

ATTACHMENT I
TROUT TEMPERATURE REQUIREMENTS (LITERATURE REVIEW)

Attachment I – Rainbow Trout Temperature Requirements

Introduction

In the PDEA, water temperature was evaluated with respect to criteria for trout found in the literature. These criteria were used to evaluate which bypass reaches may have temperatures that potentially affect habitat suitability for trout and thereby could affect meeting water quality objectives. This attachment summarizes recent literature for *O. mykiss*, with an emphasis on rainbow trout, in support of these criteria. Literature values for other fish species are summarized in Attachment H - Life History and Habitat Requirements of Fish Species in the Project Area.

Daily mean temperature criteria were developed to assess whether temperatures would be suitable for fish growth and daily maximum temperature criteria were developed to assess conditions that would stress fish. Preferred temperatures are often considered a reasonable estimator of beneficial/optimal temperatures. Fish can withstand short-term exposure to water temperatures higher than those needed for longer-term growth or survival without significant negative effects. Based upon the best available information for regional streams, the temperature evaluation criterion applied to assess conditions for suitable trout growth is a mean daily water temperature at or below 20°C. A daily maximum temperature of 24°C was applied as a criterion for short-term high-temperature exposure, above which temperatures are expected to be stressful for trout.

This section reviews studies that were used to develop these criteria. The review addresses studies that assess temperatures beneficial for fish growth and studies that assess the upper lethal limits, with an emphasis on studies that may be most relevant to the San Joaquin River basin.

Regional Literature

Substantial regional variability in rainbow trout temperature tolerances is reported in the published literature. Traditionally, published temperature criteria have relied on studies on resident and anadromous fish conducted in the Pacific Northwest, which may not directly apply to inland, resident rainbow trout in the southern portion of their range. The Big Creek study lies in the southern portion of the range of this species and contains inland resident rainbow trout. Recent research specific to California strains of rainbow trout and steelhead suggest that temperature tolerances of steelhead and rainbow trout in California may be higher than races in the Pacific Northwest.

Temperature Preference and Growth

The temperature criteria used in the PDEA primarily are based on recent studies focused on California rainbow trout stocks, which are summarized in a review by Myrick and Cech (2001) that focused on California's Central Valley *O. mykiss* populations. Myrick and Cech (2000b) conducted studies with two strains of resident California rainbow trout (Eagle Lake and Mt. Shasta, both hatchery fish stocks are planted widely

in California) at temperatures of 10 - 25°C. They found that growth rates increased to a maximum near 19°C, and declined at temperatures greater than 19°C. This indicates that growth rates were greatest at 19°C and declined at temperatures above and below 19°C. Trout grew well at temperatures near 22°C, but growth rates declined rapidly as temperatures approached 25°C. These studies suggest if daily mean summer water temperatures are less than or equal to 20°C in the Project Area, conditions would be suitable for rainbow trout growth. These growth rates were consistently higher than those of American or Feather River steelhead. The Project area has been heavily stocked and rainbow trout introduced to almost every location in which they are now found (see Attachment H - Life History and Habitat Requirements of Fish Species in the Project Area). That the two hatchery strains had higher growth rates than the steelhead stocks suggests that studies utilizing hatchery rainbow trout strains may be more appropriate for determining temperature criteria in the Big Creek Project Area than studies that used steelhead, which are not present in the Project area. Of the two hatchery strains, the Mt. Shasta strain trout grew faster at the warmest temperatures than Eagle Lake trout.

A large range of temperature preferences for rainbow trout/steelhead has been reported in the literature, with substantial regional variability. The preferred water temperatures for rearing juvenile steelhead on the American River are reported to range from 12.8°C to 15.6°C (CDFG 1991), while Bell (1986) reports a somewhat lower preferred range of 10 to 12.8°C for steelhead in the Pacific Northwest. In contrast, hatchery-reared, Central Valley steelhead consistently selected temperatures of 18 to 19°C, while wild fish selected temperatures of about 17°C (Myrick and Cech 2000a). This lends support for the idea that *O. mykiss* populations in the southern portion of their range may have higher temperature preferences than those in northern regions.

Myrick (1998) studied thermal preference of American River (Nimbus strain) steelhead over an 11 to 19°C range. The study did not reach an experimental acclimation temperature at which juvenile steelhead began to select cooler temperatures. Furthermore, selected temperatures closely matched the temperature at which highest growth rates were observed.

Myrick and Cech (2000a) found hatchery Feather River steelhead acclimated to constant and cyclical thermal regimes had similar thermal preferences and selected temperatures in the 18 to 19°C range. They found that growth rate increased with ration level. Fish on a cyclical thermal regime (14 to 18°C) grew more slowly than under a constant regime, although the difference was not statistically significant.

Stressful and Lethal Temperatures

Based on available literature drawn largely from laboratory studies (Cherry et al. 1977, Raleigh et al. 1984, Currie et al. 1998, Coutant 1977) the upper incipient lethal temperature (UILT) for rainbow trout is within the range 25 to 30°C. Eaton et al. (1995) identified upper temperature criteria for rainbow trout as 24.0°C. Myrick and Cech (2001) report critical thermal maximum (CTM) tolerances of 27.7 to 29.7°C for juvenile California steelhead, and as high as 32°C for Eagle Lake rainbow trout acclimated to

25°C. The temperatures that may be considered too warm or deleterious for a fish species depend upon the duration of exposure. USEPA (1976) identified maximum weekly temperatures for survival for rainbow trout as 24°C. UILTs reported by USEPA (2001b) for rainbow trout range from 24 to 26.9°C.

For the purposes of the analysis in the PDEA, a daily maximum temperature of 24°C was selected as a temperature evaluation criterion for short-term high temperature exposure. The use of 24°C for short-term exposure may be considered conservative (overly protective) based on available information. The exposure considered in the evaluation criteria for daily maximum temperatures is generally one-hour or less. Since the temperatures cited above represent 24-hour to seven-day exposures, 24°C the lowest UILT identified, when used in comparison to an exposure of one hour or less, is very conservative.

Brief Summaries of Relevant Literature

Myrick and Cech (2000b) found no strain-related (Eagle Lake and Mt. Shasta hatchery rainbow trout) differences in response to temperature of conversion efficiency, oxygen consumption rates, thermal tolerance or swimming performance, but the Mt. Shasta strain trout grew faster at the highest temperatures (22 to 25°C). Both strains were able to maintain weight at 25°C for 30 days, which the authors suggest may allow them to survive short (<1 month) periods of sublethal temperatures in California streams. To examine the effects of high temperatures frequently found in the lower portion of the San Joaquin River basin, Myrick and Cech (2002) tested effects of rearing temperatures of 19, 22 and 25°C on three California hatchery trout strains (Eagle Lake and Mount Shasta rainbow trout, and Kern River strain golden trout). As expected, growth rates were reduced at the higher temperatures, but the trout were capable of growing at temperatures 4 to 7°C higher than optimal temperatures, and they maintained their weight at temperatures close to incipient lethal temperatures. All strains were found to have a CTM between 29.6 to 32.0°C, although the authors recommend that the ILT values rather than CTM values should be used for determining upper temperature limits for water quality criteria.

Myrick and Cech's (2001) review indicated that steelhead can be expected to show significant mortality at chronic temperatures exceeding 25°C, although they tolerate temperatures as high as 29.6°C for short periods of time. However, the fish experience sub-lethal effects at temperatures below these limits.

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