Appendix B

Report on Defining and Alleviating Stressors to Meet Program Objectives and Stressor Ranking Figures - December 28, 2016

SAN JOAQUIN RIVER RESTORATION PROGRAM

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Defining and Alleviating Stressors to Meet Program Objectives

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1.1 Introduction

1.1.1 The Function of Stressor Identification and Ranking

Stressors (also known as *Limiting Factors*) are conditions (physical, biological or ecological) within the system that limit or inhibit the attainment, existence, maintenance, or potential for desired conditions, as characterized by the biological and environmental objectives. Because different objectives are already being achieved to different degrees under existing conditions, identification of stressors is critical in order to:

a) highlight components of desired conditions that are not being achieved, and to
b) identify the specific obstacles (i.e., stressor(s)) inhibiting desired conditions.

As a complement to this, ranking stressors further:

c) enables the development of specific actions to achieve desired conditions by resolving stressors as well as,
d) facilitates the prioritization and sequencing of those actions to maximize benefits by addressing the most significant stressors first.

In cases where other prioritization considerations (e.g., financial, political, etc.) prevent stressors from being addressed in order of importance, stressor ranking also helps to correctly set expectations about the extent of progress towards desired conditions that a given action will achieve, and/or the suite and scale of actions necessary to achieve or make progress towards desired conditions.

1.1.2 Stressor Ranking Approach

The process for identifying and ranking stressors includes the following four key steps:

1. **Identification of the range of stressors affecting each life history stage.**
   For each life stage, stressors that limit the success of that life stage were identified (e.g., lack of suitable holding habitat for migrating adult salmonids). Stressors, or drivers of stresses, were framed in terms of parameters specified in Environmental Objectives (e.g., temperature and DO). Stressors not specifically addressed in the objectives that could impact Biological or Environmental Objectives were also included (e.g., predation). In some cases, stressors may be interrelated both for a given life history stage (as when two lower magnitude stressors cumulatively result in a third higher magnitude stressor) or across life history stages (as when a stress to one life history stage results in a different stress to one or more subsequent life history stages).

2. **Assignment of stressors for each life history stage as relevant to current and future scenarios.**
   Stressors were considered as relevant to 1) current population levels and conditions, 2) target population levels and conditions, or 3) both.
   - In the first case, the stressor affects the species or ecosystem under current conditions, and/or at the current species population levels.
   - In the second case, the stressor, although not currently impacting populations or ecosystem conditions, is predicted to become impactful once Program actions have been implemented and populations approach abundance targets; when ecosystem

conditions have made progress towards desired conditions by virtue of Program actions; or as a function of some other trend, transition, or tipping point occurring in the future.

- In the third case, a stressor is currently having an impact on the species, and it is expected that the magnitude or nature (e.g., scale and predictability) of that impact will change as Program actions are implemented, population abundance increases, and or progress towards Environmental Objectives is made.

Because the SJRRP program area is anticipated to be significantly impaired until Program actions and projects have been implemented, stressors identification and assignment focused primarily on the second and third cases. Of particular interest were a) stressors that would need to be resolved through time, via program actions in order for population recovery to occur, and b) stressors anticipated to continue to affect the population even once Program actions had been implemented, and/or for which program actions had not been identified.

3. **Scoring of coarse scale stress and component fine scale stressors, by life history stage for current conditions and target of future conditions as applicable.**

   Stressors are assigned a score of 1 to 4 points (1 being lowest and 4 being highest) in two categories: magnitude and certainty. Magnitude scores are based on the scale and severity of the impact to populations from the stress. Certainty scores are based on the understanding of a stressor's related impact as a function of the available information base as well as the predictability of that impact. In combination, magnitude and certainty scores generate an overall score, guide stressor ranking, and provide indication about the appropriate stressor response. Although stressors are scored separately for each life history stage, score definitions for magnitude and certainty are common to all life history stages, allowing for ranking of stressors across life history stages.

4. **Stressor ranking and prioritization across life history stages.**

   Once scored, stressors for individual life history stages are combined for each of the two runs (fall-run Chinook salmon and spring-run Chinook salmon). Stressors are then sorted and ranked based on their magnitude and certainty scores, and assigned a stressor response type also based on scoring. In addition to the severity of the stress, a high magnitude score indicates the potential need for a major action, depending on certainty. A low magnitude score, depending on certainty, suggests a need for either 1) monitoring to ensure the magnitude does not increase, or 2) research to confirm the low magnitude score and potentially inform adaptive management. Because stressor ranking is intended to guide and prioritize the development of actions to advance objectives and achieve desired conditions, stressors with high magnitude and high certainty are considered the highest priority.

1.1.3 Stressor Identification

The SJRRP identified stressors by examining the Environmental Objectives for each life stage and identifying the following:

- Which Environmental Objectives were not being achieved under current conditions,
- Any aspects of Biological Objectives that were not being achieved under current conditions and would not be addressed by meeting the Environmental Objectives, and

- What the anticipated outcomes of identified SJRRP projects and actions are (to the extent they are known/understood) relative to environmental Objectives and Biological Objectives.

In many cases, a stressor is directly related to an Environmental Objective. For example, the lack of suitable migratory temperatures for spring-run Chinook salmon is a stressor that is directly related to the Environmental Objective for spring-run adult migration. However, in other cases, a stressor is a category that may encompass multiple Environmental Objectives. For example, lack of suitable migratory conditions for fall-run Chinook salmon can result in a stress for the juvenile rearing and migration life stage if late emergence limits their migration window and affects their exposure to other conditions specified in the objectives as critical for their success including suitable water quality, flow, habitat, and predation levels. In general, the SJRRP (Fisheries Management Team and TAC) used expert opinion to identify stressors that the group felt prevented attainment of Environmental Objectives and Biological Objectives in the Restoration Area. The collective knowledge and experience of the SJRRP was used to develop a comprehensive list of stressors. The process of stressor scoring and ranking was informed and supported by the quality and quantity of existing information (data and literature).

1.1.4 Assignment of Stressors to Current and Future Conditions

Program biologists assigned stressors according to the potential to achieve Biological Objectives under current conditions, and at the end of each 5 year vision defined in the Program's Revised Framework for Implementation completed in July 2015. The assumption that the population would grow over time as restoration actions are completed implied that habitat requirements would be greater than under current conditions and sufficient to support population goals for the SJRRP.

