# STUDY REPORT WAR-14
# TEMPERATURE CRITERIA ASSESSMENT

## ATTACHMENT A

## ADDITIONAL STUDY PLANS FOR ACQUISITION AND EVALUATION OF INFORMATION SUPPORTING DEVELOPMENT OF EMPIRICAL EVIDENCE ADDRESSING TEMPERATURE CRITERIA FOR SALMONIDS IN THE LOWER TUOLUMNE RIVER.

***Study 1 - Local Adaptation of Temperature Tolerance of O. mykiss Juveniles in the Lower Tuolumne River***

# 1.0 PROJECT NEXUS

The continued operation and maintenance (O&M) of the existing Don Pedro Project (Project) has the potential to cumulatively affect the anadromous fish populations between La Grange Diversion Dam and the confluence of the Tuolumne River and San Joaquin River.

# 2.0 STUDY GOALS

Determine the temperature tolerance of juvenile and subadult *O. mykiss* inhabiting the lower Tuolumne River (LTR) to assess any local adaptation to temperature.

# 3.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Speculation on the adaptability of anadromous salmonids to the various temperature regimes encountered throughout their range suggests that *O. mykiss* in the southern extent of their range may be innately more tolerant of warmer temperature regimes than reported in the literature. The local adaptability of LTR *O. mykiss* would allow better performance at warmer temperatures than would be predicted based on studies of *O. mykiss* populations in the northern extent of the range. A determination that LTR *O. mykiss* are locally adapted to warmer temperatures would support the reassessment and establishment of different optimum temperature thresholds (i.e., relative to EPA 2003) that may be appropriate for *O. mykiss* in the Central Valley stream system.

This study will evaluate if *O. mykiss* that inhabit the LTR are adapted to higher temperature tolerances that may better define site-specific temperature performance metrics. A case study of temperature tolerance among fishes is likely to prove extremely fruitful in addressing the more general and important question of animal resilience and adaptability to environmental change (Farrell 2009). Fishes generally have evolved around species-specific niches, living in almost every conceivable aquatic habitat and representing almost half of the earth's vertebrate species (Farrell 2009). Thus, it is expected that *O. mykiss* populations in different parts of the species range would show differences in physiological performance and in other biological traits that reflect adaptations to regional or more localized environmental conditions.

# 4.0 STUDY METHODS

## 4.1 Study Location

The study area is the reach of the lower Tuolumne River between the San Joaquin River (RM 0.0) and the La Grange Diversion Dam (RM 52.2).

## 4.2 Study Approach

The Districts would follow methods described by Parsons (2011) and others to evaluate the capabilities of local *O. mykiss* to accommodate warmer temperatures. Specifically, Parsons (2011) studied the respiratory physiological basis for temperature tolerance in sockeye salmon and examined the overall hypothesis that each sockeye salmon population has adapted to meet specific upriver migration conditions. Swimming respiratory performance was compared over a range of temperatures across wild, migrating adult sockeye salmon populations.

Fish evaluated as per Parsons (2011) were tested in Brett-type swim tunnels. The first day (24-hour duration) of the Parsons (2011) study required placement of an individual fish into the swim tunnel to acclimate it to its new environment. The Districts propose using swim tunnels to measure the optimal temperature ($T_{opt}$) and critical temperature ($T_{crit}$) for fish ranging from about 100 to 200 mm fork length (FL). The $T_{opt}$ window, as defined by Parsons (2011)**,** is *"the range in temperatures between the upper and lower $T_p$ when maximum aerobic scope is maintained*". Aerobic scope--which is measured at a given temperature--is the observed difference or range between the maximum respiratory performance (i.e., maximum oxygen consumption) and resting respiratory performance (i.e., resting oxygen consumption) at that temperature. The $T_p$ points are the pejus temperatures (pejus means getting worse); therefore, the $T_p$ points are the temperatures where aerobic scope is getting worse (i.e., becomes smaller in width) (Figure 1). If a respiratory limitation exists for exercising salmonids during warming, increases in aerobic scope should cease once $T_{opt}$ is reached (Farrell 2009). Ultimately, as warming approaches $T_{opt}$ the potential to increase maximum respiratory performance (oxygen consumption by exercising fish) fails to keep up with the required increase in respiratory rate in a resting fish (Farrell 2009). As a result, because aerobic scope does not increase above $T_{opt}$ (Figure. 1), swimming effort either declines or stops (Farrell 2009).

