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MANAGEMENT BRIEF

Air Exposure Time of Trout Released by Anglers during Catch and Release

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Abstract
Research of catch-and-release fishing has included air exposure time as a contributing factor in the lethal and sublethal impacts to fish. However, to our knowledge, no studies have observed the amount of time anglers actually expose fish to air when recreationally fishing. We observed 280 anglers on several waters where catch and release was commonly practiced for trout and timed how long they exposed trout to air before releasing them back to the water. We also noted several angling characteristics to evaluate whether they influenced air exposure times, including the type of gear (fly, lure, bait), fishing on foot or from a boat, handling method (hand, net), and a subjective measure of trout size (small, medium, large). The longest continuous interval that anglers exposed trout to air averaged 26.1 s (range, 0–160 s), and only 4% of the anglers held fish out of the water continuously for >60 s. Total air exposure averaged 29.4 s, ranged from 0 to 165 s, and differed from the longest air exposure by only 3.3 s because most of the released trout (78%) were held out of the water only one time. Anglers who handled trout by hand (rather than using a landing net) and used flies (rather than bait or lures) held fish out of water for less time. Larger trout were exposed to air longer ($\bar{x}$ = 36.0 s) than small ($\bar{x}$ = 22.5 s) or medium-sized ($\bar{x}$ = 27.1 s) trout. However, no angling characteristic increased air exposure by more than 14 s. Fight time averaged 53.0 s and ranged from 7 to 128 s. We conclude that from an air exposure perspective, most of the trout released by anglers in our study were not exposed to air for times that would cause mortality or substantively increase sublethal effects from catch and release.

The concept of catch-and-release fishing was first publicized in 1952 in a sports magazine by Hazzard (1952), who termed the practice “fishing for fun.” In 1954, several streams in Great Smoky Mountains National Park were placed under fishing-for-fun regulations that required anglers to release all (or most) of the fish they caught, with the idea that they could be caught again later. Within several years, catch rates increased dramatically and those streams were opened to year-round fishing for fun (Thompson 1958; Lennon and Parker 1960). Soon thereafter, Stroud (1964) suggested that a better term—“catch and release”—be used for the management approach that requires anglers to release the fish they catch, and the catch-and-release nomenclature was quickly adopted across the country (Barnhart 1989). Catch-and-release regulations are now a common management approach to provide public angling opportunities in fisheries that would otherwise be vulnerable to overharvest. Many of the most popular and renowned fisheries in the United States are now managed with catch-and-release regulations that are often referred to as special regulations.

Special regulations that require the release of all or some portion of the catch are effective only to the extent that the hooking mortality rates of fish that are caught and released are low. Previous research has focused on a variety of factors that could influence mortality rates or have sublethal effects on fish that are released (reviewed in Muoneke and Childress 1994 and Bartholomew and Bohnsack 2005), such as (1) deep hooking (Mason and Hunt 1967; Schill 1996; Fobert et al. 2009), (2) types of hooks used (Cooke et al. 2003a, 2003b; Aalbers et al. 2004; Graves and Horodysky 2008; High and Meyer 2014), (3) bait or artificial lures (Hulbert and Engstrom-Heg 1980; Payer et al. 1989; Schisler and Bergerson 1996), (4) exercise stress (Wood et al. 1983), (5) vulnerability to predation (Danylchuk et al. 2007), (6) types of landing nets (Barthel et al. 2003), and (7) air exposure during release (Ferguson and Tufts 1992; Davis and Parker 2004; Gingerich et al. 2007; Thompson et al. 2008). The general findings from these studies are that (1) when fish are deeply hooked, mortality increases; (2) when the hook is removed from deeply hooked fish, mortality increases; and (3) quickly and efficiently releasing fish reduces mortality and stress on the fish. Despite these generalizations, the effect of air exposure on mortality deserves further attention (Cooke et al. 2013).

