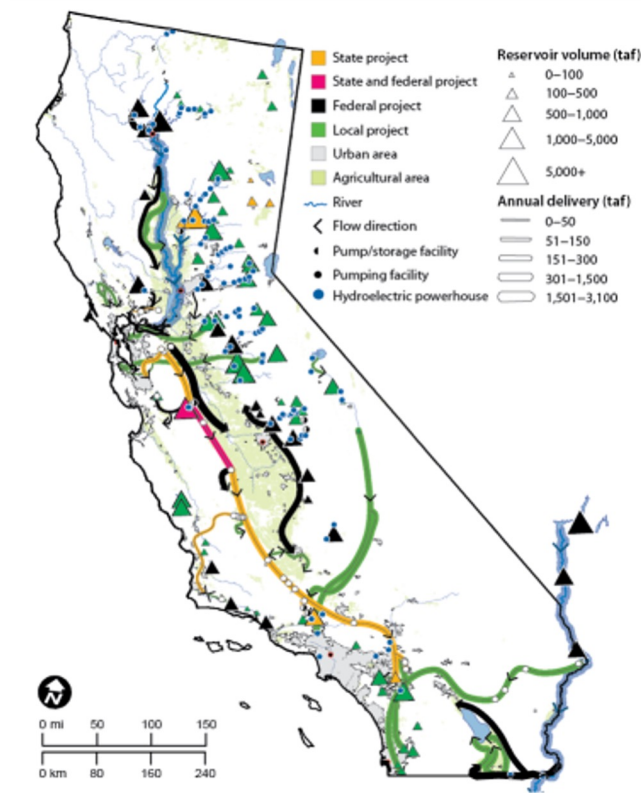
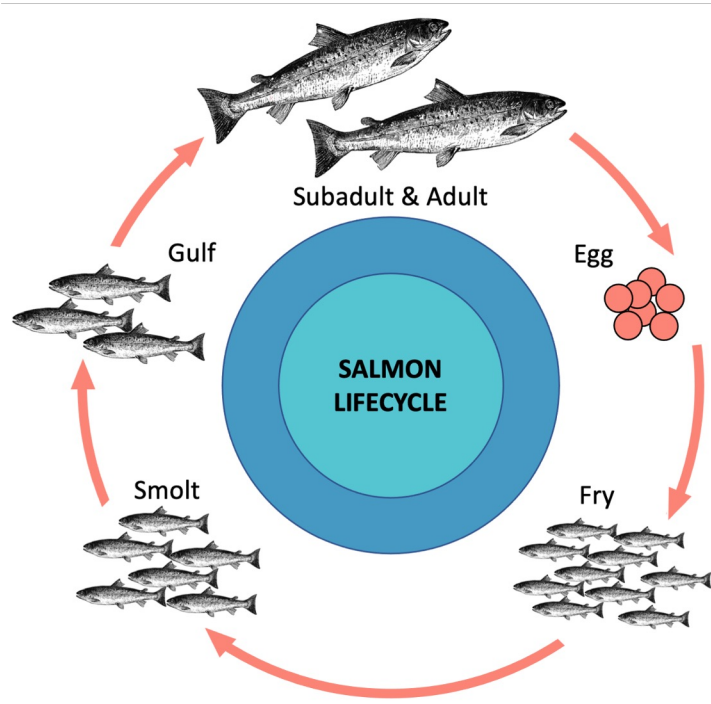


An integrated modeling framework for assessing the impacts of the CVP operations on ESA listed salmon

Eric Danner
NOAA Southwest Fisheries Science Center
eric.danner@noaa.gov
May 7, 2024



Complex life cycles and complex water management



Integrated Modeling Decision Support Framework

1. Individual elements:

Experiments, monitoring, and models (conceptual, mathematical, simulation, etc.)

2. Integrated models:

Collectively what the individual elements can tell us

Quantification of the trade-offs to inform decisions based on costs and benefits

3. The decision space:

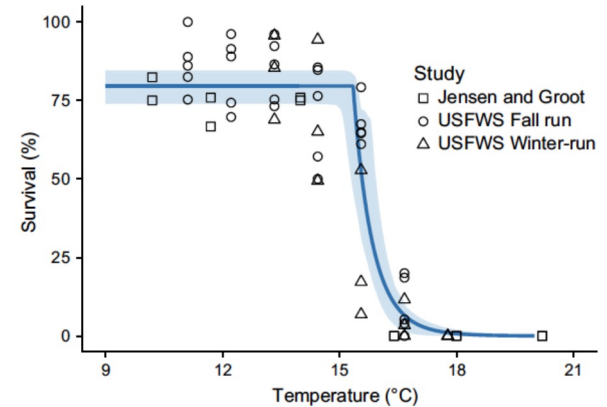
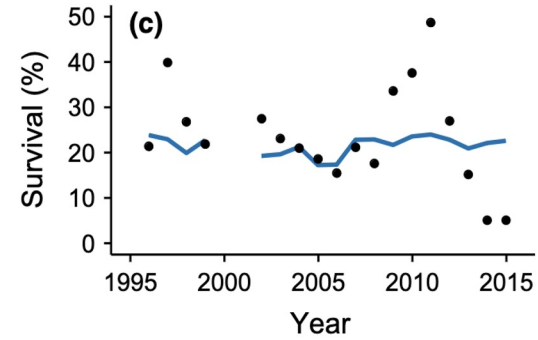
The unconstrained range of management options

4. Adaptive management:

CV water planning and operations are different processes

Monitor fish response relative to actual operations

Highly Variable Egg to Fry Survival



Egg Temperature Dependent Mortality Model

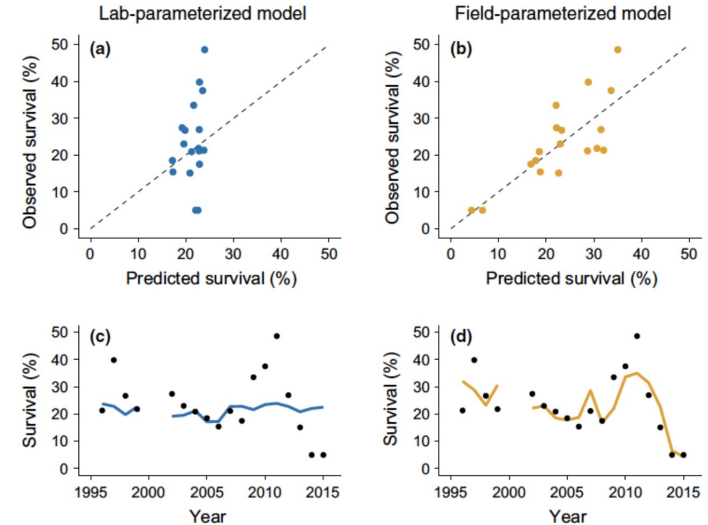
NMFS egg TDM Model

Critical temperature (T_{crit}) = 12°C

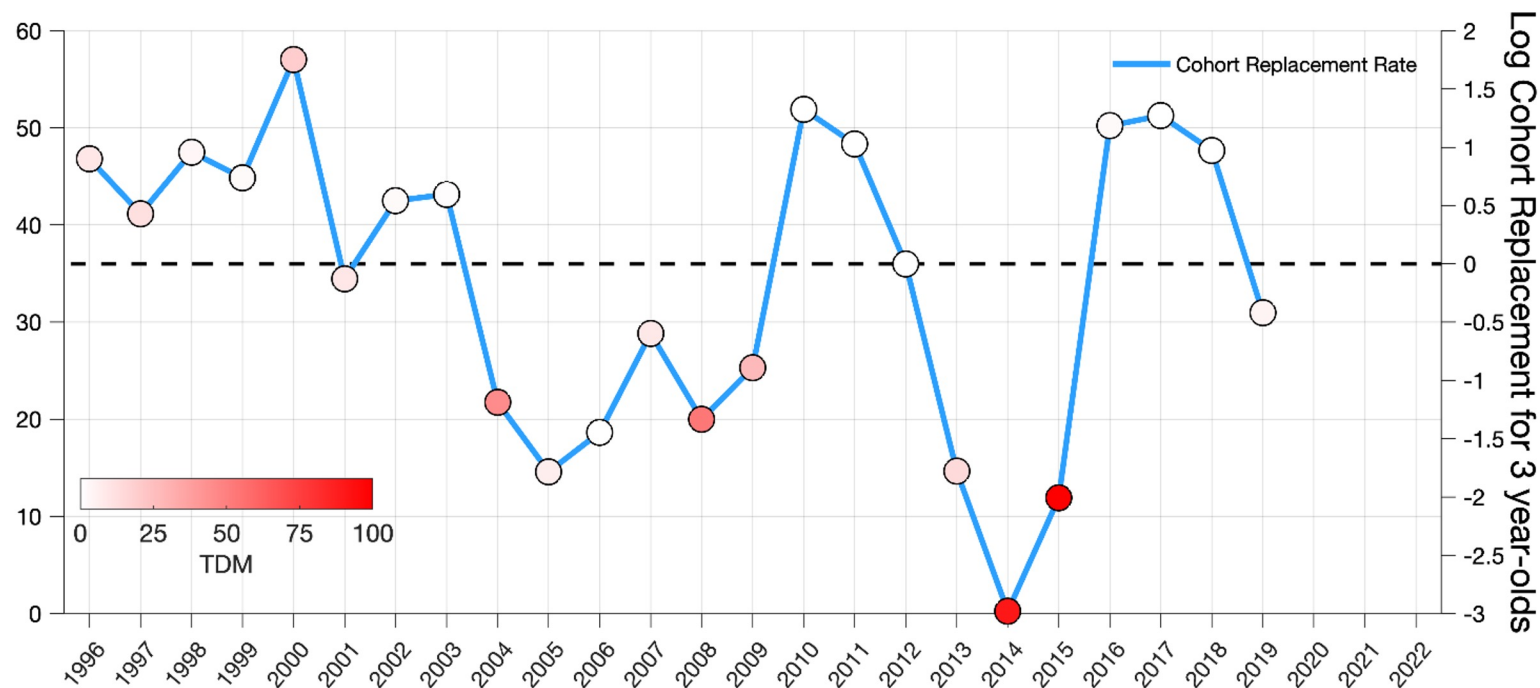
Biophysical model based on mass transfer theory Martin (2018)

Mathematical model of O₂ supply and demand Martin (2020)

- Eggs protect developing embryos, but also limit the supply oxygen
- O₂ demand increases with egg volume, but is supplied across a surface
- Salmon eggs are large - O₂ supply is precariously balanced with demand
- Metabolic demand increases with live tissue mass
- Metabolic rate of embryos increases exponentially with temperature

