DRAFT
SACRAMENTO RIVER TEMPERATURE MANAGEMENT PLAN FOR WATER YEAR 2022

INTRODUCTION

Conditions in the Central Valley are critically dry, and consequently, Shasta temperature management is limited by these dry conditions. Water year 2022 is also following a critically dry year in 2021 and a dry year in 2020. This year also had the driest January through March period on record. The Northern Sierra Precipitation 8-Station Index indicates that this year's hydrologic conditions are nearly 20 inches less than average. In mid-March, Shasta Reservoir's cold water pool used to protect winter-run Chinook salmon was projected to be comparable to other drought years such as 2014, 2015 and 2021.

This temperature management plan includes many assumptions of drought actions in order to reach the forecasted Shasta and Keswick monthly releases; however, many of these actions are system-wide rather than specific temperature actions and are therefore not included in this report.

This Water Year 2022 Sacramento River Temperature Management Plan (Plan) reflects coordination starting in February 2022 to manage operations of Shasta Reservoir for water temperatures on the Sacramento River using conservative assumptions in modeling, taking advantage of opportunities to increase the cold water pool, and managing to real-time conditions. The Plan describes how the U.S. Bureau of Reclamation (Reclamation) plans to operate Shasta Reservoir and the Temperature Control Device (TCD) on Shasta Dam consistent with the 2020 Record of Decision on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (LTO) in compliance with:

- RPM 1.a. of the 2019 National Marine Fisheries Service (NMFS) Biological Opinion to, in coordination with the Sacramento River Temperature Task Group (SRTTG), consider technical assistance from NMFS regarding the development of an annual temperature management plan and to submit a final temperature management plan to NMFS by May 20 of each year;
- Order 90-5 to consult with the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), NMFS, and Western Area Power Administration on the designation of a location upstream of the Red Bluff Diversion Dam where Reclamation will meet a daily average water temperature of 56°F; and
- Order 90-5 to provide an operation plan to the State Water Resources Control Board (SWRCB), Chief of the Division of Water Rights, on Reclamation's strategy to meet the temperature requirement at a location upstream of the Red Bluff Diversion Dam.
- The Interim Operations Plan (IOP), ordered by the US District Court on March 14, 2022, which identified priorities and planning efforts for Shasta cold water pool management to meet operational priorities and species needs. This IOP included establishing a six-agency Shasta Planning Group (SPG) to work iteratively with the technical groups (e.g., SRTTG and USST) to solicit operational guidance and risk assessments and provide policy guidance as necessary.
- Temporary Urgency Change Order(TUCO) dated April 4, 2022

The Plan establishes temperature locations and targets through October 31, and estimates winter-run Chinook salmon egg mortality, dates for operation of the side gates on the TCD, and end of September cold water pool. Reclamation will monitor the cold water pool, compare measured conditions to actual

performance during implementation, and provide regular updates through the SRTTG throughout Plan implementation.
Based on the February 90% forecast, Reclamation identified that Water Year 2022 was likely to be a Tier 4 year. In a Tier 4 year, there is less than 2.5 MAF of total storage in Shasta Reservoir at the beginning of May, and/or Reclamation cannot meet 56°F at CCR. Conditions on March 1 along with modeling based on measured reservoir profiles confirm that WY2022 is a Tier 4 temperature management season.

MODELING ASSUMPTIONS, LIMITATIONS, AND OTHER UNCERTAINTIES

A seasonal water temperature forecast describes future expected downstream water temperature. This forecast, or simulation of expected water temperature performance is based on the targets specified in the TMP. Future water temperature is forecasted using computational tools, at various elevations in the reservoirs and downstream in the river. These tools are based on conservative assumptions regarding hydrology, operations, and meteorology. Because this forecast (using conservative estimates in March to estimate what might happen at the end of October) can never exactly predict the actual hydrology, operations, and meteorology, the model results are not expected to precisely match actual water temperatures. The expectation is, however, that forecasted downstream water temperatures generally have an accepted measure of error regardless of the uncertain future conditions. In this case, there are generally two types of simulation error; uncertainty of the future conditions (e.g. inputs such as meteorology) and inherent model error or bias. To better understand the inherent model error or bias, a hindcast evaluation is typically performed. A hindcast, rather than looking forward to forecast, simply uses the actual input/forcing data after it's observed (e.g. hydrology, operations, and meteorology) to determine how well the model reproduced a condition such as actual downstream water temperatures.

