EFFECTS OF WATER TEMPERATURE AND ANGLING ON MORTALITY OF SALMONIDS IN MONTANA STREAMS

by

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency, and is ready for submission to the Division of Graduate Education.

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ABSTRACT

In Montana, angling closures are used to protect salmonids from the deleterious impacts of angling at elevated water temperatures (≥23°C). Catch-and-release angling (CR) studies have reported high levels (30-40%) of salmonid mortality at water temperatures >20°C, but few studies assess CR mortality of salmonids at water temperatures observed in Montana streams during mid-summer (≥23°C). The primary objective of this study was to measure CR mortality of rainbow trout, brown trout, and mountain whitefish in three water temperature treatments; when daily maximum water temperatures were cool (<20°C), warm (20 to 22.9°C), and hot (≥23°C). A secondary objective was to assess CR mortality of salmonids angled in morning and evening within water temperature treatments. Based on the literature, mortality of salmonids was predicted to be >30% within the hot treatment and higher in evening than morning. 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 *Oncorhynchus mykiss* increased to 9% and 16% in warm and hot treatments, respectively. Mortality of brown trout *Salmo trutta* was (4%) in the hot treatment in the Smith River. Mountain whitefish *Prosopium williamsoni* had increased mortality in the warm (20%) and hot (28%) treatments in the Smith River. No mortality for any species occurred in either river when water temperatures were <20°C. Mortality of rainbow trout angled in evening was higher than morning in the warm (14%) and hot (16%) treatments in the Smith River. Laboratory results indicated rainbow trout stressed in evening had higher mortality (7%) than those stressed in morning (0%). Angler catch rates were lower for most species in evening than morning angling events; however, catch rates remained high (0.7 fish/h) in several evening angling events. Study results indicate that salmonid mortality rates associated with catch-and-release fly-fishing are higher at elevated (≥23°C) water temperatures. Although there was a relationship between elevated water temperature and salmonid mortality, most of the mortality estimates were well below the 30% mortality that was predicted.

INTRODUCTION

Southwest Montana is a destination for anglers around the world because of the high-quality angling experience. In 2005, southwest Montana had 550,472 angler days (MTFWP 2008a). The Gallatin and Smith rivers are two popular fishing destinations and have trout abundances (rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta*) greater than 1,500 fish/mile (NRIS 2008a). Angling pressure increased 14% for the Gallatin River from 76,834 angler days in 1999 to 87,225 angler days in 2005 and increased 35% for the Smith River from 20,192 angler days in 1999 to 27,286 angler days in 2005 (MTFWP 2008b, 2008c).

Concurrent with the increase in fishing pressure, discharge has declined and water temperature has increased in southwest Montana streams because of drought conditions since 1999. Mean annual discharge declined 25% in the Gallatin River (USGS 2008a) and 52% in the Smith River during drought years (USGS 2008b). Mean summer water temperature increased 0.5°C for the Gallatin River from 2001 to 2007 and 1.1°C for the Smith River from 1996 to 2007 (USGS 2008a, 2008b). In addition, fluctuations in water temperature are greatest during summer, in part because of relatively low discharge and maximum solar radiation input (Beschta et al. 1987). Drought has also increased irrigation withdraw resulting in further decline of stream discharge and increase in water temperature (NRIS 2008b).

Catch-and-release angling (CR) has gained considerable popularity among anglers and fisheries managers, particularly in the past two decades (Lucy and Studholme 2002). Shifts in angler attitudes regarding harvest and increasing use of restrictive harvest regulations by natural resource agencies have promoted CR (Pollock and Pine 2007). Fisheries managers use CR to reduce angling mortality in fish populations where angling pressure is high, fish densities are exceedingly low, or population demographics are such that little fishing pressure will cause over-harvest (Muoneke and Childress 1994; Wilde 1998; Lucy and Studholme 2002). However, catch-and-release regulations are only effective if angled fish survive after being released (Wydoski 1977; Pollock and Pine 2007). Most trout anglers in Montana practice voluntary catch-and-release.

Salmonids angled in elevated water temperatures experience a suite of hormonal, energetic, and ionic changes (Wood 1991; Kieffer 2000; Suski et al. 2004) and increase anaerobic activity in white musculature leading to increased lactate concentrations in blood and muscle (Wood et al. 1983). Blood acidosis is one result of increased lactate concentrations and negatively influences gill function (Tufts et al. 1991). As water temperature increases the solubility of oxygen decreases (Wetzel 2001). The decrease in oxygen solubility and increased disruption of ion exchange in fish gills in warm water temperatures have negative physiological effects and can result in death (Brett 1964; Fry 1971; Thorstad et al. 2003).

A multitude of studies have examined mortality of salmonids resulting from CR. Mortality in these studies vary widely (0-80%), due to factors such as bait type (Pauley and Thomas 1993; Muoneke and Childress 1994; Cooke and Suski 2005), hook design (Nuhfer and Alexander 1989; Taylor and White 1992; Jenkins 2003; DuBois and Dubielzig 2004; Cooke and Suski 2004; Cooke and Suski 2005), angling technique (Dedual 1996; Schill 1996; Schisler and Bergersen 1996; Grover et al. 2002), hooking location (Hulbert and Engstrom-Heg 1980; Lindsay et al. 2004), and water temperature (Marnell and Hunsaker 1970; Dotson 1982; Loftus et al. 1988; Titus and Vanicek 1988; Taylor and White 1992; Lee and Bergerson 1996; Wilkie et al. 1996; Andersen et al. 1998; Dempson et al. 2002; Thorstad et al. 2003). Hooking location is currently considered the most important variable affecting mortality in CR studies (Arlinghaus et al. 2007), where probability of mortality increases following hooking in sensitive areas (esophagus or gills) (Pelzman 1978; Aalbers et al. 2004). Hooking location is controlled in part by bait type, with natural baits typically resulting in deeper hooking and artificial baits (i.e., lures and flies) more superficial hooking (Muoneke and Childress 1994; Schisler and Bergersen 1996; Arlinghaus et al. 2007).

Mortality rates for salmonids associated with catch-and-release fishing using artificial baits are typically low (<10%) (Wydoski 1977; Muoneke and Childress 1994; Schisler and Bergersen 1996; Arlinghaus et al. 2007); however, few studies assess the effects of CR with artificial baits on salmonids at water temperatures >20°C. Catch-and-release mortality of Atlantic salmon *Salmo salar* caught on lures and flies was low (<10%) at water temperatures up to 18°C (Thorstad et al. 2003), but was 40 and 30% when water temperatures were 22 and 23°C, respectively (Wilkie et al. 1996; Wilkie et al. 1997). Mortality of Lahontan cutthroat trout *O. clarki henshawi* caught with lures was less than 10% when water temperatures were below 18°C and increased to 50% when water temperatures were 21°C (Titus and Vanicek 1988). These studies suggest CR mortality rates for salmonids caught with lures and flies remain below 10% at cooler water temperatures but increase rapidly at water temperatures above 20°C.

In response to increasing angling pressure, decreasing stream discharge, and increasing stream temperatures (stream temperatures exceeding 23°C during the summer), Montana Fish, Wildlife and Parks implemented a Drought Fishing Closure Policy (DFCP). The DFCP was designed to protect fisheries from the impacts of CR during periods of warm water temperature. The policy states angling closures are warranted for waters containing salmonids (excluding bull trout *Salvelinus confluentus*) when daily maximum water temperature reaches or exceeds 73°F (23°C) for at least some period of time during three consecutive days. Closure options include time-of-day closures where angling is prohibited from 2:00 PM until 12:00 AM (midnight), 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 temperature criteria in the DFCP are based on data from the literature with regard to salmonid angling mortality and water temperature. However, maximum water temperatures currently observed in many rivers in southwest Montana during summer (USGS 2008c) exceed those reported in the literature ($\leq$23°C).

Thus, the objectives of this study were two-fold. First, to measure mortality of salmonids angled at water temperatures equal to or exceeding 23°C and second, to measure mortality of salmonids angled during morning or evening. The first objective assesses the validity of closing streams once maximum daily water temperatures equal or exceed 23°C as outlined in the DFCP. The second objective addresses the Time-of-Day closure outlined in the DFCP. Based on previous studies (Titus and Vanicek 1988;

Wilkie et al. 1996; Wilkie et al. 1997; Thorstad et al. 2003), I predicted mortality of salmonids would exceed 30% at water temperatures $\geq 23°C$. Further, mortality would be highest during evening angling events because water temperatures typically peak between 1700 and 1900 hours in Montana streams.

STUDY SITE

The Gallatin and Smith rivers were selected for this study given 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. Given time and logistic constraints, only two study rivers were sampled; however, both rivers are representative of the popular salmonid fisheries in southwest Montana. 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. Portions of both study rivers flow through open, glacial valleys with canopy vegetation dominated by broadleaf and coniferous trees (NRIS 2008c). Agricultural land use predominates and irrigation withdraw reduces water levels in both rivers, particularly during mid-summer (NRIS 2008b, 2008c). The study reach on the Gallatin River occurred near Belgrade, Montana at river kilometers (rkms) 41-43 from 2005 to 2007. The study reaches on the Smith River occurred at rkms 111-112.5 and rkms 144-146 in 2006 and 2007. The study reach on the Gallatin River and lower study reach on the Smith River were accessed through private property and allowed angling on sections of stream with less angling pressure. Private access also ensured minimal disturbance of fish within in-stream holding cages (see description in Catch-and-Release Field Experiment section in Methods). The upper study reach on the Smith River was accessed through a Montana, Fish, Wildlife and Parks Fishing Access Site and had unlimited access.

Angling pressure on the Gallatin River between rkms 15-83 has remained above 32,000 angler days since 1999 (MTFWP 2008b). Angling pressure on the Smith River between rkms 39-130 increased 86% from 7,645 angler days in 1999 to 14,188 angler days in 2005 and increased 8% between rkms 130-195 from 8,223 angler days in 1999 to 8,860 angler days in 2005 (MTFWP 2008c). Mean mid-summer discharge was 18.9 m^3/s approximately 20 km above 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 2008a, 2008b). Mean mid-summer 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 (unpublished data). Maximum daily water temperatures were $\geq$23°C for 37 d in the Gallatin River and 66 d in the Smith River from July 6 – August 6, 2006 and July 8 – August 13, 2007.

In-stream habitat for all study reaches was characterized by pool-riffle complexes; gravel, cobble, and bedrock substrate; large woody debris; and undercut banks. Salmonids present in both study rivers are rainbow trout, brown trout, mountain whitefish *Prosopium williamsoni*, and brook trout *Salvelinus fontinalis*. Arctic grayling *Thymallus arcticus* and Yellowstone cutthroat trout *O. c. bouvieri* also occurred in the Gallatin River. Other species present in the study rivers included burbot *Lota lota*, fathead minnow *Pimephales promelas*, flathead chub *Platygobio gracilis*, common carp *Cyprinus carpio*, stonecat *Noturus flavus*, longnose dace *Rhinichthys cataractae*, longnose sucker

Catastomus catastomus, mottled sculpin *Cottus bairdi*, mountain sucker *Catastomus platyrhynchus*, and white sucker *Catastomus commersoni* (MTFWP 2008b, 2008c).

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: cool treatment- daily maximum water temperatures were below 20°C, warm treatment- daily maximum water temperatures varied from 20 to 22.9°C, and hot treatment- daily maximum water temperatures $\geq$23°C. Onset Hobo® temperature loggers recorded water temperature hourly in each stream. Water temperature was recorded in the Gallatin River from July 20 – October 1, 2005, July 6 – October 1, 2006, and July 8 – October 1, 2007. Water temperature in the Smith River was recorded from June 28 – October 1, 2006 and June 10 – October 1, 2007. In addition, water temperature was measured in each in-stream holding cage (see description in Catch-and-Release Field Experiment section below).

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 mid-summer when daily maximum water temperatures were within warm and hot treatments and on days during spring and autumn when water temperatures were within 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 experience). 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 were free to 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.

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), typically at 0800. The evening-event was centered on the highest water temperature observed in diel temperatures, typically at 1800. Eight in-stream holding cages were deployed on each angling day. Four of the eight cages were designated morning-event cages while the remaining four were designated 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 5 fish >305 mm and 8 fish <305 mm were placed in each cage. All cages were anchored to the river bottom using rebar and mesh bags filled with large cobble. Cages were placed in depths greater than 61 cm and in areas that maintained flow. Cages were paired (morning and evening) and located directly cross-current from each other to eliminate any contamination resulting from dead or dying fish (Figure 1).

