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Parr Production from Adult Hatchery Steelhead Outplanted in Two Tributaries to the Headwaters of the Salmon River, Idaho

Abstract

Supplementation is a widespread response to the declining runs of anadromous salmonids in the Pacific Northwest. A common type of supplementation is the intentional release of adult hatchery fish to spawn naturally (outplanting) but this method has seldom been evaluated. Our objective was to quantify the juvenile steelhead (*Oncorhynchus mykiss*) production from the adult outplants during a 14 year period in two streams. Although densities of juvenile steelhead were highly variable, outplanting status (supplemented versus not supplemented) explained a significant proportion of the variance for the age-1 densities but not for the age-2+ densities. We used a simulation model to predict smolt production and adult returns given the observed juvenile age-1 densities from each adult cohort we outplanted. In general, predicted smolt production was greater during the mid 1990s and lower after 1999, despite the fact that more females were stocked into the study streams after 1999. Given the SAR rates measured during the study period and plausible over-winter survival rates in the study streams, we predicted that the observed juvenile production would produce few adults and would not result in a self-sustaining population. This conclusion was corroborated by adult return data. We found no evidence that adult outplanting increased wild population levels, i.e., there was no demographic boost in adult spawners. Further, the differences between the two study streams showed that supplementation programs should carefully assess each target stream.

Keywords: steelhead, *Oncorhynchus mykiss*, population supplementation, hatchery stocking, parr abundance

Introduction

Hatchery supplementation is a widespread response to the declining runs of anadromous salmonids in the Pacific Northwest (Bugert 1998). The goal of supplementation is to bolster existing populations or re-establish extirpated ones; whether it can achieve this goal is open to debate (ISAB 2003, Fraser 2008). Supplementation is defined as the stocking of fish into the natural habitat to increase the abundance of naturally reproducing fish populations (Cuenco et al. 1993). A more restrictive definition is the use of artificial propagation to maintain or increase natural production while maintaining the long-term fitness of the target population and keeping the ecological and genetic impacts to non-target populations within specified biological limits (RASP 1992). As a

comparison of these two definitions shows, there is considerable scope for how supplementation could be accomplished.

The effect of supplementation programs on salmonid populations is an area of active research. Studies on aspects of the performance of hatchery fish in the wild are becoming more common in the literature (e.g., relative fitness [Araki et al. 2008] or life history [Knudsen et al. 2006, Hoffnagle et al. 2008]) but demographic studies of supplementation programs have been more limited (e.g., Sharma et al. 2006, Berejikian et al. 2008). In general, reproductive performance of hatchery fish in natural environments is less than that of natural fish, although individual study results may be highly variable (Araki et al. 2008, ISRP 2011). Productivity of wild populations tends to be reduced in the presence of hatchery fish on the spawning grounds (Chilcote et al. 2011). However, specific analyses of abundance and productivity in supplemented populations are still needed (ISRP 2011).

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One type of supplementation is the intentional release of adult hatchery-origin fish to spawn naturally (outplanting). This is easy to do when there are excess hatchery fish and is popular, although arguably outside of the RASP definition of supplementation. There is a growing body of evidence that supplementation programs should be carefully implemented and evaluated. However, there are still many places where hatchery-origin adult steelhead are allowed to spawn in natural habitats based on expedience (ISAB 2002) without a planned evaluation. Our goal in this paper is to provide a case study of an evaluation of the adult outplanting strategy conducted with minimal infrastructure.

From 1985 to 1993, Idaho Department of Fish and Game (IDFG) outplanted adult hatchery steelhead (*Oncorhynchus mykiss*) in the Salmon River upstream of the weir at Sawtooth Fish Hatchery (SFH) to spawn naturally. The objective of the hatchery program is to provide fish for harvest but it was thought that excess hatchery fish could be used to bolster the wild population upstream of

the SFH weir. The primary population limitation identified was underseeding of spawning habitat (IDFG 1992:p.172). The supplementation objective was to provide a demographic boost by increasing spawner abundance. The initial guideline was to release up to one third of the spawning run, including all wild fish (fish with intact adipose fins and uneroded dorsal fins), upstream of the weir to spawn in the Salmon River and its tributaries. Despite this effort, returns of naturally produced adult steelhead continued to decline (Figure 1).

