California Golden Trout and Climate Change: Is Their Stream Habitat Vulnerable To Climate Warming?

Kathleen R. Matthews[1] Sebastien C. Nussle[2]

[1]USDA Forest Service, Pacific Southwest Research Station, 800 Buchanan, St Albany, CA 94710 kmatthews@fs.fed.us

[2]University of California Berkeley, Department of Environmental Science, Policy, and Management, Berkeley, CA 94720, snussle@berkeley.edu

Abstract—To determine the current range of water temperatures in streams inhabited by California Golden Trout *Oncorhynchus mykiss aguabonita*, we deployed and monitored water temperature recording probes from 2008-2013 in three meadows in the Golden Trout Wilderness in the southern Sierra Nevada, California. Ninety probes were placed in three meadow streams: Mulkey Creek in Mulkey Meadow (2,838 m), South Fork Kern River in Ramshaw Meadows (2,640 m) and Golden Trout Creek in Big Whitney Meadow (2,963 m). Year-round water temperatures were successfully downloaded from seventy-nine probes along with measurements of stream shade. Water temperatures ranged from -0.1 to 26°C in Mulkey and Ramshaw meadows while in Big Whitney Meadow maximum temperature did not exceed 21°C. Temperatures were highest in late July through mid-September. Salmonids generally prefer cool water and become stressed when temperatures exceed 22°C, and water temperatures are predicted to increase with future climate warming. Thus, these results indicate that current stream temperatures in the Golden Trout Wilderness are high and may lack the resiliency to future warming.

Introduction

The California Golden Trout *Oncorhynchus mykiss aguabonita* is native to the South Fork Kern River and Golden Trout Creek (Behnke 1992), and most of its native range lies within the Golden Trout Wilderness (GTW) in the southern Sierra Nevada (Figure 1). California Golden Trout (CGT) populations in the GTW are long lived and slow growing (Knapp and Dudley 1990; Knapp and Matthews 1996). Cattle grazing has also increased spawning habitat by widening channels and as a result, CGT exist at high densities of small fish (Knapp et al. 1998). The CGT has been the subject of management interest because of its status as California's state fish, limited natural distribution, and several perceived threats to its viability, including introduction of nonnative Brown Trout *Salmo trutta* and habitat degradation caused by livestock grazing. The CGT was the focus of a major restoration effort in the 1970s-1980s (Pister 2008) to remove exotic trout throughout its native range. Several studies have described Golden Trout habitat preferences (Matthews 1996a, 1996b) and concluded that adult trout prefer habitats (vegetated and undercut banks) that are typically reduced by cattle grazing (Kaufman and Krueger 1984). One emerging threat that has not been evaluated is the impact of climate warming that could further stress CGT streams already near their temperature maximums due to cattle grazing.

Cattle grazing typically results in reduced streamside vegetation and shallow, widened streams which in in turn increases stream warming (Armour et al. 1991; Platts 1991; Belsky et al. 1997). Climate warming models predict streams and lakes in the Sierra Nevada will experience significant warming in the next 100 years and the currently degraded streams may not have the resilience to withstand increased warming. Several recent papers have noted the similar impacts of cattle grazing and climate warming to stream habitats and recommend major changes in grazing management in Wilderness areas to increase resiliency of stream habitats (Beschta et al 2013; Hughes 2014). This project was designed to determine the range of water temperatures and stream shading currently experienced by the California Golden Trout in GTW streams. This report will highlight some preliminary water temperature and stream shade data from the ongoing study and discuss whether their habitat will be vulnerable to climate warming.

