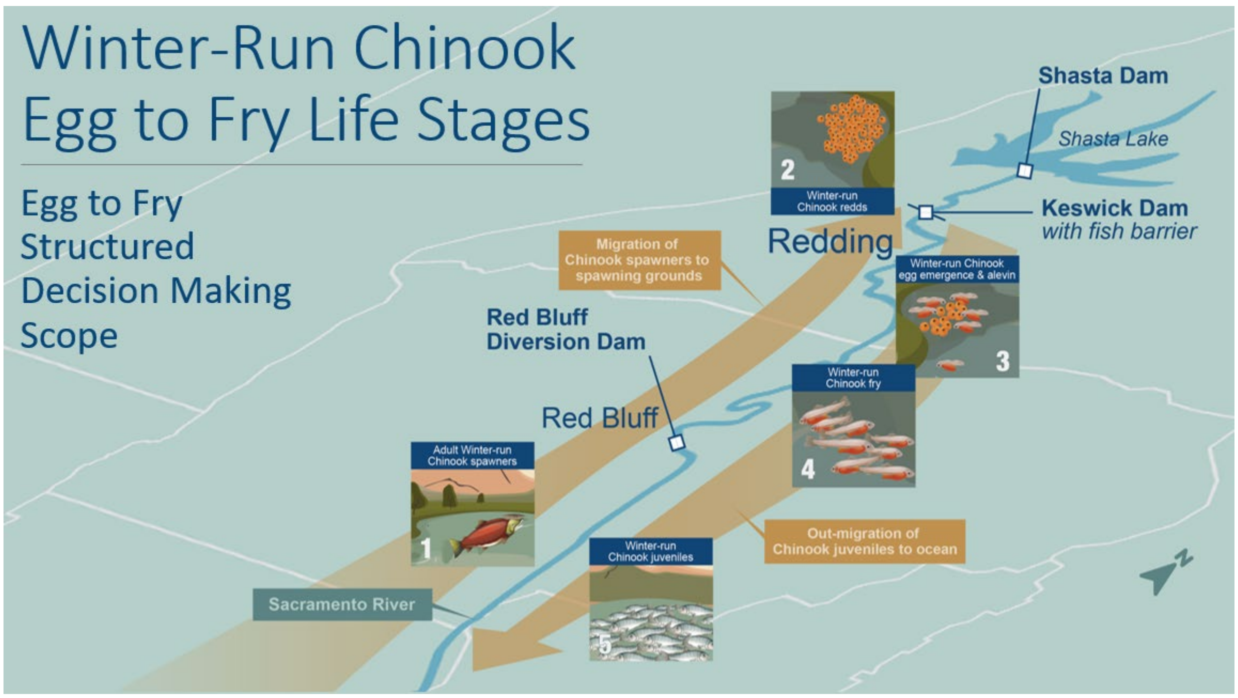
Egg-to-Fry Value of Information Interim Report:

Influence Diagram and Qualitative Analysis To Advance Structured Decision-Making



Prepared for the
Sacramento River Science Partnership

by

KEARNS WEST

October 2023

Contributors to the Report

The Kearns & West facilitation team has compiled and reflected the contributions of the following participants. There were many contributors to this report including Sacramento River Science Partnership (SRSP) member staff as well as other contributing scientists and consultants including:

- Alex Jensen, U.S. Bureau of Reclamation
- Amanda Cranford, National Marine Fisheries Service
- Craig Fleming, U.S. Fish and Wildlife Service
- Duane Massa, Sites Reservoir Authority Consultant Team
- Elissa Buttermore, U.S. Bureau of Reclamation
- Evan Sawyer, National Marine Fisheries Service
- Mike Beakes, U.S. Bureau of Reclamation
- Jason Hassrick, Sites Reservoir Authority Consultant Team
- Jim Earley, U.S. Fish and Wildlife Service
- John Spranza, Sites Reservoir Authority Consultant Team
- Josh Israel, U.S. Bureau of Reclamation
- Matt Brown, U.S. Fish and Wildlife Service
- Mike Deas, Sacramento River Settlement Contractors
- Stephen Maurano, National Marine Fisheries Service
- Steve Zeug, Sacramento River Settlement Contractors Consultant Team
- Thad Bettner, Sacramento River Settlement Contractors
- Tracy Grimes, California Department of Fish and Wildlife

Suggested citation:

Kearns & West, 2023. *Egg-to-Fry Interim Value of Information Report: Influence Diagram and Qualitative Analysis to Advance Structured Decision-Making.* Sacramento River Science Partnership.

Table of Contents

Index of Figures

Index of Tables

Executive Summary

Purpose

The report aims to identify high value areas of reduceable scientific uncertainty to inform management actions that support the recovery of salmon in the Upper Sacramento River. With this information, the SRSP seeks to select and inform the SRSP Science Activities they will pursue to support the recovery of salmon in the Upper Sacramento River. The report provides a conceptual model of egg to fry survival of Sacramento River winter-run Chinook salmon (winter-run) in the mainstem Sacramento River and an assessment of our current understanding of egg to fry survival. The report identifies areas of high uncertainty where additional information would be of value for improving management of wild origin winter-run Chinook salmon, particularly egg to fry survival between Keswick and Red Bluff Diversion Dam.

Deliverables

This report includes three deliverables:

1. Influence diagram of wild winter-run Chinook salmon egg to fry life stage (Influence Diagram)
2. Science documentation of Ecological Relationships in the influence diagram (Ecological Relationships Documentation)
3. Qualitative analysis of value of science to reduce uncertainty (Qualitative Analysis)

Together, these deliverables will enable SRSP members to:

- Inform development of science activities, science priorities and management actions regarding salmon recovery in the Upper Sacramento River;
- Develop finer granularity for existing conceptual models and improve predictions in future quantitative models regarding salmon recovery in the Upper Sacramento River; and
- Provide a framework of egg-to-fry ecological relationships within which SRSP members can track, share, and coordinate science developed unilaterally and in collaboration.

Key Takeaways

The key takeaways from this report can be drawn from: a) the 14 High Value Ecological Relationships identified as part of the Qualitative Analysis of Value of Information; and b) an examination of how those 14 High Value Ecological Relationships align with the 2019 SRSP Science Plan Science Activities identified as part of the Qualitative Analysis of Value of Information.

14 High Value Ecological Relationships

The Qualitative Analysis of Value of Information resulted in identifying 14 ecological relationships that were identified as important but for which there is low understanding, predictability, and/or low data availability. These include:

Table 1: 14 High Value Ecological Relationships

14 High Value Ecological Relationships: Low Understanding, Low Predictability and/or Low Data Availability	
#	**Ecological Relationships**
	Adult Spawner to Egg
BB	Substrate* --> Maximize spawning habitat capacity
U	Maximize # of successful spawners --> Maximize # of viable eggs
V	Maximize fertilization success rate --> Maximize # of viable eggs
W	Maximize spawning habitat capacity --> Maximize # of successful spawners
	Egg to Emergence
G	Redd stranding & dewatering* --> Maximize egg alevin survival
H	Dissolved oxygen* --> Maximize egg alevin survival
J	Temperature* --> Maximize egg alevin survival
L	Minimize thiamine deficiency* --> Maximize egg alevin survival
II	Keswick Releases/Flows* --> Minimize stranding
NN	Keswick Releases/Flows* --> Redd stranding & dewatering*
SS	Keswick Releases/Flows* --> Dissolved oxygen*
	Emergence to Fry
N	Minimize thiamine deficiency* --> Maximize fry survival
R	Predator density* --> Maximize fry survival
S	Maximize juvenile rearing habitat capacity --> Maximize fry survival
** Asterisks indicate associated management actions*	

SRSP Science Activities Relation to 14 High Value Ecological Relationships

The SRSP Science Plan 2019, includes 31 science activities. The SRSP has taken steps to prioritize and develop and implement some of the science activities. The 14 high value ecological relationships identified in this report have been examined in relation to the SRSP Science Activities. This revealing of alignment that could inform the SRSP's collaborative and individual priorities for conducting high value science to resolving conflict and informing decision-making.

Table 2: Areas of Alignment 14 High Value Ecological Relationships and SRSP Science Activities

Areas of Alignment: 14 High Value Ecological Relationships and SRSP Science Activities
• Eight SRSP science activities could encompass all 14 of the high value ecological relationships. These include: ○ ***#5: Carcass and Redd Surveys*** ○ ***#6 Redd Management*** ○ ***#8 Effects of Flow on Rearing Habitat*** ○ ***#13 Reproductive Success of Individual Spawners*** ○ ***#14 Predator Distribution*** ○ ***#19 Predator Abundance and Distribution*** ○ ***#27 Habitat Utilization Assessment*** ○ ***#28 Pathogens and Disease***
• Two SRSP science activities address 9 of the 14 high value ecological relationships, offering a high rate of return on high value information for two science activities. ○ ***#5 Carcass and Redd Surveys*** ○ ***#6 Redd Management***
• Two additional SRSP science activities could be modified to address 4 of the 14 high value ecological relationships related to thiamine. ○ ***#27 Habitat Utilization Assessment*** ○ ***#28 Pathogens and Disease***

Introduction

Purpose of Report

The report aims to identify high value areas of reduceable scientific uncertainty to inform management actions that support the recovery of salmon in the Upper Sacramento River. With this information, the SRSP seeks to select and inform development of the SRSP Science Activities they will pursue to support the recovery of salmon in the Upper Sacramento River. This report describes the approach and results for three primary deliverables.

> **Project Goal**
>
> Identify high value areas of reduceable scientific uncertainty to inform management actions that support the recovery of salmon in the Upper Sacramento River.
>
> Select and inform development of the SRSP Science Activities to reduce that uncertainty.

There has been significant debate about the science supporting various management actions management actions, environmental drivers, and habitat attributes that influence the egg to fry life stages of winter-run Chinook salmon in the Sacramento River. In service of its mission, the SRSP has engaged in long-range science planning and identification of the highest value science to reduce uncertainty and conflict in the Upper Sacramento River.

> **Sacramento River Science Partnership**
>
> This report was prepared for the Sacramento River Science Partnership (SRSP) by Kearns & West with support from the SRSP Science Subcommittee. The Sacramento River Science Partnership's mission is to establish and maintain a science enterprise for voluntary collaborative research, modeling, monitoring, and synthesis relevant to salmonid and other in-river species recovery and water management on the main stem Sacramento River to facilitate joint learning and fact-finding between and among scientists and managers. The SRSP works to investigate and communicate those areas of voluntary scientific inquiry most relevant to species recover and water management goals in the Sacramento River watershed.

Needs

In response to this debate and need to reduce uncertainty, the SRSP identified the following needs:

1. A more **detailed conceptual model** of the egg to fry life stage than that which is included in existing CVPIA SIT and WRLCM models. This level of detail is intended to improve understanding of factors influencing egg and fry survival.

2. **A shared understanding around the egg to fry life stages** between Keswick and Red Bluff Diversion Dam to significantly reduce uncertainty and to inform management decisions to support recovery of ESA listed species. The winter-run CVPIA SIT model results were most sensitive to post-fry/juvenile growth, movement, and survival. The model was somewhat sensitive to egg-to-fry survival as well.

3. A short-term qualitative analysis of **value of information** to inform science development to be followed by longer-term improvements to the quantitative models.

4. A **quantifiable, transparent, replicable** process to identify the relative value of additional science to reduce uncertainty, which would inform prioritization, modification, and implementation of certain SRSP Science Activities.

Per the SRSP Charter, the SRSP members directed the SRSP staff and facilitation team to use a Structured Decision-Making (SDM) approach meet the above needs.

Structured Decision-Making (SDM) is an approach for careful and organized analysis of natural resource management decisions. SDM is based in decision theory and risk analysis that intends to provide a rationale framework, guards against cognitive biases.[1]

> "The methods that underlie the SDM approach are draw from decision sciences, specifically multi-attribute utility analysis and behavioral decision research and from applied research by ecologists into the choice management of alternatives under uncertainty."[2]

This report includes documentation of problem definition, objectives, and alternatives but not consequences, and trade-offs. The SRSP directed the production of this Report with the information developed to date.

For more information on the Structured Decision Making applied in this effort and reported in this document, please see the section on Structured Decision Making.

Deliverables and Applicability

The SRSP aims to use the information produced in this report to inform the prioritization and development of the SRSP's science activities as well as members' science priorities. Accordingly, the SRSP's alternatives are the science activities rather than management actions. The SRSP Science Plan outlines 31 science activities. The Partnership is open to updates and modifications to these science activities to produce high value science. The Partnership members have also expressed a willingness to consider additional science activities that may need to be developed to respond to this analysis. However, they have expressed a preference to work on the existing SRSP science activities before adding more.

This report includes three deliverables that can be applied in different yet complementary ways.

1. **Influence diagram of wild winter-run Chinook salmon egg to fry life stage (Influence Diagram)**

   The Egg to Fry Influence Diagram is a conceptual model that provides finer granularity to existing conceptual models which can be used to inform quantitative models and improve predicted outcomes of different management actions.

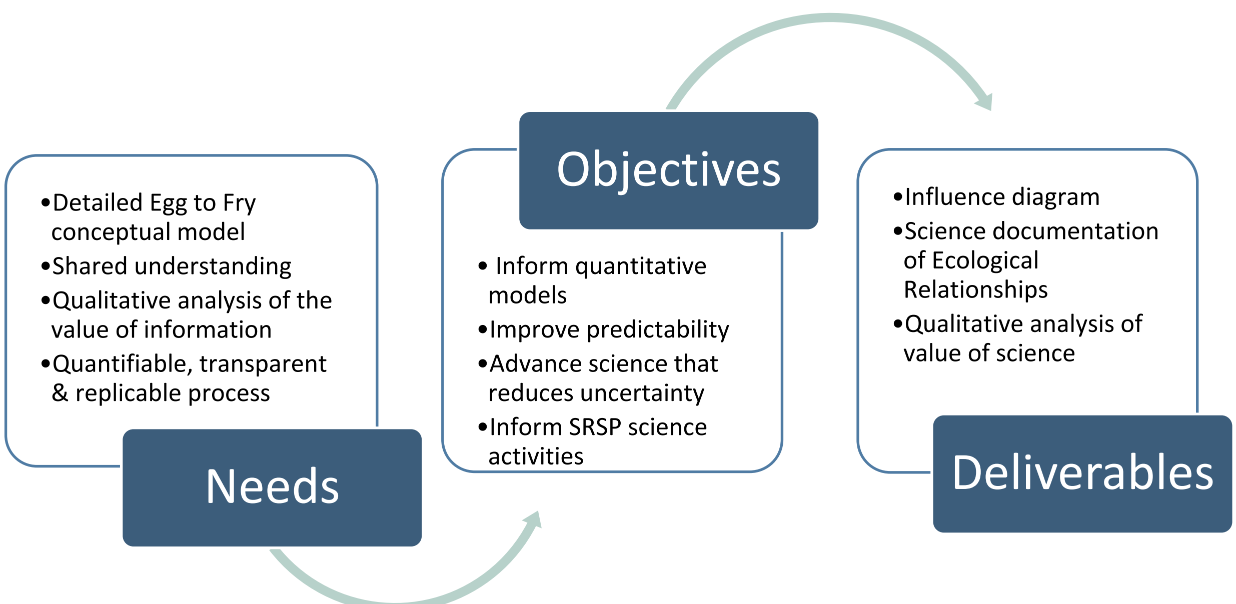
[1] Gregory R., Failing L. *Structured Decision Making: A Practical Guide to Environmental Management Choices*. (Blackwell Publishing, West Sussex, UK, 2012), p. 2-7.
[2] Gregory R., Failing L., p. 18.

2. **Science documentation of Ecological Relationships in the influence diagram (Ecological Relationships Documentation)**

SRSP members can use the science documentation of ecological relationships to focus study objectives and development. They can use the documentation on the understanding, predictability, and data availability to shape science that will reduce uncertainty for management. They can use the identified areas of divergence to identify and develop science that could contribute to scientific disagreement.

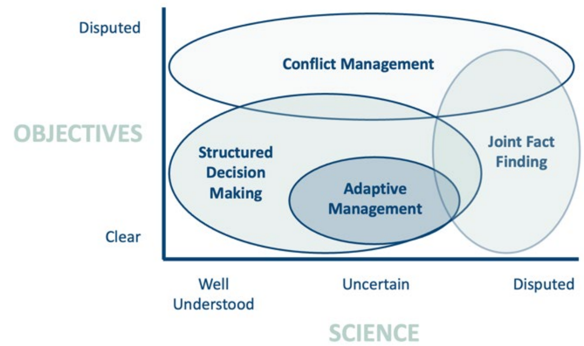
3. **Qualitative analysis of relative value of science to reduce uncertainty (Qualitative Analysis)**
   SRSP members can use this analysis indicating high value information to inform priorities for developing science.

Figure 1: Needs, Objectives, Deliverables



Structure Decision Making

Figure 2: Conditions for Application of Structured Decision Making



Structured Decision Making is best applied when parties enjoy trust, they share objectives, and there is a body of science that ranges from well understood to uncertain. In this situation, SRSP members are willing to share objectives but they range from clear to disputed and the science ranges from well understood to uncertain to disputed. In this use case, structured decision-making uncovers areas of divergence of views on science and/or disputed objectives that may require conflict management and/or joint fact finding. The Figure illustrates the conditions under which Structure Decision Making and other processes are best applied.[3]

Problem Definition: Value of Information

SDM encompasses a number of problem types and tools to address them. In this case, the SRSP seeks to select and support development of the highest value science. The SRSP's type of problem is classified as a Value of Information type problem.

