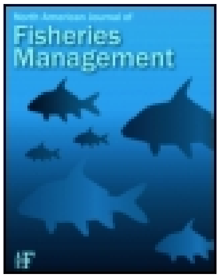

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Self-Reporting Bias in Chinook Salmon Sport Fisheries in Idaho: Implications for Roving Creel Surveys

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ARTICLE

Self-Reporting Bias in Chinook Salmon Sport Fisheries in Idaho: Implications for Roving Creel Surveys

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Abstract
Self-reporting bias in sport fisheries of Chinook Salmon *Oncorhynchus tshawytscha* in Idaho was quantified by comparing observed and angler-reported data. A total of 164 observed anglers fished for 541 h and caught 74 Chinook Salmon. Fifty-eight fish were harvested and 16 were released. Anglers reported fishing for 604 h, an overestimate of 63 h. Anglers reported catching 66 fish; four less harvested and four less released fish were reported than observed. A Monte Carlo simulation revealed that when angler-reported data were used, total catch was underestimated by 14–15 fish (19–20%) using the ratio-of-means estimator to calculate mean catch rate. Negative bias was reduced to six fish (8%) when the means-of-ratio estimator was used. Multiple linear regression models to predict reporting bias in time fished had poor predictive value. However, actual time fished and a categorical covariate indicating whether the angler fished continuously during their fishing trip were two variables that were present in all of the top a priori models evaluated. Underreporting of catch and overreporting of time fished by anglers present challenges when managing Chinook Salmon sport fisheries. However, confidence intervals were near target levels and using more liberal definitions of angling when estimating effort in creel surveys may decrease sensitivity to bias in angler-reported data.

Creel surveys are the primary means to collect information on angler effort and catch rates and to estimate the number of fish harvested and released in sport fisheries (Malvestuto 1983; Pollock et al. 1994). Most creel surveys rely on angler-reported data to estimate metrics used in managing fisheries. Total catch is estimated by multiplying estimates of effort and mean catch rate (Robson 1961; Pollock et al. 1994). Mean catch rate is based on the angler-reported amount of time fished and number of fish caught. Bias with either of these metrics can result in inaccurate estimates of total catch. As with many human behaviors, self-reporting of angling activity is subject to bias. Self-reporting bias in angler surveys is a form of nonsampling bias that includes recall, prestige, digit, and misreporting bias (Sudman and Bradburn 1974; Essig and Holliday 1991; Connelly et al. 2000). Recall bias refers to a respondent's inability to recollect and accurately report events. Prestige bias refers to a respondent's inaccurate response that they believe is socially desirable (Applegate 1984; Brown et al. 1986). Digit bias

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refers to a respondent's tendency to round numbers to those that end in zeros or fives, and misreporting bias refers to a respondent's attempt to deliberately mislead the survey administrator. In roving and access creel surveys in sport fisheries of Chinook Salmon *Oncorhynchus tshawytscha* in Idaho, estimates of effort (i.e., angling hours) and catch rely on angler self-reported data and may be susceptible to any or all of these forms of bias.

Currently, several populations of spring- and summer-run Chinook Salmon in the Snake River evolutionary significant unit are listed as threatened under the Endangered Species Act (ESA; WCCSBRT 1997). Because of their status, consumptive sport fisheries are limited to fish of hatchery origin, which are not listed under the ESA. When targeting hatchery fish, anglers may catch wild fish that must be released. The ESA limits the allowable incidental mortality of listed species that are caught and released in fisheries that target hatchery fish. Fisheries must be closed when this condition is met (Apperson and Wilson 1998). Fisheries may also be closed once a "harvest share" of hatchery fish is reached. In Idaho, the total allowable harvest is shared equally between tribal and sport fisheries. Additionally, fisheries are often closed to allow fish to escape into upriver fisheries or hatcheries for use as broodstock (McCormick et al. 2012). On-site creel surveys (i.e., roving and access surveys) are used to estimate the total number of fish harvested and released throughout the season and depend on accurate self-reported data from anglers to properly manage the fisheries.