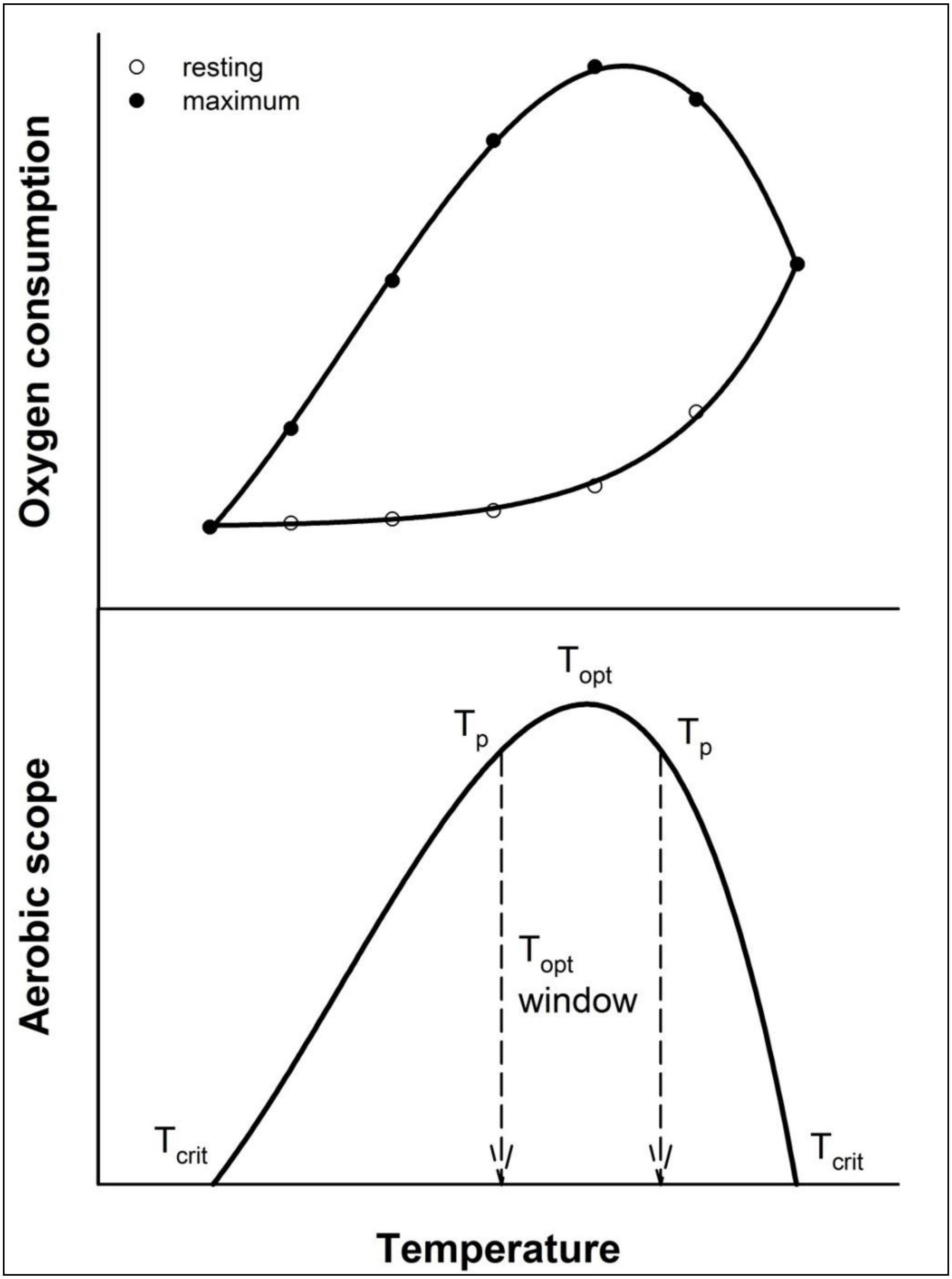

**Figure 1.** **Schematic of resting and maximum oxygen consumption and aerobic scope. See text for details. $T_{opt}$ = optimum temperature, $T_p$ = pejus temperatures, $T_{crit}$ = critical temperatures. The $T_{opt}$ window corresponds to the range of temperatures between the upper and lower $T_p$ (Source – Parsons 2011).**

The primary goal of the swim tunnel experiment would be to determine the temperatures that bound the $T_{opt}$ window for LTR *O. mykiss*, and how rapidly aerobic scope declines between the upper $T_p$ and $T_{crit}$. These temperatures and the shape of the aerobic scope curve could then be compared with those of other *O. mykiss* populations to determine if there is evidence for local temperature adaption for LTR fish compared to more northern populations. These results could also be applied to assess relative responses to temperatures including potential variation in observed $T_{opt}$ compared to EPA (2003) criteria, and relative performance between $T_{opt}$ and $T_{crit}$. This assessment should help define more accurate criteria for evaluation of temperature tolerance for juvenile *O. mykiss* rearing in the LTR.

The study is designed to measure a routine, or resting, (minimum) and a swimming (maximum) metabolic rate for each individual fish and then test each fish at a targeted temperature that occurs between the ambient temperature at the time of capture and upper $T_{crit}$. The selection of test temperatures will depend on the lifestage. Iincrements of $1^oC$ are preferred. Replication at each temperature will depend on individual variability, but at least six fish will be tested at each temperature.

Each fish will be tested at a specific temperature ranging from the ambient, or current temperature of the LTR to a potentially $T_{crit}$ (e.g., 23 $^oC$). For example, if ambient temperature is 18 $^oC$, six temperatures would be tested to determine resting and swimming metabolic rate. At least six replicates (potentially six fish tested) will be conducted for each temperature. If there are six temperatures to be tested, the study would require a minimum of 36 tests (for more detail see discussion below).

The precise protocol can be varied somewhat depending on the number of fish available and the time frame targeted for the work (e.g., 1 month, etc.) The variation in potential protocols is discussed below. Under ideal conditions, a fish would be placed in the tunnel in the evening, left overnight, a routine measurement would be made early in the morning and then the fish would be tested shortly afterwards for the maximum measurement. This fish would be tested only at one temperature. To obtain a reliable resting metabolic rate will require the fish to be undisturbed for at least 4 h after handling (capture). The measurement takes about 30 min. The swim test can be conducted immediate afterwards and takes about 2 h.

There are a number of variations of the basic swim-tunnel type of study that would generally accommodate a field-test of the aerobic metabolic performance of the *O. mykiss.* . As such, there are several ways of conducting the study in terms of experimental-design protocol. For example, individual fish might be tested for aerobic metabolic rate at a single temperature but for two different (low and high) flows, as done in the Parsons study. Alternatively, it may be feasible to test each subject fish repetitively—i.e., at two different flows for each of several test temperatures—assuming that the tested fish are allowed sufficient recovery period between testing episodes. Repetitive testing procedures have been used in Farrell‘s previous studies (pers. comm. A. Farrell, December 2012), some of which indicate that individual fish may show decreased metabolic performance (i.e., reduced aerobic scope) if repeatedly tested without sufficient recuperation time.