Methods

This study was conducted in three large (5–7 km long) montane meadows of the Golden Trout Wilderness in the Inyo National Forest of the southern Sierra Nevada, California. Mulkey Meadow (36º24’19’’N, 118º11’42.14’’W, 2,838 m), Big Whitney Meadow (36º26’23’’N 118º16’11.66’’W, 2,963 m) and Ramshaw Meadow (36º20’53’’N, 118º14’52.62’’W, 2,640m) (Figure 1). These meadows are part of the largest meadow complex in the Sierra Nevada and occur in depositional basins along the South Fork Kern River. All meadows were historically grazed by cattle and sheep since the 1800s but only Mulkey Meadow is currently grazed by cattle. The meadows are generally covered with snow from November to May, and the summer growing season lasts from approximately late May to August, depending on the timing of snow melt. The meadows occur in a semiarid region where annual precipitation is 50 –70 cm and most precipitation is in the form of snow.

To determine the water temperature vulnerability of the CGT within its stream habitat in the GTW, I deployed 90 temperature probes (Onset HOBO Water Temp Pro v2 and tidbits) throughout the stream to include a typical range of stream areas: areas degraded by cattle grazing (collapsed banks, little vegetation, shallow depth) and those in recovering areas with more streamside vegetation and greater depth. Temperatures were recorded every 20 min and were downloaded at least once per year from 2008 to 2013. Solar radiation input (opposite of shade) was measured using the Solmetric Suneye 210; measurements (0-100%) were made at each temperature probe. Measurements of 100% indicate full solar input with no shade; conversely 0% indicates no solar input and full 100% shade.

