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[Article]

Effects of Catch-and-Release Angling on Salmonids at Elevated Water Temperatures

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Abstract.—Few studies have assessed catch-and-release mortality of salmonids at water temperatures of 23°C or above, despite predictions of warming stream temperatures due to climate change. The primary objective of this study was to measure the catch-and-release mortality of rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and mountain whitefish *Prosopium williamsoni* in three water temperature treatments, namely, when daily maximum water temperatures were cool (<20°C), warm (20–22.9°C), and hot (≥23°C). A secondary objective was to assess the catch-and-release mortality of salmonids angled in morning and evening within the water temperature treatments. These objectives were related to Montana Fish, Wildlife and Parks' drought fishing closure policy. Angling (fly-fishing only) occurred in the Gallatin and Smith rivers. All angled fish were confined to in-stream holding cages and monitored for mortality for 72 h. Mortality of rainbow trout peaked at 16% in the Gallatin River and 9% in the Smith River during the hot treatment. Mortality of brown trout was less than 5% in all water temperature treatments in both rivers. Mountain whitefish mortality peaked at 28% in the hot treatment in the Smith River. No mortality for any species occurred in either river when daily maximum water temperatures were less than 20°C. Mortality of rainbow trout peaked at 16% in the evening hot treatment in the Smith River. Mortality rates of brown trout and mountain whitefish were not related to time of day. The catch-and-release mortality rates presented here probably represent fishing mortality given that most anglers in southwestern Montana practice catch-and-release angling. The mortality values we observed were lower than predicted (<30%) given reports in the literature. The difference is probably related to the in situ nature of the study and periods of cooler water temperatures between peaks, which facilitated recovery from thermal stress.

Increasing stream temperature and decreasing stream discharge during the summer are predicted to occur throughout the U.S. Intermountain West in response to global climate change (Running and Nemani 1991; Keleher and Rahel 1996; Rieman et al. 2007). These changes may decrease the distribution of salmonids (Keleher and Rahel 1996; Rieman et al. 2007). Despite changes in climatic and stream conditions, angling for salmonids continues to be a popular recreational activity (USFWS 2007). For example, in Montana angler activity in the Madison River was 132,749 angler-days for salmonids from May through September in 2007 (MTFWP 2007).

In response to changes in stream abiotic conditions as a function of climate change and high angler use during summer months, Montana Fish, Wildlife and Parks established a drought fishing closure policy (DFCP). The policy states angling closures are warranted for waters containing salmonids (excluding bull trout *Salvelinus confluentus*) when daily maximum water temperature reaches or exceeds 23°C (73°F) for at least some period of time for three consecutive days. Closure options include time-of-day closures where angling is prohibited from 1400 until 2400 hours, and full closures where angling is prohibited at any time until reopening criteria have been met. Closed waters are considered for reopening when maximum daily water temperatures do not exceed 21°C (70°F) for three consecutive days. The DFCP was designed to protect fisheries from the effects of angling during periods of high water temperature and low discharge. The maximum water temperature threshold in the DFCP was based on biological opinion and a review of the effects of varying water temperature regimes on salmonids by McCullough (1999). However, maximum water temperatures currently observed in many

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rivers in southwest Montana during the summer exceed those reported in the review (28°C, USGS 2008a).

Catch-and-release angling is commonly used to reduce angling mortality in fish populations where angling pressure is high, fish densities are exceedingly low, or population demographics are such that even little fishing pressure will cause overharvest (Muoneke and Childress 1994; Wilde 1998; Lucy and Studholme 2002). In many parts of the Intermountain West catch and release is voluntary because of the negative angler attitudes regarding harvest of salmonids. Nevertheless, catch-and-release regulations or voluntary release are only effective if fish survive after being released (Wydoski 1977; Pollock and Pine 2007). Mortality rates for salmonids associated with catch-and-release angling using artificial baits are typically low (<10%) (Wydoski 1977; Muoneke and Childress 1994; Schisler and Bergersen 1996; see Arlinghaus et al. 2007 for a review); however, few studies assess the effects of in situ catch-and-release angling with artificial baits on salmonids at water temperatures above 20°C. Further, we are aware of no field studies that evaluate the effects of maximum diel temperatures of 23°C or above on salmonids.

