Temperature-dependent Mortality
&
TDM Rapid Assessment Tools

James Gilbert

Researcher, University of California, Santa Cruz

NOAA Fisheries (affiliate), Southwest Fisheries Science Center

April 21, 2021

Outline

- Temperature-dependent egg mortality context and background
- Use of models to estimate TDM
- Rapid TDM framework
  - Factors and considerations
  - Example application and results

Southwest Fisheries Science Center

Misson:

Our mission is to generate and communicate the scientific information necessary for the conservation and management of our nation's natural resources.

Disclaimer

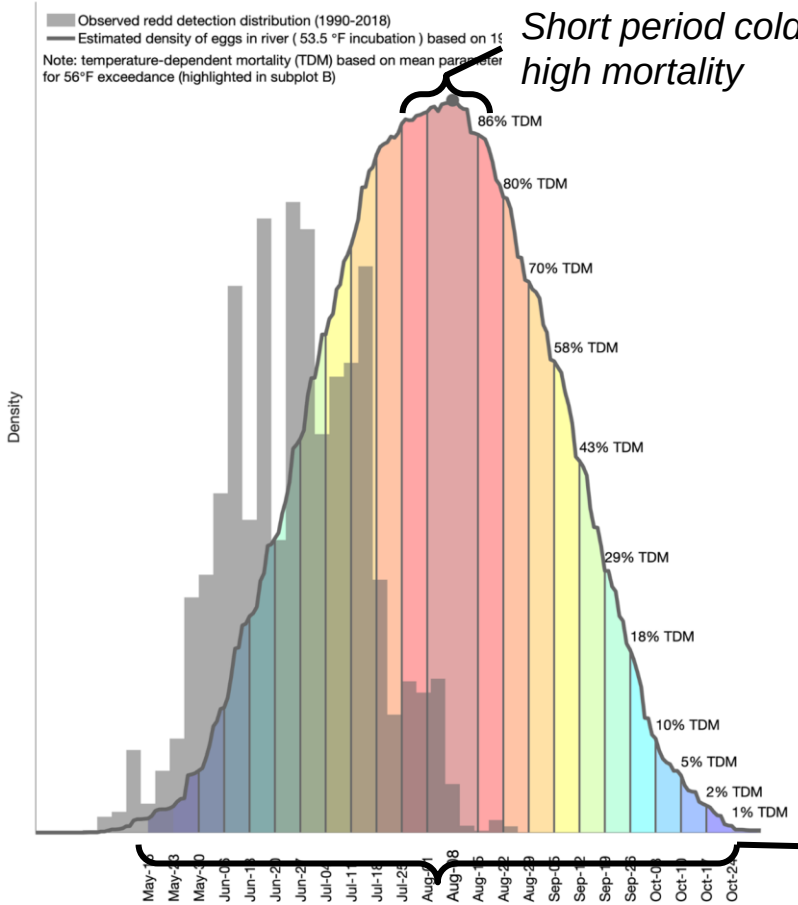
Information on the development and application of the rapid assessment TDM modeling framework is provided with the intent to assist other modelers in designing and testing scenarios for temperature management. The rapid TDM modeling framework is under continued development and has not been vetted by the community. Results from the rapid TDM modeling framework should be assessed critically with the understanding of uncertainties associated with a new model and it’s application. Any data generated through the use of the rapid TDM modeling framework should not be evaluated in isolation and should only be used as a guide for where a scenario or condition might yield useful information when simulated in a trusted, vetted model. No operational decisions or actions should be made based on the results of the rapid TDM modeling framework.

Acronyms

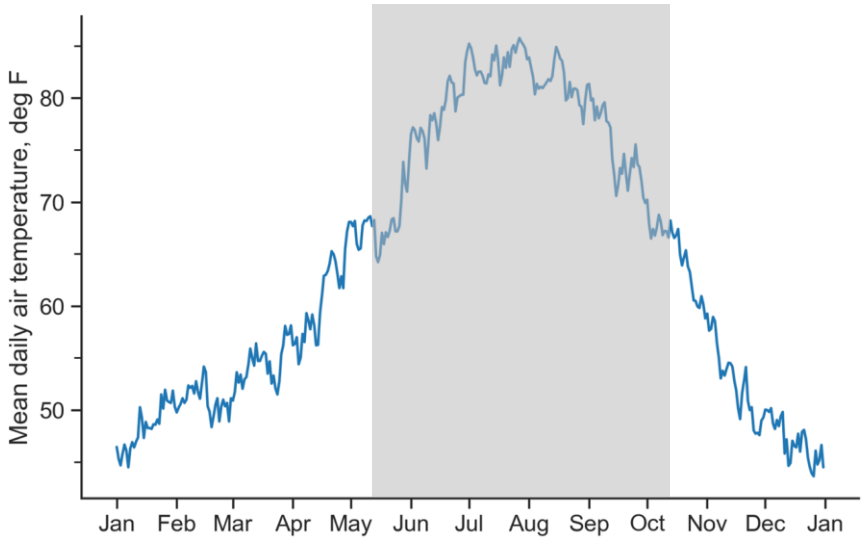
TDM:	temperature-dependent egg mortality
TCD:	temperature control device (specifically the structure used for selective withdrawal at Shasta dam)
EOS:	end of September, referring to end-of-season reservoir storage
SWFSC:	NOAA Fisheries - Southwest Fisheries Science Center

