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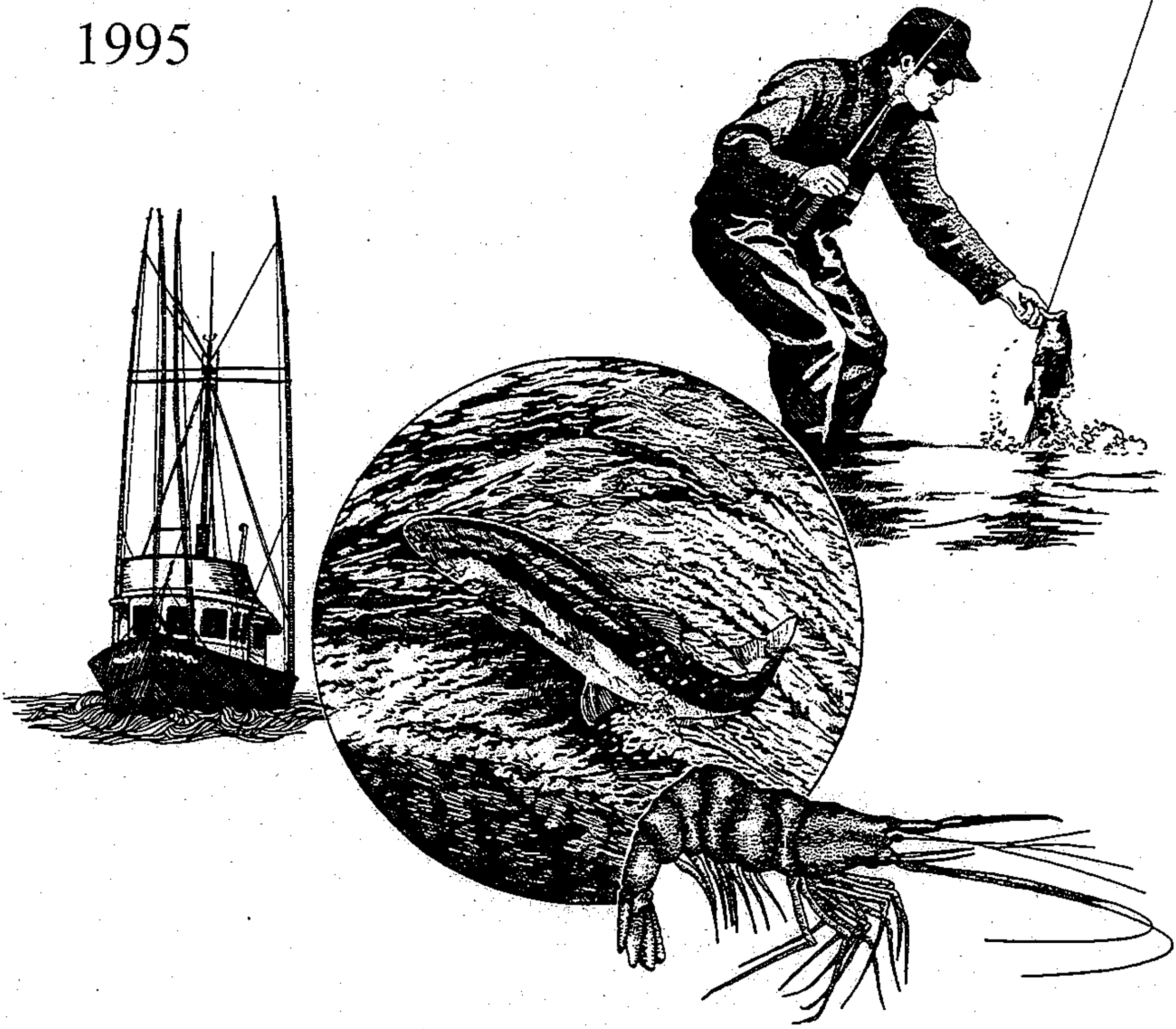

FISH DIVISION

Oregon Department of Fish and Wildlife

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

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ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT

OREGON

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

Contract Number: 14-48-0001-94543

Funding Period: 1 April 1994 to 31 March 1995

Prepared By: Brian C. Jonasson
Richard W. Carmichael
Timothy A. Whitesel

Oregon Department of Fish and Wildlife
2501 S.W. First Avenue
P.O. Box 59
Portland, OR 97207

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PREFACE

This report is for the funding period from 1 April 1994 to 31 March 1995. This report focuses on 1993 brood summer steelhead juveniles that were released in the spring of 1994. Those individuals remaining in freshwater after 20 June 1994 were considered to be residual steelhead. Although fish which remained in the mainstem 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 river basins during the summer (21 June - 20 September) and fall (21 September - 20 December) of 1994, the winter (21 December - 20 March) of 1994-95, and the spring (21 March - 20 June) of 1995. Thus, this report documents activities from 1 April 1994 through 20 June 1995. The above period represents the third 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; D. Anderson, R. Blincoe, and T. Labbe, for their dedication and persistence in conducting the field work; M. Flesher, M. Keefe, P. Lofy, R. Messmer, S. Stennfeld, T. Walters, and A. Wilson for their cooperation and assistance. This project was funded by the U.S. Fish and Wildlife Service under the Lower Snake River Compensation Plan, contract number 14-48-0001-94543 as a cooperative agreement with the Oregon Department of Fish and Wildlife.

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SUMMARY

Objectives

1. Monitor the relative abundance of residual steelhead.
2. Evaluate the potential for residual steelhead to prey on juvenile spring chinook salmon.
3. Characterize the steelhead which residualize.

Accomplishments and Findings

1. Densities of residual hatchery steelhead were relatively high (i.e. 54.4 fish/100 m^2) in Little Sheep Creek (Imnaha River) and low (i.e. 2.0 fish/100 m^2) in Deer Creek (Grande Ronde River) in summer 1994.
2. Highest densities of residual steelhead were generally found near release sites.
3. Densities of residual steelhead tended to decline from summer through the following spring in Little Sheep Creek.
4. Densities of residual steelhead remained low from summer through the following spring in Deer Creek.
5. An estimated 15,150 hatchery steelhead (5% of the fish released in 1994) remained in Little Sheep Creek and the first tributary downstream (2 km) from the release site during summer 1994.
6. An estimated 120 hatchery steelhead (0.08% of the fish released in 1994) remained in Deer Creek during summer 1994.
7. Distributions of residual steelhead overlapped with the lower ends of chinook salmon distribution in the Grande Ronde and Imnaha river basins in 1994.
8. We examined the contents of 175 stomachs from residual steelhead and found one juvenile chinook salmon. We estimated the maximum incidence of residual steelhead stomachs containing juvenile chinook salmon was 2.92%.
9. The largest prey consumed during controlled predation trials was an 89 mm naturally-produced steelhead eaten by a 202 mm residual steelhead. The largest prey relative to the predator was 44% of the predator's body length.
10. Similar to 1992 and 1993, the majority of residual steelhead originated from the smallest fish in the 1994 release groups.
11. The majority of residual steelhead originated from the male fish in the 1994 release groups, as in 1992 and 1993.

12. The majority of residual steelhead in the Imnaha River basin appeared to originate from the direct stream release groups in 1994. However, residualism of hatchery steelhead in the Grande Ronde River basin was independent of release type (direct stream vs. acclimated) in 1994, based on recoveries of coded-wire tagged fish.

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. Releases at these sites 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 at Wildcat Creek and in the mainstem Imnaha River 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 of concern. This recommendation necessitates striking a balance between the benefits to steelhead fisheries and the risks of steelhead predation on chinook salmon.

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

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

5. Consider the possibility of modifying angling regulations to allow anglers to keep residual steelhead caught during steelhead seasons.

INTRODUCTION

Associated with the construction of the mainstem 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 Fish and Wildlife Compensation Plan (LSRCP) in 1976. This plan is a federal mandate to compensate for fish and wildlife losses attributed to the construction of the dams in the lower Snake River. The original fisheries goals of this plan were to: (1) compensate for adult run sizes of salmon and steelhead and (2) restore sport and tribal fisheries. In addition, Oregon also has a goal to enhance the natural production of salmonids. 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 naturally-produced juveniles suffer in freshwater (Hoar 1988). In 1994, approximately 1,175,000 Wallowa stock and 351,000 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 do not migrate to the ocean during the initial smolt migration season after release. The rate of residualism is variable, but may reach as high as 33% (Viola and Schuck 1991). The residualism of hatchery-reared steelhead represents a 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 National Marine Fisheries Service specifically addressed the concern over residual steelhead in their proposed Salmon Recovery Plan (Schmitten et al. 1995).

The potential impacts of residual steelhead on the ecosystem, specifically interactions with naturally-produced juvenile spring chinook salmon (*O. tshawytscha*) in lower Snake River subbasins, has been recognized by fisheries biologists from Oregon (Whitesel et al., 1993), Washington (Martin et al. 1993) and Idaho (Cannamela 1993). The magnitude of the impacts of residual steelhead on the ecosystem are dependent, in part, on the number of steelhead that residualize. The magnitude of the variability in the number of residual steelhead from year to year and the factors responsible for this variability, however, are not known. **Thus, the first objective of this study is to document the seasonal abundance of residual steelhead at index areas and index streams in the Grande Ronde and Imnaha river basins and examine trends in abundance over time.**

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 per day could result in the loss of approximately 50 adult-equivalent chinook salmon (Whitesel et al. 1993). **Thus, the second objective of this study is to evaluate the potential for residual steelhead to prey on juvenile chinook salmon.**

Hatchery production strategies may predispose juvenile steelhead to residualize in freshwater rather than migrate to the ocean as smolts. Hatchery steelhead production in northeast Oregon results in fish that are released near 10 months of age with a fork length near 200 mm (Messmer et al. 1989). In contrast, naturally-produced steelhead smolts generally migrate when they are 22 months old 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 may affect residualism rates (Gross 1991). However, experimental comparisons to test these hypotheses have not generated clear results. **Thus, the final objective of this study is to characterize the steelhead in northeast Oregon which residualize after they are released.**

The three objectives of this study are addressed in the following sections. Naturally-produced steelhead density data that were collected during this project but were not associated with specific objectives are presented in **Appendix C** and catch data for residual steelhead in Grande Ronde and Imnaha river steelhead fisheries are shown in **Appendix D.**

STUDY AREA AND POPULATIONS

This study was conducted in the Grande Ronde and Imnaha river basins in the northeast corner of Oregon (Figure 1). Hatchery-reared steelhead were released by Oregon Department of Fish and Wildlife (ODFW) into the Grande Ronde and Imnaha basins and by Washington Department of Fish and Wildlife (WDFW) in the Grande Ronde Basin in 1994 (Table 1, Figure 1). 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 1993 brood year. Hatchery-reared fish from the 1993 brood which remained in freshwater after 20 June 1994 were considered to have residualized.

Table 1. Release information for hatchery-reared steelhead released into the Grande Ronde and Imnaha river basins, 1994. All releases were made by Oregon Department of Fish and Wildlife, unless otherwise noted.

