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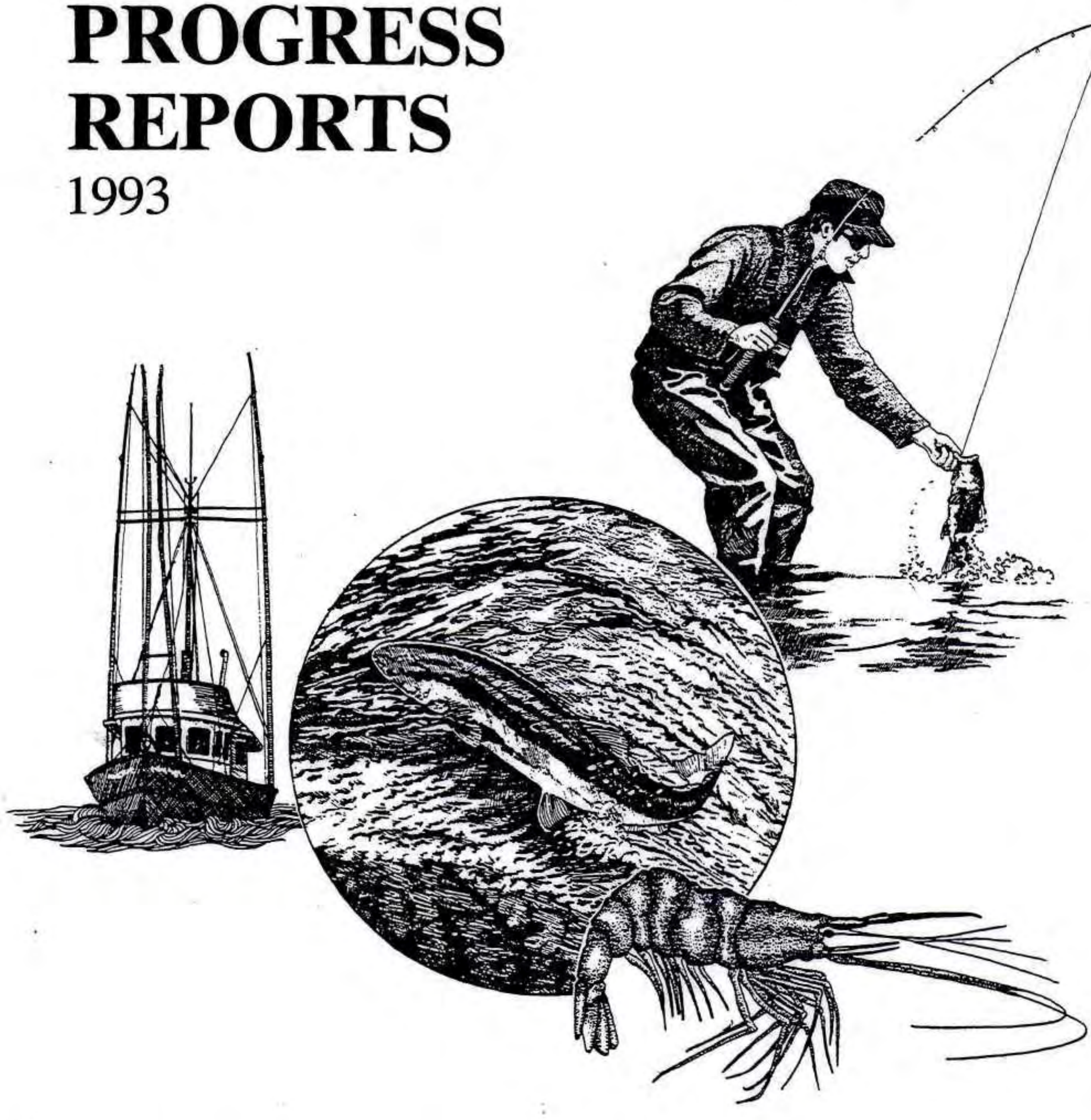

FISH DIVISION
Oregon Department of Fish and Wildlife

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 1992 to 31 March 1993. This report focuses on 1991 brood, summer steelhead juveniles that were released in the spring of 1992. Those individuals remaining in freshwater after 20 June 1992 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 rivers basins during the summer (21 June - 20 September) and fall (21 September - 20 December) of 1992, the winter (21 December - 20 March) of 1992-93, and the spring (21 March - 20 June) of 1993. Thus, this report documents activities from 1 April 1992 through 20 June 1993. The above period represents the first 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

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SUMMARY

Objectives

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

Accomplishments and Findings

1. Residual steelhead and naturally-produced, juvenile chinook salmon do exist sympatrically.
2. It is likely that residual steelhead would have their maximum impact on naturally-produced, juvenile chinook salmon in the lower Grande Ronde, lower Wallowa and lower Imnaha rivers.
3. The majority of residual steelhead originated from the smallest fish in the 1992 release groups.
4. The majority of residual steelhead originated from the male fish in the 1992 release groups.
5. Residualism of hatchery steelhead appears to be independent of release type (direct stream vs. acclimated).
6. No residual steelhead that we sampled contained juvenile chinook salmon in their stomachs.
7. Residual steelhead can persist and may grow well in streams for more than 12 months.

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 location of these release 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 apparent 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 of these releases to steelhead fisheries and the risks of residual 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.

4. Explore the possibility of reducing residualism by culling small males from the release groups.

5. Consider the long-term impacts of residual steelhead. Coded-wire-tagged steelhead that were released in the spring of 1991 (1990 brood) were observed as residuals during this study in 1992-93. Some of these fish had grown fairly well and appeared to be quite healthy.

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

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 essential component of the hatchery population.

8. Consider 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 guiding agencies.

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 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, the concept behind hatchery programs is to minimize the mortality which juveniles suffer in freshwater (Hoar 1988). In 1992, approximately 1,350,000 Wallowa stock and 332,000 Imnaha stock, 10-12 month old, hatchery-reared steelhead were released in northeast Oregon from LSRCP facilities.

Hatchery-reared steelhead (*Oncorhynchus mykiss*) 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 (residuals) 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 natural salmonid juveniles.

The potential interactions of residuals with naturally-produced, juvenile spring chinook salmon (juvenile chinook; *O. tshawytscha*) in lower Snake River drainages has been recognized by fisheries biologists from Oregon, Washington (Martin et al. 1993) and Idaho (Cannamela 1992). Within a given basin, residuals and juvenile chinook exist sympatrically. However, the overlap of local distributions is a necessary requirement for any potential, direct effects to become realized. In northeastern Oregon, it is unclear whether the smaller scale, or local distributions, of residuals and juvenile chinook overlap. Thus, one objective of this study was to document the seasonal distribution and relative abundance of residuals and juvenile chinook in northeast Oregon.

Hatchery production strategies may predispose juvenile steelhead to residualize in freshwater rather than migrate to the ocean as smolts. In northeast Oregon these strategies result in 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 of naturally-produced fish, 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 second objective of this study was to characterize the steelhead in northeast Oregon which residualize after they are released.

Current mitigation strategies for lower Snake River drainages call for the release of large numbers of hatchery-reared steelhead 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 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. Preliminary observations suggest that less than 1% of the residuals prey on juvenile chinook (Cannamela 1993; Martin et al. 1993; Viola and Schuck 1991). However, our modelling efforts (Appendix I) have suggested that if 10% of the hatchery-reared steelhead become residuals, predation rates as low as 0.001 juvenile chinook eaten/residuals/d may result in the loss of approximately 50 adult-equivalent chinook salmon. Stream interactions between hatchery-reared steelhead and juvenile chinook have not been well defined, in part, because predation rates are difficult to evaluate. Thus, the final objective of this study was to begin evaluating the actual extent to which hatchery-reared steelhead prey on juvenile chinook.

STUDY AREA AND POPULATIONS

This study was conducted in the northeast corner of Oregon (Figure 1). Sampling focused on two of the major drainages into the lower section of the Snake River, the Grande Ronde and Imnaha river basins (Figure 2). 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 1992 (Figure 1): Spring Creek, river mile (RM) 2 (approximately 662.5 K smolts from Wallowa Hatchery); Deer Creek, RM 0 (approximately 429 K smolts from the Big Canyon Facility); Catherine Creek, RM 17 (approximately 62.5 K smolts); and the Grande Ronde River at RM 162 (approximately 100 K smolts), and RM 155 (approximately 100 K smolts). Hatchery-reared steelhead were released in the Imnaha River basin near the following locations, also in April 1992 (Figure 1): Little Sheep Creek, RM 5 (approximately 250 K smolts from the Little Sheep Creek Facility), and the Imnaha River, RM 23 (approximately 25 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 1991 broodyear. Specific descriptions of each release group are presented in Messmer et al. (in preparation). Hatchery-reared fish from the 1991 brood which remained in freshwater after 20 June 1992 were considered to have residualized.

