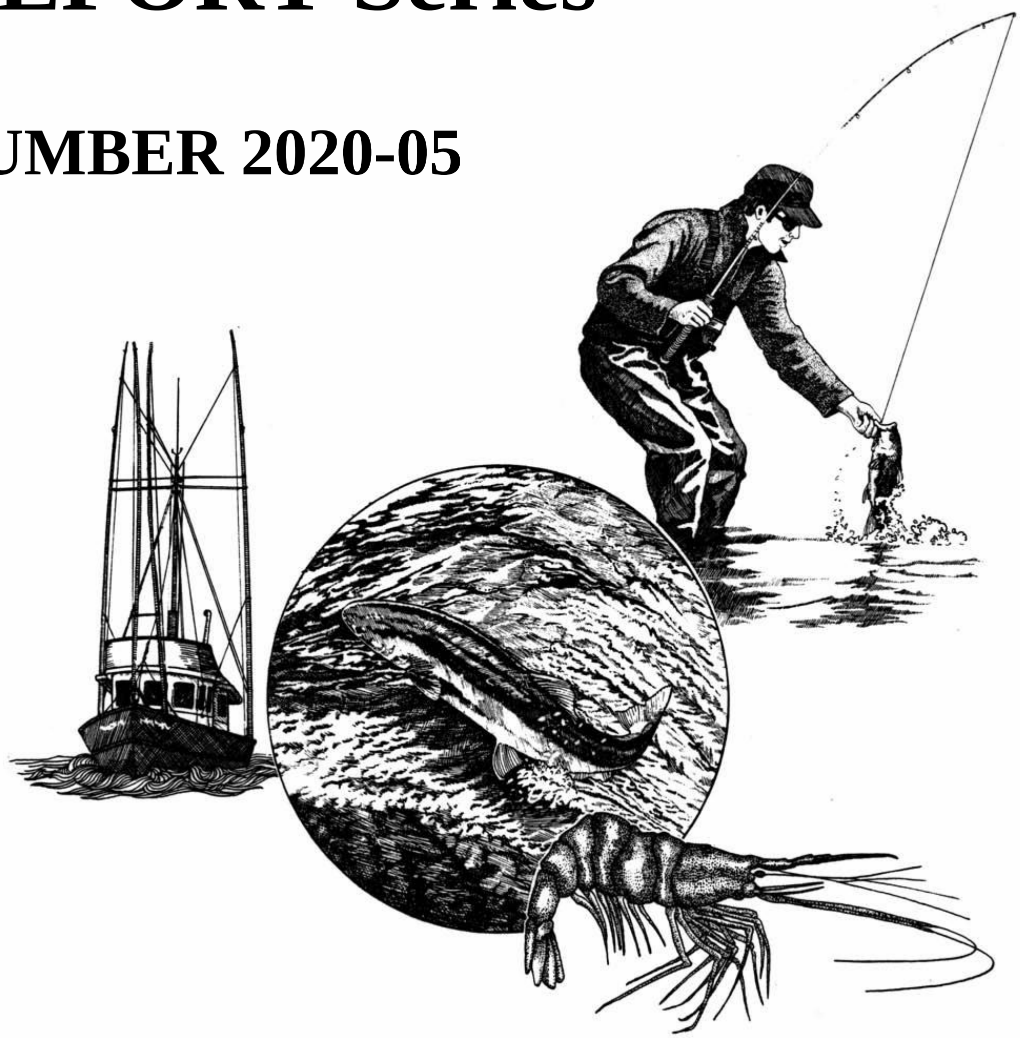
ODFW INFORMATION REPORT Series

NUMBER 2020-05



Oregon Department of Fish and Wildlife

Angler Harvest of Alsea River Hatchery Winter Steelhead: An Evaluation of Wild Broodstock Collection Techniques

Angler Harvest of Alsea River Hatchery Winter Steelhead: An Evaluation of Wild Broodstock Collection Techniques

Marc A. Johnson, ODFW Fish Conservation & Recovery, Salem

John Spangler, ODFW District Fish Biologist, Newport

Michelle Jones, ODFW Fish Division, Salem

Ryan B. Couture, ODFW Hatchery Coordinator, Corvallis

David L. G. Noakes, Oregon Hatchery Research Center

Oregon Department of Fish and Wildlife
4034 Fairview Industrial Drive SE
Salem, OR 97302

September, 2020

TABLE OF CONTENTS

EXECUTIVE SUMMARY

We conducted a multi-year study in the Alsea River, Oregon, to determine whether the method of broodstock collection affects the vulnerability to angling of hatchery winter steelhead. In 2015 and 2016, unmarked, putatively wild steelhead were collected both by anglers and with hatchery traps, tissue sampled, then spawned to produce two experimental cohorts, which were subsequently released as smolts into the Alsea River. Returning adults from these cohorts were sampled in the fishery through creel surveys and from hatchery traps. We genotyped all adult steelhead at 15 microsatellite loci, then used genetic parentage assignments to test for differences between the contribution by the two broodstock sources (anglers or traps) to adult offspring sampled in creel surveys and at hatchery traps.

In brief, we found that

- Relative to the total number of experimental fish sampled in the creel, the number of steelhead produced with angler-caught broodstock and subsequently harvested as adults was less than expected
- Broodstock collection method had a strong effect on the number of adult steelhead produced, whereby angler-caught broodstock produced significantly fewer adult returns to both the creel and trap
- Fishing effort was similar between creel sampling years, dominated by bank angling in upper-river reaches
- Our results were consistent for both experimental cohorts, suggesting a negative effect generated through broodstock collection by anglers, which reduced the production of adult hatchery steelhead.

INTRODUCTION

The Alsea Hatchery, operated by the Oregon Department of Fish and Wildlife (ODFW), produces winter steelhead (*Oncorhynchus mykiss*) for a popular recreational fishery on the Alsea and North Fork Alsea rivers. Built in 1936, the Alsea Hatchery developed a winter steelhead hatchery program by capturing wild winter steelhead from the North Fork and mainstem Alsea River, which were then used as broodstock. Returning adult offspring were then spawned in subsequent years to produce the next generation of hatchery fish. Hatchery managers typically collected and spawned the first fish returning to the hatchery to ensure that production goals were met. Over time, this approach likely selected for Alsea winter steelhead that returned earlier than wild winter steelhead, which may have truncated the run and impacted the stock's contribution to the local fishery.

During the latter half of the 1980s and through the 1990s, a precipitous decline in the harvest success of Alsea Hatchery steelhead prompted managers to develop a new approach to winter steelhead propagation. In 2001, ODFW began spawning wild winter steelhead at Alsea Hatchery, in addition to the traditional (i.e. segregated) stock. Hatchery steelhead produced from the traditional broodstock were (and continue to be) differentially marked from steelhead produced with wild broodstock. A recent analysis of mark data from Alsea Hatchery steelhead demonstrated significantly greater contribution to the local fishery by steelhead produced from wild broodstock (Wilson et al. 2018), confirming the success of the new management approach, but leaving some questions about mechanisms unresolved.

Similar to run timing, other fish behaviors may be heritable and relevant to fisheries management. For example, Philipp et al. (2009) found that vulnerability to angling, as measured through likelihood to be caught by anglers is heritable for largemouth bass (*Micropterus salmoides*). This result has implications for steelhead hatchery management. Because adult steelhead broodstock can be collected either actively by anglers or passively with fish traps, the method of collection could influence subsequent generations' behavior and contribution to harvest if angler vulnerability is heritable. For example, it might be expected that offspring of angler-caught broodstock would be more likely to be caught by anglers than offspring of trap-caught broodstock. Conversely, exclusive use of trap-caught broodstock, under this scenario, might select for steelhead that would be less likely to contribute to angler harvest. However, heritability of angler vulnerability has not been demonstrated in steelhead.

In this study, we test whether broodstock collected by anglers produce steelhead that are more frequently harvested than steelhead produced with passively trapped broodstock. Our findings suggest that, relative to trap-caught broodstock, angler-caught broodstock did not offer consistent benefit in terms of greater angler vulnerability (of their offspring) and, more importantly, severely underperformed in terms of spawner-to-adult production. We present our Methods and Results in two chapters, the first describing research designed to investigate effects from broodstock collection techniques, followed by a detailed description of the creel surveys used to collect samples and estimate fishing effort.

THE EFFECT OF BROODSTOCK COLLECTION METHODS ON THE VULNERABILITY TO ANGLING BY HATCHERY STEELHEAD

Overview

The purpose of our research was to test whether steelhead produced from angler-caught broodstock would contribute more to the local fishery than steelhead produced from trap-caught broodstock. We also investigated whether angler-caught broodstock produced as many adult steelhead as trap-caught broodstock. Our work, predicated on the hypothesis that "biters beget biters", was carried out over several years, involved researchers from the Oregon Hatchery Research Center (OHRC), and benefitted from close coordination between anglers and ODFW.

Methods

Study Area

We conducted our study in the Alsea River basin (Figure 1), which flows west through the Oregon Coast Range until it joins the Pacific Ocean at 44.4225° N, -124.0763° W. Creel surveys, used to collect samples and data for our study, were conducted over approximately 80.5 km (50 miles) of the mainstem Alsea River, from Boundary Bridge (rkm 30; rm 13) upstream and including the North Fork (but not South Fork) until the hatchery deadline.

Collection, sampling, and spawning of brood

During the winters of 2015 and 2016, unmarked adult steelhead were collected and spawned at the Alsea Hatchery for the purposes of our study. Because steelhead produced and released from the Alsea and other Oregon hatcheries are marked by adipose fin clip, these unmarked broodstock fish were presumed to be wild and unlikely to have been directly affected by hatchery selection that might reduce standing genetic variation underlying traits relevant to our study. Broodstock were collected with adult fish traps at the Alsea Hatchery and Oregon Hatchery Research Center (Figure 1), and by anglers using hook and line tactics. Steelhead collected by anglers were temporarily placed into holding tubes constructed from polyvinyl chloride (PVC; Figure 2) and maintained underwater until transported by ODFW staff to the Alsea Hatchery, typically on the same day. A small section of fin tissue was collected from each broodstock fish and these were individually stored in labeled vials containing 95% EtOH for subsequent genetic analyses. We recorded the vial number, date, location, and collection method for each broodstock fish, which were then held at the Alsea Hatchery until spawning. Each broodstock fish also received a uniquely numbered Floy tag to track its identity and collection method.