1.2 Stressor Scoring

1.2.1 Scoring Framework Adapted from DRERIP

The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), the first of four regional plans intended to implement the CALFED Ecosystem Restoration Program (ERP) developed specific guidance for the evaluation of actions and stressors to evaluate performance evaluation and guide adaptive management (http://www.dfg.ca.gov/erp/scientific_evaluation.asp). The DRERIP includes a scoring framework for ranking the effect of different actions to achieve an objective. The framework applies magnitude and certainty scores as a basis for a balanced ranking sensitive to spatial and temporal scale. The stressor ranking presented here applies an adapted version of the DRERIP framework, leveraging the same balanced and replicable approach to scoring, but with minor modifications to accommodate the application of the framework to the ranking of stressors limiting desired conditions as opposed to actions to achieve them. This stressor scoring and ranking approach was first developed for use on the Stanislaus River by the San Joaquin Tributaries Science Evaluation Panel (SEP 2016).

1.2.2 Key Concepts and Terminology

Magnitude

Magnitude assesses the size or level of the impact from a stressor. Magnitude can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale or extent.

Certainty

Certainty describes the scientific basis for scoring the scale and magnitude of a particular stressor. Certainty considers both the predictability and understanding of linkages in the driver-linkage-outcome (DLO) pathway from the stressor to the impact.

Other Key Components of Scoring

The terms *importance*, *predictability*, and *understanding* are used in the magnitude and certainty scoring definitions to characterize conceptual model linkages between a driver (i.e. stressor) and an outcome (stress).

Importance – The degree to which a stressor-stress linkage controls the outcome or impact relative to other stressors and linkages affecting that same outcome. The stressor analysis was designed to encompass all known potential stressors, linkages and outcomes, but this concept recognizes that some are more important than others in determining how the system works.

Predictability – The degree to which the performance or the nature of the outcome can be predicted from the stressor. Predictability seeks to capture the variability in the stressor-stress relationship. Predictability can encompass temporal or spatial variability in conditions of a stressor, variability in the processes that link the stressor to the outcome or variability in our level of understanding about the cause-effect relationship. Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a stressor.

Understanding – A description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single stressor and a single outcome (i.e., stress). Understanding may be limited due to lack of knowledge and information, due to disagreements in the interpretation of existing data and information, because the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms, or because conflicting results have been reported. Understanding should reflect the degree to which the stressor analysis and scoring does, in fact, represent conditions in the system.

1.2.3 Specific Scoring Criteria

Criteria for Scoring Magnitude

*4 - **High***: Expected sustained major population level effect, e.g., natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics.

*3 - **Medium***: Expected sustained minor population effect or effect on large area (regional) or multiple patches.

*2 - **Low***: Expected sustained effect limited to small fraction of a population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.

*1 - **Minimal***: Little effect.

Criteria for Scoring Certainty: Understanding and Predictability

Scoring for *Certainty* hinges on the level of a) *Understanding*, b) *Predictability*, and to a lesser extent c) *Importance*. Certainty is based on the *Understanding* score, modified (shifted up or down) by the associated predictability that accompanies that understanding. A visual depiction of this is provided as Figure 1. Matrix depicting certainty scoring based on a combination of understanding and predictability

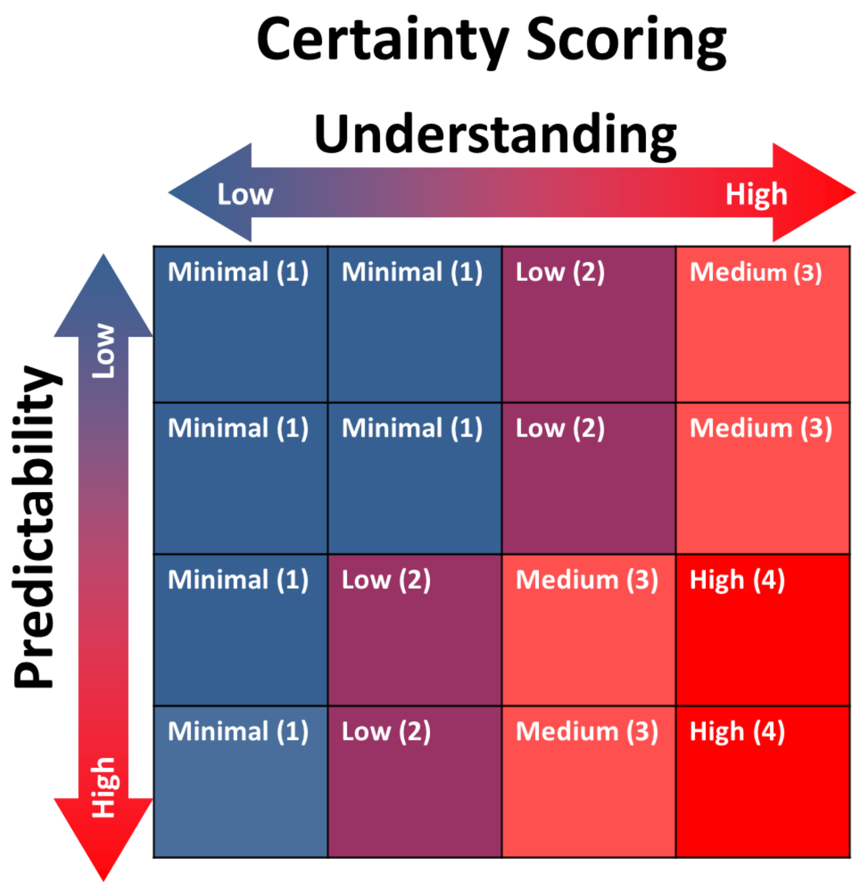

Figure 1. Matrix depicting certainty scoring based on a combination of understanding and predictability.

Scoring Understanding - as a component of Certainty scoring

Understanding is ***High*** based on:

- Near-term condition
  Either:
  a. Recent (i.e., within the last 10 years) and robust (e.g., multiple years spanning wet and dry conditions) agency data on the system for the stressor/variable of interest, **or**
  b. More than one peer-reviewed papers of conditions on the system from within the last 20 years generally support the score.