Because the outplanting program failed to provide a demographic boost, this study was initiated in 1993 to evaluate the SFH steelhead supplementation program's success in producing parr. In Idaho, steelhead spawn near the peak of the spring snowmelt, making work in the main stem areas unsafe and ineffective. The study strategy was to work in two smaller tributaries where monitoring of spawning steelhead and their progeny could be effective. Modeling was used to extend the juvenile monitoring results to adulthood to facilitate a life-cycle evaluation and

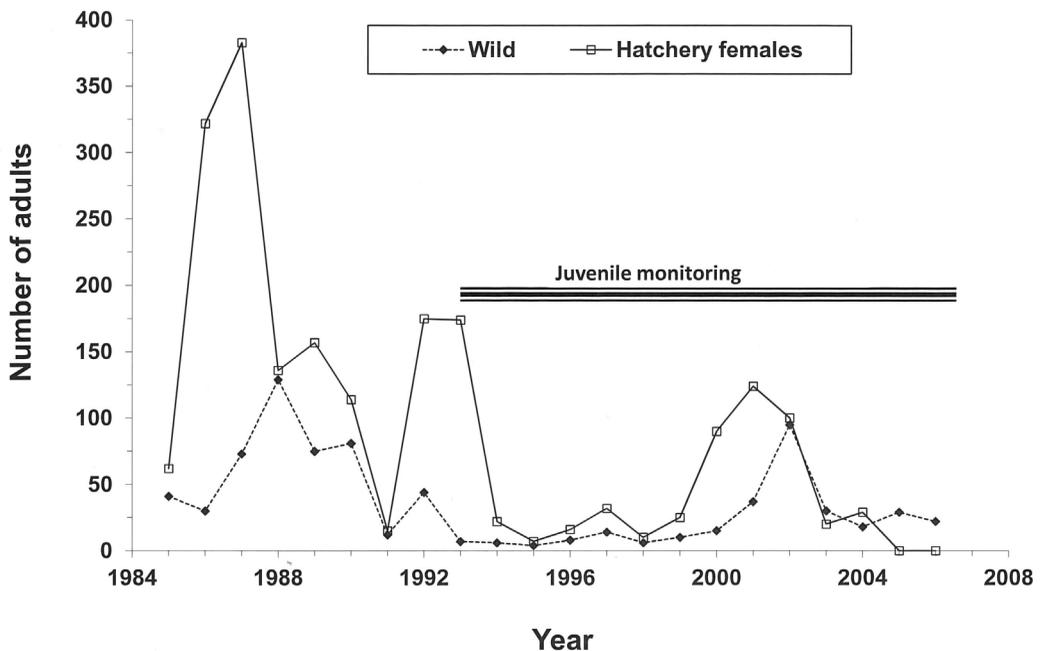


Figure 1. Number of all wild adult steelhead passed, and number of hatchery female steelhead outplanted, upstream of the Sawtooth Fish Hatchery weir from 1985 to 2006. Numbers of hatchery males outplanted equaled or exceeded numbers of females in all years. The number of hatchery steelhead includes fish used in this study plus fish released in the mainstem Salmon River. The bar indicates the period of juvenile monitoring.

a comparison to the larger-scale supplementation program. Therefore, our primary objective was to quantify the juvenile age-1 abundance that resulted from the outplanted fish over a 14-year period in the two study streams. We then used simulation modeling to ask: what level of smolt and adult yield was likely, given the estimated age-1 juvenile abundance? The results were compared with adult return data from the SFH weir, which provide the ultimate measure of program success.

Study Area

This study was done in Beaver and Frenchman creeks, which are tributaries of the Salmon River upstream of the Sawtooth Fish Hatchery in central Idaho (Figure 2). The study area is over 2100 m elevation and more than 1440 km from the Pacific Ocean. Frenchman Creek enters the Salmon River

30 km upstream of the SFH and has a drainage area of 17.9 km². The study reach in Frenchman Creek began at its mouth and extended upstream 3.1 km. Beaver Creek enters the Salmon River 25 km upstream of the SFH and has a drainage area of 39.7 km². The study reach in Beaver Creek began at an irrigation diversion, located 1.3 km upstream of its mouth, and extended upstream 2.9 km. Beaver Creek was dewatered for part of the summer downstream of the irrigation diversion in most years but there was always adequate flow to support salmonids in the study area. Runs and riffles make up more than 85% of the stream habitat in both study reaches. Angling pressure in the study streams is very light, as most fishing takes place in the main stem Salmon River and has been regulated to avoid harvest of wild *O. mykiss* < 355 mm since 1996 (Thomas Curet,

