroduction goal is for a self-sustaining population of winter-run Chinook Salmon in Battle Creek with a long-term observed productivity of 1.0 recruit per spawner	Recruit-per-spawner rates across multiple brood years are sufficient to indicate a self-sustaining population absent hatchery augmentation	Accurate counts of natural-origin adults at Coleman weir	Identify cause for low productivity and can it be attributed to a habitat factor that can be fixed? Revise reintroduction goals to consider Battle Creek a dependent population component of the Sacramento River population Acknowledge the need to continue hatchery supplementation to maintain a population in Battle Creek	BCRP AMP Population Objectives 1, 3, and 4

Program Element	Plan Assumption	Objective	Monitoring Activity	Alternative Strategy	Data Source
Adult abundance of population consistent with goal of a self-sustaining, population in Battle Creek	Reintroduction goal is for a self-sustaining population of winter-run Chinook Salmon in Battle Creek with an annual return of 850 adults or 2,500 adults per generation	Annual abundance goals at Coleman weir and natural spawning are sufficient to support a self-sustaining, population in Battle Creek	Accurate counts of adults at Coleman weir and effective natural spawners	Identify cause for low abundance and can it be attributed to a habitat factor that can be fixed? Revise reintroduction goals to consider Battle Creek a dependent population component of the Sacramento River population Recognize the need to continue hatchery supplementation Terminate program	BCRP AMP Population Objectives 1, 3, and 4
Survival back to upper Sacramento River	All hatchery release groups (Sacramento River and Battle Creek sourced) and translocated fry assume 0.28% survival from release to return	Survival rates were achieved for each release group (number of returning adults consistent with plan expectations)	Accurate counts at release and adult return by release group: Coleman weir, lower Battle Creek, Sacramento River	Identify cause for low survival and can it be attributed to an operational failure that can be fixed? Adjust program release target if consistent with reintroduction objectives Does survival differ by production group, suggesting revision in broodstock strategies?	CDFW Central Valley Salmon and Steelhead Monitoring Plan, USFWS Comprehensive Assessment and Monitoring Program (CAMP),and BCRP AMP Population Objectives 1–3
Return rate to Battle Creek and Coleman weir	Plan assumes 95% of hatchery-origin return and 75% of translocated fry surviving to the upper Sacramento River will return to the Coleman weir	Return rates were achieved for each release group to support broodstock objectives at Coleman weir and natural seeding of spawning habitat upstream of Coleman weir	Accurate counts of adults for each release group at Coleman weir and accurate estimates of adults stopping in lower Battle Creek, and straying to the Sacramento River	Identify cause for low return rate and can it be attributed to an operational failure that can be fixed? Adjust program release target if consistent with reintroduction objectives	BCRP AMP Population Objective 3, Passage Objectives 1–3, and Habitat Objective 3
Upstream fish passage to target	Plan assumes 95% passage to target spawning habitat in NF	Upstream passage rates were achieved for each release group to	Accurate count of fish passed upstream by release group at	Identify cause for low passage survival and can it be attributed to an	BCRP AMP Passage Objectives 1–3, and

Program Element	Plan Assumption	Objective	Monitoring Activity	Alternative Strategy	Data Source
spawning habitat	Battle Creek (upstream of Eagle Canyon diversion dam)	meet plan targets for number of Chinook Salmon spawning in key locations (NF Battle Creek)	Coleman weir and accurate estimates of adults within both forks of Battle Creek upstream of Coleman Weir in relation to targeted spawning habitat	operational failure that can be fixed? Adjust program release target if consistent with reintroduction objectives Consider trap-and-haul strategy to place adults in target habitat	Habitat Objective 3
Genetics	Reintroduction strategy maintains a level of diversity comparable to the Sacramento River	There is no evidence of loss of diversity as a result of genetic drift, inbreeding, or founders effect	Tissue samples collected from fish at Coleman weir and analysis of diversity relative to Sacramento River population	If objective is met: Evaluate whether change in diversity relative to Sacramento River is result of local adaptation Increase proportion of NOB from Sacramento River Increase or reinstate translocation of Sacramento River juveniles	Battle Creek HGMP (to be developed)

4.3.2.2 Annual Natural Production Monitoring Activities

The monitoring plan requires an annual accounting of the natural run through run reconstruction. The variables listed in Table 12 will be estimated each year. Adult abundance estimates at Coleman weir will be from counts at the fish ladder across the entire run, with visual identification and genetic samples during periods of overlap with late-fall and spring-run Chinook Salmon. Juvenile abundance estimates will be obtained from mark-recapture estimates using a rotary screw trap at the lower end of the NF Battle Creek above the confluence with SF Battle Creek,[3] and at the existing trapping site above Coleman weir and below the confluence of NF and SF Battle Creek. Juvenile timing and genetic sampling will be used to differentiate natural winter-run Chinook Salmon from other runs of Chinook Salmon in Battle Creek. The precision of adult abundance at Coleman weir will be high (coefficient of variation of 5 percent is a goal). Juvenile abundance estimates will be less precise (coefficient of variation of 15 percent is the goal).

Table 12. Key Natural Production Performance Indicators

Performance Indicator	Definition	Relationship to Plan	Potential Methods
Adult abundance at Coleman weir (ColeReturn)	Total number of returns at Coleman weir each year	Related to biological triggers to monitor progress and transitions between phases	Counts at Coleman weir fish ladder, differentiate groups by marking, PIT tags, and genetic parentage analysis
Spawner abundance (NatSp)	Total number of natural spawners each year	Efficiency of plan to return natural-origin spawners to targeted spawning habitat in Battle Creek	Mark recapture adult carcasses on spawning grounds
Total recruitment (TotRecs)	Annual number of adult recruits (catch plus count at Coleman weir)	Estimate of total adult recruits as relates to plan goals	Hatchery CWT recoveries in fisheries as surrogate
Juvenile abundance (Juveniles)	Annual number of natural-origin out-migrants as measured in lower Battle Creek	Estimate of Battle Creek potential for spawning and juvenile production	Rotary screw trap in Battle Creek downstream of Coleman weir
Adult recruits per spawner (NatRS)	Number of adult recruits per natural-origin spawner and total natural spawners	Estimate of Battle Creek habitat potential for winter-run Chinook Salmon, population resiliency, and trends in recruitment through phases	Total recruits (TotRecs) and spawner abundance (NatSp)
Juvenile recruits per spawner (NatRS)	Number of juvenile recruits per natural-origin spawner and total natural spawners	Estimate of Battle Creek habitat potential for winter-run Chinook Salmon, population resiliency, and trends in recruitment through	Juvenile abundance (Juveniles) and spawner abundance (NatSp)

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[3] Location to be determined based on access and Battle Creek conditions.

Performance Indicator	Definition	Relationship to Plan	Potential Methods
		phases	
Spatial distribution (Dist)	Fraction of total natural spawners in three geographic areas of Battle Creek: NF Battle Creek upstream of Eagle Canyon Dam, NF Battle Creek downstream of Eagle Canyon, and SF Battle Creek	Evaluate assumption that target habitat for winter-run Chinook Salmon is limited to NF Battle Creek	Snorkel surveys of pre-spawn adults, redd surveys, carcass surveys
Variability in habitat quality	Annual variability in habitat quality will be monitored to assess the effects of climate change on persistence of quality spawning and rearing habitat	Availability of adequate temperatures, flow, and access on a regular basis is essential to a population's ability to sustain itself	Monitoring programs from BCRP AMP habitat objectives will provide necessary data to evaluate variability in habitat performance.
PNI (proportionate natural influence)	An indicator of the influence of natural and hatchery environments on population adaptation	Monitor indicator of progress toward local adaptation	Data from hatchery broodstock collection and carcass surveys
pHOS (percent hatchery origin in natural spawning)	The percent hatchery origin in natural spawning	Evaluate plan goal of reducing hatchery augmentation through phases	Derived from spawner surveys and carcass counts

4.3.3 Phase Monitoring

As discussed earlier, the Reintroduction Plan will be implemented in three phases. It will shift from one phase to another based on predefined triggers (see Table 7). The phases reflect different states of hatchery programming and natural population viability. The phases help to define appropriate strategies for reintroduction and focus monitoring priorities during reintroduction. This section presents the information and monitoring elements discussed above in a format easily related to the specific phases of the plan.

4.3.3.1 Phase 1: Develop a Return of Winter-Run Chinook Salmon to Battle Creek

The goal of this phase is to support recovery of winter-run Chinook Salmon by providing a second population in the upper Sacramento River watershed. The population in this phase will be established via hatchery production and release, and will remain largely hatchery origin through Phase 1.

The purpose of hatchery production is to establish a population of winter-run Chinook Salmon for introduction into Battle Creek large enough to produce adult returns to seed spawning habitat in NF Battle Creek. The purpose of the translocated juvenile strategy at this phase is to augment genetic diversity of the Battle Creek population during reintroduction and reduce risks of small population and domestication effects during reintroduction.

1) Key objectives:
    a) To release 207,000 winter-run Chinook Salmon, which will return a sufficient number of adults to Battle Creek to avoid a “founders” effect (maintain a source population diversity) and establish a hatchery population in Battle Creek.
    b) To achieve survival to adult and return rates of translocated juveniles that are sufficient to effectively augment diversity during reintroduction.
    c) To demonstrate that adults passed upstream of Coleman weir continue their migration to target spawning habitat in NF Battle Creek.
    d) To demonstrate that habitat capacity of Battle Creek for winter-run Chinook Salmon is consistent with the number of adults expected in target habitats to avoid adverse demographic effects during reintroduction.
    e) To demonstrate that returns from Sacramento River-sourced adults are successful spawners in Battle Creek, and returns per spawner from natural spawning are sufficient and stable enough from year to year to establish natural production.
2) Key indicators:
    a) Trends in adult abundance at Coleman weir from hatchery production and translocated juveniles
    b) Trends in spawner abundance (NatSp)
    c) Trends in the number of natural-origin adults surviving to return to Battle Creek
3) Decision rules:
    a) The 5 year geometric mean of natural-origin adult returns at Coleman weir exceeds 100 winter-run Chinook Salmon
    b) Natural-origin returns to Battle Creek show a positive trend in abundance
    c) Trends in all key indicators support the transition to Phase 2.

4.3.3.2 Phase 2: Develop a Battle Creek Winter-Run Chinook Salmon Population and Establish Local Adaptation

The goal of Phase 2 is to support recovery of the winter-run Chinook Salmon ESU by providing a second natural population in NF Battle Creek. The population in this phase will be a combination of hatchery and natural origin, with an emphasis on improving productivity through local adaptation to environmental conditions in Battle Creek and reducing the contribution of hatchery-origin Chinook Salmon to natural spawning. Inputs from the Sacramento River (hatchery production and possible transplanted juveniles) will likely continue at a level designed to mimic natural stray rates to ensure that sufficient diversity is available upon which selective forces may operate to produce a locally adapted population.

Hatchery production will supplement natural production as needed ensure against demographic effects associated with low population size. Initial biological objectives are to establish an integrated population with a PNI greater than 0.50. That involves a managed escapement composition (pHOS) less than 50 percent and a natural-origin broodstock (pNOB) greater than 50 percent. As natural population abundance supports less of a hatchery component, biological objectives shift to achieve a population PNI greater than 0.67, meaning a managed escapement composition (pHOS) less than 30 percent, and a natural-origin broodstock (pNOB) of 100 percent.

1) Key objectives:
    a) Habitat capacity of Battle Creek for winter-run Chinook Salmon is consistent with the number of adults necessary to support an independent population (5-year geometric mean of 850 natural-origin adults per year).
    b) Returns per spawner from natural production are sufficient and stable enough to support a resilient population in Battle Creek that does not require hatchery supplementation.
2) Key indicators:
    a) Trends in counts at Coleman weir of natural-origin adults
    b) Trends in abundance of adults in spawning areas of NF Battle Creek
    c) Trends in abundance and stage of juvenile outmigrants from natural spawning parents and by parent origin (natural and hatchery origin)
    d) Trends in the number of natural-origin Chinook Salmon surviving to return to Battle Creek
3) Decision rules:
    a) The 5-year geometric mean of natural-origin adult returns at Coleman weir exceeds 1,000 Chinook Salmon.
    b) Natural-origin returns to Battle Creek show a positive trend in abundance (productivity greater than or equal to 1.0).
    c) All key indicators of habitat potential, population productivity and abundance, and spawner distribution support the transition to a self-sustaining population that no longer requires hatchery supplementation.

4.3.3.3 Phase 3: Maintain and Manage the Battle Creek Winter-Run Chinook Salmon Population

The goal of Phase 3 is to support recovery of winter-run Chinook Salmon by managing habitat in Battle Creek to support a second natural population in the upper Sacramento River. The population in this phase is entirely natural origin and is self-sustaining and locally adapted to ecological conditions in Battle Creek.

1) Key objective:
    a) The population of winter-run Chinook Salmon returning to and spawning in NF Battle Creek is capable of maintaining itself without supplementation from a hatchery or transplanted juveniles from the Sacramento River.
2) Key indicators:
    a) Trends in counts at Coleman weir of natural-origin adults
    b) Distribution of spawning adults indicating utilization of all or most of the restored habitat

3) Decision rule:
   a) The 5-year geometric mean of natural-origin adult spawners in Battle Creek exceeds 2,500 winter-run Chinook Salmon per generation

4.4 Oversight and Decision Making

Adaptive management decisions vary in the degree of policy involvement and the frequency by which they need to be revisited (Figure 10). For example, overall goals for winter-run recovery may be reviewed infrequently (possibly every 5–10 years). Interim goals and objectives, and specific winter-run Chinook Salmon management policies may be reviewed more often (possibly every 3–5 years), depending on the status of the existing winter-run Chinook Salmon population, environmental conditions, and progress toward reintroduction. However, the near-term objectives and strategies of this Reintroduction Plan should be reviewed annually.

Adaptive management requires the efficient and timely inclusion of information into the management structure, coupled to a planned process to review and act on information. Specifically, a process will be needed to audit performance, challenge key assumptions, guide decisions, and plan activities for the upcoming year. To this end, an annual project review process would help chart progress, review reintroduction plans and objectives, and review monitoring results. It would provide a basis for preparation of an annual work plan for the upcoming management period. This annual review process should include the following objectives.

- Update key assumptions (ensure a scientifically defensible working hypothesis for reintroduction);
- Update status and trends information (report and review data on key performance metrics and biological targets);
- Review and apply decision rules (e.g., ensure appropriate transition to new phase or strategies, and monitoring and evaluation consistent with the plan); and
- Update biological targets and review for consistency with reintroduction and conservation objectives.

Given that this Reintroduction Plan will be implemented by one or more of the signatories to the MOU, that this plan falls within the scope of the broader restoration program (i.e., the BCRP), and that the plan is dependent on the broader program for its success, the oversight and decision making for this plan should be incorporated into the oversight and decision-making framework established by the MOU and the BCRP AMP. This would provide an efficient framework for review of monitoring results for the objectives of this plan in conjunction with the 11 objectives of the BCRP AMP. Consolidation of oversight would ensure that discussions regarding such topics as broodstock collection, adult and juvenile survival rates, and stray rates would be informed by current information on performance of facilities and habitat elements of the BCRP. That information is essential to deciding whether to exercise a contingency, implement an adaptive change, or stay the course in reestablishing a population of winter-run Chinook Salmon in Battle Creek, while other measures in the BCRP AMP are pursued (e.g., changes in flow patterns or modification of passage facilities).

The MOU sets out clear roles and responsibilities for implementation and monitoring (MOU Section 7) and a management structure (MOU Sections 9.1.B. 1 and 2) comprising an Adaptive Management Policy Team (AMPT) and an Adaptive Management Technical Team (AMTT) for implementation of the BCRP AMP. The AMPT consists of representatives from the Resource Agencies and PG&E, who provide policy oversight and resolve issues and disputes forwarded to them by the AMTT. The AMTT consists of a representative from each of the Resource Agencies and PG&E with appropriate training and experience to effectively address the technical aspects of implementing the BCRP AMP. The AMTT receives and evaluates information from the monitoring programs. It has authority to enact minor adjustments to the program. Major modification or disputes among the members regarding an action are referred to the AMPT for resolution.

The agency implementing this Reintroduction Plan should, in collaboration with the other fish agencies, prepare an annual report(s) in which each of the performance indicators in Tables 10 and 12 is evaluated using the information from the various monitoring programs in place pursuant to the BCRP AMP and identified in Tables 9 and 11. The implementing agency should, to the extent possible, include an analysis of the assumptions in Tables 9 and 11 and, where appropriate, recommend whether adjusting the strategy is needed.

Integrating this program with the broader BCRP AMP process would allow the AMTT to serve as technical advisors to the implementing agency and to ensure that activities are coordinated among the agencies working on the Reintroduction Plan. The annual report and recommendation for this program could be incorporated into the annual report required by the BCRP AMP and reviewed at the annual meeting with the AMPT in March. The annual report would need to reflect the time required to complete analysis and therefore would reflect performance through the prior year.

In the interim, the implementing agency could still rely on the AMTT for in-season advice on adjustments to the program, which might be necessary to ensure proper functioning of the program. Any major decisions or changes in the program (e.g., a decision to delay transition between phases, to keep supplementation going even though the population appears to be self-sustaining, or to terminate the program because key habitat parameters are not achievable) should be reserved for the AMPT.

Chapter 5

Facility Needs and Program Costs

The Reintroduction Plan implements reintroduction through artificial production and transplanting of natural-origin fry captured from the Sacramento River population. Artificial production will use broodstock sourced from the Sacramento River population and eventually broodstock sourced from Battle Creek at Coleman weir. The plan is supported by a variety of existing facilities and a new fish culture facility on Battle Creek for winter-run Chinook Salmon, described in Section 5.1. Costs associated with the Reintroduction Plan are described in Section 5.2. Both facility requirements and costs to implement the plan are conceptual to help with planning for implementation. Facility requirements and associated costs will likely be refined once an implementing agency has been identified.

5.1 Overview of Facility Needs to Implement the Reintroduction Plan

Existing facilities to implement the Reintroduction Plan include the adult trap at Keswick Dam on the Sacramento River, LSNFH at the foot of Shasta Dam on the Sacramento River, and the adult weir on lower Battle Creek at CNFH (Coleman weir).

Infrastructure is in place at LSNFH for adult holding, spawning, and early incubation to implement the plan.

Improvements planned for Coleman weir identified in the CNFH AMP will allow capture and sorting of returning winter-run Chinook Salmon. Additional tanks and water chillers will be needed to hold adult winter-run Chinook Salmon temporarily at CNFH for sorting and to process genetic samples.

The capture of natural-origin fry from the Sacramento River will require temporary juvenile holding tanks adjacent to the collection site and a 250-gallon transport truck.

Alternative adult capture sites (such as the ACID Dam) are being explored to support winter-run Chinook Salmon conservation and were identified by the California Hatchery Scientific Review Group (2012) as an important measure for addressing potential bias in the genetic diversity represented in the fish trapped at Keswick Dam. While development of an alternative collection site is desirable, it is not a prerequisite to implementation of this plan.

The most significant facility needed to implement the Reintroduction Plan is a fish culture facility on NF Battle Creek for winter-run Chinook Salmon. The CNFH was used at one time for hatchery production of winter-run Chinook Salmon to supplement the Sacramento River population. However, warm water temperatures during adult holding and egg incubation required the continuous use of chillers, and equipment failure caused significant temperature fluctuations that affected survival in the hatchery. The best chance for successful reintroduction is a facility higher up in NF Battle Creek adjacent to the spawning and rearing habitats, and where reliable sources of cold water may be found.

Facilities needed to implement the Reintroduction Plan are summarized in Table 13.

Table 13. Summary of Facilities

Purpose	Facility	Additional Infrastructure Needed
Broodstock capture	Keswick Dam adult trap	None
	Alternative Sacramento River site	Adult trap and secure area for holding adults before transfer to LSNFH
	Coleman weir	Temporary adult holding tanks and plumbing with water chillers
Hatchery rearing	LSNFH	None – LSNFH has capacity for adult holding, spawning, and egg incubation to eyed-egg stage.
	NF Battle Creek hatchery	New facility with capacity for egg incubation, early rearing, juvenile winter-runChinook Salmon marking, and rearing to release size
Fry transplant	Mainstem fry capture	Temporary tanks and plumbing to hold juveniles immediately after capture for transfer to rearing ponds on NF Battle Creek

5.1.1 Broodstock Facility Details

From mid-February through July, winter-run Chinook Salmon broodstock are collected from the Sacramento River mainstem population using an adult trap at the base of Keswick Dam. Trap operations would be adjusted to capture a total of 240 adults across the entire adult migration period.

An alternative adult capture site may require modifications to an existing diversion dam (such as ACID) and construction of an adult trap and secure area to hold adults before transfer to LSNFH.

Broodstock collection from Coleman weir will require the following additional infrastructure.

- A minimum of five 12-foot circular tanks, maximum capacity of 50 adults per tank
- A 25-gallon-per-minute (gpm) water supply per tank, 100 gpm total
- Water chillers to reduce 100 gpm by 10° Fahrenheit
- Plumbing at each tank to regulate creek water and chiller water into tanks in order to acclimate fish before transfer or release
- A 2,000-gallon fish transport truck configured to transport adults

5.1.2 Fish Culture Facility Details

No modifications would be needed for LSNFH. The existing facilities for adult holding, spawning, and incubation at LSNFH have the capacity to support the additional 120 adults for Battle Creek reintroduction.