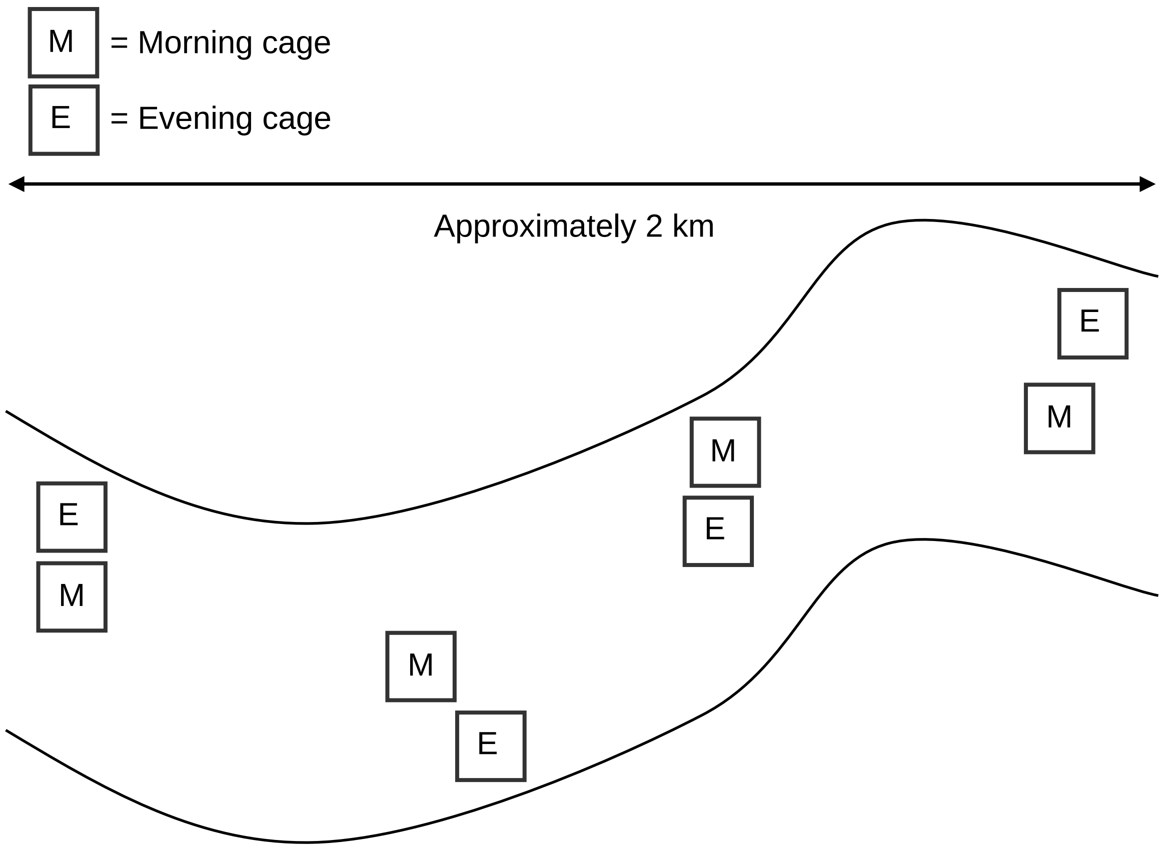

Figure 1. Schematic of a study reach with in-stream holding cages paired by morning and evening.

Water depth within each cage was measured to calculate volume and fish density.

Angling began at a predetermined start 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 following unhooking, 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, length (estimated), time of day, transport time between live bin and in-stream holding cage (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. 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. Angler catch rates were calculated by species, treatment, and river from angler data cards.

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, measured to the nearest mm, and 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.

Laboratory Study

A laboratory experiment was conducted at the U.S. Fish and Wildlife Service Bozeman Fish Technology Center (BFTC) to assess the effects of water temperature and stress from angling on mortality of rainbow trout. Rainbow trout reared at the BFTC were used in this study. All rainbow trout were held in two rectangular 2400 L aluminum tanks at 14°C prior to the experiment. Fish were fed 2% body weight daily with automatic belt feeders each weekday and were not fed on weekends. Tanks were manually cleaned and drawn down approximately 80% by volume daily to flush metabolites. Flow rate in the tanks was 64 L/min and dissolved oxygen levels were between 7.5 and 8 ppm.

Water supplied from cold (8°C) and warm (22°C) springs, and water heated with a 21 Kw electric heater was mixed to achieve varying water temperatures from 14 to 25°C in a 426 L mixing tank. The mean diel temperatures from the hot treatment in the Smith River (hereafter target diel temperatures; 16-24.5°C), 2006-2007 were reproduced in the lab. Target diel temperatures were produced by utilizing a programmable digital temperature controller, solenoid valve (warm water input), and float valve (cold water input) to regulate timing and quantity of cold and warm water mixing (Figure 2). Water in the mixing tank was aerated using pure oxygen with a diffusing stone and pumped into twelve 284 L treatment tanks at a rate of 3.8 L/min per tank. Turnover time for each treatment tank was 72 min. Dissolved oxygen levels were between 5.9 and 8 ppm and oxygen saturation varied from 83 to 111% (mean = 92%). Mean nitrogen saturation was 95% (range 18%). Total gas saturation varied from 87 to 101% (mean 94%).

Five fish were randomly assigned to each treatment tank and gradually acclimated from 14°C to target diel temperatures over 11 d (Figure 3). Water temperature remained at 14°C on day 1 allowing fish to acclimate to the treatment tanks. Water temperature was increased 2°C per day (2°C rise in temperature over 24 h) until 20°C was obtained on day 5. Water temperature remained at 20°C for days 5 and 6,

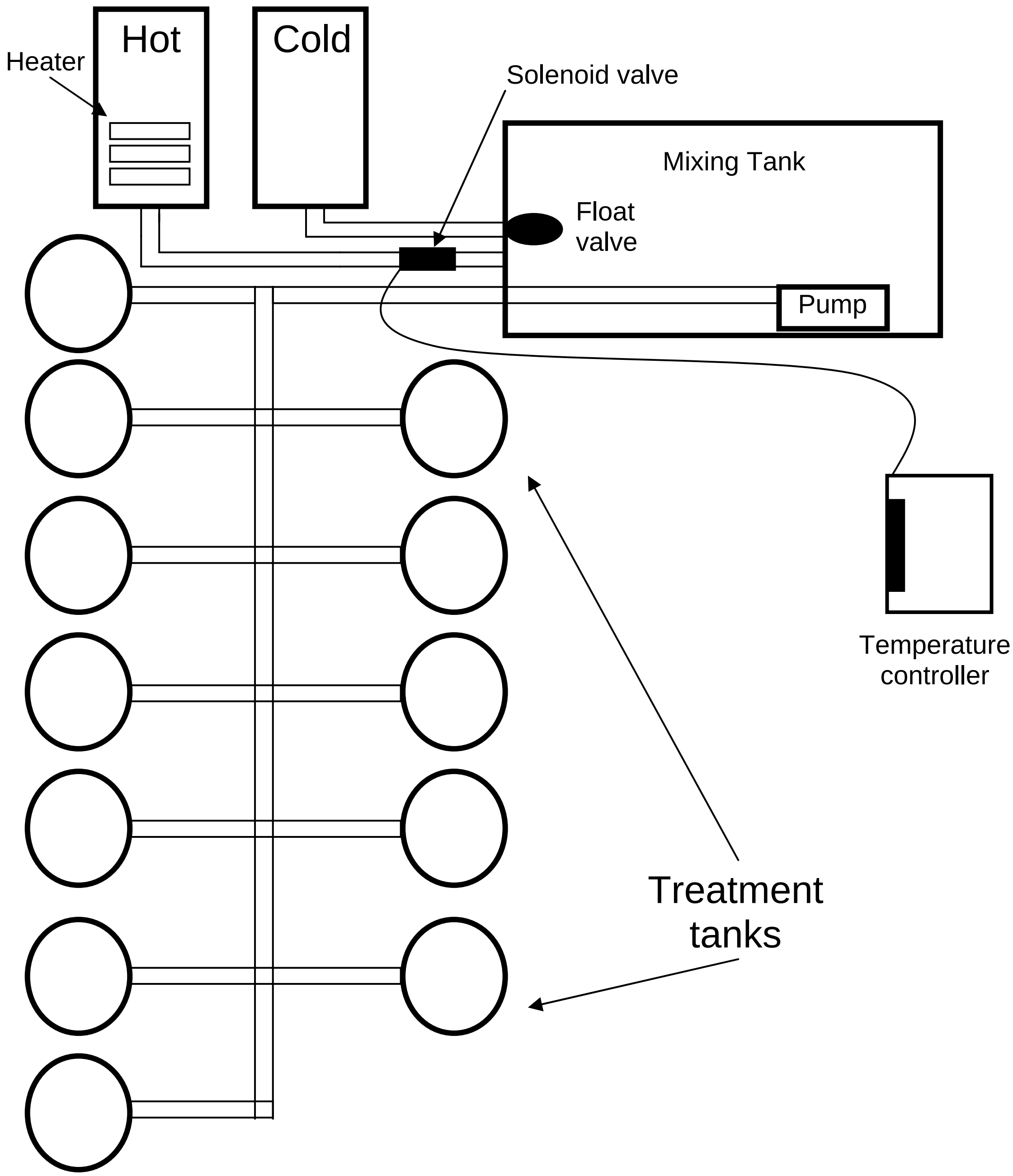

Figure 2. Schematic of laboratory design with hot and cold water inputs, mixing tank, solenoid and float valves, temperature controller, and treatment tanks.

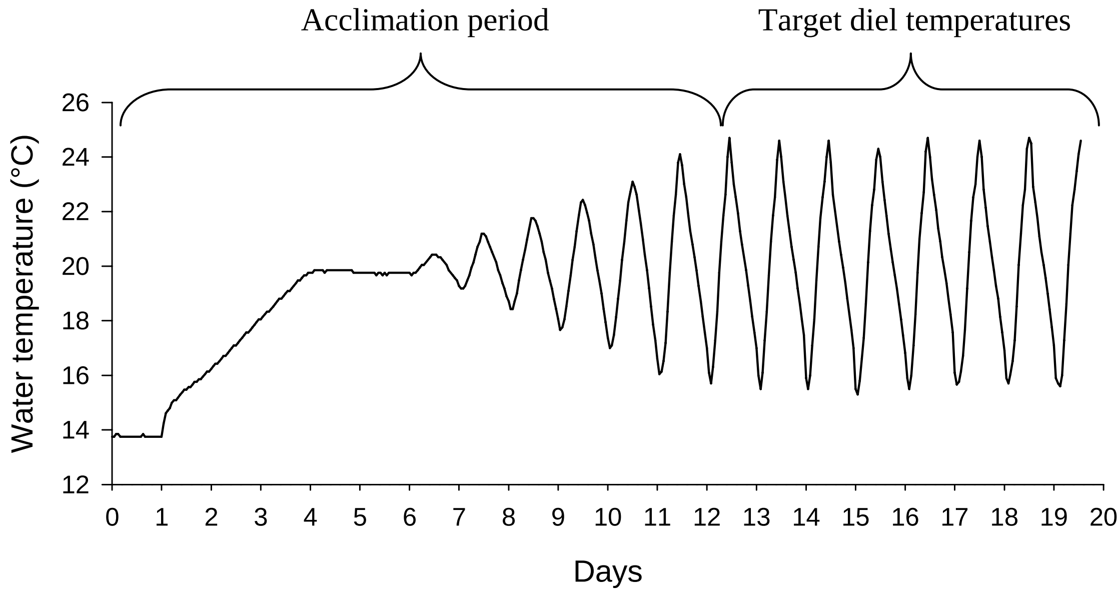

Figure 3. Water-temperature regime for acclimation of rainbow trout from 14°C to target diel temperatures.

thereby allowing fish to acclimate to the mean of target diel temperatures. Diel temperature fluctuations were initiated on day 7 where maximum and minimum temperatures departed 1°C from 20°C daily, until target diel temperatures were achieved on day 11. Fish were exposed to target diel temperatures for 7 d prior to the experiment. On day 18, treatment fish were stressed. Two replicates of control fish (i.e., not stressed) were exposed to target diel temperatures. Three replicates of treatment fish (i.e., simulated angling stress) were exposed to target diel temperatures and stressed at 0800. Three additional replicates of treatment fish were exposed to target diel temperatures and stressed at 1800. Stress times corresponded with the daily minimum (0800) and maximum (1800) target diel temperatures. The stressor included chasing fish with a net for 60 s followed by air exposure for 10 s to simulate fight time and air exposure observed in the field study (see Results). Mortality was assessed up to 72 h with tank checks every 24 h. Mean (90% CI) length of rainbow trout used in this study was 358 (15) mm.