The first objective of this study was to measure mortality of rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and mountain whitefish *Prosopium williamsoni* angled at water temperatures equal to or exceeding 23°C. This objective assessed the validity of closing streams once maximum daily water temperatures equaled or exceeded 23°C as outlined in the DFCP and determined whether the DFCP was aligned with contemporary water temperature data for southwest Montana streams. The second objective was to measure mortality of rainbow trout, brown trout, and mountain whitefish angled during morning or evening. This objective addresses the time-of-day closure outlined in the DFCP. That is, is closing streams to angling after 1400 hours effective at reducing mortality? We predicted mortality to be greater in this study than what has been reported in the literature given that water temperatures can reach 28°C in southwest Montana streams. Further, we predicted that mortality would be greater for fish angled in the afternoon during warmer water temperatures.

Study Site

The Gallatin and Smith rivers were selected for this study because both have popular salmonid fisheries and water temperatures reach or exceed 23°C. In addition, Montana Fish, Wildlife and Parks receive numerous reports of dead fish in the Smith River during summer months. The Gallatin River originates in Yellowstone National Park and flows 156 km northward to its confluence with the Madison and Jefferson rivers, near Three Forks, Montana. The Smith River originates in the Castle Mountains of central Montana and flows northwest approximately 195 km to its confluence with the Missouri River near Ulm, Montana.

Mean midsummer discharge was 18.9 m^3/s approximately 20 km upstream from the study reach in the Gallatin River from 2005 to 2007, and 1.4 m^3/s for the upper and 3.8 m^3/s for the lower study reaches in the Smith River in 2006 and 2007 (USGS 2008b, 2008c). Mean midsummer water temperature was 17.7°C for the study reach in the Gallatin River from 2005 to 2007 and 18.6°C for both study reaches in the Smith River in 2006 and 2007 (J. W. Boyd, unpublished data). Maximum daily water temperatures were at or exceeded 23°C for 37 d in the Gallatin River and 66 d in the Smith River from July 6 to August 6, 2006, and July 8 to August 13, 2007.

Methods

Water-temperature treatments.—Catch-and-release angling (fly-fishing only) was conducted during three water-temperature treatments. Treatments were defined by maximum daily water temperature: (1) cool treatment, daily maximum water temperatures were below 20°C; (2) warm treatment, daily maximum water temperatures varied from 20 to 22.9°C; and (3) hot treatment, daily maximum water temperatures were at or exceeded 23°C. Onset Hobo temperature loggers recorded water temperature hourly in each stream. Water temperature was recorded in the Gallatin River from July 20 to October 1, 2005, July 6 to October 1, 2006, and July 8 to October 1, 2007. Water temperature in the Smith River was recorded from June 28 to October 1, 2006, and June 10 to October 1, 2007. In addition, water temperature was measured in each in-stream holding cage (see description in next section).

Catch-and-release field experiment.—Catch-and-release angling occurred in the Gallatin River during April–October in 2005–2007 and in the Smith River during June–October in 2006 and 2007. Angling occurred on days during midsummer when daily maximum water temperatures were within those of the warm and hot treatments and on days during spring and autumn when water temperatures were within the regime of the cool treatment. Angling occurred in the same reaches throughout the study.

Sixty-four anglers were recruited from Trout Unlimited, Federation of Fly Fishers, and Montana State University. Angling experience varied from novice (<1 year) to experienced (>20 years). Gear used by anglers included 4–6-weight fly-fishing rods, floating fly line, various diameters of leader and tippet, and flies varying from size 2 to 20. Anglers could use any fly pattern and up to two flies (barbed or barbless) simultaneously. No restrictions were placed on anglers with regard to use of landing nets, amount of time to fight and land fish, or handling protocol (i.e., anglers were instructed to act as they normally would when angling recreationally).

Each angling day was divided into a morning and evening angling event and angling events were 4 h in duration. The morning event was centered on the lowest water temperature observed in the diel water temperature cycle (hereafter diel temperatures), which typically was at 0800 hours. The evening event was centered on the highest water temperature observed in diel temperatures, typically at 1800 hours. Eight in-stream holding cages were deployed on each angling day. Four of the eight cages were designated as morning-event cages while the remaining four were designated as evening-event cages. Cages were 1.2-m^3 polyvinyl chloride (PVC) pipe frames wrapped in 12.7-mm polyethylene mesh. An outer layer of 25.4-mm wire mesh was used to exclude predators. Cages were divided in half to separate fish less than 305 mm from those greater than 305 mm. A maximum of five fish greater than 305 mm and eight fish less than 305 mm were placed in each cage. All cages were anchored to the river bottom with rebar and mesh bags filled with large cobble. Cages were placed in depths greater than 61 cm and in areas where flow was maintained. Cages were paired (morning and evening) and located directly cross-current from each other to eliminate any contamination resulting from dead or dying fish. Water depth within each cage was measured to calculate volume and fish density.