TDM Context and Background

Factors affecting TDM - Temperature and Time



Short period cold water, high mortality



Long period cold water, low mortality

TDM is just one source of mortality

- Overall egg-to-fry survival depends on TDM *as well as* other mortality causes

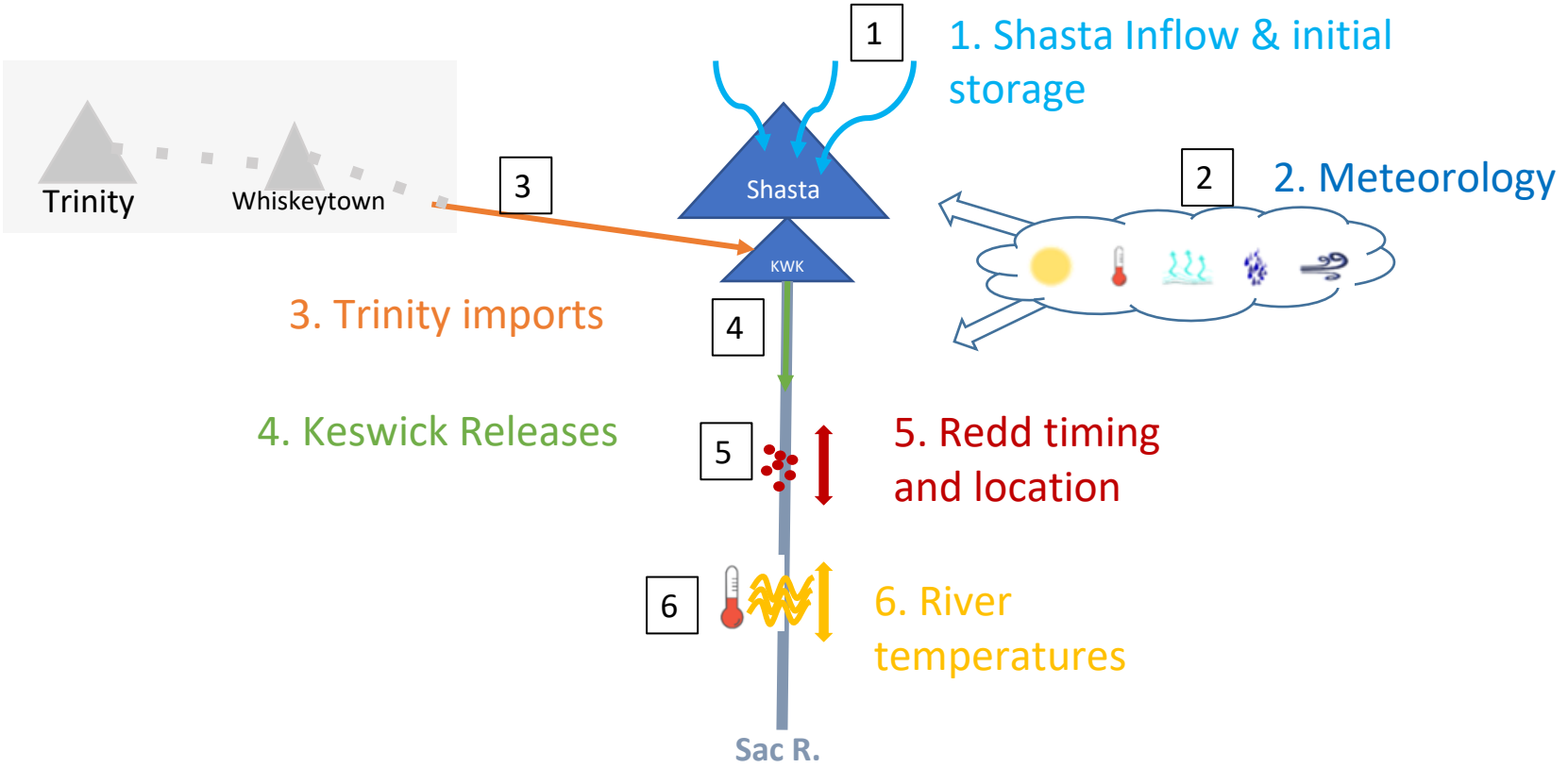
$$\text{Population}_{EGG}$$

$$\text{x (1 - Temperature-dependent mortality)}$$

$$\text{x (1 - Other Mortality Causes)}$$

$$= \text{Population}_{FRY}$$

TDM in the upper Sacramento River is the complex result of interconnected processes & components



Using models to estimate TDM

Estimating TDM using a series of physical & biological models

Shasta temperature stratification and effects of TCD operation

Simulation

- Reservoir model (CE-QUAL-W2, HEC-5Q)

Temperature change through Keswick Reservoir

Simulation

- Reservoir model (CE-QUAL-W2, HEC-5Q)

Temperature change with flow and distance along Sacramento River

Simulation

- River model (CE-QUAL-W2, HEC-5Q, RAFT)

Effects of temperature on egg mortality during incubation

Simulation

- Temperature-dependent mortality model

SWFSC's Existing Full Simulation Framework

- Shasta model (CE-QUAL-W2)*
- Keswick model (CE-QUAL-W2)*
- Sacramento River model (RAFT)*
- Temperature-dependent mortality model

- 2-dimensional reservoirs
- High spatial, temporal resolution

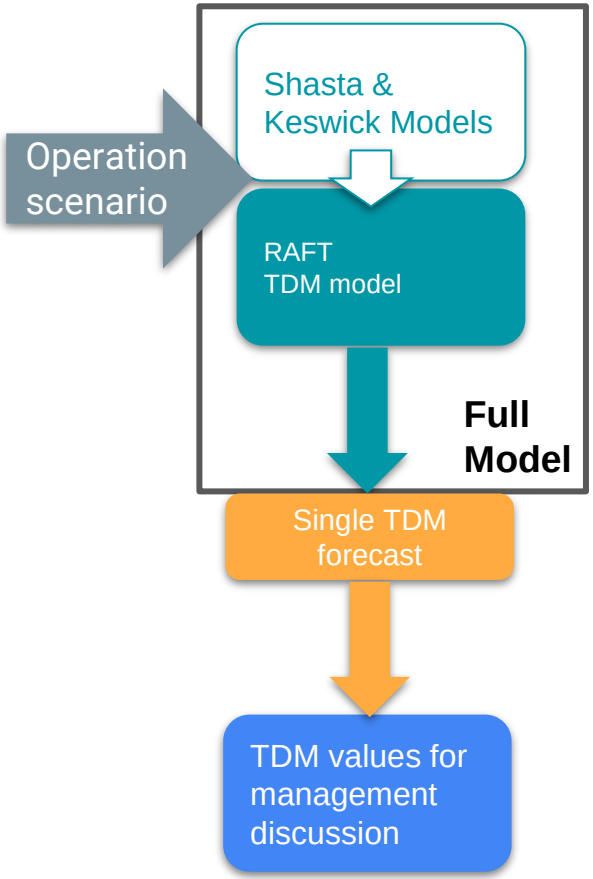
Approximate run time for one year of simulation: 30 minutes

*These models, as applied to the upper Sacramento River, have been independently reviewed by the Center for Independent Experts, see the CVTEMP website https://oceanview.pfeg.noaa.gov/CVTEMP/reference) for full text of reviews:

- *St-Hilaire, A. 2017. Evaluation of River Temperature Support Tools for California's Central Valley*
- *Lapointe, M. 2017. Center for Independent Experts (CIE) Independent Peer Review of River Temperature Decision Support Tools*
- *Cooke, S. 2017. Independent Peer Review of River Temperature Decision Support Tools for the Central Valley of California to Support Management of Sacramento River Winter-run Chinook Salmon*

Existing full simulation framework aligns with a targeted scenario analysis approach

Current approach



- Straightforward: a few scenarios → a few TDM outcomes
- Great for fine-tuning a constrained operational scenario
- Simulation time not generally limiting

Models

Analysis/
Review

Decision-
making

Rapid TDM Framework

What if you want to expand scope of TDM analysis?
Motivation for a rapid assessment tool

- We’re interested in understanding factors that drive temperature-dependent mortality outcomes in the Central Valley
- At range of scales:
  - Seasonal
  - Multi-year
  - Decadal
- Considering crucial uncertainties
  - Hydrology - volume, timing, upstream temperatures
  - Meteorology - heat waves,
  - Climate - sequences of drought and flood, trends in temperature and precipitation

What if you want to expand scope of TDM analysis?

Target factors for a rapid TDM analysis tool

Environment (not under our control):

- Hydrology (timing, volume, temperature)
- Meteorology
- Redd distributions*

Operations (controllable):

- Release rates, volumes, timing
  - Shasta
  - Trinity imports
- TCD operations
  - To the precision and access allowed by the structure

How does uncertainty here... → ***... affect options for managing TDM here***

* *Not known at beginning of temperature management season, though some evidence suggests a connection between river temperatures and spawning timing*

What if you want to expand scope of TDM analysis?

