EFFECTS OF LOST CREEK DAM ON COHO SALMON IN THE ROGUE RIVER. PHASE II COMPLETION REPORT.

Rogue Basin Fisheries Evaluation Project
Research and Development Section

Oregon Department of Fish and Wildlife

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CONTENTS

CONTENTS (continued)

FOREWORD

This report is the culmination of 12 years of research funded by the U.S. Army Corps of Engineers. 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 impetus for research on coho salmon and for analyses contained in the report. Barry McPherson supervised the project and critically reviewed the analyses, conclusions, and recommendations in the final document. This report is the first of a series of completion reports planned for anadromous salmon and steelhead stocks produced in the Rogue River basin.

Research on coho salmon was primarily an outgrowth of more intensive studies of chinook salmon and steelhead populations that began in the Rogue River in 1973. 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.

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October 31, 1989

SUMMARY

In this report, we evaluate the effects of Lost Creek Dam on coho salmon *Oncorhynchus kisutch* in the Rogue River. Field sampling began in 1975 and ended in 1986. 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. Freshwater returns of wild fish averaged about 800 age 2 jacks and about 3,600 age 3 adults annually. Landings of wild fish of Rogue basin origin in the ocean fisheries averaged about 2,700 fish annually.

2. We did not detect any influence of Lost Creek Dam or Cole M. Rivers Hatchery on the return of wild adults to areas upstream of the counting station at Gold Ray Dam.

3. Freshwater returns of hatchery fish averaged about 800 jacks and 3,200 age 3 adults annually after the program for coho salmon at Cole M. Rivers Hatchery reached production goals of about 200,000 smolts. Annual landings of hatchery fish in the ocean fisheries averaged about 3,600 fish during the same period.

4. Anglers harvested few coho salmon in the Rogue River. During 1979-86, freshwater harvest averaged about 40 wild and 200 hatchery fish annually.

5. Construction of Lost Creek Dam blocked little, if any, spawning habitat used by coho salmon.

6. Flow during autumn affected the migration timing of adults that passed Gold Ray Dam. Adults migrated earlier during years of high flow and later during years of low flow.

Juveniles

1. We did not detect any influence of Lost Creek Dam on the production of wild juveniles. Juveniles reared in tributaries, primarily within the Illinois River basin, rather than in the Rogue River.

2. The area upstream of Grants Pass produced few wild juveniles. Annual yields of wild smolts averaged 1,200 fish during 1976-80 and 6,400 fish during 1981-86. Increased smolt production in later years was probably the result of hatchery fish that strayed to spawn naturally.

3. Yearlings migrated downstream during May through early July. Analyses of scales taken from returning adults indicated that all juveniles entered the ocean as yearlings.

4. Flow during the spring affected the migration timing of yearlings that passed through the middle river. Juveniles migrated earlier during years of low flow and later during years of high flow.

Effects of Reservoir Operation

Effects of reservoir operation on coho salmon were minimal because (1) few juveniles reared in the mainstem and (2) juveniles and adults migrated at times when reservoir operation had little influence on water temperature and flow in downstream areas.

RECOMMENDATIONS

Reservoir Management and Operation of Lost Creek Dam

Management strategies for the operation of Lost Creek Dam should be directed to species other than coho salmon. The Rogue River is critical habitat for steelhead and chinook salmon, but is only important to coho salmon when yearlings migrate to the ocean during the spring and when adults migrate upstream during autumn. Strategies for reservoir management during 1978-86 did not appear to affect the migration timing of yearling or adult coho salmon.

Management and Evaluation of Fishery Resources

The following recommendations are directed 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 recommendations.

1. The utility of using estimates of seining efficiency, as developed for coho salmon, should be evaluated as a means to estimate the freshwater escapement of summer steelhead and fall chinook salmon. If reasonable estimates can be developed for other species, we recommend the clipping of left ventral fins from 100,000 yearling coho salmon scheduled for release at Cole M. Rivers Hatchery (**APPENDIX A**). The expanded marking program should continue as long as seining at Huntley Park is expected to be conducted during the succeeding year. Implementation of this recommendation would improve estimates of seining efficiency and result in more reliable estimates of freshwater escapement for summer steelhead, fall chinook salmon, and coho salmon.

2. The distribution of juvenile coho salmon rearing in the Rogue River basin should be determined. Although the basin produces significant numbers of wild fish, the location of important spawning and rearing habitat is not well documented. Surveys of subyearlings during July through September may be the most effective and economical method to identify important habitat. The Illinois River basin should receive first priority for surveys, because it appears to produce most of the wild fish (see **Abundance**, page 29). Agencies responsible for management of state and federal lands should cooperate in joint surveys of fish and habitat resources.

3. The Illinois River basin should be managed exclusively for wild fish, at least until results of surveys proposed in Recommendation 2 can be evaluated.

4. Outplanting of juvenile and adult coho salmon from Cole M. Rivers Hatchery to areas downstream of Gold Ray Dam should be discontinued at least until results of surveys proposed in Recommendation 2 can be evaluated. Surveys of juveniles suggested that few wild fish spawn in streams upstream of the Illinois River (*see* **Abundance**, page 29). Outplanting of excess hatchery fish may compromise remnant populations of wild fish with unique genetic resources.

5. Wild adults should be periodically included among broodstock spawned at Cole M. Rivers Hatchery to maintain genetic diversity within the hatchery population. If available, use coho salmon that return to the base of Elk Creek Dam. Collection of wild adults in other areas upstream of Gold Ray Dam may be difficult because of low abundance. A geneticist should develop guidelines for including wild broodstock in the hatchery program.