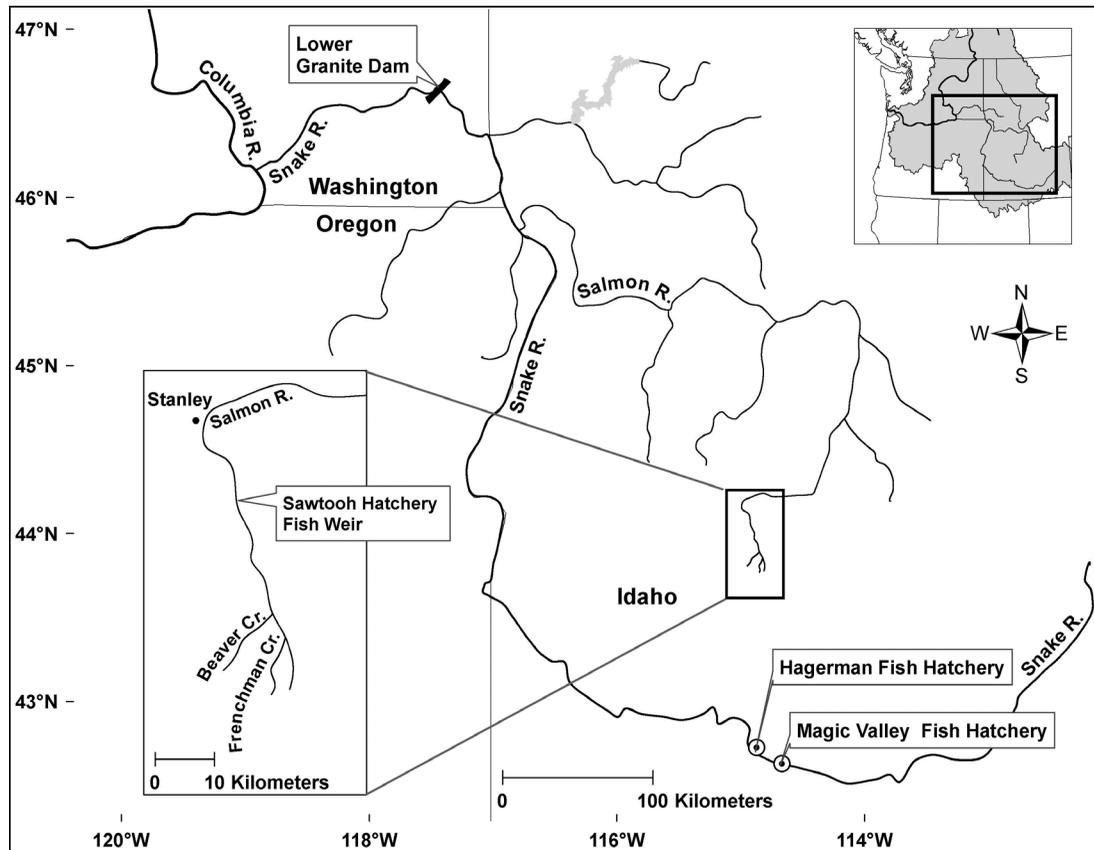


Figure 2. Map showing the location of the study sites in relation to the Columbia and Snake Rivers with Lower Granite Dam and the rearing hatcheries marked. In the lower left inset, the positions of the headwaters of the Salmon River, Sawtooth Fish Hatchery, and Beaver and Frenchman creeks are illustrated.

IDFG regional fisheries manager, personal communication).

Methods

Supplementation

The outplanting program in Sawtooth Valley used the SFH steelhead stock. This hatchery stock was founded in 1985 when the SFH weir was first operated during the steelhead spawning run. Prior to commencement of weir operations, smolts from the Pahsimeroi Hatchery, located 128 km downstream, were released upstream of SFH to provide adults for harvest and to establish the SFH stock. The SFH hatchery stock was founded on adult returns from these smolts and from naturally produced local fish. After 1985, all hatchery releases were spawned from hatchery adults returning to the SFH weir. Eyed eggs are shipped to hatcheries on the Snake River (Figure 2) where the juveniles are reared for 10 months. All hatchery juveniles had their adipose fin clipped prior to release. The smolts are trucked to SFH the next spring for release in the Salmon River. All naturally produced steelhead (adults with an unclipped adipose fin) are passed upstream of the SFH weir to spawn.