- Long-term condition
  In general, future conditions are expected to be less certain than the near-term condition (because data or published papers are not yet available). A "high" certainty in the long-term is warranted when:
  a. There is an established (high understanding per above) trend suggesting that the near-term conditions are highly likely to maintain the certainty over the next 20+ years, **or**
  b. There is a well-understood relationship between increased abundance of salmonids (the operating assumption of the "long-term" condition) and the certainty of the stressor.

Understanding is ***Medium*** based on:

- Near-term condition
  Either:
  a. Agency data on the system for the stressor/variable of interest, but the data are not as recent and/or not as abundant/robust as described for the “high” score, **or**
  b. One peer-reviewed paper from the scientific literature and/or grey literature reports on the system from multiple disparate sources (i.e., different projects, not periodic interim reports from the same project) from within the last 20 years generally support the score.

- Long-term condition
  A “medium” certainty in the long-term is warranted when:
  a. There is some evidence suggesting that the near-term conditions are highly likely to continue or to increase the certainty of the score over the next 20+ years, **or**
  b. There is evidence to suggest a relationship between increased abundance of salmonids in the system (the operating assumption of the “long-term” condition) and the certainty of the stressor.

Understanding is ***Low*** based on:

- Near-term condition
  No recent or robust data available and score is supported by one scientific grey literature report on the system from within the last 20 years.

- Long-term condition
  There is little or no evidence suggesting that the near-term conditions are predictive of conditions 20+ years into the future and little evidence suggesting that increases in salmonid abundance will make the stressor score more certain in the future.

<u>*Scoring Certainty*</u>

4 - ***High***:

- Understanding is high, and
- Nature of outcome (i.e., stress) is a) predictable (i.e., largely unconstrained by variability in ecosystem dynamics, other external factors), or b) is expected to confer effects under conditions or times of greatest importance (i.e., control over the outcome relative to other drivers and linkages affecting that same outcome).

3 - ***Medium***:

- Understanding is high (see scoring for 4) but nature of outcome is somewhat unpredictable
  or
- Understanding is Medium and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics, other external factors.

2 - ***Low***:

- Understanding is Medium but nature of outcome is somewhat unpredictable
  or
- Understanding is low and nature of outcome (i.e., stress) is predictable (i.e., largely unconstrained by variability in ecosystem dynamics or other external factors).

1 - ***Minimal***:

- Understanding is lacking **or**
- Understanding is low and nature of outcome (i.e., stress) is unpredictable (i.e., greatly dependent on highly variable ecosystem processes or other external factors).

1.3 The Application of Stressors to Stressor Response Prioritization and Planning

Stressor prioritization is a function of the combination of scores for a) Magnitude and b) Certainty. Scores in these categories not only combine to produce the overall stressor ranking, but also provide information insight into the appropriate stressor response where:

- High Magnitude → Action
- Low Magnitude → No Action
- High Certainty → Monitoring
- Low Certainty → Research

In combination, magnitude and certainty scores reveal even greater detail about appropriate stressor response and prioritization where:

- High Magnitude + High Certainty → High priority Action response
- High Magnitude + Low Certainty → High priority Research response
- Low Magnitude + High Certainty → Low priority Monitoring response
- Low Magnitude + Low Certainty → Low priority Research response

Additionally, upper mid-range certainty scores, while still strong enough to warrant action (as opposed to research), indicate the likely need for adaptive management of the action and/or subsequent associated actions in order to achieve the desired stressor reduction. Similarly, low mid-range certainty scores indicate a high research priority with a focus on clarifying the design of specific action(s) to respond to and resolve the stressor. Figure 2 presents the full range of stressor responses associated with different Magnitude and Certainty score combinations.

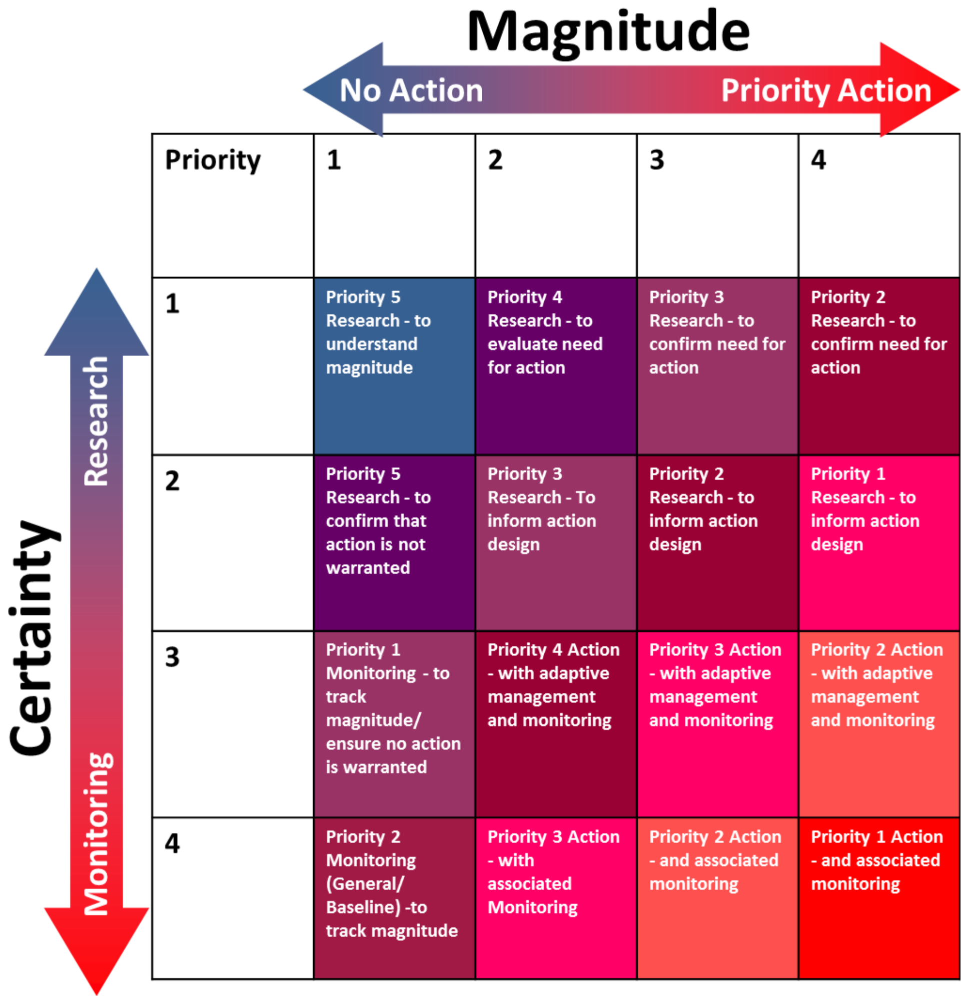

Figure 2. Stressor response priorities based on combined magnitude (horizontal) and certainty scores (vertical).