Motivation for a rapid assessment tool

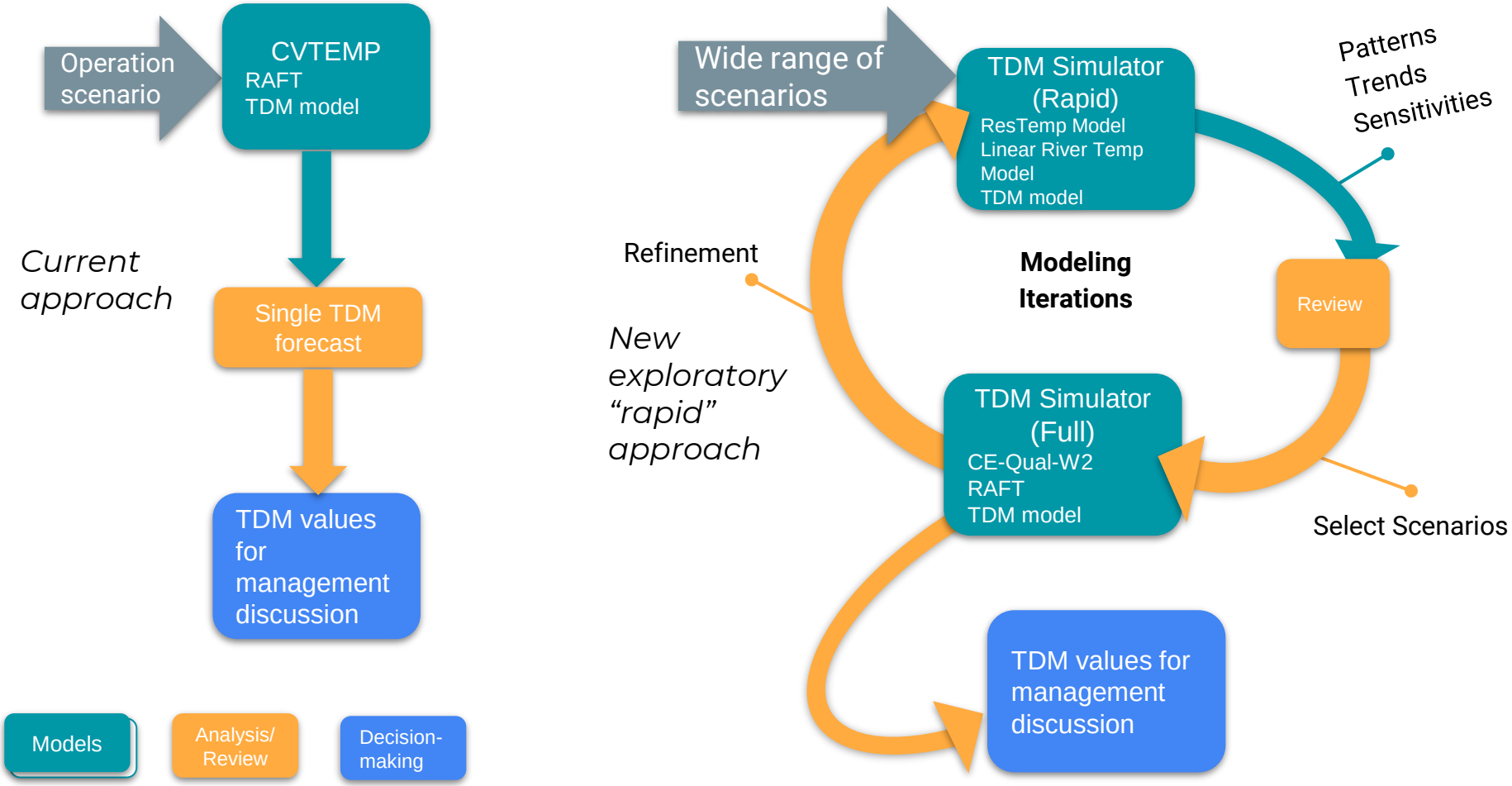
- Hypothetical scenario:
  - *March 1st - given range of water supply forecasts and meteorological uncertainty, how will different release schedules and TCD operational strategies affect TDM in the Sacramento River this year?*
- Factors we might consider:
  - Hydrologic uncertainty → 3 dry Shasta inflow scenarios
  - Meteorological uncertainty → 5 warm summer scenarios
  - Release options → 10 patterns for Shasta, 10 patterns for Trinity imports
  - Temperature targeting → 10 patterns for a target location of Sacramento River above Clear Ck
- Considering all combinations: 3 x 5 x 10 x 10 x 10 = 15,000 scenarios
- **If model runtime ~30 minutes, would take ~310 days**

What if you want to expand scope of TDM analysis?

Method for a rapid assessment tool

- Developing a modeling framework that builds on existing, simplified simulation methods to quickly (~seconds/year) model:
  - Shasta dam and reservoir (vertically-stratifying)
  - Keswick dam and reservoir (longitudinally-mixed)
  - River below Keswick Dam
- General approach - start simple, add complexity where necessary
- Iterative refinement - comparisons against more complex models identify and guide improvements
- ***A complement to, <u>not a replacement for</u>, the full simulation approach***

Proposed Seasonal Analysis Framework



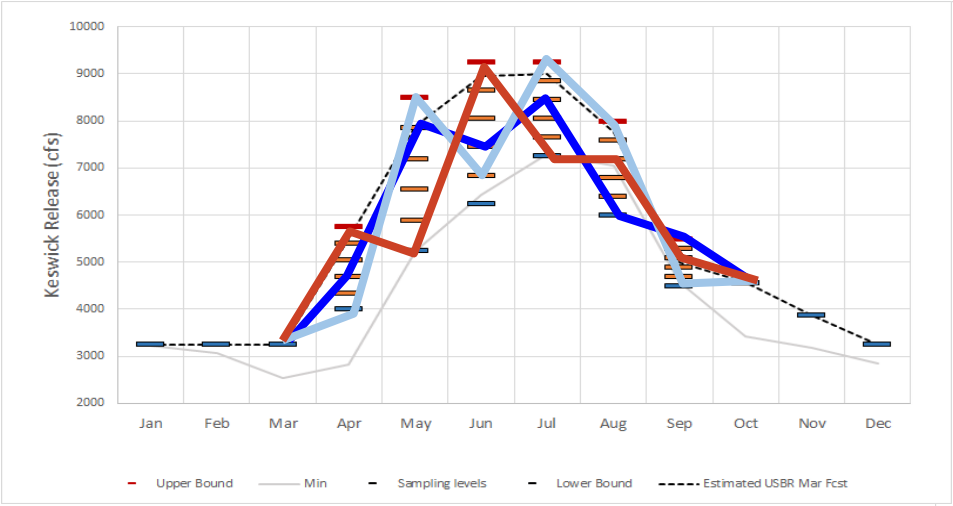
Rapid TDM analysis framework: Status and caveats

- Framework is **currently under active refinement and testing**
- All results **should be considered draft and provisional** at this time
- **Decisions on operations should be based on established and trusted models -** Rapid analysis framework is intended to help identify useful scenarios for further evaluation
- At most – Rapid analysis framework may indicate useful scenarios for consideration in trusted, more complex models
- ***A complement to, not a replacement for, the full simulation approach and other decision-making processes***