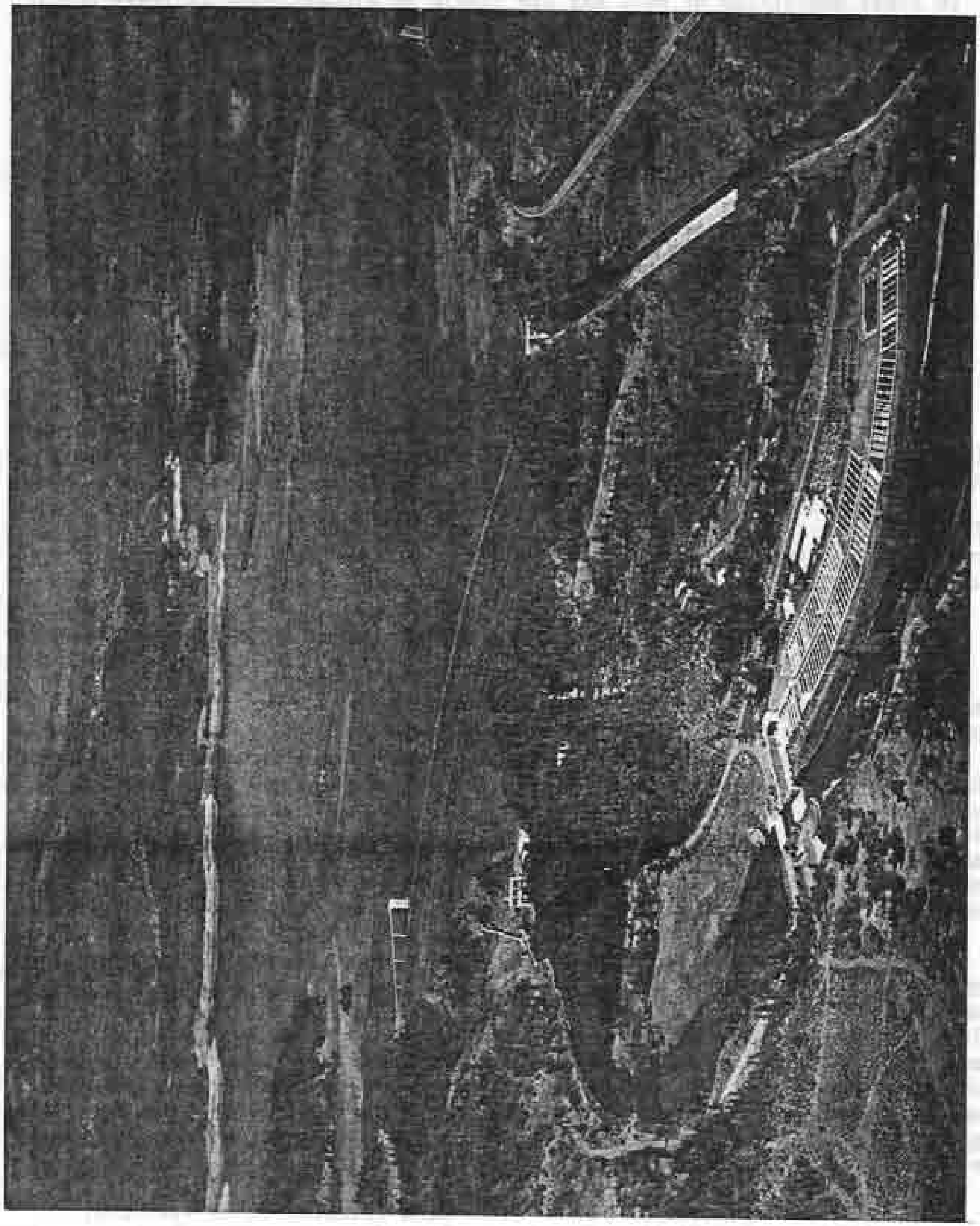
INTRODUCTION

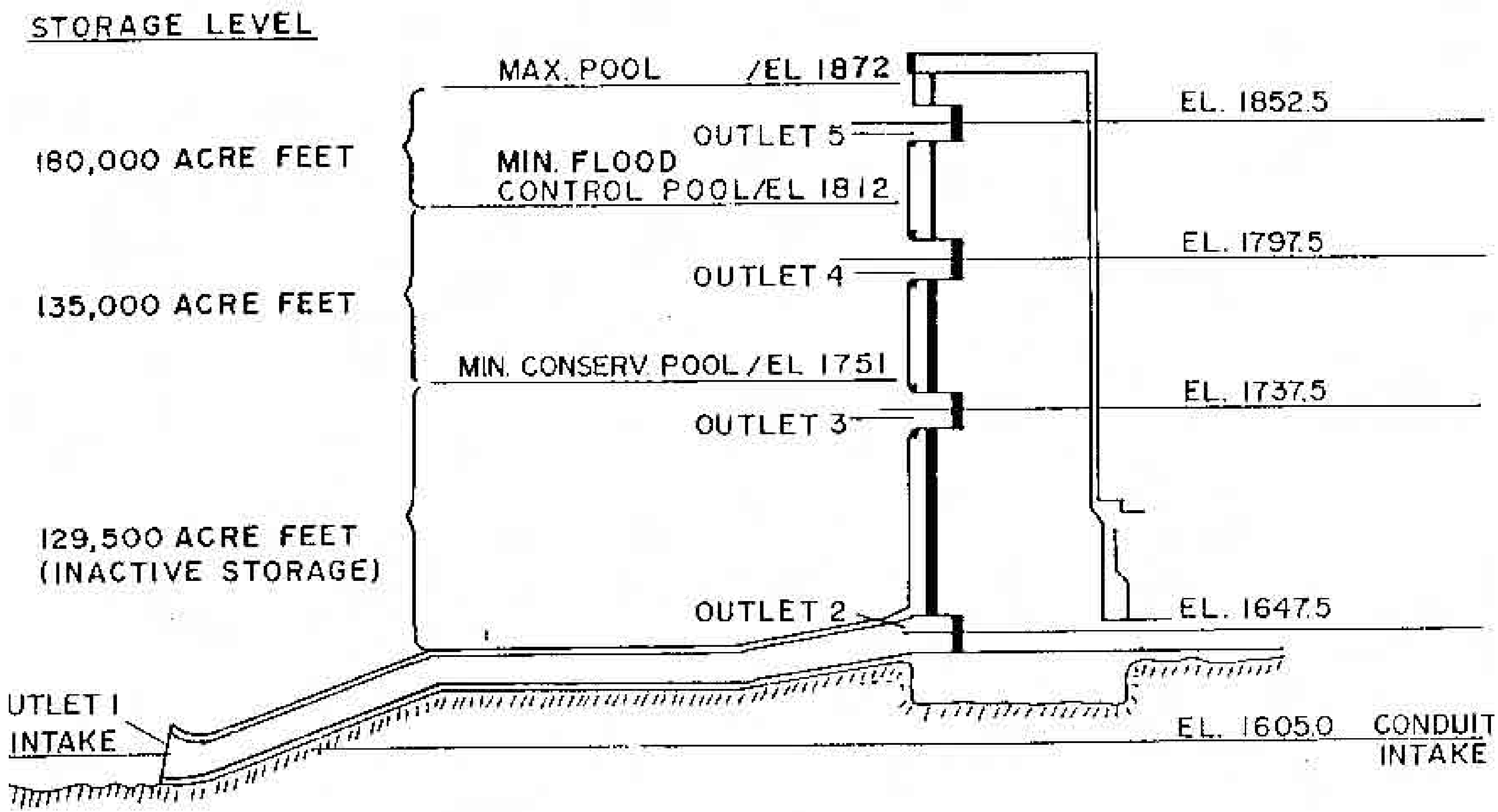
This report presents the findings for 12 years (1975-86) of work with coho salmon *Oncorhynchus kisutch* in the Rogue River basin of southwestern Oregon. The Oregon Department of Fish and Wildlife (ODFW) conducted this study, funded by the United States Army Corps of Engineers (USACE), to (1) determine the effects of Lost Creek Dam on anadromous fish 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 the construction of Lost Creek Dam at river kilometer (RK 254) (Figure 1) 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 that 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 *Oncorhynchus* spp. and steelhead *O. mykiss* blocked or inundated by the dam was to be mitigated by releases of fish reared at Cole M. Rivers Fish Hatchery (RK 252). Benefits to anadromous fish in downstream areas were expected to accrue by operating the dam to (1) decrease peak flow during the winter, (2) increase flow during the summer, and (3) decrease water temperature during the summer.