Objectives

The SRSP engaged in this SDM process to identify fundamental and means objectives. These fundamental and means objectives make up the Egg-to-Fry Influence Diagram.

Hallmarks of Structured Decision Making processes include problem decomposition and development of influence diagrams to identify fundamental and means objectives.

In service of the need to develop a more detailed conceptual model, the Partnership decided to focus on decomposition of the ecological relationships between egg to fry life stages by developing an influence diagram. The influence diagram is made up of habitat attributes, environmental drivers that lead to means objectives that describe how to arrive at a fundamental objective at the top of the hierarchy.

SDM Steps
Steps Advanced by this Report

1. Problem Definition: Value of Information
2. Objectives: Influence Diagram Means and Fundamental Objectives
3. Alternatives: SRSP Science Activities

Potential Future SDM Steps

4. Consequences
5. Trade-offs

Alternatives

Under an SDM process, the next step is development of alternatives. In this case, the SRSP's Science Plan provides 31 Science Activities which are based on the SRSP's Charter priorities. This is the first set of the alternatives to consider for value of information to meet the objectives in the influence diagram. This

[3] Runge MC, Converse SJ, Robinson KF, Alger K, Isham F. 2019. Workshop: Fundamentals of Structured Decision Making. American Fisheries Society and the Wildlife Society Joint Conference, September 29, 2019. Reno, Nevada.

SDM effort began to consider the value of the information that could be produced by the alternatives as defined by the SRSP science activities and identification of potential need for other alternatives.

Consequences and Tradeoffs

A typical SDM effort would next consider the consequences of decisions and evaluate the tradeoffs involved before making decisions. The SRSP has not yet embarked on these SDM steps.

Decision Context

Decision

The decision that this report seeks to inform is the SRSP members' selection of SRSP Science Activities to for further development and collaboration. There are several driving factors and conditions that informed the focus of work effort presented in this report. This section includes a review of the diverging viewpoints, SRSP science planning, scope and rationale, and management actions.

SRSP Members Decision

Select and support development of the highest value SRSP Science Activities

Diverging Viewpoints and Conflict

The decision context for the SRSP is also characterized by regulatory and legal conflict around management of the Upper Sacramento River and interpretations of science supporting different management actions. During the years since the development of the SRSP Science Plan, Reclamation's Central Valley Project has undergone two Consultations on Long-Term Operations involving the members of the SRSP. While some members have entered into litigation with each other, others have been deposed to provide testimony during the discovery process. Continuous regulatory and legal challenges have created a challenging atmosphere in which to collaboratively develop science activities around the most disputed scientific uncertainties.

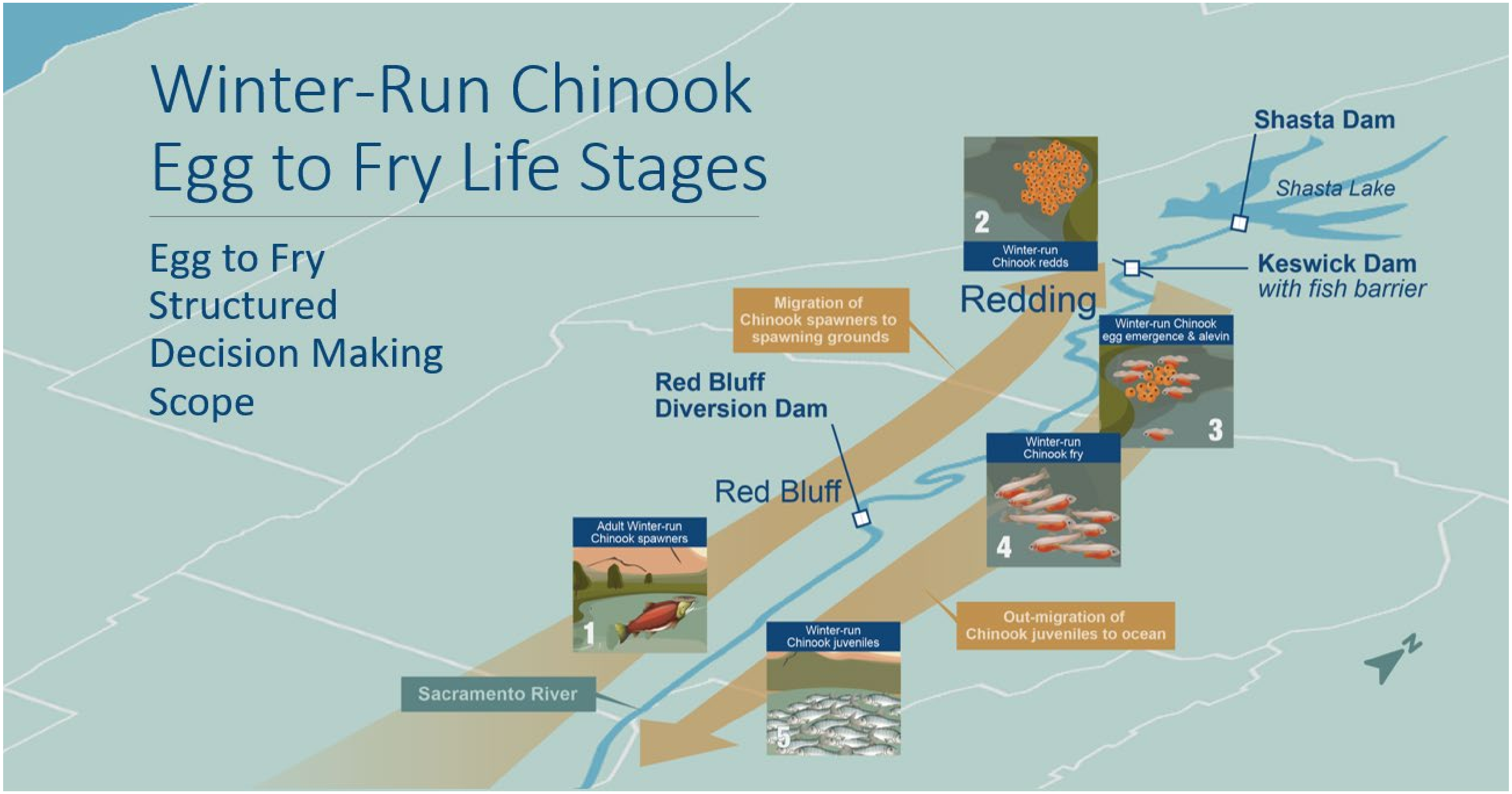
SRSP Science Planning

The SRSP developed a Science Plan in 2019, which outlines 31 science activities. Over the last three years, the SRSP has engaged in efforts to at a minimum, share understanding of each other's science priorities and at a maximum, agree to embark on priority science activities. Since the advent of the SRSP Science Plan in 2019, the SRSP has engaged in two earlier processes to categorize and prioritize the science activities, and has collaboratively developed draft briefs of science activities.

Scope and Rationale

The focus of this Egg to Fry SDM effort was specific to certain life stages, geographic areas and fish as described in the graphic and narrative below.

Figure 3: Scope of Egg to Fry Structured Decision-Making



1. Life Stages — egg to fry

The rationale for including the egg to fry life stages is two-fold. First, this is an organizing set of life stages identified in the SRSP Science Plan. Second, CVPIA SIT model results identified the egg to fry life stages and geographic area of Keswick Reservoir to Red Bluff Diversion Dam as areas of high value for additional information to reduce uncertainty.

2. Salmon Run — Sacramento River winter-run Chinook salmon

The rationale for focusing this Egg to Fry SDM effort on winter-run Chinook salmon is as follows. It is common practice to evaluate relationships in certain species then apply them more broadly. The best available science is to apply winter-run Chinook models across other salmon runs. Focusing on winter-run simplifies the influence diagram and the evaluation of science. Focus on winter-run Chinook also focuses the discussion on the Upper Sacramento River between Keswick and Red Bluff Diversion Dam where winter-run spawn. By contrast, fall-run Chinook spawn and rear farther downstream in a broader area than winter-run Chinook.

3. Origin – natural origin fish

The rationale for focusing on natural origin fish and not hatchery fish is that the managers are most interested in understanding the ecological relationships that support natural origin fish for recovery purposes. This focus on natural origin fish avoids the complexity of including hatchery fish, which could be added as a second phase.

4. Geographic Scope — Keswick to Red Bluff Diversion Dam

The rationale for focusing on Keswick Reservoir to Red Bluff Diversion Dam is that the Red Bluff Diversion Dam defines the current monitoring station for out-migrating juveniles. This is currently the best monitoring location at which the SRSP could attempt to evaluate the influences on egg to fry life stages. Members suggested that in the future, they would like to monitor emergence of out-migrating fry further upstream.

With this report, the SRSP aims to inform the decisions about which SRSP science activities to prioritize. In turn, the SRSP seeks to use the resulting science to inform decisions related to management of the Upper Sacramento watershed.

Management Actions

The SRSP seeks to inform management actions derived primarily from the 2019 Biological Opinion and the Voluntary Agreements. Previously, the SRSP employed this list of management actions to evaluate the relevance and importance of its science activities. During this process, the SRSP added to the initial list of Management Actions, resulting in the following list:

1. Biological Opinion Management Actions
    a. Flow Actions
        i. Spring Operation: Spring Baseflow
        ii. Spring Pulse Flow
        iii. Seasonal Operation: Summer CWP Tiers 1–3
        iv. Rice Decomposition Smoothing
        v. Fall and Winter Refill and Redd Maintenance

        vi. Seasonal Operation: Winter Minimum Flow
        vii. Livingston Stone Fish Hatchery
        viii. Cold Water Pool Management: Battle Creek Restoration & Reintroduction
        ix. Reintroduction of Salmon above Shasta
    b. Habitat Actions
        i. Spawning Gravel Injection/Gravel Augmentation
        ii. In Channel Habitat
        iii. Side Channel Habitat Restoration
    c. Tools
        i. Cold Water Pool Management: Temperature Modeling Platform
        ii. Cold Water Pool Management: Shasta TCD Performance Evaluation
    d. De-emphasize
        i. Operation of Shasta Dam Raise
2. Voluntary Agreement Management Actions
    a. Operation of Sites Reservoir

In service of the need to develop a more detailed conceptual model, the Partnership decided to focus on decomposition of the ecological relationships between egg to fry life stages by developing an influence diagram of egg to fry life stages.

Should the SRSP want to continue with the SDM process of identifying alternatives, estimating their consequences, and tradeoffs to select high value science, the SRSP will need to return to detailed discussion of the management actions and objectives.

Deliverable 1: Influence Diagram

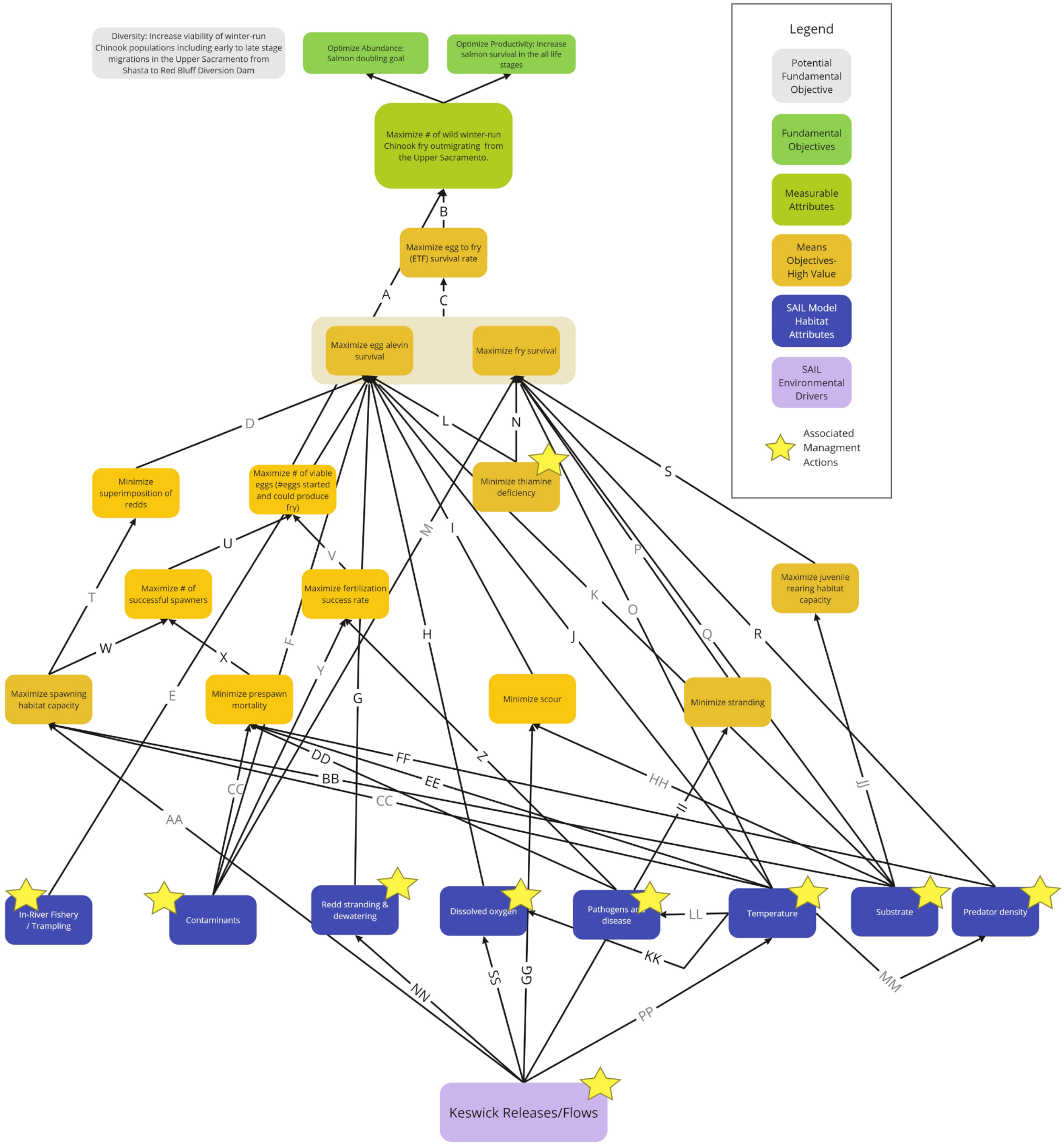
Influence diagram of wild winter-run Chinook salmon egg to fry life stage

Results: Influence Diagram

The Egg to Fry Influence Diagram includes fundamental and means objectives as well as measurable attributes. The measurable attributes are outlined below and illustrated in the Egg to Fry Influence Diagram. SRSP has iterated on the structure and hierarchy of the means objectives relationship to the habitat attributes and the fundamental objectives multiple times. These iterations are included in the Appendix.

The most recent Egg to Fry Influence Diagram has been illustrated in the figure below with a corresponding legend. This iteration includes recently proposed modifications to the influence diagram structure and new ecological relationships. A narrative outline below describes the fundamental and means objectives.

Figure 4: Egg to Fry Influence Diagram


Diversity: Increase viability of winter-run Chinook populations including early to late stage migrations in the Upper Sacramento from Shasta to Red Bluff Diversion Dam
Optimize Abundance: Salmon doubling goal
Optimize Productivity: Increase salmon survival in the all life stages
Maximize # of wild winter-run Chinook fry outmigrating from the Upper Sacramento.
Maximize egg to fry (ETF) survival rate
Maximize egg alevin survival
Maximize fry survival
Minimize superimposition of redds
Maximize # of viable eggs (#eggs started and could produce fry)
Minimize thiamine deficiency
Maximize # of successful spawners
Maximize fertilization success rate
Maximize juvenile rearing habitat capacity
Maximize spawning habitat capacity
Minimize prespawn mortality
Minimize scour
Minimize stranding
In-River Fishery / Trampling
Contaminants
Redd stranding & dewatering
Dissolved oxygen
Pathogens and disease
Temperature
Substrate
Predator density
Keswick Releases/Flows
Legend
Potential Fundamental Objective
Fundamental Objectives
Measurable Attributes
Means Objectives-High Value
SAIL Model Habitat Attributes
SAIL Environmental Drivers
Associated Managment Actions

1. Fundamental Objectives

Fundamental objectives are defined as the end outcomes that matter and should be separated from the means objectives. You can get to the fundamental objectives by asking, why is that important?

The SRSP defined the following Fundamental Objectives:

- Optimize Abundance: salmon doubling goal
- Optimize Productivity: increase salmon survival in all life stages

2. Postponed Fundamental Objectives

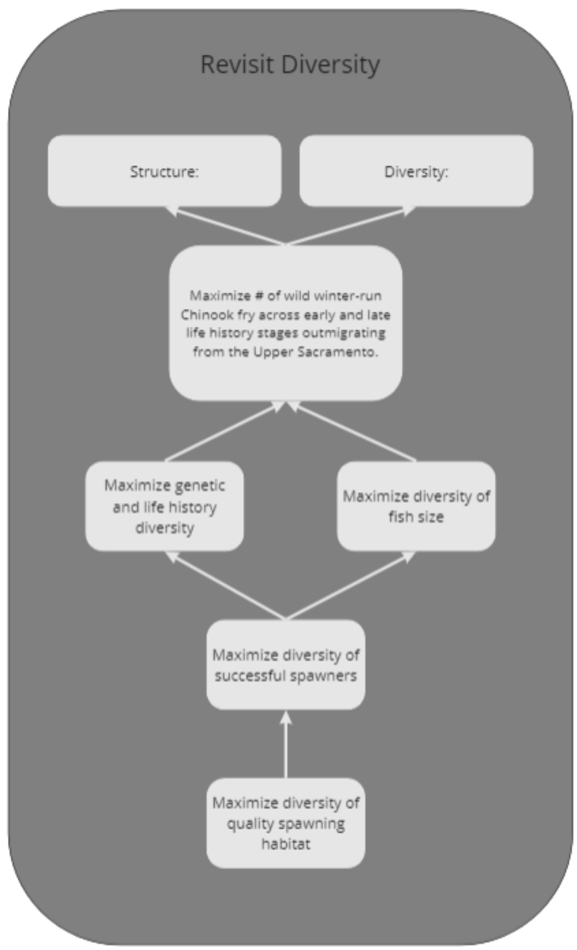
The SRSP postponed exploration and incorporation of life history diversity and structure as fundamental objectives until a future phase of work. The group postponed addressing this additional fundamental objective due to added complexity.