Much of the research on self-reporting bias in fisheries has focused on off-site survey techniques (Carline 1972; Fisher et al. 1991; Roach et al. 1999). On-site survey techniques are generally accepted as having less reporting bias because recall time is short and harvest can be verified by creel clerks (Pollock et al. 1994; Newman et al. 1997; Roach et al. 1999). The results of research focused on on-site techniques have been inconsistent. Edwards (1971) found that a group of anglers fishing for Rainbow Trout *O. mykiss* on the Colorado River substantially overestimated their fishing time. The author also found that unsuccessful anglers underestimated their fishing time, while anglers who were successful were more accurate at estimating fishing times. In contrast, no differences were found between actual and reported times for fisheries in Alberta lakes, and anglers who were more successful generally underestimated their fishing times (Radford 1973). Anglers who were less successful overestimated fishing times. No difference between actual and reported fishing times, and no correlation between length of trip and accuracy of reporting, was found in marine fisheries in Texas (McEachron et al. 1986). Similarly, Steffe and Murphy (2010) found that angler-reported times were empirically unbiased in marine fisheries in New South Wales, Australia. Johnson and Wroblewski (1962) found high variability in the accuracy of reported fishing times for individual anglers but no bias in totals hours fished for all anglers in a Walleye *Sander vitreus* fishery in Minnesota.

In addition to angler-reported fishing times, estimates of catch rate also rely on unbiased angler reports of number of fish caught, harvested, and released. Since harvested fish can usually be observed by creel clerks in on-site surveys, little bias should arise from anglers self-reporting their harvest (Newman et al. 1997). However, self-reporting bias of harvested fish was observed in fisheries with large bag limits in Florida lakes (Mallison and Cichra 2004). While harvested fish can be observed, released fish cannot (Huntsman et al. 1978; Sullivan 2003). Sullivan (2003) found that anglers overreported catch and release of protected-length Walleye by more than two-fold in Alberta lakes. The author also found that overreporting of catch and release increased exponentially with decreasing catch.

Unlike fisheries where indices of catch are sufficient to make management decisions, absolute values of catch and harvest are needed to manage Chinook Salmon fisheries in Idaho. Knowledge of the extent and direction of possible self-reporting bias is desired for proper management of sport fisheries in Idaho. Bias in self-reported catch or amount of time fished by anglers could result in reduced returns of wild fish or in insufficient return of broodstock fish to hatcheries, both of which can affect future fisheries. Therefore, the objective of this research was to evaluate self-reporting bias in Chinook Salmon creel surveys and determine its effect on mean catch rate and total catch estimates.

METHODS

Discreet observations of angling activity were conducted to quantify self-reporting bias. Observed angling activity was then compared with the angler-reported data given to Idaho Department of Fish and Game (IDFG) creel clerks conducting roving and access surveys. Direct visual observations were conducted over a 26-d period during the 2011 and 2012 seasons at one site on the Little Salmon and Middle Fork Clearwater rivers, two sites on the Salmon River, and three sites on the South Fork Salmon River. By regulation, legal fishing time on all fisheries was limited to daylight hours only. Observers arrived before legal fishing time and remained until the end of legal fishing time. Discreet observations were conducted so as not to influence angler decisions on fishing locations, fishing times, fish harvest, or reporting to IDFG creel clerks. Angling activity was observed from afar (200–400 m) using spotting scopes on the Little Salmon River and one site on the South Fork Salmon River. Two observers were used on the Middle Fork Clearwater River and two sites on the South Fork Salmon River. One observer fished and relayed information to the other observer who discreetly recorded data. For both observation approaches, data were recorded on the time each angler entered and exited the fishery, total catch, time of catch, number and origin of fish released, and the number and origin of fish harvested. Hatchery fish were identifiable to anglers and observers by an excised adipose fin. Sites were selected nonrandomly to increase sample sizes and allow for discreet observations. Survey days were selected to coincide with maximum angling activity on each river.

During the observation process, each angler was assigned a unique angler identification number at the start of their fishing episode, which was defined as the angler's first cast. The end of the fishing event was defined as the time the angler exited the fishing area and was no longer available for a roving interview or count. Anglers would frequently take a "break" from fishing or exit the fishery for short periods of time and were unavailable for counting in a roving creel survey. If an angler took a break for 5 minutes or more, they were assumed to be unavailable for counting in a roving effort count and were recorded as not fishing. An angler was assumed to be fishing and available for counting if they were actively fishing or changing tackle. Anglers that took a break or exited and reentered the fishery were reassigned their initial identification number when they reentered the fishery or resumed angling.

Anglers were interviewed by IDFG creel clerks during their normal creel survey schedule and asked the same questions as in a normal creel survey (e.g., number of fish harvested and released, amount of time fished). Roving interviews were conducted on the Little Salmon and Middle Fork Clearwater rivers, whereas a combination of access and roving interviews were conducted on the Salmon and South Fork Salmon rivers. Immediately following the interview process, IDFG creel clerks provided interview identification numbers to the observers who linked interview numbers to angler identification numbers and respective data.

