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ARTICLE

Effects of Air Exposure in Summer on the Survival of Caught-and-Released Salmonids

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Abstract
Despite the success of catch-and-release regulations, exposing fish to air during release has emerged as a growing concern over the past two decades. We evaluated the effect of air exposure during midsummer on survival of Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri*, Bull Trout *Salvelinus confluentus*, and Rainbow Trout *O. mykiss* exposed to catch-and-release angling. Fish were sampled by angling on Palisades Creek (August 2016), Sawmill Creek, and the Main Fork of the Little Lost River, Idaho (July−August 2017). After capture, fish were kept underwater while they were measured and individually tagged. Anglers, in groups of two to four, caught study fish and gave them an air exposure treatment of 0, 30, or 60 s. Single-pass backpack electrofishing was then used to recapture tagged fish and estimate relative survival. In total, 328 Yellowstone Cutthroat Trout were sampled (0 s: *n* = 110; 30 s: *n* = 110; 60 s: *n* = 108), 278 Bull Trout (0 s: *n* = 92; 30 s: *n* = 94; 60 s: *n* = 92), and 322 Rainbow Trout (0 s: *n* = 103; 30 s: *n* = 106; 60 s: *n* = 113). The majority of fish were caught using artificial flies (≥92%) and were hooked in the corner of the mouth, lower jaw, or upper jaw (≥78%) in all three species. No difference in survival was observed among air exposure treatments for all three species. Results from the present study along with those from prior field studies of air exposure times during angling suggest that mortality from exposing fish to air for ≤60 s is not likely a population-level concern in catch-and-release fisheries for these species.

Catch-and-release angling regulations are one regulatory tool available for fisheries managers (Isermann and Paukert 2010) and are implemented for a variety of reasons such as to prevent the consumption of contaminated fish (Carline et al. 1991), protect species that are easily overexploited (Sullivan 2003), improve the quality of the fishery (Perry et al. 1995; Schneider and Lockwood 2002), and for social reasons (Schill and Scarpella 1997). When

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catch-and-release regulations are implemented to improve the quality of a fishery, their success depends on whether released fish survive (Wydoski 1977; Isermann and Paukert 2010). Further, it is becoming increasingly apparent that a sizeable portion of legally harvestable fish are being released, even in yield-oriented fisheries (Myers et al. 2008). A number of factors can influence the survival of fish that have been caught and released, including the species of fish (Gale et al. 2011), hook location (Pauley and Thomas 1993), water depth at which the fish was hooked (Gitschalg and Renaud 1994), type of hook used (Mongillo 1984), type of bait or lure used (Schisler and Bergersen 1996), water temperature (Dotson 1982; Brownscombe et al. 2017), how the fish was handled (Gale et al. 2011), and air exposure.

In recent years, studies on the effects of air exposure during catch-and-release angling have become increasingly prevalent in the fisheries literature. Studies of fish exposed to air include evaluations of reproductive success (Raby et al. 2013; Richard et al. 2013), the ability to cope with thermal stress (e.g., Gale et al. 2011), and swimming performance (Schreer et al. 2005). However, the majority of air exposure studies have evaluated whether air exposure increases mortality rates in fish that have been caught and released (Ferguson and Tufts 1992; Gingerich et al. 2007; Suski et al. 2007; Graves et al. 2016). A few of these studies have reported that air exposure increases mortality of fish that have been caught and released (Ferguson and Tufts 1992; Graves et al. 2016). However, the majority of studies that have evaluated the effects of air exposure on mortality have reported that air exposure causes little or no increase in mortality of released fish (Schreer et al. 2005; Gingerich et al. 2007; Suski et al. 2007; Thompson et al. 2008; Rapp et al. 2014; Gagne et al. 2017; Louison et al. 2017).

Even though a preponderance of published studies show little or no mortality from air exposure, some constituents have continued to express concerns, with proponents of air exposure limitation consistently citing Ferguson and Tufts (1992) to support regulating the amount of time that anglers can expose fish to air (e.g., Cook et al. 2015). This reliance on Ferguson and Tufts (1992) to argue in favor of limiting air exposure is concerning. The Rainbow Trout *Oncorhynchus mykiss* used by Ferguson and Tufts (1992) had a 72% rate of mortality when exposed to air for 60 s. However, those fish were chased in a laboratory setting for 600 s, cannulated, and subjected to five consecutive blood sampling events. An unusually high proportion of the study fish died including the controls. Due to the artificial nature of the study, Ferguson and Tufts (1992) cautioned that the results of their study were not applicable to actual fisheries for fishes in the wild (Ferguson and Tufts 1992:1161).