The Reintroduction Plan calls for a fish culture facility on NF Battle Creek. Table 14 presents conceptual plans for this facility, with approximate incubation and rearing requirements.

Adult holding and spawning may be necessary in the future if LSNFH has capacity limitations due to other conservation programs or best management practices for fish culture recommend transferring adults immediately after capture to NF Battle Creek. Requirements for this optional facility component are included in Table 14.

Table 14. Conceptual Requirements for NF Battle Creek Fish Culture Facility

Purpose	Vessel Type	Number of Eggs or Fish	Number of Vessels	Water Supply	Description
Egg incubation	Sixteen-tray vertically stacked incubators	Up to 300,000 eggs	10	4 to 6 gallons per minute (gpm)	Receive eyed-eggs from LSNFH (5,000 eggs per female, spawn 60 females)
Swim-up fry tanking	30-inch diameter (10.2-cubic-foot) circular tanks	Up to 250,000 swim-up fry	60	8 gpm each, total 480 gpm	Early rearing of swim-up fry is generally by family groups
Early rearing	Rectangular fiberglass tanks (4 by 12 feet)	Up to 250,000 fry to marking stage	50 (5,000 fish per tank)	20 to 40 gpm each, total 1,000 to 2,000 gpm	Early rearing tanks in hatchery building
Outdoor rearing to release	Raceways 8 by 80 feet	280,000 juveniles to approximately 70 fish per pound	6 (50,000 fish per raceway)	500 gpm per raceway, total 3,000 gpm	Rearing to release up to 207,000 winter-runChinook Salmon from hatchery production and another 75,000 captured from Sacramento River
Optional Adult Holding and Spawning					
Adult holding	20-foot circulars	Up to 120 adults	2	100 gpm	Contingent on unforeseen conflicts with other facilities or programs

5.1.3 Transplant Fry Facility Details

Juvenile winter-run Chinook Salmon out-migrants are enumerated using four 2.4-meter-diameter rotary-screw traps at RBDD. The traps usually are operated continuously throughout 24-hour periods. They are sampled once daily, and fish are released downstream. If fry captured from these traps were used in reintroduction, additional facilities would be needed to hold fry before their transfer via tank trucks to the fish culture facility in NF Battle Creek.

Fry collection from the Sacramento River mainstem would require the following additional infrastructure.

- Two 4-foot circular tanks, maximum capacity of 10,000 fry
- A 20-gpm water supply per tank, 40 gpm total
- Piping to fill the fish transport truck and to transfer fry from the tanks to a fish transport truck
- A 200- to 250-gallon fish transport truck configured to transport small winter-run Chinook Salmon fry

5.2 Approximate Costs to Implement the Reintroduction Plan

The cost estimate developed for this Reintroduction Plan is approximate for 2016; the estimate is intended to provide a planning baseline from which a more formal estimate of costs to implement the plan can be developed. Implementation costs include new facilities, additional supporting infrastructure, and annual operating costs for hatchery production.

Also included are approximate annual costs specific to monitoring the performance of the reintroduction strategies. Included are data collection and processing for genetic parentage analysis, marking of juvenile fish, and data analyses to evaluate the specific goals and objectives for winter-run Chinook Salmon reintroduction described in this plan.

Not included in this estimate are annual costs associated with monitoring the progress of the BCRP. The program evaluation and adaptive management measures described in this Reintroduction Plan are designed to fit into the structure and decision-making process described in the BCRP AMP. Many of the monitoring costs related to habitat, fish passage, and winter-run Chinook Salmon performance in Battle Creek are expected to be covered by that program.

5.2.1 Cost Estimate for Facility Planning, Design, and Environmental Compliance

Preliminary costs for planning, design, and permitting of a new fish culture facility in NF Battle Creek assume that most of this work would be done by contractors. A placeholder of $500,000 has been identified for additional facility planning; reconnaissance of potential sites for water, power, and space; and design tasks to starting construction. Another placeholder of $500,000 has been identified for environmental compliance. Costs for facility planning, design, and environmental compliance could be substantially less if some of these tasks were completed by the agency implementing the Reintroduction Plan.

5.2.2 Cost Estimate for Facility Construction

Construction costs are concept estimates based on the cost to construct the LSNFH facilities. According to USFWS (John Rueth, Hatchery Manager at LSNFH), the cost in 1998 to construct the LSNFH was $981,000. Assuming a 3.1-percent annual rate of inflation,[1] the construction cost in 2016 would be $1.7 million. An additional 25-percent contingency would bring the construction cost to approximately $2.125 million. Construction costs could be less if an existing fish culture facility on Battle Creek was found to be suitable for the Reintroduction Plan. For example, the SJRRP built an interim facility to culture spring-run Chinook Salmon on the San Joaquin River for about $1.125 million with operating costs of about $500.000/year (Erlandsen pers. comm.). This facility was constructed on the site of an existing hatchery and takes advantage of much of the existing infrastructure. Whereas the full build out of the San Joaquin Conservation and Research Facility (SCARF) will cost about $13,081,000 with operating costs of about $1 million/year (Erlandsen pers. comm). The SCARF includes facilities that will not be necessary at the NF Battle Creek site. For example, it includes adult holding facilities and a larger captive broodstock facility, a research facility, conference rooms, visitor's center, and two residences for employees. Initially, the NF Battle Creek facility will need facilities for accepting eyed-eggs and growing them to presmolt/smolt size for release. As the program develops, it will need facilities for holding returning adults until they are ready to spawn. There are no plans for a captive broodstock program; and research facilities, meeting space, and visitors can be accommodated at CNFH. Housing for caretaker residence can be accommodated with temporary facilities (e.g., a trailer).

Additional points of reference are provided by two conservation hatcheries planned in Washington, with comparable smolt production goals. These are the Holmes Ranch Coho hatchery on the Yakama River, which is estimated to cost $8,849,104 to build—with annual operating and maintenance costs of $579,000/ per year (NPCC 2013a)—and will produce 200,000 coho smolts/year. The Walla Walla Springs Chinook Salmon hatchery on the Walla Walla River has an estimated construction cost of $11,798,217 and an annual cost of $978,668 for operations and maintenance. The Walla Walla Springs hatchery is expected to produce 500,000 Chinook Salmon smolts per year (NPC 2013b).

5.2.3 Cost Estimate for Fish Culture

A placeholder annual cost of $250,000 has been identified to culture winter-run Chinook Salmon at a facility on NF Battle Creek. This estimate is based on the reported operating costs for LSNFH (USFWS 2013a). Annual hatchery operating costs at LSNFH are approximately $250,000 for a maximum production of 250,000 winter-run Chinook Salmon, resulting in an approximate cost per fish released of $1.00. Total staff at LSNFH is four and, during periods of increased workload, additional staff are temporarily transferred from CNFH. The number of staff to operate a facility on NF Battle Creek may be less, but operations may require more staff time with broodstock collection at Keswick Dam and at Coleman weir.

Power and water are not included in the operating cost for LSNFH. A placeholder annual cost of $100,000 has been identified for these items at a NF Battle Creek facility.

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[1] Vermeulens (2015) reported that, for the past 29 years [1986–2015], construction costs have trended toward a 3.1% annually compounded escalation rate.

A total annual operating cost of $350,000 for a winter-run Chinook Salmon facility on NF Battle Creek may be on the low end of the cost range. Annual operating costs for a facility on NF Battle Creek may differ depending on the agency operating the program and staffing requirements. For example, total annual operating costs to culture spring-run Chinook Salmon at an interim culture facility on the San Joaquin River are about $500,000, and approximately $1.0 million is estimated to operate the permanent facility (Erlandsen pers. comm.).

5.2.4 Cost Estimate for Additional Facilities

Four 12-foot adult holding circular tanks are planned for Coleman weir. A placeholder cost of $20,000 has been identified for four foam-core insulated circular tanks. Adult holding tanks will require chillers to treat 100 gpm in May and June, when Battle Creek water temperatures are too warm to safely handle and hold adult winter-run Chinook Salmon. A placeholder cost of $50,000 has been identified for this item.

The capture of juvenile fry from the Sacramento River to transplant to Battle Creek will require temporary facilities adjacent to the mainstem traps to hold fry before their transfer to rearing ponds on NF Battle Creek. A placeholder cost of $20,000 has been identified for this item.

The transfer of adult broodstock from Coleman weir to LSNFH and juvenile fry from the Sacramento River capture site will require ta 2,000-gallon fish transport truck and a smaller 200- to 250-gallon truck. A placeholder cost of $150,000 has been identified for those trucks.

No attempt was made to estimate the cost to develop an additional adult collection site on the mainstem Sacramento River. Design and construction costs will vary greatly depending on where a site may be developed. Alternatively, a non-permanent solution may be best, with a minor cost to the plan.

5.2.5 Cost Estimate for Monitoring Reintroduction Strategies

As described in Section 4.3.1, the monitoring and evaluation elements of the Reintroduction Plan are organized to address monitoring priorities for hatchery broodstock targets, production targets, diversity targets, survival of released fish to adult return, and adult return rates to Battle Creek including natural production. The BCRP AMP already anticipates the need to estimate adult and jack returns (using adult counts at fish ladders and weirs, carcass counts, or redd surveys) and the need to estimate juvenile production (using outmigrant traps within the restoration project area). Costs for these monitoring activities were assumed to be covered by the BCRP AMP monitoring plan.

Hatchery production monitoring was not assumed to be covered in the BCRP AMP monitoring plan. Most of the hatchery monitoring tasks would be part of staff normal hatchery operations (e.g., monitoring the number of broodstock, sex ratios in broodstock, fecundity, and in-hatchery survival) covered under annual operating costs for the hatchery. Additional costs for hatchery monitoring include marking and injection of a CWT in all hatchery releases and transplanted fry, and data collection and processing for genetic parentage analysis. A placeholder annual cost of $300,000 has been identified for these items.

5.2.6 Combined Cost Estimate

Estimated combined costs to implement the Reintroduction Plan are presented in Table 15. As previously noted, consistent with this stage of development of the Reintroduction Plan, cost estimates are conceptual and probably on the low end based on a similar reintroduction program for spring-run Chinook Salmon in the San Joaquin River. The agency implementing the Reintroduction Plan will need to refine these estimates in future planning phases.

Table 15. Combined Estimated Costs for Implementing the Reintroduction Plan

Category	Item	Description	One-Time Cost Placeholder	Annual Cost Placeholder
Planning, design, and environmental compliance	NF Battle Creek facility planning	Additional facility planning; reconnaissance of potential sites for water, power, and space; and design tasks to starting construction	$500,000	
	Environmental compliance	NEPA, ESA, and other environmental compliance tasks to permit the facility and implementation of the Reintroduction Plan	$500,000	
Construction	Fish culture facility	Construct a new fish culture facility on NF Battle Creek	$2,125,000	
Additional supporting facilities and capital equipment	Coleman weir	Circular adult tanks, plumbing, and chillers	$70,000	
	Fry capture	Juvenile tanks and plumbing	$20,000	
	Fish transport trucks	One 2,000-gallon fish transport trucks, one 200- to 250-gallon fish transport truck	$150,000	
Annual Operations	Fish culture	Staffing, fish food, chemicals, and other annual operation expenses		$250,000
	Power and water	Annual cost for power and water lease for NF Battle Creek facility		$100,000
	Monitoring	Fish marking and injection of a coded wire tag, and data collection and processing for genetic parentage analysis		$300,000
Total one-time cost			**$3,365,000**	
Total annual cost				**$650,000**

As indicated above, these cost are meant to establish a planning baseline and are based in large part by inflation of the costs from construction and operation of LSNFH. However, comparison to several other hatchery programs under development in California and Washington indicate that the construction cost may be low. The LSNFH has the advantage of being located on existing federal land owned by the USBR, with power and water available for operations. If the NF Battle Creek has to purchase land, develop a new water supply, and bring power to the site; costs could escalate. Based on the information discussed above, a reasonable planning horizon for construction of a facility on NF Battle Creek would be between $3 and $8 million. The estimate of annual operating costs appears to be consistent with the estimate for LSNFH and the other facilities with similar production goals discussed above.

Chapter 6
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6.2 Personal Communications

B. Erlandsen, Senior Environmental Scientist San Joaquin River Restoration Program, California Department of Fish and Wildlife. May 26, 2016—email to Jim Lecky, ICF International about cost of construction and operation of San Joaquin Conservation and Restoration Facilities.

Appendix A

Battle Creek Winter-Run Chinook Salmon Reintroduction Plan Technical Advisory Committee Participants

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Battle Creek Winter-Run Chinook Salmon Reintroduction Plan Technical Advisory Committee Participants

Battle Creek Winter-Run Chinook Salmon Reintroduction Plan
Technical Advisory Committee Participants

Name	Title	Agency
Jason Roberts	Fisheries Supervisor	California Department of Fish and Wildlife
Andrew Jensen	Fisheries Supervisor	California Department of Fish and Wildlife
Doug Killam	Senior Fisheries Biologist	California Department of Fish and Wildlife
Heather McIntire	Senior Environmental Scientist, Grant Manager	California Department of Fish and Wildlife
Daniel Kratville	Central Valley Salmon Coordinator	California Department of Fish and Wildlife
Naseem Alston	Fish Biologist	National Marine Fisheries Service
Amanda Cranford	Natural Resources Management Specialist	National Marine Fisheries Service
Brian Ellrott	Central Valley Recovery Coordinator	National Marine Fisheries Service
Matt Brown	Program Manager, Battle Creek Program	U.S. Fish and Wildlife Service
Laurie Earley	Fish Biologist, Battle Creek Program	U.S. Fish and Wildlife Service
Kevin Niemela	Program Manager, Hatchery Evaluation and Monitoring	U.S. Fish and Wildlife Service
Bob Null	Supervisory Fish Biologist, Hatchery Evaluation and Monitoring	U.S. Fish and Wildlife Service
Scott Hamelberg	Project Leader, Coleman National Fish Hatchery Complex	U.S. Fish and Wildlife Service
John Rueth	Hatchery Manager, Livingston Stone National Fish Hatchery	U.S. Fish and Wildlife Service
Jim Smith	Project Leader, Red Bluff Fish and Wildlife Office	U.S. Fish and Wildlife Service
Steve Tussing	Watershed Coordinator	Battle Creek Watershed Conservancy
Jon Walsh	Aquatic Biologist	Pacific Gas and Electric Company
Trang Nguyen	Battle Creek Technical Specialist	U.S. Bureau of Reclamation
Mary Marshall	Alternate	U.S. Bureau of Reclamation

Name	Title	Agency
Brock Bernstein	Facilitator	
Joan Lynn	Meeting Reporter	Egret, Inc.
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Appendix B

Habitat Suitability of Battle Creek for Winter-Run Chinook Salmon

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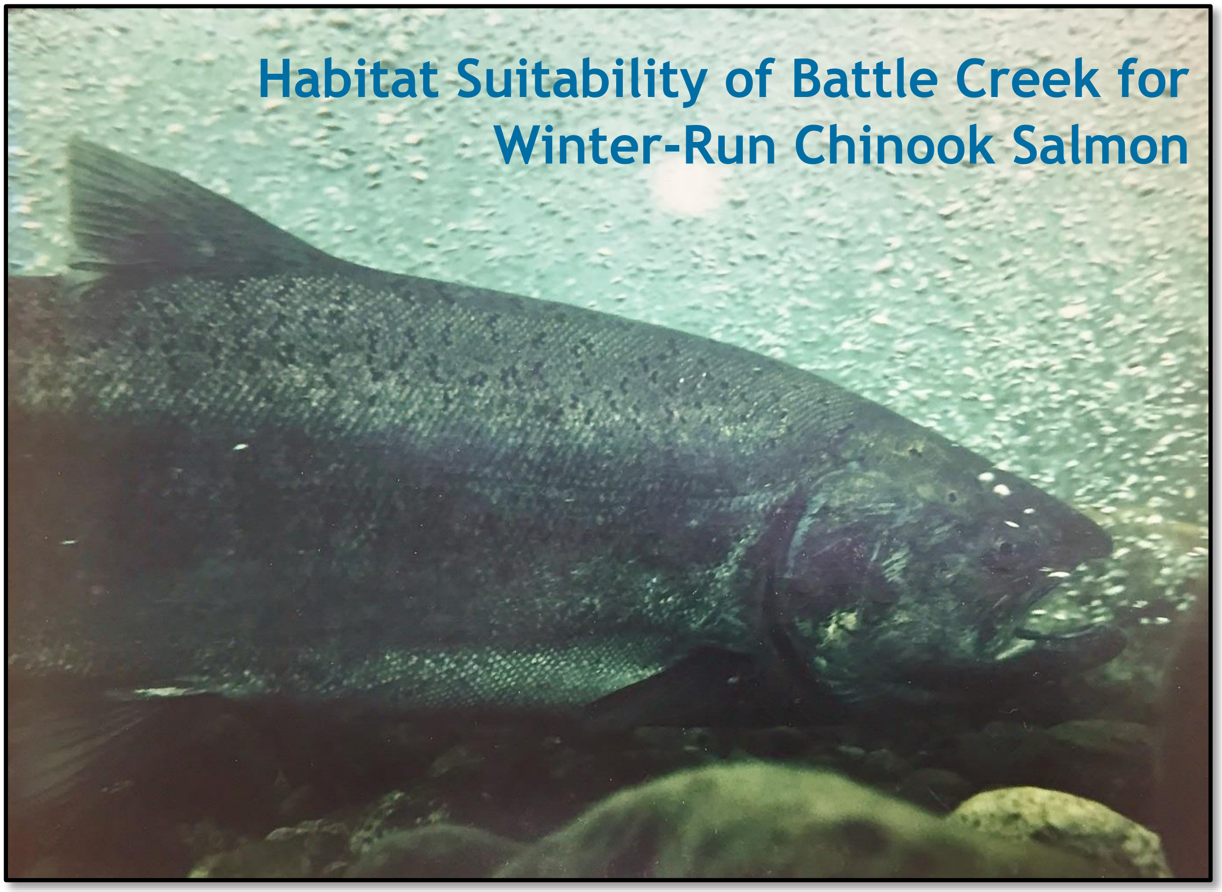

Habitat Suitability of Battle Creek for Winter-Run Chinook Salmon

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Introduction

Historically, the native distribution of winter-run chinook (winter-run) was believed to be largely restricted to spring-fed headwater reaches of the Sacramento River, including the Little Sacramento River and the McCloud River, both of which receive substantial spring accretion from the volcanic Mt. Shasta, but now occur above Shasta Dam which is impassable to anadromous fish (NMFS 2014). This highly limited historical range was largely due to this race's life-history periodicity, which involves upstream migration, spawning, and egg incubation during the warmest months of the year. Early records have revealed that winter-run also spawned and reared in Battle Creek (Yoshiyama et. al 2000). Battle Creek is unique among the Sacramento River tributaries due to the high proportion of discharge arising from cool, spring outflows draining the volcanic geology of Lassen Peak. The constant accretion of cold spring water provided high summer base flows and maintained summer water temperatures at levels tolerable to winter-run salmon. However, the development of hydropower facilities throughout the Battle Creek watershed eliminated this habitat for winter-run through severe reductions in streamflow and diversion of spring sources, which led to warming of summer baseflows. Numerous diversion dams with no or inadequate passage facilities prevented access to cooler headwater habitats, and consequently winter-run have rarely been observed in Battle Creek over the last century.

Although the mainstem Sacramento River in the Redding area was historically too warm to support winter-run spawning and incubation, cold-water releases from Shasta Dam have in part replaced the original headwater habitat and have allowed this race to survive, albeit in relatively low numbers that have led to the designation of winter-run as an endangered species in 1994 (Federal Register 59:440). Because nearly the entire population of winter-run chinook salmon are currently limited to one location below Shasta Dam (or, more specifically, below Keswick Dam downstream of Shasta), effective recovery of this race will involve re-establishment of winter-run into portions of its historical range, including Battle Creek. The Battle Creek Restoration Project, and the Five-Dam Removal Alternative (Preferred Alternative), will help to protect the winter-run race by expanding its current distribution through improved passage within the Battle Creek watershed and improved spawning and rearing conditions through increased baseflows with reduced summer water temperatures. Consequently, a winter-run reintroduction program is a significant component of the Restoration Project, which includes an assessment of available habitat for spawning and rearing of winter-run under the Preferred Alternative.

The draft multi-species Central Valley Recovery Plan (NMFS 2009), described population goals for recovery of winter-run Chinook salmon. Among other necessary criteria, the draft plan suggested that a population of 2,500 adults with a positive annual growth rate would produce a population at low risk of extinction (NMFS 2011). The USFWS also estimated that Battle Creek is capable of supporting a population of 2,500 adult winter-run given restoration goals are achieved (USFWS 1995).

Methods

This habitat assessment is largely based on two modeling analyses: the physical habitat modeling using PHABSIM (TRPA 1998a) and the SNTEMP water temperature modeling (TRPA 1998b & c, PG&E 2001), both assuming development of the Preferred Alternative. The PHABSIM analysis provided flow:habitat relationships that were used to develop the MOU flow prescriptions, which were then used in the SNTEMP model to predict mean monthly water temperatures within each reach given those prescribed flows (USBR 2005, Appendices K and R). Because temperature limitations for winter-run were expected to be most severe during late-spring and summer months, this habitat analysis will rely upon SNTEMP water temperature predictions and associated habitat or population metrics over the months of June-September.