Details of the protocol that is eventually selected depends on a variety of conditions that will be identified during the implementation of this scope of work (SOW). Ultimately, it would be the prerogative of the experimental team to decide on the specific approach to be utilized and on various details of the testing protocol. The team's decision would require coordination with NMFS to assure that the selected protocol would meet NMFS's permitting requirements and accommodate the study goal and objectives. As such, two primary options for the testing protocol have been identified and are described in more detail in scenarios presented below.

Juvenile *O. mykiss* would be collected from the LTR during spring-summer[1] 2013, using seining or similar methods that would need to be approved by CDFG and NMFS in a Section 10 permit and California Scientific Collecting Permit SCP). Parsons (2011) indicates that at least six fish will be tested for each temperature to be evaluated; as such, 30 individuals would be needed for the study if starting temperature is about 18 $^{o}$C and 42 fish if starting temperature is about 16 $^{o}$C. After collection in the field, individual fish would be placed into the Brett-type swim tube for a period of 24 hours to acclimate to the test equipment (Parsons 2011). The experiment would be conducted during the second day once the fish have acclimated to the tube. Following completion of the experiment, fish would be held until they recover. Once recovered, fish would be released downstream of the initial capture location. One fish per swim tube per use-day would be needed. Results of previous, similar tests conducted by the investigators indicate that the risk of mortality resulting from the test is extremely low.

The study will comprise four tasks:

Task 1 – Planning and Logistics

- Apply for a Section 10 Research Permit from NMFS to collect and evaluate *O. mykiss* from the LTR. The minimum number of *O. mykiss* to be collected will depend upon the selected protocol (see below).
- Secure laboratory equipment and personnel to conduct field evaluations.
- Identify source (method) and personnel to collect fish.
- Finalize schedule based on permit process and personnel and equipment availability. Setup stream-side facilities for tests.

Various questions will need to be resolved per this task, including the method to be used to collect the test fish. Based on previous year's rotary screw trap (RST) trapping results on the LTR, the likelihood is that sufficient numbers of *O. mykiss* will not be available from RST captures in a timely manner. Seining surveys of the lower Tuolumne River conducted by FISHBIO for the Districts have shown seining can most likely be used to successfully capture juvenile *O. mykiss* during the spring to support this study. The abundance of seine-caught *O. mykiss* has been low, less than would be required for the study. However, the abundance of fish required, (e.g., 30 fish over a 30 day period), would likely be accommodated with an increase in seining effort and an expansion in sampling locations. FISHBIO used angling to collect *O. mykiss* for age and growth analysis, per W&AR 20. Based on results of W&AR 20, angling

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[1] The timing of fish collection will be subject to fish availability and selected protocol that will define the duration of the testing.

would likely provide larger (> 150 mm FL) *O. mykiss*. Other methods of acquiring test fish need to be considered, potentially in conjunction with RST trapped fish, to be used in an opportunistic manner. Ultimately, a Section 10 permit would dictate the allowable capture method. Additionally, the potential effect of the capture method on the ability to acclimate the fish and to conduct the study would need to be evaluated prior to requesting the NMFS permit.

The required test equipment would be available for lease from the University of British Columbia (UBC). Alternative sources of equipment may be available locally and will be explored.

The permit application process has been started (October 2012) and will include informal discussions with NMFS staff to identify specific study details necessary to determine the potential utility of the study and associated take, as determined by NMFS. The application process includes confirmation of study protocol, options for collecting fish, the details of holding, acclimating, testing, and post-testing and how the tests are to be conducted at "streamside". Logistical requirements would be identified and accommodated based on the permit.

Task 2 – Fish collection

The conduct of the testing is proposed to occur during spring-summer of 2013. The targeted species will be *O. mykiss*, ranging in size from approximately 100 mm to 200 mm FL. Based on current studies being conducted by the Districts to collect *O. mykiss* for an age structure evaluation, collection of *O. mykiss* via angling has successfully yielded fish in this range (primarily between 150 and 200 mm FL). The results of the age structure survey should be included in an assessment of the timing of the study (e.g., if the targeted size can be obtained by angling earlier or later), or if the targeted size should be increased.

Task 3 – Field Test

The following discussion provides a more detailed description of the protocols that have been identified by the study team as the potential study design alternatives for conducting the field experiments. The protocols differ primarily in the use of test fish and in the number of replicate tests that will be required to meet the study goals and objectives to be considered.

## Protocol Option 1-- based on the methods of Parsons (2011)

- Individual fish tested only once—i.e., on only one day—allowed to recover, then released.
- Each fish will be individually measured for aerobic scope at a single temperature, but at both the basal-resting (low) flow and active-swimming (high) flow.
- Different sets of individual fish will be tested at each of the specified test temperatures—e.g., some fish at 15°C and others at 17°C, 19°C, and 21°C.
- Ideally, each fish will only be tested once and there will be a different set of individuals (e.g., minimum six fish) tested at each of the test temperatures. The proposed minimum sample (or set) size (# of fish) per test-temperature is a determination based on the experience of

researchers who have conducted such studies (e.g. Dr. Farrell & Dr. Parsons). Dr. Farrell's initial estimate is the source of the proposed number of (about) 6 fish being required for each temperature being tested. Ultimately, the number of fish used per test and the number of fish required for the entire experiment will depend upon fish availability, permit requirements, and to some degree the results of the test as it is being conducted (e.g., mortality of test fish, ambient temperature and thus the number of temperatures to be tested between ambient and Tcrit.

- Protocol Option 1 may be viewed as a "vertical" design—i.e., because each individual is tested at a single specified temperature, but at first low and then high flows.

Example Scenario using Protocol Option 1.

