



## Trinity River Restoration Program

P.O. Box 1300, 1313 South Main Street, Weaverville, California 96093  
Telephone: 530-623-1800, Fax: 530-623-5944

**TO:** KEN LINDKE, FISH WORK GROUP COORDINATOR  
**FROM:** SETH NAMAN (NOAA), KYLE DE JULIO (YUOK TRIBE), AND KATHERINE OSBORNE (HOOPA TRIBE)  
**SUBJECT:** JUVENILE SALMONID TEMPERATURE TARGET RECOMMENDATIONS  
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### Background

Current temperature thresholds for the upper Trinity River can be found in the draft 1999 Trinity River Mainstem Fishery Restoration EIS, based on the recommendations provided in USFWS and HVT (1999). Additionally, State Water Resources Control Board Water Order 90-5 mandates Reclamation meet the temperature thresholds in Table 1 (excluding the July 1-September 14 threshold). The temperature thresholds in Table 1 were also adopted by the California Regional Water Quality Control Board, North Coast Region (CRWQCB-NCR 2011). These thresholds were developed and implemented to meet the needs of adult salmonids, particularly Chinook Salmon in the Sacramento River Basin. Currently, there are no water temperature objectives for the Upper Trinity River developed specifically for rearing salmonids. The current Trinity River temperature thresholds, developed for adult salmonids, were thought to be sufficient for rearing juvenile salmonids (USFWS and HVT 1999; Table 5.13), based on the information in Brett (1952).

Table 1. Water temperature thresholds for the upper Trinity River

| Date                    | Temperature Thresholds (°F) |                                    |
|-------------------------|-----------------------------|------------------------------------|
|                         | Douglas City (RM 93.8)      | North Fork Trinity River (RM 72.4) |
| July 1 through Sept 14  | 60                          | -                                  |
| Sept 15 through Sept 30 | 56                          | -                                  |
| Oct 1 through Dec 31    | -                           | 56                                 |

The Trinity River Flow Evaluation (USFWS and HVT 1999) recommended temperature objectives for the Trinity River above the confluence with the Klamath River at Weitchpec juvenile salmonids migrants (Table 2). Temperature objectives vary annually based on the water year type (extremely wet, wet, normal, dry, and critically dry), the time of year, and target different salmonid species. The Trinity River Flow Evaluation established these temperature objectives by determining water temperature requirements of each salmonid species and grouped

them together by optimal, marginal, and unsuitable thermal tolerances based on literature reviews by Zedonis and Newcomb (1997) (Table 2). The date for the temperature objective of each species was determined by calculating 80 percent emigration at the Willow Creek rotary screw trap site based on data from 1992 to 1995.

Table 2. Temperature thresholds for outmigration in the lower Trinity River from USFWS and HVT (1999).

|                    |   |
|--------------------|---|
| Steelhead (May 22) | <55.4 °F in EW,W, N water years @ Weitchpec |
|                    | <59 °F in D, CD water years @ Weitchpec     |
| Coho (June 4)      | <59 °F in EW,W, N water years @ Weitchpec   |
|                    | <62.6 °F in D, CD water years               |
| Chinook (July 9)   | <62.6 °F in EW,W, N water years             |
|                    | <68 °F in D, CD water years                 |

Though the water temperatures in Table 1 are called “objectives” in various TRRP documents such as USFWS and HVT (1999), they are more accurately thought of as thresholds because any water temperature between 32°F and those Table 1 would comply. Managing water temperatures in this manner does not account for the range of temperatures at which a particular stock of salmonids grows at a maximum rate, for a given amount of ration. This also contributes to biologist and managers approaching water temperature management from the perspective of “colder is better” because any water temperatures colder than the objectives are thought of as either sufficient or beneficial. This is an overly simplistic management scheme because cold water temperatures that fall below the optimal growth range also impair growth. In order to develop a new recommended rearing water temperature objective for rearing salmonids, we reviewed more recent studies as well as recent Trinity River water temperature data.