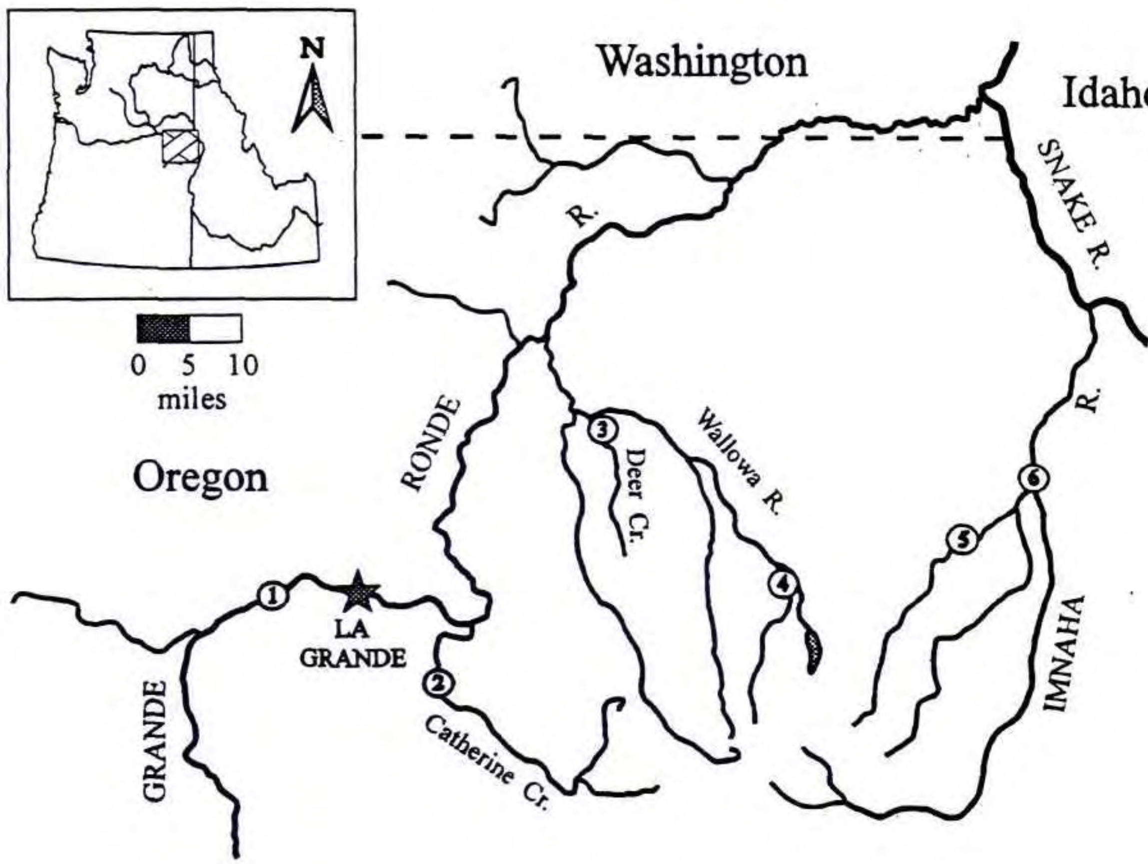

Figure 1. - The major river basins in northeast Oregon and the locations where the Oregon Department of Fish and Wildlife released summer steelhead juveniles in the spring of 1992. 1) Direct stream releases of Wallowa stock steelhead. 2) Direct stream releases of Wallowa stock steelhead. 3) Acclimated and direct stream releases of Wallowa stock steelhead. 4) Acclimated releases of Wallowa stock steelhead. 5) Acclimated and direct stream releases of Imnaha stock steelhead. 6) Direct stream releases of Imnaha stock steelhead.

OBJECTIVE 1: Map the 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 103 locations to sample during the summer of 1992 (Figure 2). Approximately 50% of these locations were sampled for the presence/absence of residuals and juvenile chinook while the other 50% of these locations were sampled for the relative density of residual steelhead and juvenile chinook salmon. We selected locations based on where hatchery-reared steelhead were released, known or anticipated spawning and rearing locations of chinook salmon, as well as stream accessibility. We classified these locations as presence/absence (distribution) locations or relative density (abundance) locations based on similar criteria. 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. In the fall of 1992, winter of 1992-93 and spring of 1993 we focused our sampling in and adjacent to locations where residual hatchery steelhead were found during our summer sampling. This strategy was chosen to maximize our efficiency, but still allowed us to explore seasonal movements of residuals.

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.

At distribution locations we made a maximum of one (snorkeling) or two (electrofishing) passes. If at least one residual and one juvenile chinook were observed, sampling was terminated at that site (i.e. they were both present). If one residual and one juvenile chinook 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.

At abundance locations we also 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 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 estimated the total length and average width of each sampling site to calculate the surface area of the sampled site. Densities of residuals and juvenile chinook were calculated for abundance sites using the surface area and the estimated number of residuals or juvenile chinook in the site.

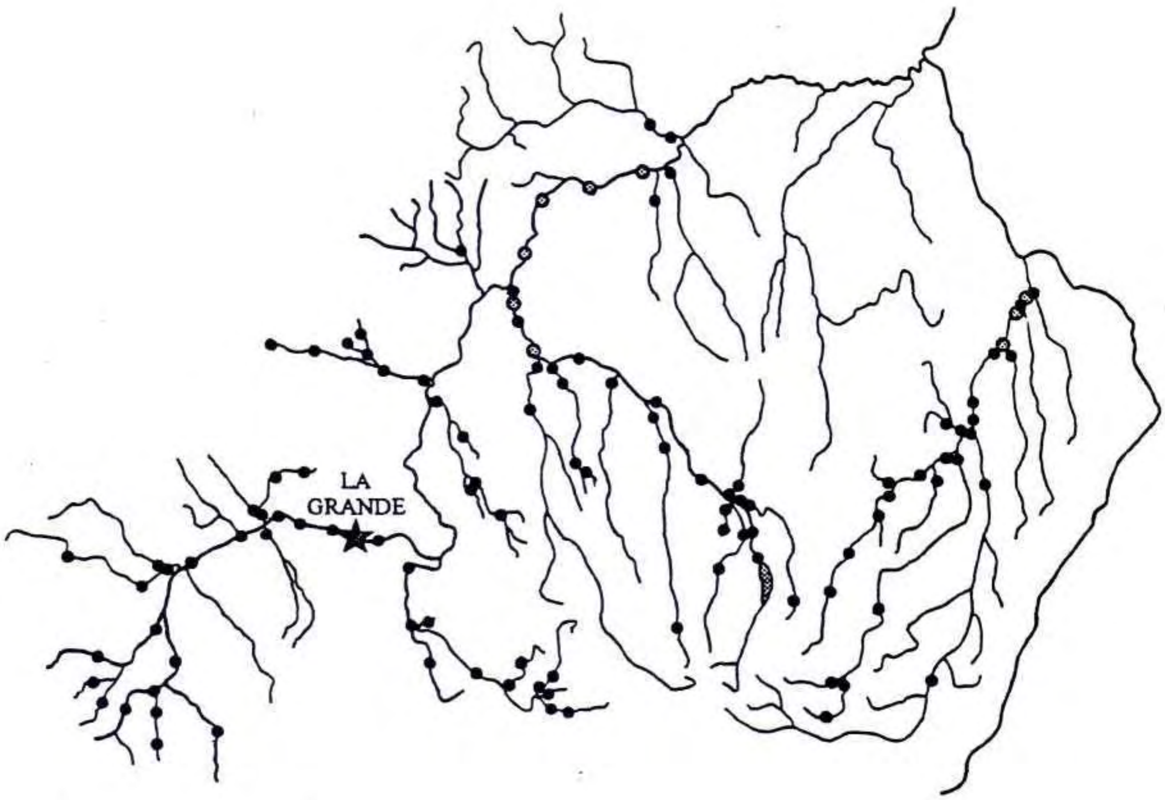

Figure 2. - The locations sampled during the summer of 1992 in the Grande Ronde and Imnaha river basins. ● indicates electrofishing or snorkeling sites. ⊗ indicates sites sampled by angling.

When we were not able to use electrofishing techniques at abundance sites, we snorkeled. Visual observations were made of the species present and the number of individuals in each salmonid species. We generally used three divers, 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.

From our sampling, a map was generated which indicated the areas where residuals were distributed. This sampling, as well as known spawning areas of adult chinook salmon, rearing areas of juvenile chinook and anecdotal information on the distribution of juvenile chinook in northeast Oregon, allowed us to generate a similar map for juvenile chinook. To determine the overlap in the distribution of residuals and juvenile chinook, the distribution patterns observed in these two maps were compared. We used ANOVA procedures to evaluate the distribution and abundance of residuals near their release sites as well as seasonal changes in the distribution and abundance of residuals. 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) of residuals and juvenile chinook was also assigned to each sampling location. Based on these relative densities, as well as observations that residuals eventually tended to distribute downstream of their release site into higher order streams, a relative level of interaction was assigned (Table 1). 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
Residuals	Juvenile chinook	interaction
low[1]	low	minimal
	medium	minimal
	high	moderate
medium[2]	low	minimal
	medium	moderate
	high	maximal
high[3]	low	moderate
	medium	maximal
	high	maximal

1 low < 1 fish / 100m^2.
2 1 fish / 100m2 ≤ medium < 9.99 fish / 100m^2.
3 high ≥ 10 fish / 100m^2.

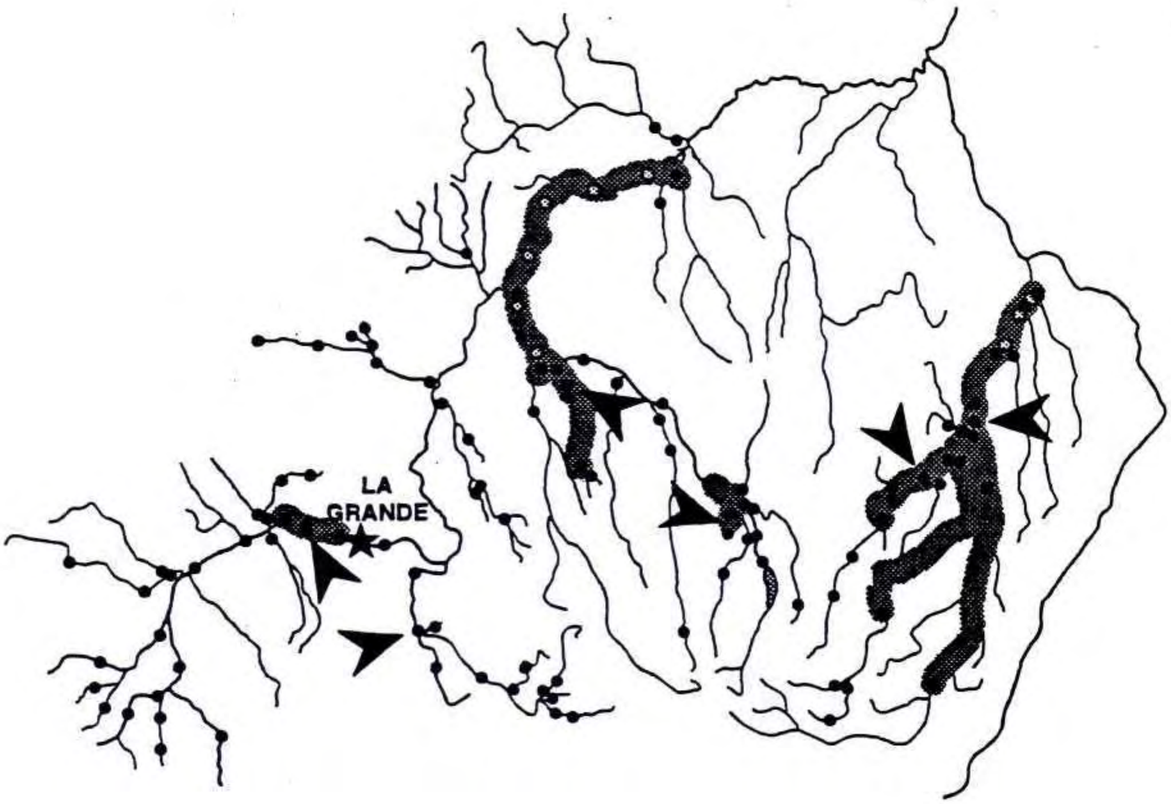

Figure 3. - The distribution of residual steelhead during the summer of 1992 in the Grande Ronde and Imnaha river basins. • indicates sites sampled by electrofishing or snorkeling. ⊛ indicates sites sampled by angling. ➤ indicates release sites.