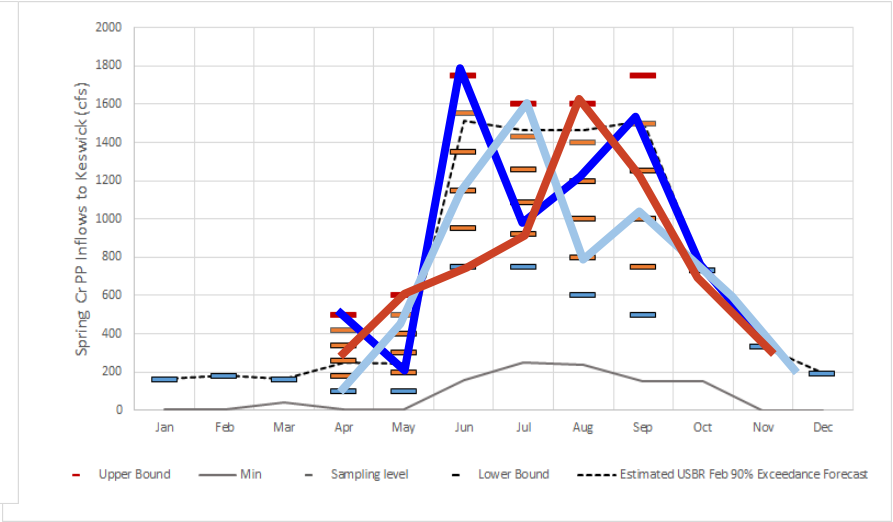
Rapid TDM Framework: Example Analysis

Hypothetical scenario development - Release Scenarios

Keswick Release Sampling Levels

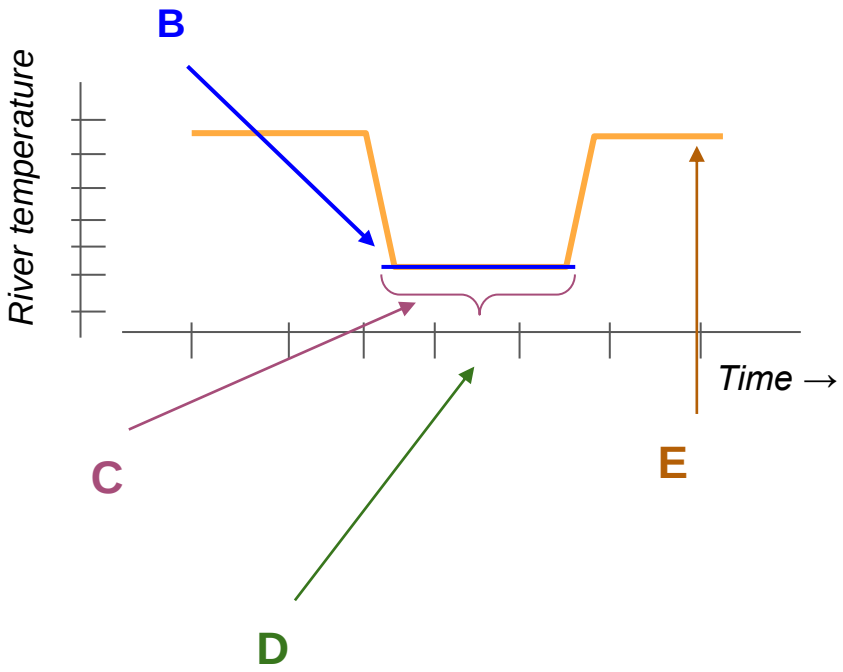


Spring Cr PP Sampling Levels

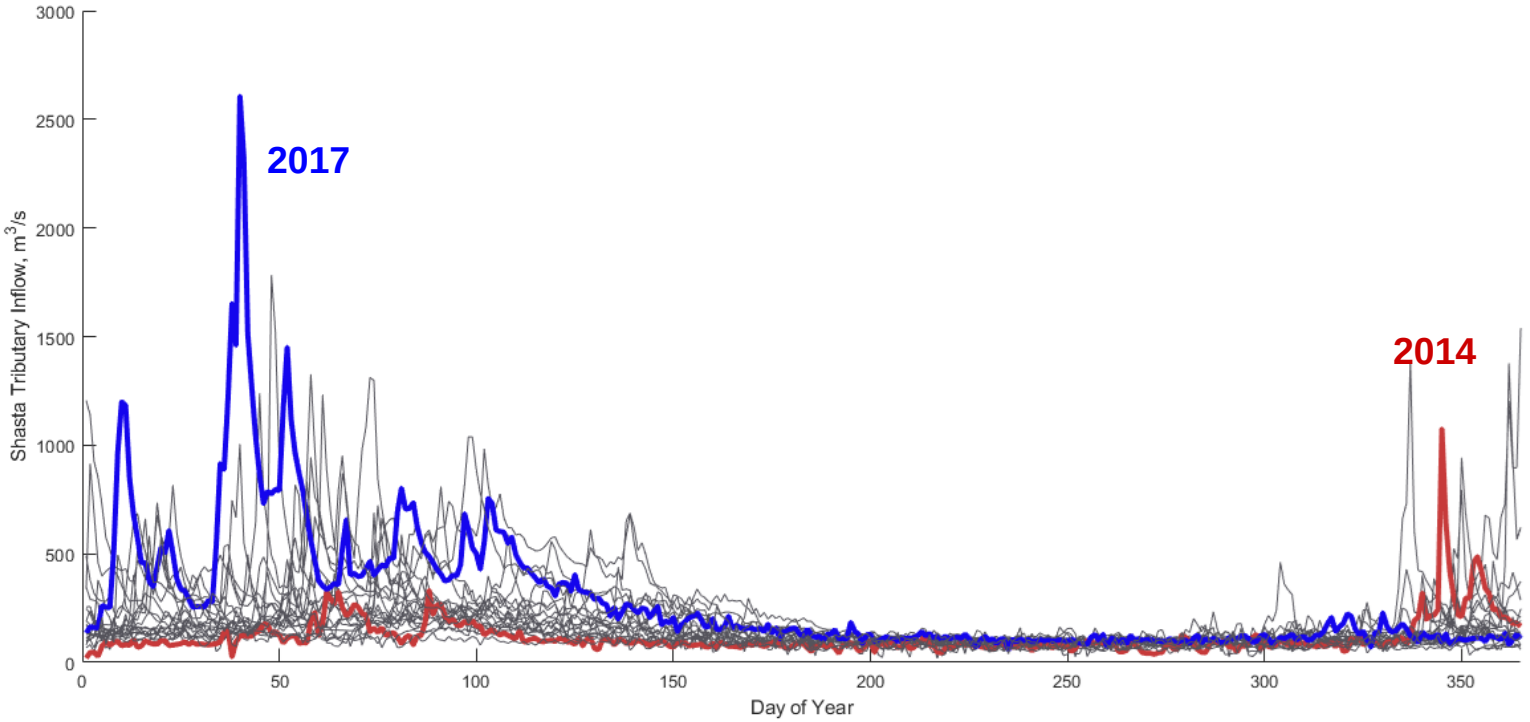


Hypothetical scenario development - Temperature targets

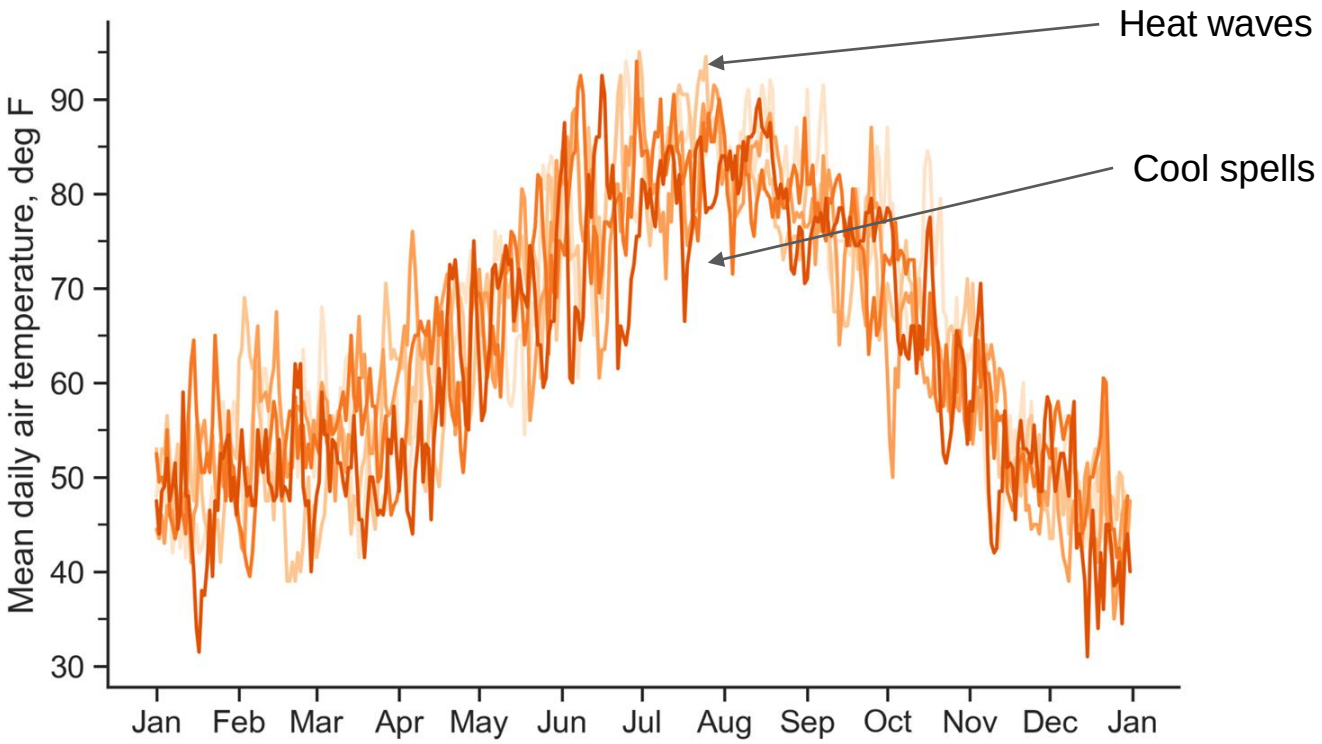
- Target temperature pattern:
  - **(A)** Target location: Where to meet a temperature objective
  - **(B)** Target temperature: What's the lowest temperature to try to maintain during the management window
  - **(C)** Target window length: How long to try to maintain the target temperature
  - **(D)** Center date: On what date should target window be centered?
  - **(E)** Shoulder temperature: What higher temperature should be maintained outside of the target window?