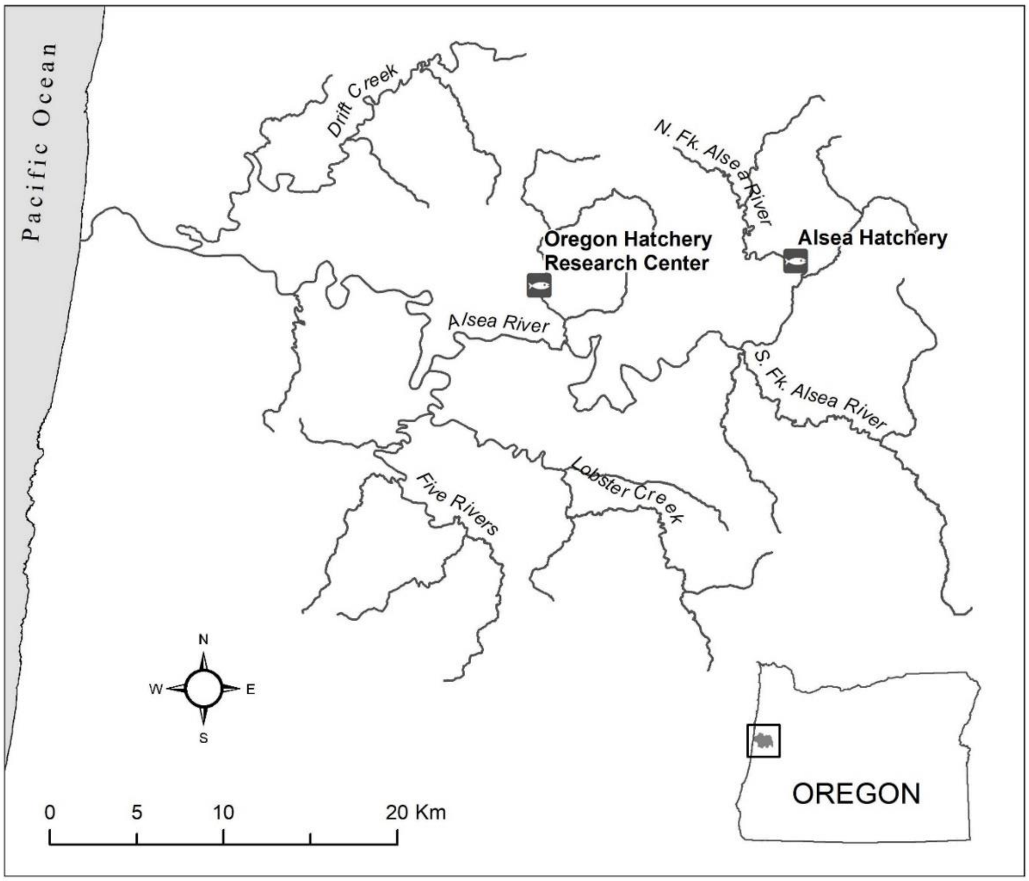


Figure 1. The Alsea River, in western Oregon. Fish traps at the Oregon Hatchery Research Center (OHRC) and Alsea Hatchery were used in this study to collect adult winter steelhead.

During spawning, only angler-caught males were used to fertilize eggs from angler-caught females. Similarly, trap-caught males were used to fertilize eggs from trap-caught females. Floy tags were used to identify individual fish and confirm their source of collection (i.e. trap- or angler-caught). With few exceptions, spawning involved unique pair matings (1M:1F), and the Floy tag numbers of fish used in each cross were recorded. Once fertilized, eggs were incubated at Alsea Hatchery according to standard ODFW practices. Juvenile steelhead from both broodstock sources were incubated and reared together at the hatchery, and all were marked by clipping the adipose fin and right maxillary lobe (ADRM mark). Experimental steelhead were released directly from the hatchery as yearling smolts into the Alsea River during the springs of 2016 and 2017. The number of pairs spawned in 2015 and 2016 are presented in Table 1, along with the estimated number of smolts released.

Figure 2. An angler uses a PVC holding tube to deliver a wild steelhead to Alsea Hatchery staff.

Our experimental design, as described above, produced two cohorts of hatchery steelhead, containing individuals that had been "tagged" through inheritance of genetic markers that could be related to their parents and, therefore, the method used to collect them. Subsequent parentage analysis relied on the detection of these tags in returning adult hatchery steelhead, sampled at the Alsea Hatchery fish trap and through creel surveys.

Table 1. The number of steelhead spawned at Alsea Hatchery in 2015 and 2016, according to broodstock collection method. Also presented are the numbers of juvenile steelhead (smolts) produced from each spawn and subsequently released into the Alsea River. The 2015 cohort was severely impacted by cold water disease mortality, which negatively affected the number of smolts released in 2016.

	2015 Spawn	2016 Spawn
Broodstock from traps	44	54
Broodstock from anglers	34	46
Smolts released	37,655	82,595

Sampling adult offspring

We used creel surveys to collect fin tissue samples from ADRM-marked steelhead caught by anglers during the winters of 2018 and 2019, as detailed in the next chapter of this report. Once collected, tissues were stored in labeled 1.5 mL vials filled with 95% EtOH. We recorded the date, location and vial number for each tissue sample collected. We collected similar data and tissue samples for all ADRM-marked steelhead captured at the Alsea Hatchery trap during the winters of 2018 and 2019. These tissue samples, along with those of broodstock used to produce our experimental cohorts were delivered to the State Fisheries Genomics Laboratory (SFGL) in Newport, Oregon, for genetic analyses

Genetic and statistical analyses

Whole genomic DNA was extracted from all tissue samples using the methods of Ivanova et al. (2006). We then amplified 15 microsatellite markers (Table 2) from each sample via polymerase chain reactions, and separated amplicons by gel electrophoresis on an ABI 3730 XL DNA Analyzer (Applied Biosystems, Inc.). We scored microsatellite alleles by size with GeneMapper software (Applied Biosystems, Inc.) and used the program CERVUS (Kalinowski et al. 2007) to conduct parentage analysis. Parentage analyses were performed using CERVUS's default strict criteria (95% confidence of assignment), estimated by evaluating individual parentage assignment likelihoods against a distribution of LOD scores previously obtained through simulations carried out with parental data (see Kalinowski et al. 2007). We conducted two rounds of single-parent assignments to identify the mothers and fathers of steelhead sampled in 2018 and 2019. Maternal and paternal assignments were then aligned and compared to spawning records that identified parental pairs and the method used to collect them.

Table 2. Microsatellite loci used to genotype steelhead spawned at the Alsea Hatchery and their putative adult offspring.

Locus	Source
Ocl1	Condrey and Bentzen (1998)
Ogo4	Olsen et al. (1998)
Oke4	Buchholz et al. (1999)
Oki23	Smith et al. (1998)
Omy1001	Spies et al. (2005)
Omy1011	Spies et al. (2005)
Omy7	Stephenson et al. (2009)
Omy77	Morris et al. (1996)
One14	Scribner et al. (1996)
Ots3	Banks et al. (1999)
Ots4	Banks et al. (1999)
Ots100	Nelson and Beacham (1999)
Ssa289	McConnell et al. (1995)
Ssa407	Cairney et al. (2000)
Ssa408	Cairney et al. (2000)

In each year, we assumed that the number of fish captured in the creel that had been produced with angler-caught broodstock was a hypergeometrically distributed variable, parameterized by the total number of smolts released and total number of fish sampled in the creel, following:

X~Hypergeometric(N,K,n), where

N = total number of smolts released

K = total number of smolts released from angler-caught brood

n = total number of fish sampled in creel

We selected the hypergeometric distribution in place of a binomial distribution because the former method (unlike the latter) accounts for sampling without replacement, as was the case for our study, during which fish were removed from the population after sampling. Furthermore, by defining the distribution through the total number of smolts released we increased our statistical power relative to alternative distributions, such as the chi square distribution, in which all proportions would be considered sub-samples from a larger population. The likelihood of the observed number of fish sampled in the creel from angler-caught brood was then calculated using the following probability density function:

$$L(k) = \frac{\binom{K}{k}\binom{N-K}{n-k}}{\binom{N}{n}}, \text{ where}$$

k is the observed number of fish from angler-caught broodstock in the creel (i.e., successes).

We evaluated the observed number of steelhead produced with angler-caught broodstock in the creel against the cumulative density function, using a critical value of $\alpha = 0.05$. We also compared the proportion of adult steelhead produced with angler-caught broodstock that were collected with traps against the proportion observed in the creel, using a chi square test with Yate's correction for continuity. Only data for steelhead confidently assigned to both parents were considered in statistical analyses, performed in R (R Core Team 2020).

We assumed equal fecundity for broodstock from different sources (i.e. collection methods), as well as equal egg-to-adult survivorship of their offspring. Should either or both of these assumptions be false, adult steelhead produced from one broodstock source could outnumber the other in collections, simply due to greater relative abundance among adult returns. In the case of samples collected through creel surveys, differential abundance could result in greater availability to anglers for one group or the other and, left unchecked, could be misinterpreted as differential vulnerability to angling.

To address this potential issue, we tested for difference in the number of adult offspring produced by trap- *v*. angler-caught broodstock. This analysis included samples of adult offspring collected through both creel surveys and the Alsea Hatchery trap, to determine if one broodstock collection method produced more adult steelhead per spawner than the other. Analysis of samples from both the trap and creel aimed to reduce possible effects from sampling bias that might occur if one group or the other was more vulnerability to angling or trap collection. Here we used Mann-Whitney U tests to compare the median number of adult steelhead that trap- and angler-caught broodstock produced, and conducted tests for each cohort separately, again using a critical value of $\alpha = 0.05$ to assess significance of results. Rejection of the null hypothesis would here suggest that either fecundity or offspring egg-to-adult survivorship differed between broodstock collected by anglers and traps.

Results

Sampling, genotyping and parentage assignments

During the winter of 2018, a total 536 ADRM-marked steelhead were sampled from the Alsea River. Of these, 369 were collected at the Alsea Hatchery fish trap and 167 were collected through creel surveys. In 2019, a total 776 ADRM-marked steelhead were sampled; 474 from the hatchery trap and 302 from anglers. These samples, along with those from putative parents (broodstock) were processed at the SFGL for genetic analyses. Genotyping success was generally high, with 93% of individuals characterized at all 15 loci, and all but one sample genotyped at >10 loci. Of the 1,311 samples genotyped at >10 loci, 87% (n = 1,142) assigned to both maternal and paternal parents with >95% confidence (Table 3). The great majority of steelhead produced in 2015 returned as adults in 2018, but an estimated 4.6% (21 of 459) returned as "three-salt" steelhead in 2019.

Table 3. The number of ADRM-marked adult steelhead sampled from the Alsea River through creel surveys and trap collections conducted during the winters of 2018 and 2019. Also presented are the number of these individuals successfully genotyped at >10 microsatellite loci and assigned to both parents.

	Traps 2018	Creel 2018	Traps 2019	Creel 2019
Sampled	369	167	474	302
Genotyped at >10 loci	369	167	473	302
Assigned to both parents	300	137	442	263

Effects from broodstock collection methods

Our research was designed to test whether hatchery steelhead produced with angler-caught broodstock would be more likely to be caught by anglers than expected. We found that for the 2015 cohort, 31% (46 of 148) of samples collected through creel surveys had been produced with angler-caught broodstock. Given that 43.6% of the 37,655 smolts in this cohort had been produced with angler-caught broodstock (Figure 3), the contribution to the fishery from steelhead produced with angler-caught broodstock was significantly less than expected (P = 0.001), such that our findings offered no support for the hypothesis that steelhead produced with angler-caught broodstock would be more likely to be caught by anglers. In 2016, the experimental cohort of 82,595 smolts was produced with 46% angler-caught broodstock. Yet offspring of angler-caught broodstock represented only 37.7% (95 of 252) of samples collected through creel surveys (Figure 3). Again, offspring of angler-caught broodstock were significantly under-represented in creel surveys (P = 0.005), offering no support for greater vulnerability to angling. Figure 4 presents the observed catch of steelhead produced with angler-caught broodstock against the distribution of catch likelihoods estimated from the size and composition of each cohort, as well as sampling effort.