Reclamation has proposed the use of NOAA-NWS Local Three-Month Temperature Outlooks (L3MTO) and historical meteorology as a means of estimating air temperature expectations for modeling purposes. In coordination with SRTTG, Reclamation has the choice of five exceedance threshold options, varying from those that serve more conservative stream temperature planning (e.g., 10% exceedance) to those that serve more aggressive planning (e.g., 90% exceedance). In past years, SRTTG has recommended the use of a conservative approach that uses the 25% exceedance L3MTO forecast. However, this approach is not available in March and Reclamation plans to apply this forecast beginning in April. Reclamation's March model runs utilized historical 25% exceedance meteorology.

RELEASE OUTLOOK

The Shasta Reservoir release strategy included in this plan and temperature modeling relies on numerous drought actions throughout the Sacramento and San Joaquin watersheds to reduce reliance on stored water from CVP and SWP reservoirs this summer. These drought actions have added a degree of flexibility to manage storage at Shasta, Oroville and Folsom reservoirs for meeting public health and safety needs, repelling salinity in the delta, producing hydropower and providing additional cold water for fishery protection throughout the summer. This release schedule is intended to guide the monthly average releases from Keswick Dam. Daily releases may vary from these flows to adjust for real-time operations. Trinity River releases below Lewiston Dam were based on a forecasted Critical Year type and diversions through Carr Powerplant were adjusted to balance flow and water temperature goals. Significant uncertainties exist within the forecast that will require intensive real-time operations management throughout the summer to achieve the various goals and targets throughout the system. Reclamation commits to reporting out on the status of this release outlook, temperature management and overall system operations at the weekly WOMT meeting. Table 1 describes the monthly forecasted operations for releases and storage targets which were taken from the March 90% CVP forecast of operation (Attachment 1).

Table 1. Monthly forecasted operations for Shasta and Keswick reservoir releases and storage estimates.

Operations Information/Month	April	May	June	July	August	September
Shasta Releases (TAF)	198	267	253	257	257	213
Keswick Releases (cfs)	3,500	4,500	4,500	4,500	4,500	4,000
Keswick Releases (TAF)	208	277	268	268	277	238
Spring Creek Power Plant (TAF)	10	10	15	20	20	25
Shasta End-of-Month Storage (TAF)	1,753	1,683	1,577	1,459	1,332	1,250

KEY AREAS OF UNCERTAINTY

Operational decisions on the upper Sacramento River are influenced by local and CVP and SWP system-wide multi-purpose objectives, including those that are planned and uncertain. Many factors contribute to operational actions including, but not limited to: flood protection, forecasted inflows, facility maintenance schedules, physical/mechanical facility limitations, upstream operations, minimum in-stream flow criteria, public health and safety criteria, downstream Delta regulatory requirements, Delta exports, power generation, recreation, fish hatchery accommodations, temperature management capabilities, and others. In addition, uncertain or unplanned events can also influence real-time operation decisions (e.g., wildfires and equipment malfunctions). To address uncertainty, Reclamation typically uses conservative estimates of future conditions in the modeling assumptions (e.g., hydrology, operations, and meteorology) and projections are updated through the management period.

The release forecast and temperature modeling used for this temperature management plan is based on a number of assumptions that each come with a level of uncertainty. A brief list of these uncertainty areas is listed below:

- Inflow hydrology
- Meteorology
- Reservoir stratification
- Accretions and depletions
- Public health and safety demands
- Infrastructure limitations
- Low River flow challenges
- Trinity River imports and Trinity River temperature management
- Low flow river and reservoir thermodynamics
- Delta water quality

TEMPERATURE STRATEGY

The Keswick Reservoir release schedule was developed through multi-agency coordination including Reclamation, NMFS, USFWS, CDFW, California Department of Water Resources (DWR), SWRCB, the California Environmental Protection Agency (CalEPA) and the Sacramento River Settlement Contractors. The release schedule was finalized in late March and Reclamation completed HEC-5Q modeling on April 4, 2022. The temperature modeling is presented here and is reflected in resulting biological and water supply performance metrics as shown in Table 2, Table 3 and Attachment 2. Further refinement to the temperature management strategy will occur through coordination with SRTTG and SPG as the season progresses.

Table 2. Estimated water temperature in degrees Fahrenheit at Shasta, Keswick and Highway 44 for April 4 SPG scenario. HEC-5Q does not perform well after mid-September. Water temperatures may be warmer than these targets and HEC-5Q results. Warmer water temperatures described in Attachment 2 describe the late season water temperatures that were used for the temperature dependent mortality modeling.