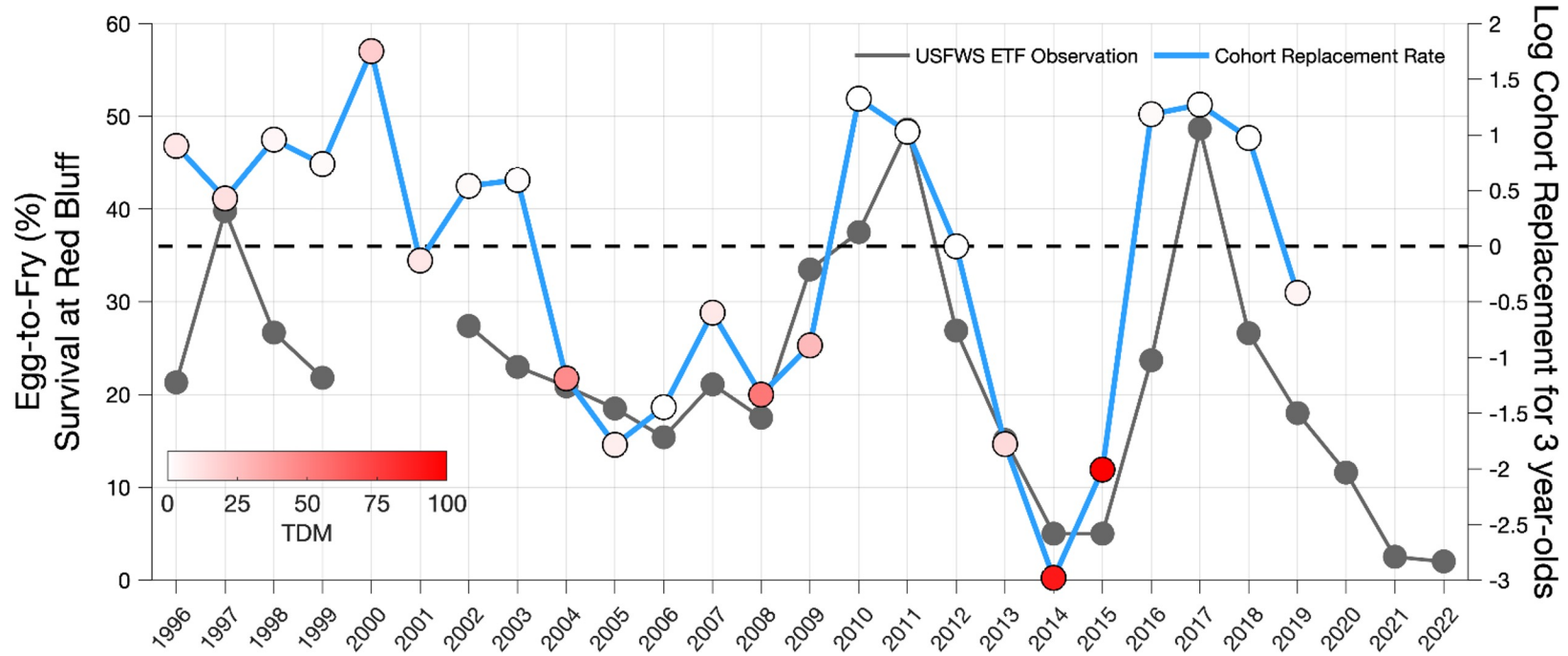


Egg TDM and CRR 3 years later

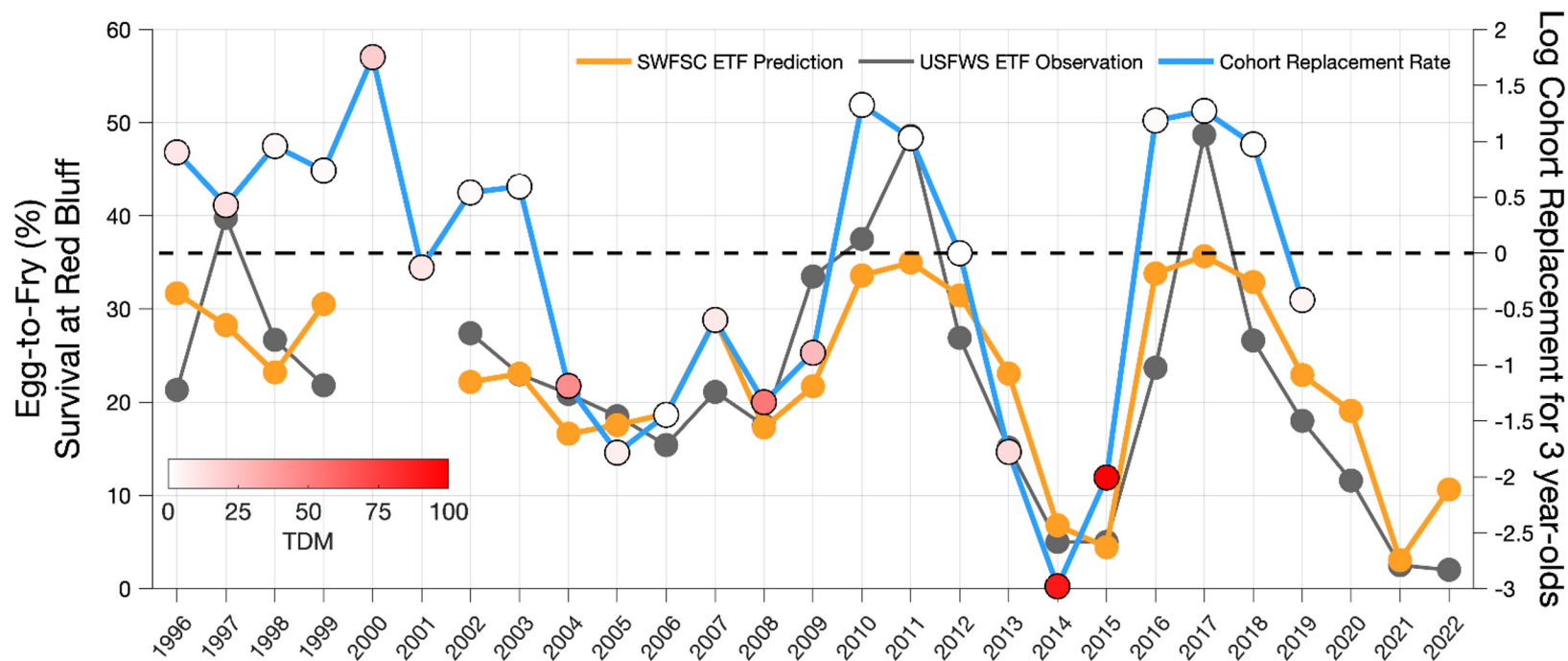


Circles are colored by the egg TDM for that year. CRR is the cohort replacement rate for 3 year-old fish.

Egg TDM, ETF survival, and CRR



Egg TDM, ETF survival, and CRR

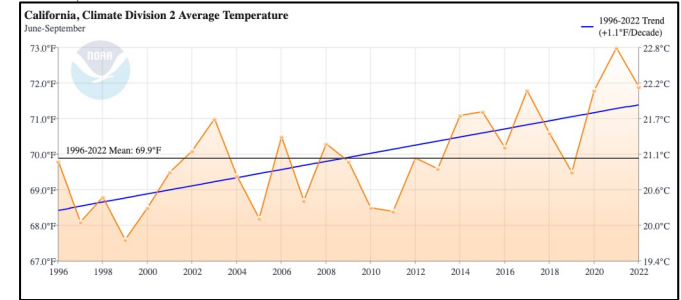
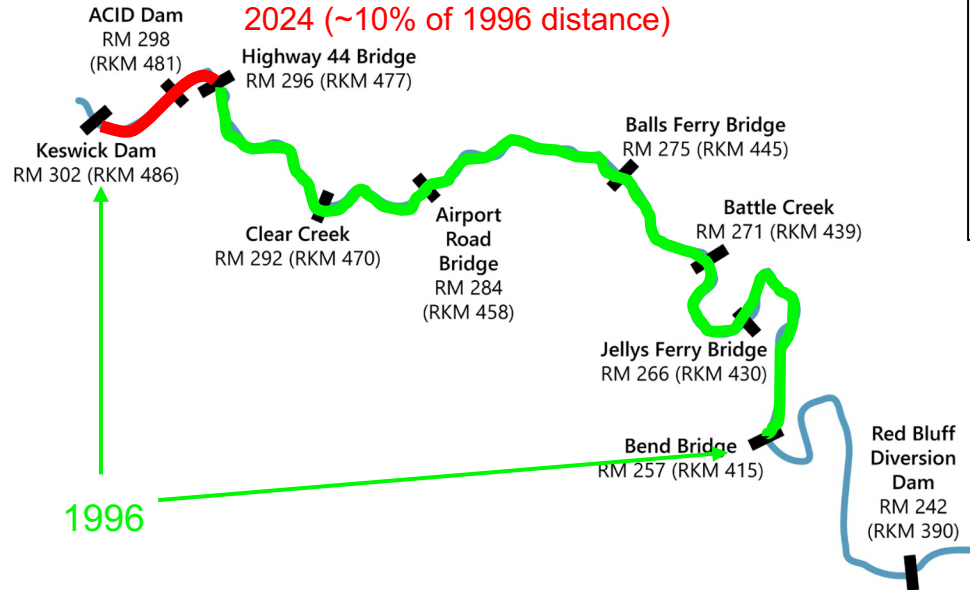