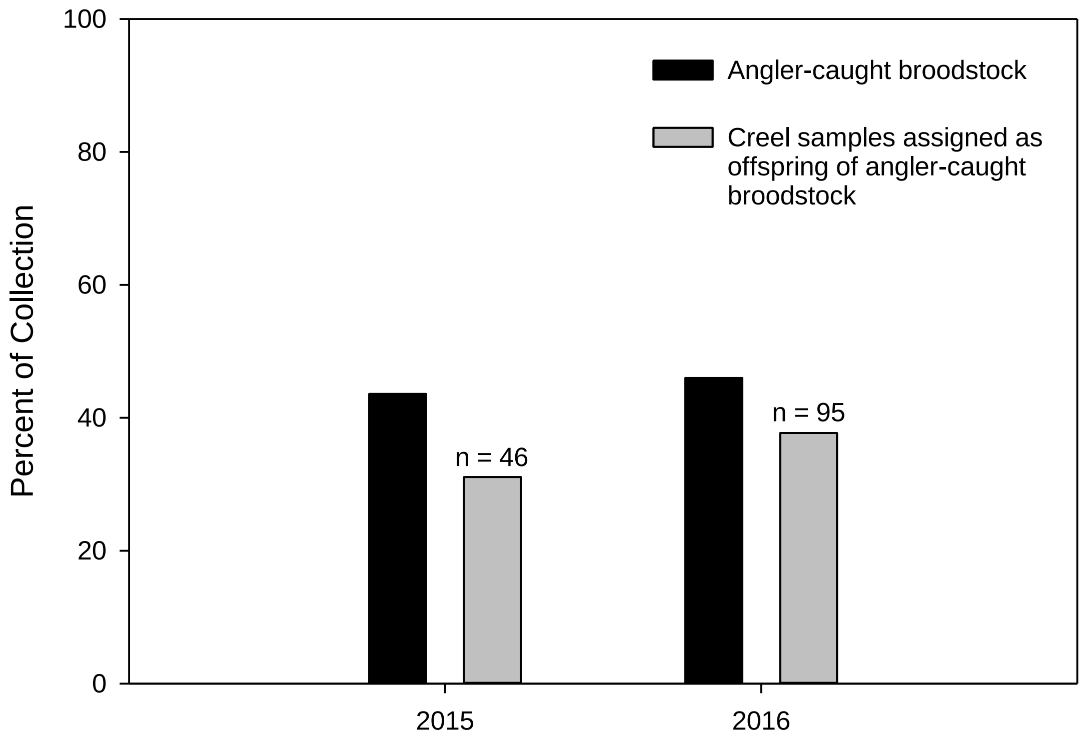


Figure 3. For the 2015 and 2016 experimental cohorts, the percent of broodstock collected by anglers, the percent of all creel samples assigned as offspring of these angler-caught broodstock.

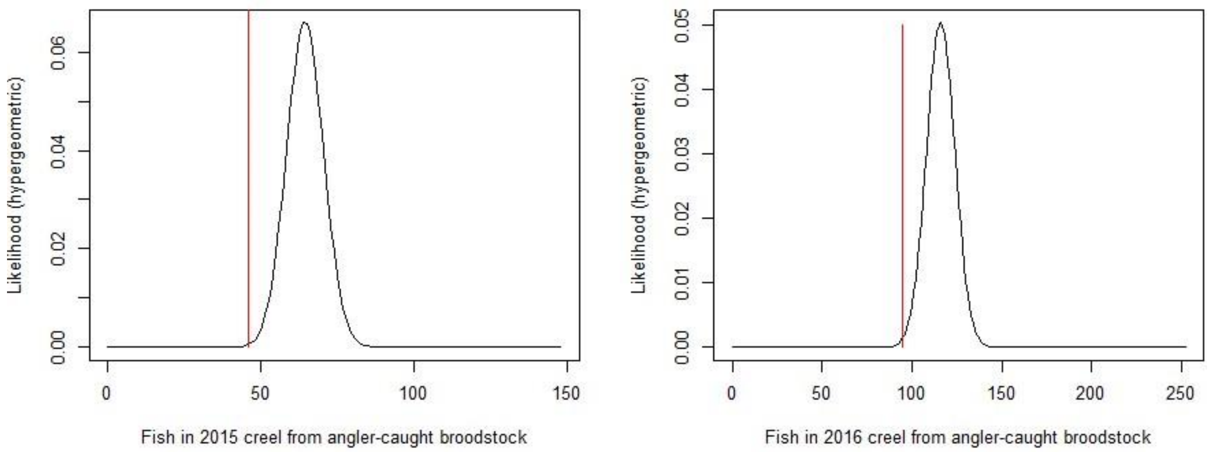


Figure 4. The likelihood (*y*-axis) that *x* number of steelhead produced with angler-caught broodstock would be observed among creel samples, given cohort size, composition and sampling effort. Actual observed numbers for each cohort are indicated by red lines.

It might be expected that the under-representation of steelhead produced with angler-caught parents in creel collections would be compensated by over-representation among samples from hatchery traps. However, this was not the case. Instead, samples collected through both creel surveys and the Alsea Hatchery trap revealed that the number of adult steelhead produced by trap-caught parents was significantly greater than the number of adult steelhead produced by angler-caught parents. Moreover, we observed this pattern in both cohorts (Figure 5). Specifically, the median number of adult steelhead that assigned to broodstock collected with traps in 2015 (12 adult offspring/pair) and 2016 (15 adult offspring/pair) was significantly greater than the number of offspring assigned to broodstock pairs collected by anglers in 2015 (4 adult offspring/pair, U = 99.5, df = 1, $P = 0.014$) and 2016 (8 adult offspring/pair, U = 167.0; df = 1; $P = 0.005$).

We did find that among all experimental fish that returned as adults, those that were produced with angler-caught broodstock spawned in 2016 comprised a greater proportion of the creel collection than of the trap collection ($\chi^2 = 17.56$; $P < 0.001$; df = 1). However, we did not see this difference in collections from the first cohort ($\chi^2 = 1.27$; $P = 0.26$; df = 1).

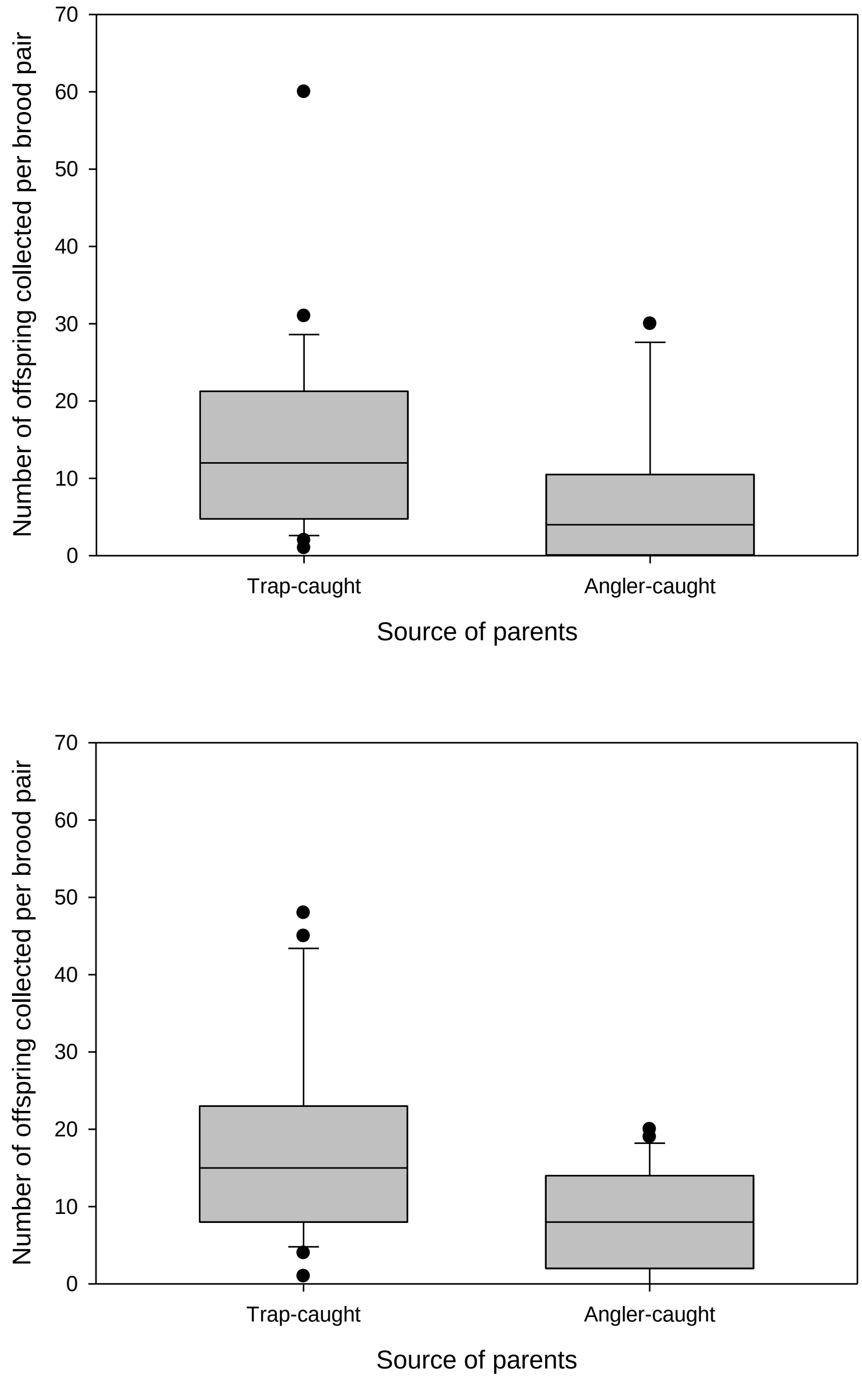


Figure 5. The number of adult hatchery steelhead that assigned as offspring of trap-caught and angler-caught broodstock. Data are for cohorts produced at the Alsea Hatchery in 2015 (top) and 2016 (bottom). Boxes contain 25-75% quantiles of the data and central lines indicate median values.

Discussion

Our findings suggest that hatchery steelhead produced with angler-caught broodstock were not consistently more vulnerable to anglers than steelhead produced with trap-caught broodstock. A variety of factors could serve to explain this result. First, angler vulnerability may represent a "state", influenced by a suite of behavioral traits, such as boldness, diel activity patterns, etc., each of which may be variably heritable and subject to contextual expression. As such, different combinations of underlying heritable traits might be expected to occur in offspring, predisposing even siblings to different fates (i.e. caught by anglers or not). Moreover, such genetically influenced fates might also be affected by temporally variable environmental conditions, further weakening potential relationships between the vulnerability to angling of parents and their offspring. Finally, we do not expect that all steelhead that do or would bite a hook are caught. Once hooked, steelhead notoriously break fishing lines or otherwise free themselves to escape anglers. Moreover, at least some steelhead that might be predisposed to bite a hook could migrate when fishing pressure is low, only to then be collected by fish traps. Accordingly, collection by fish traps may serve as a poor gauge of the natural propensity of fish to strike a lure, and many offspring of trap-caught broodstock may indeed inherit traits that ultimately render them vulnerable to angling.