The number of observed anglers interviewed was highly variable depending on the fishery and day. As a result, data were pooled from all fisheries for summary analysis. Mean catch rate for all anglers was calculated using the ratio-of-means (ROM) estimator (Jones et al. 1995; Hoenig et al. 1997; McCormick et al. 2012). Reporting bias was calculated as the difference between the reported number of fish harvested, fish released, and observed values. A value of zero indicated the data were reported accurately, a negative value indicated that the angler underreported catch or amount of time fished, and a positive value indicated that the angler overreported catch or amount of time fished.

An exploratory analysis was conducted using multiple linear regression to examine relationships among reporting bias and amount of time fished, number of fish caught, and the time the individual started fishing minus the legal start of fishing time (Fox 2008). Additionally, two categorical covariates were examined that included the river where observations were conducted and whether the angler fished continuously during their trip. Because the sample size to evaluate reporting bias in the number of fish caught was small, regression models were only created for reporting bias in the amount of time fished. The assumptions of the linear models were evaluated by examining a suite of diagnostic plots including observed versus predicted values, externally studentized residuals versus predicted values, and normal quantile–quantile plots (Fox 2008). Akaike's information criterion corrected for small sample bias (AIC_c) was used to evaluate a priori candidate models (Akaike 1973; Burnham and Anderson 2002). Akaike weights (w_i) were used to assess the relative plausibility of each candidate model. Model-averaged regression coefficients were calculated using w_i for all candidate models examined (Burnham and Anderson 2002). Model-averaged coefficients were only calculated for the predictor variables that were present in the most parsimonious model. The coefficient of determination (R^2) was calculated to evaluate the goodness of fit of each candidate model. Additionally, the predictive performance of the most parsimonious model selected using AIC_c with and without model-averaged parameter estimates was evaluated using "leave-one-out" cross validation (Efron and Gong 1983; Efron and Tibshirani 1993). During this procedure, one observation (i.e., angler-reported bias) was omitted from the data and the model was fit with the remaining observations and the predicted error was calculated. This is known as one fold. When model-averaged coefficient estimates were evaluated, all candidate models were fit with the omitted observation, model-averaged coefficients were estimated, and the predicted error was calculated. This process was repeated for all observations creating a distribution of predicted errors. The mean square error (MSE) of the cross-validation procedure for each model was estimated as follows:

$$\text{MSE} = \frac{1}{kn} \sum_{j=1}^{k} \sum_{j=1}^{n} (Y_{ij} - \widehat{Y}_{ij})^2, \tag{1}$$

where Y_{ij} is the observed ith value in the jth fold, $\hat{Y}_{ij}$ is the estimated ith value in the jth fold, n is the number of observations in one fold, and k is the number of folds.

Monte Carlo simulations were used to determine the influence of potential self-reporting bias on estimates of mean catch rate and total catch. This evaluation was conducted to determine the sensitivity of the mean catch rate estimators to self-reporting bias. Five thousand iterations were conducted where samples of angler interviews were selected using simple random sampling without replacement (Cochran 1977). McCormick et al. (2012) showed that the ROM estimator provided the most accurate estimates of mean catch rate in these fisheries. However, the authors used data that did not account for errors in angler-reported data. As a result, for each iteration mean catch rate was calculated using the ROM for the observed data and using the ROM and means-of-ratios (MOR) estimators for the angler-reported data (Jones et al. 1995; Hoenig et al. 1997; McCormick et al. 2012). Total catch was estimated for each iteration as the product of mean catch rate and the observed hours of angling effort for all anglers at the time of the interviews. To determine the influence of sample size on estimates of mean catch rate, total catch, and their confidence intervals, the number of simulated interviews conducted varied from 25 to 150 by intervals of 25. Ninety-five percent nonparametric bootstrap confidence intervals were calculated for each estimate using the percentile method (Efron and Tibshirani 1993). Bias for each population parameter was estimated as the difference between the mean of the empirical sampling distribution from the true population parameter (i.e., mean catch rate, total catch). Coverage of 95% confidence

TABLE 1. Observed and reported number of hatchery Chinook Salmon harvested and wild Chinook Salmon released by 164 anglers in three Idaho sport fisheries during the 2011 and 2012 seasons.