The proposed and then postponed fundamental objective is illustrated in gray on the influence diagram as a bookmarker for future work. The full postponed fundamental objectives and the first iteration of related means objectives is as follows:

- Fundamental Objective: Optimize Diversity and Spatial Structure
- Means Objective: Increase viability of winter-run Chinook populations including early to late-stage migrations in the Upper Sacramento from Shasta to Red Bluff Diversion Dam.

This figure illustrates the potential beginning of the Diversity and Spatial Structure fundamental objective and means objectives. This initial iteration is included for future reference and potential development.

Figure 5: Postponed Fundamental Objective - Structure and Diversity Diagram



3. Measurable Attributes

Measurable Attributes are metrics that can be measured to evaluate success towards the fundamental objectives. The group defined one key measurable attribute for the fundamental objectives of abundance and productivity as follows:

- Abundance — number of winter-run Chinook fry out-migrating at Red Bluff Diversion Dam

4. Means Objectives

The definition of means objectives is that they influence the achievement of fundamental objectives; they are means to arriving at the fundamental objectives. See the influence diagram orange boxes for the means objectives.

5. Ecological Relationships

The ecological relationships are illustrated by the arrows connecting habitat attributes to the means objectives and then fundamental objectives. They are alphanumerically labelled and documented in the Ecological Relationship Science Documentation

The ecological relationships vary in importance, data availability, understanding, and predictability.

6. Habitat Attributes

The habitat attributes from the SAIL model describe the physical attributes that contribute to the biological fish responses, which this model uses as means to achieving the fundamental objectives of abundance and productivity. See the purple boxes in the influence diagram for the habitat attributes.

7. Environmental Drivers

The environmental drivers from the SAIL model are "features that occur over a broad range of temporal and spatial scales and occur within the geographic range of the species. Environmental drivers directly influence habitat attributes." The SRSP group chose to only incorporate Keswick Flow Releases as the environmental driver from the SAIL model that represents a major management action and affects many habitat attributes, ecological relationships, and means objectives.

8. Structure Objectives in Hierarchy in an Influence Diagram

The means objectives are arranged according to the hierarchy and understanding of their ecological relationships.

Methodology: Influence Diagram

Structured Decision-making was used to develop the influence diagram for egg to fry life stage of winter-run Chinook salmon. Three key groups met and collaborated to develop the influence diagram.

The Partnership[4] started the development of the influence diagram and then charged the Science Subcommittee[5] with developing science documentation for the ecological relationships and updating the influence diagram as needed. The groups followed the following steps:

1. Discussed the Decision Context
    a. Which science activities have the highest value to inform decision-making?
    b. Reviewed relation to conceptual models and need
    c. Reviewed and added to the management actions that the decision on high value science could inform.

2. Started influence diagram
    a. Identified fundamental objectives and some means objectives (as defined in the section on Deliverable 1: Influence Diagram Results)
    b. Identified measurable attributes.

3. Iterated on scope boundaries
    a. Narrowed the scope with the life stage, race, geographic scope.
    b. Identified the first set of means objectives and hierarchy of relationships.
    c. Identified a second fundamental objective of Structure & Diversity and set aside for future discussion.
    d. Charged the Science Subcommittee[6] with iterating on the influence diagram and developing science documentation of the ecological relationships.

4. Updated the influence diagram
    a. The Science Subcommittee developed the science documentation of each ecological relationship and iteratively added means objectives and restructured the influence diagram through iterative facilitated discussions.

Relation to Existing Conceptual Models

The SRSP directed the Egg to Fry SDM effort to relate to and incorporate four different existing conceptual models. The Egg to Fry SDM effort does and is envisioned to provide more detail for three existing conceptual models to improve predictability and identification of high value science needs. The SRSP Egg to Fry Influence Diagram is intended to expand the detail of egg to fry relationships

---

[4] The Partnership includes the policy representatives of the SRSP organizational members.
[5] The Science Subcommittee includes Partnership member representatives who are technical staff. Responsibilities of the Science subcommittee include, but are not limited to, exploring, and clarifying science activities for prioritization and recommendation to the Partnership, participation in Technical Reviews as appropriate, and develop and/or oversee development of decision support models and analysis, and prioritization to inform and review science activities.

conceptualized in these existing models. In the case of the SAIL model, the SRSP Egg to Fry Influence Diagram incorporated some of its components. The SRSP Egg to Fry Influence Diagram relates to the three existing models in the following ways:

1. Central Valley Protection Improvement Act Science Integration Team (CVPIA SIT) Model

The Egg to Fry Influence Diagram is intended to provide a higher level of detail of ecological relationships included in the natural origin eggs, deposited eggs, and small juveniles of the CVPIA SIT conceptual model. See Figure 5 for area of focus within CVPIA SIT model.

2. Southwest Fisheries Science Center Winter-run Life Cycle Model (WRLCM)

The Egg to Fry Influence Diagram is intended to provide a higher level of detail of ecological relationships included in the Stages of Eggs, Fry, to River Fry of the WRLCM. See Figure 6 for area of focus within WRLCM.

3. Interagency Ecological Program Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) Model

The Egg to Fry Influence Diagram fits within and provides more detail to the SAIL Egg to Fry conceptual model. The Egg to Fry Influence Diagram expands the SAIL model arrow that points up to fish responses: survival, timing, and condition.

The Egg to Fry Influence Diagram includes the SAIL model Egg to Fry Habitat Attributes and Environmental Drivers as well as incorporates the SAIL model identification of management actions with stars.

See the figure below for the SRSP Egg to Fry area of focus within the SAIL model as well as components applied to the SRSP Egg to Fry Model.

Figure 6: Area of Focus in CVPIA SIT Model for SRSP Egg to Fry Model

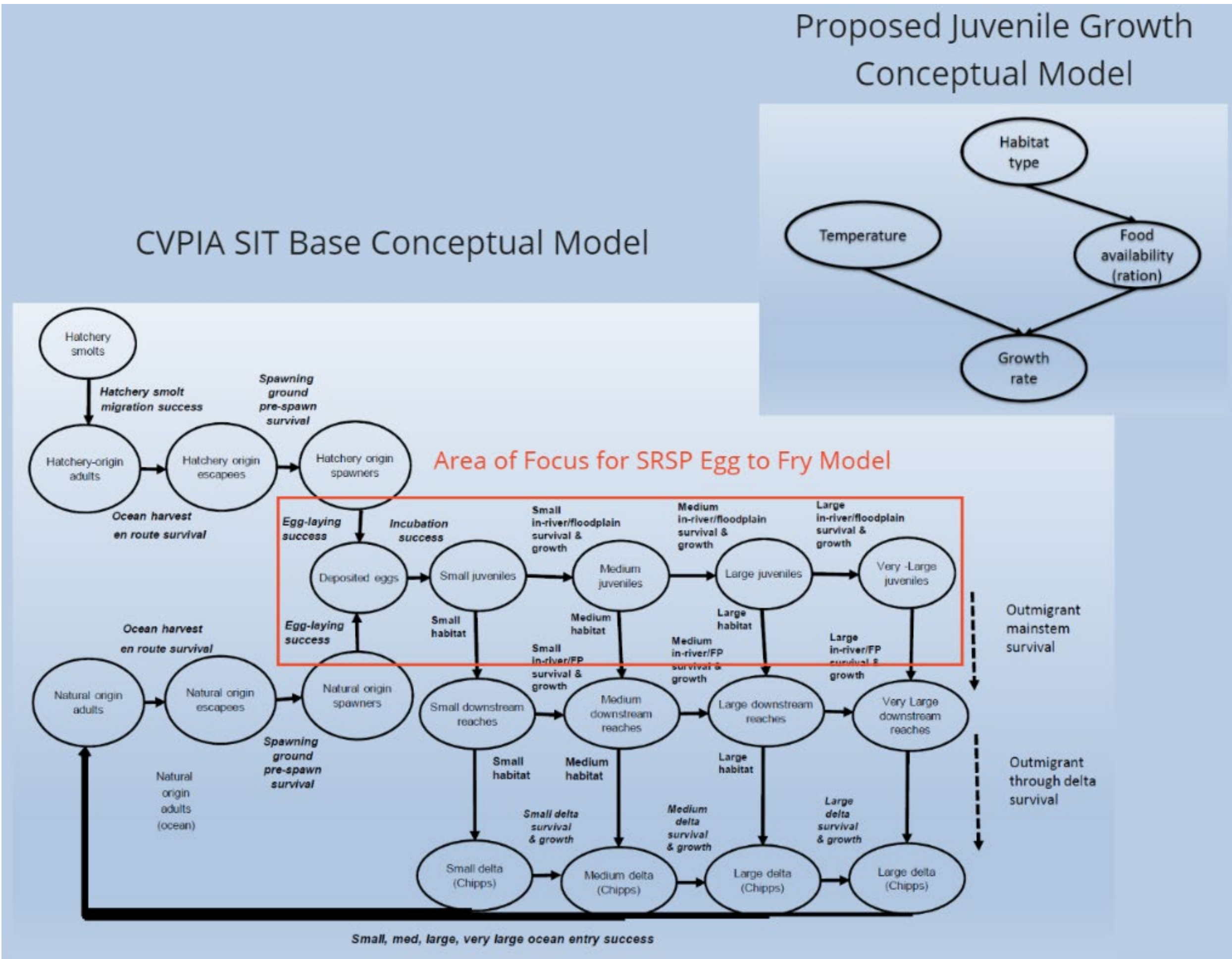


Figure 7: Area of Focus in WRLCM for SRSP Egg to Fry Model

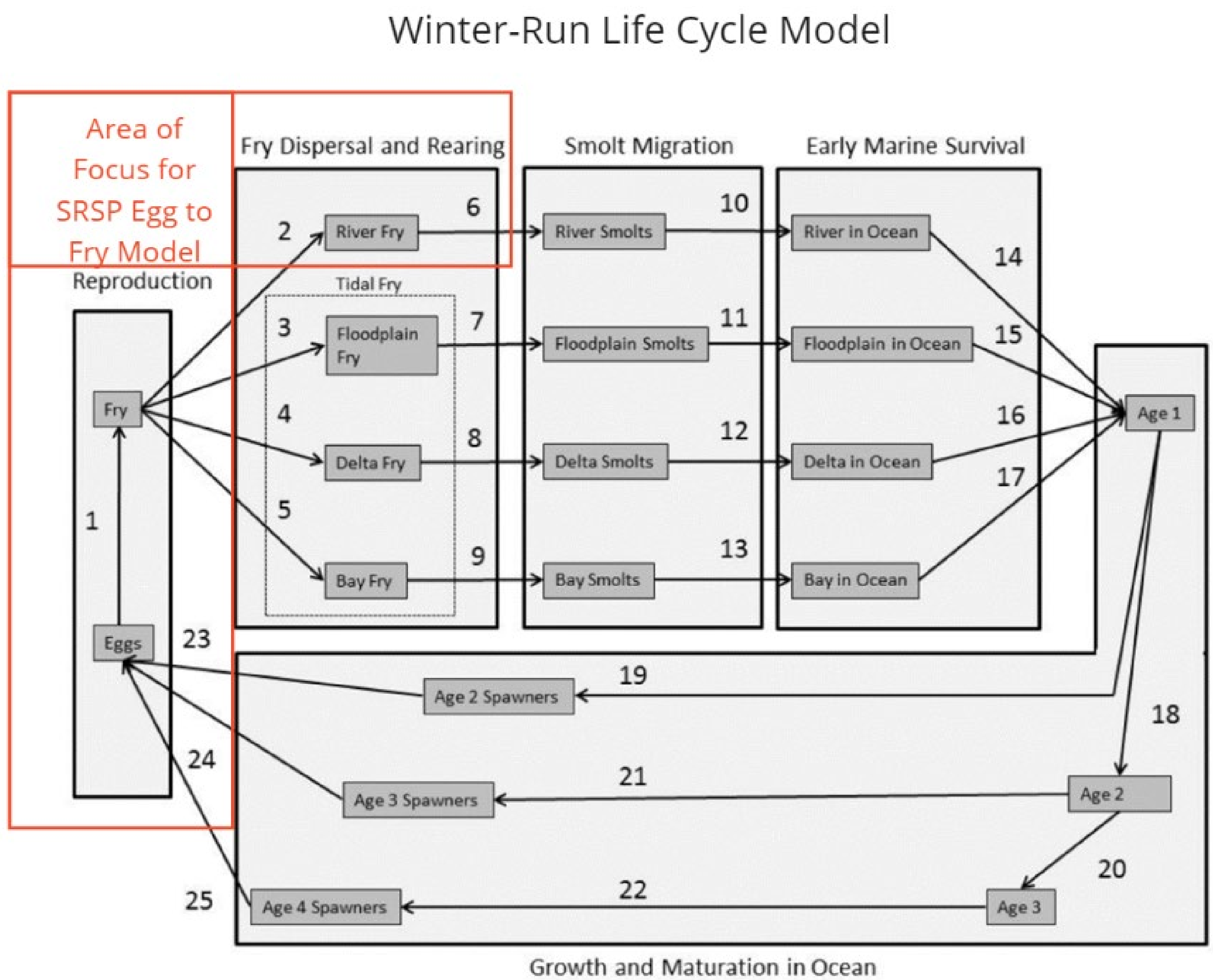


Figure 8: SRSP Egg to Fry in relation to SAIL Model

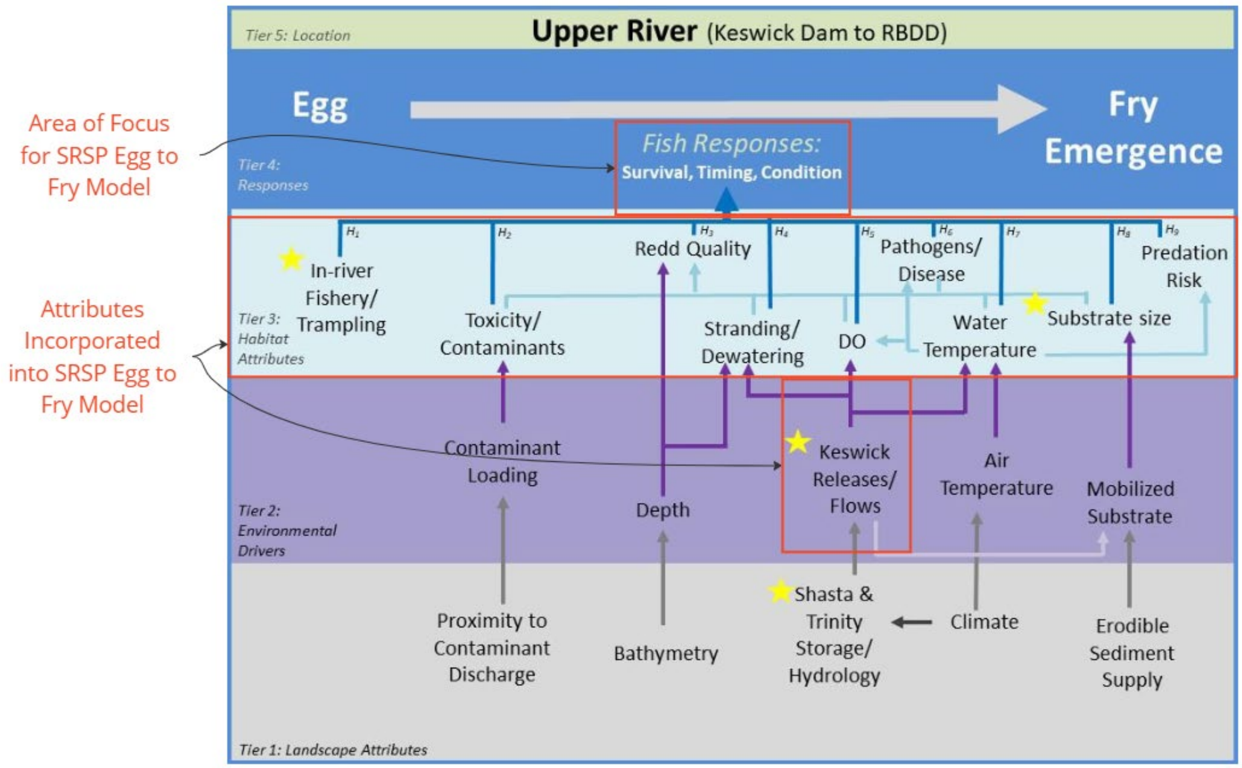
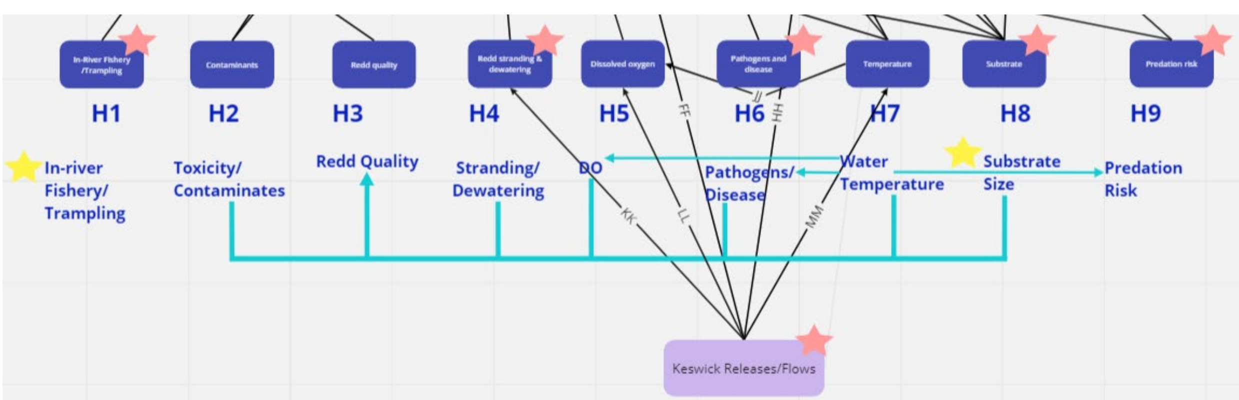


Figure 9: SRSP Egg to Fry Influence Diagram use of SAIL Model components



4. Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Criteria
    a. The Egg to Fry Influence Diagram nests within the DRERIP conceptual model and borrows some relationships from it. The Egg to Fry Influence Diagram provides more detail and documentation on the ecological relationships and areas of uncertainty for study.
    b. The documentation of ecological relationships and related qualitative analysis of the relative levels of uncertainty employs DRERIP criteria and scoring. These criteria include importance, understanding, and predictability. The SRSP Egg to Fry documentation and analysis includes a fourth criteria: data availability. DRERIP criteria were developed to evaluate management actions rather than evaluate level of uncertainty for ecological relationships.