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

Guidelines for release of stored water were intended to be flexible, reflecting the annual variation in water yield and user demand. During years when the reservoir fills, 180,000 acre-feet of storage is available for flow augmentation (USACE 1972). Of this total, 125,000 acre-feet was authorized for fishery enhancement (United States Congress 1962). The remaining 55,000





Schematic of the multipoint intake structure for water withdrawal from five levels within Lost acre-feet of storage was dedicated to other uses: irrigation supply, municipa and industrial supply, and environmental enhancement. Dedicated storage that is not purchased is also available for downstream enhancement of fishery resources (USACE 1972).

Flood control was identified 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. "No storage specifically for wildlife enhancement, power generation, water quality control, or recreation" was identified (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 that 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, 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 in releases for fisheries benefits was far-sighted because biologists are rarely accurate with predictions of postproject responses. Lack of accuracy is the result 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 influence of water temperature, flow, and turbidity on the biology and harvest of wild and hatchery coho salmon in the Rogue River basin. Preliminary findings from this work were reported in numerous annual progress reports and were summarized by Cramer et al. (1985).

Historically, coho salmon were an important fishery resource in the Rogue River basin. Cobb (1930) reported that canneries on the Rogue River packed more coho salmon than chinook salmon *O. tshawytscha* during some years in the early 1900s. However, coho salmon were of lesser economic importance compared with chinook salmon. Packing records indicate that coho salmon averaged about 34% of the cases of salmon shipped from canneries near Gold Beach during 1892-1914. Since that time, the production of wild fish has greatly decreased in the Rogue River basin.

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

STUDY AREA

The Rogue River basin encompasses 13,150 square kilometers of southwestern Oregon and a small portion of northwestern California (Figure 3).