To develop the overall stressor response prioritization for each species, stressor magnitude and certainty scores for all life history stages were combined. Stressor response priorities were then assigned. The results of this synthesis are summarized at the end of this chapter.

1.4 Summary and Prioritization of Stressors, Program Actions Addressing Stressors, and Anticipated Additional Stressor Response Needs

1.4.1 Introduction

This section summarizes the results of stressor analyses for each of the target species, across life history stages. As introduced in Chapter 3, Section 3.2 Stressors, stressor priorities were assigned for individual life history stages, based on the combination of *magnitude* and *certainty* scores. Because scores in these categories were applied consistently, using the adapted DRERIP methodology, specific stressor scores are comparable across life history stages for a given species. With this in mind, stressor priorities have been presented here, summarized across life history stages for fall-run Chinook salmon and spring-run Chinook salmon.

All stressors included in the analyses for the different species/life history stages are considered significant and of concern to the species/life history stage to which they have been assigned. However, in order to facilitate the application of the stressor analysis to a) understanding how SJRRP projects and actions are anticipated to relieve stressors through time, and b) additional needs for development and/or sequencing of Program actions to alleviate stressors, the stressors have been:

- Prioritized and grouped according to a suite of combined magnitude and certainty score-based stressor responses in the broad categories of 1) *Action*, 2) *Research*, and 3) *Monitoring* (see Stressor Introduction).
- Mapped with SJRRP Framework for implementation actions.

The analysis identifies stressors with both a high magnitude and certainty as the highest priority for response, in the form of conservation *Action(s)* that will resolve the stressors and support attainment of the environmental objectives. The analysis further defines lower priority actions as those with a lower magnitude, but also with a high degree of certainty. Stressors with a High magnitude, but a lower degree of certainty are considered the highest priority for *Research*, with other research priorities falling in below based on their relative magnitude scores. Low magnitude stressors are prioritized under baseline monitoring needs, where higher certainty indicates a higher priority for monitoring, principally to ensure that the magnitude does not increase.

Stressors are then mapped to SJRRP projects and actions that it is anticipated will resolve them and achieve desired conditions. Stressors for which there is not currently an anticipated resolution via a Program action or projects are specifically highlighted and ranked based on stressor priority.

While the stressor analysis prioritizes stressors linearly, this presentation is not meant to imply that stressor responses need to be carried out in the presented sequence in order to be effective. Stressor responses of different priorities can, in many cases, be addressed in parallel or simultaneously. Additionally, the potential suite of actions necessary to resolve a single stressor may partially or completely resolve other stressors. There are also a number of non-biological considerations (physical, political, financial) that influence the timing and sequence of SJRRP projects and actions as identified in the Framework for Implementation. However, the stressor prioritization is designed to provide guidance around a) which stressors are of greatest biological impact to the species, b) how, in the case where not all stressors can be addressed at once, actions should be optimally sequenced for greatest biological benefit, and c) what expectations for biological response are appropriate given the state of project implementation, and associated stressor resolution and environmental objective attainment.

1.5 SJRRP Stressor Scoring Results

The fish biologists working on the program identified and ranked a set of 31 potential stressors (Table 1) following the process described above. These stressors are described as limiting factors in Exhibit A of the Fisheries Management Plan (SJRRP 2010a).

As described above, the magnitude and certainty rankings were combined into a priority response score for each stressor. For this exercise, the priority response scores are shown for the 2030 and beyond time period for each life stage to help elucidate the degree of confidence by respondents that projects scheduled in the Program's Framework for Implementation will resolve stressors for establishing self-sustaining runs of fall-run and spring-run Chinook salmon. Although this later period is focused on for the analysis, actions based on the responses would be expected to take place prior to 2030 for most stressors. Research to inform action design or to refine understanding of a stressor should be implemented in a timely manner to ensure consistent progress towards meeting the Restoration Goal and should be consistent with timelines in the Program's Framework for Implementation.

Table 1. Average stressor magnitude and certainty scores for spring-run and fall-run Chinook.