Plots showing the mean monthly water temperatures during a "normal water year" with normal air temperatures against river mile were used to produce estimates of the stream lengths (according to river mile) that possess temperatures deemed unsuitable, marginal, or optimal for winter-run life-stages, according to temperature tolerance criteria listed in the EIR (USBR 2005 Appendix K) or supporting documents (described below). Stream lengths were tabulated for each temperature class for according to life-history stage, with focus on the summer months when temperature limitations are most evident. Assessment of temperature-related limitations on habitat will include four life-history stages over the summer period: 1) adult migration & holding (June-Aug); 2) spawning and egg incubation (June-Aug); 3) juvenile rearing (July-Sept); and 4) smolt outmigration (July-Sept).

It should be noted that water temperature regimes are expected to be less limiting to winter-run life-stages during wet years with cooler flows than in the normal years assessed in this chapter; however temperature limitations will likely be more restrictive during periods of drought if inflows to the remaining diversion dams are less than the scheduled release flows. This assessment utilized expected temperature scenarios under a normal water year to represent average conditions likely to be experienced by winter-run in the Battle Creek watershed. Also note that cooler water temperatures will occur throughout the spring, fall, and winter months compared to the summer months assessed in this chapter.

The EIR SNTEMP plots (USBR 2005 Appendix K) did not include data from above the North Battle Feeder Diversion Dam on the North Fork or the South Diversion Dam on the South Fork, even though approximately 4.5 and 4.9 miles of potential habitat exist above these locations, respectively. When plotting stream lengths, mean temperatures above the upper modeled locations were assumed to be equal to or less than downstream temperatures. The SNTEMP plots also did not include predicted temperatures in the mainstem below the Coleman Powerhouse, which would be releasing cooler water from upstream sources (USBR 2005, Appendix R). Consequently the stream length plots given here do not account for potentially suitable thermal conditions in the lower 8 miles of the Battle Creek mainstem.

Modeling results from the PHABSIM and SNTEMP analyses were also incorporated into a habitat and population model to produce indices of abundance for spawning and rearing winter-run in Battle Creek (USBR 2005 Chapter 4 and Appendix H). It should be noted that these indices should not be assumed to represent actual estimates of abundance, rather they were developed to compare the potential benefits of restoration alternatives, of which the Preferred Alternative was ultimately selected for further evaluation.

Although existing analysis has revealed that most potential habitat for the successful reintroduction of winter-run into Battle Creek will be in the cooler North Fork Battle Creek (North Fork), the Preferred Alternative is also expected to provide some suitable habitat in the South Fork Battle Creek (South Fork). If winter-run re-introduction efforts are ultimately limited to the North Fork, some degree of straying of adult upstream migrants or rearing juveniles into the South Fork may be expected. However, the Preferred Alternative eliminates inter-basin transfer of North Fork water into the South Fork, so false attraction is not expected to contribute to straying of North Fork adults into the South Fork.

Adult Migration and Holding

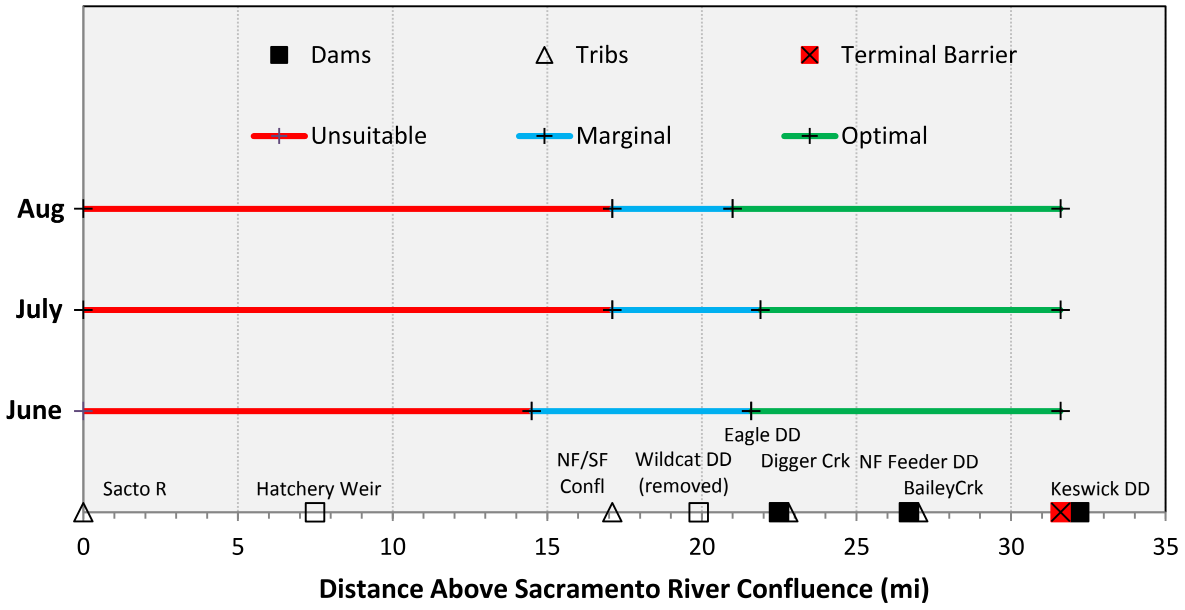
Adult winter-run migrate up the Sacramento River from December through July, with peak passage at Red Bluff Diversion Dam, approximately 30 miles downstream of the Battle Creek mouth, in April (Ward and Kier 1999, NMFS 2014). Peak migration within Battle Creek is expected to occur in April (USBR 2005, Chapter 4). Winter-run chinook exhibit migration behavior somewhat intermediate to that of fall-run chinook, which migrate directly to spawning areas and spawn immediately after arrival, and that of spring-run chinook, which migrate to holding areas downstream of spawning locations and hold in those locations for 2 or more months prior to spawning. Winter-run spawning in the Sacramento River occurs from mid-April to mid-August, with peak spawning from May to July (USBR 2005, NMFS 2014). Consequently, winter-run adults may hold-over prior to spawning for several weeks to well over a month, and late-running individuals are particularly vulnerable to the detrimental effects of high water temperatures.

Although adult holding habitat for winter-run is not well documented, holding habitat for spring-run typically consists of large, deep pools. Habitat mapping in Battle Creek was conducted under low base flows (lower than Preferred Alternative flows) in 1988, which revealed that pool habitats were widely distributed throughout the Battle Creek basin, although deeper pools (>1m maximum depth) became less abundance in the headwater reaches (TRPA 1998a). The following assessment assumes that holding pools or other holding habitat is not physically limiting to migrant or holding adult winter-run in either fork of Battle Creek.

A review of water temperature criteria for holding adult winter-run was not located, except for a single reference to 59-60°F as being the "maximum suitable water temperature reported for holding" in NMFS 2014, however the background data for this criteria was not given. Ward and Kier (1999) summarized holding temperature criteria for spring-run Chinook salmon from several studies as <60.8°F optimal, 60.8-66.2°F marginal (e.g., some mortality or infertility), and >66.2°F as unsuitable (no successful spawning). Given the larger available dataset for holding spring-run salmon, and the similarity in summer holding behavior, the spring-run temperature criteria were used to assess holding habitat for adult winter-run.

Applying these criteria to the SNTEMP-estimated mean monthly water temperatures for the Preferred Alternative under a normal water year by river mile (RM) suggested that late-migrating winter-run adults would find excessive temperatures in the mainstem in June, July, and August (Figure 1), except for a short segment below the confluence in June due to cooler water from the North Fork (Note: these plots do not account for cooler outflows from the Coleman Powerhouse affecting the mainstem below RM 8.0). The North Fork is expected to

Winter-Run Adult Holding Survival - MS + NF Battle Creek



Winter-Run Adult Holding Survival - MS + SF Battle Creek

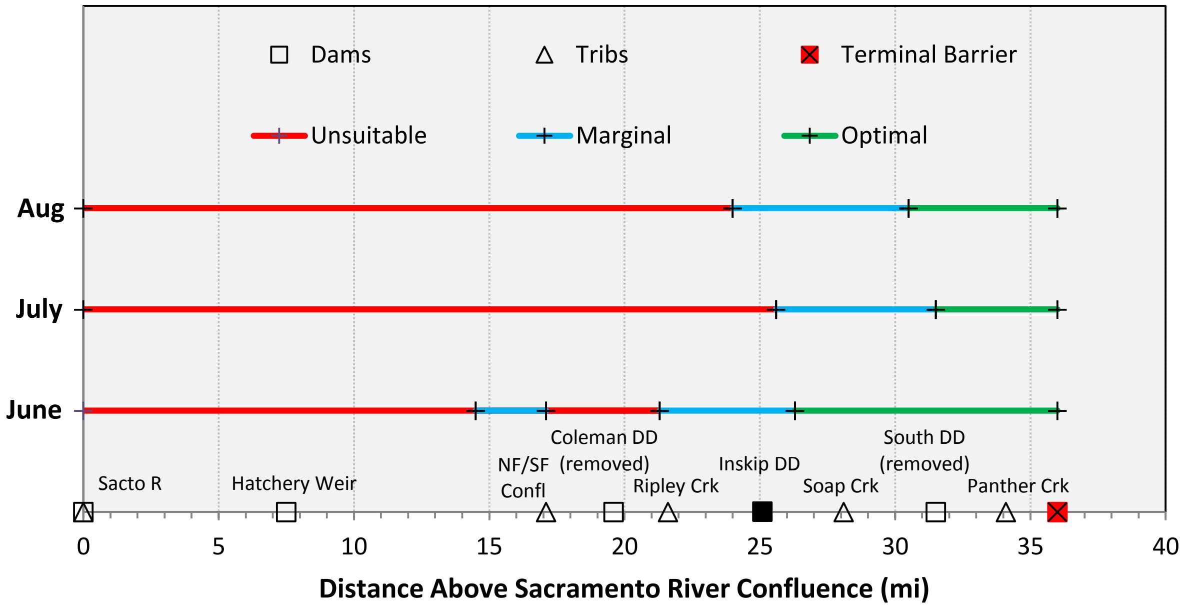


Figure 1. Stream reaches meeting temperature suitability criteria for holding adult winter-run in the mainstem and North fork (upper graph) and South Fork (lower graph) of Battle Creek according to month. Approximate locations of hydropower facilities, tributaries, and terminal barriers are also shown. See text for temperature criteria.

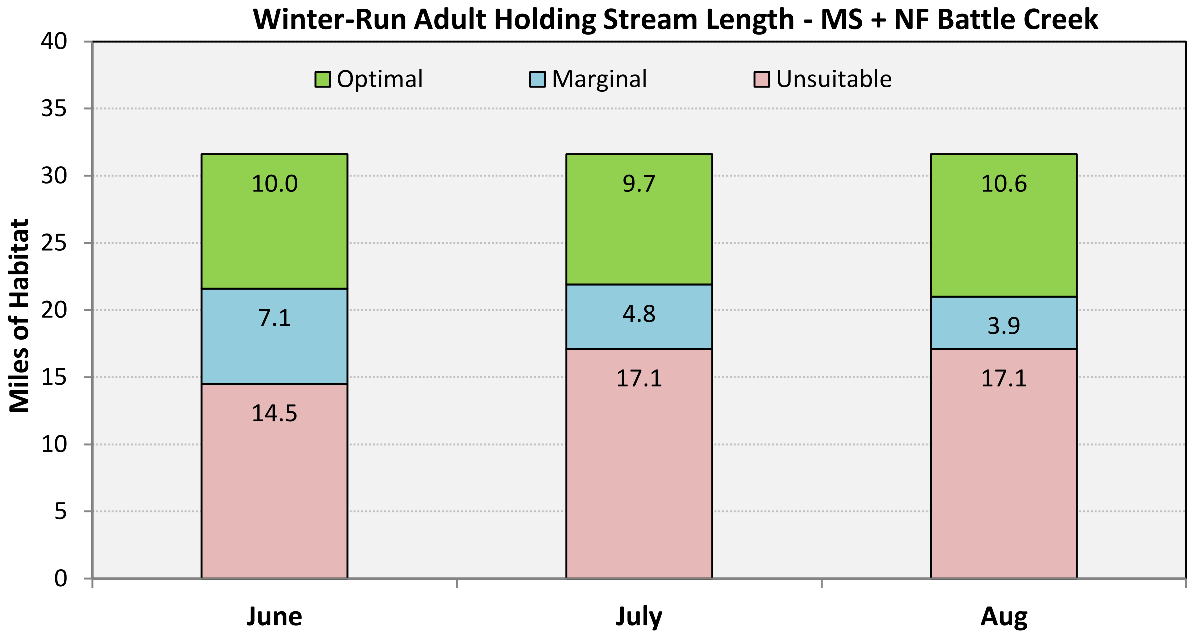
possess marginal water temperatures in each month from the confluence of the forks (Forks) up to the vicinity of the Eagle Diversion Dam (Eagle DD), and optimal temperatures upstream of Eagle DD. In contrast, the warmer South Fork is expected to have unsuitable water temperatures up to Ripley Creek in June, and up to the vicinity of Inskip Diversion Dam (Inskip DD) in July and August. Marginal water temperatures may occur as far upstream as the site of the South Diversion Dam (South DD) in July and August, with optimal temperatures to the terminal barrier at RM 36 (Note: all RMs are approximate). This data suggests that late arriving migrants may not have access to suitable holding and spawning areas in the cooler, upper reaches of either fork.

Summing the lengths of channels by temperature criteria shows that the North Fork and South Fork are expected to contain similar amounts of unsuitable, marginal, and optimal temperature-conditioned holding habitat in June, but the cooler North Fork may contain approximately twice the length of optimal habitat in July and August (Figure 2). Both forks show more marginal and optimal habitat in June than in July or August, particularly the South Fork. Note that both forks contain areas of cold spring inflow, with the largest sources being at the Eagle DD site in the North Fork and at Soap Creek in the South Fork. Ongoing focused studies are evaluating the localized and reach-wide effects of these spring sources, which are not diverted (Eagle DD) or are minimally diverted (Soap Creek) under the Preferred Alternative (USBR 2005). The effects of these springs could extend the length of optimal temperatures downstream of the locations shown in Figure 1, with consequently longer channel lengths given in Figure 2. Also, the presence of large, deep pools in the lower reaches of the forks or mainstem could lead to thermal stratification which, if not oxygen-deficient, could provide localized refuges for holding adult winter-run salmon.

Spawning and Incubation

Once re-established in the Battle Creek watershed, holding adult winter-run are anticipated to seek-out suitable spawning areas and construct redds from mid-April to mid-August, with peak spawning in June (USBR 2005, NMFS 2014). Unfortunately, water temperature suitability criteria are more limiting for the winter-run's egg incubation life-stage than for any other portion of its periodicity. The relationship between embryo survival and water temperature was described in Appendix K of the EIR (USBR 2005). Embryo survival was estimated to be 0% at temperatures >62°F, 20% at 61°F, 50% at 60°F, 75-85% at 59.5-57.5°F, and 92-100% at temperatures <57.5°F. For the assessment of stream length suitability, these temperature criteria were simplified and defined as optimal for temperatures <59.5°F (e.g., with survival ≥75%), marginal for temperatures of 59.5-62°F, and unsuitable for temperatures >62°F (e.g., with no survival).

Under the Preferred Alternative and a normal water year condition, water temperatures in the mainstem Battle Creek and the North Fork would be expected to be unsuitable for egg incubation in June, July, and August up to approximate RM 20, near the original location of the Wildcat DD (Figure 3). However, water temperatures are predicted to achieve optimal conditions (<59.5°F) only 1-2 miles farther upstream, in the approximate vicinity of the Eagle DD. Although SNTEMP plots in the EIR Appendix K did not extend upstream of the North Branch Feeder Diversion Dam (Feeder DD), optimal incubation temperatures should occur



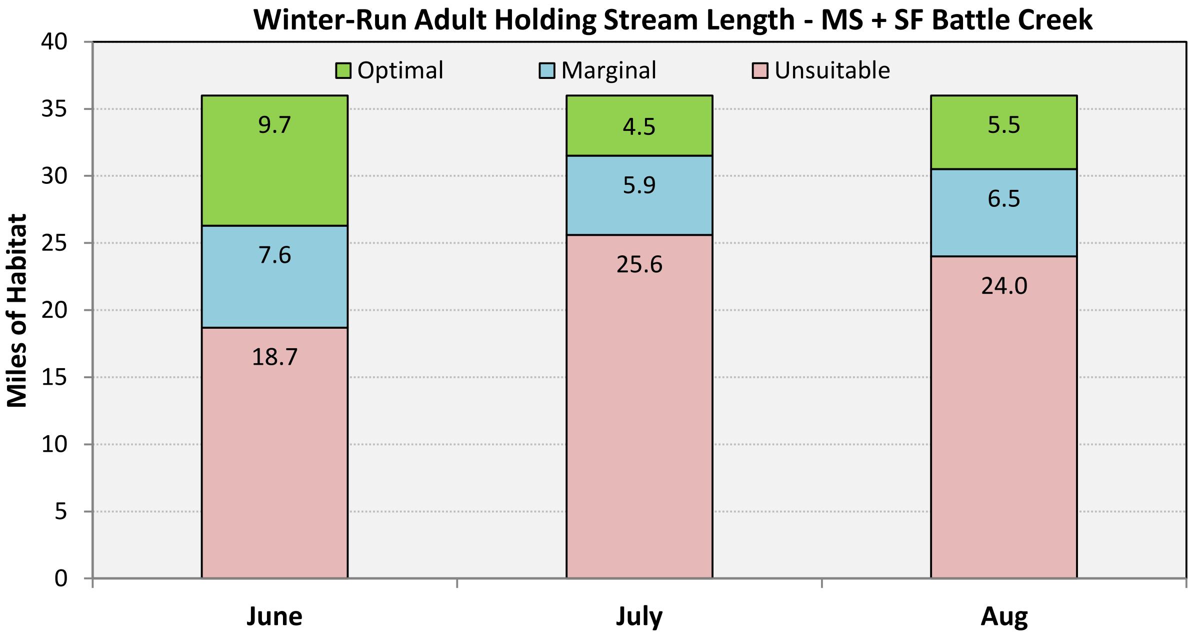
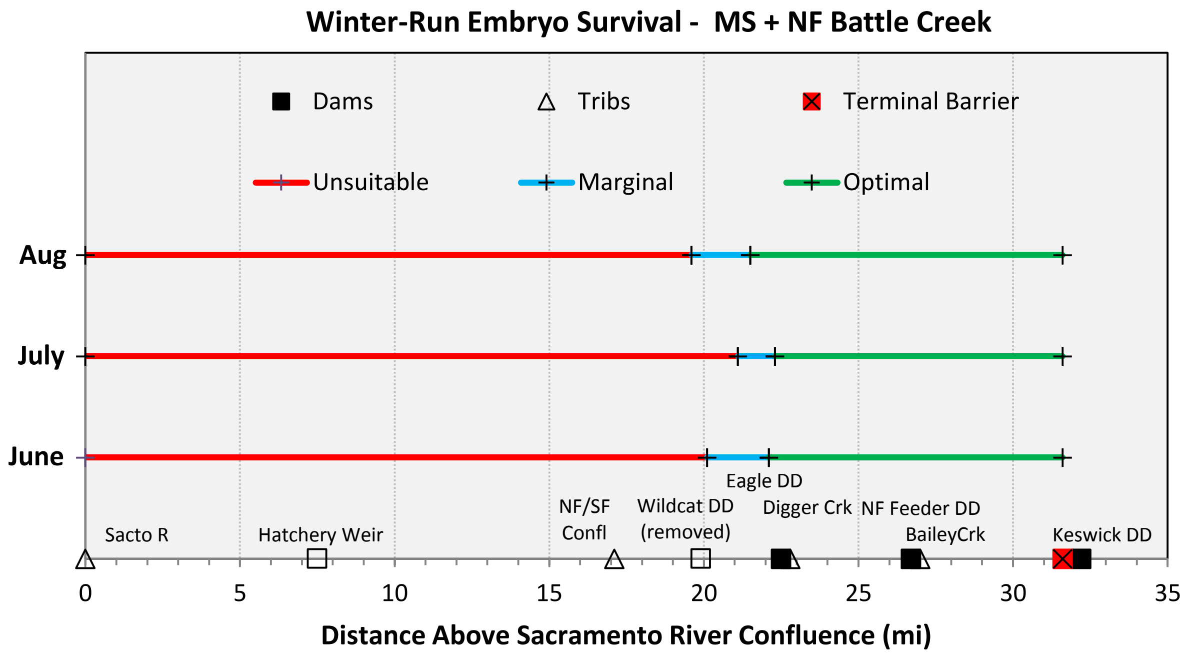


Figure 2. Length of stream reaches meeting temperature suitability criteria for holding adult winter-run in the mainstem and North fork (upper graph) or South Fork (lower graph) Battle Creek according to month. See text for temperature criteria.