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In response to research suggesting that air exposure increases mortality and stress to fish, some nongovernmental conservation and fishing organizations have recently begun requesting that management agencies implement regulations to prohibit anglers from exposing fish to the air prior to release. Requests for regulations limiting air exposure are related to the perceptions that air exposure of fish caught and released by anglers is sufficient to increase mortality and sublethal effects (Cook et al. 2015). However, the time anglers actually expose fish to air while practicing catch-and-release fishing is largely unknown. For trout, the few previous studies measuring air exposure used data from the researchers themselves or from anglers who were aware that they were being evaluated (e.g., Donaldson et al. 2011; Landsman 2011). Such awareness could alter anglers' behavior, resulting in biased information (Cooke et al. 2013). Several lab studies controlled air exposure by holding trout out of water for set, categorical time periods (Ferguson and Tufts 1992; Davis and Parker 2004; Arlinghaus and Hallerman 2007) that may not represent real-world situations. We could not find any previously published studies where researchers, observing anglers who were recreationally fishing on their own, directly measured air exposure time for caught-and-released trout. Available evidence indicates that air exposure times ≤180 s result in low rates (<3%) of incidental mortality (Schisler and Bergerson 1996; Schreer et al. 2005); consequently, population-level effects may be negligible if anglers rarely expose individual fish to air for longer time periods. Therefore, we discretely observed anglers fishing on several lentic and lotic waters in Idaho and Oregon to evaluate the amount of time they exposed trout to air while practicing catch-and-release fishing. We also evaluated the influence that several angling characteristics (i.e., gear type, angling location, landing method) and fish size had on air exposure times.

METHODS

We conducted angler observations from June through October 2014 on two lotic waters (Silver Creek in Idaho and the Owyhee River in Oregon) and three lentic waters (Henrys Lake, Chesterfield Reservoir, and Horsethief Reservoir, all in Idaho). Trout species present varied by water but included Rainbow Trout *Oncorhynchus mykiss*, Brown Trout *Salmo Trutta*, Brook Trout *Salvelinus fontinalis*, Cutthroat Trout *O. clarkii*, and Cutthroat Trout × Rainbow Trout hybrids (Table 1). Gear restrictions and harvest regulations also varied between waters (Table 1).

We discretely observed trout anglers fishing and measured the time anglers exposed fish to the air after landing a fish. Observations of trout anglers were made from covert locations so that anglers were unaware of our presence. However, locations were close enough to provide good visibility, and with the use of binoculars or spotting scopes, landing events were easily observed. Using a stopwatch, we timed each air exposure interval during the handling period and recorded the longest, continuous interval a trout was exposed to air at one time (hereafter, "longest air exposure interval"). In cases where anglers removed and returned trout to the water more than once during the handling period, we summed each individual air exposure interval to record the total amount of time a particular fish was exposed to the air (hereafter, "total air exposure"). We recorded only the first catch-and-release event we were able to observe and time per individual angler to ensure independent observations. We also recorded the time required to land a trout (fight time). Fight time (s) was timed from the moment when an angler hooked a trout until the fish was controlled in hand or a landing net by the angler. Fight time was not recorded for all landed trout because the moment a fish was hooked was often not seen by the observer, who was oftentimes monitoring several anglers at a time. We did not record the entire handling time (i.e., the time from initial to final release).

We recorded several angler and landing characteristics that could influence air exposure during catch-and-release fishing, only including those we could identify from a distance without interviewing the anglers. Characteristics included (1) the type of gear anglers used (fly, bait, or lure), (2) whether anglers were fishing from a boat or on foot (from the bank or wading), and (3) whether fish were landed by hand or using a landing net. We visually estimated the relative size of the trout landed that we categorized as small (approximately <30 cm), medium (approximately 30–45 cm), or large (approximately >45 cm), and also noted whether trout were photographed.

