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A Method to Reduce the Abundance of Residual Hatchery Steelhead in Rivers

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Abstract.—We developed and tested a release strategy designed to reduce the number of hatchery-reared steelhead *Oncorhynchus mykiss* that fail to migrate out of the Tucannon River (i.e., residualize) in southeast Washington. We also described the physical characteristics of those fish that failed to emigrate. Hatchery-reared steelhead that residualize may have negative effects on naturally produced salmonids through competition for food and space, predation, and the spread of disease. Steelhead residualism was reduced by retaining fish in the Curl Lake acclimation pond after volitional emigration had ceased. Fish that remained in the pond had a male : female ratio of 4: 1; 90% of these fish were a combination of transitional, parr, and precocious male stages. This method resulted in 2,022 residualized fish in the Tucannon River, 3.1% of the fish planted in Curl Lake. During the same year, 4,186 fish (14.0% of fish released) residualized in the Tucannon River from a direct river release. The 3.1% residualism of the fish planted in Curl Lake in 1993 was significantly lower than the 14.0% residualism that occurred in 1993 from the direct river release and the 17.7% and 10.3% percent residualism for fish planted into Curl Lake in 1991 and 1992. By retaining 13,971 probable residual fish in Curl Lake in 1993, potential negative interactions in the natural river environment were substantially reduced. Fish remaining in Curl Lake were harvested by sport anglers after June 1, 1993, when the lake opened for sport fishing.

Populations of summer-run steelhead (anadromous rainbow trout *Oncorhynchus mykiss*) in the Snake River drainage of southeast Washington became depressed in the 1970s, in part because hydroelectric dams blocked steelhead migratory routes (Raymond 1988). Large federally funded hatchery programs were initiated in the 1980s to compensate for this loss (USACE 1975). Since the advent of these programs, many hatchery reared steelhead have been released directly or through acclimation ponds into tributaries of the Snake River. We have found that large numbers of these fish fail to migrate from the rivers after release, that is, they "residualize." Similar occurrences have been documented in the Rogue River in Oregon (Evenson and Ewing 1992), the Little Manistee River in Michigan (Seelbach 1987), and the Salmon River in Idaho (D. A. Cannamella, Idaho Fish and Game Department, personal communication). Interactions between hatchery and naturally produced salmonids may reduce the number of wild salmonids through competition for food and space, predation, and the spread of disease (Miller 1958; Ratliff 1981; Bachman 1984; Vincent 1987). These interactions are of concern to us because indigenous spring chinook salmon *Oncorhynchus tshawytscha*, bull trout *Salvelinus confluentus*, and steelhead are present in the Tucannon River, a tributary to the Snake River of southeast Washington into which hatchery-reared steelhead are stocked. Spring chinook salmon are listed as threatened under the U.S. Endangered Species Act (USOFR). The Washington Department of Wildlife (WDW 1992) and the American Fisheries Society (Williams et al. 1989) have identified the bull trout as a species of special concern. The Washington Department of Wildlife (WDW) has expressed concern for the preservation of wild steelhead stocks (P. L. Hulett and S. A. Leider, WDW, personal communications).

It appears that male juvenile steelhead tend to residualize more often than do females. In 1992, males made up 90% of the residual steelhead in the Tucannon and Touchet rivers (S. W. Martin and others, WDW, personal communications). When acclimation ponds were flushed, it was found that males made up 79% or more of the juvenile steelhead that failed to emigrate. If managers could identify those fish that would residualize and remove them before liberation, potential interactions between residual steelhead and wild salmonids would be reduced. Those fish could be used elsewhere, thus increasing the efficiency of the hatchery program.