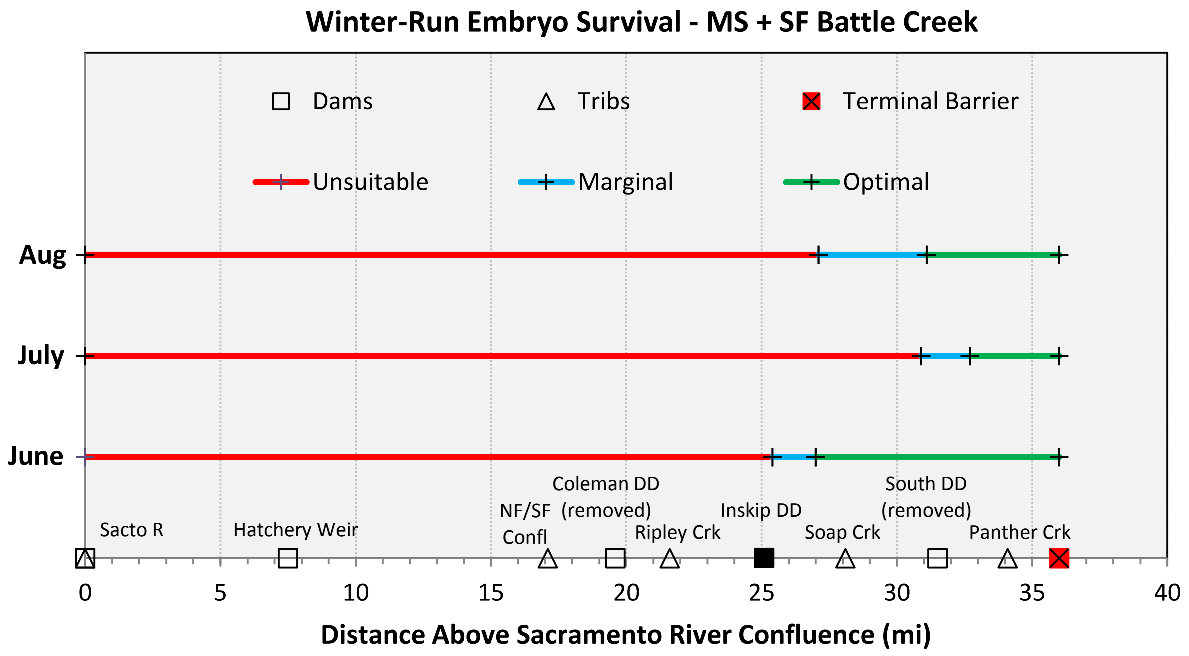


Figure 3. Stream reaches meeting temperature suitability criteria for winter-run egg incubation in the mainstem and North fork (upper graph) and South Fork (lower graph) of Battle Creek according to month. Approximate locations of hydropower facilities, tributaries, and terminal barriers are also shown. See text for temperature criteria.

throughout the summer months within the remaining 4.5 miles of channel between the Eagle DD and the terminal barrier. The warmer South Fork is expected to yield unsuitable incubation temperatures as far upstream as the Inskip DD in June, even farther to just below the location of the South DD in July, and to an intermediate location in August. Optimal thermal conditions are restricted to the uppermost reaches of the South Fork, especially in July when temperatures (estimated by extending the SNTEMP temperature profile upstream 4.9 mi to the terminal barrier) may only encompass the last 3 miles of anadromous habitat.

As noted above for adult holding, the existence of cool, spring inflows may extend the area of optimal or marginal temperatures for spawning and incubation (e.g., below Eagle DD), or produce isolated pockets of suitable habitat (e.g., below Soap Creek in July).

Summing the stream lengths according to temperature suitability criteria (Figure 4) suggests that both forks may contain similar lengths (10-12 mi) of marginal and optimal temperature-conditioned habitat during the month of June, but the North Fork is expected to contain three times the amount of optimal stream length (9.3 vs. 3.3 mi) during the warmest month of July, and twice the amount of optimal stream length (10.1 vs. 4.9 mi) in August.

The temperature-conditioned stream length estimates do not account for the distribution of spawning gravels in Battle Creek, instead they only account for channel length meeting temperature criteria under the instream flow regimes specified in the Preferred Alternative. Although gravel quantity was estimated during habitat mapping in 1988 (TRPA et al. 1998), the gravel assessment was conducted at lower flows than the restoration flows, and mapped gravel included deposits up to 2.5 ft above the base flow water surface, which may encompass deposits higher than is available to late-spring and summer spawning winter-run even under the Preferred Alternative flows.

Nevertheless, to better assess the potential quantity of spawning and incubation habitat under the various restoration alternatives, reach-specific gravel areas under different flow regimes (USBR 2005, Appendix H) were combined with literature-derived estimates of redd area requirements for spawning Chinook salmon to produce an index estimate of the “capacity” of spawning habitat in Battle Creek according to stream reach (USBR 2005, Chapter 4). This capacity index represented the physical capacity only and did not include the effects of water temperature limitations on egg and embryo survival. Incorporating the effects of water temperatures on the survival of incubating eggs and embryos resulted in indices of “production” of emerged salmon fry. It should be noted that these estimated values should not be interpreted as actual abundance estimates, but rather as indices of abundance for the purpose of comparing restoration alternatives (USBR 2005).

Figure 5 displays the estimated spawning habitat area available in each reach, excluding 4.5 mi and 4.9 mi of accessible habitat above the Feeder DD and South DD sites, respectively. The capacity and production indices do include the uppermost reach above the South DD, but no estimates are given for the North Fork above the Feeder DD. The actual index values for fry capacity and fry production were not given in the EIR, so the Figure 5 values are approximate estimates taken from the Chapter 4 graphs.

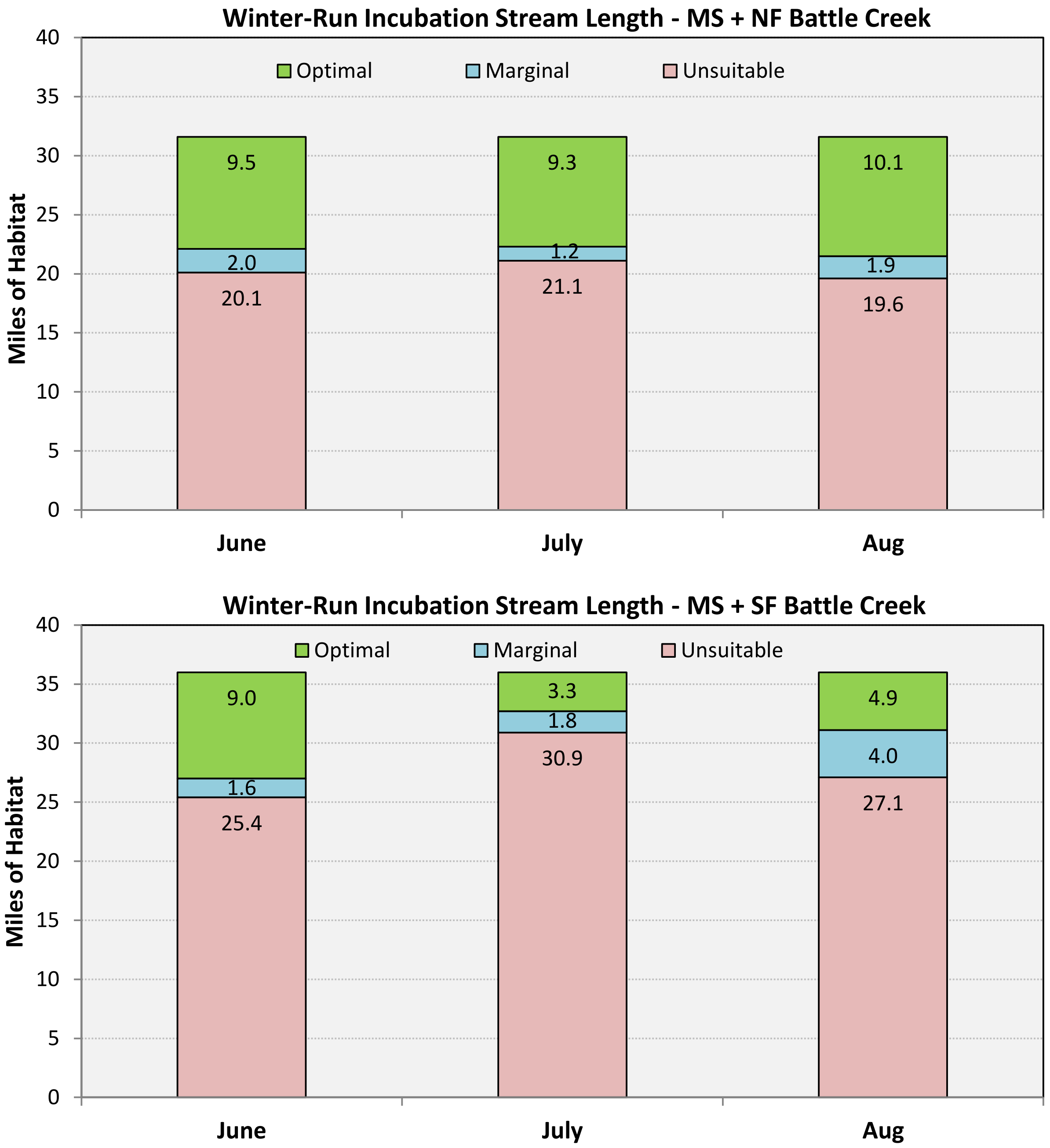


Figure 4. Length of stream reaches meeting temperature suitability criteria for winter-run egg incubation in the mainstem and North fork (upper graph) or South Fork (lower graph) Battle Creek according to month. See text for temperature criteria.

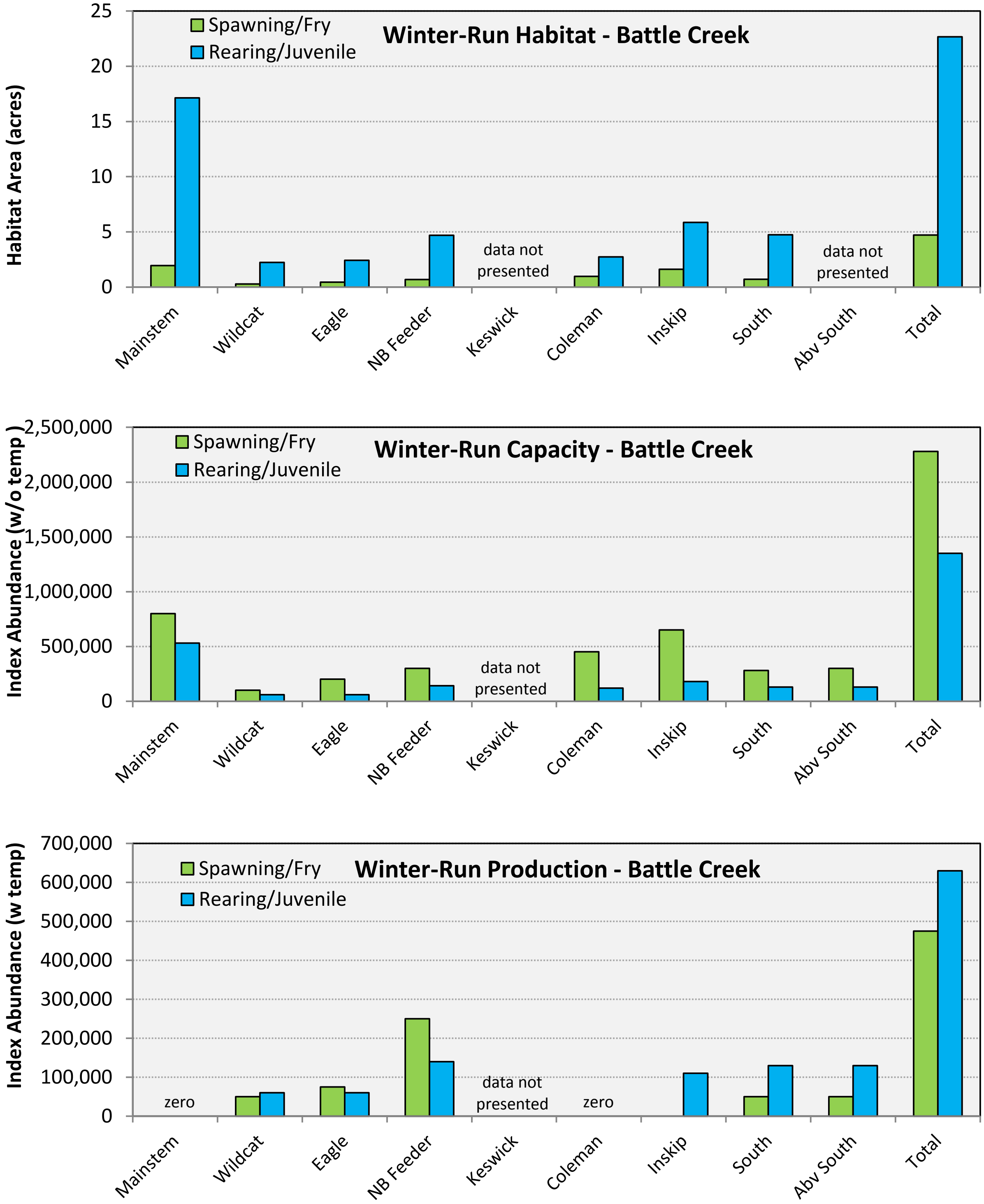


Figure 5. Estimated habitat area (upper graph), index of capacity (middle graph), and index of production (lower graph) for spawning/fry and juvenile rearing winter-run in Battle Creek by reach under the Preferred Alternative (graphs approximated from USBR 2005 Figures 4.1-6 & 7).

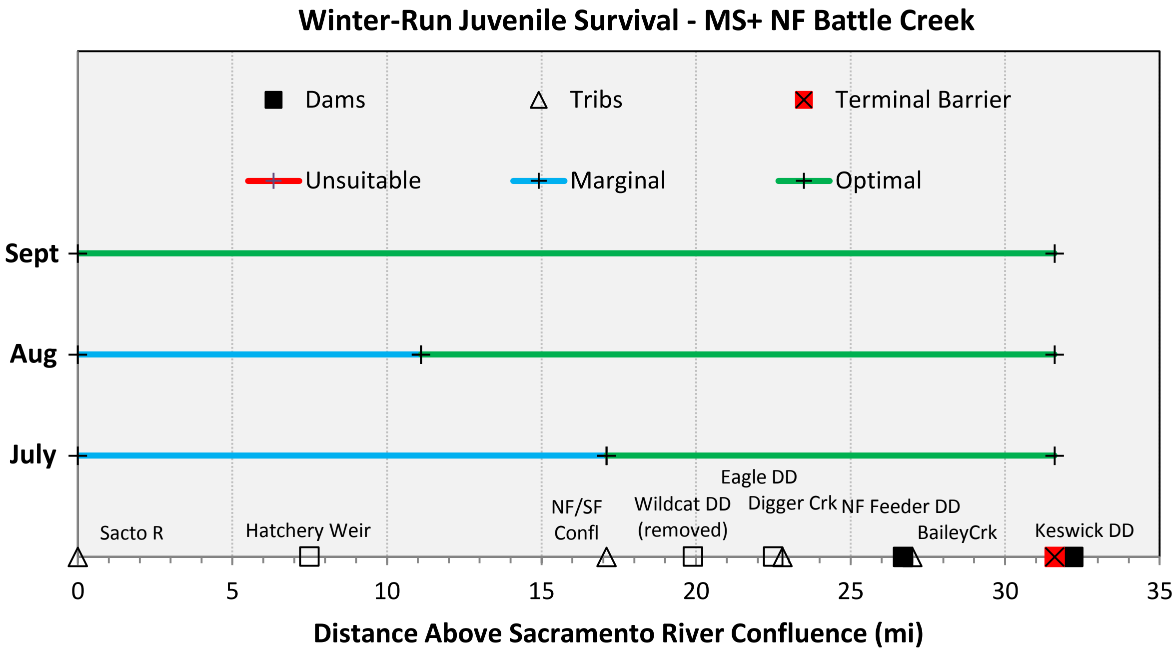
In the absence of temperature limitations, the estimated area of suitable spawning habitat under the Preferred Alternative was highest in the mainstem Battle Creek but was relatively low for most reaches in the forks, with somewhat greater habitat in the South Fork than the North Fork (Figure 5, upper graph). The trend among reaches was similar in the estimates of fry capacity (excluding effects of temperature), with highest capacity in the mainstem, followed by the Inskip and Coleman reaches, and lower but relatively similar indices for the South, above South, NB Feeder, and Eagle reaches (Figure 5, middle graph). However, because the warm-season periodicity of winter-run spawning and incubation, the overall quantity and physical capacity of habitat is greatly overestimated when temperature limitations are ignored.

Consequently, accounting for the influence of water temperatures on fry production resulted in large changes to the indices, both in the overall index of abundance and in the distribution among reaches (Figure 5, lower graph). High temperatures were predicted to result in zero fry production in the mainstem reach, the Coleman reach, and the Inskip reach, which is consistent with the stream length plots described above (Figure 4). The highest production of fry was expected to occur in the cooler reaches, particularly in the NB Feeder reach. Relatively high production might also be expected in the uppermost reach of the North Fork, but that value was not presented in the EIR. Surprisingly, the fry production index in the uppermost 4.9 miles of the South Fork was not estimated to exceed the production in the South reach immediately downstream. Overall, the North Fork was estimated to result in 3-4 times the production of fry compared to the South Fork, or approximately 80% of the total fry production in the Battle Creek basin.

Juvenile Rearing

Winter-run fry are expected to emerge from Battle Creek redds from mid-June through mid-October, with peak emergence in July and August (USBR 2005, NMFS 2014). Although most juvenile winter-run will emigrate into the Sacramento River in September, some juveniles may continue to rear in Battle Creek until the following March. Juvenile winter-run habitat and production are expected to be most limiting during the warm summer months of July, August, and September. Water temperature criteria for juvenile winter-run were taken from Figure 8-2 in Appendix H of the USBR 2005, which related water temperature to juvenile survival. Based on this temperature:survival relationship, the stream length suitability analysis classified optimal temperatures as <69°F, with associated survival of 75-100%. Marginal temperatures were defined as 69-72°F, with zero survival at ≥73°F classified as unsuitable. These temperature criteria were combined with the July-September SNTEMP plots (USBR 2005, Appendix K) to yield estimates of stream length with suitable rearing temperatures for juvenile winter-run.

The estimated mean monthly water temperatures under the Preferred Alternative during a normal water year remained below the lethal temperature of 73°F in all reaches (including the mainstem) throughout July, August, and September (Figure 6). Predicted temperatures were marginal in the lower mainstem in July and August, but were optimal throughout September. The entire length of the North Fork was estimated to contain optimal temperatures over the summer months, as was the South Fork in September. During July, the warmest month, the South Fork was predicted to contain optimal water temperatures from the vicinity of the Inskip DD upstream to the terminal barrier. When summed together, the North Fork was predicted to



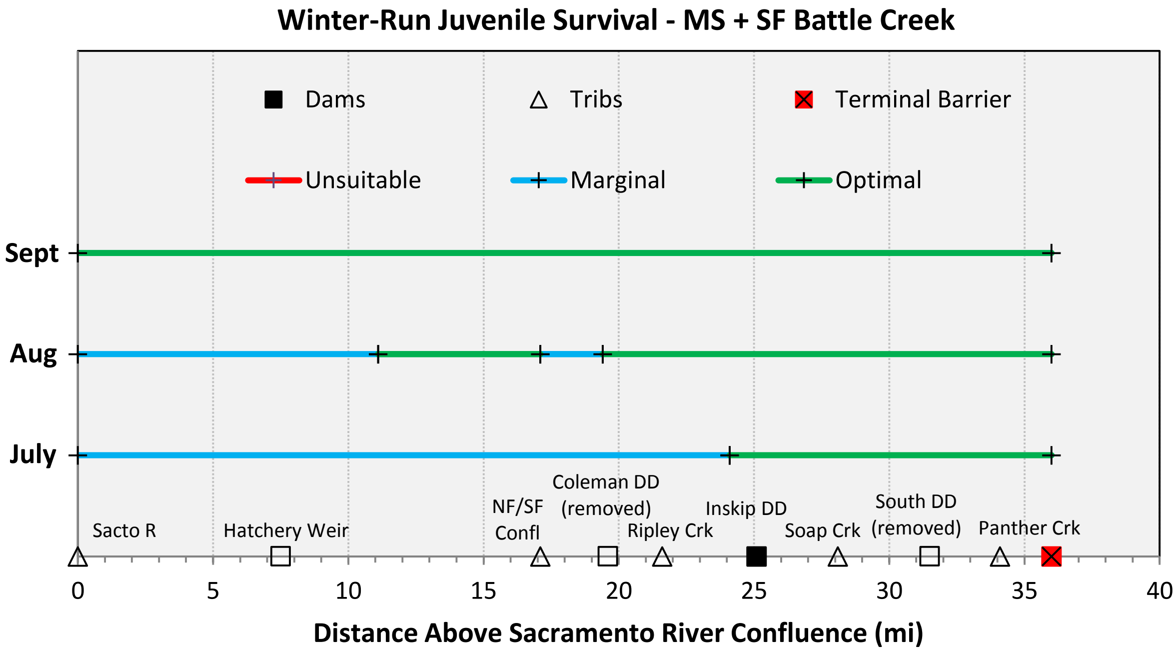


Figure 6. Stream reaches meeting temperature suitability criteria for rearing of juvenile winter-run in the mainstem and North fork (upper graph) and South Fork (lower graph) of Battle Creek according to month. Approximate locations of hydropower facilities, tributaries, and terminal barriers are also shown. See text for temperature criteria.

contain slightly longer lengths of stream channel with optimal habitat than the South Fork (14.5 vs 11.9 mi), but during the cooler months of August and September the longer extent of the South Fork would be expected to contain 2-4 additional miles of optimal temperature-conditioned habitat than the North Fork (Figure 7).

The estimated area (acres) of physical habitat available for juvenile winter-run rearing (based on PHABSIM modeling of Preferred Alternative flows), and the resulting indices of juvenile capacity (adding-in juvenile territory size and surplus fry production) and juvenile production (adding-in the effects of water temperature on survival) were presented in the EIR (USBR 2005, Chapter 4 and Appendix H). The relationship of physical habitat for juvenile winter-run among reaches showed maximum area in the mainstem, with greatest area among the forks in the NB Feeder, Inskip, and South reaches (Figure 5). As noted above, estimates of physical habitat area were not presented for the uppermost reaches in the North Fork or the South Fork.