Deliverable 2: Ecological Relationship Documentation

Science documentation of ecological relationships in the influence diagram

Results: Ecological Relationship Documentation

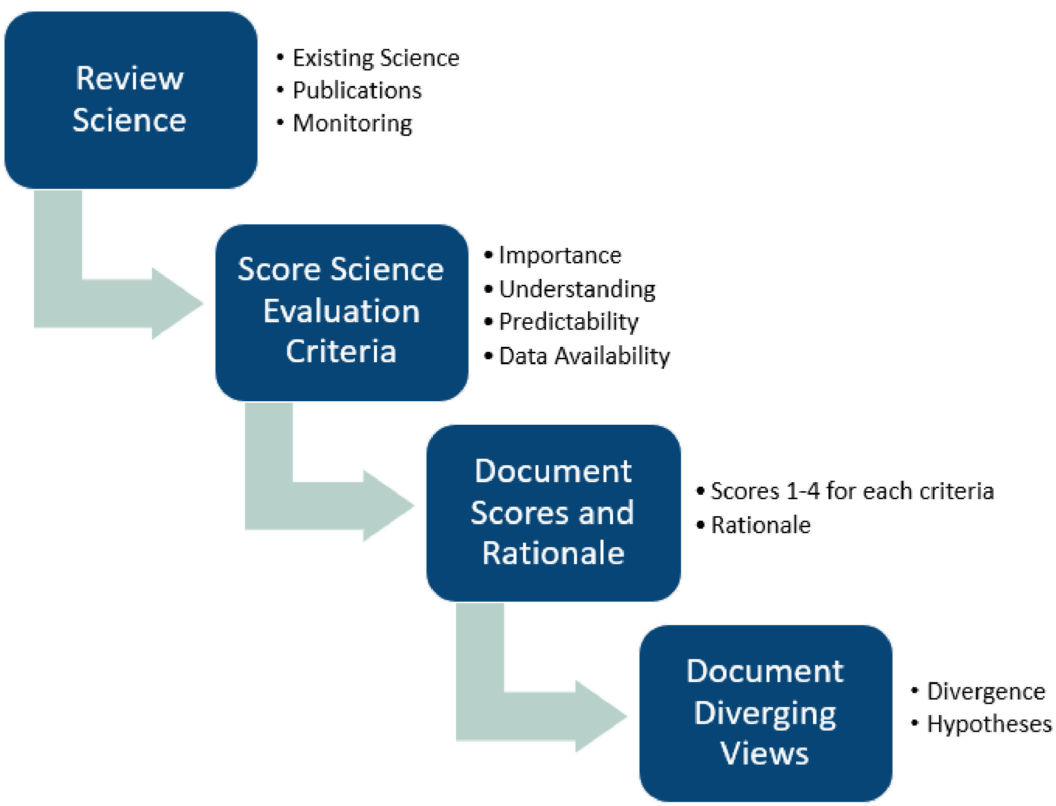
Detailed documentation for each ecological relationship in the influence diagram can be found in the: Egg to Fry SDM Ecological Relationship Spreadsheet.

Methodology: Ecological Relationship Documentation

The SRSP documented the status of science for each of the ecological relationships among means objectives, habitat attributes, and environmental drivers identified in the influence diagram. The method of documentation and evaluation included reviewing existing science, identifying evaluation criteria, and applying that criteria to score ecological relationships. The resulting evaluations of ecological relationships are expressed as scores. The methodology also involved documenting rationale for scores and documenting diverging viewpoints.

The following Figure outlines the steps in the methodology for Deliverable 2 and the steps are further detailed below.

Figure 10: Methodology Deliverable 2



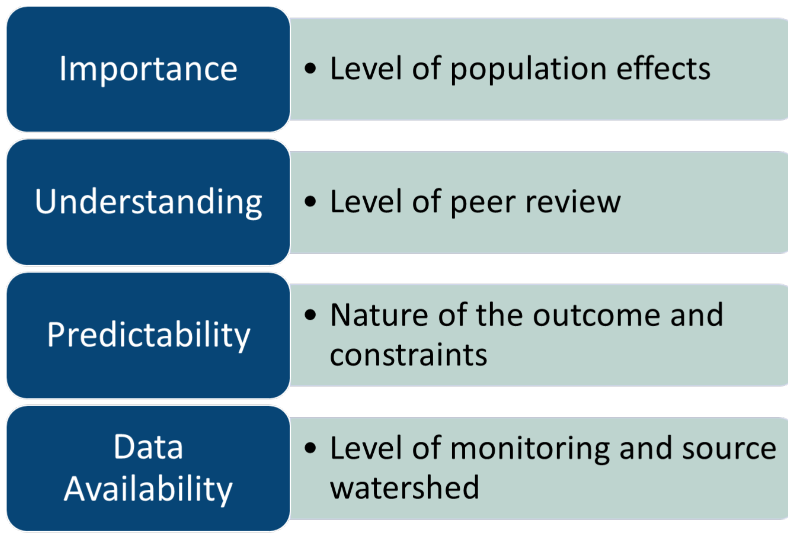
The methodology is described in more detail below:

1. Reviewed Science

The Science Subcommittee and Small Group[7] reviewed and documented existing information relevant to each ecological relationship represented by the arrows between the means objectives in the influence diagram.

2. Proposed Score for Each Science Evaluation Criteria

Figure 11: Science Evaluation Criteria



The Small Group members proposed a score for each of the four Science Evaluation Criteria. They used a standardized scoring range of 1-4 with 1 being low and 4 being high. This scoring range is based on standardized definitions from the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) process. For more information on the standardized scoring, see the Appendices. The Small Group presented these scores, rationale, and science to the Science Subcommittee.

3. Documented Range of Scores and Rationale

The Science Subcommittee discussed the Small Group's proposed scoring for each Science Evaluation Criteria and the rationale for those scores. In their discussion, the Science Subcommittee members discussed alternative scores, associated rationale, and documented the related science.

It is important to note that the Science Subcommittee did not rank, average, nor aggregate the scores for the Science Evaluation Criteria. This approach preserves the detail and differences between the application of each of the evaluation criterion to each of the ecological relationships for analysis. The facilitation team used the scores on each ecological relationship to perform the Qualitative Analysis as described Deliverable 3: Methodology.

4. Documented Diverging Viewpoints

When the Science Subcommittee members expressed diverging viewpoints on the scoring, the facilitation team documented the range of scores. If any of their Importance scores were 4 and the other criteria 1-3, then the facilitation team included it in the list of high value relationships due to the need to resolve diverging viewpoints and hypotheses. The facilitation team documented diverging viewpoints

[7] The Science Subcommittee is a group of technical scientists from the SRSP membership and parties interested in developing science for the Upper Sacramento River. The Small Group is a subgroup of the Science Subcommittee formed to support the development of the Egg to Fry science documentation and propose scoring according to the standard criteria.

within the Science Subcommittee. The Science Subcommittee sought to understand each other's viewpoints but not to resolve them at this time. In some cases, the documentation of ecological relationships led to proposed updates to the influence diagram, including additional means objectives and ecological relationships as well as adjustment to the hierarchy. The Science Subcommittee had proposed a few additional ecological relationships and had not discussed the science documentation at the time of producing this report.

Deliverable 3: Qualitative Analysis

Qualitative analysis of relative value of science to reduce uncertainty

Results: Qualitative Analysis

This section outlines the results of the qualitative analysis of value of information for the Egg to Fry life stage. The results include ecological relationships identified as relatively high value based on scoring after applying the science evaluation criteria.

The findings are presented as: 1) Summary of high importance ecological relationships sensitive to additional information; 2) Egg to Fry SDM Influence Diagram with highlighted ecological relationships sensitive to information; 3) Tables of ecological relationships with scoring and rationale according to the Science Evaluation Criteria; and 4) Table of High Value Science and Related SRSP Science Activities.

Summary of 14 High Value Ecological Relationships

Analysis of the scoring of the criteria indicated the following fourteen ecological relationships as high importance and low understanding, predictability, and/or data availability:

The fourteen high value ecological relationships are sorted by 1) Adult Spawner to Egg, 2) Egg to Emergence, and 3) Emergence to Fry.

Guide to the Table of 14 High Value Ecological Relationships

- The alphanumeric numbering corresponds to the arrows in the Egg to Fry Influence Diagram. The arrows represent the relationships or influence between certain means objectives. The alphanumeric sequence also corresponds to the sequence in the ecological relationship Documentation.
- The ecological relationships correspond to a means objective that influences another means objective or fundamental objective in the Egg to Fry Influence Diagram.
- The relationships are categorized by Adult Spawner to Egg, Egg to Emergence, and Emergence to Fry. Color coding corresponds to those stages and serves as a guide to the Summary Tables of 14 High Value Ecological Relationships.
- The reader may use the first reference summary table as an index for the 14 high value ecological relationships that follow.

Table 3: 14 High Value Ecological Relationships

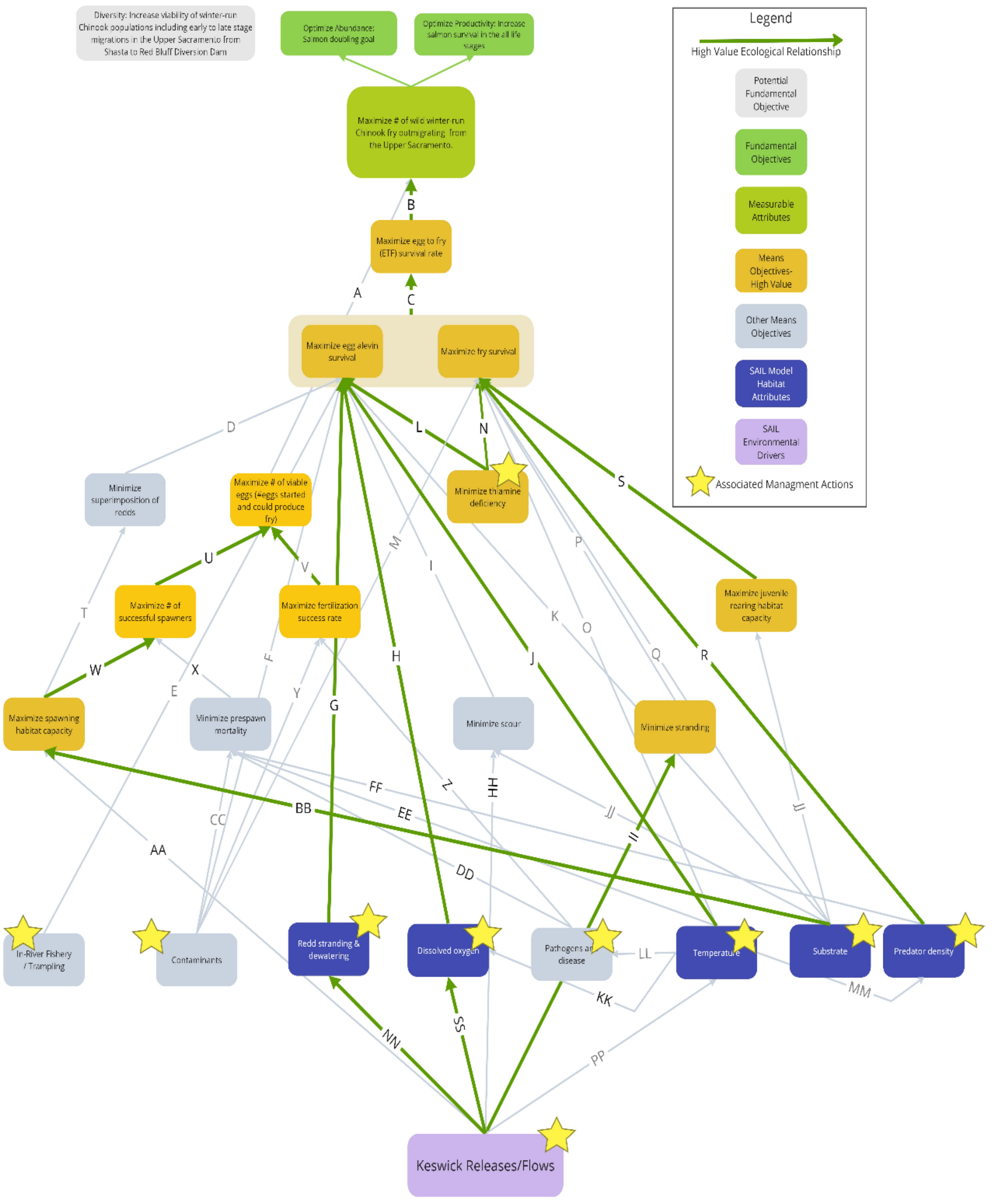
14 High Value Ecological Relationships: Low Understanding, Low Predictability and/or Low Data Availability	
#	**Ecological Relationships**
	Adult Spawner to Egg
BB	Substrate* --> Maximize spawning habitat capacity
U	Maximize # of successful spawners --> Maximize # of viable eggs
V	Maximize fertilization success rate --> Maximize # of viable eggs
W	Maximize spawning habitat capacity --> Maximize # of successful spawners
	Egg to Emergence
G	Redd stranding & dewatering* --> Maximize egg alevin survival
H	Dissolved oxygen* --> Maximize egg alevin survival
J	Temperature* --> Maximize egg alevin survival
L	Minimize thiamine deficiency* --> Maximize egg alevin survival
II	Keswick Releases/Flows* --> Minimize stranding
NN	Keswick Releases/Flows* --> Redd stranding & dewatering*
SS	Keswick Releases/Flows* --> Dissolved oxygen*
	Emergence to Fry
N	Minimize thiamine deficiency* --> Maximize fry survival
R	Predator density* --> Maximize fry survival
S	Maximize juvenile rearing habitat capacity --> Maximize fry survival
** Asterisks indicate associated management actions*	

Egg to Fry Influence Diagram with 14 High Value Ecological Relationships

The following version of the Egg to Fry Influence Diagram highlights important ecological relationships which are not well understood or for which data are lacking. Scientific investigations in these areas could reduce uncertainty and significantly inform decision-making, as well as reduce conflict.

Figure 12: Egg to Fry Influence Diagram with Highlighted 14 High Value Ecological Relationships

High Value New Science



SRSP Science Activities Related to 14 High Value Ecological Relationships

The SRSP Science Plan 2019, includes 31 science activities. The SRSP has engaged in several activities to prioritize and develop and implement the science activities.

The 14 high value ecological relationships resulting from this qualitative analysis relate to the following SRSP science activities. This information could inform the SRSP's collaborative and individual priorities for conducting high value science, resolving conflict, and informing decision-making.

The crosswalk between the science priorities and the high value ecological information generated in this report revealed a few important takeaways.

Table 4: Areas of Alignment: 14 High Value Ecological Relationships and SRSP Science Activities

Areas of Alignment: 14 High Value Ecological Relationships and SRSP Science Activities
• Eight SRSP science activities could encompass all 14 of the high value ecological relationships. These include: ○ ***#5: Carcass and Redd Surveys*** ○ ***#6 Redd Management*** ○ ***#8 Effects of Flow on Rearing Habitat*** ○ ***#13 Reproductive Success of Individual Spawners*** ○ ***#14 Predator Distribution*** ○ ***#19 Predator Abundance and Distribution*** ○ ***#27 Habitat Utilization Assessment*** ○ ***#28 Pathogens and Disease***
• Two SRSP science activities address 9 of the 14 high value ecological relationships, offering a high rate of return on high value information for two science activities. ○ ***#5 Carcass and Redd Surveys*** ○ ***#6 Redd Management***
• Two additional SRSP science activities could be modified to address 4 of the 14 high value ecological relationships related to thiamine. ○ ***#27 Habitat Utilization Assessment*** ○ ***#28 Pathogens and Disease***

The Table below illustrates the multiple nexus areas between the SRSP Science Plan 2019 and the 14 high value ecological relationships. The ecological relationships are ordered in groups related to the SRSP science activities. At the top, the table notes the number of high value ecological relationships related to each of the eight SRSP science activities.