We randomly chose hatchery fish that returned to the SFH after April 15 (the second half of the run) that were not needed to meet the egg take quota to outplant into the study reaches. Each fish had its gender determined and fork length (FL) measured to the nearest cm. We report number of females outplanted, but in all outplantings the number of males stocked equaled or exceeded the number of females. We installed two temporary picket weirs in each stream to keep the adults in the upper kilometer of each study reach. Fish were trucked to the creeks, placed in large coolers filled with water, transported to the release sites with snowmobiles, and distributed throughout the release reach. In general, outplanting took place during the last week of April and the first week of May. Personnel monitored spawning and counted redds one to three days per week from 1993 to 1996. During these years, we documented that nearly all fish spawned within five days after outplanting. Beginning in 1997, we stopped

counting redds because of the difficulty locating them during snowmelt unless fish were actively spawning. The weirs were removed two to three weeks after outplanting.

Assessment of Juvenile Production

Snorkel surveys were used to estimate the density of steelhead parr each summer at base flow using Hankin and Reeves' (1988) habitat-based protocol. Surveys were conducted in both streams every year starting at initiation of the program and continuing until two years after the last outplanting. On average, 38 sites were surveyed per study reach and the average date of the survey was August 13. Each snorkel site consisted of a single distinct habitat type (pool, pocketwater, riffle, or run) and was chosen randomly throughout the study reach. The number of snorkel sites in each habitat type was allocated in proportion to the type's abundance in the stream. Each snorkel site was separated by at least one distinct habitat type change from a prior site. After the site was surveyed, we measured thalweg length and three to six widths at evenly spaced intervals within the site to calculate surface area.

Sites were surveyed by snorkelers moving upstream, the number of divers varying according to channel width and visibility. Observers advanced slowly, identifying and counting all fish seen. Steelhead parr were aged based on observed size and were classified as age 0 (FL ≤ 75 mm), age 1 (FL 76–127 mm), or age 2+ (FL > 127 mm). These steelhead parr age class length frequencies are typically observed in most Idaho streams during the summer snorkel survey period. Although snorkelers counted steelhead fry (age-0), we excluded them from analysis because of the difficulty obtaining accurate counts and surveys were done before all fry had emerged in several years.

We computed an annual summer density of steelhead parr for each study reach. Mean densities (fish/100 m²) of steelhead parr by age group were calculated for each habitat and used to calculate the mean stream density (m_t): $m_t = \sum p_i \bar{d}_{it}$, where p_i = proportion of habitat i in the stream, \bar{d}_{it} = mean age t parr density (fish/100 m²) in habitat i , $t = 1$, or 2+ parr and, $i =$ pool, riffle, run, pocketwater.

Data Analysis

The evaluation was focused on 14 years of snorkel observations from 1993 to 2006. Beaver Creek was outplanted annually from 1993 to 2004. Frenchman Creek was supplemented eight years during this time period (1993, 1994, 1997, and 1999-2003). Juvenile data were collected beginning the year this study was initiated and continuing until two years after the last outplanting, for a total of 20 observations of supplemented years ($n_{suppl} = 12$ in Beaver Creek and $n_{suppl} = 8$ in Frenchman Creek) and 8 unsupplemented years ($n_{unsuppl} = 2$ in Beaver Creek and $n_{unsuppl} = 6$ in Frenchman Creek). We used assigned ages to allocate fish to a cohort. The number of supplemented and unsupplemented cohorts was the same for both age groups.

We analyzed parr densities by age group to evaluate the success of the supplementation program at producing parr. Two-way analysis of variance (ANOVA) was used to compare densities of supplemented versus unsupplemented cohorts. Stream identity was incorporated into the ANOVA model as a fixed factor, as was the treatment \times stream interaction. Acceptable risk of a Type I error was set *a priori* at 5%. To show effect sizes unbiased by the differential application of supplementation, we reported the least squares means by stream and treatment type. All statistics were performed in SYSTAT v. 11.

Simulation

We performed a simulation to evaluate outplanting success by estimating the number of returning adults given the observed age-1 juvenile densities of each cohort. Data were available to estimate survival of steelhead by cohort from Sawtooth Valley to Lower Granite Dam as smolts and then back to Lower Granite Dam as adults. Our strategy was to propose a set of reasonable scenarios about the conditions that affect survival of age-1 parr to emigration as a smolt from Sawtooth Valley, apply these scenarios to each cohort and predict how many smolts arrive at Lower Granite Dam and how many adults return from the ocean. We compared these numbers to the number of females stocked to produce the age-1 juveniles observed in each cohort.

