US Army Corps
of Engineers
Portland District

OREGON
Fish & Wildlife

Rogue Basin Fisheries Evaluation

Effects of Lost Creek Dam on Summer Steelhead in the Rogue River

Phase II Completion Report

February 1994

EFFECTS OF LOST CREEK DAM ON SUMMER STEELHEAD IN THE ROGUE RIVER. PHASE II COMPLETION REPORT.

Rogue Basin Fisheries Evaluation Project
Research and Development Section

Oregon Department of Fish and Wildlife

2501 SW First Avenue
Portland, OR 97207

February 1994

Primary funding for this project was provided by the United States Army Corps of Engineers under contract DACW57-77-C-0033.

CONTENTS

CONTENTS (continued)

FOREWORD

This report is the culmination of 12 years of research funded by the U.S. Army Corps of Engineers and 5 years of research funded by the Oregon Department of Fish and Wildlife. A study of this duration has necessarily involved the collective effort of many people since its inception in 1975. For this reason, it is being presented as a staff report of personnel on the Rogue Basin Fisheries Evaluation Project. The completion report was drafted by Thomas Satterthwaite who was largely responsible for the analyses and content. Barry McPherson supervised the project through the initial stages of preparation. This report is the fourth of a series of completion reports planned for anadromous salmon and steelhead stocks produced in the Rogue River basin.

James Lichatowich was responsible for the original design and guidance of research on anadromous salmonids affected by the operation of Lost Creek Dam. These duties were subsequently assumed by Steven Cramer who served as program leader until 1985. Their leadership and insights on study designs were largely responsible for the ultimate success of research conducted by personnel in the Rogue Basin Fisheries Evaluation Project.

The mainstem and tributaries of the Rogue River collectively produce the largest population of wild anadromous salmonids in Oregon. The Rogue River supports recreational and commercial fisheries of immense importance to Oregon citizens and is nationally renowned for its diversity and productivity. Authorizing documents for Lost Creek Dam stipulate that fisheries enhancement is to be an important benefit of the dam, mainly through improved temperature and flow. We hope our studies will ensure that these benefits are achieved for present and future generations of Oregon citizens.

Alan McGie
Program Leader
Research and Development Section
Oregon Department of Fish and Wildlife
Corvallis, Oregon

12 October 1993

SUMMARY

In this report, we evaluate the effects of Lost Creek Dam on summer steelhead *Oncorhynchus mykiss* in the Rogue River. Field sampling began in 1975 and ended in 1991. Lost Creek Dam closed during February 1977, but the reservoir did not fill completely until the spring of 1978. A summary of our findings follows.

Adults

1. Seining at Huntley Park produced reasonable estimates of the number of summer steelhead that entered the Rogue River in 1976-91. Estimated freshwater returns of hatchery adults were highly correlated with returns of late-run adults of hatchery origin to Cole M. Rivers Hatchery. Estimated freshwater returns of wild adults were highly correlated with passage estimates of wild late-run adults at Gold Ray Dam.

2. Freshwater returns of wild fish averaged 59,000 (range = 18,600-146,600) half-pounders and 19,100 (range = 3,200-34,000) late-run adults in 1976-91. Freshwater returns of hatchery fish averaged 46,600 (range = 6,500-105,000) half-pounders and 5,500 (range = 2,500-15,200) late-run adults in 1976-91.

3. Freshwater returns of wild late-run adults were positively related to freshwater returns of cohorts in the previous year. Residual variation was negatively related to peak flow of the Rogue River. We estimated that reductions in peak flows attributable to reservoir operation increased freshwater returns by an average of 2,400 wild late-run adults in 1978-86.

4. We could not determine the primary factors that affected the abundance of wild half-pounders, although freshwater returns from the 1975-87 brood years were positively correlated with tributary flow in late spring when juveniles migrated into the Rogue River.

5. Annual return rates of hatchery half-pounders to the Rogue River averaged 12% (range = 3-28%) in 1976-91. Return rates were correlated with ocean temperature. Similarity in annual returns of wild and hatchery fish among late-run adults suggested that ocean factors may be primary determiners of freshwater returns.

6. Hatchery fish composed an average of 43% of the half-pounders and 22% of the late-run adults that entered the Rogue River in 1975-91. Hatchery fish were more common among half-pounders because proportionally more hatchery fish matured as winter steelhead or early-run summer steelhead. The percentage of hatchery fish among half-pounders increased in 1975-91 because of increased releases of juvenile winter steelhead.

7. Life history patterns of summer steelhead in the Rogue River are diverse. We identified 15 life history patterns on scales taken from wild fish.

8. Fish that previously made a half-pounder run accounted for an average of 95% of the wild late-run adults that returned in 1976-91. We did not detect any change in the tendency of summer steelhead to migrate as half-pounders after operation of Lost Creek Dam.

9. We did not detect any changes in the lengths of half-pounders or late-run adults on their first spawning migration after operation of Lost Creek Dam. Lengths at freshwater return were most affected by juvenile age at ocean entry.

10. We did not detect any change in the time of river entry by half-pounders and late-run adults after operation of Lost Creek Dam. Entry time was correlated with ocean parameters, but not freshwater parameters. Among late-run adults, hatchery fish entered fresh water earlier than wild fish. Time of river entry also differed among adults of different life histories.

11. Returns of wild summer steelhead to the upper river decreased in 1942-68 for an unknown reason(s). An average of 6,700 (range = 1,700-13,000) wild summer steelhead passed Gold Ray Dam annually in 1969-91. Early-run fish that passed Gold Ray Dam by 15 September accounted for an average of 35% (range = 7-56%) of the wild summer steelhead that returned to the upper river annually in 1969-91.

12. We did not detect any significant change in the mean number of wild summer steelhead that returned to the upper river after operation of Lost Creek Dam. Returns of wild fish to the upper river, relative to returns of wild summer steelhead to the North Umpqua River, also did not change significantly after operation of Lost Creek Dam.

13. The increase in returns of hatchery fish to the upper river was most evident among early-run fish that passed Gold Ray Dam from the middle of May through the middle of September. Passage estimates of early-run hatchery fish averaged 600 fish in 1970-80 and 3,800 fish in 1981-91. Increased releases of smolts and changes in spawning practices at Cole M. Rivers Hatchery were responsible for the increase in returns of early-run hatchery fish. Passage estimates of late-run hatchery fish averaged 1,300 fish in 1970-80 and 1,500 fish in 1981-91.

14. Hatchery fish accounted for an average of 41% of the early-run fish and 22% of the late-run fish that passed Gold Ray Dam in 1970-91. The percentage of hatchery fish increased through time among early-run fish, but not among late-run fish.

15. Early-run fish averaged 32% of the preimpoundment returns and 36% of the postimpoundment broods among wild fish that passed Gold Ray Dam. Passage timing was correlated with river flow in summer. We estimated that increased flow attributable to reservoir operation in 1978-86 increased the percentage of wild fish that passed Gold Ray Dam by 15 September from an average of 29% to an average of 42%.

16. The migration timing of wild late-run fish at Gold Ray Dam was related to water temperature in autumn rather than summer. We estimated that increased water temperature attributable to reservoir operation in 1978-86 increased the percentage of wild fish that passed Gold Ray Dam by 30 November from an average of 32% to an average of 36%.

17. We did not detect any change in the race composition of wild steelhead that returned to the upper river after operation of Lost Creek Dam.

18. Operation of Lost Creek Dam caused summer steelhead of hatchery origin to mature earlier because water temperature of the Rogue River increased in winter. The effects on the maturation time of wild fish remain unknown.

19. Returns of hatchery summer steelhead to Cole M. Rivers Hatchery averaged 4,200 (range = 900-10,500) fish in 1976/77-1991/92. The percentage of early-run fish among the returns increased through time because of changes in broodstock selection practices.

20. Return rates of hatchery summer steelhead on the first spawning run averaged 1.6% (range = 0.7-3.9%) for the 1973-88 brood years. Return rates of first spawners were not correlated with ocean parameters.

Recreational Fisheries

1. Estimates from salmon-steelhead cards indicated that the harvest of large ($\geq$ 51 cm) summer steelhead decreased after operation of Lost Creek Dam. Harvest estimates averaged 7,170 fish in preimpoundment years and 4,039 fish in postimpoundment years. Factors responsible for the decrease remain unknown.

2. Estimates of harvest rates for late-run adult summer steelhead of hatchery origin averaged 47% and ranged from 22% and 78% annually. Harvest rates were positively related to numbers of returning adults. Residual variation was negatively related to flow when adults contributed to fisheries upstream of the Rogue River canyon. We estimated decreased flow attributable to reservoir operation in 1978-86 increased harvest rates by an average of 0.4% annually.

3. Assuming that annual harvest rates were similar among late-run adults of hatchery origin and other types of summer steelhead, anglers harvested an average of 75% of the wild summer steelhead prior to first spawning.

4. We did not detect any change in angler catch rates of summer steelhead in the Gold Beach fishery after operation of Lost Creek Dam. We did not compare catch rates in areas farther upstream because we sampled in only one preimpoundment year. Catch rates in the Gold Beach fishery were related to fish abundance, but were not related to river physical factors.

5. In the Rogue River canyon, angler catch rates were negatively related to angler effort and river flow during the fishery, and were positively related with the abundance of half-pounders. We estimated that increased flow attributable to reservoir operation in 1978-86 decreased angler catch rates in the canyon by an average of 18% annually, but the decrease was compensated by an increase in the abundance of hatchery fish.

6. The distribution of half-pounders landed in the Rogue River canyon was not correlated with river physical parameters before or during the fishery.

7. The harvest distribution of large summer steelhead was correlated with river flow in late summer and early autumn. Anglers that fished upstream of Gold Ray Dam accounted for a greater percentage of the harvest in low flow years as compared with high flow years.

8. We did not detect any change in angler effort for summer steelhead in the Gold Beach fishery after operation of Lost Creek Dam. We did not compare effort in fisheries farther upstream because we sampled in only one preimpoundment year. Weekly indexes of effort were positively related to angler catch rates, but were not correlated with river physical factors.

9. The canyon fishery accounted for 7% of the tags returned in 1968-71 and 25% of the tags returned in 1976-77. We believe the increase in later years reflected a major increase in angler effort in the canyon fishery.

10. Angler effort for summer steelhead in the November-January fisheries near Galice and Grants Pass peaked when turbidity ranged from 2 JTU to 10 JTU. Because turbidity usually exceeds 12 JTU during these fisheries, reductions in turbidity attributable to reservoir operation probably increased angler effort for late-run summer steelhead.

Juveniles

1. Subyearlings seined at sites in the middle river and in the canyon during late summer were larger after operation of Lost Creek Dam, but analyses of adult scales did not detect a change in mean lengths at annulus one. Indexes of subyearling growth were not correlated with river physical factors or abundance indexes of juvenile salmonids.

2. Yearlings seined in the lower river and in the canyon during late summer were larger after operation of Lost Creek Dam. Mean lengths at these sites were negatively related to water temperature in summer. Scale analyses also indicated that yearlings grew faster in fresh water after operation of Lost Creek Dam. However, yearling growth was not related to river physical parameters or to abundance indexes of juvenile salmonids.

3. We did not detect any change in the spring growth of smolts prior to ocean entry ("plus-growth") after operation of Lost Creek Dam. Plus-growth was positively related to water temperature of the Rogue River in spring. Reservoir operation had minimal effect on water temperature in spring.

4. We did not detect any change in the weights of juvenile steelhead after operation of Lost Creek Dam. Mean weights of 8 cm subyearlings were not related to river physical parameters or indexes of juvenile abundance. Mean weights of 15 cm yearlings were positively related to summer flow.

5. Wild late-run adults were composed of an average of 42% age-1 smolts, 55% age-2 smolts, and 3% age-3 smolts. There was a greater proportion of age-3 and age-4 smolts among half-pounders, probably because older smolts matured as winter steelhead.

6. We did not detect any change in the age at ocean entry after operation of Lost Creek Dam. However, small sample sizes and variable age composition among preimpoundment broods limited the power of the analysis. Faster growth by yearlings could have affected age at smolting.

7. We did not detect any change in catch rates of subyearling and yearling steelhead seined in the Rogue River after operation of Lost Creek Dam.

8. We concluded that operation of Lost Creek Dam probably had minimal effect on the production of juvenile summer steelhead because adults spawned in tributaries of the Rogue River. We were unable to detect any relationships between indexes of juvenile abundance and river physical parameters.

RECOMMENDATIONS

Reservoir Management and Operation of Lost Creek Dam

1. Allocation of reservoir storage to enhance habitat of juvenile steelhead in summer should be scaled to predictions of prespawning mortality between spring and fall chinook salmon. In years of low water yield, reservoir storage should be mostly used to minimize the risk of extensive prespawning mortality. In years of high water yield, reservoir storage should be allocated to maintain a relatively constant flow at Grants Pass in summer to enhance rearing habitat for juvenile steelhead.

   This recommendation is designed to maximize the benefits that result from flow augmentation. Increased flow in summer is associated with increases in the length and body condition of juvenile steelhead (*see* **Freshwater Growth** page 90 and **Body Condition**, page 97). However, in years of low water yield, these benefits are of secondary importance compared with reductions in prespawning mortality between spring chinook salmon (Cramer et al. 1985) and fall chinook salmon (ODFW 1992).

2. Outflow from Lost Creek Dam should be managed to minimize the intensity of peak flows in downstream areas from November through March. Reductions in peak flows were associated with increased survival rates of summer steelhead (*see* **Abundance**, page 35). Present strategies for reservoir operation decrease peak flows during operational seasons of flood control and conservation storage. We believe the intensity of peak flows can be decreased further in years of high water yield.

   Authorizing documents for the Rogue River basin project designate flood control as the first priority for reservoir management. Storage in excess of the rule curve decreases reservoir capability for flood control. However, maintenance of the reservoir level below the rule curve can provide for additional reductions in peak flows.

   The United States Army Corps of Engineers should further refine criteria for reservoir level during operational seasons for flood control and conservation storage. We believe reservoir level can be scaled to estimates of water yield in the area upstream of the reservoir. Reservoir level should be decreased when water content of the snowpack is great. Implementation of this recommendation would increase reservoir capacity for flood control and decrease intensity of peak flows in downstream areas.

3. Release of water stored in the reservoir during freshets should be managed so flow in downstream areas does not exceed the peak flow that previously occurred during the flood control season. We recognize this recommendation may conflict with flood control operations. For example,

managers may seek to return the reservoir level to the authorized rule curve for short periods between large storms. However, when the potential for further flooding is minimal, reservoir level should be returned to minimum pool for flood control (or lower) so as not to produce a new peak flow in downstream areas.

4. Outflow from Lost Creek Dam should be managed so there is minimal flow augmentation after 21 September. This recommendation is designed to minimize the effect of augmented flow on the fishery for summer steelhead in the Rogue River canyon (*see* **Catch Rate** page 71). However, limitations to flow augmentation in early autumn will increase flow in summer and will affect the fishery for early-run summer steelhead in the upper river (*see* **Harvest**, page 67).

   The fishery for summer steelhead in the Rogue River canyon usually begins around Labor Day weekend. We did not recommend minimal flow augmentation between Labor Day and 21 September because flow augmentation is needed to minimize prespawning mortality among fall chinook salmon (ODFW 1992).

5. Strategies for release temperature at Lost Creek Dam should be directed to management of anadromous salmonids other than summer steelhead. Water temperature directly affects the production and harvest of spring chinook salmon (Satterthwaite 1987). In contrast, we were unable to detect any effects of water temperature on the production and growth of summer steelhead in the area upstream of Gold Ray Dam (*see* **Abundance**, page 35 and **Freshwater Growth**, page 90).

Management and Evaluation of Fishery Resources

The following recommendations are directed primarily to the Oregon Department of Fish and Wildlife, the lead agency for management of fishery resources in the Rogue River basin. Cooperation of other state and federal agencies may be needed to implement these recommendations.

1. Harvest of wild half-pounders should be terminated because there were indications that the harvest rate of wild fish prior to first spawning exceeded the allowable level for maximum sustained yield of summer steelhead (*see* **Harvest Rate**, page 68). The large proportion of hatchery fish among half-pounders would still allow for a consumptive fishery in areas where anglers target half-pounders (*see* **Run Composition**, page 50).

2. The relationship between water temperature and mortality rate should be determined for summer steelhead caught and released with different types of angling gear. Catch and release regulations for wild fish may not increase spawning escapement if a large proportion of the released fish die (*see* **Harvest Rate**, page 68). Harvest of wild adult summer steelhead could be allowed if released half-pounders survive at high rates.

3. Harvest should be regulated for a minimum freshwater return of 10,000 wild, late-run adult summer steelhead. Smaller escapements were associated with low juvenile production in the succeeding year (*see* **Abundance**, page 103). Harvest of wild fish should be terminated in years after successive runs of less than 40,000 wild half-pounders.

4. Index areas should be established to monitor long-term trends in the annual production of summer steelhead fry in the Rogue River basin. Traps can be used to estimate fry production in small tributaries used by spawning adults. Sampling should include streams with and without water diversions (*see* **Abundance**, page 103).

5. Primary factors that affect fry production should be determined for small spawning streams used by summer steelhead. Fry production in these streams vary dramatically among years for unknown reasons. A research project could determine the effects of spawning escapement, spawning distribution, quality and quantity of spawning habitat, flow, and water temperature on fry production (*see* **Abundance**, page 103).

6. Accuracy of redd counts as indexes of spawning escapement for wild summer steelhead should be evaluated (*see* **Abundance**, page 35).

7. Management plans for public and private lands in the Rogue River basin should identify and minimize activities that cumulatively affect the intensity of peak flows in streams (*see* **Abundance**, page 35).

8. Populations of summer steelhead in all major drainages of the Rogue River basin should be examined for unique genetic resources. Knowledge of the distribution of stocks within the basin is needed to develop effective strategies to maintain and enhance diversity among populations of wild fish (ODFW 1986). We believe that maintenance of diversity among wild populations is needed to sustain production of summer steelhead in the basin.

9. Wild adults should be periodically included among the hatchery broodstock to maintain genetic diversity within summer steelhead produced at Cole M. Rivers Hatchery. Wild adults can be trapped at Gold Ray Dam. If surveys of genetic resources indicate that there are multiple populations upstream of Gold Ray Dam, the trap site should be moved to Elk Creek or Big Butte Creek. A geneticist should develop guidelines for including wild broodstock in the hatchery program.

10. Managers should incorporate more late-run adult summer steelhead in the broodstock at Cole M. Rivers Hatchery. Broodstocks that consist of 33% early-run adults and 67% late-run adults will produce a migration timing among hatchery fish that is comparable to that of wild fish that return to the upper river (*see* **Migration Timing**, page 55). This revision in spawning practices will increase the angler catch of hatchery fish because late-run adults contribute to the fisheries at a greater rate than early-run adults.

11. Hatchery programs designed to supplement populations of summer steelhead in the Rogue River basin should use wild broodstock. Juveniles of hatchery origin should be released near the site of broodstock collection to minimize the potential genetic exchange between populations (*see* **Abundance**, page 35). Release of juveniles and adults from the current stock of summer steelhead at Cole M. Rivers Hatchery should be restricted to areas upstream of Gold Ray Dam.

INTRODUCTION

This report presents the findings of 17 years (1975-91) of work with summer steelhead *Oncorhynchus mykiss* in the Rogue River basin of southwestern Oregon. The Oregon Department of Fish and Wildlife (ODFW) conducted this study, mostly funded by the United States Army Corps of Engineers (USACE) in 1975-86, to (1) determine the effects of Lost Creek Dam on anadromous salmonids and (2) develop operating strategies that optimize the production and harvest of fishery resources in downstream areas.

The Congress of the United States of America authorized construction of Lost Creek Dam (Figure 1) at river kilometer (RK) 254 to create a reservoir to be used for multiple purposes, including the enhancement of fishery resources in downstream areas (United States Congress 1962). An updated economic review in 1971 indicated planners projected fishery enhancement to be the third largest benefit accrued annually from the operation of the dam (USACE 1972). Spawning and rearing habitat for salmon and steelhead blocked or inundated by the dam was to be mitigated by releases of fish reared at Cole M. Rivers Hatchery. Benefits to anadromous salmonids in downstream areas were expected to accrue by operating the dam to (1) decrease peak flow in winter, (2) increase flow in summer, and (3) decrease water temperature in summer.

To regulate the outflow temperature from Lost Creek Dam, the USACE designed an intake structure capable of withdrawing water from five different levels of the reservoir (Figure 2). Selective opening of intake ports allows for mixing of water from various temperature strata in the reservoir. Choice of outflow temperature is greatest in early summer when the reservoir is full and thermally stratified. Control of release temperature diminishes in late summer as reservoir level decreases and the highest intake ports become dewatered. Control of release temperature becomes minimal in autumn after the reservoir destratifies (USACE 1983).

Guidelines for the release of stored water were intended to be flexible, reflecting annual variations in water yield and user demand. When the reservoir fills, 180,000 acre-feet of storage is available for flow augmentation (USACE 1972). Of this total, 125,000 acre-feet were authorized for fishery enhancement (United States Congress 1962). The remaining 55,000 acre-feet of storage was dedicated to other uses: irrigation supply, municipal and industrial supply, and environmental enhancement. Dedicated storage that is not purchased is also available for downstream enhancement of fishery resources (USACE 1972).

The authorizing document identified flood control as the primary benefit associated with the construction of Lost Creek Dam. Other benefits would accrue by allocating conservation storage to irrigation, future water supply, and fishery enhancement. There was to be "No storage specifically for wildlife enhancement, power generation, water quality control, or recreation" (United States Congress 1962).

The authorizing document also outlined minimum outflow and maximum water temperature to be released from Lost Creek Dam, but clearly stated these guidelines should be modified as additional information became available: "It should also be noted that project operation plans must be sufficiently flexible to permit desirable modifications in scheduled fishery releases,

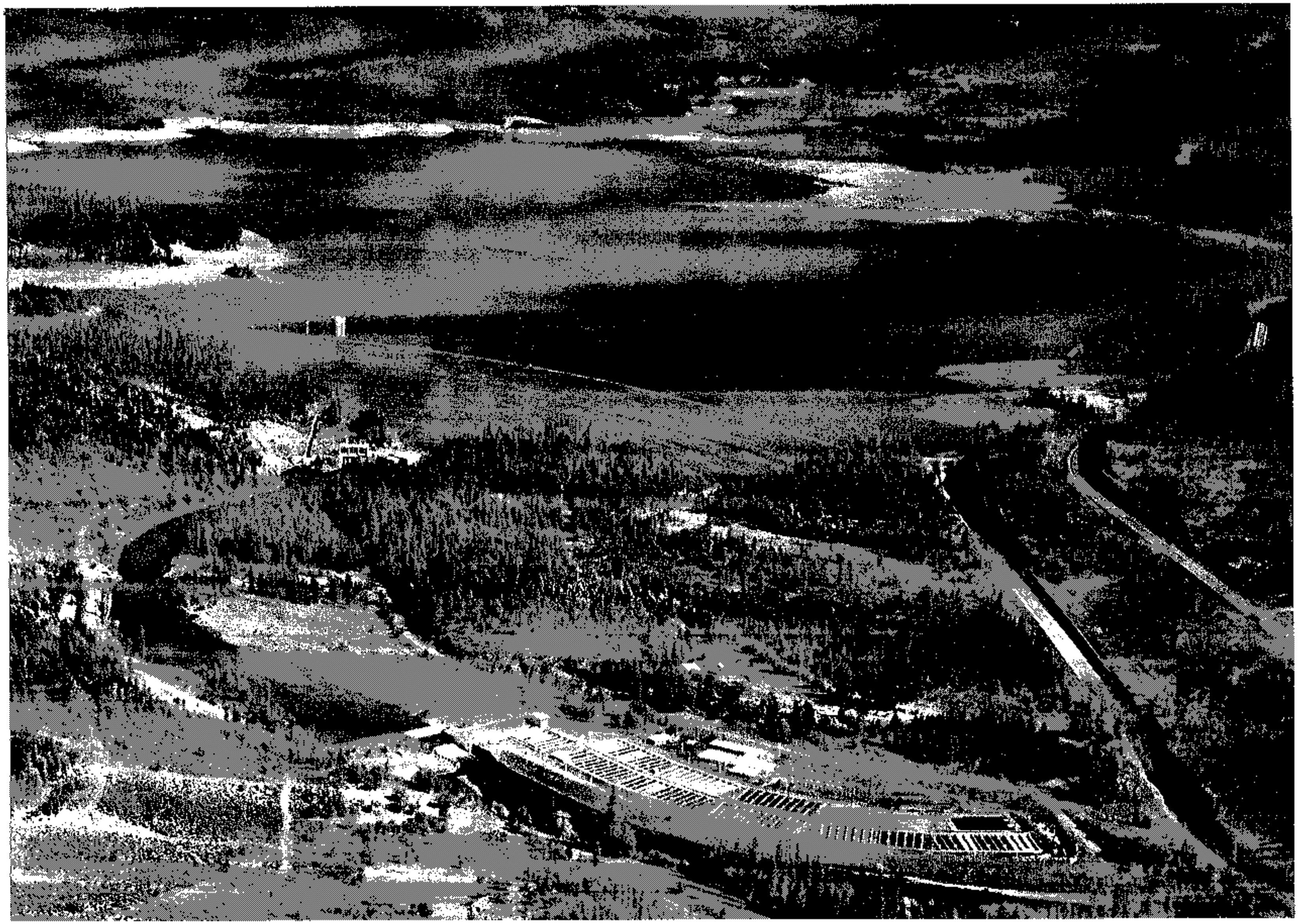

Figure 1. Lost Creek Dam and Cole M. Rivers Hatchery.

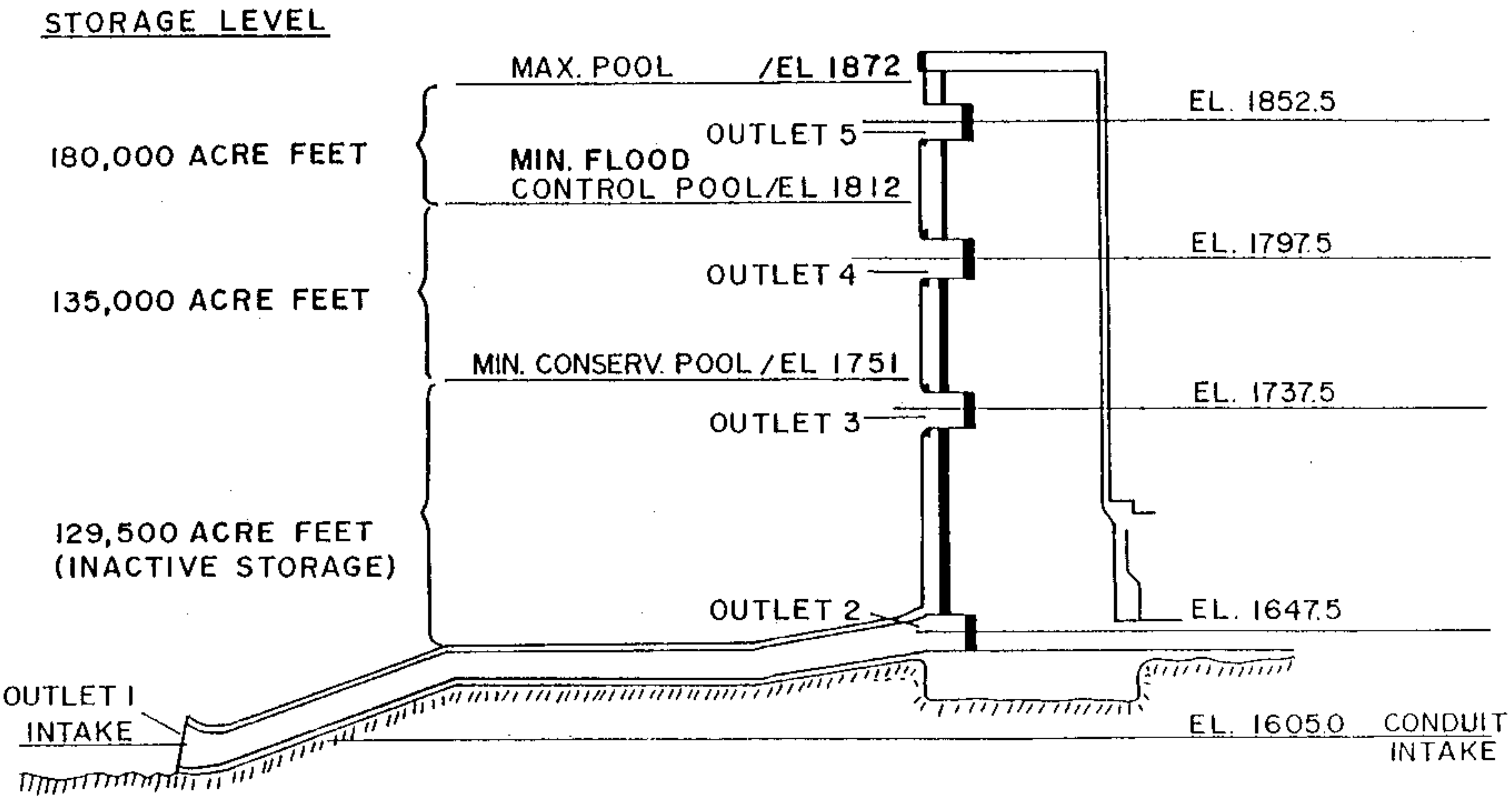

Figure 2. Schematic of the multiport intake structure for water withdrawal from five levels within Lost Creek Lake.

within the limits of storage provided therefore, if experience and further study indicates such action to be desirable for overall project benefits" (United States Congress 1962). Including provisions for modifications of release strategies for fisheries benefits was farsighted as predictions of postproject responses are rarely accurate because of the complexity of aquatic ecosystems (Rosenberg et al. 1986).

Flexibility in scheduling temperature and flow releases from Lost Creek Dam provides an opportunity to implement an operating strategy that optimizes the production and harvest of anadromous salmonids in the river downstream of the dam. To identify the most appropriate operating strategy, we examined the effect of water temperature, flow, and turbidity on the biology and harvest of wild summer steelhead in the Rogue River basin. Preliminary findings from our work were reported in numerous annual progress reports and were summarized by Cramer et al. (1985) and Cramer (1986).

Summer steelhead produced in the Rogue River basin are an important fishery resource. We found that returns to the Rogue River constitute the largest run of summer steelhead on the coast of Oregon and contribute well to recreational fisheries in the river. Presently, ODFW manages summer steelhead in the Rogue River basin as two distinct stocks located upstream and downstream of Gold Ray Dam.

In this report, we estimate the effects of Lost Creek Dam on summer steelhead and present recommendations to enhance the production and harvest of summer steelhead. Use of water releases from Lost Creek Dam to increase stock productivity would be a low-cost method of fishery enhancement. This report represents one of a series of completion reports for fisheries work in the Rogue River basin funded by the USACE.

STUDY AREA

The Rogue River basin encompasses 13,150 square kilometers of southwestern Oregon and a small portion of northwestern California (Figure 3). Approximately 13% of the basin is upstream of Lost Creek Dam. The Rogue River originates in the Cascade Mountains and flows west, breaching the Klamath Mountains prior to reaching the Pacific Ocean. Two major tributaries, the Illinois and Applegate rivers, originate in the Siskiyou Mountains and flow north, where they enter the Rogue River at RK 44 and RK 154, respectively.

The Rogue River estuary is relatively small, covering an area of about 630 acres at mean high tide. Ratti (1979) reported about 80% of the estuary could be classified as a riverine subsystem and 20% could be classified as a marine subsystem. Tideflats, marshes, and eelgrass beds are noticeably absent in the estuary.

Two USACE dams affect the timing of water yield in the Rogue River basin. Lost Creek Dam at RK 254 on the Rogue River began operating in February 1977. Applegate Dam, at RK 75 on the Applegate River, began operating in November 1980 and affects flow in the Rogue River downstream of Grants Pass. Operation of Applegate Dam has a lesser effect on flow of the Rogue River because the normally used storage capacity of Applegate Lake is one-third that of Lost Creek Lake.

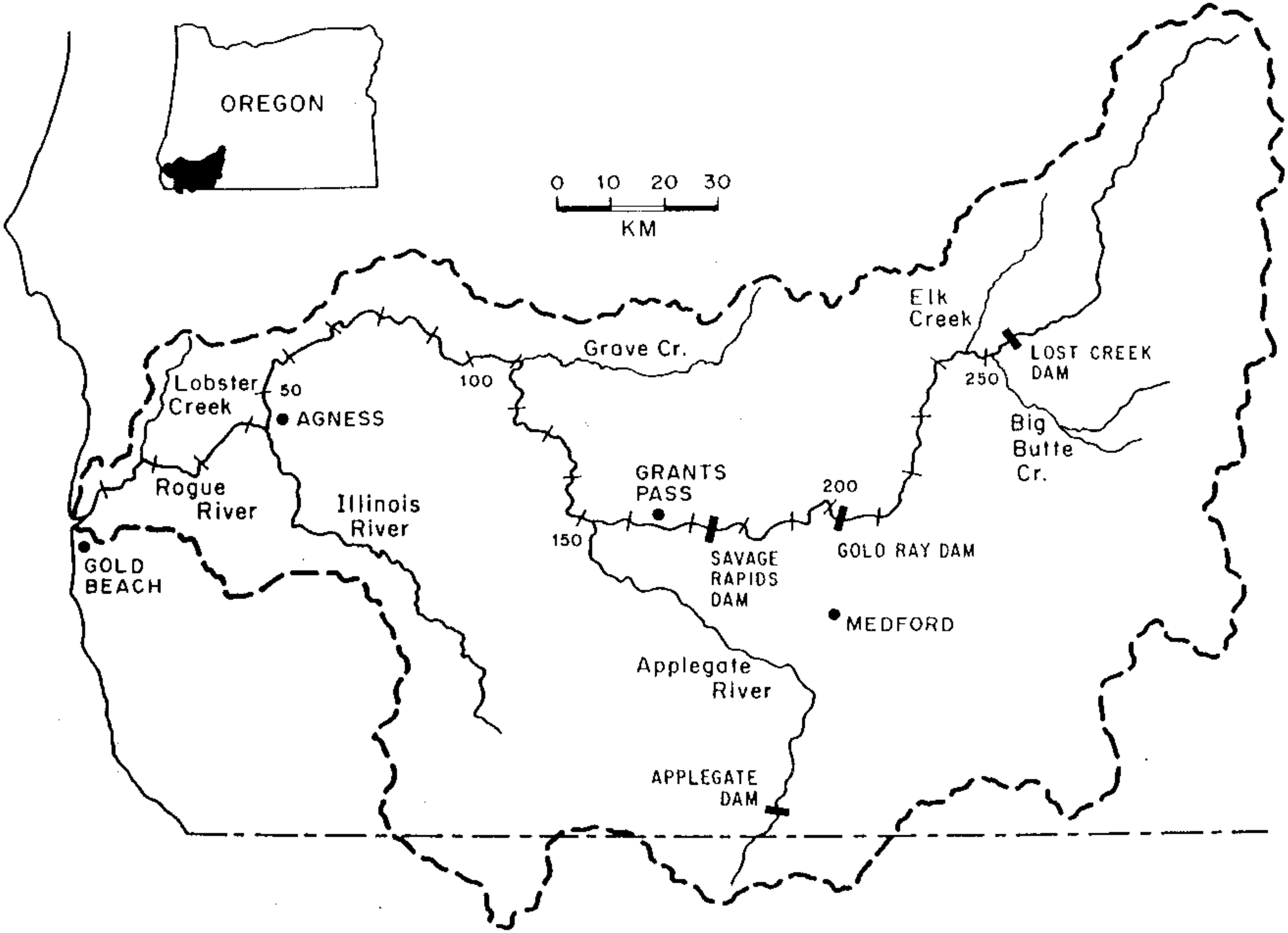

Figure 3. Map of the Rogue River basin. Numbers indicate kilometers from the river mouth.

The Rogue River basin yields an average of 7.4 million acre-feet of water annually (Friday and Miller 1984). The Illinois and Applegate rivers average approximately 40% and 7% of the water yielded annually in the basin, respectively. The Rogue River upstream of Lost Creek Dam accounted for an average of 18% of the water yielded annually in the basin.

In the lower portion of the basin, river flow varies markedly among seasons. Discharge upstream of the mouth of the Illinois River averages 1,400 cfs in September and 16,200 cfs in January. The variation in flow is less pronounced in the upper portion of the basin. Flow into Lost Creek Lake averages 1,000 cfs in September and 2,000 cfs in January (Moffatt et al. 1990). Reservoir inflow usually peaks when the snowpack in the Cascade Mountains melts at a rapid rate between April and June.

Weather patterns in the northeast Pacific greatly affect climate within the Rogue River basin. Wet, mild winters and dry, warm summers characterize the climate. Air temperature near Medford usually peaks between 32°C and 35°C in July and August. In December and January, air temperature usually peaks between 8°C and 10°C. Snow accumulates at the higher elevations in winter and is the principal source of water yield in spring and early summer. Annual precipitation averages about 50 cm in the inland valley surrounding Medford. Coastal and headwater regions receive an average annual precipitation of about 200 cm and 300 cm, respectively (ODWR 1985). About 50% of the annual precipitation falls from November through January. Less than 2% falls in July and August.

A large number of anadromous fish inhabit the Rogue River basin. Chinook salmon *Oncorhynchus tshawytscha* and steelhead are the most abundant salmonids. Coho salmon *O. kisutch* are present in tributary streams. Chum salmon *O. keta* and pink salmon *O. gorbuscha* are occasionally found in tributaries of the lower river. Resident salmonids include rainbow trout *O. mykiss*, cutthroat trout *O. clarki*, brown trout *Salmo trutta*, and brook trout *Salvelinus fontinalis*. Few resident salmonids inhabit areas accessible to anadromous salmonids. Other commonly seen game fishes include largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, green sturgeon *Acipenser medirostris*, white sturgeon *A. transmontanus*, American shad *Alosa sapidissima*, and brown bullhead *Ictalurus nebulosus*.

Nongame fishes abundant in the basin include redside shiner *Richardsonius balteatus*, Klamath smallscale sucker *Catostomus rimiculus*, common carp *Cyprinus carpio*, prickly sculpin *Cottus asper*, riffle sculpin *C. gulosus*, and Pacific lamprey *Lampetra tridentata*. The distribution of Umpqua squawfish *Ptychocheilus umpquae* is rapidly expanding after an illegal introduction in 1979.

For discussion purposes, we divided the Rogue River into four general areas. The upper river refers to the area between Lost Creek Dam and Gold Ray Dam (RK 202). The middle river refers to the area between Gold Ray Dam and Grave Creek (RK 110). The canyon refers to the area between Grave Creek and Agness (RK 44). The lower river refers to the area between Agness and the estuary (RK 6). Stream gradient averages 2.3 m/km in the upper river, 1.6 m/km in the middle river, 2.4 m/km in the canyon, and 0.7 m/km in the lower river.

APPROACH

We chose not to use the instream flow incremental methodology (Bovee 1982) for the development of flow recommendations. Although this approach has proved useful in some instances, the assumed direct relationship between weighted usable area and fish production is not always appropriate (Mathur et al. 1985; Moyle and Baltz 1985; Irvine et al. 1987). Our work centered primarily upon assessing the biological implications of modifications in flow, water temperature, and turbidity. During planning of the study, changes in these physical factors were expected to be significant in the area of the river inhabited by summer steelhead.

The study comprised four objectives:

1. Determine the changes in temperature, flow, and turbidity that result downstream from Lost Creek Dam.

2. Determine the effects of Lost Creek Dam and develop operational criteria as related to the rearing and migration of juvenile salmonids.

3. Determine the effects of Lost Creek Dam and develop operational criteria as related to the abundance, migration, and life history of adult salmonids.

4. Determine the effects of Lost Creek Dam and develop operational criteria as related to the harvest of salmonids.

We devised three types of comparisons to meet project objectives. First, we used the North Umpqua River as a statistical control for comparison with the abundance of adults that returned to the upper river. Second, we compared biological parameters of summer steelhead that inhabited the Rogue River before and after operation of Lost Creek Dam. Third, we estimated relationships between biological and physical factors to simulate biological responses to changes in physical factors influenced by the operation of Lost Creek Dam. Each method had associated strengths and weaknesses.

We chose to use the North Umpqua River as a control stream because the annual return of summer steelhead has been estimated since 1946 (Anderson et al. 1986). In addition, the stream is close to the Rogue River and exhibits some similar morphological characteristics. However, none of the winter steelhead in the North Umpqua River make a half-pounder migration. Tributaries of the Rogue River were not used as statistical controls because (1) we could not differentiate juvenile summer from juvenile winter steelhead, (2) adult returns could not be estimated for a reasonable cost, and (3) fish originating from tributaries inhabited the Rogue River for a portion of their life.

Temporal comparisons were of greater utility. Sampling conducted prior to the operation of Lost Creek Dam provided information on the interannual variability of life history parameters. Sensitivity analyses after the initial years of the study led us to terminate work with algal and invertebrate communities. High variability among the data meant there was a low probability of associating any changes in production or community structure with the operation of the dam. Life history parameters of summer steelhead exhibited less variability.

However, temporal comparisons had some limitations. Given the expected variability, many years of data are required to make effective comparisons. For some life history parameters, we had only one year of data for completed broods of half-pounders that reared as juveniles in the preimpoundment period. Although the dam was operational in 1976, low water yield produced negligible storage for flow augmentation in 1977. Reservoir releases had little effect on physical factors of the Rogue River in downstream areas. Consequently, we treated data from 1978 as the first postimpoundment year.

Comparisons of conditions in preimpoundment and postimpoundment years were confounded by changes in factors other than the treatment. For example, water yield from the basin differed significantly before and after operation of Lost Creek Dam. Consequently, we attempted to identify the factor(s) responsible for concomitant changes in parameters.

Identification of factors associated with changes in biological parameters was approached by correlation and regression analyses. We reviewed the literature for background information on causative relationships among biological and physical factors. Factors that appeared to be most important were included as independent variables in regression analyses. We used regression analysis to estimate relationships between biological and physical factors. Limitations and potential problems with this approach are discussed in detail (*see* **Analytical Procedures**, page 27).

Quantitative estimates are particularly useful if reliable predictions of impacts can be generated (Rosenberg et al. 1986). However, there are problems associated with this method. In particular, small sample sizes, irrelevant independent variables, estimation beyond the range of observed data, measurement errors, and intercorrelation among the stages of the simulation model may lead to erroneous conclusions from simulations. Potential biases, and the means we adopted to minimize biases, are discussed in greater detail (*see* **Analytical Procedures**, page 27).

METHODS

We converted Gregorian calendar dates to day-of-year and week-of-year (**APPENDIX A**) for data analyses. We present some findings as calendar dates to clarify results.

Physical Factors

The United States Geological Survey (USGS) operated automated gages at numerous sites in the Rogue River basin during the project. USACE personnel used data from USGS gages in the Rogue River basin to estimate effects of operation of Lost Creek and Applegate dams on water quality parameters in downstream areas. Hamlin and Nestler (1987) described the development of a QUAL II model specific to the Rogue River basin.

The QUAL II model was used to simulate flow, water temperature, and turbidity for regulated and unregulated conditions. Regulated conditions simulated the Rogue River with Lost Creek and Applegate dams operating. Unregulated conditions simulated the Rogue River as though the dams had not been built. Simulations encompassed the time periods of January 1978 through September 1986 for flow and January 1978 through December 1986 for water temperature and turbidity. Model simulations produced estimates of daily means for physical factors at six gages operated by the USGS (Table 1). Operation of Lost Creek Dam affected water quality and quantity at all USGS gages in downstream areas. After November 1980, operation of Applegate Dam affected physical parameters of the Rogue River at gages downstream of the Applegate River.

We used results from USACE modeling to estimate the effects of reservoir operation on water quality and quantity in downstream areas used by anadromous salmonids. We received data for flow simulations from Rock Peters, USACE, Portland District, on 24 April 1989. We received data for water temperature and turbidity simulations from Carla Haake, USACE, Portland District, on 25 May 1989.

Adults

Life History

Summer steelhead 41 cm (16 in) in length or smaller were classified as half-pounders (Everest 1973). Hatchery fish were differentiated from wild fish based on the presence of a deformed dorsal fin or fin clips. A deformed dorsal fin characterized almost all summer steelhead of hatchery origin in the Rogue River basin (personal communication dated 3 March 1989 from Michael Evenson, ODFW, Cole M. Rivers Hatchery, Trail, Oregon).

We analyzed scales to determine life history characteristics. We removed scale samples from a maximum of 35 fish within each 5 cm size interval. About 20 scales composed each sample. Scales were taken from the first four rows immediately above the lateral line and immediately posterior to the dorsal fin on both sides of the fish. Four of the larger, non-regenerated scales of regular shape were mounted on gummed cards and impressed on acetate strips at 100^{0}C under 5,000 psi for 3 minutes. Scale measurements and circuli counts were averaged for two scales from each fish.

Table 1. Stations with water quality parameters simulated by the U.S. Army Corps of Engineers.

Station	River kilometer	Parameter simulated
Near McLeod	249	Flow, water temperature, and turbidity
Dodge Bridge	224	Flow, water temperature, and turbidity
Raygold	201	Flow, water temperature, and turbidity
Grants Pass	165	Flow, water temperature, and turbidity
Marial	78	Water temperature and turbidity
Agness	48	Flow

Scales were read at a magnification factor of 88. Measurements and circuli counts in the anterior region of the scale were made along the longer of two lines oriented at 20° from the longitudinal midline of the scale. Scales with a nucleus radius larger than 15 mm (at 88X) were considered regenerated and were excluded from further analysis. We measured magnified distances (to the nearest 0.5 mm) from the scale focus to the following points: each annulus, ocean entry, each spawning check, and the outer edge of the scale. Circuli were counted from the nucleus to points of annuli, ocean entry, spawning checks, false annuli, and the scale edge.

The subjective nature of the analysis resulted in an unknown number of errors in interpretation. In particular, we found it difficult to precisely differentiate the final portion of freshwater growth from the initial portion of ocean growth. Identification of the point of ocean entry was difficult because no clear check separated plus-growth and ocean growth. Estimation errors may have varied among years because more than one person interpreted scales collected from summer steelhead. In addition, we may have been liberal in our estimate of plus-growth, which would have resulted in inflated estimates of smolt length at time of ocean entry.

Because sampling rates for scales varied greatly among half-pounders of different lengths, we became concerned that estimates of life history parameters may not have been representative of all half-pounders. To address this concern, we compared the lengths of wild half-pounders that composed the collections of measured scales with the lengths of all wild half-pounders seined at Huntley Park. We found no significant differences in mean lengths of fish with measured scales and all counterparts caught in the seine during four randomly chosen years (Table 2). Consequently, we concluded that means of life history parameters estimated from scaled half-pounders could be used to represent means of life history parameters for all half-pounders.

Scales of adult summer steelhead were sampled at greater rates. In some years, we took scale samples from all of the adults seined at Huntley Park. All adults in the size range that included salt migrants and second spawning migrants were sampled each year that we seined at Huntley Park. Biases attributable to sampling rates were possible only among first spawning migrants (*see* Table 9, page 34 for descriptions of life history terminology).

Table 2. Comparisons of mean lengths for wild half-pounders from which we measured scale parameters and mean lengths for all wild half-pounders seined at Huntley Park in four randomly chosen years. Mean lengths were compared with a t-test.

Year	Mean length (cm)		*P* for difference
	Scaled fish	All fish	
1978	33.2	33.0	0.632
1980	32.9	32.3	0.093
1984	34.6	34.2	0.371
1985	33.5	33.9	0.233

We tagged summer steelhead seined in the lower river in 1976-77 with individually numbered t-bar tags. Personnel inserted the tags so the t-bar wedged between ptergiophore bones located below the dorsal fin. Migration rates were estimated from tags returned by anglers. We also estimated the migration rates of summer steelhead tagged in 1968-70 by Everest (1973).

Abundance

We sampled summer steelhead that returned to the Rogue River by beach seining in the lower river during 1975-91. In 1975, we seined the upper end of the estuary at RK 5. In 1976-91, we seined at Huntley Park (RK 13), except low flow forced us to seine at Canfield (RK 8) in August 1977.

Seining began in early July and continued through late October. We seined 3-5 days weekly and effort ranged between 7 and 18 sets daily. We sampled between 0900 and 1700 hours in 1975-76, but only included catch rate data prior to 1300 hours in our analyses. In 1977-91, we began sampling 30 minutes after sunrise and usually finished by 1300 hours.

In 1976-91, we used a quick sinking beach seine 300 ft long with stretch mesh that varied from 2 inch mesh for the center panel to 5 inch mesh for the wing panels. Seine depth was 18 ft in the bag and tapered to 9 ft on outside edges of the wing panels. In 1975, we used a similar seine, except it was 25 ft shorter.

We estimated freshwater returns of summer steelhead by determining the seining efficiency on coho salmon of hatchery origin. We estimated seining efficiency by comparing the seine catch of coho salmon with clipped adipose fins with the estimated number that entered the river. Freshwater return of marked coho salmon was estimated as the sum of (1) return to Cole M. Rivers Hatchery, (2) freshwater harvest, (3) prespawning mortality, and (4) strays that spawned in the wild. Estimation methods were described by ODFW (1991).

We assumed that summer steelhead and coho salmon were equally vulnerable to capture by the beach seine. We know of no evidence that would either confirm or refute this assumption. Even if catchability differed between species, findings from our analyses would remain valid provided the error rate was consistent among years. We recognize that annual variations in river morphology may differentially affect capture vulnerability of each species.

We multiplied weekly catch rates by 45 to generate a standardized weekly catch. We selected 45 as a standard because this was the most common number of sets made weekly. We used weekly estimates of seining efficiency (ODFW 1991) to expand standardized catches to estimate freshwater returns of summer steelhead on a weekly basis. We used the equation

$$\hat{E} = C/(e/100)$$

where

$\hat{E}$ = estimated weekly return of summer steelhead to the Rogue River,
C = standardized seine catch based on 45 sets weekly, and
e = weekly estimate of seining efficiency (%).

We estimated freshwater returns for each life history type of wild summer steelhead with scale analyses, length frequency distributions of fish seined at Huntley Park, and estimates of the number of fish that passed Huntley Park. First, we determined the proportion of summer steelhead within each 5 cm size interval among seined fish. Second, we determined the proportion of each life history type within 5 cm length intervals among annual scale collections. Finally, we multiplied the product of the first and second steps by the estimated number of wild summer steelhead that annually passed Huntley Park.

In the upper river, passage of summer steelhead at Gold Ray Dam (RK 202) has been estimated by fishery agencies of the state of Oregon since 1942. Passing adults are counted 8 hours daily for 5 days weekly except when the counting facility is inoperable because of floods. Partial counts were designed to estimate biweekly passage with an average error of less than 10% (Li 1948). From 1942 to 1967, adults were counted as they passed above a white flashboard. Since 1968, adults have been counted as they passed an underwater viewing window. The counter recorded all fin clips seen during 1969-91. Beginning in 1977, steelhead smaller than 41 cm (16 inches) were classified as half-pounders.

Steelhead that pass Gold Ray Dam are classified into two races. Rivers (1964) found that 15 May was an appropriate date to differentiate "late-run" winter steelhead from "early-run" summer steelhead. However, no clear date is available by which to delineate late-run summer steelhead and the first winter steelhead. We chose 1 February as a demarcation date between these two races, based on three factors. First, biweekly estimates of steelhead passage at Gold Ray Dam revealed a nadir in migration during late January or early February. Second, Everest (1973) found that few known summer steelhead passed Gold Ray Dam after 1 February in 1970 or 1971. Finally, we found that few winter steelhead of hatchery origin passed Gold Ray Dam prior to February.

We also recognized two varieties of summer steelhead that passed Gold Ray Dam. Summer steelhead that passed the counting station prior to 15 September were termed as "early-run". Those that passed later were termed "late-run". We distinguished between the two groups because there was evidence of racial segregation. Rivers (1964) reported that salt migrants (summer steelhead that did not make a half-pounder run) accounted for 33% of the scales taken from early-run adults and 10% of the scales taken from late-run adults. Experimental crosses of summer steelhead at Cole M. Rivers Hatchery showed that the migration timing of adults had a heritable basis. Progeny of early-run parents returned, as mature adults, earlier in the run as compared with progeny of late-run parents (Evenson and Ewing 1984). Everest (1973) reported similar findings, but concluded that the varieties were not reproductively isolated and thus, did not constitute distinct races of summer steelhead.

At the counting station, hatchery and wild fish were differentiated on the basis of fin clips. In 1971-79, 100% of the returning summer steelhead of hatchery origin were marked. After 1979, passage estimates of hatchery and wild adults were made by expanding biweekly estimates of marked adults. To expand counts of marked adults that passed Gold Ray Dam, we used the proportion of marked fish among annual returns of hatchery fish to Cole M. Rivers Hatchery. Unmarked hatchery fish were differentiated from wild fish based on whether the dorsal fin was deformed. Percentages of marked fish among hatchery summer steelhead that entered Cole M. Rivers Hatchery are in Table 3.

Table 3. Estimated percentage of marked fish among summer steelhead of hatchery origin that entered Cole M. Rivers Hatchery, 1976-91.

	Early-run			Late-run		
Year[a]	Period[b]	*N*	% marked	Period[b]	*N*	% marked
1976	06/21-09/29	76	100.0	10/11-03/08	411	100.0
1977	06/07-09/28	115	100.0	10/01-03/03	1,780	100.0
1978	05/16-10/16	175	100.0	10/23-03/22	941	100.0
1979	06/11-10/19	266	88.7	10/22-03/31	3,381	93.5
1980	06/06-10/09	168	32.3	10/17-03/20	765	30.6
1981	05/18-10/23	317	21.7	10/29-03/22	1,820	31.4
1982	05/25-09/27	704	27.8	10/12-02/28	1,348	26.5
1983	05/27-10/10	310	30.8	10/18-03/08	412	20.2
1984	05/16-10/02	369	27.4	10/08-03/11	404	24.3
1985	05/24-10/07	251	34.5	10/21-02/24	370	36.6
1986	05/29-10/01	418	22.1	10/07-02/24	530	18.2
1987	05/29-09/28	885	26.0	10/06-02/25	1,709	24.4
1988	05/16-09/29	613	20.6	10/07-03/01	740	15.8
1989	05/19-10/11	318	11.5	10/18-03/20	301	11.3
1990	05/04-10/04	863	66.8	10/11-03/13	417	68.1
1991	05/02-10/15	587	93.5	10/29-03/03	617	94.6

[a] *Year of river entry.*
[b] *Inclusive calendar dates when fish were examined at the hatchery.*

Recreational Fisheries

We were unable to develop estimates of the total harvest of summer steelhead in the Rogue River. Surveys to estimate harvest would have had to cover 260 kilometers of river and would have lasted 9 months annually. Harvest estimates were available from salmon-steelhead cards, but included only steelhead larger than 51 cm (41 cm after 1989). Most summer steelhead were smaller than 51 cm (*see* **Length at Return**, page 63).

We assumed that harvest estimates derived from salmon-steelhead cards were an unbiased estimate of the harvest of large summer steelhead in the Rogue River. This assumption is probably erroneous because the adjustment factor for a non-response bias is only applicable on a statewide basis (Hicks and Calvin 1964). However, we believe that estimates from salmon-steelhead cards provide a reasonable, but not necessarily precise, estimate of harvest because a large number of anglers fish the Rogue River.

We also assumed that harvest estimates for May though November were comprised solely of summer steelhead. This assumption is erroneous because anglers harvest some winter steelhead in the lower river during late November (ODFW 1990). Anglers also harvested summer steelhead in the middle river and in the upper river from December through February, but it was not possible to segregate summer steelhead from winter steelhead. Harvest estimates for December-February were dominated by larger winter steelhead because few summer steelhead were large enough to require entry on salmon-steelhead cards.

We estimated the annual harvest for late-run summer steelhead of hatchery origin as the difference between (1) returns to Cole M. Rivers Hatchery adjusted for strays that naturally spawned and (2) estimated passage of adult summer steelhead of hatchery origin at Huntley Park. We assumed there was no natural mortality because we observed few carcasses of summer steelhead during extensive surveys of unspawned carcasses of spring chinook salmon and fall chinook salmon in 1974-86.

We believe that few hatchery fish strayed to spawn in areas downstream of Gold Ray Dam. Cramer (1981) and Hiss et al. (1986) concluded that hatchery steelhead stray to spawn in areas upstream, rather than downstream, of the release site. Taft and Shapovalov (1938) estimated more than 95% of the summer steelhead in small tributaries of the Klamath River, California, homed to natal streams. Lister et al. (1981) summarized data from numerous studies that indicate straying is minimal when juvenile steelhead are released directly from the rearing facility. Therefore, to account for straying, we assumed that only 5% of the hatchery adults that escaped the fisheries failed to enter Cole M. Rivers Hatchery.

We conducted surveys of anglers that fished for summer steelhead in the lower and middle river (Table 4). These surveys were designed to estimate catch rate and to index angler effort. While interviewing anglers, survey clerks followed a circular route designed to encompass the entire area. Route direction and starting point were randomly selected. Anglers were asked how long they had fished and if they had landed fish. Data from bank and boat anglers were recorded separately.

Table 4. Surveys of anglers that fished for summer steelhead in the Rogue River, 1977-78 through 1981-83.

Survey area	RK	Period	Years
Canfield to Lobster Creek	7-18	08/01-10/31[a]	1977-83[b]
Agness to Illahe	42-55	09/01-10/31	1977-80
Illahe to Grave Creek	55-110	09/01-10/31	1977-80
Grave Creek to Indian Mary Park	110-129	11/01-01/31	1977/78-1980/81
Robertson Bridge to Lathrop Landing	139-156	11/01-01/31	1977/78-1980/81
Rogue River to Gold Hill	179-193	11/15-01/31	1977/78-1978/79

[a] *Sampled during 08/01-10/15 in 1983.*
[b] *Not sampled in 1982.*

Fish retained by anglers were identified by species, examined for identifying marks, and classified by fork length. Steelhead smaller than 41 cm (16 inches) were classified as half-pounders. Larger steelhead were classified as adults. Hatchery fish were differentiated from wild fish based on the presence of fin clips or a deformed dorsal fin. When fish were landed, but not retained, anglers were queried about the number landed, species, and size of fish released. Survey clerks assumed that anglers relayed accurate information about their catch. Within both surveys, clerks worked 8 hours daily, 5 days weekly. Survey days were randomly selected within weeks.

To index angler effort, clerks counted bank anglers, boats, and boat trailers daily at 0900, 1200, and 1600 hours. Counts were made only from the side of the river offering the best view of the fishery. The direction of each route varied daily on a random basis. Anglers were not interviewed during effort counts.

We also evaluated catches from guided anglers that fished the Rogue River canyon in 1977-91. Irvine Urie, a river guide from Medford, Oregon, provided the data. During most years, anglers fished with two groups of 5-7 guides. Group 1 fished from Grave Creek (RK 110) to Foster Bar (RK 54). Group 2 fished from Grave Creek to Hideaway (RK 24). We found that data from both groups of guides were highly correlated: (1) annual catch rates ($r = 0.86$, $P < 0.001$), (2) percent of landings caught downstream of Marial ($r = 0.73$, $P = 0.011$), (3) percent half-pounders among landings ($r = 0.73$, $P = 0.003$), and (4) percent hatchery fish among landings ($r = 0.64$, $P = 0.014$).

Juveniles

Based on the findings of Everest (1973), we concluded that most of the juvenile steelhead sampled in the Rogue River were probably progeny of summer steelhead. Sampling crews seined juvenile steelhead in the Rogue River at 12 sites downstream of Lost Creek Dam, at 2 sites in the estuary, and in 2 tributary streams (Table 5). Upstream of Agness, crews used a 50 ft x 8 ft floating seine with 1/4-inch square mesh, attached to a "many ends" bottom line. In the lower river, samplers used a 100 ft x 8 ft floating seine with 1/4-inch square mesh. We seined one site in the estuary with a 350 ft x 15 ft floating seine with mesh size varying from 3/8 inch in the bag to 1 inch in the wings.

Sampling crews seined each site weekly. Personnel made two sets at each site upstream of Agness, but only one set at each site in the lower river. Catch rate of juveniles was calculated only from this standard sampling. Personnel sometimes made additional sets to meet sample requirements for lengths and weights.

Samplers also operated irrigation bypass traps at Table Rock (RK 209) and at Savage Rapids Dam (RK 173). During 1976-81 and 1983, the trap at Table Rock fished continuously from March through August. The trap at Savage Rapids Dam fished 5 nights weekly from early May through the end of September during 1976 through 1990. Juveniles diverted from an 800 cfs withdrawal were captured in a bypass trap screened with 1/4-inch square mesh.

Table 5. Sites seined for juvenile steelhead in the Rogue River basin, 1975–86.

Sampling site	RK	Period	Frequency	Years
Rogue River:				
Sand Hole	252	Jan-Oct	weekly	1975-81
High Banks	216	Jan-Oct	weekly	1975-81
Valley of the Rogue	183	Jan-Oct	weekly	1976-81
Matson Park	148	Jan-Oct	weekly	1975-86[a]
Almeda Park	116	Jan-Oct	weekly	1975-86[a]
Whiskey Bar	105	Apr-Oct	biweekly	1975-86[b]
Winkle Bar	85	Apr-Oct	biweekly	1975-86[b]
Illahe	56	Apr-Oct	biweekly	1975-81
Agness	44	Mar-Oct	weekly	1974-81
Hideaway	24	Mar-Oct	weekly	1974-81
Canfield	8	Mar-Oct	weekly	1974-82
Estuary:				
Mail Boat Point	3	Apr-Oct	weekly	1974-81
Coast Guard	1	Apr-Oct	weekly	1974-82
Tributaries:				
Big Butte Creek	1	Jan-Oct	weekly	1975-81
Applegate River[c]	1	Jan-Jul	weekly	1975-86
Illinois River	1	Mar-Oct	weekly	1976-81

[a] *Not sampled in 1982. Sampled in May-October, 1983-86.*
[b] *Not sampled in 1982-83. Sampled in May-October, 1984-86.*
[c] *Sampled as part of the Applegate Dam Fisheries Evaluation, 1978-86.*

Juveniles were segregated by species and age class. Prior to handling, samplers anesthetized juveniles with benzocaine or a mixture of tricaine methanesulfonate (MS-222) and quinaldine (Schoettger and Steucke 1970). During each trip, samplers measured the fork lengths, to the nearest 1 mm, of 30 juveniles from each age class. We segregated age-0, age-1, and older steelhead using length frequency distributions and periodic analyses of scale samples. Personnel also weighed a maximum of 25 juveniles per age class, to the nearest 0.1 gm, monthly at each site.

Life History

Steelhead that exhibited morphological changes associated with the parr-smolt transformation were segregated from other fishes. Low body condition, deciduous scales, absence of parr marks, a silvery appearance, and a black band on the distal portion of the caudal fin were visual characters used to classify juvenile steelhead as smolts (Ewing et al. 1984).

We sampled scales weekly from juvenile steelhead captured at sites in the middle river and in the lower river. In each area, we took scales from a maximum of 15 yearlings and 15 smolts. Samplers removed approximately 10 scales from the left side of each fish in an area about four rows above the lateral line and immediately posterior to the dorsal fin.

Scales taken from juveniles were mounted on glass slides with a solution of 5% glycerin and 95% sodium silicate. We mounted about 10 scales per juvenile and chose 2 of the larger, non-regenerated scales of regular shape for analysis. We analyzed juvenile scales with the same methods used to analyze adult scales.

From yearlings seined in the lower river, we found that scale radius correlated positively with fork length during each of the five years that we sampled (Table 6). We judged these relationships to be linear. Scale radius accounted for an average of 77% of the variation associated with fork length. Analysis of covariance revealed no significant differences ($P = 0.08$ for slopes and $P = 0.21$ for elevations) between regression equations, so we pooled annual regressions (Table 6). We used the pooled regression to estimate length at the time of formation for each freshwater annulus.

For smolts sampled throughout the river, we found that the timing of annulus formation varied among individuals. Based on a narrowing and subsequent widening of circuli, we judged that annulus formation was completed by May of each year. Consequently, we only used scales obtained from smolts seined after 1 May to estimate relationships between scale radius and body length. Most smolts were 16-22 cm long when captured.

Each year, we found that scale radius was correlated positively with fork length of smolts (Table 7). Variability within the relationships was greater among smolts sampled in the middle river than among those sampled in the lower river. Coefficients of determination ranged from 0.21 to 0.80 for smolts sampled in the middle river, but only ranged from 0.42 to 0.62 for smolts sampled in the lower river.

Table 6. Regressions of fork length (cm) on scale radius (mm at 88X) for wild yearling steelhead seined at Agness, 1975-79. Scales with regenerated nuclei were excluded from the analyses.

Year(s)	Regression equation[a]	Standard error	N	r^2	P
1975	$Y = 3.01 + 0.1827(X)$	0.0103	102	0.76	<0.001
1976	$Y = 4.02 + 0.1578(X)$	0.0082	118	0.76	<0.001
1977	$Y = 4.78 + 0.1438(X)$	0.0078	101	0.78	<0.001
1978	$Y = 4.38 + 0.1570(X)$	0.0081	91	0.81	<0.001
1979	$Y = 4.33 + 0.1532(X)$	0.0093	102	0.73	<0.001
1975-79	$Y = 4.18 + 0.1573(X)$	0.0038	514	0.77	<0.001

[a] *Y = fork length; X = scale radius.*

Table 7. Regressions of fork length (cm) on scale radius (mm at 88X) for wild steelhead smolts sampled in the Rogue River, 1976-80. Scales with regenerated nuclei were excluded from the analyses.

Area, year	Regression equation[a]	Standard error	*N*	r^2	*P*
Lower river:					
1976	$Y = 11.29 + 0.0908(X)$	0.0136	62	0.42	<0.001
1977	$Y = 8.05 + 0.1336(X)$	0.0077	226	0.57	<0.001
1978	$Y = 10.75 + 0.1023(X)$	0.0136	47	0.56	<0.001
1979	$Y = 7.75 + 0.1402(X)$	0.0074	220	0.62	<0.001
1980	$Y = 10.24 + 0.1068(X)$	0.0126	87	0.46	<0.001
Middle river:					
1976	$Y = 6.01 + 0.1624(X)$	0.0107	61	0.80	<0.001
1977	$Y = 6.01 + 0.1625(X)$	0.0096	151	0.66	<0.001
1978	$Y = 9.57 + 0.1138(X)$	0.0119	137	0.40	<0.001
1979	$Y = 12.50 + 0.0820(X)$	0.0199	66	0.21	<0.001
1980	$Y = 7.47 + 0.1458(X)$	0.0100	165	0.57	<0.001

[a] *Y = fork length; X = scale radius.*

Within sampling areas, relationships between fork length and scale radius varied among years. Analysis of covariance revealed a significant difference ($P = 0.003$) among slopes of regressions developed annually from smolts seined in the lower river. Slopes of regressions developed for smolts sampled in the middle river also differed significantly ($P < 0.001$). Additional comparisons suggested that sampling area affected the estimate of the relationship between fork length and scale radius. An analysis of covariance revealed that, within years, regression slopes for samples from the lower river and from the middle river were consistently different ($P < 0.05$ in 5 of 6 cases).

These findings indicated that the relationship between fork length and scale radius varied for some unknown reason(s). Possible factors include variations in water temperature and forage (Boyce 1985), sampling procedures, or genetic histories of the sampled fish. For example, the relative abundance of smolts that originated from distinct populations probably varied between years and between areas of sampling. Resultant uncertainty associated with the selection of appropriate regressions to be used for estimating smolt lengths from adult scales led us to select an alternative method.

We chose to use the Lee method (Carlander 1981) because scale samples were randomly taken among returning summer steelhead. We assumed an isometric relationship between body length and scale radius. Fork length at time of ocean entry was estimated based on measurements of scales taken from returning adults using the equation

$$L_i = a + ((L_c - a)(S_i/S_c))$$

where

L_i = fork length of juvenile at time i,
a = a constant (we used 3.5 cm, a value used by Peterson (1978) for winter steelhead in the Alsea River, Oregon),
L_c = fork length of adult at time of capture,
S_i = scale radius of juvenile at time i, and
S_c = scale radius of adult at time of capture.

For the most common life history types of summer steelhead, we estimated mean length at time of formation of freshwater annuli, mean length at ocean entry, mean increase in length during the second year of freshwater residence, and mean increase in length between the last freshwater annulus and the time of ocean entry. We termed the final increment of growth in fresh water as "plus-growth".

We estimated the life history parameters of brood years by pooling data from smolts of all ages. Estimates were weighted according to the number of cohorts estimated to return to the Rogue River. Consequently, estimates of life history parameters represent only those fish that survived to return to fresh water and probably do not represent life history parameters of all juvenile steelhead produced in fresh water (Ward and Slaney 1988).

Abundance

We did not attempt to develop population estimates for juvenile steelhead that reared in the Rogue River. We assumed that the annual catch rate of seined juveniles was a reliable index of abundance. We used catch rates in June-October to represent annual catch rates because subyearlings reared in the Rogue River consistently during that period. We assumed that annual changes in site morphology, sampling efficiency, and fish behavior accounted for minimal variation in annual catch rates. We recognize these assumptions may not be appropriate for juvenile steelhead (Parsley et al. 1989).

We used catch per trap hour in the irrigation bypass facilities as an index of the abundance of migrants. We also developed weekly estimates of the number of juvenile steelhead that migrated past Savage Rapids Dam. Passage estimates were derived from estimates of trap efficiency. We developed estimates of trap efficiency through mark-recapture experiments with juvenile chinook salmon. Results suggested that trap efficiency varied in relation to river flow. Trap efficiency increased as flow decreased, which was similar to findings reported by Raymond (1979), Fustish et al. (1988), and Lindsay et al. (1989). Regression analysis estimated the relationship as

$$\ln \text{trap efficiency} = 14.8705 - 2.3575(\ln \text{flow})$$

where flow = mean weekly flow at Grants Pass at the time of recapture.

Although only four data points composed the analysis, the regression was significant at $P \leq 0.05$. The small sample size almost certainly resulted in a relatively large amount of error within passage estimates. In addition, the assumption of similar trap efficiencies for subyearling chinook salmon and steelhead of varied age classes is likely erroneous. However, we believe that passage estimates represent abundance and migration timing better than trap catches not adjusted for the effects of varied flows.

Analytical Procedures

Data we believed to exhibit a normal distribution were analyzed with parametric statistics, primarily using Microstat statistics software (Ecosoft Inc., Release 4.1). Data with distributions judged to be other than normal were assessed with nonparametric statistics.

Because many of the data sets contained less than 10 observations, the assessment of normality was frequently subjective. Uncertainty about the normality of the data led us to defer testing for homogeneity of variances. Unless stated otherwise, we used $P \leq 0.05$ as the criteria for statistical significance. We followed analytical methods outlined by Snedecor and Cochran (1967) and Zar (1984).