Basin, stream	Rkm	Release type	Date	Number
Grande Ronde				
Catherine Creek	27	direct	04/18	23,920
Catherine Creek	29	direct	04/18	38,636
Deer Creek	0	acclimated	04/22	105,547
Deer Creek	0	direct	04/22	50,204
Grande Ronde River[a]	87	direct	04/26-27	49,500
Grande Ronde River	251	direct	04/14-15	100,300
Grande Ronde River	257	direct	04/13	100,500
Spring Creek	3	acclimated	04/18	494,342
Spring Creek	3	acclimated	05/02	211,635
Imnaha				
Imnaha River	27	direct	04/26	49,767
Little Sheep Creek	8	acclimated	04/25	252,809
Little Sheep Creek	8	direct	04/25	47,965

[a] *Released by Washington Department of Fish and Wildlife.*

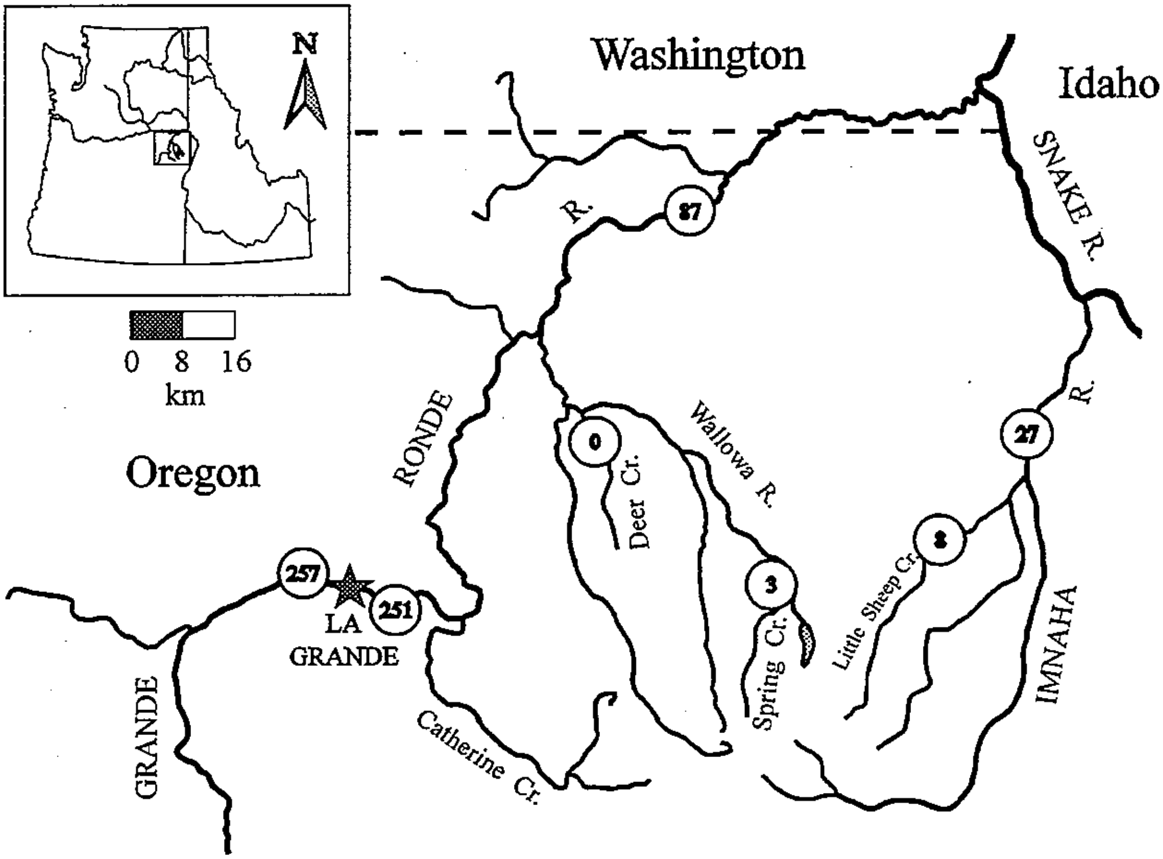

Figure 1. Major river basins in northeast Oregon and the locations where ODFW and WDFW released hatchery-reared summer steelhead in spring 1994. River kilometers are shown in circles to cross reference to Table 1 for specific release information.

RELATIVE ABUNDANCE OF RESIDUAL STEELHEAD

Methods

In 1994 we focused sampling efforts near release sites in Deer and Little Sheep creeks to more precisely characterize residual steelhead populations where abundance is greatest. Sampling during summers of 1992 and 1993 indicated that residual steelhead abundance was highest near release sites in Deer and Little Sheep creeks. We selected eight index areas in Deer Creek (including one in Sage Creek, a tributary to Deer Creek) and 12 index areas in Little Sheep Creek (including three in Bear Gulch, a tributary to Little Sheep Creek). Sampling was scheduled at these sites for each season of the year to estimate the relative abundance of residual steelhead at each area in each stream. We sampled an additional 16 locations during summer 1994 in the Grande Ronde and Imnaha basins to monitor relative abundance and distribution of residual steelhead over a wider area (Figure 2). Environmental conditions limited sampling in some locations in fall, winter, and spring. During fall we were able to sample seven of eight index areas in Deer Creek, 10 of 12 index areas in Little Sheep Creek, plus an additional 17 locations. During winter we were able to sample seven of eight index areas in Deer Creek and 10 of 12 index areas in Little Sheep Creek, plus and an additional six locations. During spring we were able to sample all eight index areas in Deer Creek, eight of 12 index areas in Little Sheep Creek, plus an additional two locations. Whenever possible, these locations were sampled for the relative abundance of residual steelhead, otherwise, the locations were sampled for the presence/absence (distribution) of residual steelhead. We selected locations based on release locations of hatchery-reared steelhead, the distribution and abundance patterns of residual steelhead in the summers of 1992 and 1993 (Whitesel et al. 1993, Jonasson et al. 1994) and stream accessibility. Two sites were sampled at each location. We attempted to sample two riffle-pool combinations at each site. If riffle-pool combinations were not available near the location, a section of stream approximately 50 m in length for each site was chosen.

Electrofishing techniques were used 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 or three passes through the site 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. A multiple pass removal method (Zippen 1958) was used to estimate the abundance of fish within the sampling site. Surface area of each sampling site was calculated from measurements of total length and average width.

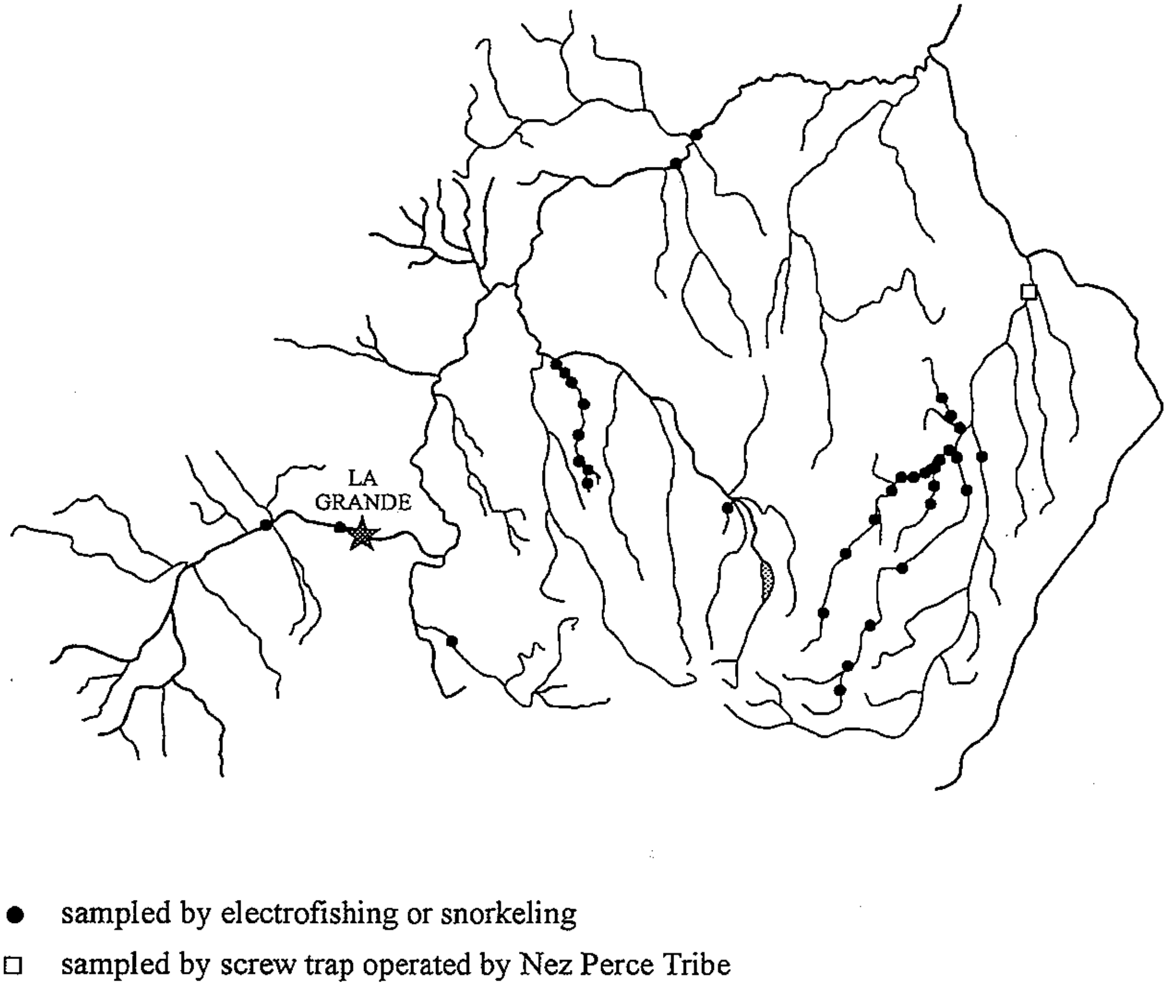

Figure 2. Locations sampled during summer 1994 in the Grande Ronde and Imnaha river basins. Information was also obtained from angler surveys that focused on Imnaha River rkm 0-18, Grande River rkm 63-132, and Wallowa River rkm 0-29.

We snorkeled at abundance sites when water conditions would not permit the use of electrofishing techniques. Visual observations were made of the species present and the number of individuals in each salmonid species. Generally, three snorkelers, swimming simultaneously and parallel, observed and counted salmonids. At abundance sites which were snorkeled, two passes were made and the highest count for each species was used as our estimate of the number present in the site.

We calculated densities of residual steelhead and juvenile chinook salmon at locations sampled for abundance using the surface area and the estimated number of residual steelhead or juvenile chinook salmon of both sites. Data from only one site was used when we were unable to make two abundance estimates at a location. We used linear regression analysis to examine relationships between residual steelhead densities during the summers of 1992, 1993, and 1994 at the Deer Creek and Little Sheep Creek release sites and the total number of hatchery steelhead released at each of these sites (Table 2) and spring stream discharge (Table 3). To begin to explore the rate at which hatchery-reared steelhead residualize, we also estimated the total abundance of residual steelhead in Deer and Little Sheep creeks. This was done using the estimated relative densities of residual steelhead at each index area, the estimated stream surface area between each index area, and interpolating densities between index areas. We were not able to calculate confidence intervals for our estimates of total abundance of residual steelhead in Deer and Little Sheep creeks. We estimated the rates of residualism in Deer and Little Sheep creeks by dividing the estimated number of residual steelhead in each stream by the number of hatchery steelhead released in the respective streams.

Table 2. Number of hatchery-reared steelhead released at Deer Creek and Little Sheep Creek release sites, 1992 to 1994.

Stream	Number released		
	1992	1993	1994
Deer Creek	476,489	432,977	155,751
Little Sheep Creek	248,787	286,694	300,744

Table 3. River discharge (m^3/s) from 16 April to 31 May for 1992 to 1994 in the Grande Ronde and Imnaha river basins. Discharge records were obtained from USGS gaging stations.

