PROGRESS REPORTS

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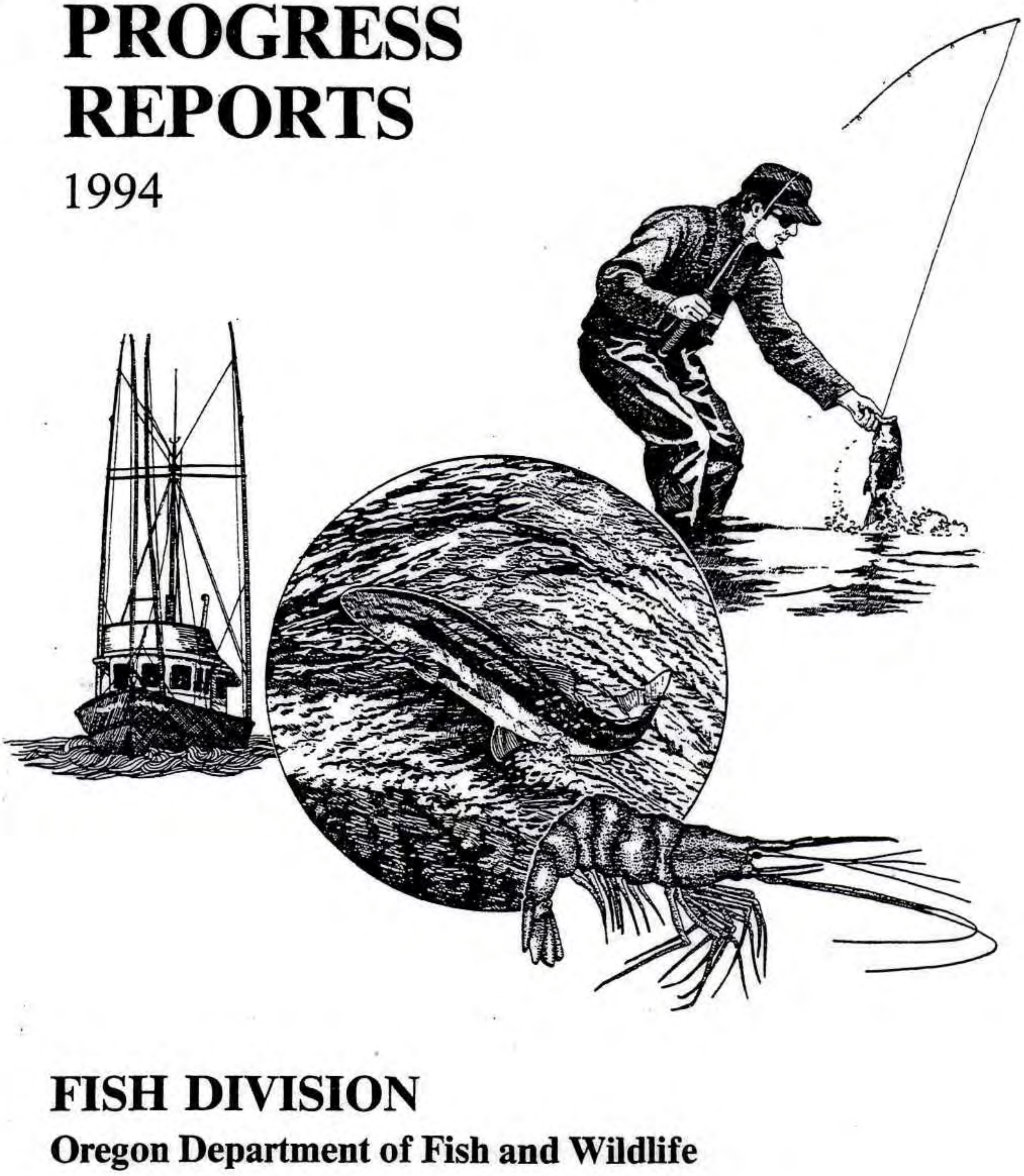

FISH DIVISION

Oregon Department of Fish and Wildlife

Residual Hatchery Steelhead: Characteristics and
Potential Interactions with Spring Chinook Salmon
in Northeast Oregon

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT

OREGON

PROJECT TITLE: Residual Hatchery Steelhead: Characteristics and Potential Interactions with Spring Chinook Salmon in Northeast Oregon

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PREFACE

This report is for the funding period from 1 April 1993 to 31 March 1994. This report focuses on 1992 brood, summer steelhead juveniles that were released in the spring of 1993. Those individuals remaining in freshwater after 20 June 1993 were considered to be residual steelhead. Although fish which remained in the main stem of the Snake or Columbia rivers (for example) would be defined as residual steelhead, this project focused only on those fish which residualized in the Imnaha or Grande Ronde river basins. We sampled in the Grande Ronde and Imnaha rivers basins during the summer (21 June - 20 September) and fall (21 September - 20 December) of 1993, the winter (21 December - 20 March) of 1993-94, and the spring (21 March - 20 June) of 1994. Thus, this report documents activities from 1 April 1993 through 20 June 1994. The above period represents the second year of data collected for a long-term study. Therefore, this report contains preliminary conclusions and the data and the report should be interpreted accordingly.

ACKNOWLEDGMENTS

We would like to thank D. Herrig and J. Krakker for working with us to develop the study design; J. Abrams, R. Blincoe, V. Ediger, and M. Lambert for their dedication and persistence in conducting the field work; D. Anderson, P. Cleary, W. Easterday, M. Flesher, M. Keefe, T. Labbe, P. Lofy, J. Mayes, R. Messmer, S. Stennfeld, T. Walters, and A. Wilson for their cooperation and assistance; C. Frost provided valuable assistance and expertise during the stomach content analysis. This project was funded by the U.S. Fish and Wildlife Service under the Lower Snake River Compensation Plan, contract number 14-48-0001-93538 as a cooperative agreement with the Oregon Department of Fish and Wildlife.

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SUMMARY

Objectives

1. Map the spatial and temporal distribution of juvenile chinook salmon and residual hatchery steelhead.
2. Monitor predation by hatchery-reared steelhead on juvenile spring chinook salmon.
3. Characterize the steelhead which residualize.

Accomplishments and Findings

1. Densities of residual hatchery steelhead were relatively low in summer 1993.
2. Residual steelhead and naturally-produced juvenile chinook salmon do exist sympatrically in the Grande Ronde River and Imnaha River basins.
3. Peak densities of residual steelhead were generally found near release sites.
4. Densities of residual steelhead tended to decline over time.
5. The relative distribution of residual steelhead also appeared to change over time.
6. Based on relative densities, it is likely that residual steelhead would have their maximum impact on naturally-produced juvenile chinook salmon in the lower Grande Ronde, Wallowa and Imnaha rivers.
7. The majority of residual steelhead originated from the smallest fish in the 1993 release groups.
8. The majority of residual steelhead originated from the male fish in the 1993 release groups.
9. Residualism of hatchery steelhead appears to be independent of release type (direct stream vs. acclimated).
10. No residual steelhead that we sampled (*N* = 358) contained juvenile chinook salmon in their stomachs.
11. Residual steelhead can persist in streams and may have reasonably good growth rates for more than 12 months.
12. Residual steelhead may contribute substantially to fisheries in the Grande Ronde and Imnaha rivers.

Management Recommendations

1. Continue releasing hatchery-reared steelhead at the current release sites in the upper Grande Ronde River, Catherine Creek, Deer Creek, Spring Creek, and Little Sheep Creek. The relative densities of residual steelhead and juvenile chinook salmon at these sites help to minimize the probability of residual steelhead interacting with naturally-produced chinook salmon juveniles.

2. Consider modifying or terminating releases of hatchery-reared steelhead in the lower Grande Ronde River (i.e. at Wildcat Creek) and in the Imnaha River (i.e. at or below the town of Imnaha). Given the dispersal and abundance patterns of residual steelhead, the lower Grande Ronde and Imnaha rivers are areas where interactions between residual steelhead and naturally-produced juvenile chinook salmon may be significant. This recommendation necessitates striking a balance between the benefits to steelhead fisheries and the risks of steelhead predation on chinook salmon.

3. Releases of hatchery-reared steelhead should not occur in or near critical rearing areas of naturally-produced juvenile chinook salmon. In particular, attempts should be made to avoid having residual steelhead in areas where chinook fry have recently emerged from redds.

4. Explore the possibility of grading out smaller fish before release to reduce residualism rates and potential impacts to listed chinook salmon. The most appropriate grade-out size will probably depend on the mean size, growth rate, and rearing practices associated with the population. The potential genetic risks of removing these small fish from the hatchery population should be assessed.

5. Investigate volitional releases from steelhead acclimation ponds and culling the fish remaining in the ponds to reduce the number of residual steelhead.

6. Examine the impacts of residual steelhead on fish species other than chinook salmon. Mature and maturing residual steelhead were observed during this study. These fish clearly had the potential to breed successfully with local populations of rainbow trout and steelhead. Furthermore, residual steelhead did prey on fish species other than chinook salmon (i.e. rainbow/steelhead trout and sculpin).

7. Explore whether or not residualism is a normal life-history strategy and/or a heritable trait in steelhead populations. Residualism may be a natural part of a steelhead-rainbow trout population continuum. Thus, when trying to supplement natural populations, residual steelhead may be an important component of the hatchery population.

8. Assess the relative contribution (cost/benefit analysis) of residual steelhead to local fisheries in northeast Oregon. Catch and harvest of residual steelhead has been reported by steelhead and rainbow trout anglers as well as by local fishing guides.

9. Continue to explore the predator-prey relationship between residual steelhead and juvenile chinook salmon.

INTRODUCTION

Associated with the construction of the main stem Snake and Columbia river dams, there has been a decline in the sizes of anadromous fish populations from basins which drain into the lower Snake River (U.S. Army Corps of Engineers 1975). These declines prompted Congress to authorize the Lower Snake River Compensation Plan (LSRCP) in 1976. This plan is a federal mandate to compensate for losses attributed to the construction of the dams in the lower Snake River. The original goals of this plan were to: (1) compensate run sizes of salmon and steelhead, (2) enhance the natural production of salmonids and (3) restore sport and tribal fisheries. In northeast Oregon, the LSRCP has been responsible for the development of the Wallowa and Irrigon fish hatcheries as well as the construction of the Wallowa, Big Canyon and Little Sheep Creek acclimation facilities. In general, hatchery programs are designed to minimize the mortality which juveniles suffer in freshwater (Hoar 1988). In 1993, approximately 1,402,000 Wallowa stock and 340,000 Imnaha stock, 10-12 month old, hatchery-reared steelhead (*Oncorhynchus mykiss*) were released in northeast Oregon from LSRCP facilities.

Hatchery-reared steelhead which are outplanted as juveniles may remain in freshwater rather than migrate to the ocean as smolts (see Partridge 1985). For the purpose of this investigation residual steelhead are defined as hatchery-reared fish which did not migrate to the ocean during the initial smolt migration season after they were released. The rate of residualism is variable, but may reach as high as 33% (Viola and Schuck 1991). The residualism of hatchery-reared steelhead represents an increased loss of anadromous fish production from hatcheries and, from the stand point of supplementation and compensation, residuals are currently viewed as undesirable. In addition, residual steelhead may interact with, and reduce the production of, naturally-produced juvenile salmonids.

The potential interactions of residual steelhead with naturally-produced juvenile spring chinook salmon (*O. tshawytscha*) in lower Snake River drainages has been recognized by fisheries biologists from Oregon (Whitesel et al. 1993), Washington (Martin et al. 1993) and Idaho (Cannamela 1992). Within a given basin, residual steelhead and juvenile chinook salmon exist sympatrically. However, the overlap of local distributions is a necessary requirement for any potential, direct effects of residual steelhead on juvenile chinook salmon to become realized. In northeastern Oregon, it appears that the distributions of residual steelhead and juvenile chinook salmon do not overlap very extensively in smaller streams and headwater tributaries (Whitesel et al., 1993). However, it is not clear whether, and to what extent, residual steelhead and juvenile chinook salmon overlap in the lower main stem areas of the major drainages. Thus, one objective of this study was to document the seasonal distribution and relative abundance of residual steelhead and juvenile chinook salmon in northeast Oregon.