Contraction of thermal habitat

The Temperature Compliance Point has shifted upstream ~40 miles since 1996

Figure 2.1-1

Diagram of the Upper Sacramento River with Key Spawner Survey Landmarks

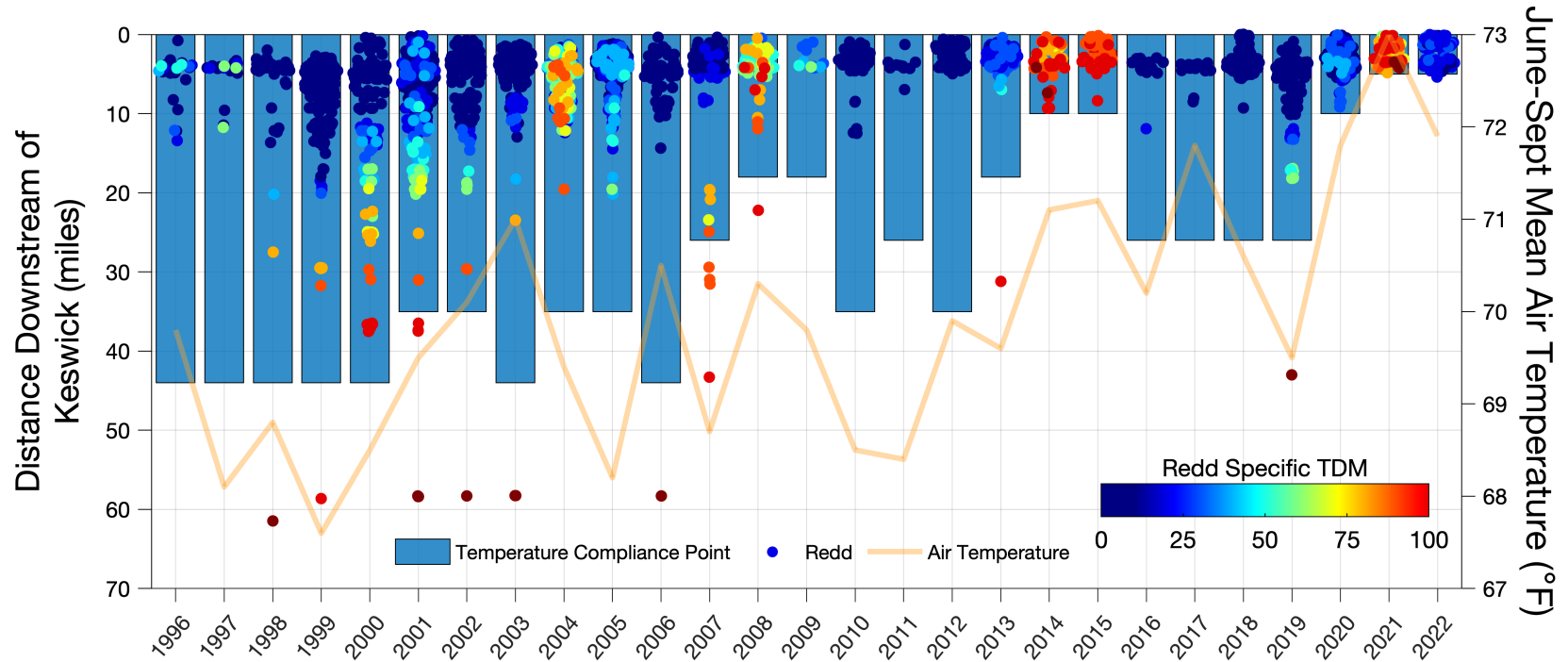


Redrawn from Anderson (2018). Note that the RM given for Clear Creek is for the Sacramento River Above Clear Creek gage (CCR). The confluence of Clear Creek with the Sacramento River is 3 miles downstream at RM 289.

Modified from Anchor QEA 2024

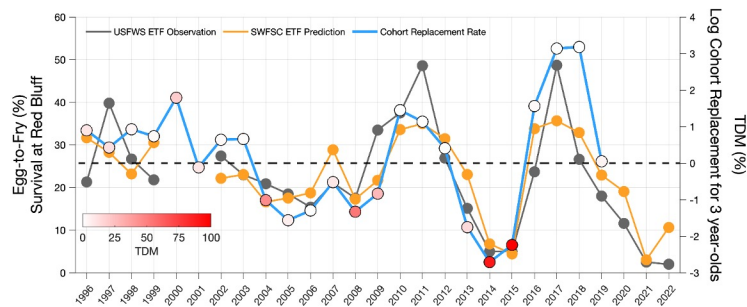
Contraction of thermal habitat

The Temperature Compliance Point has shifted upstream ~40 miles since 1996

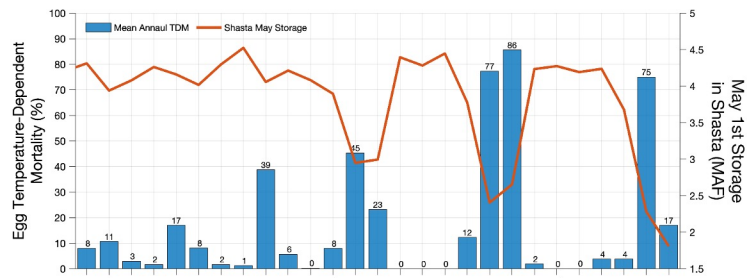


Thermal habitat and Survival

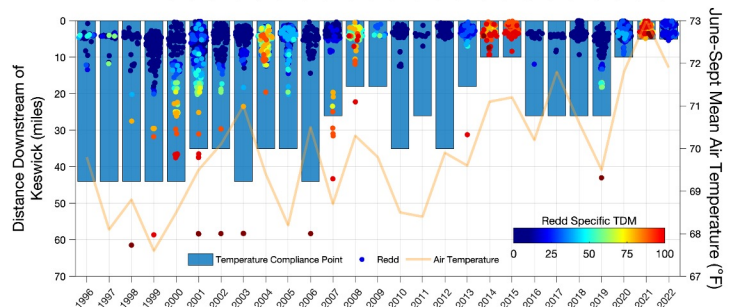
Egg TDM, ETF survival, and CRR 3 years later



Egg TDM and Shasta storage in May of same year



Temperature Compliance Point, egg TDM, and mean air temperature (Jun-Sept)



Central Valley Temperature Mapping and Prediction (CVTEMP)

🏠 About CVTEMP

🌿 Watershed Model

🌊 Reservoir Model

🌊 River Model

🌡️ Temperature Profile

🌡️ Temperature Timeseries

🐟 Mortality

🕒 Historic

🎯 Scenarios

📄 About the Model

🌤️ Meteorology

📄 Download

📄 References



Central Valley Temperature Mapping and Prediction (CVTEMP)



River Model - Temperature Profile

Below is the simulated temperature landscape which shows temperature downstream from Keswick Dam on the x-axis over time on the y-axis for the Sacramento River from Keswick Dam to Red Bluff. Results can be viewed for the two different model types (SWFSC & USBR). The SWFSC model type uses the output from the CE-QUAL-W2 model as an input, while the USBR model type uses the output from USBR's HEC-5Q model as an input for Keswick discharge temperature.

THE RESULTS BELOW ARE FOR THE MODEL RUN INITIALIZED IN FEBRUARY. FOR THE MOST UP TO DATE MODEL RESULTS, INCLUDING ASSIMILATED DATA, SEE: <https://oceanview.pfeg.noaa.gov/CVTEMP/download>

▼ MODEL TYPE

▼ SCENARIOS

Now showing:

Model: USBR (USBR_NO_W2)

Scenario: Dry Hydrology & Warm Meteorology
(JUN_06_2023_INPUT_90_OUTPUT_90_25L3MTO)

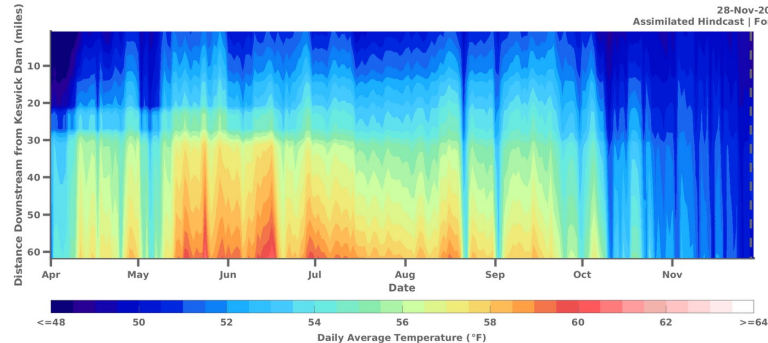
Overlay layers:

▼ STATIONS

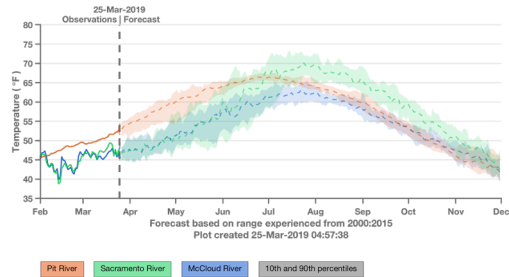
▼ TEMPERATURE
CONTOURS

PROBABILITY
-SURVIVAL
CONTOURS

▼ OTHER LAYERS

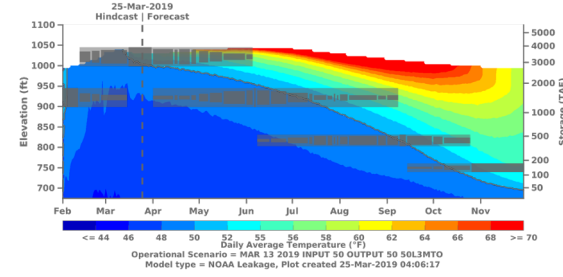


Central Valley Temperature Mapping and Prediction (CVTEMP)



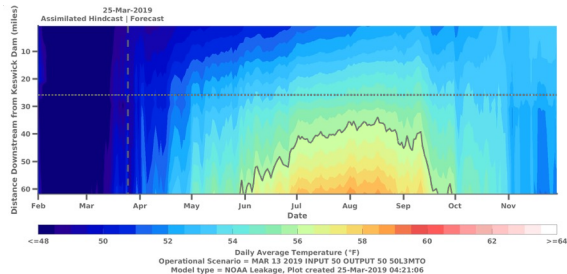
Watersheds

California Nevada River Forecast Center

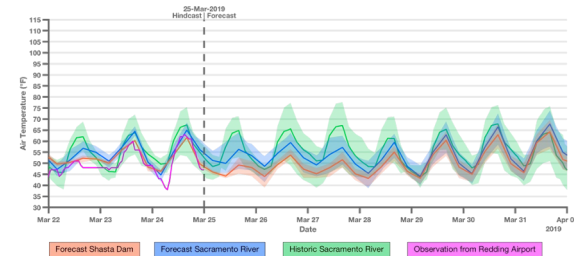


Reservoirs

CE-Qual_W2



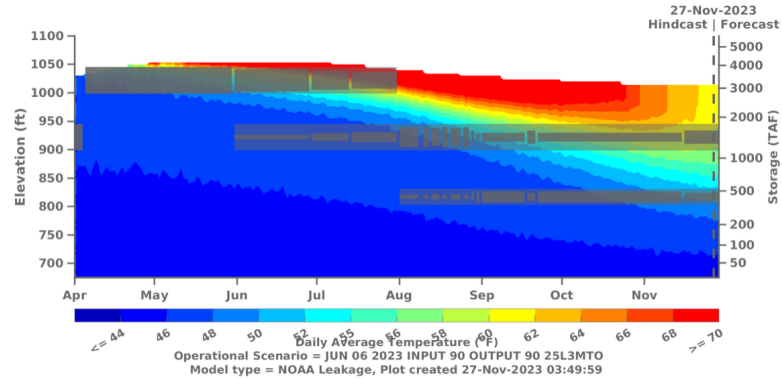
River RAFT



Meteorology

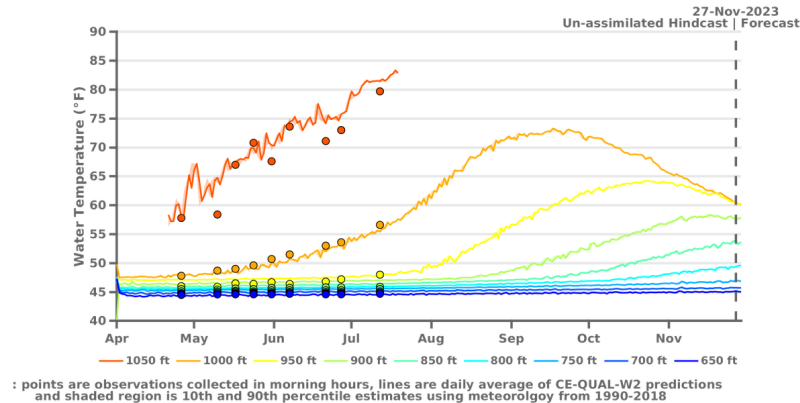
Global Forecast System (GFS)
Global Ensemble Forecast System (GEFS)
North American Regional Reanalysis (NARR)

