FISHERY RESEARCH

LOWER SNAKE RIVER COMPENSATION PLAN
Hatchery Program

STEELHEAD VOLITIONAL RELEASE EXPERIMENT

SQUAW CREEK POND, IDAHO

1999 Project Progress Report

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SQUAW CREEK POND, IDAHO

1999 Annual Report

By

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ABSTRACT

For the second consecutive year, we evaluated a hatchery steelhead *Oncorhynchus mykiss* release strategy intended to reduce the number of residual steelhead entering the Salmon River, Idaho. Residual steelhead could negatively impact ESA-listed salmon *O. nerka*, *O. tshawytscha*, steelhead *O. mykiss*, and resident fish stocks inhabiting the same waters. The release strategy included pond acclimation, volitional release, and the retention of steelhead that failed to emigrate from the pond. The use of Squaw Creek Pond meets the guidelines for reducing risks to Snake River listed species caused by Columbia River basin hatchery programs noted by National Marine Fisheries Service in several documents, including their predecisional recovery plan for Snake River salmon and the 1994-1998 Biological Opinion for hatcheries in the Columbia River basin.

In 1999, 95,995 hatchery steelhead were stocked into Squaw Creek acclimation pond and permitted to volitionally immigrate into the Salmon River. The number of steelhead that emigrated from the pond was determined by using a fish counter and by conducting a mark-recapture estimate. According to the fish counter, 65,114 steelhead emigrated between April 16 and May 25, 1999. A total of 43,088 steelhead emigrated during the daytime period, whereas 22,026 emigrated during the nighttime period. A weak correlation was found between steelhead emigration and water temperature. Using the mark-recapture method, we estimated that 61,001 steelhead emigrated from the pond.

Steelhead (n=4,100) from the prestocking population at Magic Valley Fish Hatchery were transported to Sawtooth Fish Hatchery and used to determine whether a change in the precocity rate of nonmigrants in Squaw Creek Pond could be attributed to volitional emigration of “smolts” or to the temporal aspects of precocial development. The proportion of precocial males in the Sawtooth Fish Hatchery (captive) population on May 26 was not significantly different than the prestocking population on March 30.

The sex composition of the steelhead that failed to emigrate from the pond (nonmigrants) by May 25 was not significantly different from the prestocking population. Mean fork length, weight, and condition factor of nonmigrant steelhead collected for sex composition sampling were 230 mm, 111 g, and 0.89, respectively. Of the 140 nonmigrants that were sampled, four were precocial.

A total of 300 early migrant, 300 captives, 300 general production, 303 late migrant, and 299 nonmigrant (these fish were force released) steelhead was tagged with passive integrated transponder (PIT) tags to evaluate juvenile migration success and timing. To compare migration success and timing under similar conditions, PIT-tagged steelhead from the early migrant group were compared to the captive and general production groups and steelhead from the late migrant group were compared to the nonmigrant group. A total of 195 (65.7%) late migrants and 211 (70.6%) nonmigrants was interrogated at downstream dams. PIT tag interrogation rates were not significantly different between late migrants and nonmigrants. Nonmigrants had a significantly shorter travel time to Lower Granite Dam than the late migrants. A total of 158 (52.7%) early migrants, 224 (74.7%) captives, and 189 (63.0%) general production steelhead was interrogated at downstream dams. Interrogation rates of steelhead from the early migrant, captive, and production groups were significantly different. Steelhead from the captive group were interrogated at a significantly higher rate than the production and early migrant groups. Steelhead from the production group were interrogated at a significantly higher rate than the early migrant group. Travel time to Lower Granite Dam was significantly

greater for steelhead from the captive group as compared to the early migrant and production groups.

For a second consecutive year, the release strategy we tested was unsuccessful at separating smolts from residual steelhead when assessed using PIT-tag data. Based on the PIT tag interrogation rate of nonmigrant steelhead and the number of steelhead remaining in the pond (calculated from the fish counter counts) in 1999, we estimated that a maximum of 29% (8,940) of the steelhead remaining in the pond were residual steelhead. Conversely, by detaining all nonmigrants and using them in resident fishing ponds, a minimum of 71% (21,888) of the steelhead smolts that would have immigrated, at least to the downstream dams, were prevented from doing so. Fishery managers must determine if retaining a population comprised of up to 70% smolts will impede efforts to sustain fishing opportunity on hatchery B-run steelhead in the upper Salmon River.

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INTRODUCTION

In 1991, the National Marine Fisheries Service (NMFS) listed Snake River sockeye salmon *Oncorhynchus nerka* as endangered under the Endangered Species Act, and in 1992 listed Snake River spring, summer and fall chinook *O. tshawytscha* as threatened (NMFS 1995). Snake River steelhead *O. mykiss* were listed as threatened in 1997. Sockeye and spring/summer chinook salmon are present in the upper Salmon River drainage upstream of the Pahsimeroi River where the Idaho Department of Fish and Game (IDFG) stocks hatchery steelhead annually. The stocking of hatchery steelhead in waters inhabited by listed species warrants evaluation to ensure negative interactions such as competition for food and space, predation (Miller 1958, Bachman 1984, Vincent 1987), and the spread of disease (Ratliff 1981) are minimized.

One way to limit the effects of hatchery steelhead on listed species is to reduce the number of nonmigrating (residual) steelhead released. Viola and Schuck (1995) developed a fish stocking technique that was effective in significantly reducing the number of hatchery steelhead residuals released into the Tucannon River, Washington. They found that steelhead smolts and residuals segregated themselves if liberated into an acclimation pond and then permitted to emigrate volitionally. Steelhead that failed to emigrate, defined as residuals by Viola and Schuck, were not released into the river. A majority of the residuals were precocial males. Viola and Shuck (1995) reported that the proportion of the steelhead released into the Tucannon River from the Curl Lake acclimation pond that were residuals (3.1%) was significantly lower than the proportion which resulted from a direct stream release (14.0%).

In Idaho, Rhine et al. (2000) applied a variation of the stocking technique mentioned above to hatchery steelhead acclimated in raceways at Sawtooth Fish Hatchery. Raceways at Sawtooth Fish Hatchery are constructed in a series; the water flows from upper raceways to lower raceways. Acclimated steelhead that volitionally emigrated from upper raceways were recaptured and detained in lower raceways. Some of the steelhead that emigrated (migrants) from upper raceways were detained until May 15, when the study was terminated. At that time, migrants and nonmigrants (steelhead that had failed to emigrate from upper raceways) were tagged with passive integrated transponder (PIT) tags and released into the Salmon River. Rhine et al. (2000) found that the PIT tag interrogation rate at downstream dams for migrant steelhead was significantly higher than for nonmigrant steelhead. However, about 30% of the nonmigrants tagged with PIT tags were still interrogated at downstream dams. Rhine et al. (2000) suggested that volitionally releasing steelhead from ponds, rather than raceways, may provide a better separation of true smolts and residual steelhead.

This was the second year of a study, initiated in 1998, which evaluated the volitional release of hatchery steelhead from Squaw Creek acclimation pond. We hoped that we could duplicate Viola and Schuck's (1995) results and thereby reduce the number of residual steelhead entering the Salmon River where they could potentially have a negative impact on listed salmon and steelhead. Residual steelhead would be detained in the pond to provide fishing opportunities for the public. The use of Squaw Creek Pond meets the guidelines for reducing risks to Snake River listed species caused by Columbia River basin hatchery programs noted by NMFS in several documents, including their predecisional recovery plan for Snake River salmon and the 1994-1998 Biological Opinion for hatcheries in the Columbia River basin.

GOAL

The goal of this study was to determine if the number of residual hatchery steelhead entering the Salmon River could be reduced by utilizing a release strategy that included volitional release, acclimation, and the retention of nonmigrant steelhead.

OBJECTIVES

The objectives of this study were to:

1) Describe the characteristics of the steelhead population before emigration.

2) Describe the characteristics of migrant steelhead.

3) Describe the characteristics of nonmigrant steelhead.

4) Evaluate the interrogation rates and migration timing of migrant, nonmigrant, captive, and production steelhead.

5) Evaluate emigration timing in relation to water temperature.

6) Compare two different methods of estimating the number of emigrants from Squaw Creek Pond—electronic fish counter and a mark-recapture estimate.

7) Determine if precocial development in steelhead is complete in April.

STUDY AREA

The steelhead used for this study were reared at Magic Valley Fish Hatchery and trucked to Squaw Creek Pond. Magic Valley Fish Hatchery is located in southeast Idaho, approximately 12 km northwest of Filer. Squaw Creek Pond is a man-made, earthen pond located adjacent to Squaw Creek, approximately 1 km upstream from its confluence with the Salmon River (Figure 1). Squaw Creek joins the Salmon River approximately 5 km west of Clayton, Idaho. Idaho Department of Fish and Game constructed the pond in 1997 as an acclimation pond for steelhead smolts and as a fish-out pond for stocked rainbow trout using monies from NMFS award #NA67FH0092 and the IDFG steelhead tag fund. Squaw Creek Pond has a surface area, mean depth, and volume of approximately 4,047 m^2, 1.2 m, and 4,934 m^3, respectively. Water is supplied to the pond from Squaw Creek via a 38 cm, valved polyvinyl chloride pipe. The outlet structure and tailrace are constructed of cement. Two-inch channels, recessed in the concrete walls of the outlet channel, support screens and dam boards.