Month	Shasta	Keswick	Highway 44
May	53.6	54.4	56.4
June	50.5	56.1	55.3
July	50.0	54.6	55.2
August	50.2	54.5	55.1
September	50.6	54.0	54.4
October	54.3	56.5	56.5
November	53.1	53.5	53.5

Trinity River and Clear Creek modeled temperatures are included in Attachment 2.

Table 3. Fish and water performance metrics.

Metric	April 4 Scenario
Stage-independent TDM	70.0%
Stage-dependent TDM	82.3%
End of Sept CWP Storage (TAF)	183 TAF
First Side Gate Use	July 16
Full Side Gate	September 1
End of September Storage (MAF)	1.25 MAF

Reclamation will continue to coordinate through SRTTG to review these and other model results and may update these TDM estimates based on those discussions.

Estimated CVP Operations 90% Exceedance

Attachment 1

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Trinity	**788**	**807**	**808**	**729**	**668**	**611**	**528**	**440**	**399**	**375**	**357**	**356**	**385**
	Elev.	2232	2232	2221	2212	2204	2190	2173	2165	2160	2156	2155	2162
Whiskeytown	**206**	**206**	**238**	**238**	**238**	**238**	**238**	**238**	**206**	**206**	**206**	**206**	**206**
	Elev.	1199	1209	1209	1209	1209	1209	1209	1199	1199	1199	1199	1199
Shasta	**1690**	**1727**	**1753**	**1683**	**1577**	**1459**	**1332**	**1252**	**1294**	**1339**	**1410**	**1538**	**1745**
	Elev.	941	942	938	931	922	913	907	910	914	919	928	942
Folsom	**526**	**571**	**624**	**542**	**421**	**269**	**221**	**222**	**216**	**227**	**246**	**275**	**345**
	Elev.	425	431	422	406	381	372	372	371	373	377	383	395
New Melones	**984**	**943**	**895**	**819**	**741**	**678**	**626**	**599**	**568**	**575**	**582**	**588**	**586**
	Elev.	934	927	916	903	892	883	878	871	873	874	876	875
San Luis	**314**	**330**	**333**	**246**	**88**	**-103**	**-233**	**-311**	**-305**	**-203**	**-72**	**124**	**169**
	Elev.	446	444	433	408	375	344	314	304	342	377	418	428
Total		4583	4651	4257	3732	3151	2712	2439	2378	2518	2729	3088	3435

State End of the Month Reservoir Storage (TAF)

Oroville		**1646**	**1688**	**1606**	**1360**	**1063**	**885**	**857**	**829**	**829**	**880**	**990**	**1001**
	Elev.	747	751	743	714	674	646	641	636	636	645	663	664
State San Luis		**601**	**581**	**560**	**498**	**440**	**390**	**354**	**326**	**347**	**423**	**547**	**597**
Total San Luis (TAF)	**900**	**930**	**914**	**805**	**586**	**337**	**157**	**43**	**21**	**144**	**350**	**671**	**766**

Monthly River Releases (TAF/cfs)

Trinity	TAF	18	36	92	47	28	53	52	23	18	18	18	17
	cfs	**300**	**600**	**1,498**	**783**	**450**	**857**	**870**	**373**	**300**	**300**	**300**	**300**
Clear Creek	TAF	12	12	22	9	9	9	9	12	12	12	12	11
	cfs	**200**	**200**	**360**	**150**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**
Sacramento	TAF	200	208	277	268	277	277	238	200	193	200	200	180
	cfs	**3250**	**3500**	**4500**	**4500**	**4500**	**4500**	**4000**	**3250**	**3250**	**3250**	**3250**	**3250**
American	TAF	98	59	154	167	195	91	33	48	33	34	34	34
	cfs	**1600**	**1000**	**2500**	**2812**	**3165**	**1480**	**552**	**775**	**550**	**550**	**550**	**610**
Stanislaus	TAF	31	27	25	17	9	9	9	35	12	12	13	12
	cfs	**500**	**461**	**401**	**290**	**150**	**150**	**150**	**577**	**200**	**200**	**213**	**214**
Feather	TAF	184	49	53	173	234	189	95	59	57	59	59	188
	cfs	**3000**	**825**	**860**	**2900**	**3800**	**3080**	**1600**	**960**	**960**	**960**	**960**	**3390**

