Defining Broad-Sense Recovery for Central Valley Salmonids

Reorienting to Recovery Project – Phase 1 Report

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Executive summary

The Reorienting to Recovery Project ("Project") was initiated in 2020 by members of the Collaborative Science and Adaptive Management Program (CSAMP), a consortium of State of California and federal resource management agencies, Public Water Agencies, and Non-Governmental Organizations. The Project's purpose is to develop an effective and implementable strategy for recovering listed and non-listed salmonids in California's Central Valley while considering other social, ecological, and economic interests in the region. Salmonid populations are at all-time lows, with significant environmental and socio-economic impacts on a broad range of communities. Substantial investments throughout the Central Valley watershed have been made over the years, but many potential salmon recovery actions remain unimplemented and/or controversial. Furthermore, climate change exacerbates salmon recovery issues through a variety of hydrological and water quality effects. Even for those recovery actions that have been implemented or planned, they vary in geographic scope, quantitative objectives, types of actions, and monitoring protocols. This poses significant challenges for assessing the effectiveness of individual actions, capturing the cumulative progress toward salmon recovery, and ensuring resources are used efficiently. Therefore, there is an urgent need to comprehensively integrate existing and potential recovery actions across full species' life cycles to improve conditions required to recover salmonids in the Central Valley.

To address these needs, the Project is designed to: (1) develop a set of quantitative objectives that define our collective understanding of what recovery should look like, (2) identify a suite of preferred actions that will contribute to achieving those specific targets for "broad-sense" recovery of Central Valley salmonids (i.e., recovery that incorporates but goes beyond specific thresholds required for de-listing in endangered species recovery plans), and (3) employ an inclusive, collaborative and transparent process that results in broad support and buy-in for those preferred actions across stakeholder interests. The scope of the Project includes the four distinct runs of Chinook salmon (spring-, fall-, late fall-, and winter-run) and steelhead throughout their entire life cycle in the Central Valley (including the ocean, Delta, and Central Valley watersheds).

Phase 1 process

The Project has now completed the first of three phases of work to address these goals. In Phase 1, CSAMP member agencies enlisted a group of experts on salmon biology and the Central Valley watershed to develop the Salmonid Recovery Definition framework. Two series of workshops were held with these salmon scientists and members of the Project Planning Team in June and October 2021. This document summarizes the key activities and outputs from those workshops, which culminated in a draft Recovery Definition for Central Valley salmonids that will be further refined and used in Phases 2 and 3.

The workshop participants agreed on and employed key principles that guided development of the Recovery Definition, including to (a) focus on scientific evidence to define salmon needs in this phase, acknowledging that other social, cultural, economic, and ecological interests related to salmon recovery will be addressed in Phases 2 and 3, (b) balance consolidating ideas ("keeping things simple") within the Recovery Definition and capturing complexities that are important for fully defining salmonid recovery, and (c) ensure the Recovery Definition goes beyond targets for de-listing and supports long-term stability, harvest of populations, and ecosystem services provided by salmonids.

Phase 1 outcomes – Draft Recovery Definition

A framework for the Recovery Definition was agreed to during the Phase 1 workshops consisting of measurable *objectives*, quantitative *metrics* that can be used to track the degree objectives are being met, and *targets* or *benchmarks* that define the numerical values of desired future conditions. This framework was structured around a goal statement originally developed by CSAMP's Policy Group Recovery Subcommittee and modified with feedback by Phase 1 workshop participants. The modified recovery goal statement sought to achieve and maintain viable salmonid populations that are resilient to environmental variation and have minimal dependence on human intervention (described in full in Section 2.2).

The draft Recovery Definition produced in Phase 1 leverages existing concepts by using the four viable salmonid population (VSP) parameters identified in salmonid literature including the NMFS recovery plan (McElhany et al. 2000, Lindley et al. 2007, NMFS 2014) for structuring objectives, metrics, and targets. The four VSPs are based in principles of conservation biology and are defined, in short, as follows: abundance refers to population size and variation; productivity refers to trends and variation in population dynamics over the entire life cycle (e.g., population growth rate and related parameters: McElhany et al. 2000); spatial structure refers to the arrangement of populations across the landscape; and diversity refers to trait variation in genetics and life history within and among populations. A summary of the draft Recovery Definition – including objectives, metrics, and targets for each VSP – is presented in Table ES1.

***Abundance* –** The objective focuses on achieving abundance sufficient to support viable populations that result in low extinction risk, abundant natural origin spawners, a full range of ecological roles, and healthy commercial and recreational fisheries. Conversations around abundance targets revealed a broad range of inherent social and economic values. Therefore, the group specified an approach for setting ecological benchmarks instead of abundance targets, which will serve as reference points in later phases when population abundance targets will be set. Two reference benchmarks were defined during the workshops: at the top of the range, maximum potential abundance based on habitat carrying capacity of the landscape under different scenarios of potential management efforts and ecological stressors; and at the bottom of the range, de-listing abundance numbers. Developing these specific scenarios and determining abundance targets will occur through multi-party deliberations in the SDM process in Phase 3 of the Project.

***Productivity* –** The objective focuses on achieving productivity sufficient to support viability as defined by VSP guidelines and broad-sense recovery. The group identified multiple metrics and targets based on existing research and guidelines (e.g., Lindley et al. 2007) and by using "healthy" populations as reference points. The group also specified that certain targets (e.g., Cohort Replacement Rate) will change between an initial "recovery" phase and a later "stable" phase of populations.

***Spatial Structure* –** The objective focuses on achieving representation and redundancy of populations across the Central Valley sufficient to support local adaptation, minimize risk of extinction from catastrophes, and support natural levels of connectivity between populations. The group identified minimum targets for listed species based on the NMFS Recovery Plan (NMFS 2014) and maximum targets for all species based on the number of historical, independent, viable populations for which there is still sufficient potential suitable habitat.

***Diversity* –** The two objectives focus on recovering and preserving (1) genetic diversity and (2) life history diversity of natural populations that will support resiliency to variable and changing environmental conditions. The group identified multiple metrics and targets based on existing research and guidelines (e.g., Lindley et al. 2004) and by using "healthy" populations as reference points.

A full description of each VSP in the draft Recovery Definition is provided in Section 3 that includes details on the time and spatial scale of each objective, metric, and target and how they should be modified for each run and species (steelhead). A table summarizing the evolution of draft Recovery Definition components during Phase 1 is provided in Appendix 1, a list of workshop participants is provided in Appendix 2, and a list of example recovery frameworks and case studies is provided in Appendix 3.

Next steps

The draft Recovery Definition for Central Valley salmonids will continue being refined and applied during Phases 2 and 3 of this Project. Specifically, salmonid scientists during Phase 1 workshops were able to describe approaches for defining specific targets for some objectives and metrics, but they deferred to stakeholders with more local knowledge to provide watershed-specific data in order to help the Project define appropriate values for those watershed-specific targets. Identifying watershed-specific targets will be accomplished during Phase 2 of the Project via engagement of broader stakeholders across the Central Valley and beyond. These stakeholders will also be asked to provide information on habitat availability and current and planned recovery projects that will be used to capture abundance benchmarks based on potential carrying capacity across each watershed. Lastly, the Recovery Definition will be used in Phase 3 of the Project during the SDM process. That process will engage multiple stakeholders across the salmonid life history landscape to identify potential management alternatives and predict the degree to which those alternatives achieve salmonid targets in the Recovery Definition. Targets and benchmarks identified in the Recovery Definition will be important reference points for tracking how well different management alternatives are predicted to achieve salmonid recovery. Ultimately, the collaborative SDM process in Phase 3 is intended to allow multiple parties to discuss expected tradeoffs among salmonid and other social, cultural, economic, and ecological interests and identify preferred management actions and recommendations for achieving salmon recovery.

1.1 Table ES1. Draft Recovery Definition summary details (objectives, metrics, and targets) across all viable salmonid population (VSP) parameters

The draft Recovery Definition for Central Valley salmonids seeks to address the following goal statement: "Achieve and maintain viable and naturally reproducing salmonid populations that can provide significant ecological, social, cultural, and economic benefits and are resilient to large-scale environmental variations. (sub-bullets) (a) Minimize dependence on human intervention, recognizing that establishing and maintaining recovered populations may require significant and continued human intervention to avoid falling below desired threshold levels; (b) Recognize role of hatcheries as a complementary management intervention to augment natural production in some cases; (c) Establish attainment of goal as greater than minimum viable populations or doubling requirements; and (d) Develop quantitative objectives." As approved by CSAMP PG after modifications based on feedback from workshop participants (July 2021).