Angling began at a predetermined time for each angling event and anglers dispersed themselves along the study reach. Each angler carried a portable, 43-L live bin that was temporarily anchored in the river, and each angled fish was unhooked and released into the live bin. Live bins were designed to be flow-through. Immediately after unhooking the fish, the angler contacted the nearest technician via two-way radio. The fish was then transferred to a 37-L polyethylene Bag-em Carry Bag and transported to the nearest in-stream holding cage. For each fish caught the angler recorded fight time (estimated only in 2006 and 2007), air exposure time (estimated only in 2006 and 2007), species, estimated length, time of day, transport time (2006 and 2007 only), and cage number where each fish was placed. Fight time was the amount of time from hook-set to landing. Air-exposure time was the amount of time the gills of the angled fish were exposed to air. For further information on fight and air-exposure time, see Boyd (2008). Transport time was the amount of time from release of fish into the live bin to release into an in-stream holding cage. After angling concluded, anglers recorded time angled and time not fished.

Mortality was assessed up to 72 h (Mongillo 1984; Dedual 1996) with cage inspections every 24 h. Mortalities included any fish unable to swim independently due to the onset of rigor, regardless of opercular movement. All mortalities were immediately removed from the cages. After 72 h, all remaining fish were anesthetized using clove oil (Anderson et al. 1997), weighed to the nearest 0.1 g, and measured to the nearest 1 mm. All fish in the Gallatin River (2005–2007) were tagged in the adipose eyelid tissue with VI alpha tags (Northwest Marine Technologies, Shaw Island, Washington) to estimate recapture rates, which were minimal. All fish were released at the cage location. All mortalities were weighed and measured using the above protocol. Dissolved oxygen was measured within cages periodically throughout the study.

Data analysis.—All data were analyzed using Statistical Analysis System (SAS 2003) and alpha was 0.10 for all analyses. Data were pooled for all years, as visual inspection of water temperature data suggested similar patterns among years. In addition, data were pooled for the study reaches in the Smith River. Initially, logistic regression was used to analyze binary data (mortality or survival) by maximum daily water temperature (continuous variable). However, relatively low mortality at the highest water temperatures precluded convergence of the logistic regression models. Thus, mortality estimates by species and river were calculated as the proportion of fish that died in a water temperature treatment (categorical variable) and one-tailed, upper confidence limits were calculated for these estimates (Muoneke 1992; Zar 1999). In addition, the water temperature treatments were designed to address our objectives related to the drought fishing closure policy. All mortality estimates were compared among water temperature treatments using a *G*-test (likelihood ratio chi-square) adjusted for low counts in contingency table cells (Zar 1999). Two-by-two contingency table pairwise comparisons were used when significant differences were detected (Siegel and Castellan 1988; Gotelli and Ellison 2004). Multiple regression was used to determine which variables (i.e., daily maximum temperature [continuous variable], transport time, fight time, and air exposure time) influenced mortality. Multiple regression was analyzed by species and river. All multiple regressions were analyzed for collinearity among explanatory variables. Transport times were compared among water temper-

TABLE 1.—Minimum, mean, and maximum water temperatures and range of diel water temperature by river and water temperature treatment.

		Water temperature (°C)			
River	Treatment	Minimum	Mean[a]	Maximum	Diel range
Gallatin	Cool	5.4	10.2 (0.3)	19.0	3.7
	Warm	13.0	18.4 (0.4)	22.8	7.2
	Hot	15.9	20.1 (0.5)	24.8	7.7
Smith	Cool	5.9	9.9 (0.3)	14.6	5.1
	Warm	12.3	17.8 (0.8)	22.9	8.7
	Hot	13.2	20.2 (0.4)	26.9	9.1

[a] The values in parentheses indicate the size of the 90% confidence interval, e.g., 10.2 ± 0.3.

TABLE 2.—Mean time in hours that water temperature was <20°C, 20–22.9°C, and ≥23°C within the warm and hot water temperature treatments by river during the study period; NA = not applicable.

River	Treatment	<20°C[a]	20–22.9°C[a]	≥23°C[a]
Gallatin	Warm	16.0 (1.8)	8.0 (3.5)	NA
	Hot	12.0 (1.7)	7.0 (2.9)	4.7 (4.2)
Smith	Warm	17.5 (5.1)	6.5 (4.1)	NA
	Hot	11.4 (1.7)	6.4 (1.6)	6.3 (1.3)

[a] The values in parentheses indicate the size of the 90% confidence interval, e.g., 16 ±1.8.

ature treatments by species and river using analysis of variance (ANOVA). Transport times for individual fish on a given angling day were treated as subsamples for that day. Pearson product-moment correlation was used to analyze the relationship between number of fish and number of mortalities in cages.