Reported harvest or catch	Observed harvest (hatchery)						Observed catch (wild)	
	0	1	2	3	4	5	0	1
0	119	6	0	0	0	0	146	9
1	2	25	1	0	0	0	1	7
2	0	1	6	0	0	0	0	0
3	0	1	0	2	0	1	0	0
4	0	0	0	0	0	0	1	0
5	0	0	0	0	0	0	0	0

intervals (CIs) was also evaluated. In theory, 95% of all CIs should encompass the true population parameter, and for iterations whose CIs did not encompass the true parameter values, 50% should be below the true value and 50% should be above the true value. The percentage of CIs that encompassed the true population parameter was determined. Simulations and statistical analysis were conducted using the R statistical computing language (R Development Core Team 2009).

RESULTS

During the 2011 and 2012 Chinook Salmon fishing seasons, 164 anglers were interviewed by IDFG creel clerks while their trips were discreetly observed. Observed anglers caught 74 Chinook Salmon; 58 were hatchery fish that were harvested and 16 were wild fish that were released. No hatchery fish were released and no wild fish were illegally harvested. Of the 164 anglers observed, 49 (30%) were successful in catching a fish and 10% of anglers caught 55% of the fish. One angler caught five fish, one angler caught four fish, four anglers caught three fish, 10 anglers caught two fish, and the remaining 33 anglers caught one fish (Table 1). Observed anglers reported catching 66 fish; 54 hatchery fish harvested and 12 wild fish released. Four less hatchery fish and four less wild fish were reported than observed (Table 1). Forty-four percent of observed wild fish caught and released were reported to creel clerks. No anglers falsely reported wild fish released as hatchery fish released.

Overall, anglers overreported their fishing time by 63 h. Observed anglers fished for a total of 541 h (mean, 3.44 h; range, 0.17–13.4 h) and reported fishing for 604 h. A majority of anglers reported their fishing time within 1 h of their actual amount of time fished (Figure 1). The observed angler catch rate was 0.137 fish/h. Using self-reported data, the mean daily catch rate was estimated at 0.110 fish/h. If angling effort was estimated accurately in a roving creel survey (i.e., 541 h) using a roving or aerial survey, multiplying the reported catch rate by the estimate of angler hours would result in an estimate of 60 fish. This is an underestimate of total catch by 14 fish (19%). The observed harvest rate of hatchery fish was 0.107 fish/h and the observed catch rate of wild fish was 0.030 fish/h. The reported catch rate was 0.090 fish/h and 0.020 fish/h for hatchery fish and wild fish, respectively. If angler effort was determined with 100% accuracy in a roving creel survey, the estimate of hatchery fish harvested would be 49 fish and the estimate of catch of wild fish would be 11 fish. This is an underestimate of harvest by nine fish and an underestimate of wild fish released by five fish.

Examination of diagnostic plots indicated that the data met the assumptions for linear regression analysis with the exception of the quantile–quantile plot, which indicated a slight departure from normality (Figure 2). Five of the 15 a priori regression models to predict reporting bias accounted for all of the w_i (Table 2). All of the top five models contained the actual amount of time fished and the categorical variable indicating that the angler fished continuously during their trip. The top model included only these two variables and received 55% of w_i. The second best model, according to AIC_c, included these two variables and the difference in time each angler started fishing from

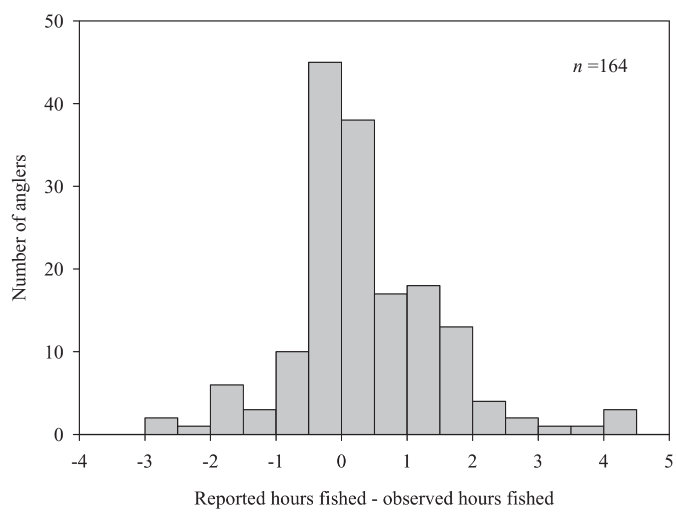

FIGURE 1. Distribution of the difference of observed and actual angler-reported fishing times of 164 anglers in three Chinook Salmon fisheries in Idaho during the 2011 and 2012 seasons.