In summary, shortcomings of current water temperature thresholds have been identified relative to juvenile salmonid growth:

- Temperature targets in the Upper Trinity River were developed for holding adult Chinook Salmon, not for rearing juvenile salmonids.
- There are no temperature targets in the upper Trinity River for rearing juvenile salmonids
- Temperature targets are expressed as “less than” a certain value (threshold), so extremely cold water temperatures, which may not suit juvenile salmonid rearing or other ecological functions, comply with the target.
- Temperature targets for outmigrants are at Weitchpec, meaning the entire length of the Trinity River must always be colder than the targets, which may negatively affect fish growth and other ecological processes upstream of Weitchpec.
- Current temperature thresholds in the upper Trinity River do not relate to or tie into ecological processes like temperature patterns of tributaries, the potentially beneficial effects of temperature heterogeneity, invertebrate production, or fish growth and movement.

## Other Ecological Considerations

In many regions throughout the US, a positive relationship between stream order and water temperature has been reported, unless the stream has a high baseflow index (Segura et al. 2015). This is likely a result of higher heat accumulation through the stream network for large basins, or the convergence of water and air temperatures as water travels downstream (Segura et al. 2015, and references therein). However, due to the constant releases from Lewiston Reservoir, as well as the current temperature thresholds imposed by regulatory processes, the mainstem Trinity River is now colder than most, if not all of the tributaries upstream of the North Fork Trinity River. For example, in 2017 (Extremely Wet) and 2018 (Critically Dry) the Rush Creek was often 10°C warmer than the mainstem Trinity River (Figure 1). The negative effects of this have been described by some authors (e.g. Wheeler et al 2014), but the consistently low water temperatures are assumed by most fisheries regulatory agencies to be either positive or at least not harmful. However this is a flawed assumption. For example, low water temperatures can mean slow metabolism and slower growth (Iwama and Tautz 1981; Railsback reducing the size at which smolts enter the sea, thereby lowering their survival rate. Additionally, smaller smolts have lower osmoregulatory capabilities, and generally lower freshwater survival.