Biological Objectives	Potential Metrics	Potential targets / benchmarks
Abundance 1: Abundance sufficient to achieve/ support: • Low Extinction Risk • Viability • Abundance of natural origin: 1) juvenile outmigrants, 2) adults in ocean, and 3) adult spawners, given carrying capacity of suitable habitat • Full range of ecological roles including regenerative ecosystem services • Healthy and well-regulated commercial/recreational salmon fishery and recreational steelhead fishery	• Abundance relative to carrying capacity (at the population and ESU scale) ○ Spawning adults ○ Holding adults ○ Rearing juveniles	• No potential targets, but rather we will be defining ecological benchmark(s)[1] – capturing maximum potential abundance based on habitat carrying capacity under different scenarios – that will be used to inform the SDM process to assess different combinations of management actions • Benchmarks will be measured in 5 year (reflecting ~1 generation) geometric mean
	• Fish in / out (for each life stage)	• To be informed by ecological benchmarks for abundance, as produced through the SIT model[2]
	• Fish caught (e.g., harvest)	• To be informed by ecological benchmarks for abundance, as produced through the SIT model[3]
Productivity 1: Productivity* is sufficient to support viability (as defined by VSP guidelines) and broad-sense recovery *Productivity refers to population growth rate and related parameters over the entire life cycle (McElhany et al. 2000)	• CRR (Cohort Replacement Rate, of natural-origin fish)	• Until near-term recovery goal is met: CRR > 1 (3-yr geometric mean), to account for variability in conditions • After recovery goal is met: no CRR < 1 (3-yr geometric mean)[4]
	• r (intrinsic growth rate, in B-H model)	• Based on recruit-to-spawner relationships from existing populations to specify appropriate range[5] • Median recruits/spawner >1 for 100% of CV populations • Median recruits/spawner ≥ between 2-3 for 25% of CV populations
	• Surplus/replacement (B-H)	• Calculated as a function of other metrics (to be specified)
	• K (carrying capacity, in B-H model)	• To be informed by ecological benchmarks for abundance, given habitat carrying capacity of scenarios
	• Population growth rate	• No trending decline/Positive escapement trend (see Lindley et al. 2007 criteria)[6]
Spatial Structure 1: For each ESU, recover and preserve spatially explicit populations that are sufficient to support redundancy* and representation** in order to: • Maintain natural straying rates among populations • Source pops should be maintained to support colonization through dispersion and straying • Maintain spatial structure processes needs to also take uncertainty into account • Support local adaptation *Species is able to withstand catastrophes and environmental variation by having multiple populations within a diversity group **Species is distributed such that the full breadth of its genetic diversity and ecological roles is captured	• Number of independent viable populations in each diversity group per ESU	• For listed species/diversity groups: Independent, viable populations identified in the NMFS recovery plan (for listed species/diversity groups until point of de-listing)[7] • For all species/diversity groups: Historical, independent, viable populations for which there is sufficient suitable habitat to support continued viability remains[8]
	• Number of dependent populations in each diversity group	• Maintain multiple (≥ 2) dependent populations in each diversity group
	• California Central Valley DPS (steelhead-only)	• Hatchery broodstock need to be native to the Central Valley
Diversity 1: Recover and preserve genetic diversity of natural populations	• Proportion of hatchery origin spawners (pHOS) • Proportion of natural influence (PNI)	• pHOS < 5% [9] • PNI ≥ 0.67 [10]
	• Genetic effective population size (Ne)	• Ne > 500 - 5,000 [11]
	• Genetic introgression between ESUs	• No greater than "low" (e.g., <2%)
Diversity 2: Recover and preserve life history diversity of natural populations	• Age distribution of spawning adults	• Min % of each age class of adults ○ Age 4 >35% ○ Age 5+ >20%
	• Variation in juvenile abundance of each life stage (fry, parr, yearling): variation across years	• Min % of each life stage[12] ○ Fry (smaller than 55 mm [2.2 in]): 20% in wetter years and 20% in drier years ○ Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]): 20% in wetter years and 30% in drier years ○ Smolt (larger than 75 mm [3 in]): 10% in wetter years and 20% in drier years
	• Amount and relative % of available habitat of different types (measured in area and days)[13]	• To be further developed, with a watershed-specific approach.
	• Adult migration and spawning timing	• To be further developed, with a watershed-specific approach.

[1] Ecological benchmark approach: Calculate the maximum potential abundance based on habitat carrying capacity under different scenarios that incorporate (a) current habitat and future potential habitat (planned projects), (b) climate change, and (c) flow influence. Minimum abundance benchmarks will be informed by Lindley et al. (2007). Further work is being conducted to develop guidelines for including high quality habitat above dams (and not all small, fragmented areas).

[2] Once we populate the SIT model with current and future potential habitat, it will inform what the maximum potential abundance template looks like.

[3] In the SIT model, if the number of fish harvested is changed, this will result in an impact to productivity of salmonids (e.g., what is coming out of the landscape/habitat included in the model). This can lead to a discussion on tradeoffs in the model related to number of fish caught and other objectives.

[4] Work is being conducted to further specify productivity targets and design an approach where productivity targets are inversely proportional to abundance.

[5] This approach will apply range of median values from Droner et al. 2017 as our objective range of median values both for (a) individual watershed populations and (b) population dynamics across the Central Valley. Dorner et al. 2017 reviewed recruitment (measured as adult recruits per spawner) from 24 wild Chinook salmon stocks from Oregon through western Alaska and reports median recruit (adult)/ spawner values.

[6] Population growth rate will approach zero as "recovery" is approached.

[7] NMFS recovery plan targets for spatial structure (i.e., maintain multiple populations at low/no risk of extinction): winter run – three populations in the Basalt and Porous Lava Diversity Group; spring run and steelhead – one population in the Northwestern California Diversity Group, two populations in the Basalt and Porous Lava Diversity Group, four populations in the Northern Sierra Diversity Group, and two populations in the Southern Sierra Diversity Group.

[8] Need to specify what is potential suitable habitat, perhaps as part of abundance/carrying capacity analysis which is calculating the maximum potential abundance based on habitat carrying capacity under different scenarios that incorporate (a) current habitat and future potential habitat (planned projects), (b) climate change, and (c) flow influence.

[9] Proportion of hatchery origin spawners (pHOS) is the percentage of hatchery origin fish detected on spawning grounds that is used as an index of genetic introgression, where higher pHOS represents higher genetic risk of hatchery fish on wild populations. Values based on recommendations in the CA Hatchery SRG 2012 review group, section 4.2 on page 34: "Standard 2.5: Natural spawning populations not integrated with a hatchery program should have less than five percent total hatchery-origin spawners (i.e., pHOS less than five percent). Spawners from segregated hatchery programs should be absent from all natural spawning populations (i.e., pHOS from segregated programs should be zero)." This target is aspirational based on current conditions, and it assumes all hatcheries are integrated (this is what the hatcheries themselves are supposed to be striving to achieve). We recognize that some rivers have hatcheries, and some do not.

[10] Proportion of natural influence (PNI) is an index of gene flow rates between hatchery and natural populations, where higher PNI represents lower genetic risk of hatchery fish on wild populations. Values based on recommendations in the Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs 2020 Annual Report (citing HSRG/WDFW/NWIFC 2004): "For the natural environment to dominate selection, PNI should be greater than 0.50, and integrated populations should have a PNI of at least 0.67. For the Wenatchee steelhead program, PNI criteria are implemented in accordance with Permit 18583 to achieve a basin-wide, five-year running average of PNI ≥ 0.67. In years when the natural-origin escapement is low (i.e., < 433 fish), the Wenatchee steelhead population will be managed to meet escapement goals rather than PNI."

[11] Based on recommendations from Lindley et al. (2004) and citations within for a Ne>500 to support low risk extinction and the CA Hatchery SRG 2012 review group for a N_e>5,000 to allow for mutation and to maintain genetic variation at quasi-neutral loci, section 4.2 on page 34: "To address inbreeding concerns, the California HSRG considered the widely adopted breakpoints for effective population size (Ne>50 to avoid inbreeding depression, Ne>500 to maintain additive genetic variation, Ne>5,000 to allow for mutation and to maintain genetic variation at quasi-neutral loci; Frankel and Soule 1981, Lande 1995) to evaluate the adequacy of the numbers of spawners used or to help develop guidelines for when to consider factorial mating designs." This target reflects the minimum N_e needed to support populations and avoid extinction but also aspirational goals for recovery. N_e will vary by watershed and carrying capacity and we have identified a need to track this metric over time and update appropriate N_e values as we learn more about each watershed and its ability to support salmonids.

[12] Values from Anchor QEA (2019; Table 12, page 75) and were specific to supporting a range of sizes at juvenile migration dates to maintain life history diversity. Values in the report referred to fall and spring run. Without additional information, these are applied to all runs in the Recovery Definition.

[13] Relative area/days of maximum usable habitat for each/across all habitat types; target habitat distributions will consider specific, representative flow conditions/water years. This metric is being further developed. A separate proxy metric is being considered: bathymetry experienced by juvenile fish. This metric could compare hydrologic deviation from an unimpaired hydrograph, with a focus on ecological functional flow dynamics specific to the watershed encompassed within the migratory path for a given population.

1 Introduction

1.1 Context & background

The rivers and creeks of California's Central Valley (CV) historically supported viable, naturally reproducing populations of salmonids (NMFS 2014), but multiple stressors including land-use change (e.g., urbanization, irrigated agriculture), altered hydrology and hydrodynamics (e.g., dams and levees), commercial harvest, and climate change have collectively resulted in substantial population declines over the last century or more (Yoshiyama 1998, Lindley et al. 2006). CV salmonid populations are now at all-time lows, with significant socioeconomic impacts to a broad range of communities. The Delta plays a critical role in the survival and success of all CV salmonid populations. However, the overall condition of CV salmonids is determined by factors throughout their range, including the ocean, San Francisco Bay, and the upstream watersheds.

