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Fight and air exposure times of caught and released salmonids from the South Fork Snake River

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ABSTRACT

Catch-and-release regulations are among the most common types of fishing regulations. In recent years, concerns have arisen regarding the exposure of fish to air during catch-and-release angling. The purpose of our study was to quantify the length of time angled fish were exposed to air by anglers in a typical catch-and-release fishery and relate it to the lengths of time reported to produce negative effects. In total, 312 individual anglers were observed on the South Fork Snake River, Idaho, from May through August 2016. Fight time varied from 1.1 s to 230.0 s, and average fight time was 40.0 s (SD = 36.8). Total air exposure times varied from 0.0 s to 91.8 s and averaged 19.3 s (SD = 15.0). Though not statistically significant, a trend in reduced fight times was observed when anglers were guided and increased air exposure times when a net was used and a picture was taken. Results of the current study suggest that anglers expose fish to air for periods that are much less than those reported to cause mortality.

1. Introduction

Unregulated harvest of fish by humans can affect the quality and viability of a fishery (Isermann and Paukert 2010). As a result, natural resource agencies often implement regulations to manage harvest. Harvest regulations are typically aimed at improving the quality of a fishery or maintaining the viability of a population, or both. One of the most common types of harvest regulations are catch-and-release regulations (C&R), where anglers are required to release all or a large portion of their catch. A basic premise of C&R regulations is that released fish survive and can be caught again by anglers (Wydoski, 1977). Although C&R regulations were originally limited to salmonid fisheries (Thompson, 1958), they have become increasingly popular in other recreational fisheries (Isermann and Paukert, 2010). Natural resource agencies typically use C&R regulations as a tool to reduce exploitation and increase density and(or) size structure of fish, and the approach has generally proven effective. For instance, after implementation of C&R regulations, increases in density (Graff and Hollender, 1977; Anderson and Nehring, 1984; Carline et al., 1991), biomass (Thompson, 1958; Anderson and Nehring, 1984; Carline et al., 1991), length structure (Anderson and Nehring, 1984; Jones, 1987; Wells, 1987; Carline et al., 1991), and catch rates (Varley, 1980; Hunt, 1981; Anderson and Nehring, 1984; Jones, 1987; Carline et al., 1991) have been reported.

Despite the success and popularity of C&R regulations, concerns remain regarding this approach to harvest management. One such concern is the length of time a fish is played before it is landed (Cooke and Suski, 2005). The primary concern with duration of angling is that longer fight times may cause physiological disturbances that lead to increased mortality of released fish. Recently, the most high-profile concern has been the potentially negative effects of exposing fish to air during C&R angling (Cook et al., 2015), including a decline in swimming performance (Schreer et al., 2005), reduced ability to cope with thermal stress (Gingerich et al., 2007), reduced reproductive success (Richard et al., 2013), and increased risk of nest predation (Philipp et al., 1997). Such concerns have emerged from a variety of sources such as social media campaigns and the scientific literature (e.g., #Keepemwet; Cook et al., 2015; Cooke et al., 2016). Natural resource agencies have also contributed to the concern. For example, the Washington Department of Fish and Wildlife recently implemented regulations making it illegal to remove salmon *Oncorhynchus* spp., steelhead *O. mykiss*, and Bull Trout *Salvelinus confluentus* from the water if it cannot be legally harvested (Washington Department of Fish and Wildlife, 2016). In addition, although concerns about sub-lethal effects of air exposure have received some attention, most research has focused on direct mortality resulting from prolonged exposure to air (Ferguson and Tufts, 1992; Davis and Parker, 2004; Suski et al., 2007; Graves

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et al., 2016; Gagne et al., 2017). Despite the concerns associated with air exposure, there is a lack of information regarding how long anglers actually expose fish to air during C&R angling.