TABLE 1. The waters, regulations, and species present where air exposure and fight time were recorded for Idaho and Oregon anglers. RBT = Rainbow Trout; BNT = Brown Trout; BKT = Brook Trout; CT = Cutthroat Trout; HYB = Rainbow Trout × Cutthroat Trout hybrids.

		Regulation			Species present				
Water	State	Catch and release	Gear restriction	Harvest limit	RBT	BNT	BKT	CT	HYB
Silver Creek	ID	Yes	Fly-fishing only; single, barbless hook	No harvest	X	X			
Owyhee River	OR	Yes (BNT)	None	Five fish	X	X			
Henrys Lake	ID	No	None	Two fish			X	X	X
Chesterfield Reservoir	ID	No	None	Two fish	X				
Horsethief Reservoir	ID	No	None	Six fish	X				

We analyzed which factors affected the longest air exposure interval using ANOVA ($\alpha = 0.05$). We calculated the least-squares (LS) mean air exposure (longest air exposure interval only) for the various factors we measured. For those factors with statistically significant results, Tukey's honestly significant difference (HSD) tests were used to identify which levels differed from one another. No difference in the LS mean air exposure was apparent between waters, so all observations were pooled. No first-order interaction terms were significant for air exposure and, therefore, were not included in the final models. We did not develop a model relating fight time to the factors we measured because sample size was too low, but we do report the mean and range of times observed.

RESULTS

Across all waters, we observed 280 anglers release landed trout. The longest air exposure interval for landed trout averaged 26.1 s (SE, 1.9) and ranged from 0 to 160 s; only 4% of anglers held fish out of the water for a continuous interval >60 s (Figure 1). Total air exposure averaged 29.4 s and ranged from 0 to 165 s. Total air exposure only differed from the longest air exposure interval by 3.3 s because most of the released trout (78%) were only removed from the water one time. Fight time ($n = 45$) averaged 53.0 s (SE, 4.2) and ranged from 7 to 128 s; only 5% of anglers took >119 s to land the trout they hooked.

Significant differences in air exposure were attributed to gear type ($F = 8.08$, $P < 0.001$), landing method ($F = 15.85$, $P < 0.001$), and trout size ($F = 7.25$, $P = 0.001$); air exposure time was marginally different between on-foot and boat anglers ($F = 3.72$, $P = 0.06$; Table 2). Tukey's HSD tests revealed that anglers using a fly ($\bar{x} = 22.2$ s [SE, 1.7]) exposed fish to air for less time than bait ($\bar{x} = 29.5$ s [SE, 2.3]) or lure anglers ($\bar{x} = 33.8$ s [SE, 2.5]; Figure 2). Anglers who released trout by hand exposed fish to air for less time ($\bar{x} = 23.7$ s [SE, 1.8]) than those who used a landing net ($\bar{x} = 33.3$ s [SE, 1.9]). The relative size of trout landed also influenced air exposure time, with larger fish being exposed to air significantly longer ($\bar{x} = 36.0$ s [SE, 2.6]) than medium-sized

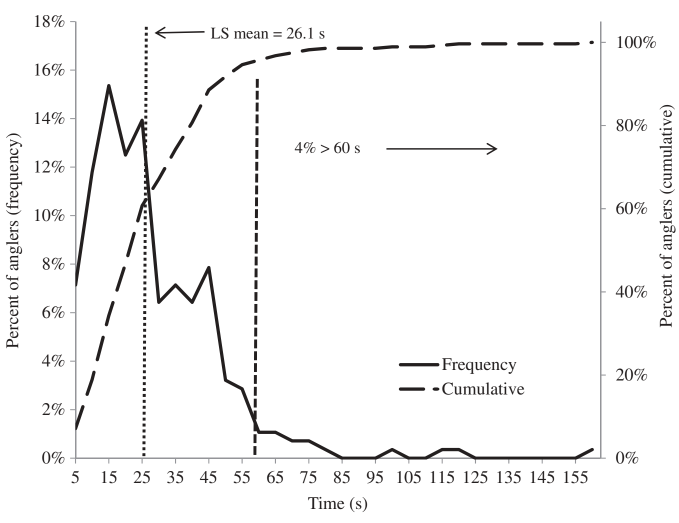

FIGURE 1. The percent frequency and percent cumulative frequency of anglers that exposed fish to air for certain times (s) after landing fish during angling. The vertical dashed lines highlight the overall LS mean time that anglers held fish out of water (dots) and the time at which 96% of anglers had exposed fish to air (small dashes).