There have been numerous salmon recovery initiatives in recent years, which tend to focus on improving conditions at more local, watershed-level scales. Although these individual efforts have merit, many potential salmon recovery actions remain unimplemented and/or controversial. Furthermore, there exists a lack of integration and coordination of activities necessary to improve the condition of CV salmonids across their full life cycle – from tributaries to the ocean. Quantitative objectives and protocols to measure progress toward recovery goals are often lacking or not comparable among geographies and sponsors, and there is no single, cohesive catalog of actions underway or planned across the full landscape. The lack of an agreed upon scientific or policy definition of "broad-sense salmonid recovery" (that is, recovery to achieve a broad set of social, ecological, cultural and economic goals for all runs and species, not just de-listing species currently listed under the U.S. and/or California Endangered Species Acts) further inhibits the ability to guide and assess effectiveness of management decisions for recovering CV salmonids.

Seeing this challenge, the Collaborative Science and Adaptive Management Program (CSAMP) Policy Group, composed of the directors, general managers and executive staff of State of California and federal resource management agencies, Public Water Agencies, and Non-Governmental Organizations, recently agreed to engage in a voluntary, multi-party effort to establish a unified strategy for salmonid recovery across the CV.

1.2 Overview of Phases 1-3

The Reorienting to Recovery Project (hereafter, "the Project") seeks to develop an effective and implementable strategy to achieve "broad-sense" recovery of CV salmonids (i.e., recovery that incorporates but goes beyond specific thresholds required for de-listing in endangered species recovery plans) through a structured engagement process with the full range of stakeholders to balance competing social, cultural, ecological, and economic values affected by salmon recovery. The Project, initiated under the sponsorship of CSAMP and funded by the Delta Stewardship Council and the State Water Contractors, is managed and executed by a group of Public Water Agencies and NGOs, working closely with state and federal agencies. The process is intended to leverage (a) existing knowledge by relying on scientists across a broad range of organizations and agencies involved with salmon in the CV and local experts who are actively engaged in initiatives at local scales, (b) existing recovery efforts that have been carried out and/or planned across CV watersheds, and (c) support tools, such as adapting the CVPIA SIT Model and NMFS Winter Run Life Cycle Model and using decision support tools where appropriate, to explore a range of possible actions and compare the degree to which they achieve recovery goals. Importantly, the process is designed to build common vision for what salmon recovery looks like with a shared commitment towards collective and coordinated action over the long term.

This overarching purpose will be addressed through three phases of work with specific goals that build off previous efforts (Table 1). In short, **Phase 1** will focus on the creation of a scientifically defensible definition of recovery (i.e., "Recovery Definition"), including (a) specific, measurable objectives, (b) quantitative metrics that can be used to track the degree objectives are being met, and (c) targets or thresholds that define the numerical values of desired future conditions. **Phase 2** will focus on engaging knowledgeable regional stakeholders across the salmonid life history landscape (including federal, state, and local agencies, tribal communities, water agencies and managers, recreational, commercial and subsistence fishers, and private land owners) to inform local and regional targets within the Recovery Definition as appropriate, provide data on baseline salmon conditions and management activities being implemented currently or planned, and to identify and characterize other values (e.g., social, cultural, ecological, and economic) that are associated with or affected by salmon recovery efforts. **Phase 3** will use structured decision making (SDM) and an iterative approach with stakeholders and modelers across the CV to collectively build and assess different combinations of management actions (referred to as draft recovery scenarios) towards a broadly supported draft recovery strategy. The assessment of different scenarios will be carried out over multiple rounds of evaluation to better explore tradeoffs between achieving salmon recovery actions and addressing other values.

There have been numerous and valuable efforts related to strategic conservation planning for salmon recovery. This Project is intended to build off previous efforts in several ways that make it unique. It seeks to address an expanded scope of salmon recovery that includes all four salmon runs and steelhead throughout the full species' life cycles (hatcheries, CV rivers and tributaries, the Bay-Delta, and ocean), and a range of actions, potentially including both regulatory and non-regulatory actions. The Project, initiated and led through collaboration between NGOs and PWAs with the cooperation of state and federal agencies, is designed to be fully inclusive of stakeholders throughout the salmonid life history landscape. It is also intended to achieve broad-sense recovery of salmonids that meets viability targets that exceed those for de-listing in ESA recovery plans or salmon doubling requirements.

Table 1. Main goals of Phases 1-3 of the Reorienting to Recovery Project for salmonid broad-sense recovery in California's Central Valley.

Phase	Goal(s)
1	Collaboratively develop a scientifically sound, measurable, and broadly supportable framework for defining salmonid recovery.
2	Assemble information about existing salmonid conditions, ongoing and planned salmonid-related actions, and related socio-ecological considerations, with the active engagement of existing regional coalitions, groups, stakeholders and others with an interest in Central Valley salmonids.
3	Collaboratively develop a suite of recommended actions that maximize progress towards salmonid recovery with the greatest possible attention to and balancing of the diverse range of stakeholder values, perspectives and priorities.

2 Recovery Definition for salmonids in California's Central Valley

2.1 Process overview

Phase 1 work was conducted through a collaborative process centered around two series of remote workshops in June and October of 2021 with additional follow-up work and peer-review of final products through February 2022 (Table 2). The workshops were structured around one main goal: collaboratively develop a scientifically sound, measurable, and broadly supportable framework for defining salmonid recovery. A team of scientists (Appendix 2) nominated by CSAMP members from across governmental, non-governmental, and private sectors participated in the workshops to develop initial objectives and metrics, expressed in quantitative terms, and quantitative targets (or an approach to developing quantitative targets). These objectives, metrics, and targets will be used as the basis for collecting information in Phase 2, assessing and modeling different groups of management actions, and informing a deliberative and collaborative process to reach agreement on a preferred recovery scenario in Phase 3.

Table 2. Process steps in Phase 1 of the Reorienting to Recovery Project.

Time period	Step	Purpose
Mar-May 2021	Engage participants	Engage and recruit scientists representative of sectors and geographies in the CV to participate in Phase 1
May 2021	Pre-workshop survey	Collect initial expectations, concerns, relevant literature citations, and example recovery frameworks from participants
Jun 2021	Workshop series 1	Review and discuss the Project, the process for developing a salmon Recovery Definition, and roles of participants; explore example recovery frameworks and relevant case studies; review the CVPIA SIT Model and NMFS Winter Run Life Cycle Model; begin drafting objectives and metrics of the Recovery Definition
Jul-Sep 2021	Interim work	Research existing data, models, and studies to inform improvements of Recovery Definition; elicit feedback from participants on draft Recovery Definition and synthesize comments
Oct 2021	Workshop series 2	Review and refine the draft Recovery Definition – specifically the objectives, metrics, approaches for defining targets; discuss ways elements in the Definition should be modified by run and species; identify specific subgroups to conduct follow-up work on outstanding issues
Nov-Dec 2021	Task-specific subgroup work	Complete work with subgroups to research existing data, models, and studies to propose final (a) target values to be included in the Recovery Definition or (b) approaches for eliciting target values from stakeholders across watersheds in Phase 2 of the Project; synthesize subgroup work into a final draft Recovery Definition
Jan-Feb 2022	Full review and final report	Elicit feedback from participants on final draft, synthesize comments, and produce report with final version of the draft Recovery Definition

Through conversations early in Phase 1, the group reviewed the overall scope and goals of the process, specifically that it is designed to operate without reference to regulatory, operational or other (e.g., current data availability) constraints, is inclusive of voices and perspectives across the CV, and is striving toward broad buy-in and consensus.

Participants were asked to provide case studies of existing recovery frameworks or initiatives that were shared and made available to everyone as pre-reading material before the first workshop session (25 unique documents: Appendix 3). These included existing salmon recovery frameworks from regulators (e.g., the ESA recovery plan for multiple species [NMFS 2014]) and multistakeholder groups (e.g., conservation planning in the Stanislaus River, Anchor QEA 2019); peer-reviewed studies on salmon population dynamics, genetics, and life history (e.g., Peterson and Duarte 2020, Waters et al. 2020); and studies highlighting principles and examples of SDM (e.g., McGowan et al. 2015, Runge et al. 2013).

The two series of workshops provided a space for the group to develop the Recovery Definition, discuss available science and additional hypotheses related to salmonid viability, and highlight key uncertainties and knowledge gaps. Because further information will be needed to refine the Definition in Phases 2 and 3 of the Project, it is referred to as the "draft Recovery Definition" for the remainder of this report. The group agreed on and employed the following key principles that guided development of the draft Recovery Definition:

- Focus on scientific evidence to define salmon needs in this phase; although other social, cultural, economic, and ecological interests related to salmon recovery were acknowledged, they will be more appropriately addressed in Phases 2 and 3
- Develop the draft Recovery Definition first for Chinook salmon and then customize necessary components for defining recovery for specific runs and steelhead
- Consider when it is appropriate to define objectives, metrics, and targets broadly at the CV scale vs. defining these elements at the watershed level to capture unique local characteristics and contexts
- Balance consolidating ideas ("keeping things simple") within the draft Recovery Definition and capturing complexities that are important for fully defining salmonid recovery
- Ensure the draft Recovery Definition accounts for future climate change impacts
- Ensure the draft Recovery Definition goes beyond targets for de-listing and supports long-term stability and harvest of populations and ecosystem services provided by salmonids
- Acknowledge that some targets will need to be informed by other groups and datasets at the watershed level, which will be completed in Phase 2 of the Project

During the workshops, there were some specific components of the draft Recovery Definition that could not be finalized during limited in-workshop time. The group highlighted these items, created a number of theme-based subgroups, and those subgroups conducted work between workshop sessions and following workshops series 2. Subgroup work consisted of reviewing published studies and reports related to salmonid biology and conservation and proposing ways to use these to inform specific targets (e.g., number of populations) or methods for defining targets (e.g., using reference populations or habitat-based models) in the draft Recovery Definition. Subgroup work that occurred between workshop sessions was discussed by the whole group in workshop series 2. The Project Team incorporated all proposed updates from subgroup work that occurred after workshop series 2 into the draft Recovery Definition, and all participants were allowed to review and approve the final version of the draft Recovery Definition described in this report.