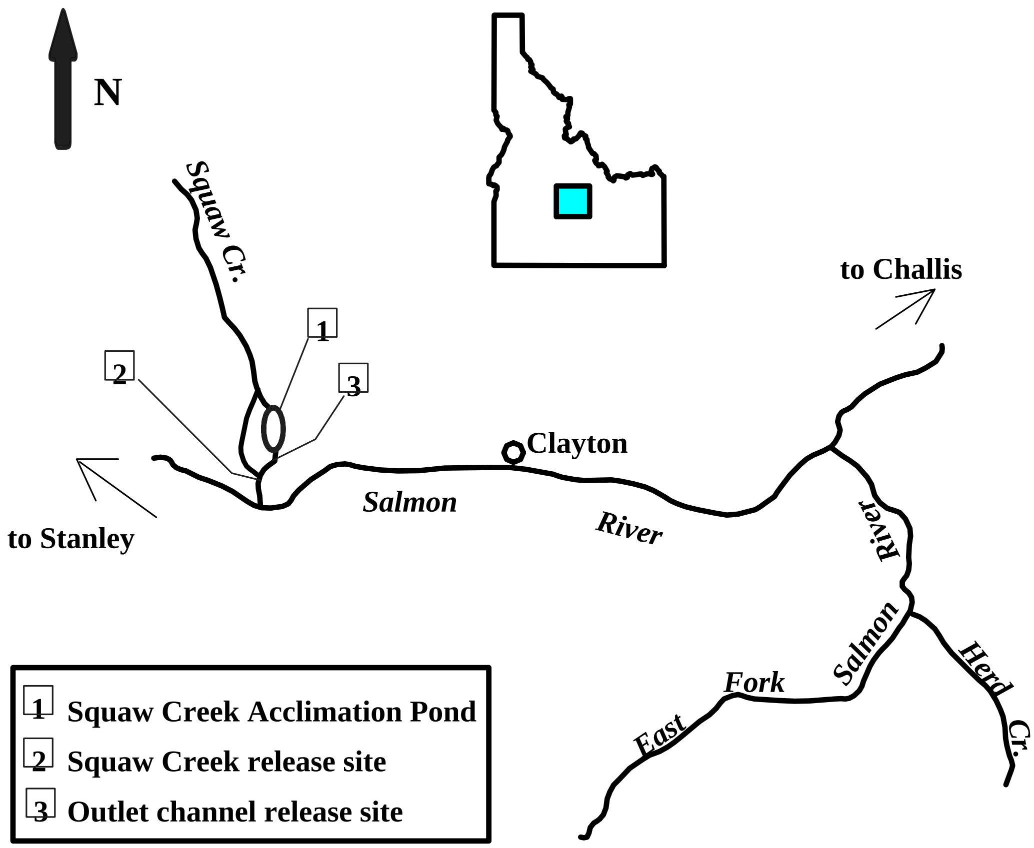

Figure 1. Location of hatchery steelhead release sites on Squaw Creek, Idaho.

METHODS

Pre-emigration Data

Dworshak B-stock steelhead from the 1998 brood were used for the study. Eggs were collected at Dworshak National Fish Hatchery, Idaho, located on the North Fork of the Clearwater River, and shipped to Magic Valley Fish Hatchery as eyed eggs in June 1998. Steelhead were reared in raceways until April 1999. Prior to being trucked to Squaw Creek Pond (March 30), steelhead were crowded and a random sample was collected using a dip net. Steelhead were taken off of feed two days prior to sampling. Sampled steelhead were euthanized, measured (FL, mm), weighed (g), sexed, and examined for sexual maturity. Steelhead with enlarged gonads were classified as sexually mature (i.e., precocious). Means for length, weight, and condition factor (K = weight/length^3 x 100,000) were calculated for the population.

Squaw Creek Pond Operations

A total of 95,995 steelhead was stocked into the pond—19,200, 40,100, and 36,695 on April 7, 8, and 12, respectively. A screen was placed in front of the outlet to prevent fish from immediately exiting the pond. The water flow was initially set at 2.2 cubic feet per second (cfs) but varied throughout the study. Pond inflow was increased on several occasions to stimulate emigration and was decreased during periods of high run-off. Water temperatures at the inlet and outlet were recorded each morning and afternoon. An average daily water temperature was calculated for each location. Daily record keeping for the pond included: the number of mortalities, weather conditions, presence of predators, and the presence of ice on the pond. Steelhead were fed a maintenance diet of Rangen's dry extruded 3.0 mm commercial fish food until May 20. Feeding was discontinued on May 21 to stimulate steelhead to emigrate from the pond.

On April 16 the outlet screen was removed and the fish counting system was activated. The water level of the pond remained the same for the first six days that emigration was permitted (4/16-4/21). On April 21, the water level was lowered four inches by removing one dam board from the outlet channel. One dam board was removed every five to six days until May 12 (4/27, 5/2, 5/7, 5/12). One dam board was also removed on May 23. Although the counters remained in place to monitor emigration, data collection for the study concluded on May 26.

Captive Population

Steelhead (n=4,100) from the prestocking population at Magic Valley Fish Hatchery was used to document precocial development over time in a captive population. Data from the captive population were used to determine whether precocial development was complete on March 30 or if the number of precocial fish increased after that date. This information will be used to determine if an observed change in the precocity rate of nonmigrants in Squaw Creek Pond could be attributed to volitional emigration of "smolts" or to the temporal aspects of precocial development.

Steelhead were transported to Sawtooth Fish Hatchery on April 12 and remained in raceway 6 until they were transported and released into the outflow channel of Squaw Creek Pond on May 26. Data were collected from the captive population on April 28 and May 26 using the methods described for the pre-emigration data. Steelhead with enlarged gonads were classified as sexually mature (i.e., precocious). Means for length (mm), weight (g), and condition factor (K) were calculated for the population. Chi-square test of independence with the Yates correction for continuity (Zar 1984) was used to test for differences between the proportion of precocial males in the prestocking sample collected at Magic Valley Fish Hatchery (raceway 15, March 30) and the final sample collected at Sawtooth Fish Hatchery (May 26).

Fish Emigration

Fish Counter

A Smith-Root fish counter, Model SR-1601, (Smith-Root, Inc., Vancouver, WA. 98686) was installed in the outflow channel of Squaw Creek Pond and tested prior to stocking. Counting tubes were attached through an aluminum dam board, which was placed into slots in the tailrace walls. Each aluminum dam board contained four, 3-inch counting tubes; the entire board is referred to as a bank of counters. Counters were checked for accuracy by forcing a known number of steelhead through the counters prior to starting the experiment. To further test the accuracy of the counters, two banks of counters were placed in a series in the tailrace to double count the number of emigrating steelhead. That is, steelhead traveling through the first bank of counters would be counted a second time as they passed through the second bank of counters.

The number of steelhead counted by each counting tube was recorded two times in each 24-hour period (approximately 0800 hours and 2000 hours). The number of steelhead emigrating at night (defined as the period of time between the morning count and the evening count of the previous day) was compared to the number of steelhead that emigrated during the day (defined as the period of time between the morning count and the evening count of the same day). Fish counters were reset after each count was recorded. The total number of steelhead that emigrated from Squaw Creek Pond was calculated for each bank of counters by summing the diel counts for each counting tube. Steelhead that were diverted and collected in the holding area for PIT-tagging were enumerated and added to the emigration total for that day. The percentage of steelhead that emigrated from the pond was calculated by dividing the number of steelhead that emigrated by the number of steelhead that were stocked, multiplied by 100. Linear regression was used to identify correlations between steelhead emigration and average water temperature of the pond. The number of steelhead counted by the fish counter tunnels was compared to the population estimate from the mark-recapture study.

Mark-Recapture Study

A direct sampling mark-recapture technique (Scheaffer et al. 1990) was used to estimate the number of non-migratory steelhead remaining in Squaw Creek Pond on May 26, the date the study was terminated. Based on observations of other Snake River stocks, we assumed a 15% residualism rate (Kent Ball, IDFG, personal communication). Therefore, approximately 14,400 steelhead were expected to be in the pond on May 26. To ensure an estimate within 80% of the population, IDFG personnel collected 8,964 steelhead from the pond using a beach seine and marked each fish with an upper caudal fin clip. Marked steelhead were returned to the pond and the population was resampled. The estimated number of steelhead remaining in the pond was compared to the number calculated using the fish counter method.

PIT Tagging of Migrant, Nonmigrant, Captive, and Production Steelhead

PIT tags were used to evaluate emigration success to dams located on the Snake and Columbia rivers. Three different groups of steelhead were PIT tagged at Squaw Creek Pond. Two of the groups were steelhead that emigrated from the pond; these were defined as early and late migrants based on the time of emigration. The other group of tagged fish were steelhead that did not volitionally emigrate from the pond by May 26; these were defined as nonmigrants.