		Mean discharge (m^3/s)		
Stream	Location	1992	1993	1994
Grande Ronde River	Troy	83.3	269.4	150.0
Catherine Creek	Union	5.0	15.1	8.1
Minam River	Minam	24.1	39.1	30.4
Imnaha River	Imnaha	15.3	49.8	29.1

When we were not able to estimate the density of residual steelhead at a site due to environmental conditions (high flow or poor visibility) we made a maximum of one snorkeling or two electrofishing passes to determine the presence or absence of residual steelhead. If at least one residual steelhead was observed, sampling was terminated at that site. If one residual steelhead was 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 or absence at each site.

We obtained additional distribution information for residual steelhead in the Imnaha basin from voluntary creel surveys. A box containing creel survey forms was located near rkm 18 on the Imnaha River. Anglers were asked to provide information regarding the number and size of fin-marked rainbow trout they caught, as well as the amount of time they spent angling. All fin-marked rainbow trout caught in the Imnaha River were assumed to be residual hatchery steelhead, as no hatchery rainbow trout were released in the Imnaha River basin in 1994.

We also used information on distribution of residual steelhead 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. A trained creel surveyor examined angler-caught fish for specific fin-marks to differentiate between residual hatchery steelhead and hatchery rainbow trout. Hatchery rainbow trout released during summer 1994 in the Wallowa River and Bear Creek were marked with an adipose and right ventral (ADRV) fin clip, whereas hatchery rainbow trout released in the Grande Ronde River and Catherine Creek were not fin-marked.

We also used capture information from a screw trap operated by the Nez Perce Tribe located near rkm 6 of the Imnaha River to add to our knowledge of distribution of residual hatchery steelhead during summer and fall 1994 and spring 1995.

We obtained information on distribution of juvenile chinook salmon from sampling conducted during this study, sampling for juvenile chinook migration studies and genetic studies, and spring chinook spawning ground surveys.

Results

We found residual hatchery steelhead near seven of the nine release sites during the summer following release (Figure 3). Residual hatchery steelhead were not found at the Grande Ronde River release sites near La Grande (rkm 251 and 257). Residual steelhead were found upstream of three of the release sites (Deer and Little Sheep creeks and Imnaha River) and downstream of the Little Sheep Creek release site. Residual hatchery steelhead were captured in a screw trap operated by the Nez Perce Tribe on the Imnaha River at rkm 6 during summer, and were harvested in the lower Imnaha and Grande Ronde rivers by anglers.

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 during summer at the release sites on Catherine, Deer and Spring creeks, and in the Imnaha River at rkm 42, Big Sheep Creek at rkm 0 and 5, and Little Sheep Creek at rkm 0. During fall the distributions of residual steelhead and juvenile chinook salmon overlapped at Mud Creek rkm 0 and Big Sheep Creek rkm 53.

Densities of residual steelhead in Deer and Little Sheep creeks were highest at the release sites and decreased as distance from the release site increased (Figures 5 and 6; Table 4). The relative densities of residual steelhead at the Little Sheep Creek release site decreased from summer through spring, whereas at the Deer Creek release site the relative densities of residual steelhead remained low (less than 3 fish/100 m^2) throughout the seasons (Figure 7).

Relative density of residual hatchery steelhead was higher at the Little Sheep Creek release site during summer 1994 than the previous two years, whereas the density of residual hatchery steelhead in Deer Creek was lower at the Deer Creek release site during summer 1994 than the previous two years (Figure 8). The number of hatchery steelhead smolts released was higher in Little Sheep Creek and lower in Deer Creek in 1994 than in the two previous years.

We did not find a significant relationship between residual steelhead density during summers 1992-94 at the Little Sheep Creek release site and the number of hatchery fish released at this site ($r^2 = 0.22$, $P = 0.690$), or between summer densities at this release site and Imnaha River discharge in the spring ($r^2 = 0.34$, $P = 0.605$). We also did not find a significant relationship between residual steelhead density during summers 1992-94 at the Deer Creek release site and the number of hatchery fish released there ($r^2 = 0.69$, $P = 0.374$), or between summer densities at this release site and Minam River discharge in the spring ($r^2 = 0.16$, $P = 0.735$).

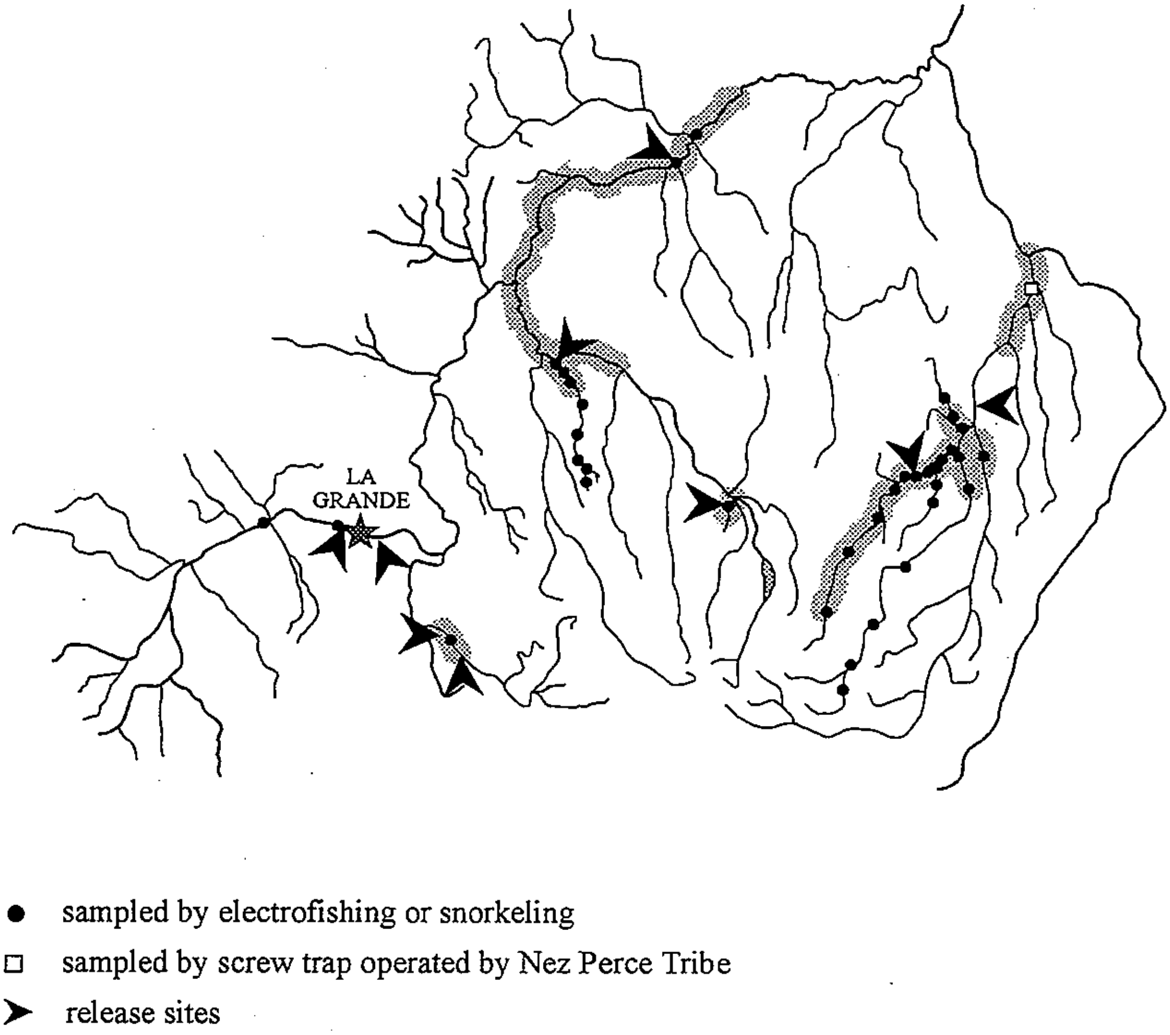

Figure 3. Probable distribution of residual steelhead (shaded areas) during summer 1994 in the Grande Ronde and Imnaha river basins.

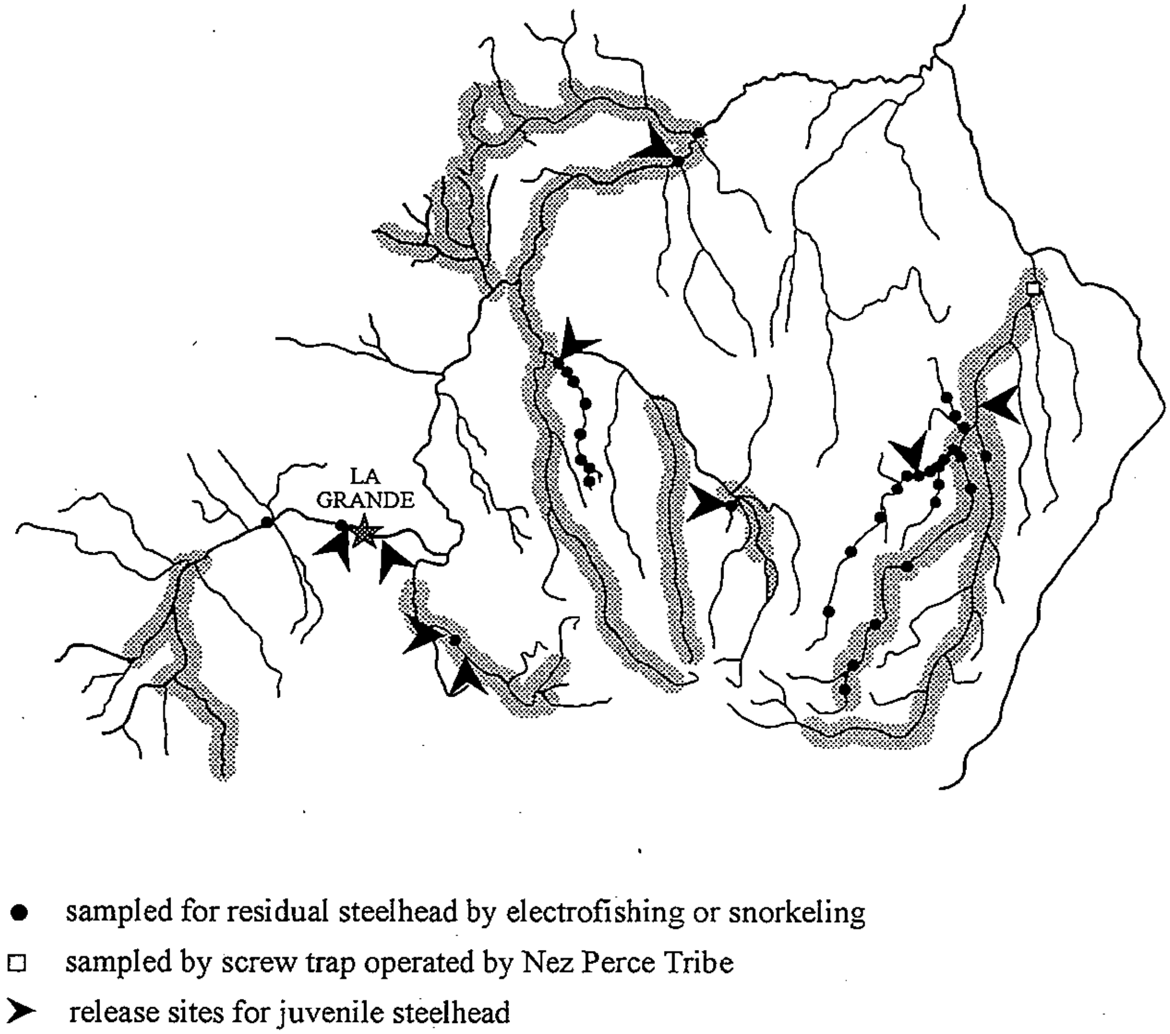

Figure 4. Expected distribution of naturally-produced juvenile chinook salmon (shaded areas) during summer 1994 in the Grande Ronde and Imnaha river basins.