The goal of our experiment was to reduce the number of hatchery-reared steelhead that residualize in the Tucannon River, thus reducing potential interactions between hatchery-reared and wild salmonids. Our primary objective was to develop and test a method to accomplish this. Other objectives were to (1) determine if an acclimation pond (Curl Lake) on the Tucannon River could be managed to prevent potential residual fish from emigrating into the river; (2) compare the number of fish that residualized from a managed Curl Lake release with those that residualized from a release of fish directly into the river adjacent to Curl Lake; and (3) compare length, weight, sex, condition factor, and external appearance of smolting between those fish that were retained in Curl Lake and those fish that residualized in the river.

Methods

We placed 65,000 hatchery-reared juvenile steelhead (Lyons Ferry Hatchery stock) at 10.4 fish/kg (group A1) into Curl Lake on February 26, 1993. The adipose fins of these fish had been clipped during the first week in February and they had been given an identifying freeze brand so that they could be distinguished from wild steelhead during field sampling efforts. Fish were fed and acclimated to Tucannon River water until April 3. On April 1 and 2, we used a 3.7-m-diameter cast net to sample 100 fish/d from Curl Lake to measure fork lengths and weights and to assess smolt development. Fish were taken from both ends and the middle of the lake to ensure an unbiased sample. Fish that lacked parr marks, were silver in coloration, had banding on the posterior portion of the caudal fin, and had a slender appearance were recorded as smolts. Fish that had well defined parr marks, lacked silver coloration and banding on the caudal fin, and were relatively less slender in appearance were recorded as parr. Fish that had an appearance intermediate between the characteristics of smolts and parr were recorded as transitional. Fish that lacked silver coloration, were robust in appearance, and released milt upon examination were recorded as precocious males. We killed 160 of these fish during the 2 d of sampling and visually determined sex and percent gonadal development.

On April 3 we lowered the pond level 0.3 m by removing the outlet screen and two water level control boards from the outlet structure of Curl Lake. Water flow into the pond was held constant during drawdown. All steelhead then could volitionally emigrate to the Tucannon River. Between April 19 and May 3, the pond water level was gradually lowered by systematically removing additional control boards from the outlet structure until the maximum depth in the pond was about 1 m and the pond surface area was about 20% of surface area when full. Water flow into the pond was held constant. Biweekly, between April 3 and May 3, about 100 fish were captured with a cast net, killed, measured, weighed, sexed, and rated for smolt development. By May 3, 78% of the fish remaining in the pond were males. On May 10 the pond was refilled and any further emigration prevented by replacing the outlet screen. On May 11 we captured 2,000 fish with a cast net from both ends and the middle of Curl Lake. A standard round paper punch was used to mark the caudal fin of each of these fish. All fish were then released back into Curl Lake. On May 16 we again captured 2,000 fish from Curl Lake with a cast net and examined them for caudal holes. The number of marked fish released on May 11 and the number of marked and unmarked fish captured on May 16 were used in a Peterson-type mark–recapture population estimate as modified by Chapman (Ricker 1958) to estimate the number of steelhead that failed to emigrate from the pond.

On April 22, 30,000 juvenile steelhead at 10.4 fish/kg (group D1) were released directly into the Tucannon River, 0.1 km upstream from Curl Lake. The adipose fins of these fish had been clipped and the fish had been given an identifying freeze band during the first week in February.

The mark–recapture sampling data needed to estimate of the number of steelhead that residualized in the Tucannon River from both release groups was collected from June 1 through June 6. High flows at this time of year precluded the use of electrofishing equipment. Therefore, we had to introduce a known number of rainbow trout into the Tucannon River to serve as the marked fish in the mark–recapture sampling to estimate the number of residual steelhead. On May 25 and 29, 6,130 hatchery-reared rainbow trout (6.4 fish/kg) were planted into the Tucannon River from Panjab Creek bridge downstream to Highway 12 (51.5 km). Curl Lake is 6.6 kilometers downstream from Panjab Creek bridge. Fieldwork in previous years by us and other WDW staff indicated that the majority of residual steelhead were located in this 51.5-km section of the river. To collect information for the estimate of residual steelhead, a creel survey was conducted from Panjab Creek bridge downstream to Highway 12 between June 1 and 6. During the survey we recorded the number of hatchery-reared juvenile steelhead and rainbow trout caught and retained by anglers. Because most anglers were unable to correctly identify the fish they released as either steelhead or rainbow trout, released fish were not included in the creel information. Residual steelhead were identified and re-