Given these caveats, it is perhaps unsurprising that the offspring of angler-caught broodstock were not more likely to be caught by anglers than offspring of trap-caught broodstock. Our findings do not, however, preclude other mechanisms of selection by hatcheries that could negatively affect steelhead harvest rates. Timing and duration of broodstock collection, for example, could shift and constrain the timing of the fishery to an earlier, shorter period, with relatively limited angler opportunity. Such an effect might be particularly noticeable if it were carried out repeatedly, over multiple generations, in a closed population. Under this scenario, it is quite possible that over the course of 40 years, without integration with wild stock, weak but consistent selection for earlier-returning steelhead might have affected the Alsea Hatchery's traditional stock of winter steelhead, which Wilson et al. (2018) found to have significantly lower catch rates than steelhead produced through the recently established wild broodstock program. Fortunately, continued integration of wild fish into the new broodstock should serve to mitigate potential selection with immigration, so as to preserve the naturally protracted return timing of Alsea River steelhead, and offer greater angler opportunity.

Although we found little evidence for heritable vulnerability to angling in steelhead, our study generated a remarkable result with clear relevance to hatchery production of this species. As measured through our genetic parentage assignments, broodstock collected with traps produced more than twice as many adult returns as angler-caught broodstock (333:126 and 490:193 for the 2015 and 2016 cohorts, respectively), even though the number of pairs spawned from the two broodstock sources were far less disparate (Table 1). The greater spawner-to-adult productivity of trap-caught broodstock consistently provided more fish to both the hatchery trap *and* to anglers than provided by angler-caught broodstock. Accordingly, in terms of angler success, the strong positive effect of trap-based broodstock collection on spawner-to-adult production overwhelmed the relatively weak and inconsistent signal of greater vulnerability to angling.

This result was unexpected, and our data cannot conclusively explain why angler-caught broodstock consistently produced fewer adult returns than trap-caught broodstock. However, we hypothesize that stress associated with collection by anglers and transport could impact the survivorship of offspring through epigenetic mechanisms. Moreover, greater holding time of angler-caught broodstock at the Alsea Hatchery, relative to trap-caught broodstock (Figure 6), might have caused additional stress to broodstock that further impacted the health and survivorship of their offspring. Although we did not measure fecundity of broodstock, we find it unlikely that presumably small differences between the mean fecundities of broodstock from different sources could explain the large and consistent disparities we observed between their spawner-to-adult production.

Together, our results support the use of traps over angler-assisted broodstock collection programs to maximize production of adult hatchery steelhead and associated harvest. This recommendation may be especially pertinent wherever wild steelhead are collected and used as broodstock, such as in the Alsea River, to maximize fishery benefits with minimal impacts to wild populations.

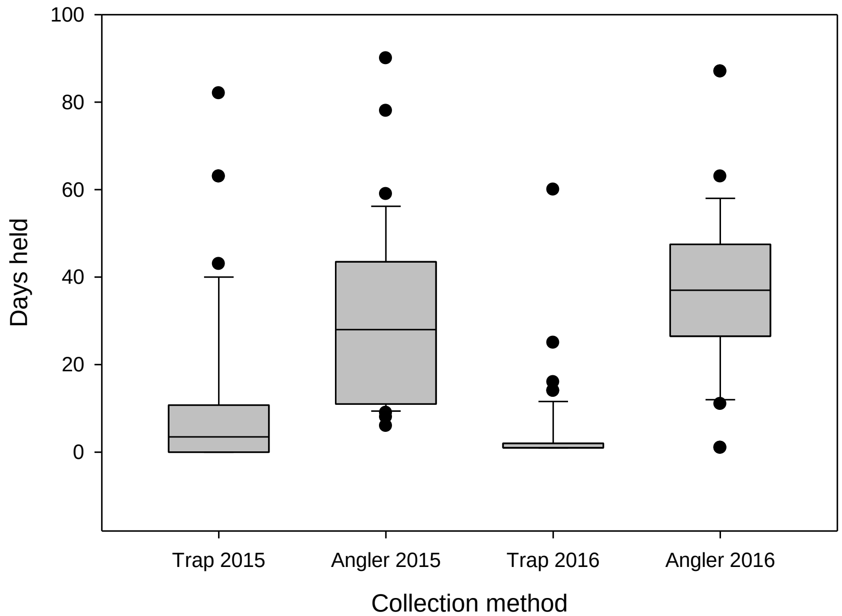


Figure 6. Box and whisker plot depicting the number of days that trap- and angler-caught broodstock were held at the Alsea Hatchery prior to spawning in 2015 and 2016. Boxes contain 25-75% quantiles and central lines indicate median values.

ALSEA RIVER CREEL SURVEYS

Overview

The primary purpose of the 2018 and 2019 Alsea River winter steelhead creel surveys was to collect genetic samples to compare adult return rates and fate of steelhead produced from trap- and angler-caught broodstock. Secondary to collecting genetic samples, the creel was used to estimate angler catch rates and total recreational harvest, which is the focus of this section of the information series report.

The Alsea winter steelhead fishery involves a mix of boat and bank angling that occurs between November and April. Anglers fish from the head of the tide to the deadline at Alsea Hatchery. A combination of boat and bank angling occurs from the head of tide to Mill Cr. near the town of Alsea. Upstream of Mill Creek to the deadline at Alsea Hatchery, angling is from the bank only. Angler access is achieved through numerous bank access locations and multiple improved and unimproved boat launches. The distribution of angling effort changes among these locations dependent on river conditions, covering approximately 45 miles of the Alsea and North Fork Alsea Rivers. To ensure that sufficient genetic samples would be collected, the creel did not cover the entire return of traditional and wild broodstock winter steelhead returning to the Alsea basin, instead focusing on the fishery through the period of the wild broodstock returns, from January through April.

Methods

Field Interview Methods

Roving-roving creel surveys were conducted on the upper (Missouri Bend Boat Ramp to Alsea Hatchery) and lower (Missouri Bend to Boundary Bridge) Alsea over 15 weeks in 2018 (January 9 - April 21) and 16 weeks in 2019 (January 11 - April 28). A roving-roving design was chosen over a roving-access design because it would be infeasible to contact enough anglers to collect the required number of genetic samples with an access-based design. Moreover, attempting to sample single access sites proportional to their anticipated fishing effort, such as by assigning unequal site selection probabilities, would be challenging because the distribution of effort changes with flow rates that are unpredictable pre-season (i.e., undefined sampling frame).

Within each week, sampling days were stratified by weekends and weekdays. All federally observed holidays were classified as weekends (e.g., President's Day and Martin Luther King Jr.'s Day). All weekend days were sampled. In the first year, three weekdays were selected by placing a consecutive two-day off period randomly within the strata. Using a two-day off period led to a slightly higher sampling probability for selecting Mondays and Fridays within the weekday strata (0.75 versus 0.25). While we acknowledge differences in Monday and Friday selection probabilities could introduce bias if the catch rates on Mondays and Fridays differ from other weekdays, we see no reason why this would be the case and believe any bias introduced would be negligible for anglers fishing the Alsea. In the second year, the three weekdays were selected at random and similar within-week patterns of fishing were observed.

On each sampling day, creelers conducted interviews over an 8-hour shift with a randomly selected start time. In the first year, separate creelers were assigned to the upper and lower river sections where they remained the entire season, providing consistency in both data sets. During the second year, a staff change occurred to both river sections mid-season. Interviews were conducted throughout the duration of each shift by driving into each access site and walking the river bank. Two pressure counts were conducted simultaneously along the upper and lower river during each shift at the same randomly selected start times. Low staffing prevented surveys from being conducted on the lower river March 16-31, 2019, and April 17 -April 21, 2019.

Potential sampling bias

There are several well documented pathways that can bias interview and pressure count data obtained in roving-roving creel surveys (e.g., Pollock et al 1994). For interview data, bias can be introduced through two main sources. First, anglers that remain fishing for longer periods are more likely to be interviewed, thus the probability of being sampled is proportional to trip-length. Secondly, because anglers are contacted while in the process of fishing many interviews represent incomplete trip information. Therefore, it is implicitly assumed that catch rates are stationary. If catch rates improve with time, such as what may occur through trial-and-error (e.g., switching lures), then estimated catch rates from roving-roving surveys from incomplete information will be biased low, differing from access-point surveys in which the final catch rate is observed (Pollock et al. 1994). To mitigate these potential sources of bias, only bank anglers that fished at least 30 minutes prior to the interview were included in the data used to generate estimates (Hoenig et al. 1997). For private boat anglers, only fully completed interviews were used to estimate catch rates.

Pressure count data is also susceptible to potential bias and uncertainty. Pressure counts provide an instantaneous snapshot of effort, relying on the assumption that the fishery is stationary during the count. As count times increase, anglers may enter or leave the fishery, breaking this assumption. Our count times were well below an hour in most cases (Figure 7). Moreover, the average fishing time for completed bank angling trips on the Alsea was over 5 times the length of pressure counts (5 hours and 9 minutes in 2018, 5 hours and 27 minutes in 2019). We believe it is unlikely anglers would switch among access points without being noticed during the count.

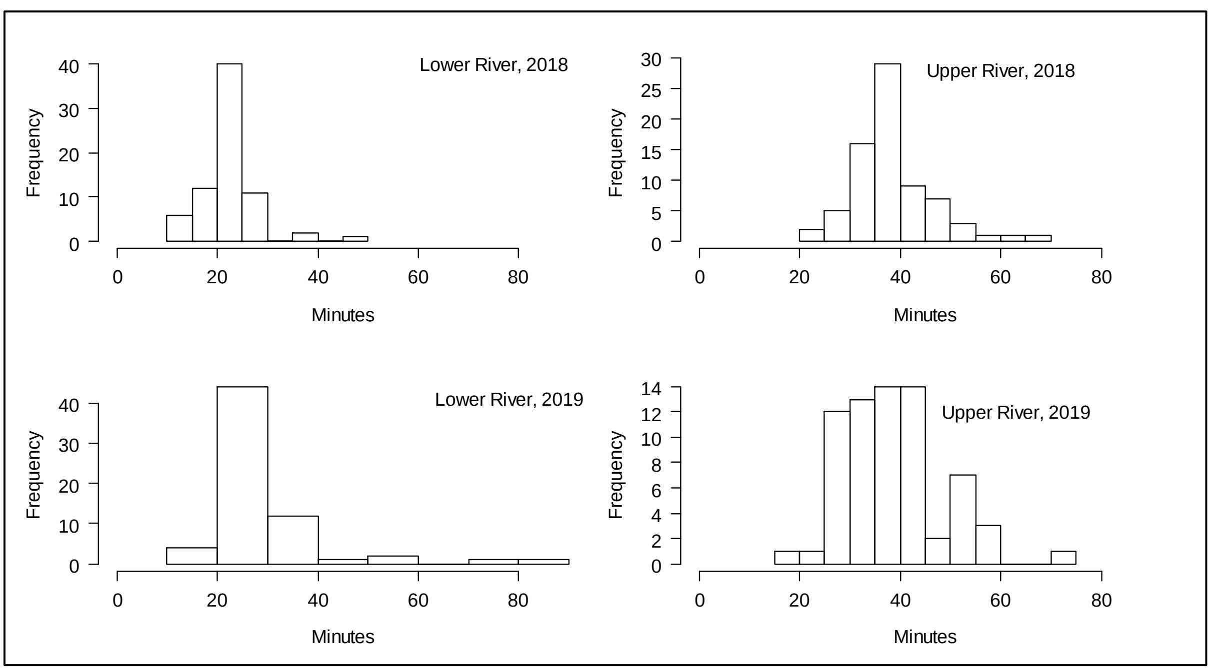


Figure 7. Average time required to complete pressure counts each day across all sampling days in each creel year. Sampling year and locations are as labeled.