Hypothetical scenario development: explore hydrologic variability



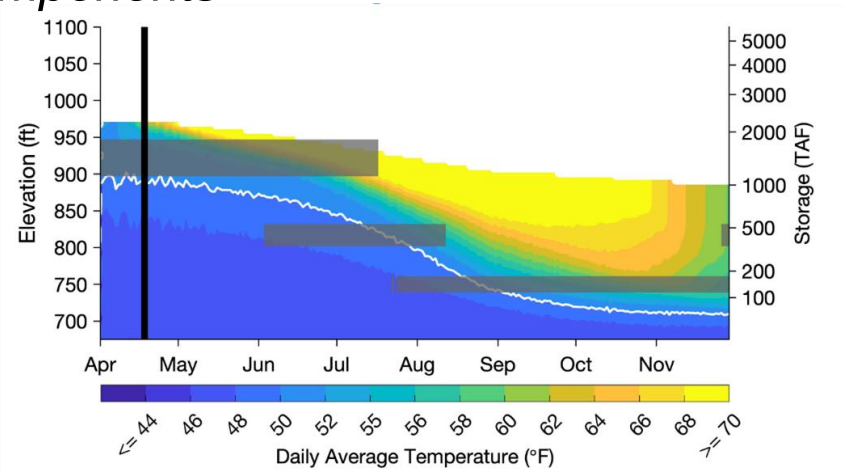
Hypothetical scenario development: meteorological variability