Results

Water Temperature

During the study period, daily maximum water temperature reached or exceeded 23°C for 44 d in the Gallatin River (2005–2007) and 66 d in the Smith River (2006–2007). Mean number of days per year when water temperature was within the hot treatment was 15 d in the Gallatin River and 33 d in the Smith River. Mean number of days per year when water temperature was within the warm treatment was 30 d in the Gallatin River and 47 d in the Smith River. Water temperature did not exceed 20°C from approximately mid-September to mid-May in either river for any year.

Mean daily water temperature was similar between rivers within treatments (Table 1). Range of diel water temperature increased from cool to hot water temperature treatments in both rivers and fluctuated 1.4°C less in the Gallatin River than in the Smith River within the hot treatment (Table 1). Similarly, diel temperatures within warm and cool treatments fluctuated less in the Gallatin River than in the Smith River (Table 1). On average, water temperature was at or exceeded 23°C (i.e., within the hot treatment) for 1.6 h longer per day in the Smith River than in Gallatin River (Table 2). Conversely, water temperatures remained between 20°C and 22.9°C (i.e., within the warm treatment) about 1.5 h longer per day in the Gallatin River than in Smith River (Table 2).

Angling

Five hundred and twenty-one fish were angled in the Gallatin River during 16 angling days, and 687 fish were angled in the Smith River during 14 angling days (Table 3). Mean length of all species was similar among water temperature treatments within river (Table 3). The number of angling days varied among water temperature treatments from 3 to 9 d in the Gallatin River and from 2 to 7 d in the Smith River (Figures 1, 2). Mean number of anglers per day varied from five to eight and was similar among treatments and between rivers. Mean transport time was similar among water temperature treatments for all species in both rivers (overall mean = 5.2 min; see Boyd 2008 for more information). Density of fish within cages was less than 14 fish/m^3 for both rivers. Number of fish and number of mortalities in a cage were not significantly correlated: Gallatin River hot ($P = 0.30$, $N = 18$, $r = 0.25$) and warm ($P = 0.85$, $N = 32$, $r = -0.03$) treatments, and Smith River hot ($P = 0.15$, $N = 51$, $r = 0.20$) and warm ($P = 0.20$, $N = 15$, $r = 0.35$) treatments.

Mortality of rainbow trout differed significantly among water-temperature treatments in the Gallatin River ($\chi^2 = 9.38$, df = 2, $P < 0.01$) and Smith River ($\chi^2 = 8.91$, df = 2, $P = 0.01$) (Figure 3). Mortality of rainbow trout was greater in the hot (16%) than in the cool treatment (0%) in the Gallatin River. In the Smith River, mortality was greater in the hot (9%) and warm (8%) treatments than in the cool treatment (0%). Mortality differed significantly among water temperature treatments for brown trout ($\chi^2 = 6.17$, df = 2, $P = 0.09$) in the Smith River (Figure 3). Mortality of brown trout angled in the hot treatment (4%) was greater than in the cool treatment (0%). Mountain whitefish mortality differed significantly ($\chi^2 = 44.53$, df = 2, $P < 0.01$) in the Smith River (Figure 3). Mortality of mountain whitefish angled in the hot (28%) and warm treatments (20%) was greater than in the cool treatment (0%). The majority (>76%) of rainbow trout, brown trout, and mountain whitefish mortality occurred within 48 h in both rivers.

Mortality did not differ significantly between morning and evening angling events in any water temperature treatment for any species in the Gallatin River (Figure 4). Mortality of rainbow trout in the

TABLE 3.—Number and mean length of fish angled by water temperature treatment, species, and river.

		Gallatin River		Smith River	
Treatment	Species	*N*	Length[a]	*N*	Length[a]
Cool	Rainbow trout	48	245 (15)	57	324 (14)
	Brown trout	142	263 (10)	78	281 (13)
	Mountain whitefish	45	380 (13)	131	323 (10)
Warm	Rainbow trout	35	224 (14)	53	288 (15)
	Brown trout	109	239 (10)	37	302 (19)
	Mountain whitefish	36	350 (14)	5	344 (41)
Hot	Rainbow trout	25	230 (15)	161	282 (11)
	Brown trout	52	251 (13)	101	279 (14)
	Mountain whitefish	29	379 (20)	64	295 (15)

[a] The values in parentheses indicate the size of the 90% confidence interval, e.g., 245 ± 15.