Parametric methods most commonly used included analysis of variance, correlation analysis, and regression analysis. We used analysis of variance to test for differences between means of preimpoundment and postimpoundment variables. Where no difference was noted, we calculated the minimum detectable difference (Zar 1984) to estimate how much the postimpoundment mean would have had to change in order for the change to be detected. Proportional or percentage data were arcsine transformed prior to analysis of variance.

We used analysis of variance to test for differences between means of life history parameters for different age classes among multiple brood years. Where differences were noted, we used a Newman-Keuls multiple range test to evaluate differences between specific age classes.

To identify relationships among variables, we used correlation analysis and assumed data were independent observations with a bivariate normal distribution and common variance. We also used correlation analysis to evaluate potential multicollinearity among independent variables considered for inclusion in multiple regression analyses. Percentage or proportional data were logit transformed prior to regression analysis.

To quantify relationships between dependent and independent variables, we used regression and multiple regression analyses. Independent variables were assumed to be measured without error. This may be a reasonable assumption for measurements of physical factors (such as flow and upwelling), but is certainly erroneous for some biological data. Associated errors were probably smallest for life history parameters reported as means (such as length at ocean entry, and scale measurements). Estimates or indexes of fish abundance almost certainly contained major sources of error, particularly where numerous estimation steps and assumptions were required to derive the data.

However, because fish abundance is of key importance to this evaluation, and other analytical procedures may be more sensitive to estimation errors, we used regression analysis to estimate the quantitative relationships between variables. Independent variables were included in regression analyses only when our previous findings (Cramer et al. 1985) or results from other research identified variables as probable causal factors associated with the dependent variable in question. Despite this step, there are probably multiple specification errors among regressions presented in this report.

Other potential problems associated with multiple regression analysis include autocorrelation, heteroscedasticity, and multicollinearity. We evaluated the potential for autocorrelation by the Durbin-Watson test. We evaluated the potential for heteroscedasticity by plotting residual values from a regression on the associated values of the dependent variable. We attempted to minimize the potential for multicollinearity by (1) use of correlation analysis to identify significant relationships between independent variables and (2) limiting the number of independent variables included in regressions.

We used regressions to predict values of a dependent variable from values of independent variable(s). Ricker (1973) and Jensen (1986) recommend use of predictive regression rather than functional regression provided that the objective is the prediction of, rather than description of, functional relationships. We chose predictive regression because our primary objective was to predict the response of dependent variables to variations in independent variables.

RESULTS AND DISCUSSION

Physical Factors

USACE personnel used the QUAL II model (Hamlin and Nestler 1987) to simulate flow, water temperature, and turbidity for regulated (with dams) and unregulated (without dams) conditions in 1978-86. In this section of the report, we summarize some of the findings that are directly relevant to the production and harvest of summer steelhead in the Rogue River.

Flow

Operation of Lost Creek Dam affected flow in downstream areas. Storage of inflow occurred primarily from January through April and peaked in February (Figure 4). The reservoir reached full pool each year, usually by 1 June. Augmentation of natural flow usually began in the middle of June, peaked in July and August, and continued through the end of November (Figure 5).

The relative effect of reservoir operation decreased with distance downstream (Figure 5). At Raygold, regulated flow generally ranged between 3,000 cfs and 5,000 cfs from January through April. Downstream at Agness, regulated flow usually ranged between 7,000 cfs and 10,000 cfs during the same time period. As tributary flow declined in the late spring and early summer, flow in the lower river became similar to flow in the upper river.

Operation of Lost Creek Dam decreased the intensity of peak flow in the Rogue River. The USACE estimated that reservoir operation decreased peak flow at Grants Pass by an average of 6,300 cfs annually (range = 200-10,900 cfs) in 1977-78 through 1985-86 (Table 8).

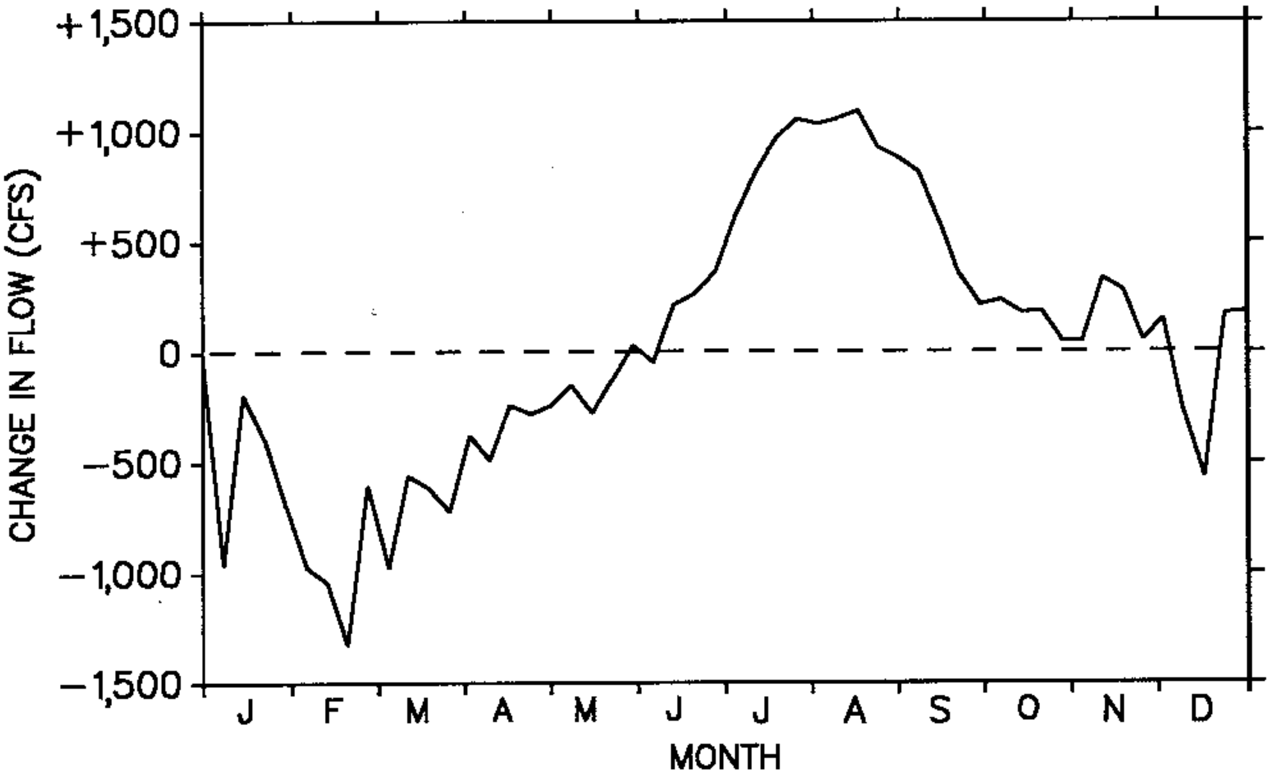

Figure 4. Change in mean weekly flow caused by the operation of Lost Creek Dam, 1978-86. The zero-line represents unregulated flow (inflow = outflow).

Table 8. Estimated peak flow (cfs) of the Rogue River at Grants Pass for regulated and unregulated conditions, 1977-78 through 1985-86.

Year	Regulated	Unregulated	Year	Regulated	Unregulated
1977-78	40,300	45,600	1982-83	50,400	57,300
1978-79	12,700	19,600	1983-84	27,600	37,700
1979-80	26,900	37,800	1984-85	19,000	19,200
1980-81	9,800	11,200	1985-86	27,800	34,900
1981-82	46,300	54,000			

Water Temperature

Throughout the river, water temperature increased in November-January, and decreased in June-September (Figure 6). Effects on water temperature diminished with distance downstream from Lost Creek Dam. Operation of the dam increased average water temperature at Raygold in November-January by about 1.5°C and by about 1.0°C at Marial. At the thermal peak in summer, operation of the dam reduced average water temperature at Raygold and Marial by 3.5°C and 3.2°C, respectively.

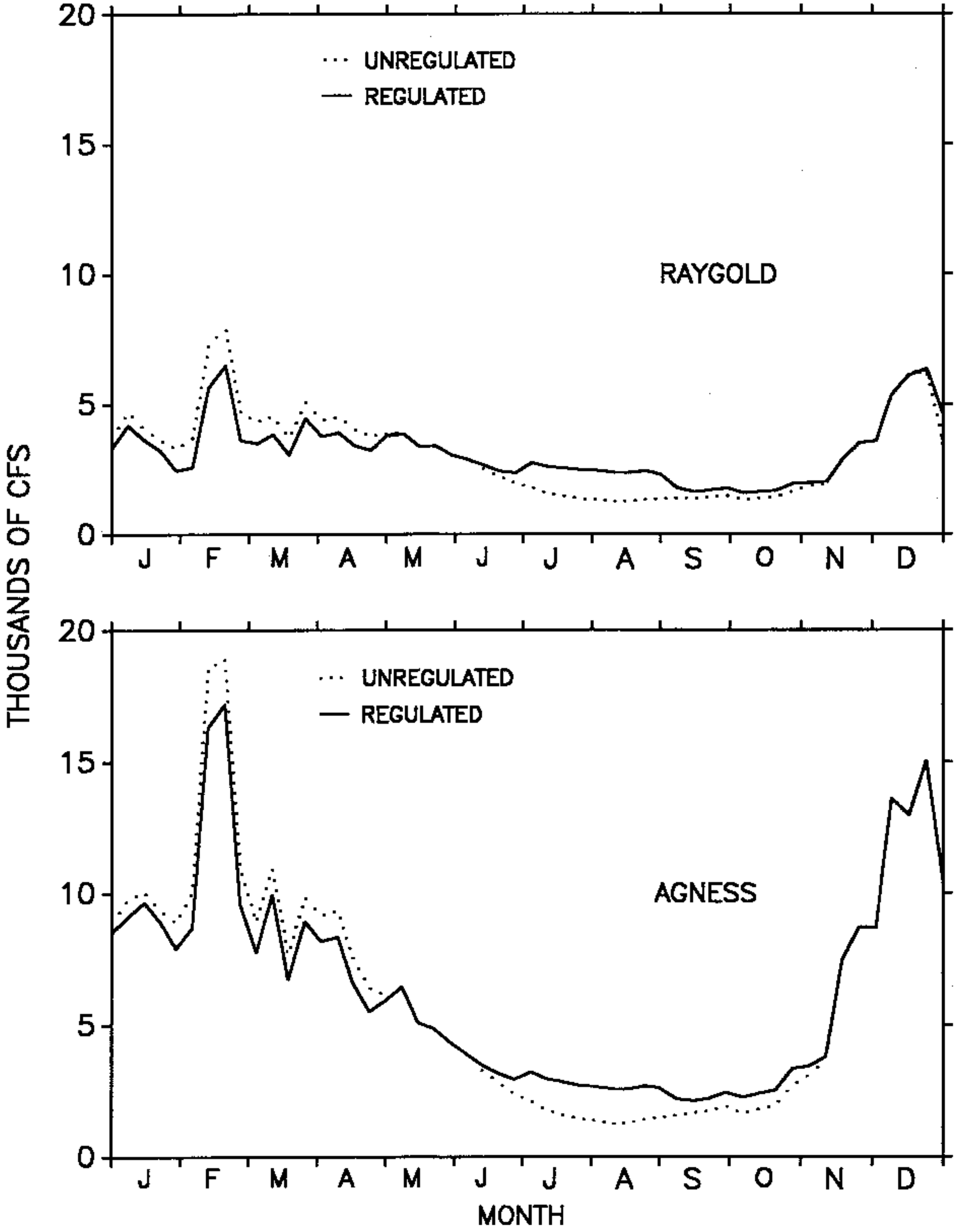

Figure 5. Mean weekly flow in the upper river at Raygold Pass, and in the lower river at Agness, simulated for regulated and unregulated conditions during 1978-86.

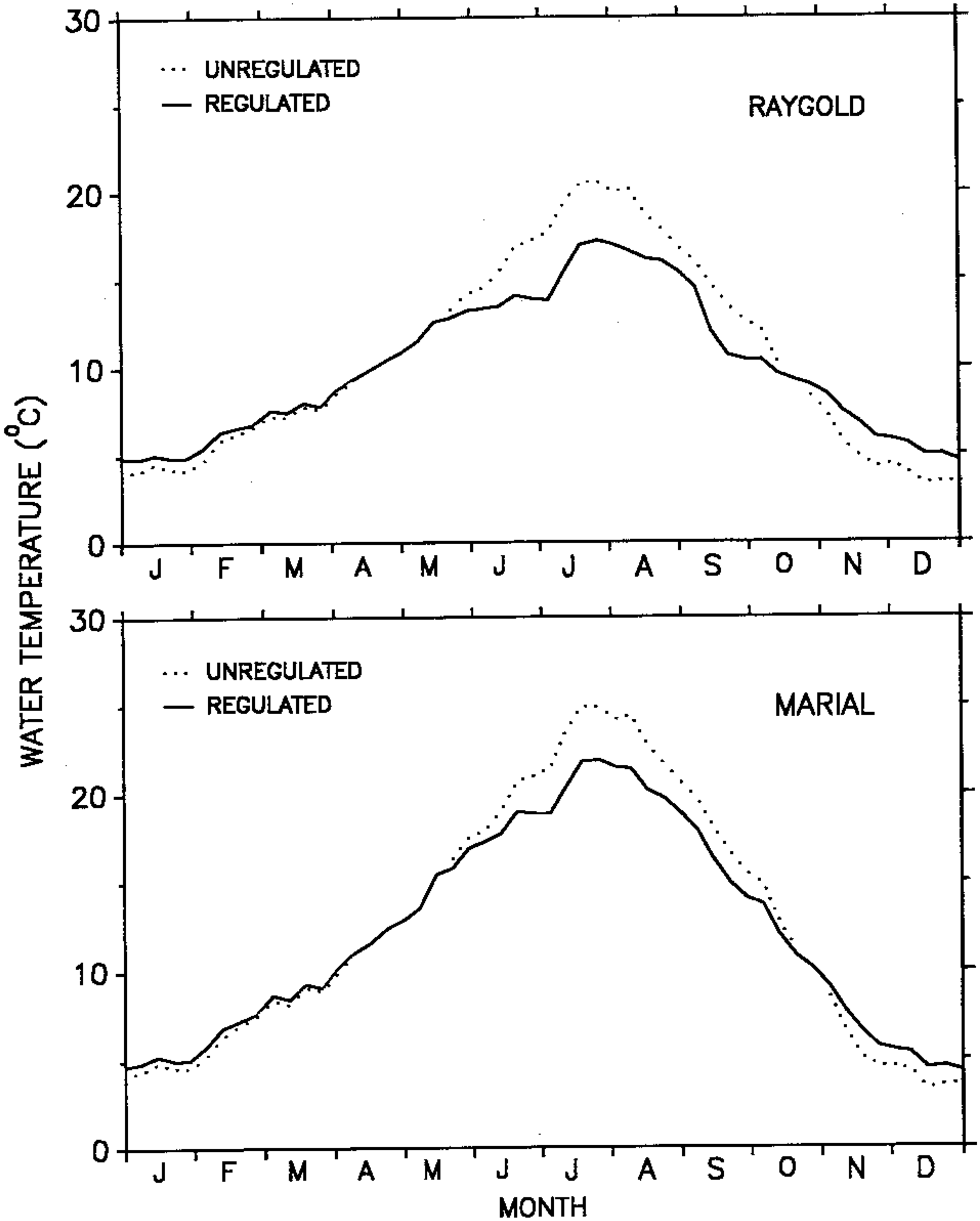

Figure 6. Mean weekly water temperature in the upper river at Raygold, and in the Rogue River canyon at Marial, simulated for regulated and unregulated conditions during 1978-86.

Turbidity

River turbidity varied greatly on a seasonal basis. We measured turbidity as high as 140 Jackson Turbidity Units (JTU) and as low as 1 JTU during angler surveys. Throughout the river, turbidity in summer usually ranged from 2 JTU to 4 JTU (Figure 7). In winter, turbidity increased with distance downstream from Lost Creek Dam, most noticeably during periods of high flow. Simulation models developed by USACE indicated that mean weekly turbidity never exceeded 20 JTU in the upper river, but exceeded 50 JTU in the canyon (Figure 7). Tributary streams increased turbidity in the mainstem, particularly when flow increased during periods of high precipitation.

Operation of Lost Creek Dam usually reduced turbidity of the Rogue River. At Dodge Bridge, regulation reduced average turbidity by 6 JTU in April-June and 3 JTU in November-March (Figure 7). Downstream at Marial, regulation reduced average turbidity by 4 JTU in November-March and 1 JTU in April-June (Figure 7). In the canyon, as well as in the upper river, operation of the dam reduced average turbidity by less than 1 JTU in July-October.

Adults

For the purposes of discussion, return years are defined as the calendar year of river entry and brood years are defined as the calendar year of spawning. Relationships between return year and brood year for four types of summer steelhead are in Appendix Table B-1.

Life History

We found three distinct life history strategies among wild summer steelhead that returned to the Rogue River. Fish that spent three to five months in the ocean were the most common life history. These steelhead are mostly immature fish known as "half-pounders". Steelhead populations that include half-pounder life histories are limited to the Rogue River basin and the Klamath and Eel river basins of northern California, although in some years a few half-pounders enter smaller streams in northern California and southern Oregon (Everest 1973). Upon maturity, half-pounders may return to fresh water as summer steelhead (Everest 1973) or winter steelhead (ODFW 1990).

We identified two life history strategies among mature summer steelhead. One strategy, which we termed "spawning migrants", characterized fish that previously returned to fresh water as half-pounders. The other strategy, which we termed "salt migrants", characterized fish that did not previously return to fresh water as half-pounders. We found that salt-migrants were relatively rare among summer steelhead that returned to the Rogue River in 1975-89.

Wild summer steelhead exhibited a diversity of life history patterns. From scale samples, we identified seven life history patterns among salt migrants and eight life history patterns among spawning migrants (Table 9). Such diversity is common among steelhead populations. Diverse life histories are common within steelhead runs in California (Shapovalov and Taft 1954;

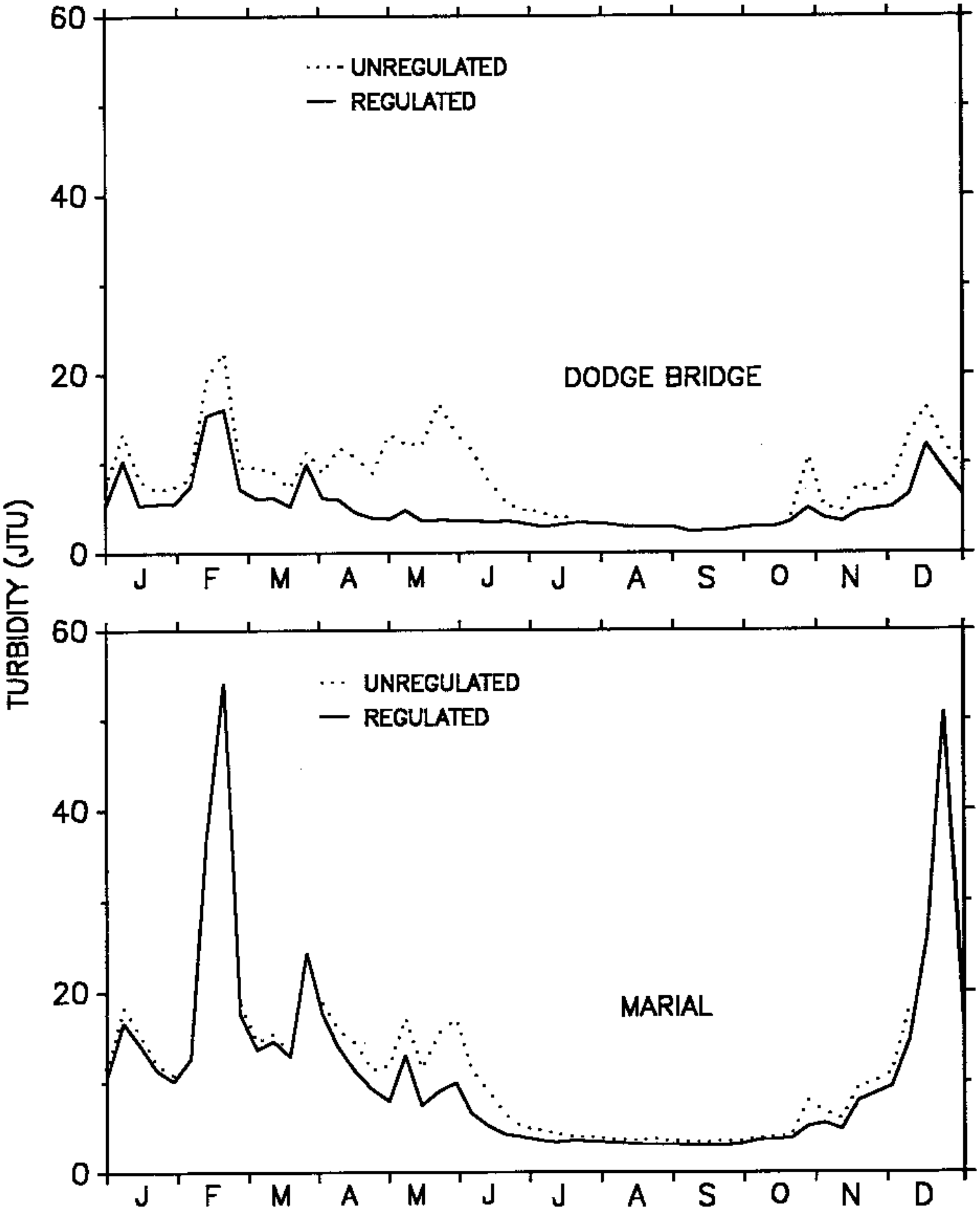

Figure 7. Mean weekly turbidity (Jackson Turbidity Units) in the upper river at Dodge Bridge, and in the Rogue River canyon at Marial, simulated for regulated and unregulated conditions during 1978-86.

Table 9. Descriptions of adult life history types as interpreted from scales of wild summer steelhead sampled at Huntley Park, 1976-89 return years. All repeat spawners spent only one spring in the ocean between spawning runs.

Life history occurrence, name	Description (symbol)
Common:	
Half-pounder	False spawning run after 3-5 months in ocean (/+).
First spawning migrant	First spawning run after one autumn-winter period in freshwater as a half-pounder, and one subsequent spring in ocean (/H).
Second spawning migrant	Second spawning run for a first spawning migrant (/HSS).
Third spawning migrant	Third spawning run for a first spawning migrant (/HSSS).
Rare:	
Fourth spawning migrant	Fourth spawning run for a first spawning migrant (/HSSS).
One-salt	First spawning run after one year in ocean (/S).
One-salt, repeat spawner	Second spawning run for a one-salt adult (/SS).
Two-salt	First spawning run after two years in ocean (/1).
Two-salt, repeat spawner	Second spawning run for a two-salt adult (/1S)
Two-salt, second repeat spawner	Third spawning run for a two-salt adult (/1SS).
Two-salt, third repeat spawner	Fourth spawning run for a two-salt adult (/1SSS).
Two-salt, first spawning migrant	First spawning run after one autumn-winter period in freshwater as a half-pounder, and two subsequent years in ocean (/H1).
Two-salt, second spawning migrant	Second spawning run for a two-salt, first spawning migrant (/H1S).
Two-salt, third spawning migrant	Third spawning run for a two-salt, first spawning migrant (/H1SS).
Three-salt	First spawning run after three years in ocean (/2).

Kesner and Barnhart 1972), Oregon (ODFW 1986), Washington (Meigs and Pautzke 1941; Leider et al. 1986), and British Columbia (Withler 1966; Hooton et al. 1987). Variations in the life history patterns of steelhead may be a means of minimizing periodic affects of adverse environmental conditions by allocating production from a single brood year to a multitude of spawning years (Leider et al. 1986).

Abundance

Freshwater Return: Passage estimates of summer steelhead at Huntley Park averaged about 105,700 half-pounders and 24,600 late-run adults in 1976-91. Return estimates for half-pounders ranged between 33,005 fish and 233,401 fish (Table 10). Return estimates for late-run adults ranged between 4,201 fish and 41,378 fish (Table 10).

Estimates of freshwater returns for wild summer steelhead averaged 59,092 half-pounders and 19,065 late-run adults in 1976-91. Return estimates for wild half-pounders ranged between 18,576 fish and 146,556 fish (Table 10). Return estimates for wild late-run adults ranged between 3,181 fish and 33,992 fish (Table 10).

Table 10. Estimated number of summer steelhead that passed Huntley Park between 9 July and 28 October, 1976-91 return years.

Return year	Half-pounders			Adults			Total return
	Wild	Hatchery	Total	Wild	Hatchery	Total	
1976	26,402	6,603	33,005	8,096	2,460	10,556	43,561
1977	119,630	22,459	142,089	20,561	5,664	26,225	168,314
1978	52,611	40,980	93,591	28,166	2,830	30,996	124,587
1979	25,114	18,142	43,256	23,786	5,500	29,286	72,542
1980	68,808	102,516[a]	171,324	14,207	5,790[a]	19,997	191,321
1981	146,556	86,845	233,401	23,935	15,194	39,129	272,530
1982	49,043	68,123	117,166	28,867	11,074	39,941	157,107
1983	52,270	46,466	98,736	8,829	3,392	12,221	110,957
1984	52,163	16,827	68,990	15,328	2,774	18,102	87,092
1985	114,515	63,563	178,078	30,975	4,738	35,713	213,791
1986	92,668	78,668	171,336	33,992	7,386	41,378	212,714
1987[b]	60,073	105,022	165,095	29,338	8,330	37,668	202,763
1988	18,576	23,324	41,900	19,234	7,390	26,624	68,524
1989	23,246	29,895	53,141	13,241	4,259	17,500	70,641
1990	23,820	10,582	34,402	3,308	1,005	4,313	38,715
1991	19,962	25,452	45,414	3,181	1,020	4,201	49,615

[a] *Returns adjusted for age-2 smolts that returned as half-pounders > 41 cm.*
[b] *Returns estimated for 6 weeks without sampling.*

Estimates of freshwater returns for summer steelhead of hatchery origin averaged 46,592 half-pounders and 5,550 late-run adults in 1976-91. Return estimates for hatchery half-pounders ranged between 6,603 fish and 105,022 fish (Table 10). Return estimates for late-run adults of hatchery origin ranged between 2,460 fish and 15,194 fish (Table 10).

Years of large returns of wild half-pounders were generally followed by years of large returns of late-run adults of wild origin (Figure 8). We found that freshwater returns of late-run adults of hatchery origin were positively correlated ($r = 0.72$, $P = 0.002$) with freshwater returns of hatchery half-pounders in the previous year. We also found that freshwater returns of wild late-run adults were positively correlated ($r = 0.74$, $P = 0.001$) with returns of wild half-pounders in the previous year. Positive relationships between half-pounder returns and adult returns in the following year lends support to the conclusion that seine catches can be used to estimate, or at least index, returns of summer steelhead to the Rogue River. Data included in these analyses are in Table 10.

We estimated that freshwater returns of wild half-pounders averaged about 66,700 fish from the 1975-87 brood years and ranged between 21,250 fish and 110,583 fish (Appendix Table B-2). Freshwater returns of wild first spawning migrants averaged about 16,700 fish from the 1974-86 brood years and ranged between 7,239 fish and 25,581 fish (Appendix Table B-2). Freshwater returns of wild second spawning migrants averaged about 2,700 fish from the 1973-85 brood years and ranged between 1,152 fish and 6,372 fish (Appendix Table B-3). Freshwater returns of wild third spawning migrants averaged about 500 fish from the 1972-84 brood years and ranged between 70 fish and 1,403 fish (Appendix Table B-3).

We estimated that annual return rates of wild second spawning migrants averaged 22% and ranged between 8% and 40%. Annual return rates of wild third spawning migrants averaged 16% and ranged between 0% and 45%. Freshwater returns of wild first spawning migrants averaged 31% of the number of wild half-pounders that returned in the previous year. This index of return rate is not an estimate of survival rate because unknown numbers of half-pounders matured as early-run summer steelhead or winter steelhead.

We estimated that freshwater returns of wild half-pounders from the 1975-87 brood years were composed of an average of about 20,800 age-1 smolts, 43,200 age-2 smolts, 2,800 age-3 smolts (Appendix Table B-2). Analysis of variance indicated that mean returns of half-pounders differed significantly ($P < 0.001$) among wild fish that smolted at ages 1-3. A Newman-Keuls multiple range test indicated that the mean freshwater return was significantly greater ($P \leq 0.05$) for wild half-pounders that smolted at age-2 than for the mean freshwater returns of wild half-pounders that smolted at age-1 or age-3. The test also indicated that the mean freshwater return of wild age-1 half-pounders was significantly greater ($P \leq 0.05$) than the mean freshwater return of wild age-3 half-pounders.

We estimated that the freshwater returns of wild first spawning migrants from the 1974-86 brood years were composed of an average of about 6,800 age-1 smolts, 9,500 age-2 smolts, and 400 age-3 smolts (Appendix Table B-2). Analysis of variance indicated that mean returns of first spawning migrants differed significantly ($P < 0.001$) among wild fish that smolted at ages 1-3.

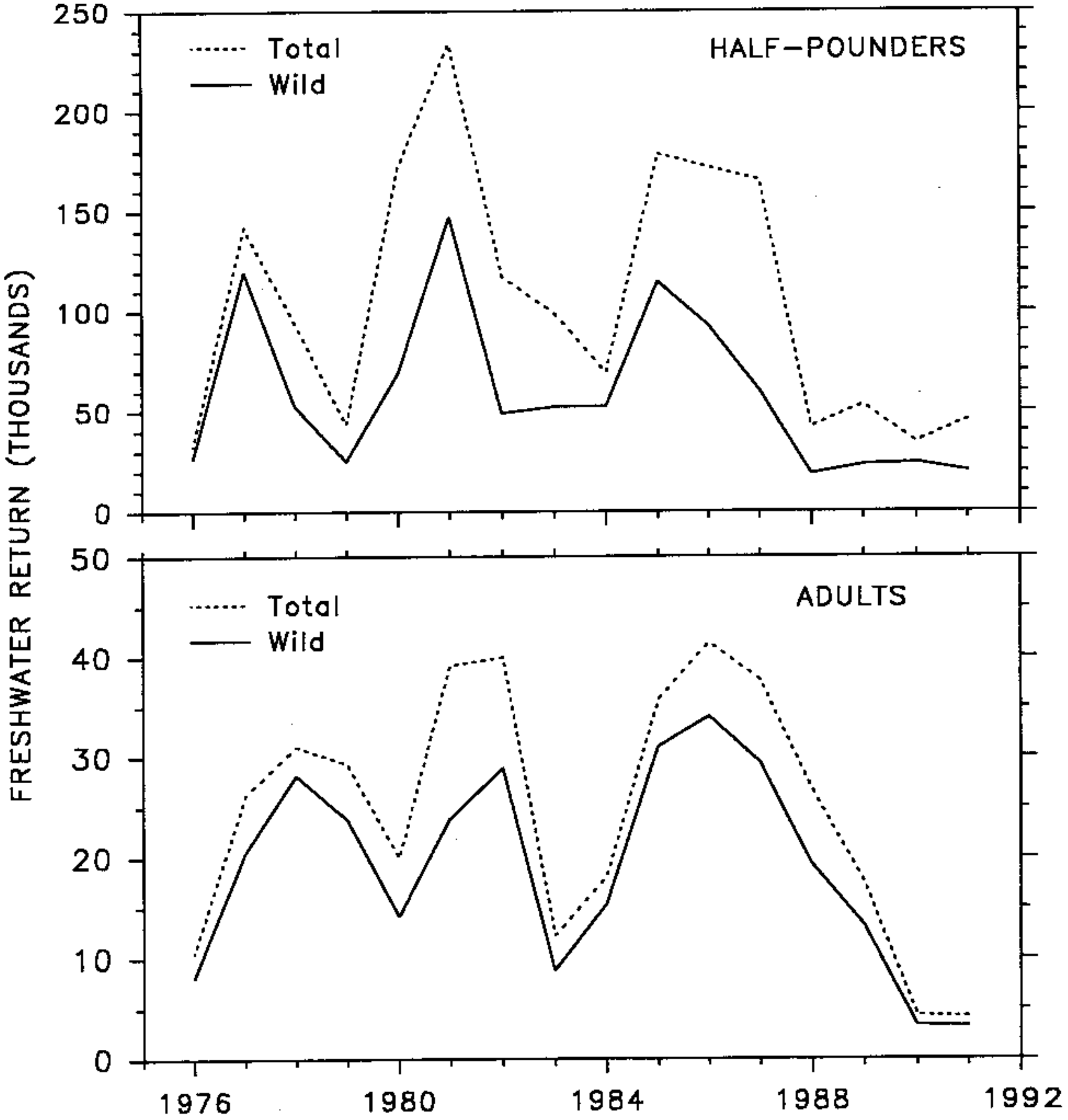

Figure 8. Estimated number of summer steelhead that passed Huntley Park from 9 July through 28 October, 1976-91 return years.

A Newman-Keuls multiple range test indicated that mean freshwater returns were significantly greater ($P \leq 0.05$) for wild first spawning migrants that smolted at ages 1 and 2 compared with freshwater returns of wild first spawning migrants that smolted at age-3. The test also indicated that mean freshwater return did not differ significantly ($P \leq 0.05$) between wild first spawning migrants that smolted at age-2 compared with wild first spawning migrants that smolted at age-1.

Year class strength of brood years for wild summer steelhead could not be estimated from the freshwater return of a single age class. Freshwater returns of wild half-pounders that smolted at age-1 were not significantly correlated with freshwater returns of cohorts that smolted at either age-2 ($r = -0.02$, $P = 0.942$) or age-3 ($r = -0.25$, $P = 0.405$). Also, freshwater returns of wild half-pounders that smolted at age-2 were not significantly correlated with freshwater returns of cohorts that smolted at age-3 ($r = 0.29$, $P = 0.339$). The lack of correlations indicated that smolt age composition differed among brood years or that ocean survival rates differed among years.

Analyses of data from wild first spawning migrants produced the same results. Freshwater returns were not significantly correlated among cohorts that smolted at different ages (all $P > 0.450$). This finding indicated that age at smolting varied between years or that survival rates varied between the life history stages of smolts and half-pounders (*see* **Determinants of Abundance:**, page 43).

Return to Gold Ray Dam: Total return of summer steelhead to the upper river increased after operation of Lost Creek Dam. Passage estimates at Gold Ray Dam averaged 8,231 fish in 1969-80 and 12,739 fish in 1981-91. The difference in means was significant ($P = 0.052$). We excluded 1942-68 data from the analysis because returns decreased during that period (Figure 9) for some unknown reason. Data included in the analyses of returns of summer steelhead to Gold Ray Dam are in Appendix Tables B-4 and B-5.

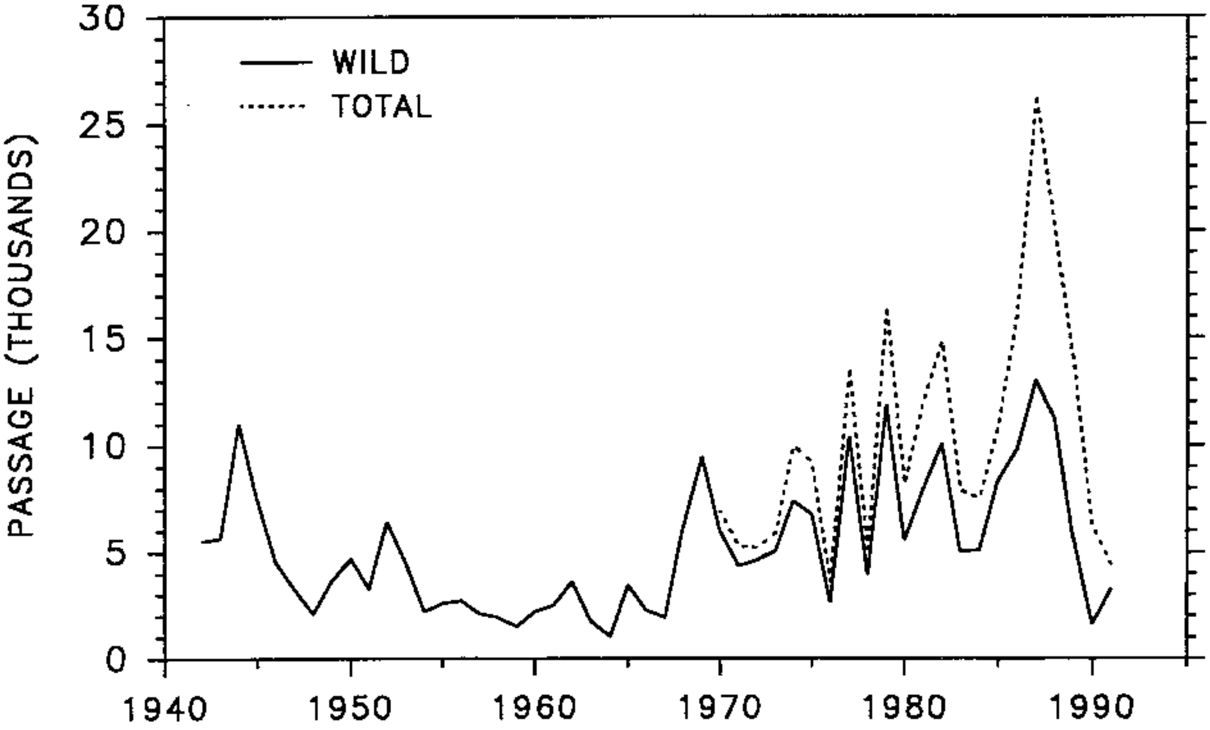

Figure 9. Estimated number of summer steelhead that passed Gold Ray Dam, 1942-91 return years.

Increased returns of hatchery fish (Figure 10) accounted for most of the increase in returns of summer steelhead to Gold Ray Dam. Passage estimates of hatchery fish averaged 1,888 fish in 1970-80 and 5,377 fish in 1981-91. The difference in means was significant at $P = 0.006$. Increased releases of hatchery fish to mitigate for blockage of spawning habitat were responsible for the increased return of hatchery fish (Appendix Tables B-6 and B-7).

In contrast to hatchery fish, returns of wild fish were variable after 1969 and did not exhibit any consistent trend in abundance through time with the exception of 1942-68 (Figure 10). We found no change in the return of wild summer steelhead to Gold Ray Dam. Passage estimates for wild summer steelhead averaged 6,500 fish in 1969-80 and 6,998 fish in 1983-91. The means did not differ significantly ($P = 0.732$). This finding suggested that the operation of Lost Creek Dam did not have a measurable affect on the production of wild summer steelhead in the Rogue River upstream of Gold Ray Dam. We excluded 1981-82 data from the analysis because these returns were a composite of preimpoundment and postimpoundment broods.

Increased return of early-run fish accounted for a portion of the increased return of all summer steelhead at Gold Ray Dam. Passage estimates of early-run summer steelhead averaged 2,265 fish in 1969-80 and 6,565 fish in 1981-91. The difference in means was significant at $P = 0.001$.

Hatchery fish accounted for most of the increase in returns of early-run summer steelhead to Gold Ray Dam (Figure 10). Passage estimates of early-run hatchery fish averaged 610 fish in 1970-80 and 3,849 fish in 1981-91. The difference in means was significant at $P = 0.001$. Increased releases of hatchery fish and changes in spawning practices at Cole M. Rivers Hatchery (*see* **Run Composition**, page 50) increased returns of early-run summer steelhead of hatchery origin.

Returns of wild early-run summer steelhead also increased in the upper river after operation of Lost Creek Dam. Passage estimates of early-run wild fish averaged 1,706 fish in 1970-80 and 2,649 fish in 1983-91. The difference in means was significant at $P = 0.058$. This finding does not necessarily mean that operation of Lost Creek Dam increased the production of wild summer steelhead in the upper river. Improvements in water quality resulted in an earlier time of passage at Gold Ray Dam, causing more summer steelhead to be classified as the early-run variety (*see* **Migration Timing**, page 55).

We did not detect a change in the total return of late-run summer steelhead to the upper river after operation of Lost Creek Dam. Passage estimates at Gold Ray Dam averaged 5,966 fish in 1969-80 and 6,174 fish in 1981-91. The difference in mean return was not significant ($P = 0.888$). We did not detect any significant changes in the mean return of wild fish ($P = 0.714$) or the mean return of hatchery fish ($P = 0.571$). Passage estimates of late-run wild fish averaged 4,794 fish in 1970-80 and 4,349 fish in 1983-91. Passage estimates of late-run hatchery fish averaged 1,278 fish in 1970-80 and 1,528 fish in 1983-91.

Comparison of returns of wild summer steelhead to Gold Ray Dam and to Winchester Dam on the North Umpqua River also suggested that the operation of Lost Creek Dam did not significantly affect production of wild summer

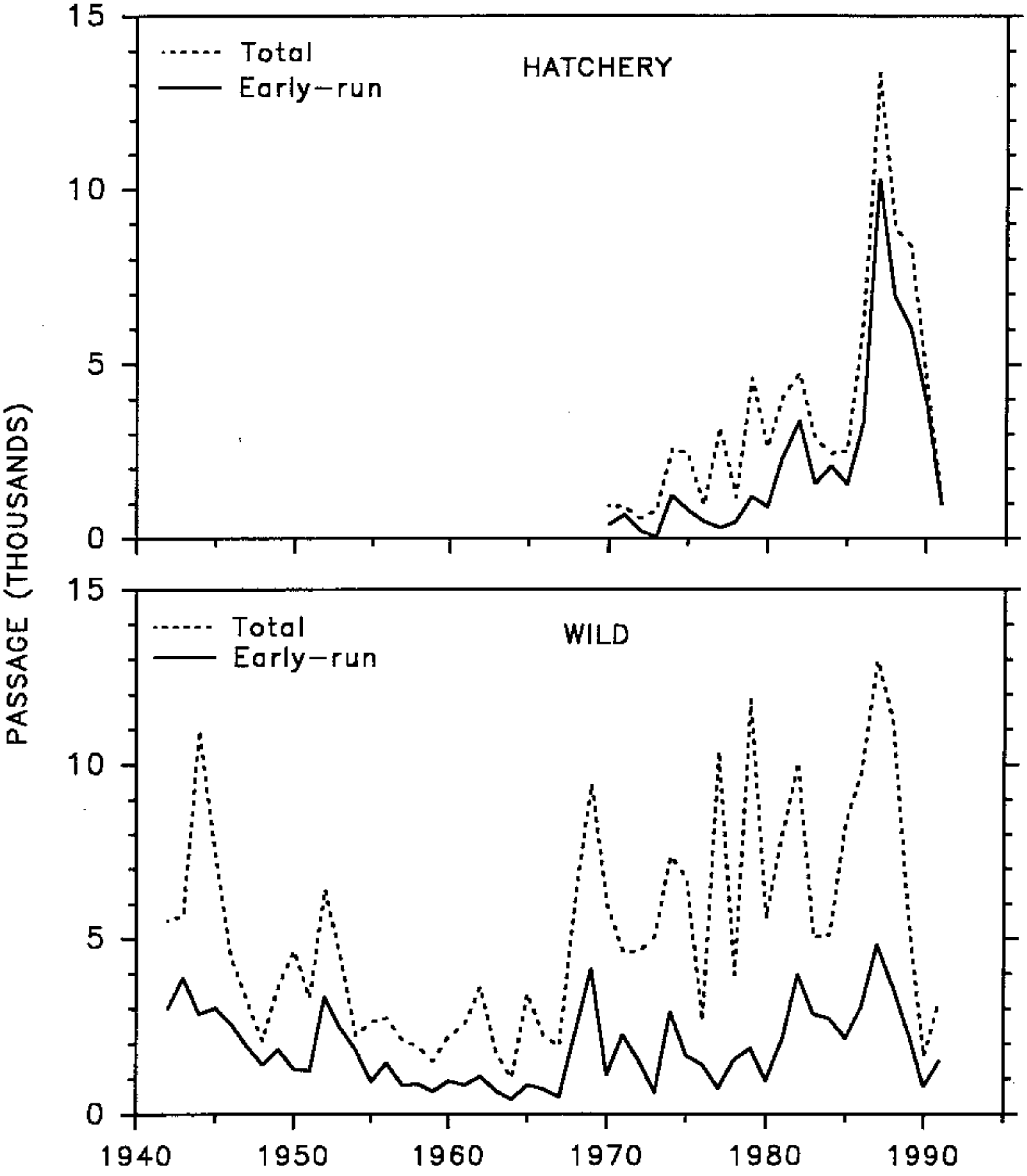

Figure 10. Estimated number of wild and hatchery summer steelhead that passed Gold Ray Dam, 1942-91 return years.

steelhead in the Rogue River. Because annual estimates of age composition were not available for either run, we assumed wild fish in both rivers passed the counting stations in their fourth year of life. We excluded the 1942-68 data from the analysis because the relative abundance of Rogue fish decreased during that period (Figure 11). Data for the North Umpqua River was reported by Anderson et al. (1986).

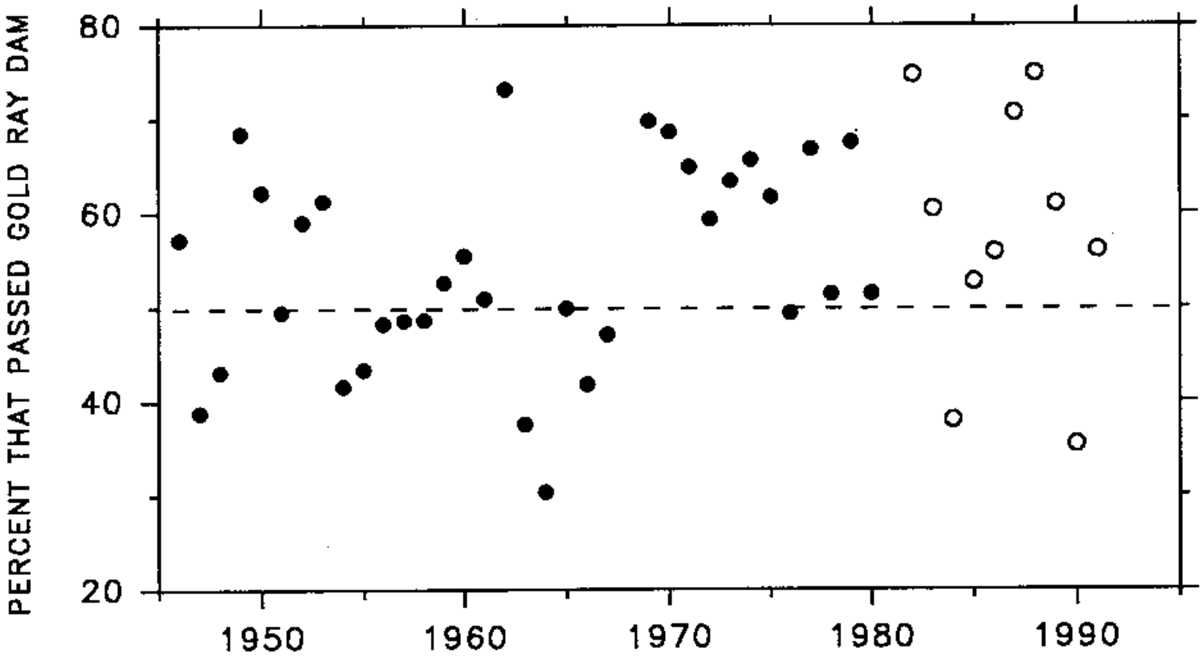

Figure 11. Percentage of fish that passed Gold Ray Dam among returns of wild summer steelhead that passed Gold Ray Dam and Winchester Dam on the North Umpqua River. Dashed line represents equal returns to both rivers. Closed and open circles represent brood years produced before and after the operation of Lost Creek Dam.

The Rogue River component averaged 62% of the returns in 1969-80 and 56% of the returns in 1983-91. Returns from 1969-80 represent juveniles produced before operation of Lost Creek Dam and returns from 1983-91 represent juveniles produced after operation of Lost Creek Dam. An analysis of variance indicated that the means did not differ significantly (*P* = 0.234). The lack of a difference was not attributable to highly variable data. With this analysis, we had a good chance of detecting a change in the abundance of wild summer steelhead in the upper Rogue River.

A sensitivity analysis indicated that to have an 80% chance of detecting a change significant at the 95% confidence level, Rogue River fish needed to increase to 74% or decrease to 48% of the total return of wild summer steelhead to both rivers in years when postimpoundment broods dominated the returns. Because we did not detect a change, we concluded that the operation of Lost Creek Dam had no major effect on the abundance of wild summer steelhead produced in areas upstream of Gold Ray Dam.

We did not attempt to develop a stock-recruitment relationship for wild summer steelhead that inhabit the Rogue River upstream of Gold Ray Dam. We lacked the necessary age data to assign adults to their respective broods. Analyses of scales taken from wild summer steelhead seined at Huntley Park showed that smolt age and adult age varied greatly among years (*see* **Life History**, page 32 and **Age at Ocean Entry**, page 98). We also chose not to attempt to identify environmental factors responsible for variations in returns of wild summer steelhead to Gold Ray Dam because we lacked the age data necessary to estimate returns by brood year.

Annual returns of wild late-run summer steelhead to Gold Ray Dam were correlated (*r* = 0.68, *P* = 0.004) with annual estimates of the number of wild late-run adult summer steelhead that passed Huntley Park. The positive relationship between abundance estimates of late-run wild adults at Huntley Park and Gold Ray Dam lends support to the conclusion that seine catches can be used to estimate, or at least index, freshwater returns of summer steelhead to the Rogue River.

Annual counts of summer steelhead redds in Foots Creek and Kane Creek during 1977-91 by the fish management staff of ODFW were not significantly correlated with passage estimates of wild late-run adults at Huntley Park (*r* = 0.24, *P* = 0.394) or passage estimates of wild late-run adults at Gold Ray Dam (*r* = 0.32, *P* = 0.225). The significant relationship between passage estimates at Huntley Park and Gold Ray Dam indicate that these indicators better represent the freshwater abundance of wild late-run summer steelhead compared with redd counts in Kane Creek and Foots Creek. Data on redd counts was received from Jerry MacLeod, ODFW, Central Point, on 5 November 1992.

Return to Cole M. Rivers Hatchery: Annual returns of summer steelhead of hatchery origin averaged 4,162 fish and ranged between 866 fish and 10,451 fish (Appendix Table B-8). Annual returns of early-run hatchery fish averaged 1,332 fish and ranged between 93 fish and 3,408 fish (Appendix Table B-8). Annual returns of late-run hatchery fish averaged 2,830 fish and ranged between 612 fish and 7,043 fish (Appendix Table B-8). Early-run fish increased in abundance relative to late-run fish because of a change in spawning practices (*see* **Run Composition**, page 50).

Annual returns of summer steelhead of hatchery origin to Cole M. Rivers Hatchery were correlated (*r* = 0.84, *P* < 0.001) with passage estimates of hatchery fish at Gold Ray Dam. Returns of early-run hatchery fish to Cole M. Rivers Hatchery were also correlated (*r* = 0.92, *P* < 0.001) with passage estimates of early-run hatchery fish at Gold Ray Dam. We also found that returns of late-run summer steelhead of hatchery origin to Cole M. Rivers Hatchery were correlated (*r* = 0.63, *P* < 0.001) with passage estimates of late-run hatchery fish at Gold Ray Dam.

A comparison of passage estimates at Gold Ray Dam and hatchery returns for early-run and late-run fish indicated that the correlation coefficients differed significantly (Z = 2.21, *P* < 0.05). The correlation coefficient was lower for late-run fish mostly because passage estimates of late-run hatchery fish at Gold Ray Dam in 1981 and 1982 were about 4,000 fish less than the number that returned to the hatchery.

It may have been difficult to identify fin clips among hatchery fish and count returning adults during those years because flow and turbidity was above average when late-run adults returned in 1981-82. There was no indication that summer steelhead passed Gold Ray Dam late enough to be classified as winter steelhead. The differences in returns of hatchery winter steelhead to Gold Ray Dam and Cole Rivers Hatchery ranged from 11 to 429 fish in those return years (ODFW 1990).

We also found that estimated returns of late-run adult summer steelhead of hatchery origin to Huntley Park were correlated (r = 0.84) with the number of late-run summer steelhead that subsequently returned to Cole M. Rivers Hatchery (Figure 12). Based on this finding, we concluded that estimation of freshwater returns derived from seining at Huntley Park was a reasonable method to estimate the abundance of summer steelhead that return to the Rogue River. Determination of the accuracy of abundance estimates derived from seine catches will require an independent method of estimating freshwater returns.

Return rates to Cole M. Rivers Hatchery of first spawning adults among marked fish from the 1973-88 brood years averaged 1.6% and ranged between 0.7% and 3.9%. Return rates of early-run adults to Cole M. Rivers Hatchery were greater than return rates of late-run adults. Progeny of early-run and late-run adults were released at comparable sizes in five years. Return rates of spawning migrants averaged 1.6% for the progeny of early-run adults and 1.3% for the progeny of late-run adults (Appendix Table B-9). A paired t-test with arcsin transformed data indicated there was a significant difference in return rates ($P = 0.091$) although the small sample size ($n = 5$) limited the power of the analysis. The greater harvest rate of late-run adults probably accounted for the difference in return rates.

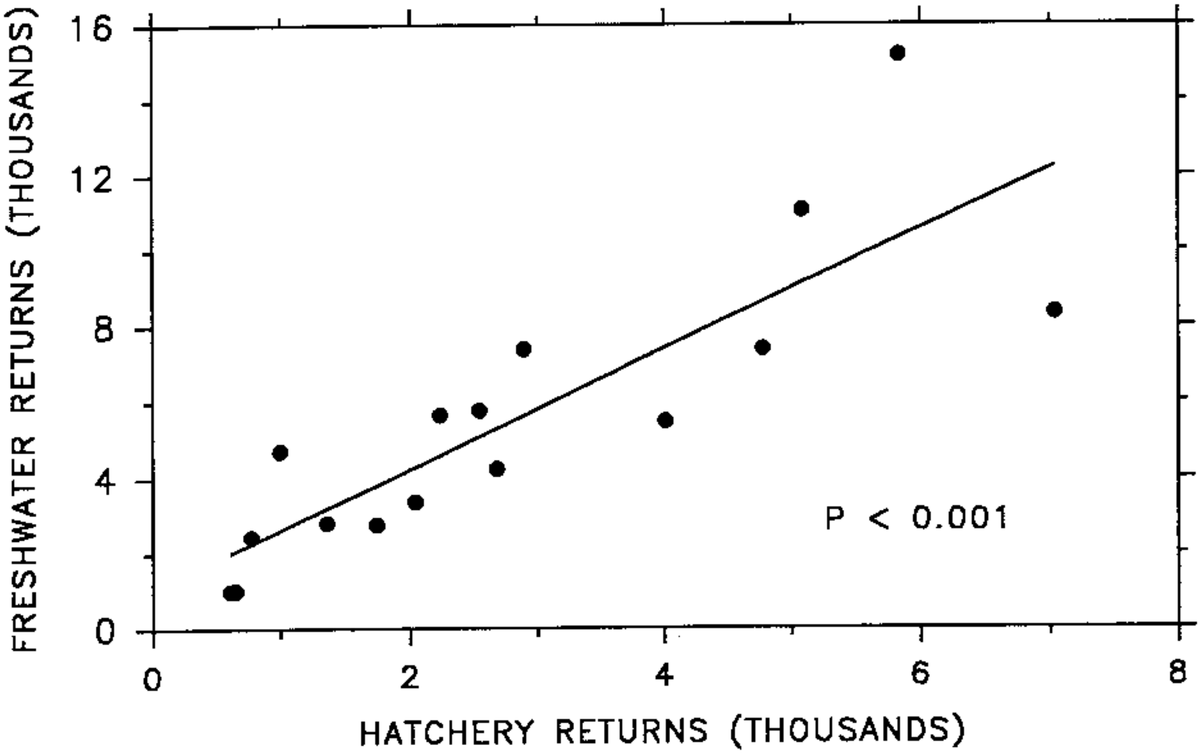

Figure 12. Relationship between estimates of late-run adult summer steelhead of hatchery origin that passed Huntley Park and returned to Cole M. Rivers Hatchery, 1976-91 return years.

Determinants of Abundance: We were unable to identify the primary factors that affected the number of wild half-pounders that returned to the Rogue River in 1976-91. Annual returns of wild half-pounders were not significantly related to any of the independent variables that we examined

(Appendix Table B-10). Independent variables examined in the correlation and regression analyses included (1) mean length of wild half-pounders at river entry, (2) the percentage of age-1 smolts among wild half-pounders, (3) mean flow at Grants Pass in the previous summer, (4) mean flow at Grants Pass when smolts migrated to the ocean, (5) ocean upwelling in spring, and (6) ocean temperature in spring (Appendix Table B-11). These six factors were selected for analysis because possible effects would have occurred proximal to the time half-pounders returned to the Rogue River. Similar analysis of smolt-to-adult survival rates of hatchery summer steelhead in the Deschutes River, Oregon, also failed to detect significant correlations with physical parameters of the ocean and fresh water (personal communication dated 23 March 1993 from Robert Lindsay, ODFW, Corvallis)

Analyses of freshwater returns from completed brood years allowed for the examination of factors that may have affected production of wild juvenile summer steelhead at the earliest stages of their life history. We found that brood year returns of wild half-pounders were significantly related to flow of a small tributary in spring when subyearling summer steelhead migrated to the Rogue River (Appendix Table B-12). This finding suggested that production increased in years when small tributaries of the Rogue River flowed at greater rates. Greater flow in tributaries may increase the amount of habitat available to rear fry, may result in fewer fry being stranded when tributaries become intermittent, or may cause fewer fry to be lost in irrigation diversions.

Residual variation from the relationship of half-pounder broods and tributary flow during fry migration was not significantly related to other independent variables examined in the analysis. Other independent variables included (1) freshwater returns of wild parents, (2) flow in Grave Creek when parents entered and spawned in tributary streams, (3) water temperature of the Rogue River when fry reared in the mainstem, and (4) smolt age composition of cohorts that returned as half-pounders (Appendix Table B-13). Also, none of these factors were significantly correlated with brood year returns of wild half-pounders (Appendix Table B-12).

Freshwater returns of wild late-run adult summer steelhead appeared to be affected by freshwater returns of cohorts in the previous year and the intensity of peak flows when half-pounders inhabited the Rogue River. We found that freshwater returns of first spawning migrants were positively related (r = 0.73) to returns of half-pounders one year earlier (Figure 13). Residual variation from this relationship was negatively related (r = -0.56) to peak flow of the Rogue River in winter when half-pounders inhabited fresh water (Figure 13). Regression analysis indicated that the abundance of half-pounders and peak flow accounted for 68% of the variability in the freshwater returns of wild first spawning migrants during the succeeding year (Appendix Table B-14).

We also found that freshwater returns of second spawning migrants were positively related (r = 0.55) to returns of first spawning migrants one year earlier (Figure 14). Residual variation from this relationship was negatively related (r = -0.63) to peak flow of the Rogue River during winter when first spawning migrants migrated into spawning tributaries (Figure 14). Regression analysis indicated that the abundance of first spawning migrants and peak flow accounted for 60% of the variability in the freshwater returns of wild second spawning migrants during the succeeding year (Appendix Table B-15).

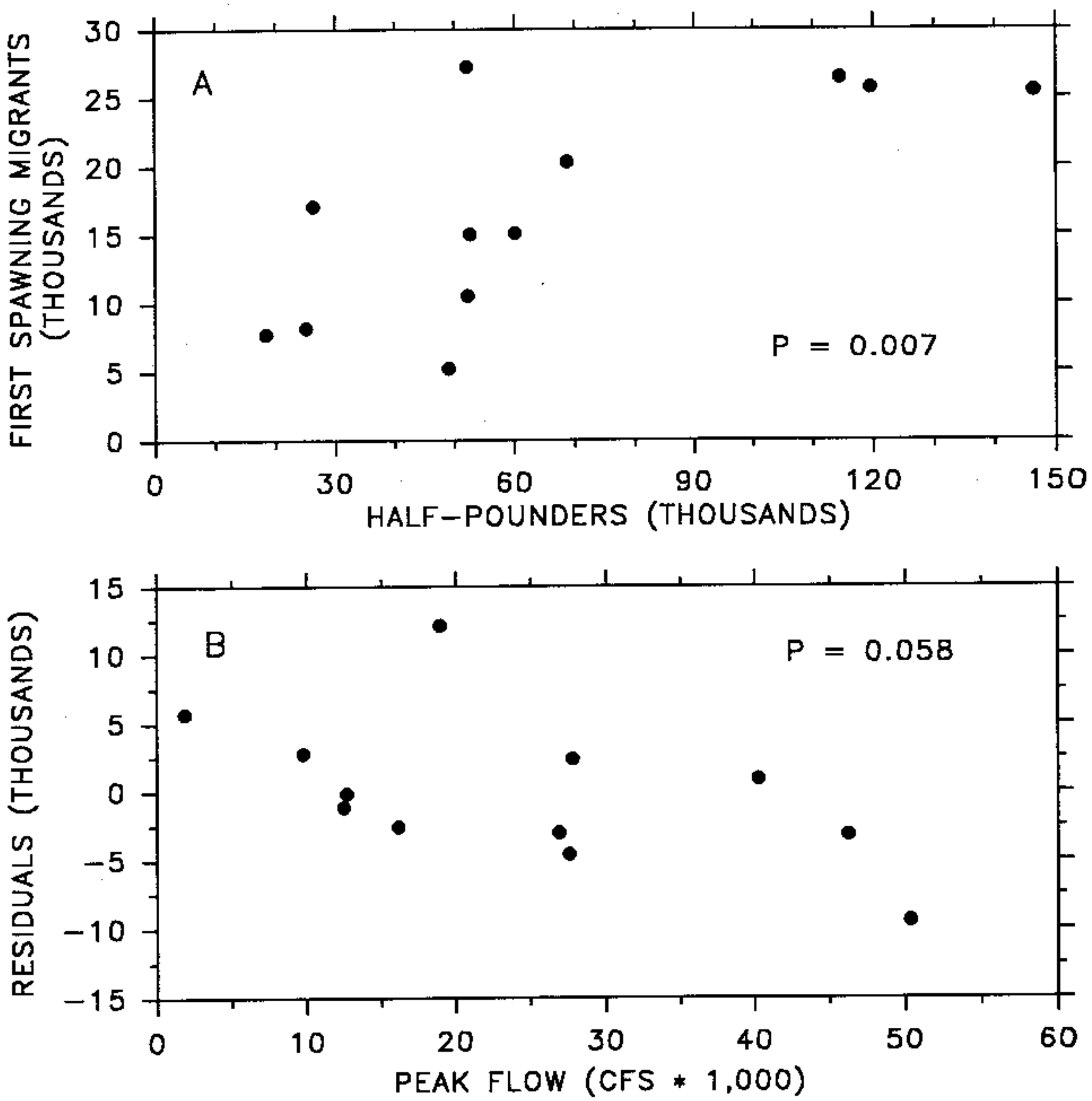

Figure 13. Relationship between the estimated freshwater returns of wild late-run first spawning migrants and wild half-pounders in the previous year (A), and the residual variation from relationship (A) and peak flow at Grants Pass when half-pounders inhabited fresh water (B), 1976-91 return years.

We also found that freshwater returns of third spawning migrants were positively related (*r* = 0.83) to returns of second spawning migrants one year earlier (Figure 15). Residual variation from this relationship was negatively related (*r* = -0.73) to peak flow of the Rogue River during winter when second spawning migrants migrated into spawning tributaries (Figure 15). Regression analysis indicated that the abundance of second spawning migrants and peak flow accounted for 82% of the variability in the freshwater returns of wild third spawning migrants during the succeeding year (Appendix Table B-16).

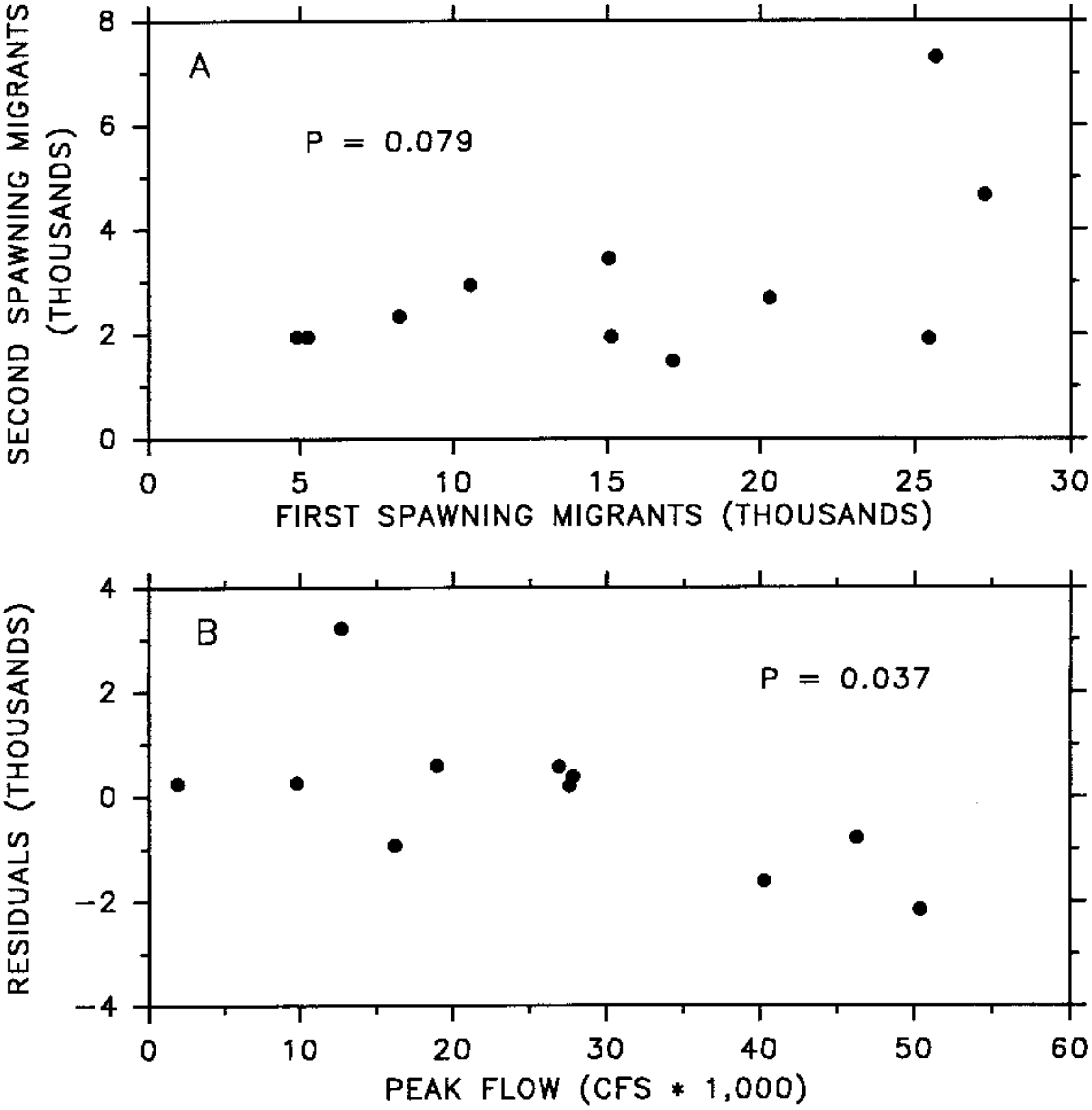

Figure 14. Relationship between the estimated freshwater returns of wild late-run second spawning migrants and wild first spawning migrants in the previous year (A), and the residual variation from relationship (A) and peak flow at Grants Pass when first spawning migrants inhabited fresh water (B), 1976-91 return years.

These findings suggested that cohort abundance in the previous year and peak flow in the Rogue River may be primary determiners of the abundance of wild late-run adult summer steelhead. The finding that adult returns are related to cohort returns in the previous year has also been found for summer steelhead in the Deschutes River (personal communication dated 23 March 1993 from Robert Lindsay, ODFW, Corvallis). However, we remain unsure how peak flow affects the survival of half-pounders and adults in the Rogue River.

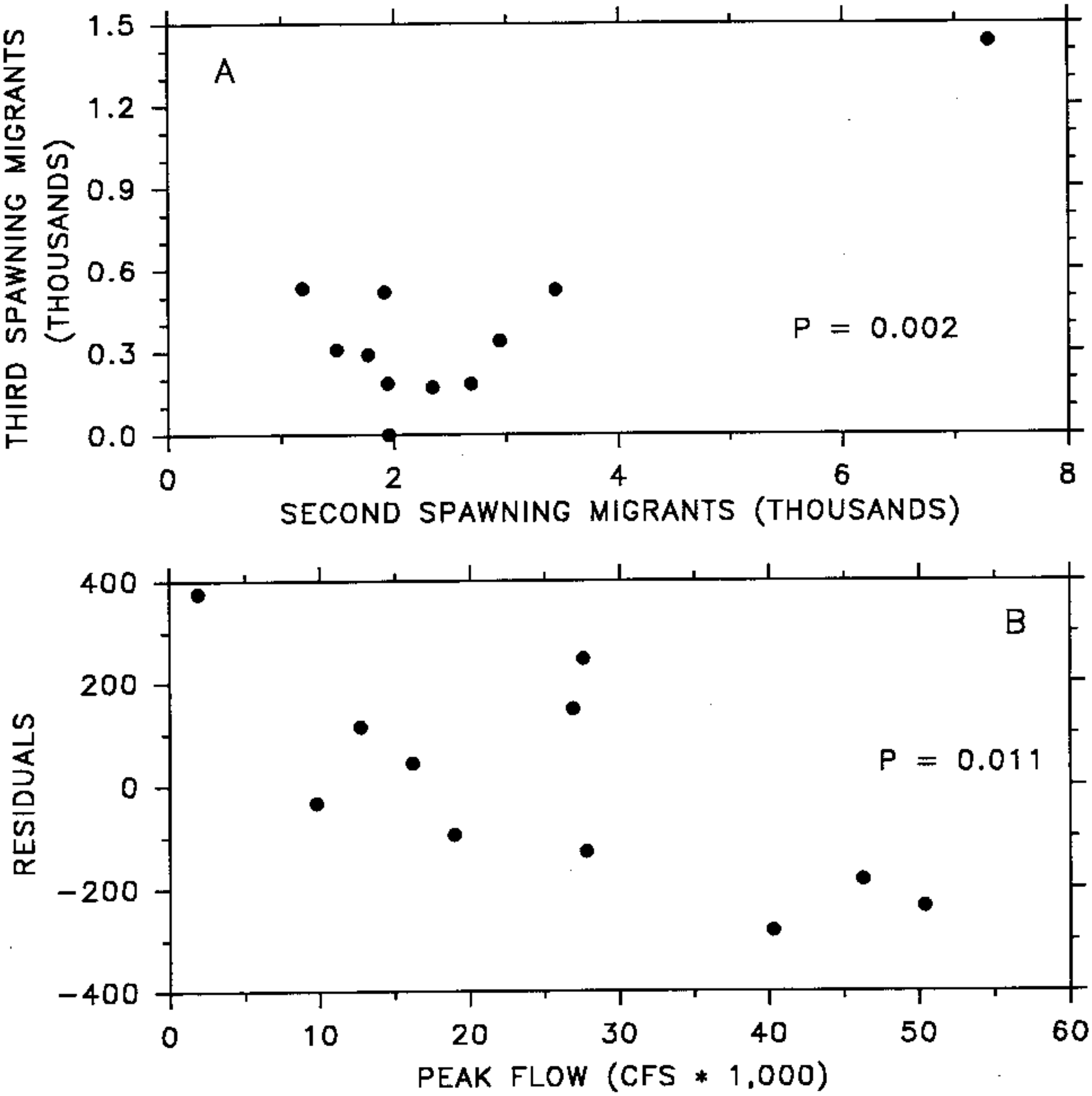

Figure 15. Relationship between the estimated freshwater returns of wild late-run third spawning migrants and wild second spawning migrants in the previous year (A), and the residual variation from relationship (A) and peak flow at Grants Pass when second spawning migrants inhabited fresh water (B), 1976-91 return years.