We used the observed densities of age-1 parr to estimate population abundance. The number of age-1 steelhead for each study reach was calculated as: $\hat{N}_1 = \sum A_i \bar{d}_{i1}$, where \hat{N}_1 is the population estimate of age-1 parr, A_i is surface area of habitat i , and \bar{d}_{i1} is average density of age-1 parr in habitat i . Data from recent snorkel surveys showed that detection efficiency of steelhead parr in a similar stream channel ranged from 75% to 100% but may be as low as 50% (T. Copeland, unpublished data). For each year-by-stream combination that adults were outplanted, we estimated number of age-1 progeny as \hat{N}_1 , $\hat{N}_1/0.75$, and $\hat{N}_1/0.5$. For each supplemented brood year (BY), these estimates were combined over both study streams to get total number of age-1 parr produced by the supplementation program.

Next, we estimated the number of fish from each age-1 cohort in both Beaver and Frenchman creeks that survived to reach Lower Granite Dam. Eighty one percent of the emigrating wild steelhead juveniles implanted with passive integrated transponder tags at SFH that were subsequently detected at dams in the Snake and Columbia rivers were age 3 (A. Byrne, unpublished data). Smith and Griffith (1994) reviewed studies of winter survival (S_w) in 24 populations of juvenile salmonids exposed to prolonged periods of 0 °C temperatures and estimated mean survival was 0.50 (SD = 0.18). Mitro and Zale (2002) estimated overwinter survival in good habitat was approximately 0.20 for young rainbow trout in Henrys Fork in Idaho (1900 m elevation). We assumed age-1 parr in Sawtooth Valley had to survive two additional winters before smolting and proposed three scenarios using moderate winter mortality ($S_w = 0.50$), high winter mortality (mean - 1 SD, approximate $S_w = 0.30$), and severe winter mortality ($S_w = 0.20$).

We estimated cohort production of smolts and adults at Lower Granite Dam from both streams for each combination of snorkel survey efficiency and winter survival scenario. From 1997-2007, we estimated survival of steelhead emigrants (hatchery and wild) from SFH to Lower Granite Dam (S_{lgd}) based on records of fish tagged with passive integrated transponders at SFH and detected in the Columbia River hydrosystem. A Cormack-Jolly-Seber model implemented in software by

Lady et al. (2004) was used to estimate $S_{l_{gd}}$ for each cohort. We used the median survival of the 1997-2007 smolt cohorts to estimate $S_{l_{gd}}$ for the 1996 cohort. Total smolt yield at Lower Granite Dam (\hat{N}_s) was $\hat{N}_1 * S_w^2 * S_{l_{gd}}$.

We computed the number of adults surviving back to Lower Granite Dam for each cohort. We used the smolt-to-adult return rates (SARs) for wild steelhead from the 1997-2007 cohorts from Tuomikoski et al. (2010). We used the median SAR during this time period for the 1996 cohort SAR. Any out-of-basin effects common to Snake River steelhead populations are incorporated into the SAR estimates. Total adults at Lower Granite Dam (\hat{N}_a) was $\hat{N}_s * SAR$.

Results

Field Study

We outplanted hatchery fish into the study reaches 12 times in Beaver Creek and 8 times in Frenchman

Creek. In Beaver Creek, the number of females outplanted averaged 13 and ranged from 6 to 29. In Frenchman Creek, the number of females outplanted averaged 13 and ranged from 10 to 20.

Densities of juveniles were highly variable (Figure 3). In Beaver Creek, densities of age-1 steelhead averaged 4.12 fish/100 m² (range 0.53 to 10.74) and densities of age-2+ steelhead averaged 1.35 fish/100 m² (range 0.17 to 3.60). In Frenchman Creek, densities of age-1 steelhead averaged 1.41 fish/100 m² (range 0.00 to 3.89) and densities of age-2+ steelhead averaged 0.54 fish/100 m² (range 0.00 to 2.53).

The ANOVA model of the parr densities explained a significant proportion of the variance for the age-1 densities but not for the age-2+ densities (Table 1). Outplanting status (supplemented versus not supplemented) was significant in the age-1 model. The stream factor was marginally significant at age 1. The treatment×stream inter-