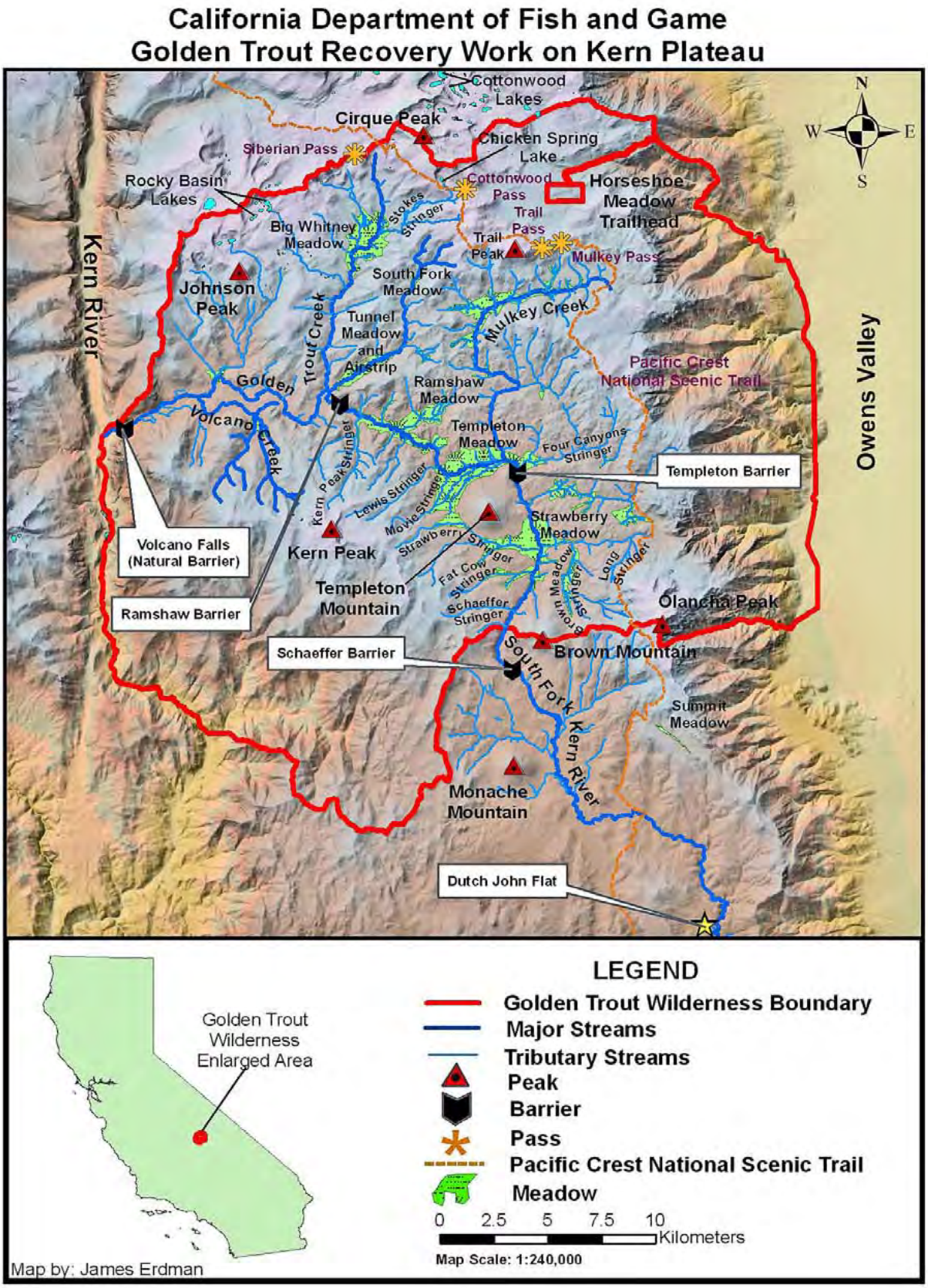

Figure 1. Map of Kern plateau from Pister 2008.

Results

Temperature probes were successfully downloaded from 79 probes; 30 from Mulkey Meadow, 29 from Ramshaw Meadow, and 20 from Big Whitney Meadow. Of the originally deployed 90 probes, nine were never recovered and two were found out of the stream and damaged by animals (likely marmots or coyotes). Year-round temperatures ranged from -0.1 to 26°C in Mulkey and Ramshaw meadows while in Big Whitney Meadow maximum temperature did not exceed 21°C (Figure 2). Median year-round temperatures were highest in Mulkey Meadow and lowest in Big Whitney Meadow. Yearly (2008-2013) water temperatures ranged from maximums of 23-26°C to minimums of 0 to 4°C (Figure 2). Water temperatures were highest during summer weeks 25-34 (late June-mid September; Figure 3a-c).

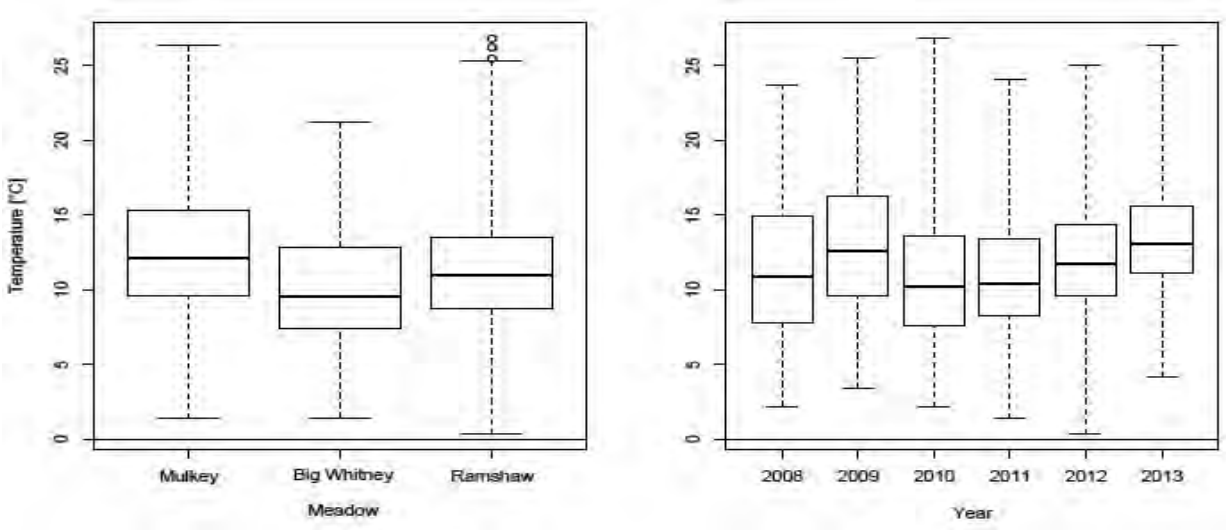

Figure 2. Boxplots of water temperatures (°C) for Mulkey, Big Whitney, and Ramshaw meadows 2008-2013 combined, and the median temperatures for individual years 2008-2013.