Peak flow in the Rogue River was significantly related to other independent variables examined in the regression analyses. We found that peak flow was significantly correlated with (1) mean flow of the Rogue River in November-January when anglers fished the middle river for summer steelhead, (2) mean flow of Grave Creek in January-March when adult summer steelhead spawned in tributary streams, and (3) mean flow of the Rogue River when spawned adults migrated downstream to the ocean (Appendix Table B-17).

Intercorrelation among the independent variables made it less certain that peak flows directly influenced the survival of summer steelhead.

However, because peak flow was related to the subsequent return of first spawning migrants, and half-pounders are mostly immature fish that do not enter tributary streams (Everest 1973), we concluded that the deleterious effect of increased flow in winter on steelhead survival probably occurs in the mainstem rather than in tributary streams. Also, because angler effort for summer steelhead in the middle river decreased as river flow increased (*see* **Angler Effort**, page 82), increased flows should have decreased fishing mortality and increased subsequent returns of adults. However, we found that increases in peak flows were associated with decreases in subsequent returns of adult summer steelhead.

Everest (1973) documented that some juvenile steelhead leave the Rogue River and enter tributary streams in winter. This behavioral pattern may have developed as a mechanism to avoid the deleterious effects of peak flows. Presumably, half-pounders could also enter tributary streams to avoid freshets, but Everest (1973) only observed mature half-pounders among summer steelhead collected in tributary streams. Lack of movement from the Rogue River may suggest that freshets do not significantly affect survival rates of summer steelhead during freshwater residence.

Assuming that the relationship between peak flows and subsequent returns is causative, we used the regressions to estimate the effect of Lost Creek Dam on the abundance of adult summer steelhead that returned in 1978-86. We used estimates of peak flows at Grants Pass under natural and regulated conditions (*see* Table 8, page 29) to estimate the change in steelhead returns that resulted from reservoir operation in 1978-86. The regressions predicted that mean returns of summer steelhead increased by 1,831 (95% CI = ± 797) first spawning migrants, 496 (95% CI = ± 216) second spawning migrants, and 63 (95% CI = ± 27) third spawning migrants. The mean increases in survival rates were estimated as 12% for first spawning migrants, 20% for second spawning migrants, and 17% for third spawning migrants. Data included in the analyses of freshwater returns of wild late-run adult summer steelhead are in Appendix Table B-18.

We were unable to detect the effects of variations in freshwater conditions on returns of wild half-pounders to the Rogue River. Variations in ocean survival rates and smolt age composition prevented estimation of cohort numbers when smolts entered the ocean (Ward et al. 1989). A review of the literature indicated that smolt abundance affects returns of adult steelhead. Ward and Slaney (1988) found that return of winter steelhead to the Keogh River in British Columbia was directly related to smolt production ($r^2 = 0.86$), and smolt size accounted for much of the residual variation. Beecher (1980) concluded that summer flow when yearlings reared in fresh water was a primary determiner of the number of adult steelhead in streams of western Washington.

Gibbons et al. (1985) developed a spawner-recruit model for steelhead inhabiting Washington streams. Difference in adult production between basins was accounted for by the amount of habitat available to rear yearlings. Errors in predictions associated with winter steelhead returns to 6 rivers averaged 12% and 16% for adults that returned during the 1986-87 and 1987-88 run years, respectively (Gibbons 1988a, 1988b). Although this does not necessarily validate the model, the relatively small amount of error in predictions may indicate that the habitat capability for yearling production is an important determiner of adult production. Because we judged that the operation of Lost Creek Dam had a minimal effect on juvenile production (*see* **Abundance**, page 103), we judged the effects on adult production were minimal.

However, operation of Lost Creek Dam may have affected the age of ocean entry of juvenile summer steelhead (*see* **Age at Ocean Entry**, page 98). While the production of younger smolts would likely increase the number of smolts that enter the ocean, returns of half-pounders would not necessarily increase. Ward and Slaney (1988) found that smolt size and survival rate were positively related for winter steelhead in the Keogh River, British Columbia. Ward et al. (1989) estimated that the survival rate of 14 cm smolts from the Keogh River was only 12% of the survival rate for 20 cm smolts. Everest (1973) estimated that the survival rate of hatchery smolts was 7 times greater for fish released at 5 per pound compared with fish released at 8 per pound.

These findings suggest that attempts to use release strategies at Lost Creek Dam to increase the growth rate of juvenile steelhead to decrease the age at ocean entry should be reconsidered. Cramer et al. (1985) recommended that outflow temperatures be increased to a maximum of 13^{o}C from March through May to increase the proportion of steelhead that smolt at age-1. Because younger smolts are smaller at ocean entry, and smaller smolts survive at lower rates, a younger age at ocean entry may decrease freshwater returns of half-pounders. Consequently, we recommend no increase in outflow temperatures from Lost Creek Dam in spring.

In contrast to wild fish, we found that ocean conditions, rather than freshwater conditions, appeared to be important determiners of abundance for summer steelhead of hatchery origin. Return rates of hatchery half-pounders to fresh water averaged 12.4% annually during 1976-91 and ranged between 2.8% and 28.4%. We found that annual return rates of hatchery half-pounders were significantly related with average ocean temperature in summer (Appendix Table B-19). Return rates tended to be greater in years when ocean temperature was relatively warm in summer.

However, ocean temperature accounted for only 27% of the variability in return rates of hatchery half-pounders. Residual variation from this relationship was not significantly related to juvenile size at release or river flow when smolts migrated to the ocean. Data included in this analysis are in Appendix Table B-20. A correlation matrix that outlines relationships among all variables examined in the analysis is in Appendix Table B-19.

Analysis of return rates of first spawning migrants to Cole M. Rivers Hatchery failed to detect a significant relationship between return rates and ocean temperature. Return rates of first spawning migrants were not significantly related to size at release, flow during downstream migration, or ocean conditions (upwelling and surface temperature) during spring. Data included in this analysis are in Appendix Table B-21. A correlation matrix that outlines relationships among variables examined in this analysis is in Appendix Table B-22.

Analyses of return rates suggested that ocean factors may be primary determinants of survival rates for juvenile steelhead released from Cole M.

Rivers Hatchery. We analyzed indexes of ocean physical factors that may not represent ocean habitat used by immature summer steelhead of Rogue River origin. Patterns of ocean currents, and how those currents affect biological communities, are poorly understood for offshore areas of northern California and southern Oregon (Bottom et al. 1989). To determine the factors that affect the survival rates of Rogue River steelhead, additional research is needed to determine the ocean distribution of juvenile steelhead, structure of biological communities within areas inhabited by steelhead, and how those communities are affected by variations in physical parameters.

Run Composition

Hatchery fish composed an average of 43% (95% CI = ±8%) of the half-pounders and 22% (95% CI = ±4%) of the late-run adult summer steelhead that returned to fresh water annually in 1975-91. We concluded that hatchery fish were relatively more abundant among half-pounders because winter steelhead of hatchery origin were more likely to make a half-pounder run than were wild counterparts. Scales taken from wild winter steelhead electrofished in the lower river from 1977-78 through 1980-81 indicated that an average of 31% previously returned as half-pounders (ODFW 1990). Among hatchery fish, about 75% previously returned as half-pounders (Evenson et al. 1982).

The percentage of hatchery fish among half-pounders at river entry increased from 16% in 1977 to 60% in 1980. Increased releases of hatchery smolts in the Rogue and Applegate rivers were likely responsible for the increase. In 1981-91, the percentage of hatchery fish among half-pounders varied between 24% and 64% annually, with no consistent trend through time (Figure 16).

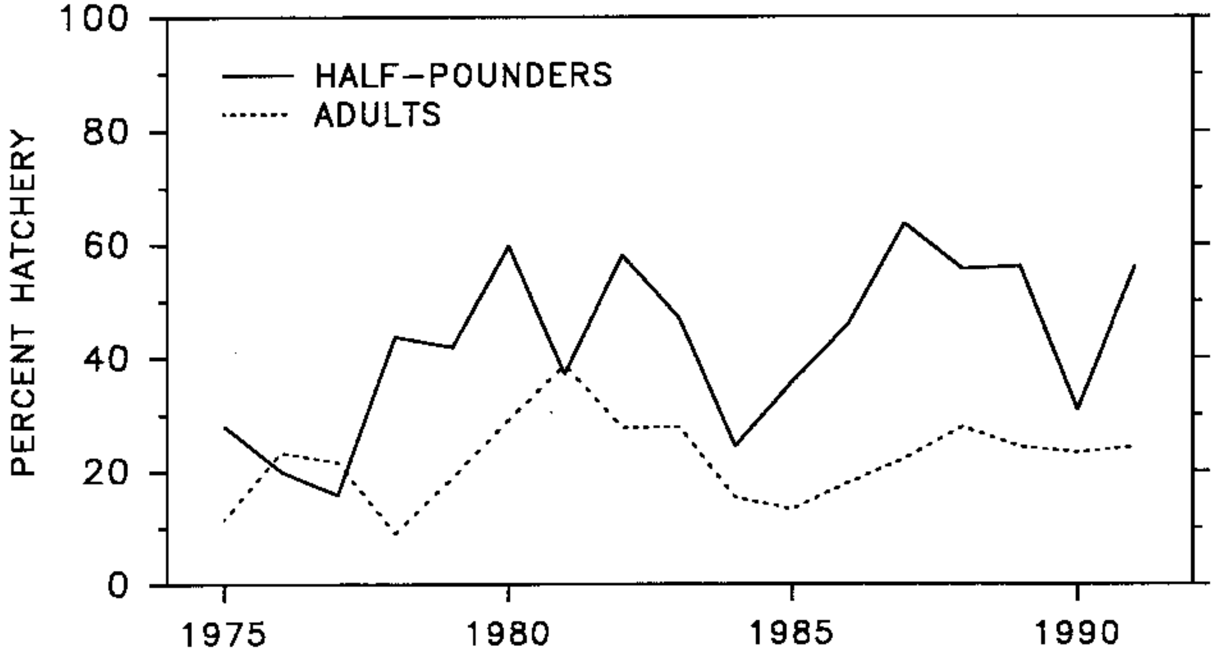

Figure 16. Composition of summer steelhead that returned to the Rogue River from 9 July through 28 October, 1975-91 return years.

The percentage of hatchery fish among late-run adult summer steelhead at river entry increased from 9% in 1978 to 39% in 1981. This increase tracked with the increase in hatchery fish among half-pounders that returned in 1977-80. In 1982-91, the percentage of hatchery fish among late-run adults varied between 13% and 28% annually. As with half-pounders, there was no consistent trend in the percentage of hatchery fish in later years (Figure 16). Lack of change in the relative abundance of hatchery fish among mature late-run summer steelhead suggested that returns of wild and hatchery fish were affected by the same environmental factors.

In the upper river, hatchery fish composed an average of 31% (95% CI = ±7%) of the summer steelhead that passed Gold Ray Dam annually in 1970-91. Hatchery fish composed a greater percentage of early-run fish compared with late-run fish. We estimated that hatchery fish averaged 41% (95% CI = ±9%) of the early-run fish, and 22% (95% CI = ±4%) of the late-run fish, that passed Gold Ray Dam in 1970-91.

Differences in the percentage of hatchery fish among early-run and late-run fish that passed Gold Ray Dam increased after spawning practices were modified to include more early-run fish within the broodstock of summer steelhead at Cole M. Rivers Hatchery. These fish began to return as adults in 1981 (Evenson et al. 1982). Consequently, the relative abundance of hatchery fish among early-run adults that returned to the upper river increased through time (Figure 17). In contrast, the percentage of hatchery fish among late-run adults did not increase in 1975-91 (Figure 17).

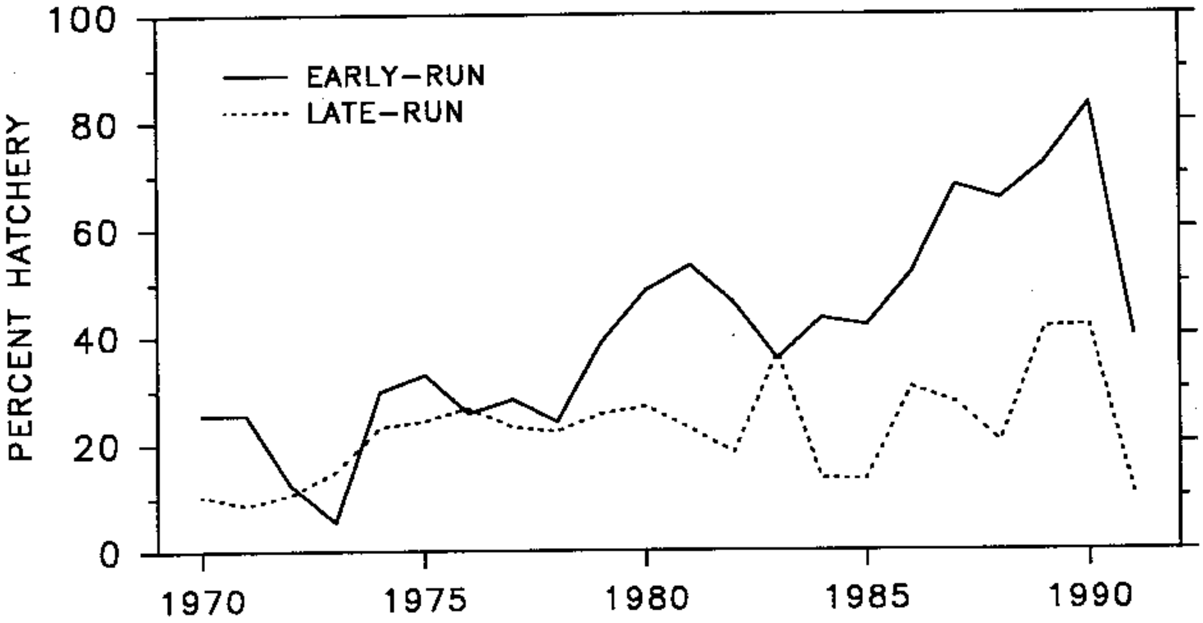

Figure 17. Composition of summer steelhead that passed Gold Ray Dam, 1975-91 return years.

A comparison of the composition of late-run adults that passed Huntley Park and Gold Ray Dam suggested that few wild summer steelhead spawned in areas downstream of Gold Ray Dam. A paired t-test indicated that the percentage of hatchery fish among late-run adults that passed both sampling locations did not differ significantly (*P* = 0.267). Hatchery fish should have been more abundant among late-run adults that passed Gold Ray Dam because Everest (1973) found that most wild adults spawned downstream of Gold Ray Dam.

The lack of a difference in run composition between the sites suggested that samplers at Huntley Park may have classified some wild fish as hatchery fish or that the sampler at Gold Ray Dam may have classified some hatchery fish as wild fish. We suspect that data from counts at Gold Ray Dam was the more likely source of error because the sampler was not able to carefully examine fish that passed the viewing chamber. Underestimation of the number of marked summer steelhead that passed Gold Ray Dam may also partially account for our finding that in some years, returns of hatchery fish to Cole M. Rivers Hatchery exceeded the number of hatchery fish estimated to have passed Gold Ray Dam (*see* **Abundance**, page 35).

Summer steelhead and winter steelhead pass Gold Ray Dam. We did not detect any change in the race composition of wild steelhead after the operation of Lost Creek Dam. Summer steelhead averaged 42% of the returns in preimpoundment years and 49% of the returns in postimpoundment years. These means did not differ significantly (*P* = 0.164). Preimpoundment data included the 1970-76 returns of summer steelhead and the 1971-77 returns of winter steelhead. Returns in later years composed the postimpoundment data. Passage estimates of wild winter steelhead at Gold Ray Dam were reported by ODFW (1990) and Satterthwaite (1992).

A sensitivity analysis suggested that the percentage of summer steelhead among postimpoundment returns would have had to decrease to 29% or increase to 55% for a change to be detected at the 95% confidence level. We recommend that fishery managers continue to estimate the race composition of wild steelhead that return to the upper river. An experiment to determine the effect of water temperature on spawning time of wild summer steelhead should be conducted if summer steelhead account for less than 30% of the returns in three or more consecutive years (*see* **Spawning**, page 66).

In the lower river, half-pounders accounted for an average of 74% (95% CI = ±8%) of the wild summer steelhead that passed Huntley Park from early July through late October in 1976-89. First spawning migrants accounted for an average of 20% of the wild fish (95% CI = ±6%). Second spawning migrants accounted for an average of 4% of the wild fish (95% CI = ±4%). Third spawning migrants averaged 1% of the wild fish (95% CI = ±1%). Remaining life histories accounted for an average of 2% of the wild summer steelhead. Annual estimates of run composition for wild summer steelhead that passed Huntley Park in 1976-89 are in Table 11.

Salt migrants were relatively rare among wild late-run adult summer steelhead that passed Huntley Park from early July through the end of October. We estimated that salt migrants composed an average of 5% (95% CI = ±3%) of the wild late-run adults that returned to fresh water in 1976-89. Salt migrants accounted for a relatively large percentage of wild late-run adults that returned in 1984 (10%) and 1989 (18%). In other years, salt migrants accounted for 1-6% of the wild late-run adults that returned to the Rogue River. Annual estimates of the percentage of salt migrants among annual returns of wild late-run adult summer steelhead are in Appendix Table B-23.

Table 11. Estimated life history composition of wild summer steelhead that passed Huntley Park, 1976-89 return years. Scales were not interpreted for the 1990-91 returns.

Return			Spawning migrants			
Year	*N*[a]	Half-pounders	First	Second	Third	Other[b]
1976	275	74.0%	15.6%	3.8%	5.0%	1.6%
1977	279	85.9%	11.7%	1.3%	0.4%	0.7%
1978	274	62.4%	34.3%	2.0%	0.0%	1.3%
1979	317	53.4%	29.5%	14.3%	0.6%	2.2%
1980	350	82.3%	10.3%	4.3%	1.8%	1.4%
1981	385	91.7%	7.9%	0.9%	0.2%	0.3%
1982	281	65.8%	30.2%	3.2%	0.2%	0.6%
1983	214	86.7%	7.9%	2.9%	0.3%	2.2%
1984	263	79.6%	14.0%	2.6%	0.7%	3.1%
1985	299	83.0%	14.9%	1.6%	0.1%	0.2%
1986	290	76.1%	18.6%	3.3%	0.2%	1.8%
1987			not sampled			
1988	415	54.2%	36.0%	4.2%	0.9%	4.6%
1989	416	61.4%	22.6%	5.7%	0.8%	9.5%

[a] *Number of scale samples interpreted.*
[b] *Includes rare life histories listed in Table 9.*

Two-salts accounted for most of the salt migrants that returned as late-run summer steelhead. Among salt migrants that returned in 1976-89, we estimated that an average of 7% were one-salts, 91% were two-salts, and 2% were three-salts. These estimates included fish on their initial and subsequent spawning runs. Because two-salts predominated the returns of salt migrants, we used only that life history to test for changes in composition of wild adult summer steelhead.

We did not detect any change in the relative abundance of salt migrants among wild late-run adults after the operation of Lost Creek Dam. Two-salts accounted for an average of 3.5% of the maiden adults from the 1974-76 broods and 4.8% of the maiden adults from the 1978-86 broods. The difference in means was not significant ($P = 0.941$). A sensitivity analysis suggested that the percentage of two-salts among maiden fish from postimpoundment broods would have had to increase to an average of 17% for a change to be detected at the 95% confidence level.

Salt migrants may have been more common among early-run adults. A review of data from Rivers (1964) suggested that 33% of the early-run summer steelhead trapped at Gold Ray Dam in July and August of 1962-63 exhibited scale parameters indicative of salt migrants. Everest (1973) also reported that salt migrants were present among early-run summer steelhead that entered the Rogue River in 1969, but their proportion among mature adults was not estimated. Because we did not sample scales from early-run adults, we were unable to determine if there were significant differences in life-history patterns among early-run and late-run summer steelhead. However, we did find that salt migrants returned earlier than spawning migrants in 1983-84 (*see* **Migration Timing**, page 55)

Spawning migrants were more likely to make repeat spawning runs than salt migrants. Repeat spawners accounted for an average of 19% of the spawning migrants and 6% of the salt migrants among wild late-run adults that returned to the Rogue River in 1976-89. Fish on their second spawning run accounted for an average of 15% of the spawning migrants and 6% of the salt migrants. Fish on their third spawning run accounted for an average of 4% of the spawning migrants and <1% of the salt migrants. Fish on their fourth spawning run were very rare and we found no fish on a fifth spawning run.

Among all wild late-run adult summer steelhead, repeat spawners composed an average of 18% of the freshwater returns in 1976-89. We did not compare the relative abundance of repeat spawners before and after the operation of Lost Creek Dam because there were only two years of preimpoundment returns.

Repeat spawners were more common among summer steelhead in the Rogue River than in most other steelhead populations on the Pacific coast of North America. Repeat spawners composed 3-7% of the summer steelhead that returned to streams in British Columbia (Withler 1966; Narver 1969; Hooton et al. 1987). Repeat spawners accounted for 6% of the wild summer steelhead that returned to the Kalama River in Washington (Leider et al. 1986) and about 10% of the wild summer steelhead that returned to the North Umpqua River in Oregon (personal communication dated 11 June 1993 from Alan McGie, ODFW, Corvallis). We found that repeat spawners accounted for 18% of the wild late-run adult summer steelhead that returned to the Rogue River.

The rate of repeat spawning among wild winter steelhead in the Rogue River was estimated to average 14% (ODFW 1990). Thus, summer steelhead in the Rogue River basin exhibit a greater rate of repeat spawning than winter steelhead. In other systems, winter steelhead also exhibit greater rates of repeat spawning than summer steelhead (Withler 1966; Leider et al. 1986; Hooton et al. 1987). Reasons for the greater rates of postspawning survival among summer steelhead in the Rogue River remain unknown, but the small size at maturity may be a significant factor.

Composition of the wild summer and winter steelhead runs in the Rogue River differed in other characteristics. Salt migrants accounted for about 69% of the winter steelhead that returned to the Rogue River (ODFW 1990). We found that salt migrants accounted for only 5% of the wild late-run adult summer steelhead that returned to the Rogue River. Winter steelhead and summer steelhead also differed in multiple characteristics of juvenile life history (*see* **Freshwater Growth**, page 90 and **Age at Ocean Entry**, page 98). These differences suggest there are genetic differences between summer and winter steelhead. Everest (1973) documented spatial and temporal differences between spawning summer and winter steelhead in the Rogue River basin.

Life history parameters may vary among summer steelhead produced in different portions of the Rogue River basin. Distinct populations may inhabit the basin. Adaptations to survive in the warm water of the middle river and the canyon may be quite different than adaptations to survive in the cooler water of the upper river. Variation in environmental factors such as water temperature, flow, forage resources, and habitat complexity in tributaries may be expressed in adult life history patterns. Possible differences in life history parameters among summer steelhead in the Rogue River basin remain unknown because we did not sample fish that spawned in tributary streams.

Electrophoretic analyses of 10 loci failed to detect significant differences in genetic composition of juvenile steelhead sampled in tributary streams of the Rogue River basin (Reisenbichler et al. 1992). However, Parkinson (1984) found differences in genetic attributes of steelhead within adjacent streams in British Columbia. Heggberget et al. (1986) identified three genetically distinct populations of Atlantic salmon *Salmo salar* in the Alta River, Norway. These findings suggest that there may be unique populations among summer steelhead in the Rogue River basin.

Our findings of very diverse life history strategies among summer steelhead, coupled with the uncertainty about the number of populations that may inhabit the Rogue River basin, should lead fishery managers to be cautious about the release of hatchery fish at sites outside of natal areas. We recommend a survey of genetic resources from sampling of adult summer steelhead that spawn in diverse areas of the Rogue River basin. Until that survey is complete, we recommend that programs designed to supplement production should use locally adapted broodstock to minimize the risk of genetic impacts on wild fish (Reisenbichler and McIntyre 1977; Chilcote et al. 1986; Waples 1991). Supplementation programs can make use of convenient hatchery facilities because transplanted steelhead smolts effectively home to release points as mature adults (Wagner 1969; Cramer 1981).

Migration Timing

Freshwater Entry: Sampling at Huntley Park indicated that half-pounders entered the Rogue River mostly in August-September while late-run adult summer steelhead entered fresh water from July through October (Figure 18). Early-run adult summer steelhead enter the Rogue River from May through July (Rivers 1964).

Wild half-pounders entered the Rogue River earlier than hatchery half-pounders. Entry time of wild half-pounders in an average year peaked one week earlier than hatchery half-pounders (Figure 18). Among late-run adults, hatchery fish returned to fresh water earlier than wild fish. In an average year, hatchery fish accounted for more than 50% of the adults that passed Huntley Park from July through the middle of August. Wild fish accounted for more than 50% of the adults that passed Huntley Park after the middle of August (Figure 18).

Analysis of variance indicated that mean time of freshwater return differed significantly among years and among types of summer steelhead (Table 12). We estimated that an average of 68% of the wild half-pounders, 59% of the hatchery half-pounders, 51% of the wild late-run adults and 61% of the hatchery late-run adults passed Huntley Park by 2 September. In years of early freshwater entry, 80-90% of all half-pounders and late-run adults passed Huntley Park by 2 September. In years of late freshwater entry, 20-30% of all half-pounders and late-run adults passed Huntley Park by 2 September.

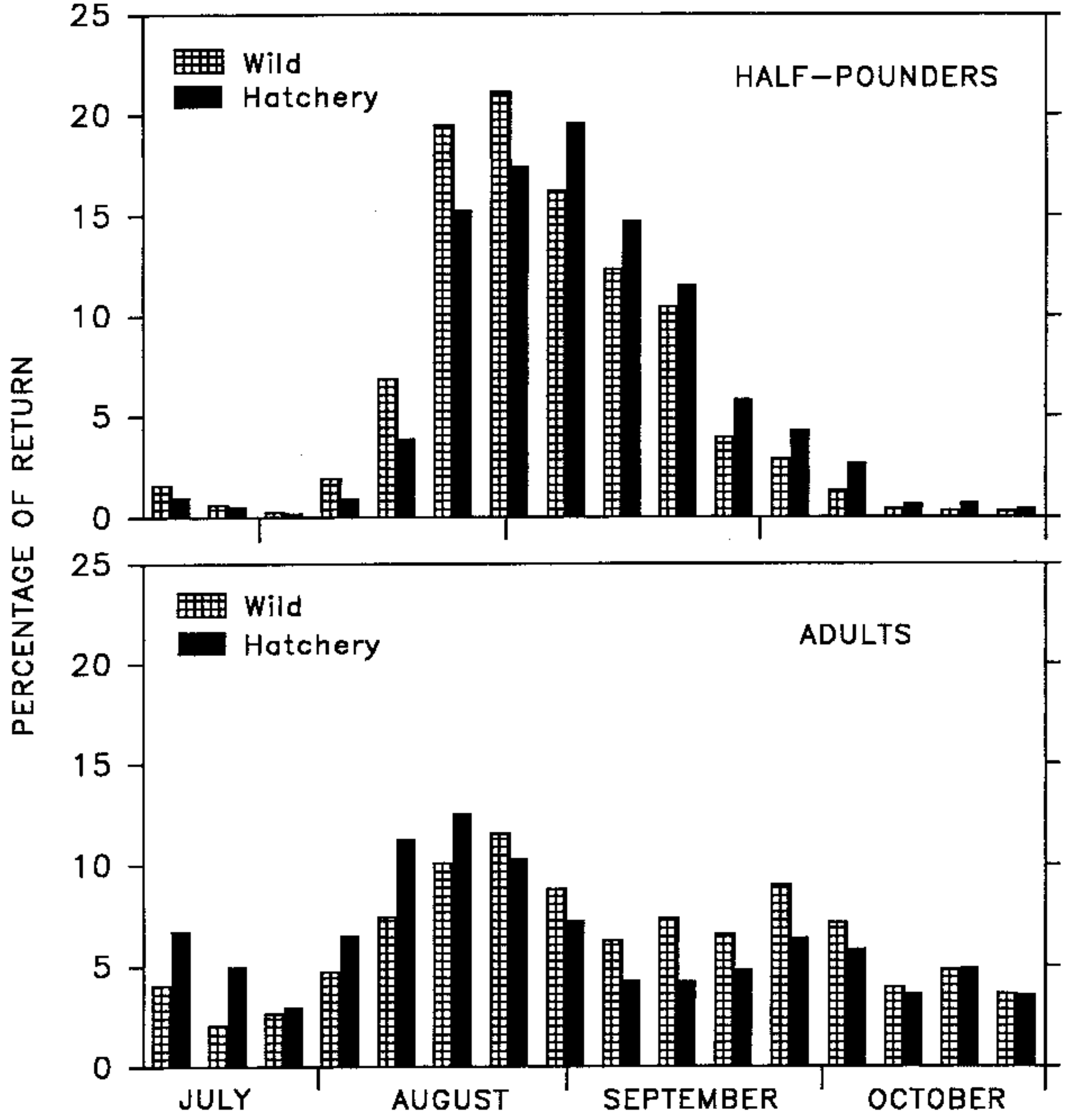

Figure 18. Estimated migration timing of summer steelhead that passed Huntley Park from 9 July through 28 October, averaged for the 1976-91 return years.

In at least two years, salt migrants returned to fresh water earlier than spawning migrants. In 1983, the mean date of passage at Huntley Park was 13 August for salt migrants and 7 September for second spawning migrants and third spawning migrants. A t-test indicated the means differed significantly at $P = 0.023$. In 1984, the mean date of passage at Huntley Park was 21 August for salt migrants and 5 September for second spawning migrants and third spawning migrants. A t-test indicated the means differed significantly at $P = 0.036$.

Table 12. Comparison of the percentage of summer steelhead that passed Huntley Park by 2 September, 1976-81. Comparisons include wild and hatchery half-pounders, and wild and hatchery late-run adults. Percentages were arcsin transformed prior to analysis.

Two factor analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Fish type	0.238	3	0.079	5.74	0.002
Year	2.869	14	0.205	14.85	<0.001
Residual	0.580	42	0.014		

We only compared migration times from 1983-84 because only in those two years did we sample and interpret scales from all fish large enough to be salt migrants, second spawning migrants, and third spawning migrants. Partial sampling of scales from large fish in other years, and from small adults in 1983-84, would have affected estimates of migration timing because temporal variations in sampling rates were not related to temporal variations in fish abundance.

We found that physical conditions in the ocean, rather than physical conditions in fresh water, appeared to affect the time summer steelhead entered the Rogue River. The percentage of wild and hatchery half-pounders that passed Huntley Park by 2 September was significantly correlated with indexes of ocean upwelling in summer (Appendix Table B-24). The percentage of wild and hatchery adults that passed Huntley Park by 2 September was significantly correlated with surface temperature of the ocean in summer (Appendix Table B-24). Migration timing of the various types of summer steelhead were not significantly correlated with flow of the Rogue River in summer (Appendix Table B-24).

Times of river entry were significantly correlated among the various types of summer steelhead (adults and half-pounders, wild and hatchery). These correlations suggested that the same environmental factors affected the migration time of half-pounders and late-run adult summer steelhead that passed Huntley Park. Migration timing of adult steelhead also appears to be a highly heritable trait (Leider 1985; Tipping 1992). Data included in the analyses of migration timing of summer steelhead that passed Huntley Park are in Appendix Table B-25.

Passage at Gold Ray Dam: Summer steelhead passed the counting station at Gold Ray Dam from late May through the end of January. On the average, passage of early-run fish peaked in June and passage of late-run fish peaked in October-December (Figure 19). Wild fish passed Gold Ray Dam later than hatchery fish (Figure 19). Data included in the analyses of the migration timing of all (early-run and late-run) wild summer steelhead that passed Gold Ray Dam are in Appendix Table B-30.

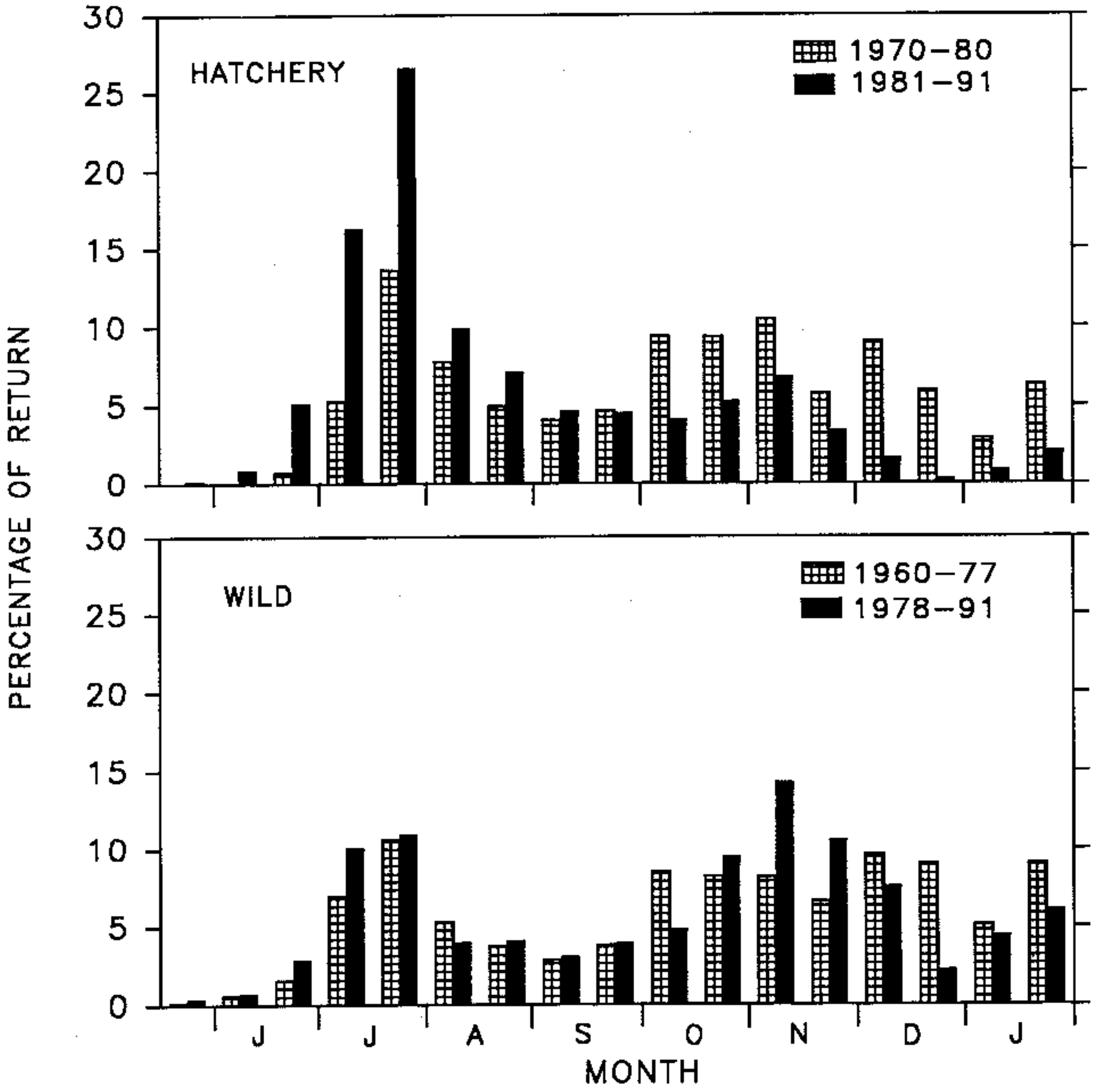

Figure 19. Estimated migration timing of summer steelhead that passed Gold Ray Dam, averaged for brood years produced before and after the operation of Lost Creek Dam.

Wild summer steelhead passed Gold Ray Dam earlier in the 1940s and 1950s compared with later years (Figure 20). Early-run fish averaged 50% of the wild summer steelhead that passed Gold Ray Dam during 1942-59. In 1960-77, early-run fish averaged 32% of the wild summer steelhead that passed Gold Ray Dam. Analysis of variance indicated the means were significantly different ($P < 0.001$). A decrease in the abundance of the early-run population, rather than a change in migration timing among summer steelhead, was responsible for the change in passage timing at Gold Ray Dam (*see* **Abundance**, page 35). Based on this finding, we used only preimpoundment data from 1960-77 in the following analyses of migration timing.

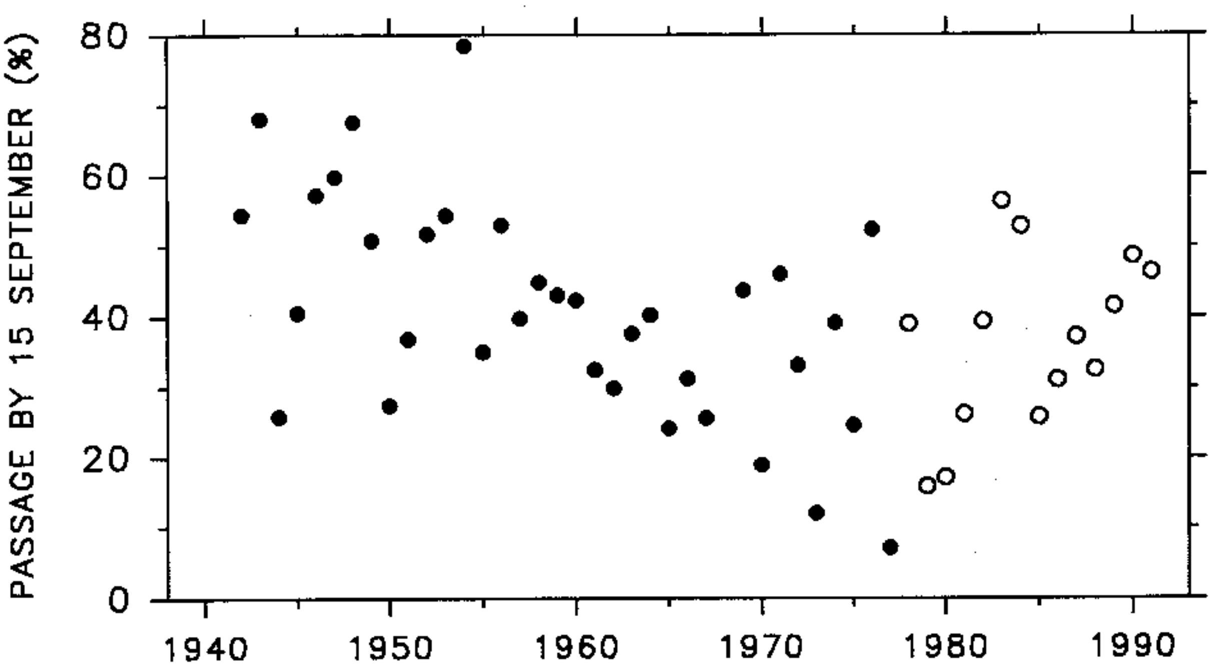

Figure 20. Percentage of wild summer steelhead that passed Gold Ray Dam by 15 September, 1942-91 return years. Closed and open circles represent fish that returned before and after the operation of Lost Creek Dam, respectively.

We did not detect a change in the migration timing of wild summer steelhead that passed Gold Ray Dam after the operation of Lost Creek Dam. Early-run fish averaged 32% of the wild summer steelhead that passed Gold Ray Dam during 1960-77. In 1978-91, early-run fish averaged 36% of the wild summer steelhead that passed Gold Ray Dam. Analysis of variance indicated that the means did not differ significantly ($P = 0.307$). A sensitivity analysis indicated that mean passage by 15 September in postimpoundment years would have had to decrease to 20% or increase to 43% for a change to be detected at the 95% confidence level.

Although the proportion of early-run fish did not change significantly among wild summer steelhead that passed Gold Ray Dam before and after operation of Lost Creek Dam, flow augmentation in summer caused some fish to migrate earlier. We found that migration timing was positively related to flow at Grants Pass during July-August (Figure 21). Proportionally more wild summer steelhead passed Gold Ray Dam by 15 September during years of greater flow in summer. This finding agreed with the findings of Everest (1973).

The migration timing of wild summer steelhead at Gold Ray Dam was also significantly correlated with water temperature in summer (Appendix Table B-33). We were unable to determine the primary factor related to migration timing because flow and water temperature in summer were significantly correlated (Appendix Table B-33). To estimate the effect of Lost Creek Dam on migration timing, we opted to use the relationship of migration timing and flow because the Agness gauge did not record water temperature data in 1988-91. These years were important to include in the analysis because early-run fish accounted for more than 40% of the wild summer steelhead that annually passed Gold Ray Dam.

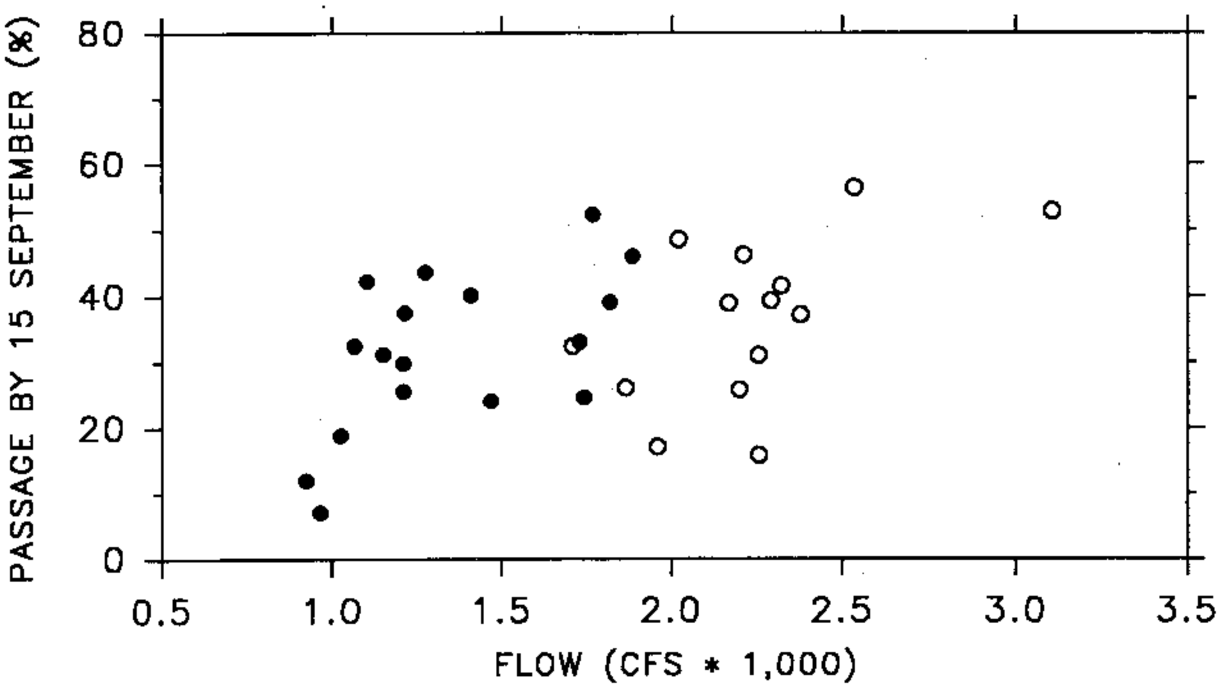

Figure 21. Relationship between the percentage of wild summer steelhead that passed Gold Ray Dam by 15 September and mean flow at Grants Pass in July and August, 1960-91 return years. Closed and open circles represent fish that returned before and after the operation of Lost Creek Dam, respectively.

We estimated the effects of operation of Lost Creek Dam by including mean flow at Agness, as simulated by the USACE for regulated and unregulated conditions during 1978-86, into a regression of flow and migration timing (Appendix Table B-34). The regression predicted that 29% and 42% of the run would pass Gold Ray Dam by 15 September under unregulated (without dam) and regulated (with dam) conditions, respectively. Data included in the analyses of the migration timing of all summer steelhead of wild origin that passed Gold Ray Dam are in Appendix Table B-30.

Operation of Lost Creek Dam was also associated with a change in the migration timing of early-run summer steelhead of wild origin. The change was not evident until postimpoundment broods began to dominate adult returns. An average of 25% of the early-run fish passed Gold Ray Dam by 15 July in 1970-77 and 1978-81. In 1982-91, an average of 43% of the early-run adults passed Gold Ray Dam by 15 July. Analysis of variance indicated that mean migration times of early-run fish differed significantly (P <0.001) among adults that returned in 1970-81 and 1982-91. Data included in the analyses of the migration timing of wild early-run summer steelhead that passed Gold Ray Dam are in Appendix Table B-35.

Migration timing of early-run adults was not significantly correlated with river physical parameters, but the percentage that passed Gold Ray Dam by 15 July increased significantly through time (Appendix Table B-36). We were unable to identify the factor(s) responsible for the increase. Improvements to water quality in summer should have most greatly affected the component of early-run adults that passed Gold Ray Dam after 15 July, rather than the component that passed before 15 July.

We found no change in the migration timing of late-run summer steelhead of wild origin after operation of Lost Creek Dam. An average of 58% of the late-run fish passed Gold Ray Dam by 30 November in 1970-77. In 1978-91, an average of 68% of the late-run fish passed Gold Ray Dam by 30 November. Analysis of variance indicated that mean migration times of late-run fish did not differ significantly ($P = 0.166$) before and after operation of Lost Creek Dam. A sensitivity analysis indicated that mean passage by 30 November among postimpoundment returns would have had to decrease to 40% or increase to 76% for a change to be detected at the 95% confidence level.

Correlation analyses suggested that the migration timing of late-run adults at Gold Ray Dam was more affected by water temperature in autumn than by water temperature in winter or flow in late summer (Appendix Table B-37). Proportionally fewer late-run adults passed Gold Ray Dam by 30 November in years when river temperature was low in October and November. Lower water temperature in autumn may have caused late-run summer steelhead to migrate at slower rates, resulting in a later time of passage into the upper river. Water temperature also affected the migration timing of winter steelhead at Gold Ray Dam (ODFW 1990).

Multiple regression analysis indicated that water temperature in autumn and winter were related with the migration timing of late-run summer steelhead of wild origin that passed Gold Ray Dam (Appendix Table B-38). Late-run adults migrated earlier when water temperature increased in autumn and decreased in winter. Greater water temperature in autumn probably caused late-run adults to migrate upstream at faster rates. Decreased water temperature in winter may have slowed migration rates and caused the latest migrating fish to pass Gold Ray Dam after January, when they would have been classified as winter steelhead.

We estimated the effects of operation of Lost Creek Dam by including mean water temperature in autumn and winter, as simulated by the USACE for regulated and unregulated conditions during 1978-86, into the regression of water temperature and migration timing. We used simulations for the Marial gage because water temperature at Agness was not modeled by the USACE. The regression predicted that 32% and 36% of the run would pass Gold Ray Dam by 30 November under unregulated (without dam) and regulated (with dam) conditions, respectively. This finding suggested that operation of Lost Creek Dam had minimal effect on the migration timing of late-run wild fish that passed Gold Ray Dam in 1978-86. Data included in the analyses of the migration timing of wild late-run summer steelhead that passed Gold Ray Dam are in Appendix Table B-39.

Hatchery fish passed Gold Ray Dam earlier in the 1980s compared with the 1970s (*see* Figure 19, page 58). Early-run fish averaged 36% of the hatchery summer steelhead that passed Gold Ray Dam in 1970-80. In 1981-91, early-run fish averaged 71% of the hatchery summer steelhead that passed Gold Ray Dam. Analysis of variance indicated that the means differed significantly at $P < 0.001$. The percentage of hatchery fish that passed Gold Ray Dam by 15 September increased through time (Figure 22). Data included in the analyses of the migration timing of hatchery summer steelhead that passed Gold Ray Dam are in Appendix Table B-40.

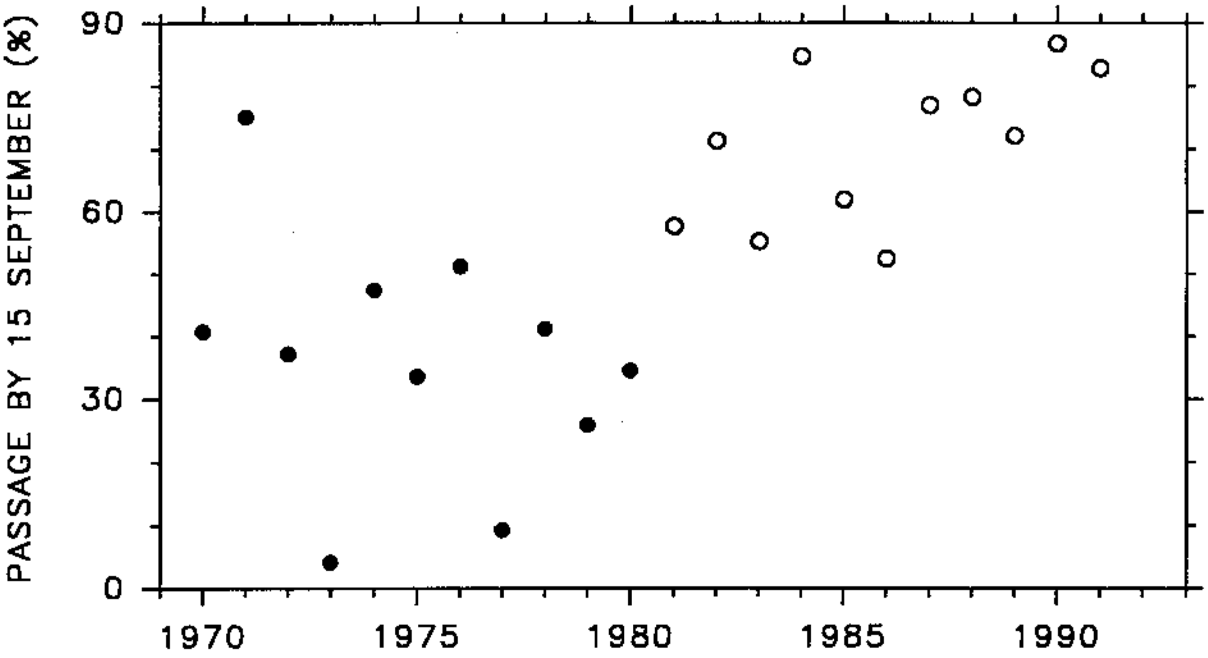

Figure 22. Relationship between the percentage of hatchery summer steelhead that passed Gold Ray Dam by 15 September and return year, 1970-91 return years. Closed and open circles represent fish that returned before and after the operation of Lost Creek Dam, respectively.

The migration timing of hatchery fish was significantly correlated with flow, water temperature, and year of return (Appendix Table B-43). We were unable to segregate the individual effects of each factor because the independent variables were significantly correlated (Appendix Table B-43). The migration time of hatchery fish was also significantly correlated with the migration timing of wild fish ($r = 0.79$, $P < 0.001$). This finding suggested that the same environmental factors affected the percentage of wild and hatchery fish that passed Gold Ray Dam by 15 September.

We believe that broodstock selection at Cole M. Rivers Hatchery was the primary factor that influenced the migration timing of hatchery summer steelhead that passed Gold Ray Dam. In the late 1970s, ODFW decided to increase the relative abundance of early-run fish within the hatchery broodstock to diversify angling opportunities for summer steelhead in the Rogue River. More early-run parents were spawned in an attempt to provide a recreational fishery upstream of Gold Ray Dam in summer. Because time of return to the hatchery has a genetic basis (Evenson and Ewing 1984), the proportion of early-run adults among the hatchery run increased through time.

We also detected a change in the migration timing of early-run hatchery fish. An average of 17% of the early-run fish passed Gold Ray Dam by 15 July in 1970-81. In 1982-91, an average of 35% of the early-run adults passed Gold Ray Dam by 15 July. Analysis of variance indicated that mean migration time of early-run fish differed significantly ($P < 0.001$) between adults that returned in 1970-81 and 1982-91.

Among early-run summer steelhead, there was no significant difference in the percentage of wild and hatchery fish that passed Gold Ray Dam by 15 July. The migration time of hatchery fish was significantly correlated ($r = 0.73$, $P < 0.001$) with the migration timing of wild fish. This finding suggested that the same environmental factors affected the percentage of wild and hatchery fish among early-run fish that passed Gold Ray Dam by 15 July.

The migration timing of early-run hatchery fish was significantly correlated with summer flow and year of return, but not water temperature in summer (Appendix Table B-44). We could not determine the primary factor related to the migration timing of early-run hatchery fish because flow and year of return were also significantly correlated (Appendix Table B-44). Greater flow in summer may have caused early-run hatchery adults to migrate earlier, but, as previously discussed, changes in broodstock selection practices were also important.

We also detected a change in the migration timing of late-run hatchery fish. An average of 65% of the late-run fish passed Gold Ray Dam by 30 November in 1970-81. In 1982-91, an average of 81% of the late-run adults passed Gold Ray Dam by 30 November. Analysis of variance indicated that mean migration times of late-run fish differed significantly ($P = 0.043$) among adults that returned in 1970-81 and 1982-91.

Among late-run summer steelhead, there was no significant difference in the percentage of wild and hatchery fish that passed Gold Ray Dam by 30 November. The migration time of hatchery fish was significantly correlated with the migration timing of wild fish ($r = 0.72$, $P < 0.001$). This finding suggested that the same environmental factors affected the percentage of wild and hatchery fish among late-run summer steelhead that passed Gold Ray Dam by 30 November.

The migration timing of late-run hatchery fish was not significantly correlated with either flow or water temperature in summer and winter (Appendix Table B-45). Again, temporal changes in broodstock selection at the hatchery may have masked the chance of detecting the influence of river physical factors on the migration timing of late-run hatchery fish at Gold Ray Dam.

Length at Return

Summer steelhead that entered the Rogue River between early July and late October during 1975-89 ranged in length between 22 cm and 91 cm. Among half-pounders, hatchery fish were larger than wild fish (Figure 23 and Appendix Table B-46). In contrast, length frequency data suggested that wild adults returned at larger sizes than hatchery adults. We believe that hatchery adults were smaller because proportionally fewer returned as repeat spawners (Hooton et al. 1987).

Length at freshwater return was dependent on the age of summer steelhead. Half-pounders, after 3-5 months in the ocean, ranged between 25 cm and 43 cm in length. Mean lengths of wild half-pounders captured annually at Huntley Park in 1975-89 averaged 33.5 cm (95% CI = $\pm$0.7 cm) and ranged between 31 cm and 35 cm (Appendix Table B-47).

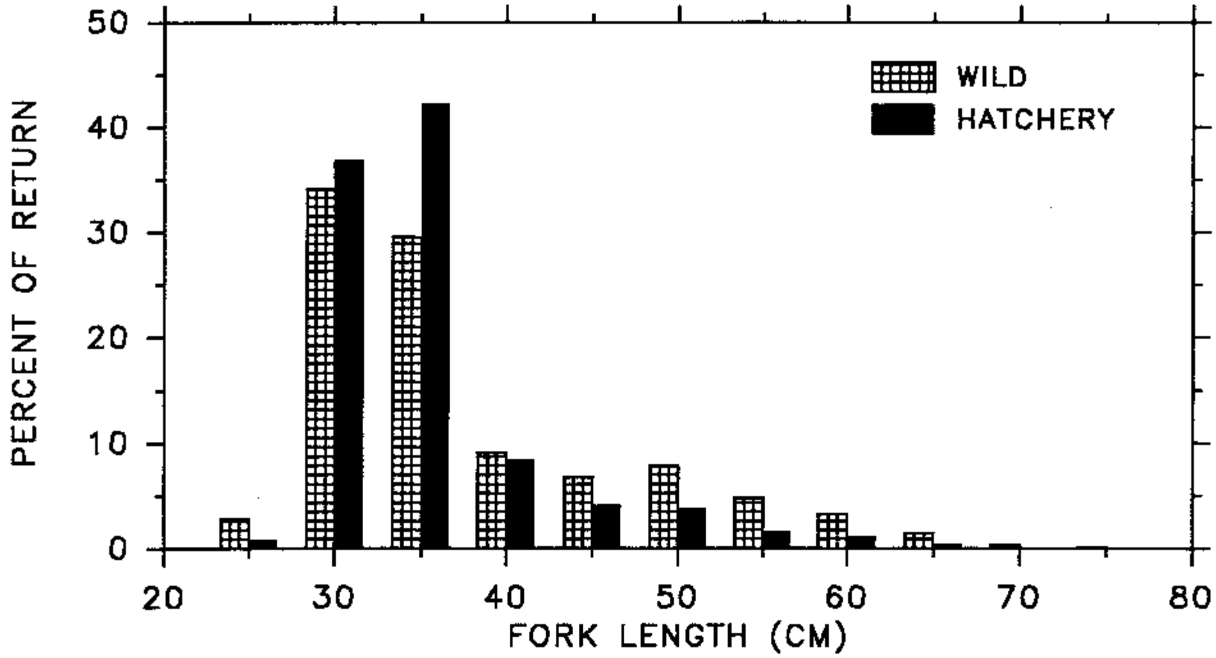

Figure 23. Length frequency distribution of summer steelhead seined at Huntley Park from 8 July through 28 October, 1976-91.

Among wild, late-run adults captured at Huntley Park in 1975-89, mean lengths of first spawning migrants averaged 48.9 cm (95% CI = ±0.9 cm). Mean lengths of second spawning migrants averaged 57.7 cm (95% CI = ±1.1 cm) and mean lengths of third spawning migrants averaged 63.6 cm (95% CI = ±1.5 cm). Adult summer steelhead that returned to the Rogue River were small in comparison to summer steelhead that return to most other streams because of the short time of ocean residence attributable to the half-pounder life history. Mean lengths of first spawning migrants and second spawning migrants seined at Huntley Park are in Appendix Table B-48.

We found that age at ocean entry affected the size of wild summer steelhead at time of freshwater return. Mean lengths of half-pounders that returned in 1975-84 averaged 29.2 cm for age-1 smolts, 34.6 cm for age-2 smolts, and 37.6 cm for age-3 smolts. An analysis of variance indicated that mean lengths differed significantly ($P < 0.001$) among half-pounders that smolted at different ages. A Newman-Keuls multiple range test indicated mean lengths were significantly greater for half-pounders that smolted at age-3 compared with half-pounders that smolted at age-1 or age-2. The test also indicated that mean lengths of half-pounders that smolted at age-2 were significantly greater than mean lengths of half-pounders that smolted at age-1.

Length at return also varied for wild late-run adults that smolted at different ages. Mean lengths of first spawning migrants that returned in 1976-89 averaged 47.0 cm for age-1 smolts and 50.3 cm for age-2 smolts. Analysis of variance indicated the means were significantly different ($P < 0.001$). Analysis of variance did not detect a difference ($P = 0.125$) among mean lengths of second spawning migrants that entered the ocean as age-1 and age-2 smolts. There was insufficient data to include adults that smolted at age-3 in these analyses.

Smolt age was one of multiple factors that affected the length of wild summer steelhead. Analyses of first spawning migrants sampled at Huntley Park in 1979 and 1980 indicated that length at return was significantly ($P \leq 0.01$) related with (1) length at the time smolts entered the ocean, (2) the increase in length during the first period of ocean residence, (3) circuli spacing during the second period of ocean residence, and (4) date of freshwater entry as mature adults. These four factors accounted for 81% of the variability in the lengths of 64 first spawning migrants that returned in 1979 and 88% of the variability in the lengths of 45 first spawning migrants that returned in 1980 (McPherson and Cramer 1982). We concluded that the operation of Lost Creek Dam was most likely to affect smolt length at ocean entry compared with the other factors related to the length of first spawning migrants.

We found that mean lengths of wild summer steelhead did not significantly change after the operation of Lost Creek Dam. Mean lengths of half-pounders from preimpoundment and postimpoundment broods averaged 29.2 cm and 29.9 cm among age-1 smolts, 34.2 cm and 35.3 cm among age-2 smolts, and 37.1 cm and 38.0 cm among age-3 smolts. Mean lengths of first spawning migrants from preimpoundment and postimpoundment broods averaged 45.7 cm and 47.4 cm for age-1 smolts, and 49.3 cm and 50.8 cm for age-2 smolts. Analysis of variance indicated that none of the differences in mean lengths were significant (all $P > 0.20$).

We also found that mean lengths of half-pounders, pooled for all smolt ages, did not significantly change after the operation of Lost Creek Dam. Mean lengths of half-pounders averaged 33.0 cm in 1975-78 and 33.8 cm in 1979-89. Analysis of variance indicated the means did not differ significantly ($P = 0.305$). Further, we also did not detect any change in mean lengths of first spawning migrants after operation of Lost Creek Dam. Mean lengths of first spawning migrants averaged 48.4 cm in 1975-79 and 49.2 cm in 1980-89. Again, the difference in means was not significant ($P = 0.390$).

These findings suggested that operation of Lost Creek Dam did not affect the age at smolting among juvenile steelhead in the Rogue River basin. A younger age at smolting should have produced smaller half-pounders and first spawning migrants at time of freshwater return. The absence of a significant decrease in size at freshwater return suggested that an increase in the production of younger smolts, if any, was masked by increased rates of natural mortality in the ocean (*see* **Age at Ocean Entry**, page 98).

Migration Rate

We estimated migration rates of wild late-run adult summer steelhead from 246 tags returned by anglers that fished the Rogue River during 1969-77. Migration rates ranged between 0.1 km/day and 12.7 km/day. The average rate of migration was 1.55 km/day (SE = 0.08) and the median rate of migration was 1.3 km/day. Migration rates of late-run adults were slower than those of early-run adults that migrated at an average of 7.2 km/day (Everest 1973). In the estuary of Dean River, British Columbia, migration rates of adult steelhead averaged 17 km/day (Ruggerone et al. 1990). We did not estimate the migration rate of half-pounders because an unknown proportion were captured by anglers after upstream migration ceased (Everest 1973).

Migration rates of wild late-run adults were not related to time of freshwater entry. An analysis of variance indicated migration rates did not differ significantly ($P = 0.77$) among fish tagged in July, August, and September (Appendix Table B-49). These findings confirmed findings reported by Everest (1973). Returns from wild adults tagged in October were insufficient to include in the analysis.

An analysis of variance indicated migration rates of wild adults did not differ significantly ($P = 0.301$) between years. Although mean migration rates ranged between 0.94 km/day and 1.70 km/day (Appendix Table B-49), variation in migration rates of individual fish decreased the power of the analysis. Because migration rates did not differ significantly between years, and migration rates could be estimated in only four years, we did not attempt to correlate mean annual rates of migration with river physical factors.

We also estimated migration rates of adult summer steelhead of hatchery origin. Anglers returned 65 tags from adult hatchery fish captured during 1969-77. Migration rates of hatchery adults ranged between 0.2 km/day and 7.6 km/day. The average rate of migration was 1.76 km/day (SE = 0.16) and the median rate of migration was 1.4 km/day.

Migration rates did not differ between adult summer steelhead of wild and hatchery origin. Analyses with a t-test indicated mean annual rates of migration did not differ significantly between wild and hatchery adults tagged in 1970 ($P = 0.097$) or 1977 ($P = 0.595$). The lack of difference in migration rates between wild and hatchery adults suggested that variations in the percentage of hatchery fish among adult summer steelhead landed by anglers probably resulted from differences in destinations of maturing adults (*see* **Catch Distribution**, page 76).

Spawning

Summer steelhead spawn mostly in small tributary streams of the Rogue and Applegate rivers (Everest 1973). In Kane Creek during 1970 and 1971, spawning began in late December, peaked in late January, and continued through late February (Everest 1973).

In a previous report (Cramer et al. 1985), we noted that the spawning time of summer steelhead at Cole M. Rivers Hatchery changed after operation of Lost Creek Dam. Mean spawning time was early April in 1975-77 and early February in 1978-80. We also reported that spawning time was significantly related to water temperature of the upper river in December and January. Because the operation of Lost Creek Dam increased water temperature of the Rogue River in winter (*see* **Water Temperature**, page 29), we concluded that reservoir operation affected the spawning time of summer steelhead held at the hatchery. Accelerated maturation of summer steelhead did not create problems within the hatchery program, but fishery managers expressed concern about possible impacts on wild fish.

Accelerated maturation of wild summer steelhead would cause fry to emerge earlier in spring. Early emergence has been implicated as a cause of decreased juvenile production among spring chinook salmon (Cramer et al. 1985) and coho salmon (Nickelson et al. 1986). In response to this concern, we proposed an experiment to determine the effects of water temperature on maturation time in summer steelhead. Since that time, research has determined that water temperature has a significant effect on maturation time in rainbow trout (Morrison and Smith 1986).

Concern about effects of increased water temperature on the spawning time of summer steelhead has decreased because (1) outflow temperatures at Lost Creek Dam are as low as possible in December-January, (2) return of wild adults to the upper river has not significantly decreased since operation of Lost Creek Dam, (3) selective mortality among early emergent fry may shift the spawning time of adults with only a temporary loss in production, and (4) summer steelhead spawn in tributary streams rather than the mainstem.

Upon entry into tributary streams, colder water would likely delay the spawning time of wild summer steelhead (Morrison and Smith 1986). We recommend experiments to determine the effects of water temperature on the spawning time of wild summer steelhead in the upper river if the run composition of wild steelhead that pass Gold Ray Dam shifts significantly to later spawning winter steelhead, which are not exposed to increased water temperatures as adults (ODFW 1990).

Recreational Fisheries

Summer steelhead supported recreational fisheries throughout the Rogue River. Distinct fisheries were present in various areas of the river. The timing of each fishery coincided with the migration timing of half-pounders and adults through respective areas.

Harvest

Estimates from salmon-steelhead cards indicated that anglers harvested an average of 5,193 large ($\geq$ 51 cm) summer steelhead annually in the Rogue River during 1956-89. Annual estimates of harvest ranged between 2,322 fish and 16,092 fish. Harvest estimates from 1990-91 were not included in the summary because the size requirement for entry on salmon-steelhead cards decreased to 41 cm.

We excluded harvest estimates for years prior to 1969 from further analysis because the abundance of summer steelhead declined during that period (*see* **Abundance**, page 35). We also excluded harvest estimates in 1981-82 from further analysis because those returns were comprised of a mixture of preimpoundment and postimpoundment broods. Data included in the analyses of angler harvest are in Appendix Table C-1.

Harvest estimates from salmon-steelhead cards indicated that the harvest of large summer steelhead in the Rogue River decreased after operation of Lost Creek Dam. Harvest estimates for June-November averaged 7,170 fish in 1969-80 and 4,039 fish in 1983-89. Analysis of variance indicated that the means differed significantly at $P = 0.037$.

A decrease in the harvest of late-run summer steelhead appeared responsible for the decrease in total harvest. Harvest estimates for

September-November averaged 6,430 fish in 1969-80 and 3,228 fish in 1983-89. The difference in means was significant at $P = 0.024$. Variations in fish abundance were not associated with the change in harvest. Mean returns of late-run adults to Gold Ray Dam did not differ significantly between preimpoundment and postimpoundment broods (*see* **Abundance**, page 35).

In contrast to late-run adults, harvest estimates of early-run summer steelhead did not significantly change after operation of Lost Creek Dam. Harvest estimates for June-August averaged 740 fish in 1969-80 and 811 fish in 1983-89. The difference in means was not significant at $P = 0.655$. A significant increase in returns of early-run summer steelhead to Gold Ray Dam (*see* **Abundance**, page 35) did not result in a detectable increase in angler harvest during June-August.

Harvest estimates from salmon-steelhead cards indicated that fisheries downstream of Gold Ray Dam accounted for most of the harvest of large summer steelhead caught in June-November. In 1984-91, anglers that fished upstream of Gold Ray Dam harvested an average of 1,418 large summer steelhead annually. Anglers that fished downstream of Gold Ray Dam harvested an average of 2,987 large summer steelhead annually in 1984-91. The area of harvest was not segregated on salmon-steelhead cards prior to 1984. Estimates of monthly harvest by area are in Appendix Table C-2.

The harvest of summer steelhead in the lower river was estimated from a combination of angler surveys and cannery records. Harvest estimates from cannery records averaged 5,091 fish in 1952-66 (Appendix Table C-3), while harvest estimates from angler surveys in 1976-83 averaged 4,596 fish (Cramer 1986). Although statistical analysis of the two data sets is not appropriate, it appears that the harvest of summer steelhead in the lower river in 1952-66 was roughly comparable to the harvest in 1976-83.

Harvest Rate

Among summer steelhead of hatchery origin, we estimated that an average of 50% of the late-run adults that entered the Rogue River in 1976-91 returned to Cole M. Rivers Hatchery. Assuming that 5% of the fish strayed to spawn naturally or died from natural mortality (*see* **Recreational Fisheries**, page 20), we estimated that the recreational fisheries harvested an average of 47% of the late-run adults of hatchery origin that returned to fresh water in 1976-91. Annual estimates varied between 23% and 78% (Appendix Table C-4).

Our estimate of an average harvest rate of 47% for late-run summer steelhead of hatchery origin was similar to estimates of harvest rates for summer steelhead in the North Umpqua River (46%) and the upper portion of the Willamette River (44%), but was higher than the 28% harvest rate estimated for summer steelhead in the Deschutes River (Kenaston 1989). Harvest rates of hatchery winter steelhead in the Rogue River were estimated to average 34% annually (ODFW 1990). Harvest rates of summer steelhead should be greater than those of winter steelhead because summer steelhead are exposed to recreational fisheries for a longer period of time.