Current mitigation strategies for lower Snake River drainages call for the release of large numbers of hatchery-reared steelhead, in specific locations, at relatively high concentrations. In Oregon, hatchery-reared steelhead are generally not released in areas where chinook salmon spawn. However, steelhead may migrate through or emigrate to areas where juvenile chinook salmon rear. In particular, this may occur near the time when chinook salmon fry have just emerged from the gravel. Therefore, steelhead migrating as smolts as well as those that residualize may have the opportunity to prey on juvenile chinook salmon. Preliminary observations suggest that less than 1% of the residual steelhead prey on juvenile chinook salmon (Cannamela 1993; Martin et al. 1993; Whitesel et al. 1993). However, our modelling efforts have suggested that if 10% of the hatchery-reared steelhead become residuals, predation rates as low as 0.001 juvenile chinook salmon eaten/residual steelhead/d may result in the loss of approximately 50 adult-equivalent chinook salmon (Whitesel et al. 1993). Stream interactions between hatchery-reared steelhead and juvenile chinook salmon have not been well defined, in part, because predation rates are difficult to evaluate. Thus, the second objective of this study was to monitor the extent to which hatchery-reared steelhead prey on juvenile chinook salmon.

Hatchery production strategies may predispose juvenile steelhead to residualize in freshwater rather than migrate to the ocean as smolts. Strategies used in northeast Oregon produce juvenile steelhead that are released near the time when they are 10 months old and with a fork length near 200 mm (Messmer et al. 1989). In contrast, wild steelhead smolts generally migrate when they are 22 months old and at a fork length of approximately 145 mm (Gaumer 1968). Growth rates of hatchery-reared fish, which are greatly accelerated over those that would be experienced naturally, may alter developmental processes and influence their tendency to residualize (Thorpe 1986). Furthermore, it is possible that release strategies as well as sexual maturation (Gross 1991) may affect residualism rates. However, experimental comparisons to test these hypotheses have not generated clear results. Thus, the final objective of this study was to characterize the steelhead in northeast Oregon which residualize after they are released.

STUDY AREA AND POPULATIONS

This study was conducted in the northeast corner of Oregon (Figure 1). Sampling focused on two of the major drainages of the lower section of the Snake River, the Grande Ronde and Imnaha river basins. For the purposes of allocating sampling effort and analyzing the data, the Grande Ronde River basin was divided into four major areas; the upper Grande Ronde River, Catherine Creek, the Wallowa River, and the lower Grande Ronde River. Hatchery-reared steelhead were released by Oregon Department of Fish and Wildlife (ODFW) into the Grande Ronde River basin near the following locations in April and the first week of May 1993 (Figure 1): Spring Creek, river mile (RM) 2 (approximately 656.2 K smolts from Wallowa Hatchery); Deer Creek, RM 0 (approximately 433 K smolts from the Big Canyon Facility); Catherine Creek at RM 17 (approximately 22.5 K smolts) and RM 18 (approximately 40 K smolts); and

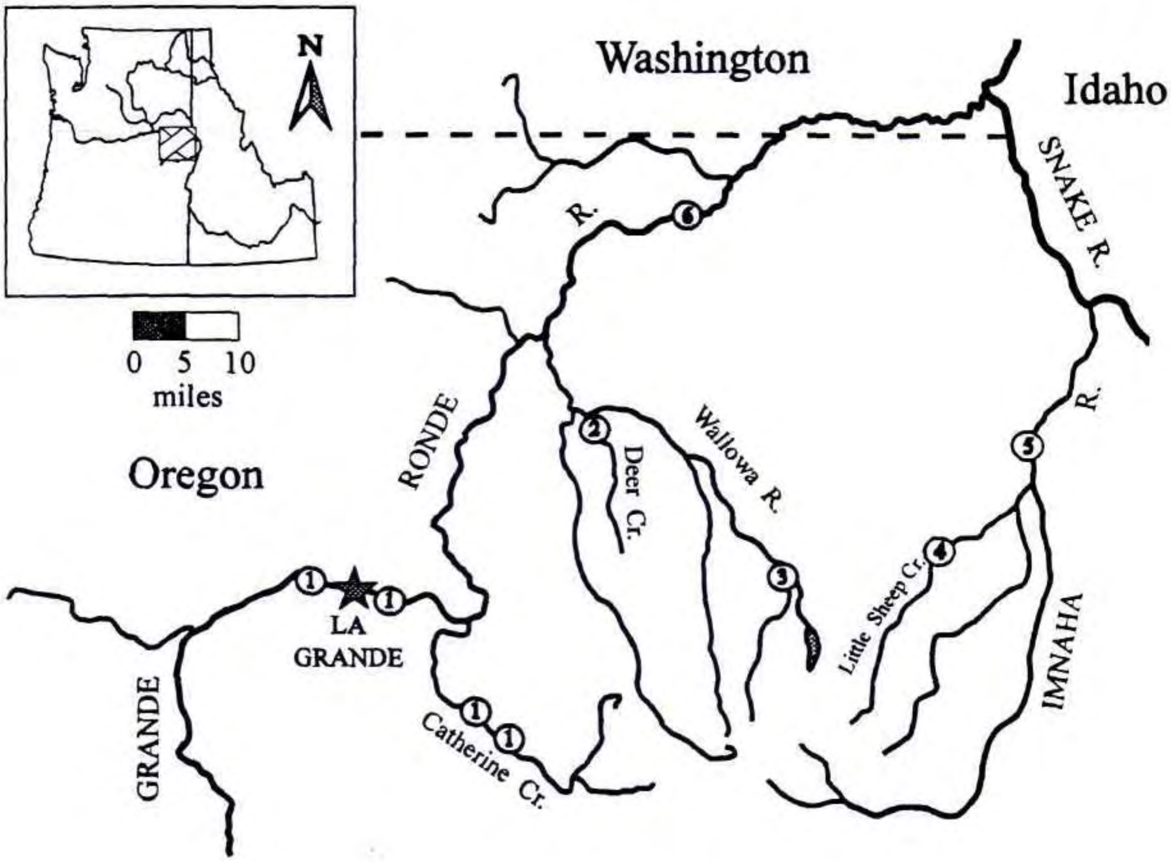

Figure 1. Major river basins in northeast Oregon and the locations where Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) released summer steelhead juveniles in spring 1993. (1) ODFW direct stream releases of Wallowa stock steelhead. (2) ODFW acclimated and direct stream releases of Wallowa stock steelhead. (3) ODFW acclimated releases of Wallowa stock steelhead. (4) ODFW acclimated and direct stream releases of Imnaha stock steelhead. (5) ODFW direct stream releases of Imnaha stock steelhead. (6) WDFW direct stream releases of Wallowa stock steelhead.

the Grande Ronde River at RM 160 (approximately 99 K smolts) and RM 156 (approximately 101 K smolts). Hatchery-reared steelhead were released by Washington Department of Fish and Wildlife (WDFW) into the Grande Ronde River at RM 54 (approximately 50 K smolts). Hatchery-reared steelhead were released by ODFW in the Imnaha River basin near the following locations, also in April 1993 (Figure 1): Little Sheep Creek, RM 5 (approximately 287 K smolts from the Little Sheep Creek Facility), and the Imnaha River, RM 17 (approximately 53 K smolts). Wallowa stock steelhead were released at each of the Grande Ronde River basin sites whereas Imnaha stock steelhead were released at each of the Imnaha River basin sites. All release groups were from the 1992 brood year. Specific descriptions of each release group are presented in Messmer et al. (in preparation). Hatchery-reared fish from the 1992 brood which remained in freshwater after 20 June 1993 were considered to have residualized.

SPATIAL AND TEMPORAL DISTRIBUTION OF JUVENILE CHINOOK SALMON AND RESIDUAL STEELHEAD.

Methods

To determine the spatial distribution of chinook salmon and residual steelhead in the Grande Ronde and Imnaha basins, we identified 53 locations to sample during summer 1993 (Figure 2). Of these locations, we sampled 32 locations during fall 1993, 19 locations during winter 1993-94 and 18 locations during spring 1994. Whenever possible, these locations were sampled for the relative density (abundance) of residual steelhead and juvenile chinook salmon, otherwise, the locations were sampled for the presence/absence (distribution) of residual steelhead and juvenile chinook salmon. We selected locations based on where hatchery-reared steelhead were released, the distribution and abundance patterns of residual steelhead in the summer of 1992 (Whitesel et al. 1993), known or anticipated spawning and rearing locations of chinook salmon, as well as stream accessibility. At each sampling location we chose two sites to sample. We attempted to sample two riffle-pool combinations at each site. If riffle-pool combinations were not available near the location, we chose a section of stream approximately 50 m in length for each site. During fall 1993, winter 1993-94 and spring 1994 we focused our sampling in and adjacent to locations where residual hatchery steelhead were found during our summer sampling and during these seasons in 1992-93. This strategy was chosen to maximize our efficiency, but still allowed us to explore seasonal movements of residual steelhead. The number of locations we were able to sample in the winter and spring seasons was limited by environmental conditions.

We used electrofishing techniques whenever possible. Snorkeling techniques were used when water conditions would not permit the use of electrofishing. We also attempted to capture residual steelhead by angling in areas we could not electrofish or snorkel effectively.

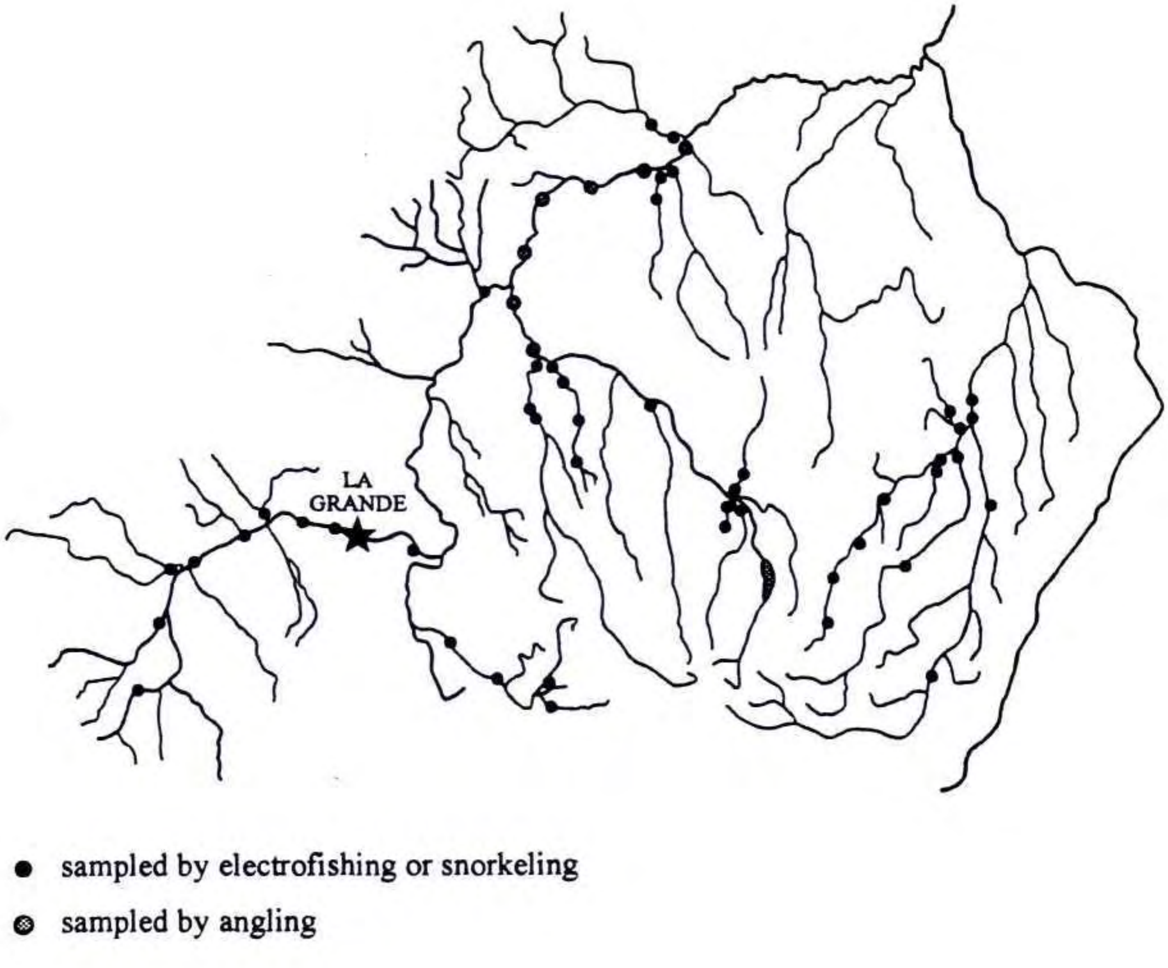

Figure 2. Locations sampled during summer 1993 in the Grande Ronde and Imnaha river basins.