Conversion of the habitat area into capacity for rearing juvenile winter-run produced similar trends among reaches as for gross habitat, with most capacity potential in the mainstem followed by the NB Feeder reach in the North Fork, and the Coleman, South, and above South reaches in the South Fork (Figure 5). As noted for the fry production indices, the estimated indices for juvenile production changes significantly when temperature was accounted for. Juvenile production dropped to zero in the mainstem and Coleman reaches, and was highest in the NB Feeder reach. Estimated production was also relatively high in the Inskip, South, and above South reaches (and presumably would also be high in the Keswick reach, if estimated). These results are inconsistent with the stream length assessments shown in Figure 6, which suggested that juvenile habitat was suitable (i.e., non-lethal) throughout both forks and the mainstem in all summer months. The reason for the discrepancy may be in how the temperature and survival relationship (from USBR 2005, Appendix H) was used in calculating juvenile production.

Smolt Outmigration

The smolt outmigration period is a critical component to successful reintroduction of winter-run into the Battle Creek basin. Successful smolt outmigration to the Pacific is dependent upon conditions in the original rearing stream as well as all downstream locations, but this analysis is restricted to Battle Creek. The temperature criteria used to assess thermal suitability of Battle Creek during July, August, and September (peak outmigration) was based on criteria listed for spring-run smolts in the EIR, which classified optimal temperatures as <62.6°F, marginal temperatures as 62.6-68°F, and unsuitable temperatures as >68°F (USBR 2005, Appendix K Figure K-14). These temperature criteria were combined with the July-September SNTEMP plots for mean monthly water temperatures under a normal water year to yield estimates of stream length with suitable rearing temperatures for smolt outmigration. Note that these temperature criteria are significantly more limiting than the juvenile criteria listed above, likely due to the physiological changes that occur in anadromous juveniles during smoltification (Myrick and Cech 2001).

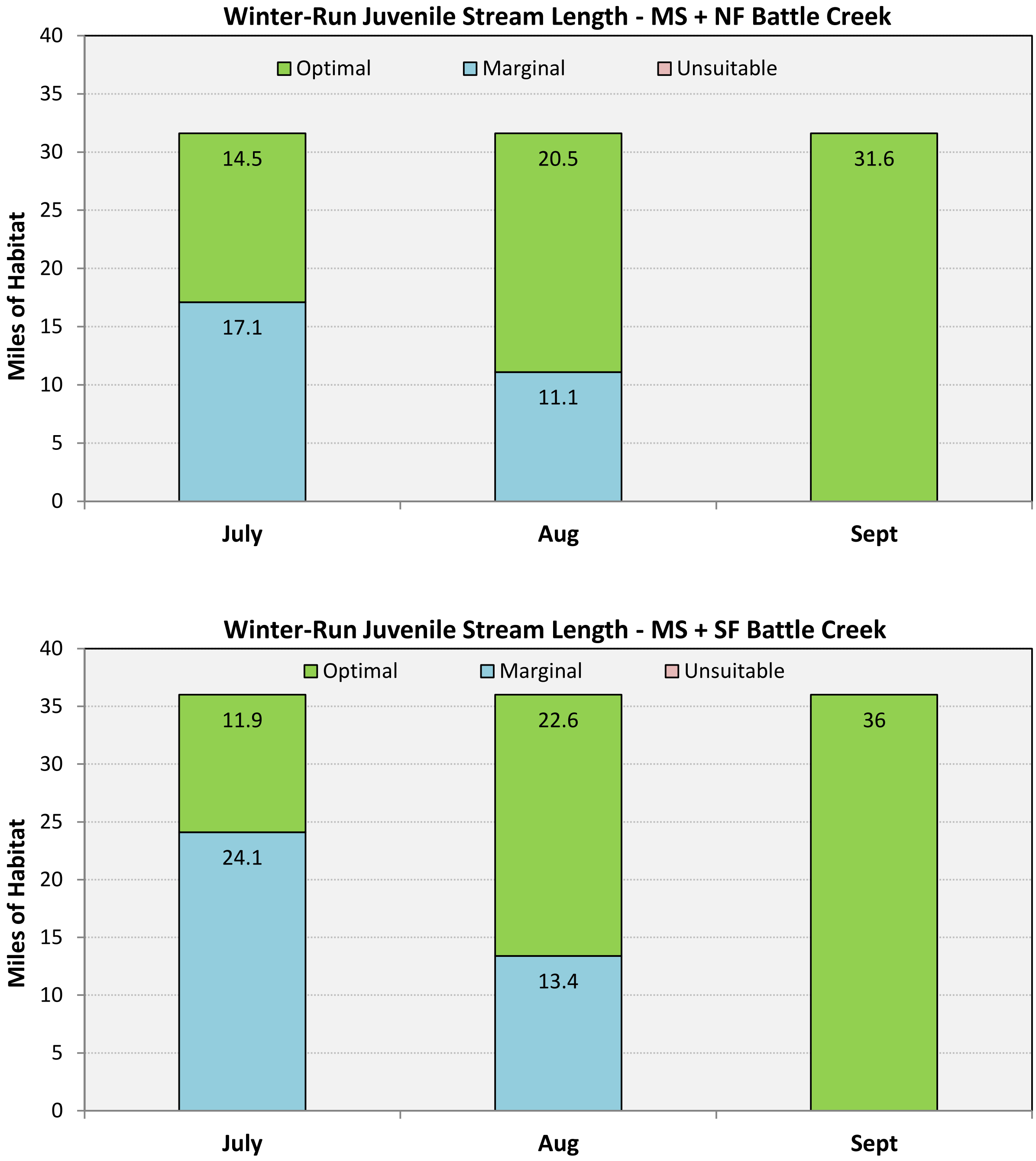


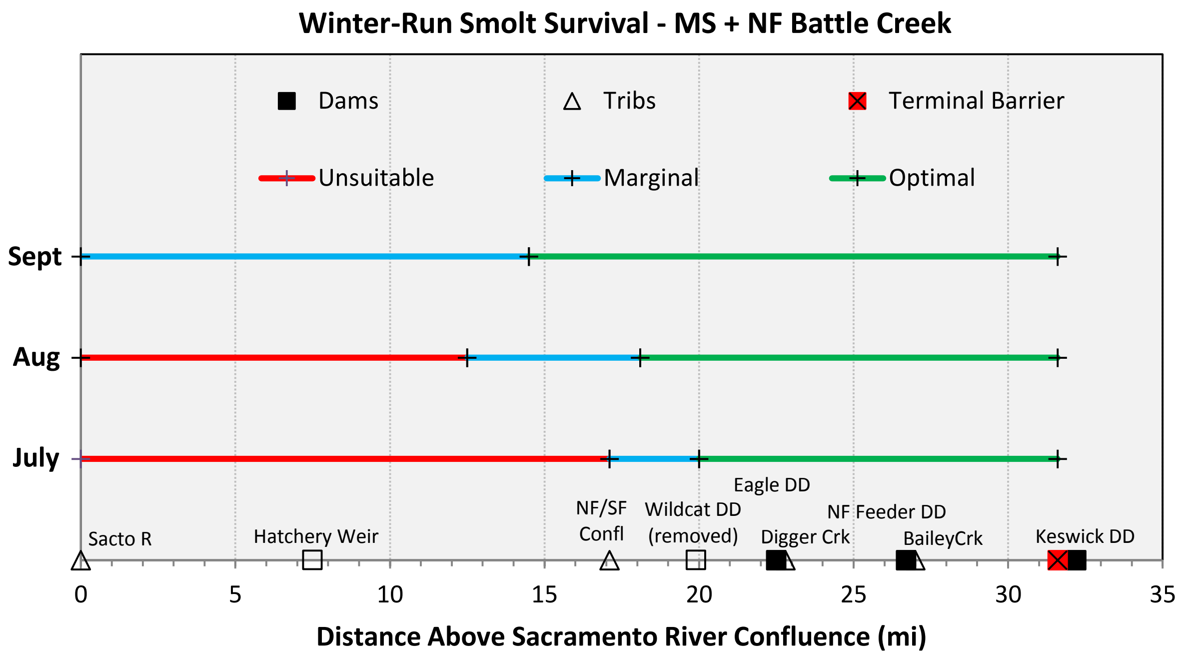
Figure 7. Length of stream reaches meeting temperature suitability criteria for juvenile winter-run in the mainstem and North fork (upper graph) or South Fork (lower graph) Battle Creek according to month. See text for temperature criteria.

Figure 8 suggests that suitable water temperatures exist in all reaches of Battle Creek for smolts that outmigrate during the peak month of September, however smolts migrating in August or especially July will likely encounter excessive temperatures in the 17 mile mainstem reach and 2-6 miles of the lower South Fork. Note that the estimated mean monthly temperatures for the mainstem do not account for the cooling effect of discharges from the Coleman Powerhouse at RM 8, therefore July or August temperatures in the lowest half of the mainstem may be suitable even during the mid-summer, but unsuitable temperatures will remain in 4 miles of mainstem habitat above the powerhouse in August and in 9 miles in July. The potential effects of cold springs at Eagle DD and from Soap Creek could result in somewhat improved outmigration temperatures in July and August; the influence of cold springs on water temperatures is the subject of a focused study by the USFWS.

Comparison of total stream lengths according to the smolt temperature criteria shows that the length of unsuitable channel a smolt must pass through on its way to the Sacramento River (again, ignoring cooling effects from Coleman Powerhouse) ranges from 17-23.5 miles in the North Fork and South Fork in July, respectively, to 12.5-15.2 miles in August, to 0 miles in September (Figure 9). Although the North Fork possesses a longer length of optimal temperatures for smolts than does the South Fork, the combined length of suitable (i.e., non-lethal) stream lengths is relatively similar in each fork in July and August. However, the North Fork is not expected to contain any unsuitable stream length for outmigrating smolts in any month, whereas the South Fork is expected to contain approximately 2 miles of unsuitable stream length in August and 6.5 miles in July, in addition to the 17.1 miles of mainstem habitat.

Conclusions

The assessments of temperature-conditioned channel habitat under conditions provided by the Preferred (5-Dam) Alternative consistently shows a higher proportion of suitable habitat for winter-run in the North Fork of Battle Creek in comparison to the South Fork; however for most life-stages the South Fork may also be capable of supporting limited winter-run re-introduction efforts. Overall, the egg incubation life-stage appears the most limiting to winter-run re-introduction, with no suitable (i.e., non-lethal) habitat in the mainstem reach, 11-12 miles of potentially suitable stream length in the North Fork, and only 5-12 miles in the South Fork. These stream lengths represent just 6-14% of the 85 miles of anadromous habitat potentially available under the Preferred Alternative. This limitation is largely due to the combination of low temperature tolerance of incubating eggs and embryos and the late-spring and summer spawning periodicity of the winter-run race. In contrast to incubation limitations, water temperatures under the Preferred Alternative flows are predicted to remain within the suitable range for juvenile rearing during all months of the year in all reaches of Battle Creek (including the mainstem), thus for juveniles the South Fork may actually possess a greater length of stream channel with non-lethal temperatures than the North Fork. Consequently, if re-introduction efforts are limited to the North Fork, straying of fish into the South Fork may not result in loss of those fish or eggs to overall production, particularly if the fish migrate to the upper reaches of the South Fork during the cooler months.



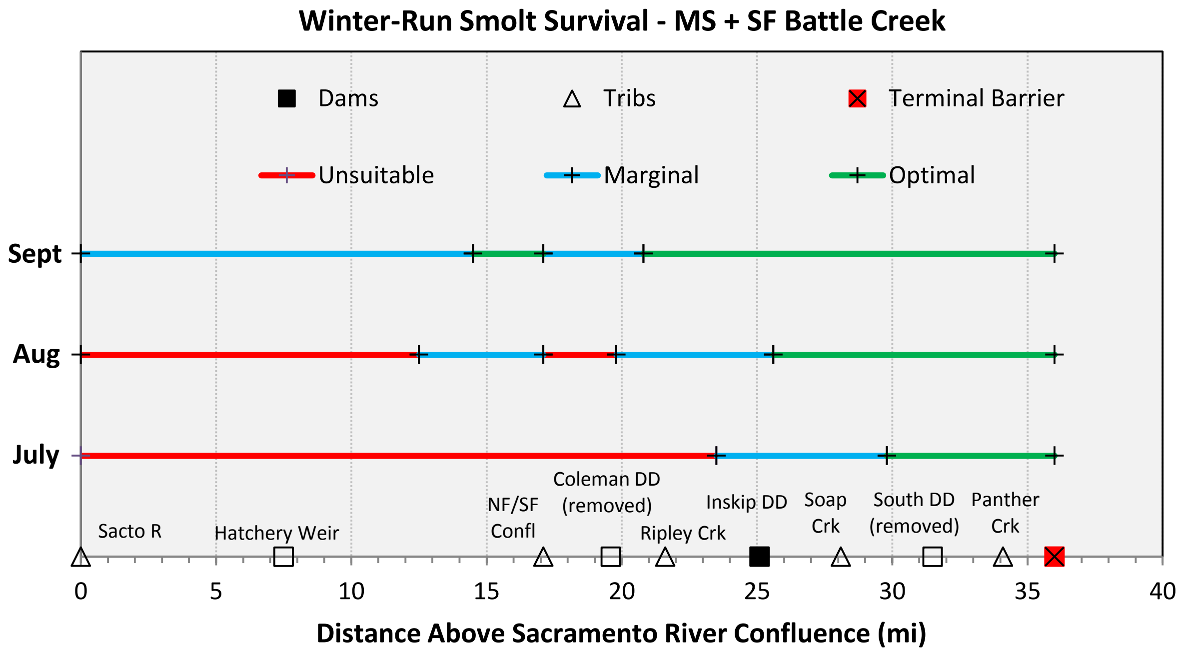


Figure 8. Stream reaches meeting temperature suitability criteria for smolt outmigration in the mainstem and North fork (upper graph) and South Fork (lower graph) of Battle Creek according to month. Approximate locations of hydropower facilities, tributaries, and terminal barriers are also shown. See text for temperature criteria.

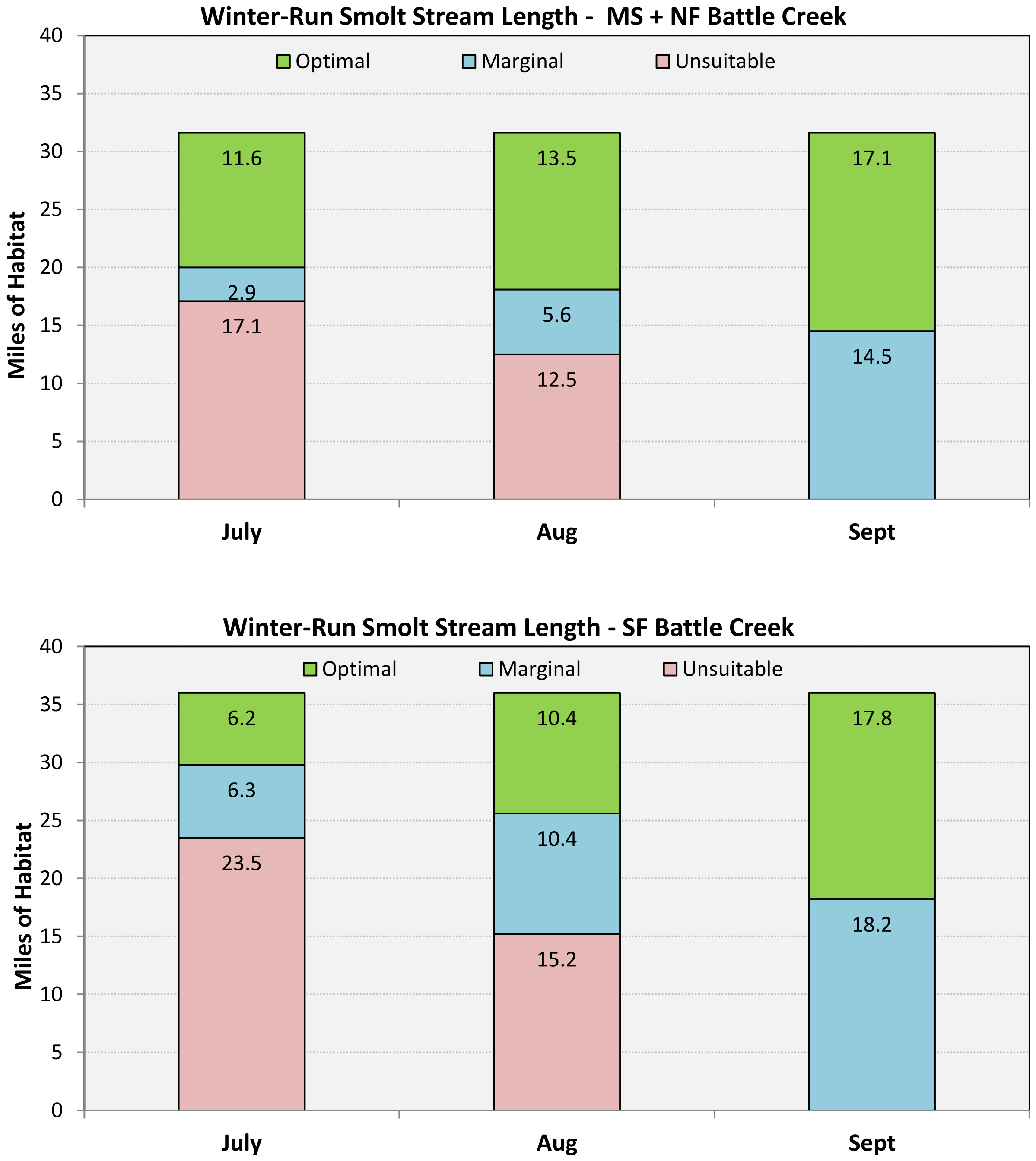


Figure 9. Length of stream reaches meeting temperature suitability criteria for smolt outmigration in the mainstem and North fork (upper graph) or South Fork (lower graph) Battle Creek according to month. See text for temperature criteria.

For the remaining two life-stages considered in this analysis (adult upstream migration and smolt downstream migration), the North Fork is expected to provide the most potential habitat for successful re-introduction under the Preferred Alternative, with the greatest difference between forks occurring in the warmest months of July and August, with little or no difference between forks in the cooler months of June and September. The mainstem is not expected to provide suitable holding habitat for late-returning adult winter-run that immigrate into Battle Creek in the summer, but spring-migrating fish should find suitable passage conditions and holding habitat in the upper reaches of either fork. Likewise, early-migrant winter-run smolts will find hostile conditions in the mainstem, whereas fish migrating during the peak in September (or thereafter) should find mainstem temperatures within the tolerable range given flows prescribed under the Preferred Alternative.

Although the EIR did not specify how many adult winter-run salmon could be supported under the Preferred Alternative, the NMFS suggested that an adult population of 2,500 individuals would pose low risk of extinction, assuming a positive growth rate and other factors are met (NMFS 2011). The EIR analysis did utilize estimates of spawning habitat availability and potential egg deposition in combination with predicted temperature regimes under Preferred Alternative flows to calculate an index of fry production (USBR 2005). The fry indices suggested greater potential production in the North Fork compared to the South Fork, particularly in the cooler, uppermost reaches of anadromous habitat. Likewise, available habitat and predicted temperatures were used to estimate an index of production for rearing of juvenile winter-run, which suggested that significant rearing habitat was available in both forks, particularly in the upper reaches.

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Appendix C

Battle Creek Winter-Run Chinook Salmon Reintroduction Plan Scenarios

Appendix C
Battle Creek Winter-Run Chinook Salmon Reintroduction Plan Scenarios

The California Department of Fish and Wildlife (CDFW) contracted with ICF International (ICF) to work with an interagency technical advisory committee to develop a *Battle Creek Winter-Run Chinook Salmon Reintroduction Plan* (Reintroduction Plan). The Advisory Committee comprised representation from CDFW, U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), NMFS, PG&E, and the Battle Creek Watershed Conservancy. This group, along with the ICF team, is referred to in the Reintroduction Plan as the "workgroup."

This appendix provides additional details regarding assumptions and expected outcomes for each phase of the Reintroduction Plan. Three hypothetical scenarios were constructed to evaluate outcomes with implementation of plan strategies, decision rules, and biological triggers.

The Reintroduction Plan assumptions for artificial propagation and post-release survival are largely based on observations from the Livingston Stone National Fish Hatchery (LSNFH) conservation hatchery program (USFWS 2013) and discussions with the workgroup. These assumptions provide a planning baseline to compare strategies and expected outcomes. Very little is known about the potential of Battle Creek to support winter-run Chinook Salmon and the demographic characteristics of a future winter-run Chinook Salmon population in Battle Creek. Population size, growth rate, variation in growth rate, and carrying capacity are critical unknowns that will influence success of the plan. These variables depend on the quality and quantity of habitat in Battle Creek and survival of winter-run Chinook Salmon in the Sacramento River, the Sacramento-San Joaquin River Delta (Delta), and the Pacific Ocean. Stray rates, suboptimal selection of spawning habitat, and variable reproductive success of reintroduced Chinook Salmon also will affect progress toward reintroduction.