Estimates of annual harvest rates of hatchery adults were positively related to the number of summer steelhead that returned to the Rogue River

(Figure 24). Residual variation from the relationship was negatively related to mean flow of the Rogue River when anglers fished for late-run adult summer steelhead upstream of the canyon (Figure 24). Regression analysis indicated that fish abundance and flow accounted for 50% of the variation in annual harvest rates of late-run adults of hatchery origin (Appendix Table C-5).

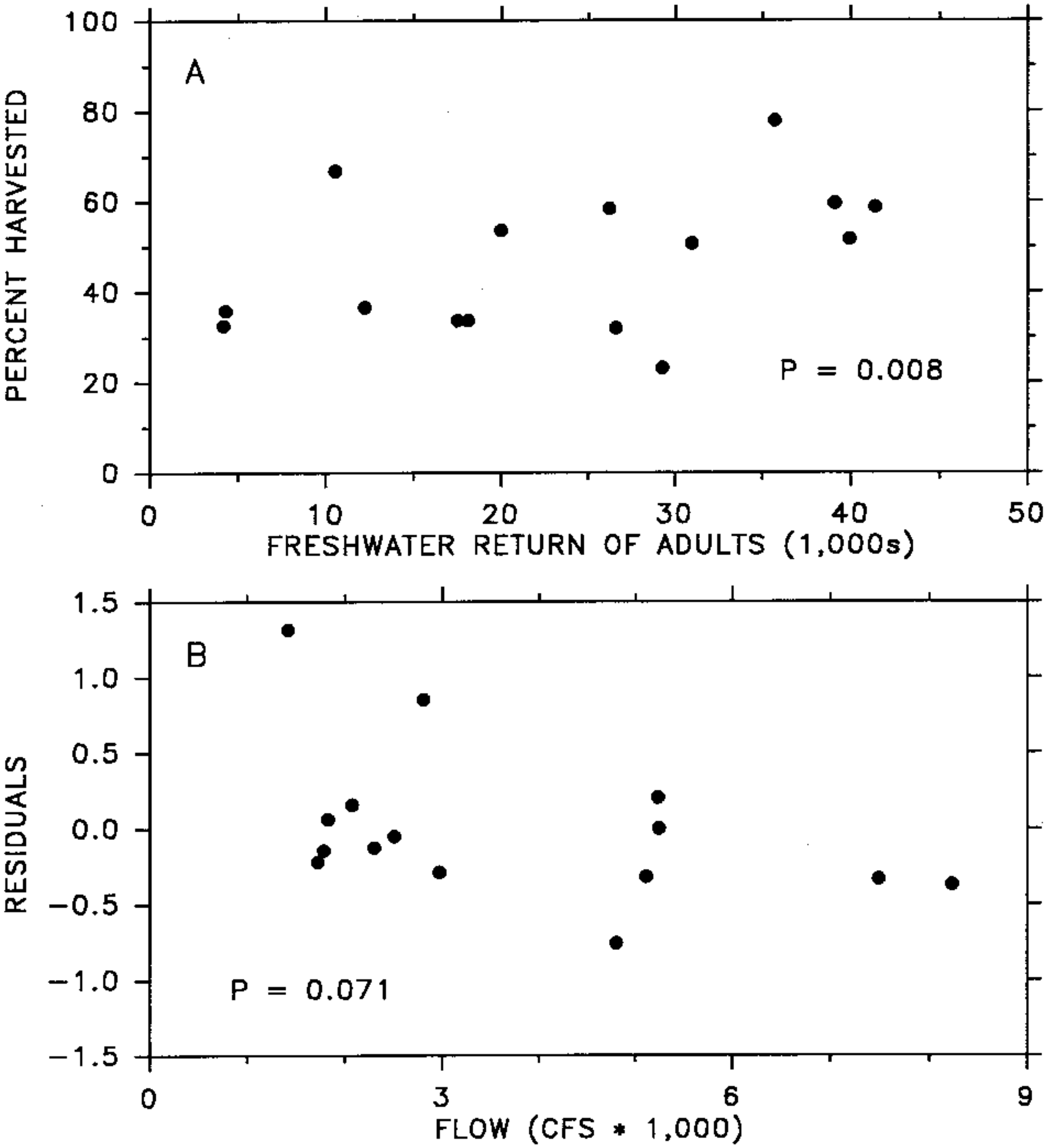

Figure 24. Relationship between the estimated harvest rate of late-run adult summer steelhead of hatchery origin and the estimated freshwater return of all late-run adult summer steelhead (A), and the residual variation from relationship (A) and mean flow at Grants Pass in November-January when anglers fished for summer steelhead in the middle river (B), 1976-91 return years.

Flow simulations developed by the USACE indicated that operation of Lost Creek Dam decreased flow at Grants Pass in November-January of 1978-79 through 1985-86 by an average of 134 cfs (95% CI = ± 15 cfs). Substitution of (1) simulated flow for regulated and unregulated conditions and (2) freshwater returns of summer steelhead, into the regression suggested that decreased flow during the autumn-winter fishery increased harvest rates by an average of 0.4% annually. From the estimated returns of late-run adults of hatchery origin, we estimated that decreased flows increased the harvest by an average of 28 fish (95% CI = ± 16 fish) annually. Based on this finding, we concluded that the operation of Lost Creek Dam had minimal affect on the harvest of late-run adult summer steelhead of hatchery origin during late autumn and winter.

Harvest rates were not significantly related with river flow when anglers fished for summer steelhead in the canyon, and were not related with the time hatchery adults entered the Rogue River. Data included in the analyses are in Appendix Table C-4 and a correlation matrix that outlines the relationships between all of the variables is in Appendix Table C-6.

Our findings suggested that harvest rates of adult summer steelhead of hatchery origin were affected by the number of summer steelhead that returned to the river. Harvest rates increased as the abundance of summer steelhead increased. Fish abundance affects the number of anglers that fish for summer steelhead in the Rogue River (*see* **Angler Effort**, page 82), but harvest rate of chinook salmon in freshwater recreational fisheries tends to decrease as fish abundance increases (Peterman and Steer 1981).

Our findings also suggested that flow in late autumn and early winter was related to harvest rates of late-run adults of hatchery origin. Harvest rates decreased as flow increased. In late autumn and early winter, late-run adults of hatchery origin pass through the middle river and the upper river (*see* **Migration Timing**, page 55). In years of greater flow, fish may be more difficult to catch. Flow increases in late autumn and early winter are also associated with decreases in angler effort (*see* **Angler Effort**, page 82). During years of high flow, summer steelhead are exposed to less angler effort and are harvested at a lower rate. High flows are also associated with decreased harvest of winter steelhead in the Rogue (ODFW 1990) and Applegate (Fustish et al. 1989) rivers.

Based on angler reports of tagged fish, Everest (1973) and Cramer (1986) estimated that annual harvest rates for summer steelhead in the Rogue River ranged between 15% and 20%. We believe their estimates of harvest rates were low because they assumed that anglers observed and reported all tags. A literature review indicated that recreational anglers usually report about 40% of the tagged fish captured (Matlock 1981). Assuming a 40% report rate for Rogue River anglers, the data of Everest (1973) and Cramer (1986) suggested that annual harvest rates of summer steelhead ranged between 38% and 50% annually. These estimates were similar to our estimate of the mean harvest rate on late-run adult summer steelhead of hatchery origin.

While we were able to indirectly estimate harvest rates for late-run adults of hatchery origin, we were unable to estimate harvest rates for wild summer steelhead in the Rogue River because we lacked the necessary data. However, assuming that harvest rates are equivalent among hatchery adults, wild adults, and wild half-pounders, then there is an indication that harvest rates in the late 1970s and 1980s exceeded optimum for wild fish. If half-pounders and adults were harvested at an average rate of 50%, then the effective harvest rate on wild summer steelhead in the Rogue River would have averaged about 75% in the late 1970s and 1980s. This estimate does not include mortality estimates for fish that were caught and released. Mortality rates of released fish may be significant because some summer steelhead are caught when water temperature exceed 21°C (Barnhart 1989).

In the absence of better data, fishery managers were justifiably concerned about the harvest of wild summer steelhead in the Rogue River. Chapman (1986) estimated a maximum sustainable harvest rate of 67-69% for wild steelhead populations inhabiting unaltered areas of the Columbia River basin. McGie (1993) estimated a maximum sustainable harvest rate of 45% for wild summer steelhead in the North Umpqua River, Oregon. Our data suggested that the 1976-91 fisheries in the Rogue River may have harvested an average of 75% of the summer steelhead prior to the first spawning of adults.

Current angling regulations prevent the harvest of wild steelhead smaller than 60 cm (24 in). This size limit protects virtually all summer steelhead in the Rogue River because few are larger than 60 cm (*see* **Length at Return**, page 63). Fishery managers should consider the possibility of allowing a consumptive fishery for wild fish when the number of summer steelhead increase in future years. Assuming that wild adults are harvested at an annual rate of about 50%, a consumptive fishery appears feasible provided there is minimal fishing-related mortality among wild half-pounders. Because released half-pounders may be susceptible to high rates of mortality in summer, we recommend a study to determine the relationship between water temperature and survival rate for caught and released fish.

Catch Rate

Annual catch rates of summer steelhead ranged between 0.024 fish per hour and 0.670 fish per hour in the fisheries surveyed during 1976-83 (Appendix Tables C-7 through C-10). Mean annual catch rates were greatest in the Rogue River canyon and decreased with distance upstream of the canyon (Table 13). Differential positioning of half-pounders and adults was likely responsible for spatial differences in catch rates of summer steelhead (*see* **Catch Distribution**, page 76). Catch rates of summer steelhead were generally greater than catch rates of winter steelhead in the Rogue River during the late 1970s and early 1980s (ODFW 1990).

Catches of summer steelhead averaged between 0.08 fish per angler day and 2.85 fish per angler day for guided parties in 1948-61. Catch rates averaged 1.36 fish per day in the RK 0-53 area, 1.49 fish per day for the RK 53-173 area, and 0.55 fish per day for the RK 173-265 area (Appendix Table C-10). Assuming guided anglers fished 6 hours daily, we estimated catch rates averaged 0.227 fish per hour for the RK 0-53 area, 0.248 fish per hour for the RK 53-173 area, and 0.092 fish per hour for the RK 173-265 area.

In 1976-81, anglers that fished from boats in the Rogue River caught summer steelhead at greater rates than anglers that fished from the bank. Annual catch rates of boat anglers that fished in the Agness area averaged 0.193 more fish per hour than annual catch rates by bank anglers. A paired

Table 13. Mean catch rate of summer steelhead by anglers that fished the Rogue River, 1977-78 through 1980-81.

Area	Fish per hour (SE)	
	Bank anglers	Boat anglers
RK 7-18	0.147 (0.011)	0.122 (0.009)[a]
RK 42-54	0.214 (0.034)	0.395 (0.064)
RK 54-77	--	0.465 (0.087)
RK 110-129	0.093 (0.008)	0.192 (0.064)
RK 139-156	0.067 (0.013)	0.152 (0.034)

[a] *Most boat anglers fished for fall chinook salmon.*

t-test indicated the difference in means was significant (P = 0.060). Also, boat anglers that fished the middle river averaged 0.092 more fish per hour than bank anglers. A paired-sample t-test indicated that the means differed significantly (P = 0.026). Based on these findings, we separately analyzed catch rate data for bank and boat anglers. Data included in these analyses are in Appendix Tables C-8 and C-9.

Catch rates of summer steelhead by bank anglers that fished the lower river did not differ significantly (P = 0.945) before and after operation of Lost Creek Dam. Annual catch rates in the fishery averaged 0.164 fish per hour in 1965-77 and 0.162 fish per hour in 1978-83. A sensitivity analysis indicated catch rates would have had to change by 0.058 fish per hour to be detected at the 95% confidence level. Data included in this analysis are in Appendix Table C-7. Preimpoundment and postimpoundment catch rates of summer steelhead in fisheries located farther upstream were not compared because there was only one year of preimpoundment data.

We were unable to identify effects of physical parameters of the Rogue River on angler catch rates of summer steelhead. Correlations between mean weekly catch rates and physical factors (flow, water temperature, and turbidity) were not significant (all $P > 0.05$) among data gathered during angler surveys in the middle river and in the Rogue River canyon (Appendix Table C-11). Lack of data related to temporal variations in fish abundance minimized the utility of these analyses. Data included in these analyses are in Appendix Tables C-12 through C-15.

Abundance of summer steelhead and time of season were related to catch rates of summer steelhead in the August-October fishery near Gold Beach. Regression analysis indicated that these factors accounted for 46% of the variability in mean weekly catch rates by bank anglers during 1976-83 (Appendix Table C-16). Weekly catch rate was positively related to fish abundance and residual variation was related to week-of-year in a curvilinear manner (Figure 25). Flow, water temperature, and turbidity were not significantly related to catch rates of summer steelhead in the fishery near Gold Beach (Appendix Table C-11). Relationships between independent variables included in the analysis are in Appendix Table C-11.

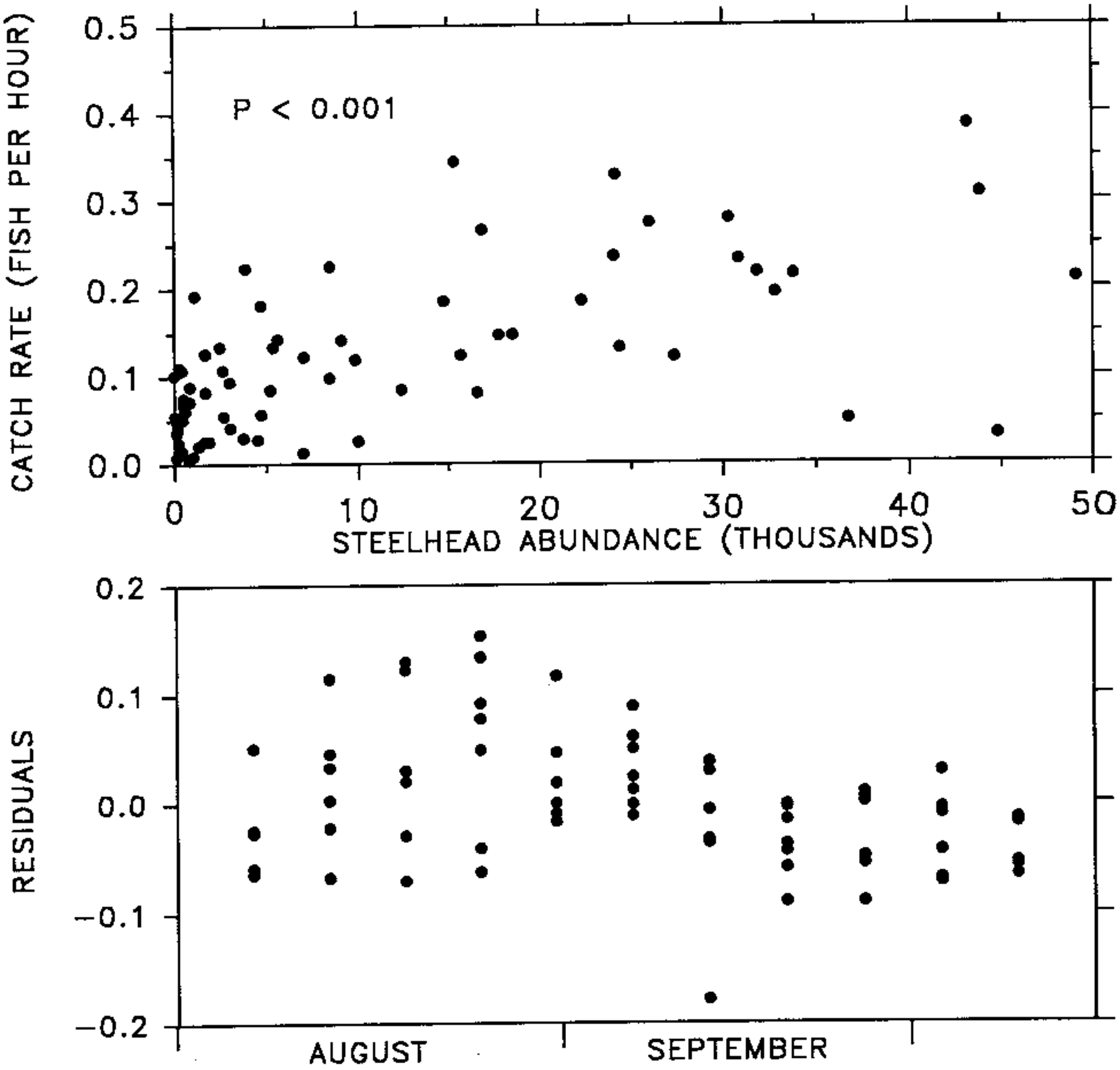

Figure 25. Relationship between the mean weekly catch rate of summer steelhead in the Gold Beach fishery (RK 7-18) and the estimated weekly passage of summer steelhead at Huntley Park (A), and the residual variation from relationship (A) and time (B), 1976-81 return years.

We believe the curvilinear relationship between week-of-year and the residual variation of catch rates reflected angler plans for participation in the fishery. Numerous non-resident anglers participated in this fishery and most planned their visit based on patterns of historic success. Residuals were probably positive during the initial and final weeks of the fishery because there was less competition among anglers for optimal fishing sites and a greater proportion of anglers were locals who likely responded to reports of angling success. Residuals were probably negative during the peak of the fishery because anglers competed for fishing sites and non-resident anglers fished regardless of variations in run timing and rates of angler success.

In the Rogue River canyon, catch rates of summer steelhead by guided boat anglers averaged 20 fish per boat trip and ranged between 10 fish per boat trip and 46 fish per boat trip annually in 1977-91 (Appendix Table C-17). Regression analysis indicated that freshwater returns of half-pounders, river flow during the fishery, and angler effort accounted for 69% of the variation in annual catch rates (Appendix Table C-18). A correlation matrix that outlines the relationships among all variables examined in the analysis is in Appendix Table C-19. We assumed that data from the 10-14 guides that annually fished the canyon was representative of the annual variations in angler success for the entire fishery.

Annual catch rates were negatively related to angler effort (Figure 26). Years with the least amount of angler effort accounted for 2 of the 3 years when catch rates exceeded more than 30 fish per boat trip. Assuming that the effort data we used were representative of the entire fishery, we estimated that a 10% increase in the average number of angler trips would decrease the catch per boat trip by 19%. Fewer anglers may allow for more time to be spent in productive locations and exposes individual fish to less gear. This finding suggested that the increase in angler effort in the canyon during the 1970s and 1980s may be a primary factor responsible for concerns about the low rates of angler success in the Rogue River canyon in the late 1980s.

Residual variation from the relationship of catch rates and effort was positively related with the annual abundance of half-pounders (Figure 26). This finding indicated that angler success increased as freshwater returns of half-pounders increased. From the regression analysis (Appendix Table C-18), we estimated that a 10% increase in the average number of half-pounders would increase catch rates of summer steelhead in the canyon by an average of 4%.

Residual variation from the second step in the regression was negatively related to river flow during the first half of the canyon fishery for summer steelhead (Figure 26). This finding suggested that increases in flow may make it more difficult to catch half-pounders in the canyon. Increases in flow may change the behavior of half-pounders that hold in the canyon during autumn. Increases in flow may also increase water velocity and make it more difficult to fish from a boat. From the regression analysis (Appendix Table C-18), we estimated that a 10% increase in flow during September would decrease catch rates by an average of 7%.

Flow simulations developed by the USACE indicated that operation of Lost Creek Dam increased flow at Agness in September during 1978-86 by an average of 535 cfs (95% CI = ± 85 cfs). Substitution of annual values for (1) simulated flow for regulated and unregulated conditions, (2) freshwater returns of half-pounders, and (3) the number of boat trips into the regression suggested that augmented flow in September decreased catch rates by an average of 3.6 (95% CI = ± 0.6) steelhead per boat trip. On a percentage basis, we estimated that flow augmentation in September decreased catch rates in the canyon by an average of 18% (95% CI = ± 5%) in 1978-86. Based on this finding, we concluded that the operation of Lost Creek Dam affected angler catch of summer steelhead in the Rogue River canyon.

The decrease in catch rates that resulted from augmented flow was compensated by an increase in catch rates that resulted from an increase in the abundance of hatchery fish. To derive this estimate, we assumed that

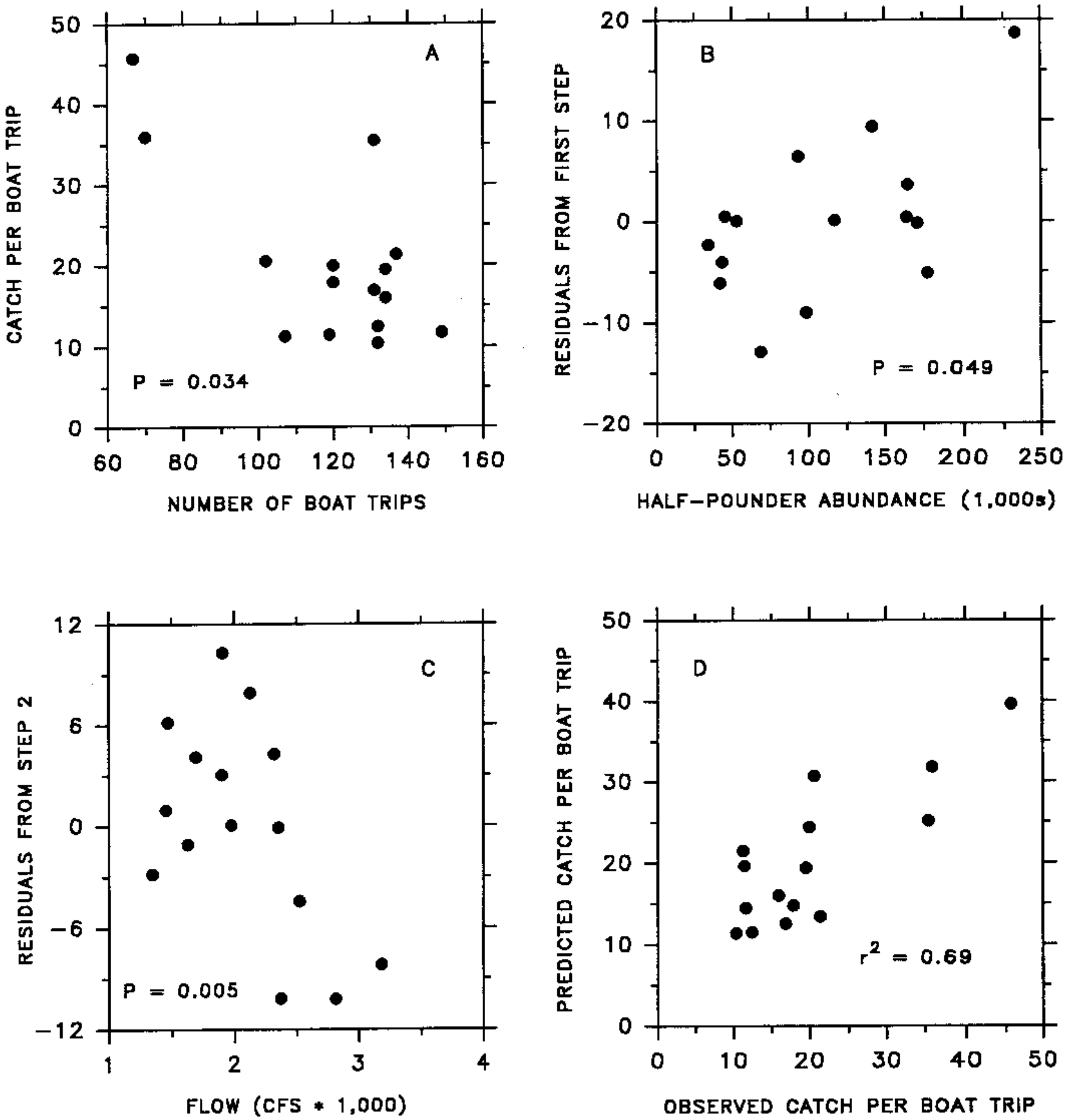

Figure 26. Steps in the analysis of catch rates of summer steelhead by guided anglers that fished the Rogue River canyon, 1977-91. Variables within plots are (A) mean catch rates of summer steelhead by guide group one and the number of annual boat trips, (B) residual variation from relationship (A) and the estimated freshwater return of half-pounders, and (C) residual variation from (B) and mean flow at Agness during September. Plot D compares values predicted from the regression with observed values.

hatchery fish would have composed 10% of the half-pounders that would have returned to the Rogue River if Lost Creek Dam had not been constructed (Everest 1973). We also assumed that construction and operation of the dam had minimal affect on the abundance of wild adult summer steelhead (*see* **Abundance**, page 35) and wild adult winter steelhead (ODFW 1990) produced in the upper river.

Substitution of annual values for (1) half-pounder returns estimated for regulated and unregulated conditions, (2) the number of boat trips, and (3) flow at Agness in September into the regression suggested that the increase in abundance of hatchery half-pounders increased catch rates in 1978-86 by an average of 3.3 (95% CI = ± 1.5) steelhead per boat trip. On a percentage basis, we estimated that the increase in numbers of hatchery half-pounders increased catch rates in the canyon by an average of 23% (95% CI = ± 12%) in 1978-86. These findings suggested that the effects of flow augmentation on angler catch rates in the canyon fishery were counteracted by supplementation of catch rates by the production of hatchery fish.

Cessation of flow augmentation in September would minimize the effects of reservoir operation on the canyon fishery for summer steelhead. However, this strategy would likely increase prespawning mortality among fall chinook salmon. ODFW (1992) found that rates of prespawning mortality were related to water temperature in the Rogue River canyon from early August through early September. Because flow is a primary determiner of water temperature in the canyon during late summer, ODFW (1992) recommended that Lost Creek Lake be managed to maintain a minimum flow of 2,300 cfs at Agness from 10 August through 10 September.

Flow augmentation in early September decreases mortality of fall chinook salmon, but also decreases angler success for summer steelhead in the Rogue River canyon. To protect fall chinook salmon from prespawning mortality and to minimize effects of augmented flow on the fishery for summer steelhead in the canyon, Lost Creek Lake should be managed so there is minimal augmentation after 21 September. Cessation of flow augmentation in late September would also negate any chance that redds of spring chinook salmon would be dewatered during the subsequent filling of the reservoir (Satterthwaite et al. 1985).

We also recommend further evaluation of the relationship between flow in early September and susceptibility of fall chinook salmon to prespawning mortality. In 1992, flows at Agness averaged 2,145 cfs during 15-31 August and 2,027 cfs during 1-11 September. Surveys of the canyon indicated there was minimal prespawning mortality among few fall chinook salmon (ODFW, unpublished data). This finding suggested that flow augmentation can be reduced in early September without an increase in the risk of extensive prespawning mortality. When operational plans call for releases of less than 2,000 cfs from Lost Creek Dam in early September, the canyon should be surveyed for prespawning mortalities.

Catch Distribution

Anglers returned tags from 110 summer steelhead caught in the Rogue River during the 1976-77 and 1977-78 fisheries. We also evaluated tags returned from 535 summer steelhead caught by anglers that fished the Rogue

River in 1968-71. Data included in the analyses of catch distribution are in Appendix Table C-20.

Tag returns indicated that catch distribution differed between wild and hatchery summer steelhead. For tagged adults reported by anglers, 1% (3/273) of the wild fish and 19% (13/67) of the hatchery fish were caught upstream of Gold Ray Dam. These percentages differed at $P < 0.001$. The catch distribution of wild and hatchery fish probably differed because many wild summer steelhead spawn in tributaries downstream of Gold Ray Dam (Everest 1973), while most hatchery fish return to areas farther upstream (*see* **Abundance**, page 35). Based on this finding, we separated data from wild and hatchery adults in the further analyses of catch distribution.

In contrast to adult summer steelhead, the catch distribution of wild and hatchery half-pounders did not differ ($P = 0.159$). Tag returns from the lower river (RK 14-54) fishery accounted for 77% (287/372) of the tags returned from wild half-pounders and 70% (79/113) of the tags returned from hatchery half-pounders.

Tag returns also indicated that half-pounders and late-run adult summer steelhead differed in catch distribution. Anglers that fished the area upstream of Grave Creek (RK 110) returned 12% (46/372) of the tags returned from wild half-pounders and 57% (148/273) of the tags returned from wild adults. The difference in the catch distribution of half-pounders and late-run adults was significant at $P < 0.001$.

We also found a change in catch distribution through time. Tags returned from wild half-pounders caught in the canyon accounted for 7% (21/279) of the tags recovered from wild half-pounders caught in 1968-71 and 25% (18/73) of the tags from wild half-pounders caught in 1976-78. These percentages differed significantly at $P < 0.001$. We believe that the upstream shift in catch distribution reflected a rapid increase in angler effort for summer steelhead in the Rogue River canyon during the early 1970s that resulted from a significant increase in freshwater returns of summer steelhead (*see* **Abundance**, page 35).

Guided anglers that fished the canyon landed most summer steelhead between Agness (RK 44) and Marial (RK 77) in 1977-91 (Appendix Table C-21). Guide reports indicated that the catch distribution of summer steelhead varied among years. The percentage of summer steelhead caught downstream of Marial ranged between 41% and 71% annually for guide group 1 and ranged between 34% and 63% annually for guide group 2.

We found that the percentage of fish caught downstream of Marial was significantly correlated between the two groups of guided anglers (Appendix Table C-22). This finding suggested that a common factor(s) influenced the distribution of annual catch of summer steelhead in the canyon fishery.

The catch distribution of summer steelhead by guided anglers that fished the canyon was not related to physical parameters of the Rogue River. The percentage of fish landed upstream of Marial was not significantly correlated with either flow or water temperature during the fishery (Appendix Table C-22). We also found that flow in August and early September was not significantly correlated with catch distribution (Appendix Table C-22).

We included flow before the fishery in the analysis in response to concern that flow augmentation in August and early September affected the distribution of half-pounders in September and October during the canyon fishery. Use of storage in the reservoir to augment flow in late summer minimizes prespawning mortality among fall chinook salmon in the Rogue River (ODFW 1992). The lack of correlation between catch distribution and flow suggested that river flow, either before or during the fishery, had minimal effect on the distribution of half-pounders in late summer and early autumn.

Analysis of harvest estimates derived from salmon-steelhead cards indicated that the harvest distribution of large adult summer steelhead varied through the fishing season. A Newman-Keuls multiple range test indicated that harvest data from June through August could be pooled for an analysis of harvest distribution (Table 14). The test also indicated that harvest data from September and October could be pooled for an analysis of harvest distribution (Table 14). Pooled data indicated that anglers that fished upstream of Gold Ray in 1984-91 accounted for an average of 61% of the large summer steelhead harvested in June-August and an average of 24% of the large summer steelhead harvested in September-October. We estimated the distribution of harvest from data in Appendix Table C-2.

The distribution of large summer steelhead harvested in June-August was significantly correlated with time of passage at Gold Ray Dam and water temperature of the upper river in June-July (Appendix Table C-23). A positive relationship between harvest distribution and passage timing indicated that anglers who fished the upper river accounted for a greater percentage of the June-August harvest in years when early-run fish accounted for a greater percentage of the return. Because the operation of Lost Creek Dam had only a minor effect on the migration timing of early-run summer steelhead that passed Gold Ray Dam (*see* **Migration Timing**, page 55), we concluded that reservoir operation had minimal effect on the distribution of large summer steelhead harvested in June-August.

A negative relationship between harvest distribution and water temperature indicated that anglers who fished the upper river accounted for a greater percentage of the June-August harvest in years when water temperature in the upper river during early summer was relatively low. We judged this correlation to be spurious because lower water temperatures delayed the time summer steelhead passed Gold Ray Dam. A later time of passage should have decreased, rather than increased, the harvest of summer steelhead in the upper river. Data included in these analyses are in Appendix Table C-24. A

Table 14. Percentage of summer steelhead landed upstream of Gold Ray Dam as estimated from salmon-steelhead cards, 1984-91. Groups of underlined values differed significantly from other groups. Percentage data was arcsin transformed prior to analysis with a Newman-Keuls multiple range test.

June	July	August	September	October	November
65%	71%	56%	25%	23%	45%

correlation matrix that outlines the relationships between all variables examined in the analyses is in Appendix Table C-23.

Among large summer steelhead harvested in September-October, we found a significant relationship between harvest distribution and river flow in late summer and early autumn (Appendix Table C-25). Harvest distribution was not related to passage timing at Gold Ray Dam or water temperature (Appendix Table C-25). The negative relationship between harvest distribution and flow indicated that anglers who fished the upper river accounted for a greater percentage of the September-October harvest in years of low flow in late summer and early autumn. Data included in this analysis are in Appendix Table C-26.

Flow could have affected the harvest of summer steelhead in the upper river during September-October of 1984-91 because angling was restricted to fly-fishing from the bank. Increased flow may make it more difficult to effectively fish flies in areas inhabited by adult steelhead. Anglers that fished downstream of Gold Ray Dam may not have been affected because they were able to fish from boats. Operation of Lost Creek Dam may have affected the harvest distribution because we previously recommended that flow be augmented from early August through early September to minimize prespawning mortality among fall chinook salmon (ODFW 1992). Affects after the middle of September should be minimal if the USACE implements our recommendation to minimize flow augmentation after 21 September (*see* **Catch Rate**, page 71).

Catch Composition

The percentage of hatchery fish in the angler harvest of summer steelhead differed significantly among years (Table 15 and Table 16). The percentage of hatchery fish in the half-pounder catch in the RK 7-18 survey area increased from 13% in 1977 to 46% in 1981. The percentage of hatchery fish in the catch of adult summer steelhead in the RK 7-18 survey area increased from 10% in 1978 to 38% in 1981. The relative abundance of hatchery fish in the angler harvest also increased in areas located farther upstream (Appendix Table C-27). The increase in the proportion of hatchery fish in the angler catch during 1977-81 reflected an increase in the proportion of hatchery fish in the run (*see* **Run Composition**, page 50).

Table 15. Comparison of the percentage of hatchery fish among half-pounders harvested by anglers, 1977-78 through 1980-81. Analysis includes only fisheries where $N \geq 40$ fish annually (Appendix Table C-27). Percentages were arcsin transformed prior to analysis.

Analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Survey area	337.5	4	84.4	5.44	0.010
Year	768.9	3	256.3	16.52	0.001
Residual	186.2	12	15.5		

Table 16. Comparison of the percentage of hatchery fish among adult summer steelhead harvested by anglers, 1977-78 through 1980-81. Analysis includes only fisheries where $N \geq 40$ fish annually (Appendix Table C-27). Percentages were arcsin transformed prior to analysis.

Analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Survey area	29.2	3	9.7	0.72	0.565
Year	584.3	3	194.8	14.41	<0.001
Residual	121.6	9	13.5		

The percentage of hatchery fish among half-pounders retained by anglers differed significantly among the fisheries surveyed from 1977-78 through 1980-81 (Table 15). The percentage of hatchery fish among half-pounders averaged 24% in the RK 7-18 survey area, 38% in the RK 42-54 survey area, 41% in the RK 55-77 survey area, 43% in the RK 110-129 survey area, and 35% in the RK 139-156 survey area.

A Newman-Keuls multiple comparison test indicated that hatchery fish composed a significantly ($P \leq 0.05$) smaller percentage of half-pounders harvested in the RK 7-18 survey area compared with survey areas farther upstream. The test revealed no significant differences in the percentage of hatchery fish among half-pounders harvested in fisheries upstream of RK 42. Data included in these analyses are in Appendix Table C-27.

We found no significant difference in the percentage of hatchery fish among adult summer steelhead harvested in different areas of the Rogue River (Table 16). The percentage of hatchery fish in the harvest of adult fish averaged 19-23% in all the fisheries that we surveyed in 1977-78 through 1980-81. During those years, hatchery fish accounted for an average of 20% of the late-run adult summer steelhead that annually passed Huntley Park.

Half-pounders dominated the angler harvest of summer steelhead in the lower river and in the Rogue River canyon. Half-pounders accounted for 82-87% of the summer steelhead harvested by anglers that fished in the lower river and in the canyon during the 1977-78 through 1980-81 fisheries. During the same years, half-pounders composed an average of 77% of the summer steelhead that passed Huntley Park.

The percentage of half-pounders among wild summer steelhead retained by anglers differed significantly among the fisheries surveyed from 1977-78 through 1980-81 (Table 17). The percentage of half-pounders among wild fish averaged 81% in the RK 7-18 survey area, 82% in the RK 42-54 survey area, 87% in the RK 55-77 survey area, 43% in the RK 110-129 survey area, and 23% in the RK 139-156 survey area.

A Newman-Keuls multiple comparison test indicated that half-pounders composed a significantly ($P \leq 0.05$) greater percentage of the wild fish

Table 17. Comparison of the percentage of half-pounders among wild summer steelhead harvested by anglers, 1977-78 through 1980-81. Analysis includes only fisheries where $N \geq 40$ fish annually (Appendix Table C-28). Percentages were arcsin transformed prior to analysis.

Analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Survey area	5,186	4	1,296	72.84	<0.001
Year	52	3	17	0.98	0.434
Residual	214	12	18		

harvested in the lower river and canyon fisheries compared with fisheries farther upstream. The test also indicated that half-pounders composed a smaller percentage of the harvest in the RK 110-129 survey area compared with the RK 139-156 survey area. There were no significant differences in the percentage of half-pounders among wild fish harvested in the lower river and canyon fisheries. Data included in these analyses are in Appendix Table C-28.

The percentage of half-pounders among hatchery summer steelhead harvested by anglers also differed significantly among areas of the Rogue River (Table 18). The percentage of half-pounders among hatchery fish averaged 78% in the RK 7-18 survey area, 90% in the RK 42-54 survey area, 88% in the RK 55-77 survey area, 70% in the RK 110-129 survey area, and 38% in the RK 139-156 survey area. A Newman-Keuls multiple range test indicated that the percentage of half-pounders among hatchery fish harvested in the RK 139-156 survey area and the RK 110-129 survey area differed significantly from all other surveys. The test indicated that the percentage of half-pounders among hatchery fish did not differ significantly for the lower river and canyon fisheries.

Table 18. Comparison of the percentage of half-pounders among hatchery summer steelhead harvested by anglers, 1977-78 through 1980-81. Analysis includes only fisheries where $N \geq 40$ fish annually (Appendix Table C-28). Percentages were arcsin transformed prior to analysis.

Analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Survey area	3,054	4	763	25.45	<0.001
Year	375	3	125	4.17	0.031
Residual	360	12	30		

Differences in seasonal positioning of half-pounders and adult summer steelhead probably accounted for differences in composition of the angler harvest of wild fish. Everest (1973) concluded that most half-pounders did not pass upstream of the Rogue River canyon. In contrast, most adult summer steelhead spawned in areas upstream of the Rogue River canyon (Everest 1973). Thus, compared with adult summer steelhead, proportionally fewer half-pounders were exposed to harvest in the middle river fisheries. Analysis of tag recoveries from the angler harvest supported this conclusion (*see* **Catch Distribution**, page 76).

Angler Effort

Counts of bank anglers in the fishery near Gold Beach (RK 7-18) peaked, on average, in late August (Figure 27). Boat counts peaked later than counts of bank anglers because most boat anglers fished for salmon rather than summer steelhead. Consequently, we excluded data from boat counts from further analysis of angler effort in the fishery near Gold Beach.

We found that fewer anglers fished in the afternoon compared with the morning or evening. A t-test indicated that mean daily counts of bank anglers in 1976-83 did not differ significantly between counts made at 0900 hours and counts made at 1900 hours ($P = 0.980$). However, mean daily counts of bank anglers at 1500 hours were significantly lower than counts made at 0900 hours ($P < 0.001$) and counts made at 1900 hours ($P < 0.001$).

We also found that more anglers fished in the afternoon on weekend days compared with weekdays. A t-test indicated that mean daily counts of bank anglers at 1500 hours were significantly greater ($P = 0.027$) on weekend days. The number of bank anglers counted on weekends and weekdays did not differ significantly for counts made at 0900 hours ($P = 0.102$) or counts made at 1900 hours ($P = 0.471$).

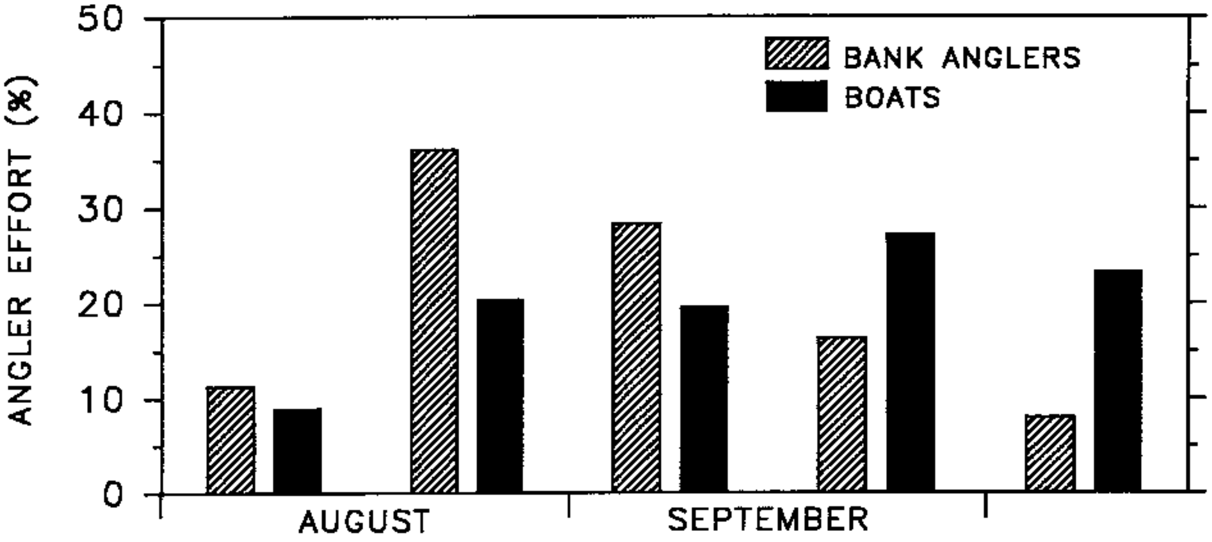

Figure 27. Mean timing of angler effort at 0900 hours for summer steelhead in the Gold Beach fishery (RK 7-18), averaged for 1976-81. Most boat anglers fished for fall chinook salmon.

We did not detect a change in angler effort in the fishery for summer steelhead near Gold Beach after operation of Lost Creek Dam. Mean annual counts of bank anglers at 0900 hours averaged 31.8 anglers in 1965-77 and 31.9 anglers in 1978-81. Analysis of variance indicated that the means did not differ significantly ($P = 0.983$). Mean annual counts of bank anglers at 1900 hours averaged 32.1 anglers in 1965-77 and 33.6 anglers in 1978-81. Analysis of variance indicated that the means were not significantly different ($P = 0.744$). Data included in the analyses are in Appendix Table C-29.

Angler success appeared to be an important determiner of angler effort in the fishery for summer steelhead near Gold Beach. We found a positive relationship between mean weekly counts of bank anglers at 0900 hours and angler catch rates of summer steelhead (Figure 28). Residual variation from

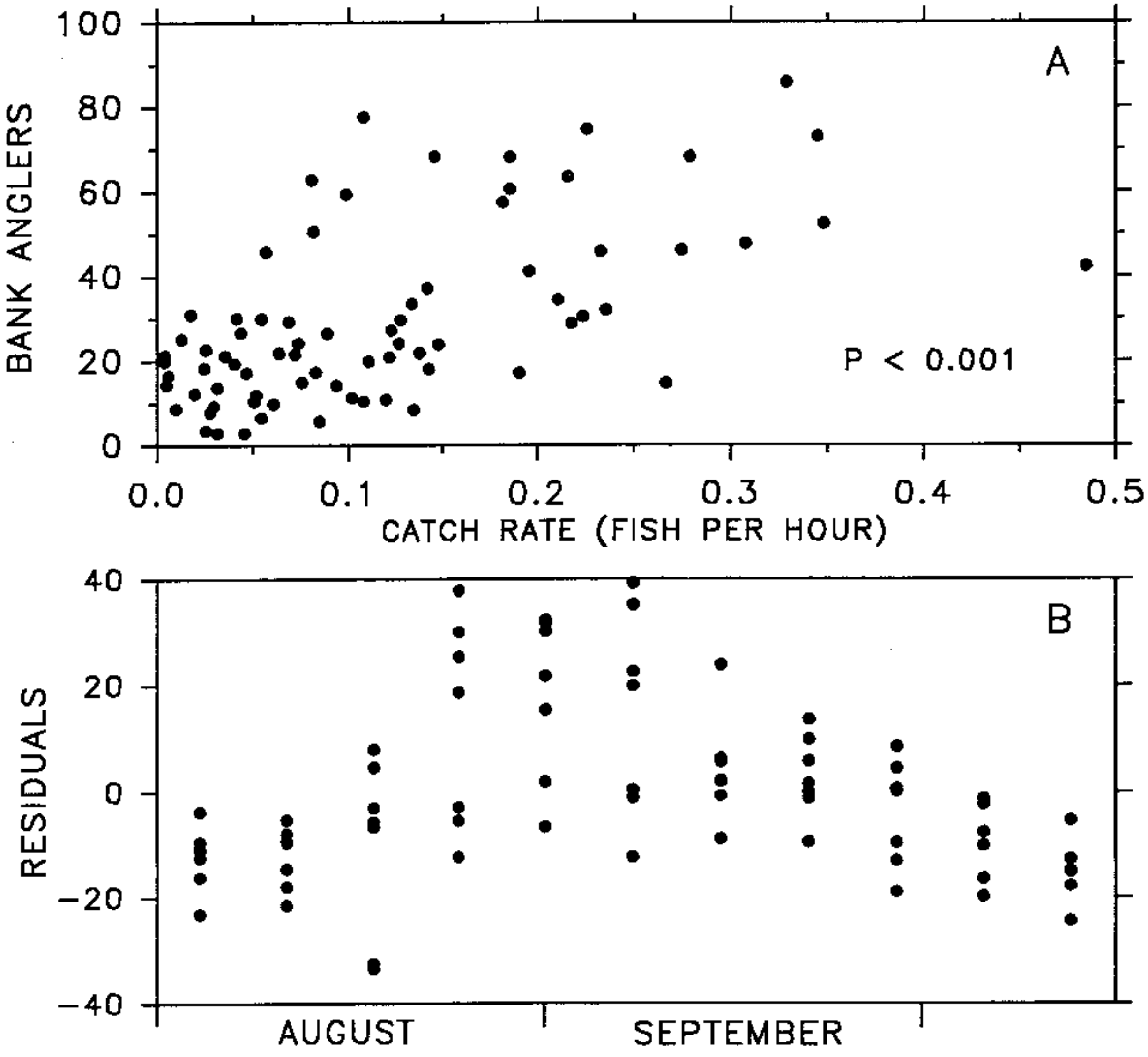

Figure 28. Relationship between the mean weekly counts of bank anglers at 0900 hours in the Gold Beach fishery (RK 7-18) and the mean weekly catch rate of summer steelhead by bank anglers (A), and the residual variation from relationship (A) and time (B), 1976-81 return years.

the relationship was not significantly related with physical parameters of the Rogue River. However, residual variation was related to time in a curvilinear manner (Figure 28). This finding may indicate that anglers planned fishing trips for summer steelhead in the lower river based on calendar date.

We estimated from a regression analysis (Appendix Table C-30) that mean weekly counts of bank anglers at 0900 hours increased by 15 bank anglers (95% confidence interval = ±4 anglers) for each 0.1 fish per hour increase in catch rate. Data included in the analysis are in Appendix Table C-12. A correlation matrix that outlines the relationships among all variables examined in the analysis is in Appendix Table C-31.

The timing of angler effort in the Gold Beach fishery for summer steelhead changed after Lost Creek Dam became operational. Bank anglers that fished during 1-15 October accounted for an average of 17% of the bank angler effort at 0900 hours in 1965-76 and an average of 7% of the bank angler effort at 0900 hours in 1977-81. The relative decrease in angler effort late in the season was significant at $P = 0.021$ for arcsin transformed data. We concluded that a change in fish abundance was the most likely cause of decreased angler effort in early October because (1) catch rate was highly correlated with angler effort, (2) fish abundance was highly correlated with angler catch rate (*see* **Catch Rate**, page 71), and (3) USACE simulation analyses suggested that the operation of Lost Creek Dam had minimal effect on river physical parameters in October (*see* **Physical Factors**, page 28). Data included in the analysis are in Appendix Table C-32.

In the fishery for summer steelhead near Agness (RK 42-54), effort by bank anglers, on average, declined from early September through the end of October (Figure 29). Conversely, effort by boat anglers, on average, was relatively constant during September-October (Figure 29). Data used to estimate the timing of angler effort are in Appendix Table C-33. Because the fishery usually began prior to September and continued after October, future surveys of this fishery should begin no later than 15 August, and should continue as long as half-pounders contribute to the fishery.

We found that angler effort in the Agness area fishery was greater on weekend days than on weekdays. In 1976-80, counts of bank anglers at 1000 hours averaged 19.4 anglers on weekend days and 8.8 anglers on weekdays. A t-test indicated that the difference in means was significant at $P < 0.001$. Significant differences in weekday and weekend counts were also found for counts of bank anglers at 1300 hours and 1600 hours. Analyses of boat counts produced comparable results. We concluded that indexes of angler effort were not directly comparable among weeks because survey days were randomly chosen without regard to day of the week. Consequently, we limited our analysis of angler effort in the Agness area fishery to mean annual indexes of angler effort.

We also found that angler effort in the fishery near Agness varied among years. Greater numbers of bank anglers fished in 1977 compared with other years (Appendix Table C-34). However, boat counts were not greater in 1977 compared with other years (Appendix Table C-34). We did not evaluate the relationships between annual indexes of angler effort and river physical parameters because we only had four years of data.

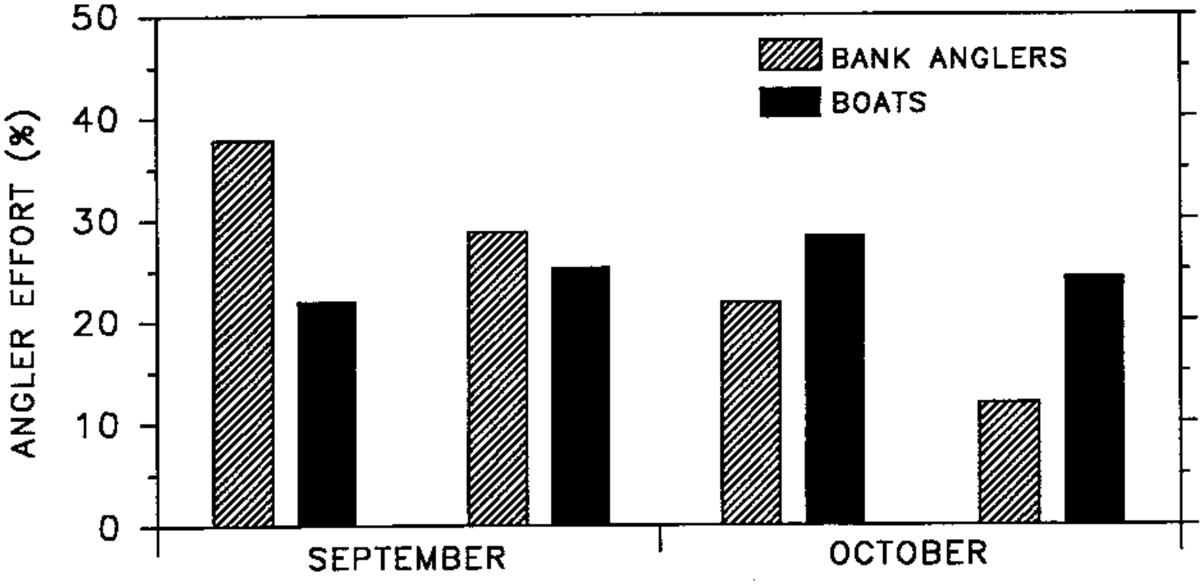

Figure 29. Mean timing of angler effort at 1000 hours in the Agness fishery (RK 42-55) for summer steelhead, averaged for the 1977-80.

In the fishery for summer steelhead near Galice (RK 110-129), angler effort, on average, peaked in early November and was relatively constant from late November through the end of January (Figure 30). Data used to estimate the timing of angler effort are in Appendix Table C-35. Because the fishery usually began prior to November, future surveys of this fishery should start by 1 October. An appropriate date for survey termination was more difficult to judge because tag returns indicated that anglers caught some summer steelhead in the Galice area during February when anglers also catch winter steelhead.

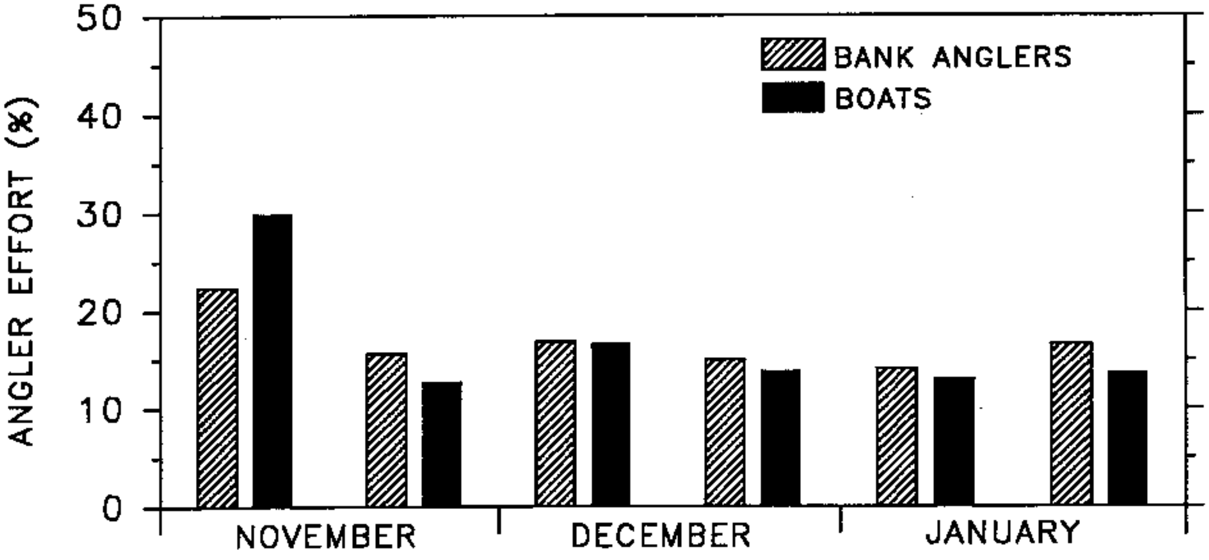

Figure 30. Mean timing of angler effort at 1200 hours in the Galice fishery (RK 110-129) for summer steelhead, averaged for 1977-78 through 1980-81.

We found that angler effort in the Galice area fishery was greater on weekend days than on weekdays. In the 1976-77 through 1980-81 fisheries, counts of bank anglers at 1200 hours averaged 23.2 anglers on weekend days and 12.8 anglers on weekdays. A t-test indicated that the difference in means was significant at $P < 0.001$. Significant differences in weekday and weekend counts were also found for counts of bank anglers at 0900 hours and 1600 hours. Analyses of boat counts and counts of boat trailers produced comparable results. We concluded indexes of angler effort were not directly comparable among weeks because survey days were randomly chosen without regard to the day of the week. Consequently, we limited our analysis of angler effort in the Galice area fishery to (1) mean annual indexes of angler effort and (2) effort counts on weekdays.

We also found that angler effort in the Galice area fishery varied among years. Greater numbers of bank anglers fished in 1977-78 compared with other years (Appendix Table C-36). However, counts of boats and boat trailers were not greater in 1977 compared with other years (Appendix Table C-36). We did not evaluate the relationships between annual indexes of angler effort and river physical parameters because we only had four years of data.

Daily effort counts at 1200 hours indicated that physical parameters of the Rogue River affected the number of anglers that fished for summer steelhead in the Galice area. A plot of bank angler counts on turbidity indicated that effort by bank anglers declined when turbidity exceeded 10 JTU (Figure 31). A plot of boat trailer counts on turbidity indicated that effort by boat anglers declined when turbidity exceeded 10 JTU (Figure 31). Effort by boat anglers and bank anglers peaked when turbidity ranged between 2 JTU and 10 JTU (Figure 31).

In the fishery for summer steelhead near Grants Pass (RK 110-129), angler effort, on average, exhibited no distinct peaks in angler effort from November through January (Figure 32). Data used to estimate the timing of angler effort are in Appendix Table C-37. Because the fishery usually began prior to November, future surveys of this fishery should begin no later than 1 October. An appropriate date for survey termination was more difficult to judge because anglers caught some tagged summer steelhead near Grants Pass in February when large numbers of winter steelhead were also captured (ODFW 1990).

We found that angler effort in the Grants Pass area fishery was greater on weekend days than on weekdays. In the 1976-77 through 1980-81 fisheries, counts of bank anglers at 1200 hours averaged 14.8 anglers on weekend days and 10.4 anglers on weekdays. A t-test indicated that the difference in means was significant at $P < 0.001$. Significant differences in weekday and weekend counts were also found for counts of bank anglers at 0900 hours and 1600 hours. Analyses of boat counts and counts of boat trailers produced comparable results. We concluded indexes of angler effort were not directly comparable among weeks because survey days were randomly chosen without regard to the day of the week. Consequently, we limited our analysis of angler effort in the Grants Pass area fishery to (1) mean annual indexes of angler effort and (2) effort counts on weekdays.

We also found that angler effort in the Grants Pass area fishery did not vary among years. Unlike fisheries farther downstream, counts of bank anglers in 1977-78 were not greater than in other years (Appendix Table C-38). We did

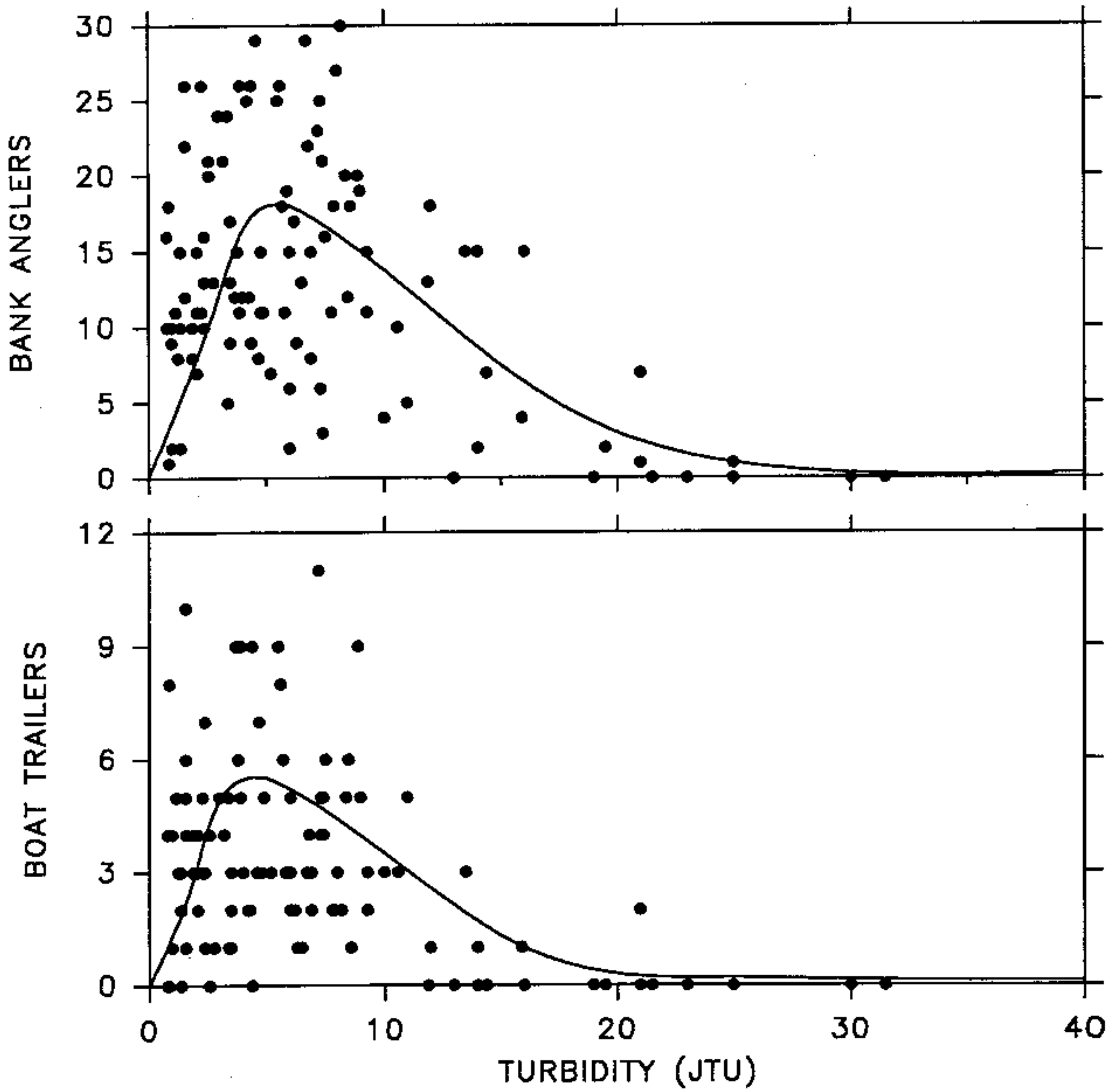

Figure 31. Relationships between mean weekly indexes of angler effort at 1200 hours in the Galice fishery (RK 110-129) for summer steelhead and mean weekly turbidity at Grants Pass, 1977/78-1980/81.

not evaluate the relationships between annual indexes of angler effort and river physical parameters because we only had four years of data.

Daily effort counts at 1200 hours indicated that physical parameters of the Rogue River affected the number of anglers that fished for summer steelhead in the Grants Pass area. A plot of bank angler counts on turbidity indicated that effort by bank anglers declined when turbidity exceeded 10 JTU (Figure 33). A plot of boat trailer counts on turbidity indicated that effort by boat anglers declined when turbidity exceeded 10 JTU (Figure 33). Effort by boat anglers and bank anglers peaked when turbidity ranged between 2 JTU and 10 JTU (Figure 33).

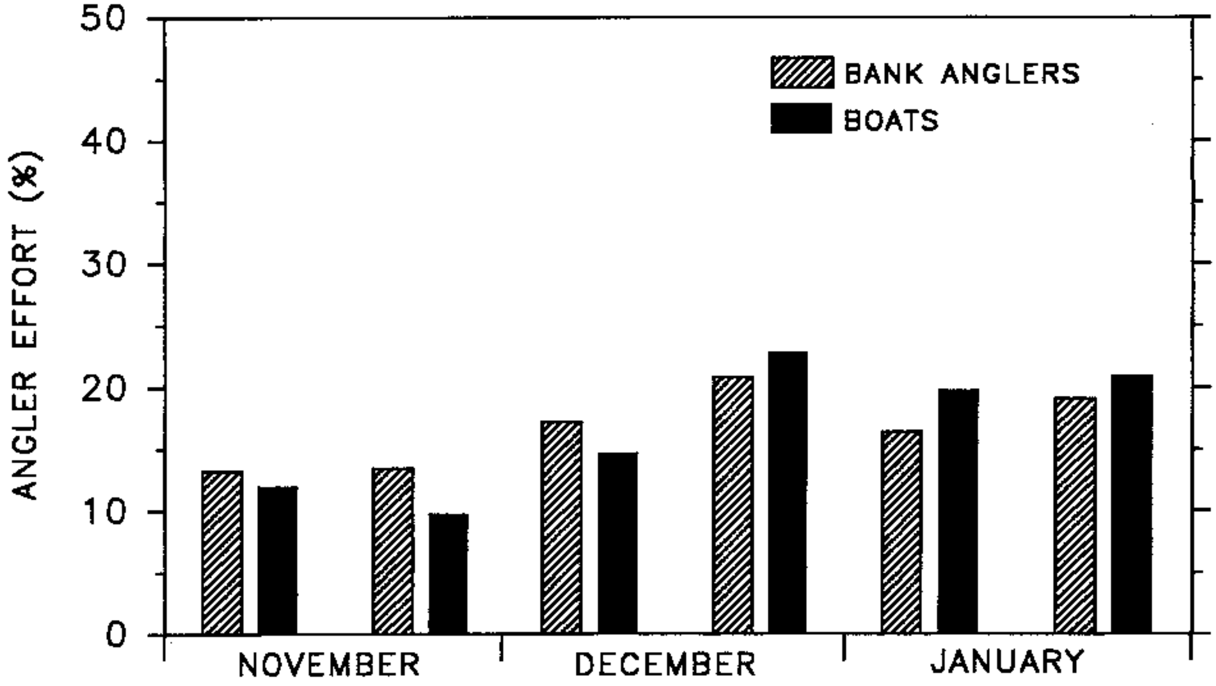

Figure 32. Mean timing of angler effort at 1200 hours in the Grants Pass fishery (RK 139-156) for summer steelhead, averaged for 1977-78 through 1980-81.

Although turbidity and flow are highly correlated in autumn and early winter when anglers fished for summer steelhead in the middle river (Appendix Table C-12), turbidity may be the more important determiner of angler effort. Lloyd et al. (1987) stated that anglers avoid turbid streams in Alaska. Rivers (1964) stated that the catch of winter steelhead in the Rogue River was negligible when turbidity increased during mining and road building. Meigs and Pautzke (1941) claimed that angler success in the Green River, Washington, was lowest "when the river was high and off color". ODFW (1990) found that angler effort for winter steelhead in the Rogue River peaked when turbidity ranged from 5 JTU to 15 JTU. Barrett et al. (1992) found that the reactive distances of rainbow trout to food items decreased when turbidity increased from 4-6 JTU to 15 JTU. These conclusions suggest that high levels of turbidity in the Rogue River reduce angler success and thus angler effort for summer steelhead.

Our findings suggested that the operation of Lost Creek Dam affected angler effort for summer steelhead in the middle river fisheries. Turbidity simulations developed by the USACE indicated that operation of Lost Creek Dam decreased turbidity at Grants Pass in November-January from 1978-79 through 1985-86 by an average of 2.0 JTU (95% CI = ± 0.6 JTU). Under regulated conditions, simulations indicated that mean turbidity averaged 11.5 JTU. Under unregulated conditions, simulations indicated that mean turbidity averaged 13.5 JTU. Because angler effort decreased when turbidity exceeded 10 JTU, we believe that reservoir operation in late autumn and early winter increased angling opportunities for summer steelhead in the middle river fisheries.

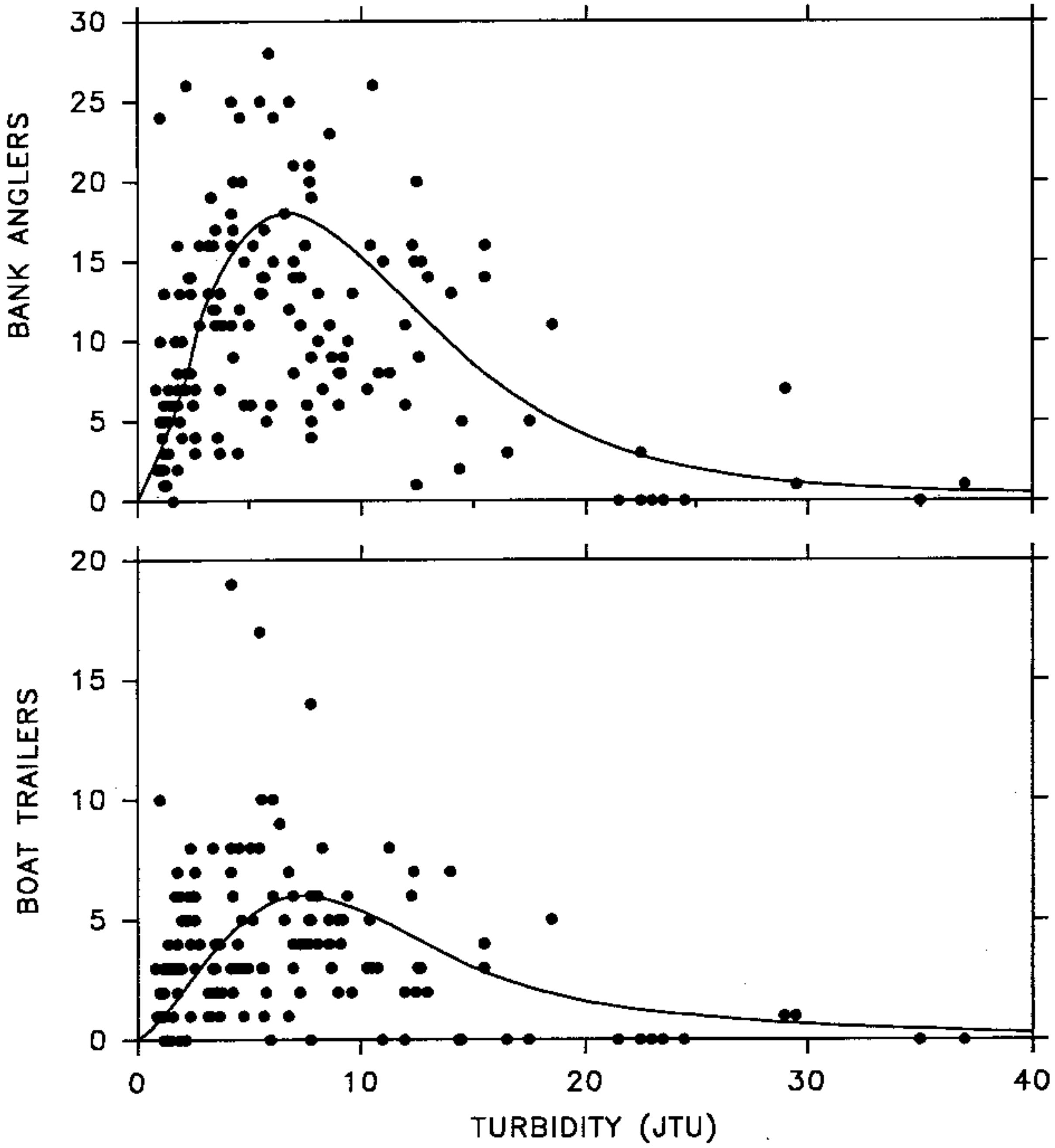

Figure 33. Relationships between mean weekly indexes of angler effort at 1200 hours in the Grants Pass fishery (RK 110-129) for summer steelhead and mean weekly turbidity at Grants Pass, 1977/78-1980/81.

Juveniles

In this section, we present some estimates of juvenile life history parameters developed from analyses of scales taken from wild summer steelhead seined at Huntley Park. These data represent only those survivors that returned to the Rogue River and may not be representative of the life history parameters of cohorts at each stage of freshwater residence.