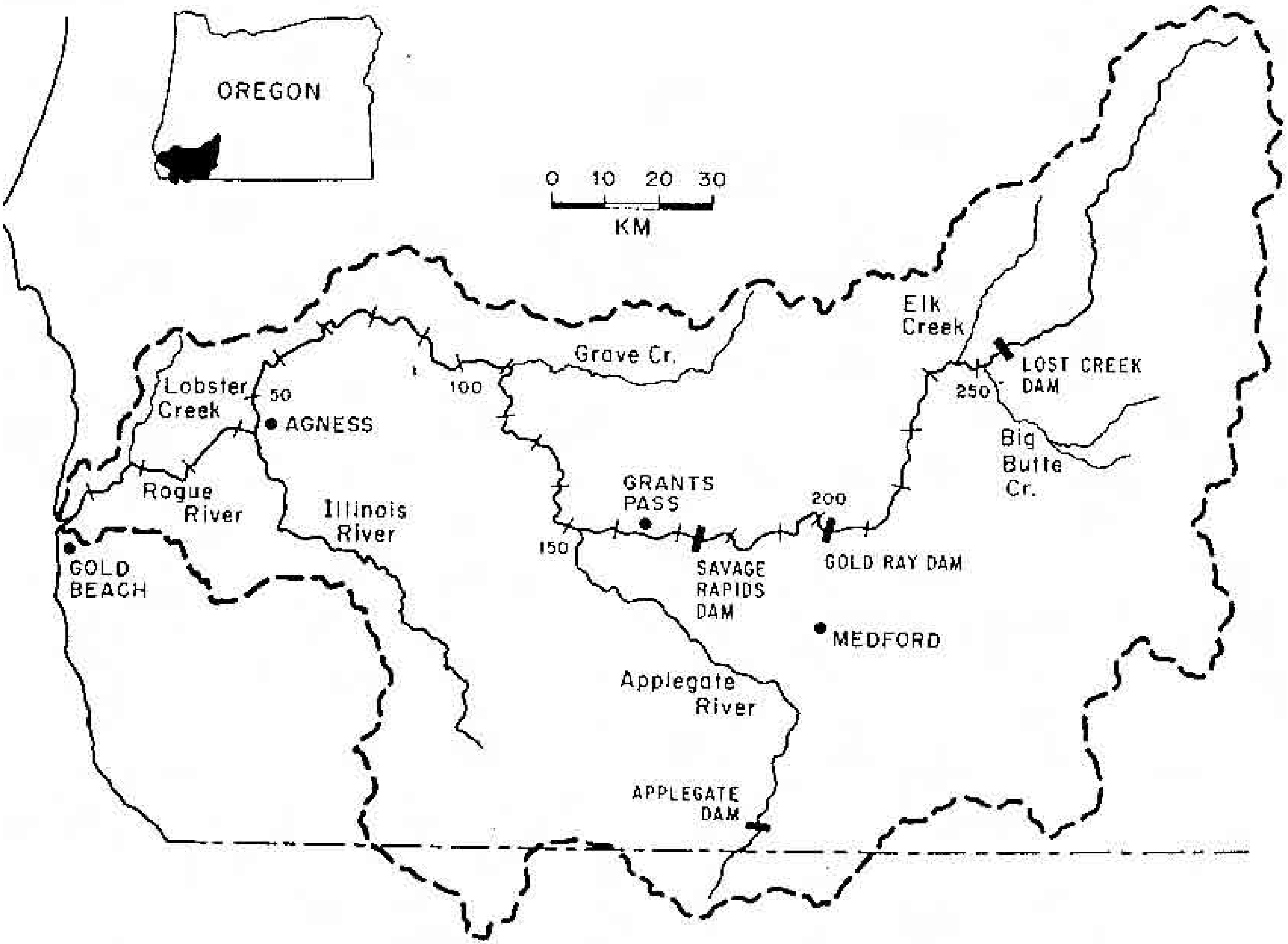


Figure 2. Map of the Rogue River basin. Numbers indicate kilometers from the river mouth.

Approximately 13% of the basin is upstream of Lost Creek Dam. The Rogue River originates in the Cascade Mountains and flows west, breaching the Coast Range 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 river kilometers (RK) 44 and 154, respectively.

The estuary of the Rogue River is relatively small, covering an area of about 630 acres at mean high tide. Ratti (1979) reported that 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 Rogue River 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 operation during February 1977 and affects flow in the Rogue River. Applegate Dam, at RK 75 on the Applegate River, began operation during November 1980 and affects flow in the Rogue River downstream of Grants Pass. Operation of Applegate Dam has a lesser effect on flow in the Rogue River because the normally used storage capacity of Applegate Lake is one-third that of Lost Creek Lake.

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

In the lower portion of the basin, river flow varies markedly between seasons. Discharge upstream of the mouth of the Illinois River averages 1,400 cfs during September and 26,600 cfs during 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 between April and June, when the snowpack in the Cascade Mountains melts at a rapid rate.

Weather patterns in the northeast Pacific greatly affect weather 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 during July and August. During December and January, air temperature usually peaks between 8°C and 10°C. Snow accumulates at the higher elevations during the winter and is the principle source of water yield during the spring and 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 (OWRD 1985). About 50% of the precipitation falls from November through January; less than 2% falls during July and August.

A large number of anadromous fish inhabit the Rogue River basin. Chinook salmon and steelhead are the most abundant salmonids. Coho salmon are common 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 northern squawfish *Ptychocheilus oregonensis* 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 254-202). The middle river refers to the area between Gold Ray Dam and Grave Creek (RK 202-110). The canyon refers to the area between Grave Creek and Agness (RK 110-44). The lower river refers to the area between Agness and the estuary (RK 44-6). Gradient in the upper river averages 2.3 m/km, in the middle river averages 1.6 m/km, in the canyon averages 2.4 m/km, and in the lower river averages 0.7 m/km.

APPROACH

We chose not to use the instream flow incremental methodology to develop 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 (Moyle and Baltz 1985; Mathur et al 1985; Irvine et al. 1987). Our work centered primarily upon assessing the biological implications of modifications in flow, water temperature, and turbidity. During the planning of the study, changes in these physical factors were expected to be significant in the area of the river inhabited by coho salmon.

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 coho salmon.

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

4. Determine the effects of Lost Creek Dam and develop operational criteria as related to the recreational and commercial harvest of coho salmon.

We used two avenues to meet the objectives. First, we compared biologic parameters of coho salmon that inhabited the Rogue River before and after full operation of the dam was started. Second, we estimated the relationship 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.

Temporal comparisons were of some use. Sampling conducted prior to full operation of the dam provided information on the interannual variability within life history parameters. Sensitivity analyses after the first years o the study led to termination of work with algal and invertebrate communities. High variability among the data indicated a low probability of associating an changes in production or community structure with the operation of the dam. Initial sampling indicated life history parameters of coho salmon exhibited less variability.

However, temporal comparisons had some limitations. Given the expected variability, many years of data are required to make effective comparisons. We had only 7 years of returns for adults that reared as juveniles during the postimpoundment period. Although the dam was operational in 1977, low water yield resulted in little water for flow augmentation. Storage releases had little effect on physical factors in downstream areas. Consequently, we treated data from 1978 as the first postimpoundment year.

Comparisons of conditions during preimpoundment and postimpoundment periods were susceptible to influences from sources other than the treatment. Data are not independent of each other. For example, weather patterns differed before and after full operation began at Lost Creek Dam. Water yiel from the basin was highly variable during preimpoundment years and was low during the first postimpoundment years. We were aware of the potential for this type of bias, and, when a change was observed, we attempted to identify the responsible factor(s).

Identification of factors responsible for changes in biological parameters was approached by correlation and regression analysis. We reviewe the literature for background information on causative relationships among biological and physical factors. Factors that appeared most important were included as independent variables in regression analyses. We used regression analysis to estimate relationships between biological and physical factors.