Data Analysis

All data were analyzed using Statistical Analysis System (SAS Institute, Inc., 2003) and alpha was 0.10 for all analyses, to reduce the chance of committing a Type II error. Data were pooled for all years and visual inspection of water-temperature data suggested similar patterns among years. In addition, data were pooled for the study reaches in the Smith River. A paired t-test was used to compare water temperature among cages and between river within water-temperature treatments. Mortality estimates by species and river were calculated as the proportion (p) of fish that died in water-temperature treatment i;

$$p = \frac{X_i}{N_i};$$

X_i = the number of fish that died in water-temperature treatment i;

N_i = total number of fish angled in water-temperature treatment i.

Mortality estimates for morning and evening angling events within water-temperature treatments by species and river, and mortality for the laboratory study were calculated as shown above. 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). Logistic regression was used to analyze binary data (mortality or survivor) by maximum daily water temperature. Multiple regression was used to determine which variable(s) (i.e., daily maximum temperature, 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. Mortality was arcsine-square root transformed (Zar 1999). For these analyses the experimental unit was the angling day. Correlation analysis was used to analyze number of fish and number of mortalities in cages. Angler catch rates were calculated by dividing total number of each species caught by angler effort among water-temperature treatments and between angling events. General linear models were used for all ANOVAs to analyze angler catch rates among water-temperature treatments and between angling events.

RESULTS

Water Temperature

Within the period of recorded water temperatures, daily maximum water temperature was ≥ 23°C for 44 d in the Gallatin River (2005-2007) and 66 d in the Smith River (2006-2007) (Figures 4 and 5). Mean number of days per year water temperature was within the hot treatment was 15 d in the Gallatin and 33 d in the Smith River. Water temperature was within the warm treatment for 91 d and 94 d in the Gallatin and Smith rivers, respectively (Figures 4 and 5). Mean number of days per year water temperature was within the warm treatment was 30 d in the Gallatin 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 temperature increased from cool to hot water-temperature treatments in both rivers and within the hot treatment was 1.4°C greater in the Smith River than the Gallatin River (Table 1 and Figure 6). Range of water temperature within warm and cool treatments was greater in the Smith River than Gallatin River (Table 1 and Figure 6).

Water temperature did not differ significantly between the cages and the river for the cool ($t = 1.29$, $df = 48$, $P = 0.20$), warm ($t = 0.58$, $df = 31$, $P = 0.57$), and hot ($t = 0.94$, $df = 18$, $P = 0.36$) water-temperature treatments in the Gallatin River. Similarly, no significant differences were observed in water temperature between the cages and the

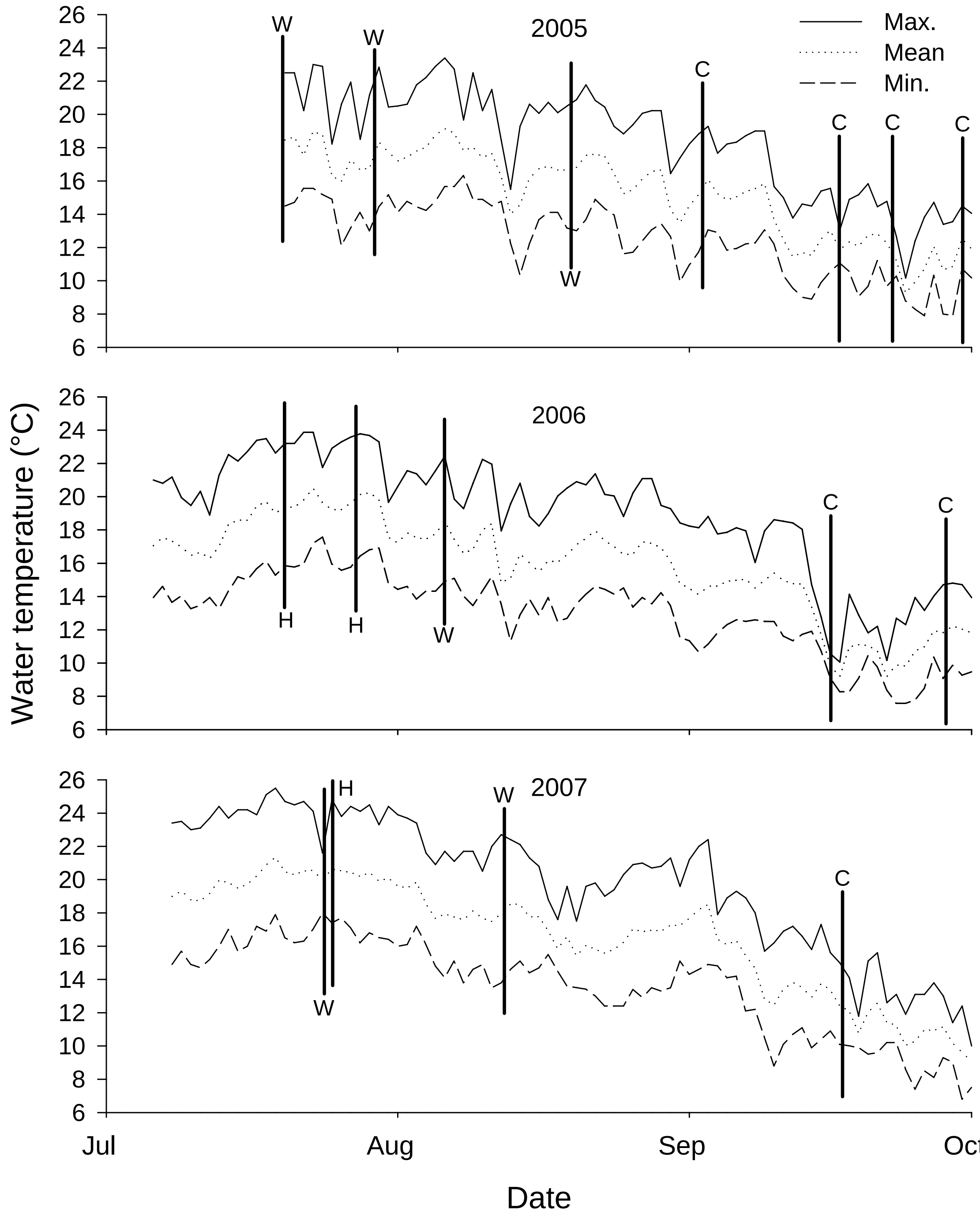

Figure 4. Maximum, mean, and minimum daily water temperatures for the Gallatin River, 2005 (July 20 – October 1), 2006 (July 6 – October 1), and 2007 (July 8 – October 1). Bold vertical lines indicate angling days and letters indicate water-temperature treatment (H = hot treatment, W = warm treatment, and C = cool treatment). Cool treatment angling days on April 22, 2006 and April 15, 2007 not shown.

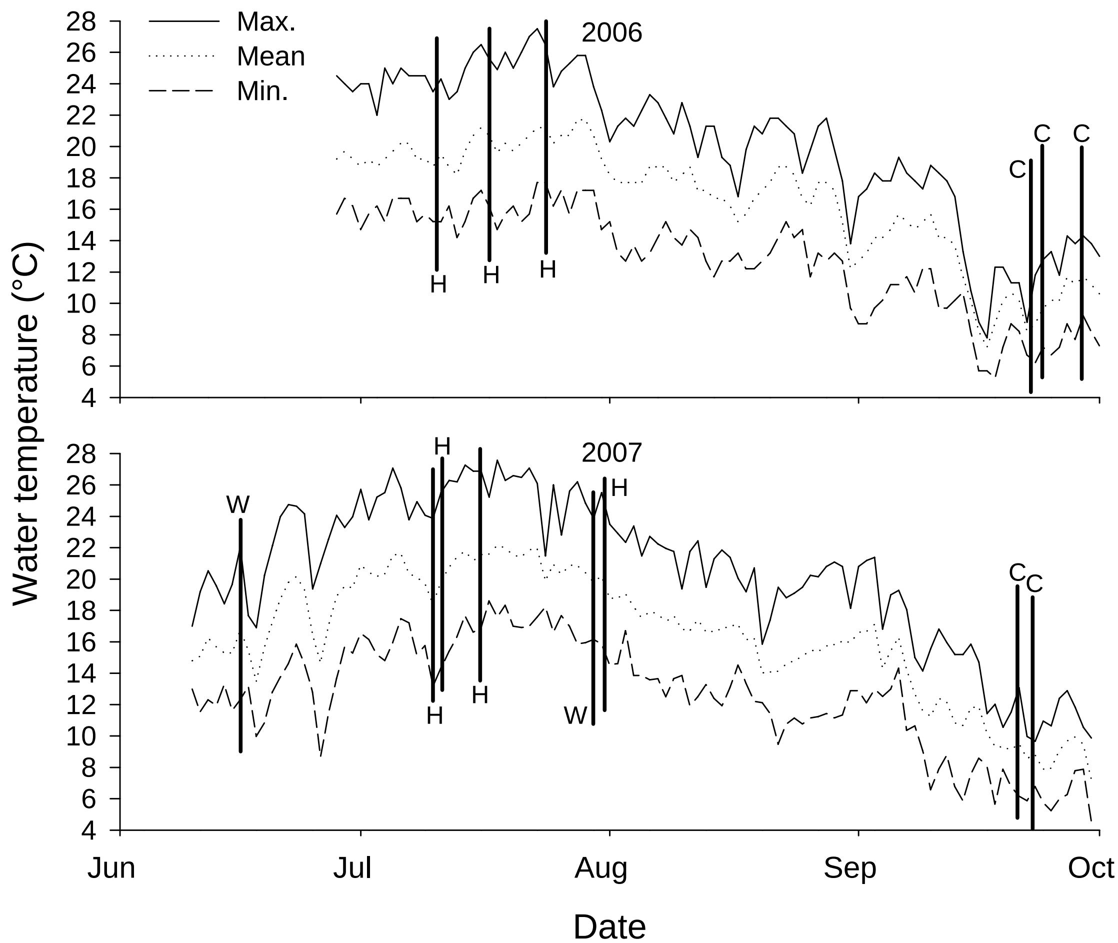

Figure 5. Maximum, mean, and minimum daily water temperatures for the Smith River, 2006 (June 28 – October 1), and 2007 (June 10 – October 1). Bold vertical lines indicate angling days and letters indicate water-temperature treatment (H = hot treatment, W = warm treatment, and C = cool treatment).

river for the cool ($t = 0.33$, df = 46, $P = 0.74$), warm ($t = -1.46$, df = 14, $P = 0.16$), and hot ($t = 1.0$, df = 54, $P = 0.32$) water-temperature treatments in the Smith River.

Water temperature was ≥23°C three times longer in the Smith River than Gallatin River and was between 20-22.9°C approximately 1.5 times longer in the Smith River than Gallatin River (Table 2). Mean time water temperature was ≥ 23°C within hot treatment was 4.1 h in the Gallatin River and 5.1 h in the Smith River. Water

Table 1. Minimum, mean (± 90% CI), maximum water temperature, and range of diel temperature by river and water-temperature treatment.

River	Treatment	Min.	Mean	Max.	Range of diel temperature
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

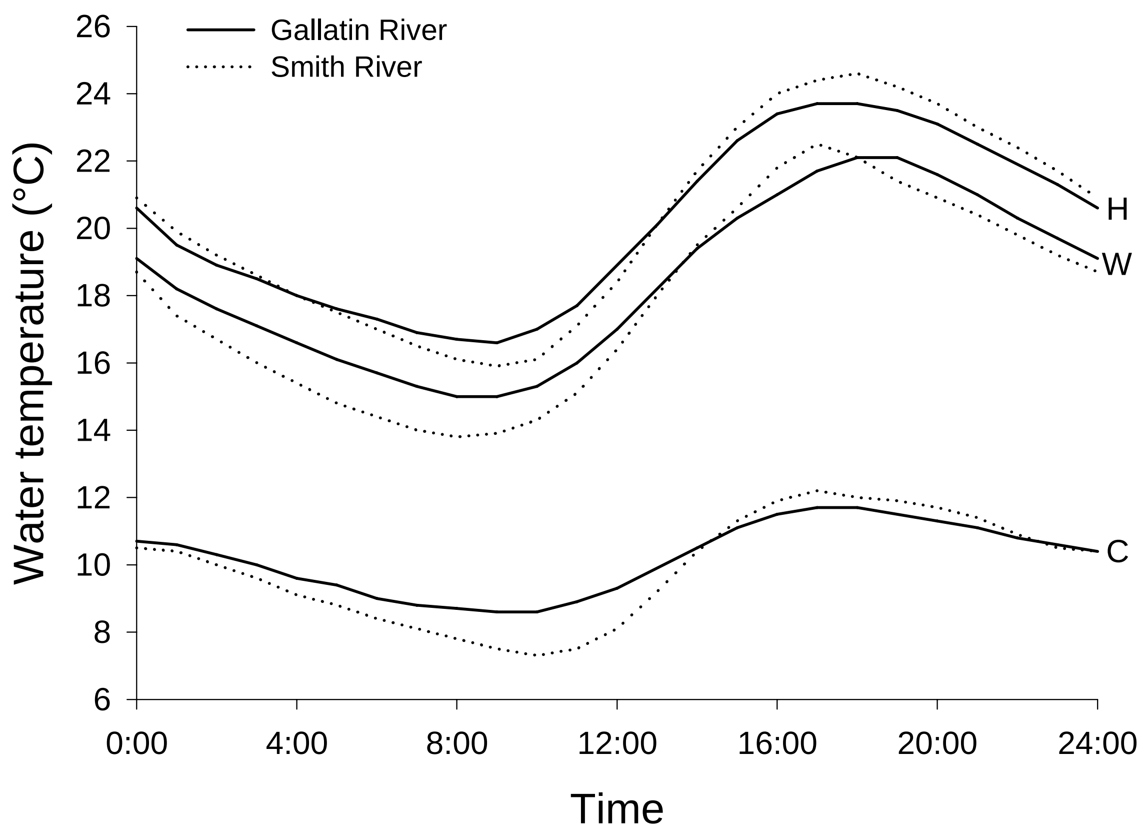

Figure 6. Mean water temperatures for a 24-h period by water-temperature treatment and river for angling days. Letters indicates water-temperature treatment (H = hot treatment, W = warm treatment, and C = cool treatment).

