Articles

Effects of Air Exposure on Survival of Yellowstone Cutthroat Trout Angled from a Stream with Warm Water Temperatures

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Abstract

We evaluated the effects of air exposure on Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* caught and released in a cold-water stream with elevated water temperatures (i.e., $> 14°C$) in southeastern Idaho. Anglers caught fish in a 2.3-km section of Fall Creek, Idaho, during August 2018. Sampled fish remained underwater while we measured and then tagged them with T-bar anchor tags. We exposed fish to air for 0, 30, or 60 s and then released them at the point of capture. We continuously monitored temperature during the study period. Water temperatures during the study varied from 10.0 to 19.7°C and averaged 14.9°C (SE = 0.08). In total, anglers caught 161 Yellowstone Cutthroat Trout over 10 d. Of those fish, we did not expose 54 to air; we exposed 54 to air for 30 s, and 53 for 60 s. We used electrofishing to recapture tagged fish and estimate relative survival. Relative survival was highest for fish exposed to air for 60 s (0.40 [SE = 0.25]) followed by 0 s (0.35 [SE = 0.25]) and 30 s (0.30 [SE = 0.27]), but differences were not statistically significant. Results from this study are consistent with other air-exposure studies suggesting that air exposure of 60 s or less is not likely a concern in Yellowstone Cutthroat Trout fisheries. Releasing fish as quickly as possible is always encouraged, but management regulations restricting air exposure seem unnecessary given the collective body of field-based research on air exposure. Nevertheless, similar studies on other systems and species are warranted.

Keywords: catch-and-release angling; air exposure; Yellowstone Cutthroat Trout

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Introduction

Fisheries managers have used catch-and-release angling since the 1950s (Thompson 1958) and have used it widely over the last several decades (Isermann and Paukert 2010). Managers have implemented catch-and-release regulations to improve fisheries or conserve fish populations (Johnson and Bjorn 1978; Anderson and Nehring 1984; Perry et al. 1995; Schneider and Lockwood 2002; Sullivan 2003). However, recent concerns regarding the effects of catch-and-release have resulted in social movements (e.g., KeepEmWet Fishing) and restrictions on angling practices (e.g., MFWP 2019; WDFW 2019). As catch-and-release angling has become more widespread, it has become increasingly important for fisheries managers to understand angler behavior and how catch-and-release angling influences fish (e.g., Wydoski 1977; Schill et al. 1986; Ferguson and Tufts 1992; Thompson et al. 2008; Lamansky and Meyer 2016; Roth et al 2018a, 2018b).

Researchers have assessed the effects of air exposure during catch-and-release angling in both the laboratory and the wild. Although laboratory physiology studies on confined fish provide valuable information, managers can readily take the results out of context and it can be difficult to apply these results directly to wild populations (Ferguson and Tufts 1992). A few studies have shown negative effects of air exposure on survival (Ferguson and Tufts 1992; Gingerich et al. 2007; Graves et al. 2016), but these studies all have limitations that make it difficult to apply their results more broadly (i.e., laboratory environment, extended fight time, unrealistic air exposure times). The majority of air exposure studies on wild populations have found minimal or no effect on survival (e.g., Thompson et al. 2008; Rapp et al. 2014; Louison et al. 2016; Gange et al. 2017; Roth et al. 2018b; Twardek et al. 2018; Roth et al. 2019).