During evenings before collecting migrant steelhead for PIT tagging (May 9 and May 25 for the early and late migrant groups, respectively), the fish counting banks were removed from the outflow channel and replaced by screens. Steelhead were allowed to migrate at night into a holding area via a diversion pipe. A total of 300 steelhead was collected on May 10 (early migrants) and 303 steelhead were collected on May 26 (late migrants) from the holding area with a dip net and transported to the PIT-tagging station in buckets where they were placed in a tricaine methanesulfonate (MS-222) anesthetic bath and PIT tagged (Prentice et al. 1990). Fork length (mm), weight (g), and other pertinent information, such as precocity, were recorded for each steelhead that was tagged. Tagged steelhead were allowed to recover in fresh water before being released into the outflow channel immediately downstream of the screen. All migrant steelhead remaining in the holding area after tagging were enumerated and released in the outflow channel immediately downstream of the screen. All mortalities were scanned for PIT tags and flagged in the tagging files. Tag files were submitted to the Columbia River Basin PIT Tag Information System (PTAGIS) (Pacific States Marine Fisheries Commission 1998).

Two groups of PIT-tagged production steelhead were released near Squaw Creek Pond on May 10 to compare emigration rates between the early migrant group and general production releases under similar migration conditions. Three hundred PIT-tagged steelhead were released into Squaw Creek proper and 300 were released into the outlet channel of Squaw Creek Pond. Both groups of Dworshak B-stock steelhead were reared at Magic Valley Fish Hatchery and were PIT tagged on March 2, 1999. The general production PIT tag group released in the outlet channel of Squaw Creek Pond was part of approximately 100,000 juvenile steelhead released at that site on May 10. Due to the small size of the channel, we feel that this group may have encountered problems associated with crowding. Therefore, interrogation and travel time information for this group (Tag File=TDR99061.01E) was mentioned but not included in the analyses. In addition, 300 steelhead from the captive population (described earlier in this report) were tagged with PIT tags and released into the outlet channel of Squaw Creek Pond on May 10. Steelhead PIT tagged from the captive population will be, hereafter, referred to as the captive group.

On May 26, a screen was placed in the outflow channel upstream of the diversion pipe to stop all emigration from the pond. Steelhead remaining in the pond at that point were classified as nonmigrants. On May 26, a random sample of nonmigrant steelhead (n=299) was collected from the pond using a beach seine and transported to the PIT-tagging station in a live well. The PIT tagging, data collection, and fish release methods for nonmigrants were as described above. PIT tag files were submitted to PTAGIS.

The number of fish interrogated for each group (e.g., early migrants, late migrants, nonmigrants, captive group, and production groups) was determined by querying the PTAGIS database in August. Interrogation systems for PIT-tagged fish are located at Lower Granite, Little Goose, and Lower Monumental dams on the lower Snake River and at McNary, John Day, and Bonneville dams on the Columbia River. The rate at which PIT-tagged steelhead were interrogated was calculated by dividing the total number of unique interrogations at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams by the number of PIT-tagged steelhead released, multiplied by 100. Median travel time to Lower Granite Dam was calculated for each group (early and late migrant, nonmigrant, captive group, and production groups). All data analyses were performed using SYSTAT (SYSTAT 1996) and tested at the 0.05 significance level. Chi-square test of independence with the Yates correction for continuity (Zar 1984) was used to determine if there was a significant difference in interrogation rates between late migrants and nonmigrants. The Mann-Whitney test was used to test for a significant difference in travel time to Lower Granite Dam between late migrants and nonmigrants. Chi-square test of independence with the Yates correction for continuity was used to test for differences in the interrogation rates of PIT-tagged steelhead in the early migrant, captive, and general production release groups; a Tukey-type multiple comparison was used to detect significant differences between groups (Zar 1984). The Kruskal-Wallis test was used to test for significant differences in the travel time to Lower Granite Dam between PIT-tagged steelhead from the early migrant, captive, and production groups. The PIT tag interrogation rate of the early migrants was not tested against interrogation rates of the late and nonmigrant groups since these steelhead were released at a different time and, thus, experienced different migration conditions.

For PIT-tagged steelhead, mean fork length (mm), weight (g), and condition factor (K) were calculated for each group (early migrants, late migrants, nonmigrants, and the captive group). Data were checked for normality. Significant differences in fork length, weight, and condition factor between late migrants and nonmigrants were tested using a *t-test* or the Mann-Whitney test, depending on normality.

Nonmigrant Data

On May 26, a random sample of nonmigrant steelhead was collected from the pond using a beach seine. Steelhead (n=140) were randomly selected and euthanized. Descriptive data for nonmigrant steelhead were collected and analyzed as described for pre-emigration data. The chi-square test of independence with the Yates correction for continuity (Zar 1984) was used to test for differences between the sex composition of steelhead classified as nonmigrants and the prestocking population. The chi-square test was also used to determine if the number of precocial males differed significantly between the prestocking population and steelhead classified as nonmigrants.

RESULTS

Pre-emigration Data

On March 30, 300 juvenile steelhead were collected at Magic Valley Fish Hatchery. Mean length, weight and condition factor (n = 295) were 223 mm, 112 g, and 0.98, respectively (Table 1). Appendix A shows the length frequency distribution of steelhead sampled from Magic Valley Fish Hatchery on March 30. The sample was comprised of 53.7% (161) females and 46.3% (139) males (Table 1). Precocious males (n=7) made up 2.3% of the total sample (males and females, n=300) and 5.0% of the male component of the sample (n=139) (Table 1). Mean length, weight, and condition factor for the precocial males in the sample (n=6) were 201 mm, 86 g, and 1.05, respectively. Mean length, weight, and condition factor for the nonprecocial males in the sample (n=131) were 222 mm, 110 g, and 0.98, respectively.

Table 1. Summary statistics and sex characteristics for steelhead sampled at Magic Valley Fish Hatchery, March 30, 1999.

SAMPLE STATISTICS			
Variable	**N[a]**	**Mean**	**SD**
Fork Length (mm)	295	223.37	18.31
Weight (g)	295	111.51	27.62
Condition Factor (K)	295	0.98	0.05
SEX COMPOSITION			
Sex	**N**	**Percent**	
Female	161	53.7	
Male	139	46.3	
PRECOCITY			
Sample	**Number Sampled**	**Number Precocial[b]**	**Percent Precocial**

Total (Males + Females)	300	7	2.3
Males Only	139	7	5.0

[a] Five observations were omitted from these analyses due to suspected erroneous lengths and/or weights.
[b] All precocial fish were males.

Captive Population

On May 26, 138 juvenile steelhead were randomly selected from the captive population at Sawtooth Fish Hatchery and euthanized. Mean length, weight, and condition factor were 236 mm, 130 g, and 0.98, respectively (Table 2). The sample was comprised of 50% (69) females and 50% (69) males (Table 2). Precocious males (n=4) made up 2.9% of the total sample (males and females, n=138) and 5.8% of the male component of the sample (n=69) (Table 2). Mean length, weight, and condition factor for the precocial males in the sample (n=4) were 247 mm, 171 g, and 1.12, respectively. Mean length, weight, and condition factor for the nonprecocial males in the sample (n=65) were 238 mm, 131 g, and 0.96, respectively. The proportion of precocial males in the captive population on May 26 was not significantly different (χ^2=0.0, P=1.000) than the prestocking population on March 30.

Table 2. Summary statistics and sex characteristics for steelhead sampled at Magic Valley Fish Hatchery (MVFH) and Sawtooth Fish Hatchery (SFH) on March 30 and May 26, respectively. All steelhead were reared in raceway 15E at MVFH, and a portion were transported to SFH on April 12.

	SAMPLE DATE					
SAMPLE STATISTICS	**March 30 (MVFH)**			**May 26 (SFH)**		
Variable	**N[a]**	**Mean**	**SD**	**N**	**Mean**	**SD**
Fork Length (mm)	147	223.71	18.22	138	235.92	19.07
Weight (g)	147	111.24	27.44	138	130.38	32.51
Condition Factor (K)	147	0.98	0.05	138	0.98	0.07
SEX COMPOSITION						
Sex	**N**	**Percent**		**N**	**Percent**	
Female	81	54.0		69	50.0	
Male	69	46.0		69	50.0	
PRECOCITY						
Sample	**No. Sampled**	**No. Precocial[b]**	**Percent Precocial**	**No. Sampled**	**No. Precocial[b]**	**Percent Precocial**
Total (Males + Females)	150	3	0.7	138	4	2.9
Males Only	69	3	1.4	69	4	5.8

[a] Three observations were omitted from these analyses due to suspected erroneous lengths and/or weights.
[b] All precocial fish were males.

Fish Emigration

Fish Counter

The first bank of counters in the tailrace counted 79,260 steelhead, while the second bank of counters counted 65,114 steelhead. We chose to use the number from the second bank of counters. Although the study was terminated on May 26, the fish counters remained in place until June 3 to monitor emigration from the pond. According to the numbers recorded by the first bank of counters, 5,738 steelhead remained in the pond on June 3 when the counters were removed. However, a minimum of 12,170 juvenile steelhead were seined from Squaw Creek Pond and transported to area reservoirs between June 3 and June 8 (Doug Engemann and Bob Esselman, Idaho Department of Fish and Game, personal communication). This is evidence that the numbers recorded by the first bank of counters were not accurate. We observed that the first bank of counters was partially submerged during periods of high flow. This may have allowed individual steelhead to swim back through the counters, thus being counted more than once.