Estimation procedures

Daily and multi-day estimators are the two primary methods used to analyze creel data (Lockwood et al. 1999; Su and Clapp 2013; McCormick and Meyer 2017). Daily estimators sum the product of daily effort and daily catch rate estimates to approximate a stratum total, while the multi-day estimators pool all interviews within a stratum to create a single estimate (i.e., ignore days as the primary sampling unit). In our analysis we decided to use daily estimators to be consistent with our sampling design. Moreover, steelhead are a migratory species, indicating that day effects across the run could be important as fish move through the area. Daily estimators account for these small day effects that can be lost by the averaging used in the multi-day estimators. Our methods follow the same general approach as proposed by Su & Clapp (2013) for Great Lakes fisheries. Throughout this section we will be using the notation provided in Table 5.

Stratum catch rates were calculated using a weighted mean of daily estimates. Although some research indicates the mean-of-ratios produces a less biased estimate of catch rates when data is collected with roving-roving creel designs (e.g., Pollock et al. 1994), recent work has indicated this may not be the case in short-duration fisheries, such as salmonids (McCormick et al. 2012). Winter run steelhead are a short-duration fishery, therefore we used the ratio of means in all cases. Catch rates were calculated for all fish, as well as by each type of fin clip. Catch rates include the combined total of harvested and released fish (a more accurate representation for full vulnerability to hooking in cases with limited harvest). Catch rates were calculated for each day and combined to provide a seasonal average following the procedures in Equations 1-9.

The mean daily catch rate ($\hat{R}_d$) was calculated directly from observed interview data for each sampling day on the upper and lower river (Equation 1).

$$\hat{R}_d = \frac{\sum_{p=1}^{P_d} c_{d,p}}{\sum_{p=1}^{P_d} a_{d,p} e_{d,p}} \text{, where} \quad (1)$$

$C_{d,p}$ is the total number of steelhead landed on day *d* by party *p*,
P_d is the total number of parties surveyed on day *d*,
$A_{d,p}$ is the total number of anglers on day *d* in fishing party *p*, &

$e_{d,p}$ is the product of the total number of hours on day *d* that party *p* was fishing prior to the interview and the total number of anglers in the party.

The daily variance for the catch rate ($Var(\hat{R}_d)$) was approximated by:

$$Var(\hat{R}_d) = \frac{1}{(\bar{e}_d)^2 P_d} \frac{\sum_{p=1}^{P_d}(c_{d,p} - \hat{R}_d e_{d,p})^2}{P_d - 1}\text{, where} \quad (2)$$

$c_{d,p}$ is the observed catch on day *d* of the p^{th} angling party,
$\bar{e}_{d,p}$ is the average total hours fished per party observed in interview data, &
$\hat{R}_d$ is the mean daily catch rate on day *d* calculated in equation 1.

(see Jones et al. 1995; Su and Clapp 2013)

Daily effort ($\bar{\hat{E}}_d$) was estimated from pressure count data. First, for each count an estimate of the daily effort was calculated ($\hat{E}_{d,n}$ - Equation 3), after which all estimates of daily effort were averaged (Equation 4).

$$\hat{E}_{d,n} = F_d A_{d,n}\text{, where} \quad (3)$$

F_d is the total number of fishable hours on day d[1], &
$A_{d,n}$ is the total number of anglers on day *d* for count *n*.

$$\bar{\hat{E}}_d = \frac{\sum_{n=1}^{N_d} \hat{E}_{d,n}}{N_d}\text{, where} \quad (4)$$

N_d is the total number of counts conducted on day *d*, &
$\hat{E}_{d,n}$ is the daily effort estimate for count *n* (Equation 3).

Variance for the daily estimates were approximated using Equation 5.

[1] Daylight hours used to estimate effort within the catch-rate calculations were obtained from Navy records available at: http://aa.usno.navy.mil/data/docs/Dur_OneYear.php. Fishable hours were assumed to start 30 minutes before sunrise and end 30 minutes after sunset.

$$Var(\bar{\bar{E}}_d) = F_d \frac{\sum_{n=1}^{N_d} A_{d,n}^2 - \frac{\left(\sum_{n=1}^{N_d} A_{d,n}\right)^2}{n_d}}{N_d(N_d-1)} \quad (5)$$

Using the results from Equations 1 and 4, the overall catch rate for each stratum was calculated as a weighted average of the daily estimates, where the weights were defined by the total angling effort sampled (Equation 6).

$$\hat{R}_s = \frac{\hat{C}}{\hat{E}} = \sum_{d=1}^{d_s}\left(\bar{\bar{E}}_{s,d} / \sum_{d=1}^{d_s} \bar{\bar{E}}_{s,d}\right) \hat{R}_{s,d}, \text{ where} \quad (6)$$

d_s is the total number of days surveyed in strata *s*,
$\bar{\bar{E}}_{s,d}$ is the mean estimated effort in strata *s* for day *d* (Equation 4), &
$\hat{R}_{s,d}$ is the estimated catch rate in strata *s* on day *d* (Equation 1).

(See Su & Clapp 2013, McCormick & Meyer 2017).

Strata estimates for the total effort in each river section by day type were calculated as the product of the average daily effort estimate multiplied by the total number of days in each strata, D_s (Equation 7), which has variance as expressed in Equation 8.

$$\hat{E}_s = D_s \frac{\sum_1^{d_s} \bar{\bar{E}}_{s,d}}{d_s}, \quad (7)$$

$$\widehat{Var}(\hat{E}_s) = D_s^2 \frac{\sum_1^{d_s}\left(\bar{\bar{E}}_{d,s} - \frac{\hat{E}_s}{D_s}\right)^2}{d_s(d_s-1)}. \quad (8)$$

(See Su & Clapp 2013, McCormick & Meyer 2017).

Daily catch was estimated as the product of the estimated daily catch rate (Equation 1) and estimated daily effort (Equation 4) for each day in each stratum. Daily catch estimates were averaged and multiplied by the total days in the strata to estimate the total catch (Equation 9). Variance of the total catch is approximated by Equation 10.

$$\widehat{C_s} = D_s \frac{\sum_{d=1}^{d_s} \bar{\bar{E}}_{s,d} \hat{R}_{s,d}}{d_s}, \quad (9)$$

$$\widehat{Var}(\hat{C}_s) = D_s^2 \frac{\sum_1^{d_s}\left(\hat{R}_{s,d}\bar{\bar{E}}_{d,s} - \frac{\widehat{C_s}}{D_s}\right)^2}{d_s(d_s-1)}. \quad (10)$$

Results

During the 2018 steelhead run 2,109 interviews were collected from anglers, which included 1,423 unique angling parties (Table 5). Fewer interviews were collected in 2019 (1,112 unique angling parties), which can be attributed to no surveys being conducted on the lower river across two sampling weeks. Average party size for bank anglers was similar between years with 1.45 people/party in 2018 (SD=0.78) and 1.42 people/party in 2019 (SD=0.66). The average number of anglers in boating parties was 2.3 anglers in both years (SD_{2018}=0.8, SD_{2019}= 0.7). Removing incomplete and repeated interviews in which anglers fished less than 30 minutes reduced the total number of interviews collected from bank anglers in each year significantly (Table 5) [2].

Our results indicate that overall fishing dynamics were remarkably similar between both years, especially on the upper river. Bank angling in both years comprised a larger component of the total recreational winter steelhead fishery than boat angling. In 2018, the total estimated effort for bank anglers was 18,180 angler-hours, versus 3,409 angler-hours for boat anglers (Table 6). In 2019 total effort estimate for bank anglers was 17,100 angler-hours, which is a minimal 13% decrease (Tables 7 & 8). Boat angling effort on the upper river increased by 19% in 2019, although even with this increase remained a smaller component of the fishery (Table 7 & 8). Boat angling on the lower river also increased in 2019 by a much larger margin (>100%, Table 8), although remained a smaller component of the overall fishery than bank angling (Table 7).

Comparing catch rates, there were no statistically significant differences among angler types in 2018, although the estimated catch rate for anglers on the lower river during weekdays was slightly lower than anglers in all other strata (0.011 fish/angler-hour bank anglers, 0.014 fish/angler-hour boat anglers; Table 6). In 2019, bank angler catch rates on the lower river during weekdays (0.40 fish/angler-hour bank anglers, 0.035 fish/angler-hours boat anglers; Table 6) were comparable to the other groups (Table 6). Across years, the catch rates were similar, ranging between 0.01 and 0.07 fish/angler-hour. Catch rate estimates for the lower

---

[2] The genetic data presented in the first chapter does include fish that were collected on repeat interviews that were excluded from the creel analysis.

river fishery were less precise than upper river catch rate estimates in both years due to fewer numbers of interviews (larger CV; Tables 6 & 7).

Catch rates among bank anglers were also relatively similar between weekends and weekdays, with no consistent pattern to corroborate whether weekday or weekend anglers are more successful (Table 4). For example, in 2018 on the upper river bank angler catch rates were higher on weekdays as opposed to weekends (0.063 fish/angler-hour versus 0.044 fish/ angler-hour), while the opposite was true on the lower river (0.011 fish/ angler-hour weekends versus 0.024 fish/angler-hour weekdays). In 2019 the similarity between weekend and weekday anglers was also observed. Bank anglers on the upper river had a slightly higher catch rate on weekdays (0.075 fish/ angler-hour versus 0.05 fish/ angler-hour), while bank anglers on the lower river had a higher catch rate on weekends (0.048 fish/ angler-hour versus 0.40 fish/ angler-hour). Angler catch rates among strata for boat anglers on the lower river were essentially the same within (but not across) both years (0.67 fish/angler-hour weekdays and 0.67 fish/angler-hour weekdays in 2018; 0.35 fish/angler-hour weekdays vs 0.39 fish/angler-hour weekends in 2019).

Examining temporal trends in the fishery, a decline in fishing effort was seen across both the lower and upper rivers between January and April (Figure 8 & 9). Catch rates displayed in Figures 8 & 9 include released fish to reflect the true hooking vulnerability of steelhead to anglers on each river section. The daily catch rates input to estimate seasonal harvest excluded these released fish (i.e., harvest-rate versus hooking-rate) (Appendix A). Not surprisingly, increased effort coupled with similar catch rates across angler types equated to bank anglers landing a much higher proportion of the estimated total catch than boat anglers (79% in 2018, 74% in 2019).

In general, dividing the catch by fin clip type wasn't particularly informative for making comparisons across years because the data became too sparse to provide meaningful results. For example, the total harvest of AD fish by boats in 2019 in the upper river is higher than expected (64). A single interview informed the daily estimate on January 26, causing the catch rate to be anomalously high, 0.15 fish/hr, which in turn caused the estimate of landings to be inflated. For comparison, the second highest catch rate for AD fish by boat anglers on weekends in the upper river was 0.0096 fish/angler-hour, which was also the only other day any AD fish were captured. Most of the fin-clipped estimate have little evidence of support, as demonstrated by large coefficients of variation (e.g., the CV for our AD fish on the upper river is 0.95). However, it is worth noting that ADRM fish were captured in the highest numbers across all strata in all years and were estimated with much greater confidence (561 ADRM in 2018; 803 ADRM in 2019; Tables 6 and 7).