Few studies have focused on mortality effects of both air exposure and water temperature during catch-and-release angling. Boyd et al. (2010) evaluated the influence of water temperature on caught-and-released Rainbow Trout *Oncorhynchus mykiss*, Brown Trout *Salmo trutta*, and Mountain Whitefish *Prosopium williamsoni* in the Smith and Gallatin rivers, Montana, by comparing survival of fish caught during "cool" water temperatures (daily maximum temperatures of 20.0°C or less), "warm" water temperatures (daily maximum temperatures of 20.0 to 22.9°C), and "hot" water temperatures (daily maximum temperatures of 23.0°C or higher). The authors found that the relationship between mortality and water temperature varied by system and species. For example, Rainbow Trout caught in hot water had higher mortality than those caught at lower temperatures in both rivers. Mountain Whitefish caught in warm and hot water in the Smith River had higher mortality than those caught during periods of cool water temperatures. In contrast, mortality of Mountain Whitefish in the Gallatin River was similar across the three water temperatures. They observed similar patterns Brown Trout. Although the primary focus of the research was on water temperature, the authors also evaluated air exposure and found that it was not a statistically significant predictor of mortality across species. The only exception was a positive relationship between air exposure and mortality of Mountain Whitefish in the Gallatin River and a negative relationship with mortality of Brown Trout in the Smith River. Although Boyd et al. (2010) provides valuable information on a wild trout fishery, it is important note that they confined fish to cages, which may have increased stress and mortality. Additionally, the study lacked a control so the effects of angling on survival are unknown. Roth et al. (2018b) evaluated relative survival of Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri*, Rainbow Trout, and Bull Trout *Salvelinus confluentus* exposed to air in several Idaho streams when summer stream temperatures were at their peak. Survival did not differ among treatments of 0, 30, or 60 s of air exposure. Although their study was conducted during the summer and air temperatures were hot (i.e., $\geq$ 25.0°C), a potential limitation of this study was that water temperatures were relatively cool during angling (8.7–13.8°C; Roth et al. 2018b). Since temperature influences fish behavior and physiology (Johnstone and Rahel 2003), fisheries managers need additional research to fully understand the effects of water temperature on survival of caught-and-released fishes as it relates to air exposure. As such, the objective of this study was to evaluate the effects of air exposure up to 60 s on caught-and-released Yellowstone Cutthroat Trout in a cold-water stream with water temperatures that frequently exceed the thermal optimum of the subspecies.

Methods

We conducted this study on Fall Creek, a tributary to the South Fork Snake River in southeastern Idaho. We selected Fall Creek because it has water temperatures that regularly exceed optimum temperatures for Yellowstone Cutthroat Trout, which are 4.5–15.5°C (Gresswell 1995). A large-scale study ($n = 378$ randomly selected streams) conducted in Idaho reported that Yellowstone Cutthroat Trout were present in streams with water temperatures varying from 4.0 to 17.0°C during July and August (K. Meyer, Idaho Department of Fish and Game, unpublished data; Meyer et al. 2006). Fall Creek's water temperatures are in the upper 99th percentile of streams that Meyer et al. (2006) sampled in July and August.

We selected a 2.3-km reach of Fall Creek based on Yellowstone Cutthroat Trout abundance, access, and historical water temperatures. The downstream terminus of the reach was located approximately 6.5 km upstream of the confluence with the South Fork Snake River. The reach terminated approximately 4.6 km downstream of the confluence with the South Fork Fall Creek. We continuously monitored water temperatures during the study with in-stream temperature loggers at the upstream and downstream ends of the reach. A Natural Resources Conservation Service site (Snotel Site 695) monitored air temperature. Anglers caught Yellowstone Cutthroat Trout from 1100 to 1700 hours in August 2018 when water temperatures were the warmest (i.e., $> 11.0^{\circ}$C). Anglers varied in experience and we randomly placed them in groups of two or three to facilitate accurate data collection. They used artificial lures and flies with barbed J-hooks. Barbed hooks have higher retention efficiency (DuBois and Kuklinski 2004) and the same mortality rates as barbless hooks (Schill and Scarpella 1997). Anglers netted fish with rubber-mesh nets. Once an angler had netted a fish, they removed the hook, measured total length to the nearest millimeter, and tagged the fish with a T-bar anchor tag in the dorsal musculature. They clipped the left pelvic fin to provide a second mark for estimates of tag loss. We recorded fight time (hook set to landing), type of gear (artificial lure or fly), hook location (corner of mouth, esophagus, eye, full mouth, gills, lower jaw, snout, tongue, unknown, or upper jaw), tag number, total length, and water temperature at capture. They conducted all fish processing with the fish held underwater, and did not expose fish to air until we applied the air exposure treatment (Roth et al. 2018b, 2019). We randomly assigned the first fish caught a treatment of 0, 30, or 60 s of air exposure. After the first fish, we applied treatments systematically. We based treatment times on angler observation studies conducted in Idaho and Oregon where, on average, anglers held fish out of water for less than 30 s and few anglers ($< 5\%$) held fish out of water for more than 60 s (Lamansky and Meyer 2016; Roth et al. 2018a). After the air exposure treatment, we released fish at the point of capture.

