Air Exposure and Fight Times for Anadromous Fisheries in Idaho

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Abstract—Increasing concern exists about the effects of air exposure and fight times on fish being caught and released. Such effects are usually tested in laboratory or hatchery settings, with little knowledge of actual angler behavior. We measured air exposure and fight times by anglers catching and releasing fish in popular salmon and steelhead fisheries in Idaho, and recorded other relevant factors such as fishing gear (fly or non-fly), occurrence of anglers photographing their catch, and landing method (net or hand). Overall air exposure time for fish caught and released averaged 28.7 s (3.2). Air exposure time did not differ with gear type but was 1.53 times (~15 s) longer if the angler took a photo of their catch. Fight time averaged 131 s (10.6) and differed with gear type, with fly anglers taking 1.57 times (76 s) longer to land fish than non-fly anglers. Deep hooking rate was 0% for fly (n = 40) and bait/jig terminal tackle (n = 49), and 1% for lures (n = 99). In the context of previous studies that have measured mortality of salmonids, the effects of these fight and air exposure times and deep hooking rates are likely negligible, particularly from a population-level perspective.

Introduction

The potential effects of catch-and-release angling on fish mortality has been a subject of extensive research for decades (see reviews by Muoneke and Childress [1994] and Bartholomew and Bohnsack [2005]) and concerns over sublethal physiological effects and general fish welfare are growing research areas (Davie and Kopf 2006; Huntingford et al. 2006; Arlinghaus et al. 2007; Cooke and Sneddon 2007). Aspects of catch-and-release angling that have been shown to affect post-release performance and survival include (among others) terminal tackle type (bait, lure, fly), fish handling (fight time and air exposure), and environmental conditions (water temperature and capture depth).

Of these factors, the effect of air exposure and fight times on post-release stress response and mortality has received perhaps the most attention in recent fisheries literature (reviewed in Cook et al. 2015). Studies conducted in laboratory or hatchery settings have generally shown negative effects of air exposure and fight times on fish (Ferguson and Tufts 1992; Schisler and Bergersen 1996; Schreer et al. 2005; Donaldson et al. 2014; Gale et al. 2014). However, taken collectively, this and other research suggests that, in most instances and for most species, unless released fish are air exposed for a minute or longer, long-term impacts are rarely life-threatening. Nevertheless, some states have been pressured by special interest groups to enact regulations prohibiting air exposure of caught-and-released fish for some species. For example, in Washington, it is now unlawful to remove salmon, steelhead *Oncorhynchus mykiss*, or Bull Trout *Salvelinus confluentus* from the water if the angler subsequently releases the fish. With regard to fight time, exhaustive exercise has been implicated as having negative consequences for caught-and-released fish (Ferguson and Tufts 1992; Schreer et al. 2001), but as with air exposure, such impacts typically do not materialize unless fight times are exorbitantly long.

Considering the breadth of research on the effects of various levels of air exposure and fight time on caught-and-released fish, surprisingly little information exists about actual angler behavior in catch-and-release fisheries, and whether fight and air exposure times are problematic. In Idaho, covertly measured angler observations at several lake and river fisheries revealed that trout anglers held fish out of the water on average for 26 s before releasing them, with only 4% of anglers holding fish out of water for >60 s; fight time averaged only 53 s (Lamansky and Meyer 2016). While such fight and air exposure times likely have a negligible impact on hooking mortality for caught-and-released trout, the extent to which these findings apply to other fisheries is unknown. Our primary study objective was to evaluate fight and air exposure times in a popular Idaho catch-and-release fishery for salmon and steelhead.

Hooking mortality associated with catch-and-release fishing for anadromous species in the Pacific Northwest is attributed, in part, to terminal gear type and anatomical hooking location (Hooton 1987; Bendock and Alexandersdottir 1993; Lindsay et al. 2004; Nelson et al. 2005; Cowen et al. 2007), though other factors such as hook size and type, species, fish size, and capture conditions are important. Bait fishing generally results in higher rates of deep hooking, which more often injures vital internal organs or the gills, and frequently leads to higher rates of catch-and-release mortality (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005). Because deep-hooking is the main driver in hooking mortality, our second study objective was to use angler observations noted above to evaluate deep hooking rates by Idaho Chinook Salmon and steelhead anglers using bait or other terminal tackle.