Smith River differed significantly between morning and evening angling events for the hot treatment ($\chi^2 = 8.43$, df $= 1$, $P < 0.01$; Figure 5). Mortality of rainbow trout was greater in evening than in morning events for the hot treatment.

Many fish of all three species survived at water temperatures where mortality occurred. Thus, logistic regression models would not converge on the binary data (mortality or survivor) by maximum daily water temperature for either river. Mortality for all species in both rivers started to occur when daily maximum water temperature reached 21.7–22°C, except for brown trout in the Smith River, where mortality started to occur when daily maximum water temperature reached 24°C.

Air exposure time, fight time, and maximum daily water temperature were significant variables in some of the multiple regression models (Table 4). No variables were significant in explaining variation in mortality for rainbow trout and brown trout in the Gallatin River. Air exposure time explained 45% of the variation in mountain whitefish mortality in the Gallatin River, while water temperature was nonsignificant. Fight time was a significant variable in explaining the variation in mortality of brown trout and mountain whitefish in the Smith River; however, the relationship was inverse. With fight time removed, maximum daily water

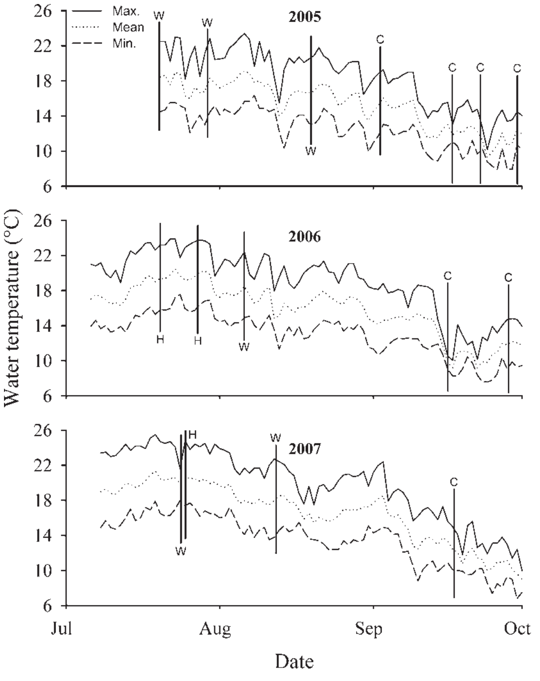

FIGURE 1.—Maximum, mean, and minimum daily water temperatures for the Gallatin River, 2005 (July 20–October 1), 2006 (July 6–October 1), and 2007 (July 8–October 1). Bold vertical lines indicate angling days and letters indicate water temperature treatment (H = hot, W = warm, and C = cool). Cool-treatment angling days on April 22, 2006, and April 15, 2007, are not shown.

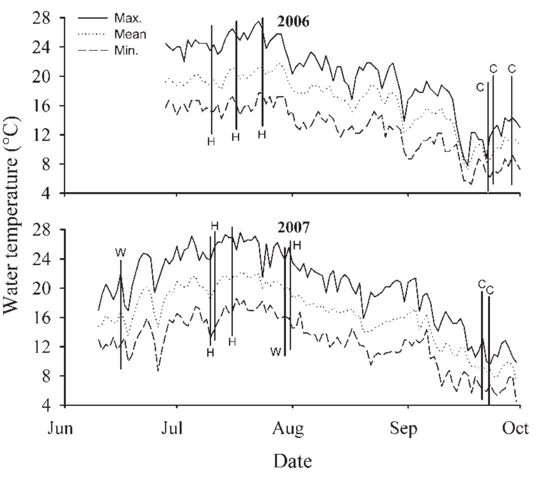

FIGURE 2.—Maximum, mean, and minimum daily water temperatures for the Smith River, 2006 (June 28–October 1) and 2007 (June 10–October 1). Bold vertical lines indicate angling days and letters indicate water temperature treatment (H = hot, W = warm, and C = cool).