Ten days after angling concluded, we electrofished the study reach to evaluate fish survival. Electrofishing began at the downstream terminus and slowly progressed in an upstream direction. We used three backpack units (Model LR-24 Backpack Electrofisher; Smith-Root, Inc., Vancouver, WA) to complete two passes through the entire stream. Two to four personnel followed the backpack units to net and process fish. We conducted a final pass through the lower 1.7 km of the reach with a canoe outfitted for electrofishing. We conducted this because this section of the stream was challenging to sample with backpack units given the water depth. The canoe electrofishing unit consisted of a canoe outfitted with a variable voltage pulsator (Infinity control box; Midwest Lake Electrofishing Systems, Inc., Polo, MO), a 1,200-W generator (American Honda Motor Co., Inc., Alpharetta, GA), and two anodes. Electrofishing with a canoe involved one person controlling the canoe and variable voltage pulsator, two personnel operating probes, and three personnel netting fish.

We estimated relative survival as the proportion of recaptured fish in each treatment group. We used the standard formula for proportions to calculate confidence intervals (95% CIs; Zar 1996):

$$p \pm 1.96\sqrt{\frac{pq}{n}} \tag{1}$$

where p is the sample proportion, $q = 1 - p$, and n is the sample size. We evaluated the relative survival among groups statistically by comparing the differences between recapture proportions with 95% CIs (Scheaffer et al. 2006). We determined the lower limit was determined by the following equation:

$$(p_1 - p_2) - c_{\infty/2}\sqrt{\frac{p_1 q_1}{n} + \frac{p_2 q_2}{n}} \tag{2}$$

and the upper limit by

$$(p_1 - p_2) + c_{\infty/2}\sqrt{\frac{p_1 q_1}{n} + \frac{p_2 q_2}{n}} \tag{3}$$

Where n are sample sizes, p_1 and p_2 are the two recapture proportions, $q_1 = 1 - p_1$, $q_2 = 1 - p_2$, and $c_{\infty/2}$ is 1.96. If 95% CIs around the differences in proportions did not contain zero, we considered them statistically different (Johnson 1999; Schill et al. 2016, Roth et al. 2018b).

Results

In total, anglers caught 161 Yellowstone Cutthroat Trout over 10 d. Of those fish, we did not expose 54 to air, exposed 54 to air for 30 s, and exposed 53 to air for 60 s. We caught the majority of the fish in the first three days of the study (71.4%). Despite similar amounts of effort, the number of fish we caught decreased from 54 fish on day 1 to 5 fish on the last day of angling. We caught most fish with artificial lures (74.5%) and the remainder with flies. We hooked the majority of fish in the corner of the mouth, lower jaw, or upper jaw (82.0%). We hooked few fish in vital areas such as the esophagus, gills, or eye ($< 5\%$). Angled fish varied in length from 124 to 375 mm and averaged 206 mm (SD $=$ 47.2; Figure 1). Average daily water temperature during the study was 14.9°C (SE $= 0.08$) and varied from 10.0 to 19.7°C. Daily air temperature during the study varied from 2.4 to 34.2°C and averaged 16.3°C (SE $=$ 0.3). During angling, water temperatures averaged 17.0°C (SE $=$ 0.18) and varied from 14.3 to 19.1°C. Water temperature at time and point of capture varied from 11.0 to 17.0°C and averaged 14.9°C (SD $=$ 1.2; Figure 2). Average fight time was 11.7 s (SD $= 6.9$) and varied from 1.3 to 76.1 s. Fight time was similar among treatment groups; average fight time for 0 s of air exposure was 12.2 s (SD $= 5.3$), for 30 s of air exposure was 11.3 s (SD $= 9.7$), and 11.6 s (SD $= 4.7$) for 60 s of air exposure. We recaptured 56 fish with tags (0 s: $n = 19$; 30 s: $n = 16$; 60 s: $n = 21$). We estimated tag loss as 4.5%.