At abundance locations we used electrofishing whenever possible. Blocking nets (6 mm mesh) were placed across the stream at the top and bottom of the sample site to prevent fish from moving into or out of the area during sampling. A two or three person sampling crew made two, three or four passes through the unit with an electrofisher to collect and remove salmonids. Fish captured during each pass were netted, held in separate containers and later anesthetized, identified to species, classified by age (salmonids only) and enumerated. We used a multiple pass removal method (Zippen 1958) to estimate the abundance of fish within the sampling site. We measured the total length and average width of each sampling site to calculate the surface area of the sampled site. Densities of residual steelhead and juvenile chinook salmon were calculated for abundance locations using the surface area and the estimated number of residual steelhead or juvenile chinook salmon of both sites.

We snorkeled at abundance sites when we were not able to use electrofishing techniques. Visual observations were made of the species present and the number of individuals in each salmonid species. We generally used three snorkelers, swimming simultaneously and parallel, to observe and count salmonids. At abundance sites which were snorkeled we made two passes and used the highest count for each species as our estimate of the number present in the site.

At distribution locations we made a maximum of one (snorkeling) or two (electrofishing) passes. If at least one residual steelhead and one juvenile chinook salmon were observed, sampling was terminated at that site (i.e. they were both present). If one residual steelhead and one juvenile chinook salmon were not observed after completing these passes they were considered absent from that site. This was done in an attempt to use a constant effort when determining the presence/absence at each site.

We angled for residual steelhead during a three day raft trip in July 1993 from Wallowa River RM 10 (Minam) to Grande Ronde River RM 46 (Troy). We also used information collected during summer steelhead creel surveys in the fall on the Grande Ronde River, and in the spring on the Grande Ronde, Wallowa, and Imnaha rivers to add to our knowledge of distribution of residual hatchery steelhead. Anglers were asked if they had caught fin-marked rainbow trout, which were actually residual hatchery steelhead as ODFW did not release fin-marked rainbow trout in spring or summer 1993.

We also used capture information from a screw trap operated by the Nez Perce Tribe located near RM 4 of the Imnaha River to add to our knowledge of distribution of residual hatchery steelhead during summer 1993.

From our sampling, a map was generated which indicated the areas where residual steelhead were distributed. This sampling, as well as known spawning areas of adult chinook salmon, rearing areas of juvenile chinook salmon and anecdotal information on the distribution of juvenile chinook salmon in northeast Oregon, allowed us to generate a similar map for juvenile chinook salmon. To determine the overlap in the distribution of residual steelhead and juvenile chinook salmon, the distribution patterns observed in these two maps were compared. We evaluated the distribution and abundance of residual steelhead near their release sites as well as seasonal changes in the distribution and abundance of residual steelhead. The relative density (in general: **low** < 1 fish/100m^2; 1 fish/100m^2 ≤ **medium** < 9.99 fish/100m^2; **high** ≥ 10 fish/100m^2) and relative interaction potential (Table 1) of residual steelhead and juvenile chinook salmon was also assigned to each sampling location as described by Whitesel et al. 1993. A composite map was then generated indicating the relative level of interaction expected at each location. This map was used to identify specific areas of concern.

Table 1. A description of the method used to determine the relative level of interaction between residual steelhead and juvenile chinook salmon. The level of interaction was estimated based on the relative density of both residual steelhead and juvenile chinook salmon.

Relative density		Level of interaction
Residual steelhead	Juvenile chinook salmon	
low[a]	low	minimal
	medium[b]	minimal
	high[c]	moderate
medium	low	minimal
	medium	moderate
	high	maximal
high	low	moderate
	medium	maximal
	high	maximal

[a] *low < 1 fish/100m^2*
[b] *1 fish/100m2 ≤ medium < 9.99 fish/100m^2*
[c] *high ≥ 10 fish/100m^2*

Results

We found residual hatchery steelhead at each of the release sites during the summer following release (Figure 3). Residual steelhead were found upstream of two of the release sites (Spring Creek and Deer Creek), and downstream of all release sites: the mouth of the Lostine River, the Wallowa River below Deer Creek, the Grande Ronde River below the Wallowa River, and the Imnaha River below Big Sheep Creek. Juvenile chinook salmon were widely distributed throughout the Grande Ronde and Imnaha river basins (Figure 4). The distributions of residual steelhead and juvenile chinook salmon overlapped at the mouths of Spring Creek and the Lostine River, from RM 0-10 of the Wallowa River, RM 46-82 of the Grande Ronde River, RM 18 of Catherine Creek, RM 0-3 of Big Sheep Creek, and RM 4-23 of the Imnaha River.

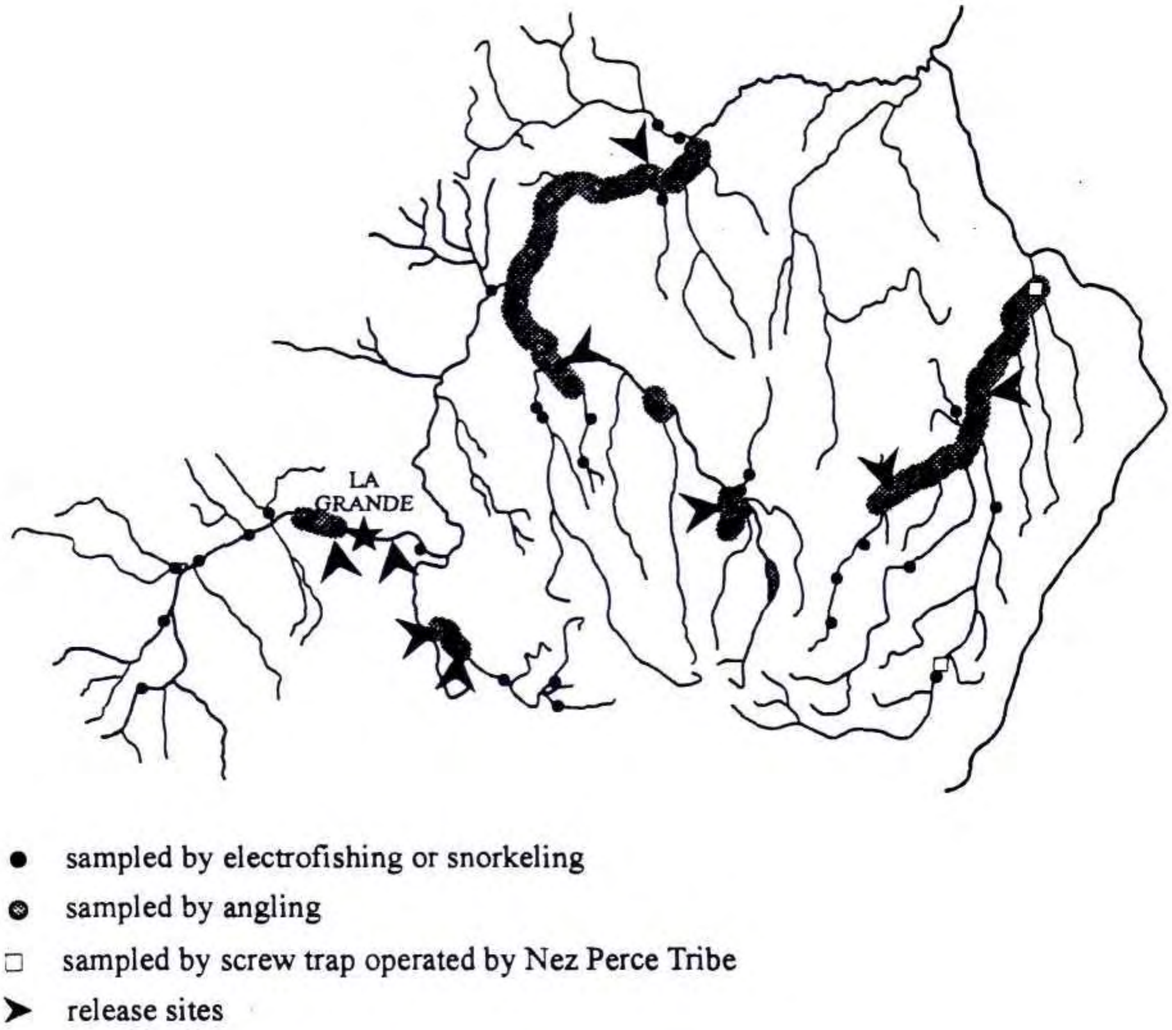

Figure 3. Distribution of residual steelhead during summer 1993 in the Grande Ronde and Imnaha river basins.