In both years there are some other apparent discrepancies in our reported results due to limited information in the data. On several days in both 2018 and 2019 no anglers were encountered for interviews because the river was blown out, making it impossible to estimate catch rates or daily harvest, despite some cases where effort estimates were still possible from pressure counts.

Discussion

Our creel survey data suggest that the Alsea winter steelhead fishery was quite similar between 2018 and 2019. Although the majority of fishing occurred on the upper river, catch rates across the entire system were similar. The fishery itself appears to taper off in mid-February, which is likely driven by a peak in early season interest that dissipates through time. With fewer anglers fishing toward the end of the season, catch rates can remain stable despite fewer fish in the system (hyper-stability). The timing of fishing pressure may still be aligned with run-timing of ADLM-marked steelhead, the traditional Alsea stock that returns from November through January. Wild fish that contribute to the new broodstock tend to return from January through April, and now support a more protracted winter steelhead fishery on the Alsea River.

We also detected few AD-marked steelhead, which could represent mis-marked fish or strays from the Siuslaw and other rivers. This finding underscores the effectiveness of Alsea marking programs and smolt acclimation practices that favor imprinting and reduce straying by hatchery steelhead from other basins.

Table 4. Notation used throughout this chapter.

Symbol	Definition
$a_{d,p}$	Number of anglers on day *d* in the p^{th} angling party.
$A_{d,n}$	Total anglers on day *d* for count *n*.
$c_{d,p}$	Catch on day *d* for the p^{th} party.
C	Catch, or total number of steelhead harvested.
D	Total number of days in sampling frame.
D_s	Total number of days in strata *s*.
d_s	Total number of days in strata *s* surveyed.
d	General index for a specific day.
$e_{d,p}$	Observed effort, or total number of angler hours, on day *d* for the p^{th} party.
$\bar{e}_d$	Observed average effort per angling party on day *d* from interview data.
$\hat{E}_{d,n}$	Estimated total effort on day *d* based on count *n*.
$\bar{\hat{E}}_d$	Mean estimated total effort on day *d* from pressure count data.
F_d	Total number of fishable hours on day *d*.
N_d	Total number of pressure counts conducted on day *d*.
n_d	Index for pressure count number on day *d*.
p	Index for specific angling party interviewed.
P	Total number of angling parties interviewed.
$\hat{R}_d$	Estimated mean catch rate for day *d*.
$\hat{R}_s$	Estimated catch rate in strata *s*.
s	Index for specific strata.
S	Total number of strata in each week.
w	Index for creel week (runs between Monday and Sunday).

Table 5. Complete interview set for creel surveys conducted on the upper and lower Alsea January through April 2018 and 2019. Numbers in bold represent the interviews used for estimates. Guided trips were not included in the analysis because of minimal sample sizes. Unique angler columns represent non-repeat interviews. Fishing>30 min includes all interviews where the angler reported fishing at least 30 minutes prior to the interview.

Fishery		2018			2019		
		All contacts	Unique anglers		All contacts	Unique anglers	
			Total	> 30 min		Total	> 30 min
Boat	All	83			142		
	Incomplete	7	4		11	11	8
	Complete	70	**69**	**69**	130	**129**	**59**
Guide	All	9			19		
	Incomplete	3	2		2	2	2
	Complete	7	6	6	17	17	6
Bank	All	2,017			1,018		
	Incomplete	1,793	1,263	**1,200**	944	895	**860**
	Complete	171	79	79	72	58	42

Table 6. Strata and total estimates of fishing pressure, catch rates, and total catch taken on the lower and upper Alsea River between January and April 2018. Catch is displayed as a total and by fin-clip type (AD=Adipose clipped fish, ADRM= Adipose and right maxillary clip, ADLM= Adipose and left maxillary clip). CV=coefficient of variation.

River Section	Angler Type	Management Parameter	Weekday Strata		Weekend Strata		Total	
			Estimate	CV	Estimates	CV	Estimates	CV
Upper River	Bank	Total Effort (hrs)	9,483	0.10	5,287	0.14	14,638	
		Catch rate (fish/hr)	0.063		0.044			
		Total Catch (fish)	567	0.15	170	0.20	737	0.11
		AD	0		4	0.19	4	0.19
		ADRM	280	0.19	97	0.21	377	0.15
		ADLM	180	0.25	68	0.39	240	0.21
	Boat	Total Effort (hrs)	1,811	0.12	786	0.31	2,597	
		Catch rate (fish/hr)	0.060		0.045			
		Total Catch (fish)	123	0.62	56	0.58	179	0.46
		AD	0		0		0	
		ADRM	110	0.69	24	0.87	134	0.68
		ADLM	12	1	31	0.62	43	1.14
Lower River	Bank	Total Effort (hrs)	2,184	0.12	1,358	0.17	3,542	
		Catch rate (fish/hr)	0.011		0.024			
		Total Catch (fish)	30	0.54	31	0.48	61	1.26
		AD	0		0		0	
		ADRM	8	0.73	24	0.50	32	0.42
		ADLM	22	1	6	0.67	28	0.52
	Boat	Total Effort	594	0.14	218	0.35	812	
		Catch rate (fish/hr)	0.014		0.042			
		Total Catch (fish)	14	0.67	12	0.66	26	0.49
		AD	0		0		0	
		ADRM	14	1	4	0.67	18	0.56
		ADLM	0	0	7	1	7	1

Table 7. Seasonal strata and total estimates of the total fishing pressure, catch rate, and total catch taken on the lower and upper Alsea river between January and April 2019. CV=coefficient of variation. Catch is displayed as both a combined total and by specific fin clips.

River Section	Angler Type	Management Parameter	Weekday Strata		Weekend Strata		Total	
			Estimate	CV	Estimates	CV	Estimates	CV
Upper River	Bank	Total Effort (hrs)	6,111	0.12	6,611	0.14	12,722	
		Catch rate (fish/hr)	0.075		0.050			
		Total Catch (fish)	395	0.18	314	0.21	709	0.12
		AD	16	0.76	5	1	21	0.62
		ADRM	277	0.22	246	0.21	523	0.15
		ADLM	102	0.34	54	0.41	156	0.27
	Boat	Total Effort (hrs)	1,529	0.14	1,568	0.22	3,097	
		Catch rate (fish/hr)	0.040		0.063			
		Total Catch (fish)	67	0.32	133	0.47	200	0.21
		AD	0		64	0.95	64	0.95
		ADRM	55	0.40	69	0.46	124	0.31
		ADLM	12	0.55	0		12	0.55
Lower River	Bank	Total Effort (hrs)	2,098	0.12	2,160	0.2	4,378	
		Catch rate (fish/hr)	0.40		0.48			
		Total Catch (fish)	79	0.41	79	0.26	158	0.22
		AD	11	1	7	0.51	18	0.48
		ADRM	54	0.33	57	0.46	111	0.31
		ADLM	8	0.69	10	0.48	18	0.97
	Boat	Total Effort	782	0.15	1,061	0.22	1,843	
		Catch rate (fish/hr)	0.35		0.39			
		Total Catch (fish)	44	0.48	54	0.39	98	0.19
		AD	7	0.60	17	0.77	24	1.61
		ADRM	19	0.46	26	0.57	45	0.54
		ADLM	4	1	20	.57	24	0.27

Table 8. Absolute (Δ) and relative percent change (%) in seasonal estimates of fishing pressure, catch rates, and landings taken on the lower and upper Alsea River between January and April 2019 relative to the same estimates in 2018. Sparse data exaggerates the percent change across many fin-clip specific estimates and should be interpreted with caution. CV=coefficient of variation.

River Section	Angler Type	Parameter	Weekday		Weekend		Total	
			Δ	%	Δ	%	Δ	%
Upper River	Bank	Total Effort (hrs)	-3,372	-36%	1,327	-25%	**1,916**	**-13%**
		Catch rate (fish/hr)	0.012	+19%	0.006	+15%		
		Total Catch (fish)	-172	+30%	144	+84%	**-28**	**-3%**
		AD	16	+1,600%	1	+25%	17	
		ADRM	-3	-1%	149	+154%	146	
		ADLM	78	-48%	-14	-21%	-84	
	Boat	Total Effort (hrs)	-282	-15%	782	+99%	**500**	**+19%**
		Catch rate (fish/hr)	0.02	-33%	.018	+40%		
		Total Catch (fish)	-146	-45%	77	138%	**115**	**+12%**
		AD	0	0	64	6400%	64	
		ADRM	-55	-50%	45	188%	-8	
		ADLM	0	0	-31	-3100%	-21	
Lower River	Bank	Total Effort (hrs)	-86	-3%	802	+99%	**836**	**+19%**
		Catch rate (fish/hr)	0.29	+300%	.024	+138%		
		Total Catch (fish)	49	+62%	48	+329%	**97**	**159%**
		AD	11	+1,100%	7	+6400%	18	
		ADRM	46	+82%	33	+188%	79	
		ADLM	14	-70%	4	-600%	10	
	Boat	Total Effort	1,504	+32%	843	+387%	**1031**	**123%**
		Catch rate (fish/hr)	0.026	+150%	-0.003	-7%		
		Total Catch (fish)	30	+214%	42	+350%	**72**	**276%**
		AD	7	+700%	17	+1700%	24	
		ADRM	5	+26%	-22	-550%	27	
		ADLM	4	+400%	13	+187%	17	