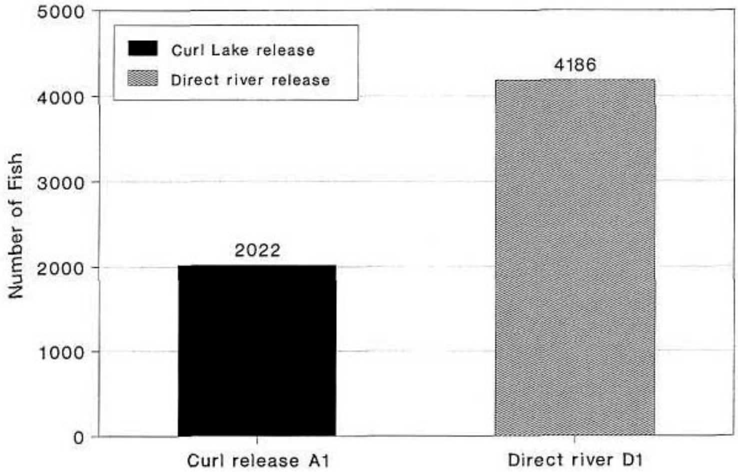

FIGURE 1.—Numbers of hatchery-reared juvenile steelhead that residualized in the Tucannon River after release from Curl Lake acclimation pond (A1) and from fish released directly into the Tucannon River 0.1 km above Curl Lake (D1).

corded according to fin clips and brands. Fork lengths and weights were measured and recorded, and fish were sexed when possible. A visual estimation of smolt development was recorded. Most angling effort took place between Panjab Creek bridge and a point 18.7 km downstream. Although areas further downstream received minimal fishing effort, primarily because they were inaccessible to the general public, they were creel surveyed and fished by WDW personnel. Information from this effort was added to the creel data.

We were concerned that anglers might select unequally between residual steelhead and rainbow trout—keeping only rainbow trout or larger fish. This might affect the validity of our estimate of residual steelhead. Therefore the difference in retention by anglers between hatchery-reared juvenile steelhead and hatchery rainbow trout was tested. Three 1.6-km sections were fished by WDW personnel who used a different terminal tackle (flies, lures, or bait) in each section. Catch composition and length frequencies of fish caught from this and other WDW angling efforts were compared to the results from our creel surveys. We found no difference in retention by anglers between hatchery rainbow trout and juvenile steelhead (χ^2 = 0.28, df = 1, P = 0.5995). It was unnecessary, therefore to adjust the creel information.

We used a Peterson-type mark–recapture population estimate as modified by Chapman (Ricker 1958) and the creel information to calculate a population estimate of the sum of both residualized steelhead and hatchery rainbow trout for each release group. The exact number of released hatchery rainbow trout was known; therefore, these fish were treated as the marked fish needed to calculate the estimate. The number of steelhead from each release group that residualized was then calculated by multiplying the percentage of residualized steelhead in the combined creel and angling sample by the total population estimate. This number was then divided by the total number of juvenile steelhead of each group released and presented as a percentage.

A chi-square procedure was used to test the difference between the frequencies (%) of steelhead that residualized from each release group. A one-way analysis of variance and a Bonferroni pairwise comparison of means were used to test differences in Fulton's condition factors (Bagenal and Tesch 1978) among and between release groups. All statistical tests were performed using Statistix analytical software (Siegel 1992). Differences in length frequencies, sex ratio, and the degree of smoltification were compared.