Pre-Test Day. Transfer an individual fish from holding tank to the swim tunnel during late-afternoon of the day before the test.

Test Day morning.

[A] If the fish is to be tested initially at the lowest test temperature (i.e., the river and holding-tank temperature):

(1) Start by measuring the metabolic rate at the basal flow;
(2) Increase flow to the specified test-flow level while keeping temperature constant, then measure metabolic rate at that flow;
(3) Test is now over for this individual; remove it from swim tunnel and release soon after.

Or,

[B] If the fish is to be tested at a temperature higher than the lowest (river or holding-tank) temperature:

(1) Increase the swim tunnel temperature above the initial, lowest temperature at a rate of 1-2°C per hour until the test temperature is reached; during this time, the flow is kept at the basal flow rate;
(2) After the test temperature is reached, measure metabolic rate (at basal flow);
(3) While keeping the swim tunnel at the specified test temperature, increase the flow up to the specified active-swimming test flow;
(4) Measure metabolic rate at that active-swimming (high) test flow;
(5) Test is now over for the individual; reduce flow to basal flow, bring the water temperature back to the ambient LTR temperature, remove fish from swim tunnel and release soon after.

Protocol Option 2—a variation of the methods of Parsons (2011)

Individual fish will be tested multiple times—i.e., metabolic rates will be measured at a different temperature on each of two or three days, depending on how many test temperatures will be used.

Hence, an individual will be held for testing for a period of 3-4 days to allow enough time for acclimation, testing and recuperation between tests.

Generally, the procedures for Protocol Option 2 will be the same as in Protocol Option 1 except that an individual will be repetitively tested at different temperatures, with intervening periods of 1-2 days to allow for recuperation of that individual between tests. Applying this option would allow the study to occur if too few fish are collected to allow six individuals to be tested for each of the study temperatures.

Task 4 – Data analysis and QA/QC

Data analysis and QA/QC would be conducted by UBC personnel following procedures reported by Parsons (2011) and references there in.

Task 5 – Report

A report will be prepared and submitted to agencies and FERC.

## 5.0 SCHEDULE

The Districts anticipate the schedule to complete the study proposal as follows, assuming appropriate permits are obtained from NMFS and CDFG by spring 2013:

Prepare implementation plan and other information necessary to prepare and submit Section 10 Permit to NMFS (Task 1) ..................................................Initiated October 2012 and is ongoing
Prepare for field survey................................................................................ February-March 2013
Collect test fish and conduct field evaluations (Task 2)...................................... March-June 2013
Conduct QA/QC and data analysis (Task 3).......................................................................July 2013
Prepare and deliver final report (Task 4) ..................................................... July - September 2013

## 6.0 REFERENCES

Farrell, A.P., Commentary – Environmental, antecedents and climate change: lessons from the study of temperature physiology and river migration of salmonids. The Journal of Experimental Biology 212, 3771-3780 Published by The Company of Biologists 2009 doi:10.1242/jeb.023671. Available online at: http://jeb.biologists.org/content/212/23/3771.full.pdf

Parsons, E.J.E. 2011. Cardiorespiratory physiology and temperature tolerance among populations of sockeye salmon (*Oncorhynchus nerka*). A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of graduate studies (Zoology) The University of British Columbia (Vancouver) August 2011.

U.S. Environmental Protection Agency (EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Available online at: http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf[1]

***Study 2. Spatial distribution juvenile O. mykiss in response to temperature***

**Objective:** Identify temperature thresholds that define rearing temperature tolerances for juvenile *O. mykiss*.

**Status:** Data availability and utility have been determined to be sufficient to support conduct of this study.

# 1.0 PROJECT NEXUS

The continued operation and maintenance (O&M) of the existing Don Pedro Project (Project) has the potential to cumulatively affect the anadromous fish populations between La Grange Diversion Dam and the confluence of the Tuolumne River and San Joaquin River.

# 2.0 STUDY GOALS

Determine the influence of temperature on spatial and temporal distribution of *O. mykiss* juvenile rearing in the LTR

Objectives:

Identify and evaluate empirical information on the distribution of juvenile *O. mykiss* rearing in the lower Tuolumne River relative to concurrent and antecedent temperatures with a focus on temperature influence on over-summer or year-long rearing habitat availability, to include assessment of:

- Intra annual distribution relative to temperature
- Inter annual distributions relative to temperature
- Range of temperatures providing useable habitat conditions expressed as occupancy
- Temperature thresholds that empirically define rearing temperature tolerances for juvenile *O. mykiss*.

# 3.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

A putative factor limiting the *O. mykiss* population in the lower Tuolumne River, downstream of La Grange Dam, is the paucity of suitable rearing habitat during the warmer, typically summer months (over summering habitat). Summaries of *O., mykiss* distributions observed during snorkel surveys of the Tuolumne River indicate that distribution and density of *O. mykiss* is related to antecedent temperature conditions (TID/MID 2012). Further evaluation of these data is required to define a more specific relationship between temperature and *O. mykiss* rearing to reduce uncertainties regarding potential water temperature-related limitations on the distribution and abundance of *O. mykiss* rearing habitat.

# 4.0 STUDY METHODS

## 4.1 Study Area

The study area is the reach of the lower Tuolumne River between the San Joaquin River and La Grange Diversion Dam.

## 4.2 Study Approach

This study is intended to provide empirical evidence of the influence of temperature on juvenile *O. mykiss* rearing. The expectation is that *O. mykiss* will occupy areas as long as water temperatures are tolerable. This study will compare occupancy with precedent temperature conditions to potentially bracket a threshold for rearing temperature tolerance. Inter-annual variations in longitudinal distribution of *O. mykiss* will be related to differences among temperature gradations. For example, when *O. mykiss* are present within a particular reach of the river subjected to one temperature regime but not there during a different (assume warmer) temperature regime, occupancy versus precedent temperature conditions would be considered an indicator of temperature tolerances. As such, temperature tolerances would be reflected in the response (occupied or vacated) to temperature longitudinally within and among years using existing information on spatial distribution of juvenile rearing and concurrent temperatures.

