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

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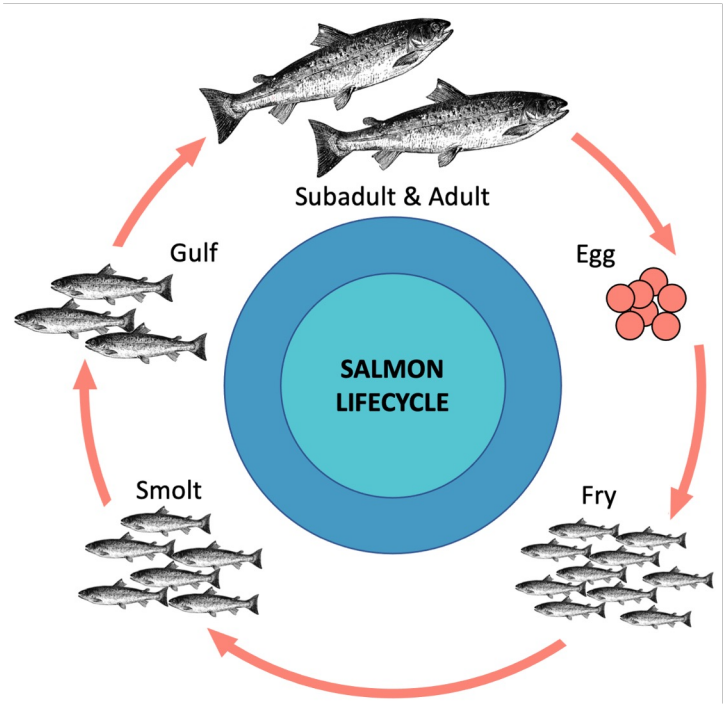
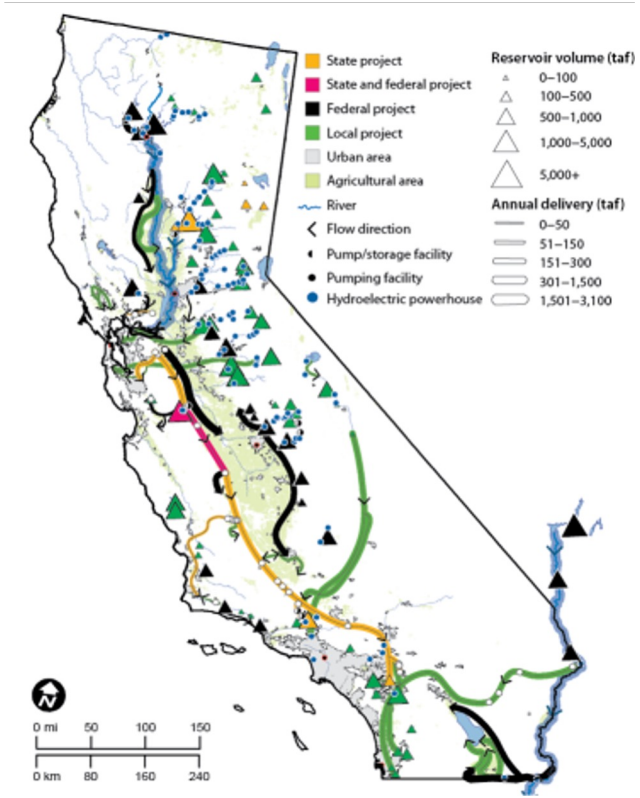
May 7, 2024

Complex life cycles and complex water management





PPIC

Integrated Modeling Decision Support Framework

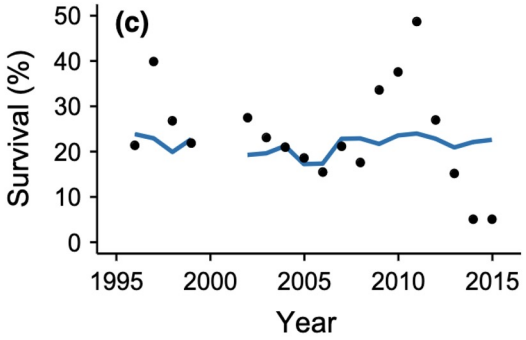
1. Individual elements:
Experiments, monitoring, and models (conceptual, mathematical, simulation, etc.)

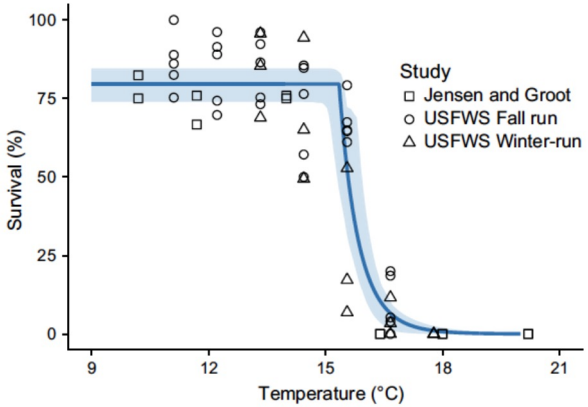
2. Integrated models:
Collectively what the individual elements can tell us
Quantification of the trade-offs to inform decisions based on costs and benefits

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



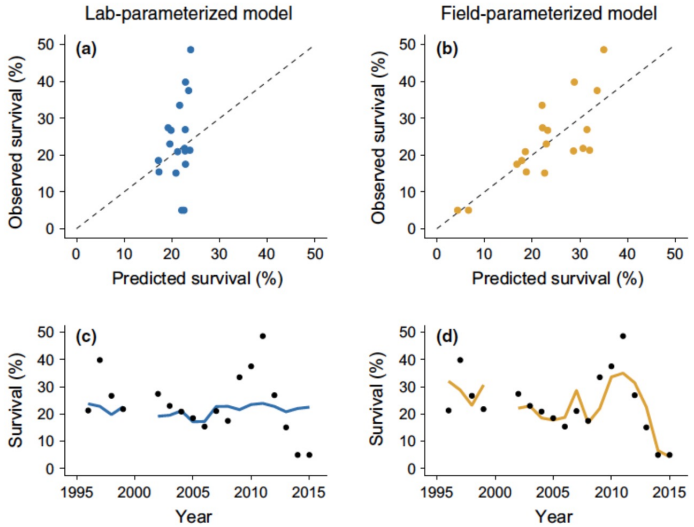


Egg Temperature Dependent Mortality Model

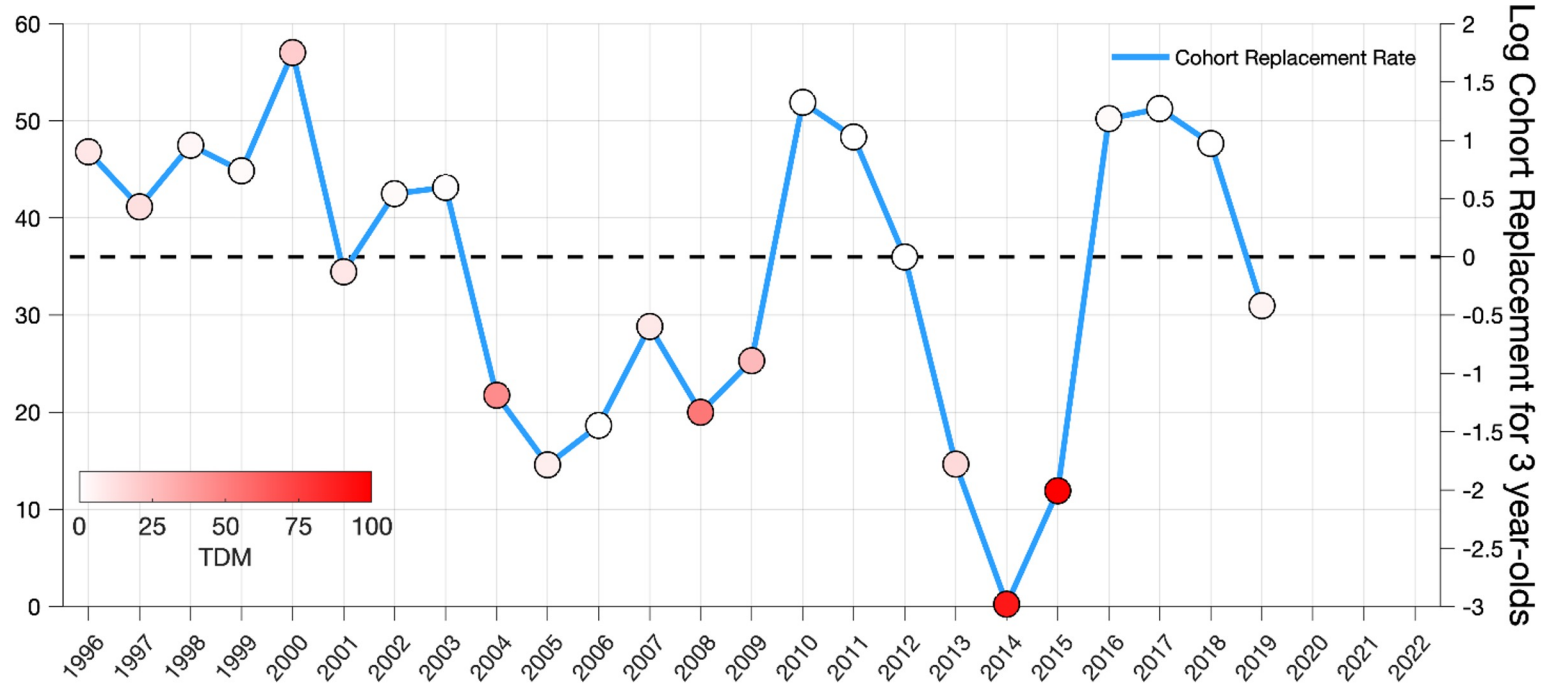
NMFS egg TDM Model

Critical temperature (T_{crit}) = 12°C
Biophysical model based on mass transfer theory Martin (2018)
Mathematical model of O_2 supply and demand Martin (2020)