Several studies have attempted to address the question of whether air exposure increases mortality and, if so, how long a fish must be exposed to air to cause mortality, but results of such studies are inconsistent. For example, some studies have reported that air exposure has no effect on mortality (Rapp et al., 2014; Louison et al., 2017), others have reported a minimal effect (Davis and Parker, 2004; Suski et al., 2007; Gagne et al., 2017), and some have reported a relatively large effect (Ferguson and Tufts, 1992; Graves et al., 2016). However, the two studies showing high mortality, Graves et al. (2016) and Ferguson and Tufts (1992), should be interpreted with caution. Graves et al. (2016) had few White Marlin *Kajikia albida* in each air exposure treatment (i.e., 1 min, $n = 6$; 3 min, $n = 5$; 5 min, $n = 7$). In addition, the control fish were from a study conducted 8 years earlier (Graves and Horodysky, 2008) and largely collected in a different location. Caution should also be used when interpreting the results of Ferguson and Tufts (1992) because fish ($n = 21$) were cannulated and repeatedly subjected to blood draws in a hatchery setting. In fact, Ferguson and Tufts (1992) explicitly noted that their results were not applicable to wild populations. Nevertheless, results of the study are regularly used to support claims of air exposure causing high mortality in wild populations subjected to C&R angling (e.g., Louison et al., 2017).

Despite the growing body of literature evaluating the effects of air exposure on fishes, air exposure times used in prior studies may bear little resemblance to the length of time anglers actually expose fish to air during C&R angling. As previously mentioned, there is a paucity of studies evaluating how long anglers expose fish to air during typical C&R angling events. The only study to date to quantify air exposure times of actual anglers (unaware they were being observed) reported that on average, the longest continuous interval during which trout anglers exposed fish to air was 26.1 s (Lamansky and Meyer, 2016). Additionally, the total amount of air exposure time averaged 29.4 s, and 96% of fish were exposed to air for 60.0 s or less. Because these air exposure times were far less than times thought to produce negative effects in wild salmonids, Lamansky and Meyer (2016) recommended that additional studies should be conducted to better contextualize the issue of air exposure in C&R fisheries. To this end, we observed anglers discreetly in a nationally known C&R trout fishery on the South Fork Snake River (SFSR), Idaho, to provide information on how long anglers actually exposed fish to air. The SFSR was chosen as the study location because it supports one of the most high-profile C&R fisheries for Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* and other salmonids in the western U.S. (High, 2010). In fact, the C&R fishery on the South Fork Snake River generates approximately US$12 million annually in local income.

2. Study area

Angler observations were conducted from May through August 2016 on the SFSR (Fig. 1), which originates in Yellowstone National Park, Wyoming. The SFSR flows south from Yellowstone National Park through Grand Teton National Park, after which it turns west and flows into Idaho where it is impounded by Palisades Dam. Following impoundment, the river continues to flow west to its confluence with the Henrys Fork Snake River, where the river is called the Snake River from that point onward. The SFSR drains an area of 16,078 km^2 (Idaho Department of Fish and Game, 2007).

The sport fishery of the SFSR includes Yellowstone Cutthroat Trout, Rainbow Trout *O. mykiss*, Rainbow Trout × Yellowstone Cutthroat Trout hybrids, Brown Trout *Salmo trutta*, and Mountain Whitefish *Prosopium williamsoni*. It is not uncommon for anglers to catch all of these species in the SFSR, but the catch-and-release fishery is almost exclusively composed of anglers targeting Yellowstone Cutthroat Trout (Brett High, Idaho Department of Fish and Game, unpublished information). Regulations on the SFSR require that anglers release all Yellowstone Cutthroat Trout. Harvest of Rainbow Trout and Rainbow Trout × Yellowstone Cutthroat Trout hybrids is unlimited. Anglers can harvest two Brown Trout over 406 mm and 25 Mountain Whitefish daily.