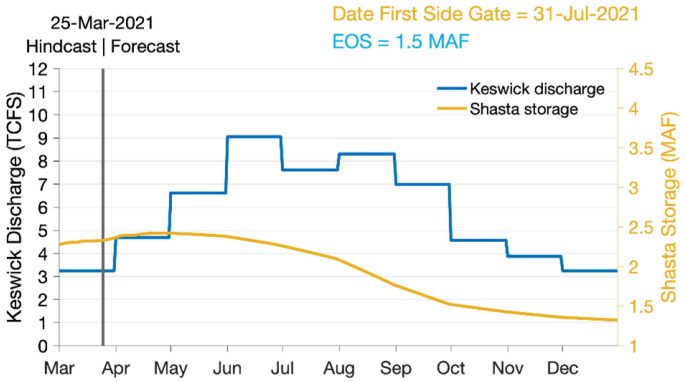


Scope of results: we can examine all parts of the system

Physical components

Shasta reservoir temperatures & TCD gate operations



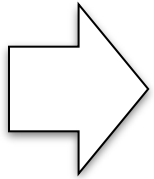


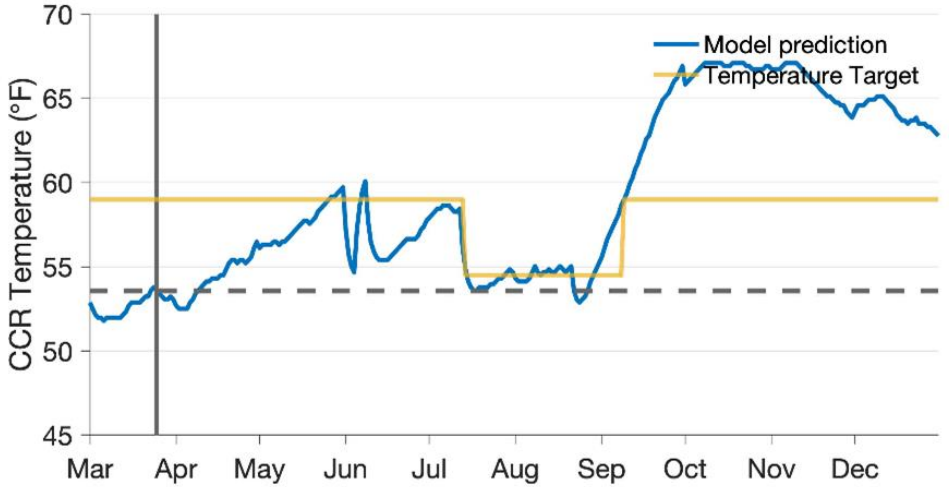
Storage and release patterns

Scope of results: we can examine all parts of the system

Physical components

River temperatures



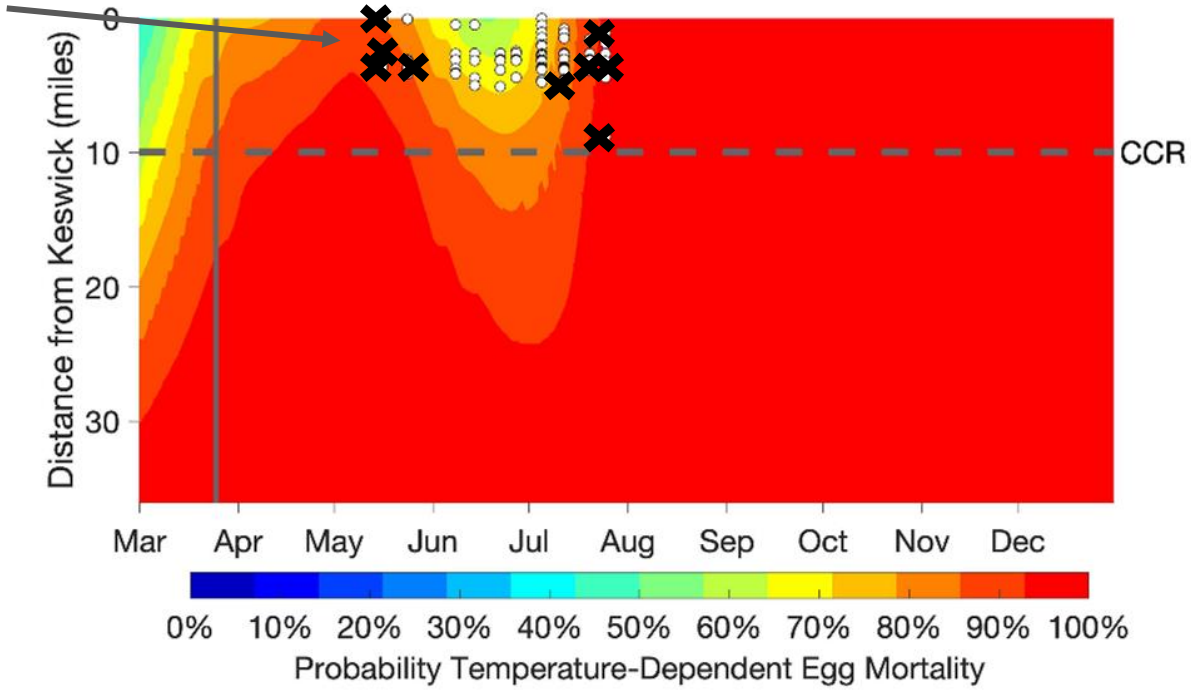


Scope of results: we can examine all parts of the system

Biological components

Can evaluate TDM outcomes for range of redd distributions

Temperature-dependent Mortality landscape



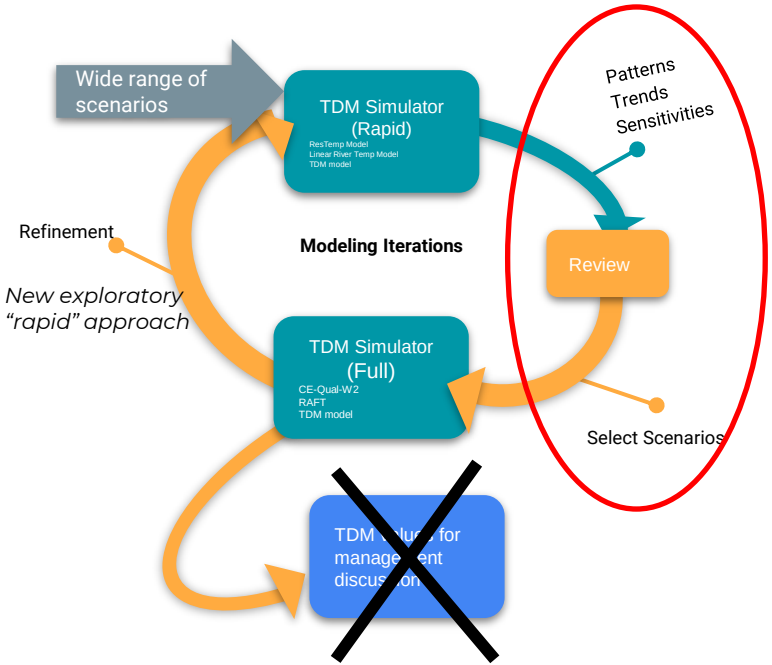
Example analysis: Exploring Alternative Operations

- Baseline scenario:
  - Single Keswick release schedule with set Trinity imports
  - Temperature target*: 56°F at CCR, May-Oct

- Rapid TDM analysis - scope
  - Many combinations of temperature target parameters
  - Different hydrology, meteorology
  - Modified release schedule

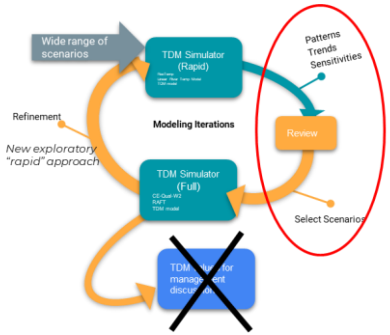
** A target temperature is just that, a target – applying a particular target in a model is no guarantee that that temperature can or will be achieved. A downstream temperature target is a required input to the model when no specific gate operations are prescribed.*

Example analysis: Reviewing results of Rapid TDM analysis

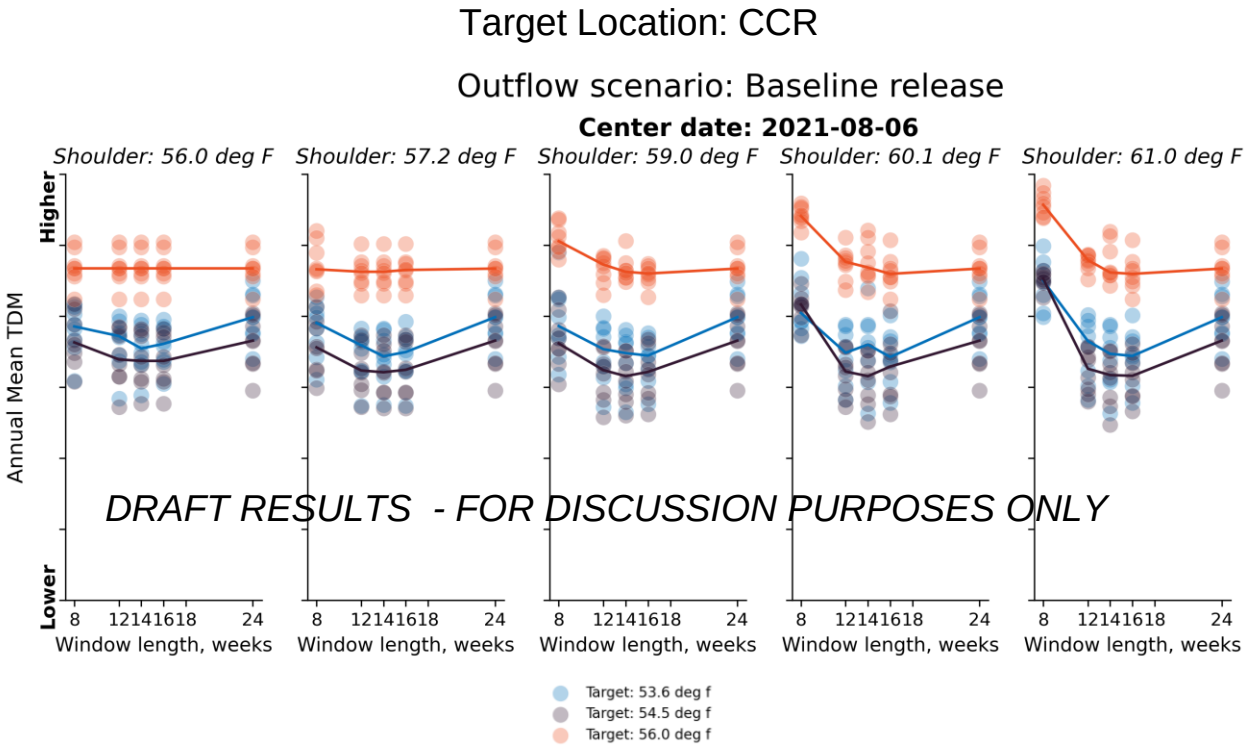


- Reminder: Rapid TDM analysis is NOT meant to prescribe or identify operations for implementation
- Rather – results indicate where the analytical power of more complex, trusted, and vetted models might be usefully directed

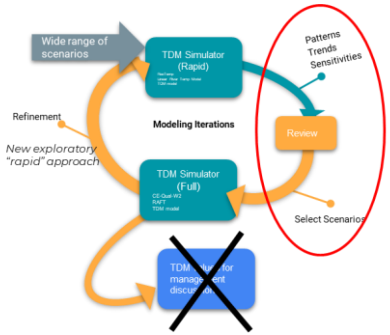
Example analysis: Reviewing results of Rapid TDM analysis