	Current-2019				2020-2024				2025-2030				2030+			
	Magnitude		Certainty		Magnitude		Certainty		Magnitude		Certainty		Magnitude		Certainty	
	SRC	FRC	SRC	FRC	SRC	FRC	SRC	FRC	SRC	FRC	SRC	FRC	SRC	FRC	SRC	FRC
Adult Migration																
Inadequate flows	4.0	3.9	4.0	4.0	3.1	2.6	2.9	3.3	2.0	2.0	2.1	2.4	1.7	2.1	1.1	2.0
High water temperatures	3.9	1.7	3.0	3.1	4.0	1.9	2.7	3.0	3.1	1.7	2.1	2.4	3.1	1.7	1.9	2.3
Physical barriers	4.0	4.0	4.0	4.0	2.9	2.9	2.6	2.6	1.6	1.9	2.4	2.0	1.4	1.6	2.4	2.0
False Pathways	3.9	3.7	3.1	3.6	2.9	3.1	2.6	3.0	2.4	2.7	2.1	2.7	1.7	1.7	2.4	2.6
In-river harvest	2.3	2.1	1.9	1.9	2.3	2.1	1.7	1.7	1.9	1.7	1.9	1.9	1.7	1.6	1.9	1.9
Adult Holding																
Habitat quantity	1.4	1.2	2.9	3.4	1.4	1.2	2.7	3.6	1.4	1.2	2.7	3.4	1.4	1.2	2.7	3.2
High water temperatures	2.1	1.0	3.0	3.5	2.0	1.0	2.9	3.3	2.0	1.0	2.6	3.0	2.0	1.0	2.6	3.0
Disease	2.0	1.4	2.3	2.8	2.0	1.4	2.0	2.6	2.0	1.4	1.9	2.4	2.0	1.4	1.7	2.4
Predation	1.3	1.2	2.9	3.4	1.3	1.0	2.7	3.2	1.1	1.2	2.7	2.8	1.1	1.2	2.7	3.0
Harvest	2.0	1.6	2.3	2.4	2.0	1.6	2.0	2.2	2.0	1.6	1.9	2.0	1.9	1.6	1.9	2.2
Spawning																
Low spawning gravel-quality	3.0	2.9	2.0	2.4	3.0	2.9	1.9	2.3	2.9	2.7	1.6	1.9	2.6	2.6	1.6	1.7
Insufficient spawning site quantity	1.6	1.7	3.0	3.1	1.7	1.9	2.6	2.6	2.0	2.0	2.1	2.1	2.4	1.9	2.1	2.1
High water temperatures	2.3	1.6	2.4	2.7	2.3	1.6	2.3	2.4	2.1	1.6	2.3	2.1	2.1	1.6	2.1	2.1
Hybridization between runs	1.6	1.4	3.1	3.1	1.7	1.6	2.0	2.0	2.1	2.0	2.0	2.0	2.1	2.0	1.9	1.9
Instream flows	2.0	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	2.0	2.0	2.0	1.9
Egg survival and Emergence																
Excessive sedimentation	2.4	2.3	1.7	2.0	2.4	2.3	1.7	1.9	2.4	2.3	1.6	1.7	2.3	2.1	1.6	1.7
High water temperatures	2.9	2.4	2.3	2.7	2.9	2.3	2.3	2.6	2.7	2.1	2.3	2.3	2.7	2.1	2.3	2.3
Redd Superimposition	1.1	1.1	2.9	3.0	1.4	1.4	2.1	2.3	2.1	2.1	1.6	1.6	2.1	2.1	1.6	1.6
Juvenile Rearing-Migration																
Inadequate food resources	1.4	1.4	2.3	2.4	1.6	1.6	2.1	2.1	1.6	1.6	1.9	1.9	1.6	1.6	1.9	1.9
Disease	1.4	1.6	1.3	1.3	1.4	1.6	1.3	1.3	1.4	1.4	1.1	1.1	1.4	1.4	1.1	1.1
Predation	3.9	3.9	3.0	3.0	3.7	3.7	2.6	2.6	3.1	3.1	2.0	2.0	3.0	3.0	2.0	2.0
Water quality	2.4	2.4	1.7	1.7	2.3	2.5	1.6	1.6	2.1	2.1	1.4	1.4	2.0	2.0	1.3	1.3
Entrainment	3.6	3.6	3.1	3.1	3.3	3.3	2.7	2.7	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9
Lack of Cover	2.6	2.7	2.7	2.7	2.6	2.6	2.3	2.3	2.0	2.0	1.9	1.9	1.7	1.7	1.7	1.7

High water temperatures	3.4	3.7	3.0	3.1	3.0	3.7	3.0	3.0	2.9	3.4	2.1	2.1	2.9	3.4	2.1	2.1
Harvest of yearling juveniles	1.3	1.2	1.4	1.3	1.1	1.0	1.4	1.3	1.1	1.0	1.3	1.2	1.1	1.0	1.3	1.2
Delta Survival	3.3	3.7	3.0	3.0	3.3	3.7	3.0	3.0	3.3	3.3	2.7	2.7	3.3	3.3	2.7	2.7
Ocean Phase																
Inadequate food availability	2.7	2.7	2.0	2.0	2.7	2.7	1.7	1.7	2.7	2.7	1.7	1.7	2.7	2.7	1.7	1.7
Marine predation	2.3	2.3	1.7	1.7	2.3	2.3	1.3	1.3	2.3	2.3	1.3	1.3	2.3	2.3	1.3	1.3
Harvest	2.3	2.3	2.7	2.7	2.3	2.3	2.3	2.3	2.0	2.3	2.3	2.3	2.3	2.3	2.3	2.3

1.5.1 Adult Migration Stressor

For the adult migration life history stage, the magnitude scores showed a general agreement that migration barriers, flows, and false pathways would become less of a stressor as the Program's identified projects are completed (Table 2). The one exception was that high water temperatures for spring-run were identified as a major stressor (magnitude of 4) for the early years of the Program and reduced to an average of slightly over 3 for the final two vision periods. The certainty for spring-run water temperatures did, however, change substantially through time with an average certainty of 4 for current conditions and reducing to 2 by the final vision period. Timing of the adult returns will determine to what extend water temperatures will inhibit adult migration, and we have no recent observation on the timing of spring-run returns to the system. If spring-run migrate late into May and June as they do in the northern central valley they are likely to encounter temperatures above critical thresholds during migration, but if the timing is earlier, the majority of the run would be able to avoid these temperatures in most water years. Additionally, our projections of water temperatures are only based on temperature modeling that has not been calibrated under restoration flow levels. The Program will improve temperature projections as the model is calibrated under restoration flow levels.

The scorings for fall-run are slightly different. The magnitude of impact from high water temperature is ranked with a much lower magnitude than for spring-run. Fall-run migrate into the Restoration Area from October through December when temperatures are cooling.

Table 2. Stressor response priority scores for the adult migration life stage after completion of identified SJRRP projects.

	Spring-run Chinook			Fall-run Chinook		
Stressor	Magnitude	Certainty	Priority	Magnitude	Certainty	Priority
Inadequate flows	2	1	4 - Research to inform need for action	2	2	3 - Research to inform action design
High water temperatures	3	2	2 - Research to inform action design	2	2	3 - Research to inform action design
Physical barriers	1	2	5 - Research to confirm no action warranted	2	2	3 - Research to inform action design
False pathways	2	2	3 - Research to inform action design	2	3	4 - Action with adaptive management and monitoring

In-river harvest	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design

1.5.2 Adult Holding Stressors

The respondents ranked all the stressors under the adult holding life stage with a fairly low magnitude. For all stressors, the average magnitude was between 1 and 2.1 (Table 3). Holding habitat quantity was ranked low for spring-run and fall-run (magnitude of 1.4 and 1.2 respectively) which is consistent with the habitat quantity estimates described in section 3.3.2 relative to the holding habitat quantity environmental objective. Spring-run had higher average magnitudes to all risks during holding which is logical because spring-run have a much longer holding period prior to spawning than fall-run, so are more susceptible to predation, disease, or temperature stress. For example, the average magnitude for high water temperatures for spring-run was 2.1 compared to a 1.0 for fall-run with a high average certainty of 3.0 and 3.5 for spring-run and fall-run respectively.