Table 5: Summary of SRSP Science Activities Related to 14 High Value Ecological Relationships

	14 High Value Ecological Relationships	5 Carcass and Redd Surveys	6 Redd Management	8 Effects of flow on rearing habitat	13 Otoliths	14 Predator distribution	19 Predator abundance & distro	27 Reproductive success of spawners	28 Pathogens & Disease
#	# of Ecological Relationships per Science Activity	3	6	2	1	1	1	2	2
BB	Substrate* --> Maximize spawning habitat capacity								
W	Maximize spawning habitat capacity --> Maximize # of successful spawners								
G	Redd stranding & dewatering* --> Maximize egg alevin survival								
H	Dissolved oxygen* --> Maximize egg alevin survival								
J	Temperature* --> Maximize egg alevin survival								
NN	Keswick Releases/Flows* --> Redd stranding & dewatering*								
SS	Keswick Releases/Flows* --> Dissolved oxygen*								
II	Keswick Releases/Flows* --> Minimize stranding								
S	Maximize juvenile rearing habitat capacity --> Maximize fry survival								
V	Maximize fertilization success rate --> Maximize # of viable eggs								
U	Maximize # of successful spawners --> Maximize # of viable eggs								
R	Predator density* --> Maximize fry survival								
L	Minimize thiamine deficiency* --> Maximize egg alevin survival								
N	Minimize thiamine deficiency* --> Maximize fry survival								

Convergence

The following ecological relationships that were identified for high value of additional information enjoyed consensus scores on all four criteria. The scoring of the relationships listed below reflected convergence of viewpoints on importance, understanding, predictability, and data availability.

Table 6: Convergence on Application of all 4 Criteria

Convergence All 4 Criteria: Importance, Understanding, Predictability, Data Availability	
#	**Ecological Relationships**
Adult Spawner to Egg	
V	Maximize fertilization success rate --> Maximize # of viable eggs
Egg to Emergence	
L	Minimize thiamine deficiency* --> Maximize egg alevin survival
** Asterisks indicate associated management actions*	

Divergence

The following table lists ecological relationships for which there was a divergence of viewpoints regarding the level of importance of the ecological relationship on population effects. For more information on the application of scores for understanding, predictability, and data availability, see the Summary Tables of 14 High Value Ecological Relationships.

Table 7: Divergence: Importance Criteria

Divergence: Importance Criteria		
Ecological Relationships		
Criteria	**Scores**	**Rationale**
Egg to Emergence		
G: Redd stranding & dewatering -> Maximize egg alevin survival		
Importance	4	• The potential for a high impact of the relationship given the extended period of time that eggs and fry are in redds (Aug-Oct) during which flows often decrease and could result in stranding and dewatering.
	2	• The effect is limited to a relatively small fraction of the population.
II: Keswick Releases/Flows -> Minimize stranding		
Importance	4	• The number of rescued fish does not accurately reflect the actual number of stranded fish or affected fish. This relationship is more important to the population than the currently available data demonstrates.
	2,3	• The magnitude of the effect is limited to a small fraction of the population. Annual surveys show relatively low numbers of fish stranded compared to the population. About 1,000 stranded fish are rescued annually.
NN: Keswick Releases/Flows -> Redd stranding & dewatering		
Importance	4	• Flow releases are one of few primary controllable actions that is a driving influence for winter-run Chinook.
	2	• Flow releases influence on dewatering redds is limited to a small fraction of the population and limited dewatering has been observed.
SS: Keswick Releases/Flows -> Dissolved oxygen		
Importance	3,4	• DO has a sustained effect on a large portion of the population. • DO has a sustained effect on a small fraction of the population and therefore is not as important on a population scale.
Emergence to Fry		
R: Predator Density -> Maximize fry survival		
Importance	4	• Expected sustained population level effect, based on occurrence of predators throughout the watershed
	2,3	• Variation of population level effect based on water year type and associated flow influences on predation density and fry survival.
S: Maximize juvenile rearing habitat capacity -> Maximize fry survival		
Importance	3,4	• The magnitude of effect is limited regardless of the water year.
	1,2	• Varies based on water year type and in some year types there is a population level effect.

Data Availability

The following table lists ecological relationships for which there was a divergence of viewpoints regarding data availability scores by at least 2 points.

Table 8: Divergence: Data Availability Criteria

Criteria	Scores	Rationale
Divergence: Data Availability Criteria		
Ecological Relationships		
Adult Spawner to Egg		
W: Maximize spawning habitat capacity -> Maximize # of successful spawners		
Data Availability	4	• Current monitoring in the Upper Sacramento River.
	3	• Pretty good information on depth and velocity. Two good spawning gravel surveys in last couple of decades but don't have census data from many years.
	2	• Lack of data on influence of sediment size, influence on successful spawning. Spawners prefer certain gravel sizes; egg to fry survival is more successful at some gravel sizes. Additional information could inform gravel augmentation management actions.
Egg to Emergence		
G: Redd stranding & dewatering -> Maximize egg alevin survival		
Data Availability	4	• Redd dewatering is surveyed annually
	2,3	• There is no data on inter-gravel environment. • Data needs to be collected at scale. There is a hypothesis that data at scale will affect understanding and predictability differently than localized data collection.
H: Dissolved oxygen -> Maximize egg alevin survival		
Data Availability	3	• DO measured at gauges but not at scale of redds
	1	• **Hypothesis:** Intergravel environment influences egg growth and survival. No data on intergravel environment; gauge-based measurements not relevant; stranding surveys - attempted to measure DO within redds; quality of data may not be great Need: collect data at intergravel scale.
SS: Keswick Releases/Flows -> Dissolved oxygen		
Data Availability	4	• Current flow monitoring of flows occurs in the Upper Sacramento and is considered reliable and representative by most experts within system. • Monitoring of flow may not occur at all necessary scales (e.g., intergravel velocity/flow).
	2	• No field data for flows through intergravel nor its influence on dissolved oxygen. Stranding surveys attempted to measure dissolved oxygen within redds; quality of data may not be great. • Stranding surveys attempt to measure dissolved oxygen within redds but the data is not reliable.

Emergence to Fry		
S: Maximize juvenile rearing habitat capacity -> Maximize fry survival		
Data Availability	3	• Relationships between flow and juvenile habitat have been developed for the Upper Sacramento River
	1,2	• Unsure of 1) extent of habitat monitoring and 2) exclusion of juveniles from habitat by conspecifics (members of the same species)

Low Scores

These 14 ecological relationships all scored a high score of "4" on the criteria of importance. Of these 14 ecological relationships, we identified the low scores of "1" for any of the three remaining criteria: understanding, predictability, and data availability. The facilitation team suggests that these relationships merit attention to reduce uncertainty to inform decision-making.

The following three ecological relationships received low scores of "1" on at least one of the three remaining criteria. Only the three relationships and the criteria that received a score of "1" are listed below.

Table 9: Low Scores of "1" for 14 High Value Ecological Relationships

Low Score of "1"		
Ecological Relationships		
Criteria	**Scores**	**Rationale**
Egg to Emergence		
H: Dissolved oxygen -> Maximize egg alevin survival		
Data availability	3	• Dissolved oxygen is measured at gauges but not at an individual redds level.
	1	• There is no data for dissolved oxygen available at the redd scale.
J: Temperature -> Maximize egg alevin survival		
Predictability	1	• The existing model outcomes are dependent on variable ecosystem processes.
Emergence to Fry		
S: Maximize juvenile rearing habitat capacity -> Maximize fry survival		
Importance	3,4	• Importance varies based on water year type and in some year types the magnitude of effect is important on a population scale.
	1,2	• Some think the magnitude of effect is limited regardless of the water year.

Understanding	1,2	• No direct peer-reviewed studies for Chinook salmon linking habitat capacity to fry survival.
Data Availability	3	• Relationships between flow and juvenile habitat have been developed for the Upper Sacramento River
	1,2	• Peer-reviewed modeling studies exist, but dedicated field and lab studies are absent. Unsure of extent of habitat monitoring.

Convergence, Divergence, and Low Scores of "1"

This section summarizes and compares the results from the above sections on convergence, divergence, and low scores of "1". Recall that all 14 ecological relationships scored high on the criteria of Importance. Ecological relationships with blank cells did not demonstrate convergence, divergence, or low scores for the criteria analyzed. Low scores of "1" are on any of the three criteria: understanding, predictability, and data availability.

#	Ecological Relationships	Convergence: Importance, Understanding, Predictability, and Data Availability	Divergence: Importance	Divergence: High Importance and Divergence on Data Availability	Low Scores of "1" Understanding, Predictability, and Data Availability
	Adult Spawner to Egg				
BB	Substrate* --> Maximize spawning habitat capacity				
U	Maximize # of successful spawners --> Maximize # of viable eggs				
V	Maximize fertilization success rate --> Maximize # of viable eggs				
W	Maximize spawning habitat capacity --> Maximize # of successful spawners				
	Egg to Emergence				
G	Redd stranding & dewatering* --> Maximize egg alevin survival				
H	Dissolved oxygen* --> Maximize egg alevin survival				
J	Temperature* --> Maximize egg alevin survival				
L	Minimize thiamine deficiency* --> Maximize egg alevin survival				
II	Keswick Releases/Flows* --> Minimize stranding				
NN	Keswick Releases/Flows* --> Redd stranding & dewatering*				
SS	Keswick Releases/Flows* --> Dissolved oxygen*				
	Emergence to Fry				
N	Minimize thiamine deficiency* --> Maximize fry survival				
R	Predator density* --> Maximize fry survival				
S	Maximize juvenile rearing habitat capacity --> Maximize fry survival				

** Asterisks indicate associated management actions*				

Summary Tables of 14 High Value Ecological Relationships

The following tables include the scoring, rationale, and diverging viewpoints that support the findings for the value of information analysis summarized above. The findings are presented in groups of life stages: 1) Adult Spawners to Egg, 2) Egg to Emergence, 3) Emergence to Fry.

The scoring discussion amongst the Science Subcommittee included a range of thoughts and opinions leading to a range in scores applied based on individual evaluation criteria. The Science Subcommittee related some scores directly to certain rationale. In some cases, the facilitation team documented a range of rationale for the range of scoring. Additionally, the facilitation team documented diverging viewpoints for rationale and hypotheses in relation to each ecological relationship.

The ecological relationships, summarized evaluation criteria, and scoring are outlined in the tables below. For more detail on the Science Evaluation Criteria, see Appendices.

Guide to the Tables of 14 High Value Ecological Relationships

- The alphanumeric numbering corresponds to the arrows in the Egg to Fry Influence Diagram. The arrows represent the relationships or influence between certain means objectives. The alphanumeric sequence also corresponds to the sequence in the ecological relationship Documentation.
- The ecological relationships correspond to a means objective that influences another means objective or fundamental objective in the Egg to Fry Influence Diagram.
- The relationships are categorized by Adult Spawner to Egg, Egg to Emergence, and Emergence to Fry. Color coding corresponds to those stages and serves as a guide to the Summary Tables of 14 High Value Ecological Relationships.
- Asterisks * next to the ecological relationship indicates there is a management action associated with the "means objective".
- The reader may use the first reference summary table as an index for the 14 high value ecological relationships that follow.

Table 10: Reference Guide to Tables of 14 High Value Ecological Relationships

14 High Value Ecological Relationships: Low Understanding, Low Predictability and/or Low Data Availability	
#	**Ecological Relationships**
	Adult Spawner to Egg
BB	Substrate* --> Maximize spawning habitat capacity
U	Maximize # of successful spawners --> Maximize # of viable eggs
V	Maximize fertilization success rate --> Maximize # of viable eggs
W	Maximize spawning habitat capacity --> Maximize # of successful spawners
	Egg to Emergence
G	Redd stranding & dewatering* --> Maximize egg alevin survival
H	Dissolved oxygen* --> Maximize egg alevin survival
J	Temperature* --> Maximize egg alevin survival
L	Minimize thiamine deficiency* --> Maximize egg alevin survival
II	Keswick Releases/Flows* --> Minimize stranding
NN	Keswick Releases/Flows* --> Redd stranding & dewatering*
SS	Keswick Releases/Flows* --> Dissolved oxygen*
	Emergence to Fry
N	Minimize thiamine deficiency* --> Maximize fry survival
R	Predator density* --> Maximize fry survival
S	Maximize juvenile rearing habitat capacity --> Maximize fry survival

** Asterisks indicate associated management actions*

Table 11: Maximize # of successful spawners -> Maximize # of viable eggs

Adult Spawner to Egg		
U: Maximize # of successful spawners -> Maximize # of viable eggs		
Criteria	Score	Rationale
Importance	4	• Population level effect based on successful spawners are needed to produce viable eggs.
Understanding	3	• Spawner success can be estimated in the field through adult surveys (i.e., redd, carcass). However, it is difficult to assess egg viability in the field without disturbing redds/incubating eggs.
Predictability	2	• Successful spawners do not always result in viable eggs. • Spawner success can be estimated in the field through adult surveys (i.e., redd, carcass). However, it is difficult to assess egg viability in the field without disturbing redds/incubating eggs. • Egg viability from hatchery fish is not included in the Egg to Fry calculations for field data. • Calculation of egg-to-fry survival estimates assumes 100% of eggs are viable but literature suggests less. • **Hypothesis** that primary controlling factors are likely temperature and thiamine deficiency, both fairly predictable. Other influencing factors that are less understood and less predictable include dissolved oxygen and metabolic waste removal in eggs via velocity and interstitial and/or hyporheic flow.
Data Availability	Div.	• **Diverging Views** about the data that should be included in the calculation of successful spawner count. Suggestion to include a calculation of egg viability. There are diverging views on the inclusion of pre-spawn mortality of females in the calculation of the spawner count.
	3	• Spawner success is currently estimated in the field through carcass surveys. However, fecundity and egg viability are primarily measured in a hatchery setting. Some emergence trapping conducted in the San Joaquin River, but uncertainty as to whether placement of the trap adversely affects incubating eggs. • Population density, food availability, and stream gradient have been suggested as factors affecting fecundity in salmon as well as in other species. • Several years of histo-pathology of in-river adults and juveniles to determine impacts of disease and pathogens should be incorporated similar to the Klamath and Trinity systems. Livingston Stone National Fish Hatchery monitors pathogens annually.
	2	• Lack of field data; There are no direct measurements of the number of viable eggs based on field data. Most data comes from the hatchery.
Questions		• *How do we define successful spawner - Escapement; pre-spawn mortality estimates vs. carcasses fully spawned out? Deposition of eggs? Outmigration of juveniles? Back calculate from genetics?*

Table 12: Maximize fertilization success rate -> Maximize # of viable eggs

Adult Spawner to Egg		
V: Maximize fertilization success rate -> Maximize # of viable eggs		
Criteria	Score	Rationale
Importance	4	• Population level effect based on successful egg fertilization is required to produce viable eggs. However, viable eggs do not always result from successful egg fertilization.
Understanding	3	• While this relationship can be assessed in a laboratory setting, fertilization success rate and egg viability cannot be easily assessed in the field. Egg viability calculations from Livingston Stone National Fish Hatchery are not part of Egg to Fry calculations for field data. • Uncertainty on whether results of studies using emergence traps or egg incubation tubes/boxes are representative of natural conditions/occurrences. Placement of traps may adversely affect egg viability.
Predictability	2	• Successful fertilization of eggs does not always lead to the production of viable eggs. External factors (redd superimposition, temp, dissolved oxygen, flow, pathogens, etc.) may affect egg viability • Calculation of egg-to-fry survival estimates assumes 100% of eggs estimated from each female are viable.
Data Availability	2	• Studies using emergence traps or egg chambers/incubation boxes have been carried out in the CV (San Joaquin and Stanislaus rivers). • Calculation for viable eggs assume 100% viability, but literature suggests it is less than 100%.
Questions		• *What is the level of certainty of using emergence traps or egg incubation tubes/boxes are representative of natural conditions/occurrences?*

Table 13: Maximize spawning habitat capacity -> Maximize # of successful spawners

Adult Spawner to Egg		
W: Maximize spawning habitat capacity -> Maximize # of successful spawners		
Criteria	Score	Rationale
Importance	4	• Population level effect based on gravel augmentation and habitat capacity building are necessary since historical habitat is blocked.
Understanding	4	• There are multiple peer reviewed studies in the Central Valley
Predictability	3	• Understanding is high but depends on variable conditions. • Thermally acceptable spawning habitat needs to be incorporated into the physical habitat capacity conversation. Although there may be ideal gravel conditions downstream, if there is not adequate pre-spawn, spawning, incubation, and emergence conditions the quality of gravel will matter very little.
Data Availability	4	• Currently monitoring in the Upper Sacramento River that provides good information on depth and velocity of water. • USBR gravel augmentation study (2020) on the Sacramento River from Keswick to the confluence of Clear Creek (approx. 13 miles) developed estimates of gravel movement through the reach to assist and improve gravel augmentation strategies (USBR 2020).
	3	• It is unclear at what frequency data collection is needed to quantify spawning habitat. • There have only been two good spawning gravel surveys in the last couple of decades but lack census data from many years. • North State Resources Study on the Sacramento River mapped spawning gravel from Keswick down to Clear Creek. However, this report does not have good information on gravel size. • Gravel augmentation downstream of Keswick since the early 2000s but lack understanding of spawner success utilization of these gravel beds. • Reclamation is funding habitat studies on the Sacramento River and data will be used by the CVPIA SIT in estimating habitat availability.
	2	• Spawners prefer certain gravel sizes; egg to fry survival is more successful at some gravel sizes. Accordingly, gravel augmentation is not all equal. • Don't have great data on substrate size influence on successful spawners. • Additional information could inform gravel augmentation management actions.