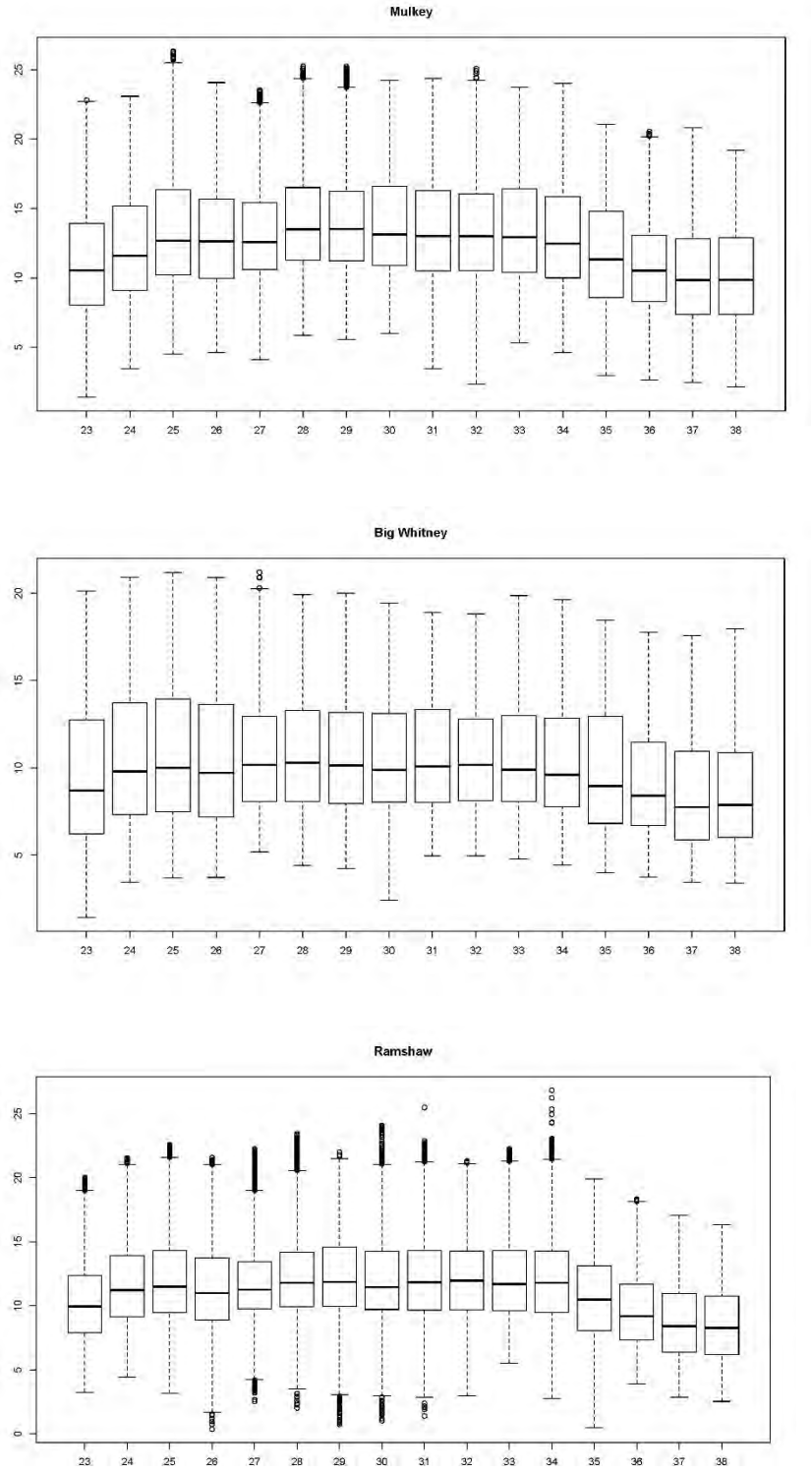

Figure 3 a-c. Boxplots of water temperatures for weeks 23-36 (2008-2013) in Mulkey, Big Whitney, and Ramshaw meadows.