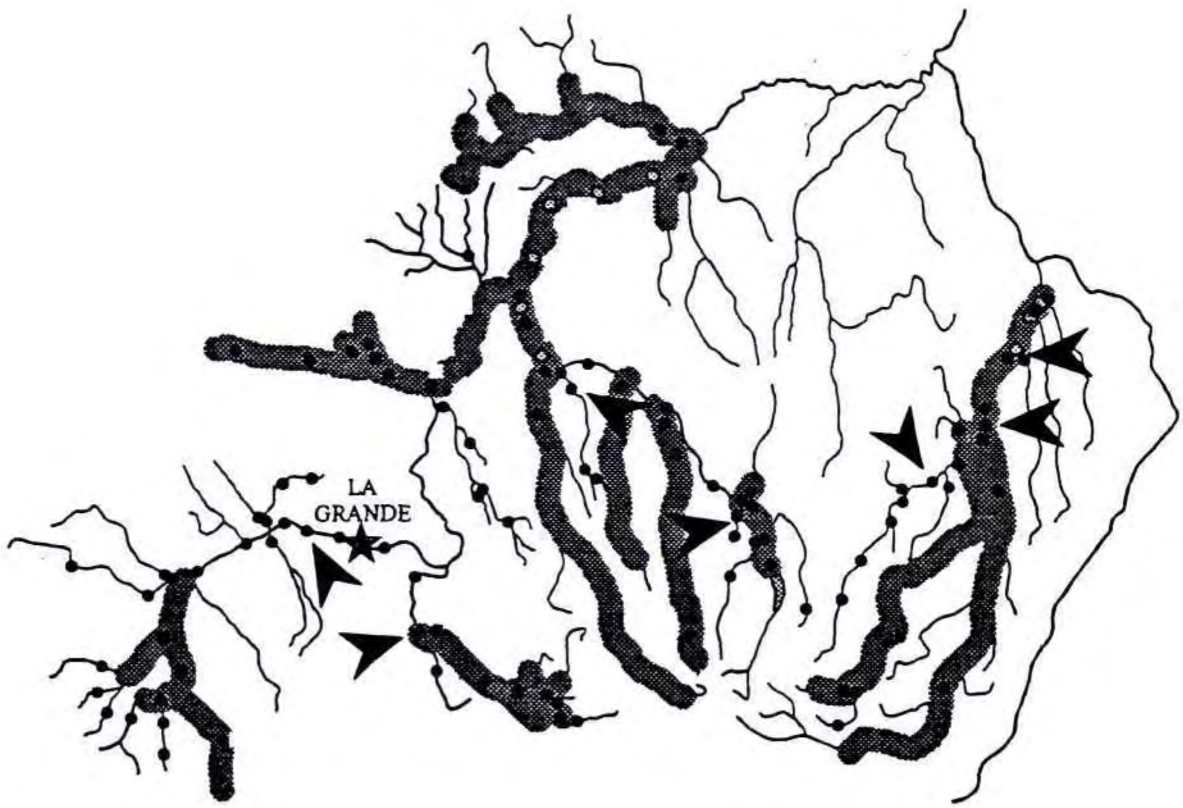

Figure 4. - The expected distribution of naturally-produced, juvenile chinook salmon during the summer of 1992 in the Grande Ronde and Imnaha river basins. This distribution was generated based on information complied from residual steelhead surveys, chinook spawning ground surveys, habitat surveys, juvenile chinook collected for migration studies, and juvenile chinook collected for genetics studies. • indicates sites sampled for residual steelhead by electrofishing or snorkeling. ⊗ indicates sites sampled for residual steelhead by angling. ➤ indicates release sites for juvenile steelhead.

Results

With the exception of Catherine Creek, residuals were always found downstream of the release sites (Figure 3). residuals also moved upstream after being released in four of the six release sites. The distribution of residuals in the Imnaha, Wallowa and lower Grande Ronde areas was more extensive than in either the Catherine Creek or upper Grande Ronde areas. We found residuals distributed over approximately 29 river-miles in the lower Grande Ronde area, 27 river-miles in the Wallowa area, and 93 river-miles in the Imnaha area, as opposed to 7 river-miles in the upper Grande Ronde area, and 0 river-miles in the Catherine Creek area. Juvenile chinook salmon are widely distributed throughout northeast Oregon (Figure 4). The distributions of residuals steelhead and juvenile chinook salmon overlapped at the mouth of the Minam River, from RM 0-10 of the Wallowa River, from RM 53-82 of the Grande Ronde River, near the mouths of Spring and Trout creeks as well as near RM 41 of the Wallowa River, from RM 0-21 of Big Sheep Creek, and from RM 4-54 of the Imnaha River.

Peak densities of residuals (31-54 fish/100m^2) were observed within one river-mile of the release sites (for example, Figure 5; also see Appendix II). The relative densities of residuals at these sites decreased nearly 3.5-fold from summer to fall and, then again, from fall to winter (see Figure 6). Although we were unable to measure densities during the spring season because of high stream velocity and volume, residuals were present at these sites. The patterns of distribution and abundance from summer through winter suggested that as the seasons progress there is some movement away from the area of release (Figure 7). Although some movement appeared to occur in the upstream direction, there appeared to be a general shift in the distribution and abundance of residuals towards more downstream locations, outside of the area we could sample quantitatively (Figure 7).

Discussion and Management Implications

The relative abundance and dispersal pattern of residuals suggests that current release locations generally help to minimize the impacts of residuals on juvenile chinook. Typically, areas of high residual density were not major rearing areas for juvenile chinook. However, maximum residual densities were very high, generally 3- to 5-fold greater than the maximum densities of naturally-produced *O. mykiss* of a similar size and age. Thus, residuals may have a substantial impact on the aquatic ecosystems in these areas.

The general dispersal pattern of residuals appeared to be downstream from release sites. However, some residuals dispersed as many as 39 miles upstream from release sites. Although the major impacts of residuals may be localized, some impact may occur over a large geographical area.

Based on relative densities, the most likely areas for moderate to maximal interactions to occur between residuals and juvenile chinook appear to be the lower Wallowa, Grande Ronde and Imnaha rivers (Figure 8). Different seasonal capture efficiencies inhibited our ability to compare relative densities of residuals between seasons at a particular location. However,

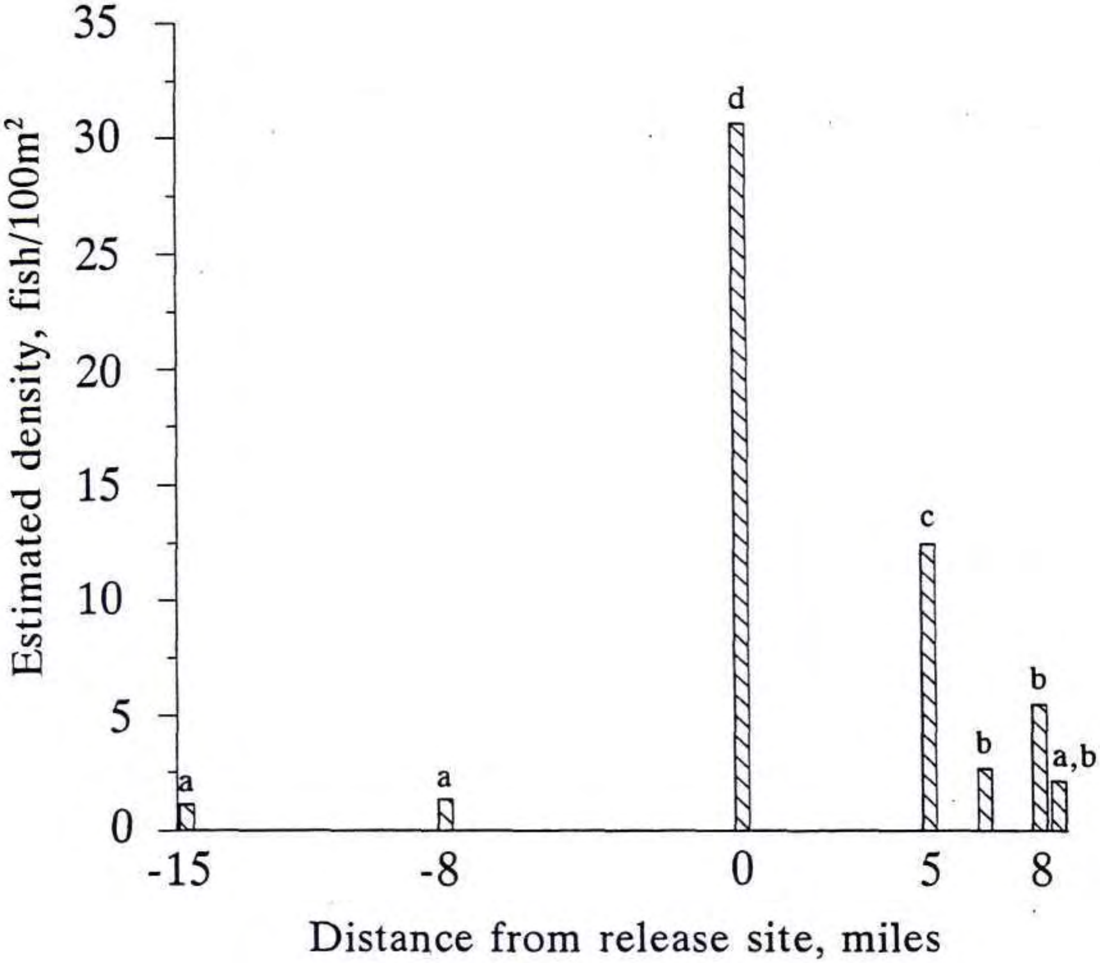

Figure 5. - The dispersal and density of residual steelhead near the Little Sheep Cr. release site during the summer of 1992. Negative distances represent upstream movements whereas positive distances represent downstream movements. Estimated densities: a < b < c < d.