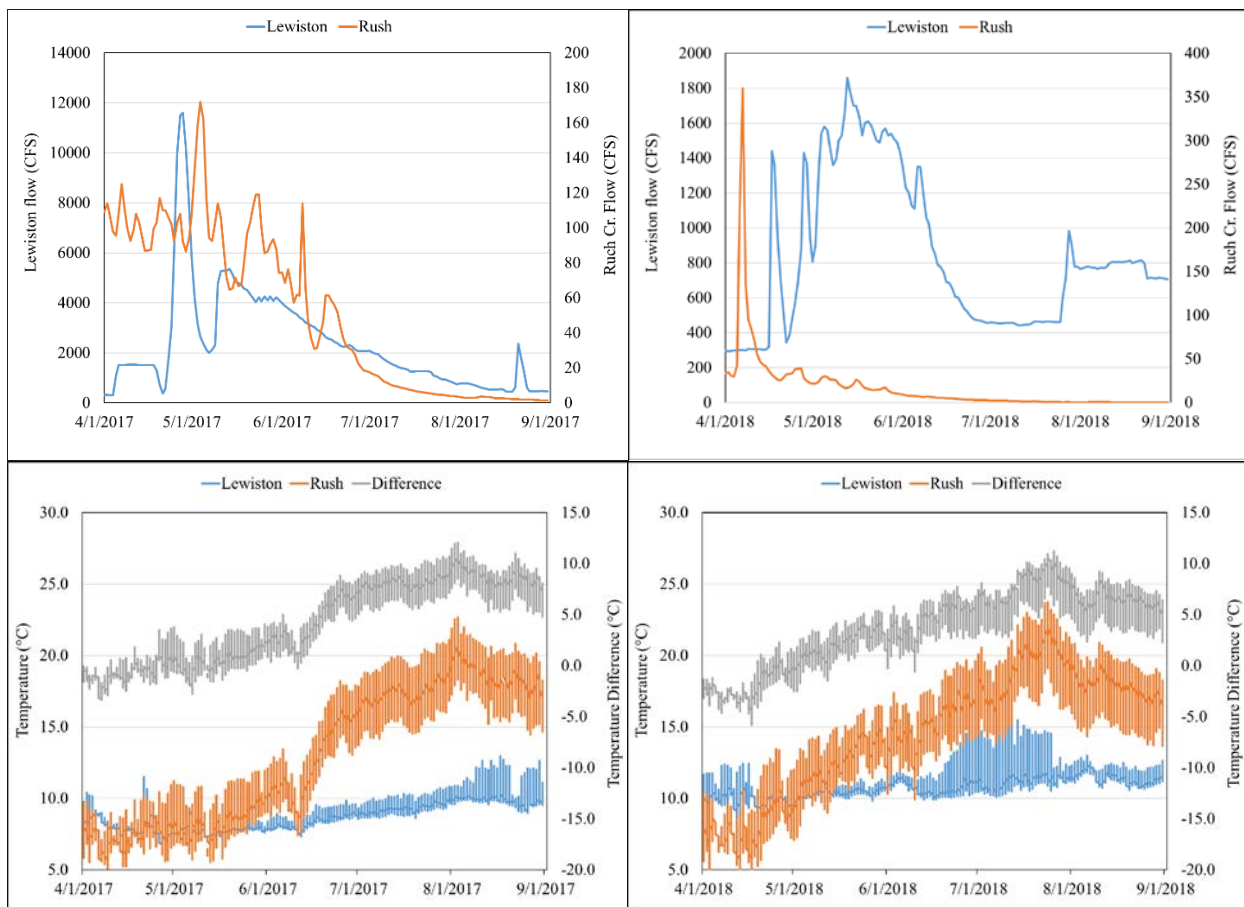


Figure 1. Discharge, water temperature, and temperature difference of the Trinity River at Lewiston and Rush Creek during the summer month of 2017 (ext. wet) and 2018 (crit. dry).

Not only has the flow regime of the Trinity River been fundamentally altered, the temperature regime has been dramatically changed as well (USFWS and HVT 1999). Little effort has been placed on understanding the ramifications the change in temperature regime has had on the invertebrate community or fish growth, behavior, migration and fitness, or other important ecological connections.

### **Alternatives to a Single Temperature Threshold**

There are several alternatives to using a single daily average temperature threshold to monitor water temperatures in a river system. The 7 day average of the daily average (7DADA), 7-Day Average of the Daily Maximum (7DADM), Maximum Weekly Average Temperature (MWAT) and Maximum Weekly Maximum Temperature (MWMT) are other metrics that could be employed to monitor water temperature objectives in the Trinity River. Additionally, these metrics have been more widely utilized other river systems in recent decades as managers have moved away from simplistic daily average thresholds. Monitoring water temperatures in these ways are also less sensitive to small daily violations, which may or may not be biologically meaningful.

MWMT is the highest seven-day average of the daily average temperature (Figure 2). In simple terms, it is the average temperature during the warmest seven-day period of the year (Asarian 2016). To calculate MWMT, first calculate maximum temperature for each day. Then calculate the 7-Day Average of the Daily Maximum (7DADM), which is calculated for each day as the average of the daily maximum temperature for the three prior days, the current day, and three following days. Finally, select highest 7DADM value of the year to obtain MWMT. A similar process is used to calculate MWAT, except daily average is used instead of daily maximum. Because there is a difference between chronic and acute temperature stress, and with the recognition that a single temperature threshold is insufficient to guide future temperature monitoring to meet fishery and restoration objectives, we recommend a range of values, using the 7 day average of the daily average (7DADA).