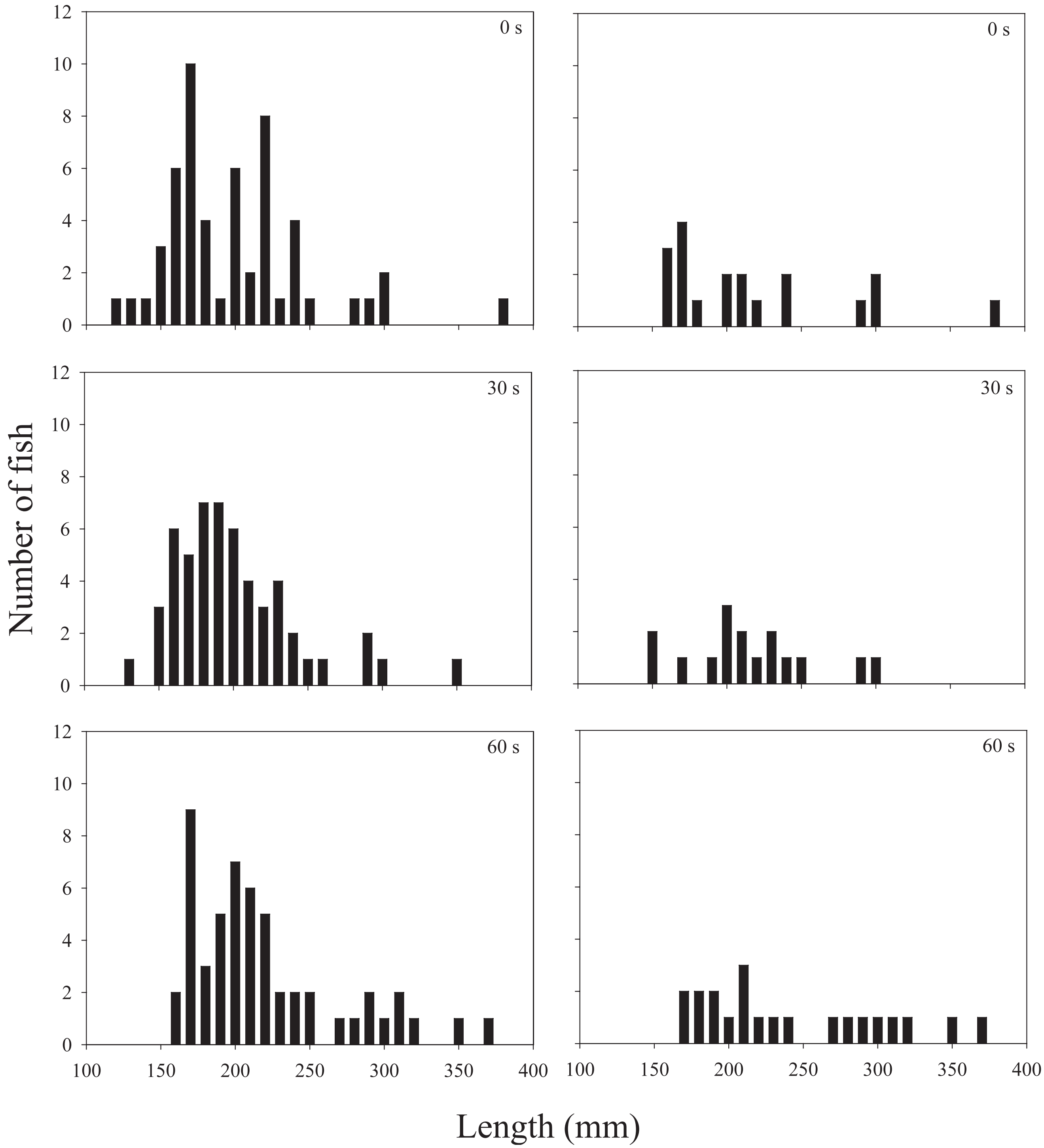

Figure 1. Length-frequency distributions for Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* tagged (left panels) and recaptured (right panels) from Fall Creek, Idaho (August 2018), by air-exposure treatment groups.

The majority of recaptured fish were those that anglers hooked in the corner of the mouth, lower jaw, or upper jaw (82.0%). The average length of recaptured fish was 225.1 mm (SD = 56.2) and varied from 151.0 to 375.0 mm (Figure 1). Tagged fish that we did not recapture averaged 194.3 mm (SD = 36.9) in length and varied from 124.0 to 349.0 mm. We directly observed five mortalities during recapture efforts: two from the 0-s air exposure treatment, one from the 30-s air exposure treatment, and two from the 60-s air exposure treatment. Comparison of treatment groups produced 95% CIs that overlapped zero indicating that relative survival did not differ statistically among treatment groups (Figure 3).

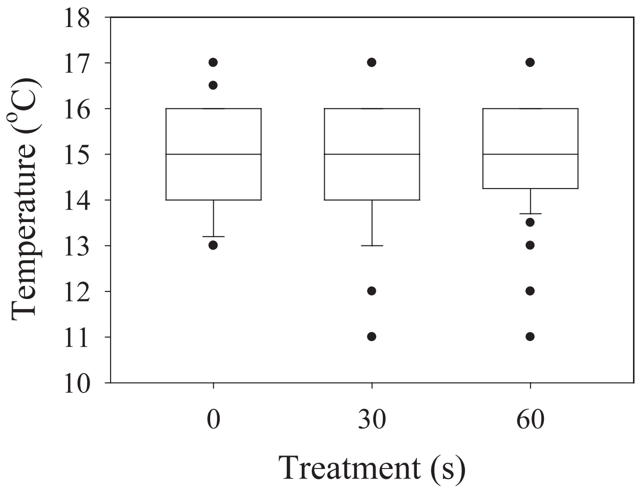

Figure 2. Water temperature at the point of capture of Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* from Fall Creek, Idaho (August 2018) for each air-exposure treatment group.

Discussion

Air exposure up to 60 s had no effect on relative survival of Yellowstone Cutthroat Trout. This finding is consistent with many other studies that have assessed the effects of air exposure on fishes (Schreer et al. 2005; Thompson et al. 