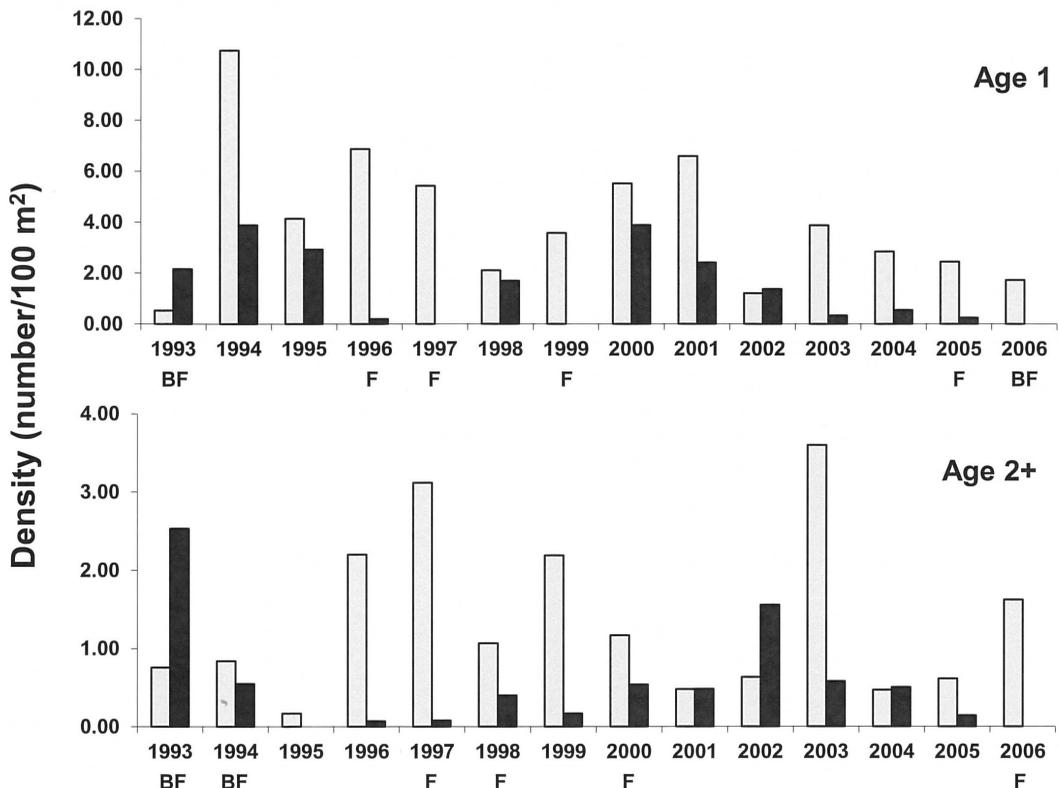


Figure 3. Observed mean densities of juvenile steelhead in Beaver (light bars) and Frenchman (dark bars) creeks by age group. Letters beneath year indicate when a stream was not supplemented for the production of that age group (B=Beaver, F=Frenchman).

TABLE 1. Analysis of variance output from steelhead parr densities (fish/100 m²) by age category. Treatments are supplemented versus unsupplemented years.

Source	Sum of squares	df	Mean square	F-ratio	P-value
<i>Age 1</i>					
Treatment	30.75	1	30.75	7.92	0.01
Stream	11.54	1	11.54	2.67	0.10
Treat×Stream	3.64	1	3.64	0.94	0.34
Error	93.25	24	3.89		
<i>Age 2+</i>					
Treatment	0.18	1	0.18	0.22	0.64
Stream	1.44	1	1.44	1.74	0.20
Treat×Stream	0.90	1	0.90	1.09	0.31
Error	19.83	24	0.83		

action was not significant for any model. The adjusted mean density during supplemented years was higher than for unsupplemented years (Table 2), although the difference was not significant for age-2+ parr. The difference between means for age-1 parr was 2.60 fish/100 m². This value is the estimate of outplanting effects after the influence of stream was statistically removed.

TABLE 2. Adjusted (least squares) means of parr densities (fish/100 m²) by age category in supplemented versus unsupplemented years. Standard errors are in parentheses.

Age	Supplemented	Unsupplemented
Age 1	3.38 (0.45)	0.78 (0.80)
Age 2+	0.94 (0.21)	0.74 (0.37)

Simulation

We began the simulation by estimating smolt production from the adult outplants. Smolt production was estimated as a deterministic function of assumptions regarding snorkel survey efficiency and winter mortality. Expanding observed age-1 densities of the supplemented cohorts (Figure 3) to abundance within the study reaches yielded smolt estimates ranging from 145 to 1134 in Beaver Creek and 33 to 352 in Frenchman Creek if snorkel survey efficiency was 100%. If lower snorkel efficiencies were used the smolt abundance increased by 133% and 200% for 75% snorkel efficiency and 50% snorkel efficiency, respectively.

The number of smolts arriving at Lower Granite Dam should have been lowest for BY 2004 and

highest for BY 1993 (Table 3, results of high winter mortality scenarios not shown). In general, smolt production should have been greater during the mid 1990s and lower after 1999, despite the fact that more females were stocked into the study streams during that time. Moderate winter scenarios gave 2.8 times more smolts than high winter mortality scenarios and 6.3 times more smolts than severe mortality scenarios.