Table 3. Adult holding stressor response priority scores for spring-run and fall-run Chinook salmon.

	Spring-run Chinook			Fall-run Chinook		
Stressor	Magnitude	Certainty	Priority	Magnitude	Certainty	Priority
Habitat quantity	1	3	1 - Monitoring track magnitude ensure no action is warranted	1	3	1 - Monitoring track magnitude ensure no action is warranted
High water temperatures	2	3	4 - Action with adaptive management and monitoring	1	3	1- Monitoring track magnitude ensure no action is warranted
Disease	2	2	3 - Research to inform action design	1	2	5 - Research to confirm no action warranted
Predation	1	3	1 - Monitoring track magnitude ensure no action is warranted	1	3	1- Monitoring track magnitude ensure no action is warranted
Harvest	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design

1.5.3 Spawning and Egg Survival Stressors

Spawning habitat quality was ranked with a fairly high average magnitude of around 3 under current conditions for both runs Table 4. Although the magnitude scorings decrease slightly over time, they remain fairly high at 2.6 for the year 2030 and beyond. The high scorings under current conditions are consistent with egg survival studies conducted by the Program that estimated egg survival well below the biological objective of 50% and a spawning gravel studies that indicated a lack of gravel mobility (e.g., SJRRP 2011, 2013). The future condition does not fare much better because the Program's Framework for Implementation does not identify specific projects to improve spawning substrate quality. Not surprisingly, the egg incubation stressors for sedimentation and temperature are similar to the spawning habitat quality stressor since these are the mechanisms affecting egg survival that determine spawning habitat quality.

The average certainty scoring for the low spawning habitat quality stressor decreases over time as does the variability among respondents on the magnitude rank. This pattern suggests that uncertainty and lack of consensus exists among biologists on whether or not future conditions such as consistent restoration flows will serve to improve spawning and egg incubation habitat quality.

Given the magnitude and certainty scorings for the spawning/egg incubation habitat quality stressors, the Program will continue investigating this element of Program success. Additional studies should be performed as restoration flows are established and spring-run are in the system to determine if egg survival or habitat function improves from flows or if the results that have been derived from fall-run are consistent for spring-run. Program staff and proponents should investigate methodologies for improving habitat quality to be prepared for potential future program actions or to take advantage of other opportunities such as outside funding sources.

The habitat quantity stressor scores reflect the assumption that salmon populations will grow in time combined with the Program's preliminary estimates of current spawning habitat quantity and the amount necessary to meet the long term population objectives. The average magnitude is ranked fairly low for both runs at 1.6 and 1.7 with a high certainty of above 3, but increases over time to 2.4 for spring-run and 1.9 for fall-run with the certainty decreasing to around 2 for both runs. A program workgroup is currently working on a report to estimate revised spawning habitat quantity estimates that will further inform the Program. Additionally, documenting the habitat use of spring-run and fall-run under growing population levels and river conditions will help to refine the understanding. As with the habitat quality question the Program will continue to evaluate the needs and be prepared to initiate actions when this stressor limits population growth and/or funding opportunities are available.

Interbreeding between fall-run and spring-run and superimposition of fall-run redds on spring-run redds follow the pattern of spawning habitat with average magnitude scores close to 1 for the early years and raising to 2 by 2030. The certainty scores decrease over time to less than 2 for both stressors for both runs indicating that these issues should be monitored. The Program currently has a protocol in place for monitoring and limiting the potential for introgression and superimposition in place (see Appendix F Draft Segregation Protocol).

Table 4. Spawning and egg incubation stressor response priority scores for spring-run and fall-run Chinook salmon.

	Spring-run Chinook			Fall-run Chinook		
Stressor	Magnitude	Certainty	Priority	Magnitude	Certainty	Priority
Habitat quality	3	2	2 - Research to inform action design	3	2	2 - Research to inform action design
Habitat quantity	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
High spawning water	2	2	3 - Research to inform action	2	2	3 - Research to inform action

temperatures			design			design
Hybridization between SRC and FRC	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
Instream flows	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
Sedimentation	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
High egg incubation water temperatures	3	2	2 - Research to inform action design	2	2	3 - Research to inform action design
Redd superimposition	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design

1.5.4 Juvenile Rearing and Migration Stressors

The Program identified nine stressors for the juvenile rearing and migration life stage. On a positive note, the average magnitude for all but one of these stressors decreases over time as restoration projects are completed (Table 5). The respondents do believe, however, that some key stressors will continue to be a challenge for the Program even after the projects in the Framework for Implementation are completed.

The one stressor that increased over time was inadequate food availability for juveniles that had a fairly low average magnitude of 1.4 in the first 5 year period and increased to 1.6 for the remainder of the time periods with no respondent scoring this stressor higher than 2. Although the demands for food resources will certainly increase over time as the populations grow, increasing flows and the creation of juvenile rearing habitat including floodplain habitat is expected to keep pace with population demands and meet estimated needs for attaining population targets and the juvenile growth rate objective.

Juvenile rearing and migration survival is of great concern for both the short and long term success of the Program. Through this stressor scoring process, respondents addressed sources of juvenile mortality. Juvenile impacts from entrainment into water diversions and lack of cover are expected to decrease as projects are completed. Juvenile entrainment has an average magnitude of 3.6 under current conditions, but drops rapidly to a score of 1.9 by 2030. This result indicates that respondents are confident that actions such as the Mendota pool bypass and completion of the Arroyo Canal/Sack Dam project will reduce the risk of entrainment significantly. The scores for this stressor ranged from 1 to 3 indicating that some uncertainty exists, so monitoring juvenile survival and entrainment post project completion is advisable.