Results

Mark–recapture data indicate that in total 15,111 ± 34.7 steelhead (±95% confidence limits) remained in Curl Lake. Fish that did emigrate from Curl Lake residualized in the Tucannon River at the rate of 3.1% (2,022 ± 2.7 fish). This was significantly lower (χ^2 = 2,570, df = 1, P = 0.000)

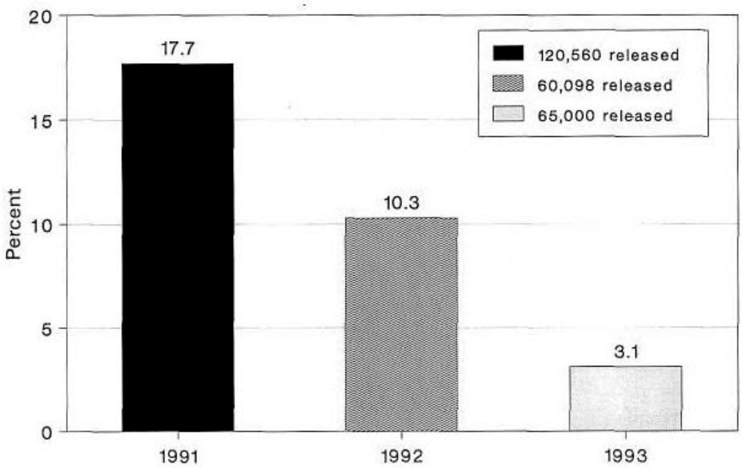

FIGURE 2.—Percentages of hatchery-reared juvenile steelhead that residualized in the Tucannon River after release from Curl Lake acclimation pond in 1991, 1992, and 1993.

than the 14% (4,186 ± 3.9 fish) of the fish that residualized from the direct stream-release group, D1 (Figure 1) and also significantly lower than the 17.7% and 10.3% residualism for fish released from Curl Lake in 1991 and 1992 (respectively, χ^2 = 5,584.7 and 1,564.8; for both, df = 1 and P = 0.000), based on unpublished WDW data (Figure 2).

The sex ratio of all groups of fish before release was 1:1 (male : female). The sex ratios of the fish that remained in Curl Lake and Curl Lake fish that residualized in the Tucannon River were at or near 4:1 (Table 1). Precocious males made up 55% of the fish that residualized and 24% of the fish that remained in Curl Lake (Table 2).

Mean condition factors of female, nonprecocious male, and precocious male juvenile steelhead that residualized in the Tucannon River and that remained in Curl Lake were significantly greater than condition factors of female, nonprecocious male, and precocious male juvenile steelhead in Curl Lake before release (P = 0.000, F = 26.31; P = 0.000, F = 63.27; and P = 0.0004, F = 9.30, respectively; Table 2).

Fish from both release groups that residualized in the Tucannon River had proportionally greater numbers of longer fish (230–250 mm) than either group of fish before release or the fish that remained in Curl Lake. Most fish from pre-release samples exhibited smolt or transitional characteristics. Fish that remained in Curl Lake exhibited predominantly transitional characteristics, and all residual fish exhibited transitional characteristics or coloration similar to rainbow trout (Table 3).

Discussion

Our (unpublished) fieldwork in 1991 suggested that hatchery-reared juvenile steelhead that fail to emigrate from the Tucannon River by June 1 would

TABLE 1.—Male : female sex ratios and percent residualism of hatchery-reared juvenile steelhead released from Curl Lake and hatchery-reared juvenile steelhead released directly into the Tucannon River, 1993.

Fish group and measure	Curl Lake release A1	Direct stream release D1
Pre-release		
Sex ratio	1:1	1:1
Steelhead that remained in Curl Lake		
Sex ratio	4:1	
Residual steelhead in Tucannon River		
Sex ratio	4:1	2.4:1
Residualism (%)	3.1	14.0

TABLE 2.—Mean Fulton condition factors (K)[a] and sexual composition of hatchery-reared juvenile steelhead; percent sexual composition is in parentheses.