2008; Rapp et al. 2014; Louison et al. 2016; Gange et al. 2017; Roth et al. 2018b, 2019). Although average fish length was relatively small (206 mm; SD = 47.2) in the present study, our findings are consistent with similar studies that sampled larger Yellowstone Cutthroat Trout and other salmonids (e.g., Gale et al. 2011; Roth et al. 2019). In contrast, several studies have demonstrated negative effects of air exposure on caught-and-released fishes (Ferguson and Tufts 1992; Gingerich et al. 2007; Graves et al. 2016). For example, Bluegill *Lepomis macrochirus* in Ontario, Canada, experienced mortality at high water temperatures and long air-exposure treatments (Gingerich et al. 2007). However, the majority of mortalities were fish treated with air exposure times of 240, 480, and 960 s at 27.4°C. If we do not consider the arguably unrealistic long air-exposure times, then they observed no significant difference in mortality among treatment groups. Rainbow Trout experienced high mortality (72%) after exhaustive exercise, cannulation, and exposure to air for 60 s (Ferguson and Tufts 1992). Fish not exposed to air, but exhaustively exercised and cannulated experienced 12% mortality. Although Ferguson and Tufts (1992) provide insight on the effects of air exposure, the conditions of their study do not mimic a typical catch-and-release fishery (e.g., cannulation) and the results may overestimate the mortality due to air exposure.