A total of 65,114 steelhead (67.9%) emigrated from Squaw Creek Pond between April 16 and May 25, 1999 (Table 3). A total of 43,088 steelhead emigrated during the daytime period, whereas 22,026 emigrated during the nighttime period (Figure 2). Diel steelhead emigration ranged from 15 fish on April 22 to 20,969 fish on May 20 (Figure 3). A weak correlation was found between diel steelhead emigration and average daily water temperature (r^2=0.27, P=0.001).

Table 3. Chronological comparison of two methods used to inventory fish emigration from Squaw Creek Pond.

EVENT	FISH COUNTER	MARK-RECAPTURE
# Stocked (April 7-12)	95,995	95,995
# Mortalities	*- 53*	*- 53*
	95,942	95,942
# Emigrated (April 16 - May 25)	*- 65,114*	*-61,001*[a]
# Remaining in Squaw Pond[b] (May 26)	**30,828**	**34,941**

[a] This number was derived following the mark-recapture study (95,942 - 34,941 = 61,001).
[b] Estimated number at the time of the mark-recapture study.

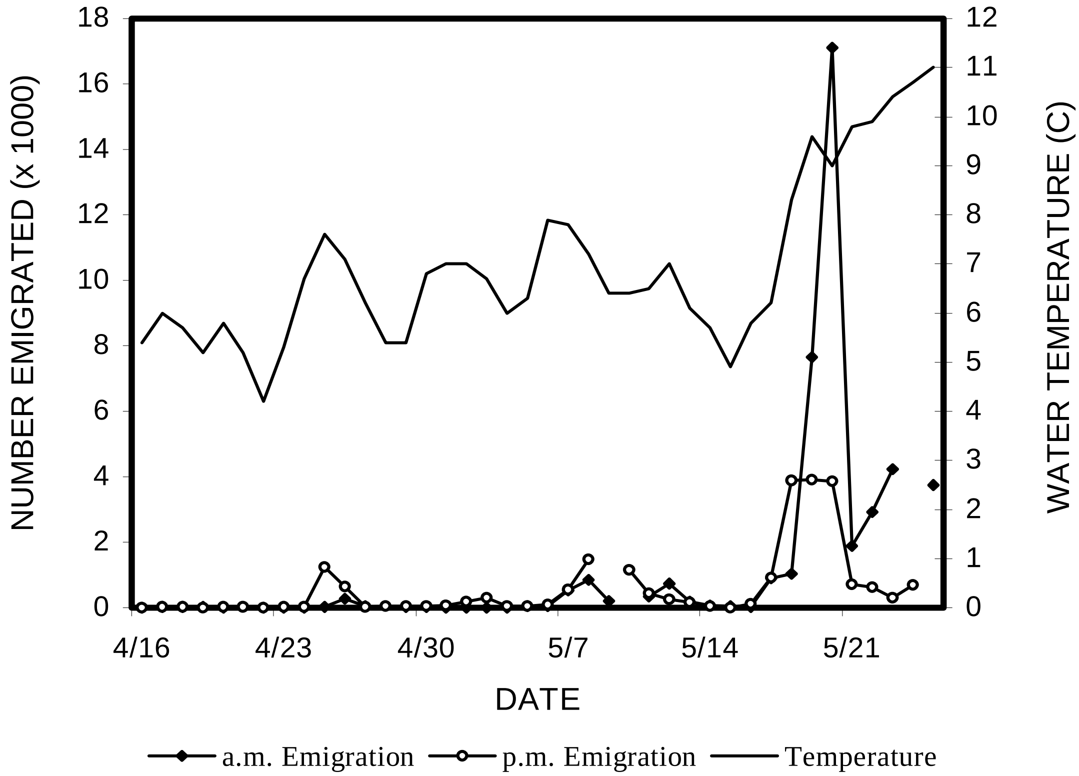

Figure 2. Fish emigration during the day (the period of time between the morning count and the evening count of the same day) and night (the period of time between the morning count and the evening count of the previous day) time periods, plotted with the average daily water temperature of Squaw Creek Pond between April 16 and May 25, 1999.

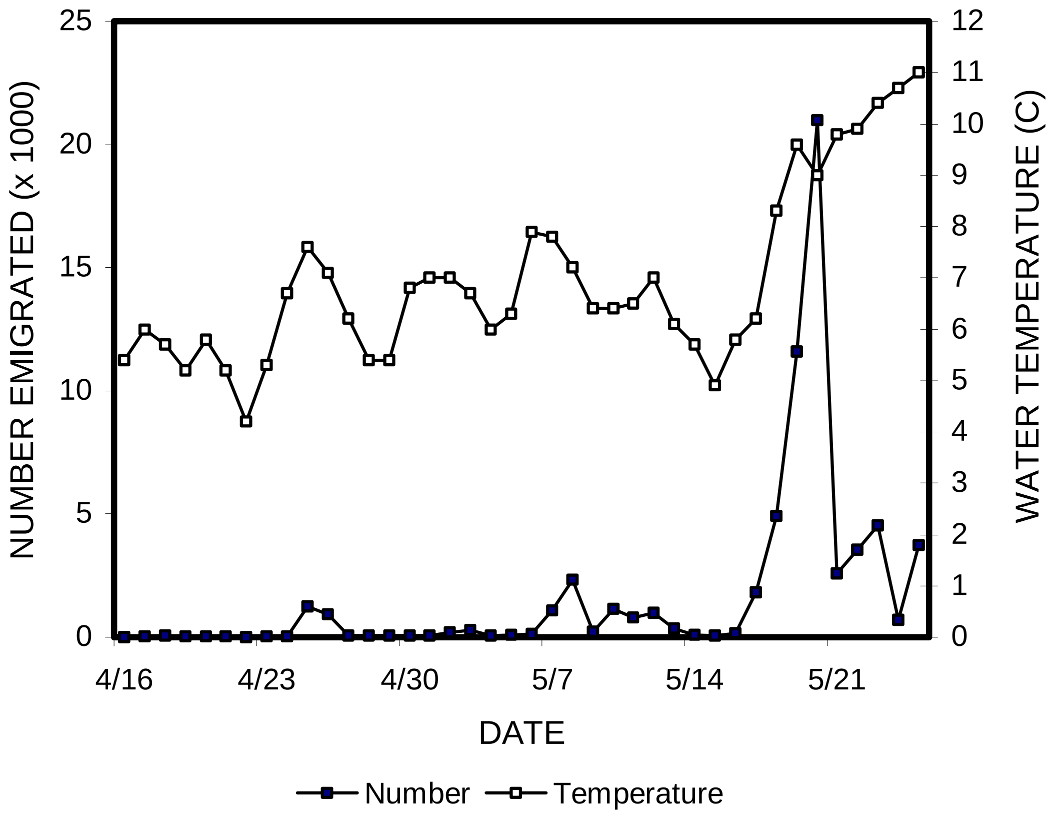

Figure 3. Diel fish emigration, plotted with average daily water temperature of Squaw Creek Pond, between April 16 and May 25, 1999.

Mark-Recapture Study

We estimated using the mark-recapture technique that 34,941 $\pm$ 1,556 (95% C.I.) steelhead did not emigrate from Squaw Creek Pond. In comparison, we calculated (using counts from the second bank of counters) that 30,828 steelhead had not emigrated from the pond at the time that the mark-recapture estimate was performed (May 26) (Table 3).

PIT Tagging of Migrant, Nonmigrant, Captive, and Production Steelhead

A total of 300 early migrant, 297 late migrant, and 299 nonmigrant steelhead was tagged with PIT tags and released into the outlet channel below Squaw Creek Pond. Six steelhead from the late migrant group died before release. Steelhead classified as early migrants were released on May 10, and steelhead classified as late migrants and nonmigrants were released on May 26. In addition, 300 PIT-tagged steelhead from the captive population were released in the outlet channel, and 300 PIT-tagged general production steelhead were released into Squaw Creek proper; both groups were released on May 10. To compare migration success and timing under similar conditions, PIT-tagged steelhead from the early migrant group were compared to the captive and general production groups, and steelhead from the late migrant group were compared to the nonmigrant group. Approximately 52.7% (158) of the early migrants, 65.7% (195) of the late migrants, 70.6% (211) of the nonmigrants, 74.7% (224) of the captives, and 63.0% (189) of the general production steelhead were interrogated at downstream dams (Table 4). Interrogation rates of late migrants and nonmigrants were not significantly different (χ^2=1.44, P=0.231) (Table 5). Steelhead from the nonmigrant group had significantly (P=0.001) shorter travel time to Lower Granite Dam than steelhead from the late migrant group. Interrogation rates of steelhead from the early migrant, captive, and production groups were significantly different (χ^2=31.34, P<0.001). Steelhead from the captive group were interrogated at a significantly (P≤0.05) higher rate than steelhead from the production and early migrant groups (Table 5). Steelhead from the production group were interrogated at a significantly (P≤0.05) higher rate than steelhead from the early migrant group (Table 5). Travel time to Lower Granite Dam was significantly greater for steelhead from the captive group as compared to the early migrant and production groups. Travel time to Lower Granite Dam was not significantly different between steelhead in the early migrant and production groups.