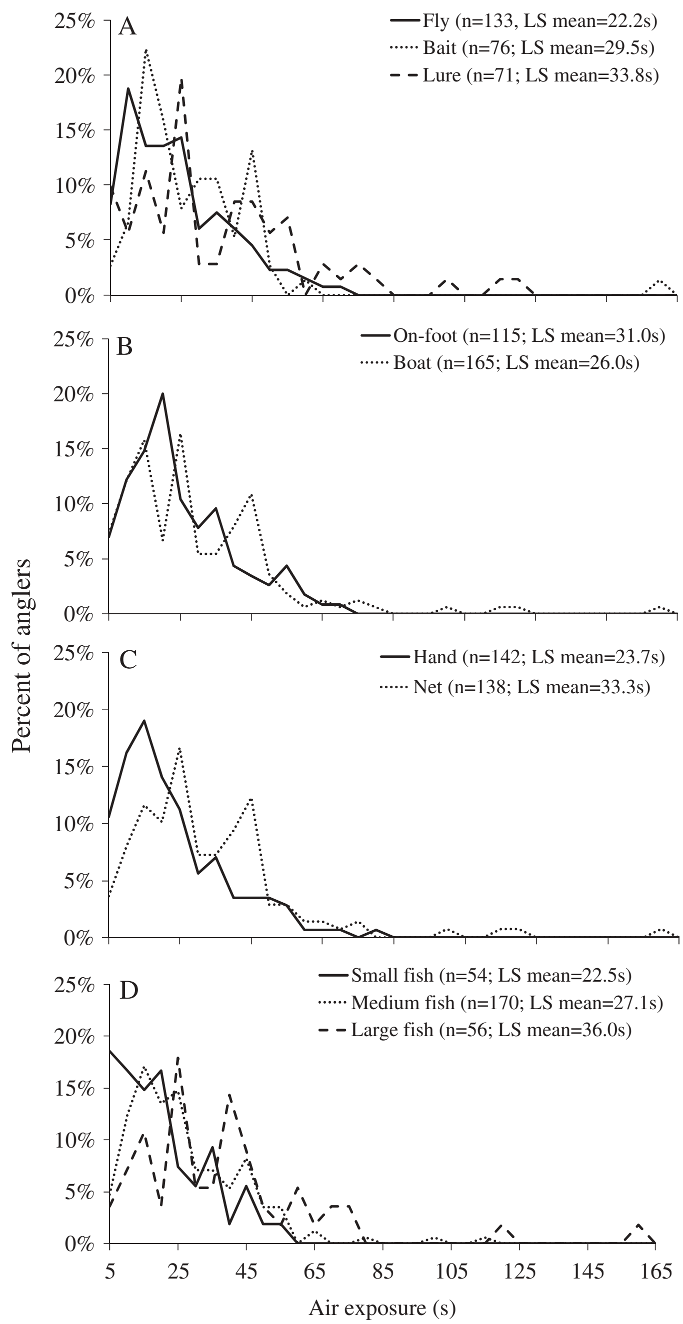

FIGURE 2. The percent frequency of anglers that exposed fish to air for certain times (s) after landing fish during angling **(A)** using different gear types, **(B)** on foot or from a boat, **(C)** using different landing methods, or **(D)** that landed different-size fish.