In-Hatchery Survival and Post-Release Survival

Plan assumptions for the winter-run Chinook Salmon hatchery operations schedule, number of broodstock, fecundity, and in-hatchery survival to release are based on reported values and program planning assumptions for the *Livingston Stone National Fish Hatchery – Hatchery and Genetics Management* Plan (LSNFH HGMP) (USFWS 2013). Table 1 presents an approximate hatchery operations schedule for the North Fork Battle Creek (NF Battle Creek) program.

As described in Chapter 3 of the Reintroduction Plan, the initial reintroduction strategy is collecting 120 adults for hatchery broodstock to produce 207,000 juveniles for release in NF Battle Creek (Figure 1). A release of 207,000 winter-run Chinook Salmon would return 580 adults to the upper Sacramento River, assuming the LSNFH median return rate. The size of the hatchery program (207,000 juveniles for reintroduction) was selected based on the workgroup's view that the median return of over 500 adults should be enough to overcome foreseeable demographic barriers to reintroduction. The workgroup also determined that 120 broodstock adults to support that size of a program was sufficient to represent genetic diversity of the Sacramento River source population during the initial phase of the plan and the newly established Battle Creek population in Phase 2.

Table 1. Approximate Winter-Run Chinook Salmon NF Battle Creek Hatchery Development Cycle

Stage	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Broodstock	X	X	X	X							X	X
Spawning		X	X	X								
Egg incubation		X	X	X	X							
Transfer eyed-eggs to NF Battle Creek			X	X	X							
Egg incubation at NF Battle Creek			X	X	X	X						
Early rearing					X	X	X	X	X	X		
Juvenile release											X	X

Figure 1. Plan Assumptions for Broodstock, Fecundity, and In-Hatchery Survival

The broodstock target is based on the fecundity of winter-run Chinook Salmon, sex ratio, and in-hatchery survival. Table 2 presents the number of green eggs and eggs per female reported for winter-run Chinook Salmon at LSNFH (USFWS 2013). The Reintroduction Plan assumes 5,000 eggs per female to produce 300,000 green eggs. LSNFH reports an average male-to-female sex ratio of approximately 1:1.

Table 2. Number of Female Chinook Salmon Spawned, Total Green Eggs, and Green Eggs per Female

Brood Year	Number of Females Spawned	Total Green Eggs	Green Eggs per Female
1999	9	38,303	4,256
2000	44	216,075	4,911
2001	49	236,864	4,834
2002	45	231,375	5,142
2003	45	223,269	4,962
2004	35	192,387	5,497
2005	51	267,803	5,251
2006	52	279,853	5,382
2007	23	117,565	5,112
2008	48	260,370	5,424
2009	61	324,321	5,317
2010	27	139,349	5,161
2011	45	213,739	4,750
		Average	**5,077**

Source: USFWS 2013 (Table 7.4.2 and Table 9.1).

The median post-release return rate to the upper Sacramento River[1] for the LSNFH program (excluding release from captive broodstock) is 0.28 percent (Figure 2). The 25th and 75th percentiles return rates are 0.13 and 0.33 percent, respectively. In 2 years, return rates exceeded 1.5 percent; and in 1 year, the return rate was 0.06 percent.

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[1] For purposes of this document, the upper Sacramento River is defined as the reach between RBDD and Shasta Dam.

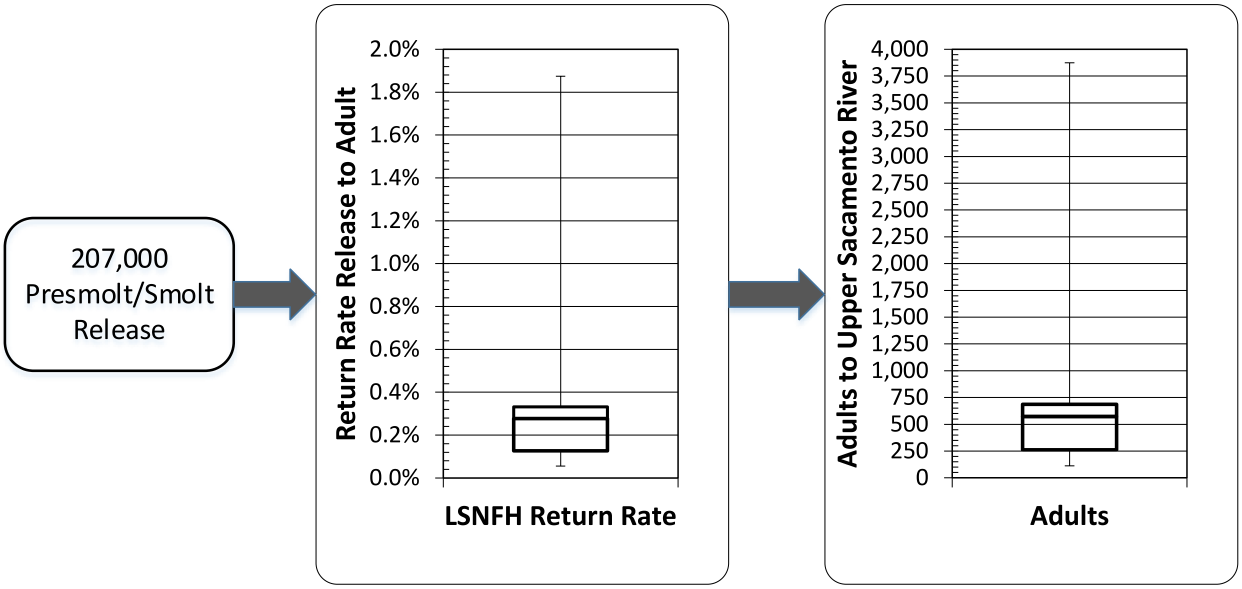

Figure 2. Distribution of Post-Release Return Rates (left) and Predicted Adult Returns to Upper Sacramento River with Release of 207,000 Fish (right)

Note: In each box-and-whisker plot, the horizontal line indicates the median, the box represents the interquartile range (25% and 75%), and the whiskers show the range of rates and predicted number of returns.
(Source: USFWS 2013 [Table 1.12]).

Not all hatchery-origin adults returning to the Sacramento River destined for Battle Creek would enter the creek. Several factors may affect homing to Battle Creek, such as imprinting that may happen during early incubation (Dittman et al. 2015) or preferential selection of Sacramento River mainstem spawning sites by returning adults because of environmental conditions in Battle Creek. The Reintroduction Plan assumes that 90 percent of Battle Creek hatchery-origin adults returning to the Sacramento River would home to Battle Creek. Assuming the LSNFH median return rate, release of 207,000 fish suggests an annual median return to the barrier weir at Coleman National Fish Hatchery (Coleman weir) of slightly more than 500 hatchery-origin adults.

During the initial phase of the Reintroduction Plan (Phase 1 Initial[2]), all broodstock (120 adults) would originate from the Sacramento River population (Table 3). An additional 120 adults would increase the total adult broodstock target at LSNFH to 240 adults to support both the LSNFH and NF Battle Creek programs. Hatchery broodstock for the LSNFH program is collected at the Keswick Dam Fish Trap (KDFT). The plan preference is to collect natural-origin adults at KDFT to support both programs. However, past experience at the KDFT indicates a need to include hatchery-origin in the broodstock or to expand adult collection to other areas in order to collect more natural-origin (Table 4).

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[2] Phases of the reintroduction plan are described in Chapter 3.

Table 3. Phase 1 Broodstock Priorities

Source/Composition	Phase 1 Initial	Phase 1 Late
Sacramento River	100%	50%
Natural origin	100% preferred	100% preferred
Hatchery origin	*Contingency to achieve juvenile release target*	*Contingency to achieve juvenile release target*
Battle Creek	0%	50%
Natural origin	NA	10% to 20%
Hatchery origin	NA	80% to 90%
Total broodstock	**120 adults**	**120 adults**

Table 4. Adult Counts at Keswick Dam Fish Trap

Year	Keswick Dam Fish Trap Counts			Natural-Origin Run Size to Upper Sacramento River	Percent of Natural Origin Trapped
	Natural Origin	Hatchery Origin	Total Observed		
2001	102	103	205	7,711	1%
2002	125	71	196	6,894	2%
2003	98	138	236	7,795	1%
2004	122	224	346	7,233	2%
2005	164	227	391	12,783	1%
2006	132	180	312	14,916	1%
2007	71	86	157	2,401	3%
2008	142	56	198	2,660	5%
2009	168	111	279	4,070	4%
2010	118	302	420	1,397	8%
2011	116	262	378	747	16%
2012	146	659	805	1,864	8%
2013	183	130	313	6,010	3%
2014	154	275	429	2,309	7%

Source: Unpublished data provided by K. Niemela, USFWS, December 2015.

An additional adult collection site described in the Reintroduction Plan would augment catch at KDFT and help to achieve annual production targets for both programs. Current guidelines for LSNFH broodstock collection limit the number collected to no more than 15 percent of the upper Sacramento River natural-origin run. This limit has not been a problem in past years because the number of natural-origin adults entering KDFT has been below 15 percent of the total run in nearly all years (Table 4). This limit may be a constraint in future years with an expanded collection target of 240 adults and anticipated depressed returns following drought years. The Reintroduction Plan acknowledges the contingency to include hatchery-origin fish in the broodstock to meet production targets for reintroduction (Table 3).

The transition to Phase 1 Late occurs when natural production has been established in NF Battle Creek and hatchery returns to Battle Creek are sufficient to collect broodstock and pass adults upstream to natural spawning areas. The Battle Creek program hatchery broodstock would transition to include 50 percent Battle Creek returns and of this, from 10 to 20 percent natural-origin adults (Table 3). The trigger for this transition is based on a 5-year geometric mean run size of 100 natural-origin Chinook Salmon returning to Coleman weir.

Key criteria used to manage the Battle Creek program in Phase 1 include the following.

- The average minimum hatchery- and natural-origin return will be 500 winter-run adult Chinook Salmon.
- The minimum proportion of natural-origin adults used in broodstock will be 10 percent.
- Returning adults will be prioritized for natural spawning in Phase 1 Initial, and a combination of natural spawning and broodstock will be used in Phase 1 Late.

The workgroup also decided that transplant of wild-caught juveniles (fry) from the Sacramento River will be an important strategy to maximize genetic diversity in the Battle Creek population in Phase 1 Late. Adult return rates for fry transplants assume the LSNFH program median post-release return rate. Collection targets are based on the assumption that a return of approximately 100–200 adults would meet the objective to increase genetic diversity of fish spawning in NF Battle Creek. However, adult returns to Battle Creek of wild-caught fry are more likely to stray to their natal mainstem spawning areas (imprinting as egg and as fry at emergence). The Reintroduction Plan assumes that 75 percent of Battle Creek transplant-origin adults returning to the upper Sacramento River would return to Battle Creek.

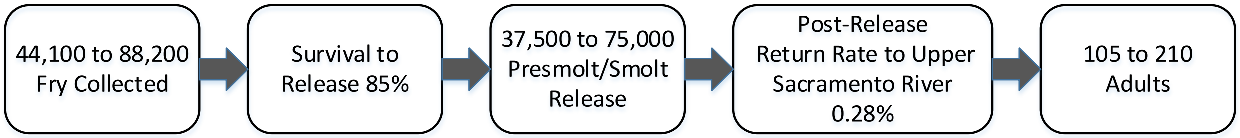

Figure 3. Plan Assumptions for Collection, Survival and Return of Transplanted Wild-Caught Fry

In Phase 1 Late, adult returns to Coleman weir will include fish from four sources: (1) Sacramento River-sourced hatchery origin; (2) Battle Creek-sourced hatchery origin; (3) returning adults from Sacramento River transplanted fry; and (4) NF Battle Creek natural origin (Figure 4). The composition will depend on the relative strength of the natural-origin run and survival rates of hatchery-origin and transplanted fish. Guidelines for collection of broodstock at Coleman weir will need to be established to collect adults over the entire adult migration in proportion to the run size. Run timing predictions, pre-season run-size forecasts, and procedures for in-season updates and adjustments will need to be established for broodstock collection. Composition of adults in the broodstock from hatchery-origin and transplanted fry releases will reflect their relative abundance because all may have the same secondary external mark to distinguish them from adipose fin-clipped late-run fall Chinook Salmon. Natural-origin winter-run Chinook Salmon will be unmarked. Alternatively, if released winter-run Chinook Salmon are PIT tagged (passive integrated transponder), broodstock may need to be adjusted to ensure equal representation of hatchery- and transplant-sourced fish.

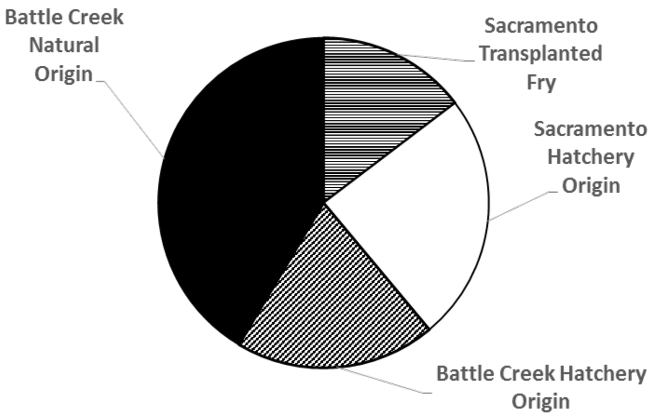

Figure 4. Example Adult Run Composition at Coleman Weir in Phase 1 Late

Hatchery broodstock rules shift in Phase 2 to include a higher percentage of Battle Creek-origin fish (Table 5). Early in Phase 2, at least half of the broodstock will be natural origin. This would shift to all natural-origin fish later in Phase 2 with improved natural abundance to further promote local adaption and reduce the risks of domestication selection. Hatchery program size would be reduced by one-half based on evidence of sufficient natural-origin fish for a self-sustaining natural population.

Table 5. Phase 2 Broodstock Priorities

Source/Composition	Phase 2 Early	Phase 2 Late
Sacramento River	10% to 20%	10% to 20%
Natural origin	100% Preferred	100% Preferred
Hatchery origin	*Contingency to achieve juvenile release target*	*Contingency to achieve juvenile release target*
Battle Creek	80% to 90%	80% to 90%
Natural origin	Greater than 50%	100% Preferred
Hatchery origin	Less than 50%	*Contingency to achieve juvenile release target*
Total broodstock	**120 adults**	**60 adults**

Key criteria used to manage the program in Phase 2 include the following.

- The geometric mean (5-year running mean) minimum natural-origin return will be more than 500 adult winter-run Chinook Salmon early in the phase and more than 850 late in the phase.
- The proportion of hatchery-origin spawners (pHOS) will be less than 50 percent early in the phase and over time will be less than 30 percent.
- The proportion of natural-origin adults used in broodstock will be greater than 50 percent early in the phase and targeted at 100 percent late in the phase.

- The proportionate natural influence (PNI)[3] will be greater than 0.50 in all years; over time, the average PNI will be greater than 0.67 based on a 3-year running average.

Expected broodstock composition and natural spawning in Phase 1 across a range of hatchery- and natural-origin run sizes are presented in Table 6. The emphasis in Phase 1 is to maximize the number of adult Chinook Salmon spawning in NF Battle Creek to establish natural production. Allowing the number of natural spawners to vary across a wide range would provide an opportunity to observe NF Battle Creek winter-run Chinook Salmon productivity and fish habitat use over a wide range of spawner levels.

In contrast, in Phase 2, the emphasis is promoting local adaptation and lowering the risk of domestication in the natural population. Broodstock composition includes a higher proportion of natural-origin (pNOB) fish, and fewer Sacramento River-sourced fish are included in the program release (Table 7). The influence of the hatchery and natural environments on the adaptation of the composite population of hatchery- and natural-origin fish is determined by the proportion of natural-origin broodstock in the hatchery (pNOB) and the proportion of hatchery-origin Chinook Salmon spawning in NF Battle Creek (pHOS). The larger the PNI. The greater the strength of selection in the natural environment relative to that of the hatchery environment. It may be necessary to manage contribution of hatchery fish to natural spawning if repeated years with hatchery-origin contributions exceed objectives for pHOS. This would mean adjusting the hatchery program size downward to reduce the number of hatchery-origin adults returning to Battle Creek. Table 8 shows the resulting PNI and pHOS in Phase 2 with run sizes and pNOB from Table 7.

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[3] $PNI = pNOB/(pNOB + pHOS)$ where pNOB is the percent of natural-origin fish in the hatchery broodstock and pHOS is the percent of hatchery-origin fish in natural spawning.

Table 6. Phase 1 Hatchery Broodstock Collected from Battle Creek

Sacramento River-Origin Broodstock	**Battle Creek-Sourced Hatchery Broodstock**						
	Battle Creek Natural-Origin Run	**Battle Creek Hatchery-Origin Run**					
		100	**200**	**300**	**400**	**500**	**600**
120	**0**	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*
120	**50**	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*
60	**100**	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*
60	**150**	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*
60	**200**	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*	*60 (6)*
60	**250**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
60	**300**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
60	**350**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
60	**400**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
60	**450**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
60	**500**	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*	*60 (12)*
Battle Creek Natural Spawning Escapement							
	Battle Creek Natural-Origin Run	**Battle Creek Hatchery-Origin Run**					
		100	**200**	**300**	**400**	**500**	**600**
	0	*100*	*200*	*300*	*400*	*500*	*600*
	50	*150*	*250*	*350*	*450*	*550*	*650*
	100	*140*	*240*	*340*	*440*	*540*	*640*
	150	*190*	*290*	*390*	*490*	*590*	*690*
	200	*240*	*340*	*440*	*540*	*640*	*740*
	250	*290*	*390*	*490*	*590*	*690*	*790*
	300	*340*	*440*	*540*	*640*	*740*	*840*
	350	*390*	*490*	*590*	*690*	*790*	*890*
	400	*440*	*540*	*640*	*740*	*840*	*940*
	450	*490*	*590*	*690*	*790*	*890*	*990*
	500	*540*	*640*	*740*	*840*	*940*	*1,040*

Note: Numbers of natural-origin fish are in parentheses.

Table 7. Phase 2 Hatchery Broodstock Collected from Battle Creek

Sacramento River-Origin Broodstock	**Battle Creek-Sourced Hatchery Broodstock**						
	Battle Creek Natural-Origin Run	**Battle Creek Hatchery-Origin Run**					
		100	**200**	**300**	**400**	**500**	**600**
18	**500**	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*
18	**550**	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*
18	**600**	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*
18	**650**	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*	*102 (51)*
9	**700**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**750**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**800**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**850**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**900**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**950**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
9	**1,000**	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*	*51 (51)*
Battle Creek Natural Spawning Escapement							
	Battle Creek Natural-Origin Run	**Battle Creek Hatchery-Origin Run**					
		100	**200**	**300**	**400**	**500**	**600**
	500	*498*	*598*	*698*	*798*	*898*	*998*
	550	*548*	*648*	*748*	*848*	*948*	*1,048*
	600	*598*	*698*	*798*	*898*	*998*	*1,098*
	650	*648*	*748*	*848*	*948*	*1,048*	*1,148*
	700	*749*	*849*	*949*	*1,049*	*1,149*	*1,249*
	750	*799*	*899*	*999*	*1,099*	*1,199*	*1,299*
	800	*849*	*949*	*1,049*	*1,149*	*1,249*	*1,349*
	850	*899*	*999*	*1,099*	*1,199*	*1,299*	*1,399*
	900	*949*	*1,049*	*1,149*	*1,249*	*1,349*	*1,449*
	950	*999*	*1,099*	*1,199*	*1,299*	*1,399*	*1,499*
	1,000	*1,049*	*1,149*	*1,249*	*1349*	*1,449*	*1,549*

Notes: Numbers of natural-origin fish are in parentheses.
Values assume that 15 percent of program release will originate from Sacramento River broodstock source.

Table 8. Phase 2 Resulting PNI and pHOS (parentheses) with Run Sizes and pNOB from Table 7

Battle Creek Natural-Origin Run	**Battle Creek Hatchery-Origin Run**					
	100	**200**	**300**	**400**	**500**	**600**
500	*0.84* *(10%)*	*0.67* *(25%)*	*0.58* *(36%)*	*0.53* *(44%)*	*0.5* *(50%)*	*0.48* *(55%)*
550	*0.85* *(9%)*	*0.68* *(23%)*	*0.6* *(33%)*	*0.55* *(41%)*	*0.51* *(47%)*	*0.49* *(52%)*
600	*0.86* *(8%)*	*0.7* *(21%)*	*0.62* *(31%)*	*0.56* *(39%)*	*0.53* *(45%)*	*0.5* *(50%)*
650	*0.87* *(8%)*	*0.72* *(20%)*	*0.63* *(29%)*	*0.58* *(37%)*	*0.54* *(43%)*	*0.51* *(48%)*
700	*0.88* *(13%)*	*0.81* *(24%)*	*0.76* *(32%)*	*0.72* *(38%)*	*0.7* *(44%)*	*0.68* *(48%)*
750	*0.89* *(13%)*	*0.82* *(22%)*	*0.77* *(30%)*	*0.73* *(36%)*	*0.71* *(42%)*	*0.68* *(46%)*
800	*0.89* *(12%)*	*0.83* *(21%)*	*0.78* *(29%)*	*0.74* *(35%)*	*0.71* *(40%)*	*0.69* *(44%)*
850	*0.9* *(11%)*	*0.83* *(20%)*	*0.79* *(27%)*	*0.75* *(33%)*	*0.72* *(38%)*	*0.7* *(43%)*
900	*0.9* *(11%)*	*0.84* *(19%)*	*0.79* *(26%)*	*0.76* *(32%)*	*0.73* *(37%)*	*0.71* *(41%)*
950	*0.91* *(10%)*	*0.85* *(18%)*	*0.8* *(25%)*	*0.76* *(31%)*	*0.74* *(36%)*	*0.71* *(40%)*
1,000	*0.91* *(10%)*	*0.85* *(17%)*	*0.81* *(24%)*	*0.77* *(30%)*	*0.74* *(35%)*	*0.72* *(39%)*

Winter-Run Chinook Salmon Reintroduction Planning Tool

Development of the Reintroduction Plan was enhanced by the use of an analytical tool to organize key assumptions and to evaluate decision rules and biological triggers. This tool was used informally in development of the reintroduction plan to review strategies and evaluate the appropriateness of transitions (biological triggers) between phases. This planning tool could be an important element of the adaptive management plan and annual project review to formalize the steps and review the key assumptions, decision rules, and triggers during program implementation.