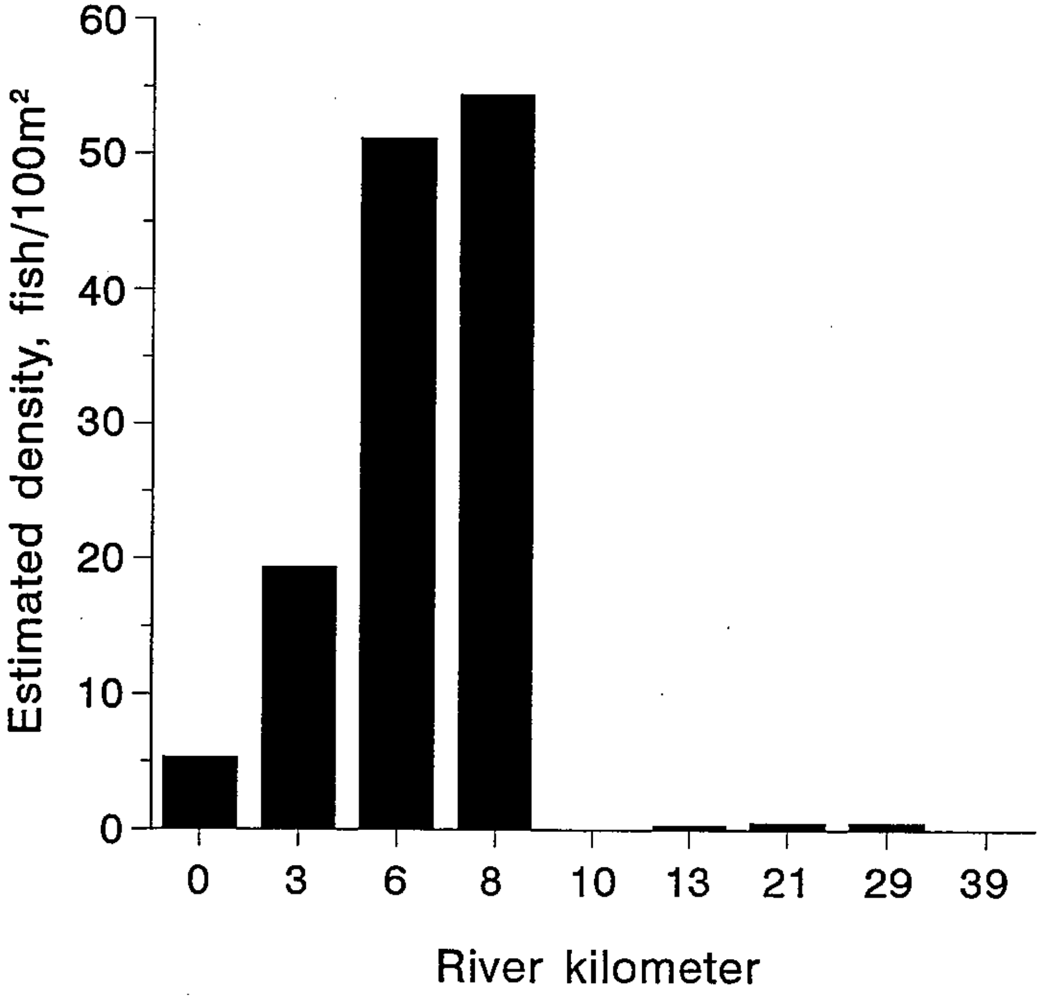

Figure 5. Density of residual steelhead in index areas of Little Sheep Creek during summer 1994. Hatchery steelhead were released at rkm 8.

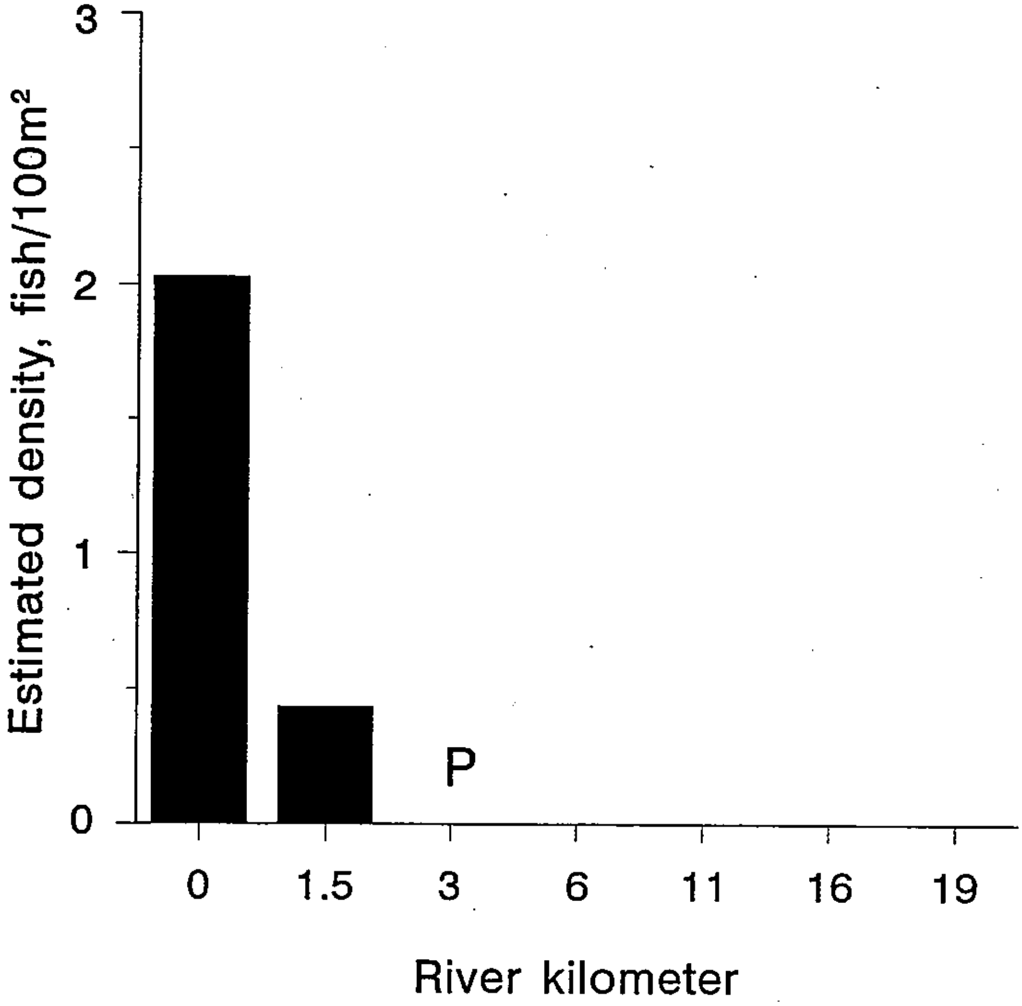

Figure 6. Density of residual steelhead in index areas of Deer Creek during summer 1994. Hatchery steelhead were released at rkm 0. "P" indicates that residual steelhead were present, but we were unable to estimate their density.

Table 4. Observed densities (fish/100 m^2) of residual steelhead at index areas in Deer Creek and its tributary Sage Creek, and Little Sheep Creek and its tributary Bear Gulch, summer 1994 to spring 1995.

Stream	Rkm	Residual steelhead density			
		Summer	Fall	Winter	Spring
Deer Creek	0	2.030	1.821	2.878	1.209
	1.5	0.435	0.375	0.000	(a)
	3	(a)	(a)	0.000	0.000
	6	0.000	0.000	0.000	0.000
	11	0.000	0.000	0.000	0.000
	16	0.000	(b)	0.000	0.000
	19	0.000	0.000	0.000	0.000
Sage Creek	0	0.000	0.000	0.000	0.000
Little Sheep Creek	0	5.324	(b)	(c)	(c)
	3	19.375	(c)	(c)	(c)
	6	51.101	3.061	0.000	(c)
	8	54.407	7.440	0.814	(a)
	9	0.000	1.277	0.000	(b)
	13	0.342	1.176	0.000	(b)
	21	0.507	0.000	0.000	(b)
	29	0.525	0.000	(c)	(c)
	39	0.000	(a)	0.000	0.000
Bear Gulch	0	18.676	4.425	0.000	0.000
	3	1.595	0.000	0.000	0.000
	6	0.000	(b)	(b)	(b)

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

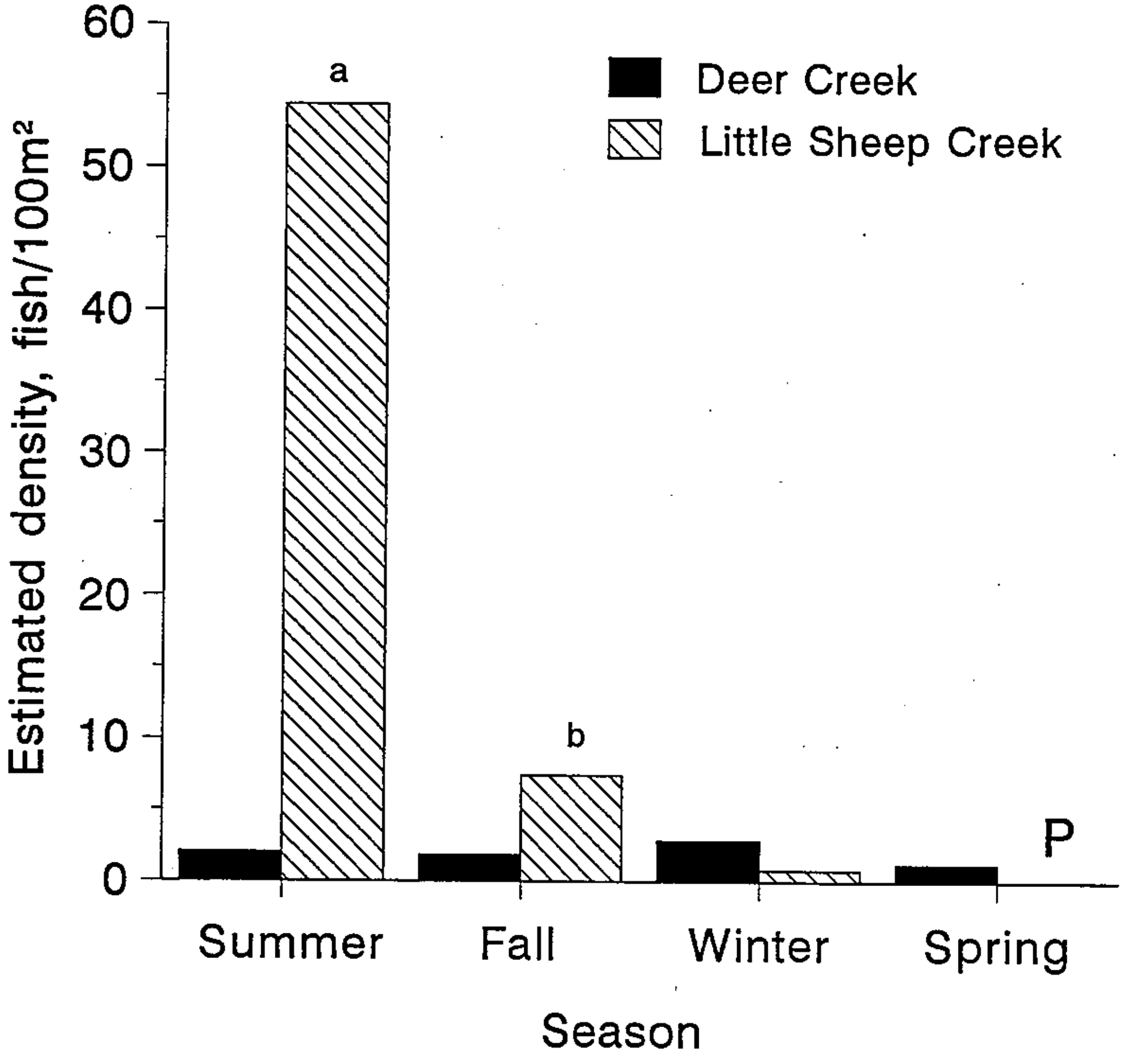

Figure 7. Seasonal patterns of residual steelhead densities at the Deer and Little Sheep creek release sites (index areas) from summer 1994 to spring 1995. "a" is significantly greater than "b". "P" indicates that residual steelhead were present, but we were unable to estimate their density.