A number of factors have made it difficult to apply the results of previous air exposure studies, including that of Ferguson and Tufts (1992), to wild fishes. For instance, fish have been held in tanks before or after exposure to air (e.g., Ferguson and Tufts 1992; Gingerich et al. 2007; Suski et al. 2007), fish have been exposed to longer "simulated" fight times than they would experience in actual catch-and-release fisheries (e.g., Ferguson and Tufts 1992), or fish were exposed to air longer than they would experience in actual catch-and-release fisheries (e.g., Gingerich et al. 2007; Suski et al. 2007; Thompson et al. 2008; Rapp et al. 2014; Louison et al. 2017). In the only three studies to date that report actual air exposure and fight times, fight and air exposure times were much shorter than those evaluated in nearly all previous physiological or mortality studies on the effects of air exposure (Lamansky and Meyer 2016; Chiaramonte et al. 2017; Roth et al. 2018). Further, the use of hatchery fish in raceways or confining study fish into raceways or a laboratory setting makes it difficult for fisheries managers to make informed decisions associated with actual catch-and-release fisheries. Our objective was to evaluate the effects of air exposure on the survival of wild, unconfined Yellowstone Cutthroat Trout *O. clarkii bouvieri*, Bull Trout *Salvelinus confluentus*, and Rainbow Trout caught via hook-and-line angling. Because water temperature has been implicated to increase mortality in a number of past hooking and air exposure studies (Dotson 1982; Gingerich et al. 2007), we purposefully conducted this work during the summer when water temperatures would be at their warmest in three Idaho streams.

METHODS

Study area.— We evaluated the effects of air exposure on survival of Yellowstone Cutthroat Trout in Palisades Creek, Idaho, a tributary of the South Fork Snake River that enters the river 5.62 km downstream from Palisades Dam (Figure 1). Discharge in Palisades Creek is typically 0.2 to 17.0 m^3/s (Moore and Schill 1984). Angling occurred during August 1–4, 2016, beginning 0.73 km upstream from Lower Palisades Lake and continuing upstream for 2.26 km. Water temperatures in Palisades Creek were monitored during the study with instream thermographs. Water temperatures in Palisades Creek during the study averaged 11.5°C (SE = 0.03) and varied diurnally from 9.9°C to 13.6°C. Stream temperatures during actual angling sessions (0800–1800 hours) averaged 11.6°C (SE = 0.1) and varied from 10.4°C to 13.2°C. Because air temperatures could also influence survival, they were monitored using Natural Resources Conservation Service data from a nearby site (Snotel Site 695). Average diurnal air temperature was 18.4°C (SE = 1.0) and varied from 4.7°C to 30.6°C during the study period.

Bull Trout and Rainbow Trout were sampled in two tributaries of the Little Lost River, Idaho: Sawmill Creek and Main Fork of the Little Lost River (Figure 2). The

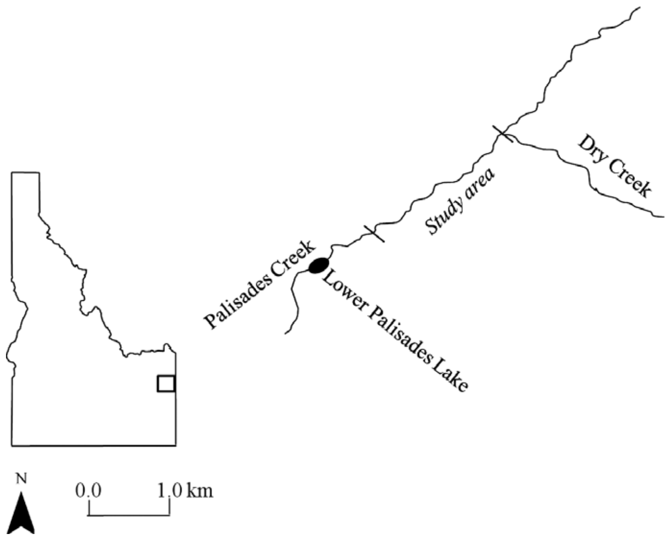

FIGURE 1. Palisades Creek from Lower Palisades Lake to its confluence with Dry Creek, Idaho. Angling took place during July 2016 to evaluate the effects of air exposure on Yellowstone Cutthroat Trout.

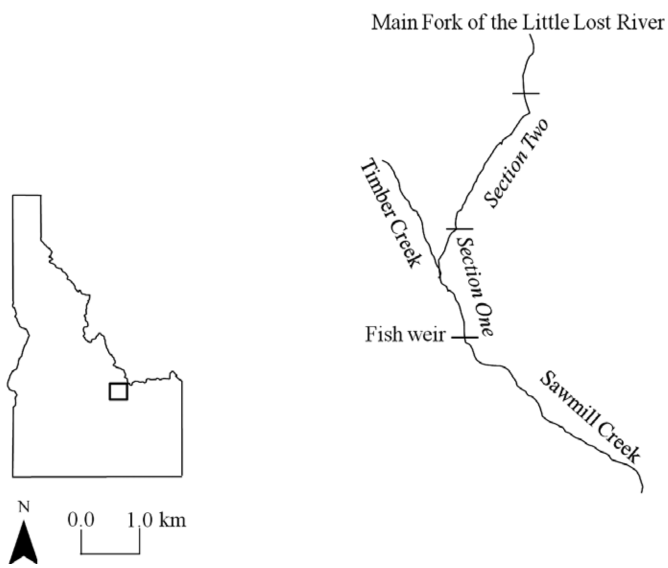

FIGURE 2. Main Fork of the Little Lost River to its confluence with Timber Creek where it is renamed Sawmill Creek, Idaho. Angling took place during July and August 2017 to evaluate the effects of air exposure on Bull Trout and Rainbow Trout.