Warm water temperatures may directly and indirectly cause mortality of fishes. Wagner et al. (2001) assessed the thermal tolerances of four subspecies of Cutthroat Trout *Oncorhynchus clarkii* spp., one of which was a population of Yellowstone Cutthroat Trout that had hybridized with Bonneville Cutthroat Trout *Oncorhynchus clarkii utah* and Rainbow Trout. They reported the lethal temperature was 24.1°C. Wagner et al. (2001) also assessed the thermal tolerance of Snake River Fine-Spotted Cutthroat Trout *Oncorhynchus clarkii behnkei*. The taxonomy of Snake River Fine-Spotted Cutthroat Trout and Yellowstone Cutthroat Trout has not been resolved, but fisheries biologists generally consider them to be the same subspecies in Idaho (Leary et al. 1987; but also see Sigler and Zoroban 2018). Wagner et al. (2001) reported the lethal temperature for Snake River Fine-Spotted Cutthroat Trout as 23.5°C. Water temperatures in Fall Creek (max = 19.7°C) did not reach the likely lethal temperature for Yellowstone Cutthroat Trout. However, temperatures were well beyond their optimal tempera-

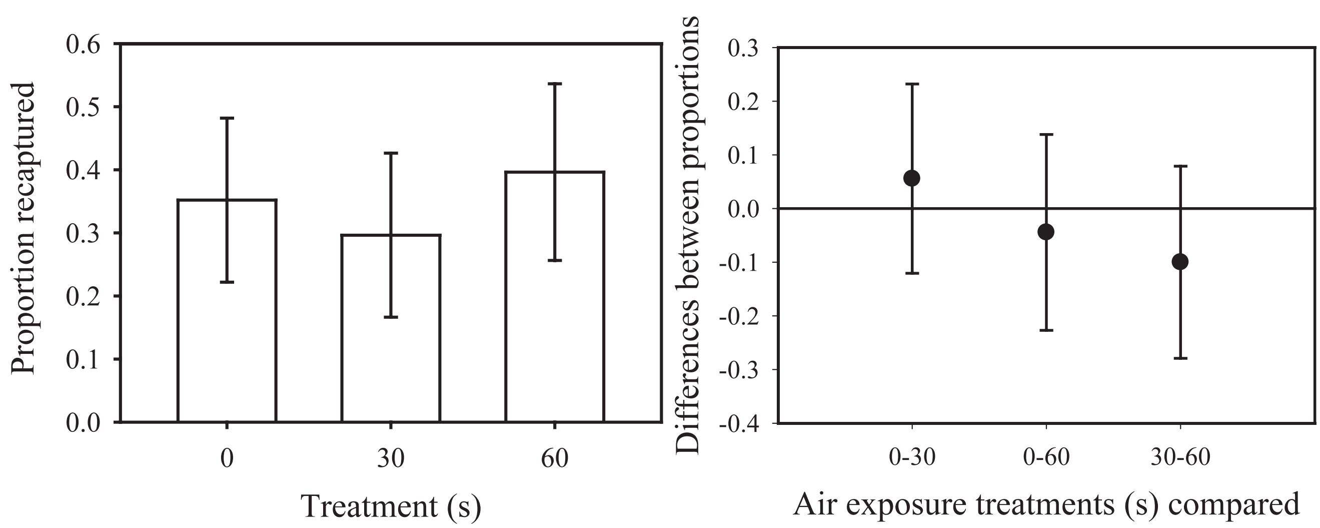

Figure 3. The proportion of Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* in each treatment group (left panel) recaptured from Fall Creek, Idaho (August 2018) and differences between the proportions of recaptured fish between treatment groups (right panel). Error bars are 95% confidence intervals.

tures of 4.5–15.5°C (Gresswell 1995) and we deliberately selected Fall Creek for this study because it experiences unusually warm water temperatures for the subspecies based on comprehensive surveys in Idaho (K. Meyer, Idaho Department of Fish and Game, unpublished data; Meyer et al. 2006).