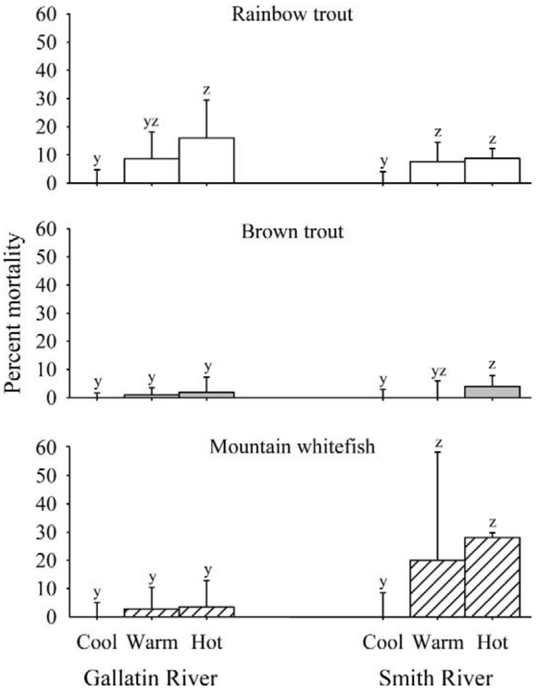

FIGURE 3.—Percent mortality by river, species, and water temperature treatment. Different letters indicate significant differences in mortality among treatments by species and river.

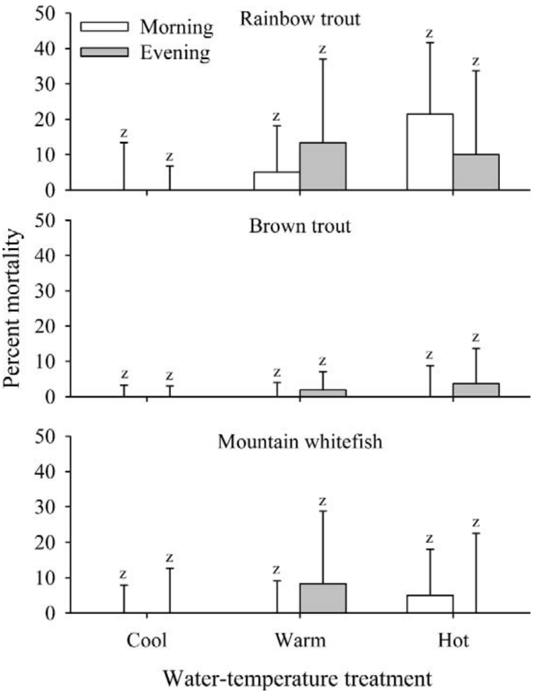

FIGURE 4.—Percent mortality for morning and evening angling events by species and water temperature treatment in the Gallatin River, 2005–2007. No significant differences in mortality were found.

temperature was a significant variable in the model for all species in the Smith River (Table 4).

Discussion

Many catch-and-release angling studies assessing mortality of salmonids are conducted at near-constant water temperatures; however, fish respond differently to diel temperatures than to constant water temperature (Hokanson et al. 1977). For example, rainbow trout acclimated to diel temperatures exhibited increased resistance to higher temperatures when periods of cooler water were present between water temperature peaks (Hokanson et al. 1977). Bonneville cutthroat trout *O. clarkii utah* were able to survive at lethal temperature (26°C) because the lethal temperature was cycled with cooler temperatures (Johnstone and Rahel 2003; Schrank et al. 2003). One of the unique aspects of this study is that it was conducted at varying peak water temperatures with concomitant diel temperature fluctuations. Thus, although water temperature peaked near 27°C in the hot treatments, mean water temperature was near 20°C. Further, the range of diel temperatures within the hot treatment in this study was up to 9.1°C. Although fish in this study were exposed to high maximum diel water temperatures, they were also exposed to longer periods of cooler water temperatures. Longer durations in cooler water temperatures allow fish to "repair" physiological damage (Meyer et al. 1995), thus potentially reducing catch-and-release angling mortality.

Mortality of rainbow trout and brown trout angled in the hot treatment in this study was lower than the few comparable studies assessing mortality of salmonids exposed to diel temperatures. For example, mortality of Atlantic salmon *Salmo salar* angled in 20 ± 2°C water was 40% (Wilkie et al. 1996). In a similar study, mortality of Atlantic salmon angled in identical water temperatures was 80%, although this estimate was based on five fish (Andersen et al. 1998). Minimum diel temperature in the two previous studies was 18°C, approximately 2°C and 5°C warmer than minimum diel temperatures in the hot treatment in the Gallatin and Smith rivers, respectively. Higher minimum diel temperatures probably contributed to increased mortality of Atlantic salmon relative to mortality of rainbow trout and brown trout in this study.