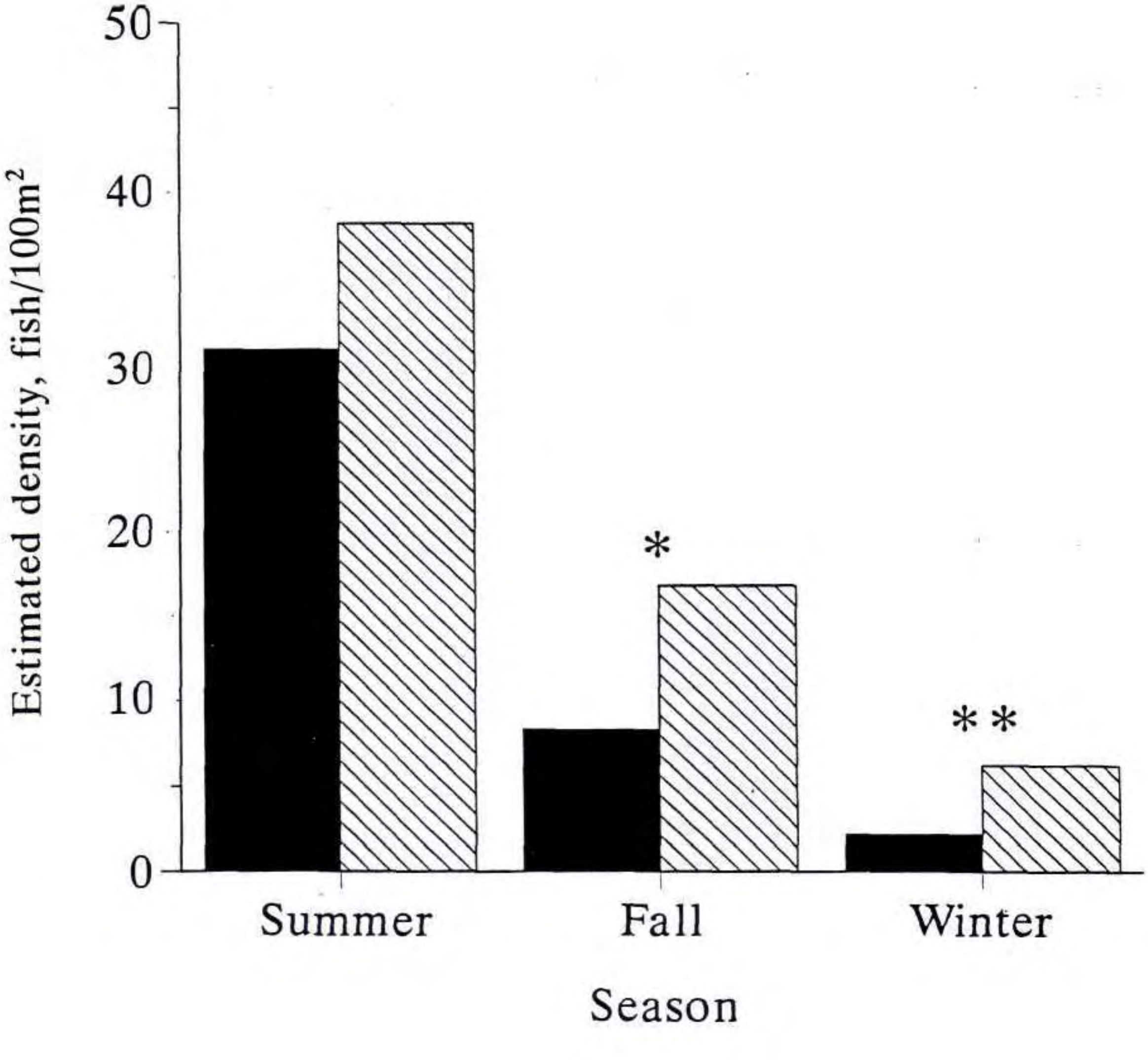

Figure 6. - The seasonal patterns of residual steelhead densities at the Deer ▧ and Little Sheep ■ Cr. release sites (index areas) during the summer of 1992. Although residual steelhead were present in the spring of 1993, their density could not be quantified. * indicates a significant decrease in densities at both sites from summer values; ** indicates a significant decrease at both sites from fall values.

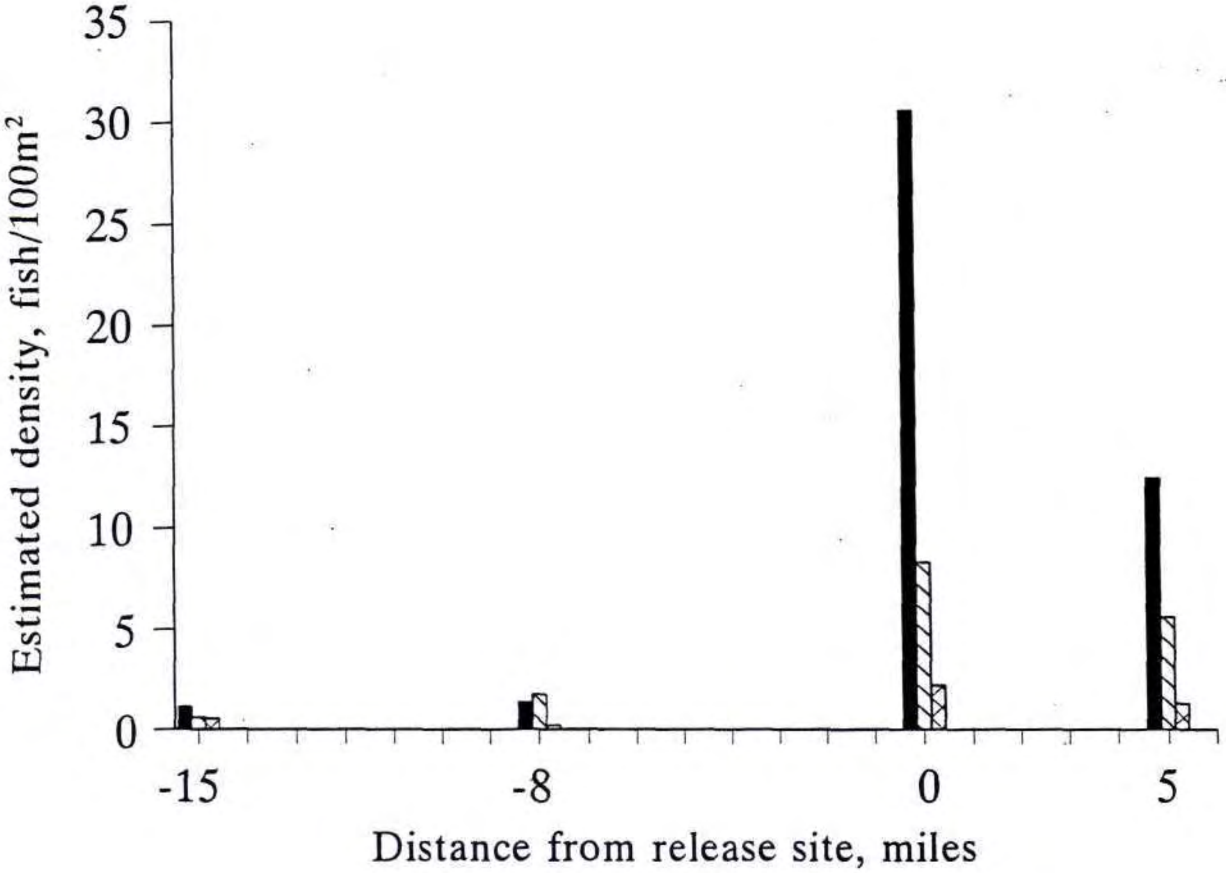

Figure 7. - Seasonal shifts in the distribution and density of residual steelhead in Little Sheep Cr. during the summer of 1992. ■ represents the summer season; ▨ represents the fall season; ⊠ represents the winter season.

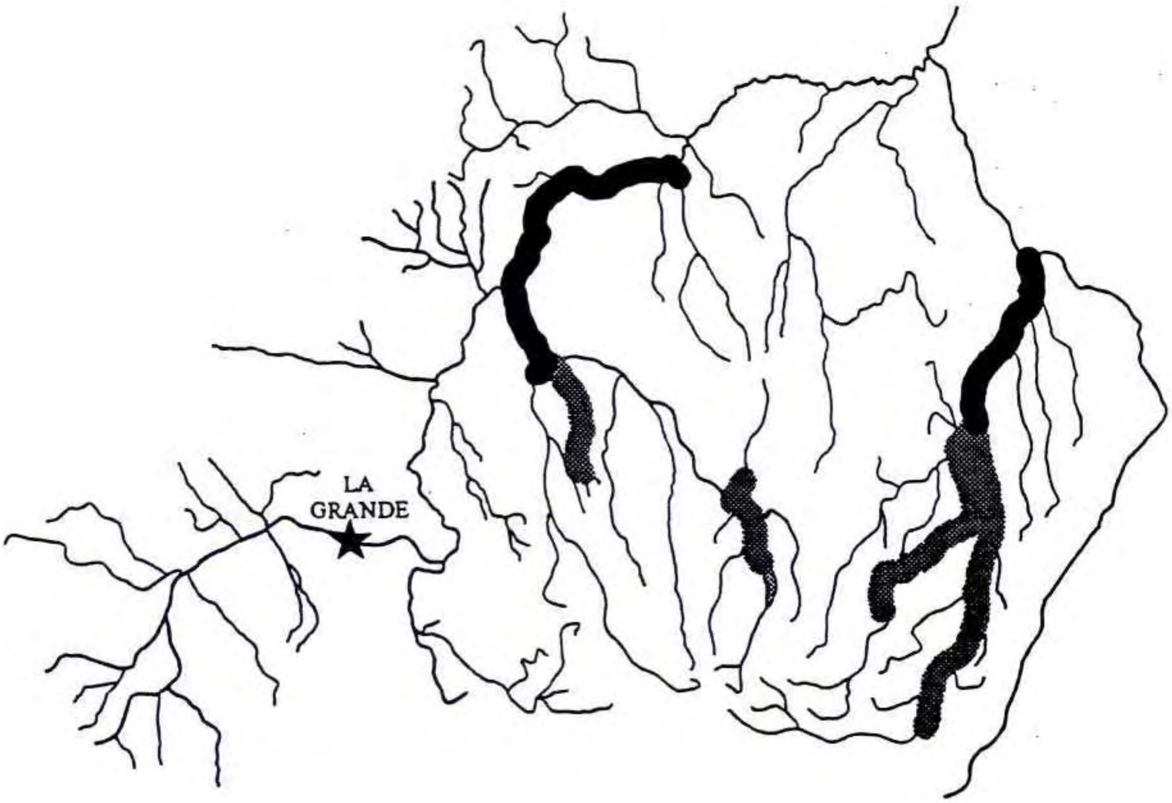

Figure 8. - Areas of overlap and potential for interaction between residual steelhead and naturally-produced, juvenile chinook salmon in the Grande Ronde and Imnaha river basins during the summer of 1992. ■ indicates areas where the potential for interaction was likely (based on relative densities). ■ indicates areas where the potential for interaction was possible (based on relative densities).

we are better able to compare relative residual densities between locations within a particular season. In general, the data suggest that the relative distribution of residuals appears to shift downstream during the fall and winter months. This is also the period when juvenile chinook presumably migrate out of tributaries, into mainstem areas of larger order streams. Therefore, the areas where residuals have their major impacts may change seasonally.

