

Table 5.D-49. Water Temperature Thresholds Used for Water Temperature Threshold Analyses, Sacramento River

Species	Life Stage	Period	Location	Threshold (F)		Sources/Notes
				Mean Monthly	7DADM ¹	
Winter-run	Spawning, egg incubation, and alevins	Apr-Oct	Keswick		55.4	USEPA 2003
			Clear Creek		55.4	USEPA 2003
			Balls Ferry		55.4	USEPA 2003
			Bend Bridge		55.4	USEPA 2003
			Red Bluff		55.4	USEPA 2003
	Fry and juvenile rearing and emigration	Jul-Mar	Keswick		61	USEPA 2003; core juvenile rearing ²
			Clear Creek		61	USEPA 2003; core juvenile rearing
			Balls Ferry		61	USEPA 2003; core juvenile rearing
			Bend Bridge		61	USEPA 2003; core juvenile rearing
			Red Bluff		61	USEPA 2003; core juvenile rearing
	Adult Immigration	Dec-Aug	Knights Landing		64	USEPA 2003; non-core juvenile rearing ³
			Keswick		68	USEPA 2003
	Adult Holding	Jan-Aug	Bend Bridge		68	USEPA 2003
			Red Bluff		68	USEPA 2003
			Keswick		61	USEPA 2003
Spring-run	Spawning, egg incubation, and alevins	Aug-Dec	Balls Ferry		61	USEPA 2003
			Red Bluff		61	USEPA 2003
			Keswick		55.4	USEPA 2003
			Clear Creek		55.4	USEPA 2003
			Bend Bridge		55.4	USEPA 2003
	Fry and juvenile rearing and emigration	Year-round	Keswick		55.4	USEPA 2003
			Clear Creek		61	USEPA 2003; core juvenile rearing
			Balls Ferry		61	USEPA 2003; core juvenile rearing
			Bend Bridge		61	USEPA 2003; core juvenile rearing
			Red Bluff		61	USEPA 2003; core juvenile rearing
Knights Landing		64	USEPA 2003; non-core juvenile rearing			

Appendix 5.D. Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale

Species	Life Stage	Period	Location	Threshold (F)		Sources/Notes
				Mean Monthly	7DADM ¹	
Spring-run (Cont)	Adult Immigration	Mar-Sep	Keswick		68	USEPA 2003
			Bend Bridge		68	USEPA 2003
			Red Bluff		68	USEPA 2003
	Adult Holding	Apr-Sep	Keswick		61	USEPA 2003
			Balls Ferry		61	USEPA 2003
			Red Bluff		61	USEPA 2003
Steelhead	Spawning, egg incubation, and alevins	Nov-Apr	Keswick	53		McCullough 2001
				56		NMFS 2009
			Clear Creek	53		McCullough 2001
				56		NMFS 2009
			Balls Ferry	53		McCullough 2001
				56		NMFS 2009
			Bend Bridge	53		McCullough 2001
				56		NMFS 2009
	Red Bluff	53		McCullough 2001		
		56		NMFS 2009		
	Kelt Emigration	Feb-May	Keswick		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
			Bend Bridge		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
Red Bluff				68	USEPA 2003	
			70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)	

Species	Life Stage	Period	Location	Threshold (F)		Sources/Notes			
				Mean Monthly	7DADM ¹				
Steelhead (Cont)	Juvenile Rearing	Year-round	Keswick	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005; and Beakes et al. 2014			
					69	Sullivan 2000			
			Clear Creek	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005; and Beakes et al. 2014			
					69	Sullivan 2000			
			Balls Ferry	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005; and Beakes et al. 2014			
					69	Sullivan 2000			
			Bend Bridge	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005; and Beakes et al. 2014			
					69	Sullivan 2000			
			Red Bluff	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005; and Beakes et al. 2014			
					69	Sullivan 2000			
			Steelhead (Cont)	Smoltification	Jan-Mar	Keswick	54		Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988
						Clear Creek	54		Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988
Balls Ferry	54					Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988			
Bend Bridge	54					Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988			