Fish group	Pre-release	Fish remaining in Curl Lake	Residual fish in the Tucannon River
Females	0.79 (50.0)	0.96 (22.6)	1.05 (21.5)
Nonprecocious males	0.80 (41.7)	0.98 (53.4)	1.06 (23.1)
Precocious males[b]	0.81 (8.3)	1.08 (24.0)	1.04 (55.4)

[a] $K = 10^5(\text{weight, g})/(\text{fork length, mm})^3$.
[b] Males with 20–100% sexual development of testes.

TABLE 3.—Percentages of hatchery-reared juvenile steelhead exhibiting smolt, parr, transitional, or precocious male characteristics.

Fish group	Pre-release	Fish remaining in Curl Lake	Residual fish in the Tucannon River
Smolts	34.0	7.5	0
Parr	4.0	0	0
Transitonal	61.0	84.5	82.2
Precocious males	1.0	8.0	17.8

not do so through the remainder of the summer and fall. Because the fishing season for trout opened on June 1 on the Tucannon River, the only time we could conduct a reliable estimate of residual steelhead was during the first week of June—after emigration had ceased and before sport anglers had removed an unknown number of fish.

Of the 65,000 fish we planted in Curl Lake, 15,023 fish remained in the lake, and 13,971 of those exhibited transitional, parr, or precocious male characteristics. We suspected that most of these 13,971 fish, if released from Curl Lake, would fail to emigrate from the Tucannon River. We believe this because they exhibited all the characteristics common to fish that residualized in 1992 and 1993. Only 7% (1,052 fish) of the fish that remained in Curl Lake exhibited smolt characteristics. If given more time, these fish may have emigrated from the pond and river. Also, it is possible that some fish, if allowed access to the river, might have emigrated to the ocean after a second year in freshwater.

The fish that remained in Curl Lake were harvested from the lake by sport anglers after June 1, 1993. This was a more benign use of the majority of those fish than allowing them to enter the Tucannon River, where they may have residualized and had negative effects on wild salmonids.

In 1993, male juvenile steelhead residualized in the Tucannon River four times more than female juveniles. Precocious males made up more than half of these fish. Similar results have been reported for steelhead on the Tucannon River in 1992 (Martin, personnel communication) and for chinook salmon on the Lemhi River in Idaho in 1957 and 1958 (Gebhards 1960). Mullan et al. (1992) reported that precocious male chinook salmon may contribute to salmon reproduction. We have observed precocious male steelhead spawning with adult females. Gross (1987) indicated that precocity evolved as an alternative life history pattern. We suspect that precocity is part of the natural life history of Tucannon River anadromous salmonids. When inadequate numbers of adult male steelhead return to spawning areas, precocious males may serve to ensure the fertilization of eggs.

The large percentage of precocious males among residual fish may be partly a result of hatchery practices. Mullan et al. (1992) suggested that the hatchery practice of releasing chinook salmon at a larger-than-natural size in order to increase survival may result in large numbers of precocious males. The same may also be true with steelhead. It is, however, unclear at this time why the nonprecocious male and female steelhead residualized in the Tucannon River.

Fish that residualized had significantly higher condition factors than fish before release. This is probably because more than half of the fish that residualized were sexually developing males, which typically have high condition factors.

Piper et al. (1982) stated, "Selective breeding is artificial selection, as opposed to natural selection. It involves selected mating of fish with a resulting reduction in genetic variability in the population." Selectively removing a portion of the hatchery-reared juvenile steelhead (i.e., potential residual fish) from the population will prevent these fish from spawning in the future and may result in a loss of a certain portion of genetic variability to that particular hatchery stock.

Fishery managers must weigh the pros and cons of removing a portion of hatchery juvenile steelhead before release. However, a method that reduces the number of residual fish in a river is warranted in cases where it is feared that negative interactions may be occurring between residual hatchery steelhead and wild salmonids. Clearly, managing Curl Lake to prevent the emigration of fish that are likely to residualize does substantially reduce the number of nonmigrant hatchery-reared steelhead in the Tucannon River and thus reduces the frequency of negative interactions between these fish and wild salmonids.

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