The magnitude scores for high temperatures also decreases over time from a 3.6 under current conditions but remains relatively high with a score of 2.9 for 2030 and beyond. Juvenile delta survival is also ranked high with an average magnitude of 3.3 and range of 3 to 4 over all time periods. This scoring suggests that respondents did not assume delta conditions would improve between now and 2030. The program has limited direct control over delta survival, but creating abundant quality juvenile habitat will improve the fate of juveniles migrating through the delta. Quality will result in healthy fish that grow rapidly. High growth rates allow juveniles to migrate at a larger size which tends to improve survival and will also allow juveniles to migrate earlier while water temperatures are cooler. Although not apparent from this process, juvenile survival in the Restoration Area and in the Delta is expected to vary greatly from year to year with survival correlating with water levels.

Table 5. Stressor response priority scores for juvenile rearing and migration.

	Spring-run Chinook			Fall-run Chinook		
Stressor	Magnitude	Certainty	Priority	Magnitude	Certainty	Priority
Inadequate Food Resources	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
Disease	1	1	5 - Research to understand magnitude	1	1	5 - Research to understand magnitude
Predation	3	2	2 - Research to inform action design	3	2	2 - Research to inform action design
Water Quality	2	1	4 - Research to evaluate need for action	2	1	4 - Research to evaluate need for action
Entrainment	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
Lack of Cover	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
High Water Temperatures	3	2	2 - Research to inform action design	3	2	2 - Research to inform action design
Harvest	1	1	5 - Research to understand magnitude	1	1	5 - Research to understand magnitude
Delta Survival	3	3	3 - Action with adaptive management and monitoring	3	3	3 - Action with adaptive management and monitoring

1.5.5 Ocean Phase

As noted above, the Program has no direct control over ocean conditions for Chinook salmon, but to complete the life cycle in this analysis, respondents scored the elements of ocean survival of food supply, predation, and harvest (Table 6). In general, ocean stressors were given moderate magnitude ranks that remained consistent through time. Predation and harvest had an average magnitude score of 2.3 whereas food availability was scored as an average of 2.7. Food availability during the early ocean phase is recognized as a major contributor to year class success for Chinook salmon and was identified as a major cause of the Sacramento River fall-run Chinook adult return decline in 2008 (Lindley et al. 2009).

Table 6. Stressor response priority scores for the ocean phase.

	Spring-run Chinook			Fall-run Chinook		
Stressor	Magnitude	Certainty	Priority	Magnitude	Certainty	Priority
Inadequate Food Availability	3	2	2 - Research to inform action design	3	2	2 - Research to inform action design
Marine Predation	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design
Harvest	2	2	3 - Research to inform action design	2	2	3 - Research to inform action design

1.5.6 Scoring and Prioritization across Life Stages

Scoring and ranking stressors within a life stage provides an elucidation on the most limiting factors for each life stage, how these factors will change over time as restoration is implemented, and provides guidance on where the Program should focus its research and monitoring dollars. Combining the scoring across life stages identifies some trends in concerns and overall guidance on setting priorities and an understanding of what the projects defined in the Settlement and Framework for Implementation are expected to provide for Chinook salmon.

Table 7 lists the stressors that had the highest average magnitude scores for the pre-restoration condition. Not surprisingly the highest scoring stressors are directly addressed by the projects defined in the Settlement and prioritized in the Program's Framework for Implementation. Essentially, removing passage barriers, protecting juveniles from entrainment, and providing flow to the river will go a long way to creating conditions suitable for Chinook salmon. The cessation of consistent flows to the river and loss of a migratory corridor was the primary factor in extirpating salmon from the Restoration Area, so alleviating that condition will have a huge impact on success.

Table 7. List of stressors with average magnitude scores of 3 or greater under current (pre-restoration) conditions.

Stressor	SRC Average Magnitude Current - 2019	FRC Average Magnitude Current - 2019	SRC Average Magnitude 2030+	FRC Average Magnitude 2030+
Adult Migration Flows	4.0	3.9	1.7	2.1
Adult Migration Physical Barriers	4.0	4.0	1.4	1.6
Adult Migration False Pathways	3.9	3.7	1.7	1.7

Adult Migration Temperatures	3.9	1.7	3.1	1.7
Juvenile Predation	3.9	3.9	3.0	3.0
Juvenile Entrainment	3.6	3.6	1.9	1.9
High Juvenile Water Temperatures	3.4	3.7	2.9	3.4
Juvenile Delta Survival	3.3	3.7	3.3	3.3
Spawning Gravel Quality	3.0	2.9	2.6	2.6

Table 8 lists the stressors with the highest average magnitude scores which highlights some areas of concern that will exist even after completion of physical projects. Among these factors is a common trend of water temperatures that is a concern for eggs, juveniles, and adults for a portion of each life stage. The concern over water temperatures is not new to the Program or to managers on other San Joaquin tributaries. Resolving temperature issues is not simple, but the Program has and will continue to gain information on ways to reduce the impact of this stressor. Some examples of Program efforts to reduce stressors are researching flow levels to control water temperatures, or trigger migration cues, providing quality juvenile habitat to promote fast growth and early migration, and testing emergency response measures for poor years such as juvenile or adult trap and haul.

Table 8. Stressors with highest average magnitude score post project completion.

Stressor	SRC Average Magnitude 2030+	FRC Average Magnitude 2030+	SRC Average Magnitude Current – 2019	FRC Average Magnitude Current – 2019
Juvenile Delta Survival	3.3	3.3	3.3	3.7
High Adult Migration Water Temperatures	3.1	1.7	3.9	1.7
Juvenile Predation	3.0	3.0	3.9	3.9
High Juvenile Water Temperatures	2.9	3.4	3.4	3.7
Egg Incubation High Water Temperatures	2.7	2.1	2.9	2.4
Ocean Food Supply	2.7	2.7	2.7	2.7
Spawning Gravel Quality	3.0	2.9	2.6	2.6

Juvenile survival through the Restoration Area and the Delta will be a persistent concern for the Program and has been documented under low water years within the Restoration area and Central Valley. We have not implemented a full range of flows within the Restoration Area, so have no actual data on what survival will be under moderate water year conditions, although we did see high survival of 55% from Friant Dam to the confluence with the Merced River for juveniles in the flood year of 2011. Spawning gravel quality also made the list of highest scored stressors and is discussed above.