Very few residuals were found in the upper Grande Ronde River or Catherine Creek areas. Although the specific reason is uncertain, the most simple explanation for this lack of is that it resulted because fewer hatchery-reared steelhead were released in these areas. Thus, if the number of hatchery-reared steelhead that are released in these areas remains low, residuals may not be a concern in the upper Grande Ronde River and Catherine Creek areas.

OBJECTIVE 2: Characterize the steelhead which residualize.

Methods

Fork length

In order to determine if residualism is independent of juvenile growth characteristics, we examined the length-frequency of residuals 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. Three relationships were developed, one for both the Wallowa and Imnaha stock juveniles as well as a model combining both stocks (since 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 residuals captured during our summer sampling. We examined the residual 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 residuals. We then calculated the mean fork length of the residuals at the time of release. We used a Student's t-test ($\alpha = 0.05$) to compare the mean fork length of residuals 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 residuals (see Appendix III).

Sex and maturity

In order to determine whether residualism is independent of sex, we compared the sex ratio of residuals 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 residuals. 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 residuals 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 that we captured for freeze 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 a good predictor of fork length. The results for equation 1.1 were:

Fork length = 180.18 (Scale radius) + 34.23; $P<0.0001$; $R^2=0.65$; *(Wallowa stock)*
Fork length = 198.10 (Scale radius) + 20.43; $P<0.0001$; $R^2=0.57$; *(Imnaha stock)*.

The lines resulting from these regressions were not different from each other. Thus, the data was pooled to generate one model (Figure 9). The result for equation 1 was:

Fork length = 187.97 (Scale radius) + 28.46; $P<0.0001$; $R^2=0.62$.

The combined model was used to back-calculate the size-at-release for residuals. The combined model had a mean error rate of 6.32% 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 2).

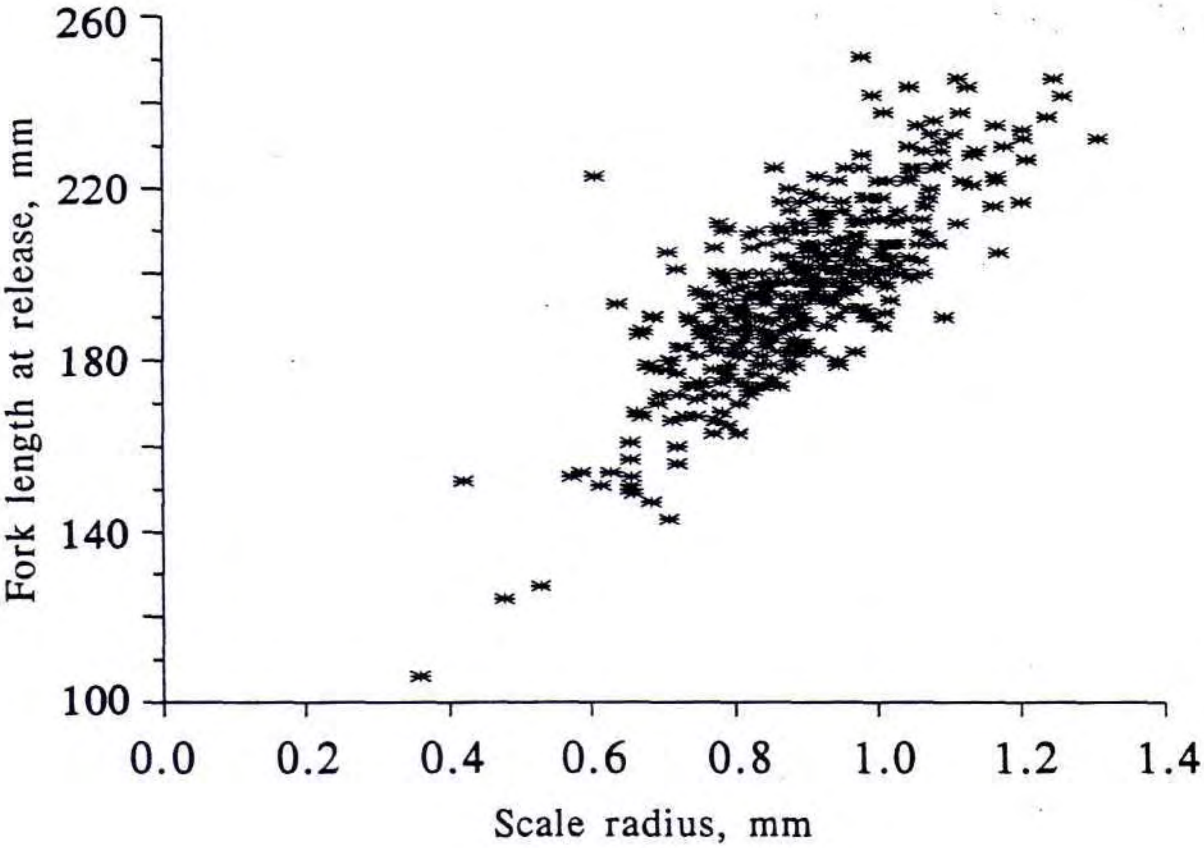

Figure 9. - The relationship between fork length (FLEN) and scale radius (SR) of hatchery-reared steelhead at release in 1992. Data from Wallowa and Imnaha stocks were pooled to generate one model. The linear regression (FLEN = 187.97 SR + 28.46; R^2 = 0.62) was significant ($P < 0.0001$).

Table 2. 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≥0.05.

Stock	Pre-release	Residuals	Differences
Imnaha	193.2 (0.66)	157.3 (2.19)	S
Wallowa	204.2 (0.38)	151.3 (2.86)	S

Sex and maturity

More males were found in the population of residuals 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 residuals captured in the summer was 81:19 (Table 3). The percent of the residual population that was composed of males remained near 80% during the fall, winter and spring (Table 3).

The majority of the male residuals sampled, during the summer following the release of the 1991 brood, were immature (Table 4). This cohort of residuals began to mature by the fall and some fish had become mature by winter. By spring, the majority of residual males from this cohort had either become mature or remained immature (i.e. very few fish were in a maturing stage of development). The majority of the female residuals sampled, during the summer following the release of the 1991 brood, were also immature (Table 4). In contrast to the male residuals, the female residuals tended to be and to remain immature during the course of this study (Table 5).

Table 3. Percent sex composition of hatchery-reared steelhead. For each sex, differences in percents between adjacent groups were judged to be significant (S) when P<0.05 and not significant (NS) when P≥0.05.

Group	*N*	Males(%)	Females(%)	Differences
Pre-release, spring	46	54.3	45.7	-
Residuals, Summer	500	81.0	19.0	S
Fall	138	79.7	20.3	NS
Winter	56	76.8	23.2	NS
Spring	19	89.5	10.5	NS

Table 4. Maturity of male residual steelhead, by season. Differences in percents between adjacent seasons were judged to be significant (S) when P<0.05 and not significant (NS) when P≥0.05.

Season	*N*	Immature (%)	Maturing (%)	Mature (%)	
Summer	405	87.7	12.1	0.2	-
Fall	110	51.8	48.2	0.0	S
Winter	43	39.5	37.2	23.3	S
Spring	17	35.3	11.8	52.9	NS

Table 5. Maturity of female residual steelhead, by season. Differences in percents between adjacent seasons were judged to be significant (S) when P<0.05 and not significant (NS) when P≥0.05.

Season	*N*	Immature (%)	Maturing (%)	Mature (%)	
Summer	93	84.9	15.1	0.0	-
Fall	28	92.9	7.1	0.0	NS
Winter	13	100.0	0.0	0.0	NS
Spring	2	100.0	0.0	0.0	NS

Release strategy

We identified acclimated- and direct-stream-released residuals by information collected from coded-wire-tagged individuals. We found no difference in the rate of residualism between release strategies from the Little Sheep Creek Facility (Table 6). We recovered too few coded-wire-tagged fish released from the Big Canyon Facility to compare residualism among release strategies. No freeze-branded residuals were observed.

Discussion and Management Implications

The majority of the residuals originated from the shortest, male fish in the release groups. This was true for both Wallowa and Imnaha stock steelhead. Thus, culling these fish from the release group may decrease overall rates of residualism.

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

Table 6. Number of coded-wire-tagged residual steelhead recovered by release type.

Release site	Release type	No. released	No. recovered
Little Sheep Facility	Direct stream	52,023	38
	Acclimated	53,647	42
Big Canyon Facility	Direct stream	52,154	10
	Acclimated	52,713	1

Residual steelhead appeared to have the potential to choose 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 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 males and most residual 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 residuals, further research is necessary 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. Although only data from Imnaha stock steelhead could be used to draw this conclusion, there is no obvious reason to expect Wallowa stock steelhead to behave differently. In any event, current release strategies do not appear to be useful tools for managers to reduce the rates of residualism.

OBJECTIVE 3: Begin to evaluate predation by hatchery-reared steelhead on juvenile spring chinook salmon.