- Eggs protect developing embryos, but also limit the supply oxygen
- O_2 demand increases with egg volume, but is supplied across a surface
- Salmon eggs are large - O_2 supply is precariously balanced with demand
- Metabolic demand increases with live tissue mass
- Metabolic rate of embryos increases exponentially with temperature

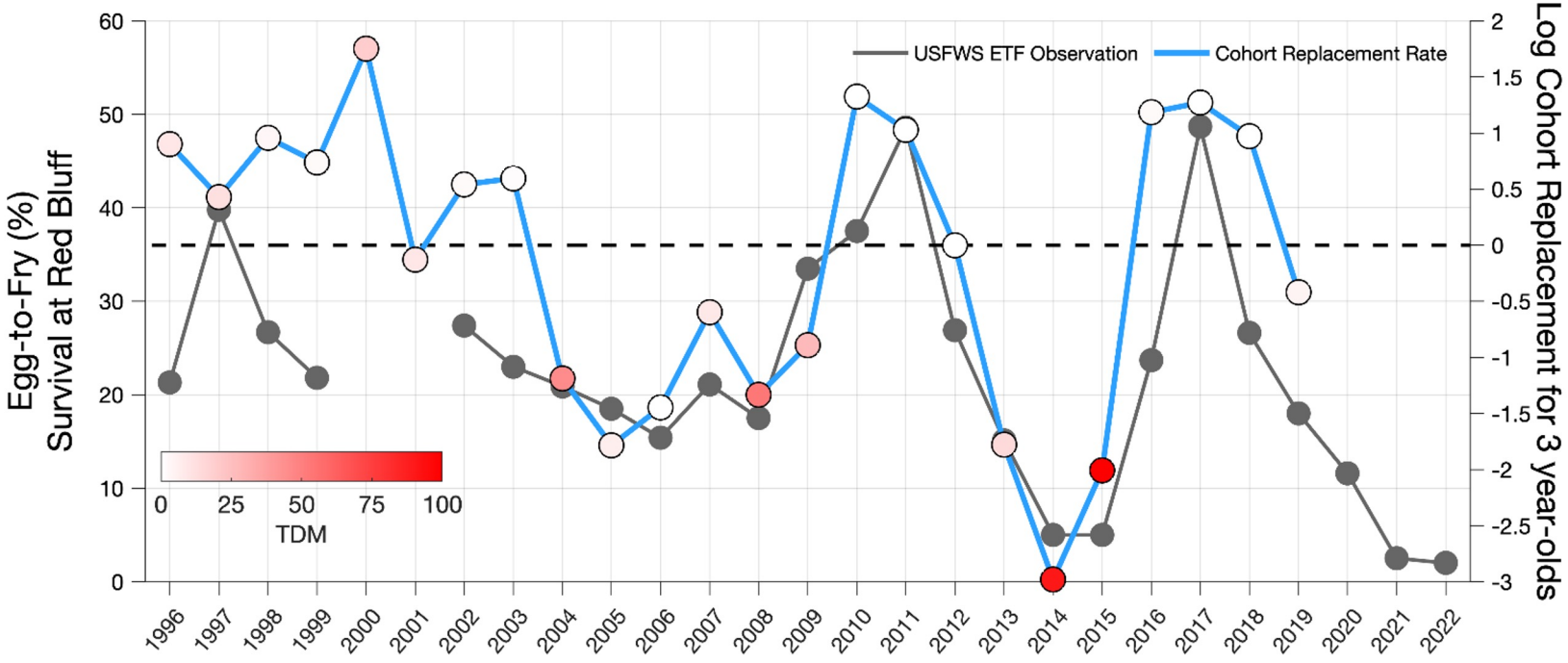


Egg TDM and CRR 3 years later



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



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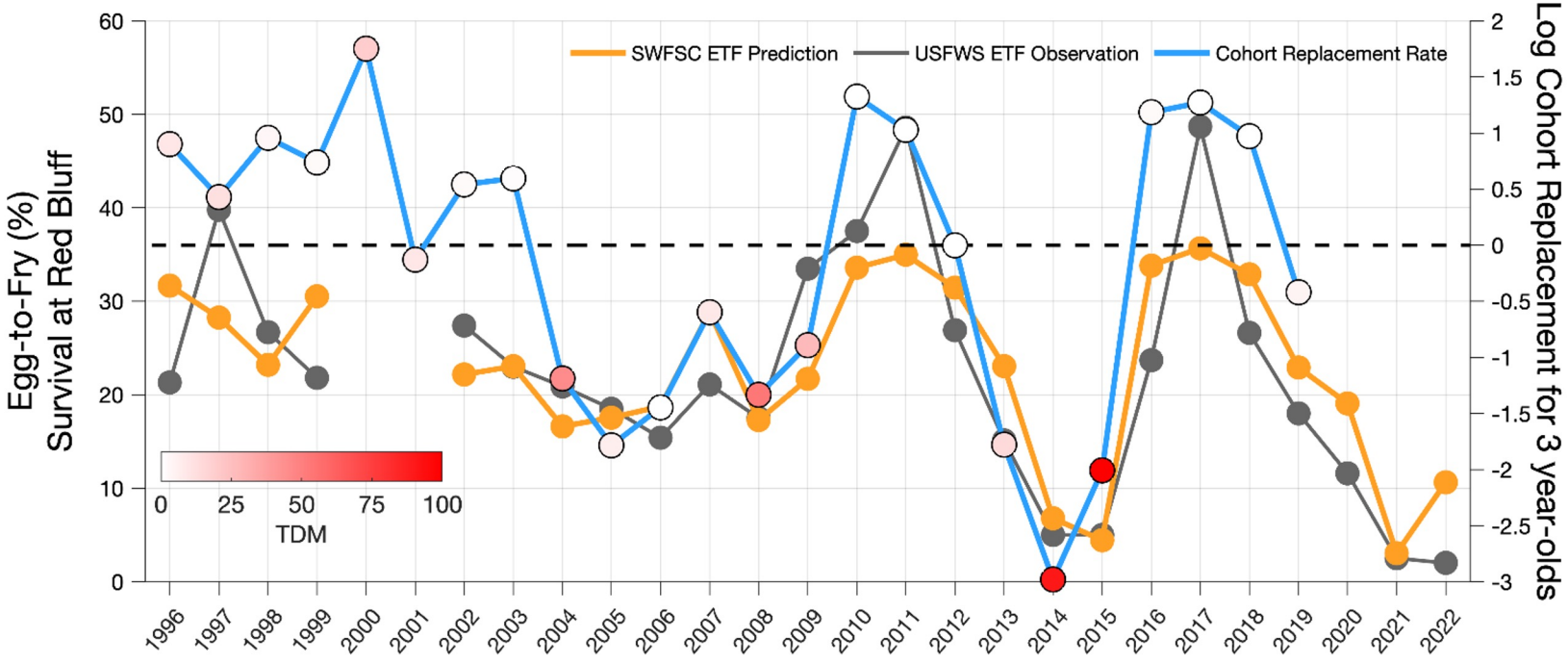
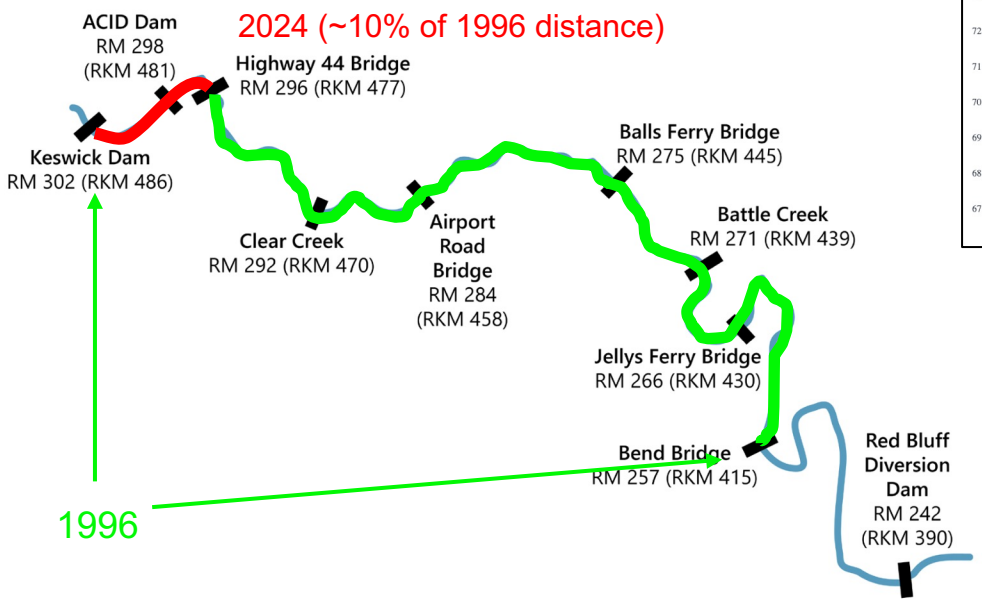