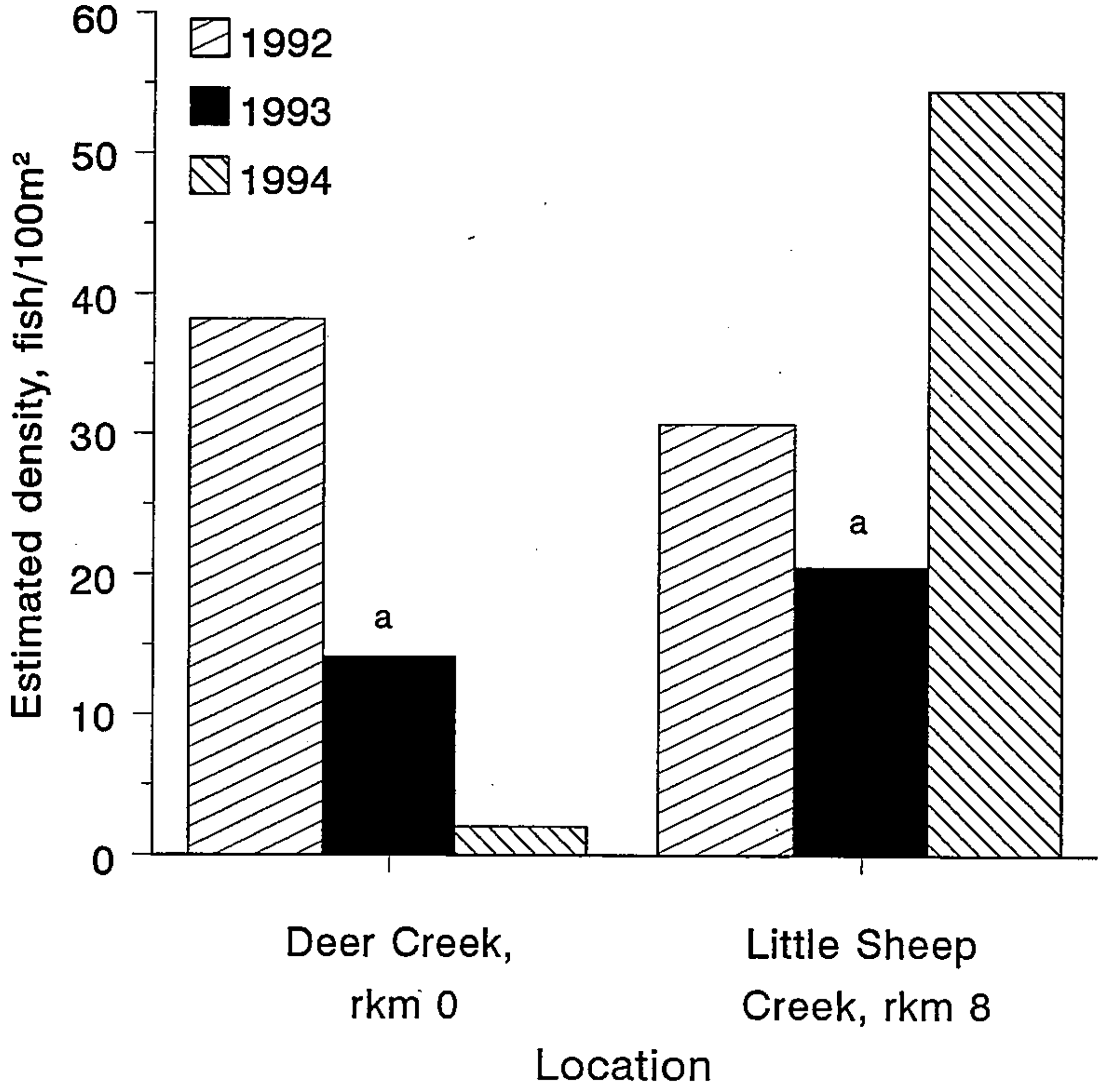

Figure 8. Densities of residual steelhead at release sites during summers 1992 to 1994. "a" indicates a significant decrease in density from the previous year. "b" indicates a significant increase in density from the previous year.

We estimated there were 14,300 residual steelhead in Little Sheep Creek and 850 residual steelhead in Bear Gulch during summer 1994. These residual steelhead represent 5% of the hatchery steelhead released as smolts into Little Sheep Creek in April 1994. We estimated there were only 120 residual steelhead in Deer Creek during summer 1994, representing 0.08% of the hatchery steelhead released as smolts into Deer Creek, although the release site in Deer Creek is at rkm 0 and the majority of the residuals may be in the Wallowa River.

Discussion and Management Implications

The number of residual steelhead in northeast Oregon is variable from year to year. Although we did not find a statistically significant relationship between number of smolts released and residual steelhead densities during summer at the release sites, the highest summer densities of residual steelhead found in Little Sheep Creek during this study coincided with the highest number of smolts released at the Little Sheep Creek Facility, and the lowest summer densities of residual steelhead found in Deer Creek during the study coincided with the lowest number of smolts released at the Big Canyon Facility. River discharge during spring, which appeared to be related to residual densities during the first two years, now do not appear to be related to the summer densities of residuals at the release sites. We are still unclear about what factors are responsible for the variability of the numbers of residuals among years.

The large number of steelhead which residualized in Little Sheep Creek during summer 1994 had the potential to have large impacts on the rearing fish populations in the basin. However, the distribution of residual steelhead was concentrated in the lower five miles of Little Sheep Creek where densities of naturally-produced juvenile chinook salmon and steelhead are typically low. The low number of residual steelhead in Deer Creek most likely did not represent a potential for large impacts on juvenile chinook salmon or steelhead in Deer Creek or nearby in the Wallowa River.

The seasonal distribution of residual steelhead in the Grande Ronde River and Imnaha River basins has been similar during the three years of the study. In general, residual steelhead tend to be found in relatively high densities near the release sites and at lower densities downstream. Residual steelhead also can be found at relatively low densities upstream of release sites. Densities of residual steelhead are highest during summer and tend to decline as the seasons progress. The spatial and temporal distribution of juvenile chinook salmon and residual steelhead in the two basins does not promote a high level of interaction between the two species as the higher densities of residual steelhead during summer tend to be at the lower ends or outside of the chinook distribution.

PREDATION BY HATCHERY-REARED STEELHEAD ON JUVENILE SPRING CHINOOK SALMON

Methods

During sampling for abundance, we collected stomachs from 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, and 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 discernible fish parts found in the stomach contents were identified to family and all salmonids were identified to species.

ODFW released spring chinook salmon parr (445 fish/kg, approximately 69 mm fork length) into streams in the Imnaha Basin in July 1994 (Table 5). We collected stomachs from residual steelhead captured in some of the areas where these outplanted fish were present.

Table 5. Release information for hatchery-reared spring chinook parr released into the Imnaha Basin, 1994. All releases were made by ODFW.

Stream	Rkm	Date	Number
Big Sheep Creek	55, 56	07/19	91,113
Big Sheep Creek	35, 39, 44	07/20	60,220
Freezeout Creek	1	07/21	7,614
Imnaha River	54, 58	07/21	36,240
Imnaha River	8	07/22	24,160
Imnaha River	18	07/22	24,260
Imnaha River	6	07/22	24,260
Little Sheep Creek	3 to 21	07/20	15,180

We calculated the incidence of residual steelhead stomachs that contained juvenile chinook salmon. The incidence was expressed as a percentage (number of stomachs containing juvenile chinook salmon x 100 / number of total stomachs sampled). Based on this percentage 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.

We conducted a controlled pilot study to relate size of predators (residual steelhead) to size of prey (hatchery-reared juvenile chinook salmon or steelhead). We held individual residual steelhead in separate net pens (0.9 x 0.6 x 0.6 m, 6 mm mesh) in ponds at our Big Canyon Facility. We collected the residual steelhead, and naturally-produced steelhead of similar size as the residual steelhead, from Deer Creek, placed them in net pens, and then starved them for 24 h or 48 h before introducing three to six hatchery-reared juvenile chinook salmon or naturally-produced juvenile steelhead. We recorded fork length and weight of each predator and prey before placing them in the net pens. We examined the pens three times per week to note the number of prey remaining in the pen with the predator. If a prey item was missing, the remaining prey items were measured to determine the size of the missing prey. We conducted one preliminary trial of 5 days with 10 predators, and six trials lasting 16 to 21 days with 9 or 10 predators. During each trial we had at least one pen containing only prey items to serve as a control. At the conclusion of three of the trials we added previously frozen steelhead eggs to the pens as positive controls to ascertain that the predators would eat while in the net pens.

We collected juvenile chinook salmon from various upstream and downstream rearing areas and measured their fork length during summer to determine the size range of juvenile chinook salmon available to residual steelhead under natural conditions.

Results

We examined stomachs from 175 residual steelhead captured throughout the year from a variety of locations (Table 6). We found fish or fish parts in seven of these stomachs, including one juvenile steelhead and one juvenile chinook salmon. We found the juvenile chinook salmon (74 mm fork length, FL) of unknown origin in the stomach of a residual steelhead (232 mm FL) captured at Big Sheep Creek rkm 53 during fall sampling. This residual steelhead was PIT-tagged before being released on 25 April 1994 at the Little Sheep Creek Facility. At this site we found outplanted hatchery chinook salmon (identified by an adipose fin clip) at a density of 314.7 fish/100 m^2, whereas naturally-produced juvenile chinook salmon were found at a density of 1.4 fish/100 m^2. The overall incidence of residual steelhead stomachs containing juvenile chinook salmon was 0.57%, with 95% confidence limits of 0.06% to 2.92%. Sculpins and dace were found in the other stomachs containing fish or fish parts.

We used 57 potential predators (51 residual steelhead, 142 mm to 322 mm FL, and 6 naturally-produced steelhead, 171 mm to 234 mm FL) in the six controlled predation trials. Juvenile chinook salmon used in the trials ranged from 50 mm to 104 mm FL, and juvenile steelhead ranged from 47 mm to 120 mm FL. Ten (20%) of the residual steelhead consumed juvenile chinook salmon or steelhead, whereas none of the naturally-produced steelhead consumed juvenile salmonids during the trials. A majority of steelhead predators held in net pens would eat while held in the pens, as 81% of the residual steelhead and 50% of the naturally-produced steelhead consumed steelhead eggs when given the opportunity at the end of the trials.