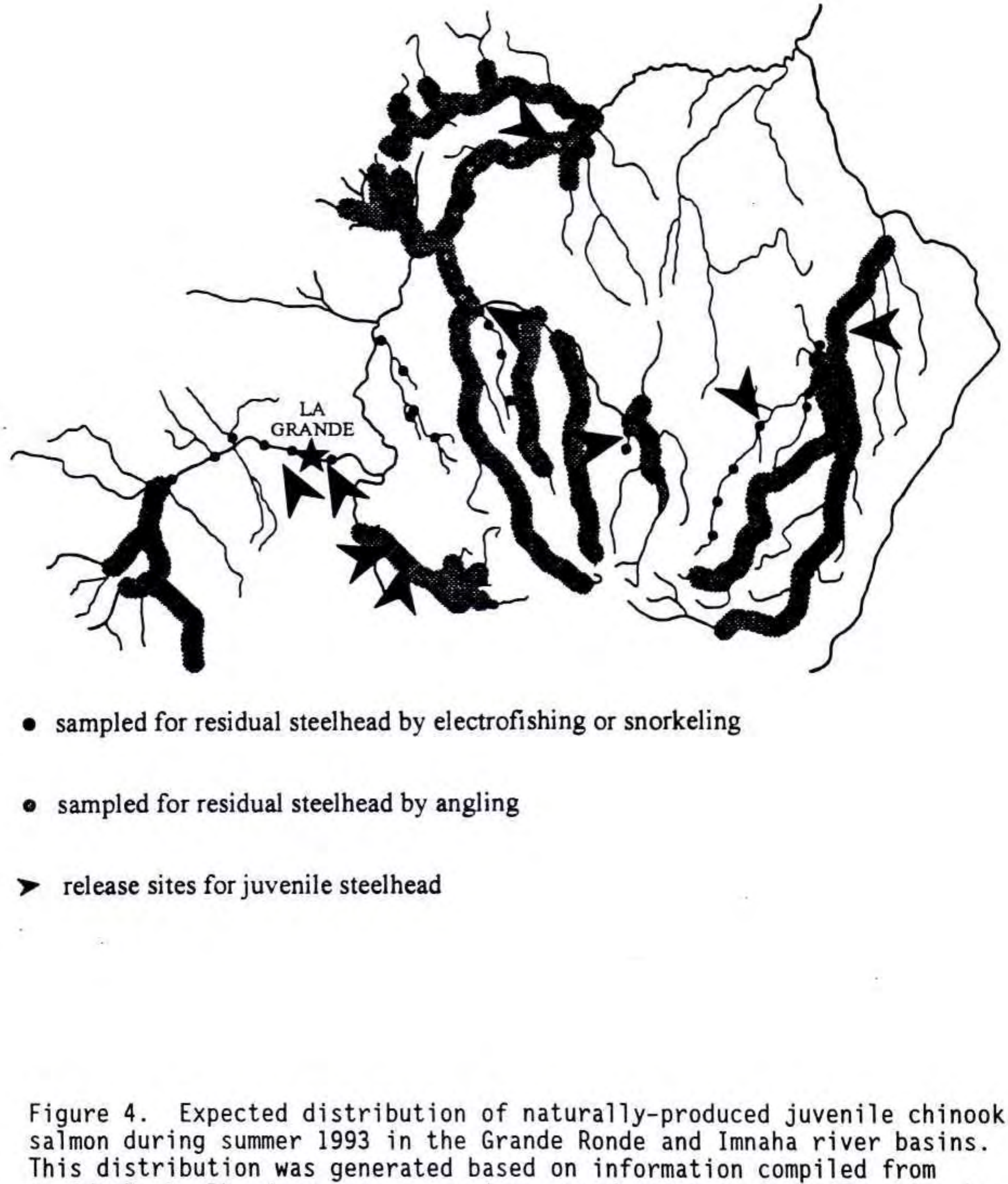

Figure 4. Expected distribution of naturally-produced juvenile chinook salmon during summer 1993 in the Grande Ronde and Imnaha river basins. This distribution was generated based on information compiled from residual steelhead surveys, spawning ground surveys, juvenile chinook collected for migration studies, and juvenile chinook collected for genetic studies.

Densities of residual steelhead in Deer and Little Sheep creeks were highest near release sites and decreased as distance from the release site increased (for example, Figure 5; see also **Appendix A**). During our summer sampling, we found residual steelhead one mile above the release site in Deer Creek, but did not find them above the release site in Little Sheep Creek. The relative densities of residual steelhead at these sites decreased from summer through winter (Figure 6). The relative density of residual steelhead at the Little Sheep Creek release site increased slightly from winter to spring.

Some residual steelhead moved upstream from the release sites on Deer and Little Sheep creeks through the seasons (see **Appendix A**). We found residual steelhead progressively farther upstream as the seasons progressed. We found residual steelhead in Spring Creek upstream of Wallowa Hatchery during summer, but did not find them there in later seasons. During spring we collected maturing male residual hatchery steelhead at our adult broodstock collection facilities on Deer and Little Sheep creeks and at Wallowa Hatchery.

Discussion and Management Implications

The relative abundance and dispersal pattern of residual steelhead from the 1993 hatchery releases was similar to that of residual steelhead from the 1992 hatchery releases (Whitesel et al. 1993) with several exceptions. We did not find relative densities of residual hatchery steelhead as high in 1993 as in 1992 (Figure 7), and we did not find that residual hatchery steelhead dispersed upstream in the Imnaha basin in 1993 to the extent we found in 1992. Although the relative densities of residual steelhead were lower in summer 1993 than in summer 1992, the highest observed densities were, again, at the release sites on Deer and Little Sheep creeks during the summer of both years. The differences in relative densities at the release sites between the two years may be a result of a lower overall rate of residualism in 1993 or that residual steelhead in 1993 dispersed differently than those in 1992. If this dispersal was into areas that we could not sample quantitatively, such as the lower Grande Ronde and Imnaha rivers or the Snake River, then the actual rates of residualism in 1992 and 1993 may have been similar. The number of hatchery steelhead released was comparable in 1992 and 1993, but the flows that these fish experienced after release were quite different. The flows in the Grande Ronde and Imnaha rivers during spring after the release of these fish were approximately 3-fold higher in 1993 than in 1992 (Table 2). The higher flows in 1993 may have stimulated more hatchery fish to migrate out of, or residual steelhead to disperse lower in, the Grande Ronde and Imnaha rivers. We found residual steelhead tended to disperse downstream from the release sites in 1993, as we found in 1992. However, some residual steelhead did move upstream above the release sites in Deer, Little Sheep, and Spring creeks again in 1993.

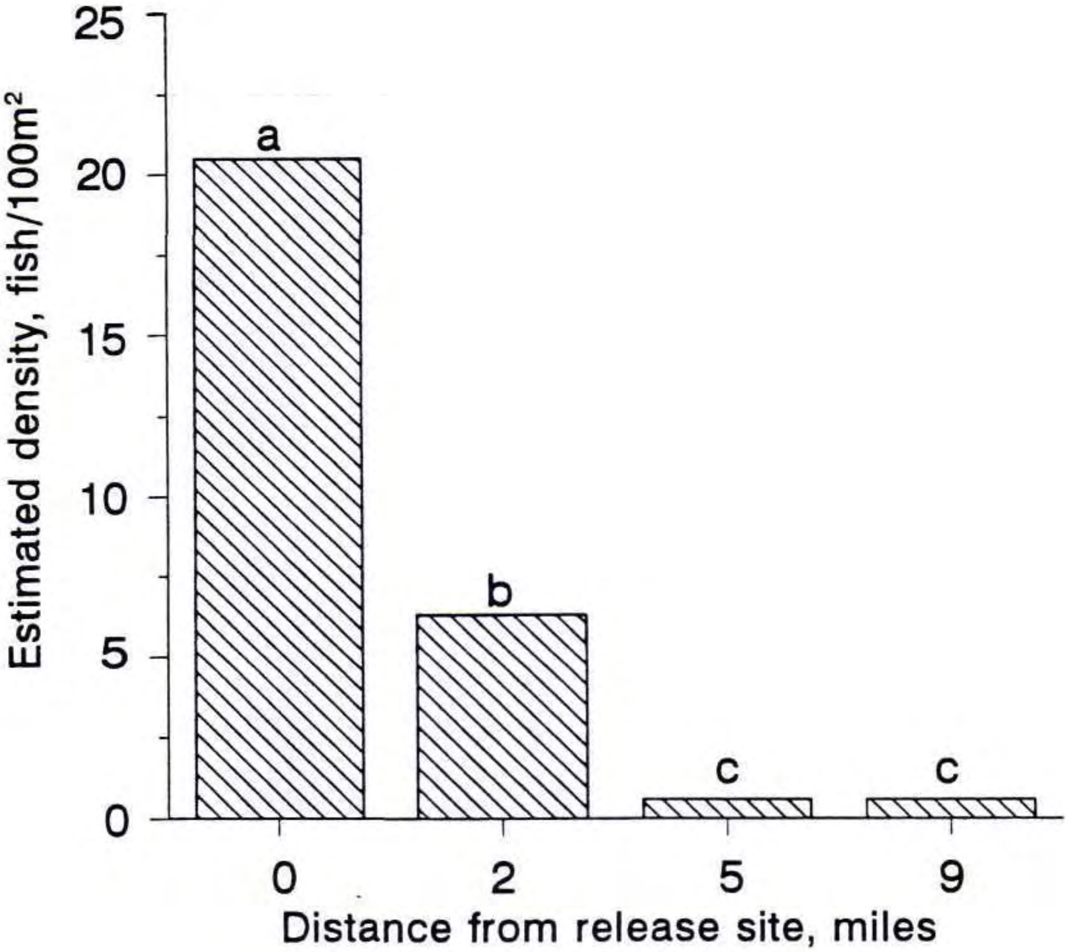

Figure 5. Dispersal and density of residual steelhead near the Little Sheep Creek release site during summer 1993. All distances represent downstream movement. "a" is significantly greater than "b". "c" indicates that sample size is inadequate to make comparisons.

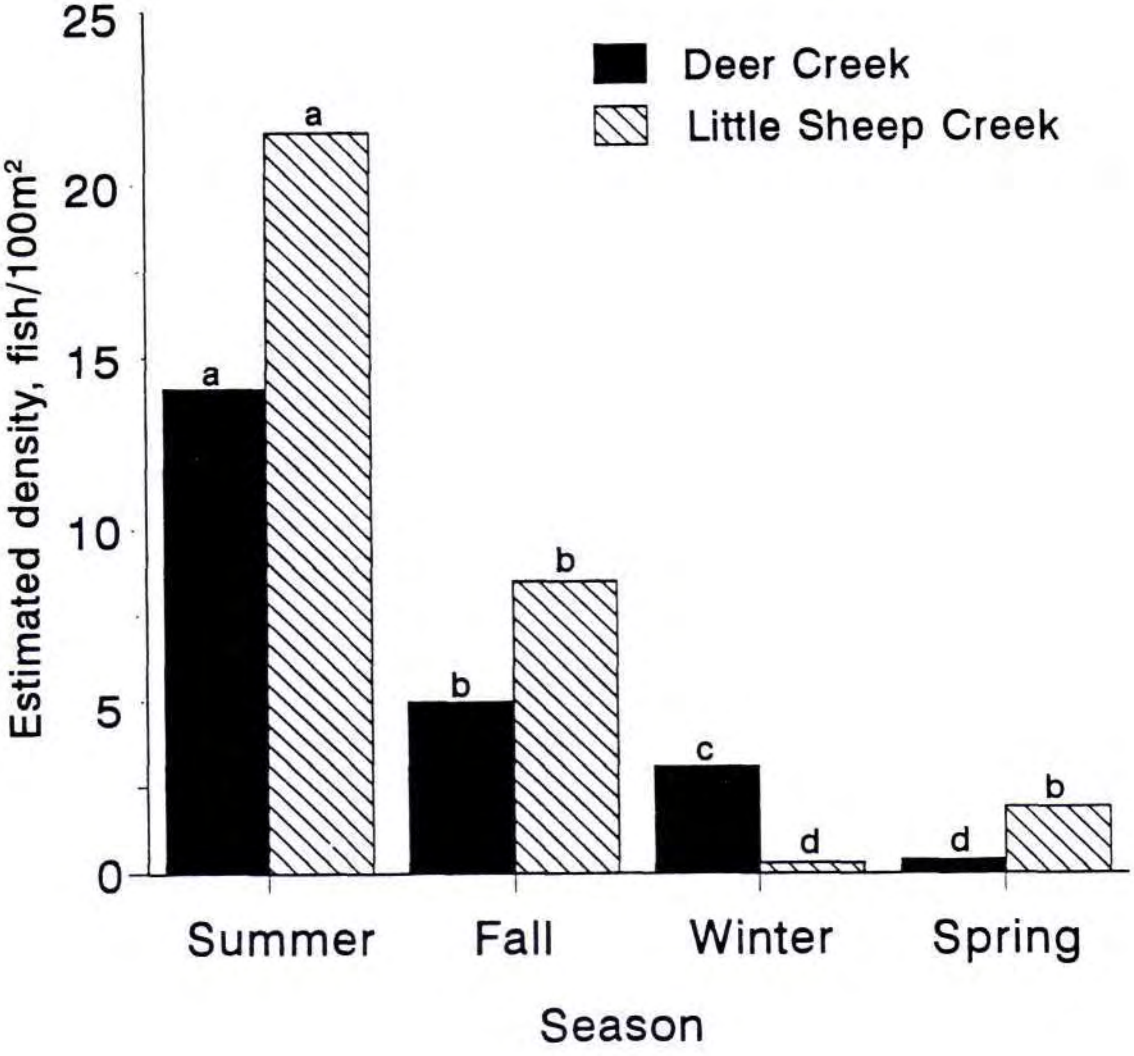

Figure 6. Seasonal patterns of residual steelhead densities at the Deer and Little Sheep creek release sites (index areas) from summer 1993 to spring 1994. For each release site, "a" is significantly greater than "b" which is significantly greater than "c". "d" indicates that sample size is inadequate to make comparisons.