METHODS

Physical Factors

The United States Geological Survey (USGS) operated automated gages at numerous sites in the Rogue River basin during the study. USACE personnel used empirical data from the Rogue River basin to adapt a water quality model for estimating the effects of the 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 30 September 1986 for flow and January 1978 through December 1986 for water temperature and turbidity. The model produced estimates of daily means for physical factors at six automated gages operated by the USGS (Table 1). The operation of Lost Creek Dam affected water quality and quantity at all gages. After November 1980, operation of Applegate Dam affected physical parameters in the Rogue River at the two gages downstream of the Applegate River

Table 1. Stations with water quality parameters simulated by the USACE.

Station	River kilometer	Parameter simulated
Near McLeod	249	Flow, water temperature, and turbidity
Dodge Bridge	224	Flow, water temperature, and turbidity
Raygold	203	Flow, water temperature, and turbidity
Grants Pass	165	Flow, water temperature, and turbidity
Marial	78	Water temperature and turbidity
Agness	48	Flow

We used modeling results to estimate the effects of dam operations on water quality and quantity in downstream areas used by anadromous fish. 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

Age at Return

Coho salmon smaller than 50 cm were classified as age 2 jacks. Larger fish were classified as age 3 adults, except during 1983 when samplers used 45 cm to differentiate jacks and adults. To ensure that jacks and adults were appropriately identified in the field, personnel measured all fish and sampled for scales during 1979, 1983, and 1986. Samplers removed scale samples from a maximum of 35 fish within each 5 cm size interval. Each sample comprised about 20 scales. Scales were taken from the first four rows immediately above the lateral line and immediately posterior of the dorsal fin. Four of the larger, nonregenerated scales of regular shape were mounted on gummed cards and impressed on acetate strips at 100°C under 5,000 psi for 3 minutes.

Scales were read at a magnification factor of 88. Readers recorded freshwater and saltwater annuli, and classified the sample as having originated from a hatchery or from a wild fish. ODFW personnel specializing in interpretation of scales from coho salmon assisted with classification. Errors, if present, would be consistent among run years because only one reader interpreted scales of returning adults.

Abundance

We seined in the lower river at Huntley Park (RK 13) during 1976-86 to index the freshwater escapement of coho salmon. Seining began in early July and continued through late October. Samplers seined 3-5 days weekly, and effort ranged between 7 and 18 seine sets daily. The time of sampling also varied between years. During 1976, crews seined between 0900 and 1700 hours. During subsequent years, crews began seining 30 minutes after sunrise, and almost always completed sampling by 1300 hours. All fish were measured and examined for fin clips.

Personnel used a quick sinking, 300 ft beach seine with stretch mesh varying from 2 inches for the center panel to 5 inches for a wing panel. The depth of the seine was 18 ft in the bag and tapered to 9 ft on the outside edge of the wing panels.

We estimated freshwater escapement of wild fish based on the capture rat (seining efficiency) of coho salmon of hatchery origin. We estimated seining efficiency by comparing the seine catch of adipose clipped (Ad-marked) adults with the estimated freshwater escapement of Ad-marked adults. Freshwater escapement of Ad-marked coho salmon was estimated as the sum of (1) returns t Cole M. Rivers Hatchery, (2) freshwater harvest, (3) prespawning mortality, and (4) strays that spawned naturally. A detailed description of the method can be found in **APPENDIX A**.

In the upper river, passage of coho salmon at Gold Ray Dam (RK 204) has been estimated by fishery agencies of the state of Oregon since 1942. Passin adults are counted 8 hours daily, 5 days weekly, except when the counting facility is inoperable because of floods. Partial counts were designed to estimate biweekly escapement 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 underwate viewing window. The counter recorded all fin clips and classified migrants according to body length. During 1942-76, coho salmon smaller than 51 cm (20 inches) were classified as age 2 jacks. During 1977-86, the counter classified coho salmon smaller than 60 cm (24 inches) as jacks.

Ocean Harvest

We used data from juvenile coho salmon marked with coded-wire tags and released from Cole M. Rivers Hatchery to estimate landings of wild and hatchery fish in the ocean fisheries. We used data from experimental groups of tagged fish that most closely reflected the size at release and release time of untagged production groups released from the hatchery. Noncatch mortality did not need to be considered because we only estimated landings in the fisheries. In addition, we assumed that an average of 15% of the adults that entered the river did not return to the hatchery. The estimate of 15% was derived from estimates of average harvest in freshwater, prespawning mortality, and natural spawning (**APPENDIX A**). Finally, we assumed that wild and hatchery fish contributed at the same rate, per recruit, to the ocean fisheries.

However, tagged juveniles that originated from Cole M. Rivers Hatchery did not begin to contribute to the ocean fisheries until 1980. To estimate harvest in earlier years, we compared catch/escapement data for the Oregon Production Index (OPI) with catch/escapement data for releases from Cole M. Rivers Hatchery (Table 2). We found the two variables to be positively correlated ($P = 0.025$), provided data from the 1978 brood year was subjectively excluded as an outlier (Figure 4). We used regression analysis to estimate the relationship between variables, and catch/escapement data from the OPI to predict catch/escapement data for coho salmon of Rogue River origin, 1973-76 brood years.

Table 2. Data used to estimate the ratio of ocean catch to freshwater escapement for wild coho salmon produced in the Rogue River basin.