Methods

The Clearwater River, its tributary forks, the Little Salmon River, the Salmon River, and the Snake River are all popular steelhead and Chinook Salmon fisheries in Idaho. In these waters, anglers may only harvest steelhead with a clipped adipose fin; otherwise, they must release the fish. Anglers must also release Chinook Salmon with intact adipose fins except in rare occasions where returns are sufficient to allow harvest of unclipped fish.

We observed anglers fishing for steelhead and Chinook salmon in the main stem, South Fork, and North Fork of the Clearwater River, the Salmon River, and the Little Salmon River in Idaho. When possible, observations were made covertly, because we assumed that angler behavior might be affected by the close presence of state agency staff. However, many observations were overt, i.e., they were collected opportunistically during an unrelated program involving volunteer steelhead broodstock collection by anglers. Covert observations of anglers were conducted with binoculars from inconspicuous locations, or directly by observers posing as anglers.

When a fish was hooked, we used a stopwatch to measure the amount of time (s) it took from initial hookup to landing of the fish. At times the initial hookup was not observed so fight times were not available for some fish. Once landed, we timed how long the fish was exposed to air before being released. Occasionally, fish were put back in the water and then re-exposed to air one or more times. As reported in Lamansky and Meyer (2016), re-exposures were relatively infrequent in the present study and did not meaningfully affect results. Thus, for the purposes of modeling analysis, we used the longest air exposure interval. During each fish landing event, we also noted various associated factors that might influence air exposure and fight times, including the method used to land the fish (net, hand), type of fishing gear used (fly, lure, bait), whether the angler was on foot or in a boat, and whether a photo was taken.

Non-fly fishing tackle such as beads, yarn, or bait drifted with or without a bobber were all fished very similarly and were not always distinguishable at a distance by anything other than the rod type and technique used, so they were combined into a non-fly gear category. Because rods used to fish lures are very similar to those used with other non-fly gear, and would be expected to have a similar effect on fight and air exposure times, lures were also included in the non-fly gear category. Thus, for fishing gear type used, we report either fly fishing or non-fly fishing when testing effects on fight time and air exposure. Water bodies were considered separately in this analysis due to differences among them that could contribute to variation in the data. For example, on the North Fork Clearwater River, many anglers fish either from the Ahsahka Bridge or from the wall below Dworshak Dam. At both locations, anglers are fishing 10-20 m above the surface of the water, which (1) precludes fly anglers from fishing those locations, and (2) greatly extends the fight time required to walk across the bridge or wall and climb down a series of stairs to reach the water and land a hooked fish. Thus, observations collected at the bridge and dam were treated separately when assessing fight times, but because this activity would not necessarily affect air exposure times, we did not separate this for air exposure data. In the interest of collecting independent observations, we tried not to collect more than one observation per angler for each day.

Hooking location was recorded for overt observations but could not be determined for covert observations; we assumed that anglers could not influence their hooking location based on their awareness of an observer, and we did not observe any snagging activities. Hooking location was recorded as deep (i.e., either in the gills or more deeply hooked), mouth (i.e., in the corner of the mouth or anything inside the mouth but not deep hooked), or foul hooked. For hooking location, gear was categorized into either bait/jig, lure, or fly because of suspected differences between lures and bait (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005).