Questions		• *Ask a fluvial geomorphologist, what frequency of spawning gravel survey is needed: annual estimate vs. decadal? Is a new survey needed now? Perhaps lower score depending on data needs. Do we want to know if there's enough habitat for a certain population? How much habitat from year to year?* • *What is the utilization of the augmented spawning beds downstream of Keswick and influence on spawner success?* • *How does gravel size influence spawner success and egg to fry survival?*

Table 14: Substrate -> Maximize spawning habitat capacity

Adult Spawner to Egg		
BB: Substrate -> Maximize spawning habitat capacity		
Criteria	Score	Rationale
Importance	4	• Population level effect based on upstream dams block gravel recruitment that is necessary for spawning habitat.
Understanding	3	• Studies from the Central Valley and peer reviewed are available, but there is uncertainty around optimal gravel size (redd building decreases with increasing substrate size, while embryo survival increases) • Generally, understanding is high because there are peer reviewed studies in the Central Valley.
Predictability	4	• It is predictable that gravel is important. • Studies show that gravel augmentation sites are used by spawning adults
	3	• Uncertainty around influence of gravel size on spawning habitat capacity
Data Availability	2	• There are limited surveys focused on gravel size at spawning sites in the river. There are also questions regarding how often gravel augmentation needs to occur and how much habitat is needed year to year.
Questions		• *How does gravel size influence spawning habitat capacity?*

Table 15: Redd stranding & dewatering -> Maximize egg alevin survival

Egg to Emergence		
G: Redd stranding & dewatering -> Maximize egg alevin survival		
Criteria	Score	Rationale
Importance	4	• Expected sustained effect limited to small fraction of population. However, population level effects of stranding may be increased as efforts are made to activate more managed floodplains • **Hypothesis** that the decreasing flows during Aug-Oct. likely highly influences in-gravel dissolved oxygen levels and therefore influences the egg alevin survival. The decreasing flow conditions and associated dissolved oxygen levels at the egg and fry life stage are different than conditions initial conditions when female spawners select their redd site.
	2	• Only an expected sustained effect limited to a small fraction of the population. • **Hypothesis** that the influence on population levels could increase with activation of managed floodplains.
Understanding	Div.	• **Diverging Views** around the adequacy of our understanding of the influences at the redd scale and under changing conditions.
	3	• Dewatering is surveyed in the Central Valley, which contributes to a higher level of understanding.
	2	• No direct peer-reviewed studies that have been conducted in the Central Valley on the population level effects of stranding. • It is unknown what effect increasing the amount of available floodplains will have at the population level. It is possible more stranding could occur with more dynamic water systems. • Salmon select their redd sites to provide conditions for successful incubation. Reductions in flows affect the hydrodynamics within redds and may negatively affect survival without complete dewatering; little is known about the magnitude of these effects.
Predictability	3	• Monitoring and models exist to estimate and forecast redd dewatering as a function of flow. • Little is known about the magnitude of effects resulting from incomplete dewatering, which does not allow for a full understanding of predictability.
Data Availability	Div.	• **Diverging Views** regarding the value of currently collected data. Some participants think the data collected is not at the appropriate scale, and/or does not reflect changing conditions over time, nor does it reflect the effects of partial dewatering of redds.
	3,4	• Redd dewatering is surveyed annually.
	2	• No data on inter-gravel environment.

		• **Hypothesis**: There is a hypothesis that collecting data at a larger scale will affect understanding and predictability differently than localized data collection. • The current gauge-based measurements are not useful. • Stranding surveys have attempted to measure dissolved oxygen within redds but the quality of data is unreliable.
Questions		• *What is the effect of floodplain reactivation on the population level effects of the relationship between redd stranding and dewatering and egg alevin survival?* • *Do surveys capture sufficient nuance to note survival? Can data be linked to specific survival value? How much is a sufficient level of detail?* • *Length of time dewatered; completely dry vs. some water (what is in literature?). Currently redds are considered dewatered if any substrate is above water but lots of variability in survival.*

Table 16: Dissolved oxygen -> Maximize egg alevin survival

Egg to Emergence		
H: Dissolved oxygen -> Maximize egg alevin survival		
Criteria	Score	Rationale
Importance	3,4	• Expected sustained population effect across a large geographic area, but there is question about whether this effect is minor or major. • There is an expected mechanistic underpinning of temperature effects. • The relationship is closely linked to flow and temperature, and velocity; specifically, velocity through gravel.
Understanding	3	• Lab studies of egg and alevin response to dissolved oxygen performed on Central Valley Chinook salmon runs other than winter-run Chinook. • There is uncertainty about optimal gravel size and flow velocity rates to optimize successful incubation to hatching rates
Predictability	2	• The outcome of survival is greatly dependent on other variable factors, such as temperature, which makes predictability low.
Data Availability	3	• Dissolved oxygen is measured at gauges but not at an individual redds level
	1	• No data on inter-gravel environment. • Data needs to be collected at a scale at which it is hypothesized to have an effect. • The current gauge-based measurements are not relevant. • Stranding surveys have attempted to measure dissolved oxygen within redds but the quality of data cannot be relied upon. • Dissolved oxygen and temperature are significantly connected and should be studied together.
Questions		• *What is optimal gravel size and flow velocity rates to optimize successful incubation to hatching rates?*

Table 17: Temperature -> Maximize egg alevin survival

Egg to Emergence		
J: Temperature -> Maximize egg alevin survival		
Criteria	Score	Rationale
Importance	4	• Expected sustained major population level effect.
Understanding	Div.	• **Diverging Views**: around the validity of the existing lab data, studies and models and the resulting understanding of the proportional influence of temperature on egg alevin survival. • Agreement that a temperature threshold exists and that temperature influences egg alevin survival.
	3,4	• Both lab and field studies on winter-run Chinook but they indicate different thresholds for temperature influences on egg alevin survival. • Lack of understanding on the likely synergistic effects of temperatures and thiamine deficiency which affect egg and alevin survival. • There is a lot of amount of information on this relationship, yet it is debated because of the political impacts of releasing water of a 'suitable' temperature avoid negatively affecting the spawner to emergence life stages. • Proposal that the closer the temperature compliance point is to Keswick, the lower the Egg to Fry values appear to be regardless of spawner abundance.
Predictability	1,2	• The existing model outcomes are dependent on variable ecosystem processes. • **Hypothesis** that there may be a linear relationship between the length of the temperature managed reach downstream of Shasta and the egg to fry values. The hypothesis is decreasing the length of the temperature management reach, decreases the egg to fry survival, regardless of spawner abundance.
Data Availability	Div.	• **Diverging Views** around the validity and weighting of lab data versus field data. Divergence over different sources of mortality and their proportional influence on egg alevin survival.
	3	• Temperature is measured at gauges but not at the scale of individual redds.
	2	• No field data on the temperature effect on incubation success and survival to test the lab study results. • Unclear how to weight lab data versus field data.
Questions		• *What is the predictable influence between decreasing the length of the temperature management reach and egg alevin survival? Does this relationship between temperature and egg alevin survival function independently of spawner abundance?* • *How could the scientific community weigh the lab v. field data?*

Table 18: Minimize thiamine deficiency -> Maximize egg alevin survival

Egg to Emergence L: Minimize thiamine deficiency -> Maximize egg alevin survival		
Criteria	Score	Rationale
Importance	4	• Population level effect based on thiamine deficiency is estimated to have killed approximately 55% of fry soon after emergence in 2022.
Understanding	3	• Over 100 publications related to thiamine deficiency in fish and other organisms outside of the Central Valley. • However, there are no publications of studies on thiamine conducted in the Central Valley. The stressor of thiamine deficiency has only recently been detected in the Central Valley, so understanding specific to Central Valley salmonids is newly emerging.
Predictability	2	• Ocean surveys and analysis on diet and forage can indicate whether anchovies are the primary prey item consumed by Chinook salmon and whether thiamine deficiency complex (TDC) is likely to be an issue in a given year. • Late-fall run Chinook salmon returning to Coleman Fish Hatchery may be an indicator to assess the level of thiamine deficiency expected for winter-run Chinook salmon.
Data Availability	3	• Current monitoring of component occurs in Upper Sacramento River but is newly emerging and evolving.
Questions		• *What data would inform management actions for treatment?*

Table 19: Keswick Releases/Flows -> Minimize stranding

Egg to Emergence		
II: Keswick Releases/Flows -> Minimize stranding		
Criteria	Score	Rationale
Importance	Div	• **Diverging Views** around the population level effects of flows on stranding. Diverging views around the completeness and accuracy of the data on stranded fish leading to different views of stranding's influence on population level effects.
	3,4	• Sustained effect on population. Stranding rescue numbers should not be a measure of impacts on juvenile stranding as many stranding sites are difficult to seine, dry up, or predation events happen before crews can reach them. • Stabilizing flows to prevent impacts on juvenile stranding and redd is important.
	2	• Expected sustained effect limited to a small fraction of the population. Annual surveys show relatively low numbers (~1000) of juvenile stranded fish are rescued annually.
Understanding	3	• Peer reviewed studies are available for other systems, and a non-peer reviewed model relating expected stranding to changing river flow has been developed for the Upper Sacramento River.
	2	• Lack of understanding on the proportional influence of Keswick flows and local flows on out-migrating juvenile stranding. • The 2019 Biological Opinion requires Keswick flow stabilization that would ideally help with stranding. • Juvenile stranding is expected to increase with greater decreases in flow and total stranding abundances are likely a function of flows, juvenile abundance, and juvenile use of seasonally flooded habitat.
Predictability	2	• Detailed predictions require understanding of habitat use and behavior of juveniles on seasonally flooded habitat as flows change.
Data Availability	4	• Current monitoring of flows occurs in the Upper Sacramento River and is considered reliable and representative by most experts within the system.
	N/A	• Stranding rescue numbers should not be a measure of impacts on juvenile stranding as many stranding sites are difficult to seine, dry up, or predation events happen before crews can reach them.
Questions		• *What is the proportional influence of Keswick flows and local flows on out-migrating juvenile stranding?* • *What is the influence of variety of factors affecting the ecological relationship, such as fish abundance and use of seasonally flooded habitat?*

Table 20: Keswick Releases/Flows -> Redd stranding & dewatering

Egg to Emergence		
NN: Keswick Releases/Flows -> Redd stranding & dewatering		
Criteria	Score	Rationale
Importance	4	• Population level effects due to flow releases as a primary control to influence the impacts of winter-run Chinook. • Uncertain influence of flow changes on redds before dewatering occurs and quantification of those influences.
	2	• Based on current summer flow regimes, drops in flow sufficient to cause dewatering are expected to be infrequent and limited dewatering has occurred and the expected sustained effect limited to small fraction of population.
Understanding	2, 3	• **Hypothesis**: Flow releases may influence redds as flows decrease but before dewatering occurs. • Understanding of influence of flows on depths and velocities downstream Keswick, but not understanding of low flow effects influences on population level scale. • No peer-reviewed studies known currently. • A non-peer-reviewed model has been developed and used on the Upper Sacramento River to estimate the expected dewatering that will occur based on flows. • Empirical relationship between flow and redd dewatering based on redd surveys on the Upper Sacramento River which supports understanding based on a binary variable, but not a continuous variable. • Need to define “dewatering” and “stranding” using competing definitions from literature and practice. • Although there is an understanding of how flows lead to dewatering, there is not a good understanding of how dewatering affects the extent of mortality.
Predictability	3	• Monitoring and models exist to estimate and forecast redd dewatering as a function of flow. • There are different understanding about whether additional information redd location and timing is needed to identify river flow at spawning. Data on redd location and timing is collected for shallow redds.
Data Availability	4	• Current monitoring of flows occurs in the Upper Sacramento River and is considered reliable and representative by most experts within system.
	3	• Lack data on the effect of flows on depth and velocity for spawning further downstream. • The data is from the last 10 years and driven by fish distribution in the Upper Sacramento River. There is no data for any current or possible expanded spawning downstream. If spawning were to occur downstream the magnitude of dewatering may be different.
Questions		• *What is the difference of influence between dewatering and stranding? There is difference between them in literature and practice.*

Table 21: Keswick Releases/Flows -> Dissolved oxygen

Egg to Emergence SS: Keswick Releases/Flows -> Dissolved oxygen Criteria	Score	Rationale
Importance	3,4	• Dissolved oxygen has a sustained effect on either a small or large fraction of the population, especially through eggs.
Understanding	Div	• **Diverging views** around the applicability of fall-run studies to winter-run eggs
	3	• Lack of understanding of the various factors influencing dissolved oxygen levels in redds. • Peer-reviewed studies in the Central Valley on fall-run Chinook eggs. • Studies have documented effects of interstitial flow on biological oxygen availability, linkages between Keswick releases/flows and interstitial flows. Interstitial dissolved oxygen concentrations are less understood. • Moderate understanding of influence of external factors, such as temperature, influence dissolved oxygen.
	2	• Lack of peer-reviewed studies on winter-run Chinook. • **Hypothesis** that influences of flows on dissolved oxygen for fall- and winter-run redds may not be comparable.
Predictability	2	• Use of oxygen limitation as a functional measure of dissolved oxygen availability in developing eggs. Increasing interstitial flow velocity exponentially decreases oxygen limitation. • External factors, such as temperature, influence predictions of oxygen in the environment. • Predicting interstitial dissolved oxygen concentrations at a scale relevant to eggs/fry is not currently possible across the Upper Sacramento River including reaches downstream of Keswick and Clear Creek.
Data Availability	Div	• **Diverging views** around the value of laboratory data and the absence of available field data at the redd scale.
	4	• Current flow monitoring of flows occurs in the Upper Sacramento and is considered reliable and representative by most experts within system. • Monitoring of flow may not occur at all necessary scales (e.g., intergravel velocity/flow).
	2	• No field data for flows through intergravel nor its influence on dissolved oxygen. Stranding surveys attempted to measure DO within redds; quality of data may not be great. • Stranding surveys attempt to measure dissolved oxygen within redds but the data is not reliable.
Questions		• *Could link dissolved oxygen measurements available at gauges in the Sacramento River to flow estimates. Would this information inform the understanding and predictability of this relationship?*

Table 22: Minimize thiamine deficiency -> Maximize fry survival

Emergence to Fry		
N: Minimize thiamine deficiency -> Maximize fry survival		
Criteria	Score	Rationale
Importance	4	• Expected sustained major population level effects. • Uncertainty about the persistence of major effects caused by the thiamine deficiency complex due to uncertainty about this trend in the Central Valley and changes in ocean conditions. • Uncertainty about thiamine deficiency's presence and background role in historical population level peaks and valleys in the Sacramento Valley.
Understanding	3	• **Hypothesis:** Thiamine deficiency may not be new to Central Valley salmon and may have played a background role in population level historically. It is uncertain if this shift will persist. • Published studies from outside the Central Valley • Once thiamine deficiency is detected there is a good understanding of how to treat it.
	2	• Less understanding about the connection between the ecosystem and thiamine deficiency. • No published studies from in the Central Valley.
Predictability	2	• Low predictability due to low understanding of the connection between ecosystem and thiamine deficiency. • Thiamine deficiency's influence on fry survival is greatly dependent on variable external factors (e.g., prey conditions). • Ocean surveys (diet/forage analysis) can help predict whether anchovies are the primary prey item consumed by Chinook salmon and whether thiamine deficiency complex is likely to be an issue in a given year. Also, late-fall Chinook salmon returning to Coleman Fish Hatchery may be an indicator to assess the level of thiamine deficiency complex expected for winter-run Chinook salmon.
Data Availability	3	• Thiamine levels are now being monitored annually on a subset of hatchery-destined fish.
	2	• There is little data to compare thiamine deficiency effects on natural origin with hatchery origin fish. • Some experts believe there is no significance between thiamine deficiency effects on hatchery versus natural origin fish.
Questions		• *What has thiamine deficiency complex's historical role been on population levels?* • *Will its effects persist for the long-term in the Central Valley continuing to have a population level effect?*

Table 23: Predator Density -> Maximize fry survival

Emergence to Fry		
R: Predator Density -> Maximize fry survival		
Criteria	Score	Rationale
Importance	3,4	• Expected sustained population effects, based on occurrence of predators throughout the watershed.
	2,3	• Predation risks for out-migrating juveniles are likely much higher during low flow, low turbidity, and high water temperature years (drought) and are much less during high flow and high turbidity years.
Understanding	3	• No direct peer-reviewed studies linking predation to survival for winter-run Chinook salmon. • Numerous studies of indirect effects of predation on migratory survival in Central Valley. • Some studies of predators and predator events in the Sacramento River.
Predictability	2	• Low predictability due to other variables which affect this relationship. The influence of predator density on fry survival are heavily dependent on predator abundance, which can fluctuate as a function of covariants, including flow, temperature, turbidity, location effects, and temporal (diurnal and seasonal) cycles, characteristics of predators and prey. • Migratory survival decreases with increasing predator density or interactions, either linearly or as a more complex response. Faster flows and lower temperatures are presumed to affect predation impacts on fish by changing exposure time and behavior. Altered habitat and lowered flows increase predation interactions. • It is difficult to quantify predation risk or inform the relationship between predation risk and survival other than concluding there is a negative relationship.
Data Availability	3	• Studies of predation in Central Valley and on Upper Middle Sacramento River. • Some monitoring and studies of predators and predator events in the Sacramento River. • One study focused on predation events for striped bass in the Lower Sacramento River.
	2	• Disparate monitoring and studies of predators and predator events in the Sacramento River. • No studies of avian predation in the Upper Sacramento River.
Questions		•