Mean daily inflow and spill of the Snake River at Lower Granite Dam ranged from approximately 80 to 180 thousand cubic feet per second (kcfs) and 30 to 80 kcfs, respectively, during emigration of steelhead in the early migrant, captive, and production groups (Figure 4). Mean daily inflow and spill of the Snake River at Lower Granite Dam ranged from approximately 110 to 180 kcfs and 40 to 80 kcfs, respectively, during emigration of steelhead in the late migrant and nonmigrant groups (Figure 4).

Descriptive statistics for length, weight, and condition factor of PIT-tagged steelhead from the early migrant, late migrant, nonmigrant, and captive groups are shown in Table 6. Length frequency distributions of PIT-tagged steelhead from the early migrant, late migrant, nonmigrant, and captive groups are shown in Appendix B, Appendix C, Appendix D, and Appendix E, respectively. Steelhead from the late migrant group were significantly longer (P=0.001) and heavier (P=0.001) than steelhead from the nonmigrant group. Mean condition factors for steelhead from the late migrant and nonmigrant groups were not significantly different (P=0.385). Precocial males comprised 2.0% (n=6), 2.9% (n=9), and 2% (n=6) of the early migrant, late migrant, and nonmigrant PIT tag groups, respectively. Precocial males comprised <1% (n=1) of the captive PIT tag group.

Table 4. Number of unique interrogations of PIT-tagged steelhead released at or near Squaw Creek Pond in 1999. PIT tag interrogation sites are Lower Granite (GRJ), Little Goose (GOJ), Lower Monumental (LMJ), McNary (MCJ), John Day (JDJ), and Bonneville (B2J, BVX, BVJ) dams. Median travel time is to Lower Granite Dam only.

File Name	Release Site	Rel. Date	No. Rel.	Number Interrogated Per Site: GRJ	GOJ	LMJ	MCJ	JDJ	B2J	BVX	BVJ	TOTAL No.	TOTAL %	Median Travel Time (Days)
Production Comparison Groups (Direct Release)														
TDR99061.12E	Squaw Creek	5/10	300	84	58	35	3	5	2	2	0	189	63.0	14.3
TDR99061.01E	Squaw Pond-Outlet	5/10	300	75	41	29	3	3	0	1	0	152	50.7	15.8
Captive Population (Transported to Sawtooth FH on 4/12)														
TDR99130.SQ1	Squaw Pond-Outlet	5/10	300	89	78	39	5	8	2	3	0	224	74.7	15.7
Early Migrant Group														
TSC99130.SQ1	Squaw Cr. Pond	5/10	300	66	54	32	2	4	0	0	0	158	52.7	14.3
Late Migrant Group														
TSC99146.SQ2	Squaw Cr. Pond	5/26	297	80	93	20	0	2	0	0	0	195	65.7	8.0
Non-migrant Group														
TSC99146.SQ3	Squaw Cr. Pond	5/26	299	95	89	27	0	0	0	0	0	211	70.6	6.4

Table 5. Interrogation rates of five groups of PIT-tagged steelhead released at or near Squaw Creek Pond in 1999. Chi-square analysis was used to identify significant differences in interrogation rates among the early migrant, captive, and production groups and between the late migrant and nonmigrant groups. A Tukey-type multiple comparison was used to identify significant differences between the early migrant, captive, and production groups. Interrogation rates not followed by the same letter indicate a significant ($P \leq 0.05$) difference among groups.

Group	**Release Date**	**Number Released**	**Number Interrogated**	**Percent Interrogated**
Early Migrant	5/10	300	158	52.7 A
Captive	5/10	300	224	74.7 B
Production	5/10	300	189	63.0 C
Late Migrant	5/26	297	195	65.7 A
Nonmigrant	5/26	299	211	70.6 A

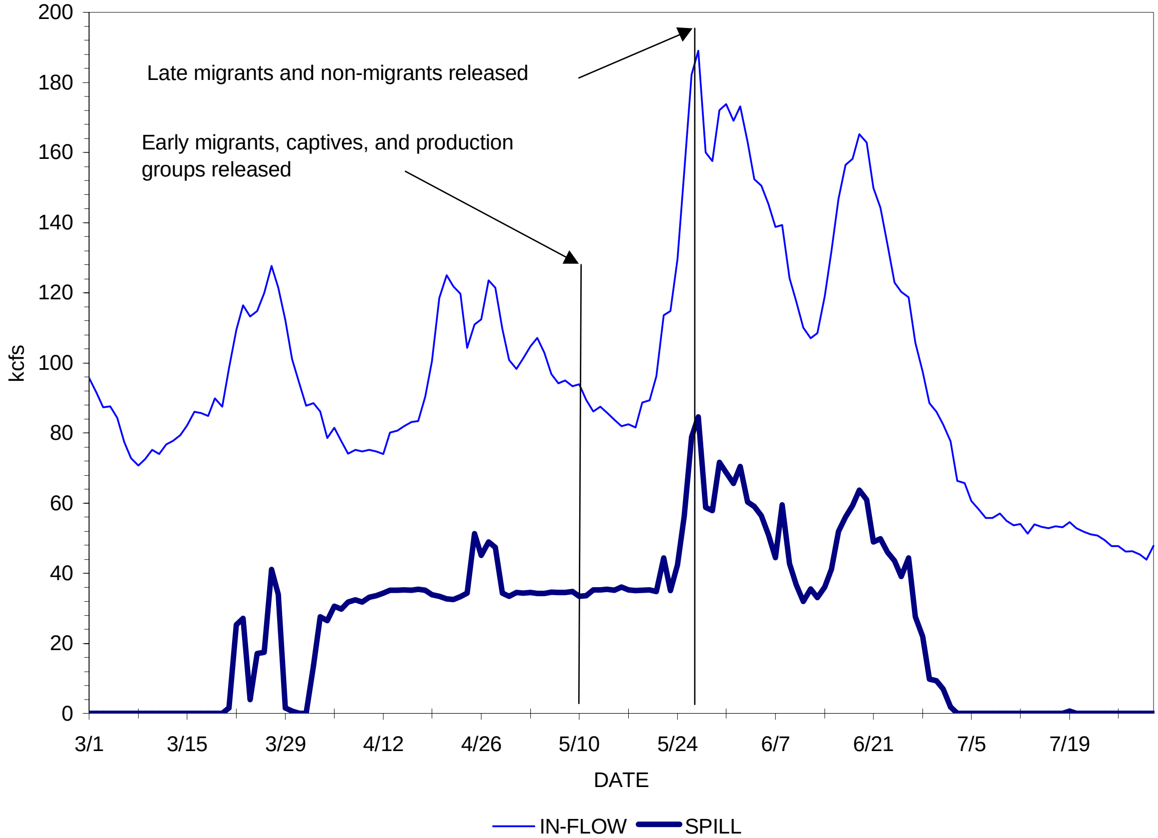

Figure 4. Mean daily inflow and spill of the Snake River at Lower Granite Dam, Washington, between March 1 and July 31, 1999. Steelhead from the early migrant group and the captive population (Sawtooth FH) were PIT tagged and released on May 10, whereas steelhead from the late migrant and nonmigrant groups were PIT tagged and released on May 26. Steelhead from the general production groups were also released on May 10 but were PIT tagged on March 2.

Nonmigrant Data

On May 26, 140 juvenile steelhead were randomly selected from Squaw Creek Pond and euthanized. Data for three steelhead were omitted from the analyses due to suspected erroneous lengths and/or weights. Mean length, weight, and condition factor (n=137) were 230 mm, 111 g, and 0.89, respectively (Table 7). Appendix F shows the length-frequency distribution of nonmigrant steelhead sampled at Squaw Creek Pond on May 26, 1999. The sample was comprised of 50.7% (71) males and 49.3% (69) females (Table 7). The sex composition of the nonmigrant steelhead did not differ significantly (χ^2=0.569, P=0.451) from the prestocking population sampled at Magic Valley Fish Hatchery on March 30. Precocial males (n=4) made up 2.9% of the total sample (males and females, n=140) and 5.6% of the male component of the sample (n=71) (Table 7). Steelhead classified as nonmigrants had a significantly higher (χ^2=0.000, P=1.000) proportion of precocial males than the prestocking population at Magic Valley Fish Hatchery. Mean length, weight, and condition factor for the precocial males in the sample (n=4) were 250 mm, 160 g, and 0.98, respectively. Mean length, weight, and condition factor for the nonprecocial males in the sample were 226 mm (n=65), 103 g (n=67), and 0.89 (n=65), respectively.

Table 6. Descriptive statistics, by group, of PIT-tagged steelhead released from Squaw Creek Pond in 1999.