The program elements described in Chapter 3 were largely a product of discussions with the workgroup. The following is an overview of a select set of scenarios evaluated with the planning tool. A high and a low habitat scenario was developed to describe a range of possible outcomes and how the program elements would support reintroduction (Figure 5). These scenarios are intended to support the rationale for the selected strategies, decision rules, and biological triggers. The scenarios are not intended to predict habitat potential for winter-run Chinook Salmon in NF Battle Creek. However, the simulations point to the high dependence of successful reintroduction on the quality of natural habitat in Battle Creek. If habitat is of high quality, the transition from a hatchery-supported program to one based on a local adaptation and natural production can occur relatively quickly, whereas if habitat in Battle Creek is of poor quality, hatchery production continues indefinitely.

Natural production was based on a multi-stage Beverton-Holt spawner recruit function (Beverton and Holt 1957). The function has two parameters: density-independent survival (or productivity) and the asymptotic carrying capacity. These parameters can be related to the quality and quantity of habitat, respectively. The replacement line is the 1:1 ratio of spawners to recruits. The "fitness adjusted" spawner-recruit curve in Figure 5 represents an initial population not adapted to the unique features of NF Battle Creek.

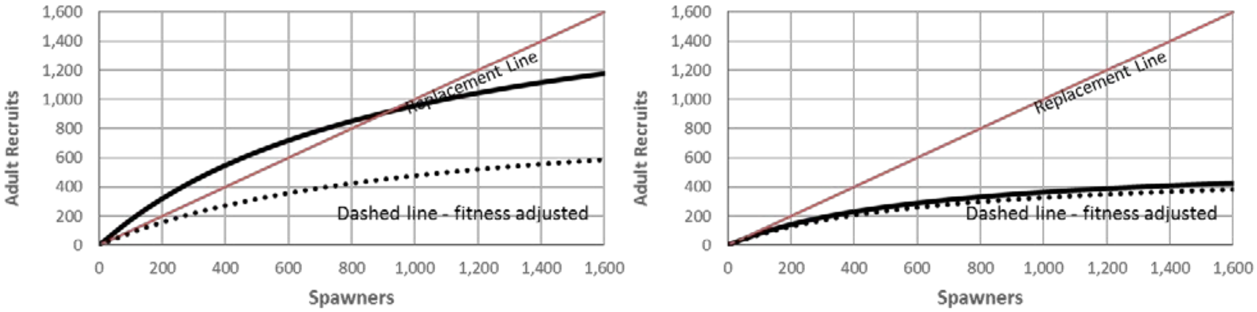

Figure 5. High and Low Habitat Potential Evaluated with the Planning Tool

Note: The dashed line indicates fitness-adjusted recruitment.

The scenarios include variable annual survival of the natural-origin population and hatchery-origin production to show how reintroduction would respond to variable abundance in the return. The same pattern of variability was applied to all scenarios.

Scenario 1: High Habitat Potential for Winter-Run Chinook Salmon

This scenario represents high habitat potential for winter-run Chinook Salmon in NF Battle Creek with no adjustment for fitness due to hatchery introgression. Reintroduction transitioned to Phase 3 after 20 years (Figure 6). Recall that the phase transitions are based on a running 5-year geometric mean; therefore, natural production is established much earlier than shown in Figure 6.

Population growth was relatively quick under this scenario, and the running 5-year geometric mean abundance of natural-origin fish exceeded 850 fish by year 20. At that point, hatchery supplementation was terminated (Figure 7). The scenario included 5 years of fry transplants in Phase 1 Late from year 9 to year 13. Natural production improved such that the transition to Phase 2 Late was quick, allowing a reduction in hatchery production prior to transitioning to Phase 3.

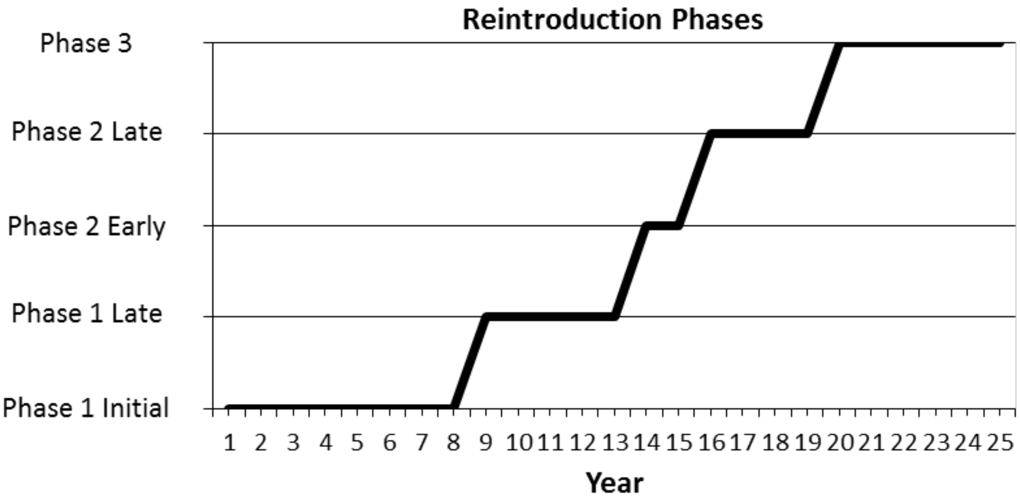

Figure 6. Scenario 1: Phase Transitions for First 25 years of Implementation

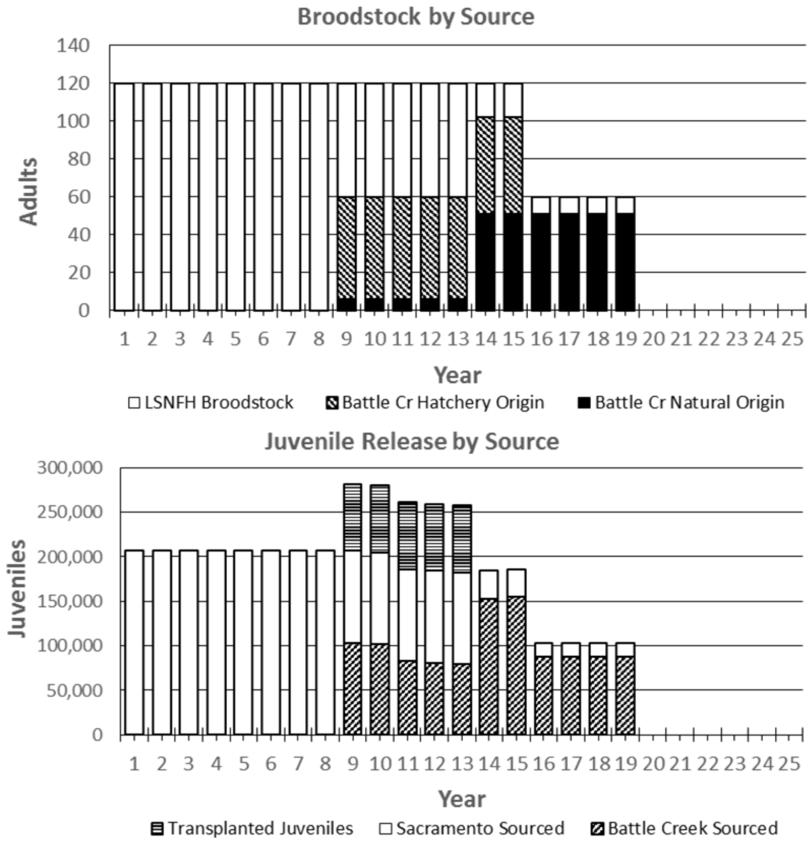

Figure 7. Scenario 1: Hatchery Broodstock Source (top) and Juvenile Release by Source (bottom)

Figure 8 describes, for the first 25 years of implementation, the number of adults at Coleman weir by source and adults passed upstream for natural spawning, and the long-term trends (running 5-year geometric mean) in natural-origin abundance at Coleman weir and natural spawning. The scenario includes variable survival to demonstrate how variable abundance may affect management decisions.

This scenario is a best case. By year 20, hatchery supplementation was terminated and the long-term number of natural-origin adults surviving to spawn varied between 750 and 1,200 adults. The scenario included a period of low survival (abundance dipped to less than 850 adults), suggesting that for some periods the implementing agency will consider reinitiating hatchery supplementation to stabilize the population.

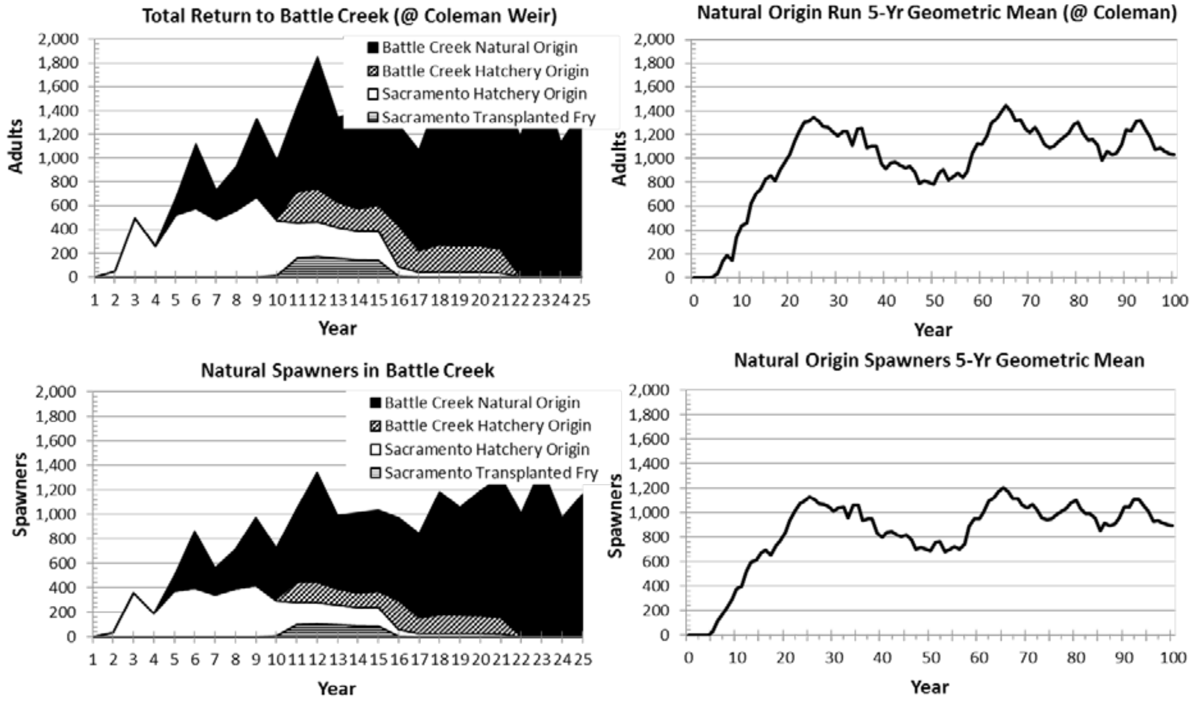

Figure 8. Scenario 1: Total Return and Number of Natural Spawners for First 25 Years (left) and Number of Natural-Origin Spawners Entering Battle Creek and Number of Spawners Projected for100 Years (right)

Figure 9 describes the degree of hatchery influence on the population over time. The transition to Phase 3 indicates that pHOS declined to 0 percent and PNI increased to 1.00 by year 25. The decline in the 5-year geometric mean around year 45 to less than 850 adults and corresponding hypothetical decision to reinitiate hatchery supplementation resulted in an increase in pHOS and a slight decline in PNI. Abundance during this period was sufficient to source program broodstock from natural-origin returns.

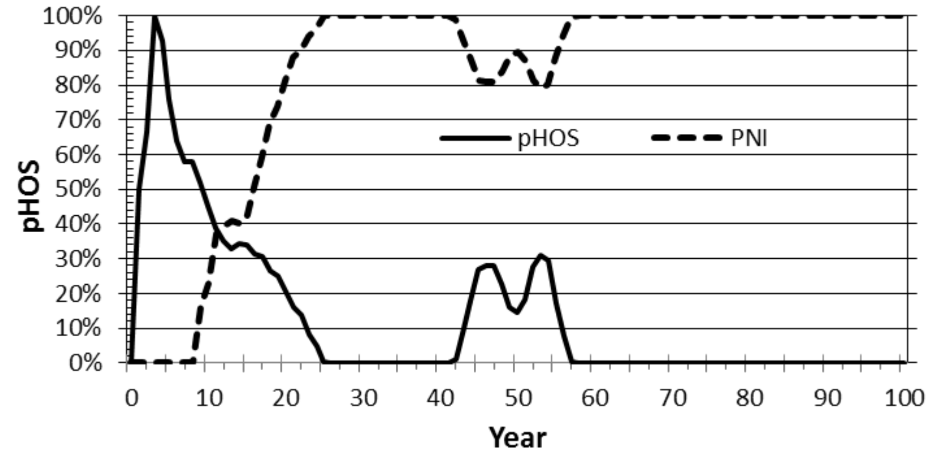

Figure 9. Scenario 1: Hatchery Influence on the Population in Terms of the Management Variables pHOS and PNI

Scenario 2: High Habitat Potential for Winter-Run Chinook Salmon, Adaptation Low

This scenario represents high habitat potential for winter-run Chinook Salmon in NF Battle Creek with low fitness due to hatchery introgression, meaning adaptation to NF Battle Creek may be a requirement to establish a population. Under this scenario, reintroduction has transitioned to Phase 2 Early after 25 years (Figure 10). In Phase 2, broodstock decision rules shift to promote local adaptation, using a higher proportion of broodstock sourced from Battle Creek (Figure 11).

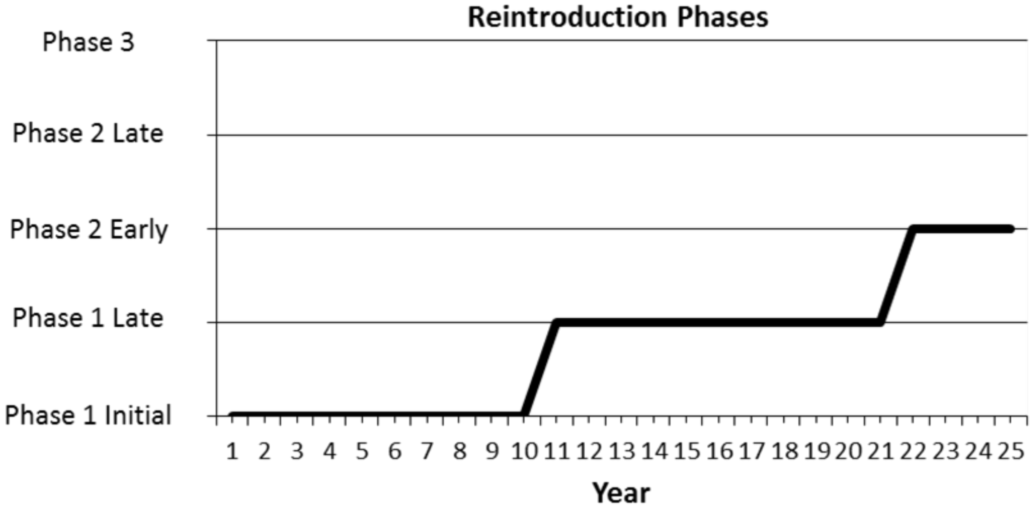

Figure 10. Scenario 2: Phase Transitions for First 25 Years of Implementation

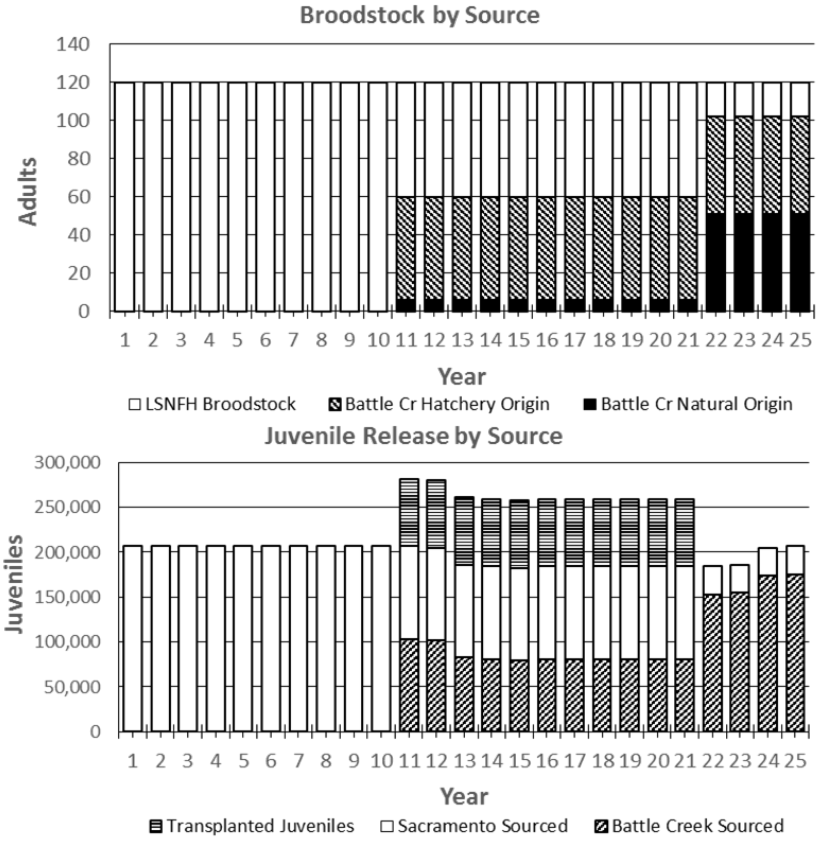

Figure 11. Scenario 2: Hatchery Broodstock Source (top) and Juvenile Release by Source (bottom)

This scenario assumes long-term supplementation of the population, as abundance never exceeded the Phase 3 trigger of 850 natural-origin adults (Figure 12). The long-term number of natural-origin adults surviving to spawn varied between 400 and 800 adults. The number of spawners never exceeded 850 adults because of reduced fitness and because natural-origin adults were removed for hatchery broodstock. Hatchery supplementation helped stabilize year-to-year variation in abundance of the natural population when compared to Scenario 1.

The transition to Phase 3 never occurred in this scenario, but natural production improved sufficiently over time such that pHOS declined and PNI increased late in the scenario (Figure 13). The time frame for local adaptation is an unknown. It may take decades or occur more quickly than represented in this scenario (see Anderson et al. 2014 for more discussion on this topic as it relates to reintroduction).