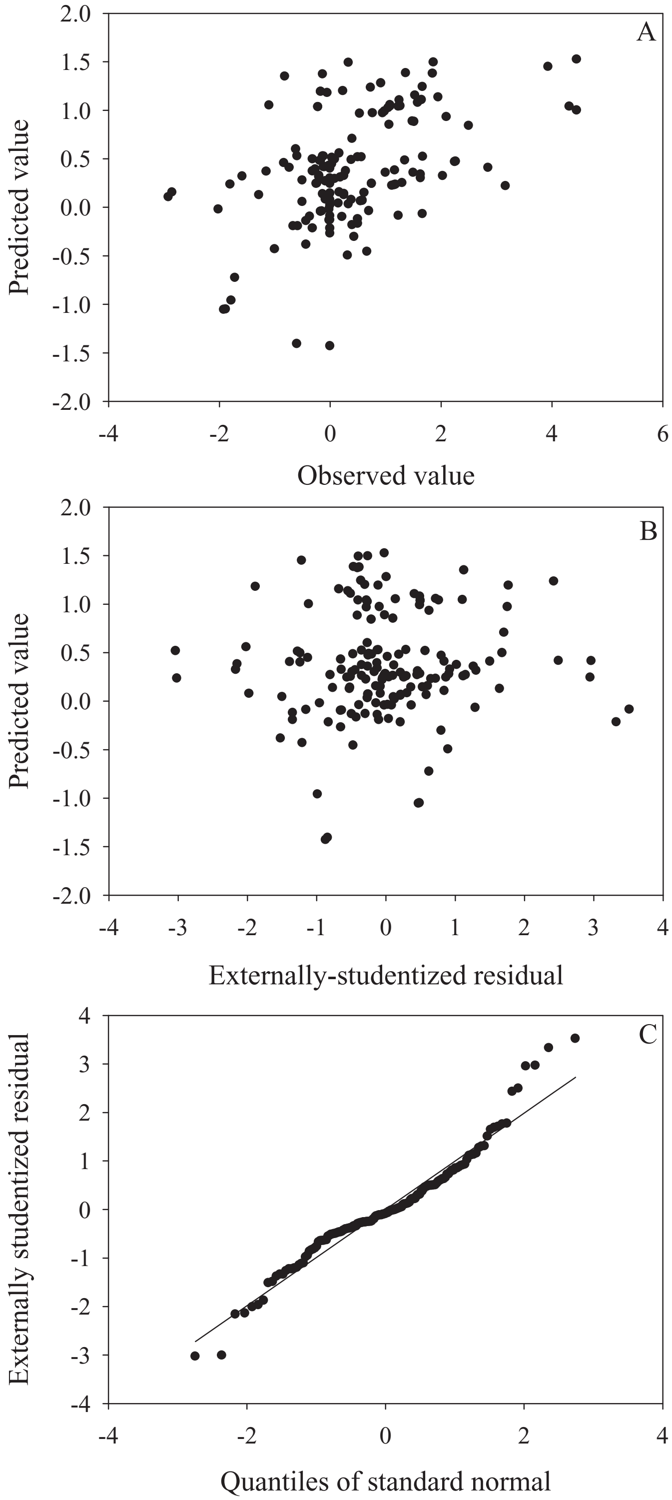

FIGURE 2. Diagnostic plots to evaluate the assumptions of a multiple linear regression model to predict angler-reported bias in fishing times in three Chinook Salmon fisheries in Idaho during the 2011 and 2012 seasons. Panel **(A)** shows the observed versus predicted bias, panel **(B)** shows externally studentized residuals versus predicted bias, and panel **(C)** is a normal quantile–quantile plot.

the legal start time, and had an AIC_c value that was 1.68 greater than the top model. The number of fish caught and the difference in time each angler started fishing from the start of legal fishing time also appeared in four of the top five models. The model containing the covariate for fishery location (i.e., river) only accounted for 1% of w_i suggesting that reporting bias was similar between fisheries. The difference between reported and observed fishing times was inversely related to actual amount of time fished, suggesting that as actual fishing time increased anglers were more likely to underreport the time they fished (Table 2). The top model and model-averaged coefficients for the categorical variable indicating whether the angler fished the entire duration of their trip were also negative. This suggests that anglers who fished continuously underreported their fishing times compared with anglers who took a break during their fishing trip. All of the models examined exhibited low R^2 (i.e., R^2 varied from 0.20 to 0.21 for the top five models; Table 2). Cross-validation MSE for the top model was 1.08 with and without model-averaged parameter estimates. With the exception of the intercept, which was 1.63 using model averaging compared with 1.60 without, model-averaged parameter estimates were nearly identical to the top model parameter estimates (Table 2).