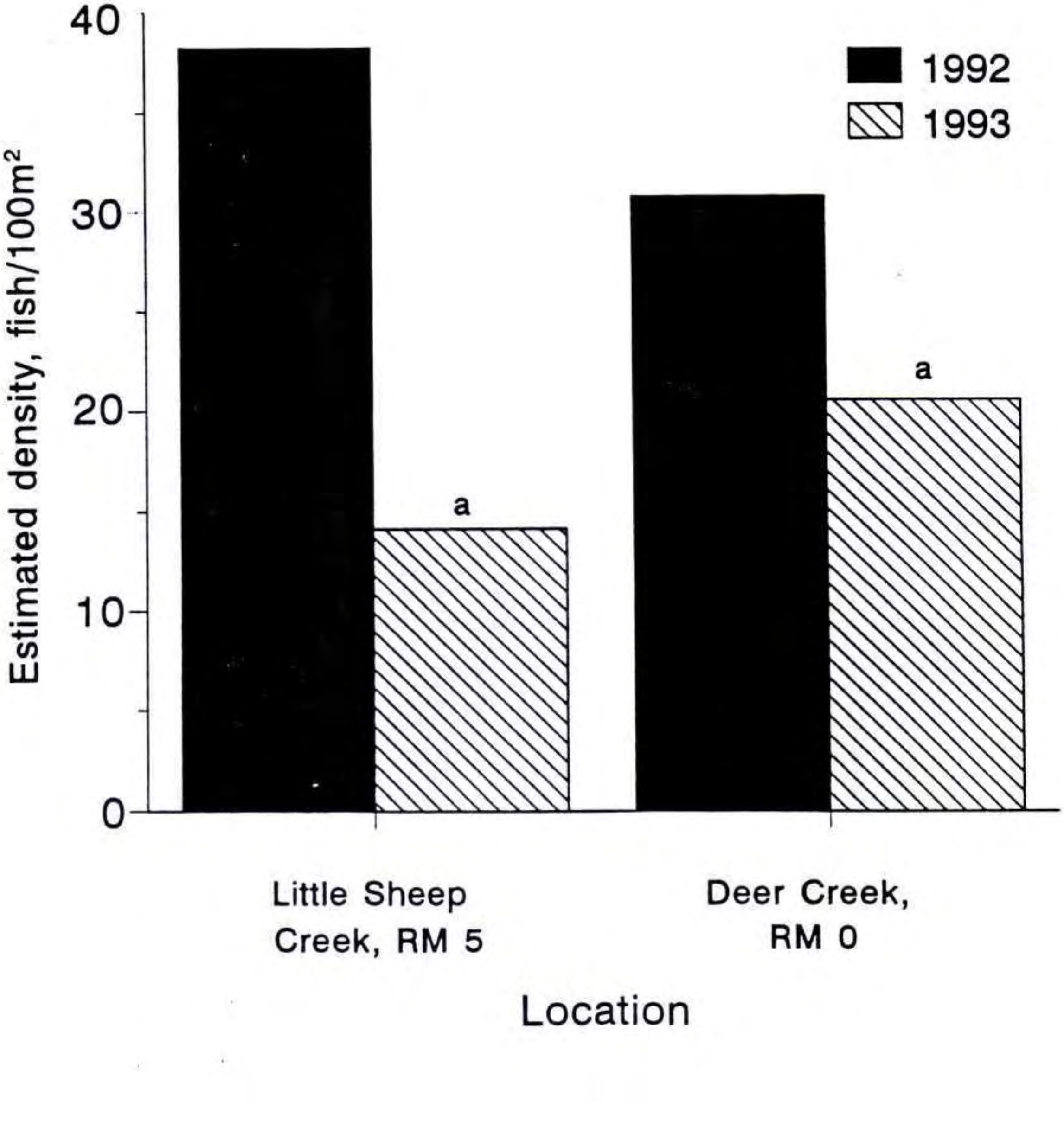

Figure 7. Estimated densities of residual steelhead at index sites during summer 1992 and summer 1993. "a" indicates a significant decrease in density from 1992 to 1993.

Table 2. River flows (cfs) from 16 April to 31 May for 1992 and 1993 in the Grande Ronde and Imnaha river basins. Flow records were obtained from USGS gaging stations.

Stream	Location	Mean flow (cfs), 16 April - 31 May 1992	1993
Grande Ronde River	Troy	2,942	9,513
Catherine Creek	Union	175	531
Minam River	Minam	852	1,379
Imnaha River	Imnaha	542	1,759

Our current hatchery steelhead release sites help to minimize the impacts of residual steelhead on juvenile chinook salmon as they are below the spawning and primary rearing areas for spring chinook salmon in the Grande Ronde and Imnaha rivers. The areas of high densities of residual steelhead appear to be near release sites and are not in major rearing areas for juvenile chinook salmon. Although the distribution of residual steelhead appears to change seasonally, the highest densities generally remained near the release sites. The most likely areas for moderate to maximal interactions to occur between residual steelhead and juvenile chinook salmon appear to be the lower Wallowa, Grande Ronde, and Imnaha rivers (Figure 8), as we found in 1992.

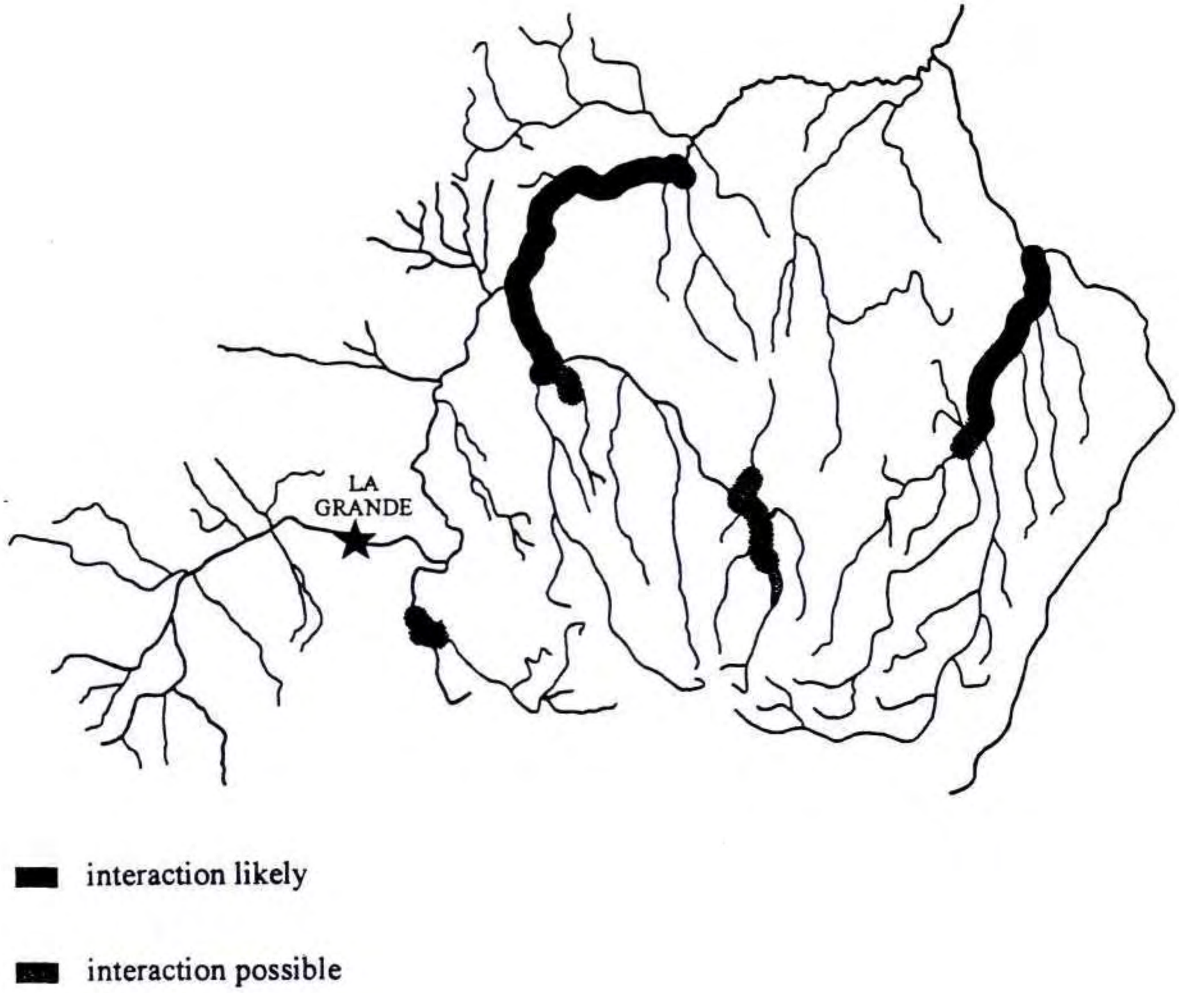

Figure 8. Areas of overlap and potential for interaction between residual steelhead and naturally-produced juvenile chinook salmon in the Grande Ronde and Imnaha river basins during summer 1993.

PREDATION BY HATCHERY-REARED STEELHEAD ON JUVENILE SPRING CHINOOK SALMON.

Methods

We collected the stomachs from the residual steelhead captured by electrofishing during our routine sampling and by angling during a three day raft trip in July 1993 from Wallowa River RM 10 (Minam) to Grande Ronde River at RM 46 (Troy). We collected stomachs from all residual steelhead collected by angling, and only those residual steelhead captured by electrofishing during the first pass of electrofishing. Stomachs (the anterior esophagus to the posterior intestine) were excised from euthanized fish and fixed in 10% formalin for 2-3 weeks. The samples were then removed from the formalin, soaked in water for 24 hr, then transferred to and stored in reagent grade alcohol (90% ethyl alcohol, 5% methyl alcohol, 5% isopropyl alcohol). Contents of the stomachs were dissected into a Petri dish and examined under a dissecting scope at 15X magnification. Whole fish and discernable fish parts found in the stomach contents were identified to family and all salmonids were identified to species.

We calculated the incidence of residual steelhead stomachs that contained juvenile chinook salmon. The incidence was expressed as a percent (number of stomachs containing juvenile chinook salmon x 100 / number of total stomachs sampled). Based on this percent and the total number of stomachs we examined, we then calculated the 95% confidence interval (CI) for both numbers. We let the upper 95% CI define the maximum incidence of steelhead stomachs containing juvenile chinook salmon.

Results

We examined stomachs from 358 residual steelhead captured throughout the year from a variety of locations (Table 3). We found fish or fish parts in three of these stomachs, including one with a young-of-the-year steelhead (63 mm fork length). Sculpins were found in the other two stomachs with fish or fish parts. We did not find juvenile chinook salmon in any of the residual steelhead stomachs. The maximum incidence of residual steelhead stomachs containing juvenile chinook salmon was 0.84%.