3. Methods

3.1. Field sampling

Anglers were observed from discrete locations so that the presence of observers would not alter angler behavior (e.g., McCormick et al., 2012). In addition, anglers were observed from a distance using either binoculars or spotting scopes to maintain discretion. Once an angler was observed hooking or playing a fish, the angler was observed to determine how long the fish was exposed to air during the C&R angling event. For each C&R event, the air exposure interval was timed using a stopwatch. Fish were considered air exposed when the fish had its gills removed from the water. The longest continuous interval of air exposure (LCIE) was recorded following Lamansky and Meyer (2016. In cases where anglers removed the fish from the water more than once, individual air exposure events were recorded, and the total amount of air exposure was calculated as the sum of individual exposure events. The first observed C&R event for each angler was recorded. In some cases, multiple C&R events per angler were also recorded. The length of time the fish was fought (fight time) was recorded when possible.

In addition to duration of air exposure and fight time, data were also collected on angler characteristics. How the angler accessed the river (i.e., boat or foot) was recorded. Observers also recorded whether a net was used to land the fish, whether the angler was guided, and whether a photograph was taken. Anglers that accessed the river initially by boat, but then got out of the boat and fished from shore were recorded as having accessed the river by foot. Observers determined if an angler was guided by observing the boat the angler used to access the river. All guides on the SFSR are required to display a sticker on the boat indicating they are guiding anglers.

3.2. Data analysis

Data were analyzed using only one C&R event per angler. In the event that multiple C&R events were recorded for an angler, one event was chosen at random for analysis. Note that fight times were not recorded for every individual C&R event because anglers often had begun fighting fish prior to being noticed by observers. Average fight time, total air exposure, and LCIE were calculated separately for each level of angler characteristic. Linear models were used to evaluate the relationship between fight time, LCIE, and angler characteristics. For modeling purposes, LCIE was used as the response variable because anglers rarely exposed fish to air more than once (i.e., 2.6% of observed anglers). A total 15 candidate models was developed for predicting fight time and 8 candidate models was developed for predicting LCIE. Models were compared using Akaike Information Criterion corrected for small sample size (AIC_c), and the top model was the model that had the lowest AIC_c value (Burnham and Anderson, 2002). Models that had an AIC_c score within 2.0 AIC_c values of the best model were also considered top models. Additionally, the sum of the Akaike weights (w) for all models in which a given predictor variable was present was used as a measure of relative importance (i.e., Burnham and Anderson, 2002; Quist et al., 2004).

4. Results

Fight time was recorded for 114 individual anglers (Table 1). The length of time that anglers fought a fish varied from 1.1 s to 230.0 s across angler characteristics. Average fight time was 40.0 s (SD = 36.8). The majority of anglers (83.3%) landed fish in under 60 s