2.2 Draft Recovery Definition structure

Through collaborative work in Phase 1, the group developed an organizing structure for defining salmon recovery in the CV that included (a) a high-level recovery goal statement and (b) the set of objectives, metrics, and targets that help measure the degree to which the salmon recovery goal is being achieved.

Organizing structure – The group supported the overall organizing structure for creating a salmon draft Recovery Definition (Table 3). The framework is composed of three tiers: (1) at the broadest level, a qualitative goal statement about desired outcomes for salmon recovery across the CV, (2) at a medium level, measurable objectives that describe the goal in quantitative terms, and (3) at the most specific level, metrics that track performance toward achieving objectives and targets/thresholds that are numerical values of a metric that indicate desired future conditions. The group discussed and supported that the focus of Phase 1 was to create scientifically defensible objectives and metrics that can be applied across the CV, and Phases 2 and 3 will focus on defining targets/thresholds at more local scales of watersheds and tributaries, as needed.

Salmon recovery goal statement – The group reviewed and discussed the original recovery goal statement as developed by CSAMP's Policy Group Recovery Subcommittee. There were varying degrees of support for the statement and diverging opinions about how to modify it. Specifically, some expressed concerns and confusion around including the term "self-sustaining" in this definition, citing that salmon will likely always be conservation-reliant to some degree, and proposed various changes. There was also debate around the inclusion of "beneficial uses" or alternate terms like "harvest" that relate to social objectives that would be considered later in this process. Ultimately, the group made recommendations for consideration by CSAMP, and this led to a revised goal statement that was accepted by workshop participants during the second series of workshops (Table 3).

Table 3. Organizing structure for the salmon Recovery Definition for the Central Valley.

Tier	Recovery Definition Terminology	Geographic Scale	Phase of process and additional details
1	**Goal(s):** *Qualitative statements of purpose or desired outcomes that are being aimed for*	Central Valley	*"Achieve and maintain viable and naturally reproducing salmonid populations that can provide significant ecological, social, cultural, and economic benefits and are resilient to large-scale environmental variations.* • *Minimize dependence on human intervention, recognizing that establishing and maintaining recovered populations may require significant and continued human intervention to avoid falling below desired threshold levels* • *Recognize role of hatcheries as a complementary management intervention to augment natural production in some cases.* • *Establish attainment of goal as greater than minimum viable populations or doubling requirements* • *Develop quantitative objectives"* *As approved by CSAMP PG after modifications based on feedback from workshop participants*
2	**Objectives:** *Measurable and specific conditions on whether overarching Goal(s) are being achieved, with quantitative targets for key landscape-level objectives*	Central Valley	Focus of Phase 1 workshops
3	**Sub-Objectives**	Watershed *(e.g., Watershed, tributary level)*	Phase 1 Workshops – focus is on defining and scoping metrics to be used at watershed level *(i.e., clarifying what we want to measure (and how)).* In Phase 2 & 3 – focus will be on defining / estimating the actual values for the watershed-level targets and thresholds.
3a	**Metrics:** *Quantitative terms defining the unit(s) of measure for tracking performance towards achieving the objectives*	Central Valley and specific watershed	Phase 1 Workshops – define and scope metrics to be used at all levels
3b	**Targets/thresholds:** *Numerical values of the desired future conditions for meeting objectives*	Central Valley and specific watershed	Phase 1 Workshops – set key landscape-level targets where they can be set based on available science, defer setting other targets to Phases 2 and 3

2.3 Recovery Definition details: Objectives, metrics, and targets

Through iterative rounds of deliberation, the group developed a full suite of objectives, metrics, and targets (or approaches for defining targets) within the salmon draft Recovery Definition while highlighting important questions and considerations that will need to be addressed later in Phases 2 and 3. The draft Recovery Definition adopted the four viable salmonid population (VSP) parameters based in principles of conservation biology and identified in salmonid literature and used in the NMFS recovery plan (McElhany et al. 2000, Lindley et al. 2007, NMFS 2014). In short, the four VSPs are defined as follows: abundance refers to population size and variation; productivity refers to trends and variation in population dynamics over the entire life cycle (e.g., population growth rate and related parameters: McElhany et al. 2000); spatial structure refers to the arrangement of populations across the landscape; and diversity refers to trait variation in genetics and life history within and among populations.

Several discussion topics emerged from the group workshops that spanned all elements of the draft Recovery Definition. These included:

- **Going beyond de-listing:** The group agreed that the main charge of this effort is to create targets for broad-sense recovery over the longer-term that exceed goals and targets outlined in de-listing criteria, VSP criteria, or doubling goals; however, it was noted that some de-listing criteria may be “aspirational” and useful to apply in the draft Recovery Definition (i.e., for Diversity targets). There were also diverging opinions about including a “floor” for more near-term targets and if the thresholds in the NMFS recovery plan (NMFS 2014) should be used for that purpose. Ultimately, the group used NMFS recovery criteria as some targets when additional information did not exist or as minimum targets (see Spatial Structure) that are paired with higher targets. The group agreed that broad-sense recovery would support ecosystem function, long-term harvest, and other beneficial uses, while minimizing dependence on hatcheries and other human interventions.
- **Achieving a balance:** The group agreed to strive to keep the definition “as simple as possible” without losing essential details needed to define broad-sense recovery.
- **Accounting for uncertainty across watersheds:** The group emphasized the importance to accommodate the unique characteristics and data limitations of local watersheds when defining targets in the Recovery Definition, as well as ensuring elements of the Definition capture population resiliency to climate change and additional sources of variability and uncertainty.
- **Accounting for multiple scales:** There was consensus that some objectives, metrics, and targets should be flexible to goals varying over time (e.g., short, medium, and long-term) and space (e.g., CV-wide, watershed-specific). Structuring metrics and targets this way will allow for the tracking of milestones at multiple points in time and adapt goals to the conditions and opportunities of each watershed.
- **Distinguishing between fish of natural and hatchery origins:** There was consensus that the Recovery Definition should focus on natural origin fish and capture the degree they were impacted by or reliant on hatcheries.
- **Completeness of preliminary targets:** Although some targets will need further refinement through local knowledge and data in Phase 2, the group agreed that the suite of objectives and metrics in the Recovery Definition captures – in total – what matters for salmonid recovery.

Key components within the draft Recovery Definition for each VSP are summarized below, and VSP-specific tables that include all details (objectives, metrics, targets, runs, steelhead, and time/spatial scales) are presented in Section 3. Furthermore, examples of how objectives, metrics, and targets evolved for each VSP throughout the course of Phase 1 are provided in Appendix 1.

Abundance **–** The objective focuses on achieving abundance sufficient to support viable populations that result in low extinction risk, abundant natural origin spawners, a full range of ecological roles, and healthy commercial and recreational fisheries. Conversations around abundance targets revealed a broad range of inherent social and economic values. Therefore, the group specified an approach for setting ecological benchmarks instead of abundance targets, which capture the maximum potential abundance based on habitat carrying capacity of the landscape under different scenarios. Developing these specific scenarios and determining abundance targets will occur through multi-party deliberations in the SDM process in Phase 3 of the Project.

Productivity **–** The objective focuses on achieving productivity sufficient to support viability as defined by VSP guidelines and broad-sense recovery. The group identified multiple metrics and targets based on existing research and guidelines (e.g., Lindley et al. 2007) and by using "healthy" populations as reference points. The group also specified that certain targets (e.g., Cohort Replacement Rate) will change between an initial "recovery" phase and a later "stable" phase of populations.

Spatial Structure **–** The objective focuses on achieving representation and redundancy of populations across the CV. Redundancy captures the degree that there are multiple, locally-adapted populations that minimizes the risk of extinction from catastrophes. Representation captures the degree that populations are spread across watersheds, diversity groups, and the historical species' range, such that it supports local adaptation and natural levels of connectivity between populations. The group identified minimum targets for listed species based on the NMFS Recovery Plan (NMFS 2014) and maximum targets for all species based on the number of historical, independent, viable populations for which there is still sufficient potential suitable habitat.