Species	Life Stage	Period	Location	Threshold (F)		Sources/Notes
				Mean Monthly	7DADM ¹	
			Red Bluff	54		Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988
			Smolt Emigration (excludes migrant parr)	Nov-Jun	Keswick	
		64				USEPA 2003; non-core location
	Clear Creek				61	USEPA 2003; core location
					64	USEPA 2003; non-core location
	Balls Ferry				61	USEPA 2003; core location
					64	USEPA 2003; non-core location
	Bend Bridge		61	USEPA 2003; core location		
			64	USEPA 2003; non-core location		
	Red Bluff		61	USEPA 2003; core location		
			64	USEPA 2003; non-core location		
	Adult Immigration	Aug-Mar	Keswick		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
			Bend Bridge		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
			Red Bluff		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)

Species	Life Stage	Period	Location	Threshold (F)		Sources/Notes	
				Mean Monthly	7DADM ¹		
Steelhead (Cont)	Adult Holding	Sep-Nov	Keswick		61	USEPA 2003	
			Balls Ferry		61	USEPA 2003	
			Red Bluff		61	USEPA 2003	
Green Sturgeon	Spawning and Embryo Incubation	Mar-Jul	Bend Bridge	63		Upper end of optimal range for embryonic development (Van Eenennaam 2005)	
			Red Bluff	63			
			Hamilton City	63			
	Non-Spawning Adult Presence (Immigration, Pre and Post- Spawn Holding)	Aug-Feb	Bend Bridge		66		Assumes that adults are at least as tolerant to temperatures as larvae and juveniles
					73		Houston 1988; Erickson et al. 2002
			Red Bluff		66		Assumes that adults are at least as tolerant to temperatures as larvae and juveniles
					73		Houston 1988; Erickson et al. 2002
			Hamilton City		66		Assumes that adults are at least as tolerant to temperatures as larvae and juveniles
					73		Houston 1988; Erickson et al. 2002
		Year-round	Knights Landing		66		Assumes that adults are at least as tolerant to temperatures as larvae and juveniles
					73		Houston 1988; Erickson et al. 2002
	Larval to Juvenile Rearing and Emigration	Year-round	Bend Bridge	66		Upper end of optimal range for bioenergetics performance of Age 0/1 sturgeon with full or reduced food supply (Mayfield and Cech 2004)	
			Red Bluff	66			
			Hamilton City	66			
Knights Landing			66				

¹ 7DADM = Seven Day Average Daily Maximum
² Core = "moderate to high density" (USEPA 2003)
³ Non-core = "low to moderate density" (USEPA 2003)

Table 5.D-50. Water Temperature Thresholds Used for Water Temperature Threshold Analyses, American River

Species	Life Stage	Period	Location	Threshold (°F)		Source/Note
				Mean Monthly	7DADM ¹	
Steelhead	Spawning, egg incubation, and alevins	Dec-May	Hazel Avenue	53		from McCullough 2001
			Watt Avenue	53		from McCullough 2001
	Kelt emigration	Feb-May	Hazel Avenue		68	USEPA 2003
			Watt Avenue	70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
			Hazel Avenue		68	USEPA 2003
			Watt Avenue	70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
	Juvenile rearing	Year-round	Hazel Avenue	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005, and Beakes et al. 2014
					69	Sullivan 2000
			Hazel Avenue	63		intermediate value of ranges of optimal growth from Grabowski 1973; Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Myrick and Cech 2005, and Beakes et al. 2014
					69	Sullivan 2000
	Smoltification	Jan-Mar	Hazel Avenue	54		Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988
			Watt Avenue	54		Zaugg and Wagner 1973; Adams et al. 1975; Zaugg 1981; Hoar 1988
	Smolt Emigration	Dec-Jun	Hazel Avenue		61	USEPA 2003; core location ²
			Watt Avenue		64	USEPA 2003; non-core location ³
	Adult Immigration	Oct-Apr	Hazel Avenue		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
			Hazel Avenue		68	USEPA 2003
				70		Average of studies cited in Richter and Kolmes 2005 (for upper end of suboptimal range)
Adult Holding	Oct-Nov	Hazel Avenue		61	USEPA 2003	
		Watt Avenue		61	USEPA 2003	