CVTEMP: reservoir conditions

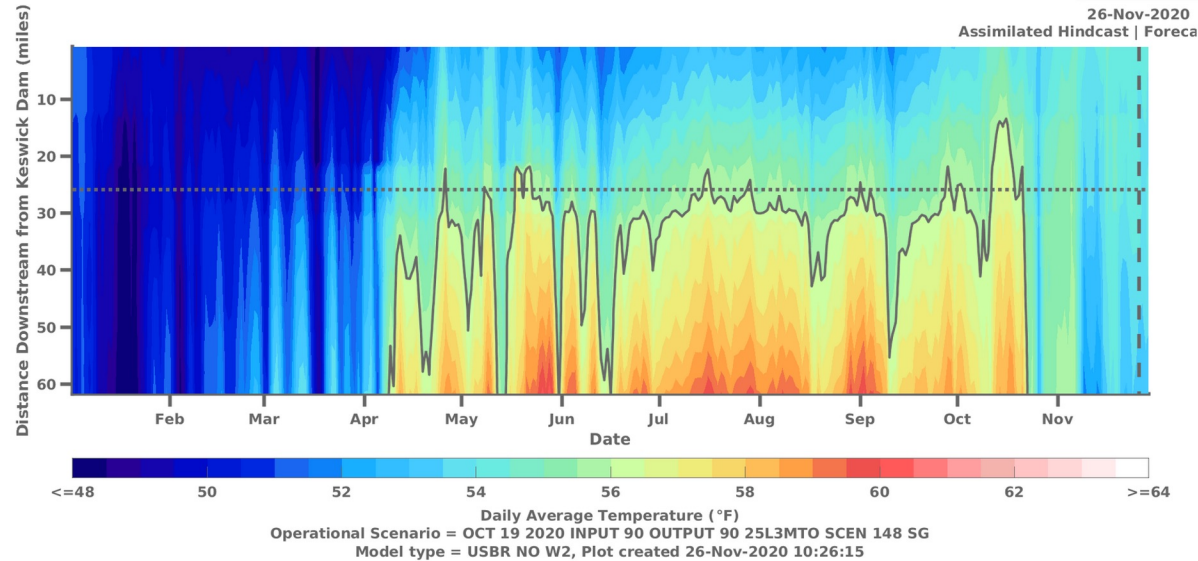


Cold pool
Gate operations
Storage
Discharge temperature

Observed Vs. Predicted Vertical Profile

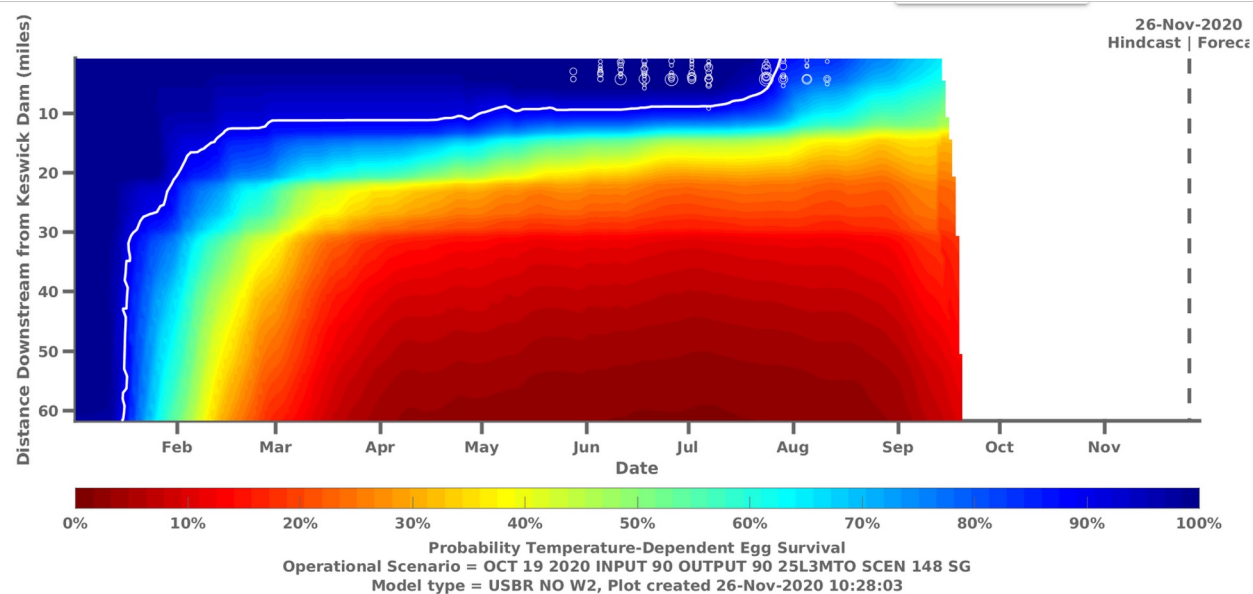


CVTEMP: river conditions



TCP
Temperature contours
Redd locations

CVTEMP: egg TDM



Egg survival probability
Survival contours
Redd locations

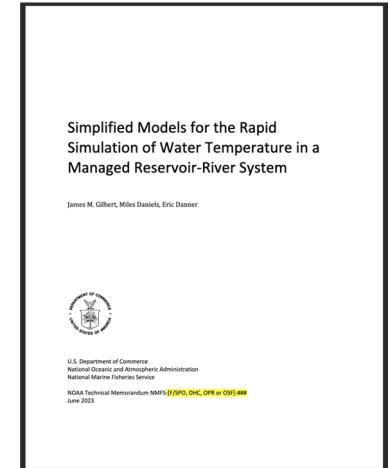
Rapid Assessment Temperature Modeling Framework

For rapidly exploring the wide range of possible combinations of:

- Reservoir inflow (both volume and temperature)
- Reservoir thermal dynamics
- Temperature Control Device (TCD) gate operations
- Shasta release volumes
- River temperatures
 - Different temperature targets and windows
- Temperature dependent egg mortality

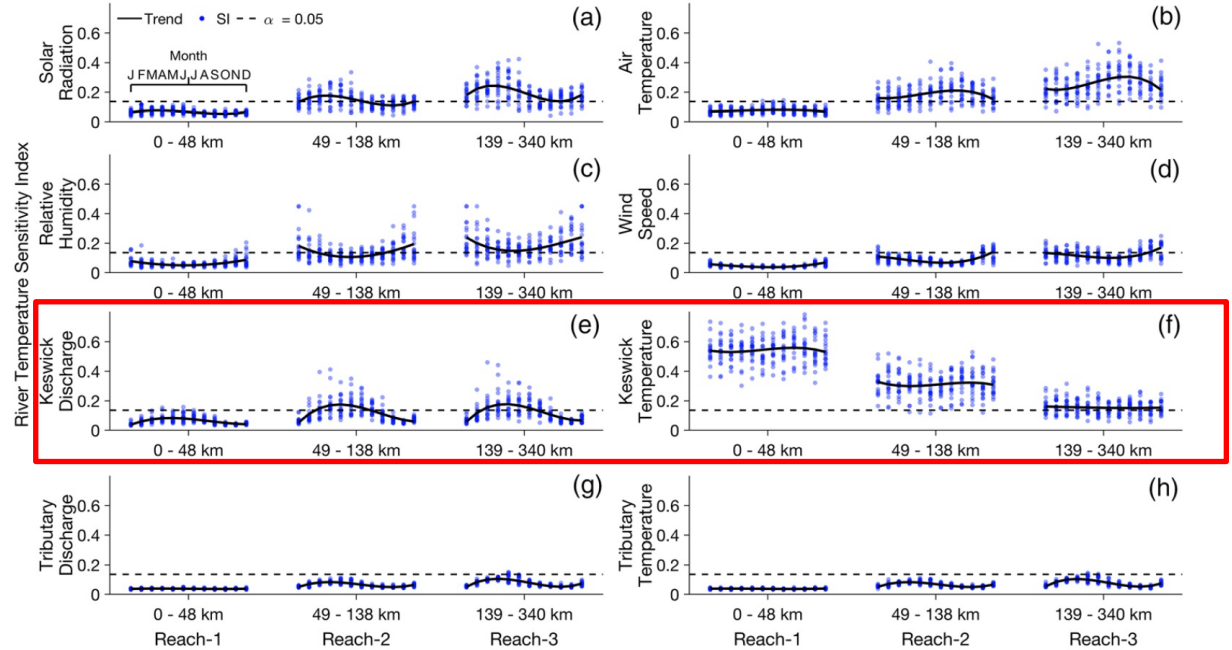
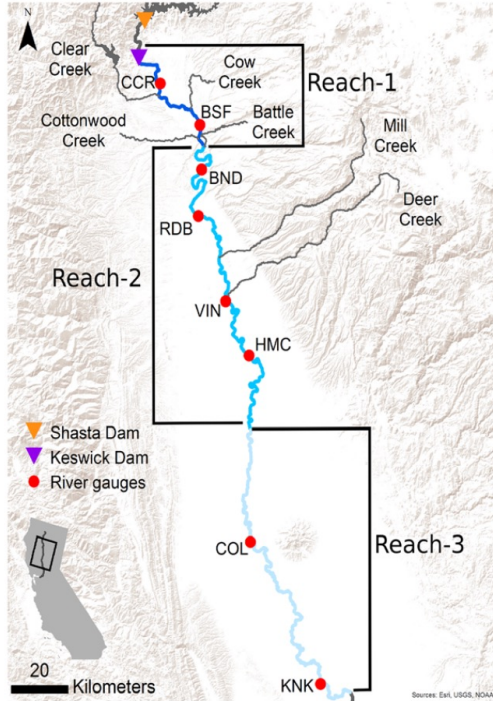
= combinatorial explosion (many thousands of scenarios)

A fully coupled forecast simulation for a year can be completed in 10 seconds or less