Table 6. 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	98	3	1[a]
Fall	23	1	1[b]
Winter	9	0	0
Spring	4	0	0
GRANDE RONDE			
Summer	21	2	0
Fall	16	0	0
Winter	4	1	0
Spring	0	0	0

[a] *Steelhead.*

[b] *Chinook salmon of unknown origin (hatchery outplant or naturally produced).*

We did not find a significant relationship between the size of a residual steelhead and the size of the salmonid prey consumed. The largest prey consumed during the controlled predation trials was an 89 mm FL naturally-produced steelhead eaten by a 202 mm FL residual steelhead (Table 7). The largest prey consumed by individual predators ranged in fork length from 23% to 44% of the fork length of the predator. The smallest predator to consume a juvenile salmonid was 184 mm FL.

Table 7. Fork lengths (mm) of predators (residual steelhead), prey consumed and prey available for all controlled predation trials in which prey were consumed. Prey fork length expressed as percentage of predator fork length is in parentheses.

Predator	Largest prey consumed		Largest prey available		Prey species
184	76	(41%)	101	(55%)	steelhead
197	68	(35%)	68	(35%)	chinook
201	64	(32%)	66	(33%)	chinook
202	89	(44%)	113	(56%)	steelhead
210	62	(30%)	73	(35%)	steelhead
223	75	(34%)	75	(34%)	steelhead
238	71	(30%)	71	(30%)	steelhead
242	80	(33%)	93	(38%)	steelhead
296	73	(25%)	73	(25%)	chinook
315	73	(23%)	73	(23%)	chinook
mean length:	73.1	(32.7%)	80.6	(36.4)	

We found naturally produced juvenile spring chinook salmon in summer rearing areas ranging in size from 33 mm FL to 102 mm FL (Table 8).

Table 8. Fork lengths (mm) of naturally-produced juvenile chinook salmon collected during summer 1994. *N* = sample size, SE = standard error of the mean, min = minimum length, and max = maximum length,

Location,		Fork length			
month	*N*	mean	SE	min	max
Upper Grande Ronde River,					
June	142	39.8	0.58	33	82
August	42	57.8	2.40	42	100
Lower Grande Ronde River					
June	37	77.9	1.26	62	96
August	25	88.7	1.17	78	102
Catherine Creek					
June	81	48.0	0.72	37	63
August	27	70.6	1.07	60	81
Lostine River					
June	127	44.9	0.54	34	65
July	36	49.9	0.55	44	59
Minam River					
June	138	51.9	0.51	39	73
July	45	58.2	0.64	48	68
Imnaha River					
August	86	58.3	0.87	40	78

Discussion and Management Implications

The overall incidence of residual steelhead stomachs that contained juvenile chinook salmon was low, but higher than we found in 1992-93 and 1993-94 when we examined 611 and 358 stomachs, respectively, and did not find juvenile chinook salmon in the contents (Whitesel et al. 1993, Jonasson et. al. 1994). Outplanted hatchery juvenile chinook salmon were very abundant in the only area where we found predation, but overall juvenile chinook salmon abundance was low in areas where most of the residual steelhead stomachs were collected. Very low rates of residual steelhead predation on juvenile chinook salmon could have substantial impacts on chinook salmon populations (see Whitesel et al. 1993).

The small number of prey consumed by residual steelhead during controlled predation trials may indicate that juvenile salmonids may not be a preferred food item of residual steelhead. This is consistent with our findings of free living residual steelhead. However, this low rate of predation in the controlled trials may indicate that most residual steelhead will not consume juvenile salmonids while held under conditions experienced during the trials.

Although we were unable to find a relationship between the size of residual steelhead predators and the size of prey, we did find that residual steelhead will consume juvenile salmonids in the size range of naturally-produced chinook salmon typically found in the Grande Ronde and Imnaha basins during summer. Our observations in this study indicate that (1) some residual steelhead will eat juvenile chinook salmon; (2) although most residual steelhead would eat under the experimental conditions, most residual steelhead would not eat juvenile salmonids; and (3) residual steelhead will eat juvenile salmonids as large as 44% of their own fork length. Predation by stream-rearing hatchery steelhead on salmonids has been found to be rare (Cannamela 1993, Martin et al. 1993) or absent (Partridge 1985) in the Snake River basin. Our understanding of the distributions of residual steelhead and juvenile chinook salmon (see previous section) lead us to believe that the interactions between these fishes will be minimal through most of the summer rearing areas of juvenile chinook salmon. In conjunction with our results of stomach sampling of free-living residual steelhead during the three years of this study, we believe that predation by residual steelhead on juvenile chinook salmon is not a significant problem in northeast Oregon.

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 to predict fork length from scale radius, we collected scale samples and measured the fork length for a portion of the hatchery-reared steelhead just prior to their release. The relationship was expressed as

$$\text{Fork length} = m\,(\text{Scale radius}) + b \qquad \textit{equation 1.1}$$

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. We compared measured fork lengths to calculated fork lengths to determine the percent error of the model. We measured the fork length of all the residual steelhead captured during our sampling for abundance and collected scale samples from a portion of these fish. 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 to 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 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. We determined sex and maturational condition by visually examining the gonads of residual steelhead captured during our sampling for abundance and at broodstock collection facilities. 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 from LV marked fish and CWTs were excised and read. We used the binomial test to compare the rate of residualism between acclimated and direct-stream-released fish.

Anadromous versus Nonanadromous Characteristics

To quantify the percentages of residual hatchery steelhead that adopt a nonanadromous life history strategy (i.e., rainbow trout) or maintain an anadromous life history (i.e., steelhead), we examined characteristics of naturally-produced rainbow trout and steelhead captured during spring to compare to characteristics of residual steelhead captured during spring one year after release. We collected naturally-produced rainbow trout from Eagle Creek and Burnt River, and naturally-produced steelhead smolts from rotary screw fish traps in the Grande Ronde River basin in May 1994. We determined the sex and measured the body weight, fork length, maturity (same criteria as for residual steelhead maturity), gonad weight, liver weight, presence or absence of parr marks and blackened fin margins, and the degree of silver coloration (1 = no silver to 5 = very silvery) of each of these fish. We also calculated the condition factor and hepatosomatic index (liver weight expressed as percentage of the body weight) for each fish. We attempted to evaluate these characteristics to determine which might help us discriminate between rainbow trout and steelhead.

Results

Fork Length

Scale radius was a good predictor of fork length. The result for equation 1.1 was:

$$\text{Fork length} = 128.57\ (\text{Scale radius}) + 91.36;\ P < 0.05;\ r^2 = 0.63.$$

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 4.9% 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 9).

Table 9. Mean (SE) fork length (mm) of hatchery-reared steelhead, by stock. Differences between groups were judged to be significant (S) when $P < 0.05$.

Stock	Pre-release	Residuals	Differences
Imnaha	200.7 (0.82)	186.9 (1.62)	S
Wallowa	218.0 (0.56)	187.1 (6.03)	S

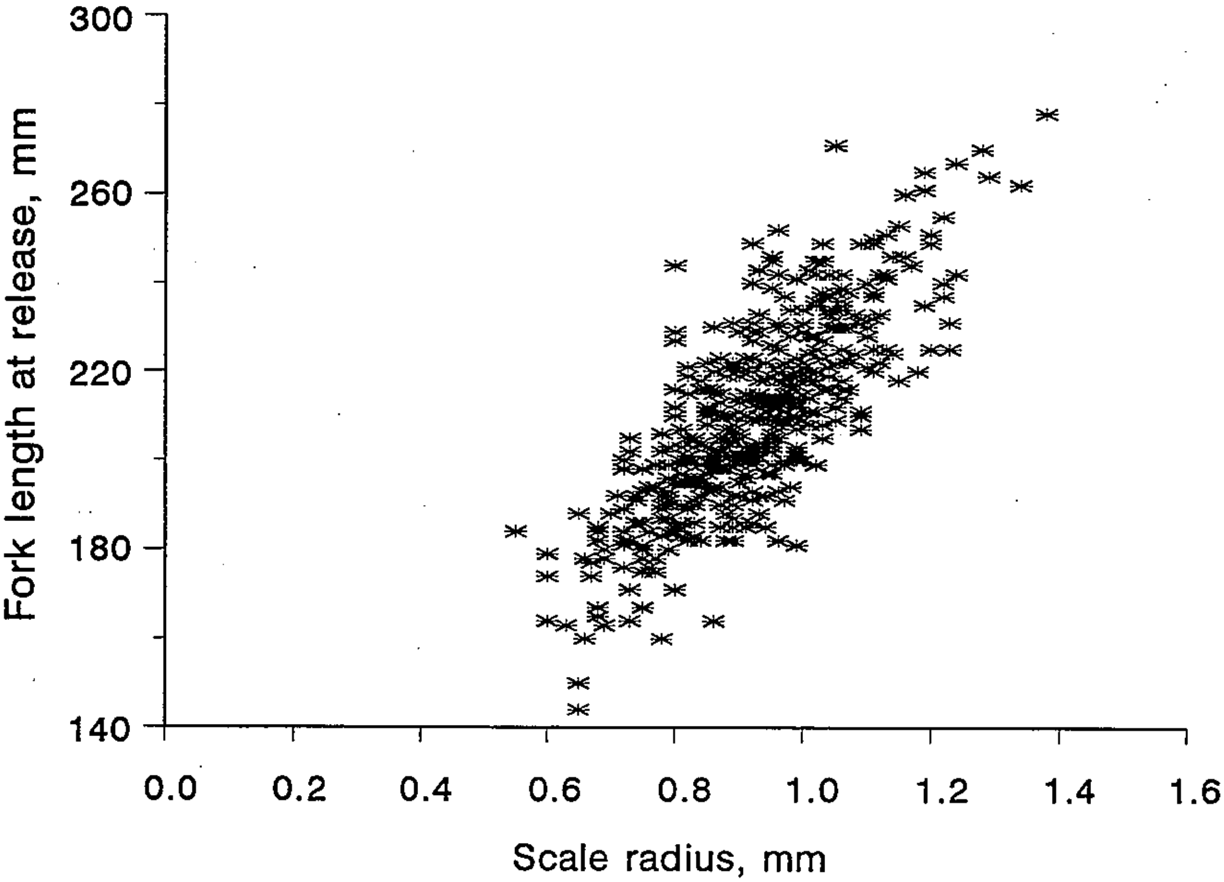

Figure 9. The relationship between fork length (FLEN) and scale radius (SR) for hatchery-reared steelhead at time of release during spring 1994. Data from Wallowa and Imnaha stocks were pooled to generate one model. The linear regression (FLEN = 128.57 SR + 91.36; $r^2 = 0.63$) was significant ($P < 0.0001$).

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 51:49, whereas the male:female sex ratio of residual steelhead captured in the summer was 91:9 (Table 10). Estimates of the percentage of the residual steelhead population that was composed of males remained above 80% during the fall, winter, and spring.

The majority of the male residual steelhead sampled were immature during the summer following release (Table 11). The percentage of residual steelhead in the "maturing" category increased through fall and winter and the majority became mature by the following spring. Forty-nine of the 51 males sampled during spring 1995 were captured at our broodstock collection facilities. All of the female residual steelhead sampled from summer to winter were immature or maturing (Table 12). Nine of the ten females examined during spring were mature. These mature females were captured at broodstock collection facilities at Wallowa Hatchery and Big Canyon Facility, and all ranged in size from 289 mm to 370 mm fork length. An immature female, 272 mm fork length, was also captured at Wallowa Hatchery.