Diversity **–** The two objectives focus on recovering and preserving (1) genetic diversity and (2) life history diversity of natural populations that will support resiliency to variable and changing environmental conditions. Collectively, these objectives captured (a) the influence of hatcheries on genetic integrity of natural populations, and (b) the concepts of resilience (the ability of populations to bounce back after disturbance) and resistance (the ability of populations to not respond to a disturbance) to climate change and other future stressors. The group identified multiple metrics for resilience and resistance that represent the related concept of the "portfolio effect": maintaining genetic, life history, and cohort diversity within and across populations to support local adaptation, connectivity, and rescue from local stressors (e.g., drought) and extirpation events. This reduces year-to-year variation in local or regional abundances and minimizes species extinction risk (Anchor QEA 2019). The group also identified multiple targets based on existing research and guidelines (e.g., Lindley et al. 2004) and by using "healthy" populations as reference points.

A full description of each VSP in the draft Recovery Definition is provided in Section 3 that includes details on the time and spatial scale of each objective, metric, and target and how they should be modified for each run and species (steelhead). A table summarizing the evolution of draft Recovery Definition components during Phase 1 is provided in Appendix 1, a list of workshop participants is provided in Appendix 2, and a list of example recovery frameworks and case studies is provided in Appendix 3.

3 Draft Recovery Definition – Full details for each VSP

Table 3a. Draft biological objectives, metrics, targets, and time and spatial scales for the viable salmonid population parameter of **abundance**. From the NMFS 2014 recovery plan: abundance refers to population size and year-to-year variation of population size. Larger populations are more likely to persist through variable environmental conditions.

Biological Objectives	Potential Metrics	Potential targets / benchmarks	Runs	Steelhead	Time/spatial scales
AO1: Abundance sufficient to achieve/ support: ● Low Extinction Risk ● Viability ● Abundance of natural origin: 1) juvenile outmigrants, 2) adults in ocean, and 3) adult spawners, given carrying capacity of suitable habitat ● Full range of ecological roles including regenerative ecosystem services ● Healthy and well-regulated commercial/recreational salmon fishery and recreational steelhead fishery	● Abundance relative to carrying capacity (at the population and ESU scale) ○ Spawning adults ○ Holding adults ○ Rearing juveniles	● No potential targets, but rather we will be defining ecological benchmark(s)[1] – capturing maximum potential abundance based on habitat carrying capacity under different scenarios – that will be used to inform the SDM process to assess different combinations of management actions. ● Benchmarks will be measured in 5 year (reflecting ~1 generation) geometric mean	● Run-specific	● The ecological benchmark approach should be applied to steelhead spawning adults, where abundance metrics are defined by the entire population of *O.mykiss*, not just anadromous adults	● Time: measured at 6, 12, 24, 48 yrs; measured as geometric mean over some number of yrs (to align with productivity) ● Spatial: Tributary. Select subset of tribs that are currently monitored and representative of regions.
	● Fish in / out (for each life stage)	● To be informed by ecological benchmarks for abundance, as produced through the SIT model[2].	● Run-specific	● Targets can be applied to steelhead (anadromous); density of freshwater fish (residents)	● Time: Not discussed ● Spatial: Measured at key locations (e.g., Knight's, Chipps)
	● Fish caught (e.g., harvest)	● To be informed by ecological benchmarks for abundance, as produced through the SIT model[3].	● Run-specific	● No metric, no commercial harvest for steelhead	● Not discussed

[1] Ecological benchmark approach: Calculate the maximum potential abundance based on habitat carrying capacity under different scenarios that incorporate (a) current habitat and future potential habitat (planned projects), (b) climate change, and (c) flow influence. This will require guidelines for calculating carrying capacity in watersheds with large dams, where upstream of dams should be included in carrying capacity estimates. For areas that could potentially be used by more than one run, specific spawning locations can contribute to either spring-run or fall-run spawning habitat carrying capacity, but not both. Minimum abundance benchmarks will be informed by Lindley et al. (2007). Further work is being conducted to develop guidelines for including high quality habitat above dams (and not all small, fragmented areas).

[2] Once we populate the SIT model with current and future potential habitat, it will inform what the maximum potential abundance template looks like.

[3] In the SIT model, if the number of fish harvested is changed, this will result in an impact to productivity of salmonids (e.g., what is coming out of the landscape/habitat included in the model). This can lead to a discussion on tradeoffs in the model related to number of fish caught and other objectives.

Table 3b. Draft biological objectives, metrics, targets, and time and spatial scales for the viable salmonid population parameter of **productivity**. From the NMFS 2014 recovery plan: productivity refers to trends in population dynamics (e.g., population growth rate and related parameters over the entire life cycle: McElhany et al. 2000), year-to-year variation around those dynamics, and the processes and environmental conditions that produce those patterns.					
Biological Objectives	**Potential Metrics**	**Potential targets / benchmarks**	**Runs**	**Steelhead**	**Time/spatial scales**
PO1: Productivity is sufficient to support viability (as defined by VSP guidelines) and broad-sense recovery	● CRR (Cohort Replacement Rate, of natural-origin fish)	● Until near-term recovery goal is met: CRR > 1 (3-yr geometric mean), to account for variability in conditions ● After recovery goal is met: no CRR < 1 (3-yr geometric mean)[1]	● Population-specific Run	● Target applies to steelhead (both anadromous and resident).	● Time: measured at 6, 12, 24, 48 yrs; measured as geometric mean over some number of yrs (to align with abundance) ● Spatial: align with abundance
	● r (intrinsic growth rate, in B-H model)	● Based on recruit-to-spawner relationships from existing populations to specify appropriate range[2] ● Median recruits/spawner >1 for 100% of CV populations ● Median recruits/spawner ≥ between 2-3 for 25% of CV populations	● Population-specific	● Target applies to steelhead	● Same as above
	● Surplus/replacement (B-H)	● Calculated as a function of other metrics (to be specified)	● Population - specific	● Target applies to steelhead	● Same as above
	● K (carrying capacity, in B-H model)	● To be informed by ecological benchmarks for abundance, given habitat carrying capacity of scenarios	● Population - specific	● Target applies to steelhead (both anadromous and resident)[3]	● Same as above
	● Population growth rate	● No trending decline/Positive escapement trend (see Lindley et al. 2007 criteria)[4]	● Population - specific	● Target will be adapted to steelhead to track growth rate and % of anadromous life history form[5]	● Same as above

[1] Work is being conducted to further specify productivity targets and design an approach where productivity targets are inversely proportional to abundance.
[2] This approach will apply range of median values from Droner et al. 2017 as our objective range of median values both for (a) individual watershed populations and (b) population dynamics across the Central Valley. Dorner et al. 2017 reviewed recruitment (measured as adult recruits per spawner) from 24 wild Chinook salmon stocks from Oregon through western Alaska and reports median recruit (adult)/ spawner values.
[3] The territory/redd size requirements would be different for each life-history type and will influence calculations of carrying capacity targets.
[4] Population growth rate will approach zero as “recovery” is approached.
[5] Tracking how the population is trending is important, potential way to estimate % of anadromous life history form. One approach is to model different proportions of anadromy and monitor impacts to population growth rate in order to maximize what is best for the population.

Table 3c. Draft biological objectives, metrics, targets, and time and spatial scales for the viable salmonid population parameter of **spatial structure**. From the NMFS 2014 recovery plan: spatial structure refers to the arrangement of populations across the landscape, the distribution of spawners within a population, and the processes that produce those patterns.

Biological Objectives	Potential Metrics	Potential targets / benchmarks	Runs	Steelhead	Time/spatial scales
SO1: For each ESU, recover and preserve spatially explicit populations that are sufficient to support redundancy* and representation** in order to: • Maintain natural straying rates among populations • Source populations should be maintained to support colonization through dispersion and straying • Maintain spatial structure processes needs to also take uncertainty into account • Support local adaptation *Species is able to withstand catastrophes and environmental variation by having multiple populations within a diversity group. **Species is distributed such that the full breadth of its genetic diversity and ecological roles is captured.	• Number of independent viable populations in each diversity group per ESU	• For listed species/diversity groups: Independent, viable populations identified in the NMFS recovery plan (for listed species/diversity groups until point of de-listing)[1] • For all species/diversity groups: Historical, independent, viable populations for which there is sufficient suitable habitat to support continued viability remains[2]	• Population-specific[3]	• 1-14 populations in the Northwestern California Diversity Group, 2-12 populations in the Basalt and Porous Lava Diversity Group, 4-21 populations in the Northern Sierra Diversity Group, 2-26 populations in the Southern Sierra Diversity Group[4]	• Time: none • Spatial: by diversity group
	• Number of dependent populations in each diversity group	• Maintain multiple (≥ 2) dependent populations in each diversity group	• Same for all runs[3]	• Maintain multiple dependent populations in each diversity group	• Time: none • Spatial: by diversity group
	• California Central Valley DPS (steelhead-only)	• Hatchery broodstock need to be native to the Central Valley	• Not applicable	• Hatchery broodstock need to be native to the Central Valley	• Time: none • Spatial: by diversity group
This row contains information on additional “indicators” for this VSP. Indicators have some relationship to species and population conditions, but they are currently difficult or impossible to quantitatively measure for salmonids.	• Number of repeat spawners (steelhead-only indicator)				

[1] NMFS recovery plan targets for spatial structure (i.e., maintain multiple populations at low/no risk of extinction): winter run – three populations in the Basalt and Porous Lava Diversity Group; spring run and steelhead – one population in the Northwestern California Diversity Group, two populations in the Basalt and Porous Lava Diversity Group, four populations in the Northern Sierra Diversity Group, and two populations in the Southern Sierra Diversity Group.