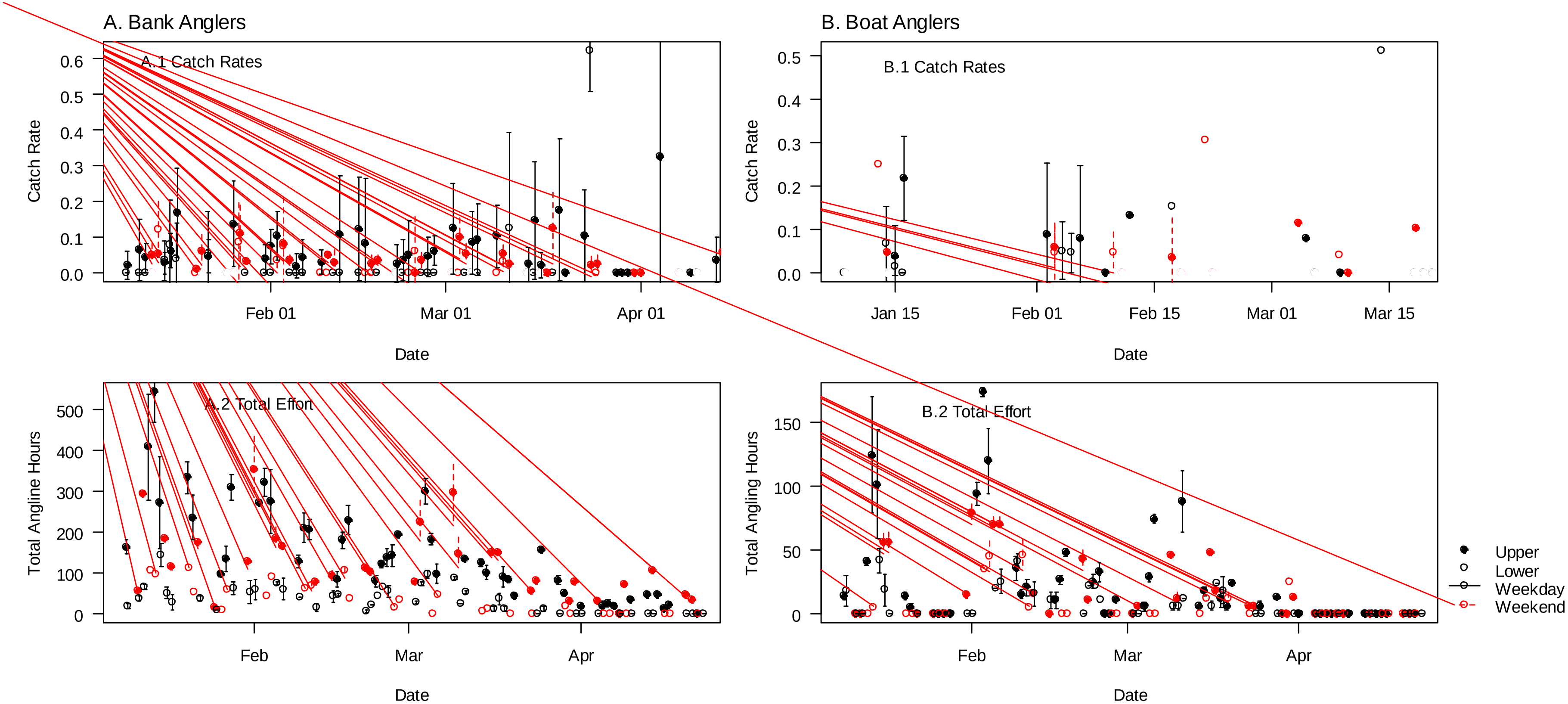


Figure 8. Daily estimated catch rates and total effort on the Alsea in 2018. Red points with dashed-line confidence intervals occurred on weekends. Black points with solid confidence intervals occurred on weekdays. Closed points are estimates on the upper river. Open points were estimates on the lower river. In some cases only a single angler was interviewed, so the variance could not be calculated for estimated catch rates. In other cases, no anglers were interviewed and catch rates could not be calculated. On a few days, only one pressure count was conducted so no variance could be calculated. Error bars extend +/- two standard deviations.

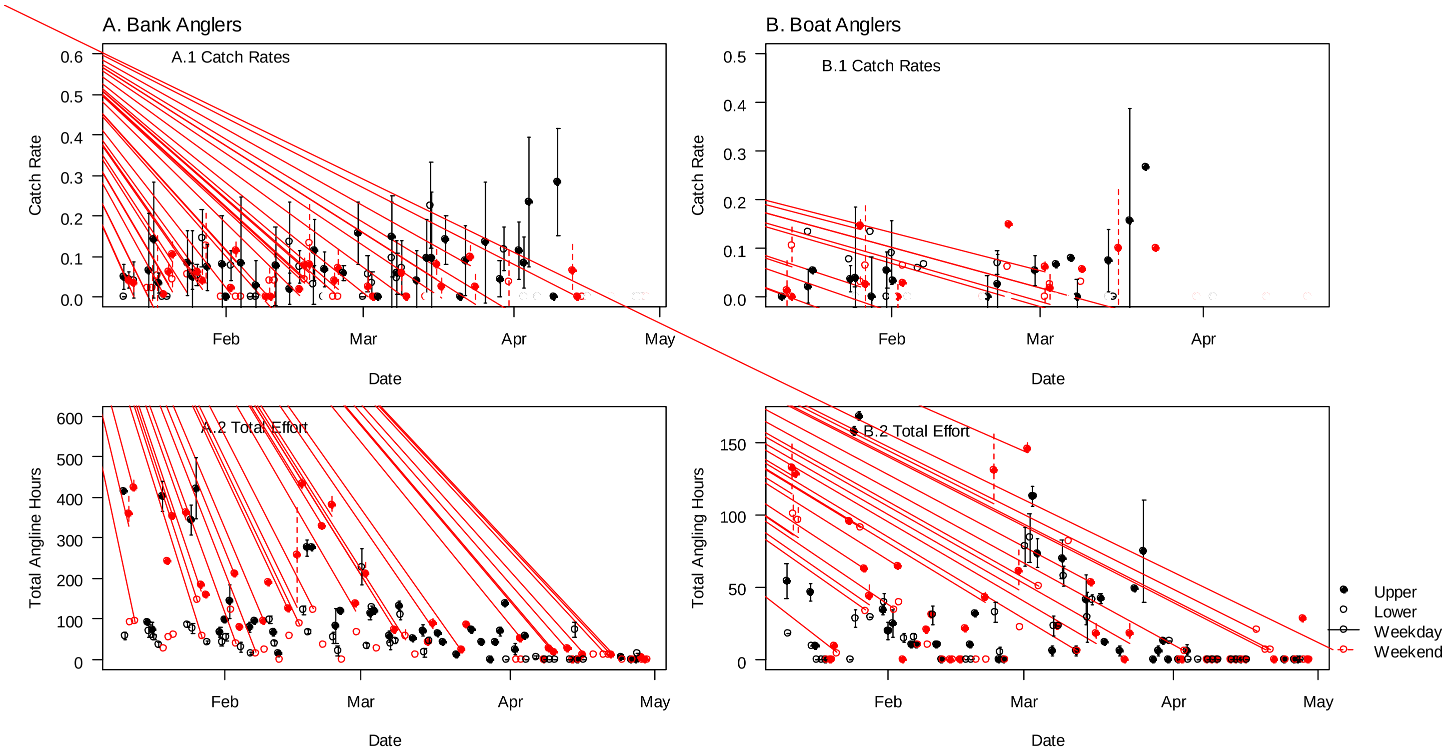


Figure 9. Daily estimated catch rates and total effort on the Alsea in 2019. Red points with dashed-line confidence intervals occurred on weekends. Black points with solid confidence intervals occurred on weekdays. Closed points are estimates on the upper river. Open points were estimates on the lower river. In some cases only a single angler was interviewed, so the variance could not be calculated for estimated catch rates. In other cases, no anglers were interviewed and catch rates could not be calculated. On a few days, only one pressure count was conducted so no variance could be calculated. Error bars extend +/- two standard deviations.

SUMMARY AND CONCLUSIONS

We found little support for the hypothesis that angler-caught broodstock produce offspring that are more vulnerable to angling than offspring of trap-caught broodstock. However, broodstock collection method does appear to have a strong effect over spawner-to-adult production of hatchery steelhead, whereby trap-caught broodstock produce significantly more adult returns than angler-caught broodstock. Therefore, collection of broodstock with traps is likely to provide more adult hatchery steelhead and greater angler opportunity than could be attained through angler-assisted broodstock collection programs.

ACKNOWLEDGMENTS

The authors thank the Alsea Sportsman's Association for the concept and support of this work. Matt Frank (ODFW) and the Alsea Hatchery staff provided invaluable help with the implementation of this study, including spawning, genetic sampling and data collection. Jitesh Pattni and Paul Olmsted (both ODFW) contributed to the design and oversight of creel surveys, which were conducted by Will Shoeneck and Bill Sigler (both ODFW). Figure 1 (Alsea map) was produced by Erin Gilbert (ODFW). Matt Falcy and Bernadette Graham-Hudson (both ODFW) reviewed an earlier draft of this report and offered advice that greatly improved analyses and presentation of our data. Kathleen O'Malley and Sandra Bohn (State Fisheries Genomics Lab, Oregon State University) collected and provided genotypic data for this work, which received financial support from the ODFW Restoration and Enhancement Program.

REFERENCES

Banks MA, Blouin MS, Baldwin BA, et al (1999) Isolation and inheritance of novel microsatellites in chinook salmon (Oncorhynchus tschawytscha). J Hered 90:281–288

Buchholz W, Miller SJ, Spearman WJ (1999) Summary of PCR primers for salmonid genetic studies. Fish Genetics Laboratory, US Fish and Wildlife Service

Cairney M, Taggart JB, Høyheim B (2000) Characterization of microsatellite and minisatellite loci in Atlantic salmon (Salmo salar L.) and cross-species amplification in other salmonids. Mol Ecol 9:2175–2178

Condrey MJ, Bentzen P (1998) Characterization of coastal cutthroat trout (Oncorhynchus clarki clarki) microsatellites and their conservation in other salmonids. Mol Ecol (United Kingdom)

Hoenig JM, Jones CM, Pollock KH, et al (1997) Calculation of catch rate and total catch in roving surveys of anglers. Biometrics 306–317

Ivanova N V, Dewaard JR, Hebert PDN (2006) An inexpensive, automation-friendly protocol for recovering high-quality DNA. Mol Ecol Resour 6:998–1002

Jones CM, Robson DS, Lakkis HD, Kressel J (1995) Properties of catch rates used in analysis of angler surveys. Trans Am Fish Soc 124:911–928

Kalinowski ST, Taper ML, Marshall TC (2007) Revising how the computer program CERVUS accommodates genotyping error increases success in paternity assignment. Mol Ecol 16:1099–1106

Lockwood RN, Benjamin DM, Bence JR (1999) Estimating angling effort and catch from Michigan roving and access site angler survey data. Michigan Department of Natural Resources, Fisheries Division Ann Arbor

McConnell S, Hamilton L, Morris D, et al (1995) Isolation of salmonid microsatellite loci and their application to the population genetics of Canadian east coast stocks of Atlantic salmon. Aquaculture 137:19–30 . doi: https://doi.org/10.1016/0044-8486(95)01111-0

McCormick JL, Meyer KA (2017) Sample Size Estimation for On-Site Creel Surveys. North Am J Fish Manag 37:970–980

McCormick JL, Quist MC, Schill DJ (2012) Effect of survey design and catch rate estimation on total catch estimates in Chinook Salmon fisheries. North Am J Fish Manag 32:1090–1101

Morris DB, Richard KR, Wright JM (1996) Microsatellites from rainbow trout (Oncorhynchus mykiss) and their use for genetic study of salmonids. Can J Fish Aquat Sci 53:120–126

Nelson RJ, Beacham TD (1999) Isolation and cross species amplification of microsatellite loci useful for study of Pacific salmon. Anim Genet 30:228–229

Olsen JB, Bentzen P, Seeb JE (1998) Characterization of seven microsatellite loci derived from pink salmon. Mol Ecol (United Kingdom)

Philipp DP, Cooke SJ, Claussen JE, et al (2009) Selection for vulnerability to angling in largemouth bass. Trans Am Fish Soc 138:189–199

R Core Team (2020) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/)

Scribner KT, Gust JR, Fields RL (1996) Isolation and characterization of novel salmon microsatellite loci: cross-species amplification and population genetic applications. Can J Fish Aquat Sci 53:833–841

Smith CT, Koop BF, Nelson RJ (1998) Isolation and characterization of coho salmon (Oncorhynchus kisutch) microsatellites and their use in other salmonids. Mol Ecol 7:1614–1616

Spies IB, Brasier DJ, O'Reilly PTL, et al (2005) Development and characterization of novel tetra-, tri-, and dinucleotide microsatellite markers in rainbow trout (Oncorhynchus mykiss). Mol Ecol Resour 5:278–281

Stephenson JJ, Campbell MR, Hess JE, et al (2009) A centralized model for creating shared, standardized, microsatellite data that simplifies inter-laboratory collaboration. Conserv Genet 10:1145–1149

Su Z, Clapp D (2013) Evaluation of sample design and estimation methods for Great Lakes angler surveys. Trans Am Fish Soc 142:234–246

Wilson DR, Martin E, McCormick JL (2018) Relative performance of Alsea Hatchery winter steelhead produced from traditional and wild broodstocks

APPENDIX A

Table A.1: Daily estimated harvest rates ($\hat{R}_d$) used to compute total winter steelhead landings in 2018. In cases where no interviews were obtained, the $\hat{R}_d$ was not estimable. In cases where only a single angling party was interviewed the SD was not estimable. SD=standard deviation; WD=day fell into the weekday strata; WE=day fell into the weekend day.