The stressors in Table 9 are a subset of the stressors in Table 8 with the addition ocean food conditions. This stressor was ranked consistently over time due in part to the limited ability to influence those conditions. The Program should be aware that ocean cycles will influence the progress towards meeting the Restoration goal, and continue to try and produce the fittest fish possible to reduce the impact of the stressor.

Table 9 lists the stressor with response priority scores of and 1 and 2. Somewhat surprising is the score of 1 given to the stressors for adult holding that received low magnitude scores. These scores illustrate how interpretation of the scores is not as simple as looking at a single number. These two stressors received a high priority, but the action identified is to monitor to ensure that no action is warranted. The Program has already begun this effort by monitoring habitat use and survival to spawning of fall-run transported to the Reach 1, and conducting a similar study on spring-run broodstock released from the Interim Facility. The priority 2 actions identified in Table 9 mirror the high magnitude scorings for post restoration conditions identified in Table 8.

Table 9. Stressors with priority response scores of 1 or 2 for conditions expected in 2030+.

Stressor	Run	Magnitude	Certainty	Priority
Adult Holding Habitat Quantity	SRC and FRC	1	3	1 - Monitoring track magnitude ensure no action is warranted
Adult Holding Predation	SRC and FRC	1	3	1 - Monitoring track magnitude ensure no action is warranted
Adult Migration High Water Temperatures	SRC	3	2	2 - Research to inform action design
Spawning Habitat Quality	SRC and FRC	3	2	2 - Research to inform action design
High Egg Incubation Water Temperatures	SRC	3	2	2 - Research to inform action design
Juvenile Predation	SRC and FRC	3	2	2 - Research to inform action design
High Juvenile Rearing and Migration Water Temperatures	SRC and FRC	3	2	2 - Research to inform action design
Inadequate Food Availability in the Ocean	SRC and FRC	3	2	2 - Research to inform action design

These scores and prioritization rankings provide a synthesis of the understanding of Program biologists based on our current level of understanding and expertise. The results should be interpreted in their totality by looking across the magnitude, certainty, priority rankings, and the range of scores among respondents to guide program research, monitoring, and actions. Ecosystem restoration is complex and these results can facilitate structured discussion especially when a high level of variability exists among individuals ranking stressors. The ranking process will be repeated as the Program gains more knowledge on the Restoration Area when projects are completed, Restoration Flows are implemented, and further Research, Monitoring and Evaluation (RM&E) is completed.

1.6 Application of Stressors to Action and Project Development as well as Adaptive Management

When combined with the Biological and Environmental Objectives, the stressor analysis provides the basis for a) prioritizing actions (including habitat enhancement actions and research) for maximum biological benefit, b) understanding the full range and extent of actions necessary to support population recovery, and c) setting expectations related to the extent of actions required to see progress towards the biological objectives for a given life history stage – by virtue of the extent of the stress to that life history stage that has been resolved.

Stressors are in essence the obstacles to achieving the desired conditions quantified through the environmental objectives and necessary for the species to attain the target population conditions quantified in the biological objectives. For this reason, for any given life history stage, progress towards the biological objectives can only be expected once the high priority stressors have been addressed and environmental objectives largely achieved. **The efficacy of SJRRP actions related to fish population and habitat conditions should therefore be measured based on the extent that those measures advance or achieve environmental objectives and reduce high priority stressors**. Once environmental objectives have been significantly advanced, or achieved via the resolution of priority stressors, biological objectives associated with the life history stage(s) for which objectives have been achieved and stressors addressed become both a) metrics to measure species response to the actions, and b) triggers for adaptive management, in the case where the species do not respond to the conditions quantified in the environmental objective as was hypothesized in the biological objectives based on existing science.

Although environmental objectives and stressors do not have a one to one relationship with biological objectives, there are several core relationships among them that, for a given life history stage, while not absolute, can serve to guide expectations around biological response to the attainment of environmental objectives. Specifically:

- ***↑Habitat Quality*** → ***↑Survival*** – Given the carrying capacity associated with a given spatial area of habitat, fish condition and survival is largely linked with habitat quality as defined by environmental objectives and stressors for a given life stage. Attainment of environmental objectives for habitat quality via resolution of high priority stressors, for a given life history stage, should therefore trigger response in biological metrics (and make progress towards objectives) related to survival rate for individuals of that life history stage, given the limits to carrying capacity. For example, attainment of the habitat quality objectives for egg incubation should be measurable in terms of progress towards biological objectives for egg survival.
- ***↑Habitat Spatial Extent*** → ***↑Abundance*** – Given habitat quality and suitability, as quantified by the environmental objectives, and associated survival rates, increased spatial extent of suitable habitat increases carrying capacity for that life history stage. Increases in habitat spatial extent should therefore be measurable in biological metrics (and make progress towards objectives) related to abundance for that life history stage, to the extent that abundance is constrained by carrying capacity. For example, attainment of the habitat quantity objectives for

adult holding and spawning habitat should be measurable in terms of progress towards biological objectives for adult in-river/spawner abundance.

- ↑***Habitat Temporal Extent*** → ↑***Diversity and Resilience*** – Given sufficient habitat quality and spatial extent, the temporal extent and availability of habitat increases the potential for a given life history stage to express diversity. The range of diversity expressions for each life history stage, across life history stages, comprise the resilience of the cohort. Similarly, the resilience of the individual cohorts, across multiple cohorts, comprise the resilience of the population. Attainment of environmental objectives for habitat temporal availability, for a given life history stage, should therefore trigger response in biological metrics (and make progress towards objectives) related to diversity in that life history stage or, across life history stages, resilience in the cohort and population. For example, attainment of the temporal extent objectives for juvenile rearing and migration should be measurable in terms of progress towards biological objectives for juvenile diversity.

Even when the primary stressors for a given life history stage have been addressed, certain biological objectives (e.g., population growth, abundance, etc.) require success across multiple or all life history stages. It therefore becomes necessary for the high priority stressors to be addressed, and environmental objectives achieved for all life history stages, in order to see meaningful progress towards the full suite of biological objectives.

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