[2] Need to specify what is potential suitable habitat, perhaps as part of abundance/carrying capacity analysis which is calculating the maximum potential abundance based on habitat carrying capacity under different scenarios that incorporate (a) current habitat and future potential habitat (planned projects), (b) climate change, and (c) flow influence.

[3] For all runs, see table for population-specific targets. For fall run, based on historical information in Yoshiyama et al. (1998) and Lindley et al. (2004). If historical records indicated run was present above current dam and suitable habitat remains, then this is assumed to represent an additional independent population in this target. If suitable habitat does not remain above dam, then this is assumed to represent an additional dependent population in the next target. If historical records indicate a population was small and likely dependent, this recovery effort will not consider moving fish above a dam. For example, because fall-run Chinook salmon on Stony Creek were historically small in abundance relative to populations in major CV rivers and the upstream habitat quantity and quality is likely limited, the rationale for investing in reintroducing fall-run Chinook salmon upstream of Black Butte Dam is also limited.

[4] Minimum goals reflect NMFS down-listing criteria and upper goals reflect historical, independent populations identified in Lindley et al. (2006). At this time, we don't know how many historical, independent populations identified in Lindley et al. (2006) can be re-established, but in Phases 2/3 watershed experts will be able to provide information on feasibility of re-establishing these independent populations and habitat capacity (information on habitat quantity and quality such as fish access to/from habitat, and if there is enough habitat to support a viable, independent population), and with time we'll have a better understanding how well populations respond to recovery actions.

Table 3d. Draft biological objectives, metrics, targets, and time and spatial scales for the viable salmonid population parameter of **diversity**. From the NMFS 2014 recovery plan: diversity refers to trait variation in genetics and life history (e.g., morphology, anadromy, fecundity, spawn timing, distribution patterns, etc.) that occur within and between populations, and the processes that produce those patterns.					
Biological Objectives	**Potential Metrics**	**Potential targets / benchmarks**	**Runs**	**Steelhead**	**Time/spatial scales**
DO1: Recover and preserve genetic diversity of natural populations	• Proportion of hatchery origin spawners (pHOS) • Proportion of natural influence (PNI)	• pHOS < 5% [1] • PNI ≥ 0.67 [2]	• Same for all runs	• Targets apply to steelhead	• Time: annual reporting of pHOS and PNI with a program review at yrs 6, 12, 24, 48 (aligning with other metrics)
	• Genetic effective population size (Ne)	• Ne > 500 - 5,000 [3]	• Same for all runs	• Target applies to steelhead (track both anadromous and resident)	• Same as above
	• Genetic introgression between ESUs	• No greater than "low" (e.g., <2%)	• Population -specific[4]	• Not applicable to steelhead	• Same as above
This row contains information on additional "indicators" for this VSP. Indicators have some relationship to species and population conditions, but they are currently difficult or impossible to quantitatively measure for salmonids.	• Allele frequencies for adaptive genes • Genetic differentiation among populations in the same ESUs (FST)	• Allele frequency: relative to frequency of anadromous/migratory alleles (no decrease from current levels, then increase) • FST: Baseline = 0; target would be some level of differentiation relative to "healthy" salmonid populations)	• Population -specific	• Not applicable to steelhead	• Not discussed

[1] Proportion of hatchery origin spawners (pHOS) is the percentage of hatchery origin fish detected on spawning grounds that is used as an index of genetic introgression, where higher pHOS represents higher genetic risk of hatchery fish on wild populations. Values based on recommendations in the CA Hatchery SRG 2012 review group, section 4.2 on page 34: "Standard 2.5: Natural spawning populations not integrated with a hatchery program should have less than five percent total hatchery-origin spawners (i.e., pHOS less than five percent). Spawners from segregated hatchery programs should be absent from all natural spawning populations (i.e., pHOS from segregated programs should be zero)." This target is aspirational based on current conditions, and it assumes all hatcheries are integrated (this is what the hatcheries themselves are supposed to be striving to achieve). We recognize that some rivers have hatcheries, and some do not.

[2] Proportion of natural influence (PNI) is an index of gene flow rates between hatchery and natural populations, where higher PNI represents lower genetic risk of hatchery fish on wild populations. Values based on recommendations in the Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs 2020 Annual Report (citing HSRG/WDFW/NWIFC 2004): "For the natural environment to dominate selection, PNI should be greater than 0.50, and integrated populations should have a PNI of at least 0.67 (HSRG/WDFW/NWIFC 2004). For the Wenatchee steelhead program, PNI criteria are implemented in accordance with Permit 18583 to achieve a basin-wide, five-year running average of PNI ≥ 0.67. In years when the natural-origin escapement is low (i.e., < 433 fish), the Wenatchee steelhead population will be managed to meet escapement goals rather than PNI."

[3] Based on recommendations from Lindley et al. (2004) for a Ne>500 to support low risk extinction and the CA Hatchery SRG 2012 review group for a N_e>5,000 to allow for mutation and to maintain genetic variation at quasi-neutral loci, section 4.2 on page 34: "To address inbreeding concerns, the California HSRG considered the widely adopted breakpoints for effective population size (Ne>50 to avoid inbreeding depression, Ne>500 to maintain additive genetic variation, Ne>5,000 to allow for mutation and to maintain genetic variation at quasi-neutral loci; Frankel and Soule 1981, Lande 1995) to evaluate the adequacy of the numbers of spawners used or to help develop guidelines for when to consider factorial mating designs." This target reflects the minimum N_e needed to support populations and avoid extinction but also aspirational goals for recovery. N_e will vary by watershed and carrying capacity and we have identified a need to track this metric over time and update appropriate N_e values as we learn more about each watershed and its ability to support salmonids.

[4] This metric may be tracked for all runs. However, the metric may apply specifically to capture issues between spring run and fall run on certain systems (e.g., Yuba and Feather Rivers).

Table 3d. Draft biological objectives, metrics, targets, and time and spatial scales for the viable salmonid population parameter of **diversity**. From the NMFS 2014 recovery plan: diversity refers to trait variation in genetics and life history (e.g., morphology, anadromy, fecundity, spawn timing, distribution patterns, etc.) that occur within and between populations, and the processes that produce those patterns.

Biological Objectives	Potential Metrics	Potential targets / benchmarks	Runs	Steelhead	Time/spatial scales
DO2: Recover and preserve life history diversity of natural populations	• Age distribution of spawning adults	• Min % of each age class of adults ○ Age 4 >35% ○ Age 5+ >20%	• Population -specific (same targets tracked for all runs)	• Not applying to steelhead[1]	• Time: annual • Spatial: by diversity group
	• Variation in juvenile abundance of each life stage (fry, parr, yearling): variation across years	• Min % of each life stage[2] ○ Fry (smaller than 55 mm [2.2 in]): 20% in wetter years and 20% in drier years ○ Parr (larger than 55 mm [2.2 in], smaller than 75 mm [3 in]): 20% in wetter years and 30% in drier years ○ Smolt (larger than 75 mm [3 in]): 10% in wetter years and 20% in drier years	• Population -specific (same targets tracked for all runs)	• Support a range of outmigration dates for life history diversity by measuring smolts (i.e., ≥ 150 mm FL) throughout the season (minimum 4 months of the year)[3].	• Time: annual • Spatial: by diversity group
	• Amount and relative % of available habitat of different types (measured in area and days)[4]	• To be further developed, with a watershed-specific approach.	• To be further developed with a watershed-specific approach[5]	• To be further developed and adapted from Chinook targets with a watershed-specific approach[2]	• To be further developed
	• Adult migration and spawning timing	• To be further developed, with a watershed-specific approach.	• To be further developed with a watershed-specific approach[6]	• To be further developed around spawning timing[7]	• Time: annual • Spatial: by diversity group
These rows contain information on additional "indicators" for this VSP. Indicators have some relationship to species and population conditions, but they are currently difficult or impossible to quantitatively measure for salmonids.	• Adult age distribution in ocean			• Not applicable to steelhead	
	• Rate of anadromy (steelhead-only)			• May be important for assessing steelhead conditions, but information currently lacking for setting targets.	
	• Heterozygosity metrics related to run timing to track (steelhead-only)			• May be important for assessing steelhead conditions, but information currently lacking for setting targets.	
	• Iteroparity and kelt survivorship (steelhead-only)			• May be important for assessing steelhead conditions, but information currently lacking for setting targets.	