Existing data have been identified that include survey results showing longitudinal distributions of *O.* mykiss and data have undergone an assessment to determine if they meet the needs of this study. Some of the results include fish density and some of the surveys occurred seasonally (during both the cool and warm seasons). An example of data that support this study is summarized by TID/MID (2012) and is provided below (Table 1 and Figure 1).

The Districts will evaluate the spatial distribution of rearing *O. mykiss* relative to temperature precedent conditions to identify temperatures where occupancy continued and occupancy ended. The temperature regime where occupancy continued would be considered tolerable and the regime where occupancy ended would be intolerable.

Response to temperature in the form of occupancy will be identified within years as seasonal temperatures increase and occupancy either continues or ends, and inter annually where sites known to be occupied during the later, warmer period at least once during the 10 year period would be evaluated to determine if and under what precedent temperature conditions occupancy either continued or ended. Where occupancy continued, the temperature regime would be considered tolerable, where occupancy was not observed, precedent temperature conditions would be considered intolerable. Temperature conditions would be characterized by several, acceptable metrics (used by other investigators to describe temperature conditions relative to fish tolerance), including 7DADM, daily max, mean daily, etc.

For example, if mean daily temperatures increased from May to September, from 15 to 20 $^{o}$C and fish continue to occupy the site, the mean daily temperature of 20 $^{o}$C would be considered tolerable (for the lifestage/age of fish size etc). If site A is occupied in year 1 when September temperatures are 19 $^{o}$C but not in year 2 when September temperatures were 25 $^{o}$C, 25 $^{o}$C would be considered intolerable, 19 °C tolerable. The expectation is that the variation in temperature conditions within the 10 year period would be sufficient to broaden understanding of temperature tolerances within the lower Tuolumne River.

Similar evaluations have been conducted for Chinook salmon and *O. mykiss* on the Mokelumne River (Pagliughi 2008) and for coho salmon rearing in northern California (Hine and Ambrose 2000)

The study will be conducted by implementing the following steps:

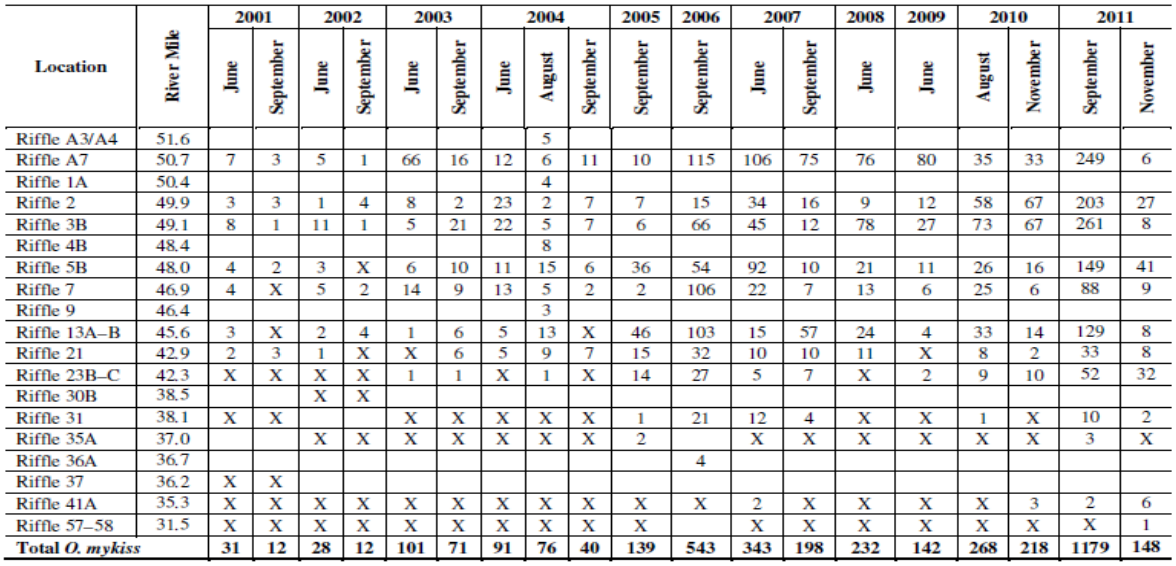
Step 1. Acquire and evaluate utility of data on *O. mykiss* distribution and abundance and associated temperature conditions. All data sources will be checked to assure that the data have been collected per prescribed methods, represent the conditions reported, and have been accurately recorded.

Step 2. Graphical depictions of the data will be developed to identify potential relationships among distribution and temperatures. Data comparing intra and inter annual distributions will be assessed. The results of this analysis will be used to identify the type and focus of additional evaluations.

Step 3. Based on results of Step 2, relationships among temperature and *O. mykiss* rearing distribution and densities will be evaluated using methods similar to those described by Pagliughi (2008) and Hines and Ambrose (2000). . Consideration will be given to use of non-parametric assessments, to be determined by a qualified biostatistician.

Step 4. A report will be prepared describing the methods, results and potential application to evaluation of influences of temperature on *O. mykiss* distribution and abundance in the lower Tuolumne River.