TABLE 2. Comparisons of LS mean and SE for the longest trout air exposure interval by Idaho and Oregon anglers for each level of each angling characteristic, and ANOVA results. Asterisk indicates means that differed significantly from other means within a characteristic.

			Maximum air exposure (s)		ANOVA			
Characteristic	Level	*n*	LS mean	SE	*F*	df	*P*	R^2
Gear					8.08	2	<0.0001	0.05
	Fly	133	22.2*	1.8				
	Bait	76	29.5	2.3				
	Lure	71	33.8	2.5				
Boat–foot					3.72	1	0.06	0.00
	On foot	115	31.0	2.1				
	Boat	165	26.0	1.6				
Landing method					15.85	1	<0.0001	0.07
	Hand	142	23.7*	1.7				
	Net	138	33.3	1.9				
Fish size					7.25	2	<0.0001	0.04
	Small	56	22.5	2.6				
	Medium	170	27.1	1.5				
	Large	50	36.0*	2.6				
Total		280	26.1	1.2	5.82	6	<0.0001	0.17

($\bar{x}$ = 27.1 s [SE, 1.5]) or smaller-sized fish ($\bar{x}$ = 22.5 s [SE, 2.6]). Despite several statistically significant relationships, retaining all four factors in the ANOVA model explained only 17% of the variation in air exposure times.

We observed 13 anglers photograph trout after landing them; we categorized eight as medium-sized fish and five as large sized. Taking photographs of trout extended air exposure by an average of 18–20 s, but with only 13 fish photographed, no statistical comparison with regard to air exposure time was made with fish that were not photographed.

DISCUSSION

Our findings demonstrate that the air exposure and fight times a trout experiences while being caught and released by anglers are substantially less than those applied in some previous studies measuring physiological responses and fish mortality due to air exposure. For example, in an often-cited physiological effects study that included air exposure as a stressor, Ferguson and Tufts (1992) exhaustively exercised hatchery Rainbow Trout by manual chasing for approximately 600 s until the fish could no longer respond to further stimulation. Fish were then exposed to air for 0, 30, and 60 s, and experienced mortality rates of 12, 38, and 72%, respectively. However, fish were also surgically cannulated before exercising so blood samples could be taken repeatedly throughout the experiment. The mortality rates were likely elevated as a result of the extreme conditions the fish encountered, as evidenced by the 12% mortality rate for fish not even exposed to air. Even the authors acknowledged that their study was not meant to predict air exposure-induced mortality in wild fish and that the use of hatchery fish, exhaustive exercise, cannulation, and repeated blood sampling may have contributed to the high levels of mortality they observed. In another study, Schisler and Bergerson (1996), incorporating air exposure only and no blood sampling, modeled that mortality for hatchery Rainbow Trout superficially hooked on a fly with little bleeding was <3% at 180 s of air exposure and 9% at 300 s. In contrast, Schreer et al. (2005), with air exposure and simulated fight times that more closely reflected our angler trout handling observations, chased Brook Trout in a hatchery setting for 30 s then exposed the fish to air for 30, 60, and 120 s, and reported 0% mortality for all treatments. Our observations of anglers and results from studies with similar air exposure times suggest that air exposure and fight times experienced by trout during real-world catch-and-release angling scenarios would not likely result in elevated mortality.

We found statistically significant differences in the air exposure times of landed trout depending on the gear the angler used, although the difference was minimal. Fly anglers exposed landed fish to the air for less time than those using either bait or lures, probably because fish caught with flies are typically hooked in the mouth (Jenkins 2003), whereas the use of bait often results in higher deep-hooking rates for trout (Schisler and Bergerson 2006. High and Meyer 2014). Deep hooking can extend hook removal times compared with shallow-hooking locations (Muoneke and Childress 1994). Meka (2004) reported that hook removal times were not different for anglers using flies or lures because most fish were hooked in the mouth. Although we were unable to determine whether anglers were using barbed or barbless hooks, barbless hooks are more commonly associated with flies than lures or bait hooks, and barbed hooks can increase hook removal times (Falk et al. 1974) and total handling times (Bloom 2013) compared with barbless hooks but are not necessarily related to increased mortality in caught-and-released fish (Schill and Scarpella 1997). Increased mortality associated with using bait or barbed hooks is usually related to deep hooking that causes organ damage when the hooks are removed (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005) and is not specifically related to air exposure or handling time.