Results from the Monte Carlo simulation showed that estimates of mean catch rate and total catch were unbiased using observed data (Table 3). Nonparametric CIs encompassed the true mean greater than 95% of the time for all samples sizes using observed data. While CIs were more than 95%, they were biased low with sample sizes of 25 and 50 interviews. Confidence intervals were relatively unbiased when 75 or more interviews were conducted. When reported data were used, the MOR estimator resulted in less-biased estimates of catch rate and total catch compared with the ROM estimator. The ROM estimator and angler-reported data resulted in negatively biased estimates that varied from 14 to 15 fish (19–20%). Using the MOR estimator improved bias and resulted in estimates that were negatively biased by six fish (8%). Bias in estimates of catch rate and total catch increased slightly with increasing sample size. Confidence interval coverage varied from 92% to 100% using the MOR estimator and 93% to 97% using the ROM estimator. Confidence interval coverage increased for both estimators with increasing sample size. However, all CIs were biased low regardless of the sample size.

DISCUSSION

A major assumption when estimating mean catch rate, total catch, and total harvest in creel surveys is that anglers accurately report data. While a majority of anglers were accurate in reporting their data, our results suggest that the minority that violated this assumption introduced bias into total catch and harvest estimates in various Chinook Salmon fisheries in Idaho. Estimates were negatively biased from 8% to 20% depending on the estimator used to calculate mean catch rate. Sullivan (2003),

TABLE 2. Multiple regression models and derived parameter estimates predicting angler-reported bias (observed-reported) in angling times in three Chinook Salmon fisheries in Idaho during the 2011 and 2012 seasons. Variables include the following: the actual amount of time fished (AT), the number of fish caught (C), the difference between the time the angler started fishing and the start of legal fishing time (ΔL), the categorical covariates for if the angler fished continuously throughout their fishing trip (FC), and the river where the fishery took place with the Little Salmon River serving as the reference for the Middle Fork Clearwater (MF), South Fork Salmon (SF), and Salmon (SR) rivers. Akaike's information criteria corrected for small sample size (AIC_c), number of parameters (K), change in AIC_c value (ΔAIC_c), and AIC_c weights (w_i) were used to select the top models from a set of a priori candidate models. The coefficient of determination (R^2) is provided as a measure of model fit.

Model	K	AIC_c	ΔAIC_c	w_i	R^2
1.60 − 1.01(FC) − 0.15(AT)	4	479.29	0	0.55	0.21
1.63 − 1.00(FC) − 0.15(AT) − 0.01(ΔL)	5	480.97	1.68	0.24	0.21
1.80 − 1.18(FC) − 0.15(AT) − 0.01(C) − 0.10(DL) + 0.10(FC × ΔL)	7	482.22	2.93	0.13	0.22
1.63 − 1.00(FC) − 0.16(AT) − 0.01(ΔL) − 0.01(C)	6	483.12	3.83	0.08	0.21
1.86 + 0.05(MF) − 0.07(SF) − 0.14(SR) − 1.17(FC) − 0.01(C) − 0.17(AT) − 0.10(ΔL) + 0.10(FC × ΔL)	10	488.38	9.1	0.01	0.20
1.05 − 0.95(FC)	3	495.27	15.98	0	0.13
1.08 − 0.91(FC) − 0.12(C)	4	496	16.71	0	0.13
1.04 − 0.95(FC) + 0.01(ΔL)	4	497.27	17.98	0	0.12
1.20 − 1.06(FC) − 0.11(C) + 0.08(ΔL)	6	498.38	19.09	0	0.13
0.81 − 0.13(AT)	3	506.38	27.09	0	0.07
0.83 − 0.13(AT) − 0.11(C)	4	507.46	28.17	0	0.07
0.87 − 0.14(AT) − 0.01(ΔL)	4	507.72	28.43	0	0.07
0.45 − 0.20(C)	3	515.4	36.11	0	0.01
0.47 − 0.01(ΔL) − 0.20(C)	4	517.41	38.12	0	0.01
0.37 − 0.01(ΔL)	3	518.88	39.59	0	0.01

who found that anglers overreported catch rates with declining catch, suggested that the failure of anglers to accurately report data could result in perceived hyperstability of the fishery and lead to collapse. While Chinook Salmon fisheries are managed based on total catch estimates instead of mean catch rate estimates, negative impacts of reporting bias are possible. The systematic underreporting of fish harvested and released and overreporting of amount of time fished could lead to the overharvest of hatchery fish and increase catch-and-release mortality of wild fish beyond desired objectives. This could result in insufficient returns of fish to hatcheries, low escapement to upriver fisheries, or depletion of sensitive wild stocks.