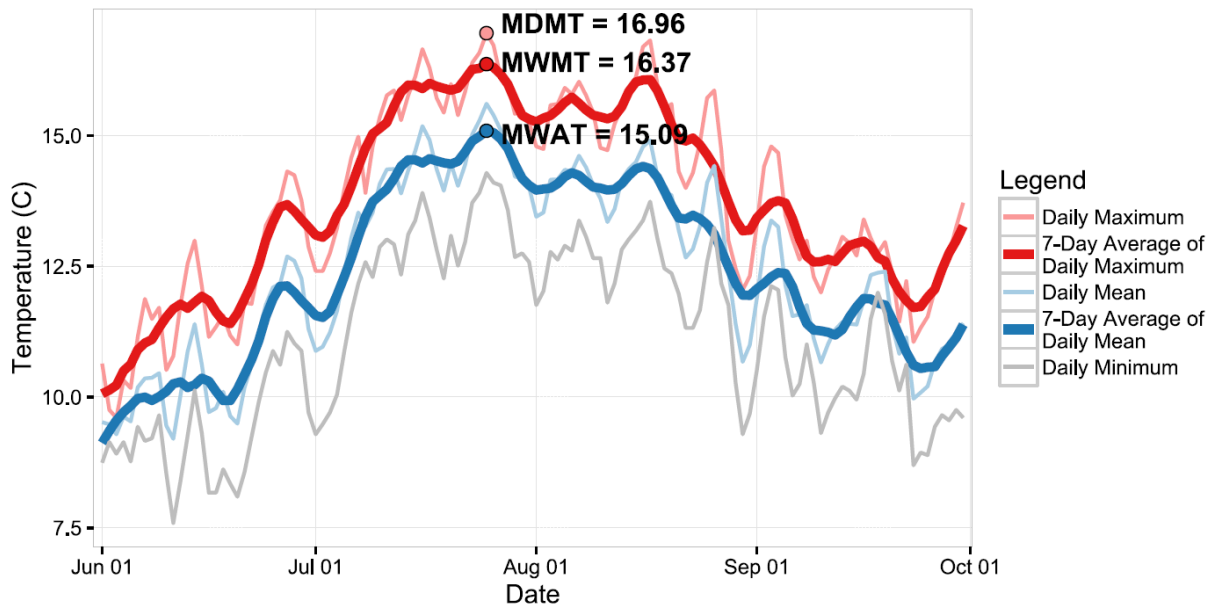


Figure 2. Comparison of daily average, daily maximum, daily minimum and MDMT, MWMT, MWAT, 7DADM, and 7DADA (Asarian 2016).

## Literature Review

In order to make an informed recommendation on new temperature targets reviewed literature on rearing water temperatures for Coho Salmon which are the least temperature tolerant of the three salmonid species in the Trinity River. Our literature review was not exhaustive, but we believed it was necessary to update the information found in Brett (1952) and Konecki et al (1991) that has largely formed the basis of previous recommendations for juvenile salmon rearing temperatures, or Coho Salmon specifically.

Elsner and Shrimpton (2019) found a mean temperature preference of Fraser River B.C. Coho Salmon of 16.5°C for parr, and 15.5°C for smolts. Lusardi et al. (2019) found that Shasta River, California Coho salmon absolute growth rates peaked at a mean daily average water temperature of 16.6 °C. It should also be noted in the study by Lusardi et al. (2019), the site with the highest growth rate also contained the greatest invertebrate biomass as this has bearing on the relationship between ration and water temperature. Results of water temperatures on salmonid growth in studies reviewed by Carter et al. (2005) are provided in Table 3. Sullivan et al. (2000) found that an MWMT of 13°C to 16.5°C would result in no more than a 10% reduction in maximum growth (Reviewed in Carter et al. 2005). Railsback and Rose (1999) found for rainbow trout that predicted growth varies with fish size and food consumption , but in general, their model predicted growth to be high between 10°C and 22°C, peaking at about 15°C (59°F).

Table 3. Salmonid growth chart based on literature reviewed by Carter (2005).

| Salmonid Growth Chart | Negative Growth Positive Growth Marginally Impaired Growth Maximum Growth |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------|---|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|
| Species               | Temperature (C <sup>0</sup> ) - MWAT                                      |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |      |
|                       | 4   | 5   | 6   | 7   | 8   | 9   | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   |
| Chinook - juvenile    | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |
| Coho - Juvenile       | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |
| Steelhead Juvenile    | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |
| Species               | Temperature (C <sup>0</sup> ) - MWMT                                      |     |     |     |     |     |      |      |      |      |      |      |      |      |      |      |      |      |
|                       | 4   | 5   | 6   | 7   | 8   | 9   | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   | 19   | 20   | 21   |
| Chinook - juvenile    | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |
| Coho - Juvenile       | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |
| Steelhead Juvenile    | ///   | /// | /// | /// | /// | /// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// | //// |

### Proposed Temperature Targets

Based on the results of the studies described above, we recommend utilizing a 7DADA of 13°C to 16.5°C (55.4°F to 61.7°F) as targets in the Trinity River upstream of the North Fork Trinity River from April 1 to July 31. Water temperatures outside of this range would be considered as impairing growth of juvenile salmonids during the rearing period (Figure 3). The 7DADA would allow for daily tracking of the target but it would not be overly sensitive to small violations in water temperatures that occurs using a single daily average threshold, which may or may not be biologically meaningful. Also using a range of values, rather than a single threshold captures the true nature of optimal salmonid growth, which occurs in a range of temperatures, falling above or below which impairs optimal growth at a given ration level.