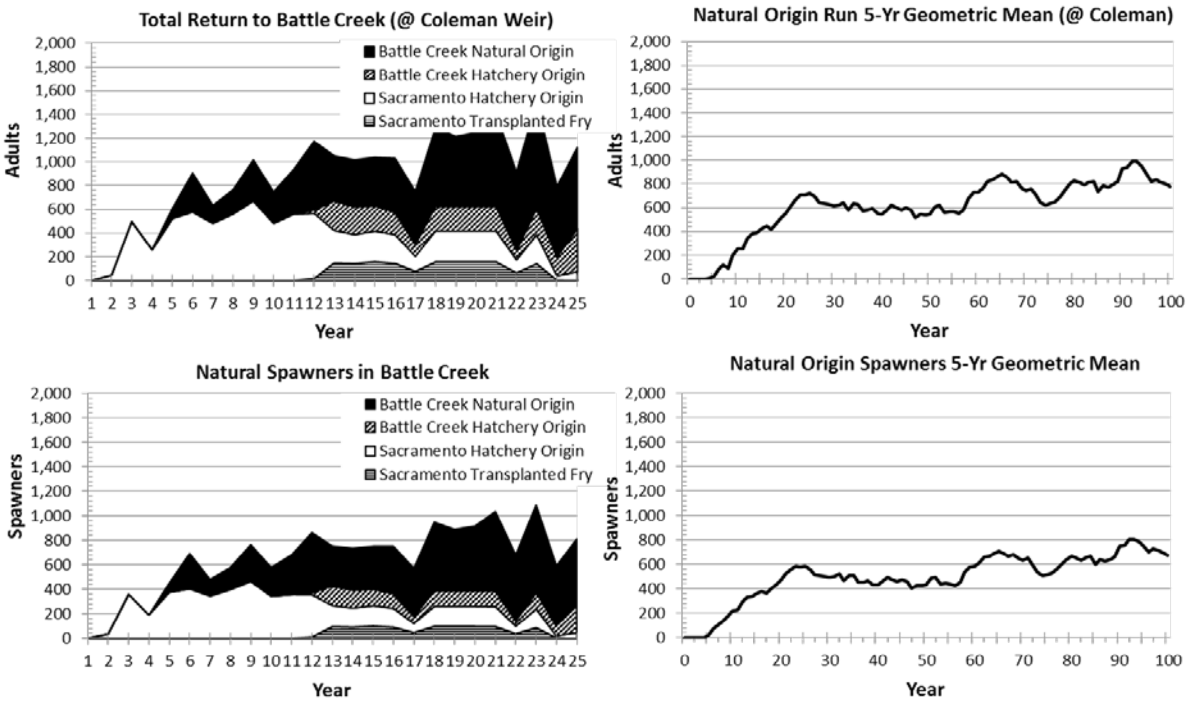

Figure 12. Scenario 2: Total Return and Number of Natural Spawners for First 25 Years (left) and Number of Natural-Origin Spawners Entering Battle Creek and Number of Spawners Projected for 100 Years (right), with Long-Term Hatchery Supplementation

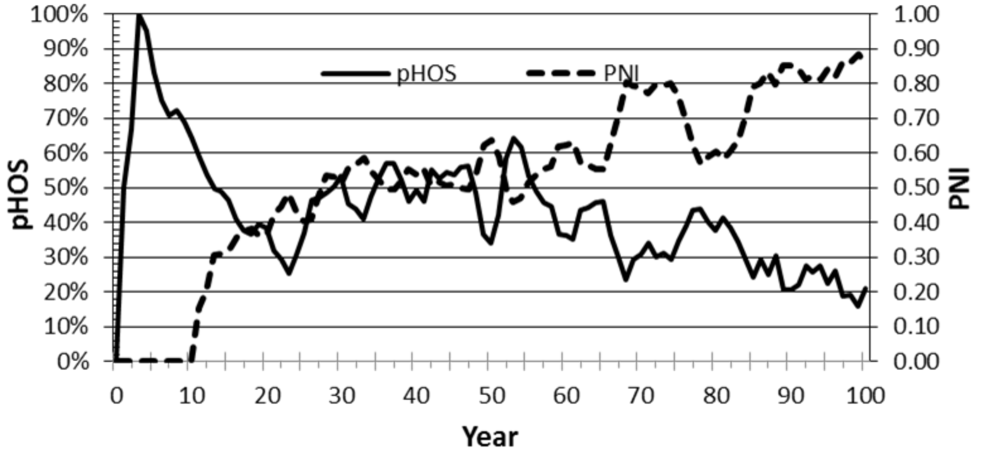

Figure 13. Scenario 2: Hatchery Influence on Population in Terms of the Management Variables pHOS and PNI, with Long-Term Hatchery Supplementation

Long-term hatchery supplementation may slow progress toward adaptation because of countervailing selection in the hatchery environment (see HSRG 2014). With that in mind, a variant of this scenario was constructed that assumed hatchery supplementation was terminated after 20 years (Figures 14 and 15). This assumed that population fitness would improve more rapidly over time. This scenario suggests that managers should consider terminating hatchery supplementation before reaching Phase 3 if evidence suggests that habitat potential is not fully realized. Better reproductive success of natural-origin spawners relative to hatchery-origin spawners may suggest terminating hatchery production early.

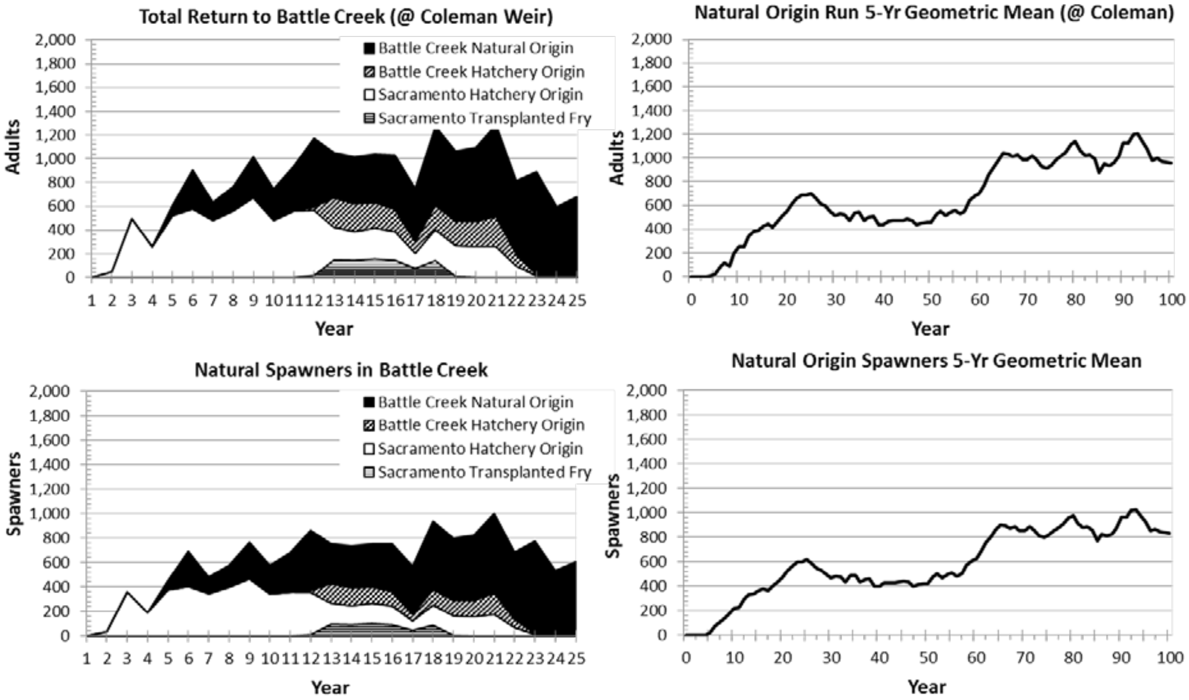

Figure 14. Scenario 2: Total Return and Number of Natural Spawners for First 25 Years (left) and Number of Natural-Origin Spawners Entering Battle Creek and Number of Spawners Projected for 100 Years (right), with Hatchery Supplementation Terminated after 20 Years

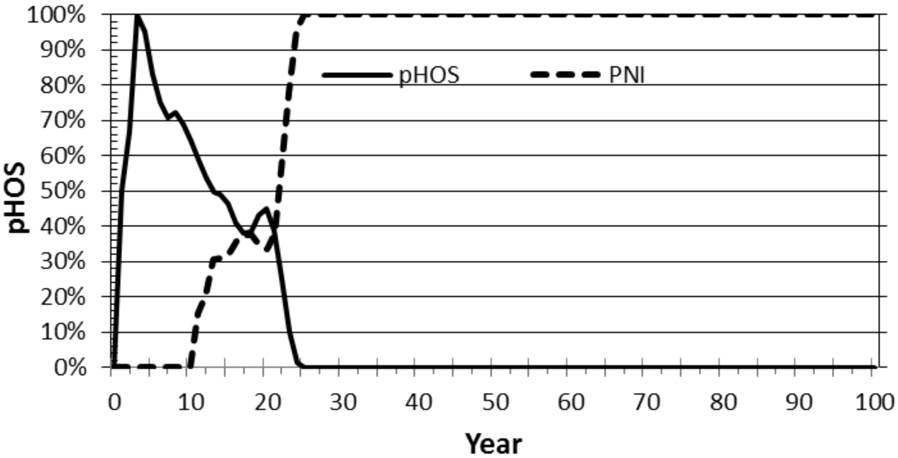

Figure 15. Scenario 2: Hatchery Influence on Population in Terms of the Management Variables pHOS and PNI, with Hatchery Supplementation Terminated after 20 Years

Scenario 3: Low Habitat Potential for Winter-Run Chinook Salmon

This scenario represents a worst-case scenario, with low habitat potential for winter-run Chinook Salmon in NF Battle Creek. Under this scenario, reintroduction transitioned to Phase 1 Late after 10 years but never transitioned to Phase 2 (Figure 16). Reintroduction strategies shifted to include hatchery-origin returns to Battle Creek with a small percentage of natural-origin fish collected for broodstock (Figure 17). The Sacramento River mainstem population continued to supply juveniles for release under this scenario.

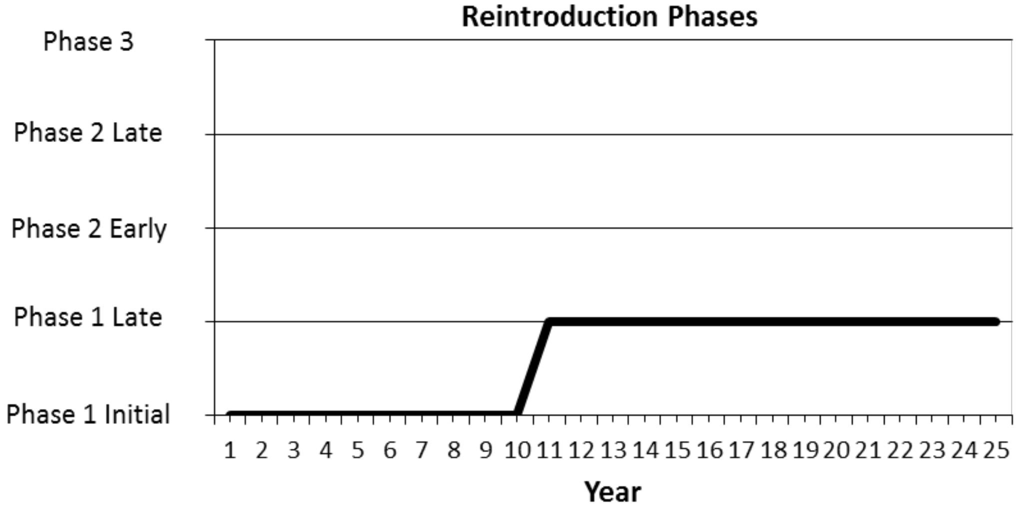

Figure 16. Scenario 3: Phase Transitions for First 25 Years of Implementation

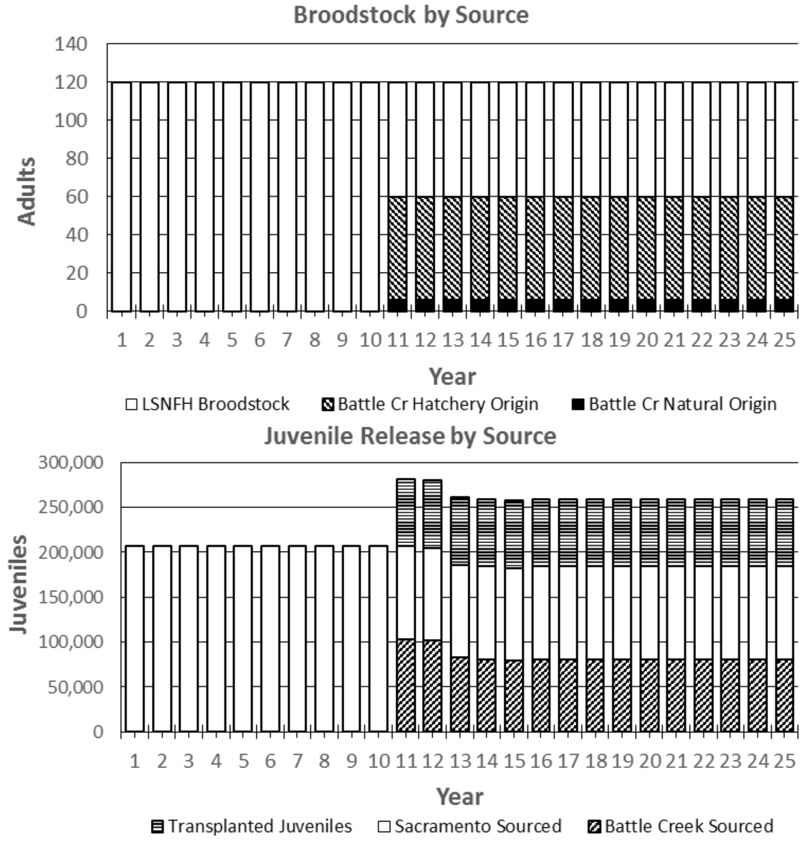

Figure 17. Scenario 3: Hatchery Broodstock Source (top) and Juvenile Release by Source (bottom)

Under this scenario, long-term hatchery supplementation was needed to maintain natural production (Figure 18), and hatchery influence remained high in all years (Figure 19). Evaluation of conditions limiting natural production and addressing these issues, if possible, would be important to achieve reintroduction goals. Terminating hatchery supplementation without addressing habitat would mean the collapse of natural production from Battle Creek (Figures 20 and 21).

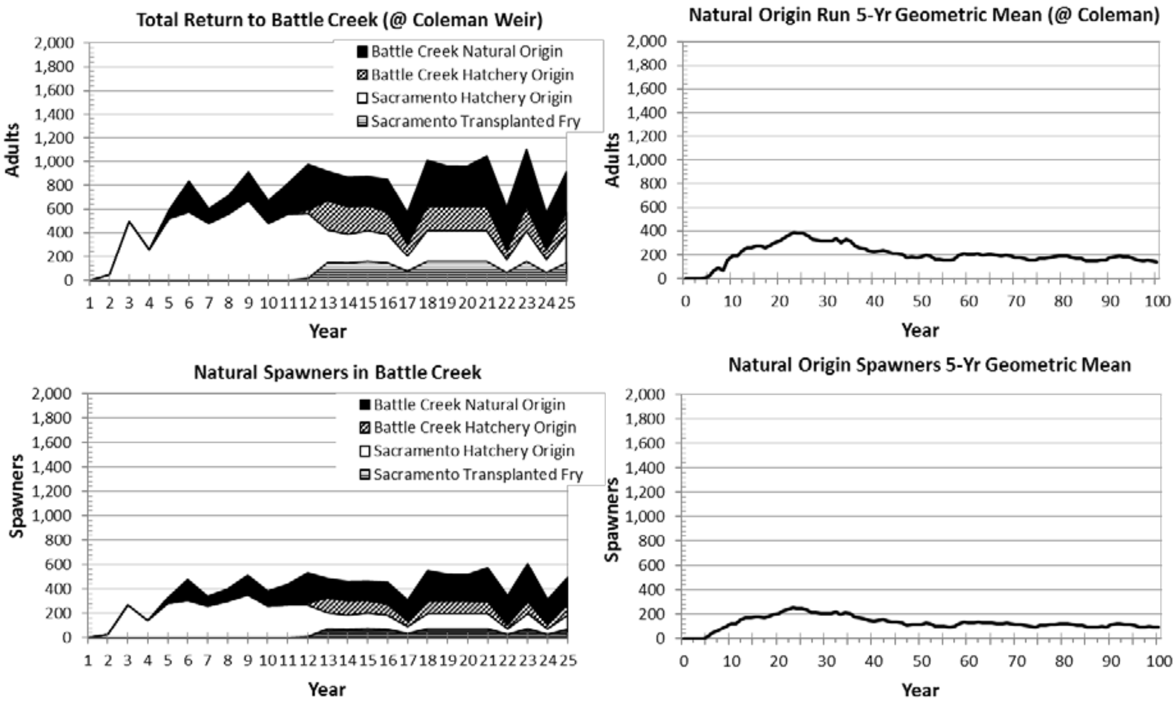

Figure 18. Scenario 3: Total Return and Number of Natural Spawners for First 25 Years (left) and Number of Natural-Origin Spawners Entering Battle Creek and Number of Spawners Projected for 100 Years (right), with Long-Term Hatchery Supplementation

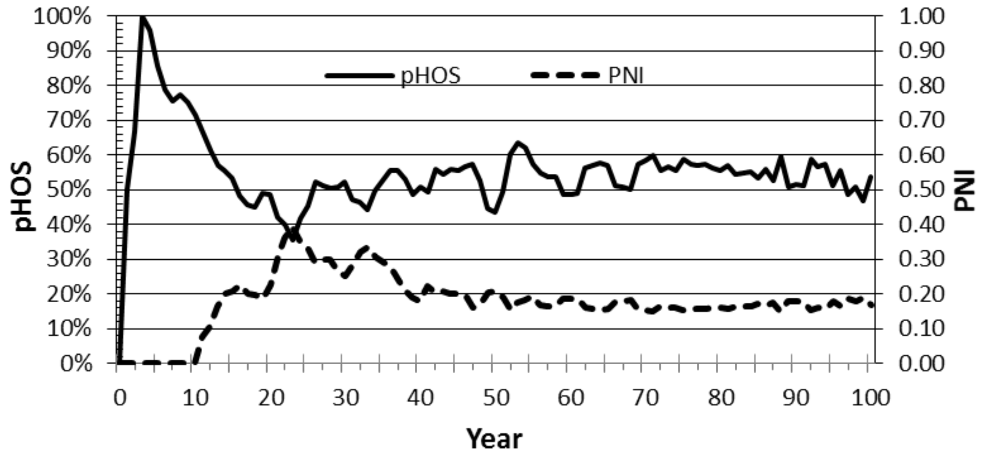

Figure 19. Scenario 3: Hatchery Influence on Population in Terms of the Management Variables pHOS and PNI, with Long-Term Hatchery Supplementation

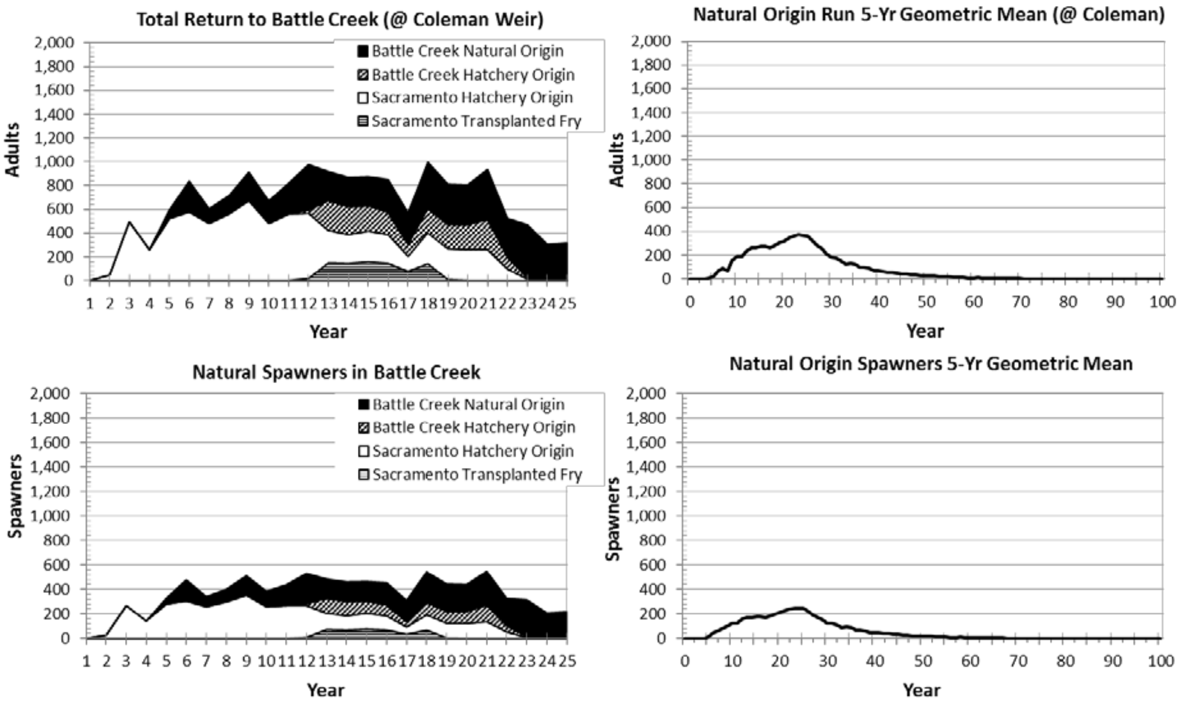

Figure 20. Scenario 3: Total Return and Number of Natural Spawners for First 25 Years (left) and Number of Natural-Origin Spawners Entering Battle Creek and Number of Spawners Projected for 100 Years (right), with Hatchery Supplementation Terminated after 20 Years

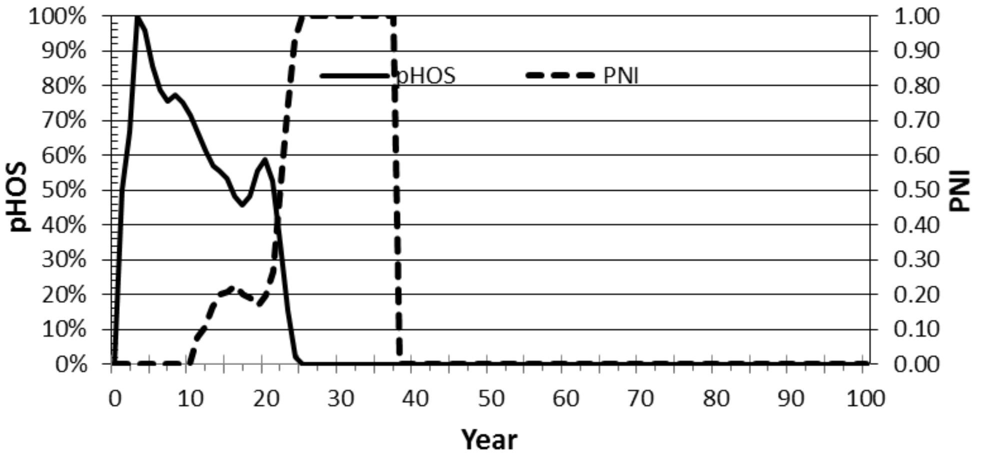

Figure 21. Scenario 3: Hatchery Influence on Population in Terms of the Management Variables pHOS and PNI, with Hatchery Supplementation Terminated after 20 Years

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