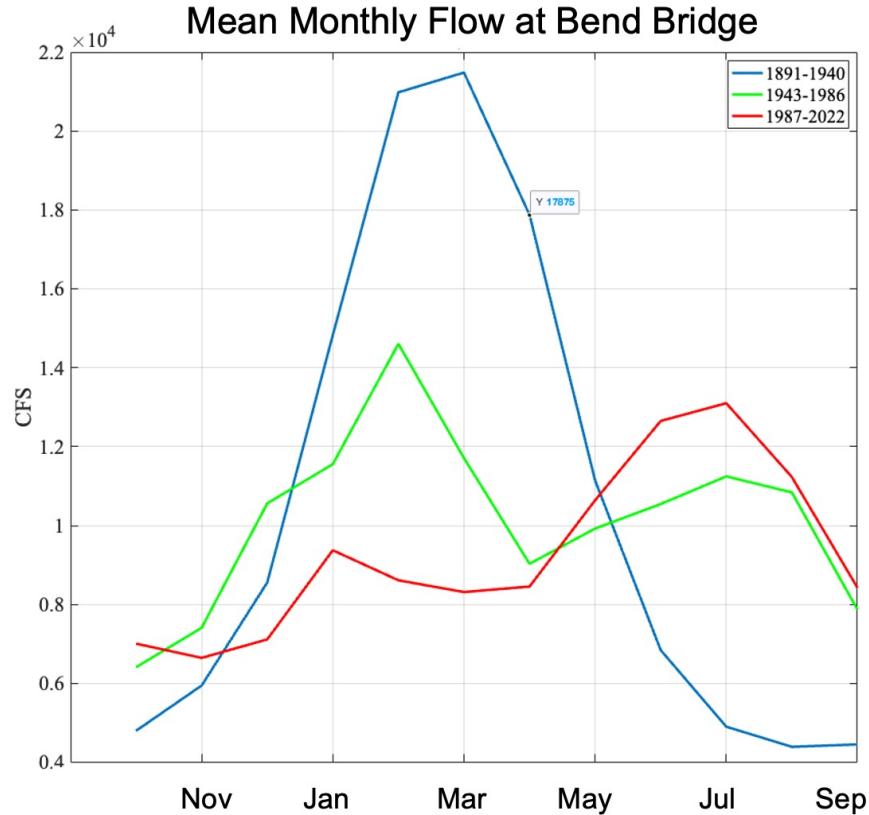


Release Temperature vs Release Flow

Sensitivity analyses by reach and input



Altered Hydrograph



The dam building era:

Before



During



After



Juvenile salmon outmigration

<https://oceanview.pfeg.noaa.gov/CalFishTrack/>

Home

2024 WY Studies ▾

Archived Studies ▾

Real-time Receivers

Receiver Deployments

Download data

Data Explorer

STARS simulations

Central Valley Enhanced

Acoustic Tagging Project

CalFishTrack

Central Valley Enhanced Acoustic Tagging Project



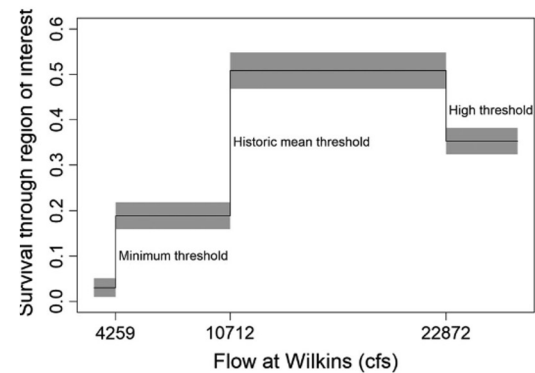
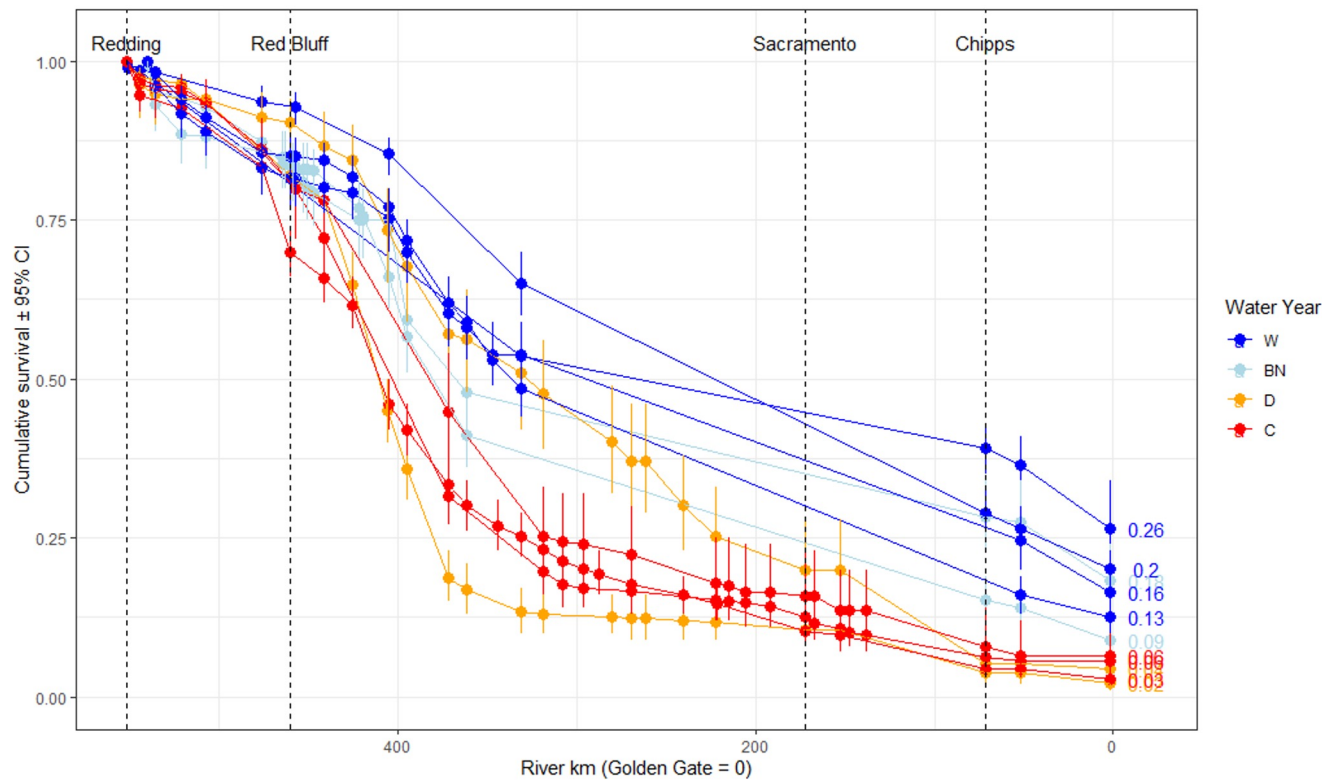
New Updates

1. [New webpage created for Georgiana Slough Fall-run study on 5/1/2024](#)
2. [New webpage created for Feather River hatchery Spring-run Chinook study on 5/1/2024](#)
3. [New webpage created for Sacramento River Spring Pulse Flow study on 4/25/2024](#)
4. [New webpage created for Sacramento River Spring-run Chinook Surrogate study on 4/25/2024](#)
5. [New webpage created for San Joaquin River hatchery steelhead study - April releases on 4/19/2024](#)
6. [New webpage created for Butte Creek wild spring-run Chinook salmon study 4/11/2024](#)
7. [New webpage created for Stanislaus River wild steelhead spring releases study 3/26/2024](#)
8. [New webpage created for Mill and Deer Creek wild steelhead study 3/23/2024](#)

Background

There is a well documented need for improved detection and associated modeling of salmon migration and survival in the Central Valley. We propose to address this need through an expanded acoustic receiver network and associated real-time and retrospective modeling of the data. The proposed work includes (1) the deployment of real-time receivers that will provide timely information on migrating salmon smolt location and timing, (2) expansion of the existing autonomous acoustic array to increase the coverage and detection efficiency; (3) development of new metrics for the real-time data for key management relevant questions such as entrainment estimates at critical junctions (Georgiana Slough and Delta Cross Channel); and (4) a retrospective analysis directly geared toward improving the quality and robustness of an existing forecasting model – the NMFS enhanced particle tracking model.

Outmigration survival



2. Integrated Models

Quantitative life-cycle models (QLCMs), a robust framework for:

- Evaluating the influence the long-term population dynamics (effects on survival propagate throughout multiple life-stages, generations)
- Integrating existing and new information
- Measuring tradeoffs and synergies among recovery actions
- Linking outcomes to costs and to co-benefits

The WRLCM

Framework: provides mathematical relationships between abiotic drivers and biotic responses

Updated with new covariates – model parameters estimated through calibration

A stage-structured, stochastic life cycle model (network of interconnected models)

Evaluate the influence on the long-term population dynamics:

- Hydrology
- Hatchery
- Habitat restoration
- Harvest
- Reintroduction

Management relevant metrics:

- Cohort replacement rate
- Smolt production
- Adult abundance

The WRLCM

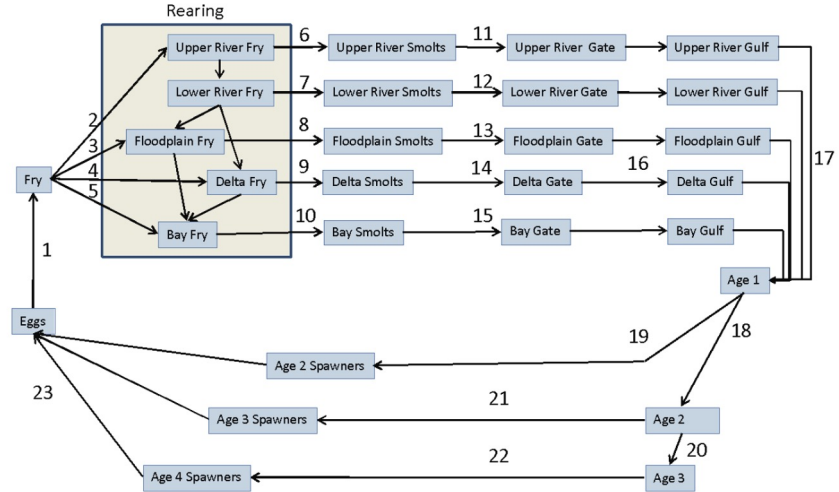
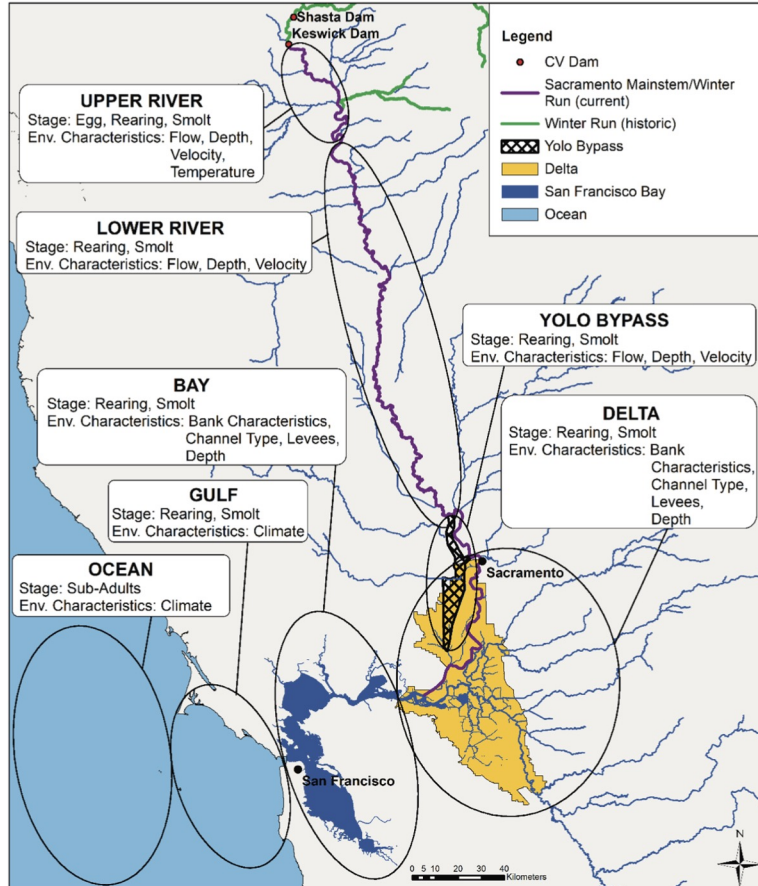


Figure 4. Central Valley Chinook transition stages. Each number represents a transition equation through which we can compute the survival probability of Chinook salmon moving from one life stage in a particular geographic area to another life stage in another geographic area.