Discussion and Management Implications

The overall incidence of residual steelhead stomachs that contained juvenile chinook salmon was low, similar to results we found in 1992-93 when we examined 611 stomachs and did not find juvenile chinook salmon in the contents (Whitesel et al. 1993). At least two explanations are possible for this apparent lack of predation. Juvenile chinook salmon did not appear to be an abundant food resource in the areas where most of the residual steelhead stomachs were collected. Furthermore, in areas where residual steelhead and juvenile chinook salmon did overlap, residual steelhead may have been too small to prey effectively on juvenile chinook salmon. However, very low rates of residual steelhead predation on juvenile chinook salmon could have substantial impacts on chinook salmon populations (see Whitesel et al. 1993).

Table 3. Number of stomachs of hatchery-reared steelhead examined to determine incidence of predation on salmonids, by season.

Basin, season	Number of stomachs		
	Examined	Containing fish	Containing salmonids
IMNAHA			
Summer	103[a]	0	0
Fall	14	1	1[b]
Winter	3	0	0
Spring	8	0	0
GRANDE RONDE			
Summer	181[c]	2	0
Fall	21	0	0
Winter	25	0	0
Spring	3	0	0

[a] *One stomach from a fish captured in the main stem Imnaha River (RM 4).*
[b] *Steelhead.*
[c] *42 stomachs from fish captured between RM 10 of the Wallowa River and RM 46 of the Grande Ronde River.*

CHARACTERISTICS OF RESIDUAL STEELHEAD

Methods

Fork Length

In order to determine if residualism is independent of juvenile growth characteristics, we examined the length-frequency of residual steelhead and compared that to the length-frequency of the hatchery release groups. To develop an equation so that scale radius could be used to predict fork length, we collected scale samples from, and measured the fork length of, a portion of the hatchery-reared steelhead just prior to their release. The relationship was expressed as

Fork length = m (Scale radius) + b *equation 1.1*

where m (slope) and b (Y intercept) were constants, and fork length and scale radius were expressed in mm. One relationship was developed using both the Wallowa and Imnaha stock juveniles, as the individual stock models were not statistically different. A modified jackknife analysis was used to determine the percent error of each model. We collected scale samples from, and measured the fork length of, a portion of the residual steelhead captured during our summer sampling. We examined the residual steelhead scales for patterns of reduced growth (check marks) laid down at the time of release and measured the radial distance to these marks. Based on the radial distance of the check mark and the equations developed from fish sampled before release, we back-calculated the fork lengths at release of these residual steelhead. We then calculated the mean fork length of the residual steelhead at the time of release. We used Student's t-test ($\alpha = 0.05$) to compare the mean fork length of residual steelhead at the time of release to that of the total release group. We also used this information to calculate the instantaneous growth rate (IGR) of these residual steelhead (see **APPENDIX B**).

Sex and Maturity

In order to determine whether residualism is independent of sex, we compared the sex ratio of residual steelhead to that of hatchery-reared steelhead sampled prior to release. To begin an assessment of their life history strategy, we also monitored the maturation of residual steelhead. Sex and maturational condition were determined by a visual examination of gonads. We classified the maturity of males using the following criteria: immature males had translucent, threadlike testes; maturing males had enlarged, opaque testes; and mature males had large, white testes from which milt could be expressed. We classified the maturity of females using the following criteria: immature females had translucent ovaries; maturing females had enlarged, opaque ovaries; and mature females had large, pigmented eggs that appeared to be fully developed. We used a binomial test ($\alpha = 0.05$) to compare the sex ratio of the release group to that of the residual steelhead captured during the summer. We used a Chi-square analysis to compare the incidence of sexual maturation between each season.

Release Strategy

Hatchery-reared steelhead released in the Grande Ronde and Imnaha river basins under the LSRCP are either acclimated at a release site for a minimum of two weeks before release or are released directly into the stream from a fish transport truck. A portion of the fish in the acclimated and direct stream release groups are differentially coded-wire-tagged and freeze-branded prior to release. In an attempt to identify which release strategy it originated from, we examined each residual steelhead that we captured for brands and left ventral (LV) fin clips (indicating the presence of a CWT). To assign tagged fish to a release strategy, snouts were collected then CWTs excised and read from LV marked fish. We used binomial test to compare the rate of residualism between acclimated- and direct-stream-released fish.

Results

Fork Length

Scale radius was an acceptable predictor of fork length. The result for equation 1.1 was:

$$\text{Fork length} = 105.20\ (\text{Scale radius}) + 101.54;\ P<0.05;\ R^2=0.48.$$

The combined model (Figure 9) was used to back-calculate the size-at-release for residual steelhead. The combined model had a mean error rate of 5.4% when estimating fork length. For both stocks, the hatchery-reared steelhead that residualized were shorter at the time of release than the overall release group (Table 4). All residual steelhead that we sampled were estimated to be shorter than 205 mm (Wallowa stock) or 220 mm (Imnaha stock) fork length at release while 50% of the fish were estimated to be shorter than 170 mm (Wallowa stock) or 175 mm (Imnaha stock) fork length at release.

Table 4. Mean (SE) fork length (mm) of hatchery-reared steelhead, by stock. Differences between groups were judged to be significant (S) when $P<0.05$ and not significant (NS) when $P\geq0.05$.

Stock	Pre-release	Residuals	Differences
Imnaha	192.0 (0.77)	170.6 (1.97)	S
Wallowa	202.8 (0.55)	163.2 (1.13)	S

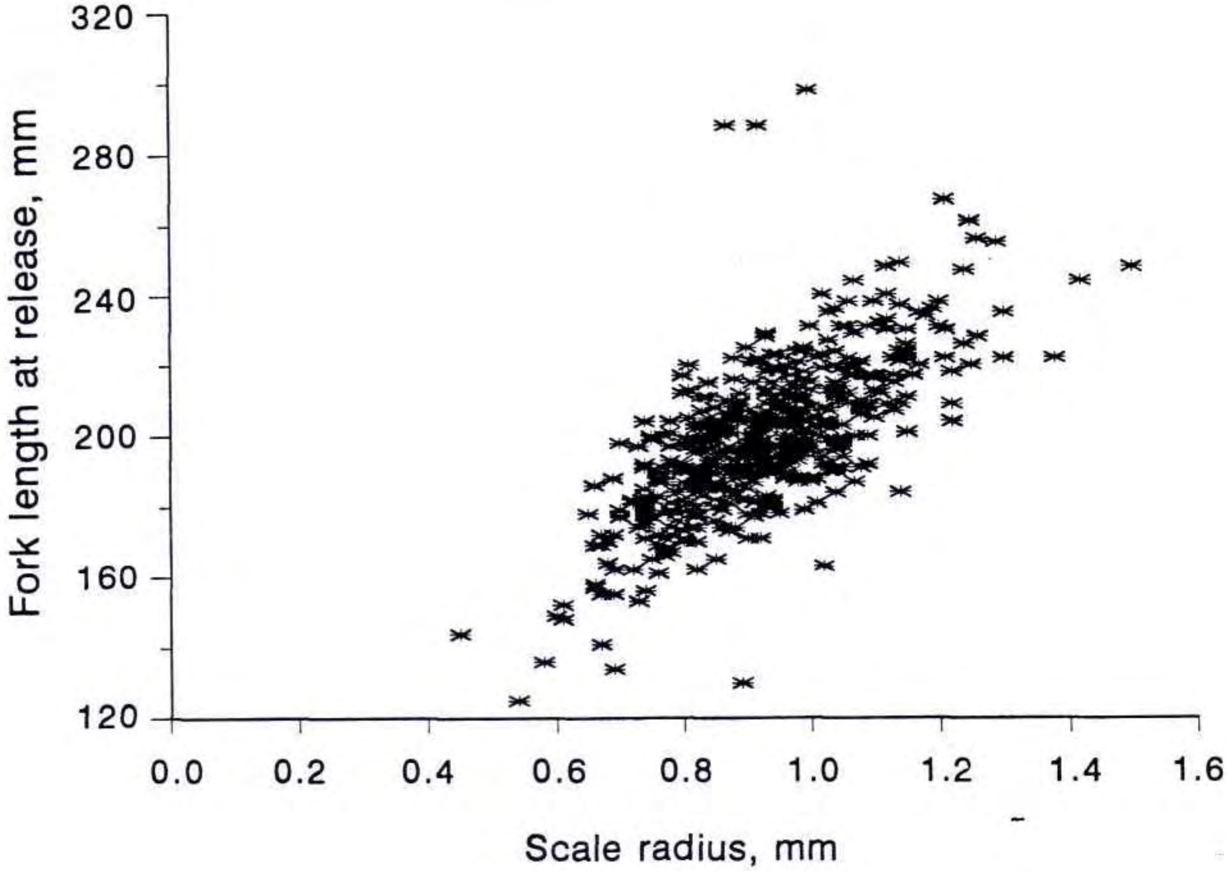

Figure 9. The relationship between fork length (FLEN) and scale radius (SR) for hatchery-reared steelhead at release during spring 1993. Data from Wallowa and Imnaha stocks were pooled to generate one model. The linear regression (FLEN = 105.20 SR + 101.54; R^2 = 0.48) was significant ($P < 0.0001$).

Sex and Maturity

More males were found in the population of residual steelhead than in the overall release group. The male:female sex ratio of hatchery-reared steelhead at release was 54:46, whereas the male:female sex ratio of residual steelhead captured in the summer was 90:10 (Table 5). The percent of the residual steelhead population that was composed of males remained near 80% during the fall and winter and was over 95% in spring (Table 5).

The majority of the male residual steelhead sampled were immature during the summer following the release of the 1992 brood (Table 6). This cohort of residual steelhead began to mature by the fall and some fish had become mature by winter. By spring, the majority of residual steelhead males from this cohort had either become mature or remained immature with very few fish in a maturing stage of development. Ninety of the 115 males sampled during spring were captured at our broodstock collection facilities. The majority of the female residual steelhead sampled were also immature during the summer following the release of the 1992 brood (Table 7). We found one maturing female each season from summer through winter, and all four females examined during spring were mature. These mature females were captured at adult collection facilities at Wallowa Hatchery and Big Canyon Facility, and all were greater than 350 mm fork length.

During summer we found males from the 1992 release (1991 brood, determined by CWT) that were immature, maturing, or mature. During spring we collected mature males from the 1992 and 1993 releases at our broodstock collection facilities. We also found a mature female from the 1992 release (determined by CWT) during summer 1993.

Table 5. Percentage sex composition of hatchery-reared steelhead. For each sex, differences in percentages between adjacent groups were judged to be significant (S) when $P<0.05$ and not significant (NS) when $P\geq0.05$.

Group, season, year	*N*	Males(%)	Females(%)	Differences
Pre-release,				
Spring, 1993	400	54.0	46.0	-
Residuals,				
Summer, 1993	367	90.2	9.8	S
Fall, 1993	51	84.3	15.7	NS
Winter, 1994	32	78.1	21.9	NS
Spring, 1994	120	95.8	4.2	NS

Table 6. Maturity of male residual steelhead, by season. Differences in percentages between adjacent seasons were judged to be significant (S) when $P<0.05$ and not significant (NS) when $P \geq 0.05$.

Season	*N*	Immature (%)	Maturing (%)	Mature (%)	
Summer	331	77.3	11.2	11.5	-
Fall	43	46.5	46.5	7.0	S
Winter	25	44.0	40.0	16.0	NS
Spring[a]	115	13.9	3.5	82.6	S

[a] *Ninety fish were captured at adult broodstock collection facilities.*

Table 7. Maturity of female residual steelhead, by season. Differences in percentages between adjacent seasons were judged to be significant (S) when $P<0.05$ and not significant (NS) when $P \geq 0.05$.