Group	Fork Length (mm)	Weight (g)	Condition Factor (K)
Early Migrants			
n	300.00	300.00	300.00
Mean	226.35	106.78	0.90
SD	22.50	31.49	0.06
Captives			
n	298.00	287.00	285.00
Mean	230.66	119.76	0.98
SD	19.95	27.74	0.06
Late Migrants			
n	297.00	296.00	296.00
Mean	232.46	110.95	0.86
SD	22.05	30.88	0.05
Nonmigrants			
n	299.00	296.00	296.00
Mean	227.03	103.16	0.87
SD	18.57	25.56	0.06

Table 7. Summary statistics and sex characteristics for nonmigrant steelhead sampled at Squaw Creek Pond, May 26, 1999.

SAMPLE STATISTICS			
Variable	**N[a]**	**Mean**	**SD**
Fork Length (mm)	137	229.99	19.92
Weight (g)	137	110.62	30.57
Condition Factor (K)	137	0.89	0.09
SEX COMPOSITION			
Sex	**N**	**Percent**	
Female	69	49.3	
Male	71	50.7	
PRECOCITY			
Sample	**Number Sampled**	**Number Precocial[b]**	**Percent Precocial**
Total (Males + Females)	140	4	2.9
Males Only	71	4	5.6

[a] Three observations were omitted from these analyses due to suspected erroneous lengths and/or weights.
[b] All precocial fish were males.

Nonmigrant Steelhead Disposition

A minimum of 12,170 juvenile steelhead were collected from Squaw Creek Pond and transported to Hayden Pond and Mosquito Flat Reservoir. Personnel from Pahsimeroi Fish Hatchery transported 1,600 steelhead to Hayden Pond on June 3 and 1,570 steelhead to Mosquito Flat Reservoir on June 8. Personnel from Hayspur Fish Hatchery transported 4,500 steelhead to Hayden Pond on June 3 and 4,500 steelhead to Mosquito Flat Reservoir on June 8. Additional steelhead were removed from Squaw Creek Pond; however, numbers and stocking location were not recorded by field personnel. The remaining nonmigrant steelhead were retained in the pond for a catch-out fishery.

DISCUSSION

Using PIT tags as our main evaluation tool, we found that this release strategy was unsuccessful at separating smolts from residual steelhead at Squaw Creek Pond for a second consecutive year. In 1998 (Osborne and Rhine 2000) and 1999 (the present study), PIT tag interrogation rates between the late migrants and nonmigrants did not differ significantly. In 1999, descriptive statistics for each group, particularly the sex composition data, added supporting evidence to our inference that late migrants were no different than nonmigrants. Viola and Schuck (1995) defined the steelhead that failed to volitionally emigrate from Curl Lake acclimation pond, Washington, as residuals and described them as being larger than average and primarily males. In 1999, steelhead we classified as late migrants in Squaw Creek Pond were significantly longer and heavier than nonmigrants. Moreover, for both years of the study we found that the sex composition of the nonmigrant population was not significantly different than that of the prestocking population. These data add some support to the results obtained from PIT tags; however, it is not overwhelming evidence, particularly when the precocity rate of the nonmigrants is considered.

In the present study, the rate of precocity was significantly lower in the prestocking population as compared to the population of nonmigrants. This would suggest that the release technique did work and that precocial males were detained in the pond. A contrary explanation of these data would be that precocial development was incomplete on March 30, 1999 (the date baseline data were collected) and that more fish became precocial by May 26, 1999 (the end of the study). However, we found no significant difference between the precocity rate of steelhead in the captive population at Sawtooth Fish Hatchery (sampled on May 26) and the prestocking population at Magic Valley Fish Hatchery (sampled on March 30). We concluded that the proportion of precocial males in the population at Squaw Creek Pond changed due to emigration, rather than the timing of precocial development in conjunction with sample date.

The evidence presented above shows that migration performance was not significantly different between the late migrant and nonmigrant groups, and this finding is supported by some morphological statistics. In 1998, Osborne and Rhine (2000) found that the PIT-tagged steelhead from the early migrant group were interrogated at a higher rate than steelhead from the late migrant and nonmigrant groups. They suggested that the technique may have been initially effective at separating true smolts from residuals but became less effective over time. Since the three groups were not released at the same time, and thus experienced different migration conditions, it was inappropriate to test interrogation data for differences among groups. To explore the plausibility of this idea, they examined the migration conditions of the early migrant group with the late migrant and nonmigrant groups and contrasted interrogation data of the early migrant group to two groups of PIT-tagged fish reared at Magic Valley Fish Hatchery and released into the East Fork Salmon River. We conducted the same comparisons in 1999; however, the early migrants were compared to PIT tag groups released at Squaw Creek Pond rather than the East Fork Salmon River.

In 1998 (Osborne and Rhine 2000) and 1999, Snake River flow measured at Lower Granite Dam and the amount of water spilled over the dam were substantially higher during the emigration of the late migrant and nonmigrant groups as compared to early migrant group. This may explain the relatively low interrogation rates of the late migrant and nonmigrant groups in 1998. That is, the difference between interrogation rates between the early and late groups may have been due to PIT tag interrogation efficiencies related to water flow and dam operations (i.e., spill) rather than migration performance (Osborne and Rhine 2000). Although the interrogation rate of the early migrant group was lower than any of the late groups in 1999, interrogation rates of the late migrant and nonmigrant groups probably would have been even higher if not for the spill generated by the higher flows.

In 1999, we compared the PIT tag interrogation rate of the early migrant group to the interrogation rates of two other groups of steelhead reared at Magic Valley Fish Hatchery and released near Squaw Creek Pond. If migrational behavior was truly an indicator of whether the fish was a true smolt or residual, one would expect the interrogation rate of the Squaw Creek Pond early migrant group to be higher than that of a general production steelhead release where the PIT-tagged fish were randomly selected from the population. In fact, interrogation rates of both general production release groups were significantly higher than the interrogation rate of the early migrant group. Dworshak B-stock steelhead were released into Squaw Creek proper and the outlet channel of Squaw Creek Pond on May 10. Steelhead released into Squaw Creek and the outlet channel had interrogation rates of 63.0% and 74.7%, respectively. In contrast, the early migrant group released from Squaw Creek Pond on May 10 had an interrogation rate of 52.7%. We expected the early migrant group to vastly outperform the other two releases, but these results add to our suspicions that the technique was ineffective in separating smolts from residuals.

A total of 65,114 steelhead emigrated from the pond according to the fish counter, whereas the number derived by the mark-recapture estimate was 61,001. Appleby and Tipping (1991) used a Smith-Root Model SR-1600 fish counter (an older model of the counter we used) to count steelhead and sea-run cutthroat trout *O. clarki* and found the accuracy to be within 1.5% of hand counts. The count on the first bank of counters was substantially higher than that of the second bank—79,260 for the first bank and 65,114 for the second. We cannot explain the discrepancy between the two counts recorded by the counters; however, we chose to use the second bank of counters. Although the study was terminated on May 26, the counters remained in place until June 3 to monitor emigration from the pond. According to the numbers recorded by the first bank of counters, 5,738 steelhead remained in the pond on June 3 when the counters were removed. However, a minimum of 12,170 steelhead were seined from the pond and transported to area reservoirs between June 3 and June 8. This is evidence that the numbers recorded by the first bank of counters were not accurate. We observed that the first set of counting tubes was partially submerged during periods of high flow. Individual steelhead that moved through the first bank of counters had the opportunity to travel back through the counting tubes and be counted multiple times. We used the data from the second bank of counters so we could examine emigration timing in relation to water temperature and photoperiod. A weak correlation was found between diel steelhead emigration and daily average water temperature. In addition, approximately twice as many steelhead emigrated during the daytime period as compared to the nighttime period.

Using numbers from the second bank of fish counters, 30,828 steelhead remained in the pond at the end of the study (May 26). Based on the 71% interrogation rate of the nonmigrants that were PIT-tagged, a minimum of 21,888 of these steelhead were actually smolts that may have emigrated had they been released. Conversely, a maximum of 8,940 of the 30,828 steelhead remaining in the pond were residual steelhead (29% of the PIT-tagged nonmigrants were not interrogated) and were prevented from entering the Salmon River. Fishery managers must determine if retaining a population comprised of up to 70% smolts is warranted to remove residuals.

Based on our evaluations using PIT tag interrogation data, the release strategies employed in 1998 and 1999 were unsuccessful at separating smolts from residuals. A large proportion of the late-migrant and nonmigrant fish tagged still exhibited migration behavior characteristic of a smolt. This does not diminish the other benefits of using Squaw Creek Pond as a release site for hatchery steelhead. For instance, returning adult steelhead could be collected at the pond, which would reduce adult straying, improve hatchery documentation and evaluation, and provide an additional egg source. In addition, using Squaw Creek Pond as a release site may provide some operational benefits by providing a backup rearing location in case of disease outbreaks or catastrophic events at the hatchery.

RECOMMENDATIONS

1) Document the disposition of all steelhead used for the study, and continue to collect morphological data from nonmigrants before removing steelhead for catch-out fisheries.

2) Continue to record daily emigration counts at 0800 hours and 2000 hours to more accurately quantify emigration during each day and nighttime period.

3) Temper pond with well water in order to lengthen acclimation period before volitional release.

4) Schedule releases of production steelhead in Squaw Creek proper so that comparisons can be made between the early migrant and production groups under similar migration conditions.

5) Document precocial development of steelhead over time in a captive population to monitor temporal changes in the proportion of precocial fish.