Few studies have explicitly evaluated the effect of air exposure at high water temperatures. Gale et al. (2011) assessed the influence of water temperature and air exposure on Sockeye Salmon *Oncorhynchus nerka* from the Fraser River, British Columbia, during a period of relatively high water temperatures (13–21°C). They caught fish and then assigned an exercise treatment: 1) "handling only", 2) "capture" which included 3 min of chasing, or 3) "capture plus air exposure" which included 3 min of chasing followed by 1 min of air exposure. They observed no significant effect on mortality, regardless of air exposure or exercise. In our study, we caught and released fish during a period of high water temperatures for the subspecies, but air exposure had no effect on mortality. One explanation for high survival may be that fish had an opportunity to "recover" when temperatures cooled at night. Johnstone and Rahel (2003) observed 100% mortality of Bonneville Cutthroat Trout exposed to constant high temperatures ($\geq$ 25°C), but observed no mortality in fish exposed to water temperatures cycled between 10 and 20°C or 16 and 26°C. These results suggest that mortality may be reduced when temperatures cycle, fish have access to cold-water refugia, or both.

Regardless of the effect of air exposure at warm water temperatures, the behavior of fish and anglers may mitigate any possible negative interactions. Specifically, catchability of fish may decrease when water temperatures are warm. Using a simple Lincoln–Peterson mark–recapture model (Ricker 1975), we estimated the total population size of Yellowstone Cutthroat Trout in the study reach as 1,314. Based on our catch, we caught approximately 12.3% of the Yellowstone Cutthroat Trout in the study area. In a similar study on a nearby stream with cooler water temperatures, Roth et al. (2018b) caught 29.9% of the Yellowstone Cutthroat Trout population over a similar time frame and with similar effort. Feeding and activity levels of fish typically decrease with warm temperatures and may reduce the susceptibility of fish to angling (Johnstone and Rahel 2003). Consequently, warm water temperatures may not be a primary management concern for catch-and-release fisheries if fish are not highly susceptible to angling during warm summer months.

This study provides information on the effects of air exposure on a thermally sensitive species during a period of relatively warm water temperature. Air exposure up to 60 s did not affect Yellowstone Cutthroat Trout survival despite water temperatures exceeding the thermal optimum of the subspecies. This finding, coupled with the majority of previous field-based air exposure studies, suggests that concern associated with air exposure in catch-and-release fisheries is primarily a social concern. Although managers have occasionally implemented regulations from social pressure and community advocacy, there may be potential social costs and credibility loss for such management agencies (Barnhart 1989; Schill and Scarpella 1997). Releasing fish as quickly as possible is always encouraged, but management regulations restricting air exposure seem unnecessary given the collective body of field-based research on air exposure. Nevertheless, similar studies in other systems and on other species are warranted.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Reference S1. Gresswell RE. 1995. Yellowstone Cutthroat Trout. Pages 36–54 *in* Young MK, editor. Conservation assessment for inland cutthroat trout. U.S. Forest Service General Technical Report RM-256. Fort Collins, Colorado.

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Found at DOI: https://doi.org/10.3996/042019-JFWM-025.S2 (720 KB PDF); also available at https://collaboration.idfg.idaho.gov/FisheriesTechnicalReports/Res-Johnson1975%20Evaluation%20of%20Angling%20Regulations%20in%20Management%20of%20Cutthroat%20Trout%20Job%20Performance%20Report.pdf.

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