Recent Trinity River water temperatures at the North Fork Trinity River are shown in (Figure 3) along with our recommended target range. Note that most water year types, just as the Trinity River begins to achieve the recommended targets in the optimal rearing range for juvenile salmonids, there is a large reduction in temperatures of 5°F to 7°F that occurs in the end of April. This is due to the large volume of water that is released annually from Lewiston Dam in accordance with the TRRP restoration flow releases. In some cases water temperatures are nearly 10°C less than our recommended juvenile salmonid rearing temperature range. It has been widely hypothesized in TRRP work groups that this has led to impaired juvenile salmonid growth, and possibly contributed to poor survival in the lower Trinity River, Klamath River, and Ocean.

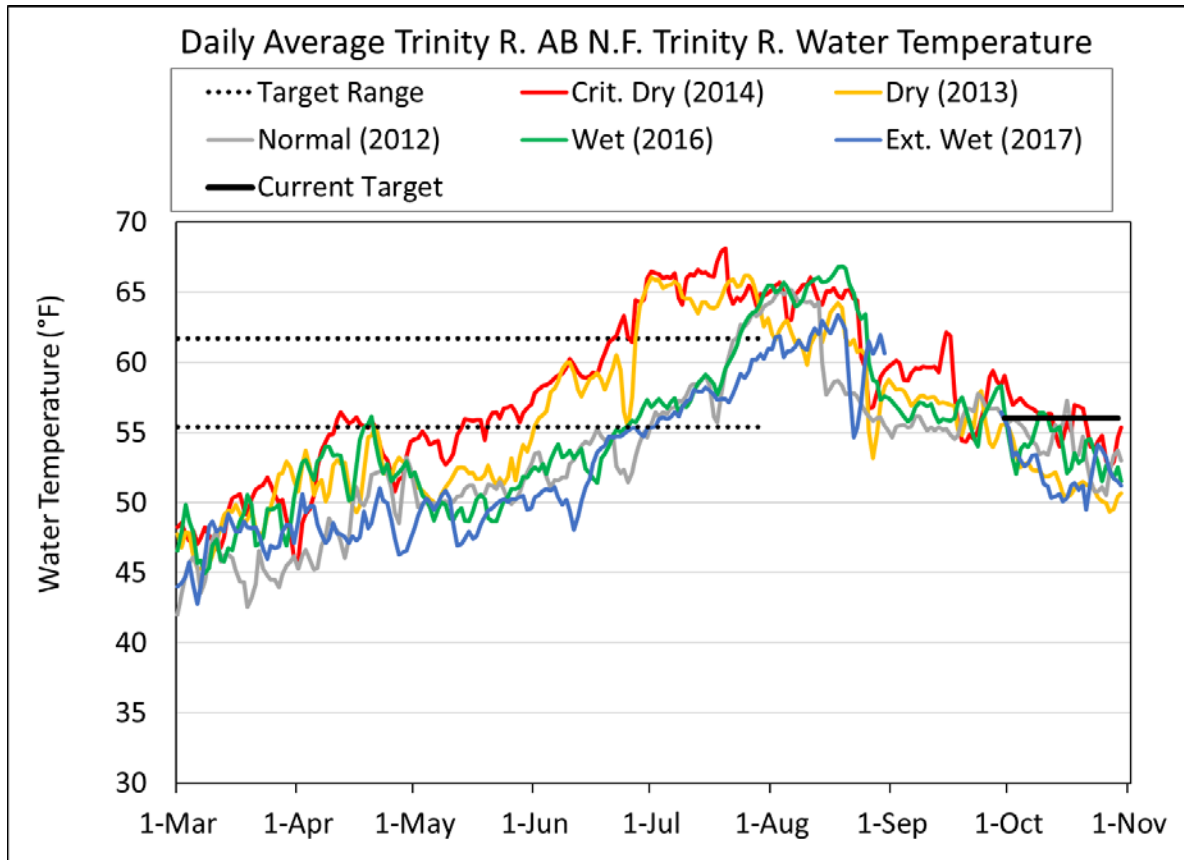


Figure 3. Water temperatures for one of each of the five water year types in the Trinity River above the North Fork Trinity River. Note the 5°F to 7°F reduction in temperature that occurs in all water year types in the end of April coincident with the onset of TRRP restoration flow releases from Lewiston Dam.

### Measure of Cumulative Thermal Deviation from Rearing Temperature Target Range

To evaluate the effectiveness of implemented and proposed hydrographs at achieving this target we propose a measure of cumulative thermal deviation (CTD) from the target range over the time period the target is intended. This would be accomplished by summation of the difference between the observed or predicted 7DADA from each day, between April 1 and July 31. Negative deviations would be subtracted from each other, and positive deviations would be added together to quantify CTD both less than and greater than the proposed temperature target range.

In addition to the CTD, the number of days of deviation could be reported. For evaluating implemented hydrographs observed data from the USGS gage would be used to calculate the 7DADA for each day, and for proposed hydrographs RBM-10 would be used to generate predicted daily average temperatures at the gage site for the period of record and the 50% and 10% exceedance would be used to report expected CTD for average (50% exceedance) and extreme (10% exceedance) conditions, consistent with the way other temperature targets in the basin are evaluated for hydrograph development and selection.

## Relationship to Juvenile Salmonid Outmigration

The average date of 60% of juvenile Chinook Salmon outmigration to the Pear Tree rotary screw trap located near the North Fork Trinity River is April 22 (Table 4). Prior to this date, Trinity River water temperatures are typically less than the optimal rearing temperatures for growth (Figure 3). Approximately half the Chinook Salmon upstream of the Pear Tree trap would remain in that reach after the start of the temperature target range on April 1, and rearing Coho Salmon and Steelhead would be present throughout the duration of the proposed temperature target range.