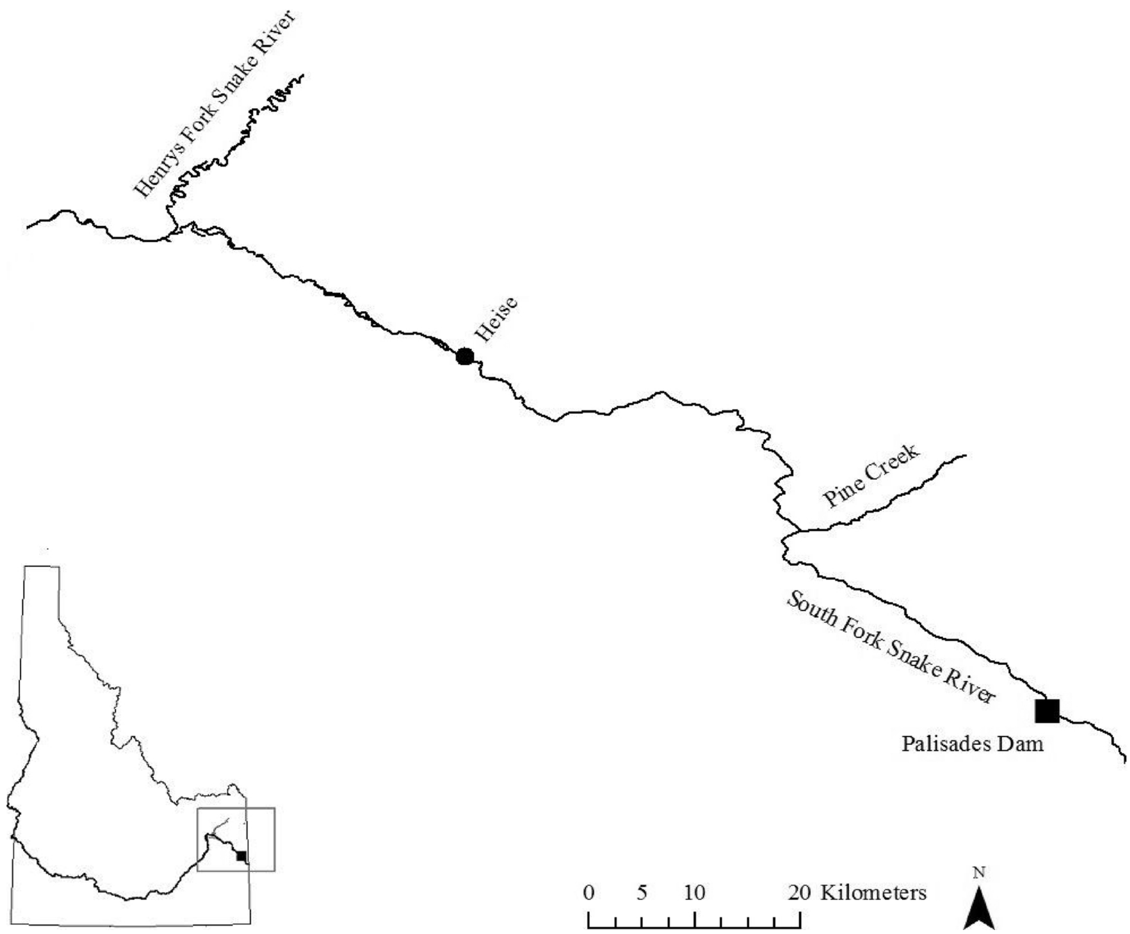

Fig. 1. South Fork Snake River from Palisades Dam to the confluence with the Henrys Fork Snake River, Idaho.

(Fig. 2A and C).

Linear regression analysis of fight times revealed that top models consistently contained the variables guide and net (Table 2). The top model for predicting fight time only included guide (i.e., whether the angler was guided or unguided) as a predictor variable and the sum of *w* for guide (0.79) also indicated that guide was of relatively high importance compared to the other predictor variables used in modeling. Based on the parameter estimates of the top model, a pattern was observed where anglers that used a guide fought fish for an average of 12.7 s (SE = 7.4) less than anglers that did not use a guide. Even though the model containing guide as the sole predictor was considered the best model, the model had poor fit (adjusted $R^2 = 0.02$) suggesting the use of a guide did not have a significant effect on fight time.

Air exposure duration was recorded for 312 C&R events (Table 1). Total air exposure and LCIE varied from 0.0 s to 91.8 s across angler characteristics. The total length of time a fish was exposed to air during a C&R event averaged 19.3 s (SD = 15.0), and the LCIE averaged 18.8 s (SD = 14.2). Nearly all anglers (99.7%) exposed fish to air (i.e., LCIE) for < 60.0 s. Observations also revealed that 84.3% of anglers exposed fish to air for < 30.0 s, 64.4% exposed fish to air for a LCIE of < 20.0 s, and 27.9% of anglers exposed fish to air for a LCIE of < 10.0 s (Fig. 2B and D).

Linear regression analysis indicated that the top model for predicting LCIE included net, picture, and guide as covariates (Table 2). Both the use of a net and taking a picture increased LCIE, whereas employing a fishing guide was associated with a reduced LCIE. In fact,

Table 1
Average of fight time, total air exposure, and longest continuous interval of air exposure by angler characteristic for catch-and-release angling on the South Fork Snake River, ID (May–August 2016). Standard deviation (SD) is included for each metric.