The air exposure and fight time data represent time-to-event data that conformed to an exponential distribution, so we used accelerated failure time models to evaluate the factors affecting each response variable (Therneau and Grambsch 2000; Therneau 2015); air exposure and fight time were modeled separately. Accelerated failure time models designate a family of models that can be generalized to include covariates on the air exposure or fight-time function (Kalbfleisch and Prentice 2002). Models included water, gear type, photo taken (yes/no), observer status (covert/overt), and landing method (net/hand) as factors potentially affecting air exposure or fight time, which were ranked using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). Once exponentiated, coefficients in the accelerated failure time models are multiplicative. For instance, if the coefficient for when a photo was taken was 1.5 for air exposure, this can be interpreted as meaning that air exposure was 1.5 times or 50% higher for anglers who took a photo compared to those who did not. Program R was used for all data analysis (R Development Core Team 2011).

Results

From May 2016 to April 2017, we observed a total of 441 fish caught, from which 401 fight times and 259 air exposure times were recorded. Steelhead comprised 99% of the fight time observations and 97% of the air exposure observations. The longest interval of air exposure for caught-and-released salmon and steelhead averaged 28.7 s (± 3.2). The longest interval constituted 93% of the total air exposure that fish experienced because only 14% of anglers held fish out of water for two separate intervals and only 3% of anglers exposed fish to a third interval of air exposure. The average fight time was 131 s (± 10.6) (Table 1). Fly anglers photographed their catch 38% of the time, while non-fly anglers photographed their catch 25% of the time.

The model that included observer status, gear type, water, and whether a photo was taken best supported our air exposure time data (Table 2). Of these factors,

Table 1. Summary statistics of Chinook Salmon and steelhead air exposure and fight times including sample numbers (N), mean, range, standard deviation (SD) and 95% confidence intervals (CI) for gear types (fly and non-fly), observer status (covert and overt), and whether the angler photographed their catch. *Fight times for non-fly gear and for covert observations include fish caught from the south fork Clearwater and Little Salmon rivers only, as these were the only sites to have fly anglers and overt observations for comparison.

	N	Mean	Range	SD	95% CI
Air exposure (s)	**259**	**28.7**	**0-185**	**26.3**	**3.2**
Fly	49	23.5	0-89	21.9	6.1
Non-fly	210	29.9	0-185	27.2	3.7
Covert	152	32.3	0-185	31.3	5.0
Overt	103	23.2	2-60	14.5	2.8
Photo	78	38.6	0-129	29.0	6.4
No photo	180	24.4	0-185	24.0	3.5
Fight time (s)	**401**	**131.0**	**5-900**	**108.7**	**10.6**
Fly	69	169.8	13-765	133.8	31.6
Non-fly*	192	78.4	5-292	58.0	8.2
Covert*	47	74.16	5-494	91.8	26.2
Overt	171	113.2	6-765	101.8	15.3
Photo	103	157.2	17-519	108.2	20.9
No photo	296	121.7	5-900	107.7	12.3

Table 2. Akaike's Information Criteria (AIC) ranking for air exposure models.

Model	df	AICc	ΔAICc	weight
AirExp~Photo+Water +Covert+Gear	9	1859.8	0	0.961
AirExp~Photo	2	1867.2	7.33	0.025
AirExp~Water	6	1868.3	8.48	0.014
AirExp~Covert	2	1876.3	16.47	0
AirExp~Gear	2	1878.3	18.44	0
AirExp~Intercept	1	1878.4	18.59	0

Table 3. Coefficients, confidence intervals (CI), and *P*-values for the most highly supported air exposure model. (LS=Little Salmon River, NFBD=North Fork Clearwater River dam wall and bridge fisheries, NFCLW= North Fork Clearwater River, SR=Salmon River, SFCLW=South Fork Clearwater River).