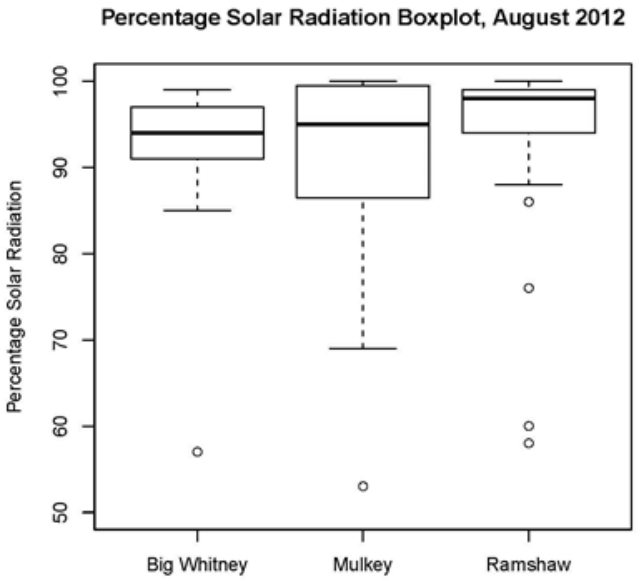

Figure 4. Boxplots of solar radiation measurements in all three meadows measured in 2012.

Median solar radiation estimates were high (>90% = 10% shade) for all three meadow streams (Figure 4). The solar radiation estimates (%) in all three streams ranged to 60% (Shading = 40%) in areas with more streamside vegetation.

Discussion

This is the first documentation of year-round water temperatures in CGT native streams. Water temperature data from 2008 to 2013 highlight several vulnerabilities: water temperatures in some areas of the GTW are already reaching stressful and possibly lethal levels for salmonids (>26°C) (Bjorn and Reiser 1991). These stream areas already are too warm and will not have the resiliency to withstand future increased warming of 1-7°C. The natural conditions of Kern Plateau open meadows combined with reduced streamside vegetation diminish the capacity of these streams to remain cool, and future warming could result in widespread lethal water temperatures.

California Golden Trout inhabit streams with temperatures at critical levels. Past research found Rainbow Trout *Oncorhynchus mykiss* in southern California streams with temperatures up to 28°C, but trout sought out coolwater seeps and did not use the warmer areas (Matthews and Berg 1997). CGT are extremely abundant throughout the stream (Knapp and Matthews 1995) and inhabit all parts (runs, pools, etc). of the GTW streams (Matthews 1996). Redband Trout, *Oncorhynchus mykiss gairdneri*, inhabit desert basin streams at mid-elevations (1,600-1,700 m) and may be found in water with temperatures as high as 29°C (Zoellick 1999; Rodnick et al 2004). Redband Trout are considered the most temperature tolerant of the salmonids. However, Meyer et al (2010) reported Redband Trout were more abundant in areas of increased shade and temperature between 10-16 °C and that they steadily declined as mean summer temperature exceeded 16°C. These high temperatures may impact condition and performance of the Redband Trout (Rodnick et al 2004). Perhaps CGT are heat tolerant, but little is known about their thermal preference and in the absence of information it would be prudent to promote management activities that cool the streams.