Table 4. Comparison of percent (%) juvenile Chinook outmigration at Pear Tree rotary screw traps by February 1 and the (%) juvenile Chinook outmigration by onset date for spring flow releases above winter baseflow.

| Year     | %<br>Outmigration<br>(February 1) | Spring Flow<br>Release Date | %<br>Outmigration<br>(release date) |
|----------|-----------------------------------|-----------------------------|-------------------------------------|
| 2003     | 11%                               | April 30                    | 74%                                 |
| 2005     | 14%                               | April 22                    | 72%                                 |
| 2006     | 0%                                | April 12                    | 50%                                 |
| 2007     | 0%                                | April 27                    | 53%                                 |
| 2008     | 1%                                | April 23                    | 46%                                 |
| 2009     | 2%                                | April 27                    | 50%                                 |
| 2010     | 8%                                | April 23                    | 62%                                 |
| 2011     | 14%                               | April 22                    | 58%                                 |
| 2012     | 1%                                | April 21                    | 49%                                 |
| 2013     | 5%                                | April 21                    | 53%                                 |
| 2014     | 0%                                | April 23                    | 47%                                 |
| 2015     | 16%                               | April 22                    | 83%                                 |
| 2016     | 46%                               | April 21                    | 87%                                 |
| Averages | 9%                                | April 22                    | 60%                                 |

Our working hypothesis is that growth of the remaining Chinook Salmon, Coho Salmon and Steelhead would be improved if water temperatures in the Trinity River were inside the proposed target range in the spring months for a longer time period. Our preliminary analyses with growth output from a bioenergetics model suggest this is the case. Further modeling and empirical observations should test this assumption.

Further work on modeling these recommendations using a variety of hypothesized rations should be undertaken, as well as modeling in the Stream Salmonid Simulator (S3). Additionally, care should be taken not negatively impact incubating Steelhead or Coho Salmon fry in the first half of April. We also recommend that potential effects to holding spring-run Chinook Salmon be evaluated. Beginning in August, adult temperature objectives could supersede those of the recommended juvenile rearing temperatures.

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