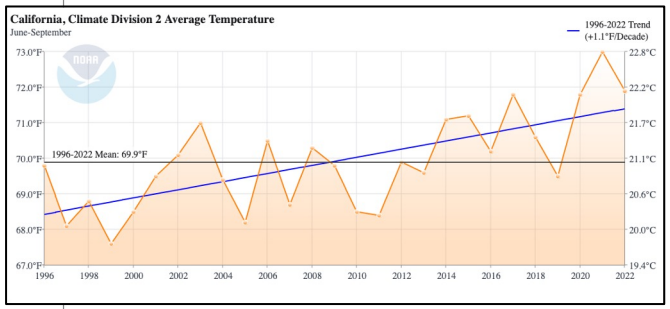
Contraction of thermal habitat

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

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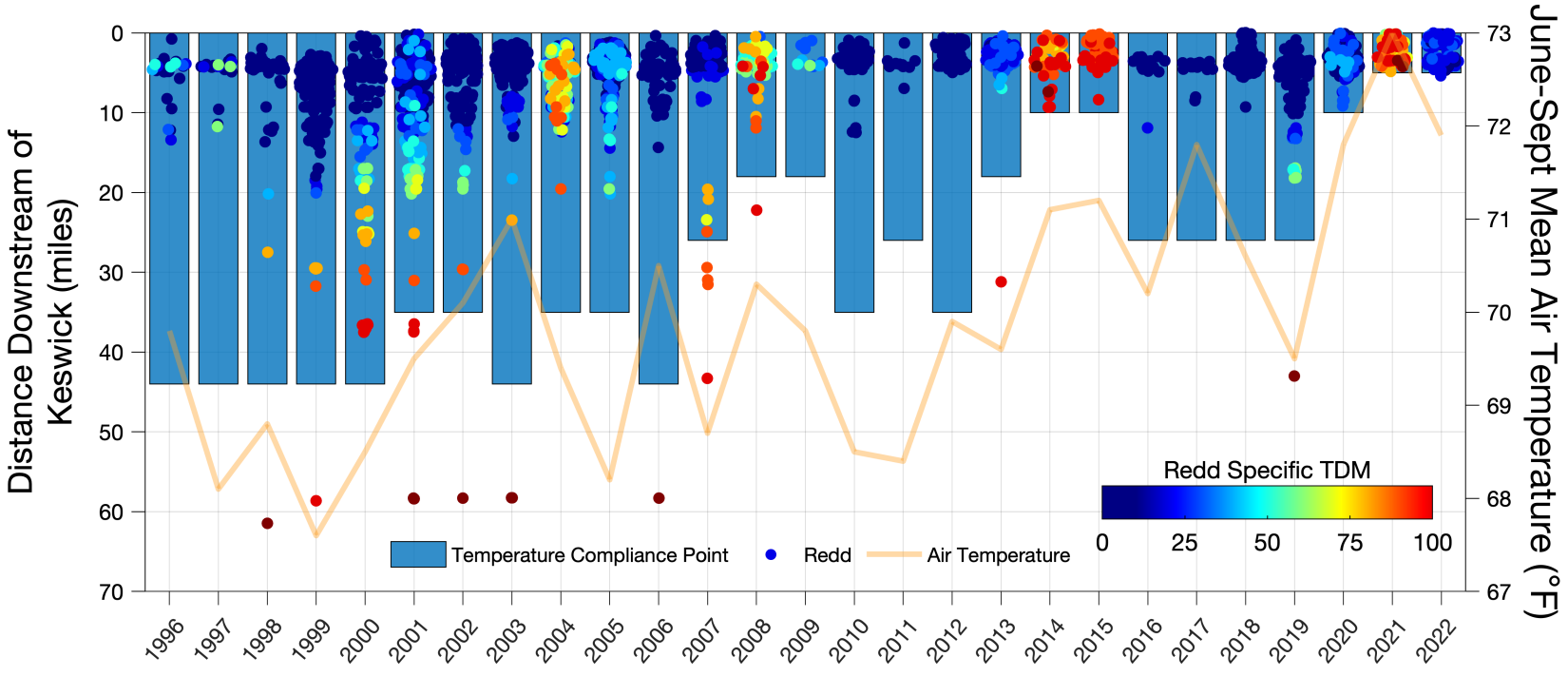
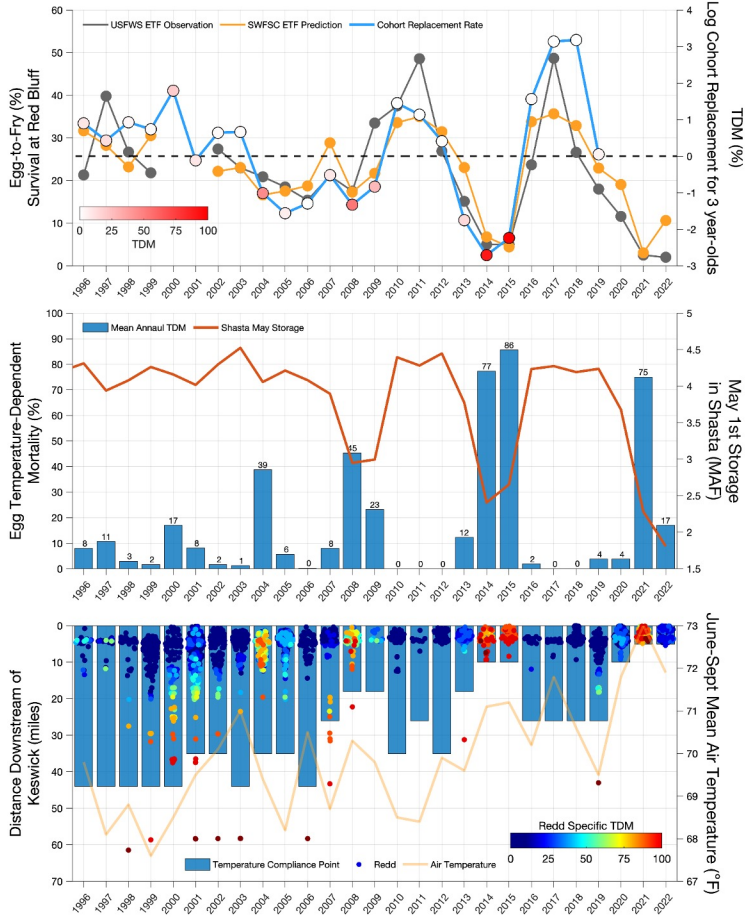


Thermal habitat and Survival

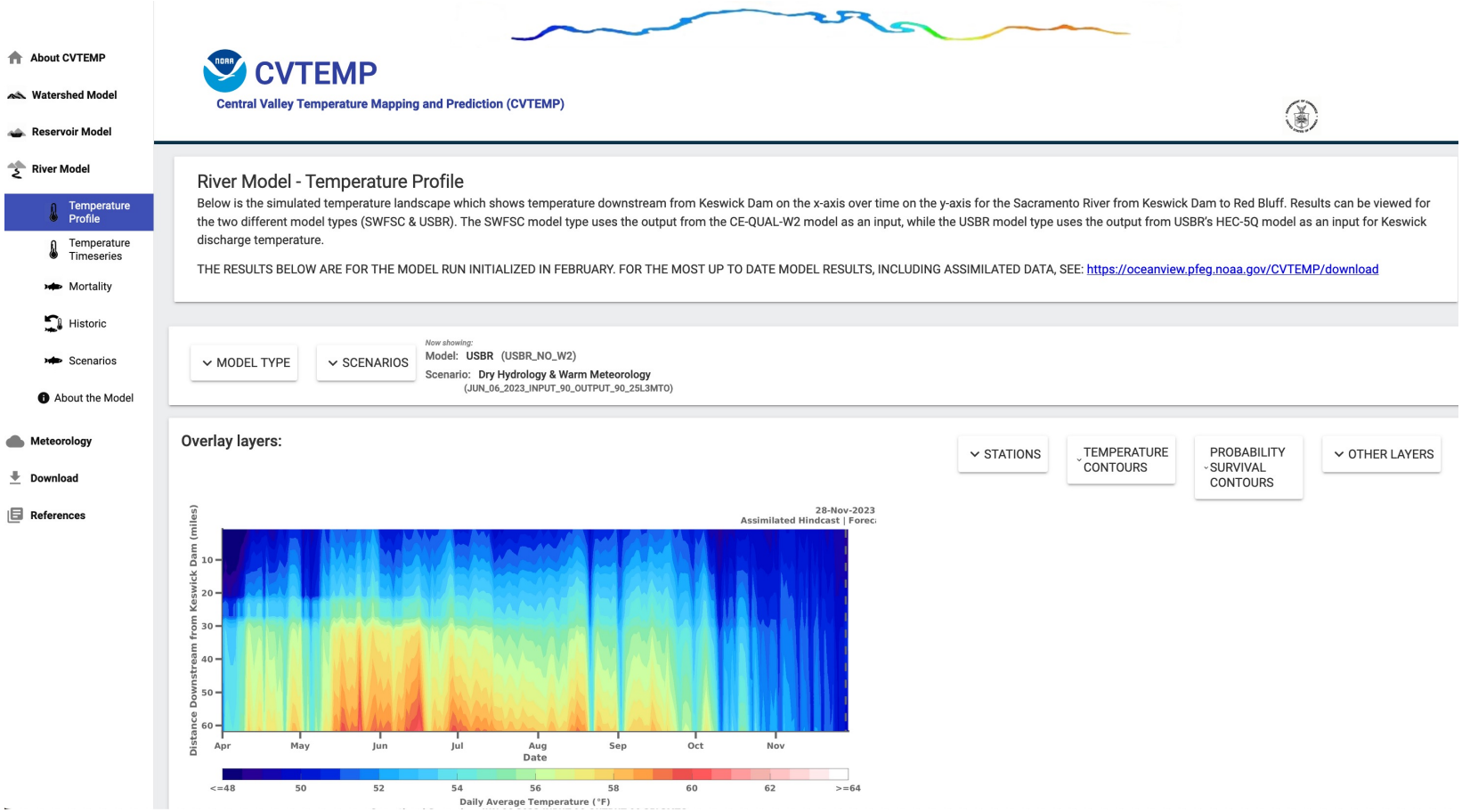
Egg TDM, ETF survival, and CRR 3 years later

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)