	Coefficient	95% CI	*P*-value
(Intercept)	17.14	6.91-42.52	<0.001
Photo Yes	1.53	1.13-2.07	0.006
Non-fly (Gear)	1.20	0.83-1.72	0.336
LS (Water)	0.39	0.17-0.92	0.030
NFBD (Water	0.97	0.43-2.21	0.948
NFCLW (Water)	0.67	0.25-1.77	0.419
SR (Water)	1.93	0.27-16.29	0.547
SFCLW (Water)	1.02	0.46-2.27	0.951
Covert Yes	1.58	1.09-2.29	0.015

photo taking had the strongest effect, with air exposure time being 1.53 times (~15 s) longer if the angler took a photo of their catch, after accounting for observer status, gear type, and water (Table 3). This effect appeared most evident for anglers using non-fly gear (Figure 1). The next most important factor affecting air exposure was observer status, with covert data collection resulting in 1.58 times longer air exposure. Other variation in air exposure was explained by differences in waterbody. Angler gear (fly vs non-fly) was not a significant explanatory variable for air exposure (Figure 2).

The model that included gear, water, observer status, and landing method best supported our fight time data (Table 4). The strongest predictor of fight time was gear, followed by observer status and

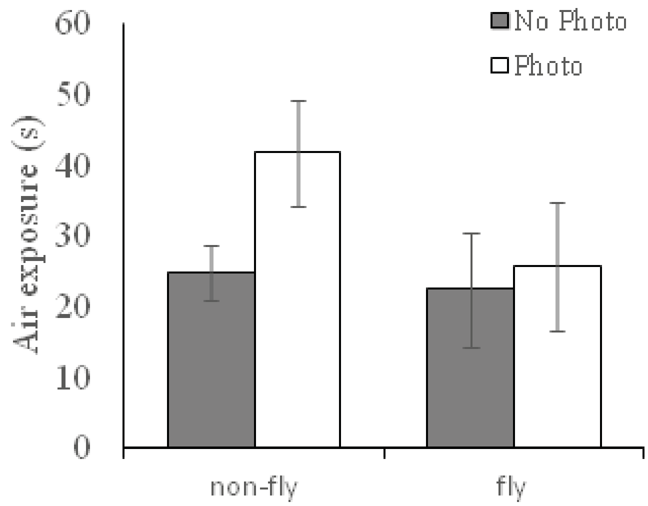

Figure 1. Average air exposure times (s) for Chinook Salmon and steelhead caught and released by non-fly and fly anglers who did or did not photograph their catch. Bars represent 95% confidence intervals.

waterbody (Table 5). When fly-gear was used, anglers fought fish for 1.57 times (76 s) longer than when non-fly gear was used (Figure 2). Fight time was also affected by observer status, but in the opposite direction as air exposure. Fight times measured covertly were 0.49 times (68 s) as long as those collected overtly. Differences in waterbody where data were collected also influenced fight time variation. Fight times from fish caught from the dam wall or bridge on the North Fork Clearwater were more than 2 times longer. However, fight times on the South Fork Clearwater were 0.45 times as long on average.

Deep hooking rates were 0% for bait/jig, 1% for lures, and 0% for flies (Table 6). Foul hooking rates were much higher for lures (40%) than for flies (8%) or bait/jig (4%).

Discussion

Our finding that most Idaho anglers exposed caught-and-released salmon and steelhead to < 30 s of air concurs with a previous study of Idaho trout anglers, which also showed that fish on average were exposed to < 30 s of air before being released (Lamansky and Meyer 2016). Our average fight times of 120 s are longer than their reported 53 s, a disparity most likely explained by the size of the fish being caught (i.e., anadromous salmonids are approximately 10 times heavier than resident trout). Although many