Methods

We collected the stomachs from the residuals captured during our routine sampling. 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 discernible fish parts found in the stomach contents were identified to family and all salmonids were identified to species.

We also collected hatchery-reared steelhead migrants from a screw trap (operated by the Nez Perce Tribe) located near RM 4 in the Imnaha River. We sampled stomachs (as described previously) from steelhead which were released at the Little Sheep Facility approximately 27 river-miles upstream. The hatchery-reared fish were collected from the screw trap and held in live cages in the river for 8-10 h before we sampled their stomachs.

We calculated the incidence of residual and hatchery-reared steelhead migrant stomachs that contained juvenile chinook. The incidence for both groups was expressed as a percent (number of stomachs containing juvenile chinook x 100 / no. 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.

After examination of the contents of the stomachs from residuals captured during summer it became apparent that our sampling methods may be artificially increasing the predation on fish by residuals. We found freshly consumed fish in some of the mouths, esophagus and stomachs of the residuals captured. We believe that, in the summer, some of the residual steelhead we examined had consumed small fish we stunned with the electrofisher during our sampling. Thus, during our fall, winter and spring sampling we only collected stomachs from residual steelhead collected during the first pass of electrofishing.

Results

We examined stomachs from 611 residuals captured throughout the year and from a variety of locations (Table 7). We found fish or fish parts in 54 of these stomachs, including eight with young-of-the-year steelhead (33-62 mm fork length). Sculpins were found in 37 stomachs, while squawfish, dace and suckers were found occasionally. We did not find juvenile chinook in any of the residual stomachs. The maximum incidence of residual stomachs containing juvenile chinook was 0.49%. We did not find any fish in the stomachs of 65 hatchery-reared steelhead migrants sampled from the Imnaha River screw trap (Table 7). The maximum incidence of hatchery-reared steelhead migrant stomachs containing juvenile chinook was 4.50%.

Discussion and Management Implications

The overall incidence of residual stomachs that contained juvenile chinook was low. Juvenile chinook did not appear to be an abundant food resource in the areas in where most of the residual stomachs were collected. However, very low rates of residual predation on juvenile chinook could have substantial impacts on chinook salmon populations (see Appendix I).

FUTURE DIRECTIONS

1. Assess annual variability in residualism and the causes of this variability by developing index areas for monitoring long-term trends in the extent of residualism.

Table 7. 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			
Spring[a]	65	0	0
Summer	277	35	4[b]
Fall	65	3	1[b]
Winter	9	1	0
Spring	2	0	0
GRANDE RONDE			
Summer	129	7	2[b]
Fall	78	4	1[b]
Winter	35	3	0
Spring	16	1	0

[a] Migrants captured by screw trap at Imnaha RM 4, spring 1992.
[b] Steelhead.

2. Better describe the movement of residuals after they are released by developing more sampling sites closer to the release locations.

3. Better assess the effects of predation by residuals on juvenile chinook by focusing sampling efforts on areas where residuals and juvenile chinook have their presumed maximum overlap.

4. Develop hatchery-rearing and release strategies for steelhead that will help to minimize the rate of residualism and continue characterizing the portion of the release groups that residualize.

5. Begin to explore protocols to estimate the overall rate of residualism.

6. Evaluate the possibility of using volitional releases of hatchery-reared steelhead to minimize the number of residuals in local drainages.

7. Begin investigating the effects of residuals on natural populations of *O. mykiss*.

8. Continue to assess sampling methodologies. Examine the relative efficiency of sampling during the four different seasons as well as day versus night distribution and abundance of residuals.

9. Develop studies to determine if the number of residuals can be reduced by grading off the smallest individuals prior to release.

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APPENDICES

Appendix I. Modelling efforts to predict the impact of residual steelhead predation on naturally-produced, chinook salmon populations.

Three major points are illustrated by the following modelling efforts. 1) If the relative abundance of residual steelhead is high, then a very low rate of predation may still have significant impacts on chinook salmon populations. 2) Small differences in the rate of predation by residual steelhead may result in very different impacts on chinook salmon populations. 3) Large sample sizes may be necessary to determine predation rates accurately and precisely.

To generate preliminary expectations concerning residual steelhead predation and assess some of the associated limitations of the data, exercises were conducted to model predation by residual steelhead. In an attempt to convert numbers of chinook salmon fry to a more meaningful currency, the data was evaluated in terms of chinook salmon adult-equivalents. Based on unpublished values, the following assumptions were used to generate this conversion for chinook salmon. Fry-to-parr survival was estimated to be approximately 0.85; parr-to-smolt survival was estimated to be approximately 0.30; and smolt-to-adult survival was estimated to be approximately 0.01 (personal observation). Thus, fry to adult survival is approximately 0.00255 and, therefore, we assumed that 392 fry are equivalent to approximately one adult returning to spawn.

The first modelling exercises were designed to evaluate the impacts that various rates of predation by residual steelhead might have on chinook salmon populations. To assess this question rigorously, it would be necessary to collect field data on at least: 1) the number of chinook salmon fry per residual steelhead stomach (which may be related to prey availability); 2) the number of residual steelhead; 3) evacuation rates of residual steelhead; and 4) the persistence of residual steelhead over time. Each of these estimates would have an associated error term (i.e. measure of uncertainty). These estimates would allow for the calculations of: 1) the rate of predation on chinook salmon fry by residual steelhead; 2) the total number of chinook salmon fry eaten by residual steelhead; and 3) the total number of chinook salmon adult-equivalents eaten by residual steelhead. In general, the error terms of each calculated variable would be multiples of the error terms associated with each estimated variable.

For this exercise, we assumed that 1,000,000 hatchery-reared steelhead were released on 15 April and, based in part on the reports of Viola and Schuck (1991), Cannamela (1992; 1993) and Martin et al. (1993), that 15% of these steelhead residualized, that all the residual steelhead had emigrated or died by 15 October, and that this decline was linear over time. We then varied the rate of residual predation between 0 and 1 chinook salmon eaten/residual steelhead/day and evaluated the number of chinook salmon adult-equivalents that would be eaten. Data from Cannamela (1993) and Martin et al. (1993) suggests that 0.01 chinook salmon fry eaten/residual steelhead/day may be a reasonable approximation. The results helped illustrate that a low rate of predation by residual steelhead may have a substantial impact on chinook salmon populations (Figures I.1 and I.2).

Furthermore, small differences in the rates of predation may result in very different effects on chinook salmon populations (Figures I.1 and I.2).

The second set of modelling exercises were designed to evaluate the sampling effort that would be necessary to adequately assess predation. To address this question it is necessary to determine the magnitude of predation that is biologically important. In other words, the sampling effort which is required to distinguish whether residual steelhead consumed 5 or 50 chinook salmon adult-equivalents is much greater than the effort required to distinguish whether residual steelhead consumed 50 or 500 chinook salmon adult-equivalents.

At the presently low escapement levels, one chinook salmon adult-equivalent may be important. Thus, these exercises focus on differences of very few chinook salmon adult-equivalents as being biologically meaningful. The results help illustrate that it may be necessary to sample an inordinately large number of residual steelhead stomachs (tens of thousands) to determine, accurately and precisely, the effects on chinook salmon populations (Figures I.3 and I.4). These models utilize variables (i.e. predation rate) without any associated error terms. Thus, these estimates represent approximations of the minimum sample that would be necessary.

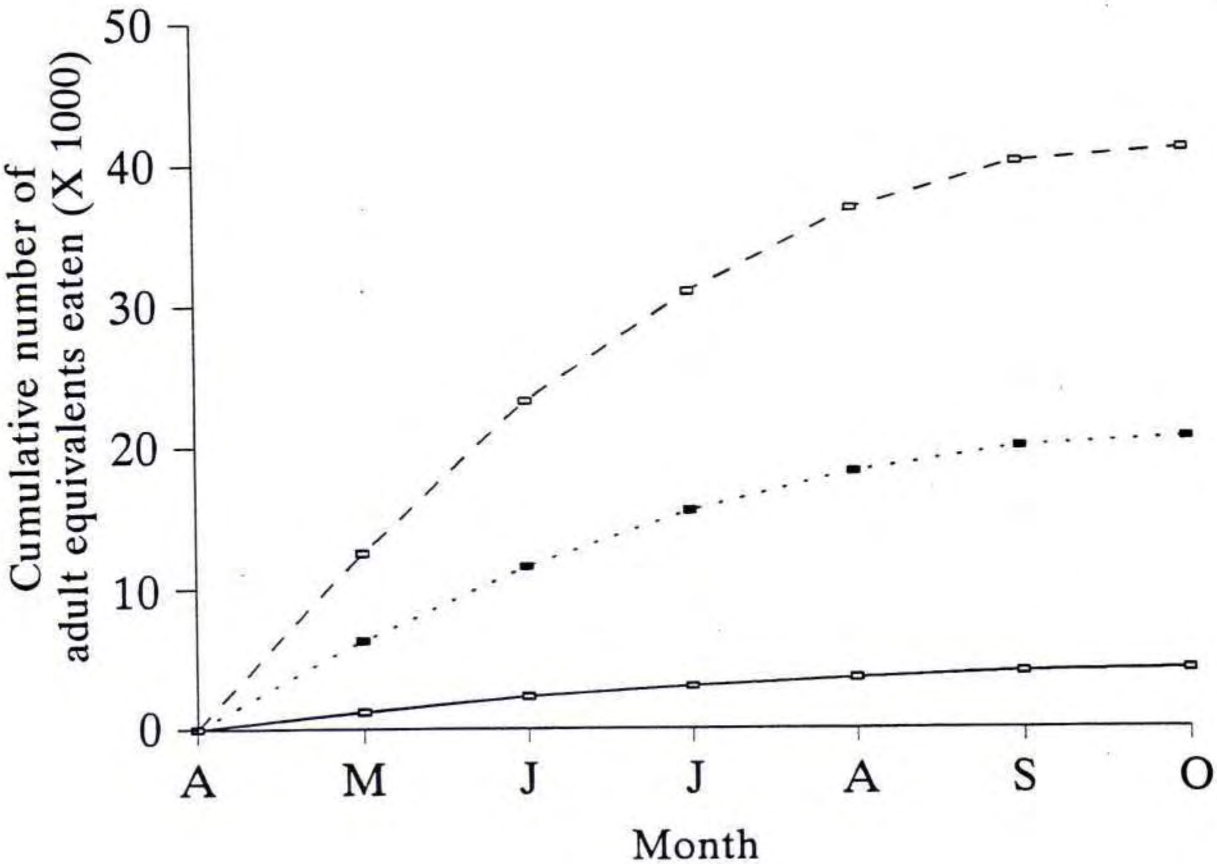

Figure I.1. - Potential adult equivalent chinook salmon (CHS) consumed by residual steelhead (RSTS). This exercise assumed 150,000 RSTS on 15 April, that all RSTS had emigrated or died by 15 October, and that the decline in RSTS numbers was linear over time. The predation rates, expressed as the number of CHS fry / RSTS / day, modelled were: 0.1 (——); 0.5 (· · ·); and 1.0 (– –).