Table 24: Maximize juvenile rearing habitat capacity -> Maximize fry survival

Emergence to Fry		
S: Maximize juvenile rearing habitat capacity -> Maximize fry survival		
Criteria	Score	Rationale
Importance	3,4	• Expected impact on the population level is very important in some years.
	1,2	• Expected sustained minor population effect is limited to those juveniles that are excluded from habitat by conspecifics (members of the species). The extent of exclusion is unclear.
Understanding	1,2	• No direct peer-reviewed studies for Chinook salmon linking habitat capacity to fry survival. Peer-reviewed modeling studies exist, but dedicated field and lab studies are absent. • Juvenile rearing habitat capacity affects fry survival indirectly through effects on movements and growth. Estimated juvenile territory sizes can result in habitat limitations, forcing dispersal of juveniles with associated migratory mortality. • Juvenile salmon growth decreases with increasing density of conspecifics and survival increases with increasing size growth.
Predictability	2	• Predictability may be confounded by many other covariates. • Stock assessment forecasts can help to estimate expected adult escapement and likelihood of density dependent/habitat limitations that may increase levels of redd superimposition. • Habitat capacity may also be limited by flow and/or temperature, as demonstrated by a reduction in preferred spawning habitat.
Data Availability	3	• Relationships between flow and juvenile habitat have been developed for the Upper Sacramento River
	1,2	• Need data on the migratory behavior of 'ocean type' winter and fall-run Chinook salmon in the Sacramento River as opposed to spring-run Chinook or Coho salmon, which have long river residence times. • Need data on number of fish are rearing in the Upper Sacramento River versus the total production at Red Bluff Diversion Dam. Including the fish that leave immediately may help determine capacity. • Need data on exclusion of juveniles from habitat by conspecifics (members of the same species). • Need better information on extent of habitat monitoring.
Questions		• *What is the migratory behavior of 'ocean type' winter and fall-run Chinook salmon in the Sacramento River in comparison to spring-run Chinook or Coho salmon, which have long river residence times.* • *What is the number of fish rearing in the Upper Sacramento River in comparison with the total production at Red Bluff Diversion Dam. Monitoring fish that immediately leave the Upper Sacramento River may help determine carrying capacity.*

		• *What is the exclusion of juveniles from habitat by conspecifics (members of the same species).* • *Does the extent of habitat monitoring need to change?*

Methodology: Qualitative Analysis

This section describes the methods used for producing the 1) Analysis of High Value Ecological Relationships, 2) SRSP Science Activities Related to the 14 High Value Ecological Relationships, and 3) identification of convergence, divergence, and low scores.

1. Sorted High Value Ecological Relationships

The facilitation team identified ecological relationships that are important to salmon on a population level but for which there is very little information, understanding, or predictability of that cause-and-effect relationship. In the analysis, the facilitation team has identified ecological relationships scored high in importance and low in data availability, understanding, or predictability. If scoring resulted in an Importance score 4, and a spread of 1-3 for the other three criteria, the facilitation team highlighted this ecological relationship as relatively higher value need for information.

2. Identified SRSP Science Activities Related to 14 High Value Ecological Relationships

The facilitation team identified the SRSP science activities whose topic and scope seem to encompass the 14 high value ecological relationships. The facilitation team used the information provided by the SRSP Science Plan to connect science activities to ecological relationships.

3. Sorted for Convergence, Divergence

The facilitation team analyzed the data to inform the value of information for supporting consensus, resolving divergence, and for informing areas where there is very low understanding.

The facilitation team analyzed the scoring of the 14 high value ecological relationships to identify areas of convergence, divergence, and low scores of “1” to inform the value of information that could resolve conflict.

The facilitation team reviewed the scoring on the 14 high value ecological relationships to summarize the ecological relationships that enjoyed convergence and divergence of scores on importance and data availability criteria. The facilitation team included any difference in scoring in these results.

4. Sorted for Low Scores of “1”

The facilitation team reviewed the 14 high value ecological relationships to identify and summarize any low scores of “1”.

Next Steps

The Partnership will consider the information herein and decide on potential next steps. Given the results of this report, the Partnership will consider revisions to the original SRSP Egg to Fry SDM Workplan and additional proposed next steps.

Appendices

A. Science Evaluation Criteria for Documenting Ecological Relationships

This document outlines the four Science Evaluation Criteria employed by SRSP to document and evaluate the state of science for each ecological relationship in the SRSP Egg to Fry Influence Diagram. The ecological relationships are illustrated as arrows connecting the habitat attributes, means objectives, and fundamental objectives in the SRSP Egg to Fry Influence Diagram.

The SRSP used four Science Evaluation Criteria – importance, understanding, predictability, and data availability. The source of the first three criteria came from the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). The SRSP added the data availability criteria.

The next two sections describe the four Science Evaluation Criteria, scoring, and relation to source.

Importance, Understanding, and Predictability Criteria

The first three criteria – importance, understanding and predictability – were developed in DRERIP. DRERIP developed a series of conceptual models intended to describe the current understanding of ecological relationships for several key species, habitat types, and processes in the Delta and Central Valley (e.g., Chinook salmon and steelhead, Delta smelt, floodplains, tidal marshes, sedimentation, etc.) (Figure 1).

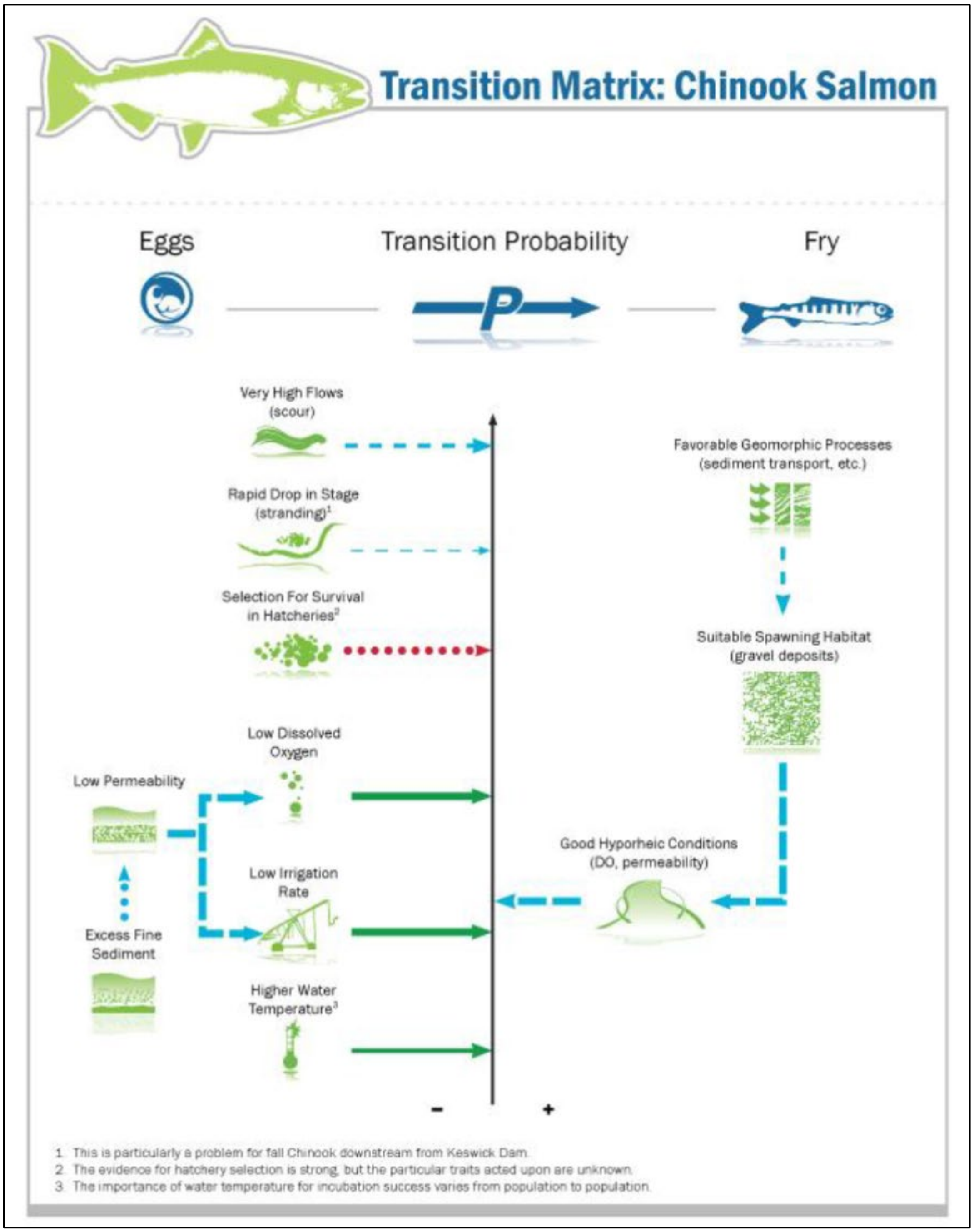


Figure 13: DRERIP Chinook Salmon Transition Matrix for Egg to Fry Life Stage (Williams 2010).

Importance, Understanding, Predictability Criteria

DRERIP authors used a constructed scale to assign the level of importance, understanding, and predictability for each ecological relationship in the model. The DRERIP criteria and scoring can be found in the table below.

Table 1: DRERIP criteria for assigning level of importance, understanding, and predictability (e.g., Israel and Klimley 2008)

DRERIP Criteria			
	Importance	**Understanding**	**Predictability**
High (4)	Expected sustained major population level effect, e.g., the outcome addresses a key limiting factor, or contributes substantially to a species population's natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics.	Understanding is based on peer-reviewed studies from within system and scientific reasoning supported by most experts within system.	Understanding is high and nature of outcome is largely unconstrained by variability in ecosystem dynamics, other external factors, or is expected to confer benefits under conditions or times when model indicates greatest importance.
Medium (3)	Expected sustained minor population effect or effect on large area or multiple patches of habitat	Understanding based on peer-reviewed studies from outside the system and corroborated by non-peer-reviewed studies within the system.	Understanding is high but nature of outcome is dependent on other highly variable ecosystem processes or uncertain external factors. **OR** Understanding is medium and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors.

Low (2)	Expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial or temporal habitat effects	Understanding based on non-peer-reviewed research within system or elsewhere.	Understanding is medium and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors. **OR** Understanding is low and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors.
Little or no (1)	Conceptual model indicates little or no effect	Lack of understanding. Scientific basis unknown or not widely accepted.	Understanding is lacking. **OR** Understanding is low and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors.

The following table provides a key to the visual representation of the criteria in the diagram.

Table 2: Key for arrows representing ecological relationships according to the DRERIP approach.

	Importance (*Line weight*)	**Understanding** (*Line color*)	**Predictability** (*Line type*)
High	Thick	Green	Solid
Medium	Medium	Blue	Dashed
Low	Thin	Red	Dotted

Data Availability Criteria

The SRSP added data availability as a fourth criteria for defining ecological relationships in the Egg to Fry SDM effort. The Table below outlines the Data Availability Criteria and scoring.

Table 2: Data Availability Criteria

	Data Availability
High (4)	Current monitoring of component occurs in the system of interest (e.g., Upper Sacramento River) and is considered reliable and representative by most experts within system.
Medium (3)	The component has been infrequently monitored in the past in the system of interest and current monitoring of the component occurs outside but near the system of interest (e.g., Clear Creek, Middle/Lower Sacramento River).
Low (2)	The component has not been monitored in the system of interest and monitoring outside but near the system has occurred infrequently in the past.
Little or no (1)	No relevant monitoring data exist for the component in or near the system.

SRSP Application of Four Science Evaluation Criteria

The following Table provides an example of the SRSP's application of these four Science Evaluation Criteria to the ecological relationships in the Egg to Fry Influence Diagram.

Table 3: Example SRSP Application of Science Evaluation Criteria from the Egg to Fry Influence Diagram Ecological Relationship Tracking Spreadsheet

Arrow Label	Starting Box	Ending Box	Importance	Understanding	Predictability	Data Availability	Quantitative Information (e.g., magnitude, rate)	Supporting Information
K	Substrate	Maximize egg alevin survival	2	3	3	2 / 3	Survival declines rapidly (in a threshold response) when percent fines <0.85 mm exceed 10%. Higher contributions (25–30%) of larger fines are required to produce decreases in survival. Survival may decrease if gravel sizes are too large. Variability in fine intrusion explains variation in survival among reaches. Increasing fines also increases emergence of alevin with unabsorbed yolk sac	Tappel and Bjornn 1983 (OCV, PR): Lab study / Reiser and White 1988 (OCV, PR): Lab study on sediment effects on eggs / Greig et al. 2005 (OCV, PR): Field and lab studies / Jensen et al. 2009 (OCV, PR): Meta-analysis of published studies / Louhi et al. 2011 (OCV, PR): Lab experiment / Roni et al. 2016 (OCV, PR): Experimental observations of survival in the field / Merz et al. 2018 (ICV, PR): Field experiment with gravel augmentation
O	Temperature	Maximize fry survival	3	4	3	4	The upper incipient lethal temperature (50% of fish can tolerate for 7 days) is between 24 and 26°C; critical thermal maxima (short-term lethal) range between 27 and 29.5°C; optimal growth at 19C when fed to satiation	Hanson 1991 (ICV, NPR): Lab study on FRCS fry / Cech and Myrick 1999 (ICV, NPR): Lab study on FRCS fry / Myrick and Cech 2002 (ICV, PR): Lab study on FRCS / Marine and Cech 2004 (ICV, PR): Lab study on FRCS fry / Zillig et al. 2020 (ICV, NPR): Lab study on WRCS fry [Rich 1987 (ICV, NPR), Brett 1982 (OCV, PR), and Williams 2006 (ICV, PR) from past DRERIP may also be referenced]

References

The following references are for the DRERIP model and its criteria:

Israel, J. A. and Klimley, A. P. 2008. Life History Conceptual Model for North American Green Sturgeon (*Acipenser medirostris*). DRERIP Delta Conceptual Model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=29310

Williams, G. J. 2010. Life History Conceptual Model for Chinook salmon and Steelhead. DRERIP Delta Conceptual Model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=28422

B. Egg to Fry SDM Ecological Relationships Spreadsheet

This spreadsheet contains the full documentation of the Science Subcommittee's documentation on the state of science for each ecological relationship in the Egg to Fry Influence Diagram. It includes the detailed rationale supporting each of the four Science Evaluation Criteria and the scoring.

Please access the spreadsheet at: Egg to Fry SDM Ecological Relationship Spreadsheet

C. SRSP Science Plan and Science Activities

The SRSP Science Plan and Science Activities are also on the SRSP SharePoint and can be accessed for reference.

Please access on SRSP's website at the following links:

- SRSP Science Plan
- SRSP Science Activities

D. Meeting Content for SRSP Egg to Fry SDM Effort

Starting in June 2022, the SRSP convened the SRSP Egg to Fry SDM effort including the development of the Egg to Fry Influence Diagram and documentation and scoring of the ecological relationships.

The SRSP's work from June through February 2023 focused on:

Task 1: Develop the Egg to Fry Influence Diagram (July 2022 – July 2023).

- June 15: Partnership Quarterly Meeting
    - Clarify the decision context:
        - Identified management actions identified in the 2019 Biological Opinion and Voluntary Agreements.
        - Discussed predictive models' representation of the egg to fry life stage: CVPIA SIT model, SAIL model, and winter-run life cycle model (WRLCM).

- July 8: Partnership SDM Session
    - Developed biological fundamental and means objectives in the Egg to Fry Influence Diagram.
    - Documented potential performance metrics and areas of uncertainty.

- August 3: Partnership Meeting SDM Session
    - Developed biological objectives and ecological relationships in influence diagram for egg to fry life stage.
    - Identified additional management actions and relation to the Egg to Fry Influence Diagram.
    - Documented potential performance metrics and areas of uncertainty.

- September 7: Partnership Meeting SDM Session
    - Developed biological objectives and ecological relationships in the Egg to Fry Influence Diagram.
    - Shared SRSP member plans and options for updating conceptual and numeric models using the SRSP Egg to Fry Influence Diagram.
    - Documented potential performance metrics and areas of uncertainty.

- October 5: Partnership Meeting SDM Session
    - Discuss Updated SDM Approach.
    - Discuss process for compiling science and discussing quantitative relationships at Science Subcommittee.
    - Review and update the Egg to Fry Influence Diagram based on member proposals.
    - Review and update ecological objectives and performance metrics for egg to fry life stage.

- October 14: Science Subcommittee

- Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022.
- Using the DRERIP definitions, identify the importance, predictability, and understanding of each ecological relationship in the influence diagram.
- Update documentation of relationships in the influence diagram for Partnership review.

- November 2: Partnership Meeting SDM Session
  - Review SDM approach and objectives.
  - Discuss Science Subcommittee proposal to add a fourth criteria for defining ecological relationships (data availability).

- November 3: Science Subcommittee Meeting
  - Discuss next steps for reviewing available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022.
  - Discuss next steps for identifying the importance, predictability, understanding, and data availability for each ecological relationship in the influence diagram.

- January: SDM Small Group Meeting
  - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022.
  - Propose scores and rationale for the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram.

- February 2: Science Subcommittee Meeting
  - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022; propose additional references as appropriate.
  - Review scores and rationale provided by the Small Group for the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram; propose alternate scores and/or rationale as appropriate.
  - Update documentation of relationships in the influence diagram for Partnership review.
  - Propose candidate performance measures for Partnership review.