Main Fork of the Little Lost River is renamed Sawmill Creek after its confluence with Timber Creek. Sawmill Creek and the Main Fork of the Little Lost River were divided into two contiguous sections for angling. The lowermost section (section 1) began in Sawmill Creek directly upstream from an existing fish weir and continued upstream into the Main Fork of the Little Lost River for 2.73 km. Section 1 was angled during July 10–14, 2017. The second section (section 2) began at the upstream terminus of section 1 and continued upstream for 2.79 km. Angling took place in section 2 during August 7–11, 2017. Water temperatures were monitored using instream thermographs in both sections. Water temperature averaged 10.1°C (SE = 0.1) and varied from 6.6°C to14.4°C in section 1. Average water temperature was similar in section 2 (mean ± SE; 9.8 ± 0.1°C) and varied from 6.8°C to 16.7°C. Stream temperatures during actual angling (0800–1800 hours) in section 1 averaged 11.4°C (SE = 0.2) and varied from 8.7°C to 13.8°C. Temperatures were similar during angling (0800–1800 hours) in section 2 (10.8 ± 0.1°C) and varied from 9.3°C to 12.6°C. Air temperature data for both sections were obtained from the Natural Resources Conservation Service (Snotel Site 636). Air temperatures averaged 15.8°C (SE = 0.5) and varied from 5.7°C to 28.4°C in section 1. Air temperature in section 2 was slightly cooler (12.0 ± 0.7°C) and varied from 4.0°C to 23.7°C.

Field sampling.— Fish were caught by hook-and-line angling using artificial lures or flies and general methods used by a typical angler. Barbed hooks were used since barbed and barbless hooks have similar unhooking times and mortality rates (Schill and Scarpella 1997), but the retention efficiency is higher for barbed hooks (Dubois and Kuklinski 2004; Bloom 2013) and we sought to lose as few fish as possible to maximize sample size. All hooks were in-line Jhooks and varied in size from size 6 to 22. Anglers, spanning a considerable range of angling experience, worked in groups of two to four. Anglers were fisheries biologists, summer technicians, and university students, and angling experience varied from <1 year to >30 years. Anglers were not purposefully grouped; groupings were only experienced anglers, experienced and inexperienced anglers, and only inexperienced anglers to mimic actual fisheries. A total of 37 anglers participated in angling efforts. The amount of time it took to play the fish (fight time), the type of gear used (i.e., artificial lure or fly), and where the fish was hooked (e.g., corner of the mouth, lower jaw, upper jaw) was recorded for each capture event (Sullivan et al. 2013). Fish were landed using rubber-meshed nets. After capture, fish remained in the net and underwater while they were measured for TL (mm) and tagged in the upper dorsal musculature using a T-bar anchor tag (Dell 1968). Each fish received a pelvic fin clip as a secondary mark to evaluate tag retention. For each angling group, the first fish captured was randomly assigned to a treatment group and exposed to air for 0, 30, or 60 s. Air exposure treatments were then systematically cycled. Air exposure times were based on the findings of Lamansky and Meyer (2016), who reported that anglers in catch-and-release fisheries in Oregon and Idaho exposed trout to air for an average of 29.4 s and that 96% of anglers exposed trout to air for less than 60 s. After approximately 2 weeks (Palisades Creek = 12 d, section 1 = 10 d, section 2 = 12 d), single-pass backpack electrofishing was conducted in each study section to recapture tagged fish. Electrofishing was conducted using two backpack units, beginning at the downstream boundary of the study sections and moving upstream in tandem. Power output and pulse frequency during electrofishing was optimized to elicit a galvanotaxic response from the fish, and all available habitat was sampled. An additional four to five people accompanied the operators of the electrofishing units to net and process fish.

The proportion (p) of fish recaptured from each treatment group was calculated using the number of individuals, by species, recaptured in each treatment group divided by the total number tagged in that group. These proportions provided an estimate of relative survival. Confidence intervals (95% CIs) were calculated for each using the standard formula for proportions (Zar 1996):

$$\widehat{p} = \pm 1.96\sqrt{\frac{\widehat{p}(1-\widehat{p})}{n}}$$

where $\widehat{p}$ is the sample proportion and n is the sample size.

Data from angling events for Rainbow Trout and Bull Trout that took place in section 1 and section 2 were pooled by species for analysis because they were contiguous and comprised virtually the same water body. The effects of air exposure on survival were then evaluated statistically by calculating 95% confidence bounds around the differences between proportions of recaptured fish using the formula of Fleiss (1981) where the lower limit is given by

$$(p_2 - p_1) - c_{\alpha/2}\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}} - \frac{1}{2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)$$

and the upper limit by

$$(p_2 - p_1) + c_{\alpha/2}\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}} + \frac{1}{2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right),$$

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 $c_{\alpha/2}$ is 1.96. Estimates of relative survival were considered significantly different among the three groups for each species when 95% CIs around the differences did not contain zero (Fleiss 1981; Johnson 1999; Schill et al. 2016). Such an approach is a direct statistical test with the added benefit of clearly identifying both an effect size and the associated precision (Johnson 1999).