Differences in mortality of salmonids in previous catch-and-release angling studies and this study could

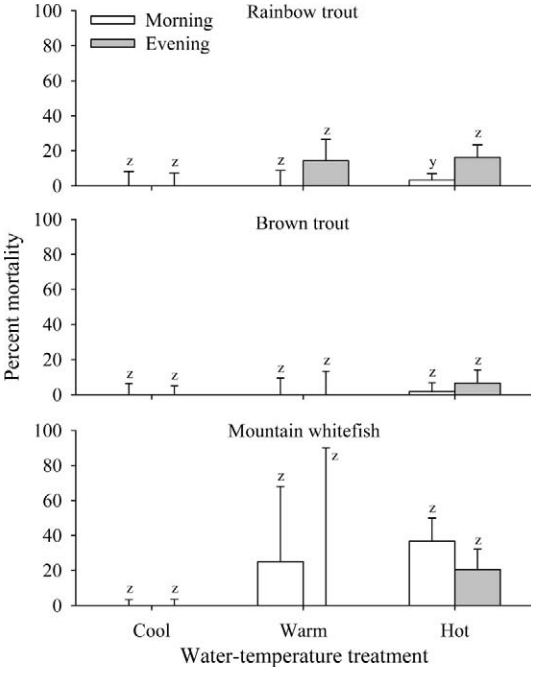

FIGURE 5.—Percent mortality for morning and evening angling events by species and water temperature treatment in the Smith River, 2006–2007. Different letters indicate significant differences in mortality between angling events by species and treatment.

be attributed to several factors. First, fish species exhibit different thermal tolerances (Beitinger et al. 2000). For example, upper lethal temperatures for Lahontan cutthroat trout *O. clarkii henshawi* are between 22°C and 24°C (Dickerson and Vinyard 1999) and between 25°C and 27°C for rainbow trout (Hokanson et al. 1977; Kaya 1978; Bear et al. 2007). Angling stress on Lahontan cutthroat trout at 21°C is probably more severe than angling stress on rainbow trout at 21°C. Mortality of brown trout angled with flies is lower than mortality for other salmonids (Taylor and White 1992), probably because upper lethal temperatures for brown trout (29–30°C) are higher than for most salmonids (Elliott 1981; Elliott and Elliott 1995). Upper lethal temperatures for mountain whitefish have not been defined. However, weekly mean temperature tolerances for mountain whitefish were estimated at 23.1°C and are lower than rainbow trout and brown trout (Eaton and Scheller 1996). Second, thermal history largely dictates the acclimatization state in fish (Fry 1971). Responses of fish within the same species to a temperature stressor vary depending on acclimation temperature. For example, upper lethal temperature was greater for sockeye salmon *O. nerka* acclimated to 16°C than to 8°C (Brett 1952). Thus, differences in thermal history among and within species of salmonids can potentially influence responses to catch-and-release angling at varying temperatures.

No catch-and-release angling mortality was observed for any species in either study river when water temperatures were less than 20°C. The lack of mortality at this temperature was surprising given that several studies have shown mortality rates of salmonids associated with fly-fishing are 2–5% at cooler water temperatures (Muoneke and Childress 1994; Schisler and Bergersen 1996). However, no mortality occurred in fly-caught Atlantic salmon angled at 16.5 ± 1°C and 8 ± 1°C (Andersen et al. 1998).

Differences in mortality of mountain whitefish between study rivers may be attributable to the range of diel temperature and dose or exposure to maximum diel temperature. Range of diel temperature within the hot treatment was 1.4°C greater in the Smith River than the Gallatin River. Small increases in range of diel temperature and duration of maximum diel temperatures could have a greater effect on mountain whitefish compared with other species with higher thermal limits. Mountain whitefish were exposed to daily doses of water temperatures at or exceeding 23°C for almost 2 h longer in the Smith River than in the Gallatin River and

TABLE 4.—Multiple regression models for factors influencing mortality, by species and river. The independent variables are as follows: air = air exposure time, fight = fight time, and temp = daily maximum water temperature.

River	Species	Model	*P*-value	r^2
Gallatin	Rainbow trout	No model		
	Brown trout	No model		
	Mountain whitefish	−0.24 + 0.03(air)	0.03	0.45
Smith	Rainbow trout	No model		
	Brown trout	0.61 − 0.01(fight)	0.04	0.31
	Mountain whitefish	−0.12 − 0.009(fight) + 0.05(temp)	<0.01	0.77
Smith River (without fight time included in the model)				
	Rainbow trout	−0.23 + 0.02(temp)	<0.01	0.56
	Brown trout	−0.01 − 0.02(air) + 0.01(temp)	0.06	0.39
	Mountain whitefish	−0.51 + 0.04(temp)	<0.01	0.47

were exposed for over twice as long to temperatures at or exceeding 23°C during midsummer in the Smith River than in Gallatin River. Longer dose and exposure times probably contributed to increased levels of catch-and-release angling mortality of mountain whitefish in the Smith River compared with the Gallatin River.