Season	*N*	Immature (%)	Maturing (%)	Mature (%)	
Summer	36	94.4	2.8	2.8	-
Fall	8	87.5	12.5	0.0	NS
Winter	7	85.7	14.3	0.0	NS
Spring[a]	4	0.0	0.0	100.0	S

[a] *All four were captured at adult broodstock collection facilities and were from releases in 1992 or 1993.*

Release Strategy

We identified acclimated- and direct-stream-released residual steelhead by information collected from coded-wire-tagged individuals. We found no difference in the rate of residualism between these release strategies for releases at the Little Sheep Creek Facility or the Big Canyon Facility (Table 8). We recovered too few freeze-branded residual steelhead to use brands to compare residualism among release strategies.

Table 8. Number of coded-wire-tagged residual steelhead recovered by release type.

Release site	Release type	No. released	No. recovered
Little Sheep Facility	Direct stream	45,942	23
	Acclimated	49,163	28
Big Canyon Facility	Direct stream	48,085	10
	Acclimated	51,112	10

Discussion and Management Implications

The residual steelhead from both Wallowa and Imnaha stocks originated primarily from the small male component of the release groups, as we found in 1992 (Whitesel et al. 1993). Thus, culling these fish from the release group may decrease overall rates of residualism.

The majority of steelhead that residualized were immature during summer following release. However, a substantial portion of the residual males did become mature by the following spring. These mature residual steelhead may interbreed with natural populations of both rainbow and steelhead trout.

Residual steelhead appeared to have the potential to exhibit one of at least two life history strategies. Residual steelhead exhibited the potential to adopt the nonanadromous strategy of either a precocious steelhead or a rainbow trout. This was evident when some residual steelhead males became sexually mature in the spring following their release. Residual steelhead also exhibited the potential to maintain an anadromous strategy but migrate as 2- rather than 1-year-old smolts. This possibility began to emerge when some residual steelhead males and most residual steelhead females remained sexually immature, and when some of these fish exhibited smolt morphology the spring following their release. Although it appears that many life history strategies along the steelhead-rainbow continuum are available to residual steelhead, further information is needed to specifically quantify the alternatives.

Hatchery-reared steelhead that were acclimated before release residualized at a similar rate to those that were released directly into a stream. Therefore, current release strategies do not appear to be useful tools for managers to reduce the rates of residualism.

FUTURE DIRECTIONS

1. Monitor index areas for long term trends in the extent of residualism.
2. Develop more sampling sites closer to the release locations to better describe the movement of residual steelhead after release.
3. Conduct controlled experimental studies to better assess the predator-prey relationship between residual steelhead and juvenile chinook salmon.
4. Develop hatchery-rearing and release strategies for steelhead that will help to minimize the rate of residualism, and continue to characterize the portion of the release groups that do residualize.
5. Explore the choice of life history strategies, anadromous or non-anadromous, by residual steelhead.
6. Evaluate the possibility of using volitional releases of hatchery-reared steelhead to minimize the number of residual steelhead in local drainages.
7. Begin investigating the effects of residual steelhead on natural populations of *O. mykiss*.
8. Evaluate the contribution of residual steelhead to trout fisheries in NORTHEAST Oregon.
9. Examine the relationship between residual steelhead and wild steelhead distributions.

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APPENDIX A

The Relative Densities of Residual Steelhead and Naturally-produced Juvenile Chinook Salmon in the Grande Ronde and Imnaha River Basins During the 1993-94 Sampling Period

Appendix Table A-1. Observed densities (fish/100m^2) of residual steelhead in the Grande Ronde and Imnaha river basins, summer 1993 to spring 1994.

Basin, stream	RM	Residual steelhead density			
		Summer	Fall	Winter	Spring
GRANDE RONDE					
Grande Ronde River	151	0.000	(a)	(a)	(a)
	155	(a)	0.000	(a)	(a)
	158	0.285	0.175	(a)	(a)
	161	(b)	(a)	(a)	(a)
	165	0.000	(a)	(a)	(a)
	167	(a)	0.000	(a)	(a)
	171	0.000	0.000	(a)	(a)
	180	0.000	(a)	(a)	(a)
Catherine Creek	18	1.647	1.680	(a)	(c)
	27	0.000	0.000	(a)	(c)
North Fork	1	0.000	(a)	(a)	(a)
South Fork	0	0.000	(a)	(a)	(a)
Five Points Creek	1.5	0.000	(a)	(a)	(a)
Fly Creek	0	0.000	(a)	(a)	(a)
Lookingglass Creek	0	0.000	(a)	(a)	(a)
Meadow Creek	0	0.000	(a)	(a)	(a)
Mud Creek	0	0.000	0.000	(a)	(a)
Sheep Creek	1.5	0.000	(a)	(a)	(a)
Wallowa River					
Deer Creek	0	14.128	4.970	3.146	0.427
	1	1.270	3.913	6.536	(c)
	4	(a)	0.499	0.000	0.000
	5	0.000	(a)	(a)	(a)
	7	(a)	0.000	(c)	0.000
	10	0.000	0.000	0.432	0.000
Hurricane Creek	0	0.000	(a)	(a)	(a)
Lostine River	0	0.409	0.252	0.000	(a)
Minam River	0	0.000	0.000	(a)	(a)
	5	0.000	(a)	(a)	(a)
	6	0.000	(a)	(a)	(a)
Spring Creek	0	(b)	(b)	0.000	(a)
	2.5	2.886	(a)	(a)	(a)
	3	(a)	(a)	0.000	0.000
	5	(a)	0.000	(a)	(a)
Trout Creek	0	0.000	(c)	0.271	0.000
Wildcat Creek	0	(b)	(a)	(a)	(a)
	4	0.000	(a)	(a)	(a)
Wenaha River	4	0.000	0.000	(a)	(a)

Appendix Table A-1. Continued.

Basin, stream	RM	Residual steelhead density			
		Summer	Fall	Winter	Spring
IMNAHA					
Imnaha River	18	(b)	(a)	(a)	(a)
	22	0.578	(a)	(a)	(a)
	23	(a)	0.078	(a)	(a)
	33	(c)	0.000	(a)	(a)
	53	0.000	(a)	(a)	(a)
Big Sheep Creek					
Camp Creek	0	0.000	0.716	0.000	0.461
	5	0.000	(a)	(a)	(a)
Little Sheep Creek	0	0.580	1.093	(c)	(c)
	2	(a)	(b)	(b)	(b)
	5	20.458	8.516	0.326	1.874
	8	(a)	(b)	0.566	0.000
	12.5	0.000	0.000	(c)	(b)
	18	0.000	0.000	0.000	0.000
	24	0.000	0.000	0.000	0.000
Bear Gulch	0	6.261	0.980	0.000	0.776

[a] *Area not sampled.*
[b] *Residuals present, but unable to estimate density.*
[c] *Residuals not seen, but unable to estimate density.*

Appendix Table A-2. Observed densities (fish/100m^2) of juvenile chinook salmon in the Grande Ronde and Imnaha river basins, summer 1993 to spring 1994.

Basin, stream	RM	Juvenile chinook salmon density			
		Summer	Fall	Winter	Spring
GRANDE RONDE					
Grande Ronde River	151	0.102	(a)	(a)	(a)
	155	(a)	0.000	(a)	(a)
	158	0.000	0.000	(a)	(a)
	161	0.000	(a)	(a)	(a)
	165	0.000	(a)	(a)	(a)
	167	(a)	0.000	(a)	(a)
	171	0.000	0.000	(a)	(a)
	180	0.000	(a)	(a)	(a)
Catherine Creek	18	3.765	30.778	(a)	(c)
	27	3.268	3.811	(a)	(b)
North Fork	0	0.000	(a)	(a)	(a)
South Fork	0	(b)	(a)	(a)	(a)
Five Points Creek	1.5	0.000	(a)	(a)	(a)
Fly Creek	0	0.000	(a)	(a)	(a)
Lookingglass Creek	0	0.000	(a)	(a)	(a)
Meadow Creek	0	0.000	(a)	(a)	(a)
Mud Creek	0	0.000	0.000	(a)	(a)
Sheep Creek	1.5	0.000	(a)	(a)	(a)
Wallowa River					
Deer Creek	0	0.000	0.451	0.000	0.000
	1	0.000	0.000	0.000	(c)
	4	(a)	0.000	0.000	0.000
	5	0.000	(a)	(a)	(a)
	7	(a)	0.000	(c)	0.000
	10	0.000	0.000	0.000	0.000
Hurricane Creek	0	16.845	(a)	(a)	(a)
Lostine River	0	0.204	0.000	0.000	(a)
Minam River	0	8.530	0.000	(a)	(a)
	5	14.875	(a)	(a)	(a)
	6	16.754	(a)	(a)	(a)
Spring Creek	0	(c)	(b)	0.000	(a)
	2.5	(b)	(a)	(a)	(a)
	3	(a)	(a)	0.000	0.000
	5	(a)	0.000	(a)	(a)
Trout Creek	0	1.180	(b)	0.000	0.000
Wildcat Creek	0	(b)	(a)	(a)	(a)
	4	0.000	(a)	(a)	(a)
Wenaha River	4	0.000	0.000	(a)	(a)

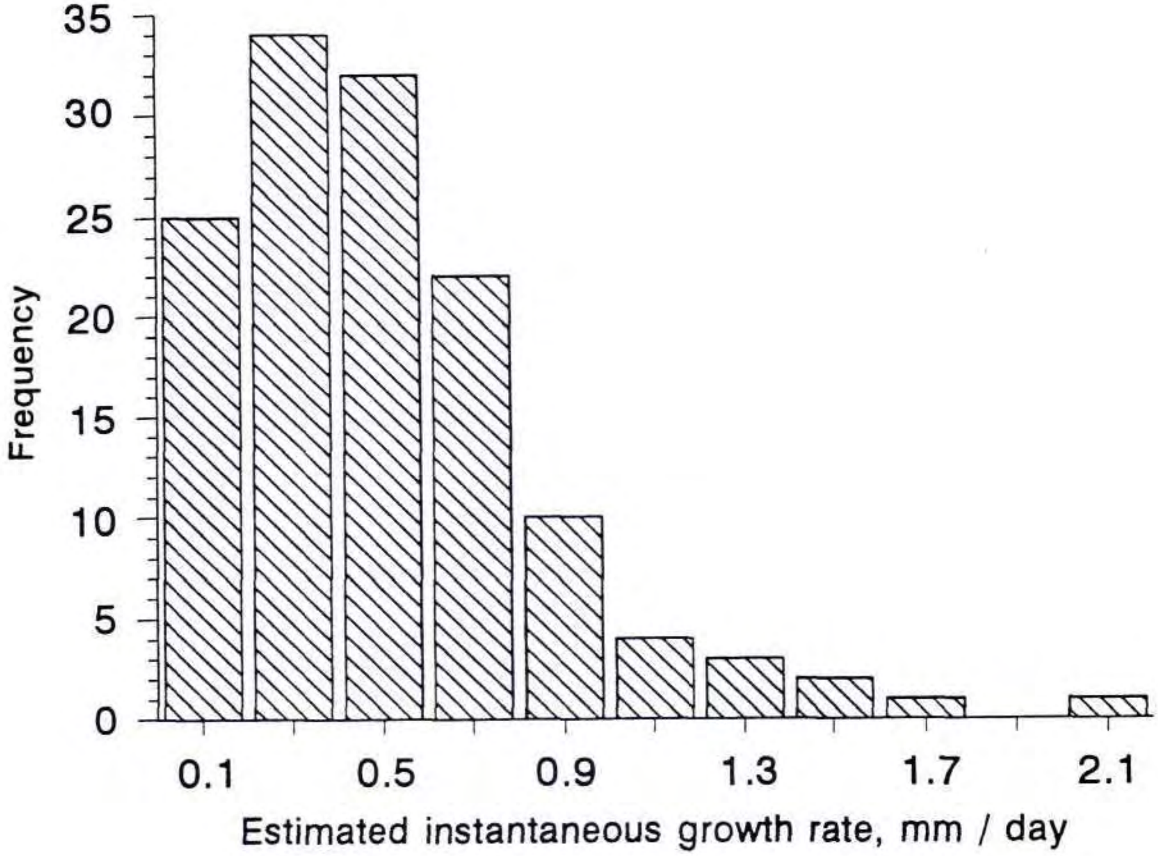
Appendix Table A-2. Continued.