Length-frequency distributions were constructed for each species by treatment group. A Kolmogorov–Smirnov (KS) test was used to evaluate whether length distributions of caught and tagged fish were similar among treatment groups (Zar 1996; Neuman and Allen 2007). Length distributions were also compared between fish that were recaptured and fish that were not recaptured by treatment group using a KS test for all three species. Because multiple pairwise comparisons were conducted, significance levels were adjusted using a Bonferroni correction (Koopmans 1987); length distributions were considered statistically different when $P < 0.006$.

RESULTS

In total, 328 Yellowstone Cutthroat Trout were caught on Palisades Creek. Of the fish sampled, 110 received 0 s of air exposure, 110 were exposed to air for 30 s, and 108 were exposed to air for 60 s (Table 1). The majority of fish were captured with flies (92%) and hooked in the corner of the mouth, lower jaw, or upper jaw (78%; Figure 3). Few fish (<2%) were hooked in vital areas such as the esophagus, gills, or eye. Length distributions were not significantly different among treatment groups (KS test: $D = 0.10$–0.13, $P = 0.28$–0.63) with an average TL of 232.8 mm (SE = 2.8; Figure 4). The average fight time for Yellowstone Cutthroat Trout was 16.9 s (SE = 0.5) and was similar among treatment groups (i.e., 0 s = 17.4 ± 0.9 s, 30 s = 16.5 ± 0.9 s, 60 s = 17.0 ± 0.9 s). Of the 328 tagged fish, 204 were recaptured with electrofishing (0 s: $n = 75$, 68%; 30 s: $n = 63$, 57%; 60 s: $n = 66$, 61%; Table 1). Tag retention rates were high for Yellowstone Cutthroat Trout; only one Yellowstone Cutthroat Trout (<1% of all tagged fish) was found with a pelvic fin clip but no tag during recapture efforts. Although length distributions were not significantly different ($D = 0.14$–0.32, $P = 0.01$–0.64), recaptured fish were slightly larger on average (240.9 ± 3.6 mm [mean ± SE], minimum = 129.0 mm, maximum = 354.0 mm) than fish that were not recaptured (219.9 ± 4.6 mm, minimum = 117.0 mm, maximum = 336.0 mm; Table 1). Additionally, comparisons of length distributions revealed that the length distribution of fish that were recaptured were not significantly different between treatment groups ($D = 0.10$–0.16, $P = 0.32$–0.87) and length distributions of fish that were not recaptured were not significantly different between treatment groups ($D = 0.12$–0.15, $P = 0.76$–0.90). No significant difference in relative survival was observed among the three groups (i.e., CIs around their differences overlapped zero; Figure 5).

A total of 278 Bull Trout was caught in Sawmill Creek and in the Main Fork of the Little Lost River (Table 1). The number of fish in each air exposure treatment group was similar; 92 fish received no air exposure, 94 received 30 s of air exposure, and 92 fish received 60 s of air exposure. Bull Trout were predominantly captured with flies (99%) and hooked in the corner of the mouth, lower jaw, or upper jaw (90%; Figure 3). As with Yellowstone

TABLE 1. Sample size, length statistics (mean TL [SD], minimum, maximum) of recaptured fish and the proportion (SE) of recaptured fish by species and treatment group. Fish were sampled, treated, and tagged via angling and then recaptured using single-pass backpack electrofishing. Air exposure treatments were 0, 30, or 60 s. Angling for Yellowstone Cutthroat Trout took place in Palisades Creek, Idaho (July 2016). Bull Trout and Rainbow Trout angling took place in Sawmill Creek and the Main Fork of the Little Lost River, Idaho (July–August 2017).

	Sample size		Length (mm)			
Treatment (s)	Treated	Recaptured	Mean (SD)	Minimum	Maximum	Proportion (SE)
Yellowstone Cutthroat Trout						
0	110	75	239.6 (50.7)	158.0	342.0	0.68 (0.04)
30	110	63	240.6 (50.8)	129.0	354.0	0.57 (0.05)
60	108	66	242.7 (50.3)	141.0	331.0	0.61 (0.05)
Overall	328	204	240.9 (51.4)	129.0	354.0	0.62 (0.05)
Bull Trout						
0	92	48	198.4 (39.7)	135.0	320.0	0.52 (0.05)
30	94	56	205.4 (40.0)	137.0	315.0	0.59 (0.05)
60	92	59	203.2 (40.0)	130.0	312.0	0.64 (0.05)
Overall	278	163	202.5 (39.6)	130.0	320.0	0.58 (0.05)
Rainbow Trout						
0	103	65	189.8 (39.8)	128.0	272.0	0.63 (0.05)
30	106	61	194.4 (39.8)	130.0	288.0	0.58 (0.05)
60	113	58	193.1 (40.0)	124.0	274.0	0.51 (0.05)
Overall	322	184	192.4 (39.3)	124.0	288.0	0.57 (0.05)