With the exception of two anglers, one who overreported catch and release of wild fish by four and one angler who overrerported by one, prestige bias (Applegate 1984; Brown et al. 1986) did not appear to influence the estimates of total catch. More often anglers underreported the number of wild fish caught and released. While the reasons for this are uncertain, anecdotal evidence suggests that anglers are doing so in an attempt to extend season lengths. This form of bias (i.e., misreporting bias) had a greater influence on the estimates of mean catch rate in this study than prestige bias. The low reporting rates of fish that were caught and released suggests that managers should consider using other methods to estimate catch rates of wild

TABLE 3. Estimated bias and percent confidence interval (CI) coverage of total catch estimates in three Chinook Salmon fisheries in Idaho during the 2011 and 2012 seasons using Monte Carlo simulations. Estimates were calculated using observed and angler-reported data. Mean catch rate was estimated using the means-of-ratios (MOR) estimator and the ratio-of-means (ROM) estimator and n represents the number of interviews conducted.

	Observed MOR		Reported ROM		Reported MOR	
n	Catch bias	% CI coverage	Catch bias	% CI coverage	Catch bias	% CI coverage
25	0.73	98	−14.12	93	−6.07	92
50	0.55	99	−14.64	94	−5.91	95
75	0.17	99	−14.76	94	−5.99	97
100	0.12	100	−14.85	93	−6.25	98
125	0.03	100	−14.97	94	−6.16	99
150	−0.06	100	−15.05	97	−6.35	100

Chinook Salmon. For instance, Sullivan (2003) used a test-fishery with a known catch rate to compare reported catch-and-release rates of Walleyes. It may be possible to create a ratio of hatchery fish to wild fish caught based on a sample of trustworthy anglers in Chinook Salmon fisheries throughout Idaho. This ratio could then be applied to correct the estimate of the number of wild fish that were caught and released. However, caution should be taken when using this approach due to possible spatial and temporal heterogeneity in such a ratio.

Because harvested fish can typically be visually observed (Newman et al. 1997), prestige bias was low in the reporting of harvested fish. When anglers overreported the number of fish harvested, it was likely a result of one angler taking credit for the catch of another angler in their party. This occurred when one angler in the party was more successful than the other(s) and was an attempt to avoid reaching the bag limit of the successful angler. Because catch rate for the party is likely similar regardless of which angler actually harvests the fish, false reporting of catch by other members of a party may have little influence on estimates of harvest in creel surveys.

More commonly, anglers underreported harvest. This usually occurred when an angler harvested a fish and transported it to their vehicle or campsite before being surveyed by a creel clerk. In Idaho, anglers are required to immediately record every harvested fish on a harvest card. Estimates of harvest using angler-reported data may be improved if creel clerks examine angler harvest cards to verify harvest or with increased law enforcement presence. Similar to the underreporting of wild fish that are released, anglers may be underreporting harvest in attempt to extend season lengths. Due to relatively small sample sizes of fish caught, data were pooled across fisheries and the extent to which seasons may have been shortened based on self-reporting bias was not assessed. Additionally, a majority of the wild fish that were caught and released in this study were on the South Fork Salmon River and relatively few wild fish were caught in the other fisheries.

Although there was individual heterogeneity in the accuracy of reported time spent angling, Chinook Salmon anglers in Idaho overreported the time they spent angling. In combination with underreporting of catch, overreporting of time spent angling contributed to the underestimate of mean catch rate and total catch. Edwards (1971) found similar results; however, many other researchers found no significant difference between actual and reported times spent angling or its effect on total catch estimates (Radford 1973; McEachron et al. 1986; Phippen and Bergersen 1987; Phippen and Bergersen 1991; Steffe and Murphy 2010). No hypothesis tests were conducted in our study because sampling units were not selected randomly. Additionally, results of the Monte Carlo simulation are more meaningful than assigning an arbitrary significance level to evaluate differences.