Table 2. Time (h) water temperature was between 20-22.9°C and ≥23°C in the Gallatin and Smith rivers, 2006 (July 6 – August 6) and 2007 (July 8 – August 13).

	Water temperature range	
River	20-22.9°C	≥23°C
Gallatin	385	132
Smith	541	411

temperature was between 20-22.9°C in warm treatment for 8 h in the Gallatin River and 6.5 h in the Smith River. Mean time water temperature was <20°C within warm and hot treatments was 16 h and 12 h in the Gallatin River and 17 h and 11 h in the Smith River, respectively.

Angling

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 (Table 3). Mean number of anglers per day was similar among treatments and between rivers (Table 3). Number of

Table 3. Number of angling days and mean (±90% CI) number of anglers per day by water-temperature treatment and river.

	Gallatin River		Smith River	
Treatment	Angling days	Anglers	Angling days	Anglers
Cool	9	6.4 (1.6)	6	4.7 (2.4)
Warm	6	6.8 (1.6)	2	6.0 (6.3)
Hot	3	7.7 (2.5)	7	6.1 (1.3)

fish angled was generally higher in the Smith River than the Gallatin River, with the exception of brown trout in the warm and cool treatments and mountain whitefish in the warm treatment (Table 4). Mean length of all species was similar among water-temperature treatments within river (Table 4). Rainbow trout and brown trout angled

Table 4. Number and mean (± 90% CI) length (mm) of fish angled by water-temperature treatment, species, and river.

		Gallatin River		Smith River	
Treatment	Species	N	Length	N	Length
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)

were slightly larger in the Smith River and mountain whitefish were slightly larger in the Gallatin River. Density of fish within cages was <14 fish/m^3 for both rivers. No correlations were found between number of fish and number of mortalities in a cage (Figure 7).

Mortality of rainbow trout differed significantly among water temperature-treatments in the Gallatin River and Smith River (Figure 8). Mortality of rainbow trout was higher in the hot (16%) and warm (9%) treatments than the cool treatment (0%) in the Gallatin River and followed a similar pattern in the Smith River, where mortality was 9% in the hot treatment and 8% in the warm treatment compared to 0% in the cool treatment. Mortality differed significantly among water-temperature treatments for brown trout and mountain whitefish in the Smith River (Figure 8). Brown trout angled in the hot treatment (4%) had higher mortality than the warm (0%) and cool (0%) treatments and mountain whitefish angled in the hot (28%) and warm treatment (20%) had higher mortality than the cool treatment (0%). The majority of rainbow trout (86%), brown trout (100%), and mountain whitefish (100%) that experienced mortality did so within 48 h in

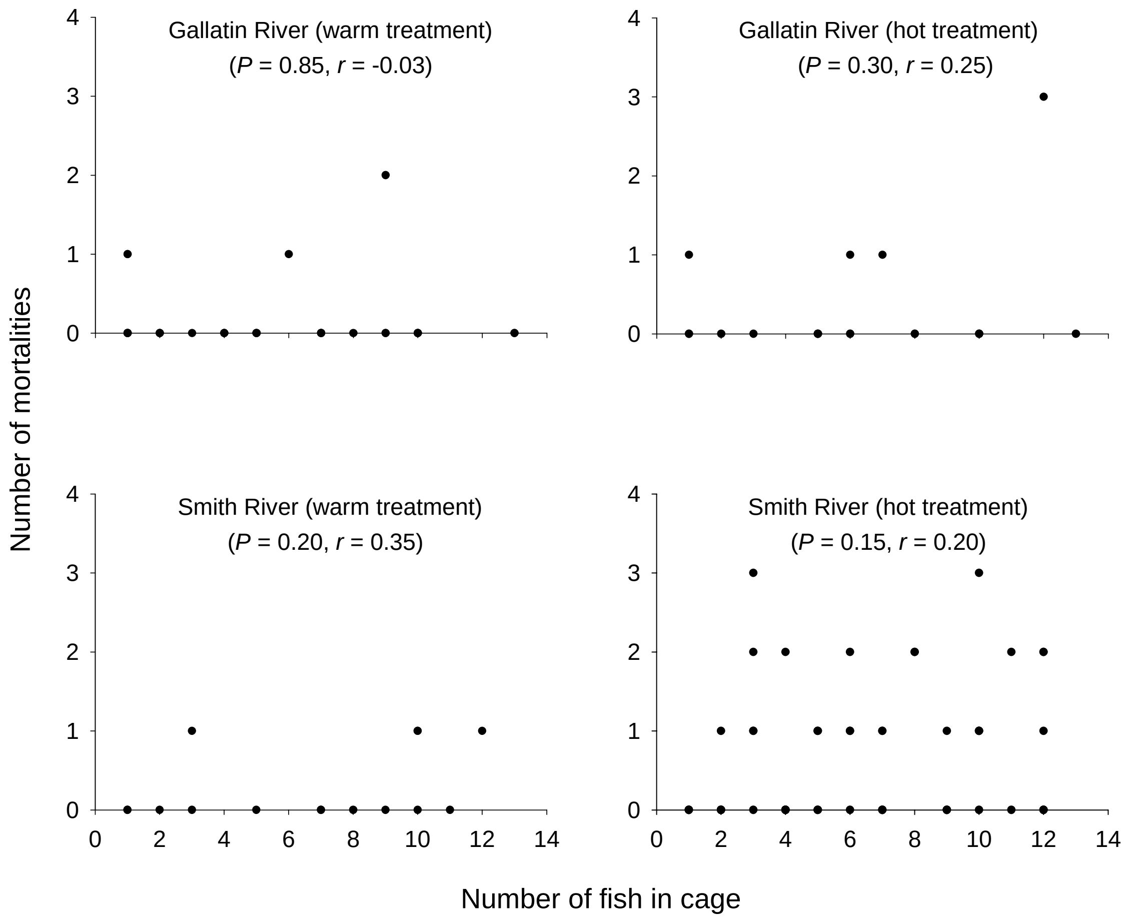

Figure 7. Correlation of number of fish in a cage and number of mortalities in a cage for warm and hot water-temperature treatments in the Gallatin and Smith rivers, Montana. Symbols overlap for some x-y coordinates.

the Gallatin River. Similarly, most rainbow trout (83%), brown trout (100%), and mountain whitefish (79%) that experienced mortality did so within 48 h in the Smith River.

Many fish of all species survived at water temperatures where mortality occurred (Figures 9 and 10). Thus, logistic regression models would not converge on the binary data (mortality or survivor) by maximum daily water temperature for either river.

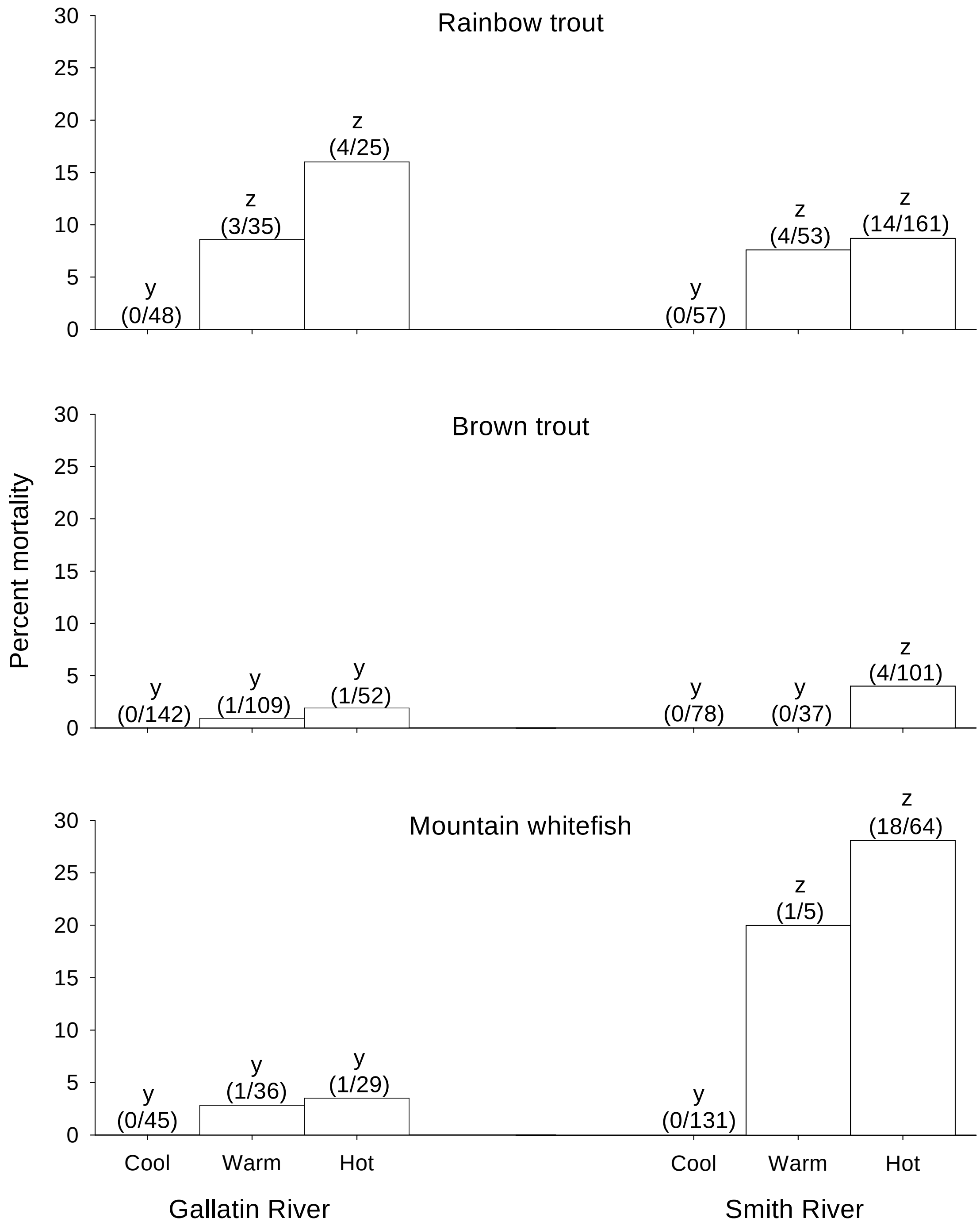

Figure 8. Percent mortality by river, species, and water-temperature treatment. Numbers in parentheses are: number of mortalities / number of individuals angled. Dissimilar letters indicate significant differences in mortality among water-temperature treatment (i.e., cool, warm, hot) by species within river.