Cutthroat Trout, few fish (<1%) were hooked in vital locations. Length distributions were not significantly different (D = 0.06–0.09, P = 0.77–0.99) among the treatment groups (197.2 ± 2.3 mm; Figure 4). Average fight time for Bull Trout was 14.6 s (SE = 0.6) and was similar among treatment groups (0 s = 15.9 ± 1.1 s, 30 s = 14.4 ± 1.1 s, 60 s = 13.7 ± 1.1 s). We recaptured 163 Bull Trout (0 s: n = 48, 52%; 30 s: n = 56, 60%; 60 s: n = 59, 64%; Table 1). Tag retention rates were high. Only four Bull Trout (1%) were captured with a pelvic fin clip but no tag during recapture efforts. Although not statistically significant (D = 0.16–0.18, P = 0.37–0.50), fish that were recaptured had a slightly larger TL (202.5 ± 3.1 mm, minimum = 130.0 mm, maximum = 320.0 mm) than fish that were not recaptured (189.6 ± 3.7 mm, minimum = 124.0 mm, maximum = 320.0 mm; Table 1). Length distributions of fish that were recaptured were not significantly different between treatments (D = 0.08–0.17, P = 0.45–0.99). Additionally, comparisons of length distributions also revealed that there was no significant difference in the length distributions of fish that were not recaptured between treatment groups (D = 0.13–0.16, P = 0.54–0.82). No difference in relative survival was observed among the three groups (Figure 5).

A total of 322 Rainbow Trout was sampled from Sawmill Creek and the Main Fork of the Little Lost River. Sample sizes in each treatment group were similar; 103 received no air exposure, 106 received 30 s of air exposure, and 113 received 60 s of air exposure (Table 1). The majority of Rainbow Trout were captured with flies (99%) and most were hooked in the corner of the mouth, lower jaw, or upper jaw (79%; Figure 3). As with Yellowstone Cutthroat Trout and Bull Trout, few Rainbow Trout were hooked in vital areas. Rainbow Trout were fought for an average of 14.7 s (SE = 0.6) and fight times were similar among treatment groups (0 s = 15.7 ± 1.0 s, 30 s = 13.4 ± 1.0 s, 60 s = 14.9 ± 1.0 s) (<1%). Of the 322 initially captured, 184 fish were recaptured (0 s: n = 65, 63%; 30 s: n = 61, 68%; 60 s: n = 58, 51%; Table 1). As with the previous two species, tag retention rates were high. In fact, no Rainbow Trout (0%) were found with a pelvic fin clip but no tag during recapture efforts. The average length of sampled Rainbow Trout was 190.5 mm TL (SE = 2.2) and length distributions were not significantly different between recapture and nonrecaptured fish (D = 0.07–0.13, P = 0.32–0.97) among treatment groups (Figure 4). Although not significantly different (D = 0.15–0.22, P = 0.13–0.56), recaptured fish were somewhat larger (192.4 ± 2.9 mm, minimum = 124.0 mm, maximum = 288.0 mm) than fish that were not recaptured (188.0 ± 3.4 mm, minimum = 125.0 mm, maximum = 306.0 mm; Table 1). As with the other two species, comparisons of length distributions revealed that the length distributions of fish that were recaptured were not significantly different between treatment groups (D = 0.07–0.12, P = 0.80–1.00), and length distributions of fish that were not recaptured were not significantly different between treatment groups (D = 0.17–0.25,