¹ 7DADM = Seven Day Average Daily Maximum
² Core = "moderate to high density" (USEPA 2003)
³ Non-core = "low to moderate density" (USEPA 2003)

Table 5.D-51. Conversion Factors (°F) for EPA Seven-Day Average Daily Maximum Water Temperature Thresholds to monthly mean, Sacramento River¹.

Month	Keswick	Clear Creek	Balls Ferry	Bend Bridge	Red Bluff	Wilkins Slough ²
January	-0.36	-1.01	-0.75	-0.67	-0.86	0.0
February	-0.28	-1.11	-0.86	-0.62	-0.97	-0.3
March	-0.17	-1.29	-0.94	-0.66	-1.23	-0.3
April	-0.25	-1.66	-1.47	-0.95	-1.55	-0.6
May	-0.36	-1.73	-2.18	-1.59	-1.47	-1.4
June	-0.32	-1.55	-2.25	-1.87	-0.96	-1.2
July	-0.36	-1.41	-2.18	-2.01	-0.90	-1.3
August	-0.43	-1.74	-2.06	-1.61	-0.94	-1.3
September	-0.30	-2.00	-1.76	-1.16	-1.70	-2.0
October	-0.25	-1.73	-1.25	-0.91	-1.83	-1.4
November	-0.38	-1.37	-1.10	-0.99	-1.53	-1.3
December	-0.82	-1.42	-1.30	-1.24	-1.48	-1.0

¹ Based on historical data from 2003-2014 for all sites except Wilkins Slough, which is based on historical data from November 2012 through June 2015. For a given location and month, values in this table were added to 7DADM thresholds in Table 5.D-49 such that actual thresholds used in the evaluation for each month were lower than those listed in Table 5.D-49.

² Because there is no flow gage at Knights Landing, Wilkins Slough data were used to calculate the conversion factor for Knights Landing

Table 5.D-52. Conversion Factors (°F) for EPA Seven-Day Average Daily Maximum Water Temperature Thresholds to monthly mean, American River¹.

Month	Folsom Dam	Hazel Ave	William P Pond Park	Watt Ave
January	-0.74	-0.44	-1.16	-1.01
February	-0.44	-0.15	-1.28	-1.05
March	-0.55	-0.25	-1.71	-1.29
April	-0.80	-0.40	-2.09	-1.72
May	-0.89	-0.60	-2.32	-2.05
June	-0.55	-0.44	-2.32	-2.55
July	-1.09	-0.50	-2.61	-3.17
August	-2.07	-0.70	-3.01	-3.11
September	-1.54	-0.59	-3.02	-2.52
October	-1.46	-0.60	-2.53	-2.01
November	-1.82	-0.80	-2.01	-1.65
December	-1.10	-0.77	-1.51	-1.26

¹ Based on historical data from 2003-2014. For a given location and month, values in this table were added to 7DADM thresholds in Table 5.D-50 such that actual thresholds used in the evaluation were lower than those listed in Table 5.D-50.

5.D.2.1.2.3 Reclamation Egg Mortality Model

The Reclamation Egg Mortality Model was used to evaluate water temperature-related mortality to pre-spawned eggs, fertilized eggs, and pre-emergent fry of winter-run and spring-run Chinook salmon in the Sacramento River. Attachment 5.D-1, *Reclamation Egg Mortality Model*, describes the details of the model. NMFS believes this model underestimates temperature related