Trinity Diversions (TAF)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Carr PP	18	39	26	22	30	31	35	25	20	21	15	10
Spring Crk. PP	**10**	**10**	**10**	**15**	**20**	**20**	**25**	**46**	**10**	**12**	**10**	**10**

Delta Summary (TAF)

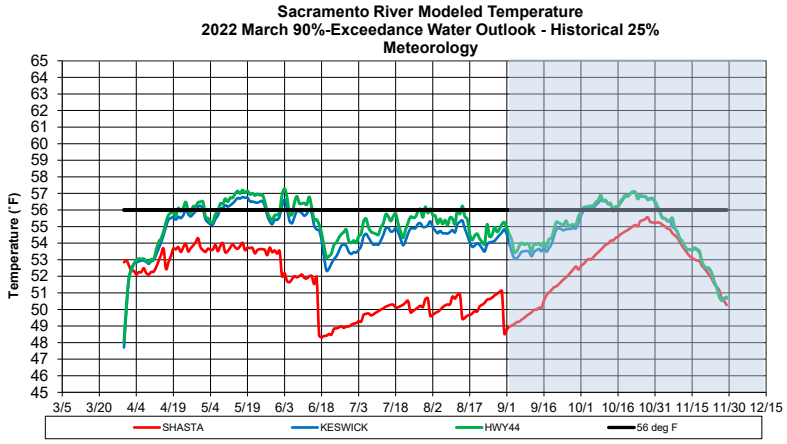
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Tracy		60	60	62	48	49	49	49	90	144	153	209	78
USBR Banks		0	0	0	0	7	7	7	0	0	0	0	0
Contra Costa		3.5	3.2	3.2	3.2	2.5	2.8	3.2	3.5	4.2	4.6	4.6	3.5
Total USBR		64	63	65	51	59	59	59	94	148	158	214	82
State Export		22	30	31	18	20	21	19	18	50	95	161	75
Total Export		86	92	96	69	79	80	78	112	198	253	375	157
COA Balance		337	337	337	276	202	163	177	137	137	137	137	26
Vernalis	TAF	56	60	58	42	32	34	40	64	46	40	74	78
Vernalis	cfs	907	1012	951	710	524	557	671	1049	772	655	1205	1403
Old/Middle River Std.													
Old/Middle R. calc.		-1,253	-1,331	-1,362	-1,166	-1,337	-1,339	-1,300	-1,515	-2,808	-3,459	-4,740	-2,129
Computed DOI		10688	5026	4099	4001	4002	2993	3009	2993	3614	3628	6117	11400
Excess Outflow		1643	1025	98	0	0	0	0	0	118	130	114	0
% Export/Inflow		12%	20%	19%	13%	13%	16%	19%	28%	42%	49%	53%	20%
% Export/Inflow std.		35%	35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%

Hydrology

	Trinity		Shasta		Folsom		New Melones	
Water Year Inflow (TAF)	453		2,859		1,374		465	
Year to Date + Forecasted % of mean	38%		52%		50%		44%	

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

3/31/2022



	Shasta	Keswick	Hwy44	Igo	Trinity	Lewiston
	deg F	deg F	deg F	deg F	deg F	deg F
Apr	53.1	54.4	54.6	48.2	45.3	48.3
May	53.6	56.1	56.4	48.6	45.8	49.0
Jun	50.5	54.6	55.3	52.2	46.4	52.6
Jul	50.0	54.4	55.2	53.3	47.1	54.3
Aug	50.2	54.5	55.1	54.1	48.8	53.4
Sep	50.6	54.0	54.4	54.8	52.4	54.8
Oct	54.3	56.5	56.5	56.9	55.8	56.9
Nov	53.1	53.5	53.5	54.9	53.4	53.3