Angler characteristics	Level	Average fight time (s)	SD	*n*	Average total air exposure (s)	SD	*n*	Average longest continuous interval of air exposure (s)	SD	*n*
Access	Boat	40.2	36.8	81	19.5	15.0	225	18.9	14.2	225
	Foot	39.3	36.1	33	19.0	15.3	87	18.7	14.4	87
Net	Yes	41.8	36.9	87	22.2	15.0	211	21.5	14.2	211
	No	34.0	37.6	27	13.3	15.1	101	13.3	14.3	101
Picture	Yes	75.2	36.8	10	41.1	15.5	23	35.8	14.6	23
	No	37.0	36.8	104	17.6	15.0	289	17.5	14.2	289
Guide	Yes	36.1	34.5	79	18.6	15.0	200	18.4	14.3	200
	No	48.8	37.0	35	20.7	15.1	112	19.7	14.2	112
Overall		40.0	36.8	114	19.3	15.0	312	18.8	14.2	312

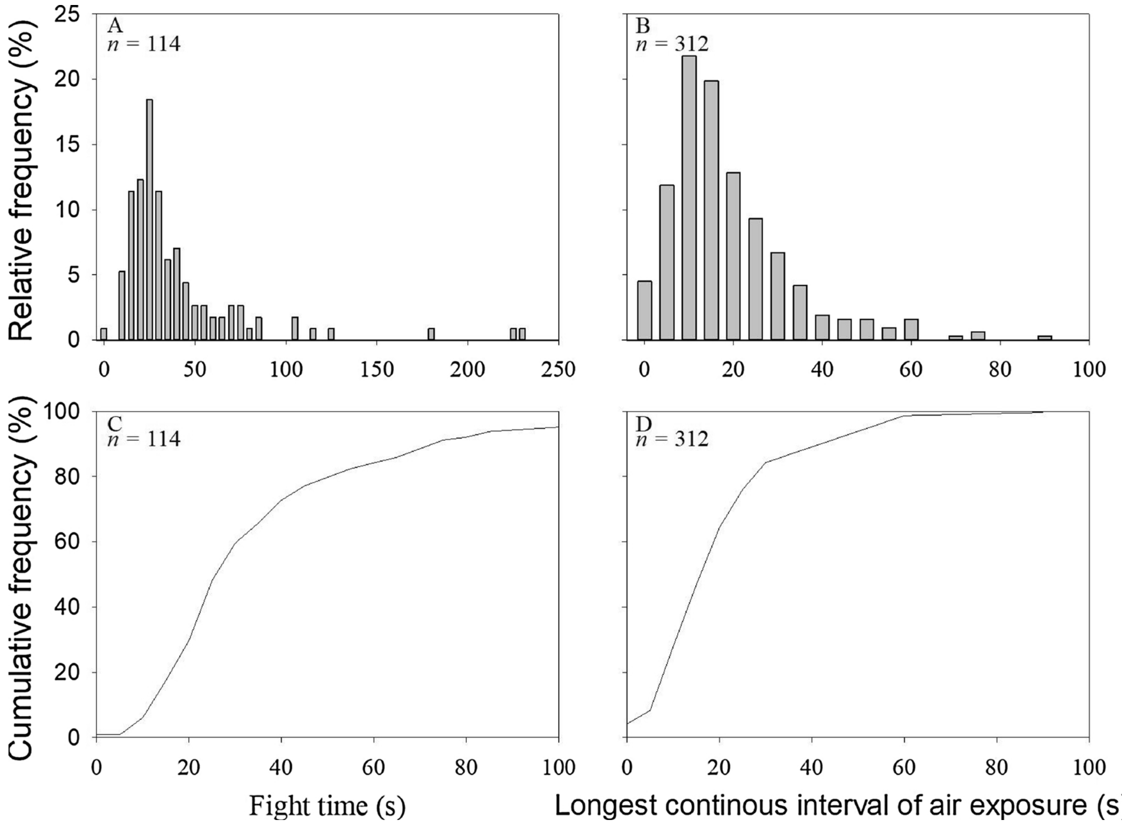

Fig. 2. Frequency distributions and cumulative frequencies of the time anglers fought fish and the longest continuous interval of air exposure that anglers exposed fish to during catch-and-release angling in the South Fork Snake River, Idaho (May–August 2016).

based on the parameter estimates from the top model, anglers that used a net exposed fish to air for 7.2 s (SE = 1.6) longer than anglers that landed the fish by hand, anglers that took a picture exposed fish to air for 16.2 s (SE = 2.9) longer than anglers that did not take a picture, and anglers that used a guide exposed fish to air for 2.8 s (SE = 1.6) less than anglers that did not use a guide. When the sums of Akaike weights were calculated to evaluate the relative importance of each variable, two of the three variables (i.e., net and picture) had relatively high importance compared to the other predictor variables used for modeling. The sums of *w* for both net and picture were 1.00. However, the model only explained 16.1% of the variation in air exposure times. As with the models predicting fight time, it is important to recognize that poor fit of the models indicates the effect of both net and picture was not significant.

5. Discussion

Results of the current study corroborate the findings of Lamansky and Meyer (2016) in that air exposure and fight times experienced by trout in an actual C&R fishery were low, and considerably less than times evaluated in air exposure experiments. In the study conducted by Lamansky and Meyer (2016), 280 catch-and-release events were observed for trout anglers in two lotic systems (Silver Creek, Idaho and Owyhee