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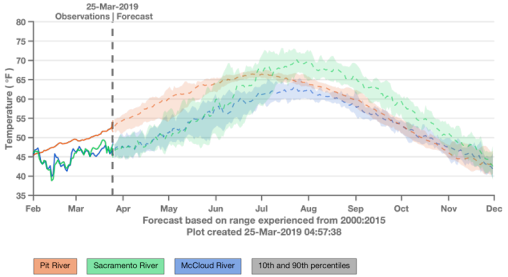
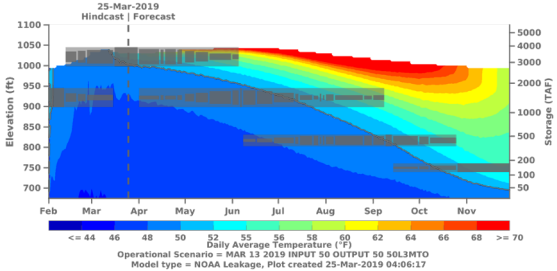


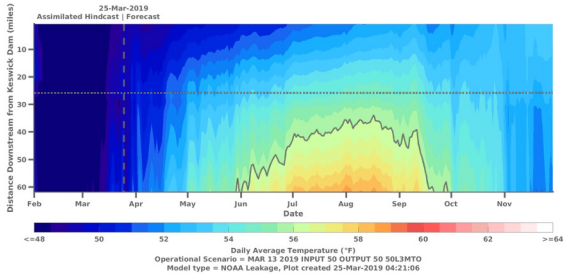
Watersheds

California Nevada River Forecast Center



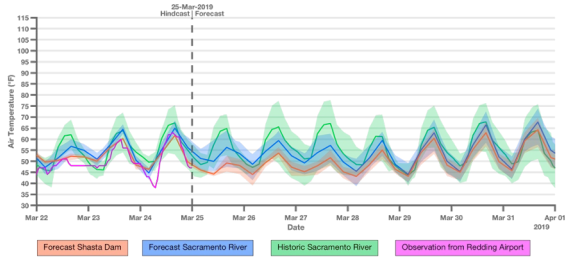
Reservoirs

CE-Qual_W2



River

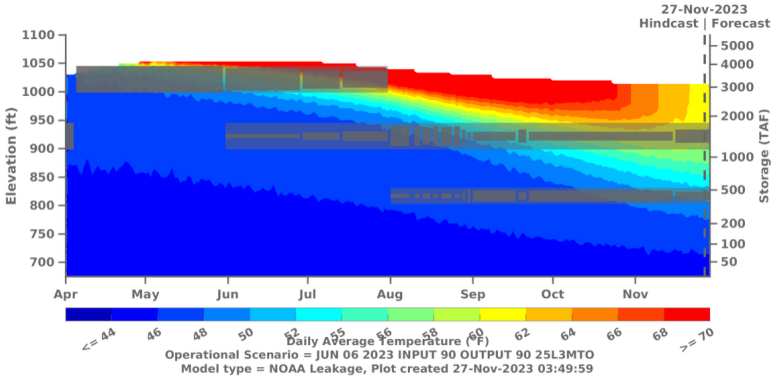
RAFT

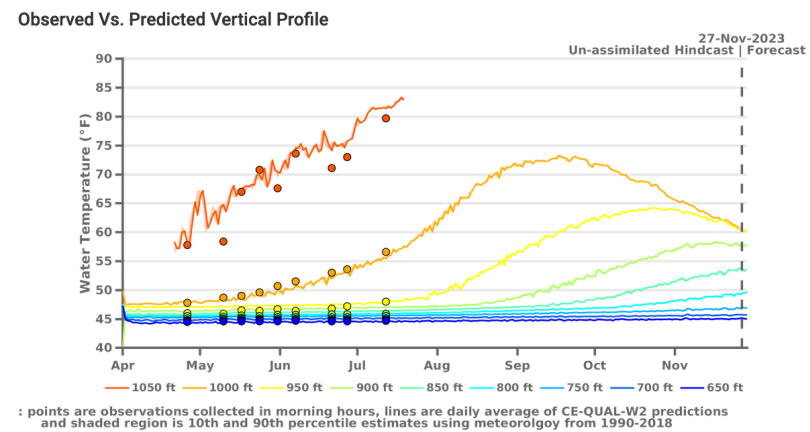


Meteorology

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

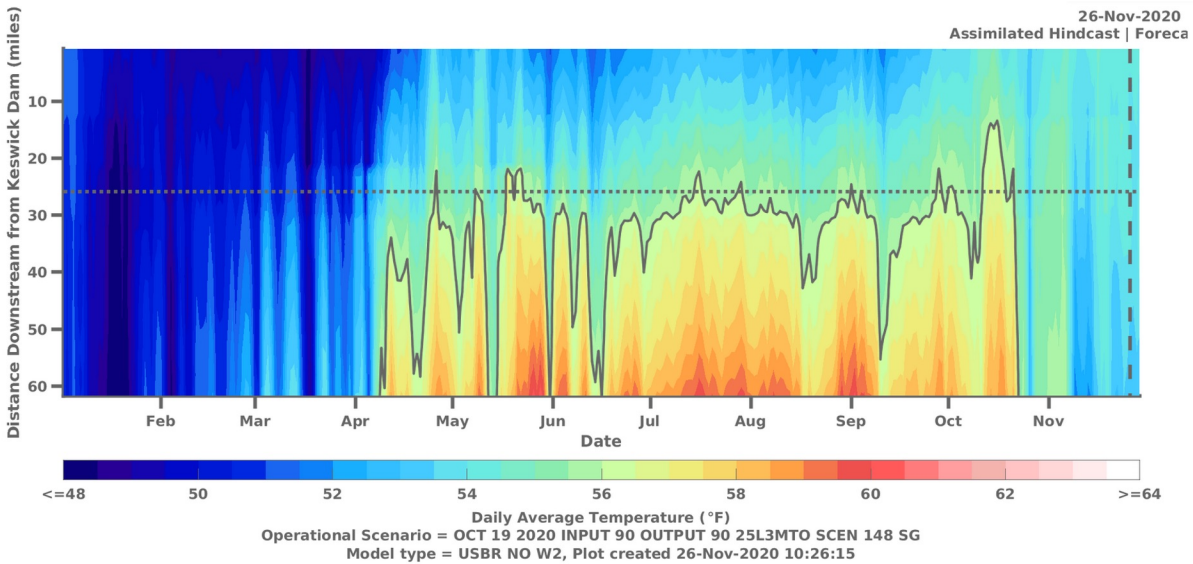
CVTEMP: reservoir conditions





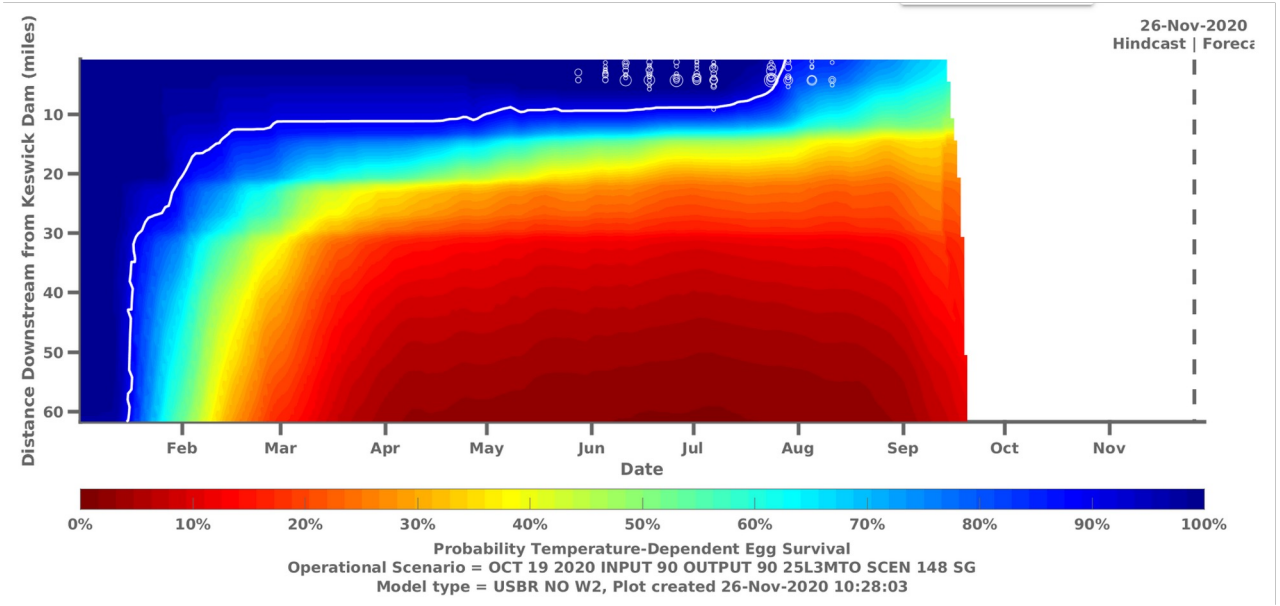
Cold pool
Gate operations
Storage
Discharge temperature

CVTEMP: river conditions



TCP
Temperature contours
Redd locations

CVTEMP: egg TDM



Egg survival probability
Survival contours
Redd locations

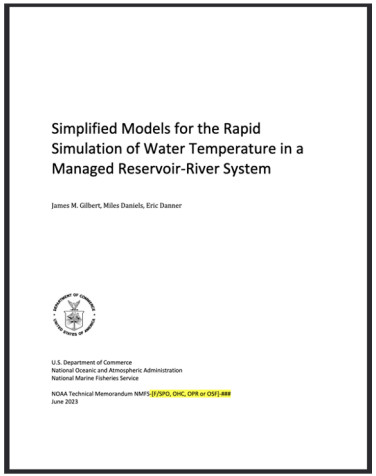
Rapid Assessment Temperature Modeling Framework

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


Simplified Models for the Rapid Simulation of Water Temperature in a Managed Reservoir-River System