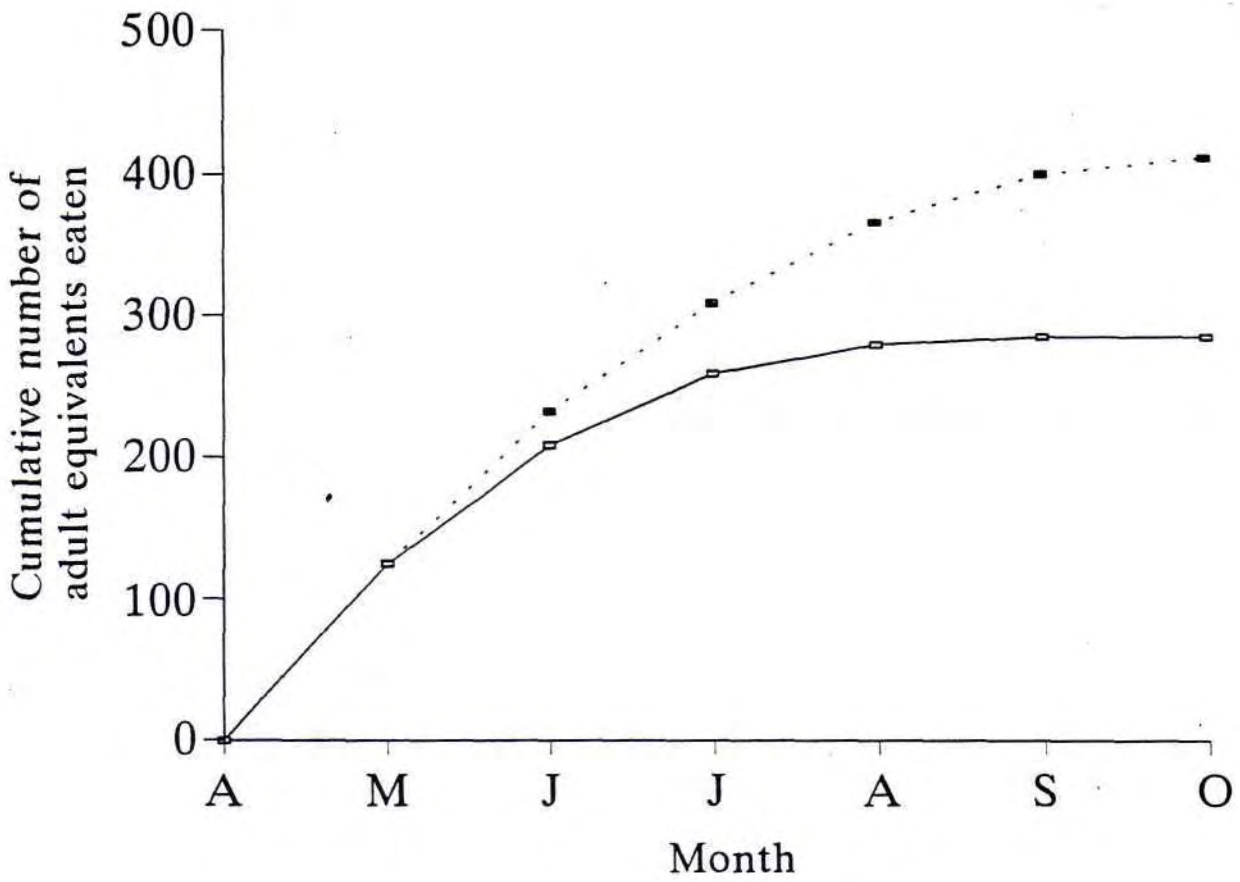

Figure I.2. - Potential adult equivalent chinook salmon (CHS) consumed by residual steelhead (RSTS). This exercise assumed 150,000 RSTS on 15 April, that all RSTS had emigrated or died by 15 October, and that the decline in RSTS numbers was linear over time. The predation rates, expressed as the number of CHS fry / RSTS / day, modelled were: variable from 0.0 to 0.01 (——); and fixed at 0.01 (- - --).

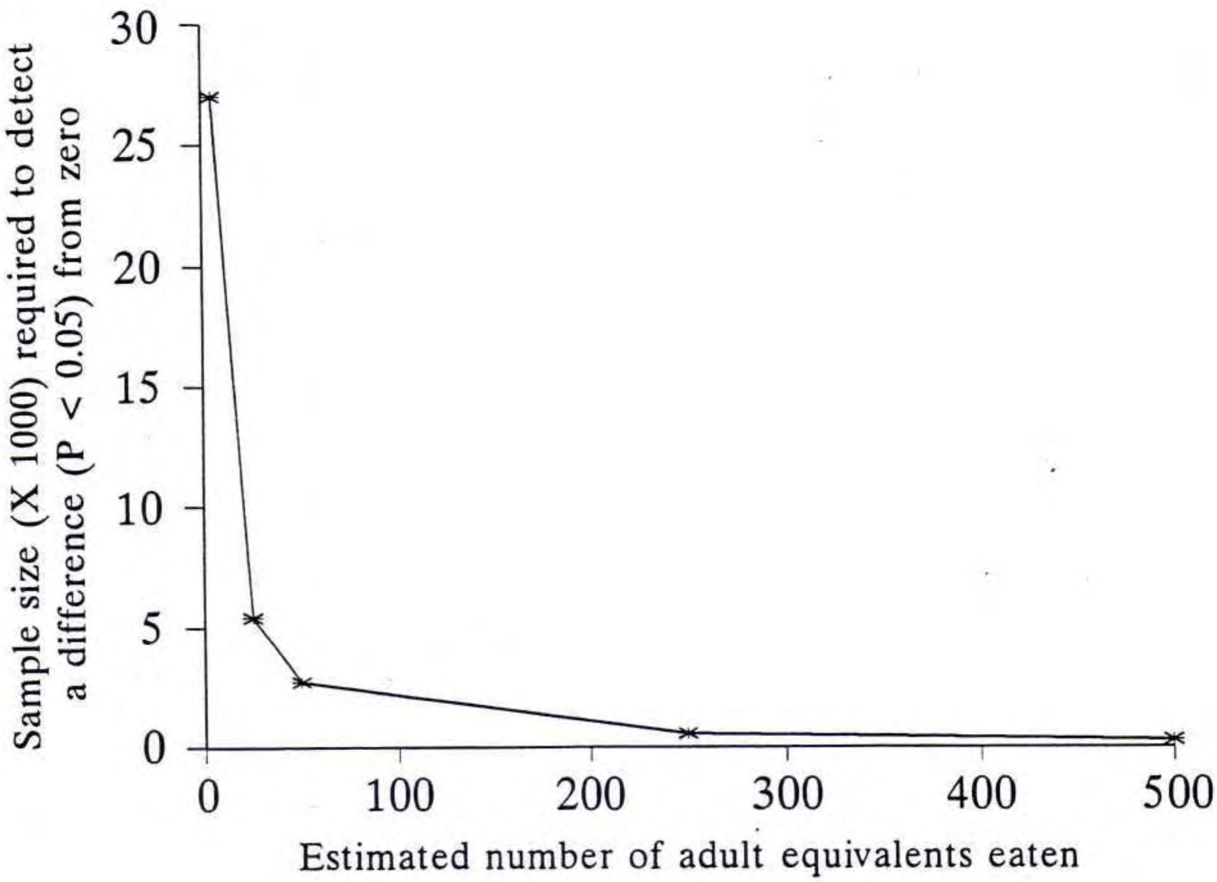

Figure I.3. - The sample size that would be required to detect (at the $P < 0.05$ level) that an estimated number of adult equivalent chinook salmon that were eaten was different from zero. For this exercise we assumed a 10% rate of residualism. For example: this model indicates that, if one estimated that 100 adult equivalent chinook salmon were eaten, one would need to sample approximately 2290 residual steelhead stomachs to be able to claim (with 95% certainty) that this estimate was different from 0 adult equivalents eaten.