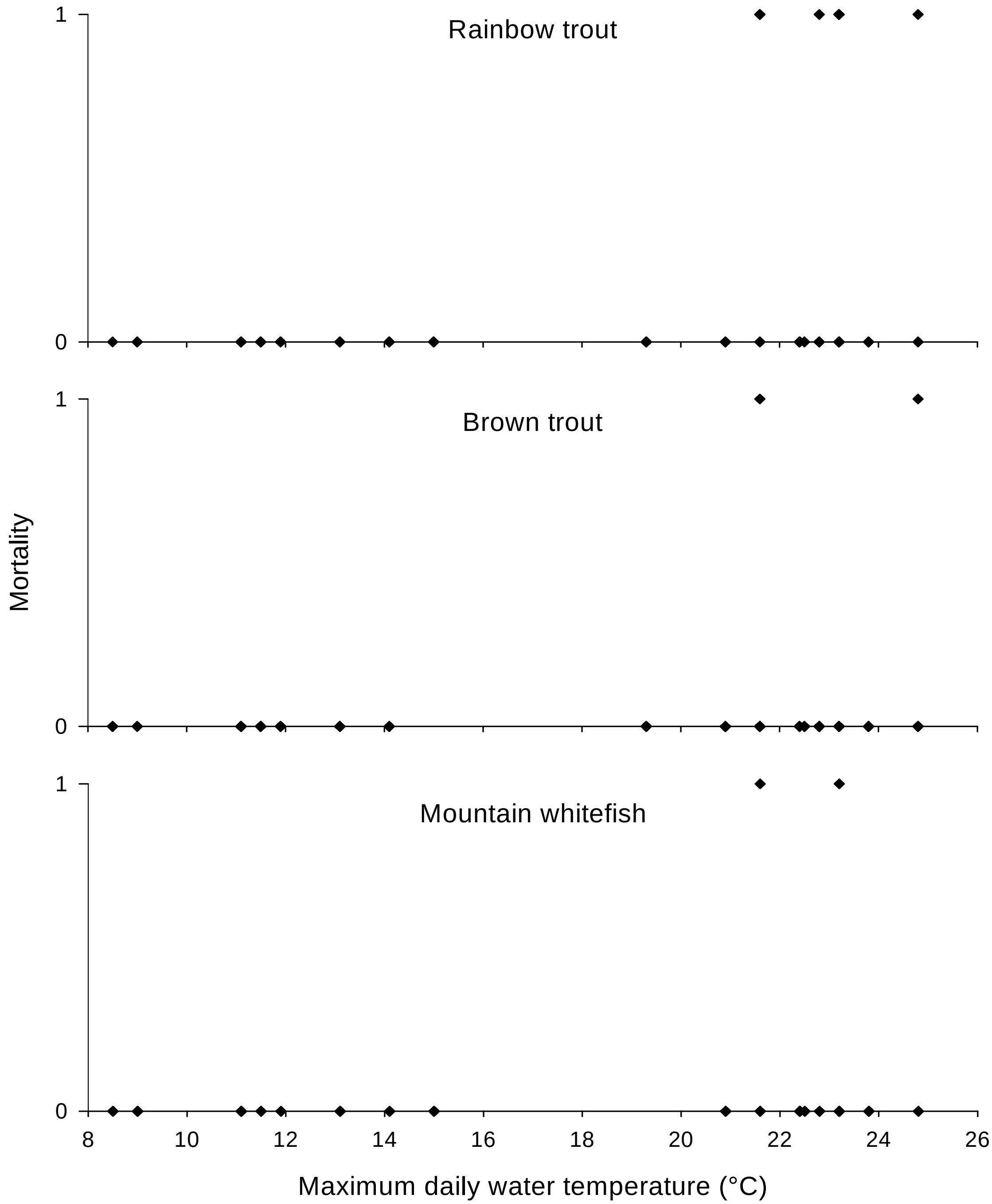

Figure 9. Binary mortality and survivor data by maximum daily water temperature on angling days for species angled in the Gallatin River, Montana, 2005-2007. Survivors are denoted by 0 and mortality is denoted by 1. Symbols overlap at some water temperatures: [mortalities; rainbow trout (n=7), brown trout (n=2), mountain whitefish (n=2) and survivors; rainbow trout (n= 97), brown trout (n=301), mountain whitefish (n=108)].

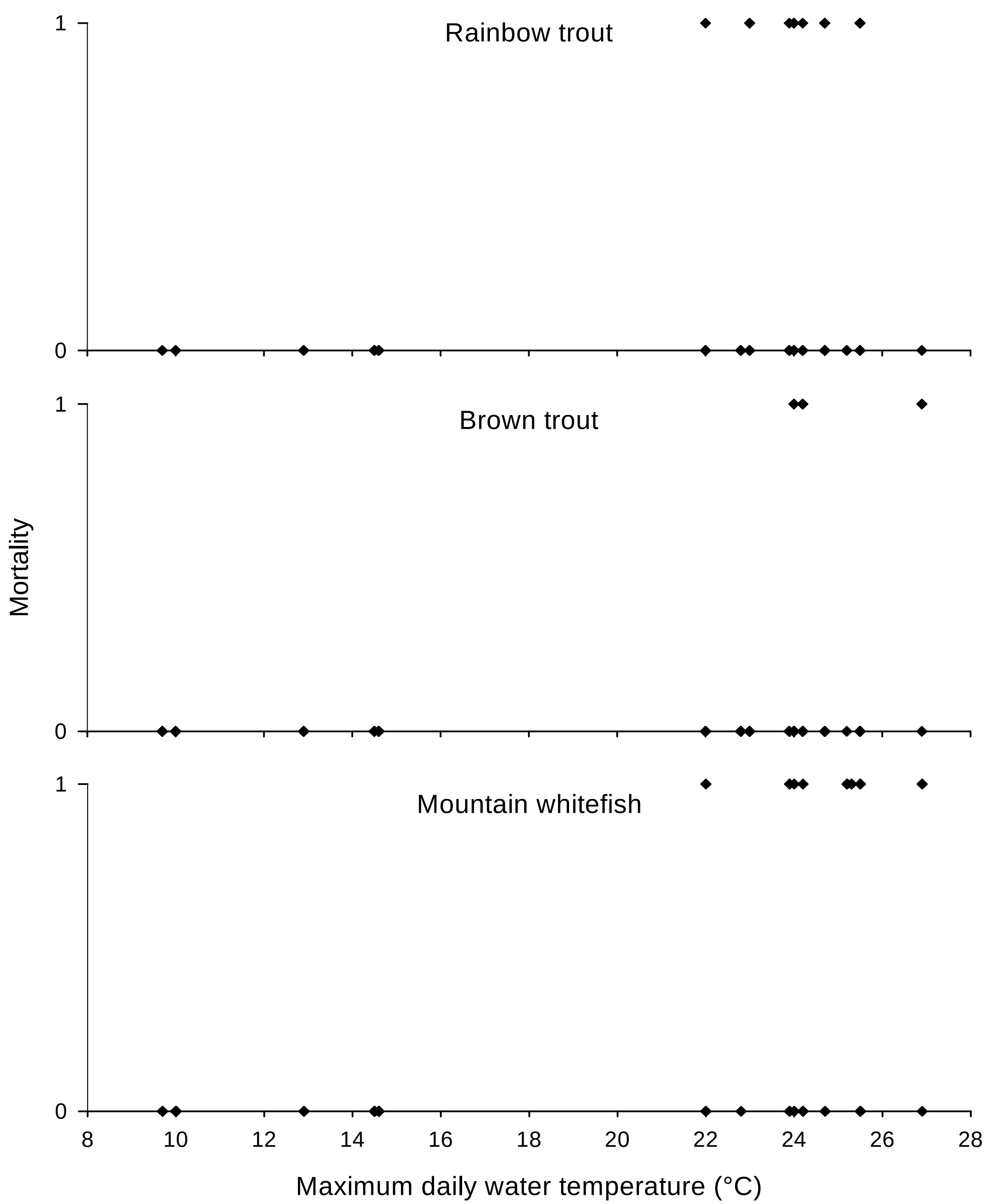

Figure 10. Binary mortality and survivor data by maximum daily water temperature on angling days for species angled in the Smith River, Montana, 2006-2007. Survivors are denoted by 0 and mortality is denoted by 1. Symbols overlap at some water temperatures: [mortalities; rainbow trout (n=18), brown trout (n=4), mountain whitefish (n=19) and survivors; rainbow trout (n= 253), brown trout (n=212), mountain whitefish (n=181)].

Mortality for all species in both rivers started to occur when daily maximum water temperature reached 21.7-22°C, except brown trout in the Smith River, where mortality started to occur when daily maximum water temperature reached 24°C.

Mean transport time was less than 8.5 min for all species among water-temperature treatments in both rivers (Table 5). Mean fight time varied from 42 to 79 s and mean air exposure time was less than 27 s among water-temperature treatments for all species in both rivers (Table 5). Air exposure time, fight time, and maximum daily water temperature were significant variables in some of the multiple regression models (Table 6). 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 non-significant. 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 temperature was a significant variable for all species (Table 6).

Mortality did not differ significantly between morning and evening angling events in any water-temperature treatment for any species in the Gallatin River (Figure 11). Mortality of rainbow trout in the Smith River differed significantly between morning and evening angling events for warm and hot treatments (Figure 12). Mortality of rainbow trout was higher in evening events than morning events for warm and hot treatments.

Angler catch rates for rainbow trout differed significantly in the Gallatin River but were similar in the Smith River among water-temperature treatments (Figure 13).

Table 5. Mean (± 90% CI) transport (min), fight (s), and air exposure (s) times by river, species, and water-temperature treatment. (RB = rainbow trout, BRN = brown trout, MWF = mountain whitefish)

		Cool			Warm			Hot		
River	Species	Transport	Fight	Air	Transport	Fight	Air	Transport	Fight	Air
Gallatin	RB	4.3 (1.9)	44 (8)	11 (4)	4.3 (1.3)	55 (9)	6 (3)	5.9 (2.0)	62 (10)	15 (5)
	BRN	3.3 (0.9)	42 (5)	12 (4)	5.0 (1.3)	63 (12)	8 (2)	4.1 (1.1)	58 (13)	18 (5)
	MWF	4.7 (2.6)	57 (9)	8 (2)	5.3 (2.0)	62 (12)	9 (2)	3.2 (1.6)	79 (11)	11 (4)
Smith	RB	8.1 (1.4)	78 (12)	10 (5)	4.6 (0.9)	61 (9)	13 (3)	5.4 (0.8)	54 (5)	9 (1)
	BRN	5.9 (1.2)	54 (7)	9 (2)	5.7 (1.4)	62 (9)	13 (2)	6.4 (1.2)	50 (6)	8 (2)
	MWF	6.0 (1.1)	50 (5)	9 (2)	7.5 (4.3)	55 (9)	26 (15)	4.6 (1.4)	57 (9)	18 (4)

Table 6. Multiple regression models by species and river, P-value, and r^2.

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
		Without fight time		
Smith	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

Anglers caught more rainbow trout in the hot treatment (0.54 fish/h) than the warm (0.31 fish/h) and cool treatment (0.25 fish/h) in the Gallatin River. Angler catch rates for brown trout were similar among treatments in both rivers (Figure 13). Angler catch rates were similar among treatments for mountain whitefish in the Gallatin River, but differed significantly in the Smith River, where anglers caught more whitefish in the cool treatment (1.0 fish/h) than the hot (0.3 fish/h) and warm treatment (0.1 fish/h) (Figure 13).

Angler catch rates for rainbow trout differed significantly between morning and evening angling events in the Gallatin River for cool and hot treatments (Figure 14), and were similar in the Smith River between angling events within all water-temperature treatments (Figure 15). Angler catch rates for rainbow trout were higher for evening events (0.3 fish/h) than morning events (0.1 fish/h) for the cool treatment and lower for evening events (0.3 fish/h) than morning events (0.7 fish/h) for the hot treatment in the Gallatin River. Angler catch rates were similar for brown trout between morning and