We found that half-pounders and adult summer steelhead differed in some parameters of juvenile life history. Consequently, when we attempted to identify the factors that affected the life history parameters of juvenile summer steelhead, we limited analyses to parameters estimated from scales of first spawning migrants. We chose data from first spawning migrants because (1) some half-pounders were juvenile winter steelhead (ODFW 1990), (2) some half-pounders were strays from the Klamath River basin (Satterthwaite 1988) and (3) sample sizes were greater for first spawning migrants than for second or third spawning migrants.

Emergence

Emergence of fry in tributary streams used by spawning summer steelhead begins in the middle of April and ends in the middle of June (Faudskar 1980). We were unable to evaluate the effect of Lost Creek Dam on emergence timing because we did not consistently catch newly emergent fry at any of the sites that we seined in the Rogue River or in tributary streams. Operation of Lost Creek Dam did not affect the development rate of eggs and alevins because adults spawned in tributary streams. However, operation of the dam may have caused adults in the upper river to mature at an earlier date (*see* **Spawning**, page 66). Accelerated maturation among wild fish would lead to an earlier timing of fry emergence.

Freshwater Growth

Length of Subyearlings: Lengths of subyearling steelhead seined in the middle river and in the canyon increased after operation of Lost Creek Dam. Analysis of variance indicated that subyearlings seined at Matson Park and Whiskey Bar were significantly larger in postimpoundment years compared with preimpoundment years (Table 19). We were not able to detect any change in the lengths of subyearlings seined at two sites in the upper river (Table 19). Mean lengths used in these analyses were predicted from annual regressions of mean length on sampling date for a sampling date of 1 September (Appendix Table D-1). We predicted lengths from regressions because we sometimes lacked estimates of mean length on dates proximal to 1 September.

We found that the length attained by juvenile steelhead in the first year of freshwater residence was related to rearing area. Mean lengths of subyearlings in early September increased with distance downstream from Lost Creek Dam. Among postimpoundment broods, mean lengths of subyearlings were 3.7 cm greater at Whiskey Bar in the canyon than at Sand Hole, which is located just downstream of Lost Creek Dam (Table 19). This finding indicated that subyearlings in the upper river grew at slower rates than counterparts in downstream areas.

Mean lengths of subyearling steelhead at Sand Hole were not significantly correlated with (1) flow or water temperature in summer, (2) abundance indexes of subyearling steelhead and subyearling chinook salmon that reared in the upper river, or (3) water temperature of a tributary stream in spring. Data included in the analyses are in Appendix Table D-2. Correlation matrixes that outline relationships between variables examined in the analyses are in Appendix Table D-3.

Table 19. Comparisons of mean lengths for subyearling steelhead on 1 September before and after operation of Lost Creek Dam. Data were predicted from annual regressions on mean length on day-of-year (Appendix Table D-1). Means were compared with a t-test.

Site	Years	Mean of predicted lengths (cm)	*P* for difference
Sand Hole	1975-77	5.3	0.957
	1978-82	5.3	
High Banks	1975-77	7.1	0.419
	1978-81	7.6	
Matson	1975-77	8.1	0.044
	1978-86	8.9	
Whiskey Bar	1975-77	7.8	0.001
	1978-86	9.0	

Mean lengths of subyearling steelhead at High Banks were significantly correlated with the water temperature of Big Butte Creek, a tributary of the upper river. Subyearling steelhead were larger in years when Big Butte Creek was relatively warm. We concluded that summer steelhead fry grew faster, or emerged earlier, in years when water temperature was greater in tributary streams. Mean lengths were not significantly related to either physical parameters of the Rogue River or abundance indexes of juvenile salmonids. Data included in the analysis of subyearlings seined at High Banks are in Appendix Table D-2. Correlation matrixes that outline relationships between variables examined in the analyses are in Appendix Table D-3.

In the middle river and in the canyon, lengths of subyearling steelhead in early September were related to water temperature in summer. We found that mean lengths of subyearlings seined at Matson Park and Whiskey Bar were negatively correlated with mean water temperature in July and August. Subyearlings were larger when water temperature in the middle river was lower in summer. Residual variation from the relationships of mean length of subyearling and water temperature in summer were not significantly related to any of the other independent variables that we examined. Data included in the analyses of mean lengths for subyearlings sampled in the middle river and in the canyon are in Appendix Table D-4. Correlation matrixes that outline relationships between variables in the analyses are in Appendix Table D-5.

Mean lengths of subyearlings sampled at Matson Park and Whiskey Bar were not significantly related to either water temperature of a tributary stream in spring or indexes of the abundance of subyearling salmonids. Mean lengths of subyearlings seined at Whiskey Bar were positively correlated with summer flow. Because water temperature and flow are highly correlated in summer (Appendix Table D-5), we could not determine from our analysis which factor was more highly correlated with subyearling lengths.

Length at Annulus One: Scale analyses indicated that most subyearlings reached 8-13 cm when the first annulus formed (Appendix Table D-6). Younger smolts grew faster than older smolts during the first year of freshwater residence. Among half-pounders, mean lengths at the first annulus averaged 10-12 cm for age-1 smolts, 9-10 cm for age-2 smolts and 9-10 cm for age-3 smolts (Appendix Table D-6). Size at the first annulus was greater among summer steelhead of Klamath River origin (Kesner and Barnhart 1972) but was smaller among winter steelhead of Rogue River origin (ODFW 1990) and winter steelhead produced in Vancouver Island streams (Hooton et al. 1987).

Analysis of variance indicated that mean length at annulus one differed significantly ($P < 0.001$) among age 1-3 smolts from the 1974-81 brood years that returned as half-pounders. A Newman-Keuls multiple range test indicated that mean length at the first annulus was significantly greater for age-1 smolts compared with age-2 or age-3 smolts. The test did not detect a difference in mean lengths at annulus one for age-2 and age-3 smolts.

Scale analyses also indicated that first spawning migrants were larger at the time of formation of the first annulus compared with half-pounders. Among the 1975-81 brood years, mean lengths at annulus one averaged 0.3 cm larger for first spawning migrants compared with cohorts that returned as half-pounders. A paired t-test indicated that the difference in mean lengths was significant at $P = 0.033$.

We did not detect a change in juvenile length at time of formation of the first annulus after operation of Lost Creek Dam. Among age 1-3 smolts that returned as first spawning migrants, we estimated that mean lengths at annulus one averaged 10.2 cm for the 1974-77 broods and averaged 10.5 cm for the 1978-81 broods. Analysis of variance indicated that preimpoundment and postimpoundment broods did not differ significantly ($P = 0.470$) in mean length when the first annulus formed. A sensitivity analysis indicated that mean lengths at the first annulus of postimpoundment broods would have had to decrease to 8.8 cm or increase to 11.6 cm in order to detect a change significant at the 95% confidence level.

Mean lengths of first spawning migrants at time of formation of annulus one were not significantly correlated with (1) physical parameters of the Rogue River in spring and summer or (2) abundance indexes for subyearling steelhead and subyearling chinook salmon that reared in the middle river. Data included in the analyses of mean lengths at annulus one are in Appendix Table D-7. Correlation matrixes that outline relationships between variables examined in the analyses are in Appendix Table D-8.

Length of Yearlings: Seining surveys indicated that mean lengths of yearling steelhead in some areas of the Rogue River increased after the operation of Lost Creek Dam. We found that yearlings that reared in the canyon and in the lower river were significantly larger in postimpoundment years compared with preimpoundment years. Yearling lengths used in these analyses were predicted from regressions of mean length on sampling date for the date of 1 September (Appendix Table D-9).

At Whiskey Bar, mean lengths of yearlings averaged 13.5 cm in 1975-77 and averaged 15.0 cm in 1978-86. Analysis of variance indicated that the means differed significantly at *P* = 0.014. In the lower river at Agness, mean lengths of yearlings averaged 13.7 cm in 1975-77 and averaged 14.5 cm in 1978-81. Analysis of variance indicated that the means differed significantly at *P* = 0.090. Data included in the analyses are in Appendix Table D-9. Potential changes in lengths of yearling steelhead in the middle river and in the upper river were not investigated because there were insufficient data to conduct the analyses.

We found that the mean lengths of yearling steelhead in early September at Whiskey Bar were negatively correlated with water temperature, and were positively correlated with flow, of the Rogue River in summer. Yearling steelhead were larger in years of greater flow and lower water temperature. Yearling lengths at Whiskey Bar were not significantly related to either water temperature in spring or abundance indexes of subyearling salmonids.

However, we were unable to detect significant relationships between mean lengths of yearling steelhead seined at Agness and the independent variables that we examined. Data included in the analyses of predicted lengths of yearlings sampled in the canyon and in the lower river are in Appendix Table D-10. Correlation matrixes that outline relationships between all variables examined in the analyses are in Appendix Table D-11.

Length at Annulus Two: Scale analyses indicated that most yearlings were 13-16 cm when the second annulus formed (Appendix Table D-12). Size at the second annulus was greater among summer steelhead of Klamath River origin (Kesner and Barnhart 1972) but was smaller among winter steelhead of Rogue River origin (ODFW 1990) and winter steelhead produced in Vancouver Island streams (Hooton et al. 1987).

Younger smolts were larger than older smolts after the second year of freshwater residence. Among half-pounders from the 1973-82 brood years, mean lengths at annulus two averaged 15.3 cm for age-2 smolts and 14.1 cm for cohorts that smolted at age-3. A paired t-test indicated that the difference in mean lengths was significant (*P* = 0.004).

Scale analyses indicated that mean lengths of first spawning migrants and half-pounders did not differ at the time of formation of the second annulus. Among the 1975-81 brood years, mean lengths at annulus one averaged only 0.1 cm greater for first spawning migrants compared with cohorts that returned as half-pounders. A paired t-test indicated that the difference in mean lengths was not significant (*P* = 0.901).

Juvenile length at time of formation of the second annulus increased after operation of Lost Creek Dam. Among first spawning migrants that smolted at age-2 and age-3, we estimated that mean lengths at annulus two averaged 14.6 cm for the 1974-76 broods and 15.9 cm for the 1978-81 broods. Analysis of variance indicated that preimpoundment and postimpoundment broods differed significantly (*P* = 0.094) in mean length at the second annulus.

We were unable to determine the factors responsible for the increase in yearling lengths after the operation of Lost Creek Dam. Mean lengths of first spawning migrants at time of formation of annulus two were not significantly correlated with (1) physical parameters of the Rogue River in spring and summer or (2) abundance indexes of subyearling steelhead and subyearling chinook salmon that reared in the middle river. Data included in the analyses of mean lengths of annulus two are in Appendix Table D-12. Correlation matrixes that outline relationships between variables examined in the analyses are in Appendix Table D-13.

Yearling Growth: Scale analyses indicated that most juvenile summer steelhead grew 5-7 cm during the second year of freshwater residence (Appendix Table D-14). Younger smolts grew faster than older smolts during the second year of freshwater residence. Among half-pounders from the 1973-82 brood years, yearlings that smolted at age-2 grew an average of 5.8 cm and cohorts that smolted at age-3 grew an average of 4.8 cm. A paired t-test indicated that the difference in mean growth during the second year of freshwater residence was significant ($P = 0.001$).

Scale analyses also indicated that freshwater growth in the second year of life did not differ between first spawning migrants and half-pounders. Among the 1975-81 brood years, second year growth averaged only 0.1 cm more for first spawning migrants than for cohorts that returned as half-pounders. A paired t-test indicated that the difference in freshwater growth during the second year of life was not significant ($P = 0.699$).

Juvenile growth in the second year of freshwater residence increased after operation of Lost Creek Dam. Among first spawning migrants that smolted at ages 2-3, we estimated that the increase in mean lengths averaged 5.2 cm for the 1974-76 broods and averaged 6.2 cm for the 1978-81 broods. Analysis of variance indicated that preimpoundment and postimpoundment broods differed significantly ($P = 0.018$) in mean growth during the second year of life.

We were unable to determine the factors responsible for the increase in yearling growth rates after the operation of Lost Creek Dam. Annual increases in lengths during the second year of freshwater residence were not significantly correlated with (1) physical parameters of the Rogue River in spring and summer or (2) abundance indexes of subyearling steelhead and subyearling chinook salmon that reared in the middle river. Data included in the analyses of growth rates of yearlings are in Appendix Table D-14. Correlation matrixes that outline relationships between variables examined in the analyses are in Appendix Table D-15.

Plus-growth: Growth rate between the time of formation of the last freshwater annulus and the time of ocean entry ("plus-growth") also varied between summer steelhead with different life histories. Smolts of younger ages exhibited greater plus-growth compared with older smolts. Among half-pounders, plus-growth averaged 7-9 cm for age-1 smolts, 5-8 cm for age-2 smolts, and 3-7 cm for age-3 smolts (Appendix Table D-16).

Analysis of variance indicated that mean plus-growth differed significantly ($P < 0.001$) among age 1-3 smolts from the 1974-81 brood years that returned as half-pounders. A Newman-Keuls multiple range test indicated that plus-growth was significantly greater for age-1 smolts compared with age-2 or age-3 smolts. The test did not detect a difference in plus-growth between age-2 and age-3 smolts. Greater plus-growth among younger smolts has also been noted for winter steelhead in the Rogue River (ODFW 1990) and for winter steelhead in streams of Vancouver Island (Hooton et al. 1987).

We were unable to compare plus-growth for complete broods produced before and after the operation of Lost Creek Dam. Among first spawning migrants, only the 1974 brood reared in fresh water solely during preimpoundment years. However, there was sufficient data to test for changes among individual age classes. These analyses indicated that plus-growth did not change significantly after the operation of Lost Creek Dam.

Among age-1 smolts that returned as first spawning migrants, plus-growth averaged 8.4 cm for preimpoundment broods and 9.1 cm for postimpoundment broods. The difference in means was not significant at $P = 0.376$. A sensitivity analysis indicated that mean plus-growth among age-1 smolts within postimpoundment broods would have had to decrease to 6.7 cm or increase to 10.3 cm in order to detect a change significant at the 95% confidence level.

Among age-2 smolts that returned as first spawning migrants, plus-growth averaged 6.7 cm for preimpoundment broods and 7.0 cm for postimpoundment broods. The difference in means was not significant at $P = 0.611$. A sensitivity analysis indicated that mean plus-growth among age-2 smolts within postimpoundment broods would have had to decrease to 5.2 cm or increase to 8.3 cm in order to detect a change significant at the 95% confidence level.

We found that plus-growth was related to physical parameters of the Rogue River in spring. Among age-1 smolts that returned as first spawning migrants, plus-growth was positively correlated with water temperature and was negatively correlated with flow (Appendix Table D-17). Plus-growth of age-2 smolts that returned as first spawning migrants was also positively correlated with water temperature and was negatively correlated with flow in spring (Appendix Table D-18). These relationships indicated that smolts grew more in spring when water temperature was relatively warm and flow was relatively low.

Reservoir operation appeared to have minimal affect on the plus-growth of juvenile steelhead. Plus-growth occurs in March-May prior to when smolts enter the ocean. Model simulations by USACE indicated that water temperature near McLeod in March-May of 1978-86 averaged 7.2^{o}C for regulated and 7.3^{o}C for unregulated conditions. Other simulations indicated that mean water temperatures for regulated and unregulated conditions also differed by only 0.1^{o}C at Raygold and Grants Pass in March-May of 1978-86.

Plus-growth among age-1 and age-2 smolts that returned as first spawning migrants was not significantly correlated with mean length at the first annulus (Appendix Tables D-17 and D-18). These findings suggested that larger juveniles do not grow more than smaller cohorts during the parr-smolt transformation even though larger fish probably have greater energy reserves. Data included in the analyses are in Appendix Table D-19.

Determinants of Growth: We found that the size of subyearling steelhead in early summer increased with distance downstream from Lost Creek Dam. Subyearlings probably grew to larger sizes in downstream areas because water temperature in summer was closer to optimum for growth of juvenile steelhead.

Water temperature directly affects the growth rate of juvenile salmonids. Hokanson et al. (1977) found a positive relationship between water temperature and the growth rate of rainbow trout reared at 8-17°C. Growth rates decreased at water temperatures greater than 17°C. Wurtsbaugh and Davis (1977) reported similar findings for a different strain of rainbow trout. These studies confirm that changes in river temperature affected the growth rate of juvenile summer steelhead that reared in the Rogue River. Effect on growth rate was probably greatest in the area just downstream of Lost Creek Dam.

Model simulations by the USACE indicated that water temperature near McLeod in June-August of 1978-86 averaged 11.6°C for regulated and 13.7°C for unregulated conditions. Decreased water temperature reduced the growth rate of juvenile steelhead that reared in the mainstem for some distance below the dam. The effect on growth rate of juvenile steelhead in the upper river must have diminished with distance downstream from the dam. At Raygold, simulations indicated that water temperature in June-August averaged 15.4°C for regulated and 18.1°C for unregulated conditions.

In the middle river and in the canyon, reservoir operation decreased water temperature in summer to levels closer to those needed for optimal growth of juvenile steelhead. At Grants Pass, simulations indicated that water temperature in June-August averaged 17.5°C for regulated and 20.2°C for unregulated conditions. At Marial, simulations indicated that water temperature in June-August averaged 19.8°C for regulated and 22.1°C for unregulated conditions.

We concluded that the decrease in summer water temperature after operation of Lost Creek Dam decreased the growth of juvenile steelhead that reared in the upper river, but increased the growth of cohorts that reared in areas farther downstream. However, lengths of subyearling steelhead did not decrease in the upper river after operation of Lost Creek Dam. An increase in forage resources for juvenile salmonids that reared in the upper river (Jacobs et al. 1984) may have compensated for the decrease in water temperature.

Increased flow of the Rogue River in summer may have also directly affected the growth rate of juvenile steelhead. Flow augmentation decreases water temperature, but probably also increased the volume of habitat available to juvenile steelhead. An increase in habitat is likely associated with a decrease in the density of juvenile steelhead and a concomitant decrease in competition among cohorts. Bjornn (1978) concluded that high density reduced the growth rate of juvenile steelhead in Big Springs Creek, Idaho. Density also affected the size of subyearling and yearling steelhead in Lynn Creek, British Columbia (Hume and Parkinson 1987).

Competition with non-salmonids also affects the freshwater growth rate of juvenile salmonids. Reeves et al. (1987) found that the presence of redside shiners did not affect biomass production of juvenile steelhead when water temperature was 12-15°C, but reduced production when water temperature was 19-22°C. Flow augmentation in summer decreases the water temperature of the Rogue River (Hamlin and Nestler 1987) and may help juvenile steelhead compete with redside shiners.

Body Condition

Regressions of $\log_{10}$ weight on $\log_{10}$ length were significant ($P < 0.001$) for subyearling steelhead seined in August-September at High Banks, Matson Park, and Winkle Bar. We used the regressions to predict the mean weight of 8 cm fish sampled annually at each site in 1975-81 (Appendix Table D-20). Regressions of $\log_{10}$ weight on $\log_{10}$ length were also significant ($P < 0.001$) for yearling steelhead seined in August-September at High Banks, Almeda Park, and Winkle Bar (Appendix Table D-20). We used these regressions to predict the mean weight of 15 cm fish sampled annually at each site in 1975-81 (Appendix Table D-21) and used the predictions in the following analyses.

Mean weights of subyearling steelhead did not significantly change after operation of Lost Creek Dam (Table 20). Mean weights of yearling steelhead increased in the upper river at High Banks, but did not change significantly at sites farther downstream (Table 20).

Table 20. Comparisons of mean weights for juvenile steelhead before and after operation of Lost Creek Dam. Mean weights were predicted from annual regressions of weight on length for 8.0 cm subyearling and 15.0 cm yearling steelhead. Means were compared with a t-test.

Site	Years	Mean of predicted weight (g)	P for difference
		SUBYEARLINGS	
High Banks	1975-77 1978-81	5.7 5.6	0.604
Matson	1975-77 1978-81	6.1 5.9	0.661
Winkle Bar	1975-77 1978-81	6.1 6.2	0.834
		YEARLINGS	
High Banks	1975-77 1978-81	37.6 35.5	0.056
Almeda Park	1975-77 1978-81	34.9 37.6	0.262
Winkle Bar	1975-77 1978-81	35.9 38.8	0.166
Agness	1975-77 1978-81	36.3 36.8	0.841

We did not detect any significant correlations between mean weights of subyearling steelhead and the physical parameters of the Rogue River during summer (Appendix Table D-22). We also did not detect any significant correlations between mean weights of subyearlings and abundance indexes of cohorts or juvenile chinook salmon (Appendix Table D-22).

Mean weights of 15 cm steelhead captured at sites in the middle river and in the canyon were significantly correlated with physical parameters of the Rogue River in summer. Mean weights of yearlings seined at Almeda Park were positively related to flow in July-August (Appendix Table D-23). Mean weights of yearlings seined at Winkle Bar were also positively related to flow in July-August and were negatively related to water temperature in July-August (Appendix Table D-24).

Weights of 15 cm steelhead in the upper river were also correlated with physical parameters of the Rogue River. Mean weights of yearlings seined at High Banks were positively related to water temperature and were negatively related to flow (Appendix Table D-23). Mean weights of yearlings were not significantly correlated with abundance indexes of subyearling steelhead or chinook salmon among any of the data sets that we examined.

Our findings suggested that the operation of Lost Creek Dam increased the weight of yearling steelhead that reared in the Rogue River during summer. Flow augmentation in summer may have indirectly increased the body condition of yearling steelhead if greater flow increased the amount of habitat available for aquatic invertebrates that constitute the forage base of juvenile steelhead. Forage abundance is a primary factor that affects the body condition of salmonids (Ellis and Gowing 1957).

Age at Ocean Entry

Seine catches in spring suggested that most juvenile steelhead entered the ocean as age-2 smolts (Appendix Table D-25). In 1976-81, the age composition of smolts seined in the upper river and in the middle river averaged 34% age-1 smolts, 59% age-2 smolts, 7% age-3 smolts, and <1% age-4 smolts. Age composition of smolts caught at sites in the lower river averaged 20% age-1 smolts, 59% age-2 smolts, 20% age-3 smolts, and 1% age-4 smolts.

Smolts seined in the lower river were older than smolts caught in areas farther upstream and were older than counterparts that returned as summer steelhead. The percentage of age-3 smolts averaged 20% among smolts seined in the lower river in 1975-81, 7% among smolts seined in middle river and upper river in 1975-81, 6% among half-pounders that returned in 1975-81, and 3% among first spawning migrants that returned in 1976-82. Analysis of variance indicated that smolt age composition differed among the four groups ($P < 0.001$).

A Newman-Keuls multiple range test indicated that the percentage of age-3 smolts was significantly greater among smolts seined in the lower river than the percentage of age-3 smolts among the other three groups. This finding may indicate that juvenile steelhead produced in the lower portion of the Rogue River basin entered the ocean at older ages compared with counterparts produced in areas farther upstream. The Newman-Keuls multiple range test did not detect any significant differences in the percentage of age-3 smolts among smolts seined in the upper river and the middle river, half-pounders, or first spawning migrants.

Analyses of scales taken from summer steelhead seined at Huntley Park indicated that most smolts entered the ocean at age-1 or age-2 (Table 21). Age composition estimates for adult summer steelhead from the 1975-82 brood years averaged about 42% age-1 smolts, 55% age-2 smolts, 3% age-3 smolts, and no age-4 smolts. Age-3 and age-4 smolts were more common among half-pounders as compared with adult summer steelhead (Table 21). Older smolts were probably less common among adult summer steelhead because many returned to fresh water as winter steelhead. Scale analyses indicated that age-3 smolts accounted for about 8% of the winter steelhead that made a half-pounder run (ODFW 1990).

Table 21. Mean age at ocean entry for juvenile steelhead as estimated from scales of half-pounders and late-run adults, 1975-82 brood years.

Life history	Age at ocean entry			
	Age 1	Age 2	Age 3	Age 4
Half-pounders	32%	61%	6%	1%
First spawning migrants	42%	55%	3%	0%
Second spawning migrants	44%	55%	1%	0%

Analysis of variance indicated that the percentage of age-1 smolts among half-pounders, first spawning migrants, and second spawning migrants from the 1975-82 brood years did not differ significantly ($P = 0.615$). Large variation in the data suggested there was a minimal chance to detect differences in smolt age composition among summer steelhead of different life history types. Data included in these analyses are in Appendix Tables D-26 and D-27.

We did not detect a change in the age at ocean entry by juvenile summer steelhead after operation of Lost Creek Dam. However, we concluded there was a minimal chance to detect a change because the age composition of smolts varied greatly among brood years. Among first spawning migrants, age-1 smolts accounted for an average of 33% of the preimpoundment broods and 40% of the postimpoundment broods. A sensitivity analysis indicated that the percentage of age-1 smolts among postimpoundment broods would have had to decrease to 3% or increase to 74% in order to detect a change significant at the 95% confidence level.

Among second spawning migrants, age-1 smolts accounted for an average of 33% of the preimpoundment broods and 41% of the postimpoundment broods. A sensitivity analysis indicated that the percentage of age-1 smolts among postimpoundment broods would have had to decrease to 4% or increase to 67% in order to detect a change at the 95% confidence level. We did not compare the age composition of half-pounders because there were complete data for only two preimpoundment broods.

Age at ocean entry was related to growth in the first year of freshwater residence and plus-growth. Among first spawning migrants from the 1974-81 brood years, the percentage of age-1 smolts was positively related to mean plus-growth (Figure 34). Residual variation from the relationship was positively related to the mean length at annulus one (Figure 34). A multiple regression indicated that length at the first annulus and plus-growth accounted for 80% of the variation in the percentage of age-1 smolts among first spawning migrants (Appendix Table D-28). A correlation matrix that outlines relationships between all variables examined in the analysis is in Appendix Table D-29.

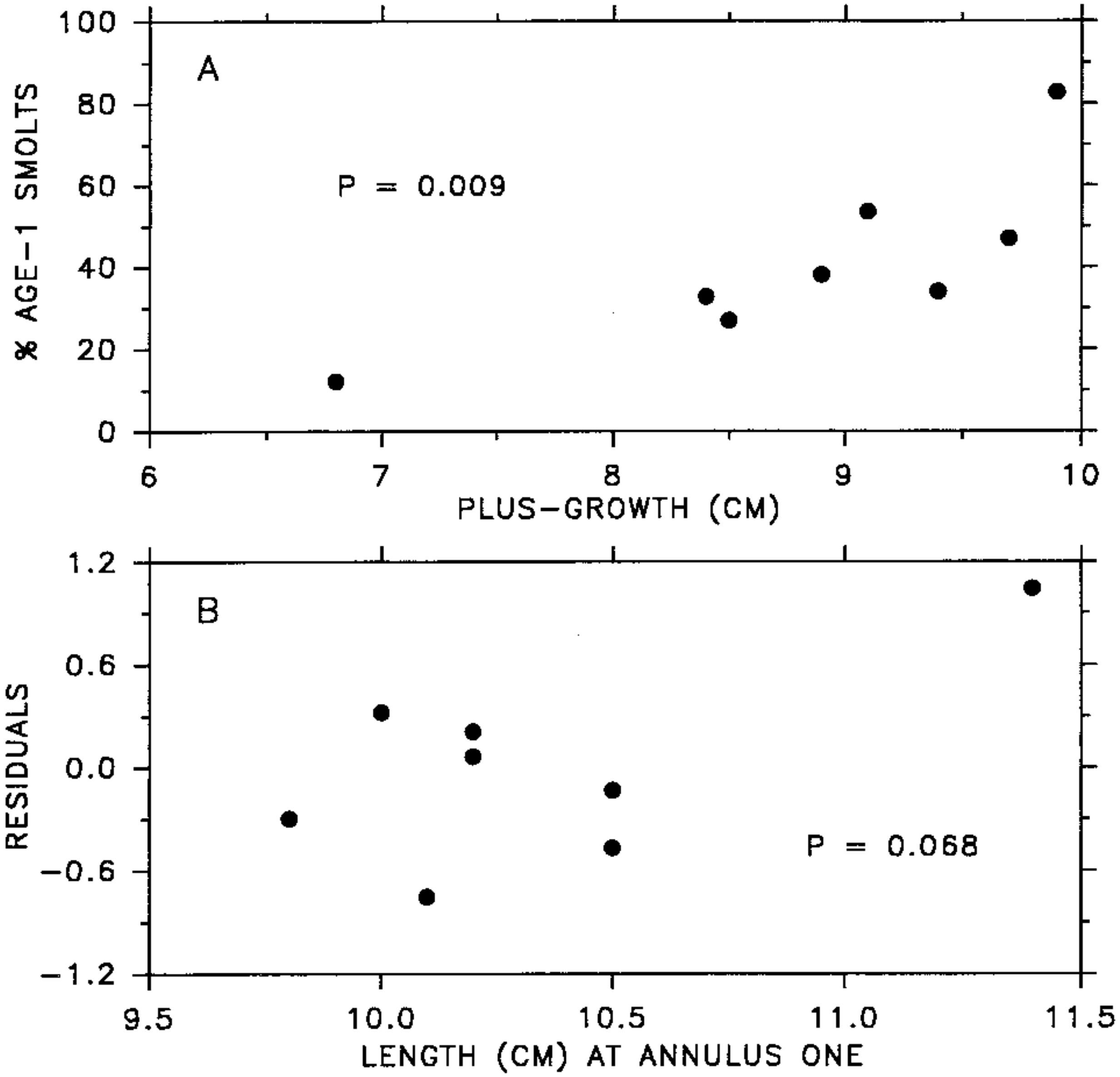

Figure 34. Relationship between smolt age composition and mean plus-growth for complete broods (1974-83) of first spawning migrants (A), and the residual variation from relationship (A) and mean length at formation of the first annulus.

Analysis of the age composition of half-pounders also suggested that plus-growth and length at annulus one affected age at ocean entry. Among half-pounders from the 1975-82 brood years, the percentage of age-1 smolts was positively related to plus-growth. Residual variation from the relationship was positively related to mean length at annulus one. A multiple regression indicated that length at the first annulus and plus-growth accounted for 74% of the variation in the percentage of age-1 smolts among half-pounders (Appendix Table D-30). A correlation matrix that outlines relationships between all variables examined in the analysis is in Appendix Table D-31.

We found that age-1 smolts accounted for a average of 42% of the first spawning migrants that returned to the Rogue River. Age-1 smolts accounted for 36% of the adult summer steelhead in the Klamath River of northern California (Kesner and Barnhart 1972). Like summer steelhead in the Rogue River, most of the fish return as half-pounders prior to maturity. Populations of summer steelhead in streams at higher latitudes entered the ocean at older ages. Age-1 smolts composed 0-20% of the summer steelhead that returned to streams in Washington (Leider et al. 1986) and British Columbia (Narver 1969; Hooton et al. 1987).

Summer steelhead and winter steelhead in the Rogue River basin differed in age at ocean entry. ODFW (1990) reported that winter steelhead in the Rogue River were comprised of 12% age-1 smolts, 66% age-2 smolts, 21% age-3 smolts, and 1% age-4 smolts. We found that adult summer steelhead in the Rogue River were comprised of 42% age-1 smolts, 55% age-2 smolts, and 3% age-3 smolts. Differences in smolt age between the two races may indicate that the races are reproductively isolated because smolt age is partially determined by genetic history (Ricker 1972).

However, body size also affects age at ocean entry for juvenile steelhead (Wagner 1974; Johnsson and Clarke 1988). We found that summer steelhead that grew faster in fresh water entered the ocean at a younger age compared with cohorts that grew slower. Other studies of steelhead have also found a negative relationship between growth rate and smolt age (Wagner et al. 1963; Narver and Withler 1974; Hooton et al. 1987). In the Rogue River basin, juvenile winter steelhead may grow more slowly in less productive tributary streams while cohorts destined to mature as summer steelhead grow faster.

Our findings indicated that changes in plus-growth and growth in the first year of freshwater residence would affect the age of ocean entry for juvenile summer steelhead that reared in the Rogue River. We also concluded that the operation of Lost Creek Dam did not have a significant effect on these growth parameters (*see* **Length at Annulus One:**, page 92 and **Plus-growth:**, page 94). Consequently, we concluded that reservoir operation had a minimal impact on the age at ocean entry for juvenile summer steelhead.

We previously recommended that outflow temperature from Lost Creek Dam be increased in spring to encourage a younger age at ocean entry among wild juvenile summer steelhead produced in the upper river (Cramer et al. 1985). However, research on winter steelhead in the Keogh River, British Columbia, determined that smaller smolts survived at lower rates than larger smolts (Ward and Slaney 1988). Reservoir operation strategies designed to decrease the age of smolting would increase returns of summer steelhead only if mortality that results from an additional year of freshwater residence exceeds the increase in ocean mortality that results from production of smaller smolts.

Because we cannot be confident that a younger age at ocean entry will increase returns of summer steelhead to the Rogue River, we recommend that outflow temperatures in spring be managed for the production of spring chinook salmon (Satterthwaite 1991). Decreased outflow temperatures in summer may increase the age at ocean entry for juvenile summer steelhead produced in the upper river, but should increase the scope for growth for wild juvenile summer steelhead that rear in areas farther downstream.

Length at Ocean Entry

From scales of first spawning migrants, we estimated that most juvenile summer steelhead entered the ocean at lengths that ranged between 19 cm and 24 cm (Appendix Table D-32). Older smolts were larger at time of ocean entry compared with younger smolts. Among half-pounders, length at ocean entry averaged 19-22 cm for age-1 smolts, 21-23 cm for age-2 smolts, and 23-26 cm for age-3 smolts (Appendix Table D-32).

Analysis of variance indicated that mean length at ocean entry differed significantly ($P < 0.001$) among age 1-3 smolts from the 1974-81 brood years that returned as half-pounders. A Newman-Keuls multiple range test indicated that smolt lengths were significantly greater for age-3 smolts compared with age-1 or age-2 smolts. The test also indicated that mean lengths of age-2 smolts were significantly greater than mean lengths of age-1 smolts. Older smolts were also the largest smolts in other populations of steelhead on the Pacific coast (Maher and Larkin 1955; Narver and Withler 1974; Hooton et al. 1987; ODFW 1990).

We were unable to compare the length at ocean entry for complete broods produced before and after the operation of Lost Creek Dam. Among first spawning migrants, only the 1974 brood reared in fresh water solely in preimpoundment years. However, there was sufficient data to test for changes among individual age classes. These analyses suggested that length at ocean entry did not change significantly after the operation of Lost Creek Dam.

Among age-1 smolts that returned as first spawning migrants, length at ocean entry averaged 20.1 cm for preimpoundment broods and 20.7 cm for postimpoundment broods. The difference in means was not significant at $P = 0.280$. A sensitivity analysis indicated that mean lengths at ocean entry among age-1 smolts from postimpoundment broods would have had to decrease to 18.7 cm or increase to 21.5 cm in order to detect a change at the 95% confidence level.

Among age-2 smolts that returned as first spawning migrants, length at ocean entry averaged 22.4 cm for preimpoundment broods and 23.0 cm for postimpoundment broods. The difference in means was not significant at $P = 0.507$. A sensitivity analysis indicated that mean lengths at ocean entry among age-2 smolts from postimpoundment broods would have had to decrease to 20.3 cm or increase to 25.5 cm in order to detect a change at the 95% confidence level.

Mean length at ocean entry for completed broods of first spawning migrants was not significantly correlated with (1) smolt age composition, (2) plus-growth, or (3) length at annulus one (Appendix Table D-33). However, a multiple regression indicated that length at ocean entry was positively related to length at annulus one ($P = 0.046$) and was negatively related to the percent of age-1 smolts in the brood ($P = 0.044$). These relationships suggested that steelhead smolts entered the ocean at a larger size when cohorts reach a larger length as subyearlings and smolt at a younger age.

However, because smolt age composition and length at the first annulus were significantly correlated (Appendix Table D-33), estimates of the regression coefficients probably represented the combined effects of both variables. Because we were unable to separate the singular effect of each variable, we could not estimate the effects of reservoir operation on the length at ocean entry for summer steelhead. The principal effect would likely be related to the increase in growth rates among yearlings (*see* **Length of Yearlings:**, page 92 and **Length at Annulus Two:**, page 93) because reservoir operation had minimal effects on the growth rate of subyearlings (*see* **Length at Annulus One:**, page 92) and on the plus-growth of smolts (*see* **Plus-growth:**, page 94).

Our data indicated that most juvenile summer steelhead migrated from the Rogue River at a length of 19-24 cm. Other studies have found that steelhead smolt at a length greater than 20 cm (Meigs and Pautzke 1941; Maher and Larkin 1954; Narver 1969; Bjornn 1978). Juvenile steelhead as large as 30 cm have been trapped in streams of California (Shapovalov and Taft 1954) and British Columbia (Ward and Slaney 1988).

Juvenile summer steelhead of Rogue River origin entered the ocean at sizes comparable to juvenile winter steelhead of Rogue River origin. ODFW (1990) found that most juvenile winter steelhead entered the ocean at lengths of 20-24 cm. In general, juvenile steelhead of Rogue River origin entered the ocean at a larger size compared with most other steelhead in streams along the Pacific coast.

From adult winter steelhead that returned to the Nanaimo River, British Columbia, Narver and Withler (1974) estimated that length at ocean entry averaged 13.2 cm for age-2 smolts, 14.0 cm for age-3 smolts, and 16.0 cm for age-4 smolts. Mean length at ocean entry averaged 16.4 cm for winter steelhead that returned to eight streams on Vancouver Island (Hooton et al. 1987). Peterson (1978) estimated that winter steelhead that returned to the Alsea River, Oregon, entered the ocean at a mean length of 16.0-18.4 cm. Kesner and Barnhart (1972) found that among first spawning migrants among summer steelhead that returned to the Klamath River, age-1 smolts averaged 18.7 cm, age-2 smolts averaged 19.9 cm, and age-3 smolts averaged 24.7 cm.

Abundance

Subyearlings: Annual catch rates of subyearling steelhead in 1975-81 averaged 47 fish per seine haul in the upper river at Sand Hole and High Banks, 9 fish per seine haul in the middle river at Matson and Almeda parks, 18 fish per seine haul in the canyon at Whiskey Bar and Winkle Bar, and 5 fish per seine haul in the lower river at Agness, Hideaway, and Canfield. Catch rates of subyearlings differed significantly among sites in the upper river, the middle river, and the canyon (Table 22). A Newman-Keuls multiple range test indicated that catch rates were significantly greater at sites in the upper river compared with sites farther downstream. We excluded catch rates from sites in the lower river from the analysis because we sampled those sites with a longer seine.

Annual catch rates averaged for areas upstream of the lower river did not differ significantly among years (Table 22). Mean catch rates for pooled sites in the upper river, the middle river, and the lower river annually ranged between 11 and 36 subyearlings per seine haul. Data included in the analysis are in Appendix Table D-34.

Catch rates of subyearling steelhead in various areas of the Rogue River did not vary in a similar manner through time. We found no significant correlations among annual catch rates of subyearlings seined in the four areas of the Rogue River (Appendix Table D-35). It is possible that fry production may have varied between different areas of the Rogue River basin. However, it seems more likely that seine catches may not have effectively indexed annual variations in the abundance of subyearling steelhead in the Rogue River.

Annual catch rates of subyearling steelhead seined in four areas of the Rogue River did not change significantly after operation of Lost Creek Dam (Table 23). Changes in catch rates were difficult to detect because annual catch rates varied greatly within preimpoundment broods. For example, annual catch rates of preimpoundment broods in the upper river averaged 50 fish per seine haul. A sensitivity analysis indicated that mean catch rates of postimpoundment broods would have had increase to 97 fish per seine haul or decrease to 3 fish per seine haul for a change to be detected by an analysis of variance for untransformed data. Sensitivity analyses of catch rates at sites in the other three areas of the Rogue River produced comparable results.

Annual estimates of the number of subyearling steelhead that passed Savage Rapids Dam averaged 145,526 fish and ranged between 9,673 fish and 337,706 fish in 1976-90 (Appendix Table D-36). Because there were only two years of data from preimpoundment broods, we did not compare the number of subyearling steelhead before and after the operation of Lost Creek Dam.

Table 22. Comparison of mean catch rates for subyearling steelhead seined in three areas of the Rogue River, 1975-81.

Two factor analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Area	5,554	2	2,777	12.72	0.001
Year	1,089	6	181	0.83	0.570
Residual	2,626	12	219		

Table 23. Comparisons of mean annual catch rates for subyearling steelhead seined in four areas of the Rogue River before and after operation of Lost Creek Dam. Means were compared with a t-test.

Area	Years	Catch rate[a]	*P* for difference
Upper river[b]	1975-77	49.8	0.786
	1978-81	44.7	
Middle river[c]	1975-77	6.9	0.321
	1978-86	21.8	
Canyon[d]	1975-77	12.5	0.450
	1978-86	18.3	
Lower river[e]	1975-77	1.6	0.315
	1978-81	7.0	

[a] *Mean annual fish per seine haul.*
[b] *Includes Sand Hole and High Banks.*
[c] *Includes Matson Park and Almeda Park.*
[d] *Includes Whiskey Bar and Winkle Bar.*
[e] *Includes Agness, Hideaway, and Canfield.*

Annual estimates of the number of subyearling steelhead that passed Savage Rapids Dam were not significantly correlated with annual catch rates of subyearlings seined at sites in the upper river, the middle river, the canyon, and the lower river (Appendix Table D-35). The lack of correlation among the various indexes of subyearling abundance made it difficult to choose an appropriate data set for an analysis of factors that may have affected the abundance of subyearling steelhead.

We concluded that seine catches were probably a more reliable abundance index for subyearling steelhead than estimates of passage at Savage Rapids Dam. Mark-recapture experiments conducted in 1974-75 indicated that subyearlings did not migrate extensively in the Rogue River (see **Migration**, page 113). Thus, subyearling migration at Savage Rapids Dam may represent a migration to rearing habitat proximal to spawning streams (Everest 1973). We chose to analyze catch rates of subyearling steelhead seined at sites in the middle river and in the canyon. There were 10 years of data from those sites compared with 7 years of data from sites farther upstream.

Multiple regression indicated that freshwater returns of parents and spring flow in a tributary stream accounted for 58% of the annual variation in catch rates of subyearling steelhead seined at sites in the middle river and in the canyon (Table 24). Freshwater returns of wild late-run adults were positively related to catch rates of fry later in the summer (Figure 35). Residual variation of the relationship was negatively related to the mean flow in spring of a tributary stream (Grave Creek) used by spawning summer steelhead (Figure 35). Flow of Grave Creek when parents migrated into and spawned in tributary streams was not related to seine catches of subyearlings (Table 24). Data included in the analysis are in Appendix Table D-37. A correlation matrix that outlines the relationships between all variables in the analysis is in Appendix Table D-38.

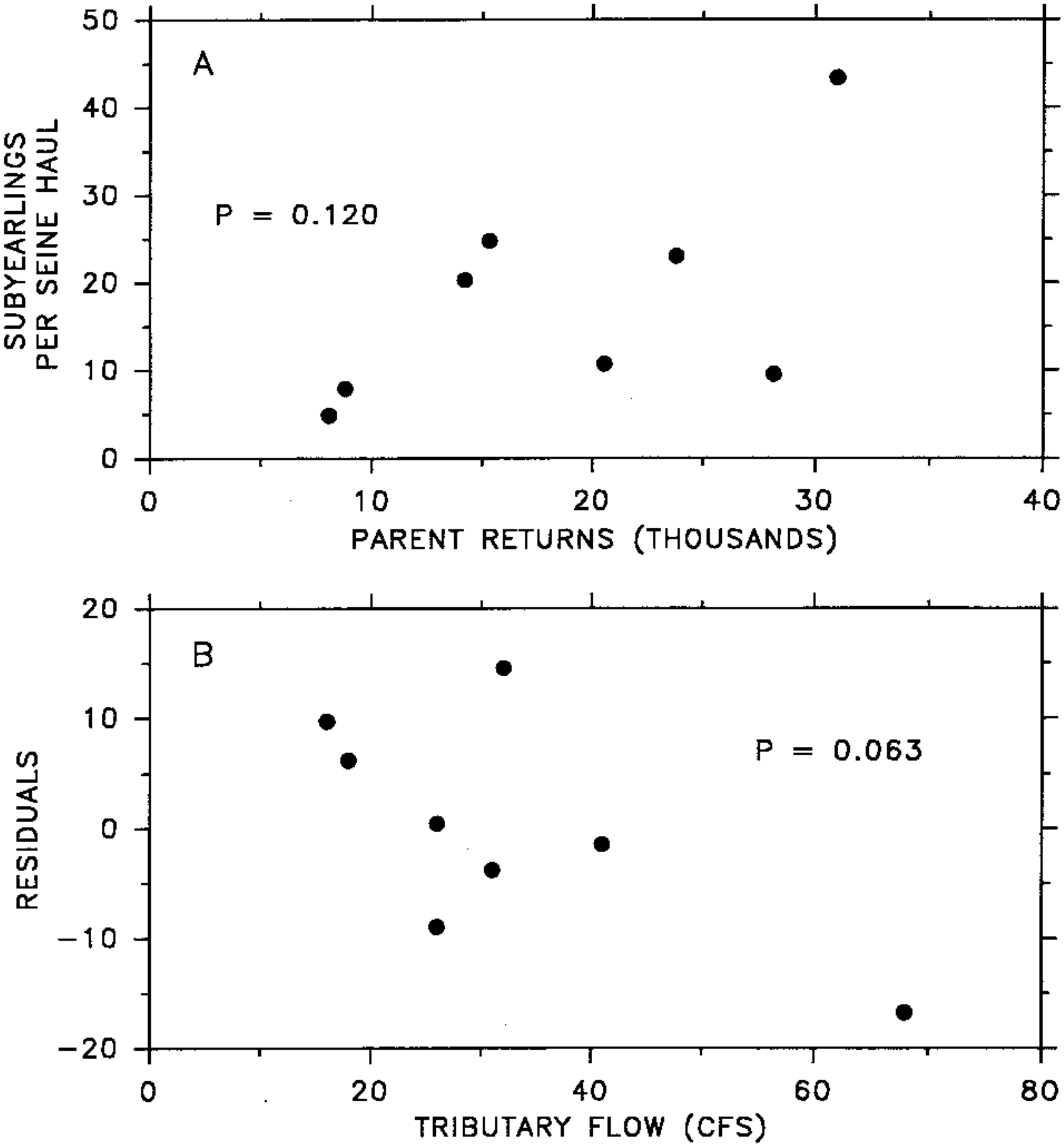

Figure 35. Relationship between catch rates of subyearling steelhead seined at sites in the canyon and in the middle river and estimated freshwater returns of wild late-run adult summer steelhead during the previous year (A), and the residual variation from relationship (A) and mean flow of Grave Creek in May, 1977-86. Sites were not seined in 1982-83.

Results from the multiple regression suggested that the production of juvenile summer steelhead in the Rogue River basin is limited by spawner abundance in years of low parental returns. Seine catches of subyearlings were lowest in years when less than 10,000 wild late-run adults returned to the Rogue River (Figure 35). While confidence in the results of the analysis is limited by uncertainty related to the reliability of seine catches as an index of juvenile abundance and a small sample size, we believe that harvest closures are appropriate when less than 10,000 wild late-run adult summer steelhead are expected to return. Freshwater returns of less than 10,000 wild adults can be expected when less than 40,000 wild half-pounders return to the Rogue River in successive years (*see* **Abundance**, page 35).

Results from the regression analysis also suggested that spring flow in tributary streams affected the production of subyearling steelhead in the Rogue River basin (Table 24). We found that flow in Grave Creek during May was negatively related to seine catches of subyearlings (Figure 35). We suspect that seine catches may have decreased in years of greater flow because

Table 24. Regression analysis of the annual catch rates of subyearling steelhead seined in the middle river and in the canyon, 1975-86. Sites were not sampled in 1982-83. Variables are described in Appendix Table D-37.

Independent variable	Regression coefficient	Standard error	*P*
Parent abundance	11.96×10^{-4}	3.87×10^{-4}	0.027
Migration flow	-0.4793	0.201	0.063
Constant	11.11		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	780.8	2	390.4	5.77	0.050
Residual	338.3	5	67.7		

Variables tested	Partial r^2 Step 1	Partial r^2 Step 2
Parent abundance	0.35	--
Spawning flow	0.09	0.03
Migration flow	0.19	0.53

subyearlings reared in tributaries for a longer period. Everest (1973) and Faudskar (1980) found that large numbers of steelhead fry migrate from tributary streams in the Rogue River basin just before cessation of flow. It is also possible that spring flow affected the survival rates of eggs deposited in tributary streams.

Yearlings: Annual catch rates of yearling steelhead in 1975-81 averaged 3 fish per seine haul in the upper river, 3 fish per seine haul in the middle river, 12 fish per seine haul in the canyon, and 9 fish per seine haul in the lower river. Catch rates of yearlings differed significantly among sites in the upper river, the middle river, and the canyon (Table 25). A Newman-Keuls multiple range test indicated that catch rates were significantly greater at sites in the canyon compared with sites farther upstream. We excluded catch rates from sites in the lower river from the analysis because we sampled those sites with a longer beach seine.

Annual catch rates of yearlings averaged for areas upstream of the lower river did not differ significantly among years (Table 25). Mean catch rates for all sites in the upper river, the middle river, and the lower river ranged annually between 2 yearlings per seine haul and 9 yearlings per seine haul. Catch rates of yearlings in various areas of the Rogue River are in Appendix Table D-39.

Unlike catch rates of subyearlings, catch rates of yearlings in various areas of the Rogue River varied in a similar manner through time. Annual catch rates of yearlings in the middle river were significantly correlated with annual catch rates of yearlings in the canyon and in the lower river (Appendix Table D-40). However, catch rates of yearlings in the upper river were not significantly correlated with catch rates in other areas of the Rogue River (Appendix Table D-40).

Annual catch rates of yearling steelhead were not significantly related to annual catch rates of subyearlings in the same areas during the previous year (all $r < 0.30$, all $P > 0.333$). This finding may indicate that survival rates during the first winter of freshwater residence are highly variable or that seine catches do not effectively index the abundance of juvenile steelhead that rear in the Rogue River.

Table 25. Comparison of mean catch rates for yearling steelhead seined in three areas of the Rogue River, 1975-81.

Two factor analysis of variance					
Source of variation	Sum of squares	df	Mean square	*F*	*P*
Area	307.1	2	153.5	13.62	<0.001
Year	94.8	6	15.8	1.40	0.291
Residual	135.3	12	11.3		

Annual catch rates of yearling steelhead seined in three of the four areas of the Rogue River did not change significantly after operation of Lost Creek Dam (Table 26). However, the mean catch rate of yearlings was significantly greater in preimpoundment years at sites in the canyon (Table 26). This finding suggested that the abundance of yearlings in the canyon may have decreased after operation of Lost Creek Dam.

Annual estimates of the number of yearling steelhead that passed Savage Rapids Dam averaged 30,782 fish and ranged between 11,535 fish and 61,723 fish in 1976-90 (Appendix Table D-36). Because there were only two years of data from preimpoundment broods, we did not compare the number of yearling steelhead that passed Savage Rapids Dam before and after the operation of Lost Creek Dam.

Annual estimates of the number of yearling steelhead that passed Savage Rapids Dam were not significantly correlated with annual catch rates of yearlings seined at sites in the upper river, the middle river, the canyon, or the lower river (Appendix Table D-40). We also found that passage estimates of yearlings were poorly correlated with passage estimates of subyearlings during the previous year ($r = 0.49$, $P = 0.073$). The lack of correlation between the various indexes of yearling abundance made it difficult to choose an appropriate data set for an analysis of factors that may have influenced the abundance of yearling steelhead.

Table 26. Comparisons of mean annual catch rates for yearling steelhead seined in four areas of the Rogue River before and after operation of Lost Creek Dam. Means were compared with a t-test.

Area	Years	Catch rate[a]	*P* for difference
Upper river[b]	1975-77 1978-81	2.4 3.1	0.469
Middle river[c]	1975-77 1978-86	3.4 2.6	0.595
Canyon[d]	1975-77 1978-86	16.7 8.1	0.017
Lower river[e]	1975-77 1978-81	11.1 7.4	0.537

[a] *Mean annual fish per seine haul.*
[b] *Includes Sand Hole and High Banks.*
[c] *Includes Matson Park and Almeda Park.*
[d] *Includes Whiskey Bar and Winkle Bar.*
[e] *Includes Agness, Hideaway, and Canfield.*

We concluded that seine catches were probably a more reliable abundance index for yearling steelhead than estimates of passage at Savage Rapids Dam. Unknown proportions of yearlings passed Savage Rapids Dam annually prior to the installation of the trap (*see* **Migration**, page 113). Also, mark-recapture experiments conducted during 1974-75 indicated that yearlings did not migrate extensively in the Rogue River (*see* **Migration**, page 113). Yearling migration at Savage Rapids Dam may represent a migration into rearing habitat proximal to tributaries inhabited during the previous winter (Everest 1973).

Catch rates of yearling steelhead at seining sites in the middle river and in the canyon were not significantly correlated with any of the variables we examined. Variables in the analysis included (1) freshwater returns of parents, (2) catch rates of cohorts at the same sites in the previous year, (3) summer flow of the Rogue River during the first year of life, and (4) peak flow of the Rogue River during the first winter of life (Appendix Table D-41). A correlation matrix that outlines the relationships between all variables examined in the analysis is in Appendix Table D-42. We analyzed catch rates at sites in the middle river and in the canyon because there were 10 years of data from those sites and only 7 years of data from sites farther upstream.

Age 2+ Smolts: Annual catch rates of age-2+ steelhead smolts seined during March-May in the upper river and the middle river averaged 0.9 fish per seine haul and ranged between 0.2 fish per seine haul and 2.4 fish per seine haul in 1975-81 (Appendix Table D-43). Annual catch rates of smolts seined during March-May at sites in the lower river averaged 3.2 fish per seine haul and ranged between 0.2 fish per seine haul and 11.2 fish per seine haul in 1975-81. Use of a longer seine in deeper water partially accounted for the greater catch rates in the lower river. Also, smolts were more abundant in the lower river because all smolts produced in the Rogue River basin must pass through the lower river prior to ocean entry.

Annual estimates of the number of age-2+ smolts that passed Savage Rapids Dam after 14 May averaged 10,853 fish and ranged between 1,235 fish and 35,982 fish in 1976-90 (Appendix Table D-36). Our analysis of migration timing suggested that most steelhead smolts passed Savage Rapids Dam prior to initiation of sampling (*see* **Migration**, page 113). Consequently, our passage estimates of steelhead smolts are too low and are probably of minimal value because of annual variations in migration timing. Also, our estimates suggested there was a 30-fold variation in smolt production among years. Other studies have found that annual production of steelhead smolts varies between twofold and sixfold (Ward and Slaney 1988; Loch et al. 1988).

Abundance indexes of age-2+ smolts were not related among the various sampling sites. Annual catch rates at sites in the lower river were not significantly correlated ($P = 0.186$) with annual catch rates at seining sites farther upstream. We also found that annual passage estimates at Savage Rapids Dam were not significantly correlated with catch rates at seining sites in either area of the Rogue River (both $P > 0.671$).

Determinants of Abundance: Operation of Lost Creek Dam did not affect the survival rates of eggs, alevins, and newly emergent fry because summer steelhead spawn in tributary streams rather than the Rogue River (Everest

1973). Reservoir operation could have affected juvenile summer steelhead after fry migrated from natal tributaries to rear in the Rogue River.

The effect of reservoir operation on survival rates of juvenile steelhead that reared in the Rogue River could not be evaluated because this study was not designed to address the question. Estimation of survival rates of juvenile salmonids is difficult in large streams, particularly in streams where fish migrate between sampling areas. The lack of correlations among abundance indexes of cohorts sampled at various locations lead us to conclude that abundance indexes were of questionable value.

Survival rates of juvenile steelhead rearing in streams have been estimated in numerous studies (ODFW 1986; Bley and Moring 1988). However, information that relates survival rates to environmental factors is lacking. Consequently, we can only make a qualitative assessment of the effects of the reservoir operation on the abundance of juvenile summer steelhead.

A literature review indicated that modifications in river physical factors probably produced changes in the habitat used by juvenile steelhead. Key habitat for juvenile summer steelhead in the Rogue River includes rearing habitat in summer and hiding habitat in winter. In the following text, we discuss how operation of the dam affected each of these habitat types.

Decreased water temperature in summer probably did not increase production of juvenile summer steelhead in the upper river. Water temperature was near optimum for juvenile growth in the upper river prior to the construction of Lost Creek Dam (*see* **Freshwater Growth**, page 90). The decrease in water temperature during summer slowed growth rates and probably caused juveniles to smolt at older ages (*see* **Age at Ocean Entry**, page 98). If smolts migrated at older ages, then total mortality among presmolts probably increased because of additional residence time in fresh water. However, if the older smolts were larger at ocean entry, survival rates in the ocean probably increased (Ward et al. 1989).

However, in areas other than the upper river, increases in flow and decreases in water temperature during summer probably increased survival rates of juvenile summer steelhead. Subyearling steelhead generally inhabit areas less than 20 cm in depth (Everest and Chapman 1972; Bustard and Narver 1975; Sheppard and Johnson 1985). Because fry inhabit shallow water, augmented flow in summer probably increased the amount of rearing habitat for steelhead fry. Increased habitat may have resulted in increased rate of survival, especially in years when fry density was high (Hume and Parkinson 1987).

Decreased water temperature in downstream areas during summer also may have allowed juvenile summer steelhead to compete more effectively with sympatric redside shiners. Reeves et al. (1987) determined that the presence of redside shiners did not affect the production of juvenile steelhead when water temperature was 12-15°C. However, when water temperature was 19-22°C, the production of juvenile steelhead decreased by 54% when redside shiners were present (Reeves et al. 1987).

Decreased water temperature also may have limited the upstream spread of Umpqua squawfish in the Rogue River. Umpqua squawfish escaped from a pond and entered the Rogue River at Grave Creek in 1979. In the interim, they have spread throughout the Rogue River basin downstream of Grants Pass, but few are found upstream of Grants Pass (ODFW, unpublished data). Juvenile Umpqua squawfish may compete with juvenile steelhead and adults may prey on small juvenile steelhead. Brown and Moyle (1991) found that the presence of Sacramento squawfish was associated with a decrease in the use of pool habitat by juvenile rainbow trout. They also cited multiple studies that show the abundance of Sacramento squawfish is low in streams with cool water temperatures in summer.

Based on the results of the literature review, we concluded that decreases in water temperature of the Rogue River in summer probably increased total production of juvenile summer steelhead by limiting the distribution of competitors and potential predators. Consequently, we recommend that reservoir storage that is not needed to minimize prespawning mortality among adult chinook salmon (ODFW 1992) should be used to decrease water temperature of the Rogue River by flow augmentation in summer. Flow augmentation is an effective tool to decrease water temperature in the middle river and in areas farther downstream (Hamlin and Nestler 1987).

Changes in river physical parameters in winter may also affect the production of juvenile summer steelhead in the Rogue River. Some biologists have postulated that the quantity and quality of hiding cover during the winter is an important determinant of steelhead production. Bustard and Narver (1975) found that juvenile steelhead in Carnation Creek, British Columbia, increased habitation of areas with hiding cover as water temperature decreased from 9°C to 2°C. Yearlings most commonly used logs and exposed tree roots for cover. Subyearlings primarily used interstices between large rocks for cover. The authors theorized that the availability of stable cover may be an important factor that affects survival rate of juveniles during the winter, particularly during periods of peak flow. Bjornn (1971) and Swales et al. (1986) also reported extensive use of hiding cover by juvenile steelhead when water temperature decreased below 5°C.

Construction of Lost Creek Dam may result in a decreased amount of winter cover for juvenile steelhead that inhabit the upper river. The dam blocks recruitment of large woody debris and large gravel into downstream areas. Significant changes in availability of winter habitat may not manifest for many years, or may be ameliorated by recruitment of large woody debris and cobble from tributary streams. We found that large numbers of juvenile steelhead rear in the upper river during summer. Because some juvenile steelhead remain in mainstem during winter (Everest 1973), we recommend that surveys be conducted to estimate the amount of winter habitat available to juvenile steelhead.

It is also possible that the annual production of juvenile summer steelhead in the Rogue River basin is mostly dependent on fry production in spawning tributaries. Faudskar (1980) estimated that 83,000 steelhead fry migrated from Kane Creek in 1970 and 106,000 migrated from Kane Creek in 1971. Subsequent surveys in 1991 and 1992 indicated that less than 5,000 steelhead fry migrated from Kane Creek annually (ODFW, unpublished data). The 20-fold variation in production among years suggests that parental abundance and environmental conditions in spawning streams may affect the production of summer steelhead fry in the Rogue River basin.

A project should be conducted to determine the primary factors that affect the production of summer steelhead fry in small spawning streams. Factors to be estimated should include spawning escapement (Chadwick 1982), spawning distribution (*see* **Abundance**, page 35), quality and quantity of spawning habitat, flow during the period eggs and alevins incubate in the gravel (Seegrist and Gard 1972), flow in summer (Havey and Davis 1970), and water temperature in summer (Hokanson et al. 1977).

Migration

Sampling at Savage Rapids Dam did not characterize the migration timing of wild steelhead smolts because the trap could not be operated in early spring (*see* **Juveniles**, page 22). We concluded that most smolts probably passed Savage Rapids Dam prior to the middle of May because passage usually peaked on the first week of sampling (Figure 36). Smolt migration usually ended by late June (Figure 36). In tributary streams of the Rogue River, smolts migrated from the middle of April through the middle of May (Everest 1973).

Most yearling steelhead passed Savage Rapids Dam before the end of June (Figure 36). As with smolts, the data suggested that a large percentage of yearlings passed Savage Rapids Dam prior to the start of sampling in the middle of May (Figure 36). For the period that we sampled, we estimated that an average of 70% of the yearlings passed Savage Rapids Dam by 17 June. Estimates of annual passage ranged between 22% and 81% in 1976-90. Data used to estimate the migration timing of yearling steelhead are in Appendix Tables D-44 through D-46.

Passage of subyearling steelhead tended to peak in late May through the middle of June (Figure 36). Migration of subyearlings increased sharply in late May, when large numbers of steelhead fry migrated from tributary streams to rear in the Rogue River (Everest 1973; Faudskar 1980). Relatively few subyearlings passed Savage Rapids Dam in summer. For the period of sampling, we estimated that an average of 50% of the subyearlings passed Savage Rapids Dam by 17 June. Estimates of annual passage ranged between 47% and 92% in 1976-90. Data used to estimate the migration timing of subyearling steelhead are in Appendix Tables D-44 through D-46.

Factors responsible for annual variations in the migration timing of subyearling and yearling steelhead at Savage Rapids Dam remain unknown. Annual estimates of migration timing were not significantly related to physical parameters of the Rogue River in spring and were not significantly related to the number of migrants. We did not examine the possible influence of water temperature and flow in summer because relatively few juvenile steelhead migrated at that time. Data included in the analyses are in Appendix Table D-47. A correlation matrix that outlines the relationships between all the variables examined in the analyses is in Appendix Table D-48.

Lack of significant relationships between the migration timing of steelhead that passed Savage Rapids Dam and independent factors may indicate that subyearlings and yearlings were dispersing to rear in proximal areas. Mark-recapture experiments conducted in 1974-75 indicated that subyearlings and yearlings did not migrate within the Rogue River in summer. We recaptured

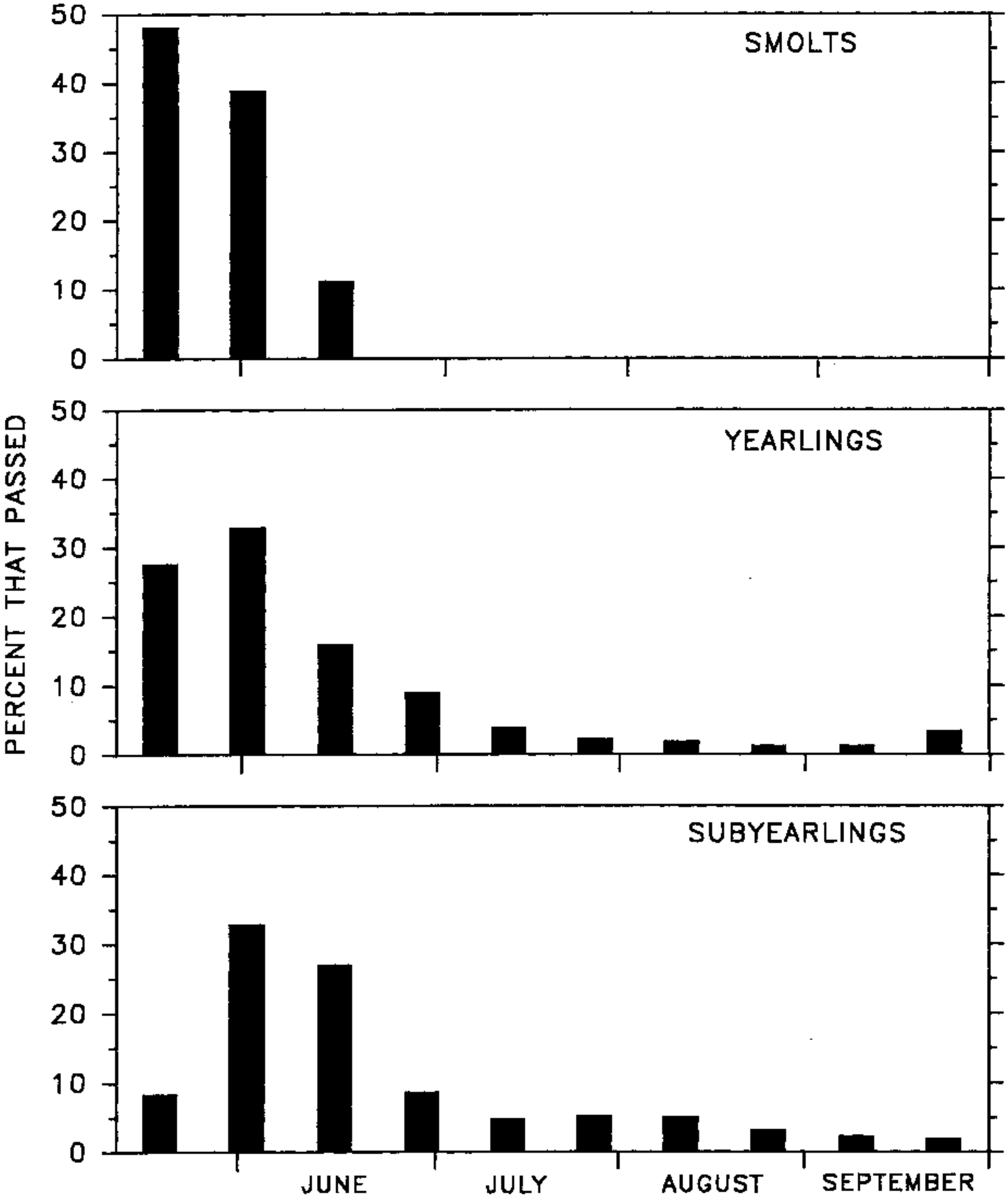

Figure 36. Migration timing of juvenile steelhead that passed Savage Rapids Dam from 14 May through 30 September, averaged for 1976-90.

54 of the 1,236 juvenile steelhead that were uniquely branded and released at various sites along the Rogue River in 1974. In 1975, we recaptured 148 of the 2,420 juvenile steelhead that were branded and released. During both years, fish were recaptured only at the site of release. We recaptured subyearlings and yearlings, but did not recapture any branded smolts.

Rivers (1964) suggested that trap catches of juvenile steelhead at Savage Rapids Dam indicated that subyearlings and yearlings migrate downstream to rear in the lower river. This hypothesis is not supported by the results of our branding experiments or those conducted by Everest (1973). Trap catches may have been composed of fish that moved a relatively short distance to locate suitable rearing areas.

We were unable to evaluate the effects of the operation of Lost Creek Dam on the migration timing of juvenile summer steelhead because most migrated prior to installation of the trap at Savage Rapids Dam. However, we found there was minimal movement of juvenile steelhead in summer either before or after reservoir operation. From this finding, we concluded that changes in flow and water temperature did not affect the migration timing of those presmolt steelhead that moved in the Rogue River during summer.

We were unable to determine the effects of reservoir operation on the migration timing of smolts because the trap at Savage Rapids Dam could not be operated until most smolts passed. However, we believe that operation of Lost Creek Dam had minimal effect on the migration timing of smolts in spring because photoperiod (Wagner 1974) and body size (Wagner 1968) are primary factors that affect the parr-smolt transformation in juvenile steelhead. Similar to the findings of Wagner et al. (1963) and others, all of the smolts that we trapped were 15 cm or larger.

Water temperature greater than $13^{o}C$ has been shown to inhibit the parr-smolt transformation among juvenile steelhead (Adams et al. 1973; Zaugg and Wagner 1973). Late migration may account for our observation that some steelhead smolts appeared to be in the process of reverting to parr. Operation of Lost Creek Dam probably had minimal effect on loss of smolt characteristics because reservoir operation had minimal effect on water temperature in April and May (*see* **Physical Factors**, page 28).

ACKNOWLEDGEMENTS

We thank U.S. Army Corps of Engineers personnel for water quality data, U.S. Geological Survey personnel for provisional water quality data, and Irvine Urie for detailed catch records from guides that fished in the Rogue River canyon.

ODFW personnel with the Southwest Region assisted with sampling in 1975-86, conducted the sampling at Huntley Park in 1987-91, and sampled adult summer steelhead that returned to Cole M. Rivers Hatchery in 1975-92. Michael Evenson provided data for juvenile releases from, and adult returns to, the hatchery.

Ron Boyce interpreted scales from juvenile steelhead and developed most of the methods used to estimate the life history parameters of summer steelhead. Lisa Borgerson, Ron Boyce, Patrick Frazier, and Bruce Williams interpreted scale samples from adults. Mary Buckman, Lyle Calvin, Michael Evenson, Nancy MacHugh, Alan McGie, William Nagy, Rock Peters, Robert Stansell, and Beth Stewart reviewed and improved the report with comments. Finally, we thank the numerous seasonal assistants who helped with field sampling.

REFERENCES

Adams, B.L., W.S. Zaugg, and L.R. McLain. 1975. Inhibition of salt water survival and Na-K-ATPase elevation in steelhead trout (*Salmo gairdneri*) by moderate water temperatures. Transactions of the American Fisheries Society 104:766-769.

Anderson, D.M., D.P. Liscia, and D.W. Loomis. 1986. North Umpqua River Fish Management Plan. Oregon Department of Fish and Wildlife, Portland.

Barnhart, R.A. 1989. Symposium review: catch-and-release fishing, a decade of experience. North American Journal of Fisheries Management 9:74-80.

Barrett, J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society 121:437-443.

Beecher, H.A. 1980. Instream flows and steelhead production in western Washington. Proceedings of the Annual Conference of the Western Association of Fish and Wildlife Agencies 60:396-410.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream cover, and population density. Transactions of the American Fisheries Society 100:423-435.