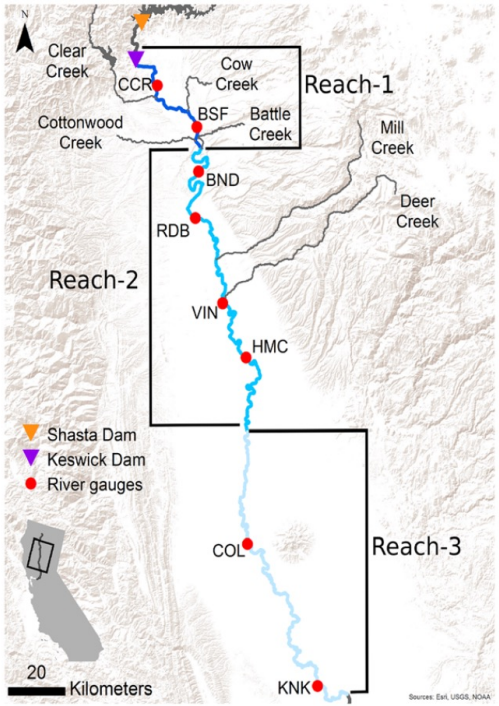
James M. Gilbert, Miles Daniels, Eric Danner

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

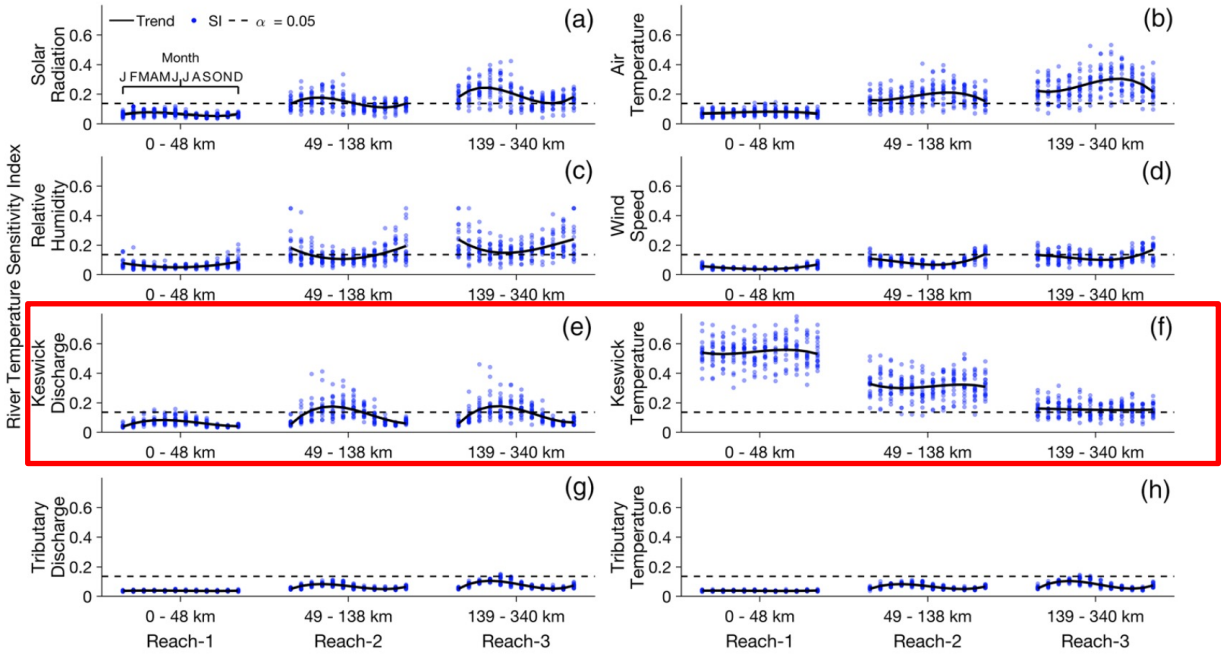
NOAA Technical Memorandum NMFS-[F/SPO, OHC, OPR or OSF]-###
June 2023

Gilbert et al. 386 pages (in review)

Release Temperature vs Release Flow

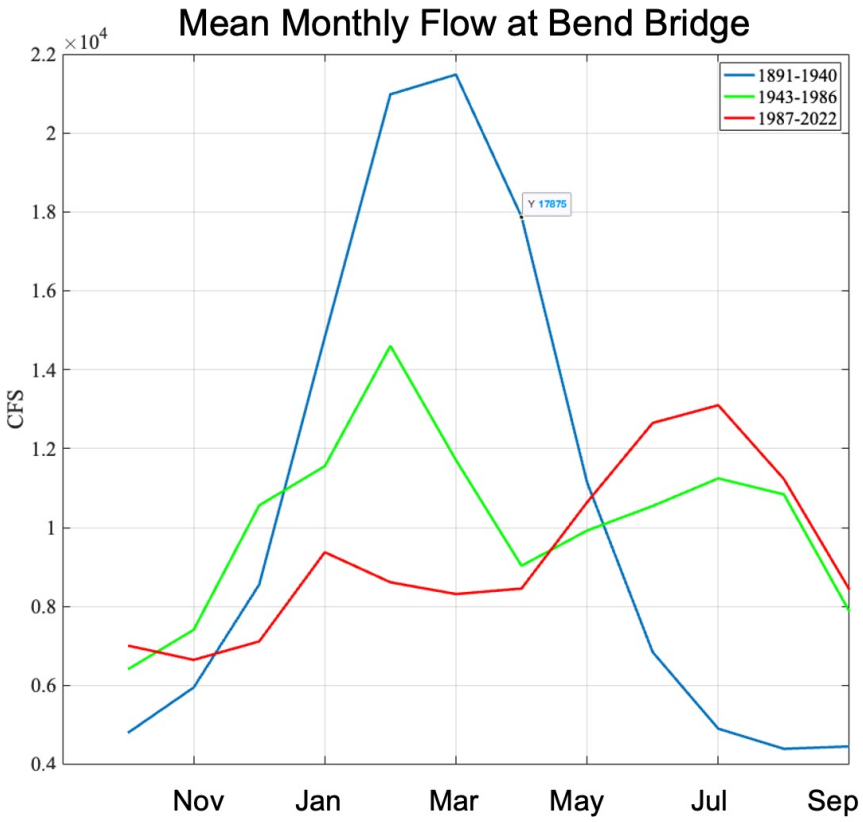


Sensitivity analyses by reach and input



Daniels and Danner 2020

Altered Hydrograph



The dam building era:

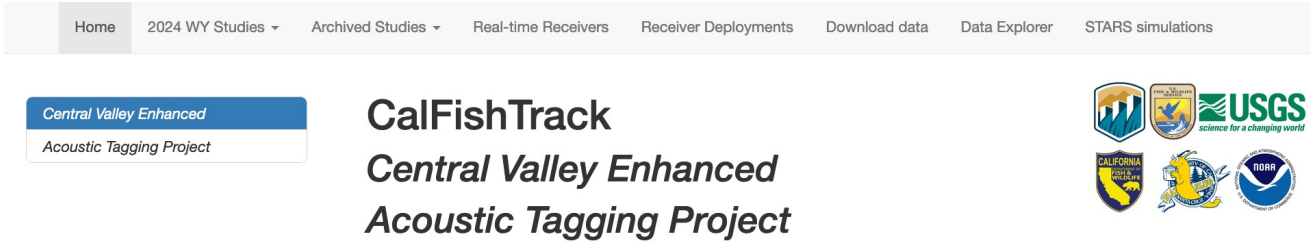
Before

During

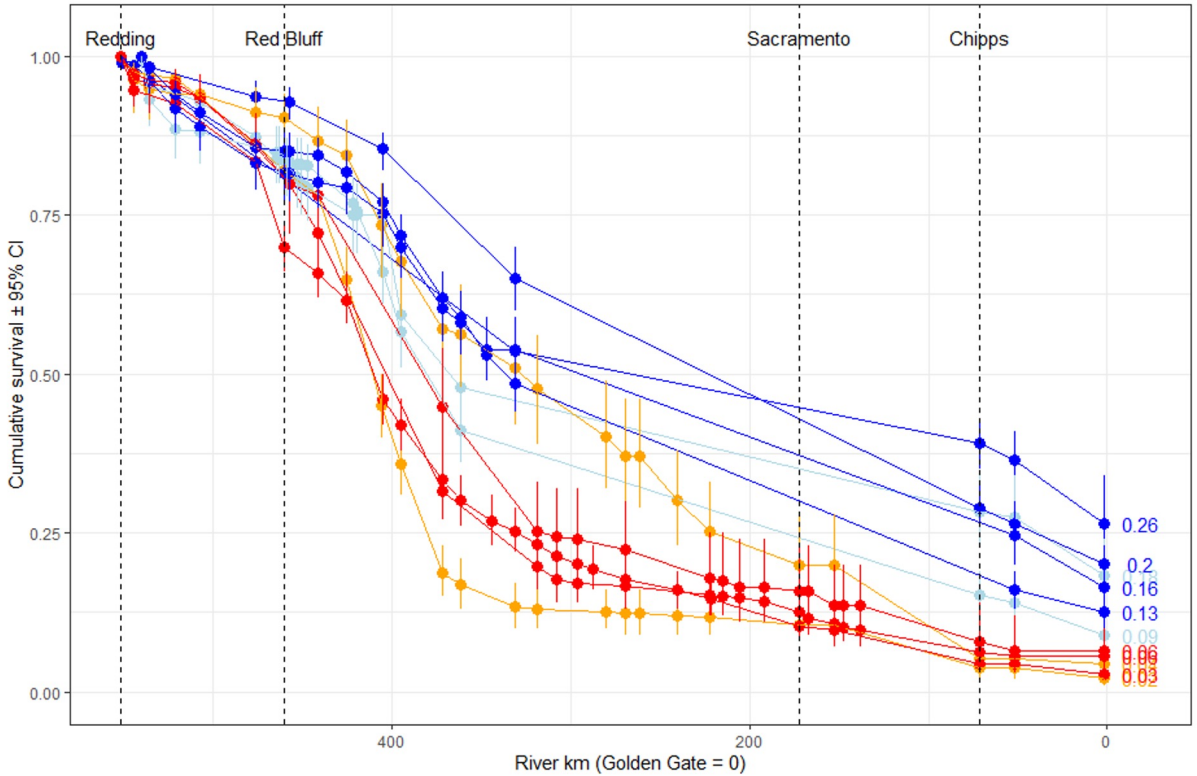
After

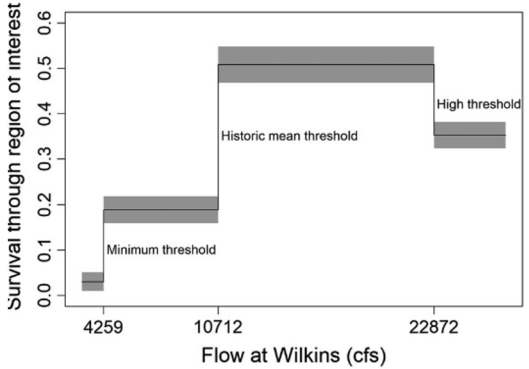
Juvenile salmon outmigration

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



Outmigration survival





Michel et al. 2021

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)