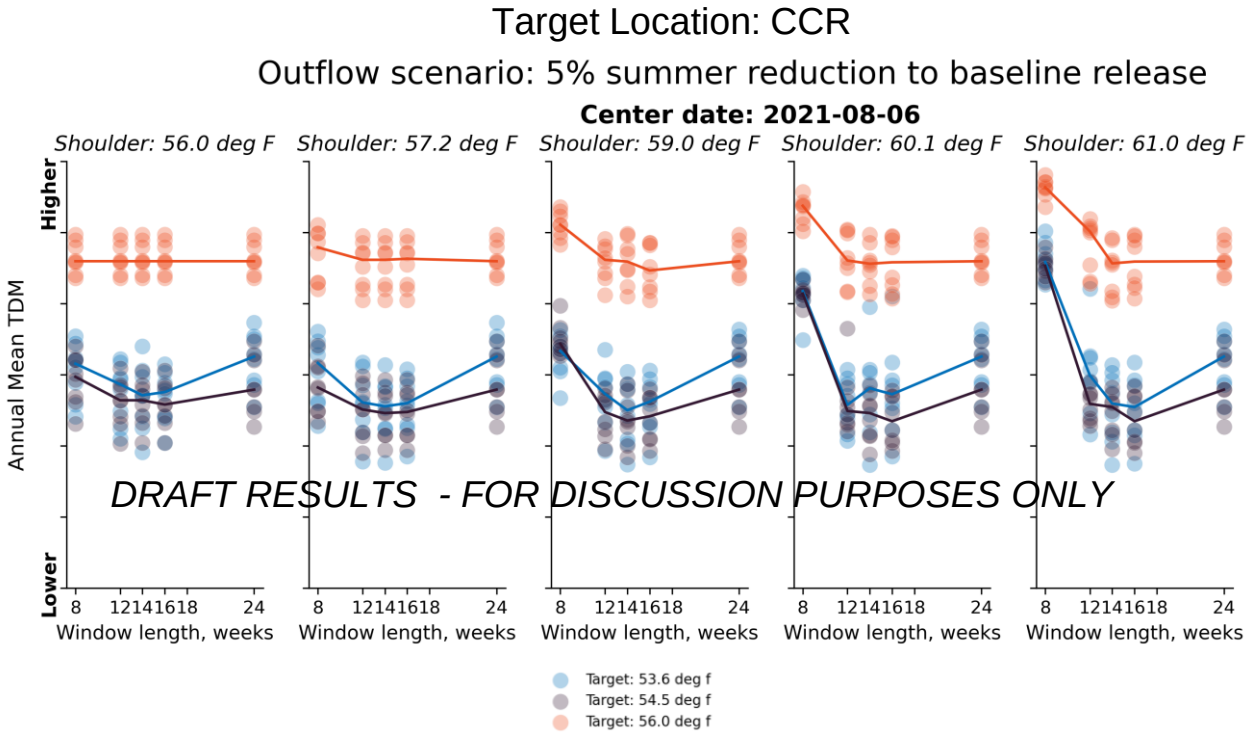
Visualizing temperature targeting parameters **helps identify potential sensitivities for further testing** in trusted, more detailed models



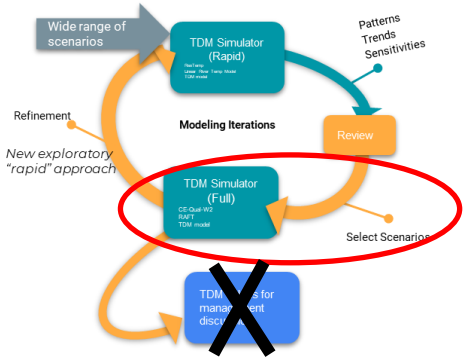
Example analysis: Reviewing results of Rapid TDM analysis



Visualizing temperature targeting parameters **helps identify potential sensitivities for further testing** in trusted, more detailed models



Example analysis: Potential guidance from rapid TDM framework



- Rapid TDM framework suggests directing full, detailed, trusted modeling analysis at the following factors may provide further insight on lowering mean annual TDM:
  - Target temperatures 53.5 to 54.5 deg F (at CCR)
  - Shoulder temperatures >56 deg F (at CCR)
  - Window length 12-16 weeks
  - Reductions in release volume
- ***Necessary next step: Test this with "full" (detailed, trusted, vetted) models***

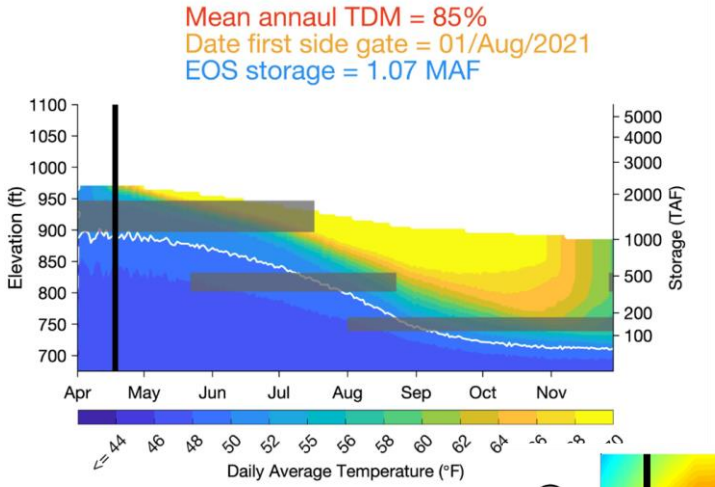
Example analysis: Check selected scenarios with full-complexity models

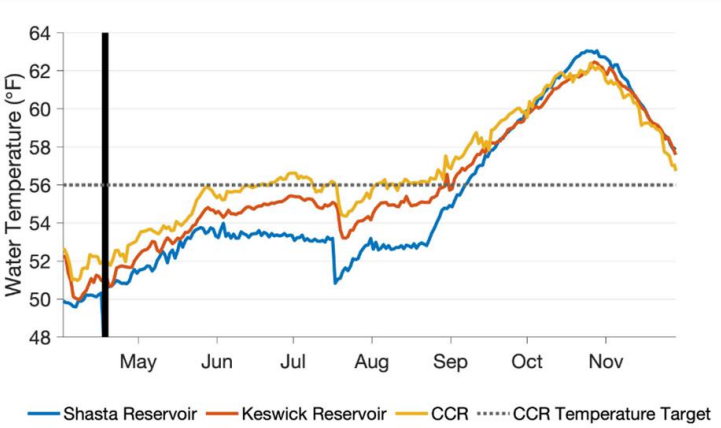
I. “Full” model framework simulations (SWFSC’s CE-QUAL-W2 reservoir models, RAFT river model)

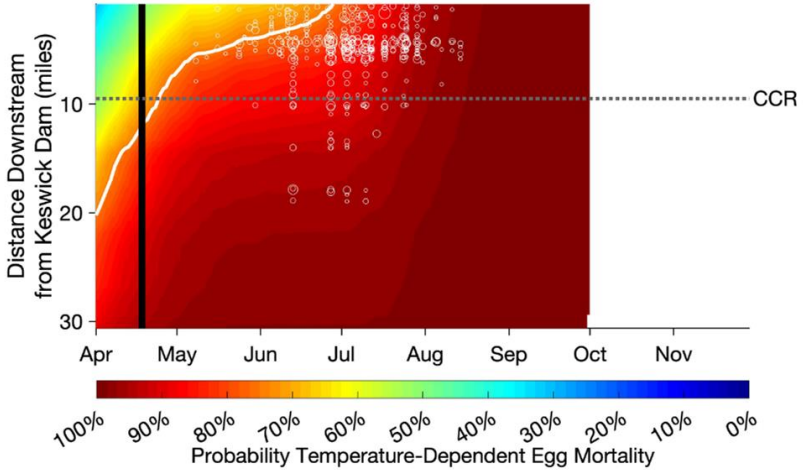
II. Selected three scenarios – start checking if the rapid TDM analysis is pointing in an informative direction
   A. Base
   B. Base with temperature target shaping (TT):
      A. Target: 54.5°F, Shoulder: 59°F, window: 14 weeks, 2015 meteorology, 90% exceedance hydrology forecast
   C. Same as (B) with 5% reduction in monthly Shasta releases

Scenario	Mean Annual TDM from Full model analysis
A. Base	85%
B. Temp Target (TT)	78%
C. Temp Target (TT) + Reduction	69%

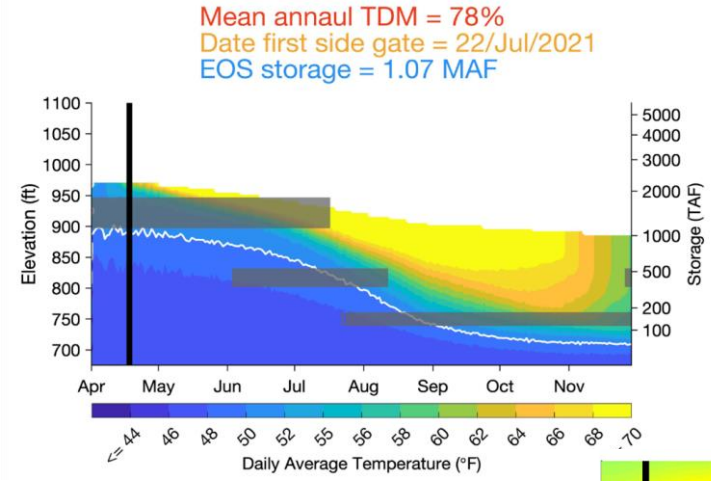
Example Full-complexity models: Baseline Results