Climate models predict water temperature will increase 1 to 7°C in the Sierra Nevada (Dettinger 2012; Null et al. 2013) and none of the streams currently have resiliency to withstand increased temperatures. While Golden Trout Creek (Big Whitney Meadow) temperatures were lower than Mulkey Creek and South Fork Kern River (Ramshaw Meadow), Golden Trout Creek would experience stressful levels (>25°C) when temperatures rise. Beschta et al. (2013) reported that climate warming has many similar impacts to overgrazing. They recommended that grazing on public lands especially in wilderness areas be eliminated to help meadow streams recover and become more resilient to climate warming impacts. Because future climate warming could increase water temperatures to lethal levels, the current results stress the importance of continued monitoring and restoration activities that promote stream cooling.

Acknowledgments

This project was funded in part by the National Fish and Wildlife Foundation and the Sierra Pacific Flyfishers. Julia Anderson and Debbie Sharpton assisted with the fieldwork and the data analysis.

Literature Cited

Armour, C. L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16:7-11.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, Maryland.

Belsky, A.J., A. Matzke, and S. Uselman. 1997. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation: 54:416-531.

Beschta, R. L., Donahue, D. L., DellaSala, D. A., Rhodes, J. J., Karr, J. R., O'Brien, M. H., Fleischner, T. L., and Williams, C. D. (2013). Adapting to climate change on western public lands: Addressing the ecological effects of domestic, wild, and feral ungulates. Environmental Management, 51:474-491

Bjornn, T. C. and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 In W. R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. Bethesda, Maryland.

Dettinger, M.D. 2013. Projections and downscaling of 21st century temperatures, precipitation, radiative fluxes and winds over the southwestern US, with a focus on Lake Tahoe. Climatic Change116:17-33

Hughes, R. 2014. Livestock Grazing in the West: Sacred Cows at the Public Trough Revisited, Fisheries, 39:339, 388.

Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: A review. Journal of Range Management 37:430–437.

Knapp, R. A., and T. L. Dudley. 1990. Growth and longevity of golden trout, *Oncorhynchus aguabonita*, in their native streams. California Fish and Game 76:161-173.

Knapp, R. A., V. T. Vredenburg, and K.R. Matthews. 1998. Effects of stream channel morphology on golden trout spawning habitat and population structure. Ecological Applications 8:1104-1117.

Knapp, R. A. and K. R. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: impacts and management implications. North American Journal of Fisheries Management 16:805-820.

Matthews, K.R. 1996a. Golden trout habitat selection and movement patterns in degraded and recovering sites within the Golden Trout Wilderness, California. North American Journal of Fisheries Management 16:578-590.

Matthews, K. R. 1996b. Diel movement and habitat use of the golden trout *Oncorhynchus mykiss aguabonita* in their native habitat on the Golden Trout Wilderness, California. Transactions of the American Fisheries Society 125:78-86.

Matthews, K. R. and N. H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. Journal of Fish Biology 49:1-18.

Null, S. E., J. H. Viers, M. L. Deas, S. K. Tanaka, and J. F. Mount. 2013. Stream temperature sensitivity to climate warming in California's Sierra Nevada: Impacts to coldwater habitat. Climatic Change, 116:149–170.

Pister, E. P. 2008. Restoration of the California golden trout in the South Fork Kern River, Kern plateau, Tulare County, California, 1966-2004, with reference to golden trout creek. California Department of Fish and Game Administrative Report No. 2008-1, Sacramento.

Platts, W.S. 1991. Livestock grazing. p. 389-424. In: W.R. Meehan (ed)., Influences of forest and rangeland management on salmonid fishes and their habitats. American. Fisheries Society Special Publication 19:389-423.

Rodnick, K.J., A.K. Gamperl,, K.R. Lizars, M.T. Bennett, R.N. Rausch, and E.R.Keeley. 2004. Thermal tolerance and metabolic physiology among redband trout populations in south-eastern Oregon. Journal of Fish Biology 64:310-335.

Zoellick, B. W. 1999. Stream temperatures and the elevational distribution of redband trout in southwestern Idaho. Great Basin Naturalist 59:136-143.