Bjornn, T.C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. University of Idaho, College of Forestry, Wildlife, and Range Sciences, Bulletin 27, Moscow.

Bley, P.W., and J.R. Moring. 1988. Freshwater and ocean survival of Atlantic salmon and steelhead: a synopsis. U.S. Fish and Wildlife Service, Biological Report 88(9), Washington, D.C.

Bottom, D.L., K.K. Jones, J.D. Rogers, and R.F. Brown. 1989. Management of living marine resources: a research plan for the Washington and Oregon continental margin. National Coastal Resources Research and Development Institute, Publication NCRI-T-89-004, Newport, Oregon.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. U.S. Fish and Wildlife Service, Instream Flow Information Paper 12, Fort Collins, Colorado.

Boyce, R.R. 1985. Effects of feeding level, temperature, and photoperiod on growth and selected scale characteristics of juvenile steelhead trout. Master's thesis. Oregon State University, Corvallis.

Brown, L.R., and P.B. Moyle. 1991. Changes in habitat and microhabitat partitioning within an assemblage of stream fishes in response to predation by Sacramento squawfish (*Ptychocheilus grandis*). Canadian Journal of Fisheries and Aquatic Sciences 48:849-856.

Bustard, D.R., and D. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 32:667-680.

Carlander, K.D. 1981. Caution on the regression method of back-calculating lengths from scale measurements. Fisheries (Bethesda) 6(1):2-4.

Chadwick, E.M.P. 1982. Stock-recruitment relationship for Atlantic salmon (*Salmo salar*) in Newfoundland rivers. Canadian Journal of Fisheries and Aquatic Sciences 39:1496-1501.

Chapman, D.W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Transactions of the American Fisheries Society 115:662-670.

Chilcote, M.W., S.A. Leider, and J.J Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society 115:726-735.

Cramer, D.P. 1981. Effect of smolt release location and displacement of adults on distribution of summer steelhead trout. Progressive Fish-Culturist 43:8-11.

Cramer, S.P. 1986. The influence of river temperature and flow on the production and harvest of summer steelhead in the Rogue River. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-77-C-0027, Special Report, Portland.

Cramer, S.P., T.D. Satterthwaite, R.R. Boyce, and B.P. McPherson. 1985. Lost Creek Dam fisheries evaluation phase I completion report. Volume I. Impacts of Lost Creek Dam on the biology of anadromous salmonids in the Rogue River. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-77-C-0027, Portland.

Ellis, R.J., and H. Gowing. 1957. Relationship between food supply and condition of wild brown trout, *Salmo trutta* L., in a Michigan stream. Limnology and Oceanography 2:299-308.

Evenson, M.D., and R.D. Ewing. 1984. Cole Rivers Hatchery evaluation. Oregon Department of Fish and Wildlife, Fish Research Project AFS-78-1, Portland.

Evenson, M.D., R.D. Ewing, E.K. Birks, and A.R. Hemmingsen. 1982. Cole Rivers Hatchery evaluation. Oregon Department of Fish and Wildlife, Fish Research Project AFS-71-5, Portland.

Everest, F.H. 1973. Ecology and management of summer steelhead in the Rogue River. Oregon State Game Commission, Fishery Research Report 7, Portland.

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29:91-100.

Ewing, R.D., M.D. Evenson, and E.K. Birks. 1984. Indices of parr-smolt transformation in juvenile steelhead trout (*Salmo gairdneri*) undergoing volitional release from Cole Rivers Hatchery. Aquaculture 40:209-222.

Faudskar, J.D. 1980. Ecology of underyearling summer steelhead trout in intermittent streams tributary to the Rogue River. Master's thesis. Oregon State University, Corvallis.

Friday, J., and S.J. Miller. 1984. Statistical summaries of streamflow data in Oregon. Volume 2. Western Oregon. U.S. Geological Survey, Open-file Report 84-454, Portland.

Fustish, C.A., S.E. Jacobs, B.P. McPherson, and P.A. Frazier. 1988. Applegate Dam Evaluation. Phase I Completion Report. Impacts of Applegate Dam on the biology of anadromous salmonids in the Applegate River. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-77-C-0027, Portland.

Fustish, C.A., B.P. McPherson, and S.E. Jacobs. 1989. Effects of Applegate Dam on steelhead in the Applegate River and recommendations for water regulation. Oregon Department of Fish and Wildlife, Fish Research Project, DACW57-77-C-0033, Completion Report, Portland.

Gibbons, R. 1988a. Anadromous fish investigations in Washington. Washington Department of Game, Fisheries Management Division Report 88-5, Olympia.

Gibbons, R. 1988b. Anadromous fish investigations in Washington. Washington Department of Game, Fisheries Management Division Report 88-15, Olympia.

Gibbons, R.G., P.K.J. Hahn, and T.H. Johnson. 1985. Methodology for determining MSH steelhead spawning escapement requirements. Washington Department of Game, Fisheries Management Division Report 85-11, Olympia.

Hamlin, D.E., and J.M. Nestler. 1987. Development of a model to predict longitudinal water temperatures for the Rogue River, Oregon. U.S. Army Corps of Engineer Waterways Experiment Station, Miscellaneous Paper EL-87-15, Vicksburg, Mississippi.

Havey, K.A., and R.M. Davis. 1970. Factors influencing standing crops and survival of juvenile salmon at Barrows Stream, Maine. Transactions of the American Fisheries Society 99:297-310.

Heggberget, T.G., R.A. Lund, N. Ryman, and G. Stahl. 1986. Growth and genetic variation of Atlantic salmon (*Salmo salar*) from different sections of the River Alta, North Norway. Canadian Journal of Fisheries and Aquatic Sciences 43:1828-1835.

Hicks, R.H., and L.D. Calvin. 1964. An evaluation of the punch card method of estimating salmon-steelhead sport catch. Oregon State University, Agricultural Experiment Station Technical Report 81, Corvallis.

Hiss, J.M., J.H. Meyer, R.S. Boomer, and D. Cole. 1986. Hatchery winter steelhead contribution to the Hoh River fisheries and potential impacts on the native stock. U.S. Fish and Wildlife Service, Final Report, Olympia, Washington.

Hokanson, D.E.F., C.F. Kleiner, and T.W. Thorslund. 1977. Effects of constant and diel temperature fluctuations on specific growth and mortality rates and yield of rainbow trout. Journal of the Fisheries Research Board of Canada 34:639-648.

Hooton, R.S., B.R. Ward, V.A. Lewynsky, M.G. Lirette, and A.R. Facchin. 1987. Age and growth of steelhead in Vancouver Island populations. Ministry of Environment and Parks, Fisheries Technical Circular 77, Victoria, Canada.

Hume, J.M.B., and E.A. Parkinson. 1987. Effect of stocking density on the survival, growth, and dispersal of steelhead trout fry (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 44:271-281.

Irvine, J.R, I.G. Jowett, and D. Scott. 1987. A test of the instream flow incremental methodology for underyearling rainbow trout, *Salmo gairdnerii*, in experimental New Zealand streams. New Zealand Journal of Marine and Freshwater Resources 21:35-40.

Jacobs, S.L., W.T. Noll, and J.D. Rogers. 1984. Increase in growth of juvenile chinook salmon (*Oncorhynchus tshawytscha*) rearing immediately below Lost Creek Dam on the Rogue River. Oregon Department of Fish and Wildlife, Information Reports (Fish) 84-6, Portland.

Jensen, A.L. 1986. Functional regression and correlation analysis. Canadian Journal of Fisheries and Aquatic Sciences 43:1742-1745.

Johnsson, J., and W.C. Clarke. 1988. Development of seawater adaptation in juvenile steelhead and rainbow trout--effects of size, temperature, and photoperiod. Aquaculture 71:247-264.

Kenaston, K.R. 1989. Estimated run size of winter steelhead in Oregon coastal streams, 1980-85. Oregon Department of Fish and Wildlife, Information Reports (Fish) 89-1, Portland.

Kesner, W.D., and R.A. Barnhart. 1972. Characteristics of the fall-run steelhead trout (*Salmo gairdneri gairdneri*) of the Klamath River system with emphasis on the half-pounder. California Fish and Game 58:204-220.

Leider, S.A. 1985. Precise timing of upstream migrations by repeat steelhead spawners. Transactions of the American Fisheries Society 114:906-908.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout *Salmo gairdneri*: evidence for partial reproductive isolation. Canadian Journal of Fisheries and Aquatic Sciences 41:1454-1462.

Leider, S.A., M.W. Chilcote, and J.J. Loch. 1986. Movement and survival of presmolt steelhead in a tributary and the mainstem of a Washington river. North American Journal of Fisheries Management 6:526-531.

Li, J.C.R. 1948. A sampling plan for estimating the number of fish crossing Gold Ray Dam on the Rogue River. Oregon State Game Commission, Portland. (Unpublished report.)

Lindsay, R.B., B.C. Jonasson, and R.K. Schroeder. 1989. Spring chinook salmon in the Deschutes River, Oregon. Oregon Department of Fish and Wildlife, Information Reports (Fish) 89-4, Portland.

Lister, D.B., D.G. Hickey, and I. Wallace. 1981. Review of the effects of enhancement strategies on the homing, straying, and survival of Pacific salmonids, volumes I + II. D.B. Lister and Associates, Ltd., West Vancouver, Canada. (Report prepared for the Canadian Department of Fisheries and Oceans, Vancouver, Canada.)

Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Loch, J.J., S.A. Leider, M.W. Chilcote, R. Cooper, and T.H. Johnson. 1988. Differences in yield, emigration-timing, size, and age structure of juvenile steelhead from two small western Washington streams. California Fish and Game 74:106-118.

Maher, F.P., and P.A. Larkin. 1954. Life history of the steelhead trout of the Chilliwack River, British Columbia. Transactions of the American Fisheries Society 84:27-38.

Mathur, D., W.H. Bason, E.J. Purdy, Jr., and C.A. Silver. 1985. A critique of the instream flow incremental methodology. Canadian Journal of Fisheries and Aquatic Sciences 42:825-831.

Matlock, G.C. 1981. Nonreporting of recaptured tagged fish by saltwater recreational boat anglers in Texas. Transactions of the American Fisheries Society 110:90-92.

McGie, A.M. 1993. Stock-recruitment in summer-run steelhead of the North Umpqua River, Oregon. Oregon Department of Fish and Wildlife, unpublished manuscript, Portland.

McPherson, B.P., and S.P. Cramer, editors. 1982. Rogue basin fisheries evaluation program, adult salmonid studies. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-77-C-0027, Annual Progress Report, Portland.

Meigs, R.C., and C.F. Pautzke. 1941. Additional notes on the life history of the Puget Sound steelhead (*Salmo gairdnerii*) with suggestions for management of the species. Washington Department of Game, Biological Bulletin 5, Seattle.

Moffatt, R.L., Wellman, R.E., and J.M. Gordon. 1990. Statistical summaries of streamflow data in Oregon: Volume 1. Monthly and annual streamflow and flow-duration values. United States Geological Survey, Open File Report 90-118, Portland.

Morrison, J.K., and C.E. Smith. 1986. Altering the spawning cycle of rainbow trout by manipulating water temperature. The Progressive Fish-Culturist 48:52-53.

Moyle, P.B., and D.M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114:695-704.

Narver, D.W. 1969. Age and size of steelhead trout in the Babine River, British Columbia. Journal of the Fisheries Research Board of Canada 26:2754-2760.

Narver, D.W., and F.C. Withler. 1974. Steelhead of the Nanaimo River. Aspects of their biology and the fishery from three years of angler's catches. Canada Fisheries and Marine Service, Pacific Biological Station Circular 99, Nanaimo, Canada.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (*Oncorhynchus kisutch*) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

ODFW (Oregon Department of Fish and Wildlife). 1986. Steelhead management plan, 1986-1992. Portland.

ODFW (Oregon Department of Fish and Wildlife). 1990. Effects of Lost Creek Dam on winter steelhead in the Rogue River. Phase II Completion Report. Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of Fish and Wildlife). 1991. Effects of Lost Creek Dam on coho salmon in the Rogue River. Phase II Completion Report. Oregon Department of Fish and Wildlife, Portland.

ODFW (Oregon Department of Fish and Wildlife). 1992. Effects of Lost Creek Dam on fall chinook salmon in the Rogue River. Phase II Completion Report. Oregon Department of Fish and Wildlife, Portland.

ODWR (Oregon Department of Water Resources). 1985. Rogue River basin study. Oregon Department of Water Resources, Salem.

Parsley, M.J., D.E. Palmer, and R.W. Burkhardt. 1989. Variation in capture efficiency of a beach seine for small fishes. North American Journal of Fisheries Management 9:239-244.

Parkinson, E.A. 1984. Genetic variation in populations of steelhead trout (*Salmo gairdneri*) in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 41:1412-1420.

Peterman, R.M., and G.J. Steer. 1981. Relation between sport-fishing catchability coefficients and salmon abundance. Transactions of the American Fisheries Society 110:585-593.

Peterson, N.M. 1978. Biological characteristics of wild and hatchery steelhead trout (*Salmo gairdneri*) in two Oregon rivers. Master's thesis. Oregon State University, Corvallis.

Ratti, F. 1979. Natural resources of Rogue estuary. Oregon Department of Fish and Wildlife, Estuary Inventory Report 2-8, Portland.

Raymond, H.L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Reeves, G.H., F.H. Everest, and J.D. Hall. 1987. Interactions between the redside shiner (*Richardsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: the influence of water temperature. Canadian Journal of Fisheries and Aquatic Sciences 44:1603-1613.

Reisenbichler, R.R, and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, *Salmo gairdneri*. Journal of the Fisheries Research Board of Canada 34: 1603-1613.

Reisenbichler, R.R, J.D. McIntyre, M.F. Solazzi, and S.W. Landino. 1992. Genetic variation in steelhead of Oregon and northern California. Transactions of the American Fisheries Society 121:158-169.

Ricker, W.E. 1972. Heredity and environmental factors affecting certain salmonid populations. Pages 27-160 *in* The stock concept in Pacific salmon. University of British Columbia, H.R. MacMillan Lectures in Fisheries, Vancouver, Canada.

Ricker, W.E. 1973. Linear regressions in fishery research. Journal of the Fisheries Research Board of Canada 30:409-434.

Rivers, C.M. 1964. Rogue River fisheries. Oregon State Game Commission, Portland. (Unpublished manuscript.)

Rosenberg, D.M., R.A. Bodaly, R.E. Hecky, and R.W. Newbury. 1986. The environmental assessment of hydroelectric impoundments and diversions in Canada. Pages 71-103 *in* M.C. Healey and R.R. Wallace, editors. Canadian aquatic resources. Canadian Bulletin of Fisheries and Aquatic Sciences 215.

Ruggerone, G.T., T.P. Quinn, I.A. McGregor, and T.D. Wilkinson. 1990. Horizontal and vertical movements of adult steelhead trout, *Oncorhynchus mykiss*, in the Dean and Fisher channels, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 47:1963-1969.

Satterthwaite, T.D. 1987. Effects of Lost Creek Dam on spring chinook salmon in the Rogue River, Oregon: An update. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-77-C-0027, Portland.

Satterthwaite, T.D. 1988. Influence of maturity on straying rates of summer steelhead into the Rogue River, Oregon. California Fish and Game 74:203-207.

Satterthwaite, T.D. 1991. Evaluation of spring chinook salmon in relation to operation of Lost Creek Dam. Oregon Department of Fish and Wildlife, Fish Research Project (unnumbered), Annual Progress Report, Portland.

Satterthwaite, T.D. 1992. Rogue River studies. Oregon Department of Fish and Wildlife, Fish Research Project (unnumbered), Annual Progress Report, Portland.

Satterthwaite, T.D., B.P. McPherson, P.A. Frazier, and S.P. Cramer 1985. Rogue Basin fisheries evaluation program, Lost Creek Dam studies. Oregon Department of Fish and Wildlife, Fish Research Project DACW57-75-C-0109, Annual Progress Report, Portland.

Schoettger, R.A., and E.W. Steucke, Jr. 1970. Synergic mixtures of MS-222 and quinaldine as anesthetics for rainbow trout and in northern pike. Progressive Fish-Culturist 32:202-205.

Seegrist, D.W., and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:478-482.

Shapovalov, L., and A.C. Taft. 1954. The life histories of steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game, Fish Bulletin 98, Sacramento.

Sheppard, J.D., and J.H. Johnson. 1985. Probability-of-use for depth, velocity, and substrate by subyearling coho salmon and steelhead in Lake Ontario tributary streams. North American Journal of Fisheries Management 5:277-282.

Snedecor, A.W., and W.G. Cochran. 1967. Statistical methods, 6th edition. Iowa State University Press, Ames.

Swales, S., R.B. Lauzier, and C.D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. Canadian Journal of Zoology 64:1506-1514.

Taft, A.C., and L. Shapovalov. 1938. Homing instinct and straying among steelhead and silver salmon. California Fish and Game 24:118-125.

Tipping, J.M. 1992. Heritability of age at maturity in steelhead. North American Journal of Fisheries Management 11:105-108.

United States Congress. 1962. Rogue River basin, Oregon and California. Public Law 87-874, 87th Congress, 2nd Session, House Document 566.

USACE (United States Army Corps of Engineers). 1972. Final environmental statement, Lost Creek Lake Project, Rogue River, Oregon. Portland District, Portland.

USACE (United States Army Corps of Engineers). 1983. Water quality investigations--1981, Lost Creek Lake project, Rogue River, Oregon. Portland District, Portland.

Wagner, H.H. 1968. Effect of stocking time on survival of steelhead trout, *Salmo gairdneri*, in Oregon. Transactions of the American Fisheries Society 97:374-379.

Wagner, H.H. 1969. Effect of stocking location of juvenile steelhead trout, *Salmo gairdneri*, on adult catch. Transactions of the American Fisheries Society 98:27-34.

Wagner, H.H. 1974. Photoperiod and temperature regulation of smolting in steelhead trout (*Salmo gairdneri*). Canadian Journal of Zoology 52:219-234.

Wagner, H.H., R.L. Wallace, and H.J. Campbell. 1963. The seaward migration and return of hatchery-reared steelhead trout, *Salmo gairdneri*, in the Alsea River, Oregon. Transactions of the American Fisheries Society 92:202-210.

Waples, R.S. 1991. Genetic interactions between hatchery and wild salmonids: lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Resources 48 (Supplement 1):124-133.

Ward, B.R., and P.A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Ward, B.R., P.A. Slaney, A.R. Facchin, and R.W. Land. 1989. Size-biased survival in steelhead trout (*Oncorhynchus mykiss*): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1853-1858.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific Coast of North America. Journal of the Fisheries Research Board of Canada 23:365-393.

Wurtsbaugh, W.A., and G.E. Davis. 1977. Effects of temperature and ration level on the growth and food conversion efficiency of *Salmo gairdneri* (Richardson). Journal of Fish Biology 11:87-98.

Zar, J.H. 1984. Biostatistical analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Zaugg, W.S., and H.H. Wagner. 1973. Gill ATPase activity related to parr-smolt transformation in steelhead trout (*Salmo gairdneri*): influence of photoperiod and temperature. Comparative Biochemistry and Physiology 45:955-965.

APPENDIX A

Relation Between Gregorian Day, Day-of-Year and Week-of-Year.

Gregorian day	Day-of-year	Week-of-year
1-7 January	1-7	1
8-14 January	8-14	2
15-21 January	15-21	3
22-28 January	22-28	4
29 January-4 February	29-35	5
5-11 February	36-42	6
12-18 February	43-49	7
19-25 February	50-56	8
26 February-4 March	57-64	9[a]
5-11 March	65-71	10
12-18 March	72-78	11
19-25 March	79-85	12
26 March-1 April	86-92	13
2-8 April	93-99	14
9-15 April	100-106	15
16-22 April	107-113	16
23-29 April	114-120	17
30 April-6 May	121-127	18
7-13 May	128-134	19
14-20 May	135-141	20
21-27 May	142-148	21
28 May-3 June	149-155	22
4-10 June	156-162	23
11-17 June	163-169	24
18-24 June	170-176	25
25 June-1 July	177-183	26
2-8 July	184-190	27
9-15 July	191-197	28
16-22 July	198-204	29
23-29 July	205-211	30

---

[a] *Eight-day week during leap years.*

Gregorian day	Day-of-year	Week-of-year
30 July-5 August	212-218	31
6-12 August	219-225	32
13-19 August	226-232	33
20-26 August	233-239	34
27 August-2 September	240-246	35
3-09 September	247-253	36
10-16 September	254-260	37
17-23 September	261-267	38
24-30 September	268-274	39
1-7 October	275-281	40
8-14 October	282-288	41
15-21 October	289-295	42
22-28 October	296-302	43
29 October-4 November	303-309	44
5-11 November	310-316	45
12-18 November	317-323	46
19-25 November	324-330	47
26 November-2 December	331-337	48
3-9 December	338-344	49
10-16 December	345-351	50
17-23 December	352-358	51
24-31 December	359-366	52[b]

[b] *Eight-day week.*

APPENDIX B

Tables of Data Related to Studies of Adult Summer Steelhead

Appendix Table B-1. Relationship between return year and brood year for wild summer steelhead seined near the mouth of the Rogue River, 1975-91.

	Brood year				Brood year		
Return year	Age-1 smolts	Age-2 smolts	Age-3 smolts	Return year	Age-1 smolts	Age-2 smolts	Age-3 smolts
	HALF-POUNDERS				**FIRST SPAWNING MIGRANTS**		
1975	1974	1973	1972	1975	1973	1972	1971
1976	1975	1974	1973	1976	1974	1973	1972
1977	1976	1975	1974	1977	1975	1974	1973
1978	1977	1976	1975	1978	1976	1975	1974
1979	1978	1977	1976	1979	1977	1976	1975
1980	1979	1978	1977	1980	1978	1977	1976
1981	1980	1979	1978	1981	1979	1978	1977
1982	1981	1980	1979	1982	1980	1979	1978
1983	1982	1981	1980	1983	1981	1980	1979
1984	1983	1982	1981	1984	1982	1981	1980
1985	1984	1983	1982	1985	1983	1982	1981
1986	1985	1984	1983	1986	1984	1983	1982
1987	1986	1985	1984	1987	1985	1984	1983
1988	1987	1986	1985	1988	1986	1985	1984
1989	1988	1987	1986	1989	1987	1986	1985
1990	1989	1988	1987	1990	1988	1987	1986
1991	1990	1989	1988	1991	1989	1988	1987
SECOND SPAWNING MIGRANTS					**THIRD SPAWNING MIGRANTS**		
1975	1972	1971	1970	1975	1973	1972	1971
1976	1973	1972	1971	1976	1974	1973	1972
1977	1974	1973	1972	1977	1975	1974	1973
1978	1975	1974	1973	1978	1976	1975	1974
1979	1976	1975	1974	1979	1977	1976	1975
1980	1977	1976	1975	1980	1978	1977	1976
1981	1978	1977	1976	1981	1977	1976	1975
1982	1979	1978	1977	1982	1978	1977	1976
1983	1980	1979	1978	1983	1979	1978	1977
1984	1981	1980	1979	1984	1980	1979	1978
1985	1982	1981	1980	1985	1981	1980	1979
1986	1983	1982	1981	1986	1982	1981	1980
1987	1984	1983	1982	1987	1983	1982	1981
1988	1985	1984	1983	1988	1984	1983	1982
1989	1986	1985	1984	1989	1985	1984	1983
1990	1987	1986	1985	1990	1986	1985	1984
1991	1988	1987	1986	1991	1987	1986	1985

Appendix Table B-2. Estimated number of wild half-pounders and wild first spawning migrants that returned to the Rogue River, 1970-1988 brood years.

Brood year	Half-pounders				First spawning migrants			
	Smolt age (years)				Smolt age (years)			
	1	2	3	4	1	2	3	4
1972	--	--	--	0	--	--	405	0
1973	--	--	1,690	0	--	3,095	274	0
1974	--	15,551	4,869	0	1,374	9,677	231	0
1975	9,161	69,254	2,157	176	7,159	12,869	979	0
1976	45,507	37,196	2,361	0	12,587	10,660	181	0
1977	13,258	13,913	4,885	879	3,418	3,151	670	0
1978	8,664	41,904	7,474	0	4,894	12,341	891	0
1979	22,019	84,709	2,354	0	7,287	11,763	0	0
1980	53,493	31,338	1,464	0	12,807	2,313	348	0
1981	15,350	34,916	3,495	0	2,931	5,800	218	0
1982	15,890	39,800	3,275	0	4,408	17,363	502	0[c]
1983	8,868	77,710	4,837	0[c]	9,677	15,392	512[b]	0
1984	33,530	73,328	3,725[a]	0	10,526	--	484	0
1985	14,503	35,023[a]	195	0	--	6,645	0	--
1986	21,326[a]	10,169	246	0[c]	8,007	2,982	224[b]	0[c]
1987	8,212	12,613	425[b]	0[c]	4,764	--	--	--
1988	10,386	--	--	--	--	--	--	--

[a] *Estimated by regression analysis with age composition data from cohorts that returned as first spawning migrants.*

[b] *Assumed age-3 smolts composed 2% of brood returns.*

[c] *Assumed age-4 smolts composed 0% of brood returns.*

Appendix Table B-3. Estimated number of wild second spawning migrants and wild third spawning migrants that returned to the Rogue River, 1970-1986 brood years.

Brood year	Second spawning migrants, Smolt age (years) 1	2	3	4	Third spawning migrants, Smolt age (years) 1	2	3	4
1970	--	--	--	0	--	--	0	0
1971	--	--	0	13	--	625	0	0
1972	--	814	289	0	938	465	0	0
1973	376	1,312	0	0	70	0	0	0
1974	246	812	146	0	0	206	0	0
1975	681	3,067	113	0	103	638	0	0
1976	4,089	2,283	0	0	796	211	0	0
1977	1,042	1,084	0	0	316	0	0	0
1978	1,262	1,912	0	0	173	93	0	0
1979	773	379	0	0	93	0	0	0
1980	1,537	1,143	0	0	521	62	0	0[b]
1981	804	2,031	135	0[b]	124	272	0[b]	0
1982	912	2,329	66[a]	0	68	--	0	0
1983	2,193	--	64	0	--	202	0	--
1984	--	1,138	0	--	202	194	0[b]	0[b]
1985	568	572	23[a]	0[b]	97	--	--	--
1986	1,374	--	--	--	--	--	--	--

[a] *Assumed age-3 smolts composed 2% of brood returns.*
[b] *Assumed age-4 smolts composed 0% of brood returns.*

Appendix Table B-4. Estimated number of summer steelhead that passed Gold Ray Dam, 1942-69 return years.

Return year	Early-run	Late-run	Total	Return year	Early-run	Late-run	Total
1942	3,008	2,509	5,517	1956	1,452	1,285	2,737
1943	3,857	1,808	5,665	1957	840	1,270	2,110
1944	2,847	8,126	10,973	1958	870	1,067	1,937
1945	3,017	4,419	7,436	1959	648	858	1,506
1946	2,574	1,920	4,494	1960	940	1,280	2,220
1947	1,940	1,304	3,244	1961	820	1,702	2,522
1948	1,415	677	2,092	1962	1,079	2,531	3,610
1949	1,846	1,783	3,629	1963	660	1,094	1,754
1950	1,282	3,385	4,667	1964	412	612	1,024
1951	1,217	2,083	3,300	1965	831	2,606	3,437
1952	3,315	3,093	6,408	1966	704	1,549	2,253
1953	2,449	2,054	4,503	1967	493	1,430	1,923
1954	1,833	391	2,224	1968	--	--	--
1955	920	1,705	2,625	1969	4,120	5,312	9,432

Appendix Table B-5. Estimated number of wild and hatchery summer steelhead that passed Gold Ray Dam, 1970-91 return years.

Return year	Wild			Hatchery		
	Early-run	Late-run	Total	Early-run	Late-run	Total
1970	1,123	4,823	5,946	383	556	939
1971	2,010	2,355	4,635	681	225	906
1972	1,530	3,080	4,610	216	364	580
1973	612	4,457	5,069	34	778	812
1974	2,892	4,492	7,384	1,222	1,352	2,574
1975	1,664	5,084	6,748	816	1,621	2,437
1976	1,401	1,272	2,673	485	462	947
1977	741	9,630	10,371	293	2,891	3,184
1978	1,550	2,430	3,980	489	697	1,186
1979	1,871	9,960	11,831	1,192	3,408	4,600
1980	955	4,638	5,593	899	1,705	2,604
1981	2,080	5,873	7,953	2,364	1,736	4,100
1982	3,953	6,091	10,044	3,378	1,364	4,742
1983	2,837	2,198	5,035	1,571	1,277	2,848
1984	2,699	2,404	5,103	2,063	375	2,438
1985	2,158	6,192	8,350	1,548	951	2,499
1986	3,042	6,743	9,785	3,242	2,945	6,187
1987	4,822	8,137	12,959	10,263	3,083	13,346
1988	3,663	7,611	11,274	6,934	1,934	8,868
1989	2,332	3,280	5,612	6,031	2,328	8,359
1990	793	840	1,663	3,947	608	4,555
1991	1,496	1,735	3,231	1,001	207	1,208

Appendix Table B-6. Juvenile summer steelhead of hatchery origin released in the Rogue River basin, 1958-74. Releases reported for only those groups where fish averaged less than 20 per pound.

Month, year of release	Number released	Number per pound	RK of release	Rearing station
03-04/58	37,055	8.3-16.5	165-171	Bandon
04/58	22,371	7.2-12.5	165	Butte Falls
03/59	34,838	7.6-7.9	154-171	Bandon
03/60	11,451	7.7-8.1	134-141	Bandon
03/61	58,283	10.4-14.9	116-160	Bandon
03/62	17,027	14.5	194	Bandon
03/63	37,036	14.2-15.8	184	Bandon
03/64	32,290	9.6-10.5	184	Bandon
04/65	37,715	8.3-8.6	184	Bandon
03/66	25,232	7.9-8.4	212	Bandon
05/66	7,441	13.2	251	Medco Pond
03/67	41,039	7.3-8.1	212	Bandon
05/67	10,884	12.3	265	Butte Falls
05/67	24,888	12.0-12.3	265	Medco Pond
03/68	24,582	6.6-8.4	212	Bandon
04/68	10,055	9.2	251	Butte Falls
04/68	11,682	12.0	--	Medco Pond
03/69	53,608	5.0-5.7	184-212	Bandon
04-05/69	98,650	8.1-13.3	153-212	Butte Falls
04/68	44,634	7.4-11.0	--	Medco Pond
03/70	91,900	4.9-6.7	153-200	Bandon
03-04/70	84,453	7.8-15.0	212-254	Butte Falls
03/71	36,228	4.8-5.2	212-254	Bandon
04/71	104,295	7.9-10.9	212-254	Butte Falls
03/72	50,493	5.3-5.9	212-254	Bandon
05/72	88,330	6.0-12.3	171-254	Butte Falls
03-04/73	52,705	3.5-4.1	212-251	Bandon
04/73	77,250	5.5-8.8	212-251	Butte Falls
05/74	57,481	5.2	212-251	Bandon

Appendix Table B-7. Juvenile summer steelhead of hatchery origin released in the Rogue River basin, 1974-89. All were mitigation fish reared at Cole M. Rivers Hatchery (data received from Michael Evenson, Oregon Department of Fish and Wildlife, Cole M. Rivers Hatchery, Trail, Oregon).

Month, year of release	Brood year	Number released	Number per pound	Variety	RK of release
04/74	1973	18,322	8.7	--	253
04/75	1973	77,505	3.5-4.8	--	253
04/76	1974	126,445	3.7-5.1	--	253
04/77	1975	178,530	4.4-5.2	--	253
04/78	1976	192,222	4.3	--	253
04/79	1977	160,946	4.2	--	253
04/80	1978	68,896	2.7	early	253
04/80	1978	62,471	2.7	late	253
04/80	1979	52,450	4.5	early	253
04/80	1979	95,985	4.2-4.5	late	253
04/81	1980	52,583	4.2	early	253
04/81	1980	88,784	4.1	late	253
04/82	1981	47,287	5.8	early	253
04/82	1981	91,707	5.8	late	253
04/83	1982	43,270	5.6	early	253
04/83	1982	88,126	5.6	late	253
04/84	1983	34,559	5.8	early	251
04/84	1983	61,435	5.8	late	251
04-05/85	1984	115,587	5.8	early	253
04-05/85	1984	83,701	5.8	late	253
04/86	1985	53,968	4.5	early	253
04/86	1985	123,532	4.4	late	253
04/87	1986	151,565	4.9	--	253
04/88	1987	159,610	4.7	--	253
04-05/89	1988	111,295	4.6	--	253
05/90	1989	97,655	4.3	--	253
05/91	1990	162,980	4.5	--	253

Appendix Table B-8. Estimated number of hatchery summer steelhead that returned to Cole M. Rivers Hatchery, 1976-91 return years. Data were received from Michael Evenson, Oregon Department of Fish and Wildlife, Cole M. Rivers Hatchery, Trail, Oregon.

Return year	Early-run (period)	Late-run	Total
1976	93 (06/22-09/29)	773	866
1977	153 (06/10-09/27)	2,236	2,389
1978	207 (05/16-10/16)	1,362	1,569
1979	300 (06/11-10/19)	4,012	4,312
1980	520 (06/18-10/09)	2,548	3,068
1981	1,463 (05/18-10/23)	5,835	7,298
1982	2,534 (05/25-09/27)	5,086	7,620
1983	1,007 (05/27-10/10)	2,039	3,046
1984	1,346 (05/16-10/02)	1,744	3,090
1985	727 (05/24-10/07)	996	1,723
1986	1,888 (05/29-10/01)	2,895	4,783
1987	3,408 (05/29-09/28)	7,043	10,451
1988	2,970 (05/16-09/29)	4,775	7,745
1989	2,776 (05/19-10/11)	2,680	5,456
1990	1,291 (05/04-10/04)	612	1,903
1991	628 (05/14-10/01)	652	1,264

Appendix Table B-9. Return rate of first spawning migrants to Cole M. Rivers Hatchery for progeny of early-run and late-run summer steelhead. Paired data include only those brood years where mean weight of smolts did not differ at time of release.

	Parental variety			
	Early-run		Late-run	
Brood year	Mark	% return[a]	Mark	% return[a]
1978	AdRVRM	2.47	AdLVRM	1.90
1981	AdLV	1.50	AdRV	1.05
1982	AdLP	1.21	AdRP	1.20
1983	LVRM	1.06	LVLM	1.10
1984	LPLM	1.58	LPRM	1.22

[a] *One year after release.*

Appendix Table B-10. Correlation matrix for variables examined in the analysis of the number of wild half-pounders that passed Huntley Park, 1976-91 return years. Variables are described in Appendix Table B-11.

	Return	Size	Percent age-1	Rearing flow	Migration flow	Upwelling	Ocean temperature
Return	1.00						
Size	0.18	1.00					
Percent age-1	-0.20	0.00	1.00				
Rearing flow	0.17	0.32	-0.15	1.00			
Migration flow	-0.46	-0.02	-0.22	0.14	1.00		
Upwelling	-0.11	-0.78[a]	0.20	-0.47	0.24	1.00	
Temperature	0.19	0.22	0.03	0.03	-0.23	-0.54[a]	1.00

[a] *Significant at $P \leq 0.05$.*

Appendix Table B-11. Data used to assess factors related to the number of wild half-pounders that passed Huntley Park, 1976-91 return years.

Return year	Number[a]	Size[b]	Percent age-1[c]	Rearing flow[d]	Migration flow[e]	Upwelling[f]	Ocean temperature[g]
1976	26,402	31.1	34.7	1,745	4,086	313	10.6
1977	119,630	32.9	38.0	1,768	1,267	266	11.2
1978	52,611	33.2	25.2	966	2,592	208	11.6
1979	25,114	31.5	34.5	2,167	4,580	266	11.3
1980	68,808	32.4	32.0	2,258	3,239	211	12.1
1981	146,556	34.4	36.5	1,960	1,884	188	12.2
1982	49,043	33.4	31.3	1,864	5,083	258	10.9
1983	52,270	32.9	30.4	2,291	6,100	141	12.2
1984	52,163	35.1	17.0	2,533	6,094	140	11.4
1985	114,515	34.4	29.3	3,104	4,110	142	10.9
1986	92,688	33.6	15.6	2,198	2,840	96	11.5
1987	60,073	--	--	2,255	2,273	149	11.4
1988	18,576	35.3	44.2	2,378	2,152	84	11.5
1989	23,246	34.6	44.7	1,710	5,306	149	11.6
1990	23,820	--	--	2,322	2,570	102	12.0
1991	19,962	--	--	1,860	6,215	344	10.9

[a] *Estimated passage at Huntley Park.*
[b] *Mean length (cm) at freshwater return.*
[c] *Percent age-1 smolts among wild half-pounders.*
[d] *Mean flow (cfs) at Grants Pass in July-August of the previous year.*
[e] *Mean flow (cfs) at Grants Pass in April-May.*
[f] *Sum of Bakun units near Crescent City, California, in April-June.*
[g] *Mean surface temperature (^{o}C) near Charleston, Oregon, in April-June.*

Appendix Table B-12. Correlation matrix for variables examined in the analysis of the return of wild half-pounders and wild late-run first spawning migrants to the Rogue River, 1975-87 brood years. Variables are described in Appendix Table B-13.

	Half-pounders	Adults	Parents	Spawning flow	Migration flow	Water temperature	Percent age-1
Half-pounders	1.00						
Adults	0.70[a]	1.00					
Parents	-0.11	0.64[a]	1.00				
Spawning flow	0.27	0.60	0.66[a]	1.00			
Migration flow	0.55[a]	0.19	0.05	0.34	1.00		
Temperature	-0.05	-0.36	-0.51	-0.58[a]	0.21	1.00	
Percent age-1	-0.30	-0.43	0.06	-0.21	-0.31	0.10	1.00

[a] *Significant at* $P \leq 0.05$.

Appendix Table B-13. Data used to assess factors related to the freshwater return of wild half-pounders and wild late-run first spawning migrants, 1975-87 brood years.

Brood year	Half-pounders[a]	Adults[b]	Parents[c]	Spawning flow[d]	Migration flow[e]	Water temperature[f]	Percent age-1[g]
1975	80,748	21,007	--	157	44	18.7	11.4
1976	85,064	23,428	--	78	13	18.6	53.5
1977	32,935	7,239	8,096	17	20	20.5	40.3
1978	58,042	18,126	20,561	119	17	17.5	14.9
1979	109,082	19,050	28,166	92	39	17.9	20.2
1980	86,295	15,468	23,786	131	21	17.5	62.0
1981	53,761	8,949	14,207	74	15	17.1	28.6
1982	58,965	22,273	23,935	137	22	16.6	27.0
1983	91,415	25,581	28,867	209	23	16.5	9.7
1984	110,583	--	8,829	108	28	17.0	30.3
1985	49,721	--	15,328	65	13	17.1	29.2
1986	31,741	11,213	30,935	154	27	17.0	67.2
1987	21,250	--	33,992	111	7	16.7	38.6

[a] *Estimated passage at Huntley Park.*
[b] *Estimated passage of first spawning migrants at Huntley Park.*
[c] *Estimated passage of parents at Huntley Park.*
[d] *Mean flow (cfs) in Grave Creek in January-March.*
[e] *Mean flow (cfs) in Grave Creek in May-June.*
[f] *Mean water temperature* (^{o}*C) at Grants Pass in July-September.*
[g] *Smolt age among wild pounders.*

Appendix Table B-14. Regression analysis of the number of wild late-run summer steelhead that returned to the Rogue River as first spawning migrants, 1977-89 return years.

Independent variable	Regression coefficient	Standard error	*P*
Half-pounders	0.2034	0.0400	0.001
Peak flow	-0.2915	0.1071	0.024
Constant	10,783		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	5.21×10^8	2	2.60×10^8	12.90	0.002
Residual	1.82×10^8	9	0.20×10^8		

	Partial r^2	
Variables tested	Step 1	Step 2
Half-pounders	0.53	--
Autumn flow	0.00	0.00
Winter flow	0.18	0.15
Peak flow	0.30	0.45
Spawning flow	0.14	0.40
Kelt flow	0.01	0.39
Upwelling	0.13	0.09
Ocean temperature	0.01	0.41

Appendix Table B-15. Regression analysis of the number of wild late-run summer steelhead that returned to the Rogue River as second spawning migrants, 1977-89 return years.

Independent variable	Regression coefficient	Standard error	*P*
First spawners	0.1922	0.0485	0.004
Peak flow	-0.0790	0.0256	0.015
Constant	1,914		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	1.96×10^7	2	0.98×10^7	8.60	0.010
Residual	0.91×10^7	8	0.11×10^7		

	Partial r^2	
Variables tested	Step 1	Step 2
First spawning migrants	0.30	--
Autumn flow	0.00	0.00
Winter flow	0.01	0.17
Peak flow	0.18	0.54
Spawning flow	0.35	0.37
Kelt flow	0.06	0.15
Upwelling	0.04	0.12
Ocean temperature	0.05	0.13

Appendix Table B-16. Regression analysis of the number of wild late-run summer steelhead that returned to the Rogue River as third spawning migrants, 1977-89 return years.

Independent variable	Regression coefficient	Standard error	*P*
Second spawners	0.2028	0.0306	<0.001
Peak flow	-0.0101	0.0033	0.015
Constant	128		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	1.24×10^6	2	0.62×10^6	24.02	<0.001
Residual	0.21×10^6	8	0.03×10^6		

	Partial r^2	
Variables tested	Step 1	Step 2
Second spawning migrants	0.69	--
Autumn flow	0.03	0.20
Winter flow	0.00	0.09
Peak flow	0.01	0.54
Spawning flow	0.08	0.37
Kelt flow	0.01	0.08
Upwelling	0.03	0.02
Ocean temperature	0.12	0.03

Appendix Table B-17. Correlation matrix for independent variables used in the analyses of the number of wild late-run adult summer steelhead that returned to the Rogue River. Variables are described in Appendix Table B-18.

	Flow					Ocean	
	Autumn	Winter	Peak	Spawning	Kelt	Upwelling	Temperature
Autumn flow	1.00						
Winter flow	0.47	1.00					
Peak flow	0.30	0.77[a]	1.00				
Spawning flow	0.35	0.49[a]	0.87[a]	1.00			
Kelt flow	0.54[a]	0.72[a]	0.72[a]	0.70[a]	1.00		
Upwelling	-0.51[a]	0.14	-0.08	-0.28	-0.34	1.00	
Ocean temp.	0.10	0.06	0.40	0.65[a]	0.35	-0.37	1.00

[a] *$P \leq 0.05$.*

Appendix Table B-18. Independent variables used to assess factors related to the number of wild late-run adult summer steelhead that returned to the Rogue River, 1977-89 return years.

Return year	Flow					Ocean	
	Autumn[a]	Winter[b]	Peak[c]	Spawning[d]	Kelt[e]	Upwelling[f]	Temperature[g]
1977	1,444	1,421	1,900	17	1,204	107	10.6
1978	1,440	5,232	40,300	119	2,908	121	11.2
1979	1,598	2,076	12,700	92	3,762	116	10.9
1980	1,519	4,810	26,900	131	3,881	150	11.5
1981	1,410	2,303	9,800	74	1,634	109	11.6
1982	1,588	8,229	46,300	137	5,946	190	10.5
1983	2,078	5,255	50,400	209	7,481	-65	12.3
1984	2,462	7,492	27,600	108	6,800	30	11.4
1985	2,154	5,116	19,000	65	3,864	58	9.9
1986	1,905	2,810	27,800	154	4,120	42	11.2
1987	1,882	2,999	18,400	111	2,852	42	11.0
1988	1,574	2,205	12,500	64	1,470	30	10.7
1989	1,281	2,972	16,200	79	5,306	28	10.9

[a] *Mean flow (cfs) at Grants Pass in the previous September-October.*
[b] *Mean flow (cfs) at Grants Pass in the previous November-January.*
[c] *Peak flow (cfs) at Grants Pass in the previous November-March.*
[d] *Mean flow (cfs) of Grave Creek in January-March.*
[e] *Mean flow (cfs) at Grants Pass in March-April.*
[f] *Sum of Bakun units near Crescent City, California, in March-May.*
[g] *Mean surface temperature (^{o}C) near Charleston, Oregon, in March-May.*

Appendix Table B-19. Correlation matrix for variables examined in the analysis of the return rate to fresh water for hatchery half-pounders, 1976-91 return years. Percentage data were logit transformed prior to analysis. Variables are described in Appendix Table B-20.

	Percent return	Juvenile size	Flow	Upwelling	Ocean temperature
Percent return	1.00				
Juvenile size	0.25	1.00			
Flow	-0.20	-0.48	1.00		
Upwelling	-0.36	0.05	0.24	1.00	
Ocean temperature	0.51[a]	0.49	-0.23	-0.54[a]	1.00

[a] $P \leq 0.05$.

Appendix Table B-20. Data used to assess factors related to the return rate of hatchery half-pounders to the Rogue River, 1976-91 return years.

Return year	Return rate[a]	Juvenile size[b]	Flow[c]	Upwelling[d]	Ocean temperature[e]
1976	3.54	99.5	4,086	313	10.6
1977	6.28	88.8	1,267	266	11.2
1978	11.10	104.0	2,592	208	11.6
1979	6.05	99.9	4,580	266	11.3
1980	25.60	119.7	3,239	211	12.1
1981	28.36	117.2	1,884	188	12.2
1982	13.60	82.3	5,083	258	10.9
1983	17.08	83.7	6,100	141	12.2
1984	9.56	86.4	6,094	140	11.4
1985	13.04	84.0	4,110	142	10.9
1986	23.70	96.3	2,840	96	11.5
1987	19.20	97.3	2,273	149	11.4
1988	6.36	99.0	2,152	84	11.5
1989	6.72	94.7	5,306	149	11.6
1990	2.78	102.9	2,570	102	12.0
1991	4.85	96.5	6,215	344	10.9

[a] *Percent that returned to the Rogue River. Estimates were developed from data in Table 10 and Appendix Table B-7.*
[b] *Mean weight (g) at time of release.*
[c] *Mean flow (cfs) at Grants Pass in April-May.*
[d] *Sum of Bakun units near Crescent City, California, in April-June.*
[e] *Mean surface temperature (^{o}C) at Charleston, Oregon, in April-June.*

Appendix Table B-21. Data used to assess factors related to the return of first spawning migrants to Cole M. Rivers Hatchery, 1973-88 brood years. Data were limited to groups with a pectoral or ventral fin clip and groups with mean weights that ranged between 70 g and 120 g.

Brood year	Mark	Return rate[a]	Juvenile size[b]	Flow[c]	Upwelling[d]	Ocean temperature[e]
1973	AdRV	1.03	116	5,574	410	10.7
1974	AdLV	1.17	105	4,086	313	10.6
1975	LV	0.73	87	1,267	266	11.2
1976	AdLP	1.78	105	2,592	208	11.6
1977	AdLVLM	0.78	108	4,580	266	11.3
1979	RPRM	1.88	108	3,239	211	12.1
1980	AdRVLM	2.79	111	1,884	188	12.2
1981	AdRV	1.05	78	5,083	258	10.9
1982	AdRP	1.20	81	6,100	141	12.2
1983	LVLM	1.10	78	6,094	140	11.4
1984	LPRM	1.22	78	4,110	142	10.9
1986	LPLM	2.31	93	2,273	149	11.4
1987	LV	1.58	96	2,152	84	11.5
1988	AdLPLM	0.77	99	5,306	149	11.6

[a] *Returns of marked cohorts to Cole M. Rivers Hatchery one year later.*
[b] *Mean weight (g) at time of release.*
[c] *Mean flow (cfs) at Grants Pass in April-May.*
[d] *Sum of Bakun units near Crescent City, California, in April-June.*
[e] *Mean surface temperature (°C) at Charleston, Oregon, in April-June.*

Appendix Table B-22. Correlation matrix for variables examined in the analysis of the return rate of first spawning migrants to Cole M. Rivers Hatchery, 1973-88 brood years. Percentage data were logit transformed prior to analysis. Variables are described in Appendix Table B-21.

	Percent return	Juvenile size	Flow	Upwelling	Ocean temperature
Percent return	1.00				
Juvenile size	0.25	1.00			
Flow	-0.48	-0.25	1.00		
Upwelling	-0.33	0.49	0.14	1.00	
Ocean temperature	0.48	0.09	-0.18	-0.56[a]	1.00

[a] $P \leq 0.05$.

Appendix Table B-23. Estimated composition of wild late-run adult summer steelhead that passed Huntley Park from early July through late October, 1976-89 return years. Scales were not sampled in 1987. Symbols are described in Table 9.

Return year	Percent of adults													
	/H	/HS	/HSS	/HSSS	/H1	/H1S	/H1SS	/S	/SS	/1	/1S	/1SS	/1SSS	/2
1976	59.84	14.58	19.18	0.00	0.96	0.00	0.00	0.00	0.00	4.91	0.00	0.00	0.00	0.54
1977	83.32	9.46	2.57	1.66	0.38	0.00	0.00	0.00	0.00	2.54	0.00	0.00	0.00	0.07
1978	91.15	5.32	0.00	0.00	0.00	0.00	0.00	0.48	0.00	2.79	0.27	0.00	0.00	0.00
1979	63.30	30.69	1.29	0.00	2.58	0.00	0.00	0.64	0.00	1.07	0.43	0.00	0.00	0.00
1980	57.86	24.16	10.11	0.00	2.39	1.03	0.00	0.00	0.34	3.42	0.34	0.00	0.00	0.34
1981	85.06	9.82	2.18	0.35	1.45	0.21	0.00	0.00	0.00	0.00	0.60	0.00	0.34	0.00
1982	88.23	9.34	.58	0.00	.83	0.00	0.54	0.00	0.00	0.48	0.00	0.00	0.00	0.00
1983	59.40	21.65	2.10	0.00	11.90	0.00	0.00	0.97	0.00	3.97	0.00	0.00	0.00	0.00
1984	68.78	12.70	3.43	0.00	3.59	1.42	0.00	0.00	0.00	10.08	0.00	0.00	0.00	0.00
1985	88.49	9.52	.66	0.26	0.79	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00
1986	77.81	13.68	1.00	0.00	1.08	0.46	0.00	0.00	0.00	4.89	0.77	0.30	0.00	0.00
1988	78.67	9.16	2.04	0.48	4.30	0.46	0.00	1.50	0.00	2.92	0.00	0.00	0.00	0.46
1989	58.46	14.72	2.18	0.00	5.54	1.01	0.00	0.00	0.44	17.64	0.00	0.00	0.00	0.00

Appendix Table B-24. Correlation matrix for variables examined in the analyses of the migration timing of summer steelhead that passed Huntley Park, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Table B-25.

	Migration timing						
	Half-pounders		Adults				Ocean
	Wild	Hatchery	Wild	Hatchery	Flow	Upwelling	temperature
Wild half-pounders	1.00						
Hatchery half-pounders	0.92[a]	1.00					
Wild adults	0.79[a]	0.67[a]	1.00				
Hatchery adults	0.76[a]	0.71[a]	0.81[a]	1.00			
August flow	0.18	0.11	-0.16	-0.21	1.00		
Upwelling	-0.50[a]	-0.50[a]	-0.56[a]	-0.55[a]	-0.38	1.00	
Ocean temperature	0.65[a]	0.58[a]	0.42	0.51[a]	0.23	-0.56[a]	1.00

[a] *$P \leq 0.05$.*

Appendix Table B-25. Data used in analyses of the migration timing of wild summer steelhead that passed Huntley Park, 1976-91 return years.

	% that passed by 2 September[a]						
Return	Half-pounders		Adults				Ocean
year	Wild	Hatchery	Wild	Hatchery	Flow[b]	Upwelling[c]	temperature[d]
1976	97.1	94.6	66.7	85.0	1,925	139	13.0
1977	94.2	85.2	86.4	92.0	948	271	12.0
1978	46.7	26.6	21.1	23.8	2,024	265	12.0
1979	91.2	87.5	85.8	89.2	1,870	108	13.8
1980	37.5	27.4	12.5	15.6	1,735	331	11.9
1981	86.2	78.5	55.2	64.8	1,845	279	12.4
1982	52.2	33.5	73.6	51.2	2,361	148	12.6
1983	99.8	99.1	66.4	82.2	3,263	104	14.1
1984	83.6	67.8	54.3	44.4	3,289	244	12.0
1985	69.6	50.0	55.9	49.5	2,477	143	11.3
1986	78.0	72.9	41.7	68.3	2,248	195	11.2
1987	53.3	49.4	--	--	2,468	206	11.5
1988	33.6	51.6	16.5	30.7	2,056	258	11.0
1989	44.2	28.4	18.2	50.7	2,717	237	12.7
1990	43.6	35.4	44.3	75.9	2,262	167	12.6
1991	78.6	57.2	70.5	86.2	2,108	220	11.6

[a] *Estimated from data in Appendix Tables B-26 through B-29.*

[b] *Mean flow (cfs) at Agness from 13 August through 9 September.*

[c] *Sum of Bakun units near Crescent City, California, in July-August.*

[d] *Mean surface temperature (°C) at Charleston, Oregon, in July-August.*

Appendix Table B-26. Estimated number of wild summer steelhead that passed Huntley Park weekly from 9 July through 2 September, 1976-91 return years. Week-of-year calendar is in **APPENDIX A.**

Return year	Week-of-year							
	28	29	30	31	32	33	34	35
				HALF-POUNDERS				
1976	0	0	40	3,232	4,376	14,699	2,646	624
1977	32	260	3,663	2,687	21,696	39,375	31,902	13,018
1978	45	0	0	111	179	6,043	10,082	8,092
1979	6,206	2,075	43	0	38	1,109	10,887	2,549
1980	34	0	0	65	604	3,319	6,053	15,729
1981	0	0	0	1,444	25,386	76,460	18,700	4,378
1982	241	111	159	314	6,797	9,963	2,827	5,214
1983	0	123	0	1,663	698	25,086	13,832	10,787
1984	0	0	0	323	8,145	14,390	10,463	10,286
1985	0	0	313	6,310	17,053	20,287	15,730	19,991
1986	0	0	0	41	749	4,005	32,590	34,696
1987	--	--	--	2,386	1,756	9,566	5,695	11,482
1988	0[a]	76	0	0	608	581	1,180	3,711
1989	0[a]	44	0	294	303	317	4,900	4,585
1990	0[a]	0	0	0	192	450	6,103	3,641
1991	0[a]	46	82	77	120	2,050	10,499	2,822
				ADULTS				
1976	74	179	164	381	1,279	1,567	984	771
1977	0	521	1,133	1,099	2,798	4,045	4,312	3,857
1978	0	0	0	224	36	1,603	1,472	2,613
1979	9,680	1,988	173	80	190	957	5,932	1,412
1980	0	71	0	69	370	435	350	476
1981	78	198	116	429	2,758	7,015	1,962	647
1982	3,003	954	4,647	6,234	3,648	1,423	697	630
1983	130	123	257	343	0	1,188	1,645	2,179
1984	0	0	621	806	2,305	2,667	1,285	633
1985	171	755	445	4,638	4,745	2,553	2,241	1,765
1986	439	458	427	294	667	1,585	4,752	5,561
1987	--	--	--	2,133	438	1,175	807	519
1988	99[a]	153	71	357	786	466	529	694
1989	202[a]	310	130	503	86	212	598	297
1990	0[a]	0	35	38	116	41	644	592
1991	92[a]	141	82	118	437	523	687	166

[a] *Returns estimated for periods not sampled.*

Appendix Table B-27. Estimated number of wild summer steelhead that passed Huntley Park weekly from 3 September through 28 October, 1976-91 return years. Week-of-year calendar is in **APPENDIX A**.

Return year	Week-of-year							
	36	37	38	39	40	41	42	43
				HALF-POUNDERS				
1976	416	21	51	21	115	119	42	0[a]
1977	1,366	2,840	1,499	645	541	53	53	0[a]
1978	8,124	15,652	2,454	786	72	68	368	535
1979	1,411	35	108	108	0	0	38	507
1980	11,179	13,915	6,274	7,375	3,864	268	98	31
1981	8,246	2,741	4,621	1,893	2,068	447	172	0[a]
1982	9,536	2,982	6,651	2,572	1,078	552	46	0[a]
1983	0	0	0	81	0	0	0	0
1984	4,701	2,432	1,107	41	43	173	59	0[a]
1985	18,822	13,535	1,127	542	611	117	77	0
1986	9,029	5,498	3,277	2,351	41	276	115	0
1987	10,204	8,512	5,929	1,678	1,964	--	--	--
1988	2,959	4,892	1,035	2,215	535	35	535	214
1989	4,460	4,730	1,196	1,572	349	461	35	0
1990	7,351	4,833	429	143	178	286	143	71
1991	2,847	421	357	214	392	0	0	35
				ADULTS				
1976	93	167	448	431	692	362	342	162[a]
1977	590	563	590	797	176	80	0	0[a]
1978	2,149	6,559	4,015	3,430	607	1,138	1,876	2,444
1979	1,068	214	0	35	0	35	0	2,022
1980	239	1,043	1,189	4,404	3,092	508	1,106	855
1981	840	523	3,916	2,642	1,034	726	572	479[a]
1982	263	117	231	1,168	3,527	905	843	577[a]
1983	678	183	344	408	816	64	193	278
1984	921	3,192	655	580	259	859	238	307[a]
1985	3,108	3,657	685	659	3,392	738	975	448
1986	3,440	2,534	4,917	4,365	1,257	1,504	1,085	707
1987	776	1,432	3,357	2,107	5,607	--	--	--
1988	720	500	821	3,786	2,393	1,715	4,929	1,215
1989	301	907	1,952	2,454	1,670	2,147	964	508
1990	673	598	108	71	143	35	71	143
1991	361	38	108	108	71	35	71	143

[a] *Returns estimated for periods not sampled.*

Appendix Table B-28. Estimated number of hatchery summer steelhead that passed Huntley Park weekly from 9 July through 2 September, 1976-91 return years. Week-of-year calendar is in **APPENDIX A**.

Return year	Week-of-year							
	28	29	30	31	32	33	34	35
				HALF-POUNDERS				
1976	0	0	0	258	620	4,096	813	402
1977	0	0	500	456	2,054	4,741	6,562	4,821
1978	0	0	0	0	107	1,311	4,872	4,609
1979	2,830	1,503	216	39	0	460	6,555	4,275
1980	51	0	0	56	403	3,085	5,710	16,878
1981	0	78	39	820	14,232	40,113	9,004	3,236
1982	0	0	52	210	4,948	9,656	2,392	5,548
1983	0	0	0	392	299	16,266	9,797	19,275
1984	140	0	0	483	461	2,285	3,346	4,694
1985	0	47	88	1,433	5,309	7,882	6,581	10,448
1986	48	0	0	0	124	1,461	23,970	31,722
1987	--	--	--	1,465	3,590	14,836	13,992	17,872
1988	0[a]	0	0	0	1,000	1,358	4,193	5,343
1989	0[a]	0	0	168	43	160	3,376	4,824
1990	0[a]	0	0	0	0	328	1,418	2,003
1991	0[a]	0	0	0	0	1,086	8,279	5,189
				ADULTS				
1976	0	50	40	127	685	871	216	103
1977	95	448	869	288	834	964	1,098	616
1978	47	0	0	111	107	145	189	73
1979	3,177	485	0	39	0	191	780	235
1980	83	54	167	133	314	210	296	704
1981	951	1,663	314	1,054	2,439	2,576	655	190
1982	645	730	211	575	1,700	1,219	174	420
1983	65	62	412	97	150	687	741	573
1984	0	0	0	159	613	287	85	89
1985	115	0	223	525	752	224	279	226
1986	391	642	342	292	165	543	1,892	776
1987	--	--	--	836	878	649	359	311
1988	174[a]	268	35	321	500	660	123	123
1989	315[a]	484	43	168	173	105	382	418
1990	25[a]	38	0	38	154	205	257	45
1991	60[a]	93	0	118	39	161	283	125

[a] *Returns estimated for periods not sampled.*

Appendix Table B-29. Estimated number of hatchery summer steelhead that passed Huntley Park weekly from 3 September through 28 October, 1976-91 return years. Week-of-year calendar is in **APPENDIX A**.

Return year	Week-of-year							
	36	37	38	39	40	41	42	43
				HALF-POUNDERS				
1976	129	19	75	19	21	59	151	0[a]
1977	535	1,205	911	380	294	0	0	0[a]
1978	7,147	14,063	3,198	2,286	72	101	871	2,343
1979	1,907	251	35	71	0	0	0	0
1980	12,001	15,086	10,260	17,053	14,029	482	410	198
1981	5,382	1,783	5,874	3,822	1,724	279	459	0[a]
1982	12,175	3,718	16,628	8,183	3,479	805	329	0[a]
1983	96	0	0	81	0	64	127	69
1984	1,751	2,203	906	125	259	57	117	0[a]
1985	15,102	13,903	926	465	839	273	117	150
1986	7,739	7,526	4,875	841	126	159	77	0
1987	12,532	16,824	11,679	5,035	4,571	--	--	--
1988	2,640	4,108	643	2,679	572	108	572	108
1989	11,453	5,829	1,714	920	388	806	214	0
1990	3,907	1,997	108	71	178	321	143	108
1991	6,134	776	1,107	964	1,536	178	178	35
				ADULTS				
1976	0	56	68	58	63	92	19	12[a]
1977	161	133	53	75	30	0	0	0[a]
1978	352	496	335	501	72	34	167	201
1979	343	0	0	0	0	0	0	250
1980	654	813	810	3,025	3,407	421	847	666
1981	306	348	1,292	1,499	402	447	687	371[a]
1982	439	310	740	1,636	1,274	638	234	129[a]
1983	96	0	57	0	62	128	193	69
1984	91	380	301	41	130	230	238	130[a]
1985	390	609	201	38	611	233	312	0
1986	644	428	713	166	41	157	194	0
1987	180	358	251	214	429	--	--	--
1988	40	286	108	751	894	357	1,821	929
1989	182	239	120	383	194	537	178	338
1990	168	40	0	0	0	0	0	35
1991	0	0	35	35	0	0	0	71

[a] *Returns estimated for periods not sampled.*

Appendix Table B-30. Data used to assess factors that affected the migration timing of wild summer steelhead at Gold Ray Dam, 1942-91 return years.

Return year	Migration timing[a]	Flow[b]	Water temperature[c]	Return year	Migration timing[a]	Flow[b]	Water temperature[c]
1942	54.5	962	--	1967	25.6	1,208	24.0
1943	68.1	1,534	--	1968	--	855	23.3
1944	26.0	1,025	--	1969	43.7	1,274	22.2
1945	40.6	1,031	--	1970	18.9	1,025	23.1
1946	57.3	1,244	--	1971	46.0	1,885	22.3
1947	59.8	1,078	--	1972	33.2	1,731	23.2
1948	67.6	1,440	--	1973	12.1	926	23.1
1949	50.9	1,160	--	1974	39.2	1,819	21.2
1950	27.5	1,344	--	1975	24.7	1,744	20.9
1951	36.9	1,220	--	1976	52.4	1,768	22.2
1952	51.7	1,842	--	1977	7.1	966	24.4
1953	54.4	1,982	--	1978	38.4	2,167	22.1
1954	82.4	1,468	--	1979	15.8	2,258	21.7
1955	35.0	1,170	--	1980	17.1	1,960	22.2
1956	53.0	1,758	--	1981	26.2	1,864	22.8
1957	39.8	1,266	--	1982	39.4	2,292	21.2
1958	44.9	1,618	--	1983	56.4	2,534	20.6
1959	43.0	1,064	--	1984	52.9	3,104	20.8
1960	42.3	1,102	--	1985	25.8	2,198	22.2
1961	32.5	1,065	--	1986	31.1	2,255	22.1
1962	29.9	1,208	--	1987	37.2	2,378	21.5
1963	37.6	1,212	--	1988	32.5	1,710	--
1964	40.2	1,409	22.4	1989	41.6	2,322	--
1965	24.2	1,470	22.8	1990	48.6	2,109	--
1966	31.2	1,151	22.6	1991	46.3	2,210	--

[a] *Percentage that passed by 15 September. Percentages were estimated from data in Appendix Tables B-31 and B-32.*

[b] *Mean flow (cfs) at Grants Pass in July-August.*

[c] *Mean maximum water temperature (^{o}C) at Agness in July-August.*

Appendix Table B-31. Estimated number of wild summer steelhead that passed Gold Ray Dam from 16 May through 30 September, 1942-91 return years.

Return year	May	June		July		August		September	
	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-30
1942	0	53	697	962	818	141	79	258	171
1943	311	65	371	1,271	1,238	242	138	221	114
1944	71	62	466	798	701	296	277	176	186
1945	6	5	138	667	1,097	633	253	218	110
1946	103	15	254	1,214	650	183	105	50	58
1947	36	116	463	323	461	394	85	62	120
1948	80	88	268	444	309	107	84	35	67
1949	147	224	223	481	337	173	127	134	90
1950	98	2	156	423	290	179	98	36	144
1951	28	9	173	185	506	168	80	68	135
1952	59	5	473	1,366	1,005	216	47	144	165
1953	44	31	235	805	780	282	55	217	89
1954	30	23	383	655	437	159	81	65	142
1955	7	74	289	361	152	9	28	0	14
1956	9	12	257	399	525	88	157	5	91
1957	45	30	112	114	294	84	98	63	117
1958	7	19	201	324	167	61	56	35	47
1959	14	7	23	260	68	97	140	39	129
1960	2	38	161	347	166	61	97	68	53
1961	16	47	80	347	112	118	61	39	63
1962	0	119	51	186	339	151	196	37	49
1963	2	17	11	182	301	88	12	47	70
1964	0	0	0	63	159	104	68	18	30
1965	15	2	10	51	250	284	136	83	51
1966	0	0	29	119	258	235	55	8	67
1967	0	2	50	115	140	82	69	35	189
1968	0	0	0	--	--	79	49	18	--
1969	0	9	77	1,402	1,827	339	331	135	331
1970	37	21	65	132	155	472	127	114	103
1971	9	15	17	348	901	178	223	319	151
1972	13	6	57	278	424	413	192	147	89
1973	0	24	60	135	128	9	115	141	238
1974	14	10	116	395	1,313	275	354	415	146

Appendix Table B-31. Continued.

Return year	May	June		July		August		September	
	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-30
1975	5	10	50	392	581	223	161	242	268
1976	2	0	58	227	487	214	263	150	253
1977	0	0	67	162	191	36	42	243	637
1978	32	10	42	212	147	305	433	369	407
1979	24	8	67	526	579	88	250	329	325
1980	0	23	29	262	208	130	201	102	98
1981	5	15	106	162	864	666	169	93	430
1982	13	41	267	1,446	1,414	341	215	216	444
1983	50	47	241	780	1,189	119	244	167	390
1984	36	3	82	715	1,000	347	345	171	154
1985	0	69	155	696	482	251	212	293	148
1986	7	51	436	730	864	485	287	182	285
1987	36	127	396	664	2,057	561	547	434	168
1988	86	93	537	1,699	738	183	119	208	282
1989	59	157	225	680	910	218	68	15	58
1990	16	29	116	357	92	28	84	72	125
1991	15	17	97	352	453	162	260	140	88

Appendix Table B-32. Estimated number of wild summer steelhead that passed Gold Ray Dam from 1 October through 31 January, 1942-91 return years.

Return year	October		November		December		January	
	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31
1942	151	253	281	674	870	69	28	12
1943	8	555	732	331	43	8	0	17
1944	792	754	690	48	67	58	5,331	200
1945	477	649	282	1,198	1,245	320	0	138
1946	112	201	14	710	777	2	0	46
1947	356	544	80	69	53	56	0	26
1948	140	10	301	117	16	12	14	0
1949	400	131	150	848	143	10	1	10
1950	308	322	1,475	584	19	428	98	7
1951	467	487	127	663	33	103	0	68
1952	191	48	173	2	108	93	805	1,508
1953	121	221	381	149	150	271	266	406
1954	84	40	54	58	11	0	2	0
1955	32	93	0	322	194	121	77	852
1956	236	5	404	28	0	509	0	12
1957	175	156	2	33	0	0	276	511
1958	44	35	52	23	145	77	52	592
1959	41	47	0	0	0	0	0	641
1960	108	173	42	35	198	485	16	170
1961	100	205	124	266	478	352	114	0
1962	77	1,347	248	196	217	390	7	0
1963	117	238	225	127	36	35	82	164
1964	49	28	36	33	219	9	0	208
1965	94	142	509	484	33	0	544	749
1966	103	7	19	107	586	499	60	101
1967	529	358	39	0	0	29	92	194
1968	--	50	22	254	133	88	426	77
1969	276	768	177	5	413	1,679	1,605	58
1970	124	107	2,240	1,027	409	32	15	766
1971	1,119	88	242	248	110	78	168	151
1972	328	336	355	173	0	338	407	1,054
1973	216	374	185	852	1,192	890	0	510
1974	105	341	538	880	418	419	338	1,307

Appendix Table B-32. Continued.

Return year	October 1-15	October 16-31	November 1-15	November 16-30	December 1-15	December 16-31	January 1-15	January 16-31
1975	355	468	927	215	957	1,168	356	370
1976	410	44	318	141	15	0	50	41
1977	2,480	767	209	143	2,273	1,250	1,238	633
1978	640	152	9	318	582	186	68	68
1979	273	4,507	1,877	383	1,066	299	916	314
1980	232	757	719	923	424	877	72	536
1981	636	673	1,034	2,514	495	2	12	77
1982	302	422	2,086	930	730	154	316	707
1983	222	52	875	282	68	20	169	120
1984	190	512	844	383	155	34	119	13
1985	140	1,037	828	411	796	0	685	2,147
1986	530	877	1,870	1,430	542	26	115	1,068
1987	617	1,040	2,266	1,095	1,701	136	259	855
1988	540	676	2,507	1,892	830	25	136	723
1989	153	469	389	260	581	64	1,094	212
1990	69	109	130	116	69	34	121	66
1991	79	113	636	323	245	39	98	113

Appendix Table B-33. Correlation matrix for variables examined in the regression analysis of the migration timing of wild summer steelhead that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Table B-30.

	Migration timing	Flow	Water temperature
Migration timing	1.00		
Flow	0.46[a]	1.00	
Water temperature	-0.61[a]	-0.76[a]	1.00

[a] $P \leq 0.05$.

Appendix Table B-34. Regression analysis of the percentage of wild summer steelhead that passed Gold Ray Dam by 15 September, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Table B-30.

Independent variable	Regression coefficient	Standard error	r^2
Water temperature	-0.4458	0.1248	0.38
Constant	9.084		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	F	P
Regression	4.09	1	4.09	12.76	0.002
Residual	6.73	21	0.32		

Appendix Table B-35. Data used to assess factors that affected the migration timing of early-run wild summer steelhead at Gold Ray Dam, 1970-91 return years.