Run date: 4/4/22

EOM Sept storage: 1.25 MAF

Trinity profile date: 3/3/22

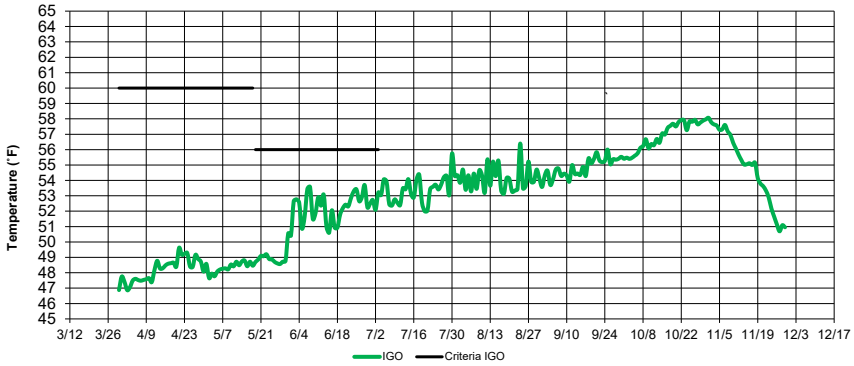
Whiskeytown profile date: 3/1/22

Shasta profile date: 3/30/22

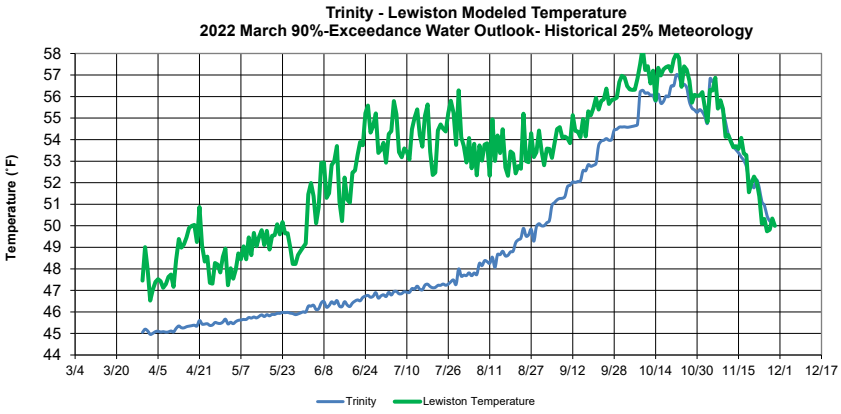
Projected Side gates: First Jul 16 Full Sep 1

Shaded area denotes period of model limitations - see Fall Temperature Index

End of September Cold-Water-Pool less than 56 deg F: 183 TAF



	Igo
	deg F
Apr	48.2
May	48.6
Jun	52.2
Jul	53.3
Aug	54.1
Sep	54.8
Oct	56.9
Nov	54.9



	Trinity	Lewiston
	deg F	deg F
Apr	45.3	48.3
May	45.8	49.0
Jun	46.4	52.6
Jul	47.1	54.3
Aug	48.8	53.4
Sep	52.4	54.8
Oct	55.8	56.9
Nov	53.4	53.3

Attachment 3. Biological Modeling

Spatially-explicit daily average Sacramento River water temperatures forecasts from the HEC-5Q model results are used as inputs to generate temperature-dependent egg mortality estimates. For this period, historical temperatures on the Sacramento River at Shasta Dam, Keswick Dam, above Clear Creek, Balls Ferry, Jelly's Ferry, and Bend Bridge are interpolated to estimate temperatures at river miles where simulated redds were located.

Temperature-dependent egg mortality estimates are calculated by modeling a redd's lifetime based on the days required to cross a known cumulative degree-day threshold and estimating mortality as an increasing function of temperature past a temperature threshold. Martin et al (2017) was used to estimate stage-independent modeling whereby a single temperature threshold is used from spawning and incubation through emergence (Figure 1). Anderson et al. (2021) was used to estimate stage-dependent modeling for targeting different temperatures before, during, and after the most sensitive stages during egg incubation (Figure 1). The methods are applied to a set of simulated redds representative of redd construction timing and location from 2016-2021 and the results summarized on a population level for comparison. Further information about the model's assumptions are documented in Table 1 below.