[1] Monitoring programs typically do not track age distribution of steelhead, and resident fish are spawning year-round.
[2] Values from Anchor QEA (2019; Table 12, page 75) and were specific to supporting a range of sizes at juvenile migration dates to maintain life history diversity. Values in the report referred to fall and spring run. Without additional information, these are applied to all runs in the Recovery Definition.
[3] Using size criteria for smolts may be problematic to apply across tributaries in the CCV due to varying growth rates. Some smolts may not meet the 150 mm size criteria. Refinements to this length criteria will be made in phase 2 by watershed specific stakeholders based historical size of migration information. Current values adapted from Anchor QEA (2019; Table 18, page 116) that includes outmigration dates for smolts throughout the season. Other metrics and targets were investigated (e.g., min % of each outmigrating age class), but information is currently lacking for steelhead.
[4] Relative area/days of maximum usable habitat for each/across all habitat types; target habitat distributions will consider specific, representative flow conditions/water years. This metric is being further developed. A separate proxy metric is being considered: bathymetry experienced by juvenile fish. This metric could compare hydrologic deviation from an unimpaired hydrograph, with a focus on ecological functional flow dynamics specific to the watershed encompassed within the migratory path for a given population.
[5] In phase 2, watershed specific stakeholders will be providing information on the amount and relative % of available habitat of different habitat types (e.g., habitats related to spawning, rearing, floodplain, migration corridors) measured in area and wetted days.
[6] In phase 2, watershed specific stakeholders will be providing information on the historical timing of adult migration and spawning.
[7] In phase 2, watershed specific stakeholders will be providing information on the historical timing of adult migration and spawning. Targets for spawn timing can be developed from information from Busby et al. (1996): early run, ocean maturing – Dec, Jan, Feb; late run, ocean maturing – Jan, Feb, Mar, Apr, May; American River, ocean maturing – Dec, Jan, Feb, Mar, Apr, May; Feather River, ocean maturing – Nov, Dec, Jan, Feb, Mar, Apr, May, Jun; Mokelumne River, ocean maturing – Dec, Jan, Feb, Mar, Apr.

4 Next steps

The draft Recovery Definition for Central Valley salmonids will continue to be refined and applied during Phases 2 and 3 of this Project. Specifically, salmonid scientists during Phase 1 workshops were able to describe *approaches* for defining specific targets for some objectives/metrics, but they deferred to stakeholders with more local knowledge to provide watershed-specific data to help define appropriate *numerical values* for those watershed-specific targets. Identifying watershed-specific targets will be accomplished during Phase 2 of the Project via information from broader stakeholders across the Central Valley and engagement of watershed experts with the Phase 1 scientists and Project management team in an ongoing science team. Stakeholders will also provide information on habitat availability and current and planned recovery projects that will be used to capture abundance benchmarks based on potential carrying capacity across each watershed. Lastly, the draft Recovery Definition objectives and targets will be used in Phase 3 of the Project during the SDM process. That process will engage multiple stakeholders across the Central Valley to identify potential management alternatives and predict the degree to which those alternatives achieve salmonid objectives in the draft Recovery Definition. Targets and benchmarks identified in the draft Recovery Definition will be important reference points for tracking how well different management alternatives are predicted to achieve salmonid recovery. Ultimately, the collaborative SDM process in Phase 3 will allow multiple parties to discuss expected tradeoffs between salmonid recovery and other social, cultural, economic, and ecological values and identify preferred management actions and recommendations for achieving salmonid recovery. At the conclusion of the Project, the anticipated result is an effective, broadly supported, and implementable strategy describing a suite of integrated actions that achieves or promotes achievement of the objectives and targets in the final (non-draft) Recovery Definition for Central Valley salmonids and that can be used to guide coordinated conservation efforts in the region.

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Appendix 1 – Evolution of Recovery Definition elements through Phase 1

Table A1. Evolution of selected elements of the Recovery Definition for salmonids in California's Central Valley that were developed by salmon scientists through Phase 1 of this project.

VSP / category	Early version	Final version	Rationale
Abundance – objectives	**AO1:** Abundance sufficient to achieve/ support: ● Low Extinction Risk ● Viability ● Abundance of natural origin: 1) juvenile outmigrants, 2) adults in ocean, and 3) adult spawners given a) carrying capacity of suitable habitat; Viability (attainment of other VSP parameters) ● Full range of ecological roles including regenerative ecosystem services ● Healthy and well-regulated commercial/recreational salmon fishery ○ Abundance needed to hit MSY based on broad-sense recovery	**AO1:** Abundance sufficient to achieve/ support: ● Low Extinction Risk ● Viability ● Abundance of natural origin: 1) juvenile outmigrants, 2) adults in ocean, and 3) adult spawners, given carrying capacity of suitable habitat ● Full range of ecological roles including regenerative ecosystem services ● Healthy and well-regulated commercial/recreational salmon fishery and recreational steelhead fishery	The group supported removing the sub-bullet point ("Abundance needed to hit MSY") from the objective, believing that the language is too prescriptive to fisheries, and the Fishery Management Council can set regulations needed to achieve abundance that supports a healthy fishery. This illustrates the group's focus on salmonid science in this phase, while values related to fisheries and other interests will be explored in later phases through a structured decision making process.
Abundance – metrics	● Abundance relative to carrying capacity ○ Spawning adults ○ Holding adults ○ Rearing juveniles ● Abundance relative to human harvest ● Abundance relative to supporting orca populations and ecosystem services	● Abundance relative to carrying capacity (at the population and ESU scale): ○ Spawning adults ○ Holding adults ○ Rearing juveniles ● Fish in/fish out (for each life stage) ● Fish caught (e.g., harvest)	The concepts of the previous metrics (2nd and 3rd bullet points) were sufficiently captured by the language of the objective and potential targets. The new metrics of fish in/out/caught by life stage inform where any population bottlenecks are (e.g., high mortality of outmigrating juveniles). This illustrates the group's striving to balance consolidating ideas while capturing key complexities.
Abundance – targets (for the metric: Abundance relative to carrying capacity)	None	● No potential targets, but rather we will be defining ecological benchmark(s) – capturing maximum potential abundance based on habitat carrying capacity under different scenarios – that will be used to inform the SDM process to assess different combinations of management actions.	The group initially struggled with defining recovery targets for abundance that were defensibly based in science (and not values). The group decided to structure this "target" as a set of "ecological benchmarks" using the NMFS target for de-listing as a minimum benchmark and abundance (carrying capacity) estimates under current and potential habitat as higher benchmarks for

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		● Benchmarks will be measured in 5 year (reflecting ~1 generation) geometric mean	recovery. The group agreed that estimates of potential habitat and carrying capacity should explicitly account for climate change scenarios. The structured decision making process in Phase 3 will evaluate outcomes of different management alternatives along this set of abundance benchmarks while discussing any tradeoffs with other salmon recovery objectives and non-salmonid interests in the Central Valley.
Productivity – objectives	● Productivity is sufficient to support viability (as defined by VSP guidelines) and broad-sense recovery ● Broad trajectory of populations: Achieve population growth rates that minimize probability of near-term extinction and maximize probability of longer-term population growth and stability ● Population resiliency: Ensure populations are resilient to episodic / catastrophic events ● Juvenile focus: Maximize juvenile production, survival ● Population productivity to support other objectives: Achieve productivity beyond carrying capacity to ensure ecological functions and no net impacts of human use (e.g., harvest, recreational use)	**PO1:** Productivity is sufficient to support viability (as defined by VSP guidelines) and broad-sense recovery	The group heavily consolidated earlier ideas for productivity objectives, choosing to create a single, holistic objective and move many of the earlier ideas to be captured as metrics in the final Recovery Definition.
Productivity – metrics	● Intrinsic productivity (juveniles produced/adult spawner) ● CRR ● Escapement trend ● [Resilience?]	● CRR (Cohort Replacement Rate, of natural-origin fish) ● r (intrinsic growth rate, in B-H model) ● Surplus/replacement (B-H) ● K (carrying capacity, in B-H model) ● Population growth rate	The group refined and included additional productivity metrics over the course of Phase 1. The group agreed to use multiple metrics from population and stock-recruitment models to track different drivers of overall productivity (e.g., intrinsic growth rates, harvest). This illustrates the

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			importance of capturing key complexities around measuring productivity that can inform management.
Productivity – targets (for the metric: CRR)	● CRR > 1 ● No CRR < 1 (3 yr avg) ● No decline/Positive escapement trend (see Lindley et al criteria) ● Increasing intrinsic productivity (initially) ● Coefficient of variation in year-to-year productivity (e.g., CRR), abundance ● [Life-stage specific targets?]	● Until near-term recovery goal is met: CRR > 1 (3-yr geometric mean), to account for variability in conditions ● After recovery goal is met: no CRR < 1 (3-yr geometric mean)	The group refined productivity targets to vary temporally (i.e., different target levels for a short-term rebuilding phase followed by a long-term recovery phase), as well as allow them to interact with abundance.
Spatial structure – objectives	**SO1:** Spatial structure for population redundancy and representation ● **SO1.1:** Populations that are at low risk of extinction within each spatial unit (e.g., diversity group, watershed) ● **SO1.2:** Populations are present in multiple diversity groups **SO2:** Maximize number of historical wild populations (want multiple poplns) **SO3:** Spatial structure for population resiliency: ● **SO3.1:** Ensure adequate abundance in adjacent populations for recolonization and straying. ● **SO3.2:** Increase and support localized adaptation	**SO1:** For each ESU, recover and preserve spatially-explicit, independent populations that are sufficient to support redundancy* and representation** in order to: ● Maintain natural straying rates among populations ● Source pops should be maintained to support colonization through dispersion and straying ● Maintain spatial structure processes needs to also take uncertainty into account ● Support local adaptation *Species is able to withstand catastrophes and environmental variation by having multiple populations with a diversity group. **Species is distributed such that the full breadth of its genetic diversity and ecological roles is captured.	The group heavily refined and consolidated early versions of spatial structure objectives. Early versions of SO1 and SO2 were combined into one objective focused on redundancy and representation; SO3 was sufficiently captured by the life history diversity objective (DO2) and removed as a spatial structure objective.