Integrated Modeling Decision Support Framework

1. Individual elements:

Experiments, monitoring, and models (conceptual, mathematical, simulation, etc.)

2. Integrated models:

Collectively what the individual elements can tell us

Quantification of the trade-offs to inform decisions based on costs and benefits

3. The decision space:

The unconstrained range of management options

4. Adaptive management:

CV water planning and operations are different processes

Monitor fish response relative to actual operations

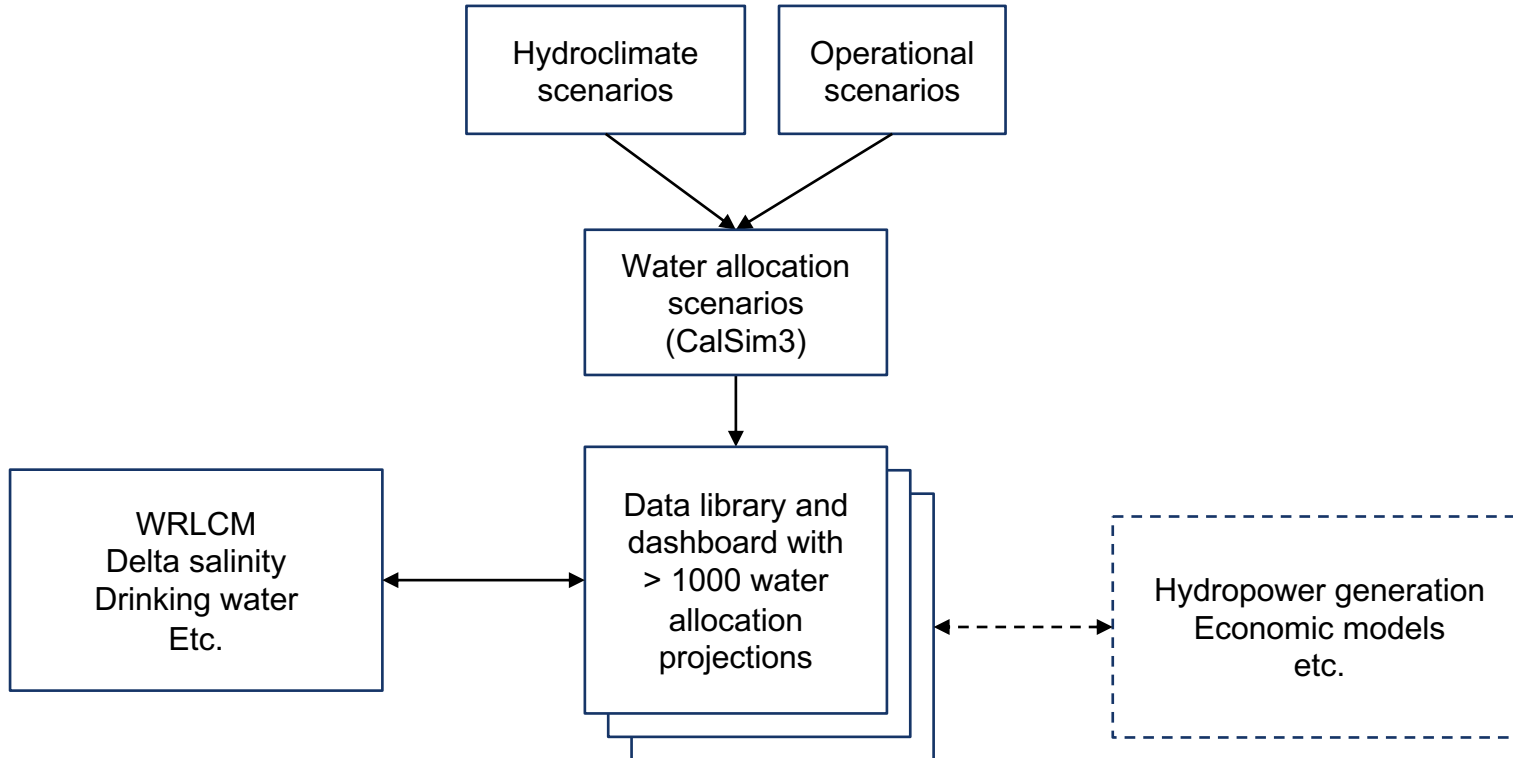
COEQWAL Project



“Building a resilient water future requires new water planning tools that advance sustainable, inclusive, and equitable water stewardship.”

- Produce and analyze a library of user-informed scenarios of water system allocations
- Facilitate collaborative learning about California's water system, water allocation decision-making, and community perceptions and values around water
- Develop an accessible data dashboard that illuminates consequences, risks, and trade-offs within and among alternative water futures
- Demonstrate relevance of the dashboard to decision-making through "use case" applications