Brood year	Tag Code[a]	Number released	Freshwater escapement[b]	Ocean catch[c]	Catch/escapement CRH[d]	OPI[e]
1973	--	--	--	--	7.09[f,g]	9.65
1974	--	--	--	--	7.74[f,g]	10.54
1975	--	--	--	--	3.73[f]	5.04
1976	--	--	--	--	3.21[f]	4.33
1977	07 17 58	25,982	510	664	1.30	3.04
1978	07 20 02	27,134	1,467	2,235	1.52	5.70
1979	07 23 27	13,021	140	431	3.08	2.04
1980	07 25 44	24,984	94	403	4.29	5.74
1981	07 26 25	23,433	540	139	0.26	0.59
1982	07 28 54	27,149	333	178	0.53	1.03
1983	07 30 11	26,479	543	178	0.33	0.56

[a] *Data from experimental releases that were most similar in size and migration timing to production groups.*
[b] *Age 3 fish only. Estimated by expansions of returns to Cole M. Rivers Hatchery.*
[c] *Age 3 fish only. Estimates received 5 May 1989 from Michael Evenson, ODFW, Cole M. Rivers Hatchery.*
[d] *Applicable to releases from Cole M. Rivers Hatchery (CRH).*
[e] *Applicable to stocks composing the Oregon Production Index (OPI).*
[f] *Estimated by regression analysis, 1978 data excluded as an outlier.*
[g] *Estimates are out of the range of data included in the regression.*

Freshwater Harvest -

We used harvest estimates from salmon-steelhead cards returned to ODFW from 1976-86 to estimate the monthly and annual harvest of coho salmon in the Rogue River. Because of angling regulations, no adults were harvested in tributary streams. Anglers were required to record the harvest of coho salmon larger than 51 cm (20 inches) prior to 1977. Beginning in 1977, the size criteria increased to 60 cm (24 inches). Harvest estimates of coho salmon were not available prior to 1975.

We estimated harvest rates from a combination of harvest estimates from salmon-steelhead cards and the estimated escapement of adults that were larger than the size of fish required to be recorded on the salmon-steelhead cards. We assumed contribution rates to the river fishery were similar for smaller fish (age 2 jacks).

We assumed that catch estimates derived from salmon-steelhead cards were an unbiased estimate of the harvest of coho salmon in the Rogue River. This assumption may be erroneous because the adjustment factor for a nonresponse bias is only applicable on a statewide basis (Hicks and Calvin 1964).

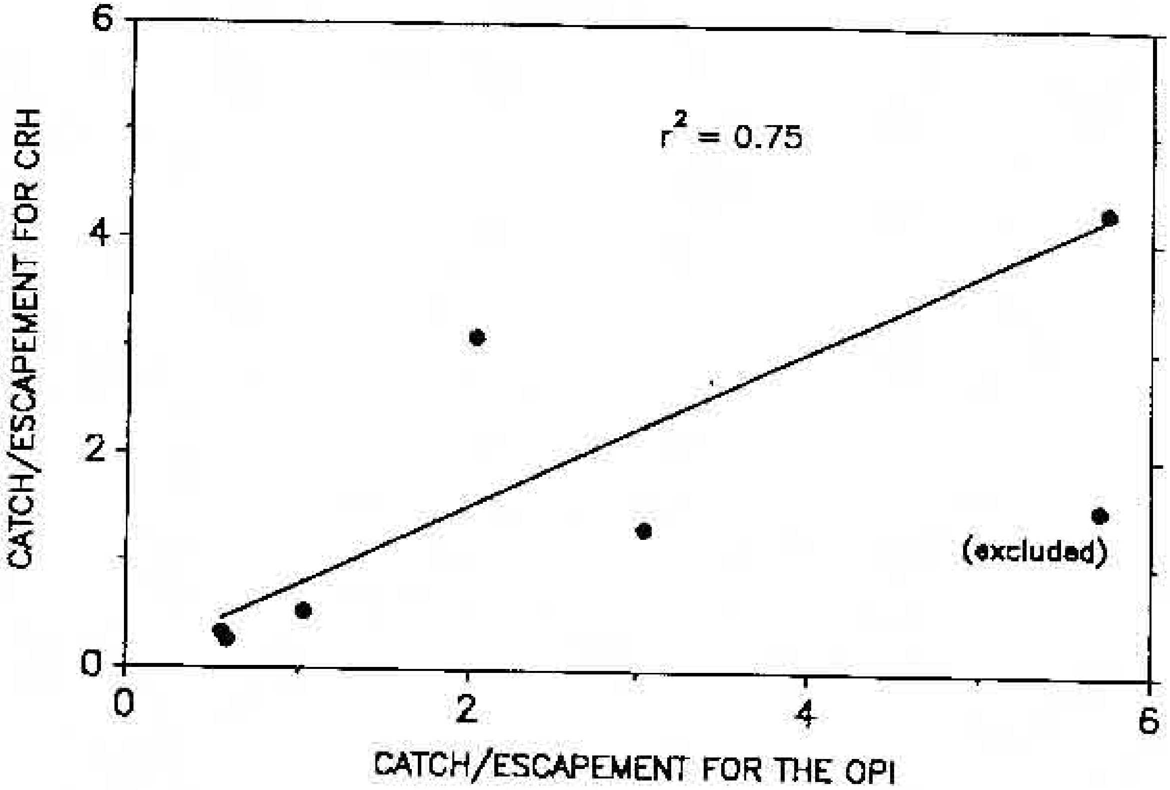


Figure 4. Relationship between catch to escapement ratios for coho salmon reared at Cole M. Rivers Hatchery (CRH) and stocks composing the Oregon Production Index (OPI), 1977-83 brood years. Data from the 1978 brood year excluded as an outlier.

However, because the Rogue River is fished by a large number of anglers from throughout the region, we believe that catch estimates from salmon-steelhead cards provide an unbiased, but not necessarily precise, estimate of harvest.

While surveying anglers that fished for summer steelhead during 1976-81, personnel observed that coho salmon also contributed to these fisheries. From 1 August-15 October, we surveyed anglers that fished between Claybanks (RK 7) and Lobster Creek (RK 18). During 1 September-31 October, we surveyed anglers that fished between Agness (RK 43) and Foster Bar (RK 55), and boat anglers that floated between Grave Creek (RK 110) and Foster Bar.

During angler interviews, 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. Fish retained by anglers were identified by species, classified as jacks or adults based on fork length, and examined for identifying marks. Larger coho salmon were classified as adults. Hatchery fish were differentiated from wild fish based on fin clips. When fish were landed but not retained, anglers were queried about the number, species, and size of fish released. Survey clerks assumed that anglers relayed accurate information about released fish. Within both surveys, clerks worked 8 hours daily, 5 days weekly. Survey days were randomly selected.