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VSP / category	**Early version**	**Final version**	**Rationale**
Spatial structure – metrics	• [Floor] Number of populations at low risk of extinction per spatial unit *(temporal aspects – e.g., rate of decline within some period of time)** • Area-based metric for # of groups • # of populations in distinct spatial units (ESU/ DPS) • Could be based off % of historical extent / area occupied – stratified by diversity group • # of populations in distinct spatial units • Geographic distance (Euclidean) and/or environmental dissimilarity mirrors the genetic distance and/or dissimilarity among poplns measured by FST / GST • Maintain diversity of genetics are available now (e.g., battle creek groups,) – single nucleotide polymorphisms? • Natural origin fish • Stray rates • % of tributaries where there were wild populations (historically) • Frequency and duration of access to habitats (e.g. floodplains, rearing, migratory corridors, etc.) • A range of suitable habitat / Ensure Access / variability of suitable habitat across space and time • Effective popln size	• # of independent, viable populations in each diversity group per ESU • # of dependent populations in each diversity group • California Central Valley DPS (steelhead-only)	The group heavily consolidated earlier ideas for spatial structure metrics. Reasons for consolidation included: removing metrics that were believed to be difficult to define, measure, and monitor (e.g., stray rates); removing metrics that were adequately captured in other VSPs (e.g., maintain diversity of genetics, natural origin fish); and converting metrics into the approach for defining the final set of metrics and targets (e.g., [Floor] Number of populations at low risk of extinction and area-based metric for number of groups).

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Spatial structure – targets (for the metric: Number of independent viable populations)	● 1) define the number of historical, independent, viable populations for which there is still sufficient potential suitable habitat*/the possibility of them existing (being housed somewhere) and being viable (factoring in climate change) ○ Need to specify what is potential suitable habitat (perhaps as part of abundance/carrying capacity analysis) ● 2) We prioritize/ set as a minimum. ○ a) recovery (our version – attainment of all of our objectives) of the populations specified in the NMFS recovery plan (for listed species/diversity groups), and ○ b) recovery (our version) of all potential independent, viable populations for non-listed species/diversity groups.	● For listed species/diversity groups: Independent, viable populations identified in the NMFS recovery plan (for listed species/diversity groups until point of de-listing) ● For all species/diversity groups: Historical, independent, viable populations for which there is sufficient suitable habitat to support continued viability remains	The group recognized that NMFS recovery targets for the number of independent, viable populations could serve as a useful minimum for listed species targets. However, setting higher targets for listed and non-listed species may be a values-based decision (similar to the issue of setting abundance targets). The group agreed on a science-based approach, similar to that used for the abundance targets, where minimum targets are defined by the NMFS recovery plan (for listed species) and the SIT model (for non-listed species), and maximum targets are defined by potential future habitat under restoration and climate change scenarios. This approach aligns with the methods used for abundance targets, incorporates potential effects of climate change when defining targets, and illustrates adapting components of the Recovery Definition to different salmonid runs.
Diversity – objectives	**DO1:** Recover and preserve genetic diversity of natural populations: ● **DO1.1:** Hold genetic introgression below certain threshold over time ● **DO1.2:** Reduce domestication selection within runs ● Genetic diversity for Central Valley Population resiliency **DO2**: Maintain adaptive capacity/capability **DO3:** Recover and preserve life history diversity of natural populations: ● **DO3.1:** Max. resistance and resilience to uncertain/variable/ changing conditions	**DO1:** Recover and preserve genetic diversity of natural populations **DO2:** Recover and preserve life history diversity of natural populations	The group consolidated earlier objectives around two final objectives that made a distinction between evolutionary (DO1: genetic diversity) and ecological (DO2: life history diversity) time scales. The group agreed that the concepts of the earlier objectives were sufficiently captured in metrics/targets within final objectives for Diversity, as well as Productivity (e.g., DO3.1) and Abundance (e.g., DO3.2).

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	● **DO3.2:** Max. ecosystem services & ecological role of salmon *Different opinions were expressed regarding the genetic diversity objective, including if it is important on its own vs. only important as a means to life history diversity and pop resilience.		
Diversity – metrics (DO1)	● % introgression over time (see Lindley paper, Fig 1) ● Heterozygosity metrics (need to consult other genetics research) ● Allele frequencies for adaptive genes (in some cases presence/absence) ● Effective population size (from spatial structure S05 above) ● Genetic differentiation within populations in the same ESUs (baseline = zero, target would be some level of differentiation, metric= FST)	● Proportion of hatchery origin spawners (pHOS)/ Proportion of natural influence (PNI) ● Genetic effective population size (Ne) ● Genetic introgression between ESUs	The group removed some earlier metrics from the final Recovery Definition but captured these ideas in this documentation, as they are important for salmonid diversity and may warrant more development of research and monitoring programs (e.g., heterozygosity metrics, allele frequencies). The final set of metrics are well-supported and commonly used in salmonid studies and recovery plans and are sufficiently straightforward for communication of the Recovery Definition.
Diversity – metrics (DO2)	● Coefficient of variation in juvenile abundance of each life stage (fry, parr, yearling) across years ● Alt version: Coefficient of variation in juvenile size (measured at different locations and time intervals) ● Juvenile size, timing, location: rearing timing, emergence timing, migration timing, life stage transition timing ● Resistance (and resilience): need metric that captures consistency over time ● Measures common to biodiversity (richness and evenness) – may need to specify the highest achievable diversity numbers for context ● Nutrient subsidies and cycling ● Adult (in ocean)	● Age distribution of spawning adults ● Variation in juvenile abundance of each life stage (fry, parr, yearling): variation across years ● Amount and relative % of available habitat of different types (measured in area and days) ● Adult migration and spawning timing	The group consolidated earlier ideas for life history diversity metrics. Reasons for consolidation included: removing metrics that were more indirectly linked to life history diversity (e.g., predator and nutrient monitoring) when more direct metrics were available; and removing metrics that were adequately captured in other VSPs (e.g., adults in ocean). The final set of metrics captured concepts of the portfolio effect that is influenced by year-to-year variability and effects of future climate change.

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	● Predator monitoring ● Benthic invertebrate communities to gauge productivity of systems ● Age distribution of spawning adults ● Adult age distribution in ocean (Chinook, only hatchery fall-run) ● Rate of anadromy (steelhead)		
Diversity – targets (DO1) (for the metrics: pHOS and PNI)	● None	● pHOS < 5% ● PNI ≥ 0.67	The group relied on existing targets and guidelines from the CA Hatchery SRG (2012) and the Monitoring and Evaluation of the Chelan and Grant County PUDs Hatchery Programs 2020 Annual Report). The group reviewed these studies and extracted values for many targets in sub-group work following the second workshop series.
Diversity – targets (DO2)	● Min % of each size class (life stage) of juveniles (look at SEP) ● Shannon diversity $H = -\sum[(pi) * \ln(pi)]$ ● Evenness $E = H / \ln(k)$	● Min % of each age class of adults ○ Age 4 >35% ○ Age 5+ >20%	The group structured targets around a min % of each size class rather than diversity/evenness for ease of communication of the Recovery Definition. The group agreed that minimum %s should be set on the low end to not be overly prescriptive and to represent thresholds for avoiding bad outcomes.

Appendix 2 – Workshop participants in Phase 1 workshops

Participants, observers, and presenters (note: this is not complete; * indicates limited engagement)

- Ann Marie Osterback (National Oceanic and Atmospheric Administration)
- Brad Cavallo (Cramer Fish Sciences)
- Brett Harvey (California Department of Water Resources)
- Brian Ellrot (National Oceanic and Atmospheric Administration)
- Bruce Herbold
- Carl Wilcox (California Department of Fish & Wildlife)
- Cathy Marcinkevage (National Oceanic and Atmospheric Administration)
- Chuck Hanson (Hanson Environmental)
- Erin Foresman (California State Water Resources Control Board)
- John Ferguson (Anchor QEA)
- Josh Israel (U.S. Bureau of Reclamation)
- Julie Zimmerman (The Nature Conservancy)
- Kate Spear (National Oceanic and Atmospheric Administration)*
- Matt Dekar (U.S. Fish & Wildlife Service)
- Megan Cook (U.S. Fish & Wildlife Service)*
- Michael Macon (California State Water Resources Control Board)*
- Mike Beakes (U.S. Bureau of Reclamation)
- Noble Hendrix (QEDA Consulting)
- Pascale Goertler (Delta Science Program)
- Patty Dornbusch (National Oceanic and Atmospheric Administration)*
- Rachel Johnson (National Oceanic and Atmospheric Administration)
- Sam Luoma (University of California, Davis)*
- Stephen Louie (California State Water Resources Control Board)*
- Steve Lindley (National Oceanic and Atmospheric Administration)

Facilitators & support

- Brian Crawford (Compass Resource Management)
- Bruce DiGennaro (Essex)
- Lindsay Tryba (Kearns & West)
- Michael Harstone (Compass Resource Management)
- Rafael Silberblatt (Kearns & West)

Project Planning Team

- Alison Collins (also participant: Metropolitan Water District of Southern California)
- Frances Brewster (Santa Clara Valley Water District)
- Gary Bobker (The Bay Institute)
- Natalie Stauffer-Olsen (also participant: Trout Unlimited)
- Rene Henery (also participant: Trout Unlimited)

Appendix 3 – References relating to example recovery frameworks

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