ACKNOWLEDGMENTS

We would like to thank the personnel at Magic Valley Fish Hatchery for rearing the fish for this study and for their assistance with data collection. We would also like to thank Kent Ball, Tom Curet, Mike Larkin, and Sawtooth Fish Hatchery personnel for their efforts in pond operation and data collection. A word of thanks is also extended to the personnel from the Nampa Fishery Research Office for helping PIT tag fish for this study. We express our appreciation to the United States Fish and Wildlife Service, Lower Snake River Compensation Plan Office, for providing funding for this study.

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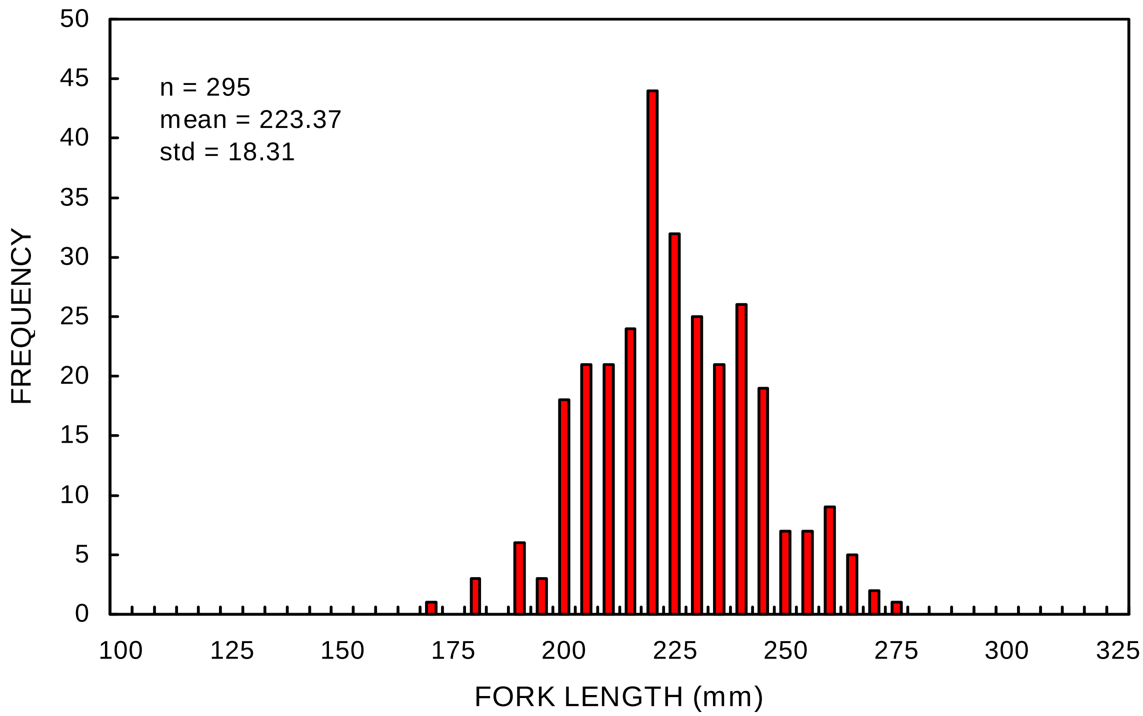
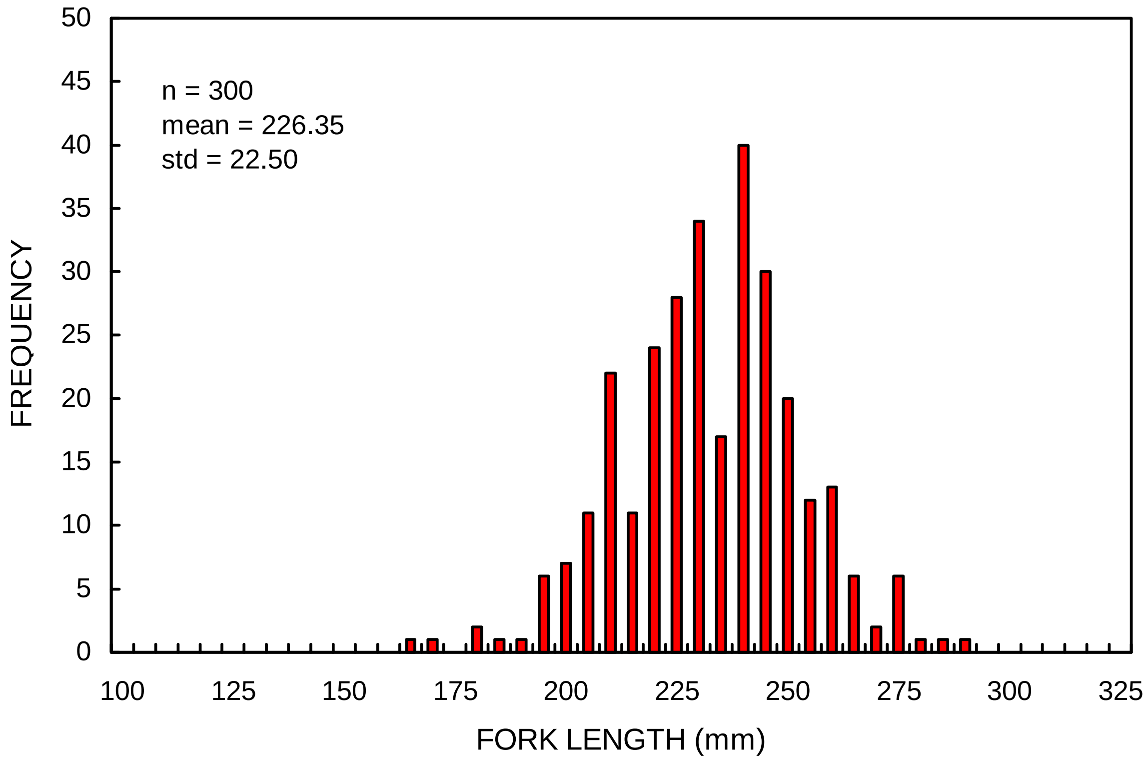
APPENDICES

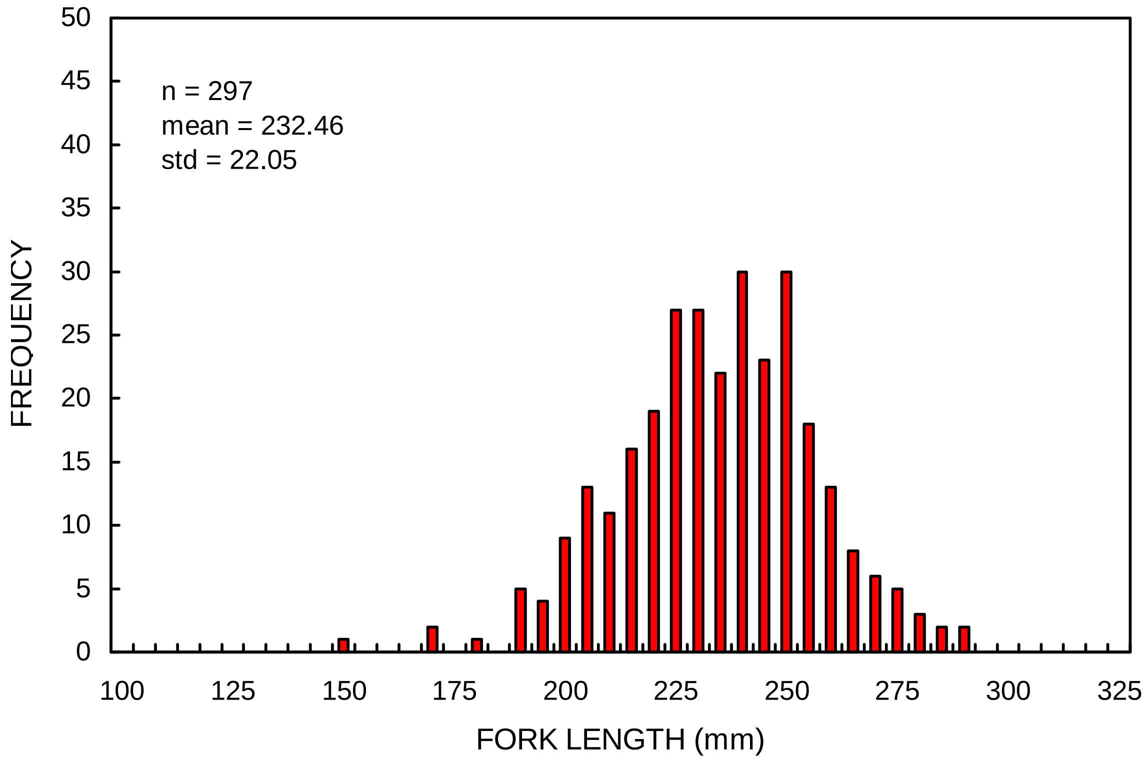
Appendix A. Length frequency distribution of steelhead sampled at Magic Valley Fish Hatchery, March 30, 1999.