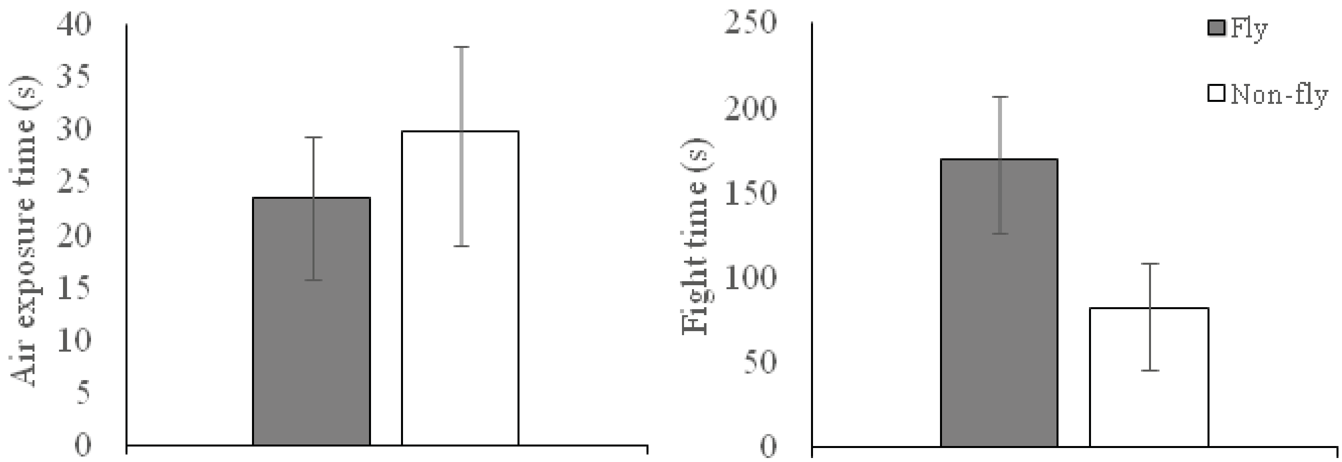

Figure 2. Average air exposure and fight times (s) for Chinook Salmon and steelhead caught and released by fly and non-fly anglers in Idaho. Bars represent 95% confidence intervals. Fight times are from the south fork Clearwater and Little Salmon rivers because these are the only sites that allowed for comparison of fly and non-fly anglers.

Table 4. Akaike's Information Criteria (AIC) ranking for fight time models.

Model	Df	AICc	ΔAICc	weight
Fight~Gear+Water+Covert+Landing method	9	4471.6	0	0.767
Fight~Photo+Gear+Water+Covert +Landing method+Harvest	11	4474	2.39	0.233
Fight~Water	6	4515.1	43.5	0
Fight~Harvest	2	4533.5	61.89	0
Fight~Gear	2	4535.9	64.27	0
Fight~Photo	2	4536.6	65.05	0
Fight~Covert	2	4537.8	66.2	0
Fight~Intercept	1	4540.2	68.65	0
Fight~Landing method	2	4542	70.37	0

Table 5. Coefficients, confidence intervals (CI), and *P*-values for the most highly supported fight time model. (LS=Little Salmon River, NFBD=North Fork Clearwater River dam wall and bridge fisheries, NFCLW= North Fork Clearwater River, SR=Salmon River, SFCLW=South Fork Clearwater River).

	Coefficient	95% CI	P-value
Intercept	454.89	216.35-956.43	<0.001
Gear (Non-fly)	0.43	0.32-0.57	<0.001
LS (Water)	0.63	0.31-1.24	0.177
NFBD (Water)	2.07	1.07-3.99	0.031
NFCLW (Water)	1.84	0.89-3.78	0.098
SR (Water)	0.68	0.09-5.40	0.714
SFCLW (Water)	0.45	0.23-0.88	0.020
Covert (Yes)	0.49	0.35-0.68	<0.001
Landing method (No net)	1.28	0.86-1.91	0.222

Table 6. Hooking locations for Chinook Salmon and steelhead caught on various gear types.

Hook location	Bait/Jig	Lure	Fly
Mouth	47	58	37
Foul	2	40	3
Deep (Gills/Esophagus)	0	1	0

physiology studies have simulated fight times for anadromous fish of up to 10 min or more, our results suggest that salmon and steelhead anglers in riverine settings land fish much more quickly. Minimizing fight times inherently reduces the cumulative stressful effects of handling by anglers. Until other studies demonstrate contrasting results, we suggest that future experimental research focus more closely on realistic fight times to evaluate the effect that exhaustive exercise may have on hooking mortality of caught-and-released fish.