Prespawning Mortality

Sampling crews surveyed the Rogue River canyon biweekly from 1 August through 15 October during 1975-86, except crews surveyed weekly during period of high mortality for fall chinook salmon. Crews also surveyed weekly in the middle river and in the lower river during 1975-81. All carcasses were examined for identifying marks, sexed, and were classified as age 2 jacks or older adults.

To avoid counting the same carcasses more than once, samplers cut carcasses in two during 1975-79. In 1979, personnel conducted a study to evaluate the need for this procedure. Results indicated that carcasses of fall chinook salmon disappeared or decomposed quickly during the late summer and early fall. Consequently, during 1980-86, crews did not cut carcasses ir two, but counted only those carcasses that appeared fresh dead, or on which the majority of the flesh was present.

Juveniles

We seined juvenile coho salmon in the Rogue River at 12 sites downstrean of Lost Creek Dam, at 2 sites in the estuary, and in 2 tributary streams (Table 3). Upstream of Agness, crews used a 50 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 x 8 ft floating seine with 1/4-inch square mesh. In the estuary, crews seined one site with a 350 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 eact 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. At times, crews made additional sets to meet sample requirements for lengths anc weights.

Samplers also operated irrigation bypass traps at Table Rock (RK 209) ar 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 Rapic Dam fished 5 nights weekly from early May through the end of September durinc 1976-86. Juveniles diverted from an 800 cfs withdrawal were captured in a bypass trap screened with 1/4-inch square mesh.

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). Unmarked coho salmon larger than 14 cm were classified as hatchery fish. During each trip, samplers measured the fork lengths, to the nearest 0.1 cm, of 30 juveniles from each age class. Samplers also weighed a maximum of 25 yearlings, to the nearest 0.1 g, monthly at each site.

We used the date of first capture at each site as an index of first emergence of coho salmon fry from gravel redds. We judged emergence to be complete on the date when, thereafter, the mean length of fry continuously exceeded 3.9 cm.

Table 3. Sites seined for juvenile coho salmon in the Rogue River basin, 1975-86.

Location	River kilometer	Time period	Frequency of sampling	Years
Rogue River:				
Sand Hole	252	Jan-Oct	weekly	1975-82
High Banks	206	Jan-Oct	weekly	1975-81
Valley of the Rogue	183	Jan-Oct	weekly	1976-81
Matson Park	148	Jan-Oct	weekly	1975-81
Almeda Bar	116	Jan-Oct	weekly	1975-81
Whiskey Bar	105	Apr-Sep	biweekly	1975-81
Winkle Bar	85	Apr-Sep	biweekly	1975-81
Illahe	56	Apr-Sep	biweekly	1975-81
Agness	44	Mar-Oct	weekly	1975-81
Hideaway	24	Mar-Oct	weekly	1975-81
Canfield	8	Mar-Oct	weekly	1975-82
Estuary:				
Mail Boat Point	3	Apr-Oct	weekly	1975-81
Coast Guard	1	Apr-Oct	weekly	1975-82
Tributaries:				
Applegate River	1	Jan-July	weekly	1975-86
Illinois River	1	Mar-Oct	weekly	1975-81

Abundance

We made no attempt to develop population estimates for subyearlings that reared in the Rogue River. We assumed that annual catch rate from seining operations was a reliable index of year class strength. To be reliable, variation in year class strength should account for a predominant amount of variation in the annual catch rate of seined juveniles. Annual changes in site morphology, sampling efficiency, and fish behavior should account for little variation in annual catch rate.

We used catch per trap hour in the irrigation bypass facilities as an index of the abundance of subyearlings and yearlings. We also developed weekly estimates of the number of yearlings 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. (1989), 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 probably resulted in a relatively large amount of error within passage estimates. In addition, the assumption of similar trap efficiencies for yearling coho salmon and subyearling chinook salmon 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 (Release 4.1). 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. In general, we used $P \leq 0.05$ as the criteria for statistical significance. However, if sample sizes were small, we used $P \leq 0.10$. We referred to Snedecor and Cochran (1967) and Zar (1984) for analytical procedures.

Parametric methods most commonly used included analysis of variance, correlation analysis, and regression analysis. We used analysis of variance to test for differences between the means of preimpoundment and postimpoundment variables and to test for differences between means of life history parameters among age classes. 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 to detect a change.

To identify relationships among variables, we used correlation analysis and assumed data were independent observations and errors were normally distributed. We also used correlation analysis primarily to evaluate potential multicollinearity among independent variables considered for inclusion in regression analyses. Percentage or proportional data were logit transformed prior to analysis.

To quantify relationships between dependent and independent variables, we used regression analysis. Independent variables were assumed to be measured without error. This may be a reasonable assumption for measurements of physical factors (flow, upwelling, etc.), but is certainly erroneous for some biological data. Associated errors were probably smallest for life history parameters reported as means (length at ocean entry, scale measurements, etc.). Estimates or indexes of fish abundance probably contain some major sources of error, particularly where numerous assumptions and steps were required to derive the data. However, because abundance is of key importance to this evaluation, and other analytical procedures may be less robust, we used regression analysis to test for factors that affected abundance. Independent variables were included in regression analyses only when our previous findings (Cramer et al. 1985) or other literature identified variables as probable causal factors associated with the dependent variable.

Finally, we used predictive regression analysis to estimate the relationship between values of the dependent variable and values of the independent variables. This procedure minimizes the sums of squares for the vertical distances of points from the regression line. Both Ricker (1973) and Jensen (1986) recommend use of predictive regression rather than functional regression if the objective is prediction rather than quantitative description of functional relationships. We do not propose any of the regressions as functional relationships. We chose to use predictive regression because our primary objective was to predict the response of dependent variables to variations in independent variables.