River, Oregon) and three lentic systems (Henry's Lake, Chesterfield Reservoir, and Horsethief Reservoir, Idaho). In the systems observed by Lamansky and Meyer (2016), average fight time was 53.0 s, average total air exposure was 29.4 s, and the longest air exposure interval averaged 26.1 s. Similar results were observed in our study where average fight time was 40.0 s, average total air exposure was 19.3 s, and LCIE averaged 18.8 s in the SFSR. The majority of previous studies evaluating the effects of air exposure on mortality of salmonids have used longer fight times and have exposed fish to air for

Table 2
Top regression models predicting the length of time anglers fought fish and the longest continuous interval of air exposure anglers exposed fish to based on angler observations in the South Fork Snake River, Idaho (May–August 2016). Covariates include whether the angler was guided, net use, how the angler accessed the river, whether a photograph was taken, and angler sex. Models were evaluated using the number of parameters in the model (K), Akaike's information criterion (AIC_c), the change in Akaike's information criterion between models (ΔAIC_c), and Akaike's weight (*w*). The adjusted coefficient of determination (R^2) was used to evaluate model fit.

Response variable	Model parameters	K	AIC_c	ΔAIC_c	*w*	Adjusted R^2
Fight time	$48.75 - 12.70 \bullet Guide_{yes}$	3	1147.67	0.00	0.28	0.02
	$41.90 + 10.44 \bullet Net_{yes} - 14.30 \bullet Guide_{yes}$	4	1148.14	0.47	0.22	0.02
	$36.10 \bullet Net_{yes} - 3.81 \bullet Guide_{yes} - 14.62 \bullet Net_{yes} \times Guide_{yes}$	5	1149.53	1.86	0.11	0.02
	$50.33 - 13.44 \bullet Guide_{yes} - 3.70 \bullet Access_{foot}$	4	1149.58	1.91	0.11	0.01
	$33.95 - 7.86 \bullet Net_{yes}$	3	1149.67	2.00	0.10	0.00
Longest continuous interval of air exposure	$17.55 + 7.18 \bullet Net_{yes} + 16.17 \bullet Picture_{yes} - 2.75 \bullet Guide_{yes}$	5	2490.14	0.00	0.34	0.16
	$13.69 + 7.54 \bullet Net_{yes} + 16.27 \bullet Picture_{yes} - 2.60 \bullet Guide_{yes} + 1.85 \bullet Access_{foot}$	6	2491.01	0.87	0.22	0.16
	$13.16 + 6.61 \bullet Net_{yes} + 16.31 \bullet Picture_{yes}$	4	2491.22	1.07	0.20	0.16
	$12.27 + 7.06 \bullet Net_{yes} + 16.42 \bullet Picture_{yes} + 2.10 \bullet Access_{foot}$	5	2491.71	1.57	0.16	0.16