Return year	Migration timing[a]	Flow		Water temperature	
		June[b]	August[c]	Raygold[d]	Agness[e]
1970	22.7	2,006	1,019	--	24.0
1971	19.4	4,254	1,683	--	21.0
1972	23.1	3,712	1,603	--	23.6
1973	35.8	1,457	902	--	24.0
1974	18.5	4,482	1,583	18.2	--
1975	27.5	4,577	1,685	19.2	21.2
1976	20.5	2,728	1,925	20.0	23.0
1977	30.9	1,170	948	18.9	24.4
1978	19.1	2,278	2,024	17.7	22.8
1979	33.4	2,018	1,870	17.4	21.8
1980	32.8	2,150	1,735	17.3	22.9
1981	13.8	1,834	1,845	18.1	23.1
1982	44.7	2,894	2,361	16.8	21.3
1983	39.4	3,211	3,263	16.6	20.5
1984	31.0	4,241	3,289	14.8	21.5
1985	42.6	3,147	2,477	18.9	23.7
1986	40.2	2,691	2,248	16.6	19.8
1987	25.4	2,320	2,468	16.0	21.2
1988	65.9	3,299	2,056	17.3	--
1989	48.1	3,241	2,717	16.5	--
1990	65.3	2,273	2,262	17.4	--
1991	32.2	2,467	2,108	17.2	--

[a] *Percent that passed by 15 July. Estimates were derived from data in Appendix Tables B-31 and B-32.*

[b] *Mean flow (cfs) at Agness in June.*

[c] *Mean flow (cfs) at Agness from 13 August through 9 September.*

[d] *Mean maximum water temperature (°C) at Raygold in July.*

[d] *Mean maximum water temperature (°C) at Agness in July.*

Appendix Table B-36. Correlation matrix for variables examined in the regression analysis of the migration timing of wild early-run summer steelhead that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Table B-35.

	Migration timing	Flow		Water temperature		Year
		June	August	Raygold	Agness	
Migration timing	1.00					
June flow	-0.06	1.00				
August flow	0.34	0.37	1.00			
Raygold temperature	-0.28	-0.11	-0.69[a]	1.00		
Agness temperature	-0.26	-0.51[a]	-0.64[a]	0.60[a]	1.00	
Year	0.65[a]	-0.09	0.68[a]	-0.57[a]	-0.47[a]	1.00

[a] $P \leq 0.05$.

Appendix Table B-37. Correlation matrix for variables examined in the regression analysis of the migration timing of wild late-run summer steelhead that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Table B-39.

	Migration timing	Flow		Water temperature	
		August	Autumn	Autumn	Winter
Migration timing	1.00				
August flow	0.33	1.00			
Autumn flow	0.15	-0.04	1.00		
Autumn temperature	0.57[a]	0.21	0.25	1.00	
Winter temperature	-0.16	-0.15	0.21	0.31	1.00

[a] $P \leq 0.05$.

Appendix Table B-38. Regression analysis of the percentage of late-run wild summer steelhead that passed Gold Ray Dam by 30 November, 1970-91 return years. Percentage data were logit transformed prior to analysis. Variables are described in Appendix Table B-39.

Independent variable	Regression coefficient	Standard error	r^2
Autumn temperature	0.6640	0.1935	0.41
Winter temperature	-0.3495	0.1736	
Constant	-4.5348		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	F	P
Regression	6.65	2	3.33	6.40	0.011
Residual	7.28	14	0.52		

	Partial r^2	
Variables tested	Step 1	Step 2
August flow	0.20	0.17
Autumn flow	0.02	0.00
Autumn temperature	0.33	--
Winter temperature	0.04	0.22

Appendix Table B-39. Data used to assess factors that affected the migration timing of late-run wild summer steelhead at Gold Ray Dam, 1970-91 return years.

Return year	Migration timing[a]	Flow		Water temperature	
		August[b]	Autumn[c]	Autumn[d]	Winter[e]
1970	74.7	1,019	3,316	11.4	5.4
1971	78.4	1,683	2,411	10.0	5.8
1972	41.6	1,603	1,884	9.9	5.0
1973	41.8	902	5,262	11.3	7.4
1974	44.8	1,583	1,662	10.3	6.0
1975	43.9	1,685	2,338	9.9	6.0
1976	91.6	1,925	1,489	12.2	4.2
1977	44.0	948	2,447	12.0	8.2
1978	62.8	2,024	1,518	11.4	5.4
1979	74.0	1,870	2,156	12.6	7.4
1980	58.8	1,735	1,604	12.0	7.4
1981	90.0	1,845	2,666	11.6	7.4
1982	68.7	2,361	2,429	10.8	7.2
1983	82.8	3,263	3,578	12.3	7.1
1984	86.6	3,289	4,771	12.3	5.4
1985	41.4	2,477	1,962	9.7	5.9
1986	74.0	2,248	2,464	11.9	6.6
1987	63.7	2,468	1,195	--	--
1988	77.5	2,056	1,912	--	--
1989	40.5	2,717	1,482	--	--
1990	65.4	2,262	1,333	--	--
1991	71.4	2,108	1,327	--	--

[a] *Percent that passed by 30 November. Estimates were derived from data in Appendix Tables B-31 and B-32.*

[b] *Mean flow (cfs) at Agness from 13 August through 9 September.*

[c] *Mean flow (cfs) at Grants Pass in October-November.*

[d] *Mean maximum water temperature (°C) at Agness in October-November.*

[e] *Mean maximum water temperature (°C) at Agness in December-January.*

Appendix Table B-40. Migration timing of hatchery summer steelhead that passed Gold Ray Dam, 1970-91 return years. Migration timing was estimated from data in Appendix Tables B-41 and B-42.

Return year	All[a]	Early run[b]	Late run[c]	Return year	All[a]	Early run[b]	Late run[c]
1970	40.8	12.0	93.4	1981	57.7	6.3	91.5
1971	75.2	16.6	76.4	1982	71.2	46.5	80.6
1972	37.2	0[d]	44.9	1983	55.2	40.2	99.1
1973	4.2	0[d]	35.4	1984	84.6	27.6	78.7
1974	47.5	11.6	52.4	1985	61.9	48.7	47.0
1975	33.5	19.6	62.2	1986	52.4	36.2	91.8
1976	51.2	18.0	100[d]	1987	76.9	23.1	78.4
1977	9.2	13.0	52.9	1988	78.2	40.8	97.0
1978	41.2	30.3	50.9	1989	72.2	33.3	78.9
1979	25.9	15.9	80.3	1990	86.6	31.3	86.8
1980	34.5	29.2	72.7	1991	82.9	20.0	74.9

[a] *Percent that passed by 15 September.*
[b] *Percent that passed by 15 July.*
[c] *Percent that passed by 30 November.*
[d] *Data excluded from analyses because of small sample sizes.*

Appendix Table B-41. Estimated number of hatchery summer steelhead that passed Gold Ray Dam from 16 May through 30 September, 1970-91 return years.

Return year	May	June		July		August		September	
	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-30
1970	0	5	17	24	48	203	41	45	41
1971	0	0	6	107	325	66	85	92	9
1972	0	0	0	0	40	110	48	18	6
1973	0	0	0	0	0	0	10	24	17
1974	0	0	6	136	882	110	40	48	87
1975	0	0	0	160	323	136	83	114	143
1976	0	0	10	77	218	60	95	25	104
1977	0	0	0	38	83	20	11	141	267
1978	0	0	21	127	118	93	91	39	84
1979	0	0	21	168	354	307	192	150	118
1980	0	0	48	214	296	154	104	83	109
1981	0	0	38	111	1,192	766	174	83	230
1982	0	0	145	1,426	1,125	226	179	277	265
1983	0	0	91	541	512	138	149	140	240
1984	33	57	119	361	741	265	441	46	12
1985	0	23	227	504	399	100	192	103	71
1986	0	26	283	866	1,262	463	125	217	427
1987	0	21	407	1,944	5,659	1,317	395	520	149
1988	42	239	967	1,579	2,238	551	884	434	232
1989	0	125	525	1,360	1,564	1,483	608	366	949
1990	24	74	375	763	1,603	388	347	372	70
1991	0	3	33	164	404	192	116	89	38

Appendix Table B-42. Estimated number of hatchery summer steelhead that passed Gold Ray Dam from 1 October through 31 January, 1970-91 return years.

Return year	October		November		December		January	
	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31
1970	22	8	325	123	23	0	0	14
1971	115	0	19	29	10	0	23	21
1972	44	64	28	22	0	30	43	127
1973	68	82	19	89	261	108	0	134
1974	52	158	219	193	112	76	62	393
1975	236	195	370	66	203	288	69	51
1976	125	36	159	38	0	0	0	0
1977	868	232	131	32	691	338	224	108
1978	183	38	0	49	216	74	30	23
1979	108	1,571	821	118	257	81	251	83
1980	54	464	218	253	142	348	39	78
1981	341	199	389	429	113	0	0	35
1982	138	181	333	181	157	0	0	109
1983	152	174	582	116	0	0	13	0
1984	52	131	100	0	52	16	9	3
1985	27	216	98	35	54	0	110	340
1986	591	657	710	318	0	51	0	191
1987	195	643	1,002	429	333	96	19	217
1988	630	379	336	299	58	0	0	0
1989	263	431	146	48	237	0	236	18
1990	99	161	128	70	21	18	22	20
1991	26	12	33	46	16	12	13	12

Appendix Table B-43. Correlation matrix for variables examined in the analysis of the migration timing of hatchery summer steelhead that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Tables B-30 and B-40.

	Migration timing	Flow	Water temperature	Year
Migration timing	1.00			
Flow	0.68[a]	1.00		
Water temperature	-0.59[a]	-0.76[a]	1.00	
Year	0.66[a]	0.63[a]	0.59	1.00

[a] $P \leq 0.05$.

Appendix Table B-44. Correlation matrix for variables examined in the analysis of the migration timing for early-run summer steelhead of hatchery origin that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Tables B-35 and B-40.

	Migration timing	Flow		Water temperature		Year
		June	August	Raygold	Agness	
Migration timing	1.00					
June flow	0.16	1.00				
August flow	0.63[a]	0.37	1.00			
Raygold temperature	-0.32	-0.11	-0.69[a]	1.00		
Agness temperature	-0.34	-0.51[a]	-0.64[a]	0.60[a]	1.00	
Year	0.55[a]	-0.09	0.68[a]	-0.57[a]	-0.47[a]	1.00

[a] $P \leq 0.05$.

Appendix Table B-45. Correlation matrix for variables examined in the analysis of the migration timing for late-run summer steelhead of hatchery origin that passed Gold Ray Dam, 1970-91 return years. Estimates of migration timing were transformed to logits prior to analysis. Variables are described in Appendix Tables B-39 and B-40.

	Migration timing	Flow		Water temperature	
		August	Autumn	Autumn	Winter
Migration timing	1.00				
August flow	0.34	1.00			
Autumn flow	0.08	-0.13	1.00		
Autumn temperature	-0.11	0.21	0.25	1.00	
Winter temperature	-0.13	-0.15	0.21	0.31	1.00

[a] $P \leq 0.05$.

Appendix Table B-46. Length frequency distributions of summer steelhead seined at Huntley Park, 1976-91 return years. Numbers represent mid-points of the size intervals. Data do not include four fish 83-91 cm in length.

Return	Fork length (5 cm size interval)											
year	20	25	30	35	40	45	50	55	60	65	70	75
						WILD						
1976	0	65	357	136	45	56	72	38	54	20	2	0
1977	1	213	1,584	1,433	355	215	170	89	53	18	2	0
1978	0	45	576	478	182	238	262	77	34	12	2	0
1979	0	53	308	142	59	140	140	99	74	21	2	0
1980	0	87	1,106	613	118	100	96	69	61	25	9	0
1981	0	55	1,598	1,667	466	217	126	41	16	6	2	1
1982	0	27	496	409	152	149	202	115	34	9	2	0
1983	0	26	338	260	66	22	23	18	24	11	0	0
1984	0	7	213	255	93	31	41	39	25	19	7	1
1985	2	27	815	1,146	423	157	204	136	44	22	8	1
1986	0	17	655	1,176	358	177	222	130	79	23	12	1
1987					not sampled							
1988	0	6	163	267	100	81	172	135	63	23	11	0
1989	0	7	163	204	78	63	93	62	40	33	6	1
1990	0	31	332	172	42	36	17	8	11	4	2	1
1991	0	14	252	200	40	29	15	7	23	9	2	1
						HATCHERY						
1976	0	1	113	90	10	28	15	6	11	2	0	1
1977	0	7	243	384	53	36	76	29	28	6	1	0
1978	0	8	367	486	94	17	35	12	3	0	0	1
1979	0	15	207	200	23	50	36	12	5	3	1	1
1980	0	19	931	1,277	532	134	71	23	7	6	0	0
1981	0	13	624	1,215	372	163	157	76	16	9	1	0
1982	2	10	557	763	132	45	89	32	12	2	4	0
1983	0	6	368	170	15	10	21	5	4	3	0	0
1984	0	3	74	82	42	14	6	4	1	3	0	0
1985	0	2	330	748	206	33	16	14	4	4	0	1
1986	0	13	660	1,028	112	51	61	19	9	4	1	0
1987					not sampled							
1988					not sampled							
1989	0	3	191	335	40	17	21	15	17	8	3	1
1990	0	4	164	73	3	10	7	3	4	1	0	0
1991	0	1	297	311	47	6	4	3	6	3	0	0

Appendix Table B-47. Mean length (cm) of wild half-pounders that passed Huntley Park, 1975-89 return years. Scales were not interpreted for the 1990-91 returns. Data not shown where $N \leq 5$.

Return year	95% confidence interval			
	Age-1 smolt	Age-2 smolt	Age-3 smolt	All ages[a]
1975	30.4 ± 2.6	35.4 ± 1.2	37.6 ± 3.1	34.6 ± 0.5
1976	28.7 ± 0.7	32.4 ± 0.8	32.9 ± 2.7	31.1 ± 0.3
1977	28.5 ± 0.8	35.3 ± 1.0	39.4 ± 3.6	32.9 ± 0.3
1978	30.1 ± 1.5	33.9 ± 0.9	39.4 ± 3.9	33.2 ± 0.4
1979	28.3 ± 0.6	32.6 ± 0.8	36.4 ± 2.7	31.5 ± 0.3
1980	28.5 ± 2.6	34.0 ± 0.9	36.1 ± 2.0	32.4 ± 0.3
1981	30.1 ± 0.8	36.6 ± 0.8	40.1 ± 1.9	34.4 ± 0.3
1982	29.0 ± 0.8	35.2 ± 0.9	37.6 ± 2.9	33.4 ± 0.3
1983	28.4 ± 0.9	34.8 ± 0.8	37.9 ± 3.9	32.9 ± 0.3
1984	30.1 ± 1.7	35.9 ± 1.5	38.5 ± 3.2	35.1 ± 0.6
1985	29.4 ± 1.1	36.2 ± 1.3	--	34.4 ± 0.5
1986	29.8 ± 1.6	34.4 ± 0.9	--	33.6 ± 0.8
1987		not sampled		
1988	32.8 ± 0.7	37.2 ± 0.9	--	35.3 ± 0.6
1989	32.1 ± 0.8	36.5 ± 0.8	--	34.6 ± 0.6

[a] *Includes a few age-4 smolts.*

Appendix Table B-48. Mean length (cm) of wild first spawning migrants and wild second spawning migrants that passed Huntley Park, 1975-89 return years. Scales were not interpreted for the 1990-91 returns. Data not shown where $N \leq 5$.

Return year	95% confidence interval			
	Age-1 smolt	Age-2 smolt	Age-3 smolt	All ages[a]
		FIRST SPAWNING MIGRANTS		
1975	--	50.4 ± 1.6	--	50.3 ± 0.7
1976	44.7 ± 0.5	48.5 ± 1.1	49.5 ± 1.8	47.5 ± 0.5
1977	46.1 ± 1.4	50.1 ± 0.9	--	48.5 ± 0.4
1978	46.2 ± 1.1	49.0 ± 1.2	--	47.6 ± 0.4
1979	46.0 ± 1.4	48.7 ± 1.0	49.6 ± 3.5	48.1 ± 0.4
1980	45.2 ± 0.8	49.7 ± 1.4	--	47.1 ± 0.4
1981	46.1 ± 1.3	47.7 ± 0.8	--	47.1 ± 0.3
1982	46.4 ± 1.1	51.9 ± 1.2	--	49.0 ± 0.4
1983	46.7 ± 1.6	49.7 ± 1.9	--	48.0 ± 0.6
1984	50.2 ± 1.7	52.5 ± 1.0	--	51.7 ± 0.5
1985	49.2 ± 1.2	53.5 ± 1.9	--	52.0 ± 0.6
1986	46.2 ± 1.4	50.3 ± 1.4	--	48.6 ± 1.0
1987		not sampled		
1988	49.0 ± 0.8	52.6 ± 1.0	--	50.6 ± 0.6
1989	48.5 ± 0.7	49.4 ± 1.1	--	48.8 ± 0.6
		SECOND SPAWNING MIGRANTS		
1975	56.7 ± 1.3	58.7 ± 1.6	--	57.6 ± 0.5
1976	55.4 ± 3.7	55.6 ± 2.1	--	55.5 ± 0.8
1977	--	58.1 ± 1.9	60.2 ± 3.9	58.8 ± 0.7
1978	58.4 ± 2.8	58.5 ± 1.4	--	58.5 ± 0.6
1979	58.1 ± 1.3	57.4 ± 1.2	--	57.8 ± 0.4
1980	55.3 ± 1.8	56.5 ± 1.2	--	56.0 ± 0.5
1981	53.6 ± 1.9	57.5 ± 2.3	--	55.4 ± 0.7
1982	--	57.6 ± 1.8	--	56.3 ± 0.7
1983	57.2 ± 1.5	--	--	57.2 ± 0.6
1984	57.4 ± 4.2	60.7 ± 3.5	--	59.3 ± 1.2
1985	62.4 ± 4.1	62.2 ± 2.3	--	62.3 ± 0.9
1986	56.8 ± 2.6	58.8 ± 2.5	--	57.9 ± 1.6
1987		not sampled		
1988	58.2 ± 2.6	61.1 ± 1.6	--	60.0 ± 1.2
1989	54.8 ± 1.8	56.8 ± 2.7	--	55.4 ± 1.4

Appendix Table B-49. Mean migration rate (km per day ± 1 SE) for wild adult summer steelhead tagged in the lower river and captured by anglers in areas upstream of Huntley Park, 1969-77. Data reported only when $N \geq 10$.

Return year	Month tagged			Annual[a]
	July	August	September	
WILD				
1969	--	1.58 ± 0.14	1.65 ± 0.19	1.61 ± 0.11
1970	1.44 ± 0.11	1.70 ± 0.26	--	1.56 ± 0.12
1976	--	0.84 ± 0.13	--	0.94 ± 0.09
1977	--	--	1.35 ± 0.18	1.70 ± 0.46
HATCHERY				
1969	--	--	--	--
1970	2.03 ± 0.27	1.64 ± 0.18	--	1.96 ± 0.22
1976	--	--	--	--
1977	--	1.54 ± 0.21	--	1.41 ± 0.17

[a] *Includes fish tagged in October.*

APPENDIX C

Tables of Data Related to Studies of Recreational Fisheries for Summer Steelhead

Appendix Table C-1. Estimated harvest of summer steelhead in the Rogue River during June-November, 1956-91. Harvest was estimated from volitional returns of salmon-steelhead cards.

Year	June	July	August	September	October	November
1956	82	47	274	906	1,538	1,913
1957	47	53	143	394	1,075	641
1958	--	--	--	--	--	--
1959	120	141	226	1,530	2,393	1,611
1960	96	137	230	1,047	2,988	1,524
1961	66	87	171	986	1,822	1,447
1962	118	129	358	785	2,331	1,867
1963	65	71	186	647	1,474	1,066
1964	67	40	160	838	1,540	1,492
1965	67	87	758	1,798	4,193	3,260
1966	53	109	257	1,406	2,149	1,578
1967	33	61	163	1,207	3,658	1,827
1968	30	37	429	958	1,424	1,737
1969	76	152	366	1,375	3,189	2,191
1970	93	97	348	1,635	2,478	1,824
1971	61	137	914	2,402	5,245	1,810
1972	80	86	439	1,415	2,837	2,647
1973	50	70	271	1,409	1,627	666
1974	69	117	810	3,038	4,988	7,070
1975	185	180	651	1,150	2,381	2,913
1976	61	123	404	847	1,699	1,440
1977	74	102	320	1,006	2,676	1,384
1978	69	86	352	1,111	1,849	1,952
1979	54	487	957	1,438	1,828	3,439
1980	69	119	352	504	830	869
1981	38	316	1,285	1,668	3,246	1,453
1982	25	375	1,007	1,265	2,807	2,110
1983	37	352	525	890	988	657
1984	24	92	248	757	889	312
1985	21	118	890	878	1,945	1,308
1986	42	107	210	396	921	784
1987	46	356	691	831	1,460	1,506
1988	95	443	464	870	1,731	1,452
1989	78	339	499	806	1,600	1,617
1990[a]	70	342	560	1,025	1,114	1,622
1991[b]	29	182	328	316	360	437

[a] *Size required for entry on salmon-steelhead cards changed to* $\geq$ *41 cm.*

[b] *Only fish marked with fin clips could be legally harvested.*

Appendix Table C-2. Estimated harvest of summer steelhead in the Rogue River upstream and downstream of Gold Ray Dam, 1984-91. Areas of harvest were not segregated prior to 1984. Harvest was estimated from volitional returns of salmon-steelhead cards.

Year	June	July	August	September	October	November
UPSTREAM OF GOLD RAY DAM						
1984	24	85	177	112	115	122
1985	8	46	215	110	295	249
1986	27	65	126	65	194	293
1987	31	217	356	258	315	655
1988	70	353	238	316	410	730
1989	39	252	338	326	385	771
1990[a]	40	269	315	156	338	932
1991[b]	19	156	220	115	121	284
DOWNSTREAM OF GOLD RAY DAM						
1984	0	7	71	645	774	190
1985	13	72	675	768	1,654	1,059
1986	15	42	84	331	727	491
1987	15	139	335	573	1,145	851
1988	25	90	226	554	1,321	722
1989	39	87	161	480	1,215	846
1990[a]	30	73	245	869	776	690
1991[b]	10	26	108	201	239	153

[a] *Size required for entry on salmon-steelhead cards changed to* $\geq$ *41 cm.*
[b] *Only fish marked with fin clips could be legally harvested.*

Appendix Table C-3. Estimated harvest of summer steelhead in the lower river based on fish processed at canneries in Gold Beach and angler surveys in the RK 0-27 area. Data were taken from annual reports of the Oregon Game Commission.

Year	Harvest Estimate		Year	Harvest Estimate	
	Cannery[a]	Survey		Cannery[a]	Survey
1952	4,764	--	1960	7,133	--
1953	--	--	1961	5,693	--
1954	5,069	--	1962	5,230	--
1955	3,074	--	1963	3,255	--
1956	4,175	--	1964	4,282	--
1957	3,112	--	1965	5,402	7,227
1958	7,200	--	1966	3,037	5,284
1959	9,853	--	1967	--	4,993

[a] *Harvest was estimated as 60% of the cannery records.*

Appendix Table C-4. Data used to assess factors that affected the harvest rate for late-run summer steelhead of hatchery origin, 1976-91. Data from 1987 were excluded from the analysis because migration time could not be estimated.

Year	Harvest rate[a]	Flow		Migration timing[d]	Fish abundance	
		Autumn[b]	Winter[c]		Adults[e]	All[f]
1976	66.9%	1,593	1,421	33	10,556	43,561
1977	58.4%	1,520	5,232	33	26,225	168,314
1978	50.7%	1,804	2,076	37	30,996	124,587
1979	23.2%	1,818	4,810	28	29,286	72,542
1980	53.7%	1,416	2,303	39	19,997	191,321
1981	59.6%	2,036	8,230	33	39,129	272,530
1982	51.7%	2,924	5,244	35	39,941	157,107
1983	36.7%	3,025	7,492	34	12,221	110,957
1984	33.8%	2,746	5,116	36	18,102	87,092
1985	77.9%	2,254	2,810	36	35,713	213,791
1986	58.7%	2,329	2,504	34	41,378	212,714
1988	32.0%	1,526	2,972	40	26,624	68,524
1989	33.8%	2,200	1,728	36	17,500	70,641
1990	35.9%	1,786	1,831	34	4,313	38,715
1991	32.7%	1,609	1,793	34	4,201	49,615

[a] *Percent of late-run adults of hatchery origin that returned to Cole M. Rivers Hatchery.*
[b] *Mean flow (cfs) at Agness in September-October.*
[c] *Mean flow (cfs) at Grants Pass in November-January.*
[d] *Median week-of-year (**APPENDIX A**) for passage at Huntley Park.*
[e] *Estimated freshwater return of all late-run adults.*
[f] *Estimated freshwater return of all half-pounders and late-run adults.*

Appendix Table C-5. Regression analysis of the harvest rate for late-run adult summer steelhead of hatchery origin, 1976-91. Harvest rates were transformed to logits prior to analysis. Variables are described in Appendix Table C-4.

Independent variable	Regression coefficient	Standard error	*P*
Fish abundance	7.69×10^{-6}	1.94×10^{-6}	0.002
Winter flow	-1.29×10^{-4}	0.65×10^{-4}	0.071
Constant	-0.611		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	3.592	2	1.80	7.87	0.007
Residual	2.738	12	0.23		

	Partial r^2	
Variables tested	Step 1	Step 2
Fish abundance	0.43	--
Autumn flow	0.01	0.04
Fishery flow	0.01	0.25

Appendix Table C-6. Correlation matrix for variables examined in the analysis of the harvest rate for late-run adult summer steelhead of hatchery origin. Variables are described in Appendix Table C-4. Percentages were transformed to logits prior to analysis.

		Flow		Migration	Fish abundance	
	% harvest	Autumn	Winter	timing	Adults	All
% harvest	1.00					
Autumn flow	-0.03	1.00				
Winter flow	-0.05	0.51	1.00			
Migration timing	0.13	-0.07	-0.32	1.00		
Adult abundance	0.43	0.23	0.34	-0.01	1.00	
All abundance	0.65[a]	0.17	0.44	0.07	0.76[a]	1.00

[a] *Significant at $P \leq 0.05$.*

Appendix Table C-7. Annual catch rate of summer steelhead by anglers that fished the lower river, 1965-83. Data reported only for years of intensive angler surveys. Most boat anglers probably fished for fall chinook salmon.

Year	Survey area	Survey period	Fish per hour	
			Bank anglers	Boat anglers
1965	RK 0-27	08/01-10/15	0.223	0.144
1966	RK 0-27	08/01-10/15	0.164	0.190
1967	RK 0-27	08/01-10/31	0.165	0.399
1976	RK 7-18	08/01-10/15	0.133	0.097
1977	RK 7-18	08/01-10/15	0.133	0.146
1978	RK 7-18	08/01-10/15	0.124	0.109
1979	RK 7-18	08/01-10/15	0.166	0.128
1980	RK 7-18	08/01-10/15	0.166	0.107
1981	RK 7-18	08/01-10/15	0.190	0.082
1983	RK 7-18	08/01-09/30	0.165	0.046

Appendix Table C-8. Annual catch rate of summer steelhead by anglers that fished the Rogue River canyon, 1965-80. Data reported only for years of intensive angler surveys.

Year	Survey area	Survey period	Fish per hour	
			Bank anglers	Boat anglers
1965	RK 42-54	09/01-10/31	0.144	0.370
1976	RK 42-54	09/29-10/31	0.163	0.369
1977	RK 42-54	09/01-10/31	0.260	0.556
1978	RK 42-54	09/01-10/31	0.157	0.430
1979	RK 42-54	09/01-10/31	0.154	0.334
1980	RK 42-54	09/01-10/31	0.284	0.260
1976	RK 55-110	09/29-10/31	--	0.489
1977	RK 55-110	09/01-10/31	--	0.670
1978	RK 55-110	09/01-10/31	--	0.430
1979	RK 55-110	09/01-10/31	--	0.252
1980	RK 55-110	09/01-10/31	--	0.509

Appendix Table C-9. Annual catch rate of summer steelhead by anglers that fished the middle river from 1 November through 31 January, 1977-78 through 1980-81. Data reported only for years of intensive angler surveys.

Year	Survey area	Fish per hour	
		Bank anglers	Boat anglers
1977-78	RK 110-129	0.115	0.379
1978-79	RK 110-129	0.089	0.121
1979-80	RK 110-129	0.084	0.159
1980-81	RK 110-129	0.083	0.109
1977-78	RK 139-156	0.095	0.245
1978-79	RK 139-156	0.076	0.157
1979-80	RK 139-156	0.063	0.119
1980-81	RK 139-156	0.032	0.087
1977-78	RK 179-193	0.050	0.102
1978-79	RK 179-193	0.024	0.036

Appendix Table C-10. Angler catch rate of summer steelhead as reported by licensed guides, 1948-1961. Data were taken from annual reports of the Oregon Game Commission.

Year	Angler days reported	Catch per angler day		
		RK 0-53	RK 53-173	RK 173-265
1948	--	0.76	2.16	1.44
1949	--	1.69	0.80	0.81
1950	--	1.38	2.85	0.38
1951	--	1.89	1.47	0.30
1952	--	1.17	1.53	0.96
1953	--	1.74	1.45	0.19
1954	750	1.56	0.99	0.38
1955	681	1.45	1.36	0.33
1956	464	1.09	1.35	0.66
1957	615	0.93	1.07	0.08
1958	231	1.80	1.53	--
1959	304	1.83	1.91	--
1960	215	--	--	--
1961	89	0.36	0.87	--

Appendix Table C-11. Correlation matrixes for variables included in analyses of weekly catch rates of summer steelhead by anglers that fished the Rogue River, 1976-83. Variables are described in Appendix Tables C-12 through C-15.

	Catch rate					
	Bank	Boat	Flow	Water temperature	Turbidity	Fish abundance
			RK 7-18			
Catch rate (bank)	1.00					
Flow	0.12	--	1.00			
Water temperature	0.22[a]	--	-0.19	1.00		
Turbidity	-0.05	--	0.67[a]	-0.16	1.00	
Fish abundance	0.62[a]	--	0.03	0.26[a]	0.09	1.00
			RK 42-54			
Catch rate (bank)	1.00					
Catch rate (boat)	-0.11	1.00				
Flow	-0.01	0.09	1.00			
Water temperature	-0.23	-0.28	-0.27	1.00		
			RK 110-129			
Catch rate (bank)	1.00					
Catch rate (boat)	0.12	1.00				
Flow	-0.02	0.31	1.00			
Water temperature	0.05	-0.22	0.12	1.00		
Turbidity	0.17	0.01	0.85[a]	0.10	1.00	
			RK 139-156			
Catch rate (bank)	1.00					
Catch rate (boat)	0.49[a]	1.00				
Flow	0.11	0.10	1.00			
Water temperature	0.03	-0.15	0.12	1.00		
Turbidity	0.20	-0.02	0.87[a]	0.11	1.00	

[a] *Significant at* $P \le 0.05$.

Appendix Table C-12. Data used to assess factors that affected weekly catch rates and weekly indexes of angler effort for summer steelhead in the RK 7-18 survey area, 1976-83 (Week-of-year calendar is in **APPENDIX A**). Catch rates are not reported when interviews totaled less than 100 hours of angler effort.

Year	Week-of year	Catch rate[a]	Effort[b]	Fish abundance[c]	Flow[d]	Water temperature[e]	Turbidity[f]
1976	31	--	14.3	3,034	1,802	23.1	--
1976	32	0.143	18.2	5,654	2,222	21.3	--
1976	33	0.267	14.7	16,850	2,557	20.0	--
1976	34	0.224	30.5	3,869	2,091	21.7	--
1976	35	0.127	24.2	1,713	1,657	22.8	--
1976	36	0.064	22.0	564	1,394	21.6	--
1977	37	0.111	20.0	257	1,481	19.5	--
1976	38	0.074	24.3	619	1,905	19.2	--
1976	39	0.076	15.0	523	1,617	19.3	--
1976	40	0.072	21.7	868	1,742	17.4	--
1976	41	0.061	10.0	604	1,527	16.4	--
1977	31	0.028	8.0	4,530	818	26.0	--
1977	32	0.122	21.0	27,382	850	26.1	--
1977	33	0.211	34.5	49,125	817	24.8	--
1977	34	0.308	47.7	43,874	940	23.2	--
1977	35	0.186	68.2	22,312	1,062	22.0	--
1977	36	0.108	77.7	2,652	973	23.1	--
1977	37	0.057	46.0	4,741	1,062	20.8	--
1977	38	0.042	30.2	3,053	1,408	17.3	--
1977	39	0.026	22.8	1,897	2,578	16.6	--
1977	40	0.009	8.8	1,041	1,951	15.5	--
1977	41	0.008	20.0	133	1,501	15.3	--
1978	31	0.051	10.5	446	2,048	22.9	2.7
1978	32	0.108	10.5	429	1,817	24.1	2.0
1978	33	0.142	37.3	9,102	1,917	20.2	2.4
1978	34	0.081	63.0	16,615	2,087	19.7	2.4
1978	35	0.345	73.0	15,387	1,895	21.8	1.9
1978	36	0.147	68.3	17,772	2,197	19.8	2.0
1978	37	0.050	26.8	36,770	2,640	17.4	4.7
1978	38	0.026	31.0	10,002	2,024	16.8	2.2
1978	39	0.013	25.2	7,003	1,751	18.6	1.7
1978	40	0.005	14.5	823	1,734	17.2	1.7
1978	41	0.021	12.3	1,341	1,421	16.3	1.2
1979	31	0.047	17.3	158	1,997	22.5	1.9
1979	32	0.052	12.0	228	1,750	22.7	1.3

---

[a] *Fish per angler hour.*
[b] *Mean count of bank anglers at 0900 hours.*
[c] *Estimated number of summer steelhead that passed Huntley Park.*
[d] *Mean flow (cfs) at Agness.*
[e] *Mean maximum water temperature (^{o}C) at Agness.*
[f] *Mean turbidity (JTU) at Canfield.*

Appendix Table C-12. Continued.

Year	Week-of year	Catch rate[a]	Effort[b]	Fish abundance[c]	Flow[d]	Water temperature[e]	Turbidity[f]
1979	33	0.055	30.0	2,717	1,802	21.4	1.9
1979	34	0.329	85.7	24,154	1,945	21.0	1.3
1979	35	0.226	74.7	8,471	1,972	19.9	1.7
1979	36	0.182	57.5	4,729	1,762	20.5	1.4
1979	37	0.069	29.3	500	1,197	20.8	0.6
1979	38	0.036	21.2	143	1,308	20.5	0.5
1979	39	0.025	18.5	214	1,421	19.0	0.4
1979	40	0.102	11.3	0	1,157	18.7	0.5
1979	41	0.055	6.7	35	1,055	17.9	0.4
1980	31	--	3.0	323	2,097	23.0	2.4
1980	32	0.083	17.5	1,691	2,091	21.8	2.2
1980	33	0.123	27.3	7,049	2,087	21.3	2.2
1980	34	0.085	50.7	12,409	1,734	21.0	1.6
1980	35	0.216	63.5	33,787	1,558	20.3	1.8
1980	36	0.236	32.0	24,073	1,562	20.7	1.9
1980	37	0.233	46.0	30,857	1,241	19.7	1.4
1980	38	0.148	24.0	18,533	1,358	17.8	1.2
1980	39	0.218	29.0	31,857	1,142	18.4	1.5
1980	40	0.133	22.0	24,392	1,062	18.3	1.3
1980	41	0.026	3.5	1,679	1,157	15.9	1.6
1981	31	0.030	9.4	3,747	1,947	22.6	2.1
1981	32	0.032	13.8	44,815	2,058	24.3	2.0
1981	33	0.348	52.4	126,164	2,022	22.8	1.8
1981	34	0.279	68.2	30,321	1,852	21.3	1.2
1981	35	0.099	59.6	8,451	1,730	20.6	1.5
1981	36	0.186	60.6	14,774	1,774	20.3	1.9
1981	37	0.134	33.6	5,395	2,308	18.7	1.3
1981	38	0.124	29.8	15,703	1,965	16.7	1.1
1981	39	0.120	11.0	9,856	1,630	15.5	2.5
1981	40	0.085	5.8	5,228	1,812	14.8	1.5
1981	41	--	3.0	1,899	2,235	13.1	5.4
1983	31	0.135	8.6	2,495	2,527	23.0	--
1983	32	0.193	17.2	1,147	2,557	22.0	--
1983	33	0.386	42.4	43,227	2,818	21.4	--
1983	34	0.275	46.2	26,015	3,090	19.6	--
1983	35	0.195	41.2	32,814	3,735	17.8	--
1983	36	0.089	26.6	870	3,411	18.0	--
1983	37	0.041	19.5	183	3,325	18.3	--
1983	38	0.016	21.4	401	2,734	16.7	--
1983	39	0.005	16.3	570	3,071	16.6	--

Appendix Table C-13. Data used to assess factors that affected weekly catch rates of summer steelhead for anglers that fished the Rogue River canyon, 1976-80. Catch rates are not reported when weekly interviews totaled less than 100 hours of angler effort. Week-of-year calendar is in **APPENDIX A**.

		Mean catch rate[a]				
		Bank anglers	Boat anglers			
Year	Week-of year	RK 42-54	RK 42-54	RK 54-77	Flow[b]	Water temperature[c]
1976	41	--	0.689	0.561	1,527	16.4
1976	42	--	0.419	0.466	1,501	13.3
1976	43	0.163	0.313	--	1,608	11.2
1977	36	0.201	0.422	0.728	973	23.1
1977	37	0.138	0.563	0.700	1,062	20.8
1977	38	0.283	0.470	0.466	1,408	17.3
1977	39	0.299	0.612	0.459	2,578	16.6
1977	40	0.270	0.397	0.727	1,951	15.5
1977	41	0.259	0.433	0.864	1,501	15.3
1977	42	0.294	0.646	0.674	1,412	15.2
1977	43	0.416	--	0.936	1,647	13.5
1978	36	0.220	0.341	0.476	2,197	19.8
1978	37	0.098	0.303	--	2,640	17.4
1978	38	0.177	0.418	0.453	2,024	16.8
1978	39	0.144	0.534	0.518	1,751	18.6
1978	40	0.132	0.365	0.427	1,734	17.2
1978	41	0.098	0.538	0.296	1,421	16.3
1978	42	0.118	0.484	0.349	1,382	15.5
1978	43	--	0.620	0.496	1,407	13.3
1979	36	0.253	--	0.475	1,762	20.5
1979	37	0.109	--	0.281	1,197	20.8
1979	38	0.119	0.213	0.243	1,308	20.5
1979	39	0.092	--	0.270	1,421	19.0
1979	40	0.049	0.333	0.280	1,157	18.7
1979	41	--	0.335	0.156	1,055	17.9
1979	42	--	0.259	--	1,877	15.2
1980	36	0.148	0.086	0.487	1,562	20.7
1980	37	0.340	0.070	0.879	1,241	19.7
1980	38	0.346	0.141	0.525	1,358	17.8
1980	39	0.436	0.295	0.419	1,142	18.4
1980	40	0.196	0.258	0.555	1,062	18.3
1980	41	0.272	0.363	0.391	1,157	15.9
1980	42	--	0.227	0.492	1,951	12.9
1980	43	--	0.526	0.575	1,705	11.8

[a] *Fish per angler hour.*
[b] *Mean flow (cfs) at Agness.*
[c] *Mean maximum water temperature (^oC) at Agness.*

Appendix Table C-14. Data used to assess factors that affected weekly catch rates of summer steelhead in the RK 110-129 survey area, 1977-78 through 1980-81. Catch rates are not reported when weekly interviews totaled less than 100 hours of angler effort. Week-of-year calendar is in **APPENDIX A.**

Year	Week-of year	Mean catch rate[a]		Flow[b]	Water temperature[c]	Turbidity[d]
		Bank anglers	Boat anglers			
1977	46	0.132	0.264	1,655	9.8	1.8
1977	47	0.258	0.219	7,114	5.6	25.4
1977	49	0.227	--	5,344	8.2	9.4
1977	50	0.300	0.424	19,393	7.6	27.9
1977	52	0.108	--	6,886	7.1	13.0
1978	1	0.137	0.340	7,081	6.7	8.0
1978	2	0.059	0.253	6,852	7.9	9.5
1978	3	0.038	--	10,696	8.0	20.0
1978	4	0.045	0.429	5,668	6.6	7.5
1978	47	0.087	--	1,768	6.7	1.1
1978	49	0.140	--	2,563	4.8	5.5
1978	50	0.118	--	2,349	4.3	5.4
1978	51	0.096	--	1,997	3.9	2.1
1978	52	0.045	0.120	1,861	3.9	1.4
1979	3	0.102	0.139	2,765	4.2	7.7
1979	4	0.039	0.429	2,029	3.6	2.4
1979	44	0.087	0.208	2,121	10.3	4.7
1979	45	0.131	0.101	2,389	9.3	4.8
1979	46	0.165	0.334	2,004	7.4	2.6
1979	47	0.040	--	5,178	6.7	13.8
1979	48	0.058	--	5,107	6.3	8.3
1979	49	0.080	--	8,519	6.9	29.2
1979	50	0.110	0.169	3,289	4.6	5.2
1979	52	0.103	--	4,422	5.4	9.8
1980	1	0.076	--	4,962	7.0	10.2
1980	4	0.018	--	5,868	4.5	8.9
1980	44	0.071	0.095	1,531	9.5	3.1
1980	45	0.092	0.070	2,340	10.5	7.1
1980	46	0.102	--	1,548	6.9	2.7
1980	50	0.157	0.222	2,214	3.8	5.8
1980	51	0.102	--	2,224	5.9	4.4
1980	52	0.046	0.073	4,905	7.2	10.3
1981	1	0.039	0.065	2,555	6.1	3.7
1981	2	0.076	--	1,705	5.5	2.4
1981	3	0.063	0.142	1,591	6.4	2.0
1981	4	0.065	--	1,976	7.4	2.9

[a] *Fish per angler hour.*
[b] *Mean flow (cfs) at Grants Pass + Wilderville.*
[c] *Mean maximum water temperature (^{o}C) at Merlin.*
[d] *Mean turbidity (JTU) at Indian Mary Park (RK 129).*

Appendix Table C-15. Data used to assess factors that affected weekly catch rate of summer steelhead in the RK 139-156 survey area, 1977-78 through 1980-81. Catch rates are not reported when weekly interviews totaled less than 100 hours of angler effort. Week-of-year calendar is in **APPENDIX A.**

		Mean catch rate[a]			Water	
Year	Week-of year	Bank anglers	Boat anglers	Flow[b]	temperature[c]	Turbidity[d]
1977	46	0.046	--	1,655	9.8	2.1
1977	49	0.163	--	5,344	8.2	15.0
1977	50	0.200	--	19,393	7.7	30.8
1978	2	0.049	0.249	6,852	7.9	9.3
1978	4	0.058	0.232	5,668	6.6	9.0
1978	45	0.082	--	1,573	7.8	1.1
1978	47	0.074	0.217	1,768	7.0	1.2
1978	48	0.058	0.064	2,296	6.4	5.3
1978	49	0.113	0.176	2,563	5.3	7.4
1978	50	0.110	0.180	2,349	5.0	7.2
1978	51	0.089	0.089	1,997	4.6	2.0
1978	52	0.014	0.112	1,861	4.5	2.0
1979	1	0.040	0.138	1,727	3.6	1.6
1979	3	0.063	0.124	2,765	4.8	6.9
1979	4	0.081	0.128	2,029	4.2	3.6
1979	44	0.108	0.126	2,121	10.0	3.9
1979	45	0.065	0.091	2,389	9.2	4.1
1979	46	0.044	0.200	2,004	7.6	5.6
1979	47	0.054	0.048	5,178	7.1	18.0
1979	48	0.083	0.094	5,107	6.8	7.7
1979	49	0.056	0.155	8,519	7.6	22.5
1979	50	0.054	0.146	3,289	5.6	5.3
1979	51	0.051	0.093	3,315	6.8	8.1
1979	52	0.026	0.031	4,422	6.2	8.3
1980	1	0.084	--	4,962	7.5	12.6
1980	2	0.145	--	16,246	7.2	36.8
1980	4	0.070	0.107	5,868	5.2	11.2
1980	45	0.022	0.006	2,340	9.9	7.9
1980	46	0.046	0.125	1,548	6.9	2.2
1980	47	0.080	0.216	2,005	7.5	5.5
1980	48	0.016	0.050	3,464	7.1	4.3
1980	50	0.081	0.228	2,214	4.3	5.6
1980	51	0.007	0.081	2,224	6.1	4.4
1980	52	0.014	0.047	4,905	7.2	13.2
1981	1	0.028	0.082	2,555	6.1	4.5
1981	2	0.030	0.034	1,705	5.6	2.4
1981	3	0.025	0.136	1,591	6.6	2.2
1981	4	0.030	0.020	1,976	7.4	2.8

[a] *Fish per angler hour.*
[b] *Mean flow (cfs) at Grants Pass + Wilderville.*
[c] *Mean maximum water temperature (^{o}C) at Merlin.*
[d] *Mean turbidity at Griffin Park (RK 145).*

Appendix Table C-16. Regression analysis of the weekly catch rates of summer steelhead in the RK 7-18 survey area, 1976-83. Variables are described in Appendix Table C-12.

Independent variable	Regression coefficient	Standard error	*P*
Fish abundance	3.41×10^{-6}	0.65×10^{-6}	<0.001
Week-of-year^2	2.47×10^{-3}	1.00×10^{-3}	0.016
Week-of-year^3	-4.73×10^{-5}	1.84×10^{-5}	0.013
Constant	-0.892		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	0.277	3	0.092	20.29	<0.001
Residual	0.301	66	0.005		

	Partial r^2		
Variables tested	Step 1	Step 2	Step 3
Fish abundance	0.39	--	--
Flow	0.01	0.02	0.01
Water temperature	0.05	0.04	0.01
Week-of-year^2	0.12	0.07	0.08
Week-of-year^3	0.14	0.08	--

Appendix Table C-17. Data used to assess factors that affected catch rates of summer steelhead by guided anglers that fished the Rogue River canyon, 1977-91.

			Fish abundance		Flow	
Year	Catch per trip[a]	Effort[b]	Half-pounders[c]	All[d]	River entry[e]	Fishery[f]
1977	45.8	67	33,005	168,314	948	1,471
1978	21.4	137	142,089	124,587	2,024	2,127
1979	12.5	132	93,591	72,542	1,870	1,456
1980	11.7	149	164,510	191,321	1,735	1,346
1981	35.5	131	233,401	272,530	1,844	1,908
1982	16.0	134	117,166	157,107	2,361	2,352
1983	11.5	119	98,736	110,957	3,264	3,187
1984	11.3	107	68,990	87,092	3,289	2,816
1985	20.6	102	178,078	213,791	2,583	2,374
1986	20.0	120	171,336	212,714	2,248	2,521
1987	19.5	134	165,095	202,763	2,468	1,974
1988	10.4	132	41,900	68,524	2,150	1,630
1989	16.9	131	53,141	70,641	2,717	2,323
1990	17.9	120	34,402	38,715	2,257	1,900
1991	36.0	70	45,414	49,615	2,108	1,695

[a] *Catch of summer steelhead per boat trip for guide group one.*
[b] *Number of boat-trips.*
[c] *Estimated freshwater return of half-pounders.*
[d] *Estimated freshwater return of half-pounders and adults.*
[e] *Mean flow (cfs) at Agness from 13 August through 9 September.*
[f] *Mean flow (cfs) at Agness in September.*

Appendix Table C-18. Regression analysis of the catch rate of summer steelhead in the Rogue River canyon by guided anglers, 1977-91. Variables are described in Appendix Table C-17.

Independent variable	Regression coefficient	Standard error	*P*
Angler effort	-3.21×10^{-1}	0.67×10^{-1}	<0.001
Half-pounders	7.18×10^{-5}	2.54×10^{-5}	0.016
Fishery flow	-6.60×10^{-3}	3.00×10^{-3}	0.049
Constant	64.5		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	1,171	3	390	11.15	0.001
Residual	385	11	35		

	Partial r^2		
Variables tested	Step 1	Step 2	Step 3
Angler effort	0.47	--	--
Half-pounders	0.12	0.32	--
Fishery flow	0.11	0.19	0.31

Appendix Table C-19. Correlation matrix for variables examined in the analysis of the catch rates of summer steelhead by guided anglers that fished the Rogue River canyon, 1977-91. Variables are described in Appendix Table C-17.

	Catch per trip	Effort	Fish abundance		Flow	
			Half-pounders	All	Entry	Fishery
Catch per trip	1.00					
Angler effort	-0.69[a]	1.00				
Half-pounder abundance	0.34	0.10	1.00			
Fish abundance - all	0.30	0.16	0.99[a]	1.00		
Entry flow	-0.32	0.19	-0.23	-0.24	1.00	
Fishery flow	-0.34	0.03	0.03	0.02	0.84[a]	1.00

[a] *Significant at $P \leq 0.05$.*

Appendix Table C-20. Spatial distribution of tagged summer steelhead captured by anglers that fished the Rogue River, 1968-77. Data is not reported for tagged fish captured downstream of RK 14.

Year	RK 14-54	RK 55-110	RK 111-204	RK 205-260
WILD HALF-POUNDERS				
1968	21	0	2	0
1969	91	8	13	0
1970	130	13	18	3
1976	19	7	0	0
1977	26	11	10	0
HATCHERY HALF-POUNDERS				
1968	1	0	2	0
1969	20	7	9	0
1970	43	6	3	0
1976	2	1	1	0
1977	13	2	2	1
WILD ADULTS				
1969	39	5	53	1
1970	50	7	78	2
1976	7	3	4	0
1977	8	6	9	0
HATCHERY ADULTS				
1969	1	0	1	0
1970	12	5	22	6
1976	0	1	2	0
1977	7	0	3	7

Appendix Table C-21. Distribution of summer steelhead landed by two groups of guided anglers that fished the Rogue River canyon, 1977-91.

	Group 1				Group 2			
	Percent caught by area (RK)				Percent caught by area (RK)			
Year	54-62	63-77	78-96	97-110	23-45	46-57	58-77	78-110
1977	16.4	34.4	31.9	17.3	--	--	--	--
1978	23.1	28.1	26.6	22.2	8.2	35.6	29.8	26.4
1979	--	--	--	--	13.9	39.4	29.6	17.1
1980	22.8	38.1	22.1	17.0	--	--	--	--
1981	12.2	28.8	35.0	24.0	3.0	34.7	26.6	35.7
1982	26.1	34.9	23.2	15.8	4.9	43.9	31.6	19.6
1983	22.7	30.3	26.2	20.8	6.0	36.8	30.0	27.2
1984	27.7	30.8	25.4	16.1	10.5	51.1	28.6	9.8
1985	27.2	39.3	18.5	15.0	--	--	--	--
1986	28.8	34.1	21.5	15.5	11.7	48.9	32.4	7.0
1987	35.0	38.5	15.8	10.7	10.5	49.4	35.4	4.7
1988	31.0	40.4	16.5	12.1	19.3	43.5	30.9	6.3
1989	14.3	44.6	22.9	18.2	19.2	29.5	39.1	22.2
1990	19.0	34.5	28.7	17.8	10.2	23.5	42.1	24.1
1991	20.7	41.2	27.5	10.6	8.6	35.7	40.6	15.1

Appendix Table C-22. Correlation matrix for variables examined in the analysis of the distribution of summer steelhead caught by guided anglers that fished the Rogue River canyon, 1977-91. Percentages were transformed to logits prior to analysis.

	Harvest distribution		Flow		Water
	Group 1[a]	Group 2[b]	River entry[c]	Fishery[d]	temperature[e]
Group 1	1.00				
Group 2	0.73[f]	1.00			
Entry flow	0.23	0.14	1.00		
Fishery flow	-0.14	0.01	0.72[f]	1.00	
Water temperature	-0.32	-0.08	-0.79[f]	-0.74[f]	1.00

[a] *Percent caught between RK 54 and RK 77.*
[b] *Percent caught between RK 23 and RK 77.*
[c] *Mean flow at Agness from 13 August through 9 September.*
[d] *Mean flow at Agness in September-October.*
[e] *Mean maximum water temperature (°C) at Agness in September-October.*
[f] *Significant at $P \leq 0.05$.*

Appendix Table C-23. Correlation matrix for variables examined in the analysis of the distribution of large summer steelhead harvested in the Rogue River in June-August, 1984-91. Variables are described in Appendix Table C-24. Percentages were transformed to logits prior to analysis.

	Harvest distribution	Flow	Water temperature	Passage timing
Harvest distribution	1.00			
Flow	0.46	1.00		
Water temperature	-0.81[a]	-0.08	1.00	
Passage timing	0.80[a]	0.49	-0.44	1.00

[a] *Significant at* $P \leq 0.05$.

Appendix Table C-24. Data used to assess factors that affected the catch distribution of large summer steelhead harvested in the Rogue River in June-August, 1984-91.

Year	Harvest distribution[a]	Flow[b]	Water temperature[c]	Passage timing[d]
1984	78.6	3,700	16.4	52.9
1985	26.1	2,337	18.2	25.8
1986	60.7	2,274	16.2	31.1
1987	55.3	2,030	16.2	37.2
1988	66.0	2,288	16.2	32.5
1989	68.7	2,532	15.9	41.6
1990	64.2	2,082	16.7	48.6
1991	73.3	2,333	16.4	46.3

[a] *Percent of the June-August harvest caught upstream of Gold Ray Dam. Data were estimated from salmon-steelhead cards.*

[b] *Mean flow (cfs) at Raygold in June-July.*

[c] *Mean maximum water temperature (*^{o}C*) at Raygold in June-July.*

[d] *Percent of summer steelhead that passed Gold Ray Dam by 15 September.*

Appendix Table C-25. Correlation matrix for variables examined in the analysis of the distribution of large summer steelhead harvested in the Rogue River during September-October, 1984-91. Variables are described in Appendix Table C-26. Percentages were transformed to logits prior to analysis.

	Harvest distribution	Flow	Water temperature	Passage timing
Harvest distribution	1.00			
Flow	0.77[a]	1.00		
Water temperature	0.32	-0.73[a]	1.00	
Passage timing	0.17	0.17	-0.14	1.00

[a] *Significant at $P \leq 0.05$.*

Appendix Table C-26. Data used to assess factors that affected the catch distribution of large summer steelhead harvested in the Rogue River in September-October, 1984-91.

Year	Harvest distribution[a]	Flow[b]	Water temperature[c]	Passage timing[d]
1984	13.8	2,056	12.0	52.9
1985	14.3	1,834	11.4	25.8
1986	19.7	1,743	11.9	31.1
1987	25.0	1,543	11.2	37.2
1988	27.9	1,429	12.3	32.5
1989	29.6	1,784	12.2	41.6
1990	23.1	1,582	12.5	48.6
1991	34.9	1,514	12.0	46.3

[a] *Percent of the September-October harvest caught upstream of Gold Ray Dam. Data were estimated from salmon-steelhead cards.*

[b] *Mean flow (cfs) at Raygold in September-October.*

[c] *Mean maximum water temperature (°C) at Raygold in September-October.*

[d] *Percent of summer steelhead that passed Gold Ray Dam by 15 September.*

Appendix Table C-27. Percent hatchery fish among summer steelhead harvested by anglers in 1977-83. Anglers were not surveyed in 1982.

Return year	% hatchery(*N*)					
	RK 7-18	RK 42-55	RK 55-77	RK 110-129	RK 139-156	RK 179-193
HALF-POUNDERS						
1976	14.5(393)	30.5(413)	35.9(117)	--	--	--
1977	13.0(599)	34.6(945)	26.3(860)	21.8(179)	12.7(63)	12.5(16)
1978	24.9(393)	40.2(831)	47.0(368)	42.9(70)	41.9(74)	60.0(5)
1979	20.3(310)	32.0(228)	42.2(199)	43.5(46)	29.8(47)	--
1980	37.5(429)	45.2(325)	46.7(107)	61.2(121)	54.6(55)	--
1981	45.8(489)	--	--	--	--	--
1983	32.2(363)	--	--	--	--	--
ADULTS						
1976	19.6(46)	22.9(70)	44.4(9)	--	--	--
1977	10.0(140)	10.0(209)	14.4(181)	13.8(160)	13.4(127)	5.9(119)
1978	22.6(53)	16.7(132)	25.0(28)	7.7(65)	13.4(253)	18.8(16)
1979	32.2(87)	25.9(54)	56.7(30)	24.3(47)	20.4(206)	--
1980	28.8(73)	40.9(44)	50.0(18)	31.3(67)	31.7(104)	--
1981	38.2(68)	--	--	--	--	--
1983	15.6(45)	--	--	--	--	--

Appendix Table C-28. Percent half-pounders among summer steelhead harvested by anglers in 1977-83. Anglers were not surveyed in 1982.

Return year	% half-pounders(*N*)					
	RK 7-18	RK 42-55	RK 55-77	RK 110-129	RK 139-156	RK 179-193
WILD						
1976	90.1(373)	84.2(341)	93.8(80)	--	--	--
1977	80.5(647)	78.4(872)	80.4(789)	50.4(278)	33.3(165)	11.1(126)
1978	87.7(334)	81.9(607)	90.3(216)	40.0(100)	16.4(262)	13.3(15)
1979	80.7(306)	79.5(195)	89.8(128)	31.7(41)	16.8(197)	--
1980	83.8(320)	87.2(204)	86.4(66)	50.5(93)	26.0(96)	--
1981	86.3(307)	--	--	--	--	--
1983	86.6(284)	--	--	--	--	--
HATCHERY						
1976	86.4(66)	88.7(142)	91.3(46)	--	--	--
1977	84.8(92)	94.5(382)	89.7(252)	63.9(61)	32.0(35)	22.2(9)
1978	68.4(48)	93.8(356)	96.1(180)	85.7(45)	47.7(65)	50.0(6)
1979	69.2(91)	83.9(87)	83.2(101)	52.6(77)	25.0(56)	--
1980	88.5(182)	89.1(165)	84.8(59)	77.9(95)	47.6(63)	--
1981	89.6(250)	--	--	--	--	--
1983	94.4(124)	--	--	--	--	--

Appendix Table C-29. Mean annual counts of bank anglers and boats seen in the lower river fishery for summer steelhead from 1 August through 15 October, 1965-81. Survey areas were RK 0-27 in 1965-69 and RK 7-18 in 1976-83. Most boat anglers probably fished for fall chinook salmon.

Year	Survey area	95% confidence interval		
		0900 hours	1500 hours	1900 hours
		BANK ANGLERS		
1965	RK 0-27	27.8 ± --	--	29.4 ± --
1966	RK 0-27	33.5 ± --	--	32.1 ± --
1967	RK 0-27	37.3 ± --	--	39.1 ± --
1969	RK 0-27	37.3 ± 7.2	--	41.7 ± --
1976	RK 8-17	20.1 ± 2.7	15.6 ± 3.1	22.2 ± 3.1
1977	RK 8-17	34.8 ± 7.9	25.8 ± 5.2	28.3 ± 6.0
1978	RK 8-17	32.9 ± 8.8	24.5 ± 5.9	36.1 ± 8.9
1979	RK 8-17	31.8 ± 9.6	19.6 ± 5.7	34.2 ± 8.5
1980	RK 8-17	30.7 ± 7.0	20.7 ± 4.2	30.6 ± 7.7
1981	RK 8-17	32.1 ± 7.2	20.4 ± 4.7	--
		BOATS		
1969	RK 0-27	2.9 ± 0.6	--	3.6 ± 0.9
1976	RK 8-17	1.0 ± 0.3	1.2 ± 0.6	0.8 ± 0.4
1977	RK 8-17	1.4 ± 0.4	1.4 ± 0.5	1.2 ± 0.4
1978	RK 8-17	4.6 ± 1.2	3.1 ± 0.8	4.0 ± 1.2
1979	RK 8-17	3.3 ± 0.8	1.9 ± 0.8	2.8 ± 0.6
1980	RK 8-17	3.2 ± 0.9	1.9 ± 0.5	2.5 ± 0.8
1981	RK 8-17	3.1 ± 0.6	1.8 ± 0.4	--

Appendix Table C-30. Regression analysis of the mean weekly number of bank anglers counted at 0900 hours in the RK 7-18 fishery for summer steelhead, 1976-83. Variables are described in Appendix Table C-12.

Independent variable	Regression coefficient	Standard error	*P*
Catch rate	73.94	18.16	<0.001
Week-of-year	93.05	13.79	<0.001
Week-of-year^2	-1.30	0.19	<0.001
Constant	-1,632		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	19,003	3	6,334	36.04	<0.001
Residual	12,476	71	176		

Variables tested	Partial r^2 Step 1	Partial r^2 Step 2
Catch rate	0.35	--
Flow	0.01	0.01
Water temperature	0.04	0.01
Week-of-year	0.03	0.01
Week-of-year^2	0.04	0.01

Appendix Table C-31. Correlation matrix for variables examined in the analysis of the mean number of bank anglers counted at 0900 hours in the RK 7-18 fishery for summer steelhead, 1976-83. Variables are described in Appendix Table C-12.

	Bank anglers	Catch rate	Flow	Water temperature	Turbidity
Bank anglers	1.00				
Catch rate	0.59[a]	1.00			
Flow	-0.27	0.08	1.00		
Water temperature	0.21	0.22	-0.22	1.00	
Turbidity	-0.10	-0.12	0.67[a]	-0.16	1.00

[a] *Significant at* $P \leq 0.05$.

Appendix Table C-32. Mean counts at 0900 hours of bank anglers and boats seen in the lower river fishery for summer steelhead, 1965-83. Survey areas were RK 0-27 in 1965-69 and RK 7-18 in 1976-83. Most boat anglers probably fished for fall chinook salmon.

	95% confidence interval				
Year	1-15 August	16-30 August	1-15 September	16-30 September	1-15 October
			BANK ANGLERS		
1965	19.3 ± --	55.2 ± --	28.6 ± --	19.8 ± --	16.1 ± --
1966	7.0 ± --	21.8 ± --	50.2 ± --	59.5 ± --	29.0 ± --
1967	5.2 ± --	20.0 ± --	63.8 ± --	58.4 ± --	39.0 ± --
1968	33.8 ± 32.2	86.2 ± 27.7	--	--	7.6 ± 6.6
1969	13.1 ± 8.8	47.2 ± 22.4	47.3 ± 19.3	44.3 ± 9.6	34.3 ± 8.9
1976	16.4 ± 4.8	28.2 ± 8.5	19.3 ± 4.8	21.4 ± 6.1	17.0 ± 8.9
1977	20.0 ± 8.8	56.4 ± 14.6	61.2 ± 19.2	26.1 ± 10.5	13.6 ± 9.2
1978	13.3 ± 6.6	61.2 ± 11.0	44.6 ± 32.8	27.7 ± 8.2	13.6 ± 3.4
1979	13.9 ± 4.7	72.4 ± 22.9	44.8 ± 16.0	21.4 ± 4.9	9.0 ± 4.2
1980	14.2 ± 9.1	47.8 ± 11.3	46.6 ± 13.5	26.5 ± 2.5	12.8 ± 14.8
1981	18.9 ± 9.7	67.1 ± 12.0	48.3 ± 10.0	20.4 ± 7.7	4.6 ± 2.5
1983	15.1 ± 5.6	40.3 ± 7.8	30.8 ± 11.6	19.0 ± 5.7	--
			BOATS		
1968	1.6 ± 1.0	5.2 ± 1.8	--	--	2.6 ± 2.6
1969	1.7 ± 1.7	3.0 ± 1.3	4.6 ± 1.9	6.3 ± 2.9	5.1 ± 1.8
1976	1.0 ± 0.4	0.5 ± 0.8	0.7 ± 0.5	1.2 ± 0.9	2.0 ± 2.5
1977	0.6 ± 0.4	1.6 ± 0.9	1.0 ± 0.9	1.8 ± 0.7	1.9 ± 1.4
1978	0.6 ± 0.7	4.2 ± 0.6	4.0 ± 3.7	8.4 ± 3.0	5.9 ± 1.4
1979	2.0 ± 1.0	5.9 ± 2.2	2.2 ± 2.1	3.3 ± 1.8	3.3 ± 1.3
1980	1.5 ± 1.0	3.8 ± 2.4	4.6 ± 2.4	4.0 ± 1.8	1.8 ± 2.4
1981	0.9 ± 1.0	3.6 ± 1.0	3.4 ± 1.0	4.7 ± 1.4	3.7 ± 1.8
1983	2.2 ± 0.4	3.5 ± 0.8	9.3 ± 2.3	10.1 ± 1.6	--

Appendix Table C-33. Mean counts at 1000 hours of bank anglers and boats seen in the Agness area (RK 42-54) fishery for summer steelhead, 1976-80.

	95% confidence interval			
Year	1-15 September	16-30 September	1-15 October	16-30 October
		BANK ANGLERS		
1976	--	--	--	6.9 ± 3.4
1977	34.9 ± 20.7	25.3 ± 12.6	12.5 ± 5.7	13.4 ± 2.5
1978	12.8 ± 7.1	15.9 ± 4.4	12.6 ± 4.6	5.3 ± 2.0
1979	21.7 ± 14.3	7.6 ± 4.3	7.6 ± 1.9	2.3 ± 1.5
1980	11.2 ± 8.4	12.8 ± 5.9	10.4 ± 4.0	5.9 ± 2.3
		BOATS		
1976	--	--	--	8.0 ± 2.2
1977	5.2 ± 1.7	6.7 ± 3.6	5.8 ± 2.1	6.9 ± 1.9
1978	7.8 ± 3.2	10.1 ± 3.4	13.0 ± 4.7	8.0 ± 3.0
1979	8.2 ± 5.9	8.1 ± 1.8	9.4 ± 3.4	10.0 ± 2.0
1980	5.7 ± 2.9	6.0 ± 2.2	7.2 ± 0.9	4.9 ± 1.7

Appendix Table C-34. Mean annual counts of bank anglers and boats seen in the Agness area (RK 42-54) fishery for summer steelhead in September-October, 1977-80.

	95% confidence interval		
Year	1000 hours	1300 hours	1600 hours
		BANK ANGLERS	
1977	22.0 ± 6.7	12.9 ± 3.9	14.0 ± 4.1
1978	11.3 ± 2.5	6.4 ± 1.9	10.0 ± 2.6
1979	8.5 ± 3.3	5.1 ± 2.2	8.5 ± 4.2
1980	10.1 ± 2.4	6.4 ± 1.7	6.4 ± 1.4
		BOATS	
1977	6.1 ± 1.1	2.5 ± 0.7	3.6 ± 1.0
1978	9.6 ± 1.7	3.6 ± 1.1	5.0 ± 1.0
1979	7.3 ± 1.5	2.2 ± 0.8	5.0 ± 1.1
1980	6.0 ± 0.9	2.3 ± 0.8	4.5 ± 1.2

Appendix Table C-35. Mean counts at 1200 hours of bank anglers, boats, and boat trailers seen in the Galice area (RK 110-129) fishery for summer steelhead in November-January, 1977-78 through 1980-81.

Month, days	95% confidence interval			
	1977-78	1978-79	1979-80	1980-81
		BANK ANGLERS		
November:				
1-15	39.8 ± 28.7	14.6 ± 4.7	18.9 ± 7.9	20.3 ± 4.9
16-30	16.8 ± 15.3	17.0 ± 14.1	13.7 ± 11.3	14.7 ± 5.7
December:				
1-15	19.9 ± 9.5	19.4 ± 11.9	21.5 ± 10.3	6.1 ± 4.2
16-31	9.5 ± 6.6	22.2 ± 6.4	11.5 ± 9.7	15.1 ± 4.0
January:				
1-15	23.5 ± 10.4	5.4 ± 4.5	9.6 ± 6.2	19.4 ± 6.1
16-31	28.1 ± 15.1	24.1 ± 10.2	5.1 ± 3.9	14.3 ± 5.0
		BOATS		
November:				
1-15	11.0 ± 7.7	4.4 ± 2.6	5.4 ± 2.6	7.4 ± 2.0
16-30	2.4 ± 2.2	3.9 ± 2.5	2.9 ± 2.3	2.4 ± 1.3
December:				
1-15	3.9 ± 3.0	4.8 ± 4.8	3.8 ± 2.4	2.7 ± 2.3
16-31	1.4 ± 1.0	4.5 ± 2.5	2.3 ± 3.6	4.4 ± 3.0
January:				
1-15	4.6 ± 2.5	1.1 ± 1.2	2.0 ± 1.7	4.7 ± 2.1
16-31	4.8 ± 4.1	5.5 ± 1.8	1.2 ± 1.0	1.9 ± 0.8
		BOAT TRAILERS		
November:				
1-15	9.8 ± 6.4	5.3 ± 2.3	9.9 ± 4.4	7.7 ± 2.5
16-30	3.2 ± 3.1	4.1 ± 3.6	2.4 ± 2.8	3.3 ± 1.1
December:				
1-15	3.8 ± 2.6	4.4 ± 4.2	6.5 ± 3.1	3.7 ± 3.0
16-31	1.4 ± 1.0	5.5 ± 3.0	3.3 ± 5.1	5.4 ± 3.5
January:				
1-15	5.6 ± 2.9	1.4 ± 1.4	3.0 ± 3.0	5.3 ± 2.6
16-31	6.6 ± 6.0	7.4 ± 3.3	2.7 ± 2.1	3.0 ± 1.6

Appendix Table C-36. Mean annual counts of bank anglers, boats, and boat trailers seen in the Galice area (RK 110-129) fishery for summer steelhead in November-January, 1977-78 through 1980-81.

	95% confidence interval		
Year	0900 hours	1200 hours	1600 hours
	BANK ANGLERS		
1977-78	15.3 ± 4.3	21.5 ± 5.1	11.5 ± 3.4
1978-79	10.8 ± 3.2	17.3 ± 3.7	10.5 ± 2.7
1979-80	9.3 ± 2.7	13.2 ± 3.3	7.5 ± 2.1
1980-81	8.0 ± 1.4	14.6 ± 2.2	6.2 ± 1.3
	BOATS		
1977-78	2.6 ± 0.9	4.1 ± 1.3	1.8 ± 0.6
1978-79	2.0 ± 0.6	4.0 ± 0.9	2.7 ± 0.7
1979-80	1.7 ± 0.6	2.9 ± 0.9	1.6 ± 0.7
1980-81	2.0 ± 0.7	3.7 ± 0.9	2.1 ± 0.5
	BOAT TRAILERS		
1977-78	3.2 ± 1.2	4.6 ± 1.5	1.8 ± 0.7
1978-79	2.5 ± 0.7	4.8 ± 1.2	2.8 ± 0.7
1979-80	3.4 ± 1.1	4.8 ± 1.4	2.6 ± 1.2
1980-81	3.3 ± 0.8	4.6 ± 1.0	2.3 ± 0.6

Appendix Table C-37. Mean counts at 1200 hours of bank anglers, boats, and boat trailers seen in the Grants Pass area (RK 139-156) fishery for summer steelhead in November-January, 1977-78 through 1980-81.