COEQWAL Project

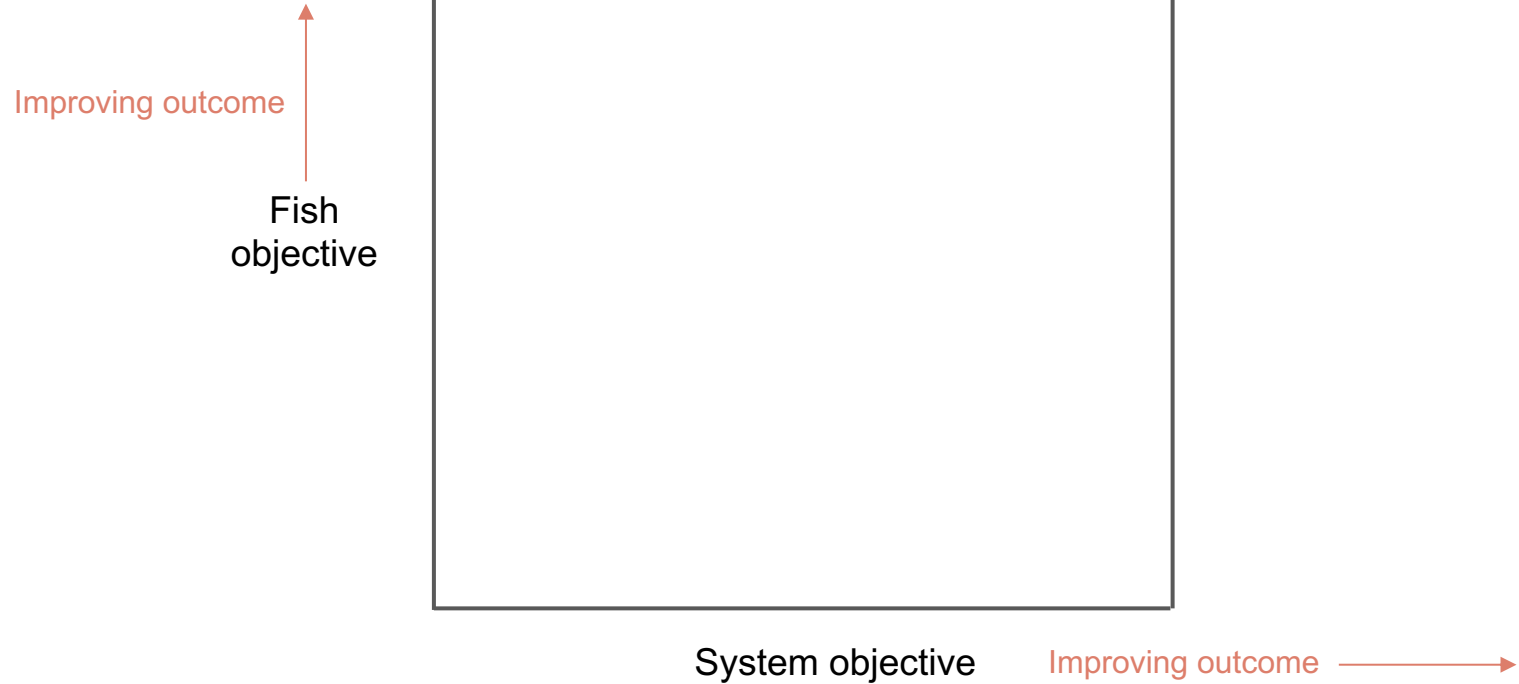


3. Decision Space

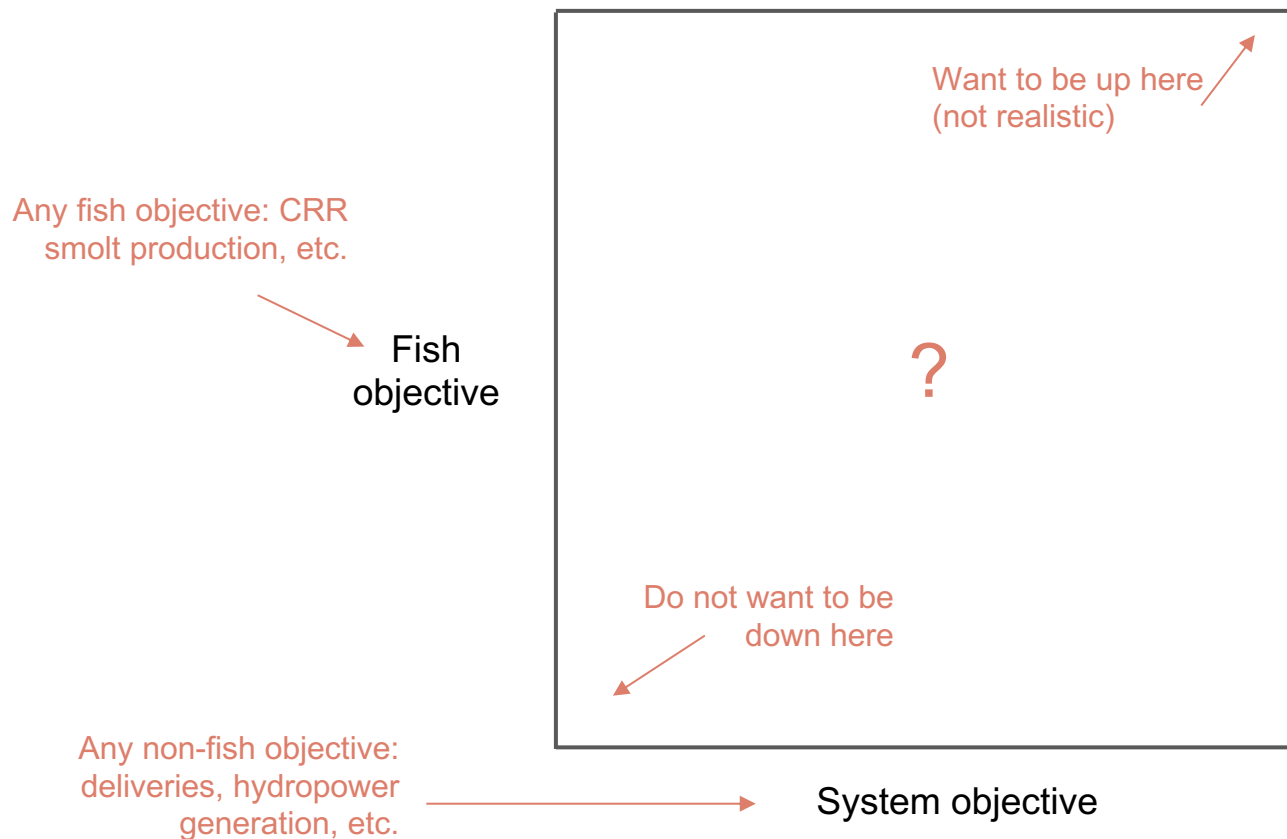
The framework assessing the impacts of the CVP operations on endangered species (...and many other objectives)

- Independent of policy constraints
- Independent of specific fishery management goals
- Open and transparent
 - Model code
 - Results
- Accessible to the public
- Scalable and expandable