Mortality of rainbow trout was greater in evening than in morning angling events when daily maximum water temperatures reached or exceeded 23°C in the Smith River; however, no patterns in mortality were observed for brown trout and mountain whitefish between morning and evening angling events. Given higher thermal tolerances of brown trout relative to other salmonids, maximum diel temperatures in this study may have not been high enough to cause mortality from catch-and-release angling. Conversely, maximum diel temperatures were probably close to upper thermal tolerances of mountain whitefish, thus affecting mortality of mountain whitefish to a greater extent, regardless of time of day mountain whitefish were angled. Upper thermal limits for rainbow trout are lower than those for brown trout, yet probably greater than those for mountain whitefish. Water temperatures approached upper thermal limits of rainbow trout in some evening angling events, probably contributing to increased mortality relative to morning angling events.

Mean times for handling variables (i.e., transport, fight, and air exposure) were similar among water temperature treatments and between rivers; thus, handling variables were not informative in explaining the variation in mortality for any species. Interestingly, air-exposure time was an important variable for mountain whitefish in the Gallatin River, although no significant increases in mortality were observed among water temperature treatments. Mean fight times were less than 80 s for all species in all water temperature treatments; this is well below the 180 s that is reported to significantly increase physiological disturbance in angled rainbow trout (Wydoski 1977). In a previous study, mortality of angled rainbow trout exposed to air for 30 and 60 s was 38% and 72%, respectively (Ferguson and Tufts 1992). However, mean air exposure times in this study were generally below 19 s. Mean time of air exposure for mountain whitefish within the warm treatment in the Smith River was 26 s; however, the estimate was based on five fish and should be interpreted with caution.

No control fish were used to account for potential cage × temperature interactions at water temperatures higher than 20°C in this study. Thus, a cage effect on mortality cannot be unequivocally ruled out and results from this study should be interpreted with caution. Ideally, fish caught with another gear type other than hook and line (e.g., electrofisher, seine) could be used for controls; however, true control fish must be collected without inducing mortality in a catch-and-release study (Muoneke 1992; Pollock and Pine 2007). It is unlikely that electrofishing or seining could be conducted in water temperatures higher than 20°C without inducing some mortality. The use of hatchery-reared fish as controls was another possibility, although behavioral differences between hatchery and wild fish are well documented and would probably not provide insight into potential cage effects (Pollock and Pine 2007). Maximum fish densities within cages in this study were below densities reported in several other published catch-and-release studies that used similar-sized salmonids (Titus and Vanicek 1988; Dubois and Dubielzig 2004). Further, mortality was not correlated with density of fish within individual cages and no mortality occurred at water temperatures less than 20°C in this study, suggesting the cage × temperature interactions were probably negligible.

This study assessed immediate and short-term mortality (<72 h) of rainbow trout, brown trout, and mountain whitefish. Mortality beyond 72 h could have occurred due to indirect effects of catch-and-release angling. For example, angled fish may be unable to avoid predators because of injury or exhaustion (Burns and Restrepo 2002). Cage studies prevent predation following release, thus potentially underestimating catch-and-release angling mortality. Another indirect effect of stress resulting from catch-and-release angling is increased susceptibility to disease (Pickering 1981; Schreck 2000). Fish may succumb to disease days or weeks after being stressed. However, 90% of catch-and-release angling mortality occurs within 48 h (Mongillo 1984) and the results from this study were similar.

Montana Fish, Wildlife and Parks full angling closure policy appears warranted given the objective. Catch-and-release mortality of rainbow trout and mountain whitefish increased when daily maximum water temperature was higher than 20°C and mortality of brown trout increased when daily maximum water temperature was at or exceeded 23°C. The time-of-day angling closure was supported by the rainbow trout data from the hot treatment in the Smith River, although the lack of a relationship between mortality and the time of day at which other species were angled may be a function of small sample size. Estimation of the amount of mortality that would elicit a population-level response was beyond the scope of this project. However, these values probably represent fishing mortality given that most anglers in southwest Montana practice catch-and-release angling. The angling mortality for mountain whitefish in the Smith River is certainly cause for concern and warrants further research. With the predicted increase in summer temperatures associated with global climate change it is reasonable to expect that the duration of daily cool-temperature periods will decrease. The decrease in time suitable for recovery will certainly influence all salmonids and probably mountain whitefish the most.

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