We anticipated that trout would be exposed to air for a longer period of time if a landing net was used, presumably because fish or hooks became entangled in the net, delaying release. Barthel et al. (2003) compared injury and mortality rates of Bluegill *Lepomis macrochirus* landed using nets constructed of different materials and design; they attributed all the mortality (4–14%) observed in the study to injuries caused by the nets, not to air exposure.

We expected that smaller trout would be easier to handle than larger fish and, therefore, would be exposed to air for less time. Meka (2004) reported that landing and handling times increased with fish size in an Alaskan wild Rainbow Trout fishery and that landing time increased for experienced anglers mainly because they caught larger fish. In our study, the longer air exposure times of large trout suggests that anglers had more difficulty handling and removing hooks from large fish. The air exposure time of larger trout was only increased slightly because anglers photographed their catch, mainly because photographs occurred so infrequently. Because of the numerous factors that influence mortality rates or sublethal effects related to catch-and-release fishing, the minimal differences in air exposure times for the factors we measured (<14 s) are not likely biologically meaningful, regardless of the statistical significance of the factors.

From a fisheries management perspective, the most important aspect of using catch-and-release regulations as a management strategy is the elimination of mortality due to harvest; however, minimizing lethal and sublethal impacts to fish that are caught and released by anglers is also important (Cooke and Suski 2005; Cooke and Schramm 2007; Danylchuk et al. 2007). Releasing a fish alive not only allows the opportunity for that fish to be caught again, but also allows fish to grow older and larger and reproduce more often with higher fecundity (Wydoski 1977). We certainly encourage anglers to reduce stress and injury to fish during capture by landing and releasing fish as quickly as possible. However, the studies often cited by anglers and nongovernmental organizations to support angling regulations prohibiting exposing fish to air should be interpreted with caution when linking air exposure to mortality because real-life situations may not meet the lethal or sublethal thresholds previously established in the literature. For example, research on trout catch-and-release mortality suggests that fight times of 600 s (Ferguson and Tufts 1992) and air exposure of up to 300 s (Schisler and Bergerson 1996) caused mortality in caught-and-released trout. In our study, nearly all anglers fought trout to landing in <120 s (maximum, 128 s), and exposed trout to air for <60 s (maximum, 160 s). As with the catch-and-release debate regarding the use of barbed or barbless hooks (Schill and Scarpella 1997), we believe that many of the concerns with air exposure during catch and release are social in nature, not biological. Regardless, in the absence of harvest by anglers, the high natural mortality rates (30–75%) that most trout populations experience (e.g., McFadden 1961; Carline 2006; Meyer et al. 2012) likely far exceeds any mortality associated with air exposure that occurs during catch-and-release angling.

Our study focused on several trout fisheries in Idaho and Oregon and, as far as we know, is the first to report the time that anglers (unaware they were being observed) exposed trout to air while practicing catch and release. Furthermore, our study only focused on air exposure, and we recognize that numerous factors, alone or interactively, can influence lethal and sublethal impacts to caught-and-released fish. Nevertheless, based on our results, we conclude that additional angling restrictions to prohibit removing trout from the water would likely have no measurable benefit in Idaho trout fisheries. We encourage similar research for other species and fisheries that may experience different environmental or physiological conditions than trout to better inform managers on how anglers actually handle fish when some or all of their catch are released, prior to instituting any angling regulations based on previous air exposure studies that may not reflect conditions a fish would experience in a real-life catch-and-release situation.

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