Previous research has suggested that it is necessary to apply a correction factor to accurately estimate mean catch rate when observed angling times are significantly different than angler-reported data (Radford 1973). Various authors have found a relationship between other angling metrics (e.g., catch, time spent fishing) and the accuracy of angler-reported data that could be used to create a model-based correction factor (Edwards 1971; Radford 1973; Sullivan 2003). All of the models that we examined to describe the relationship between various angling metrics and the accuracy of angler-reported time spent fishing exhibited low predictive value. This suggests that a correction factor is of little value in Idaho's Chinook Salmon fisheries based on the explanatory variables evaluated. We attempted to increase the predictive value and improve bias and precision of our models by incorporating uncertainty of model selection by averaging model coefficients (Burnham and Anderson 2002). However, model-averaging coefficients did not improve the predictive value of the models.

While a correction factor based on the models we examined may be of low value, the modeling exercise helped elucidate factors that influence reporting accuracy of time spent fishing. Perhaps the most meaningful of these factors was whether or not anglers fished continuously during their trip. This variable was included in 9 of the 15 candidate models, all of which were ranked higher than the 6 models in which it was not included. A large number of anglers who overestimated their time spent fishing did not fish continuously throughout their trip (i.e., took a "break"). When these anglers were interviewed, they included all or a portion of the time they did not fish. For some anglers this was an hour or more. Such errors may be accounted for in the questionnaire process by asking anglers if they fished continuously. If not, the angler should be asked to estimate the amount of time they did not fish. The bias in overreporting the amount of time fished may also be corrected by adjusting the definition of angling during effort counts (Phippen and Bergersen 1987; Phippen and Bergersen 1991). The definition of angling should be the same when conducting angler counts as when anglers report their amount of time fished. Adopting a more liberal definition of angling when conducting angler counts can increase estimates of effort and correct for the negative bias observed in angler-reported catch rates.

Previous research has shown that using the ROM estimator based on completed trip data provided unbiased estimates of total catch when multiplied by an unbiased estimate of angling effort (Jones et al. 1995; Hoenig et al. 1997; McCormick et al. 2012). Results of our simulation show that the MOR estimator provided estimates that were less biased regardless of sample size. Overall, anglers tended to overreport the time that they fished, which resulted in negatively biased estimates of mean catch rate. Angler-reported fishing time has no effect on mean catch rate when using the MOR estimator for anglers who were unsuccessful in catching a fish, which was the case with a majority of observed anglers. However, angling time of unsuccessful anglers is incorporated in the ROM estimator and a larger negative bias was observed. Additionally, the MOR estimator provided more accurate CIs at smaller sample sizes than the ROM estimator. In the absence of reporting bias, the MOR estimator will not provide an unbiased estimate of total catch when multiplied by an estimate of effort (Jones et al. 1995; McCormick et al. 2012). Using the ROM estimator in combination with a more liberal definition of angling will likely provide the most unbiased estimate of total catch.

Although sample size may have been a limitation, the results of this study are based on the largest sample size of observed anglers in any published study. For instance, Edwards (1971) was based on a sample of 44 anglers, Radford (1973) was based on a sample of 33 angling parties, and McEachron et al. (1986) was based on a sample of 94 interviews. The catch rates of Chinook Salmon in Idaho are relatively low compared with other fisheries where self-reporting bias studies have been conducted, which further limits the sample size of observations of successful anglers. Observation locations and times were selected to maximize observations of angling activity and were assumed to be representative of the general angling population. This assumption was not explicitly evaluated. However, on many days, angling activity was sparse and the same general trends in self-reporting bias were observed on these days as on days when more angling activity was taking place. Sample sizes in self-reporting studies are generally low due to the large amount of effort required to observe angling activity in fisheries similar to Chinook Salmon sport fisheries where angling activity is diffuse. Due to the conservation status of Chinook Salmon and their importance as a sport fishery, the implications of self-reporting bias in Chinook Salmon fisheries are arguably much greater than those in previous studies on this topic.

While previous research on self-reporting bias in other fisheries has been mixed (Edwards 1971; Radford 1973; McEachron et al. 1986; Sullivan 2003), results of our study are somewhat discouraging. The underreporting of catch and overreporting of the amount of time fished produced negatively biased estimates of total catch. Unlike other fisheries that may be managed based on indices (e.g., mean catch rate or catch estimates over time), accurate estimates of total catch are necessary to properly manage Chinook Salmon fisheries in Idaho. While overestimating total catch can limit angling opportunity, underestimating total catch can potentially impact future fisheries. High variability in angler-reported data resulted in poor predictive performance of regression models that could be used to account for self-reporting bias and suggests that correction factors may also be of little use. Nonetheless, we are encouraged that CIs in our simulations encompassed the true population parameters near targeted levels. This suggests that estimates of total catch may be robust to self-reporting bias if variability and CIs are considered and fisheries are conservatively managed.

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