far longer than those observed in the current study. For example, Ferguson and Tufts (1992) used manual chasing and tail grabbing for 600 s to simulate fight time, and other authors have employed simulated fight times of 240 s (Suski et al., 2007). Furthermore, most studies have exposed fish to air for a minute or more (e.g., Davis and Parker, 2004; Suski et al., 2007; Rapp et al., 2014; Graves et al., 2016; Louison et al., 2017). For instance, Bonefish *Albula vulpes* were exposed to air in a laboratory setting at Cape Eleuthera Institute, The Bahamas, for either 1 min or 3 min (Suski et al., 2007). Northern Pike *Esox lucius* from Grand Lake, Wisconsin, were exposed to air for either 2 min or 4 min (Louison et al., 2017). Studies using air exposure times similar to those observed on the SFSR have typically reported that air exposure had little or no effect on mortality. Specifically, in a laboratory study at the State University of New York, Potsdam, New York, Brook Trout *Salvelinus fontinalis* were exposed to air for 30 s and no mortality was observed (Schreer et al., 2005). Similarly, Bluegill *Lepomis macrochirus* from Lake Opinicon, Ontario, were exposed to air for 30 s and no mortality was reported (Gingerich et al., 2007).

Regression models revealed that of the variables used to predict fight time, the use of a guide was the most important. Although the use of guide did not significantly affect how long a fish was played, the data suggested that the use of a guide may reduce fight time. The use of a guide likely reduces fight time because anglers are able to focus on playing the fish while the guide maneuvers the boat and(or) assists in landing the fish. Guides may also have encouraged faster playing, but this could not be evaluated using our methods. Fight time was also longer when a picture of the fish was subsequently taken. The process of taking a picture likely did not cause an increase in fight time; rather, the increase was likely due to the angler catching a large fish. Regardless, only 7.4% of anglers took a picture. Although various factors were related to fight time, the models had poor fit suggesting high variation in fight times within and among angler groups.

Linear regression modeling revealed that of the predictor variables used to predict LCIE, net and picture were the most important. Although not statistically significant, using a net generally increased the length of time a fish was exposed to air. Increased air exposure times due to the use of a net were also observed by Lamansky and Meyer (2016). The authors hypothesized that increased air exposure was due to the fish and(or) hook becoming entangled in the net. A pattern was also observed where taking a picture increased the length of time a fish was exposed to air by adding a step to the release process. Taking a picture also increases the chances of the fish struggling to escape the angler's grasp and(or) dropping the fish, thereby increasing air exposure time. As with models predicting fight time, models predicting air exposure had relatively poor fit.

Although salmonids have been shown to be among the most sensitive taxa with regard to hypoxic stress (Doudoroff and Shumway, 1970), the average air exposure times reported in the current study and those reported by Lamansky and Meyer (2016) are far less than what has been reported to cause mortality in salmonids and other taxa (e.g., Suski et al., 2007). As such, it is unlikely that the catch-and-release fishery on the SFSR, or similar systems, would benefit from implementing regulations that limit the length of time anglers can expose fish to air. Further research into how long anglers expose fish to air during C&R angling for other fisheries should be conducted before regulations limiting air exposure are considered. In particular, research on anadromous fisheries or fisheries targeting species of conservation concern may be warranted.

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