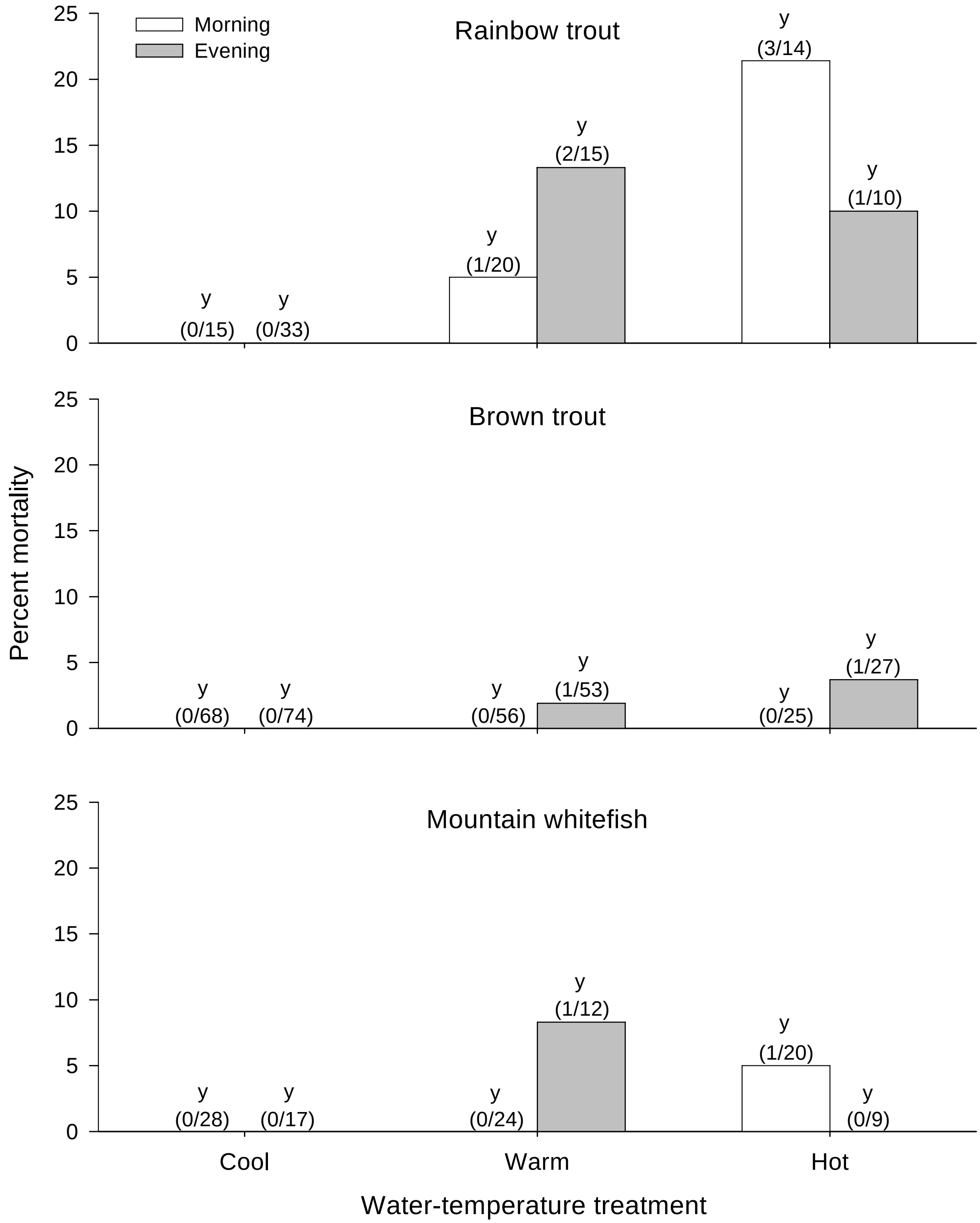

Figure 11. Percent mortality for morning and evening angling events by species and water-temperature treatment in the Gallatin River, Montana, 2005-2007. Numbers in parentheses are: number of mortalities / number of individuals angled. Dissimilar letters indicate significant differences in mortality between angling events by species within water-temperature treatment (i.e., cool, warm, hot).

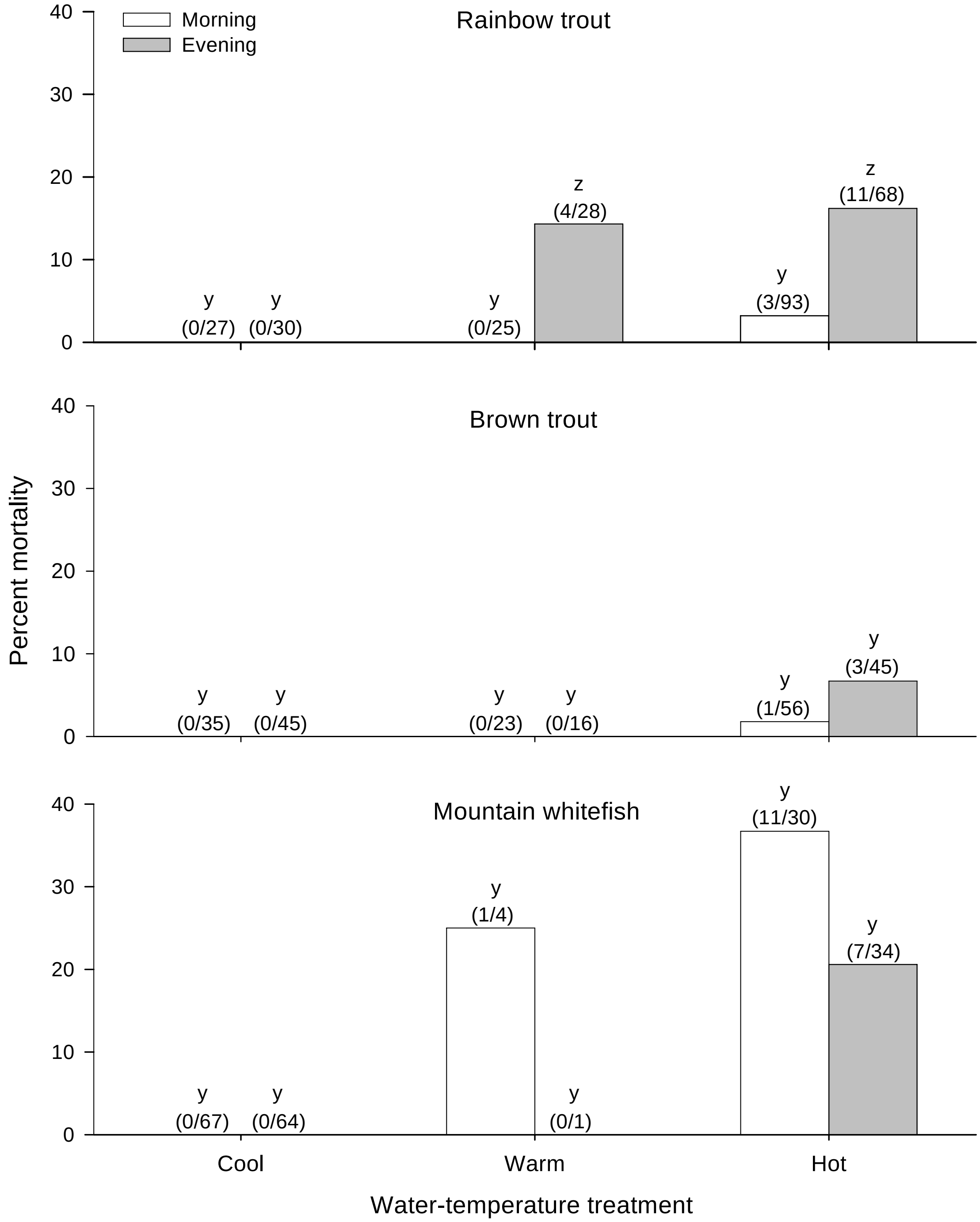

Figure 12. Percent mortality for morning and evening angling events by species and water-temperature treatment in the Smith River, Montana, 2006-2007. Numbers in parentheses are: number of mortalities / number of individuals angled. Dissimilar letters indicate significant differences in mortality between angling events by species within water-temperature treatment (i.e., cool, warm, hot).

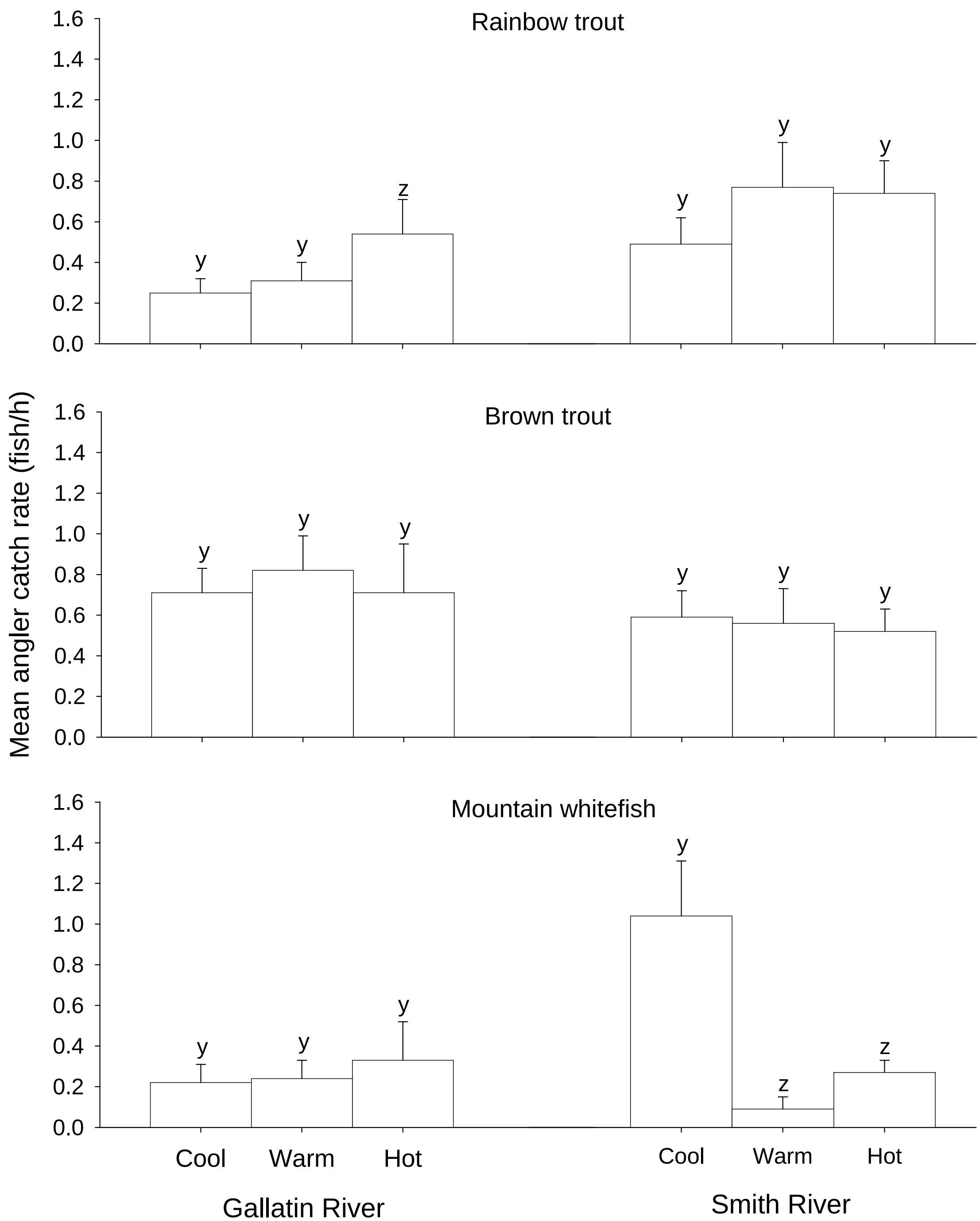

Figure 13. Mean angler catch rate by species and water-temperature treatment in the Gallatin (2005-2007) and Smith (2006-2007) rivers, Montana. Dissimilar letters indicate significant differences in angler catch rates by species among water-temperature treatment. Error bars denote 90% confidence intervals.

evening angling events within water-temperature treatments in the Gallatin River (Figure 14), but differed significantly for the hot treatment in the Smith River, where anglers had higher catch rates of brown trout for morning events (0.6 fish/h) than evening events (0.4 fish/h) (Figure 15). Angler catch rates differed significantly between morning and evening events for mountain whitefish for the hot and warm treatments in the Gallatin River (Figure 14), but were similar between angling events among water-temperature treatments for the Smith River (Figure 15). Anglers caught more mountain whitefish in morning events (0.5 fish/h) than evening events (0.2 fish/h) in the hot treatment and more in morning (0.4 fish/h) than evening (0.1 fish/h) in the warm treatment in the Gallatin River.

Laboratory Study

Target diel temperatures varied from 15.3 to 24.7°C (Figure 16). Mean range of diel temperatures was 8.5°C and mean daily water temperature was 19.2°C (Figure 16). Mean time water temperature was $\geq$23°C was 4 h and mean time water temperature was <20°C was 12.5 h.

Mortality of rainbow trout did not differ significantly between treatment and control (Figure 17). Mortality of treatment rainbow trout differed significantly between stress events. Mortality of rainbow trout exposed to stress in the evening (7%) was higher than morning (0%) (Figure 18).