We predicted that few adults would return to Lower Granite Dam. Of the 108 year-by-scenario combinations we simulated, 75% of them returned 0 or 1 adults to LGR (Table 4, results of high winter mortality scenarios not shown). The median adult production over all brood years and scenarios was 1. The largest adult return in all scenarios was 8 from a female outplant of 18 in BY 1993 under our most optimistic scenario. Replacement of female spawners did not occur in any scenario.

Discussion

The major contribution of this study is the evaluation of supplementation by outplanted hatchery adults, which is currently lacking in the published literature (but see McLean et al. 2003, 2004 for a short-term exception). The strength of this study is in the length of the evaluation data set in Beaver and Frenchman creeks coupled with the accompanying record of the population response from all adults outplanted upstream of SFH (the SFH adult weir data). The SFH weir returns include adults from all hatchery and wild origin fish that were released upstream of the SFH weir, not just

TABLE 3. The predicted number of smolts at Lower Granite Dam (LGR) by brood year under moderate and severe winter survival scenarios, three snorkel sampling efficiency levels (50%, 75%, and 100%), and the smolt survival estimate (S_{lgr}) from the streams to LGR. The total number of females stocked each year in Frenchman and Beaver creeks is also shown.

Brood year	Total females stocked	Survival to LGR (S_{lgr})	Winter survival scenario					
			Moderate			Severe		
			100%	75%	50%	100%	75%	50%
1993	18	66.5%	243	322	484	39	51	77
1994	18	70.1%	143	191	286	23	30	45
1995	7	70.7%	156	207	311	25	33	50
1996	13	67.6%	109	145	218	17	23	35
1997	23	66.5%	75	100	149	12	16	24
1998	10	63.7%	74	98	147	12	16	24
1999	25	55.6%	142	189	284	23	30	46
2000	30	41.0%	97	129	193	15	21	31
2001	40	53.2%	37	50	75	6	8	12
2002	31	69.5%	86	114	170	14	18	27
2003	20	76.4%	86	115	172	14	18	28
2004	29	59.1%	38	51	76	6	8	12

TABLE 4. The predicted number of adults returning to Lower Granite Dam (LGR) by brood year under moderate and severe winter survival scenarios, three snorkel sampling efficiency levels (50%, 75%, and 100%), and the smolt-to-adult survival (SAR) used in the model. The SAR was calculated as smolts from LGR to adults returning to LGR and was obtained from Tuomikoski et al. (2010). The total number of females stocked each year in Frenchman and Beaver creeks is also shown.

Brood year	Total females stocked	SAR	Winter survival scenario					
			Moderate			Severe		
			100%	75%	50%	100%	75%	50%
1993	18	1.57%	4	5	8	0	1	1
1994	18	1.16%	2	2	3	0	0	0
1995	7	0.30%	0	1	1	0	0	0
1996	13	2.84%	3	4	6	0	1	1
1997	23	2.66%	2	3	4	0	0	0
1998	10	2.47%	2	2	4	0	0	1
1999	25	2.14%	3	4	6	0	0	1
2000	30	1.57%	1	2	3	0	0	0
2001	40	0.85%	0	0	0	0	0	0
2002	31	0.80%	1	1	1	0	0	0
2003	20	1.14%	1	1	2	0	0	0
2004	29	2.56%	1	1	2	0	0	0

our study streams. Although there were statistically significant increases in the abundance of age-1 parr following supplementation, our simulations estimated few adults would return. This result is conservative because: (1) some age-1 parr could have been the offspring of wild fish (resident and/or anadromous); (2) some of the age-1 parr observed could have been migrants from outside the study reaches; (3) some of the age-1 parr could have been age-2 and; (4) although mortal-

ity occurs throughout the year, we only modeled over-winter mortality.