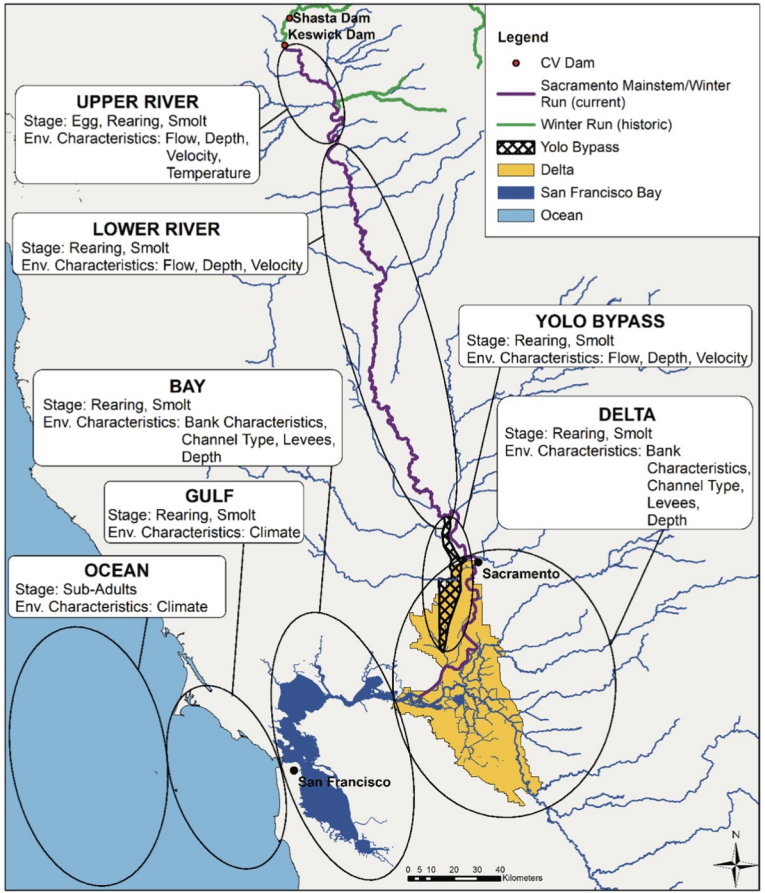
Evaluate the influence on the long-term population dynamics:

- Hydrology
- Hatchery
- Habitat restoration
- Harvest
- Reintroduction

Management relevant metrics:

- Cohort replacement rate
- Smolt production
- Adult abundance

The WRLCM



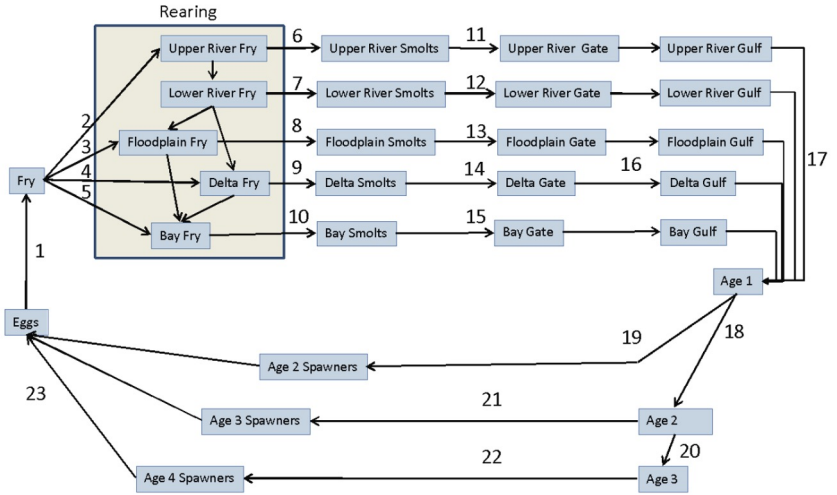


Figure 4. Central Valley Chinook transition stages. Each number represents a transition equation through which we can compute the survival probability of Chinook salmon moving from one life stage in a particular geographic area to another life stage in another geographic area.

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

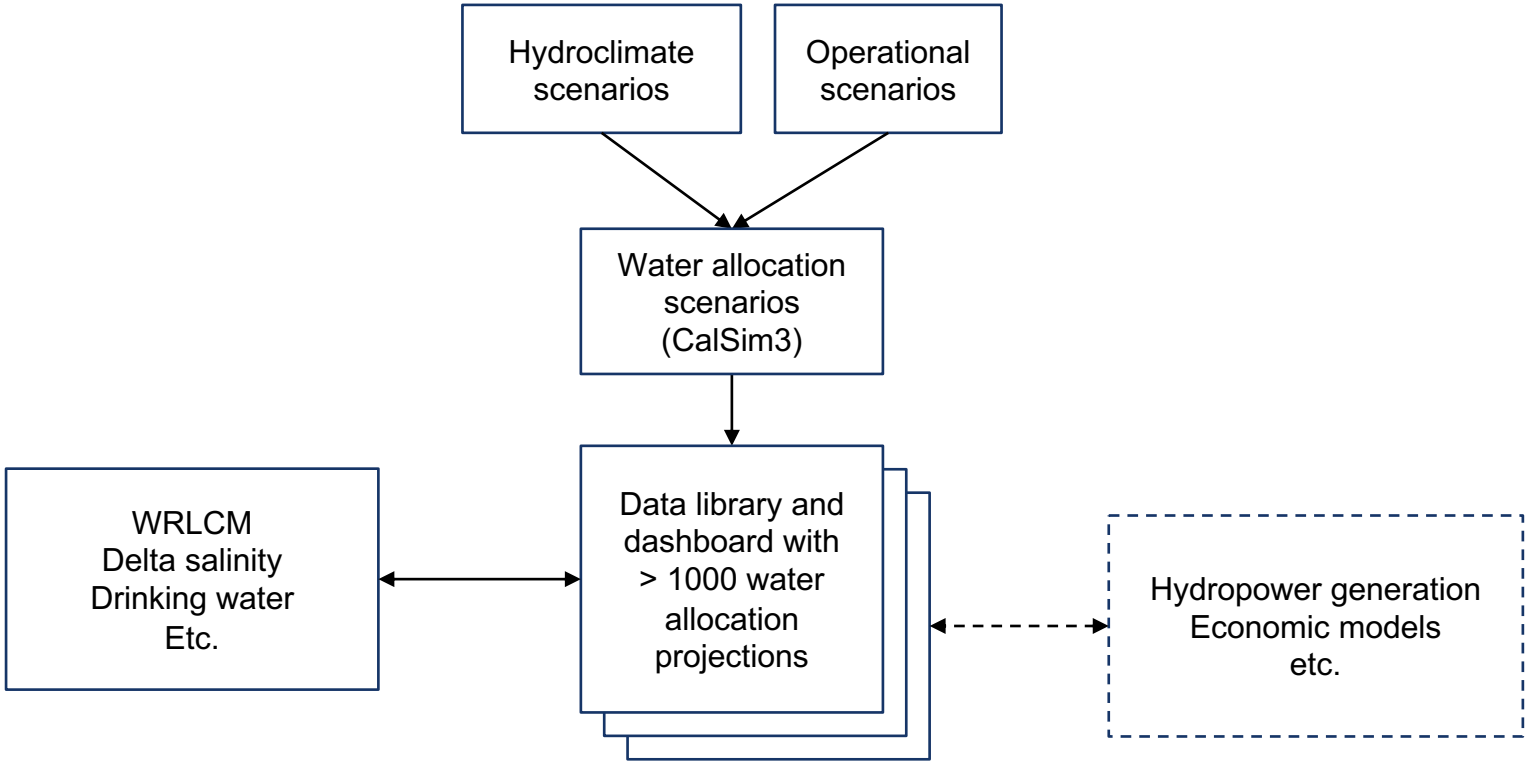
4. Adaptive management:
CV water planning and operations are different processes
Monitor fish response relative to actual operations