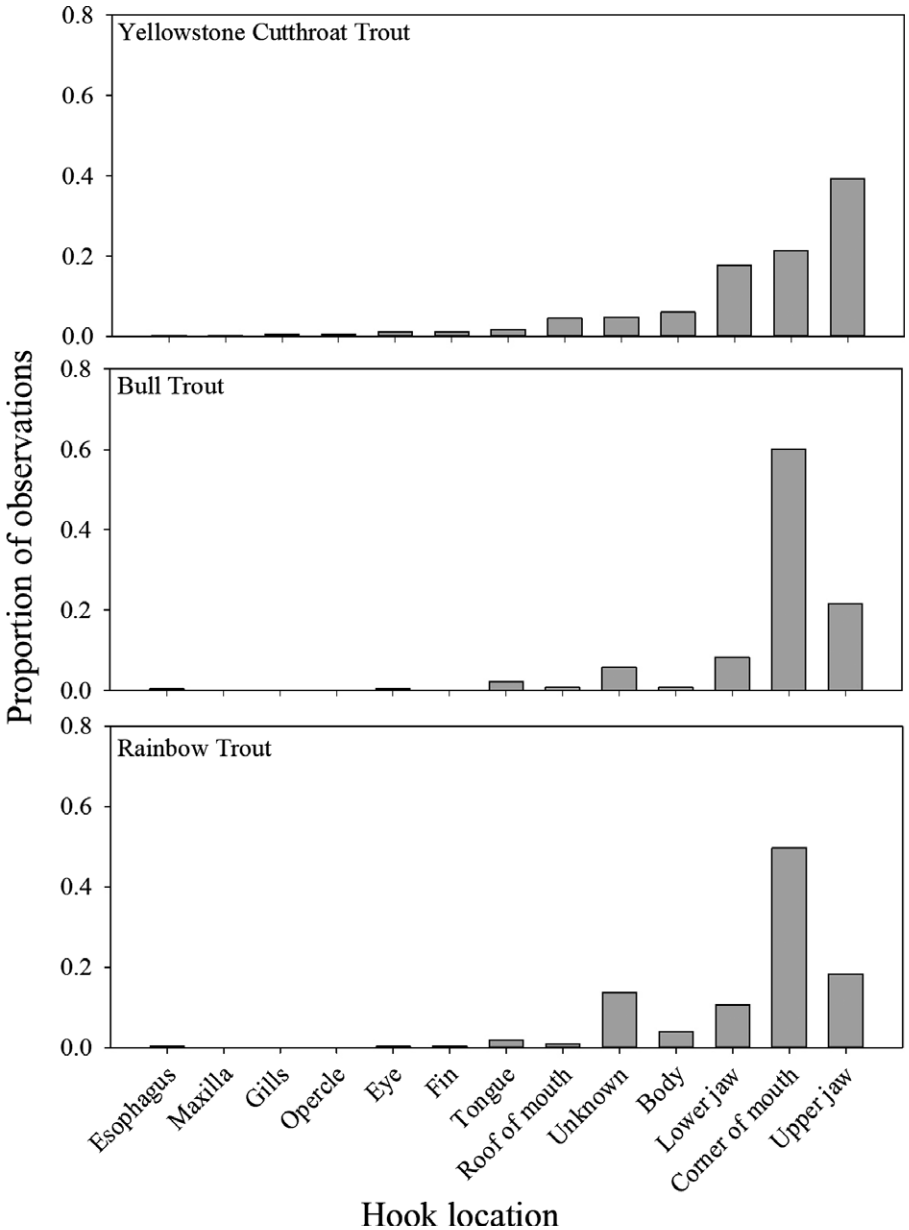

FIGURE 3. The proportion of fish hooked in various locations during hook-and-line angling surveys. Yellowstone Cutthroat Trout were sampled in Palisades Creek, Idaho (August 2016). Bull Trout and Rainbow Trout were sampled in Sawmill Creek and the Main Fork of the Little Lost River, Idaho (July–August 2017).

P = 0.41–0.43). No differences in survival among groups were observed (Figure 5).

DISCUSSION

Relative to control groups, no increase in mortality was observed in Yellowstone Cutthroat Trout, Bull Trout, or Rainbow Trout exposed to air for up to 60 s. Previous studies evaluating the effect of air exposure on mortality have also reported low mortality when fish were exposed to air for times similar to those in our study (e.g., Schreer et al. 2005; Gingerich et al. 2007; Suski et al. 2007; Thompson et al. 2008). For example, Brook Trout *S. fontinalis* were exposed to air in a laboratory setting at the State University of New York, Potsdam, for either 0, 30, 60, or 120 s, and no mortality was reported (Schreer et al. 2005). Bluegills *Lepomis macrochirus* from Lake Opinicon, Ontario, had a mortality rate of 7% after 30 s of air exposure and 9% at 60 s of air exposure (Gingerich et al. 2007). Bonefish *Albula vulpes* exposed to air for 60 s in a