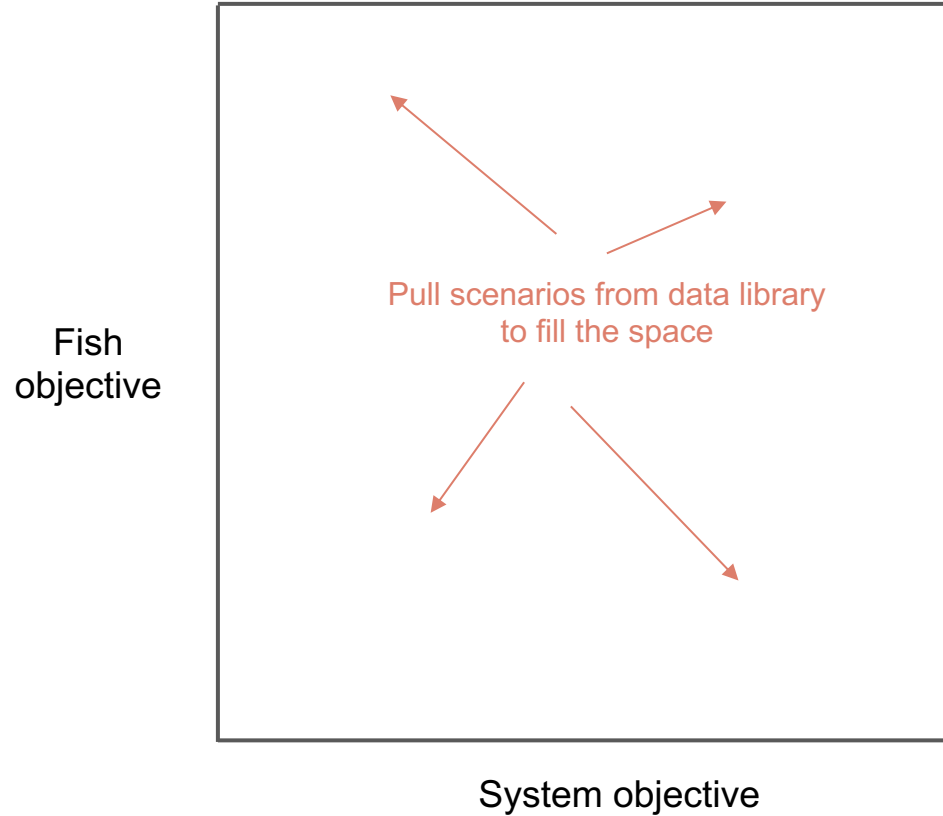
Decision Space



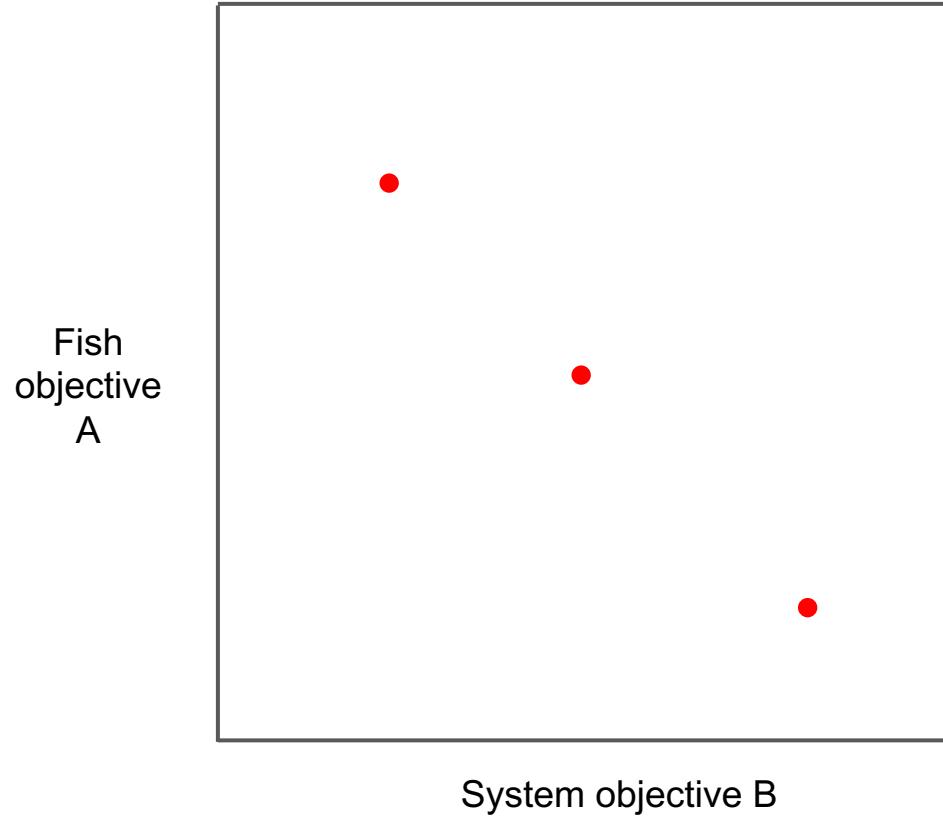
Decision Space



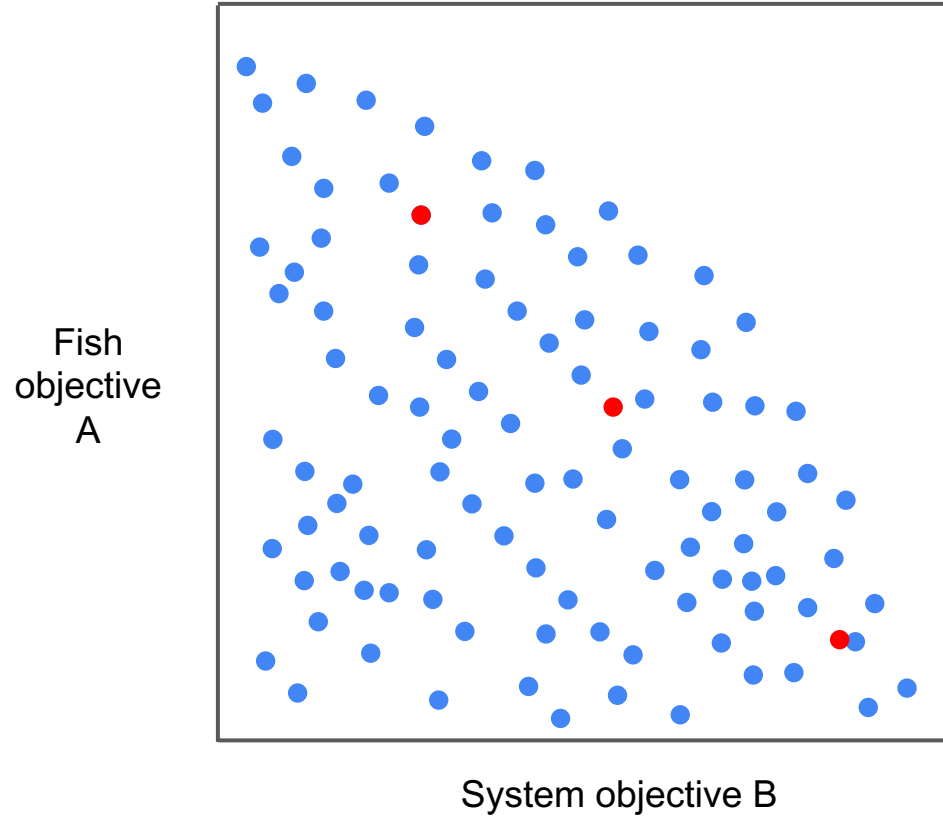
Decision Space



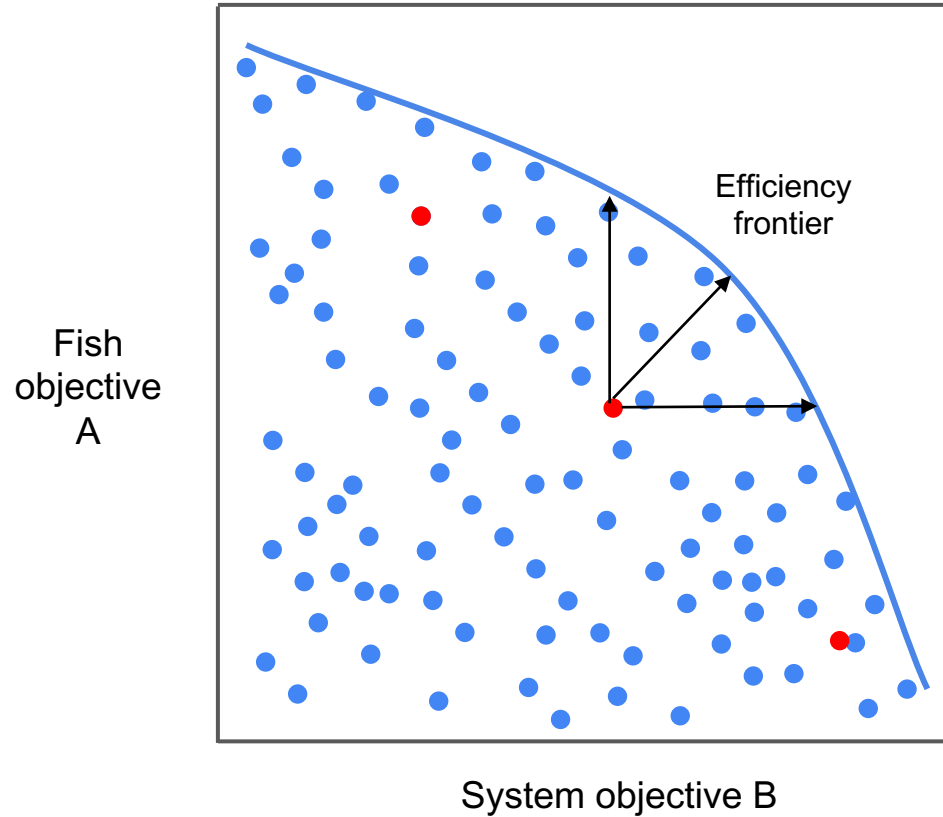
Decision Space



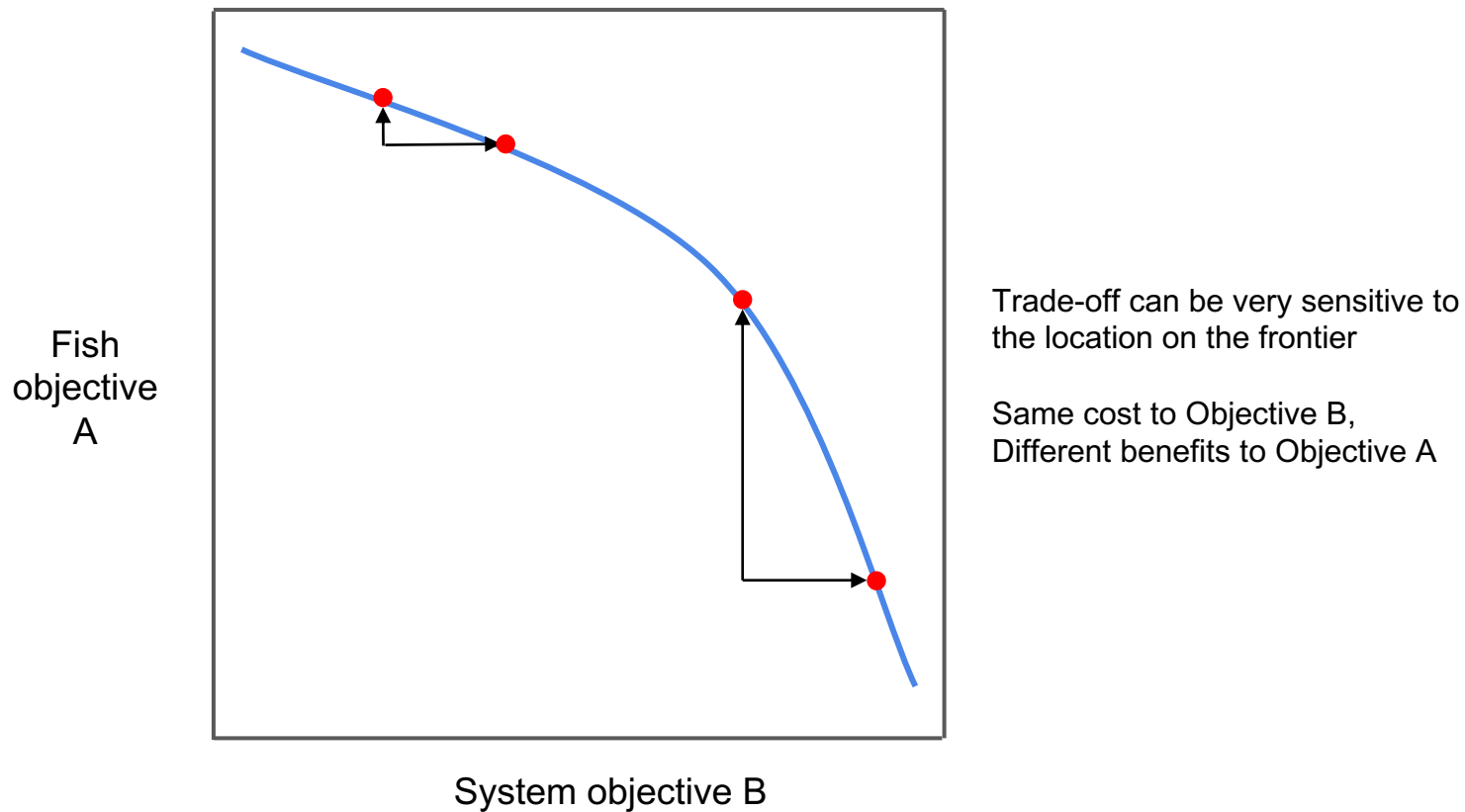
Decision Space



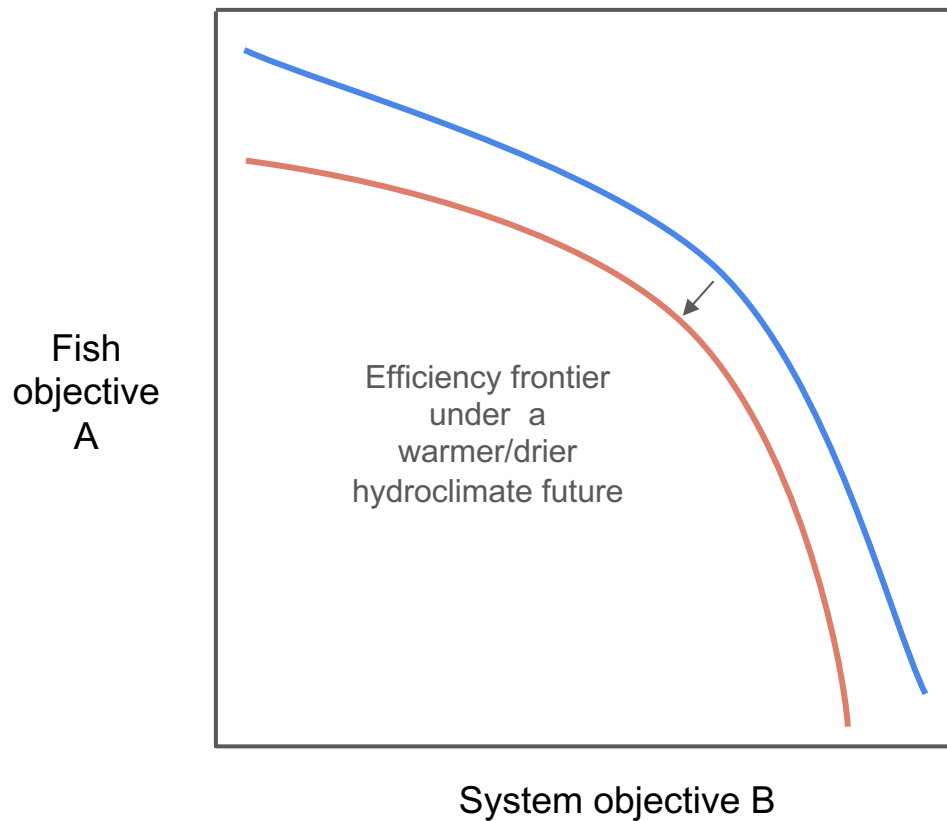
Decision Space



Decision Space



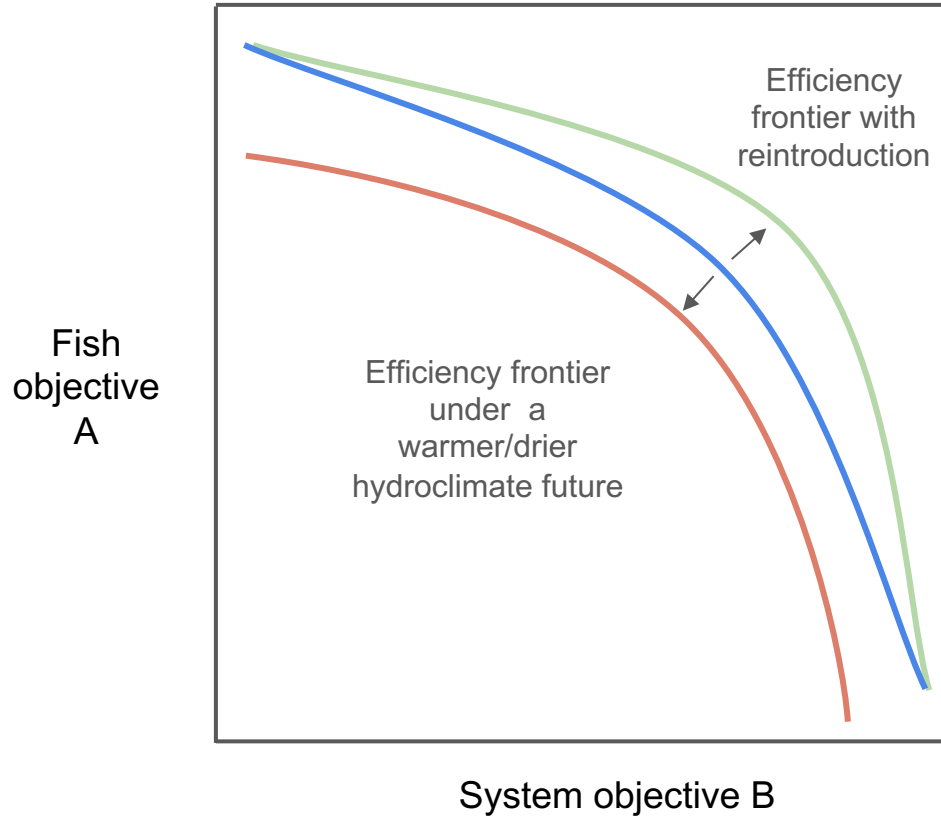
Decision Space



The decision space may contain multiple frontiers depending on what is modeled:

Many factors could change the shape of the frontier: Infrastructure, etc.

Decision Space



The decision space may contain multiple frontiers depending on what is modeled\

Many factors could change the shape of the frontier: Infrastructure, etc.

4. Evaluation of results (adaptive management)

CV water planning and operations are different processes

Monitor fish response relative to actual operations

Ideally in real-time