Date	Week	Strata	Bank- upper		Bank -lower		Boat-upper		Boat -lower	
			$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD
1/9/2018	2	WD	0.0199	0.02	0	0	0	0	0	0
1/11/2018	2	WD	0.0635	0.0432	0	0				
1/12/2018	2	WD	0.0204	0.0148	0	0				
1/13/2018	2	WE	0.041	0.0168						
1/14/2018	2	WE	0.0355	0.0141	0.0734	0.0385	0.0471	0	0	0
1/15/2018	3	WD	0.0182	0.0124	0.0338	0.0277	0.0184	0.0179	0.014	3.00E-04
1/16/2018	3	WD	0.0406	0.0207	0.0793	0.0622	0.2162	0.0487	0	0
1/17/2018	3	WD	0.1679	0.063	0.0393	0.0490				
1/20/2018	3	WE	0	0	0	0				
1/21/2018	3	WE	0.0377	0.015	0	0				
1/22/2018	4	WD	0.0468	0.0233	0.0524	0.0590				
1/25/2018	4	WD			0	0				
1/26/2018	4	WD	0.1356	0.0599	0	0				
1/27/2018	4	WE	0.0545	0.0407	0.0853	0.0658				
1/28/2018	4	WE	0.0211	0.0153	0	0				
1/31/2018	5	WD	0.039	0.0194	0	0				
2/1/2018	5	WD	0.0408	0.0188	0	0				
2/2/2018	5	WD	0.0773	0.0292	0.0123	0.0124	0	0		
2/3/2018	5	WE	0.0511	0.0266	0.0739	0.0827	0.052	0.0237	0.046	0.0021
2/4/2018	5	WE	0.017	0.0094	0	0			0	0
2/5/2018	6	WD	0.0175	0.0169	0	0			0.0451	0.000888
2/6/2018	6	WD	0.0423	0.0246	0	0	0.0264	0.0279		
2/9/2018	6	WD	0.0293	0.0174	0	0	0	0		
2/10/2018	6	WE	0.0372	0.0154	0	0			0.0226	0.0008
2/11/2018	6	WE	0.0149	0.016	0	0	0	0		
2/12/2018	7	WD	0.1075	0.0825	0	0	0.1333	0		
2/15/2018	7	WD	0.1221	0.073	0	0				
2/16/2018	7	WD	0	0	0	0				
2/17/2018	7	WE	0.0245	0.0226	0	0	0.0356	0.0544	0	0
2/18/2018	7	WE	0.0072	0.0073	0	0	0	0		
2/21/2018	8	WD	0.0244	0.0264	0	0			0.3061	0
2/22/2018	8	WD	0.035	0.0283	0	0			0	0
2/23/2018	8	WD	0	0	0	0				
2/24/2018	8	WE	0	0	0	0				
2/25/2018	8	WE	0.0345	0.0254	0	0				
2/26/2018	9	WD	0.0221	0.0214	0	0				
2/27/2018	9	WD	0.0539	0.0198	0	0				

Table A.1 Continued.

Date	Week	Strata	Bank- upper		Bank -lower		Boat-upper		Boat -lower	
			$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD
3/2/2018	9	WD	0.0921	0.0563	0	0				
3/3/2018	9	WE	0.0607	0.0234	0	0				
3/4/2018	9	WE	0.0262	0.0105	0	0	0.0571	0		
3/5/2018	10	WD	0.0631	0.0373	0	0	0.04	0		
3/6/2018	10	WD	0.0927	0.0501	0	0	0	0		
3/9/2018	10	WD	0.058	0.0272	0	0	0	0	0	0
3/10/2018	10	WE	0.0514	0.0223	0	0	0	0		
3/19/2018	12	WD	0.1172	0.0926			0	0		
3/20/2018	12	WD	0	0	0	0	0	0		
3/23/2018	12	WD	0	0						
3/24/2018	12	WE	0.0214	0.0227	0.2069	0.2568				
3/25/2018	12	WE	0	0	0	0	0	0		
3/28/2018	13	WD	0	0						
3/29/2018	13	WD	0	0	0	0				
3/30/2018	13	WD	0	0						
3/31/2018	13	WE	0	0			0.0723	0		
4/1/2018	13	WE	0	0	0	0				
4/4/2018	14	WD	0.3261	0.241						
4/7/2018	14	WE	0	0						
4/9/2018	15	WD	0	0						
4/10/2018	15	WD	0	0	0	0				
4/13/2018	15	WD	0	0						
4/14/2018	15	WE	0.0186	0.02						
4/15/2018	15	WE	0	0						
4/16/2018	16	WD	0	0						
4/20/2018	16	WD	0	0						
4/21/2018	16	WE	0	0						

Table A.2: Daily estimated harvest rates ($\hat{R}_d$) used to compute total winter steelhead landings in 2019. In cases where no interviews were obtained, the $\hat{R}_d$ was not estimable. In cases where only a single angling party was interviewed the SD was not estimable. SD=standard deviation; WD=day fell into the weekday strata; WE=day fell into the weekend day.

Date	Week	Strata	Bank-Upper		Bank-Lower		Boat-Upper		Boat-Lower	
			$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD
1/11/2019	1	WD	0.0509	0.0152	0	0	0	0		
1/12/2019	1	WE	0.0368	0.0099	0.043	0.0104	0	0	0.007	0.037
1/13/2019	1	WE	0.0363	0.0243	0.028	0.0141	0	0	0.0702	0.0261
1/16/2019	2	WD	0.0654	0.0713	0.023	0.0154	0.0225	0.0175	0.1353	0
1/17/2019	2	WD	0.0712	0.0409	0.024	0.0288	0	0		
1/18/2019	2	WD	0.0353	0.0124	0.052	0.0548				
1/19/2019	2	WE	0.0085	0.0061	0	0				
1/20/2019	2	WE	0.0246	0.0096	0	0				
1/21/2019	2	WE	0.1069	0.0166	0.045	0.0225				
1/24/2019	3	WD	0.0336	0.0226	0	0	0.0252	0	0.0779	0
1/25/2019	3	WD	0.0414	0.0156	0.0304	0.0364	0.0193	0	0	0
1/26/2019	3	WE	0.0533	0.0148	0.0219	0.0112	0.1465	0	0.0324	0.0105
1/27/2019	3	WE	0.02	0.0121	0.1461	0.0353	0.0181	0	0.0323	0.0667
1/28/2019	4	WD	0.0245	0.0215	0.0632	0.0569	0	0	0.1333	0
1/31/2019	4	WD	0.0822	0.0592	0	0	0	0	0	0.0294
2/1/2019	4	WD	0	0	0	0	0.0351	0	0.092	0.0243
2/2/2019	4	WE	0.0114	0.0109	0.078	0.0180	0	0		
2/3/2019	4	WE	0.0967	0.0193	0	0	0.0284	0	0.0433	0
2/4/2019	5	WD	0.0839	0.0816	0	0			0	0
2/6/2019	5	WD			0	0			0.0609	0
2/7/2019	5	WD	0.0295	0.0304	0	0			0.069	
2/9/2019	5	WE	0	0	0	0				
2/10/2019	5	WE	0	0	0.0205	0.0182				
2/11/2019	6	WD	0.0384	0.0448	0.0402	0.0449				
2/14/2019	6	WD	0	0	0.0906	0.0456				
2/16/2019	6	WE	0.0209	0.0138	0.0758	0.0198				
2/17/2019	6	WE	0.0704	0.0179	0.0436	0.0107				
2/18/2019	6	WE	0.0698	0.0161	0.054	0.0369	0	0		
2/19/2019	7	WD	0.0997	0.0353	0.031	0.0240	0	0		
2/21/2019	7	WD	0.0487	0	0	0	0.0258	0	0.0714	0.0123
2/23/2019	7	WE	0.0402	0.0206	0	0	0.0749	0	0.0615	0
2/24/2019	7	WE	0.072	0.0319	0	0				
2/25/2019	8	WD	0.0598	0.0088						
2/28/2019	8	WD	0.0991	0.025			0	0		

Table A.2 Continued.

Date	Week	Strata	Bank-upper		Bank-lower		Boat-Upper		Boat-Lower	
			$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD	$\hat{R}_d$	SD
3/3/2019	8	WE	0	0	0.017	0.0161	0.0192	0	0	0.0109
3/4/2019	9	WD	0	0	0	0	0.0669	0		
3/7/2019	9	WD	0.05	0.041	0	0	0.08	0		
3/8/2019	9	WD	0.0584	0.026	0	0	0	0		
3/9/2019	9	WE	0.0607	0.0337	0.0243	0.0280	0.0576	0	0.0328	0
3/10/2019	9	WE	0	0	0	0				
3/12/2019	10	WD	0.0411	0.0366						
3/14/2019	10	WD	0.0979	0	0	0	0.0373	0	0	0
3/15/2019	10	WD	0.097	0.0809	0.227	0.0526			0	0
3/16/2019	10	WE	0.0822	0			0.0333	0		
3/17/2019	10	WE	0.0273	0.0203						
3/18/2019	11	WD	0.1423	0.03			0.1176	0		
3/21/2019	11	WD	0	0			0.0667	0		
3/22/2019	11	WD	0.0907	0.0425						
3/23/2019	11	WE	0.0778	0.0174			0	0		
3/24/2019	11	WE	0.0261	0.0282						
3/26/2019	12	WD	0.0455	0.0401						
3/28/2019	12	WD								
3/29/2019	12	WD	0.0451	0.0225						
3/30/2019	12	WE			0.0896	0.028				
3/31/2019	12	WE			0	0			0	0
4/2/2019	13	WD	0.0571	0.0366						
4/3/2019	13	WD	0.0641	0.0373	0	0			0	0
4/4/2019	13	WD	0.1406	0.0513					0	0
4/6/2019	13	WE			0	0				
4/8/2019	14	WD			0	0				
4/9/2019	14	WD	0	0						
4/10/2019	14	WD	0.213	0.0601						
4/13/2019	14	WE	0.067	0.0361			0	0		
4/14/2019	14	WE	0	0	0	0				
4/15/2019	15	WD			0	0				
4/16/2019	15	WD	0	0	0	0				
4/18/2019	15	WD								
4/20/2019	15	WE	0	0						
4/21/2019	15	WE	0	0					0	0
4/22/2019	16	WD	0	0						
4/24/2019	16	WD			0	0				
4/26/2019	16	WD			0	0				
4/27/2019	16	WE			0	0				
4/28/2019	16	WE	0	0	0	0				

4034 Fairview Industrial Drive SE
Salem, Oregon 97302