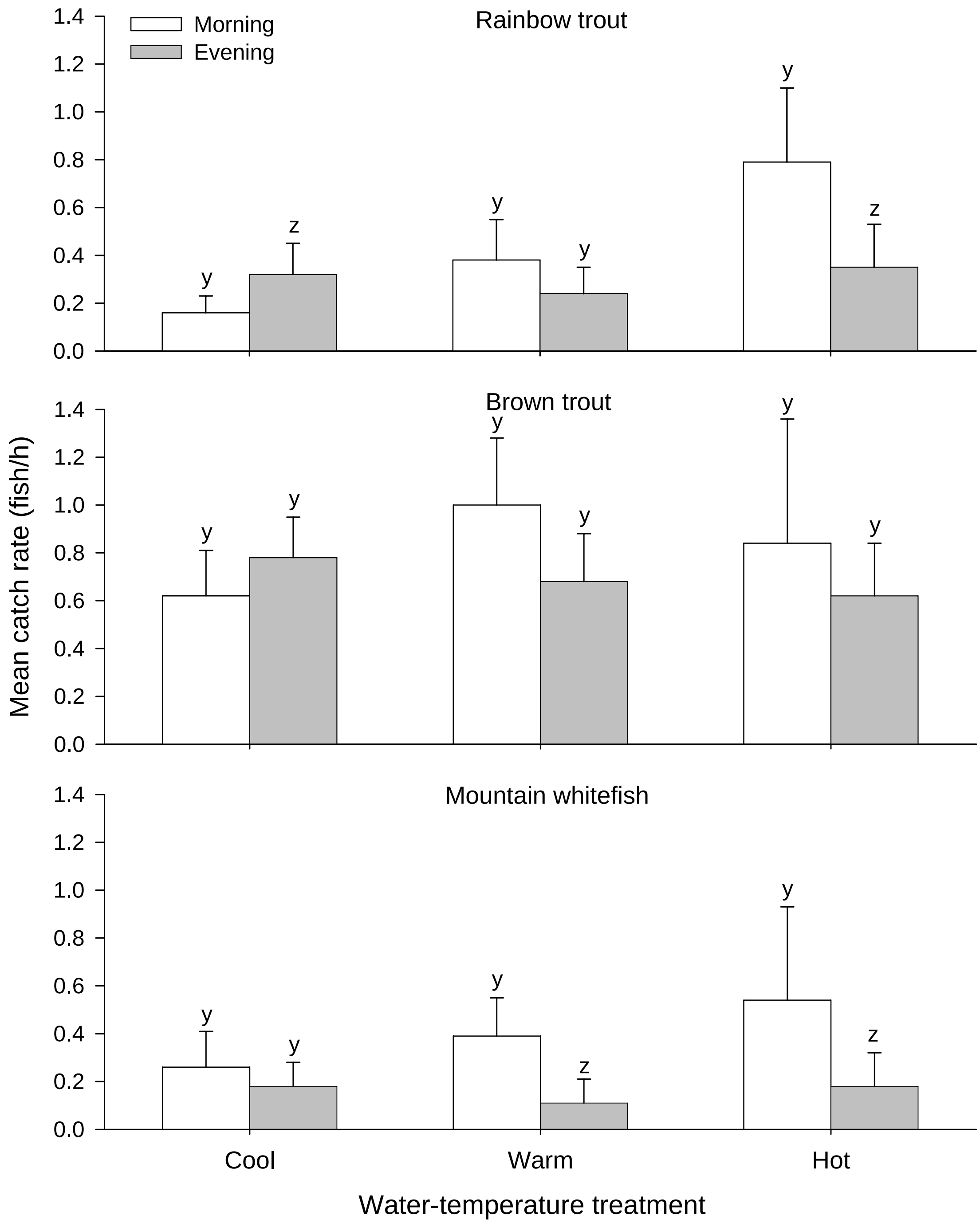

Figure 14. Mean angler catch rate for morning and evening angling events by species and water-temperature treatment in the Gallatin River, Montana, 2005-2007. Dissimilar letters indicate significant differences in angler catch rates between angling event by species within water-temperature treatment. Error bars denote 90% confidence intervals.

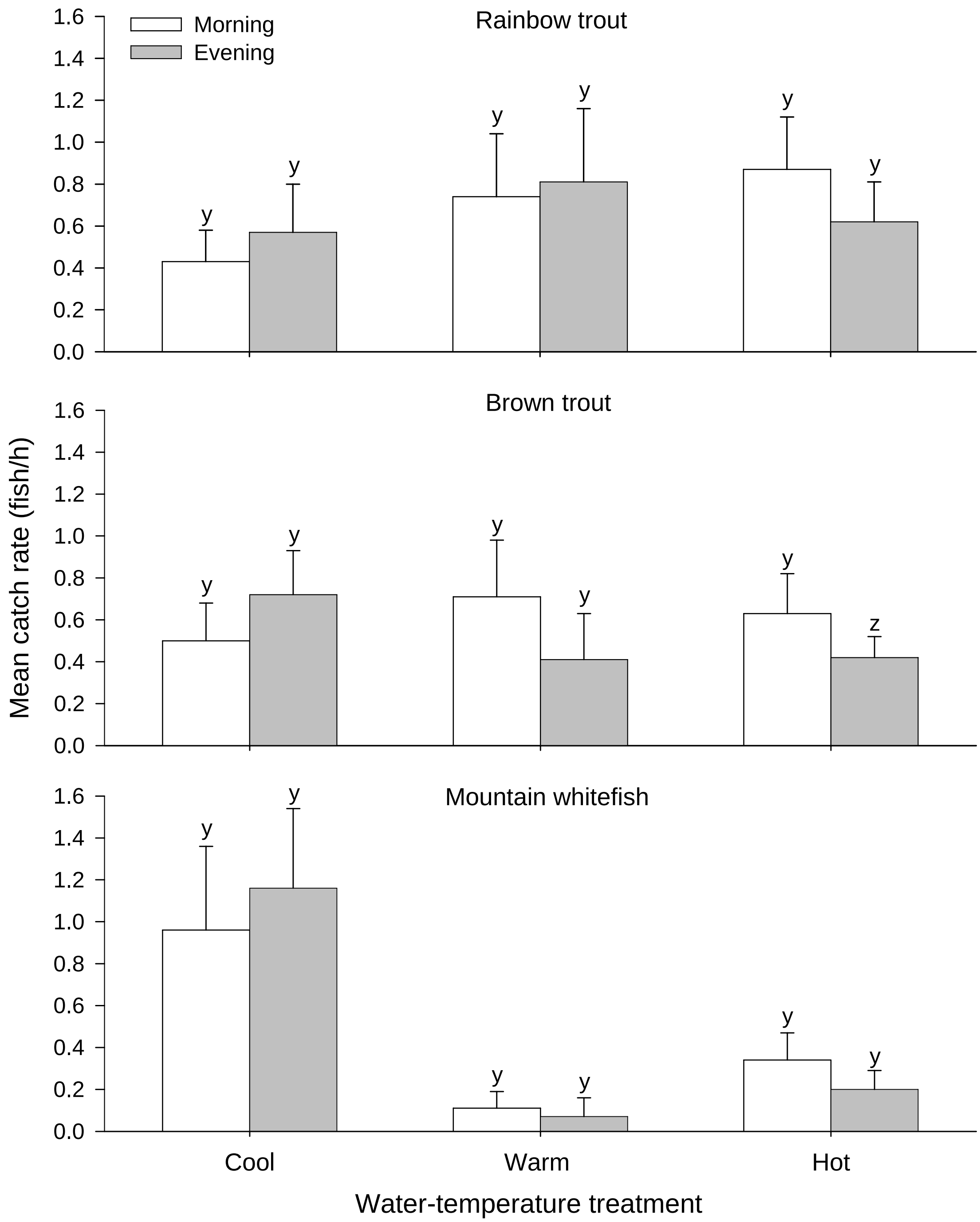

Figure 15. Mean angler catch rate for morning and evening angling events by species and water-temperature treatment in the Smith River, Montana, 2006-2007. Dissimilar letters indicate significant differences in angler catch rates between angling event by species within water-temperature treatment. Error bars denote 90% confidence intervals.

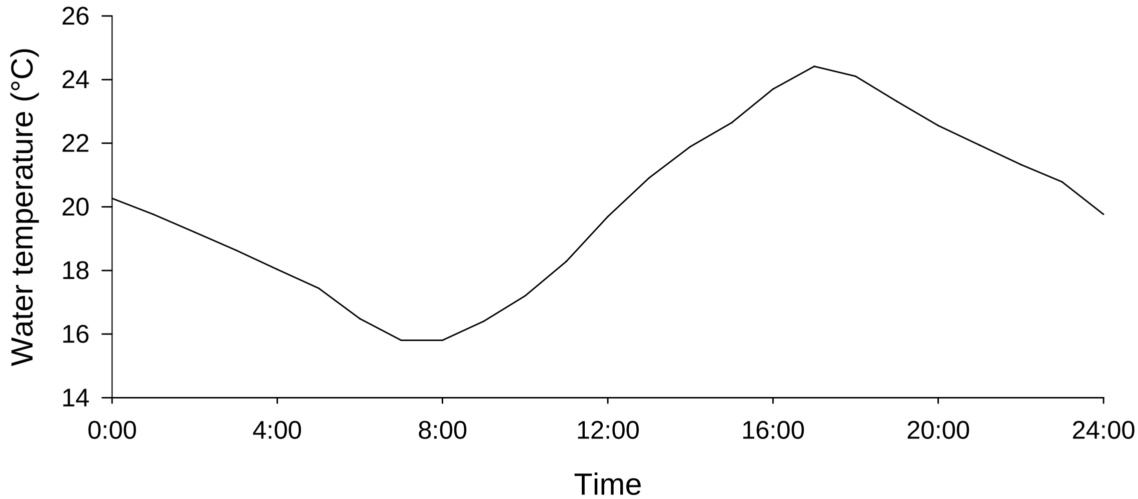

Figure 16. Mean diel temperatures during 7-d target diel temperature period for laboratory study.

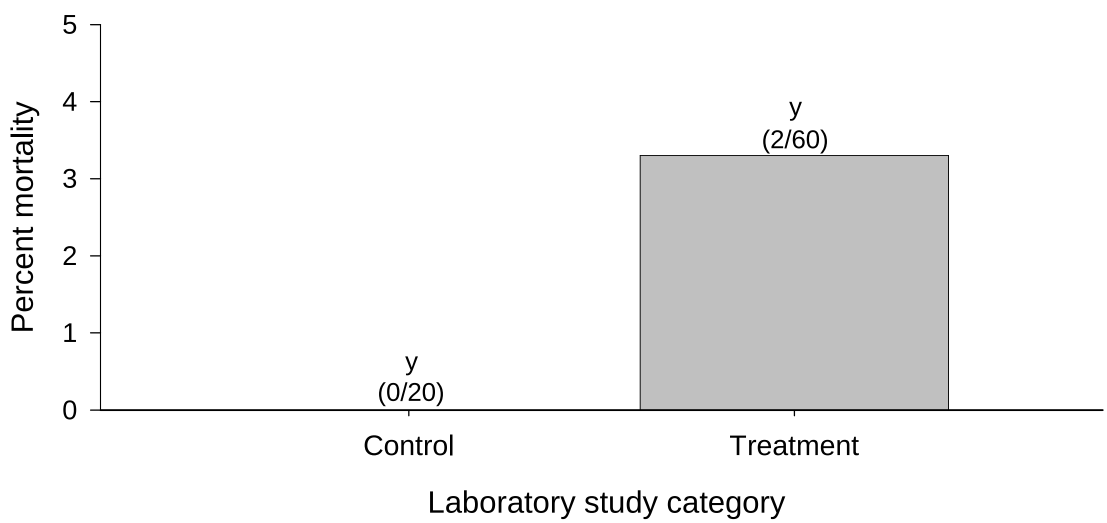

Figure 17. Percent mortality of rainbow trout for control and treatment in the laboratory study. Numbers in parentheses are: number of mortalities / number of individuals in treatment. Dissimilar letters indicate significant differences in mortality between control

and treatment.

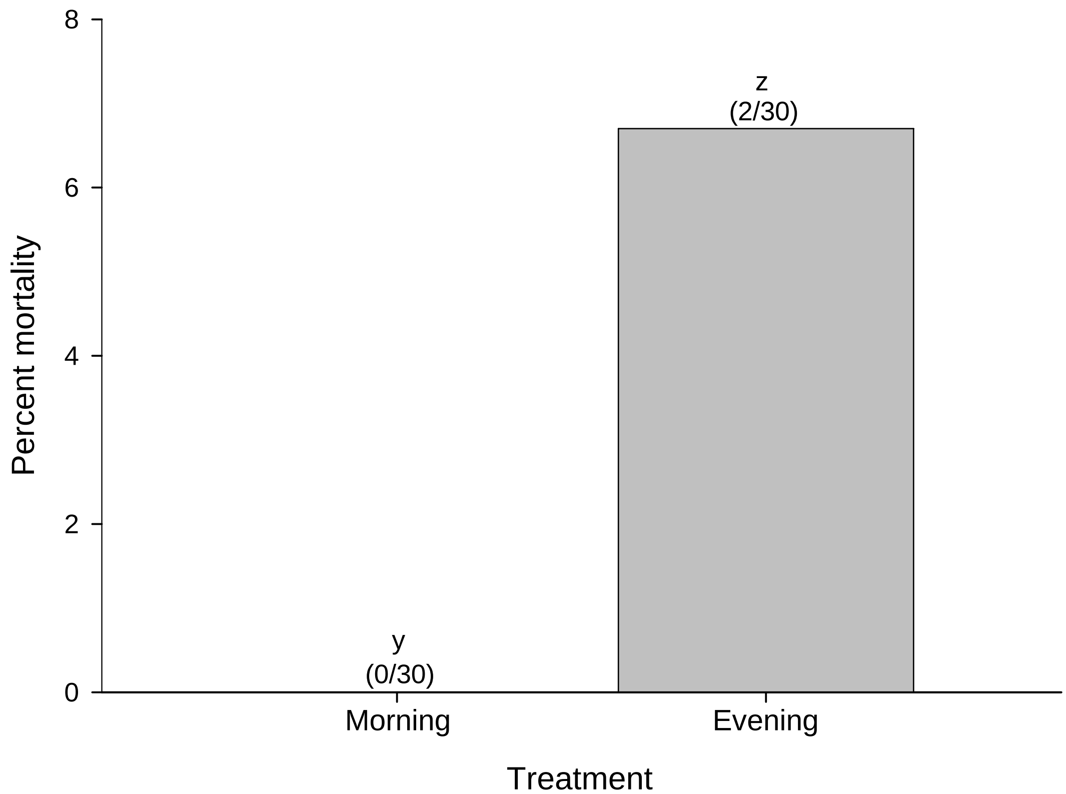

Figure 18. Percent mortality of rainbow trout by morning and evening stress event for the laboratory study. Numbers in parentheses are: number of mortalities / number of individuals stressed. Dissimilar letters indicate significant differences in mortality between stress events.