Month, days	95% confidence interval			
	1977-78	1978-79	1979-80	1980-81
		BANK ANGLERS		
November:				
1-15	9.0 ± 15.4	4.2 ± 2.2	12.8 ± 3.8	10.6 ± 3.0
16-30	4.6 ± 3.2	11.8 ± 6.0	10.5 ± 3.7	10.4 ± 5.8
December:				
1-15	13.3 ± 7.5	14.8 ± 4.8	12.2 ± 4.7	8.2 ± 3.8
16-31	10.2 ± 5.4	18.0 ± 5.3	14.8 ± 9.1	15.1 ± 6.8
January:				
1-15	12.3 ± 7.1	6.8 ± 5.3	16.6 ± 5.7	10.4 ± 4.9
16-31	19.5 ± 6.3	16.1 ± 4.3	8.9 ± 4.8	8.8 ± 2.6
		BOATS		
November:				
1-15	1.5 ± 1.6	0.5 ± 0.5	2.4 ± 1.1	0.8 ± 0.8
16-30	0.4 ± 0.6	1.6 ± 1.7	1.8 ± 1.6	0.7 ± 0.7
December:				
1-15	1.3 ± 0.8	2.9 ± 1.4	1.9 ± 1.3	0.6 ± 0.5
16-31	1.2 ± 0.7	3.6 ± 1.0	3.0 ± 1.5	2.3 ± 1.4
January:				
1-15	1.9 ± 2.2	1.0 ± 1.1	1.9 ± 1.2	3.3 ± 2.2
16-31	3.3 ± 1.8	2.7 ± 1.8	1.4 ± 1.0	1.5 ± 0.8
		BOATS		
November:				
1-15	5.0 ± 9.6	2.4 ± 1.4	4.2 ± 1.2	2.7 ± 1.3
16-30	1.7 ± 1.4	3.4 ± 2.9	3.2 ± 2.7	5.7 ± 5.9
December:				
1-15	4.0 ± 3.0	4.1 ± 2.2	6.1 ± 4.1	3.3 ± 1.4
16-31	3.6 ± 1.6	6.4 ± 2.5	6.4 ± 3.7	5.5 ± 2.4
January:				
1-15	6.0 ± 4.6	3.1 ± 3.4	5.4 ± 4.4	8.3 ± 3.9
16-31	11.7 ± 5.8	7.8 ± 3.9	4.6 ± 3.0	4.2 ± 1.1

Appendix Table C-38. Mean annual counts of bank anglers, boats, and boat trailers seen in the Grants Pass area (RK 139-156) fishery for summer steelhead in November-January, 1977-78 through 1980-81.

	95% confidence interval		
Year	0900 hours	1200 hours	1600 hours
	BANK ANGLERS		
1977-78	6.6 ± 1.7	12.0 ± 2.7	8.8 ± 2.0
1978-79	6.5 ± 1.7	12.3 ± 2.1	9.6 ± 1.9
1979-80	9.4 ± 1.8	12.3 ± 2.1	9.9 ± 2.0
1980-81	5.7 ± 1.3	10.5 ± 1.7	8.6 ± 1.5
	BOATS		
1977-78	0.6 ± 0.3	1.6 ± 0.6	1.9 ± 0.8
1978-79	1.3 ± 0.4	2.1 ± 0.6	1.2 ± 0.4
1979-80	0.7 ± 0.3	2.0 ± 0.5	1.7 ± 0.5
1980-81	0.9 ± 0.3	1.5 ± 0.5	1.1 ± 0.3
	BOAT TRAILERS		
1977-78	3.4 ± 1.2	5.4 ± 1.7	3.4 ± 1.3
1978-79	3.3 ± 1.0	4.7 ± 1.2	2.4 ± 0.6
1979-80	3.3 ± 1.0	5.0 ± 1.2	2.8 ± 0.6
1980-81	2.7 ± 0.8	4.9 ± 1.2	2.4 ± 0.6

APPENDIX D

Tables of Data Related to Studies of Juvenile Summer Steelhead

Appendix Table D-1. Regressions of mean length on day-of-year for subyearling steelhead seined at four sites in the Rogue River.

Year	Sample dates	*N*	*r*	*P*	Regression[a]		Predicted mean length (cm) ± SE[b]
					Intercept	Slope	
				SAND HOLE			
1974	08/12-09/26	4	0.96	0.036	-0.31	0.0227	5.3 ± 0.1
1976	06/27-09/26	12	0.94	<0.001	-1.54	0.0267	5.0 ± 0.2
1977	06/21-10/04	14	0.95	<0.001	-1.31	0.0286	5.7 ± 0.1
1978	08/20-09/05	9	0.96	<0.001	-0.67	0.0228	4.9 ± 0.1
1979	06/18-09/28	15	0.97	<0.001	-0.12	0.0214	5.1 ± 0.1
1980	06/12-09/05	13	0.92	<0.001	0.59	0.0199	5.5 ± 0.1
1981	06/16-09/01	9	0.89	0.001	-0.57	0.0258	5.7 ± 0.3
1982	06/30-09/02	9	0.98	<0.001	-2.70	0.0330	5.4 ± 0.1
				HIGH BANKS			
1975	07/11-09/26	7	0.93	<0.001	-3.95	0.0428	6.5 ± 0.2
1976	06/20-10/17	17	0.72	0.001	3.46	0.0128	6.6 ± 0.1
1977	06/14-11/01	19	0.95	<0.001	0.77	0.0298	8.1 ± 0.1
1978	05/22-09/26	21	0.96	<0.001	-0.98	0.0336	7.3 ± 0.1
1979	06/12-10/03	17	0.95	<0.001	0.32	0.0277	7.1 ± 0.1
1980	06/24-09/25	14	0.83	<0.001	-0.37	0.0312	7.3 ± 0.2
1981	05/26-09/08	16	0.98	<0.001	-3.25	0.0489	8.7 ± 0.2
				MATSON PARK			
1975	08/22-10/27	9	0.92	<0.001	2.91	0.0216	8.2 ± 0.1
1976	06/20-11/14	16	0.99	<0.001	2.23	0.0248	8.3 ± 0.1
1977	05/31-11/07	20	0.98	<0.001	1.51	0.0258	7.8 ± 0.1
1978	06/06-10/02	11	0.98	<0.001	-0.92	0.0419	9.3 ± 0.1
1979	06/06-10/22	15	0.96	<0.001	0.55	0.0317	8.3 ± 0.1
1980	06/10-09/30	15	0.97	<0.001	-0.25	0.0411	9.8 ± 0.1
1981	05/19-10/28	22	0.99	<0.001	-0.59	0.0403	9.3 ± 0.1
1984	06/29-10/24	12	0.97	<0.001	-2.11	0.0457	9.1 ± 0.1
1985	06/23-10/22	12	0.92	<0.001	2.52	0.0246	8.5 ± 0.1
1986	06/03-10/21	21	0.99	<0.001	0.49	0.0317	8.3 ± 0.1
				WHISKEY BAR			
1975	08/03-10/18	5	0.90	0.036	1.54	0.0263	8.0 ± 0.1
1976	06/04-10/15	9	0.85	0.004	3.87	0.0154	7.6 ± 0.2
1977	05/29-10/05	6	0.96	0.002	1.76	0.0248	7.8 ± 0.2
1978	05/23-10/05	8	0.93	0.001	0.41	0.0365	9.4 ± 0.3
1979	07/05-09/19	6	0.89	0.019	1.64	0.0301	9.0 ± 0.3
1980	06/26-09/22	7	0.92	0.004	3.91	0.0190	8.6 ± 0.1
1981	05/20-09/24	9	0.98	<0.001	1.22	0.0293	8.4 ± 0.1
1984	06/22-09/15	9	0.94	<0.001	-0.84	0.0414	9.3 ± 0.2
1985	06/06-09/22	9	0.94	<0.001	0.27	0.0367	9.3 ± 0.3
1986	06/19-09/23	10	0.99	<0.001	1.30	0.0323	9.2 ± 0.1

---

[a] *Y = mean fork length (cm), X = day-of-year (**APPENDIX A**).*

[b] *Predicted for a sampling date of 1 September.*

Appendix Table D-2. Data used to assess factors related to predicted mean lengths of subyearling steelhead seined at Sand Hole and High Banks. Predicted mean lengths are in Appendix Table D-1.

	Water temperature			Flow		Juvenile abundance	
Year	Summer[a]	Summer[b]	Spring[c]	Summer[d]	Summer[e]	Chinook[f]	Steelhead[g]
1974	15.0	--	10.5	1,736	--	--	--
1975	14.2	18.8	9.9	1,829	1,976	--	17.8
1976	15.1	19.4	9.8	1,630	1,916	585	74.2
1977	14.4	19.4	11.9	1,061	1,146	843	57.4
1978	12.8	17.5	12.0	2,154	2,341	47	68.2
1979	12.6	17.4	11.9	2,182	2,259	518	50.5
1980	11.9	16.8	11.6	2,022	2,087	193	28.8
1981	12.0	17.5	12.5	2,041	1,978	372	31.4
1982	11.1	--	10.5	2,199	--	--	--

[a] *Mean maximum water temperature (^{o}C) near McLeod in July-August, used in the analysis of lengths from samples at Sand Hole.*

[b] *Mean maximum water temperature (^{o}C) at Raygold in July-August, used in the analysis of lengths from samples at High Banks.*

[c] *Mean maximum water temperature (^{o}C) of Big Butte Creek in March-May.*

[d] *Mean flow (cfs) near McLeod in July-August, used in the analysis of lengths from samples at Sand Hole.*

[e] *Mean flow (cfs) at Raygold in July-August, used in the analysis of lengths from samples at High Banks.*

[f] *Mean catch per seine haul of subyearling chinook salmon at Sand Hole and High Banks 1 month after emergence completion.*

[g] *Mean catch per seine haul of subyearling steelhead at Sand Hole and High Banks in June-October.*

Appendix Table D-3. Correlation matrixes for variables examined in analyses of mean lengths of subyearling steelhead on 1 September as predicted from annual regressions for Sand Hole and High Banks. Variables are described in Appendix Table D-2.

Sand Hole

	Mean length	Water temperature			Juvenile abundance	
		Summer	Spring	Flow	Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.23	1.00				
Spring temperature	0.36	-0.40	1.00			
Flow	-0.36	-0.73[a]	0.12	1.00		
Chinook abundance	0.36	0.67	-0.25	-0.81[a]	1.00	
Steelhead abundance	-0.70	0.79	-0.58	-0.31	0.23	1.00

High Banks

	Mean length	Water temperature			Juvenile abundance	
		Summer	Spring	Flow	Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.23	1.00				
Spring temperature	0.82[a]	-0.60	1.00			
Flow	-0.36	-0.69	0.02	1.00		
Chinook abundance	0.12	0.78	-0.25	-0.81[a]	1.00	
Steelhead abundance	-0.10	0.34	-0.01	-0.07	0.23	1.00

[a] $P \leq 0.05$.

Appendix Table D-4. Data used to assess factors related to predicted mean lengths of subyearling steelhead seined at Matson Park and Whiskey Bar. Predicted mean lengths are in Appendix Table D-1.

	Water temperature			Juvenile abundance	
Year	Summer[a]	Spring[b]	Flow[c]	Chinook[d]	Steelhead[e]
1975	21.7	9.9	1,744	63	6.9
1976	21.7	9.8	1,768	174	17.2
1977	22.6	11.9	966	82	4.9
1978	20.0	12.0	2,167	20	10.7
1979	20.0	11.9	2,258	104	9.6
1980	19.6	11.6	1,960	64	23.0
1981	20.8	12.5	1,864	77	20.3
1984	19.4	10.5	3,104	108	7.9
1985	20.5	11.1	2,198	267	24.8
1986	20.4	11.6	2,255	273	43.4

[a] *Mean maximum water temperature (°C) at Merlin in July-August.*
[b] *Mean maximum water temperature (°C) of Big Butte Creek in March-May.*
[c] *Mean flow (cfs) at Grants Pass in July-August.*
[d] *Mean catch per seine haul of subyearling chinook salmon at Matson and Almeda in May-August (ODFW 1992).*
[e] *Mean catch per seine haul of subyearling steelhead at four sites in June-October (Appendix Table D-41).*

Appendix Table D-5. Correlation matrixes for variables examined in analyses of mean lengths of subyearling steelhead on 1 September as predicted from annual regressions for Matson Park and Whiskey Bar. Variables are described in Appendix Table D-3.

Matson Park

	Mean length	Water temperature		Flow	Juvenile abundance	
		Summer	Spring		Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.72[a]	1.00				
Spring temperature	0.30	-0.22	1.00			
Flow	0.43	-0.85[a]	-0.15	1.00		
Chinook abundance	-0.39	0.01	-0.20	0.20	1.00	
Steelhead abundance	0.12	-0.25	0.18	0.17	0.72[a]	1.00

Whiskey Bar

	Mean length	Water temperature		Flow	Juvenile abundance	
		Summer	Spring		Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.82[a]	1.00				
Spring temperature	0.34	-0.22	1.00			
Flow	0.77[a]	-0.85[a]	-0.15	1.00		
Chinook abundance	0.22	0.01	-0.20	0.20	1.00	
Steelhead abundance	0.31	-0.25	0.18	0.17	0.72[a]	1.00

[a] $P \leq 0.05$.

Appendix Table D-6. Mean length (cm) at the first annulus estimated for three life history types of wild summer steelhead seined at Huntley Park, 1971-1984 brood years. Data not shown where $N \leq 5$ or if brood year composition could not be estimated.

Brood year	95% confidence interval			
	Age-1 smolts	Age-2 smolts	Age-3 smolts	All ages
		HALF-POUNDERS		
1972	--	--	9.1 ± 1.3	--
1973	--	9.3 ± 0.5	8.9 ± 0.7	--
1974	11.8 ± 1.0	9.7 ± 0.3	9.5 ± 1.0	--
1975	12.2 ± 0.3	9.5 ± 0.3	9.3 ± 0.9	9.8 ± 0.2
1976	10.6 ± 0.4	8.7 ± 0.3	8.8 ± 0.5	9.7 ± 0.2
1977	10.9 ± 0.7	9.5 ± 0.3	8.9 ± 0.6	10.0 ± 0.3
1978	11.6 ± 0.4	9.2 ± 0.3	9.3 ± 0.9	9.5 ± 0.2
1979	11.5 ± 0.5	9.6 ± 0.2	9.4 ± 1.4	10.0 ± 0.2
1980	11.4 ± 0.4	9.5 ± 0.3	10.3 ± 1.1	10.7 ± 0.3
1981	11.6 ± 0.6	10.1 ± 0.3	9.0 ± 0.7	10.5 ± 0.2
1982	11.4 ± 0.4	9.8 ± 0.4	8.9 ± 1.8	10.2 ± 0.3
1983	11.4 ± 0.6	9.1 ± 0.2	--	--
1984	10.5 ± 0.5	--	--	--
		FIRST SPAWNING MIGRANTS		
1972	--	9.8 ± 0.6	9.7 ± 1.1	--
1973	--	9.6 ± 0.3	--	--
1974	12.5 ± 0.7	9.9 ± 0.4	--	10.2 ± 0.3
1975	11.7 ± 0.5	9.3 ± 0.4	8.8 ± 1.3	10.1 ± 0.3
1976	10.8 ± 0.4	9.0 ± 0.3	--	10.0 ± 0.2
1977	11.6 ± 1.0	9.8 ± 0.4	--	10.5 ± 0.5
1978	11.6 ± 0.3	9.1 ± 0.6	--	9.8 ± 0.2
1979	11.6 ± 0.4	9.8 ± 0.3	--	10.5 ± 0.2
1980	11.6 ± 0.4	10.7 ± 0.5	--	11.4 ± 0.3
1981	12.3 ± 0.5	9.2 ± 0.3	--	10.2 ± 0.2
1982	11.3 ± 0.6	9.3 ± 0.3	--	--
1983	11.3 ± 0.3	--	--	--
		SECOND SPAWNING MIGRANTS		
1971	--	9.7 ± 0.6	--	--
1972	12.3 ± 0.5	9.8 ± 0.5	--	--
1973	13.1 ± 1.6	9.6 ± 0.7	--	10.4 ± 0.6
1974	--	9.5 ± 0.8	--	10.1 ± 0.6
1975	11.4 ± 1.0	9.1 ± 0.3	--	9.5 ± 0.3
1976	10.7 ± 0.3	8.7 ± 0.3	--	10.0 ± 0.3
1977	11.3 ± 0.9	9.9 ± 0.8	--	10.6 ± 0.6
1978	12.4 ± 1.2	9.1 ± 0.7	--	10.4 ± 0.6
1979	--	--	--	10.6 ± 0.6
1980	12.2 ± 0.6	8.6 ± 0.6	--	10.4 ± 0.6
1981	10.7 ± 1.1	9.7 ± 0.6	--	--
1982	11.4 ± 1.1	--	--	--

Appendix Table D-7. Independent variables used to assess factors related to estimates of mean length at annulus one, mean length at annulus two, and freshwater growth in the second year of life, for first spawning migrants, brood years 1974-81.

	Water temperature		Flow		Juvenile abundance	
Year	Spring[a]	Summer[b]	Spring[c]	Summer[d]	Chinook[e]	Steelhead[f]
1974	12.3	18.0	5,862	1,674	--	--
1975	11.8	18.7	5,185	1,598	63	6.9
1976	13.0	18.6	3,580	1,646	174	17.2
1977	16.9	20.5	1,183	1,105	82	4.9
1978	14.5	17.5	2,436	2,025	20	10.7
1979	14.0	17.9	3,719	2,005	104	9.6
1980	14.1	17.5	2,854	1,751	64	23.0
1981	15.6	17.1	1,857	1,829	77	20.3
1982	13.5	16.6	4,356	2,189	--	--

[a] *Mean maximum water temperature (°C) at Grants Pass in April-June.*
[b] *Mean maximum water temperature (°C) at Grants Pass in July-September.*
[c] *Mean flow (cfs) at Grants Pass in April-June.*
[d] *Mean flow (cfs) at Grants Pass in July-September.*
[e] *Mean catch per seine haul of subyearling chinook salmon at Matson Park and Almeda Park in May-August (ODFW 1992).*
[f] *Mean catch per seine haul of subyearling steelhead at four sites in June-October (Appendix Table D-41).*

Appendix Table D-8. Correlation matrix for variables examined in the analysis of mean lengths at annulus one for first spawning migrants, brood years 1974-81. Independent variables are described in Appendix Table D-7.

	Mean length	Water temperature		Flow		Juvenile abundance	
		Spring	Summer	Spring	Summer	Chinook	Steelhead
Mean length	1.00						
Spring temperature	0.20	1.00					
Summer temperature	-0.03	0.26	1.00				
Spring flow	-0.18	-0.94[a]	-0.16	1.00			
Summer flow	-0.15	-0.30	-0.89[a]	0.19	1.00		
Chinook abundance	-0.06	-0.20	0.25	0.19	-0.20	1.00	
Steelhead abundance	0.41	-0.06	-0.68	-0.13	0.37	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-9. Regressions of mean length on day-of-year for yearling steelhead seined at two sites in the Rogue River. Regressions are reported only for sites were catches commonly exceeded 10 fish weekly in a minimum of 3 preimpoundment and 3 postimpoundment years.

					Regression[a]		
Year	Sample dates	*N*	*r*	*P*	Intercept	Slope	Predicted mean length (cm) ± SE[b]
				WHISKEY BAR			
1975	06/27-09/28	7	0.94	0.002	5.92	0.0307	13.4 ± 0.2
1976	06/04-10/15	9	0.89	0.001	9.91	0.0145	13.5 ± 0.1
1977	06/09-11/05	5	0.96	0.011	7.94	0.0235	13.7 ± 0.2
1978	05/19-09/06	7	0.95	0.001	7.70	0.0338	16.0 ± 0.5
1979	05/31-09/19	7	0.93	0.003	6.96	0.0304	14.4 ± 0.3
1980	05/29-09/23	8	0.89	0.003	5.71	0.0379	15.0 ± 0.4
1981	05/07-09/25	11	0.86	0.001	8.14	0.0264	14.6 ± 0.3
				AGNESS			
1975	04/14-11/07	13	0.98	<0.001	5.70	0.0315	13.4 ± 0.2
1976	04/21-11/24	20	0.94	<0.001	8.61	0.0222	14.1 ± 0.2
1977	04/15-11/03	21	0.96	<0.001	9.68	0.0155	13.5 ± 0.1
1978	05/10-11/02	20	0.97	<0.001	5.71	0.0392	15.3 ± 0.1
1979	05/01-10/18	15	0.88	<0.001	9.01	0.0212	14.2 ± 0.2
1980	05/29-10/16	11	0.87	<0.001	7.92	0.0269	14.5 ± 0.4
1981	05/20-10/20	12	0.86	<0.001	8.75	0.0210	13.9 ± 0.4

[a] *Y = mean fork length (cm), X = day-of-year (**APPENDIX A**).*
[b] *Predicted for a sampling date of 1 September.*

Appendix Table D-10. Data used to assess factors related to the predicted mean lengths of yearling steelhead seined at Whiskey Bar and Agness. Predicted mean lengths are in Appendix Table D-9.

	Water temperature				Flow		Juvenile abundance	
Year	Summer[a]	Summer[b]	Spring[c]	Spring[d]	Summer[e]	Summer[f]	Chinook[g]	Steelhead[h]
1975	21.7	21.2	11.6	10.6	1,744	2,148	63	6.9
1976	21.7	22.2	13.2	13.4	1,768	1,984	174	17.2
1977	22.6	24.4	15.9	15.4	966	915	82	4.9
1978	20.0	22.2	13.4	13.5	2,167	2,215	20	10.7
1979	20.0	21.7	13.2	13.8	2,258	2,130	104	9.6
1980	19.6	22.2	13.5	14.0	1,960	2,068	64	23.0
1981	20.8	22.8	15.1	14.8	1,864	1,969	77	20.3

[a] *Mean maximum water temperature (°C) at Merlin in July-August, used in the analysis of lengths from samples at Whiskey Bar.*

[b] *Mean maximum water temperature (°C) at Agness in July-August, used in the analysis of lengths from samples at Agness.*

[c] *Mean maximum water temperature (°C) at Merlin in April-May, used in the analysis of lengths from samples at Whiskey Bar.*

[d] *Mean maximum water temperature (°C) at Agness in April-May, used in the analysis of lengths from samples at Agness.*

[e] *Mean flow (cfs) at Grants Pass in July-August, used in the analysis of lengths from samples at Whiskey Bar.*

[f] *Mean flow (cfs) at Agness in July-August, used in the analysis of lengths from samples at Agness.*

[g] *Mean catch per seine haul of subyearling chinook salmon at Matson Park and Almeda Park 1 month after emergence completion.*

[h] *Mean catch per seine haul of subyearling steelhead at Sand Hole and High Banks in June-October.*

Appendix Table D-11. Correlation matrixes for variables examined in analyses of mean lengths of yearling steelhead on 1 September as predicted from annual regressions for Whiskey Bar and Agness. Independent variables are described in Appendix Table D-10.

Whiskey Bar

	Mean length	Water temperature		Flow	Juvenile abundance	
		Summer	Spring		Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.79[a]	1.00				
Spring temperature	0.09	0.27	1.00			
Flow	0.58	-0.86[a]	-0.56	1.00		
Chinook abundance	-0.66	0.37	0.00	-0.15	1.00	
Steelhead abundance	0.30	-0.51	0.06	0.37	0.18	1.00

Agness

	Mean length	Water temperature		Flow	Juvenile abundance	
		Summer	Spring		Chinook	Steelhead
Mean length	1.00					
Summer temperature	-0.21	1.00				
Spring temperature	0.14	0.81[a]	1.00			
Flow	0.50	-0.91[a]	-0.58	1.00		
Chinook abundance	-0.36	0.01	0.08	-0.12	1.00	
Steelhead abundance	0.32	-0.14	0.24	0.40	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-12. Mean length (cm) at the second annulus estimated for three life history types of wild summer steelhead seined at Huntley Park, 1971-1983 brood years. Data not shown if *N* ≤ 5 or if brood year composition could not be estimated.

Brood	95% confidence interval		
year	Age-2 smolts	Age-3 smolts	All ages
	HALF-POUNDERS		
1972	--	13.1 ± 1.6	--
1973	14.4 ± 0.8	12.7 ± 1.2	--
1974	14.8 ± 0.5	15.0 ± 1.8	--
1975	15.2 ± 0.4	14.4 ± 2.5	15.2 ± 0.4
1976	14.4 ± 0.5	13.4 ± 1.4	14.3 ± 0.4
1977	14.8 ± 0.5	12.9 ± 0.8	14.3 ± 0.4
1978	14.9 ± 0.5	14.9 ± 1.5	14.9 ± 0.5
1979	15.7 ± 0.4	14.1 ± 2.0	15.6 ± 0.4
1980	15.9 ± 0.6	15.4 ± 1.6	15.8 ± 0.6
1981	16.9 ± 0.6	13.8 ± 1.4	16.6 ± 0.5
1982	16.3 ± 0.7	14.0 ± 5.7	16.1 ± 0.7
1983	15.7 ± 0.7	--	--
	FIRST SPAWNING MIGRANTS		
1972	16.1 ± 0.9	13.8 ± 1.7	--
1973	15.6 ± 0.6	--	--
1974	15.0 ± 0.6	--	14.9 ± 0.6
1975	14.4 ± 0.7	13.8 ± 1.7	14.3 ± 0.7
1976	14.6 ± 0.5	--	14.6 ± 0.5
1977	15.2 ± 0.6	--	14.7 ± 0.6
1978	14.8 ± 0.9	--	14.7 ± 0.9
1979	16.2 ± 0.5	--	16.2 ± 0.5
1980	17.8 ± 1.1	--	17.1 ± 1.1
1981	15.5 ± 0.6	--	15.4 ± 0.6
1982	15.2 ± 0.5	--	--
	SECOND SPAWNING MIGRANTS		
1971	15.4 ± 0.8	--	--
1972	16.4 ± 1.5	--	--
1973	14.4 ± 0.7	--	14.4 ± 0.7
1974	14.0 ± 1.5	--	14.1 ± 1.5
1975	14.1 ± 0.6	--	14.1 ± 0.6
1976	14.4 ± 0.5	--	14.4 ± 0.5
1977	16.2 ± 1.1	--	16.2 ± 1.1
1978	15.2 ± 1.1	--	15.2 ± 1.1
1979	--	--	--
1980	14.8 ± 1.3	--	14.8 ± 1.3
1981	15.4 ± 1.1	--	--

Appendix Table D-13. Correlation matrix for variables examined in the analysis of mean lengths at annulus two for first spawning migrants, 1974-81 brood years. Independent variables are described in Appendix Table D-7.

	Mean length	Water temperature		Flow		Juvenile abundance	
		Spring	Summer	Spring	Summer	Chinook	Steelhead
Mean length	1.00						
Spring temperature	0.24	1.00					
Summer temperature	-0.55	0.30	1.00				
Spring flow	-0.25	-0.95[a]	-0.29	1.00			
Summer flow	0.22	-0.39	-0.92[a]	0.42	1.00		
Chinook abundance	-0.29	-0.20	0.25	0.19	-0.20	1.00	
Steelhead abundance	0.69	-0.05	-0.68	-0.13	0.37	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-14. Mean increase in length during the second year of freshwater residence estimated for three life history types of wild summer steelhead seined at Huntley Park, 1971-1983 brood years. Data not shown if *N* ≤ 5 or if brood year composition could not be estimated.

Brood year	95% confidence interval		
	Age-2 smolts	Age-3 smolts	All ages
	HALF-POUNDERS		
1972	--	4.0 ± 1.9	--
1973	5.1 ± 1.0	3.8 ± 1.2	--
1974	5.2 ± 0.5	5.4 ± 1.4	--
1975	5.7 ± 0.5	5.1 ± 2.4	5.7 ± 0.3
1976	5.9 ± 0.5	4.7 ± 1.2	5.8 ± 0.3
1977	5.3 ± 0.6	4.1 ± 1.4	5.0 ± 0.3
1978	5.7 ± 0.6	5.7 ± 0.5	5.7 ± 0.3
1979	6.1 ± 0.4	4.7 ± 2.0	6.1 ± 0.2
1980	6.3 ± 0.6	5.1 ± 1.6	6.3 ± 0.4
1981	6.7 ± 0.6	4.8 ± 0.9	6.5 ± 0.6
1982	6.5 ± 0.5	5.1 ± 3.9	6.4 ± 0.5
1983	6.6 ± 0.6	--	--
	FIRST SPAWNING MIGRANTS		
1972	6.3 ± 0.6	4.1 ± 1.2	--
1973	6.1 ± 0.5	--	--
1974	5.1 ± 0.3	--	5.1 ± 0.3
1975	5.1 ± 0.4	4.9 ± 1.1	5.0 ± 0.3
1976	5.6 ± 0.4	--	5.6 ± 0.4
1977	5.4 ± 0.4	--	5.2 ± 0.4
1978	5.7 ± 0.3	--	5.6 ± 0.3
1979	6.4 ± 0.5	--	6.4 ± 0.5
1980	7.1 ± 0.9	--	6.7 ± 0.8
1981	6.3 ± 0.4	--	6.3 ± 0.4
1982	5.9 ± 0.3	--	--
	SECOND SPAWNING MIGRANTS		
1971	5.7 ± 0.6	--	--
1972	6.2 ± 1.0	--	--
1973	4.8 ± 0.4	--	4.8 ± 0.4
1974	4.5 ± 0.8	--	4.8 ± 0.7
1975	5.0 ± 0.6	--	5.0 ± 0.5
1976	5.7 ± 0.5	--	5.7 ± 0.5
1977	6.2 ± 0.8	--	6.2 ± 0.8
1978	6.2 ± 0.7	--	6.2 ± 0.7
1979	--	--	--
1980	6.1 ± 1.0	--	6.1 ± 1.0
1981	5.7 ± 0.8	--	5.7 ± 0.8

Appendix Table D-15. Correlation matrix for variables examined in the analysis of mean increases in length during the second year of freshwater residence for first spawning migrants, 1974-81 brood years. Independent variables are described in Appendix Table D-7.

	Mean increase	Water temperature		Flow		Juvenile abundance	
		Spring	Summer	Spring	Summer	Chinook	Steelhead
Mean length	1.00						
Spring temperature	0.24	1.00					
Summer temperature	-0.55	0.30	1.00				
Spring flow	-0.25	-0.95[a]	-0.29	1.00			
Summer flow	0.22	-0.39	-0.93[a]	0.42	1.00		
Chinook abundance	-0.29	-0.20	0.25	0.19	-0.20	1.00	
Steelhead abundance	0.69	-0.05	-0.68	-0.13	0.37	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-16. Plus-growth (cm) estimated for three life history types of wild summer steelhead seined at Huntley Park, 1971-1983 brood years. Data not shown if $N \leq 5$ or if brood year composition could not be estimated.

Brood year	95% confidence interval			
	Age-1 smolts	Age-2 smolts	Age-3 smolts	All ages
HALF-POUNDERS				
1972	--	--	5.8 ± 2.4	--
1973	--	6.5 ± 1.0	5.4 ± 2.0	--
1974	8.7 ± 2.5	7.0 ± 0.5	7.3 ± 2.0	--
1975	7.3 ± 0.7	8.2 ± 0.5	6.9 ± 1.5	8.0 ± 0.6
1976	9.1 ± 0.5	7.2 ± 0.6	5.6 ± 1.2	8.2 ± 0.4
1977	8.7 ± 1.1	6.3 ± 0.6	6.8 ± 1.5	7.4 ± 1.5
1978	8.1 ± 0.6	7.5 ± 0.4	7.1 ± 1.3	7.6 ± 0.4
1979	8.5 ± 0.7	7.5 ± 0.4	5.0 ± 2.6	7.7 ± 0.4
1980	9.1 ± 0.4	6.7 ± 0.4	3.1 ± 2.5	8.2 ± 0.3
1981	7.9 ± 0.7	5.5 ± 0.4	7.1 ± 1.9	6.3 ± 0.4
1982	7.9 ± 0.8	6.0 ± 0.6	--	6.7 ± 0.5
1983	9.0 ± 1.0	--	--	--
FIRST SPAWNING MIGRANTS				
1972	--	6.6 ± 1.3	4.4 ± 1.2	--
1973	--	5.0 ± 0.6	--	--
1974	6.8 ± 1.2	7.6 ± 0.5	--	7.5 ± 0.5
1975	9.4 ± 0.7	7.6 ± 0.9	6.1 ± 2.3	8.2 ± 0.3
1976	9.1 ± 0.6	7.2 ± 0.6	--	8.2 ± 0.4
1977	9.7 ± 0.8	7.2 ± 0.5	--	8.3 ± 0.5
1978	8.5 ± 0.7	7.1 ± 0.4	--	7.3 ± 0.6
1979	8.9 ± 0.5	7.8 ± 0.7	--	8.2 ± 0.5
1980	9.9 ± 0.6	6.0 ± 1.0	--	9.2 ± 0.6
1981	8.4 ± 0.6	6.8 ± 0.7	--	7.4 ± 0.5
1982	9.1 ± 0.7	--	--	--
SECOND SPAWNING MIGRANTS				
1971	--	8.0 ± 1.0	--	--
1972	9.6 ± 0.8	6.4 ± 0.9	--	--
1973	7.7 ± 2.3	6.1 ± 1.6	--	6.4 ± 1.3
1974	--	7.4 ± 2.0	--	8.2 ± 1.4
1975	9.2 ± 2.4	7.7 ± 0.8	--	7.9 ± 0.9
1976	10.1 ± 0.6	7.8 ± 0.6	--	9.3 ± 0.4
1977	9.0 ± 1.1	6.9 ± 1.1	--	8.0 ± 0.7
1978	7.9 ± 0.8	7.3 ± 1.2	--	7.5 ± 0.6
1979	--	--	--	10.2 ± 2.6
1980	9.8 ± 1.8	7.9 ± 1.4	--	9.0 ± 0.8
1981	10.8 ± 1.6	--	--	--

Appendix Table D-17. Correlation matrix for variables examined in the analysis of mean plus-growth for age-1 smolts among first spawning migrants, 1974-82 brood years. Variables are described in Appendix Table D-19.

	Plus-growth	Water temperature	Flow	Length at annulus 1
Plus-growth	1.00			
Water temperature	0.62[a]	1.00		
Flow	-0.67[a]	-0.94[a]	1.00	
Length at annulus 1	-0.56	-0.70[a]	0.59	1.00

[a] $P \leq 0.05$.

Appendix Table D-18. Correlation matrix for variables examined in the analysis of mean plus-growth for age-2 smolts among first spawning migrants, 1974-82 brood years. Variables are described in Appendix Table D-19.

	Plus-growth	Water temperature	Flow	Length at annulus 2
Plus-growth	1.00			
Water temperature	0.75[a]	1.00		
Flow	-0.73[a]	-0.93[a]	1.00	
Length at annulus 2	-0.47	-0.38	0.41	1.00

[a] $P \leq 0.05$.

Appendix Table D-19. Data used to assess factors related to the mean plus-growth of age-1 and age-2 smolts that returned as first spawning migrants, 1972-82 brood years.

Brood year	Plus-growth[a]	Water temperature[b]	Flow[c]	Parr length[d]
AGE-1 SMOLTS				
1974	6.8	9.3	6,856	12.5
1975	9.5	10.2	4,029	11.7
1976	9.1	13.0	1,315	10.8
1977	9.7	11.8	2,704	11.6
1978	8.5	11.3	4,129	11.6
1979	9.0	11.4	3,467	11.6
1980	9.8	12.6	1,761	11.6
1981	8.4	10.3	5,185	12.3
1982	9.1	10.0	6,773	11.3
AGE-2 SMOLTS				
1972	6.6	9.8	7,993	16.1
1973	5.0	9.3	6,856	15.6
1974	7.6	10.2	4,029	15.0
1975	7.7	13.0	1,315	14.4
1976	7.3	11.8	2,704	14.6
1977	7.2	11.3	4,129	15.2
1978	7.1	11.4	3,467	14.8
1979	7.8	12.6	1,761	16.2
1980	6.0	10.3	5,185	17.8
1981	6.8	10.0	6,773	15.5

[a] *Mean plus-growth of first spawning migrants.*
[b] *Mean maximum water temperature (°C) at Grants Pass in March-May.*
[c] *Mean flow (cfs) at Grants Pass in March-May.*
[d] *Mean lengths at the last freshwater annulus for first spawning migrants.*

Appendix Table D-20. Regressions of weight on length for subyearling steelhead seined at three sites in the Rogue River. All regressions were significant at $P < 0.001$. Results are reported only for sites where regressions could be developed for a minimum of 3 preimpoundment and 3 postimpoundment years.

			Regression[a]		
Year	N	r	Intercept	Slope	Predicted mean weight (g) ± SE[b]
			HIGH BANKS		
1975	50	0.98	-2.0179	3.0681	5.7 ± 0.1
1976	50	0.99	-1.9401	2.9825	5.6 ± 0.1
1977	50	0.98	-1.9829	3.0406	5.8 ± 0.1
1978	50	0.99	-1.8638	2.8938	5.6 ± 0.2
1979	50	0.93	-1.7324	2.7338	5.5 ± 0.1
1980	44	0.97	-2.0752	3.0676	5.0 ± 0.1
1981	45	0.99	-1.7265	2.7819	6.1 ± 0.1
			MATSON PARK		
1975	50	0.98	-1.9773	3.0553	6.1 ± 0.1
1976	50	0.98	-2.0808	3.1538	5.9 ± 0.1
1977	50	0.98	-1.9063	2.9846	6.2 ± 0.1
1978	50	0.99	-1.9493	3.0139	5.9 ± 0.1
1979	50	0.97	-2.0065	3.0683	5.8 ± 0.1
1980	50	0.97	-2.9412	3.9719	5.4 ± 0.1
1981	50	0.97	-1.5065	2.5786	6.6 ± 0.1
			WINKLE BAR		
1975	50	0.97	-1.9437	3.0522	6.5 ± 0.1
1976	50	0.98	-2.0486	3.1373	6.1 ± 0.1
1977	24	0.98	-1.6248	2.6477	5.8 ± 0.1
1978	50	0.99	-2.0714	3.1575	6.0 ± 0.1
1979	41	0.99	-2.2751	3.3632	5.8 ± 0.1
1980	50	0.99	-2.0661	3.1613	6.2 ± 0.1
1981	38	0.97	-1.6398	2.7389	6.8 ± 0.1

[a] *$Y = \log_{10}$ weight (g), X = fork length (cm).*

[b] *Predicted for a steelhead 8 cm in length.*

Appendix Table D-21. Regressions of weight on length for yearling steelhead seined at four sites in the Rogue River. All regressions were significant at $P < 0.001$. Results are reported only for sites where regressions could be developed for a minimum of three preimpoundment and postimpoundment years.

			Regression[a]		
Year	N	r	Intercept	Slope	Predicted mean weight (g) ± SE[b]
			HIGH BANKS		
1975	50	0.98	-1.9627	3.0015	36.9 ± 0.5
1976	31	0.99	-1.9651	3.0104	37.6 ± 0.7
1977	32	0.99	-2.0779	3.1130	38.3 ± 0.6
1978	8	0.96	-2.9159	3.7884	34.6 ± 1.3
1979	20	0.97	-2.2391	3.2176	34.7 ± 0.7
1980	43	0.97	-1.4583	2.5571	35.4 ± 0.6
1981	41	0.99	-1.8672	2.9246	37.4 ± 0.4
			ALMEDA PARK		
1975	50	0.96	-1.7414	2.8205	37.6 ± 0.7
1976	50	0.94	-1.9270	2.9749	37.3 ± 0.8
1977	18	0.88	-1.1259	2.2103	29.8 ± 1.1
1978	24	0.96	-2.3728	3.3607	38.0 ± 0.7
1979	41	0.98	-1.7338	2.8172	38.9 ± 0.4
1980	46	0.98	-2.0204	3.0695	36.6 ± 0.4
1981	12	0.98	-2.3796	3.3529	37.1 ± 0.9
			WINKLE BAR		
1975	50	0.93	-1.3937	2.5194	37.1 ± 0.7
1976	50	0.96	-2.1424	3.1686	38.4 ± 0.6
1977	50	0.95	-1.7317	2.7557	32.3 ± 0.7
1978	44	0.97	-1.7237	2.8163	38.8 ± 0.4
1979	42	0.97	-2.0604	3.1172	40.3 ± 0.6
1980	41	0.98	-2.0782	3.1262	39.7 ± 0.5
1981	50	0.92	-1.3942	2.5146	36.6 ± 0.6
			AGNESS		
1975	12	0.98	-1.7255	2.7964	36.6 ± 1.3
1976	45	0.97	-2.1604	3.1898	39.0 ± 0.7
1977	49	0.97	-2.1146	3.0916	33.2 ± 0.7
1978	50	0.97	-2.0734	3.1239	39.9 ± 0.6
1979	50	0.91	-2.1037	3.1104	34.5 ± 1.1
1981	37	0.95	-1.9337	2.9667	35.9 ± 0.8

[a] *$Y = \log_{10}$ weight (g), X = fork length (cm).*
[b] *Predicted for a steelhead 8 cm in length.*

Appendix Table D-22. Correlation matrixes for variables examined in analyses of mean weight of 8 cm steelhead in August-September as predicted from annual regressions for three sites on the Rogue River, 1975-81. Variables are described in Appendix Tables D-2, D-4, and D-20.

High Banks

	Predicted weight	Summer temperature	Summer flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	0.41	1.00			
Summer flow	-0.33	-0.69[a]	1.00		
Chinook abundance	0.36	0.78[a]	-0.81[a]	1.00	
Steelhead abundance	0.05	0.34	-0.07	0.23	1.00

Matson Park

	Predicted weight	Summer temperature	Summer flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	0.53	1.00			
Summer flow	-0.37	-0.86[a]	1.00		
Chinook abundance	-0.01	0.37	-0.15	1.00	
Steelhead abundance	-0.22	-0.51	0.37	0.18	1.00

Winkle Bar

	Predicted weight	Summer temperature	Summer flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	-0.02	1.00			
Summer flow	0.11	-0.86[a]	1.00		
Chinook abundance	-0.13	0.37	-0.15	1.00	
Steelhead abundance	0.47	-0.51	0.37	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-23. Correlation matrixes for variables examined in analyses of mean weight of 15 cm steelhead in August-September as predicted from annual regressions for High Banks and Almeda Park, 1975-81. Variables are described in Appendix Tables D-2, D-4, and D-21.

High Banks

	Predicted weight	Summer temperature	Summer flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	0.77[a]	1.00			
Summer flow	-0.84[a]	-0.72	1.00		
Chinook abundance	0.72	0.79[a]	-0.81[a]	1.00	
Steelhead abundance	0.08	0.67	-0.07	0.23	1.00

Almeda Park

	Predicted weight	Summer temperature	Summer flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	-0.67	1.00			
Summer flow	0.94[a]	-0.86[a]	1.00		
Chinook abundance	0.01	0.37	-0.15	1.00	
Steelhead abundance	0.35	-0.51	0.37	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-24. Correlation matrixes for variables examined in analyses of mean weight of 15cm steelhead in August-September as predicted from annual regressions for Winkle Bar and Agness, 1975-81. Variables are described in Appendix Table D-2, Appendix Table D-3, and Appendix Table D-21.

Winkle Bar

	Predicted weight	Summer temperature	Summer Flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	-0.83[a]	1.00			
Summer flow	0.94[a]	-0.86[a]	1.00		
Chinook abundance	0.05	0.37	-0.15	1.00	
Steelhead abundance	0.46	-0.51	0.37	0.18	1.00

Agness

	Predicted weight	Summer temperature	Summer Flow	Juvenile abundance	
				Chinook	Steelhead
Mean weight	1.00				
Summer temperature	-0.47	1.00			
Summer flow	0.65	-0.91[a]	1.00		
Chinook abundance	-0.04	-0.01	-0.09	1.00	
Steelhead abundance	0.41	-0.12	0.39	0.39	1.00

[a] $P \leq 0.05$.

Appendix Table D-25. Estimated age composition of steelhead smolts captured in two areas of the Rogue River, 1976-81.

Year	Upper river & middle river					Lower river				
	N	Age-1	Age-2	Age-3	Age-4	*N*	Age-1	Age-2	Age-3	Age-4
1976	61	16.4	78.7	4.9	0.0	62	25.8	62.9	11.3	0.0
1977	151	35.1	55.6	8.6	0.7	226	32.3	50.4	17.3	0.0
1978	137	24.1	69.3	6.6	0.0	47	0.0	72.3	27.7	0.0
1979	66	60.6	34.8	4.6	0.0	218	25.2	53.7	20.2	0.9
1980	165	18.8	69.1	12.1	0.0	86	4.7	74.4	20.9	0.0
1981	133	48.1	45.1	6.8	0.0	74	29.7	43.2	23.0	4.1

Appendix Table D-26. Estimated age at ocean entry for half-pounders and first spawning migrants that returned to the Rogue River, 1972-87 brood years.

Brood year	Half-pounders (%)				First spawning migrants (%)			
	Age-1	Age-2	Age-3	Age-4	Age-1	Age-2	Age-3	Age-4
1974	--	--	--	--	12.18	85.77	2.05	0.00
1975	11.35	85.77	2.67	0.22	34.08	61.26	4.66	0.00
1976	53.50	43.73	2.78	0.00	53.73	45.50	0.77	0.00
1977	40.26	42.24	14.83	2.67	47.22	43.53	9.26	0.00
1978	14.93	72.20	12.88	0.00	27.00	68.08	4.92	0.00
1979	20.19	77.66	2.16	0.00	38.25	61.75	0.00	0.00
1980	61.99	36.31	1.70	0.00	82.80	14.95	2.25	0.00
1981	28.55	64.95	6.50	0.00	32.75	64.81	2.44	0.00
1982	26.95	67.50	5.55	0.00	19.79	77.96	2.25	0.00[c]
1983	9.70	85.01	5.29	0.00[c]	37.83	60.17	2.00[b]	0.00
1984	30.32	66.31	3.37[a]	0.00	--	--	--	--
1985	29.17	70.44[a]	0.39	0.00	--	--	--	--
1986	67.19[a]	32.04	0.78	0.00[c]	71.41	26.59	2.00[b]	0.00[c]
1987	38.64	59.36	2.00[b]	0.00[c]	--	--	--	--

[a] *Estimated by regression analysis with age composition data of cohorts that returned as first spawning migrants.*

[b] *Assumed age-3 smolts composed 2% of brood returns.*

[c] *Assumed age-4 smolts composed 0% of brood returns.*

Appendix Table D-27. Estimated age at ocean entry among second and third spawning migrants that returned to the Rogue River, 1972-87 brood years.

Brood year	Second spawning migrants (%)				Third spawning migrants (%)			
	Age-1	Age-2	Age-3	Age-4	Age-1	Age-2	Age-3	Age-4
1972	--	--	--	--	66.86	33.14	0.00	0.00
1973	22.27	77.73	0.00	0.00	100.00	0.00	0.00	0.00
1974	20.43	67.44	12.13	0.00	0.00	100.00	0.00	0.00
1975	17.64	79.44	2.93	0.00	13.90	86.10	0.00	0.00
1976	64.17	35.83	0.00	0.00	79.05	20.95	0.00	0.00
1977	49.01	50.99	0.00	0.00	100.00	0.00	0.00	0.00
1978	39.76	60.24	0.00	0.00	65.04	34.96	0.00	0.00
1979	67.10	32.90	0.00	0.00	100.00	0.00	0.00	0.00
1980	57.35	42.65	0.00	0.00	89.37	10.63	0.00	0.00[b]
1981	27.07	68.38	4.55	0.00	31.31	68.69	0.00[b]	0.00
1982	27.58	70.43	2.00[a]	0.00[b]	--	--	--	--
1983	--	--	--	--	--	--	--	--
1984	--	--	--	--	51.01	48.99	0.00[b]	0.00[b]
1985	48.84	49.18	1.98	0.00[b]	--	--	--	--

[a] *Assumed age-3 smolts composed 2% of brood returns.*
[b] *Assumed age-4 smolts composed 0% of brood returns.*

Appendix Table D-28. Regression analysis of the percentage of age-1 smolts among first spawning migrants, 1974-81 brood years. Percentage data were transformed to logits prior to analysis.

Independent variable	Regression coefficient	Standard error	*P*
Plus-growth	0.660	0.395	0.020
Length at annulus 1	0.919	0.197	0.068
Constant	-15.74		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	6.263	2	3.132	15.35	0.007
Residual	1.020	5	0.204		

	Partial r^2	
Variables tested	Step 1	Step 2
Plus-growth	0.71	--
Length at annulus 1	0.55	0.52

Appendix Table D-29. Correlation matrix for variables examined in the analysis of the percent of first spawning migrants that entered the ocean as age-1 smolts, 1974-81 brood years. Percentage data were transformed to logits prior to analysis.

	% age-1 smolts	Length at annulus 1	Plus-growth
% age-1 smolts	1.00		
Length at annulus 1	0.73[a]	1.00	
Plus-growth	0.84[a]	0.47	1.00

[a] $P \leq 0.05$.

Appendix Table D-30. Regression analysis of the percentage of age-1 smolts among half-pounders, 1974-81 brood years. Percentage data were transformed to logits prior to analysis.

Independent variable	Regression coefficient	Standard error	*P*
Plus-growth	1.112	0.232	0.005
Length at annulus 1	0.789	0.366	0.084
Constant	-18.04		

Analysis of variance

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	4.790	2	2.395	16.23	0.006
Residual	0.738	5	0.148		

Variables tested	Partial r^2 Step 1	Partial r^2 Step 2
Plus-growth	0.74	--
Length at annulus 1	0.25	0.48

Appendix Table D-31. Correlation matrix for variables examined in the analysis of the percent of half-pounders that entered the ocean as age-1 smolts, 1975-82 brood years. Percentage data were transformed to logits prior to analysis.

	% age-1 smolts	Length at annulus 1	Plus-growth
% age-1 smolts	1.00		
Length at annulus 1	0.50[a]	1.00	
Plus-growth	0.86[a]	0.18	1.00

[a] $P \leq 0.05$.

Appendix Table D-32. Mean length (cm) at ocean entry estimated for three life history types of wild summer steelhead seined at Huntley Park, 1971-1983 brood years. Data not shown if *N* ≤ 5 or if brood year composition could not be estimated.

Brood year	95% confidence interval			
	Age-1 smolts	Age-2 smolts	Age-3 smolts	All ages
		HALF-POUNDERS		
1972	--	--	23.8 ± 3.0	--
1973	--	20.9 ± 0.9	23.5 ± 1.4	--
1974	20.5 ± 2.1	21.7 ± 0.6	26.8 ± 2.5	--
1975	19.5 ± 0.8	23.3 ± 0.7	25.9 ± 3.9	23.0 ± 0.6
1976	19.7 ± 0.5	21.6 ± 0.6	23.9 ± 2.3	20.6 ± 0.4
1977	19.5 ± 1.1	21.2 ± 0.6	23.1 ± 1.5	20.8 ± 0.5
1978	19.7 ± 0.6	22.4 ± 0.6	26.3 ± 1.5	22.5 ± 0.5
1979	20.0 ± 0.8	23.2 ± 0.5	23.4 ± 1.6	22.5 ± 0.4
1980	20.5 ± 0.5	22.6 ± 0.7	25.5 ± 2.9	21.3 ± 0.4
1981	19.5 ± 0.7	22.3 ± 0.6	25.0 ± 2.0	21.7 ± 0.4
1982	19.2 ± 0.7	22.3 ± 0.8	--	21.9 ± 0.6
1983	20.4 ± 1.0	--	--	--
		FIRST SPAWNING MIGRANTS		
1972	--	23.4 ± 2.2	22.2 ± 2.4	--
1973	--	20.6 ± 0.7	--	--
1974	19.3 ± 1.2	22.6 ± 0.9	--	22.2 ± 0.6
1975	21.1 ± 0.8	23.1 ± 2.5	22.8 ± 1.1	22.4 ± 0.5
1976	19.9 ± 0.6	21.9 ± 0.7	--	20.8 ± 0.4
1977	21.3 ± 1.0	22.6 ± 0.8	--	22.0 ± 0.6
1978	20.1 ± 0.6	21.9 ± 1.0	--	21.4 ± 0.4
1979	20.6 ± 0.5	24.0 ± 0.8	--	22.7 ± 0.5
1980	21.4 ± 0.6	23.8 ± 0.9	--	21.8 ± 0.5
1981	20.7 ± 0.6	22.3 ± 0.8	--	21.9 ± 0.6
1982	20.5 ± 0.7	--	--	--
		SECOND SPAWNING MIGRANTS		
1971	--	23.4 ± 1.5	--	--
1972	21.8 ± 0.7	22.4 ± 1.2	--	--
1973	22.3 ± 5.4	20.5 ± 1.1	--	20.9 ± 1.4
1974	--	21.4 ± 2.6	--	22.7 ± 1.7
1975	20.6 ± 3.7	21.8 ± 0.8	--	21.7 ± 0.7
1976	20.8 ± 0.8	22.2 ± 0.7	--	21.3 ± 0.5
1977	20.4 ± 1.2	23.1 ± 1.5	--	21.8 ± 0.9
1978	20.2 ± 1.2	22.5 ± 1.0	--	21.6 ± 0.7
1979	--	--	--	22.4 ± 1.9
1980	22.0 ± 1.5	22.6 ± 1.7	--	22.3 ± 1.0
1981	21.5 ± 0.8	--	--	--

Appendix Table D-33. Correlation matrix for variables examined in the analysis of the mean length at ocean entry for first spawning migrants, 1974-81 brood years. Percentage data were transformed to logits prior to analysis.

	Length at ocean entry	% age-1 smolts	Length at annulus 1	Plus-growth
Length at ocean entry	1.00			
% age-1 smolts	-0.27	1.00		
Length at annulus 1	0.26	0.74[a]	1.00	
Plus-growth	0.06	0.87[a]	0.82[a]	1.00

[a] $P \leq 0.05$.

Appendix Table D-34. Mean catch per seine haul of subyearling steelhead at sites in the Rogue River from June through October, 1975-86. Sites were not sampled in 1982-83.

	Lower river		Middle river		Canyon		Lower river		
Year	Sand Hole	High Banks	Matson Park	Almeda Park	Whiskey Bar	Winkle Bar	Agness	Hideaway	Canfield
1975	19.6	16.1	7.0	2.1	11.3	7.9	5.6	1.1	0.3
1976	32.7	115.6	11.8	7.1	36.3	13.5	3.4	0.2	0.2
1977	77.6	37.1	12.5	0.8	2.0	4.3	2.3	0.1	1.0
1978	48.8	87.7	5.6	7.7	22.4	7.1	54.4	2.0	1.1
1979	55.2	45.8	15.8	6.2	10.6	5.9	11.4	0.4	0.2
1980	33.8	23.9	11.2	4.5	66.2	9.9	1.4	0.1	0.2
1981	14.5	48.2	29.7	2.2	39.5	9.8	8.4	0.3	0.1
1984	--	--	10.7	2.4	17.4	0.9	--	--	--
1985	--	--	58.6	7.1	33.1	0.6	--	--	--
1986	--	--	135.8	5.1	29.2	3.7	--	--	--

Appendix Table D-35. Correlation matrix for variables examined in the analysis of the abundance indexes for subyearling steelhead that reared in five areas of the Rogue River, 1975-86. Variables are described in Appendix Tables D-34 and D-36.

	Upper river	Middle river	Canyon	Lower river	Savage Rapids Dam
Upper river	1.00				
Middle river	-0.04	1.00			
Canyon	-0.19	0.05	1.00		
Lower river	0.39	-0.11	-0.15	1.00	
Savage Rapids Dam	0.62	-0.25	0.09	0.72	1.00

Appendix Table D-36. Estimated number of juvenile steelhead that passed Savage Rapids Dam from 14 May through 30 September, 1976-90.

Year	Subyearlings	Yearlings	Age-2+ smolts
1976	242,695	31,632	2,422
1977	9,673	15,305	7,670
1978	337,706	11,699	3,741
1979	134,697	61,109	1,235
1980	115,245	14,790	4,404
1981	58,644	40,117	35,982
1982	96,710	14,432	20,518
1983	30,410	40,905	9,244
1984	180,899	11,535	3,633
1985	51,502	61,723	34,163
1986	113,694	33,567	23,945
1987	140,348	26,654	11,877
1988	226,501	40,060	15,246
1989	331,148	16,787	1,527
1990	113,022	41,419	5,040

Appendix Table D-37. Data used to assess factors related to the annual catch rate of subyearling steelhead seined in the Rogue River, 1975-86. Sites were not sampled in 1982-83.

	Abundance		Flow	
Year	Subyearling[a]	Parent[b]	Spawning[c]	Migration[d]
1975	--	--	157	76
1976	6.9	--	78	19
1977	17.2	8,096	17	31
1978	4.9	20,561	119	26
1979	10.7	28,166	92	68
1980	9.6	23,786	131	26
1981	23.0	14,207	47	18
1984	--	8,829	108	41
1985	7.9	15,328	65	16
1986	24.8	30,975	154	32

[a] *Mean catch per seine haul at sites in the middle river and in the canyon (Appendix Table D-34).*

[b] *Estimated freshwater return of wild late-run adult summer steelhead in the previous year.*

[c] *Mean flow (cfs) of Grave Creek in January-March.*

[d] *Mean flow (cfs) of Grave Creek in May.*

Appendix Table D-38. Correlation matrix for variables examined in the analysis of the annual catch per seine haul of subyearling steelhead caught at sites in the middle river and in the canyon, 1975-86. Variables are described in Appendix Table D-37.

	Abundance		Flow	
	Subyearling	Parent	Spawning	Migration
Subyearling abundance	1.00			
Parent abundance	0.46	1.00		
Spawning flow	0.30	0.16	1.00	
Migration flow	-0.43	0.02	0.43	1.00

Appendix Table D-39. Mean catch per seine haul of yearling steelhead at sites in the Rogue River from June through October, 1975-86. Sites were not sampled in 1982-83.

Year	Sand Hole	High Banks	Matson Park	Almeda Park	Whiskey Bar	Winkle Bar	Agness	Hideaway	Canfield
1975	0.4	6.0	2.1	3.3	25.4	6.2	7.6	0.7	0.8
1976	0.2	4.9	1.6	1.7	20.3	9.0	14.8	2.2	2.8
1977	0.3	2.5	8.6	2.8	9.1	28.2	27.9	4.5	48.7
1978	0.1	2.1	0.2	1.9	6.4	2.5	14.9	2.1	6.1
1979	0.2	7.6	1.0	3.7	8.1	9.1	16.4	6.6	10.3
1980	0.0	6.4	1.6	1.8	6.1	6.2	13.0	1.1	5.0
1981	0.2	8.2	3.1	0.8	7.8	3.9	9.5	0.6	3.4
1984	--	--	0.5	2.4	6.5	0.8	--	--	--
1985	--	--	7.5	5.8	28.0	4.6	--	--	--
1986	--	--	2.5	3.9	18.7	4.8	--	--	--

Appendix Table D-40. Correlation matrix for variables examined in the analysis of abundance indexes for yearling steelhead that reared in the Rogue River, 1975-86.

	Upper river	Middle river	Canyon	Lower river	Savage Rapids Dam
Upper river	1.00				
Middle river	-0.28	1.00			
Canyon	-0.28	0.77[a]	1.00		
Lower river	-0.51	0.85[a]	0.52	1.00	
Savage Rapids Dam	0.75[a]	0.40	0.29	-0.19	1.00

[a] $P \leq 0.05$.

Appendix Table D-41. Data used to assess factors related to annual catch rates of yearling steelhead seined in the Rogue River, 1975-86. Sites were not sampled in 1982-83.

	Abundance			Flow	
Year	Yearling[a]	Subyearling[b]	Parent[c]	Summer[d]	Peak[e]
1975	9.2	--	--	1,674	30,000
1976	8.2	6.9	--	1,598	17,900
1977	12.6	17.2	--	1,646	1,950
1978	2.8	4.9	8,096	1,105	40,300
1979	5.5	10.7	20,561	2,025	12,700
1980	4.0	9.6	28,166	2,005	26,900
1981	4.1	23.0	23,786	1,571	9,820
1984	2.6	--	28,867	2,570	27,600
1985	11.4	7.9	8,829	2,849	19,000
1986	7.5	24.8	15,328	2,159	27,800

[a] *Mean catch per seine haul at sites in the middle river and in the canyon (Appendix Table D-39).*
[b] *Mean catch per seine haul at sites in the middle river and in the canyon during the previous year (Appendix Table D-34).*
[c] *Estimated freshwater return of wild late-run adult summer steelhead in the previous year.*
[d] *Peak flow (cfs) at Grants Pass in the previous winter.*
[e] *Mean flow (cfs) at Grants Pass in July-September of the previous year.*

Appendix Table D-42. Correlation matrix for variables examined in the analysis of the annual catch rates of yearling summer steelhead seined in the Rogue River, 1975-86. Variables are described in Appendix Table D-41.

	Abundance			Flow	
	Yearling	Subyearling	Parent	Summer	Peak
Yearling abundance	1.00				
Subyearling abundance	0.04	1.00			
Parent abundance	-0.55	0.34	1.00		
Summer flow	0.16	0.12	0.17	1.00	
Peak flow	-0.44	-0.37	-0.30	-0.12	1.00

Appendix Table D-43. Mean catch per seine haul of age-2+ steelhead smolts at sites in the Rogue River from April through May, 1975-81.

Year	Upper river + middle river[a]	Lower river[b]
1975	1.0	0.2
1976	0.3	3.5
1977	2.4	11.2
1978	0.5	0.6
1979	0.2	3.3
1980	1.5	2.0
1981	0.7	1.7

[a] *High Banks, Matson Park, and Almeda Park.*
[b] *Agness, Hideaway, and Canfield.*

Appendix Table D-44. Estimated number of wild subyearling and yearling steelhead that passed Savage Rapids Dam weekly from 14 May through 1 July, 1974-90. Week-of-year calendar is in **APPENDIX A**.

	Week-of-year						
Year	20	21	22	23	24	25	26
				SUBYEARLINGS			
1974	--	--	--	--	--	--	--
1975	--	--	2,148	--	--	--	3,831
1976	2,800	11,788	30,477	13,114	13,233	31,926	11,218
1977	0	157	307	4,228	1,003	650	96
1978	9,619	34,314	14,043	24,899	28,341	14,445	17,619
1979	13,948	1,686	5,665	3,153	4,868	70,671	9,272
1980	2,396	2,866	6,660	27,894	24,650	19,044	8,952
1981	7,353	1,280	11,512	7,700	4,339	10,683	3,334
1982	0	1,750	10,420	7,807	29,254	23,516	14,887
1983	0	0	9,545	5,642	4,742	3,043	728
1984	0	6,545	13,472	14,783	15,972	67,908	19,272
1985	0	1,537	5,600	8,091	19,959	5,592	535
1986	623	5,213	35,130	32,430	6,367	3,991	1,553
1987	1,791	2,494	12,179	11,070	10,800	11,656	5,443
1988	12,328	19,331	98,824	18,875	26,889	16,834	3,124
1989	6,580	25,740	75,696	118,213	22,869	15,217	4,753
1990	858	29,572	24,641	13,981	8,442	15,606	2,435
				YEARLINGS			
1974	--	--	--	--	--	--	--
1975	--	--	10,739	--	--	--	2,483
1976	2,600	2,126	2,477	6,943	7,202	1,419	1,391
1977	262	3,493	6,735	3,074	220	45	77
1978	1,836	1,338	500	1,288	1,444	1,711	504
1979	11,910	30,044	3,662	3,431	1,716	2,217	1,929
1980	835	1,252	2,927	901	1,075	1,189	1,952
1981	5,628	4,917	4,964	7,588	2,945	2,571	1,966
1982	1,131	1,556	1,523	2,381	2,302	532	1,183
1983	9,639	12,886	9,068	5,485	474	659	381
1984	0	2,864	1,981	1,796	1,627	1,027	399
1985	1,006	11,576	8,244	13,045	8,961	7,583	3,419
1986	3,203	5,213	5,753	4,234	3,172	2,177	1,848
1987	1,531	2,494	2,265	5,860	2,936	2,607	1,463
1988	2,906	5,772	19,224	1,000	6,101	1,121	587
1989	3,920	2,460	1,304	1,711	966	1,039	725
1990	933	5,455	7,706	13,052	1,513	4,296	1,606

Appendix Table D-45. Estimated number of wild subyearling and yearling steelhead that passed Savage Rapids Dam weekly from 2 July through 19 August, 1974-90. Week-of-year calendar is in **APPENDIX A.**

	Week-of-year						
Year	27	28	29	30	31	32	33
				SUBYEARLINGS			
1974	0	0	0	226	258	96	90
1975	1,412	11,526	1,895	1,436	581	484	159
1976	11,267	5,204	3,421	2,293	29,213	25,908	45,333
1977	61	71	219	54	82	118	216
1978	83,495	23,042	22,272	10,042	2,637	1,790	2,023
1979	5,476	2,000	2,496	5,287	2,402	2,100	244
1980	4,044	2,805	2,746	2,736	2,090	1,267	862
1981	3,523	1,402	1,104	1,057	565	799	740
1982	2,561	1,709	1,282	757	287	233	412
1983	2,329	683	800	0	0	154	213
1984	10,000	5,940	1,551	4,065	6,976	4,520	4,109
1985	267	142	744	396	307	992	2,070
1986	4,992	2,428	2,786	1,004	3,742	4,999	2,575
1987	3,765	4,831	16,864	30,558	6,738	5,000	3,572
1988	1,177	1,048	4,990	2,755	3,309	4,212	4,894
1989	11,649	4,848	3,092	3,223	3,196	5,828	6,292
1990	1,174	1,212	2,360	2,481	2,161	1,221	1,274
				YEARLINGS			
1974	0	0	0	388	149	36	0
1975	706	2,668	256	321	242	114	38
1976	1,470	262	107	127	2,311	1,080	1,828
1977	94	78	83	33	21	45	30
1978	1,716	616	73	106	0	75	0
1979	2,676	864	158	521	216	305	162
1980	1,614	623	343	257	306	181	81
1981	2,367	959	543	273	293	333	393
1982	1,889	717	244	126	72	500	0
1983	153	184	0	119	0	0	170
1984	250	120	119	135	144	0	130
1985	1,241	616	744	53	461	175	900
1986	2,134	1,293	1,316	705	531	391	481
1987	1,088	1,273	1,153	583	117	53	0
1988	313	278	578	295	454	135	251
1989	705	596	551	342	192	282	160
1990	1,217	743	1,030	498	716	215	152

Appendix Table D-46. Estimated number of wild subyearling and yearling summer steelhead that passed Savage Rapids Dam weekly from 20 August through 30 September, 1974-90. Week-of-year calendar is in **APPENDIX A.**

	Week-of-year					
Year	34	35	36	37	38	39
			SUBYEARLINGS			
1974	80	18	36	29	18	0
1975	162	134	118	14	229	38
1976	3,138	808	116	399	821	218
1977	400	418	371	265	687	270
1978	4,150	14,886	8,019	9,133	12,404	533
1979	508	216	1,080	1,847	731	1,047
1980	841	671	1,615	587	534	1,985
1981	602	258	503	864	930	96
1982	281	294	286	333	290	351
1983	237	906	880	97	155	256
1984	1,819	1,479	656	479	752	601
1985	1,533	1,297	982	523	479	456
1986	2,003	1,259	306	638	1,403	252
1987	6,131	3,141	2,327	687	881	420
1988	2,967	1,327	958	1,357	1,074	228
1989	1,687	7,550	6,596	5,492	2,122	505
1990	2,272	1,107	543	383	743	556
			YEARLINGS			
1974	11	18	0	0	0	0
1975	37	41	32	0	54	15
1976	46	40	77	12	22	92
1977	167	340	109	69	94	236
1978	0	0	86	103	303	0
1979	44	259	159	489	138	209
1980	0	68	186	179	209	612
1981	241	353	204	1,263	973	1,343
1982	0	53	48	0	121	54
1983	356	227	469	0	155	480
1984	520	99	0	0	145	179
1985	467	543	302	448	571	1,368
1986	114	0	0	40	710	252
1987	73	90	108	215	1,929	816
1988	46	92	106	146	531	124
1989	169	0	90	345	638	592
1990	444	454	407	85	284	613

Appendix Table D-47. Data used to assess factors related to the migration timing of juvenile steelhead that passed Savage Rapids Dam, 1976-90.

Year	Migration timing		Water temperature[b]	Flow[c]	Steelhead abundance		Chinook abundance[d]
	Fry[a]	Yearlings[a]			Fry[d]	Yearlings[d]	
1976	29.6	67.4	12.9	4,009	243	32	1,295
1977	58.9	90.0	15.2	1,538	10	15	1,306
1978	33.0	54.7	14.3	2,296	338	12	140
1979	21.8	83.1	13.8	4,862	135	61	2,032
1980	56.0	47.3	14.2	2,639	115	15	250
1981	81.0	80.6	15.7	2,014	59	40	794
1982	50.9	61.7	14.1	3,662	97	14	133
1983	65.6	91.9	12.6	5,357	30	41	332
1984	28.0	71.7	12.5	5,587	181	12	87
1985	68.4	69.4	14.4	2,810	52	62	731
1986	70.1	64.1	13.8	3,262	114	34	1,848
1987	27.4	56.6	15.0	1,958	140	27	2,154
1988	77.7	87.4	--	2,619	227	40	5,335
1989	75.3	61.9	--	4,334	331	17	1,883
1990	68.7	69.3	--	2,503	113	41	2,807

[a] *Estimated percent that passed Savage Rapids Dam by 17 June.*
[b] *Mean maximum water temperature (°C) at Grants Pass in May.*
[c] *Mean flow at Grants Pass in May.*
[d] *Estimated passage (thousands) at Savage Rapids Dam, 14 May to 30 September.*

Appendix Table D-48. Correlation matrixes for variables examined in analyses of the migration timing of juvenile steelhead that passed Savage Rapids Dam, 1976-90. Variables are described in Appendix Table D-47.

	Migration time		Water temperature	Flow	St. abundance		Chinook abundance
	Fry	Yearlings			Fry	Yearlings	
Fry migration	1.00						
Yearling migration	0.26	1.00					
Water temperature	0.36	-0.09	1.00				
Flow	-0.28	0.18	-0.89[a]	1.00			
Fry abundance	-0.26	-0.42	-0.28	0.15	1.00		
Yearling abundance	0.18	-0.45	0.01	0.09	-0.34	1.00	
Chinook abundance	0.29	0.31	0.26	-0.23	0.20	0.35	1.00

[a] $P \leq 0.05$.