The effects of air exposure and fight time on trout and salmon mortality has been tested in numerous studies (e.g., Ferguson and Tufts 1992; Schisler and Bergersen 1996; Schreer et al. 2005; Donaldson et al. 2014; Gale et al. 2014). In nearly all studies conducted to date, mortality rates are usually negligible when air exposure and fight times are representative of actual angler behaviors. The most cited study on fight and air exposure impacts to caught-and-released fish was conducted by Ferguson and Tufts (1992), who found mortality rates of 38% and 72% for hatchery Rainbow Trout exposed to only 30 and 60 s of air, respectively. In their study, test fish were chased for 10 minutes (simulating fight time), to the point of complete exhaustion for most fish, before exposing fish to air. Fish were then cannulated and repeatedly bled (five times) over the next several hours. Test conditions were so stressful in this experiment that even those fish not exposed to air suffered a mortality rate of 12%. For this reason, the authors explicitly stated that their results should not be applied to trout fisheries in the wild. Nonetheless, their results are repeatedly touted as demonstrating the severe negative impacts of small levels of air exposure on caught-and-released fish (Schisler and Bergersen 1996; Cooke and Suski 2005).

Our study confirms the importance of covertly collecting angler observational data so as not to bias their behavior. As suspected, anglers did not hold fish out of the water as long when the data were overtly collected, presumably because they knew their behavior was being monitored. Previous studies that have reported angler fight and air exposure times have only included anglers participating in a particular study (e.g., Landsman et al. 2011). One surprising result was that covertly collected data had lower fight times than overt observations. This could be because most overt observations were collected opportunistically when biologists were cooperating with anglers that caught brood fish for spawning at a nearby hatchery. This situation may have placed greater importance on landing the fish, making the anglers more careful not to hurry the capture, thereby prolonging the process.

Deep hooking rates are important in the context of catch-and-release angling because for a variety of species (including resident and anadromous salmonids) it has been shown that (1) bait fishing results in higher rates of deep hooking, (2) deep hooking more often results in injury to critical internal organs, and (3) such injuries greatly increase the mortality rate for released fish (Muoneke and Childress 1994; Bartholomew and Bohnsack 2005). While we did not estimate hooking mortality, we observed deep hooking rates (≤1%) that were lower than those reported in most other anadromous salmonid studies. For example, Chinook Salmon in the Willamette River experienced a 13% deep hooking rate, including rates of 15% for bait anglers and 8% for anglers using spinners (Lindsay et al. 1004). Chinook Salmon in the Yakima River experienced an 8% deep hooking rate, with 99% of anglers fishing with bait (Fritts et al. 2016). Other anadromous salmonid studies investigating hooking locations have included the tongue and roof of the mouth as vital areas during data collection (e.g., Bendock and Alexandersdottir 1993; Cowen et al. 2007) because they can result in bleeding. However, the goal in any catch-and-release fishery is to maximize the rate at which anglers hook fish in the jaw or mouth while minimizing gill and esophagus hooking. Our results suggest that for anadromous fisheries in Idaho, hooking in areas that can cause internal organ damage (i.e., gills and deeper) is negligible regardless of terminal tackle.

Often the most vocal anglers calling for restrictions on gear type or air exposure are fly anglers, who tout such restrictions as reducing handling stress for caught-and-released fish. In our study, fly anglers took considerably longer to land salmon and steelhead, did not expose fish to less air, were more likely to hold a fish out of water for picture taking, and did not deep hook fish less often compared to other terminal tackle. These results suggest that fish caught and released by fly anglers in Idaho anadromous fisheries experience more stressful handling conditions than fish caught by non-fly anglers. This result should not be surprising given the physical differences between rod types. Fishing rods used with bait, bobbers, and lures typically have much greater resistance and strength than fly rods used in similar fisheries. However, it should be noted that these differences, though statistically significant, are likely not biologically meaningful in the context of increasing post-release mortality rates or population-level impacts.

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