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



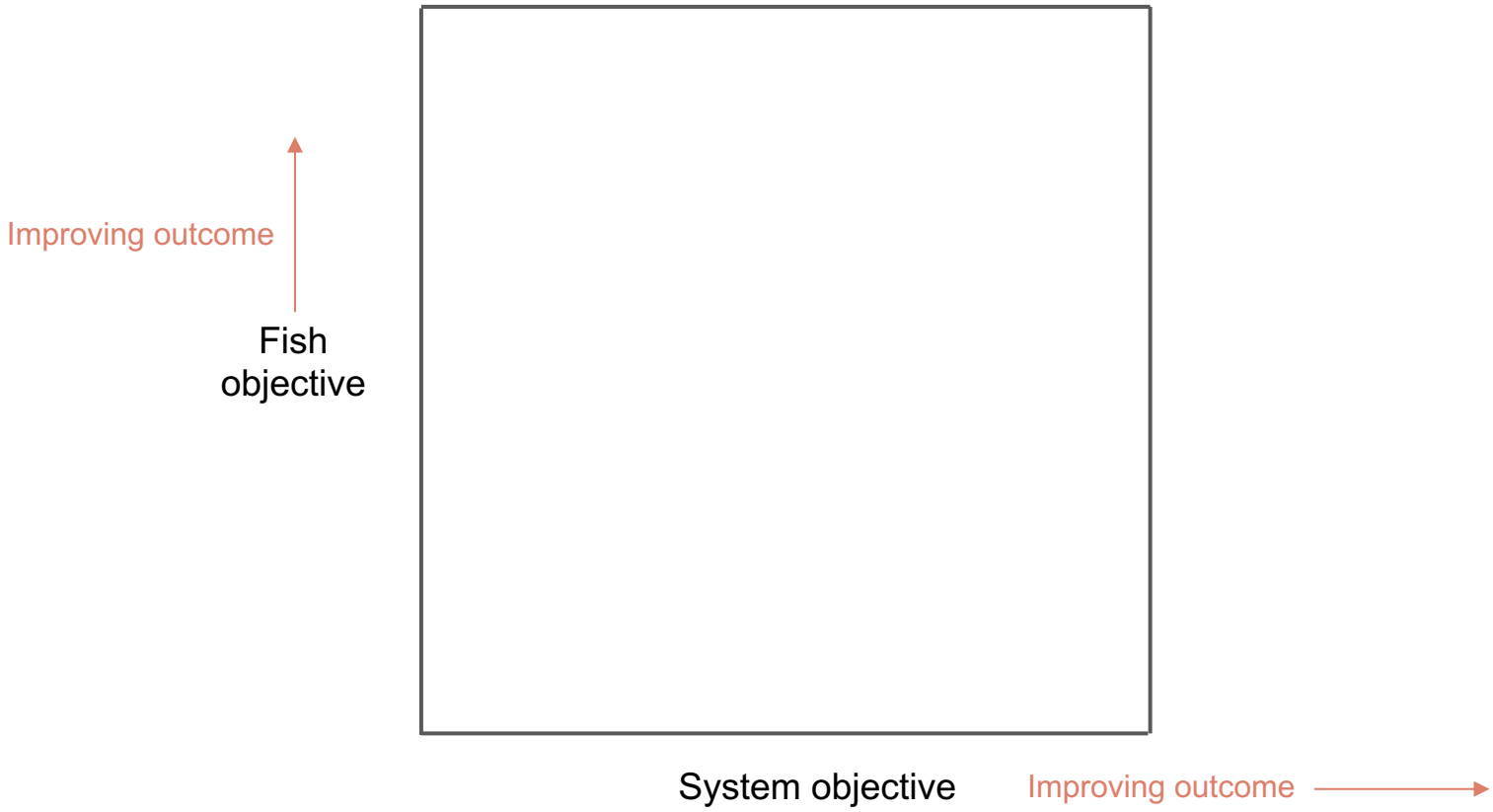
3. Decision Space

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



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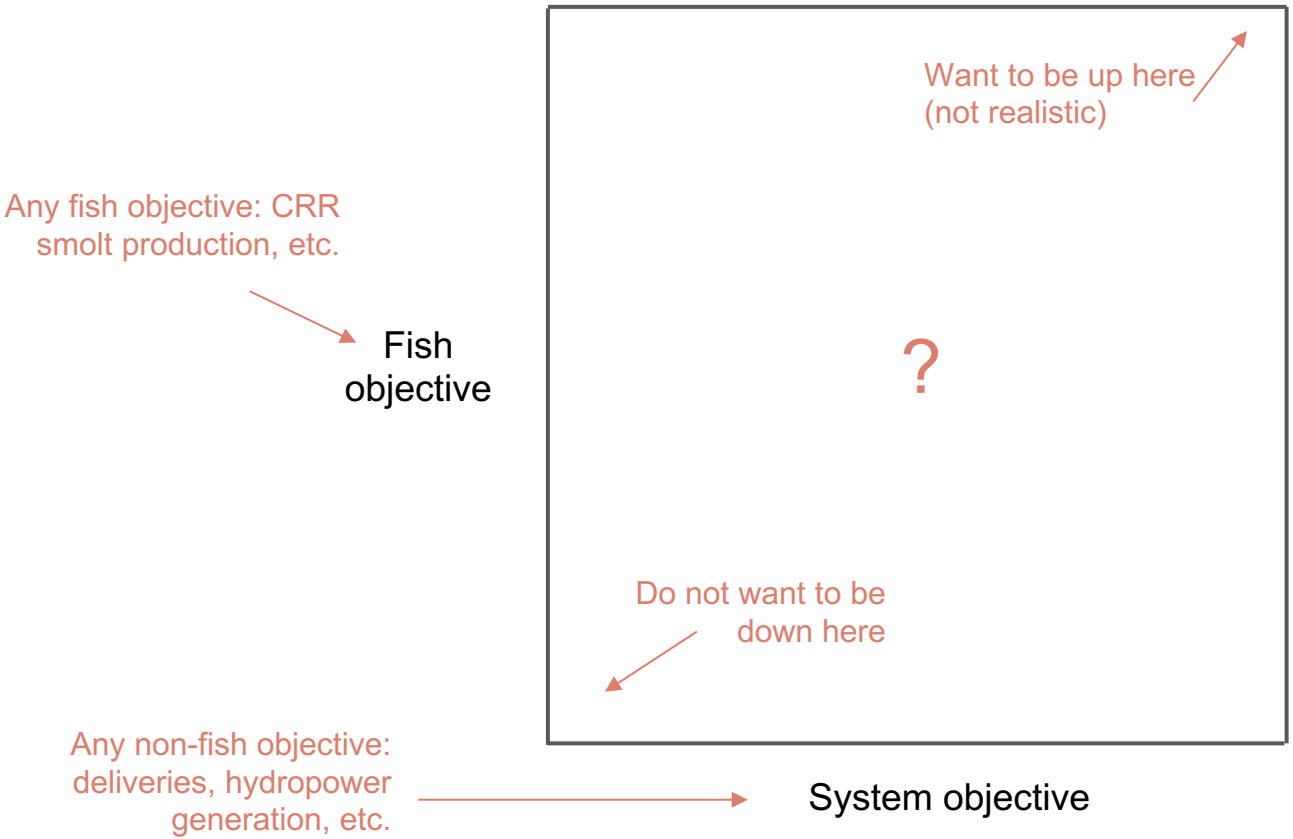

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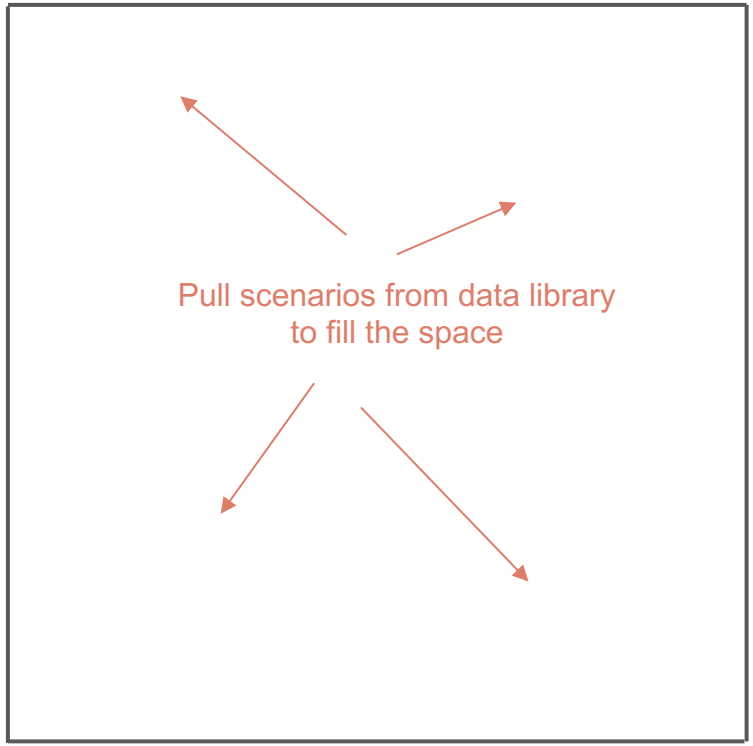
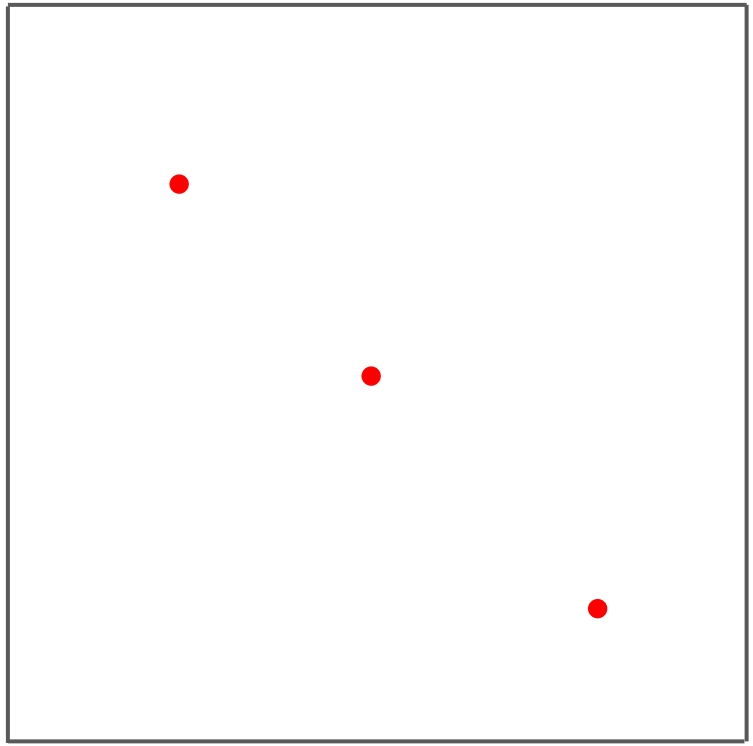