Table 10. 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 $P \geq 0.05$.

Group, season, year	*N*	Males(%)	Females(%)	Differences
Pre-release,				
Spring, 1994	400	51.0	49.0	-
Residuals,				
Summer, 1994	382	90.6	9.4	S
Fall, 1994	45	82.2	17.8	NS
Winter, 1995	17	94.1	5.9	NS
Spring, 1995	65	83.1	16.9	NS

Table 11. 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	346	83.3	14.7	2.0	-
Fall	37	56.8	40.5	2.7	S
Winter	16	50.0	43.8	6.2	NS
Spring[a]	51	11.8	3.9	84.3	S

[a] *Forty-nine fish were captured at adult broodstock collection facilities.*

Table 12. 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	5.6	0.0	-
Fall	8	75.0	25.0	0.0	NS
Winter	1	0.0	100.0	0.0	NS
Spring[a]	10	10.0	0.0	90.0	S

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

Release Strategy

We identified acclimated and direct-stream-released residual steelhead by information collected from coded-wire-tagged individuals. We found significantly (*P* < 0.05) more residual steelhead originating from the direct stream releases than the acclimated releases at the Little Sheep Creek Facility, but we did not find a difference between release strategies at the Big Canyon Facility, where we had relatively few recoveries of coded-wire-tagged fish (Table 13).

Table 13. Number of coded-wire-tagged residual steelhead recovered by release type. Differences in proportions recovered within a release site were judged to be significant (S) when *P* < 0.05 and not significant (NS) when *P* ≥ 0.05.

Release site	Release type	Released	Recovered	
Little Sheep Facility	Direct stream	47,087	102	
	Acclimated	48,534	61	S
Big Canyon Facility	Direct stream	45,268	4	
	Acclimated	53,818	11	NS

Anadromous versus Nonanadromous Characteristics

We collected 24 naturally-produced steelhead smolts, but were able to collect only eight rainbow trout with fork length comparable to residual hatchery steelhead collected during spring. With the small sample size of rainbow trout, we were unable to determine specifically which characteristics allowed discrimination between rainbow trout and steelhead. Preliminary results indicate that condition factor (rainbow trout: mean = 1.16, variance = 0.0231; steelhead: 1.01, 0.0034), liver weight/body weight index (rainbow trout: 1.35, 0.2891; steelhead: 1.13, 0.0366), and degree of silver coloration (rainbow trout: 1.13, 0.1250; steelhead: 3.71, 0.7373) may be used to distinguish between rainbow trout and steelhead.

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 and 1993 (Whitesel et al. 1993, Jonasson et al. 1994). Thus, culling these fish from the release group may decrease overall rates of residualism. A possible method for culling these fish may be to use a volitional release strategy from an acclimation pond and removing the fish remaining in the pond after a specific date. Washington Department of Fish and Wildlife used a volitional release strategy from an acclimation pond in an attempt to reduce the number of residual steelhead in the Tucannon River in southeast Washington (Viola and Schuck 1995). Fish that remained in Curl Lake acclimation pond after volitional emigration ceased were predominantly males and were not subsequently released into the Tucannon River.

Hatchery-reared steelhead that were acclimated at Little Sheep Creek Facility before release apparently residualized at a lower rate than those that were released directly into Little Sheep Creek in 1994. We did not find a difference between release types in the two previous years we examined the role of release strategies, however the number of coded-wire tagged fish recovered in 1994 was substantially greater than the number recovered in 1992 and 1993 (Whitesel et al. 1993, Jonasson et al. 1994). Because this was the first year in which we did see a difference, we will continue to monitor this in future years to see if the relationship continues.

The majority of steelhead that residualized were immature during summer following release. This suggests that males are residualizing because they do not undergo smoltification rather than because they are sexually mature. However, a substantial portion of the residual males that survived did become mature by the following spring. These mature residual steelhead may interbreed with natural populations of both rainbow and steelhead trout.

In our attempt to quantify the percentage of residual steelhead which adopt a nonanadromous life history strategy, we were not successful in determining discriminatory characteristics between nonanadromous *O. mykiss* from anadromous *O. mykiss* during spring 1995. We will attempt to collect more known rainbow trout earlier in spring 1996 to continue this portion of the study.

Residual steelhead did appear 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 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 and migrate as 2- rather than 1-year-old smolts. This possibility became apparent when some residual steelhead males remained sexually immature, and when some of these fish exhibited typical smolt morphology the spring following their release.

FUTURE DIRECTIONS

1. Continue to monitor index areas for long term trends in the extent of residualism.
2. Continue to explore the predator-prey relationship between residual steelhead and juvenile salmonids.
3. Begin to explore how growth rates and overall size influence the tendency of hatchery steelhead to residualize.
4. Develop and evaluate hatchery rearing and release strategies for steelhead that will minimize the rate of residualism.
5. Evaluate the feasibility of using volitional releases of hatchery-reared to reduce the number of residual steelhead.
6. Explore the extent to which residual steelhead adopt a nonanadromous life-history strategy, or maintain an anadromous life history strategy.

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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 1994-95 Sampling Period

Appendix Table A-1. Observed densities (fish/100 m^2) of residual steelhead in the Grande Ronde and Imnaha river basins, summer 1994 to spring 1995.

Basin, stream	Rkm	Residual steelhead density			
		Summer	Fall	Winter	Spring
GRANDE RONDE					
Grande Ronde River	64	0.000	(a)	(a)	(a)
	84	(a)	(b)	(a)	(a)
	85	0.214	(a)	(a)	(a)
	253	0.000	0.000	(a)	(a)
	264	(a)	0.000	(a)	(a)
	269	0.000	(a)	(a)	(a)
Catherine Creek	27	0.249	0.000	(b)	(a)
Five Points Creek	0	(a)	(b)	(a)	(a)
Mud Creek	0	(a)	3.747	(a)	(a)
Wallowa River					
Deer Creek	0	2.030	1.821	2.878	1.209
	1.5	0.435	0.375	0.000	(c)
	3	(c)	(c)	0.000	0.000
	6	0.000	0.000	0.000	0.000
	11	0.000	0.000	0.000	0.000
	16	0.000	(a)	0.000	0.000
	19	0.000	0.000	0.000	0.000
Sage Creek	0	0.000	0.000	0.000	0.000
Spring Creek	0	14.379	(b)	1.030	(a)
Wenaha River	0	(a)	(b)	(a)	(a)
IMNAHA					
Imnaha River	39	(a)	(b)	(a)	(a)
	42	0.656	(a)	(a)	(a)
	53	(a)	(a)	(b)	(a)
	74	(a)	(b)	(a)	(a)
Big Sheep Creek	0	0.248	(b)	(a)	(a)
	3	(a)	(b)	(b)	(a)
	5	1.852	(a)	(a)	(a)
	34	0.000	(a)	(a)	(a)
	43	0.000	0.000	(a)	(a)
	53	0.000	1.410	(a)	(a)
Camp Creek	0	0.000	0.000	0.455	0.000
	3	1.066	0.872	1.005	0.000
	6	0.000	(a)	(a)	(a)
Lick Creek	3	0.000	0.000	(a)	(a)

Appendix Table A-1. Continued.

Basin, stream	Rkm	Residual steelhead density			
		Summer	Fall	Winter	Spring
IMNAHA					
Little Sheep Creek	0	5.324	(a)	(b)	(b)
	3	19.375	(b)	(b)	(b)
	6	51.101	3.061	0.000	(b)
	8	54.407	7.440	0.814	(c)
	10	0.000	1.277	0.000	(a)
	13	0.342	1.176	0.000	(a)
	21	0.507	0.000	0.000	(a)
	29	0.525	0.000	(b)	(b)
	39	0.000	(c)	0.000	0.000
Bear Gulch	0	18.676	4.425	0.000	0.000
	3	1.595	0.000	0.000	0.000
	6	0.000	(a)	(a)	(a)

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

Appendix Table A-2. Observed densities (fish/100 m^2) of naturally-produced juvenile chinook salmon in the Grande Ronde and Imnaha river basins, summer 1994 to spring 1995.

Basin, stream	Rkm	Juvenile chinook salmon density Summer	Fall	Winter	Spring
GRANDE RONDE					
Grande Ronde River	64	0.000	(a)	(a)	(a)
	84	(a)	(b)	(a)	(a)
	85	0.000	(a)	(a)	(a)
	253	0.000	0.000	(a)	(a)
	264	(a)	0.000	(a)	(a)
	269	0.000	(a)	(a)	(a)
Catherine Creek	27	5.999	9.906	(c)	(a)
Five Points Creek	0	(a)	(b)	(a)	(a)
Mud Creek	0	(a)	2.602	(a)	(a)
Wallowa River					
Deer Creek	0	19.529	3.643	0.000	0.000
	1.5	0.000	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.000
	11	0.000	0.000	0.000	0.000
	16	0.000	(a)	0.000	0.000
	19	0.000	0.000	0.000	0.000
Sage Creek	0	0.000	0.000	0.000	0.000
Spring Creek	0	2.876	0.000	0.000	(a)
Wenaha River	0	(a)	(b)	(a)	(a)
IMNAHA					
Imnaha River	39	(a)	(c)	(a)	(a)
	42	9.262	(a)	(a)	(a)
	53	(a)	(a)	(c)	(a)
	74	(a)	(c)	(a)	(a)
Big Sheep Creek	0	0.743	(c)	(a)	(a)
	3	(a)	(c)	(c)	(a)
	5	0.285	(a)	(a)	(a)
	34	1.403	(a)	(a)	(a)
	43	0.459	3.474	(a)	(a)
	53	3.575	1.410	(a)	(a)
Camp Creek	0	0.772	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000
	6	0.000	(a)	(a)	(a)
Lick Creek	3	63.824	6.128	(a)	(a)

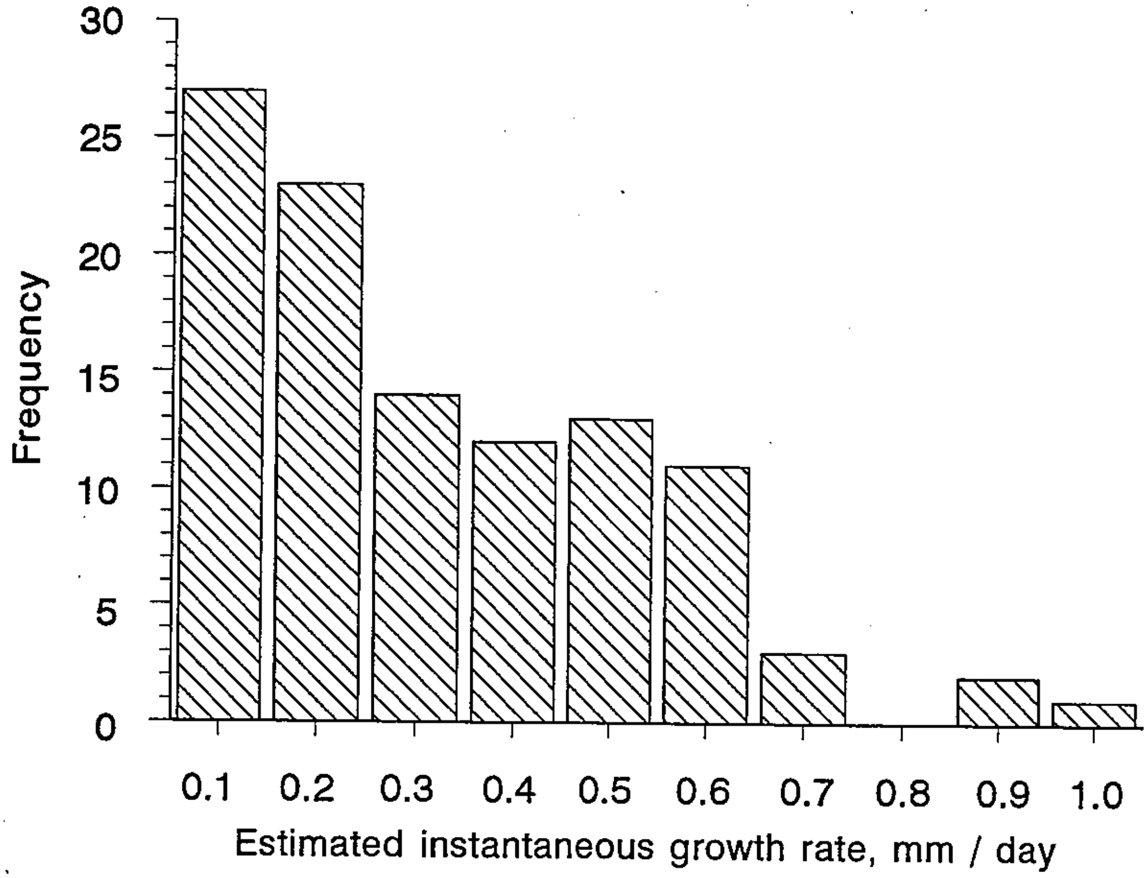
Appendix Table A-2. Continued.