**Table 1. Example of distribution data available to conduct this study (Source: Stillwater 2012)**



| Location | River Mile | 2001 | | 2002 | | 2003 | | 2004 | | | 2005 | 2006 | 2007 | | 2008 | 2009 | 2010 | | 2011 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | September | June | September | June | September | June | August | September | September | September | June | September | June | June | August | November | September | November |
| Riffle A3/A4 | 51.6 | | | | | | | | 5 | | | | | | | | | | | |
| Riffle A7 | 50.7 | 7 | 3 | 5 | 1 | 66 | 16 | 12 | 6 | 11 | 10 | 115 | 106 | 75 | 76 | 80 | 35 | 33 | 249 | 6 |
| Riffle 1A | 50.4 | | | | | | | | 4 | | | | | | | | | | | |
| Riffle 2 | 49.9 | 3 | 3 | 1 | 4 | 8 | 2 | 23 | 2 | 7 | 7 | 15 | 34 | 16 | 9 | 12 | 58 | 67 | 203 | 27 |
| Riffle 3B | 49.1 | 8 | 1 | 11 | 1 | 5 | 21 | 22 | 5 | 7 | 6 | 66 | 45 | 12 | 78 | 27 | 73 | 67 | 261 | 8 |
| Riffle 4B | 48.4 | | | | | | | | 8 | | | | | | | | | | | |
| Riffle 5B | 48.0 | 4 | 2 | 3 | X | 6 | 10 | 11 | 15 | 6 | 36 | 54 | 92 | 10 | 21 | 11 | 26 | 16 | 149 | 41 |
| Riffle 7 | 46.9 | 4 | X | 5 | 2 | 14 | 9 | 13 | 5 | 2 | 2 | 106 | 22 | 7 | 13 | 6 | 25 | 6 | 88 | 9 |
| Riffle 9 | 46.4 | | | | | | | | 3 | | | | | | | | | | | |
| Riffle 13A–B | 45.6 | 3 | X | 2 | 4 | 1 | 6 | 5 | 13 | X | 46 | 103 | 15 | 57 | 24 | 4 | 33 | 14 | 129 | 8 |
| Riffle 21 | 42.9 | 2 | 3 | 1 | X | X | 6 | 5 | 9 | 7 | 15 | 32 | 10 | 10 | 11 | X | 8 | 2 | 33 | 8 |
| Riffle 23B–C | 42.3 | X | X | X | X | 1 | 1 | X | 1 | X | 14 | 27 | 5 | 7 | X | 2 | 9 | 10 | 52 | 32 |
| Riffle 30B | 38.5 | | | X | X | | | | | | | | | | | | | | | |
| Riffle 31 | 38.1 | X | X | | | X | X | X | X | X | 1 | 21 | 12 | 4 | X | X | 1 | X | 10 | 2 |
| Riffle 35A | 37.0 | | | X | X | X | X | X | X | X | 2 | | X | X | X | X | X | X | 3 | X |
| Riffle 36A | 36.7 | | | | | | | | | | | 4 | | | | | | | | |
| Riffle 37 | 36.2 | X | X | | | | | | | | | | | | | | | | | |
| Riffle 41A | 35.3 | X | X | X | X | X | X | X | X | X | X | X | 2 | X | X | X | X | 3 | 2 | 6 |
| Riffle 57–58 | 31.5 | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | 1 |
| **Total *O. mykiss*** | | **31** | **12** | **28** | **12** | **101** | **71** | **91** | **76** | **40** | **139** | **543** | **343** | **198** | **232** | **142** | **268** | **218** | **1179** | **148** |

X = Locations that were sampled with no *O. mykiss* observed.

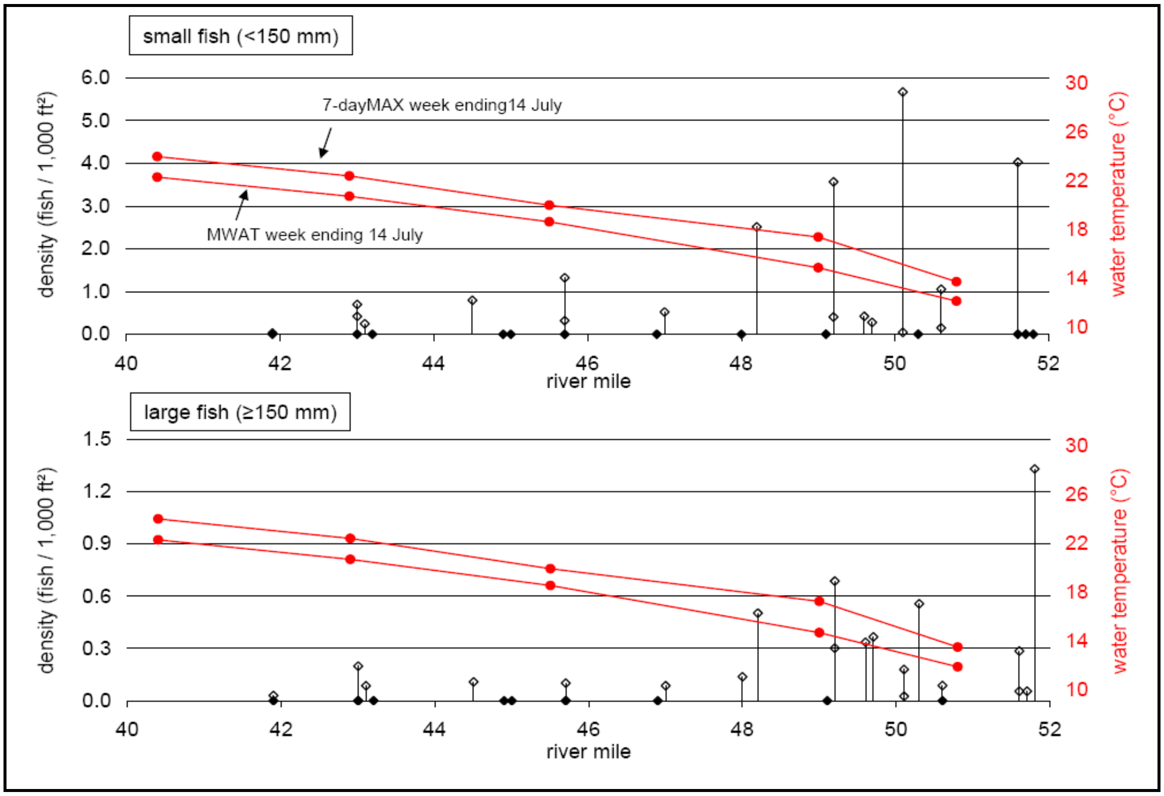


**Figure 1.** **Longitudinal distribution of observed *O. mykiss* and water temperature in the lower Tuolumne River, July 2009. Solid diamonds are observed zeros; open diamonds are observed non-zero values). Source: Stillwater 2009**