Basin, stream	RM	Juvenile chinook salmon density			
		Summer	Fall	Winter	Spring
IMNAHA					
Imnaha River	18	(b)	(a)	(a)	(a)
	22	1.389	(a)	(a)	(a)
	23	(a)	0.078	(a)	(a)
	33	(b)	0.000	(a)	(a)
	53	14.085	(a)	(a)	(a)
Big Sheep Creek					
	0	(a)	(b)	(a)	(a)
	2	(a)	(b)	(c)	(a)
	21	(b)	(a)	(a)	(a)
Camp Creek	0	0.000	0.000	0.000	0.000
	5	0.000	(a)	(a)	(a)
Little Sheep Creek	0	0.000	0.000	(c)	(c)
	2	(a)	(b)	(c)	(c)
	5	0.000	0.000	0.000	0.000
	8	(a)	(c)	0.000	0.000
	12.5	0.000	0.000	(c)	(c)
	18	0.000	0.000	0.000	0.000
	24	0.000	0.000	0.000	0.000
Bear Gulch	0	0.000	0.000	0.000	0.000

[a] *Area not sampled.*
[b] *Chinook present, but unable to estimate density.*
[c] *Chinook not seen, but unable to estimate density.*

APPENDIX B

The Instantaneous Growth Rate of Residual Steelhead

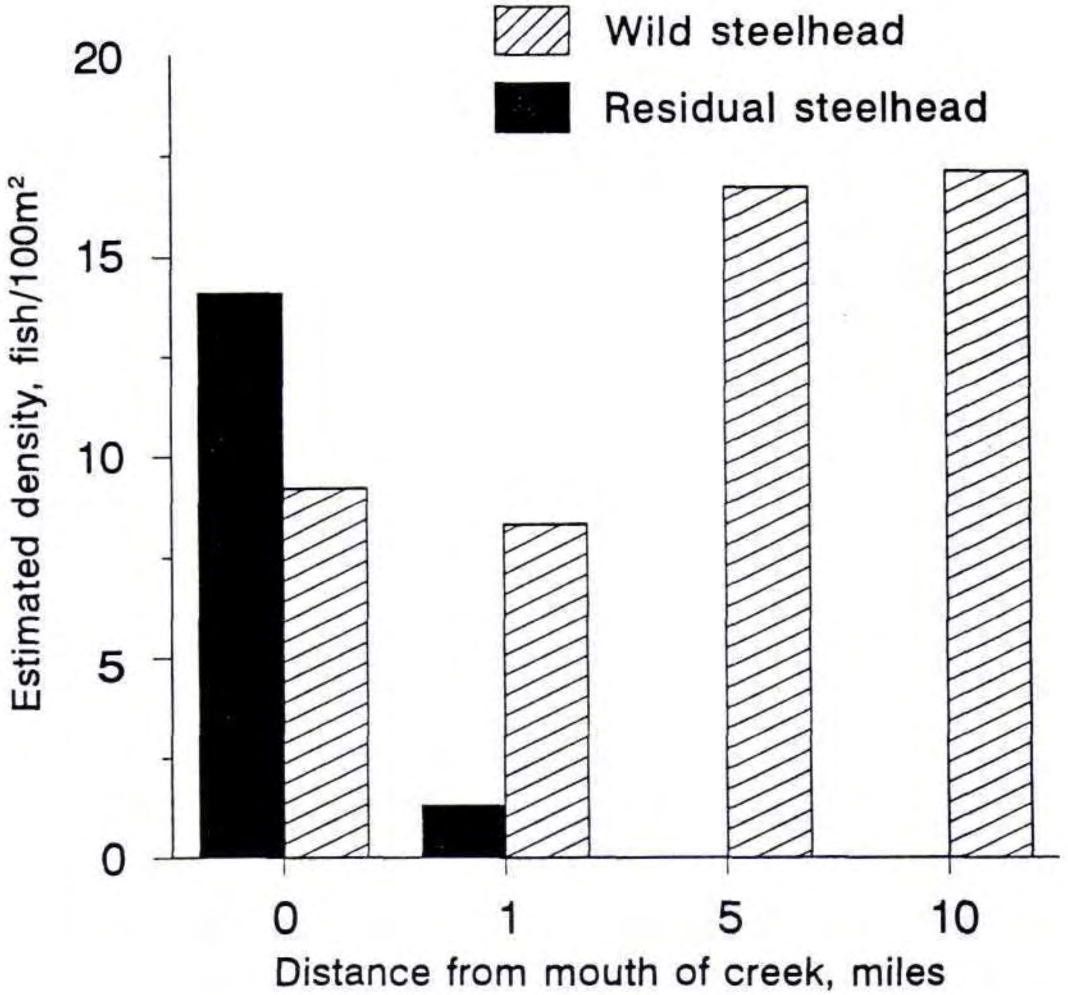


Appendix Figure B-1. Estimated instantaneous growth rate of residual steelhead sampled in the Grande Ronde and Imnaha river basins. Fish were released in the spring of 1993 and then sampled during the summer and fall of 1993. Growth rate was calculated as (size at recovery - back-calculated size at release) / (days between release and recovery). Size at release was back-calculated from scale models.

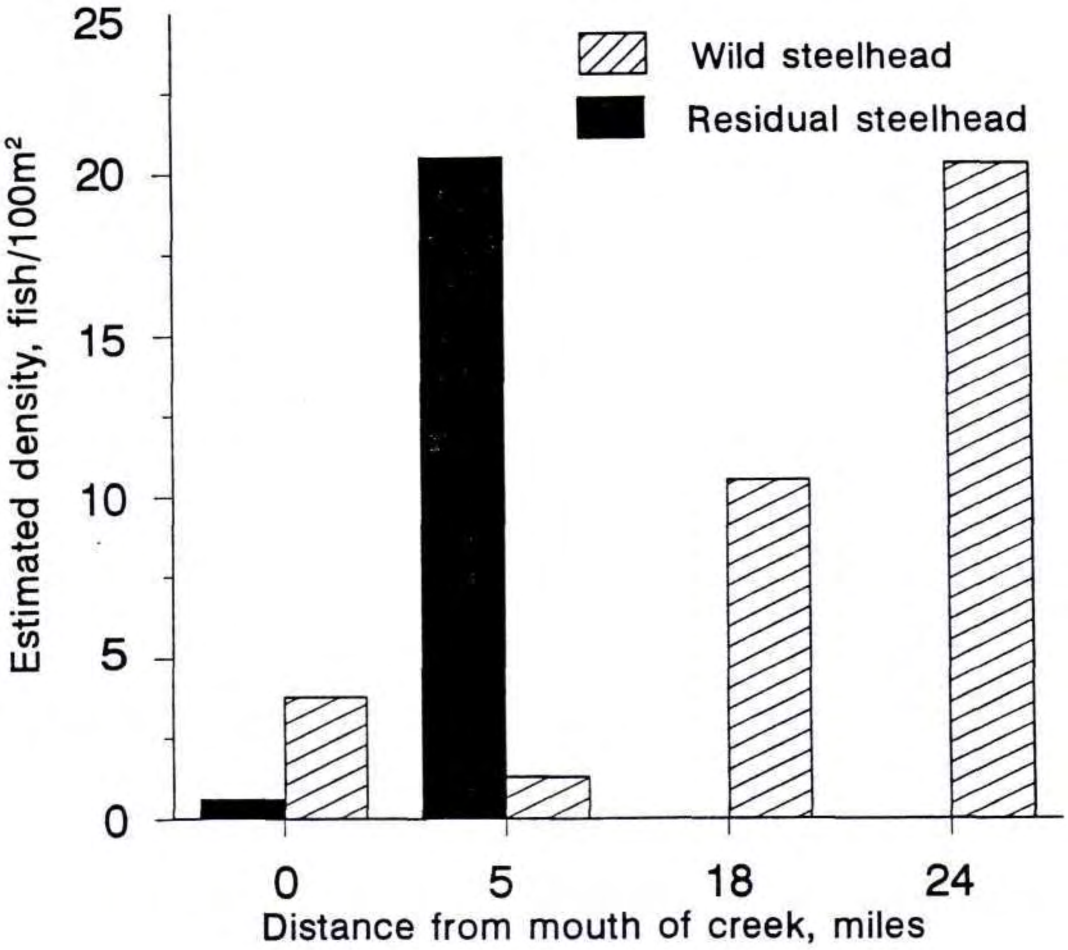
APPENDIX C

The Relative Densities of Wild Juvenile Steelhead in Deer and Little Sheep Creeks

We examined the relative densities of juvenile steelhead age-1 and older in Deer and Little Sheep creeks during summer 1993 to see if there was any indication that residual steelhead were displacing wild juvenile steelhead. Young-of-the-year steelhead were distinguished from age-1 and older steelhead based on length. When we sampled sites for abundance of residual steelhead and juvenile chinook salmon using a multiple pass removal method, we did not apply the same rigorous standards for reduction of wild steelhead as we did for residual steelhead and juvenile chinook salmon. Therefore, we did not obtain good abundance estimates (estimates with low standard errors) of wild juvenile steelhead at every site we sampled. The relative densities of wild and residual steelhead in Deer Creek during summer 1993 are shown in **Appendix Figure C-1**. The relative densities of wild and residual steelhead in Little Sheep Creek during summer 1993 are shown in **Appendix Figure C-2**. The densities of wild steelhead are higher upstream than downstream in both Deer and Little Sheep creeks and lowest in areas where residual steelhead are present. However, it is unclear whether this is a result of displacement of wild steelhead by residual steelhead in the downstream areas, or whether wild steelhead are naturally at higher densities in these upstream areas. To examine the relationship between residual and wild steelhead densities, we need to look at other streams with similar habitats and without residual steelhead.



Appendix Figure C-1. The relative densities of residual steelhead and wild steelhead (age 1 and older) in Deer Creek during summer 1993. Hatchery steelhead were released at RM 0.



Appendix Figure C-2. The relative densities of residual steelhead and wild steelhead (age 1 and older) in Little Sheep Creek during summer 1993. Hatchery steelhead were released at RM 5.

APPENDIX D

Catch of Residual Hatchery Steelhead in Summer Steelhead Fisheries in Northeast Oregon

We collected catch information for residual hatchery steelhead during summer steelhead creel surveys in the fall on the Grande Ronde River, and in the spring on the Grande Ronde, Wallowa, and Imnaha rivers. Anglers were asked if they had caught fin-marked rainbow trout, which were actually residual hatchery steelhead as ODFW did not release fin-marked rainbow trout in spring or summer 1993.

Anglers interviewed during steelhead creel surveys reported catching residual steelhead in the Grande Ronde River basin in the fall and spring and in the Imnaha River in the spring (**Appendix Table D-1**), indicating that residual steelhead do contribute to fisheries in northeast Oregon. The majority of the catch of residual steelhead in the Lower Grande Ronde River survey area occurred during the fall.

Appendix Table D-1. Number of residual hatchery steelhead, wild rainbow trout and adult steelhead reported caught during steelhead creel surveys in the Imnaha and Grande Ronde river basins, fall 1993 to spring 1994.

Survey area	Season	Anglers interviewed	Residual steelhead	Wild trout	Adult steelhead
Imnaha River	spring	134	13	72	44
Rondowa	spring	174	0	14	91
Lower Grande Ronde River	fall	1,072	277	97	169
	spring	797	9	10	429
Upper Grande Ronde River	spring	323	14	13	17
Wallowa River	spring	570	39	31	102