Basin, stream	Rkm	Juvenile chinook salmon density			
		Summer	Fall	Winter	Spring
IMNAHA					
Little Sheep Creek	0	0.484	(a)	(b)	(b)
	3	0.000	(c)	(b)	(b)
	6	0.000	0.000	0.000	(b)
	8	0.000	0.000	0.000	0.000
	10	0.000	0.000	0.000	(a)
	13	0.000	0.000	0.000	(a)
	21	0.000	0.000	0.000	(a)
	29	0.000	0.000	(b)	(b)
	39	0.000	0.000	0.000	0.000
Bear Gulch	0	0.000	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000
	6	0.000	(a)	(a)	(a)

[a] *Area not sampled.*
[b] *Chinook not seen, but unable to estimate density.*
[c] *Chinook present, 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 1994 and then sampled during the summer and fall of 1994. 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

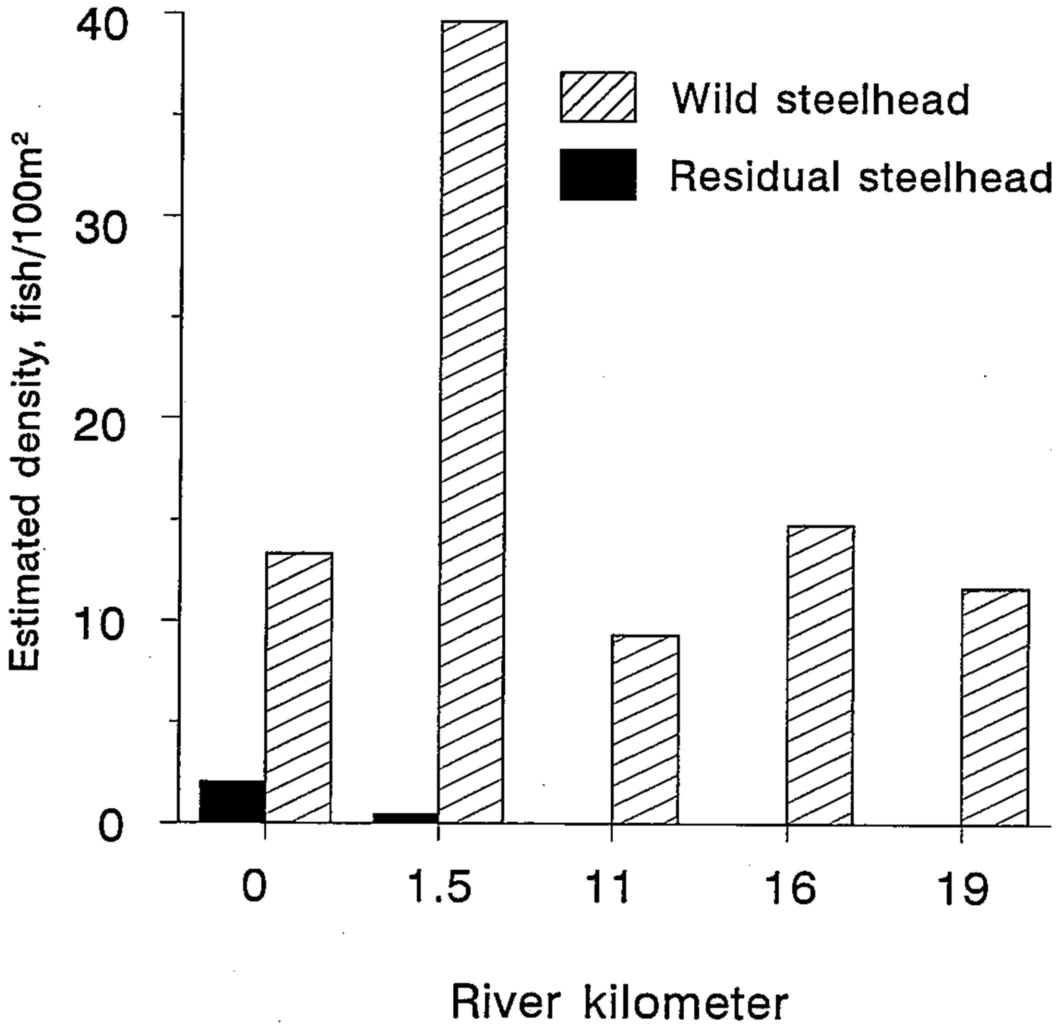
The Relative Densities of Naturally-produced Juvenile Steelhead in Deer and Little Sheep Creeks

We examined the relative densities of juvenile steelhead age-1 and older in Deer and Little Sheep creeks during summers 1993 and 1994 to see if there was any indication that residual steelhead were displacing naturally-produced juvenile steelhead. Young-of-the-year steelhead were distinguished from age-1 and older steelhead based on length. The relative densities of naturally-produced and residual steelhead in Deer and Little Sheep creeks during summer 1993 were reported in Jonasson et al. (1994).

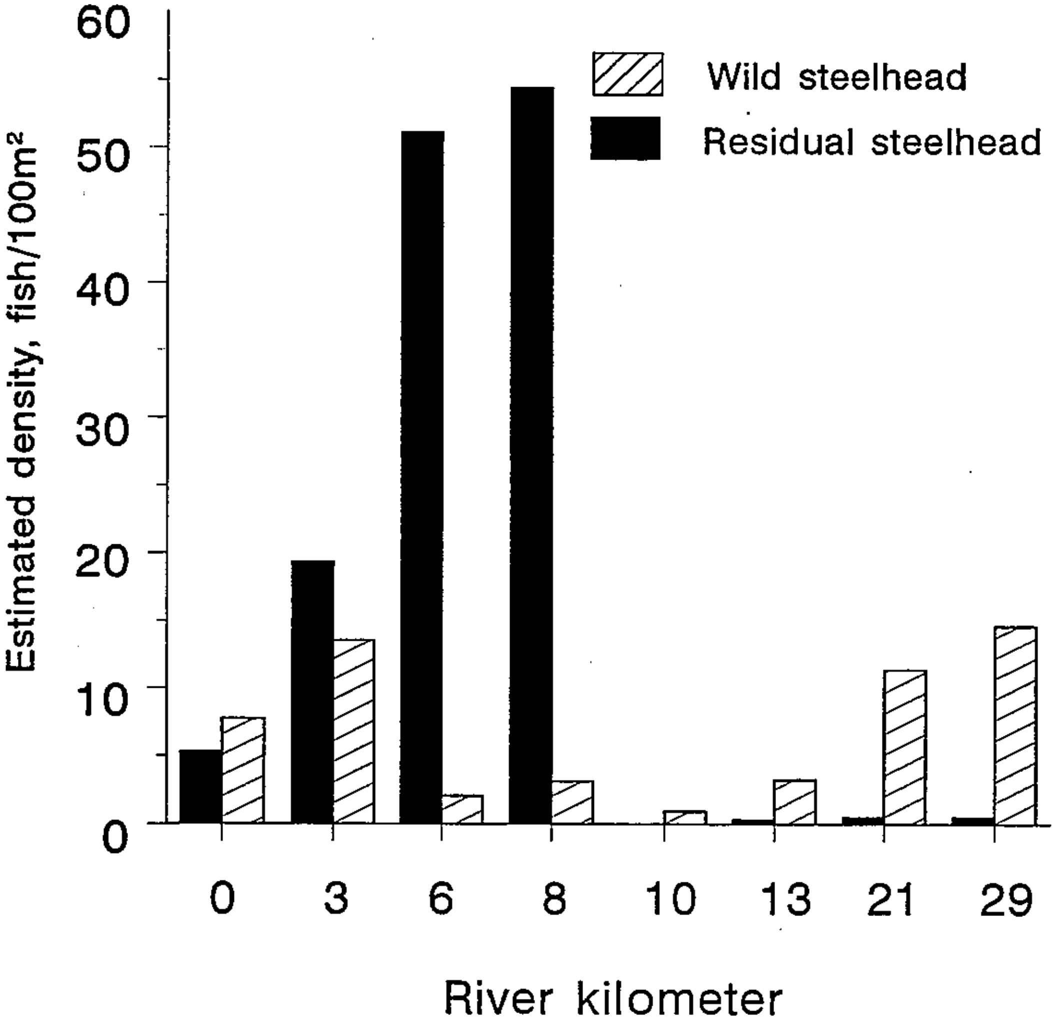
The relative densities of naturally-produced and residual steelhead in Deer Creek during summer 1994 are shown in **Appendix Figure C-1**. The relative densities of naturally-produced steelhead during summer 1994 were near 10 fish/100 m^2 at rkm 0, 11, 16, and 19. At rkm 1.5, the density was about 40 fish/100 m^2. Displacement of naturally-produced steelhead by residual steelhead was not apparent in Deer Creek at the low densities of residual steelhead observed during summer 1994.

The relative densities of naturally-produced and residual steelhead in Little Sheep Creek during summer 1994 are shown in **Appendix Figure C-2**. Densities of naturally-produced steelhead were low in areas where densities of residual steelhead were high in 1994, but they were also low above the release and collection facility (rkm 8) where residual steelhead densities were low. After two years of sampling, it is still unclear whether residual steelhead displace naturally-produced steelhead in Little Sheep Creek.

This is anecdotal information collected during this project, and the sampling was not designed to determine whether residual steelhead were displacing naturally-produced juvenile steelhead.



Appendix Figure C-1. The relative densities of residual steelhead and naturally-produced steelhead (age 1 and older) in Deer Creek during summer 1994. Hatchery steelhead were released at rkm 0.



Appendix Figure C-2. The relative densities of residual steelhead and naturally-produced steelhead (age 1 and older) in Little Sheep Creek during summer 1994. Hatchery steelhead were released at rkm 8.

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 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 1994 to spring 1995.

Survey area	Season	Anglers interviewed	Residual steelhead	Wild trout	Adult steelhead
Imnaha River	spring	88	12	0	27
Rondowa	spring	109	7	0	44
Lower Grande Ronde River	fall	423	602	139	74
	spring	610	20	8	296
Upper Grande Ronde River	spring	192	1	1	16
Wallowa River	spring	938	78	26	183

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Post Office Box 59
Portland, Oregon 97207