## 5.0 SCHEDULE

The Districts anticipate the schedule to complete the study proposal as follows:

| | |
|---|---|
| Step 1 | Ongoing, to be completed February 2013 |
| Step 2 | February – March 2013 |
| Step 3 | March – April 2013 |
| Report Preparation | April – June 2013 |
| Report Issuance | June 2013 |

## 6.0 CONSISTENCY OF METHODOLOGY WITH GENERALLY ACCEPTED SCIENTIFIC PRACTICES

This study will apply methods that are consistent with other, similar investigations,

## 7.0 REFERENCES

Hines, D. and J.Ambrose. 2000. Evaluation of stream temperatures based on observations of juvenile coho salmon in northern California streams. Accessed at:

http://vwvvv.krisweb.com/krisrussian/krisdb/html/krisweb/biblio/gen_afs_hinesetal_xxxx.pdf

Pagliughi, S.W. 2008. Lower Mokelumne River, Reach Specific Thermal Tolerance Criteria by Life Stage for Fall-Run Chinook Salmon and Winter-Run Steelhead. East Bay Municipal Utility District, Lodi, CA.

Stillwater Sciences. 2009. March and July 2009 population size estimates of *Oncorhynchus mykiss* in the Lower Tuolumne River. Prepared for the Turlock Irrigation District and the Modesto Irrigation District by Stillwater Sciences, Berkeley, CA. November. Accessed at: http://www.tuolumnerivertac.com/Documents/2009%20BCE%20Report2009Nov.pdf

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2012. *Oncorhynchus mykiss* Habitat Survey Study Plan (W&AR-12). Attachment to Don Pedro Hydroelectric Project Revised Study Plan. April 2012.

***Study 3. Influence of temperature on growth of juvenile Chinook salmon***

**Status:** Evaluation of the availability and utility of data to support this study has shown that data are available to conduct an evaluation of the observed influence of temperature on growth of juvenile Fall-run Chinook salmon in the lower Tuolumne River.

# 1.0 PROJECT NEXUS

The continued operation and maintenance (O&M) of the existing Don Pedro Project (Project) has the potential to cumulatively affect the anadromous fish populations between La Grange Diversion Dam and the confluence of the Tuolumne River and San Joaquin River.

# 2.0 STUDY GOALS

**Objective**: Identify temperature thresholds that support "acceptable/expected" growth of juvenile Chinook salmon in the lower Tuolumne River.

# 3.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Concern has been expressed that Chinook salmon growth in the lower Tuolumne River is too slow, potentially delaying Chinook salmon from reaching a larger, smolt-sized fish in time to successfully emigrate. For example, growth would be considered as expected if the majority of Fall-run Chinook salmon achieve 70-90 mm FL by end of April and essentially all Fall-run Chinook salmon have the opportunity to achieve smolt size by the end of May. By tracking RST size composition from the earliest migrating juvenile Chinook salmon, a trend in growth can be identified and the timing and cumulative composition of emigrating smolt-sized fish can be determined and contrasted with the precedent temperature regime to evaluate occurrence of adverse effects on Chinook salmon growth.

Data have been collected on size of Chinook salmon during their migrations during the previous eight years using rotary screw traps. Fish length data are typically collected daily from throughout the entire emigration period (typically January through May). Additionally, temperature data are available to describe the conditions present during the growth period.

# 4.0 STUDY METHODS

## 4.1 Study Area

The study area is the reach of the lower Tuolumne River between the San Joaquin River and La Grange Diversion Dam.

## 4.2 Study Approach

This study is intended to provide empirical evidence of the influence of temperature on growth of juvenile Chinook salmon in the lower Tuolumne River.

**Approach**: Compare observed size at time/age, interpreted as growth, of Chinook salmon in the lower Tuolumne River with expected growth based on literature and growth rates observed/reported in other, similar waters. Relate temperature regime associated with observed growth in the lower Tuolumne River to identify those temperature conditions that either support or do not support expected growth.

This study would evaluate growth of Fall-run Chinook salmon in lower Tuolumne River as a function of precedent temperature conditions. Growth would be evaluated by comparing observed growth in the lower Tuolumne River with expected growth to be defined based on the literature or observations from other similar watersheds. The size at time, to be estimated based on timing of spawning and emergence, (as data are available), would be contrasted with reported, acceptable or expected size at time

Similar evaluations have been conducted for Chinook salmon on the Stanislaus, Mokelumne, American, and Yuba Rivers.

The study will be conducted by implementing the following steps:

Step 1. Acquire and evaluate utility of data on juvenile Chinook salmon size at time and associated temperature conditions. All data sources will be checked to assure that the data have been collected per prescribed methods, represent the conditions reported, and have been accurately recorded.

Step 2. Graphical depictions of the data will be developed to identify potential relationships among size at time (growth) and temperatures. Data comparing intra and inter annual distributions will be assessed. The results of this analysis will be used to identify the type and focus of additional evaluations.