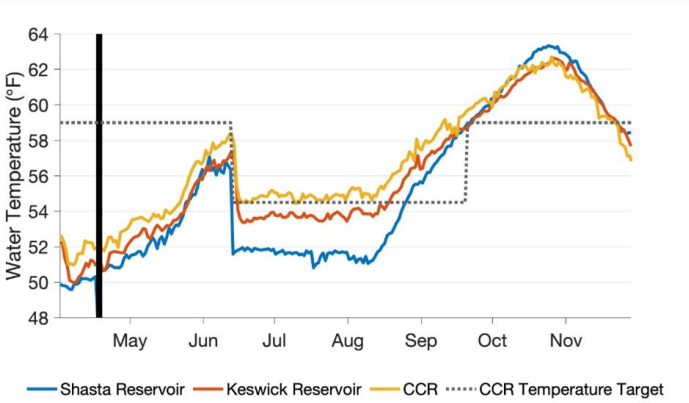


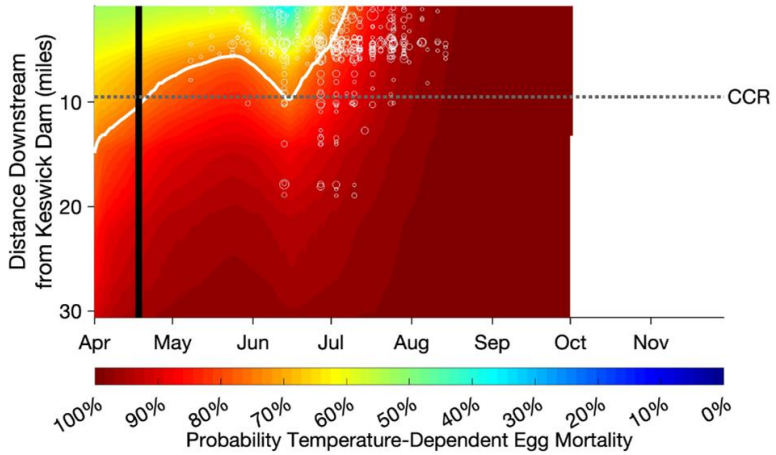




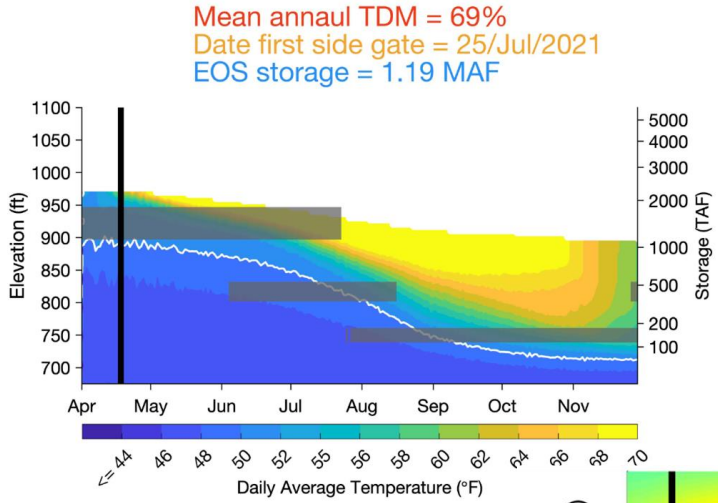
Example Full-complexity models: Temperature Target (TT) Results

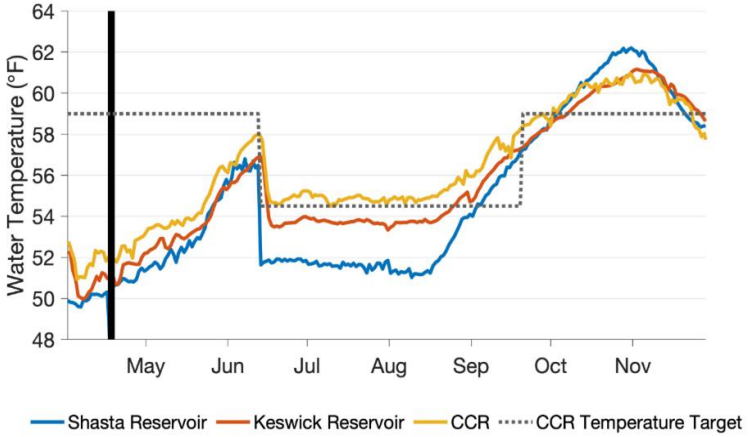


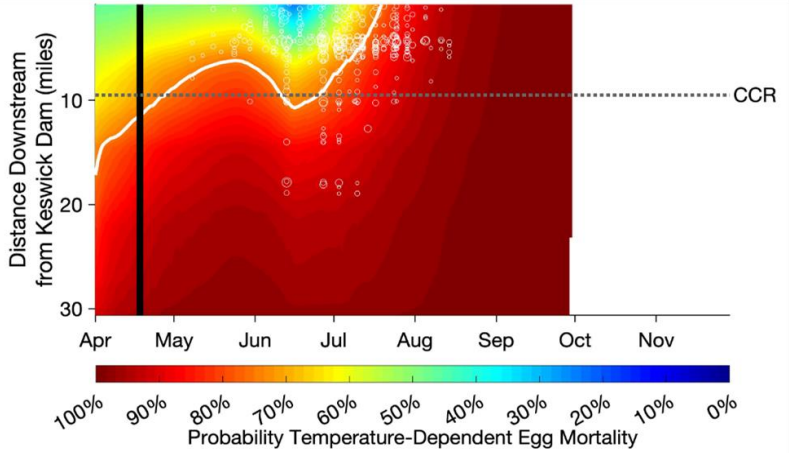




Example Full-complexity models: TT + 5% Reduction Results







Next steps

- Continue to test and refine the rapid TDM simulation framework
  - Iteration & comparison with more complex models and observations will be key
  - What can we learn from a challenging temperature management season?
- Documentation, sensitivity analysis
- Scientific perspective: work towards expanding to consider multi-year & multi-decadal scale analysis

Summary points

- An integrated tributary-to-TDM simulation framework allows consistent evaluation of temperature-dependent mortality resulting from environment and operations
- Scientific goal: understanding drivers of TDM at seasonal scale and beyond
- Limitations of existing approach led to development of a rapid analysis framework → a way to examine wide range of operational and hydrometeorological scenarios
- Working toward using rapid TDM analysis framework to identify scenarios to evaluate with traditional, full-complexity models
- Still early - need continued work to refine and test the rapid TDM analysis framework

Summary points

- The rapid TDM analysis framework is NOT:
  - A replacement for trusted, vetted models established for use by managers and decision-makers with community acceptance and buy-in
  - A prescription for a particular operation
  - A standalone assessment of temperature and TDM management options – it is meant only as a guide that MUST be tested, checked against trusted models
- It is imperative to consider the limits of the rapid TDM analysis framework – it is only one method, among many, for identifying possible scenarios for evaluation with more detailed, trusted, and vetted modeling and analysis processes

Summary points

- Further caveats and limitations
  - Rapid TDM analysis framework does not take into account limits or constraints imposed by realities of integrated CVP-SWP operations
  - Significant uncertainties, especially in meteorological conditions and distribution of redds in time and space, may affect real outcomes in a way not tested in any models, the rapid TDM framework included