- March 2: Science Subcommittee Meeting
  - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022; propose additional references as appropriate.
  - Review DRERIP scores and rationale provided by the Small Group for the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram; discuss additional rationale and interpretations to propose refinement of scores and/or rationale.
  - Update egg-to-fry influence diagram to reflect any revised understanding of ecological relationships.
- March 15: Partnership Quarterly Meeting

- Review summary outcomes of Science Subcommittee work to define and document egg-to-fry ecological relationships.
- Review proposed updates to the Egg-to-Fry Influence Diagram.
- Pilot value of information discussion of qualitative evaluation of one egg-to-fry related science activity against the egg-to-fry objectives.
- Each member shared and considered information on intended development of numeric models and consider partnership opportunities.

Task 2: Qualitatively estimate the value of science activities to improve decision-making in relation to the Egg to Fry Influence Diagram. (March – July 2023)

- March: Science Subcommittee Meeting
    - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022; propose additional references as appropriate.
    - Review scores and rationale provided by the Small Group for the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram; propose alternate scores and/or rationale as appropriate.
    - Update documentation of relationships in the influence diagram for Partnership review.
    - Propose candidate performance measures for Partnership review.

- April: Partnership Meeting SDM Session
    - Review and update Influence Diagram.
        - Report on Science Subcommittee definitions and documentation of ecological relationships.
        - Consider providing updated influence diagram to CVPIA SIT, WRLCM, or other groups for consideration of updates to numeric models.
    - Review documentation of estimated value of information of science activities in relation to the egg to fry influence diagram, for each Partner including convergence and divergence among Partnership.
      Qualitatively estimate value of information of science activities to improve decision making and prediction of performance towards objectives.

- April: Science Subcommittee Meeting
    - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022.
    - Identify the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram.
    - Update documentation of relationships in the influence diagram for Partnership review.
    - Propose candidate performance measures for Partnership review.

- April: Science Subcommittee Meeting
    - Review available scientific documentation of egg to fry life stages compiled by DRERIP until 2010 and by USBR through 2022; propose additional references as appropriate.

- Review scores and rationale provided by the Small Group for the importance, predictability, understanding, and data availability of each ecological relationship in the influence diagram; propose alternate scores and/or rationale as appropriate.
- Update documentation of relationships in the influence diagram for Partnership review.
- Propose candidate performance measures for Partnership review.

- May: Partnership Meeting SDM Session
    - Review and update Influence Diagram.
        - Report on Science Subcommittee definitions and documentation of ecological relationships.
        - Consider providing updated influence diagram to CVPIA SIT, WRLCM, or other groups for consideration of updates to numeric models.
    - Review documentation of estimated value of information of science activities in relation to the egg to fry influence diagram, for each Partner including convergence and divergence among Partnership.
    - Qualitatively estimate value of information of science activities to improve decision making and prediction of performance towards objectives.

- June: Partnership Quarterly Meeting
    - Egg-to-Fry Influence Diagram and Distribution
        - Review Updated Influence Diagram.
        - Consider providing updated egg-to-fry influence diagram to CVPIA SIT, WRLCM, or other groups for consideration of updates to numeric models. Value of Information Discussion
        - For each egg-to-fry science activity, review and discuss the DRERIP scores and rationale for the ecological relationships as proposed by the Science Subcommittee.
        - Given this information, discuss and document each agencies' viewpoint on the value of information that could be produced by each egg-to-fry related science activity to improve decision making in relation to identified egg-to-fry objectives. Use a consequence table to document the qualitative evaluation of egg-to-fry related science activities benefits to the identified egg-to-fry objectives.
        - Identify converging and diverging viewpoints on value of information. Where convergence emerges, identify next steps for SRSP development of the identified science activity. Where divergence emerges, invite parties to share with the SRSP next steps for development of the egg to fry science activity they evaluated as important.

E. Quantitative Analysis Options

The SRSP has discussed the potential of using numerical models to evaluate the value of information to improve decision making and meeting objectives through actions. The SRSP has discussed the general capabilities, potential next steps, and timelines for using the following models as outlined below. The SRSP acknowledges that some of these tools, particularly the CVPIA SIT Model and WRLCM, are managed via independent processes and protocols and the SRSP may inform but does not control these processes.

- CVPIA SIT Model
    - Alternative types: Habitat actions only
    - Next Steps: USBR is seeking to update the CVPIA SIT model to evaluate additional types of management actions.
        - The SRSP SDM process including the influence diagram, objectives, and performance metrics could inform the USBR's proposal to the CVPIA SIT.
    - Timeline:
        - To run sensitivity analyses to habitat actions
        - To update the model and include flow actions - one year.
        - USBR is confirming when the SIT will next accept new proposals to update the model; the SIT timeline may not align with the SRSP's SDM process.
- Winter-run Life Cycle Model (WRLCM)
    - Alternative types: Habitat and flow actions
    - Next Steps: SRSP members could propose to run sensitivity analyses to quantify the value of information in the near-term.
        - It may be possible to use components of the WRLCM focused on early life stages rather than running a full life cycle model.
    - Timeline: Months
- Production Model (e.g., InSalmo)
    - Alternative types: Habitat, flow, and temperature actions
    - Next Steps: SRSP members could propose to run sensitivity analyses to quantify the value of information in the near-term.
    - Timeline: Months
- SALMOD
    - Alternative types: Habitat, flow, and temperature actions
    - Next Steps: This model would require updates prior to applying to a value of information analysis; USBR may have staff who could lead this effort.
    - Timeline: Months to year

F. SRSP Science Subcommittee Meeting Summaries

The SRSP Science Subcommittee Meeting Summaries provide further documentation of the discussion that resulted in the Relationships Spreadsheet.

Please access the spreadsheet on SRSP's Sharepoint site at: SRSP Science Subcommittee Meetings .

G. Egg to Fry SDM Influence Diagram Iterations

The facilitation team documented multiple iterations of the Egg to Fry Influence Diagram throughout its development. These are included below for reference.

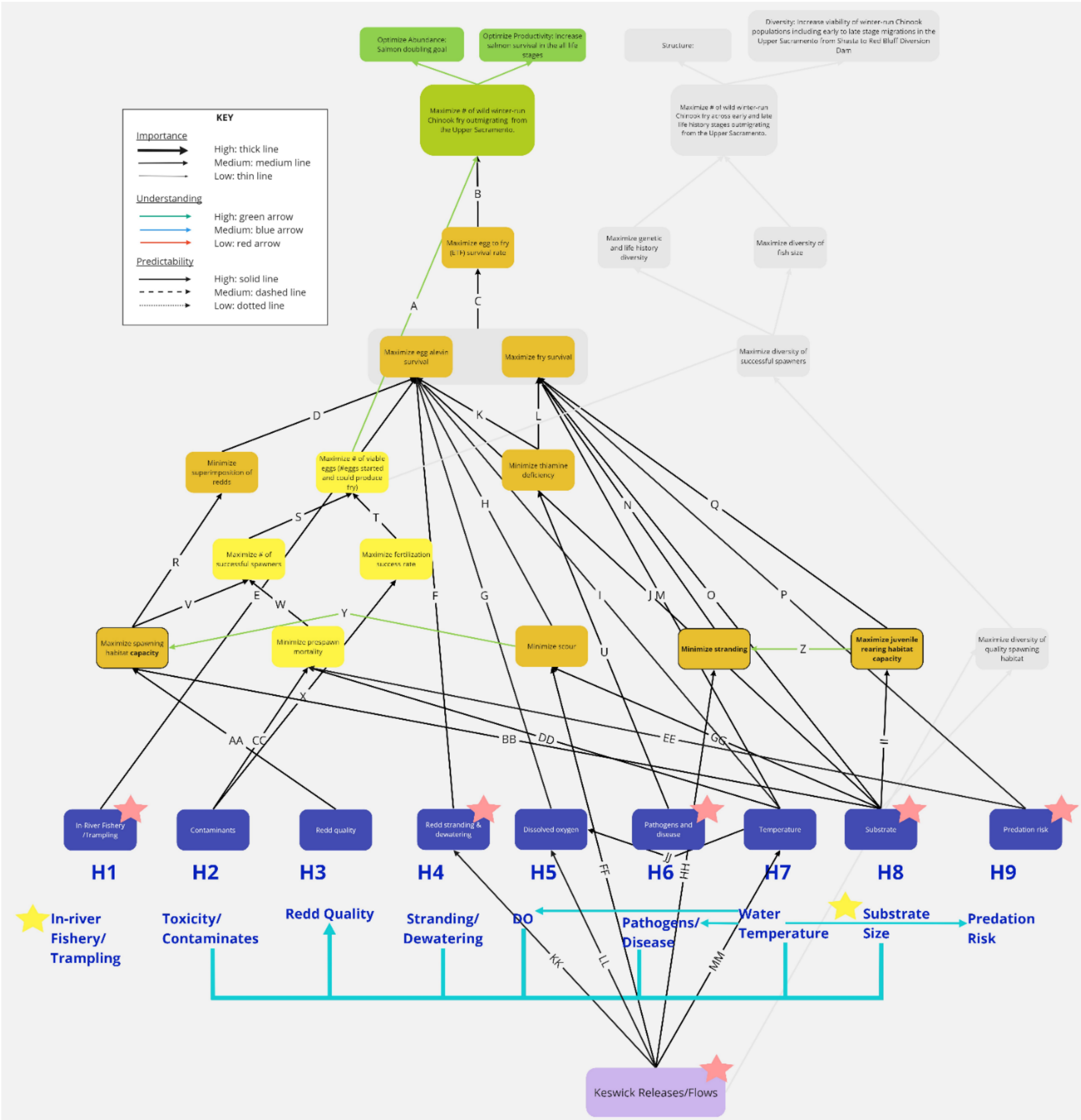


Figure 14: 10/5/2022 Egg to Fry Influence Diagram

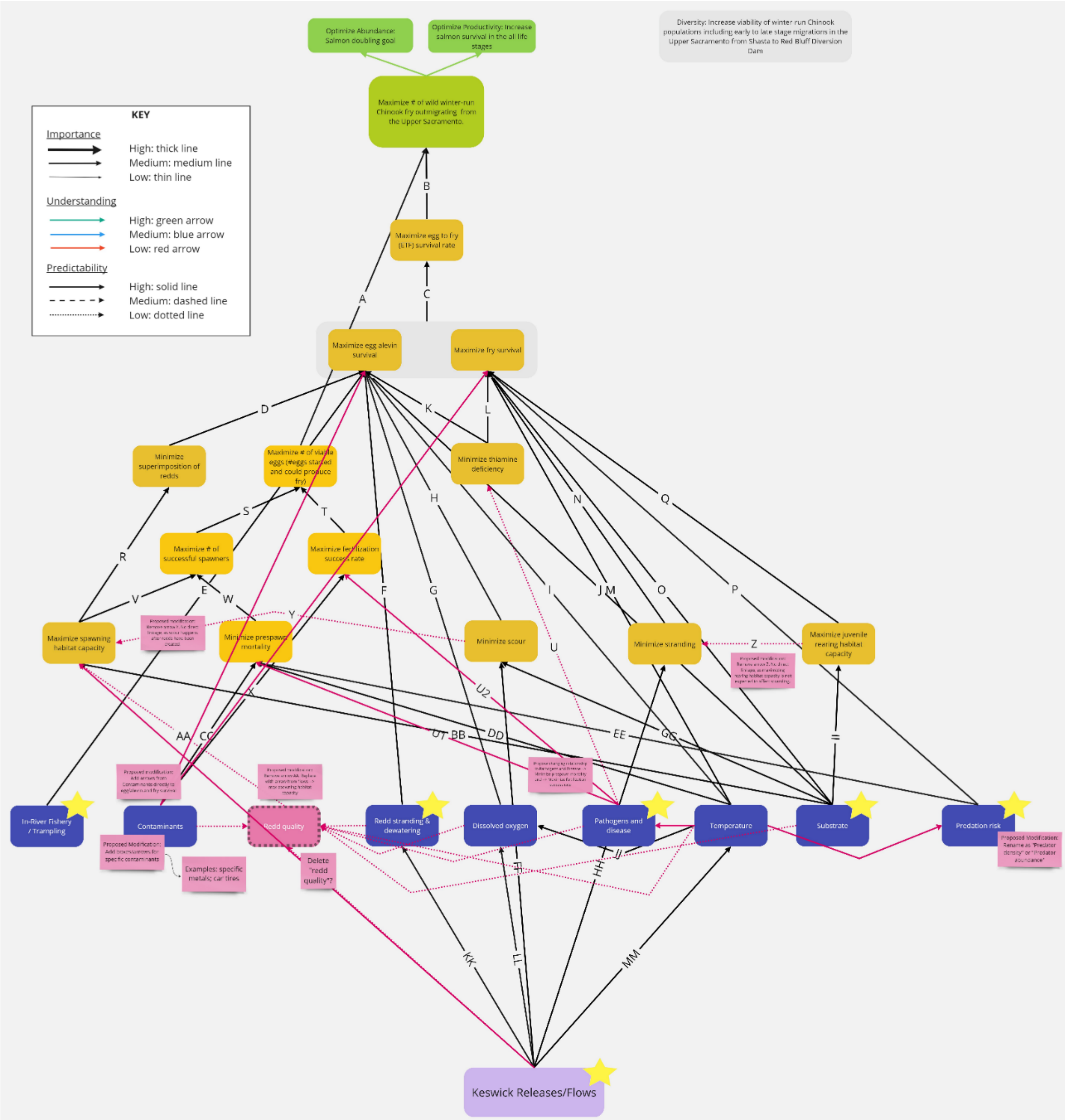


Figure 15: 3/15/2023 Egg to Fry Influence Diagram

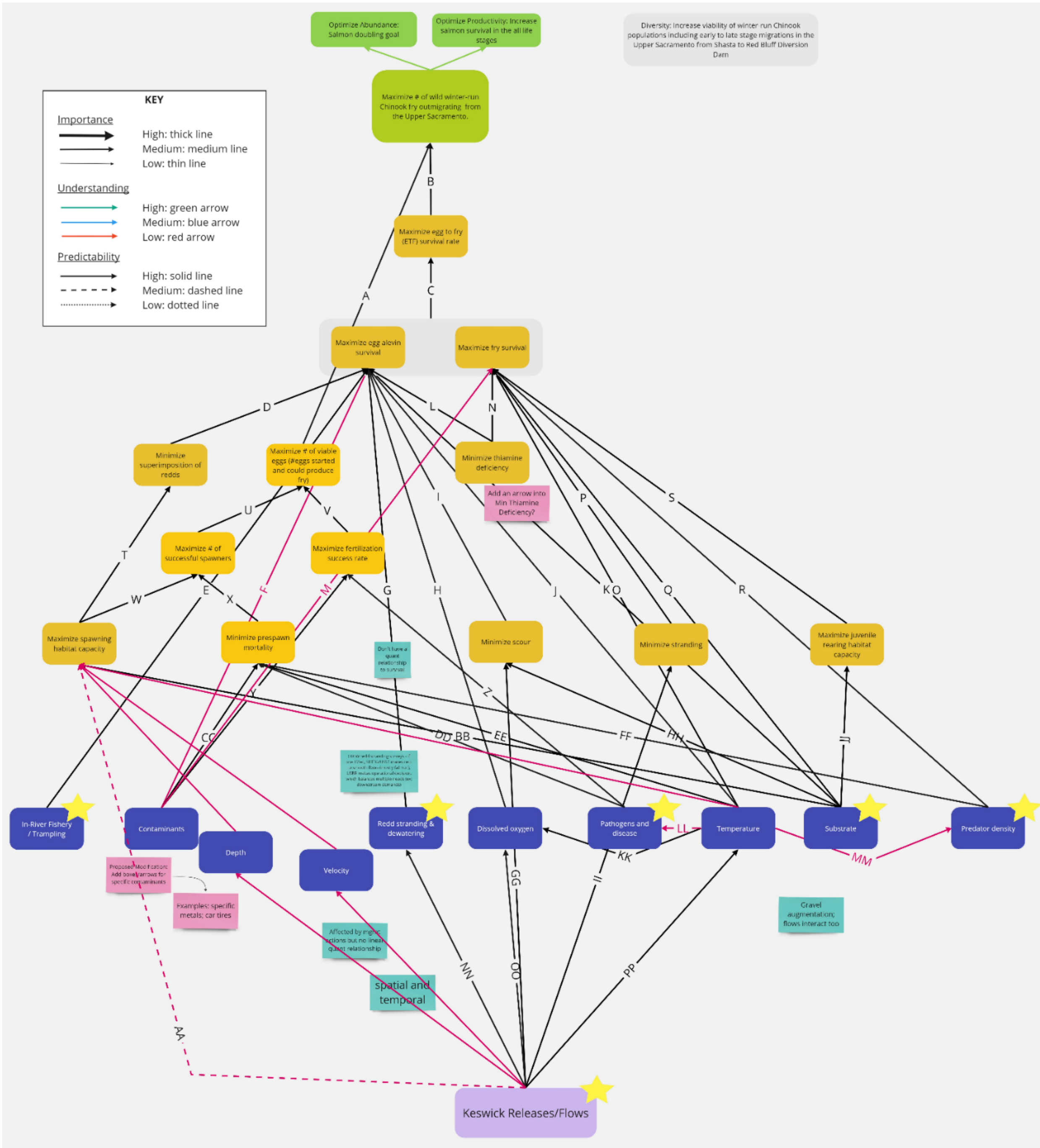


Figure 16: 6/1/2023 Egg to Fry Influence Diagram