Step 3. Based on results of Step 2, relationships among temperature and Chinook salmon growth will be evaluated using methods similar to those described by Campos and Massa (2010) and Pyper and Justice (2006) Anderson and Neumann (1996), Richards (1959), Ricker (1975)and others, as appropriate. The appropriate application of these methods will be determined by a qualified biostatistician.

Step 4. A report will be prepared describing the methods, results and potential application to evaluation of influences of temperature on Chinook salmon growth in the lower Tuolumne River.

## 5.0 SCHEDULE

The Districts anticipate the schedule to complete the study proposal as follows:

| | |
|---|---|
| Step 1 | Ongoing, to be completed February 2013 |
| Step 2 | February – March 2013 |
| Step 3 | March – April 2013 |
| Report Preparation | April – June 2013 |
| Report Issuance | June 2013 |

## 6.0 CONSISTENCY OF METHODOLOGY WITH GENERALLY ACCEPTED SCIENTIFIC PRACTICES

This study will apply methods that are consistent with other, similar investigations,

## 7.0 REFERENCES

Anderson, R.O. and R.M. Neumann. 1996. Length, Weight, and Associated Structural Indices. Pages 447-482 in B.R. Murphy and D. W. Willis, ed. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Campos, C. and D. Massa (2010). Lower Yuba River Accord monitoring and evaluation plan annual rotary screw trapping report, October 1, 2008—August 31, 2009. Prepared for: The Lower Yuba River Accord Planning Team by Pacific States Marine Fisheries Commission, May2010.

Pyper, B. and C. Justice. 2006. Analysis of rotary screw trap sampling of migrating juvenile Chinook salmon in the Stanislaus River, 1996-2005. Cramer Fish Sciences, Gresham, OR 97030 August 2006

Richards, F.J. 1959. A flexible growth function for empirical use. Journal of Exp. Botany, 10:290-300.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191 of the Fisheries Research Board of Canada. Ottawa.

***Study 7. Influence of temperature on timing of initial spawning of Chinook salmon***

**Objective**: Identify adult Chinook salmon response to typically warmer temperatures occurring in the lower Tuolumne River in the early portion of the spawning period. Evaluation of inner annual timing of spawning will be compared with temperatures during early spawning period using redd surveys or carcass survey results to identify temporal distribution of early spawning, and pre-spawning mortality, potentially measured as egg retention during carcass surveys.

# 1.0 PROJECT NEXUS

The continued operation and maintenance (O&M) of the existing Don Pedro Project (Project) has the potential to cumulatively affect the anadromous fish populations between La Grange Diversion Dam and the confluence of the Tuolumne River and San Joaquin River.

# 2.0 STUDY GOALS

**Objective**: Identify the potential influence of water temperature on the timing of initial Chinook salmon spawning in the lower Tuolumne River.

# 3.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Chinook salmon are known to migrate to the Tuolumne River and other San Joaquin River tributaries early in fall, before water temperatures are suitable for spawning. The response of early arriving Chinook salmon to warmer temperatures, such as delayed spawning and/or prespawning mortality of eggs is undocumented. CDFG and the Districts have monitored timing of arrival of adult Chinook salmon at the Tuolumne River, timing and distribution of spawning, and prespawning mortality, indicated by egg retention in spawned Chinook salmon.

# 4.0 STUDY METHODS

## 4.1 Study Area

The study area is the reach of the Tuolumne River between the San Joaquin River and La Grange Diversion Dam.

## 4.2 Study Approach

This study is intended to provide empirical evidence of the influence of temperature on early, temporal distribution of Chinook salmon spawning in the lower Tuolumne River.

**Approach**: Compare timing of initial spawning with precedent temperature conditions using CDFG redd survey results.

Redd count data by survey date and redd location are available from 1987-2004, with no survey data in 2003 or since 2004. The Districts' approach is to evaluate water temperature at the time of first spawning and during the first 3-4 weeks after the observation of the first spawning and compare those data with precedent temperatures. Timing of Chinook salmon adult arrival at the Tuolumne River will be compared with timing of spawning and temperature for those years when both adult immigration was monitored using a counting weir, and redd or carcass surveys were also conducted.

Similar evaluations have been conducted for Chinook salmon on the American River (SWRI 2004).

The study will be conducted by implementing the following steps:

Step 1. Acquire and evaluate utility of data on Chinook salmon spawning, including redd surveys and carcass surveys and associated temperature conditions. All data sources will be checked to assure that the data have been collected per prescribed methods, represent the conditions reported, and have been accurately recorded.

Step 2. Graphical depictions of the data will be developed to identify potential relationships among timing of spawning, egg retention, and temperatures. Data comparing intra and inter annual distributions will be assessed. The results of this analysis will be used to identify the type and focus of additional evaluations.

Step 3. Based on results of Step 2, relationships among temperature and Chinook salmon spawning will be evaluated using methods to be determined by a qualified biostatistician.

Step 4. A report will be prepared describing the methods, results and potential application to evaluation of influences of temperature on the timing of Chinook salmon spawning and potentially related prespawning mortality in the lower Tuolumne River.

## 5.0 SCHEDULE

The Districts anticipate the schedule to complete the study proposal as follows:

| | |
|---|---|
| Step 1 | Ongoing, to be completed February 2013 |
| Step 2 | February – March 2013 |
| Step 3 | March – April 2013 |
| Report Preparation | April – June 2013 |
| Report Issuance | June 2013 |

## 6.0 CONSISTENCY OF METHODOLOGY WITH GENERALLY ACCEPTED SCIENTIFIC PRACTICES

This study will apply methods that are consistent with other, similar investigations,

## 7.0 REFERENCES

SWRI. 2004. Aquatic Resources of the Lower American River: Draft Baseline Report. Sacramento, CA: Surface Water Resources, Inc.