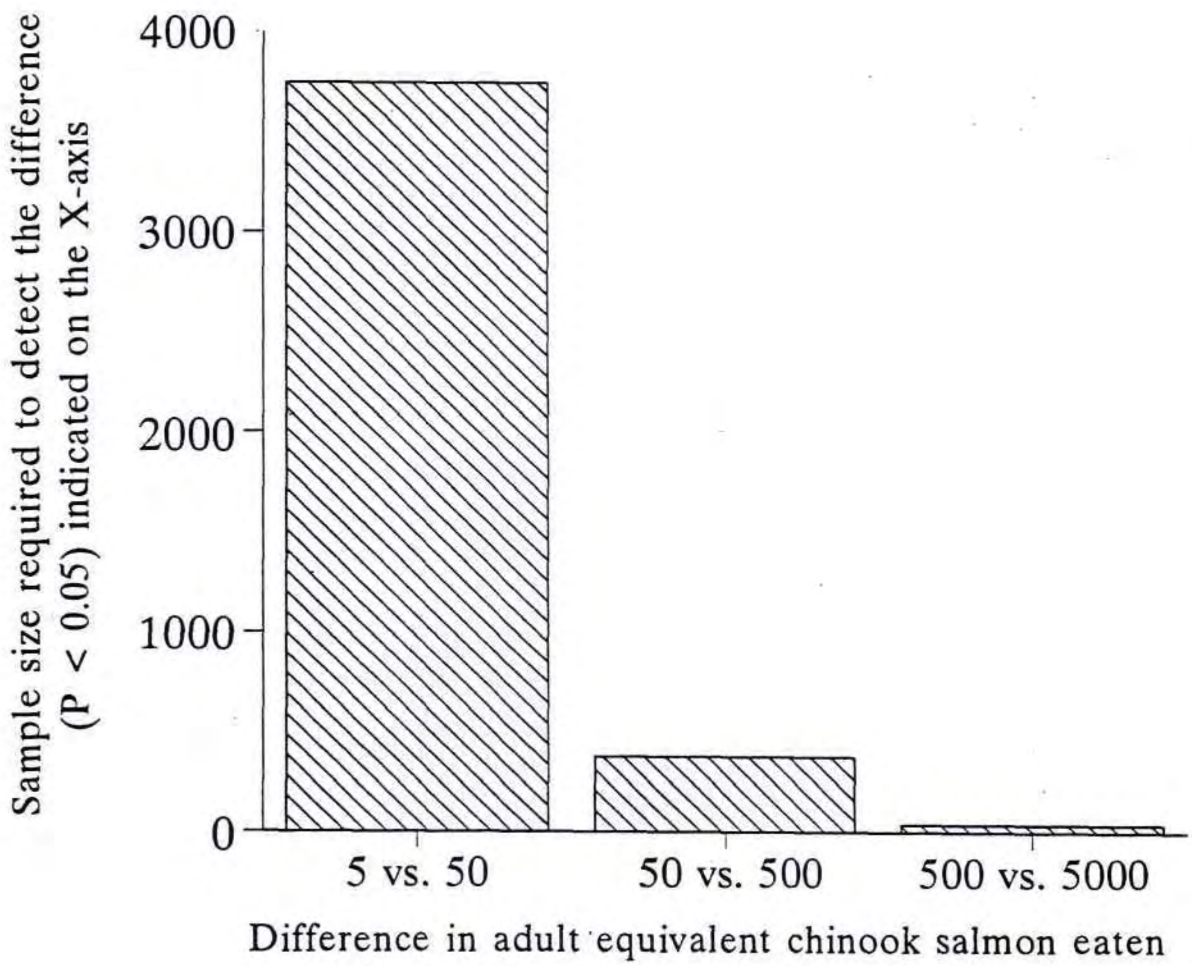

Figure I.4. - The sample size that would be required to detect (at the $P < 0.05$ level) a difference between estimated numbers of adult equivalent chinook salmon that were eaten. For this exercise we assumed a 10% rate of residualism. For example: this model indicates that one would need to sample approximately 3750 residual steelhead stomachs to be able to distinguish between 5 and 50 adult equivalents being eaten (with 95% certainty).

Appendix II. The relative densities of residual steelhead and naturally-produced, juvenile chinook salmon in the Grande Ronde and Imnaha river basins during the 1992-93 sampling period.

Table II.1. Observed densities (fish/100m^2) of residual steelhead in the Grande Ronde and Imnaha river basins, summer 1992 to spring 1993.

Basin, stream	RM	Residual steelhead density summer	fall	winter	spring
GRANDE RONDE					
Grande Ronde R.	40	0	a	a	a
	54	0	a	a	a
	82	0	a	a	a
	155	0	a	a	a
	158	0.455	a	a	a
	171	0	a	a	a
	180	0	a	a	a
	191	0	a	a	a
	201	0	a	a	a
Catherine Cr.	9	0	a	a	a
	18	0	a	a	a
	27	0.103	a	a	a
L. Catherine Cr.	5	0	a	a	a
NF Catherine Cr.	0	0	a	a	a
SF Catherine Cr.	5	0	a	a	a
Chicken Cr.	2	0	a	a	a
Five Points Cr.	0	0	a	a	a
	2	0	a	a	a
Fly Cr.	0	0	a	a	a
	10	0	a	a	a
Lookingglass Cr.	0	0	a	a	a
Meadow Cr.	0	0	a	a	a
	5	0	a	a	a
Mud Cr.	0	b	a	a	a
Sheep Cr.	6	0	a	a	a
Wallowa R.	4	0	a	a	a
	16	0	a	a	a
	41	b	b	a	a
	46	0	a	a	a
Bear Cr.	1	0	a	a	a
Deer Cr.	0	38.182	16.822	6.237	b
	1	5.150	1.659	b	b
	10	0.476	0.351	a	a
Lostine R.	0	0	0	0	0
Minam R.	0	b	a	a	a
Spring Cr.	0	6.116	b	b	a
Trout Cr.	0	0.308	0.210	0	0
Wildcat Cr.	0	0	a	a	a
Wenaha R.	0	0	a	a	a

Table II.1. Continued.

Basin, stream	RM	Residual steelhead density summer	fall	winter	spring
IMNAHA					
Imnaha R.	22	2.146	a	a	a
	46	b	a	a	a
Big Sheep Cr.	0	5.470	b	b	a
	21	b	a	a	a
Camp Cr.	0	2.703	0	0	b
Little Sheep Cr.	0	12.500	5.603	1.286	a
	5	30.753	8.333	2.203	a
	13	1.357	1.739	0.201	a
	20	1.130	0.585	0.531	a
Bear Gu.	0	b	1.720	0	0.775
Lightning Cr.	0.5	b	a	a	a

[a] Area not sampled or no estimate.
[b] Residuals present, but unable to estimate density.

Table II.2. Observed densities (fish/100m^2) of juvenile chinook salmon in the Grande Ronde and Imnaha river basins, summer 1992 to spring 1993.

Basin, stream	RM	Juvenile chinook salmon density summer	fall	winter	spring
GRANDE RONDE					
Grande Ronde R.	40	0	a	a	a
	44	b	a	a	a
	54	0	a	a	a
	82	0	a	a	a
	155	0	a	a	a
	158	0	a	a	a
	171	0	a	a	a
	180	0	a	a	a
	191	b	a	a	a
	201	b	a	a	a
Catherine Cr.	9	0	a	a	a
	18	1.000	a	a	a
	27	0.755	a	a	a
L. Catherine Cr.	5	0	a	a	a
NF Catherine Cr.	0	0.659	a	a	a
SF Catherine Cr.	5	0	a	a	a
Chicken Cr.	2	0	a	a	a
Five Points Cr.	0	0	a	a	a
	2	0	a	a	a
Fly Cr.	0	b	a	a	a
	10	0	a	a	a
Lookingglass Cr.	0	5.250	a	a	a
	5	b	a	a	a
L. Lookingglass Cr.	2	b	a	a	a
Meadow Cr.	0	0	a	a	a
	5	0	a	a	a
Sheep Cr.	6	0	a	a	a
Wallowa R.	4	0	a	a	a
	16	0	a	a	a
	41	b	a	b	a
	46	b	a	a	a
Bear Cr.	1	0	a	a	a
Deer Cr.	0	5.682	1.168	0.215	a
	1	b	0.711	a	a
	10	0	0	a	a
Lostine R.	0	1.000	a	a	a
Minam R.	0	b	a	a	a
	6	b	a	a	a
Spring Cr.	0	0	a	a	a
Trout Cr.	0	b	0	0	1.140
Wildcat Cr.	0	1.798	a	a	a
Wenaha R.	0	1.271	a	a	a
	4	b	a	a	a

Table II.2. Continued.

Basin, stream	RM	Juvenile chinook salmon density summer	fall	winter	spring
IMNAHA					
Imnaha R.	11	0	a	a	a
	18	b	a	a	a
	22	b	a	a	a
	46	b	a	a	a
Big Sheep Cr.	0	0.085	0	b	a
	21	b	a	a	a
Camp Cr.	0	b	1.575	0	0
Little Sheep Cr.	0	0	0	0	a
	5	0	0	0	a
	13	a	0	0	a
	20	0	0	0	a
Bear Gu.	0	a	0	0	0

[a] Area not sampled or no estimate.
[b] Chinook present, but unable to estimate density.

Appendix III. The instantaneous growth rate of residual steelhead.

Figure III.1. Estimated instantaneous growth rate of residual steelhead sampled in the Grande Ronde and Imnaha river basins. Fish were released in the spring of 1992 and then sampled during the summer and fall of 1992. 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 IV. Quality control experiments for the sampling techniques used during 1992-93.

Experiments were conducted to assess the relative amounts of effort needed to produce comparable results from electrofishing and snorkeling. A sample area of stream was chosen and, to prevent immigration or emigration of fish, each end of the area was blocked with a seine (6 mm mesh). Initially, multiple snorkel passes were conducted to enumerate the residuals in the area. The time taken to snorkel, personpower used for each snorkeling pass and environmental conditions encountered while snorkeling were recorded. A modified, multiple pass removal survey was then conducted in the same area with an electrofisher. Electrofishing passes were made until no more residual steelhead were captured, thus giving a measure of the actual abundance. The time taken, number of people used and environmental conditions encountered during this survey were recorded. Both sets of data were then evaluated in an attempt to develop a relationship between electrofishing effort and snorkeling effort. This relationship was used to help standardize the sampling effort used when making abundance estimates.

Table IV.1 The precision and accuracy of snorkel and electrofishing estimates of residual steelhead abundance (conducted under standard protocols as described previously in the methods). Precision was measured as the coefficient of variation. Accuracy was calculated as the percent of the total number captured during electrofishing. Electrofishing passes were conducted until no residuals were captured on consecutive passes. No statistical differences existed between either method for either measure. These surveys were conducted when conditions were sunny and visibility was clear.

	Snorkeling	Electrofishing
Precision (%)	7-9	2-7
Accuracy (%)	101	78

Experiments were also conducted to evaluate whether all sizes of residuals, each sex of residuals, and residuals from both release strategies are equally likely to be captured (therefore not biasing the data). A stream and sampling area were chosen and each end of the area blocked off with a net (6 mm mesh). This area was then electrofished with a single pass. Captured fish were placed in a live pen. This procedure was repeated until no residuals were captured. Fish from each pass were kept in a separate live pen. We recorded the fork length, sex and brand of each of the residuals captured. To see if our sampling was biased (i.e. we captured smaller fish first), we compared the fork length, sex ratio and release strategy ratio, respectively, of residuals captured during each pass. Data on fork length was compared using ANOVA procedures whereas data on sex ratio and release strategy were compared using Chi-square analyses.

Table IV.2 Comparison of percent male and mean fork length between the first three passes of electrofishing. No statistical differences were detected between any pass within either variable. Release strategies were not evaluated because no branded fish were observed and too few coded-wire-tagged fish were observed.

	Electrofishing Pass		
	1	2	3
Percent male	88	81	91
Mean fork length (±SE), mm	164(5.5)	179(5.9)	180(6.1)