Our measure of juvenile production depends on the assumption that young steelhead did not leave the natal stream until their second autumn. Juveniles produced by outplanted females would have to disperse at least 2 km to exit our study reaches. The de-watered stretch downstream of the Beaver Creek study area would inhibit emigration during the first summer. Everest and

Chapman (1972) found that most age 0 and age 1 steelhead enter the substrate in late October, so fish of those age classes would likely remain in Beaver Creek. Young salmonids usually settle quickly and do not make movements > 1 km until some factor impels them (e.g., ontogeny). When the animal's needs are being met, it stays where it is; when they are not, it moves until it finds appropriate conditions for its current demands (Thorpe 1994). Hume and Parkinson (1987) found that median dispersal distance of age-1 steelhead from locations where they were planted as fry did not exceed 600 m. Kahler et al (2001) found that only 1% of marked YOY coho left their study reach and most movements were short distances that were as apt to be upstream as downstream. Steingrimsson and Grant (2003) found few YOY Atlantic salmon moved more than 10 m during the summer. Only 8% of the steelhead parr < 120 mm FL that emigrated from the Salmon River upstream of SFH before August 1 were detected as a smolt at dams in the Snake and Columbia rivers (A. Byrne, unpublished data). Because these fish make a minor contribution to smolt production, the observed age-1 parr densities were a good measure of juvenile production on which to base our evaluation. However, if there was significant rearing downstream of the study reaches, one would expect to see an increase in the number of adults to the SFH weir even in the absence of higher parr densities in the study reaches. Instead, the wild adult returns were what would be expected if our assumption was correct.

In nearly all our simulations, parr and smolt production from outplanted SFH adults was inadequate to return many adults, a prediction corroborated by wild adult returns to SFH (Figure 1). The observed juvenile production from hatchery outplants was capable of producing a few spawning adults under some conditions but never achieved replacement. Our assumed parr survival rates were only for winter and hence optimistic. Recent SARs (1997-2007 migratory cohorts) for wild steelhead in the Snake River basin range from 0.03% to 2.84% and for hatchery fish the SAR's ranged from 0.39% to 2.08% (Tuomikoski et al. 2010). Given SARs in this range, replacement of hatchery parents would never occur in our study

streams. However, combined with moderate winter conditions, we estimated that adult supplementation could produce a spawning pair back to Beaver Creek but not Frenchman Creek (data not shown). We concluded that the SFH adult outplant program resulted in a trickle of naturally produced adults, which was observed (Figure 1).

This conclusion is consistent with other studies on steelhead supplementation. Hatchery steelhead spawning in Forks Creek, Washington, did not replace themselves (McLean et al. 2003). In general, smolt productivity of naturally spawning hatchery steelhead is low (Chilcote et al. 1986, Kostow et al 2003, Kostow 2004, McLean et al. 2004, Araki et al. 2007). For the simulation, we assumed winter survivals based on wild origin *O. mykiss* and a S_{lgd} estimate for hatchery and wild steelhead combined. Caroffino et al. (2008) found fry-smolt survival was lower for progeny of hatchery steelhead compared to the progeny of wild fish, so our assumed S_{lgd} may also be optimistic. Despite this optimistic assumption, we estimated few adults would be produced by outplanting; a conservative conclusion consistent with other studies on steelhead supplementation.

The use of excess adult hatchery steelhead for supplementation is convenient but poses demographic and genetic risks (ISAB 2002, Araki et al. 2007, Chilcote et al. 2011). There is extensive evidence that hatchery-wild hybrids from production hatcheries are less fit than wild fish (Naish et al. 2008). In general, supplementation by hatchery fish imposes a fitness cost on the target population (Araki et al. 2008); the question is whether the demographic boost provided by hatchery fish can overcome this loss of fitness (Fraser 2008). Genetic risks may be reduced by using local brood stocks and demographic gains may be realized by committing a certain number of fish to be outplanted, rather than whatever excess is available.

In this study, we found no evidence that adult outplanting increased wild population levels, i.e., there was no demographic boost in adult spawners. Because of the low natural spawning densities, one would expect that the effect of hatchery supplementation to produce parr would be evident,

which it was (Table 1). However, the resultant parr yield was insufficient to yield enough adults to replace their parents. Given the harsh aquatic environments in Sawtooth Valley, the inherent productivity of the supplemented fish would have to be much higher than the SFH stock to achieve a demographic boost. Further, the differences between the two study streams (stream effect, Table 1) showed that supplementation programs should carefully assess each target stream. The use of hatchery adult outplants, as was done in this case, is usually based on expedience (ISAB 2002); therefore, the necessary planning usually is not done and the results often are not evaluated. Here we have provided a long-term evaluation.

Even the most well-planned supplementation programs may have unpredictable consequences and should be carefully monitored to avoid nega-

tive effects (Naish et al. 2008). Unfortunately, evaluations of *ad hoc* adult outplant programs are seldom done. Decisions to introduce hatchery-reared adults for spawning in the wild should be based on the needs of the target population and the ability of the habitat to support additional reproduction and rearing (ISAB 2002).

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