Fish objective

System objective

Decision Space



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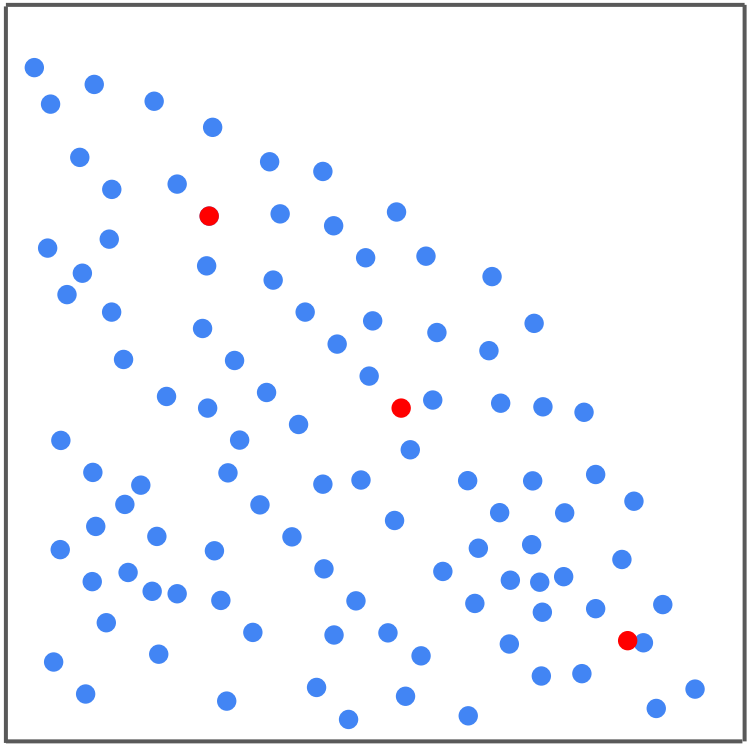

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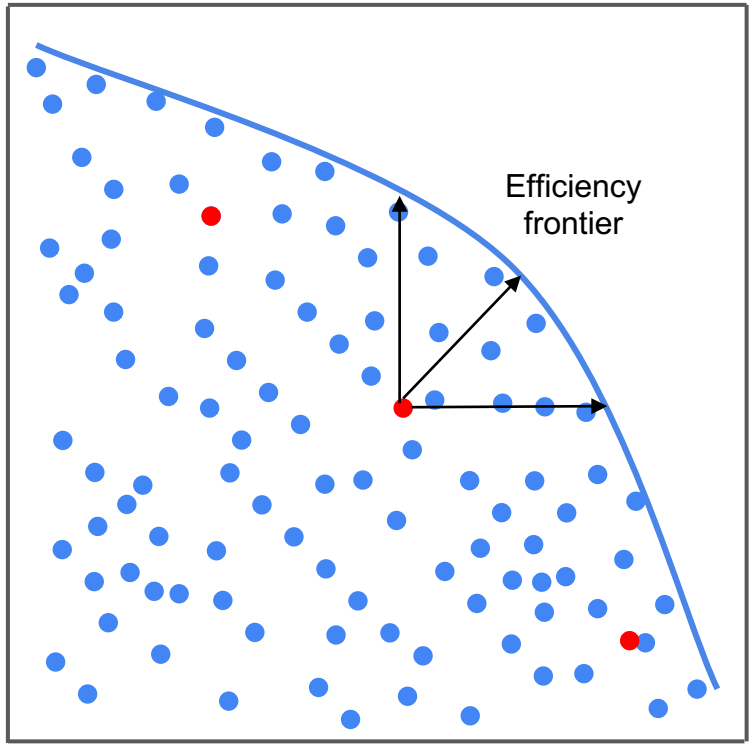

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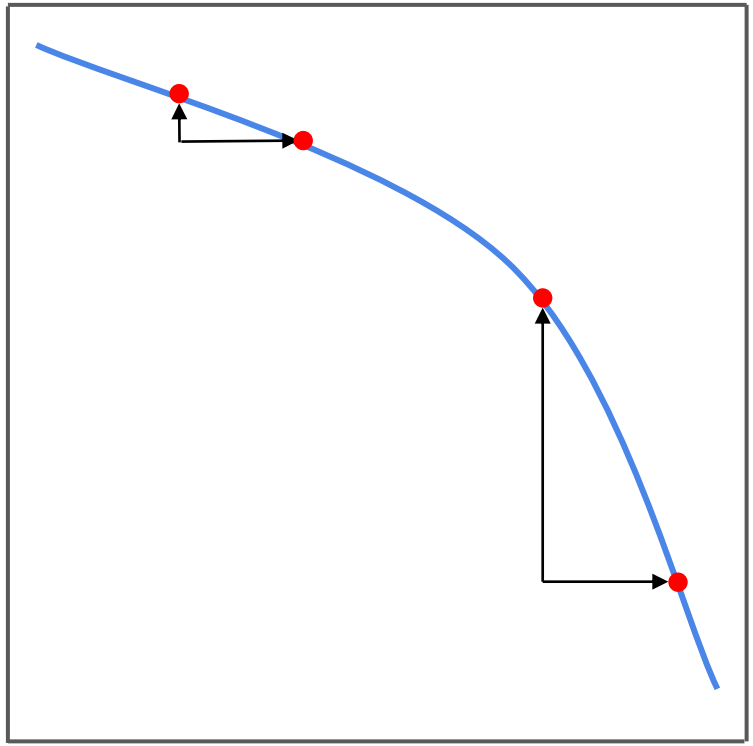


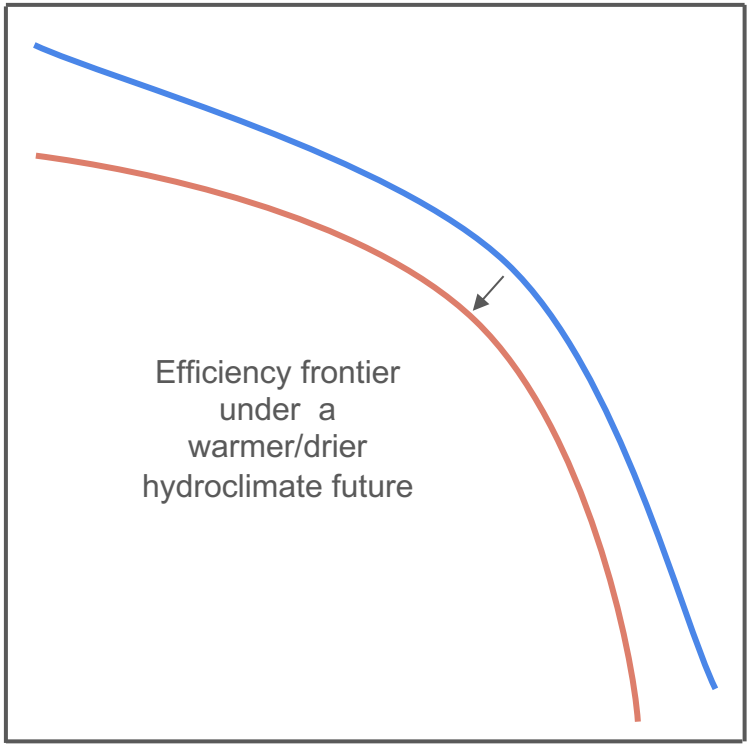
Fish objective A

System objective B

Trade-off can be very sensitive to the location on the frontier

Same cost to Objective B, Different benefits to Objective A

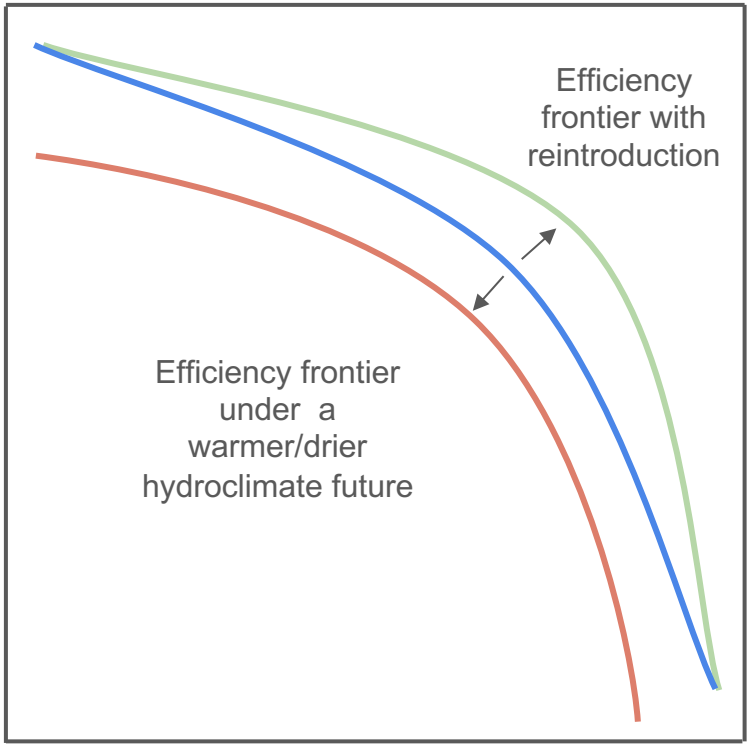
Decision Space



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