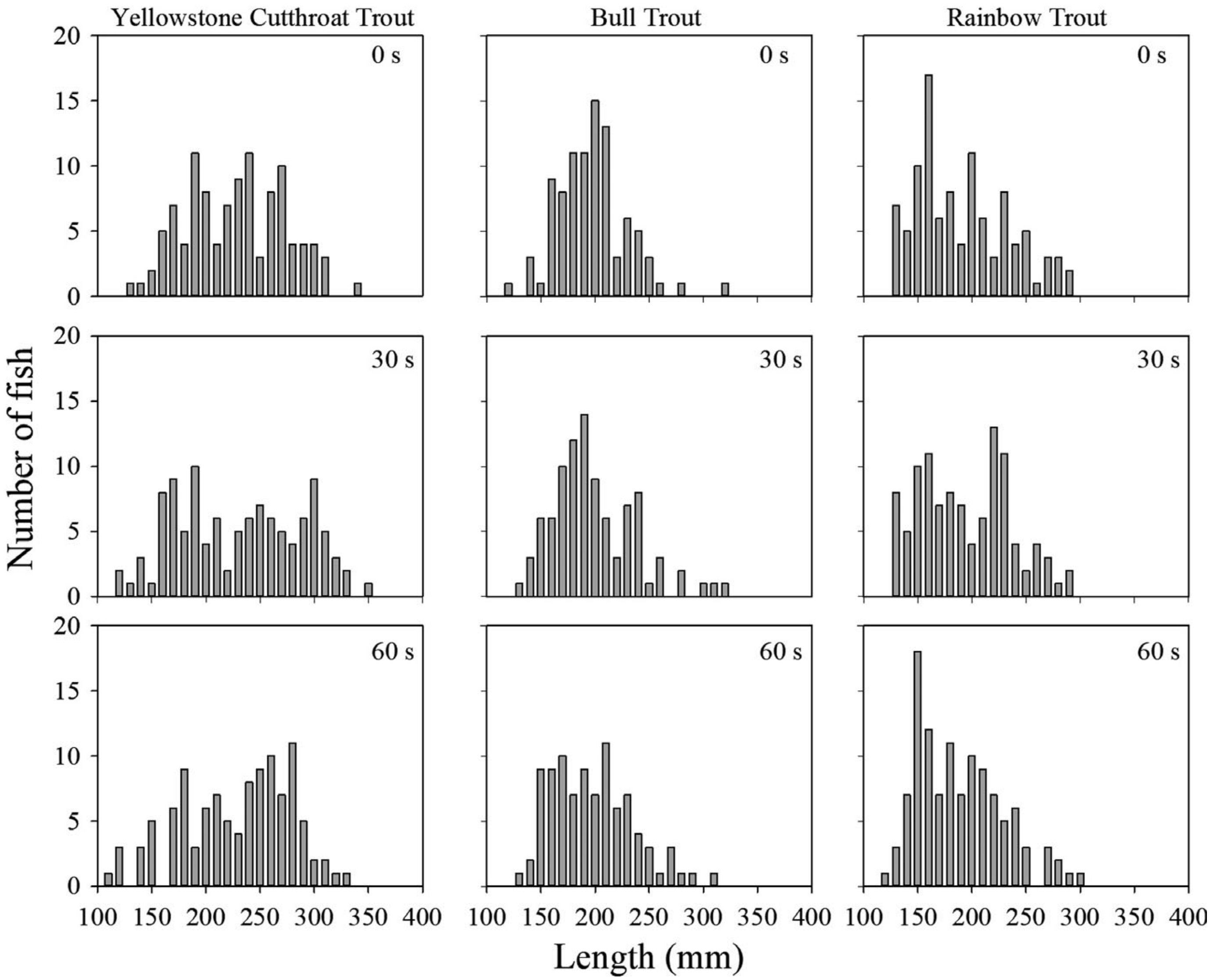

FIGURE 4. Length distributions by air exposure treatment group of Yellowstone Cutthroat Trout, Bull Trout, and Rainbow Trout sampled via hook-and-line surveys. Air exposure treatments were 0, 30, and 60 s. Yellowstone Cutthroat Trout were sampled in Palisades Creek, Idaho (August 2016). Both Bull Trout and Rainbow Trout were sampled in Sawmill Creek and the Main Fork of the Little Lost River, Idaho (July–August 2017).

laboratory setting at Cape Eleuthera Institute, The Bahamas, displayed no increase in mortality relative to fish that were not exposed to air (Suski et al. 2007). Warm water temperatures can increase stress and hooking mortality in salmonids (Strange et al. 1977; Dotson 1982), and it should be noted that our study occurred in midsummer when water and air temperatures were higher than they would be during other portions of the angling season. In addition to warmer water temperatures, the handling protocol associated with our study (e.g., the difficult act of applying a T-bar anchor tag, collecting a length measurement, and administering a pelvic fin clip all while the fish remains underwater) was more intensive than the handling treatment fish would receive in a typical catch-and-release fishery. Even under these conditions, no increase in mortality was observed due to air exposure.

The majority of previous studies evaluating the effect of air exposure have limited applicability to wild fish populations. Only a handful of studies have studied wild, unconfined fish, and most have reported no effect on mortality (Thompson et al. 2008; Gagne et al. 2017; Louison et al. 2017). For instance, wild Northern Pike *Esox lucius* from Grand Lake, Wisconsin, exposed to air for up to 4 min during ice angling displayed no immediate mortality (Louison et al. 2017). Similarly, wild Golden Dorado *Salminus brasiliensis* captured via angling from the Juramento River, Argentina, displayed no immediate mortality after 2 min of air exposure (Gagne et al. 2017). The one