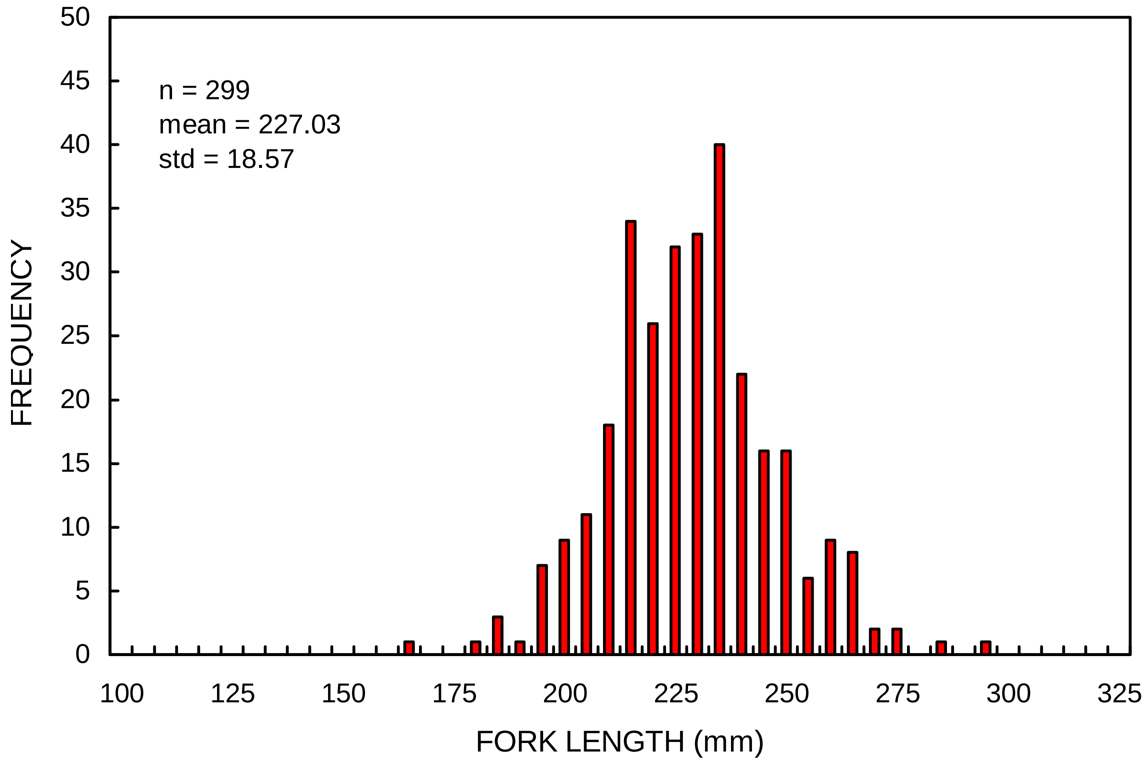
Appendix B. Length frequency distribution of steelhead from the early migrant group, PIT tagged and released at Squaw Creek Pond on May 10, 1999.



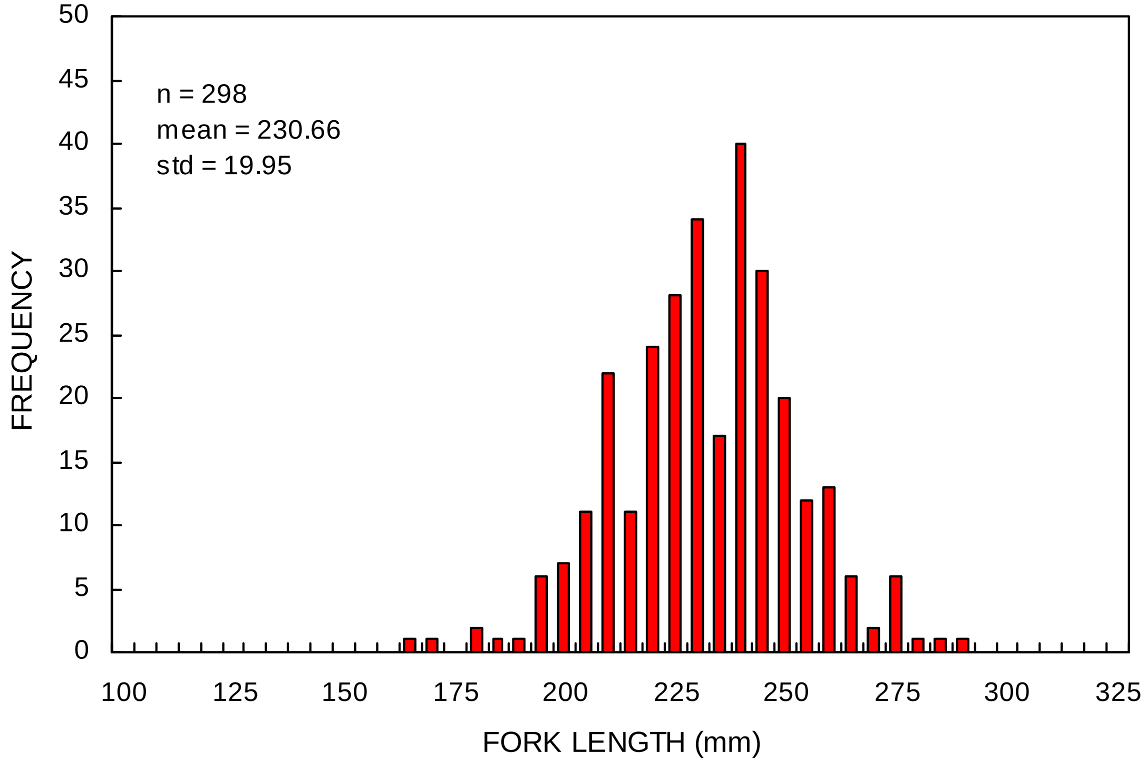
Appendix C. Length frequency distribution of steelhead from the late migrant group, PIT tagged and released at Squaw Creek Pond on May 26, 1999.



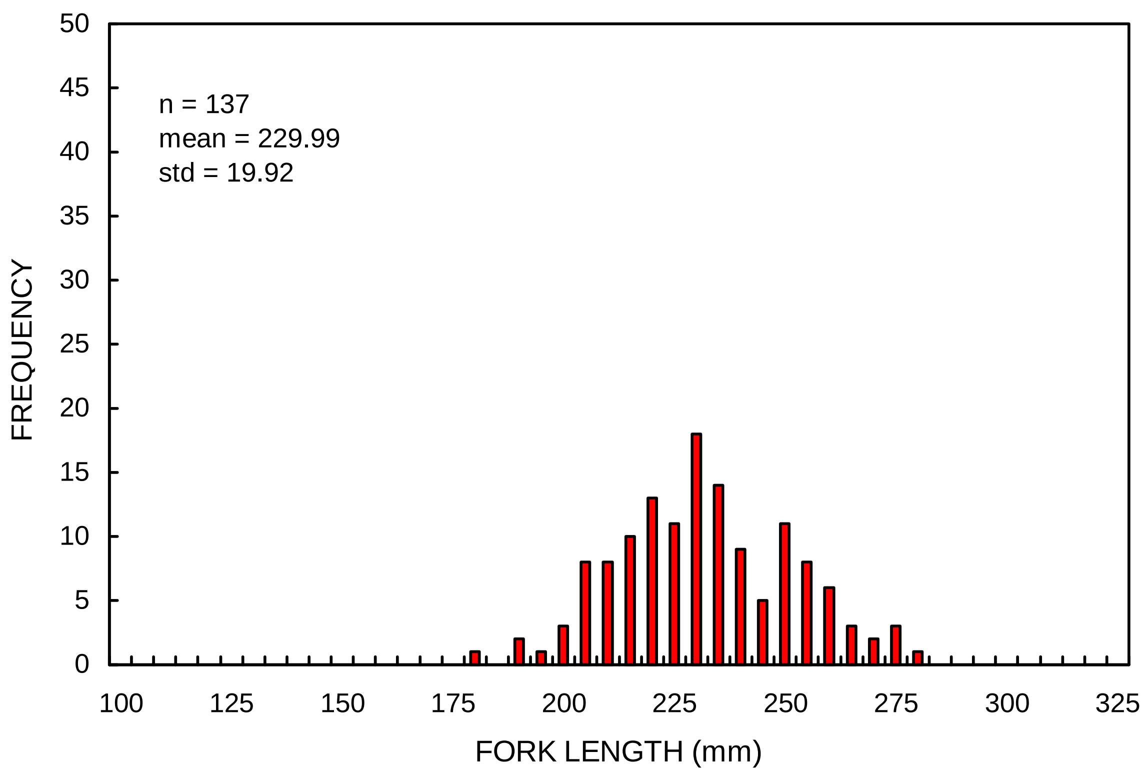
Appendix D. Length frequency distribution of steelhead from the nonmigrant group, PIT tagged and released at Squaw Creek Pond on May 26, 1999.



Appendix E. Length frequency distribution of steelhead from the captive population at Sawtooth Fish Hatchery, PIT tagged and released in the outlet channel of Squaw Creek Pond on May 10, 1999.



Appendix F. Length frequency distribution of nonmigrant steelhead sacrificed for sex composition information at Squaw Creek Pond, May 26, 1999.



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