DISCUSSION

Mortality of rainbow trout increased when water temperatures were >20°C in both study rivers, but mortality remained well below the predicted level of >30%. Water temperatures >20°C have been shown to increase CR mortality of salmonids (Titus and Vanicek 1988; Wilkie et al. 1996; Wilkie et al. 1997; Andersen et al. 1998; Thorstad et al. 2003) and other fishes (Nelson 1998; Wilde et al. 2000); however, these studies have reported higher mortality rates than observed for rainbow trout in this study. For example, CR mortality of Atlantic salmon was 30% and 40% when water temperatures were 23°C and 22°C, respectively (Wilkie et al. 1996; Wilkie et al. 1997). Mortality of lure-caught Lahontan cutthroat trout was 50% when water temperatures were 21°C (Titus and Vanicek 1988). Variation in CR mortality between this study and similar studies suggest mortality is influenced by more than daily maximum water temperature.

Differences in mortality of salmonids in previous CR studies and mortality of rainbow trout in this study could be attributed to individual species exhibiting different thermal tolerances (Beitinger et al. 2000). For example, upper lethal temperatures for Lahontan cutthroat trout are between 22-24°C (Dickerson and Vinyard 1999) and 25-27°C for rainbow trout (Hokanson et al. 1977; Kaya 1978; Bear et al. 2007). Angling stress on Lahontan cutthroat trout at 21°C is likely more severe than angling stress on rainbow trout at 21°C. Thus, CR mortality of salmonids varies among species at similar water temperatures.

Most CR studies assessing mortality of salmonids are conducted in constant water temperature; however, fish respond differently to diel temperatures than constant water temperature (Hokanson et al. 1977). For example, rainbow trout exposed to diel temperatures exhibited increased resistance to higher temperatures when periods of cooler water were present between peaks (Hokanson et al. 1977). In addition, Bonneville cutthroat trout *O. c. 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).

Range of diel temperature and exposure time to maximum diel temperatures may also help explain differences in CR mortality of salmonids between this study and similar studies. For example, Atlantic salmon angled in Canada were exposed to a 4°C range of diel temperatures (i.e., daily water temperatures fluctuated from 18-22°C) and experienced 40-80% mortality (Wilkie et al. 1996; Andersen et al. 1998). 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 higher maximum diel temperatures, they were also exposed to longer periods of cooler water temperature between peaks than those observed in the previous two studies. Longer durations in temperatures below or near maximum thermal tolerances allow fish to "repair" physiological or physical damage (Meyer et al. 1995), thus reducing CR mortality.

Low mortality of brown trout (<4%) among water-temperature treatments and between rivers in this study suggest the effects of CR at elevated water temperatures on brown trout are minimal. Similarly, mortality of brown trout angled with flies has been shown to be lower than mortality for other salmonids (Taylor and White 1992). Upper lethal temperatures for brown trout (29-30°C) are higher than most salmonids (Elliott

1981; Elliott and Elliott 1995), thus lower mortality than other salmonids at similar water temperatures might be expected.

Mortality of mountain whitefish within the hot treatment in the Smith River approached the predicted value of >30%, but remained low for all water-temperature treatments in the Gallatin River. Differences in mortality of mountain whitefish between rivers may be attributable to the range of diel temperature and dose/exposure to maximum diel temperature. 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 (24.0°C) and brown trout (24.1°C) (Eaton and Scheller 1996). Thus, upper lethal limits may be lower for mountain whitefish than rainbow trout or brown trout. 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 water temperature and duration of maximum diel temperatures could have a greater impact on mountain whitefish compared to other species, assuming upper thermal limits for mountain whitefish are likely lower than other salmonids. Mountain whitefish were exposed to daily doses of water temperatures ≥23°C one hour longer in the Smith River than the Gallatin River and over three times longer exposure to water temperatures ≥23°C during mid-summer in the Smith River than Gallatin River. Longer dose and exposure times likely contributed to increased levels of CR mortality of mountain whitefish in the Smith River compared to the Gallatin River.

No CR mortality was observed for any species in either study river when water temperatures were <20°C. The lack of mortality at water temperatures <20°C was surprising, given similar studies have shown mortality rates of salmonids associated with fly-fishing are 2-5% at cooler water temperatures (Muoneke and Childress 1994; Schisler and Bergerson 1996). Differences in mortality between similar studies and this study could be attributed to angler experience. For example, mortality of striped bass *Morone saxatilis* and rainbow trout were lower when angled by experienced anglers than inexperienced anglers (Diodati and Richards 1996; Meka 2004). This study relied on anglers from Trout Unlimited and Federation of Fly Fisher's. It is likely that anglers from these organizations are more experienced and better educated on handling protocols that minimize stress of angled fish. However, 64 anglers were recruited for this study and should have represented the abilities of the fly-fishing population well, as at least 12 anglers fly-fished for their first time in this study.

Angled rainbow trout died more frequently in evening than morning events when daily maximum water temperatures were >20°C in the Smith River; however, no patterns in mortality were observed for brown trout and mountain whitefish between morning and evening angling events. Mean water temperature was higher in evening than morning events in both rivers for all water-temperature treatments, but low sample size likely limited the power of statistical tests for the Gallatin River. Mortality of brown trout was low overall for both rivers and was likely attributable to their higher temperature tolerances. Mountain whitefish mortality in the Smith River was more affected by daily maximum water temperature than angling event, suggesting angling on days when water temperature is ≥23°C may be too close to their upper lethal limits to allow for recovery. The field study supports the prediction that mortality would be higher in evening than morning and lend support to Montana, Fish, Wildlife and Parks time-of-day angling closures.

Mortality of treatment rainbow trout in the laboratory study did not differ from control fish and was less than mortality observed in the field study. Several factors likely contributed to differences in mortality of rainbow between the laboratory and field study. First, simulated angling stress did not involve hooking and may not have been as rigorous as angling. Second, differences may exist between hatchery-reared and wild rainbow trout with regard to stress exposure. Hatchery-reared fish are exposed to daily human disturbances (feeding and tank cleaning) and may decrease sensitivity to subsequent disturbances (Pickering 1981; Schreck 2000). For example, mortality of angled hatchery-reared fish was shown to be significantly lower than wild fish at similar water temperatures, presumably due to acclimation of hatchery fish to stress associated with hatchery operation (Taylor and White 1992).

Mortality results from morning and evening stress events in the laboratory followed a similar pattern to field results, where higher mortality occurred in fish stressed in evening than morning. However, only two mortalities occurred in the laboratory study and results should be interpreted with caution. Despite low mortality of fish stressed in evening, both studies suggest that fish angled during peak water temperatures may be more susceptible to mortality, even though fish were recovering on the descending limb of the thermograph. This further indicates that water temperature during an angling event may be more important than water temperature during the recovery period because fish angled at low water temperatures in morning experienced lower mortality, yet were recovering on the ascending limb of the thermograph.

Mortality estimates in this study were based on a single capture. Tagging results from an ancillary study showed low (<8%) recapture rates in the Gallatin River and no mortality of recaptured fish, suggesting effects from recapture did not influence mortality results in this study. However, fish can be recaptured multiple times over a relatively short time span in rivers with high angling pressure. For example, Yellowstone cutthroat trout were captured an average of 9.7 times in the Yellowstone River over 40 d (Schill et al 1986). One individual fish was recaptured 4 times within 24 h and several other fish were recaptured within 2 h of original capture (Schill et al 1986). Mortality rates of fish recaptured multiple times can be estimated, assuming a constant mortality rate per capture event. The probability of mortality (P_m) for a given fish captured k times is expressed as;

$P_m = 1-(1-P_1)^k$;

P_1 = probability of mortality based on a single capture,

k = number of capture events.

Using the mortality estimate for rainbow trout (9%) within the hot treatment for the Smith River in this study, and 4 recapture events (mean number of times rainbow trout are recaptured in the Missouri River) (T. Horton, Montana Fish, Wildlife and Parks, personal communication), probability of mortality would be 38%. Mortality of fish can increase substantially with increasing number of recapture events, thus this result supports angling closures in streams with high recapture rates.

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 that 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; well below 180 s reported to significantly increase physiological disturbance in angled rainbow trout (Wydoski et al. 1976). 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 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.

Angler catch rates for all three species generally declined in evening angling events when water temperatures were ≥ 23°C. Similarly, angler catch rates of rainbow trout and brown trout in the Madison River declined to 0.4-0.6 fish/h at water temperatures >19°C (McMichael 1989). Catch rates are influenced in part by feeding rates and typically peak at a species-specific temperature (Elliott 1975a, 1975b), then decline with additional increases in water temperature (Taylor 1978). Interestingly, angler catch rates of rainbow trout were not significantly different between morning and evening angling events within the warm and hot treatments in the Smith River. This results suggests rainbow trout are equally vulnerable to angling in evening as morning in the Smith River and provides support for the time-of-day angling closure. Variability in angler catch rates for all species was likely due in part to angler experience. For example, some anglers caught no fish despite angling in a treatment or event associated with the highest mean catch rates. Other factors that were not measured but may have affected catch rates include water turbidity, insect activity, and weather (McMichael 1989).

All angled fish were confined to cages in this study, possibly confounding results because of stress related to confinement. However, fish densities in this study were kept below 14 fish/m^3; well below a study in Wisconsin that found no density-dependant mortality of control fish (mean length 171 mm) held at 79 fish/m^3 (DuBois and Dubielzig 2004). Further, low correlation was found between number of fish in a cage and number of mortalities in this study, suggesting minimal "cage effect" on mortality.

This study assessed immediate and short-term mortality (<72 h) (Pollock and Pine 2007) of rainbow trout, brown trout, and mountain whitefish. Mortality beyond 72 h could have occurred due to indirect effects of CR. 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 underestimating CR mortality. Another indirect effect of stress resulting from CR is increased susceptibility to disease (Pickering 1981; Schreck 2000). Fish may succumb to disease days or weeks after being stressed. However, 90% of CR mortality often occurs within 48 h (Mongillo 1984) and the results from this study were similar.

Although much is unknown about the effects of CR at the population level, several studies have implicated recreational angling in population-level changes including reduced biomass, population declines, and altered age structure of fish (Post et al. 2002; Sullivan 2003; Almodovar and Nicola 2004). Fish populations experiencing high rates of CR mortality could experience the same effects as fisheries experiencing over-harvest (Arlinghaus et al. 2007). Mortality of fish resulting from CR has been suggested to be excessive if it exceeds 20% (Muoneke and Childress 1994), however factors such as environmental conditions and life-history characteristics (e.g., slow growth, old age at maturation) must be considered when deriving such an estimate (Arlinghaus et al. 2007).

Catch-and-release mortality of rainbow trout and mountain whitefish increased when daily maximum water temperature was >20°C and mortality of brown trout increased when daily maximum water temperature was ≥23°C. Montana Fish, Wildlife and Parks full angling closures at water temperatures ≥23°C are conserving rainbow trout and brown trout from increased mortality. Mortality of mountain whitefish approached 30% at water temperatures ≥23°C in the Smith River and this result warrants further investigation. Mortality of rainbow trout angled in the evening when daily maximum water temperature was >20°C was higher than rainbow trout angled in the morning. Laboratory results corroborate field results with respect to increased mortality of rainbow trout stressed in evening. These results support Montana Fish, Wildlife and Parks time-of-day angling closures. Although there was a relationship between elevated water temperature and salmonid mortality in this study, most of the mortality estimates were well below predicted values. Given the low mortality values and decreased angler catch rates at warmer water temperatures, the population-level effect of CR in Montana streams may be negligible. However, the impact of multiple captures is unknown; thus, current closure regulations are conservative and likely warranted.

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