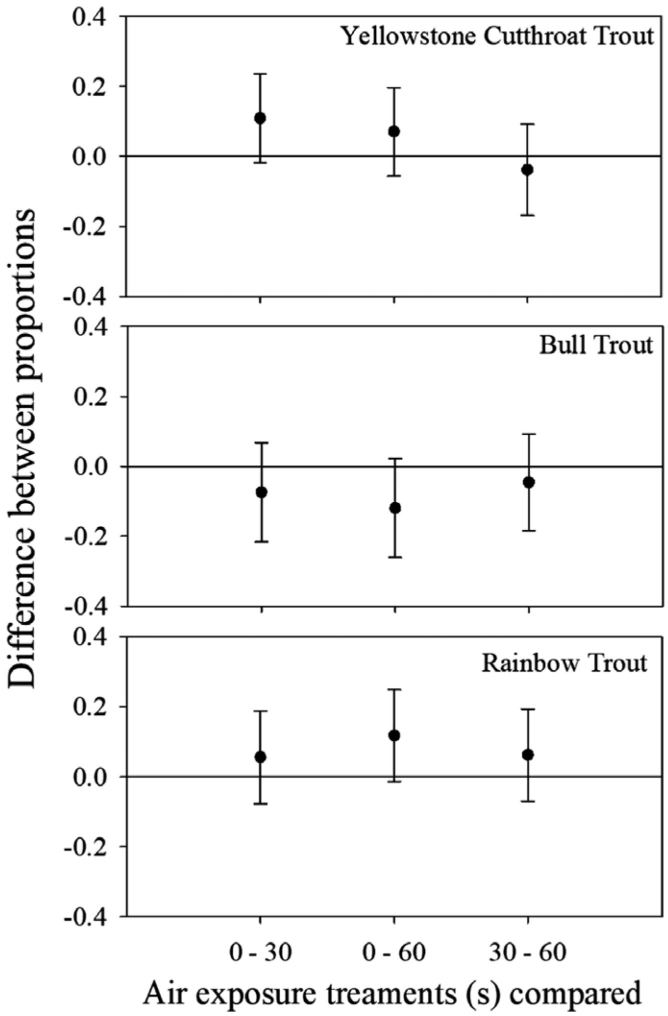

FIGURE 5. Differences between the proportions of fish recaptured via single-pass backpack electrofishing between treatment groups and by species. Comparison were made by constructing 95% confidence bounds on the difference between proportions and were considered significantly different if the confidence bound did not contain zero. Fish were originally sampled using hook-and-line surveys and then given one of three air exposure treatments (0, 30, or 60 s). Sampling for Yellowstone Cutthroat took place in Palisades Creek, Idaho (August 2016). Sampling for Bull Trout and Rainbow Trout took place in Sawmill Creek and, the Main Fork of the Little Lost River, Idaho (July–August 2017).

exception was a study of White Marlin *Kajikia albida* captured off the coast of Virginia Beach, Virginia (Graves et al. 2016). In that study, fish experienced a 17% rate of mortality when exposed to air for 1 min compared with a 2% rate of mortality when not exposed to air. However, results of Graves et al. (2016) must be interpreted with caution. The sample size of fish in each treatment was remarkably small (i.e., 1 min, n = 6; 3 min, n = 5; 5 min, n = 7), and, more notably, control fish were captured 8 years earlier in other locations as part of a different study (Graves and Horodysky 2008). Determining whether increased mortality rates were due to the fish being exposed to air or some other unknown factor is impossible given the limited study design. When results of the current study are combined with the results of previous studies, it seems unlikely that increased mortality due to air exposure is a concern in most catch-and-release fisheries. Further support for this conclusion is provided by Lamansky and Meyer (2016), Chiaramonte et al. (2017), and Roth et al. (2018), who all reported the length of time anglers actually expose fish to air in a catch-and-release fishery. In those studies, six species of salmonids were, on average, exposed to air for 19.3 s to 29.4 s—far less than times used in previous air exposure studies (e.g., Thompson et al. 2008; Gagne et al. 2017; Louison et al. 2017).

Even though length distributions were not significantly different, the length of recaptured fish was slightly larger than for all tagged fish. Although it is possible that there was differential survival between large and small fish, a more plausible explanation is simply the known sampling bias associated with electrofishing. Electrofishing routinely selects for larger individuals (Cooper and Lagler 1956; McFadden 1961; Dolan and Miranda 2003). Compounding the selective nature of the gear is that large fish are often easily observed and preferentially (though inadvertently) captured by netters (Reynolds and Kolz 2010).

Management Implications

As with any study, results of the current study are limited to the species and systems in which they were conducted, but when coupled with previous studies it appears that concerns regarding air exposure in catch-and-release fisheries may largely be a social issue. In the past, catch-and-release angling regulations have occasionally been implemented for social reasons, regardless of existing science (Schill and Scarpella 1997; Isermann and Paukert 2010). However, the lack of research demonstrating increased mortality or population-level effects from air exposure in wild fish suggests that additional studies need to be conducted with designs focused on replicating actual angling scenarios as close as possible. Laboratory studies and the use of hatchery fish should be avoided because, as Ferguson and Tufts (1992) noted in their discussion, such studies provide little insight into actual wild fish populations. A number of physiological studies have indicated that air exposure in the catch-and-release context increases stress, and a wise course of action would be to simply remind anglers to release their fish carefully and quickly—something that is routinely included in regulatory pamphlets produced by management agencies (e.g., IDFG 2016). In the meantime, addressing the concern of air exposure via regulations as has been advanced (e.g., Cook et al. 2015) seems unnecessary because the vast majority of salmonid anglers (>96%) release fish in less than 60 s without regulations mandating such behavior (Lamansky and Meyer 2016; Chiaramonte et al. 2017; Roth et al. 2018). Further, results of a recent air exposure duration study for warmwater and coolwater fishes suggest that air exposure times of fish by anglers in such fisheries are strikingly similar to those of salmonid anglers (K. A. Meyer, Idaho Department of Fish and Game, unpublished data). Nevertheless, additional studies discretely measuring actual air exposure times of fish during real catch-and-release angling events in a variety of species would be useful. Doing so will enable fisheries managers to put existing and future air exposure studies into better context. Finally, because elevated temperature can increase stress, additional field-based air exposure studies should be conducted in a variety of settings and for other species to allow the air exposure issue to be more thoroughly evaluated.

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