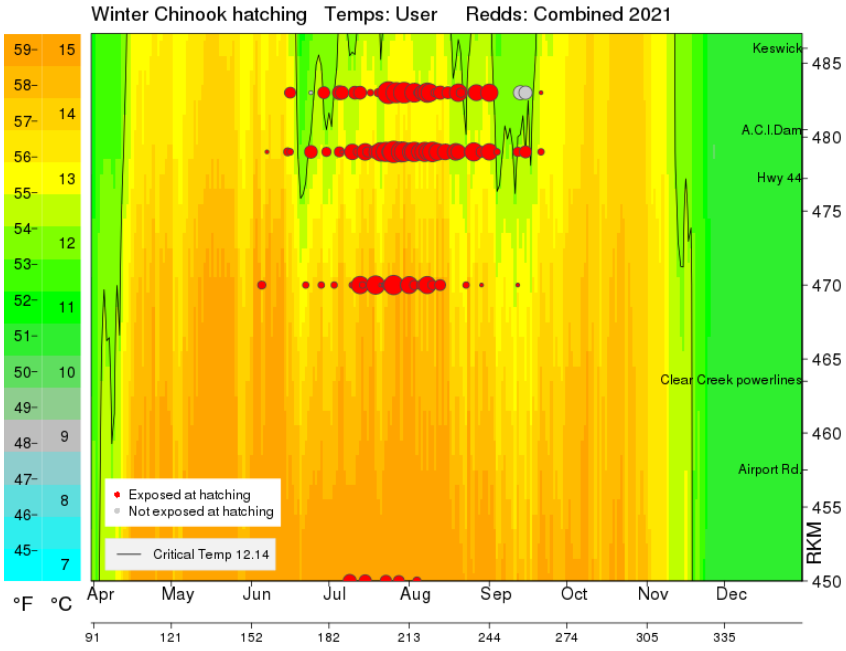


Figure 1. April 4 temperature landscape and 2016-2021 redd locations and timing (Stage-independent mortality).

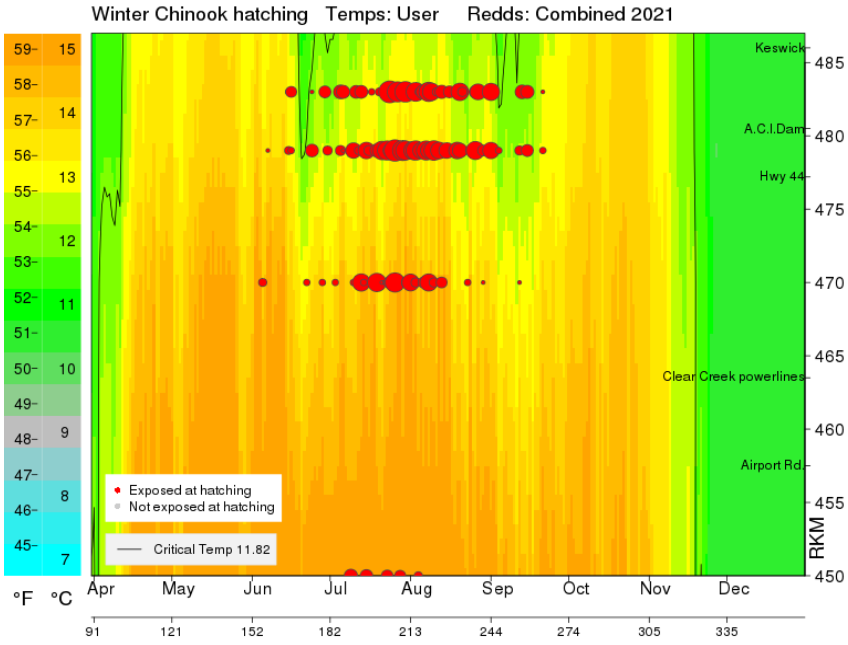


Figure 2. April 4 temperature landscape and 2016-2021 redd locations and timing (Stage-dependent mortality).

Table 1. Biological modeling parameter information.

Parameter	April 4, 2022 Scenario
Meteorology source	Historical Meteorology 25%
Time period	1/1/21-3/30/21: Observed temperature 3/31/22-11/29/22: Simulated
Reservoir Model used	HEC-5Q
River Model used	HEC-5Q
Shasta Profile date	3/30/22
TCD Gate operations	HEC-5Q
Sacramento water temperatures used	HEC-5Q output at Keswick, Highway 44, Clear Creek, and Balls Ferry.
Biological Model used	SacPAS Fish model (Temperature effect only)
Temperature Mortality Models	Stage-independent mortality Stage-dependent mortality
Egg emergence timing model	Linear. 958 ATUs (degrees C), as indicated for Zeug et al. on SacPAS under Egg to emergence timing model.
TDM redd time distribution	Aerial Surveys 2016-2021 (1736 redds)
TDM redd space distribution	Aerial Surveys 2016-2021 (1736 redds)
TDM Tcrit (50th percentile)	Stage-independent mortality: 12.14°C Stage-dependent mortality: 11.82°C
TDM bT (50th percentile)	Stage-independent mortality: $0.026°C^{-1}d^{-1}$ Stage-dependent mortality: $0.436°C^{-1}d^{-1}$
Critical Days	Stage-independent mortality: All Stage-dependent mortality: 3 days
TDM estimate	See Table 2