RESULTS AND DISCUSSION

Physical Factors

In 1988 USACE personnel simulated flow, water temperature, and turbidity for regulated (with dams) and unregulated (without dams) conditions during 1978-86. In this section of the report, we summarize some of the findings that are directly relevant to the production and harvest of coho salmon in the Rogue River.

Flow

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

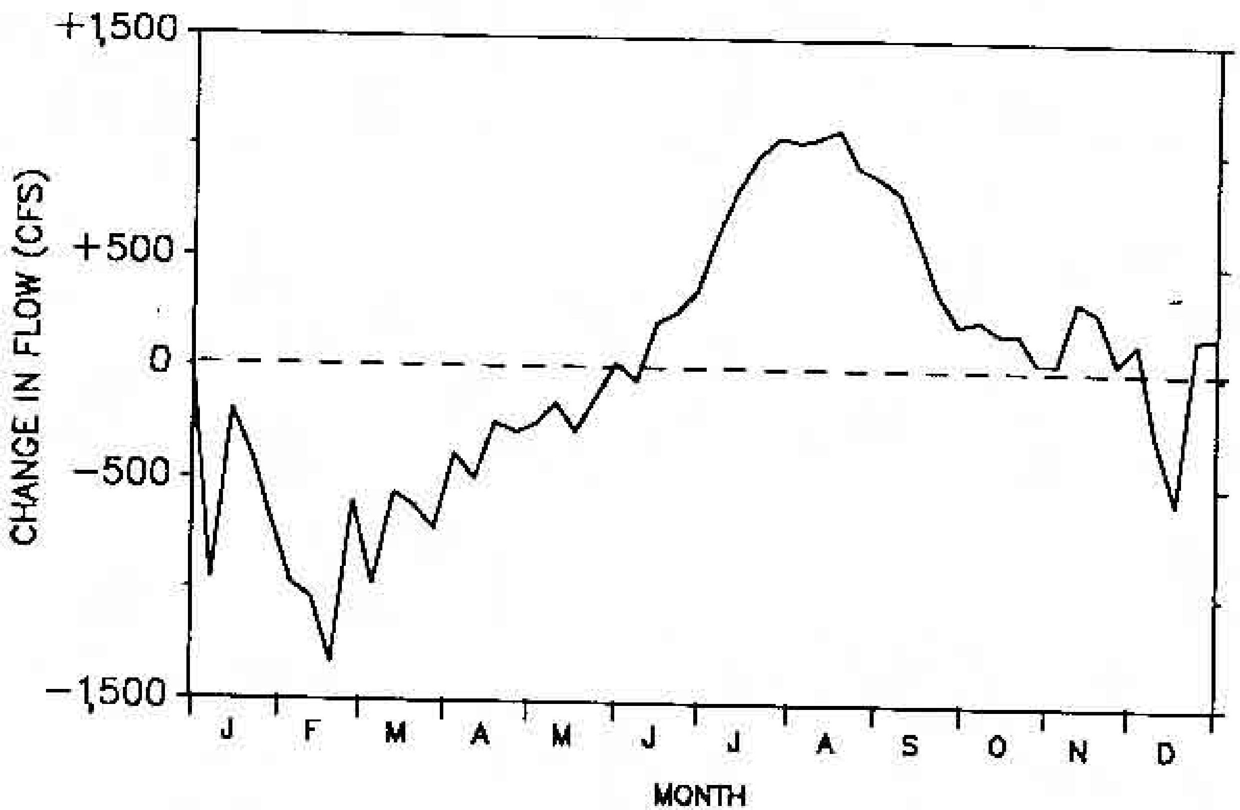


Figure 5. Change in mean weekly flow caused by the operation of Lost Creek Dam, 1978-86. The zero-line represents unregulated flow (inflow = outflow).

On a proportional basis, effect decreased with distance downstream from Lost Creek Dam (Figure 6). At Raygold, regulated flow generally ranged between 3,000 and 5,000 cfs during January through April. Downstream at Agness, regulated flow usually ranged between 7,000 and 10,000 cfs during the same time period. As tributary flow declined during the late spring and early summer, flow in the lower river became similar to flow in the upper river.

Water Temperature

Throughout the river, water temperature increased during November-January, and decreased during June-September (Figure 7). Effect on water temperature diminished with distance downstream from Lost Creek Dam. Operation of the dam increased average water temperature at Raygold and Marial by about 1.5°C and 1.0°C during November-January. At the thermal peak during the summer, operation of the dam reduced average water temperature at Raygold and Marial by 3.5°C and 3.2°C.

Turbidity

The operation of Lost Creek Dam generally reduced turbidity in downstream areas. At Grants Pass, regulation reduced average turbidity by 5-8 Jackson Turbidity Units (JTU) and 1-2 JTU during April-June and July-October (Figure 8). Operation of the dam did not appreciably influence turbidity during peaks in flow. Tributary streams increased the turbidity in the mainstem, particularly when flow increased after periods of high precipitation.

Adults

Age at Return

Lengths of adults seined at Huntley Park suggested that coho salmon matured after one or two summers in the ocean. A length of 50 cm appeared to be a good criteria for differentiating the two age groups of adults, except during 1983 (Appendix Table B-1) when adults returned at smaller sizes, probably because of slower growth caused by unusual ocean conditions during El Niño (Johnson 1988).

Scale samples indicated that 45 cm was an appropriate criteria for differentiating age 2 and age 3 coho salmon during 1983. Van Dyke and Wood (1984) found that 46 cm was a good criteria to separate jacks and adults returning to other hatcheries on the Oregon coast during 1983. In other years, 50 cm was a more accurate division. Use of these length criteria resulted in correct classification of the ages of all 38 adults seined in 1979, 25 of 26 adults seined in 1983, and 111 of 112 adults seined in 1986.

Abundance

Annual returns of coho salmon to Gold Ray Dam fluctuated between about 100 and about 9,500 fish during 1942-86 (Figure 9). Except for possible strays from hatcheries outside of the basin, only wild adults returned until the mid-1970s. Releases of hatchery-reared coho salmon began in 1976

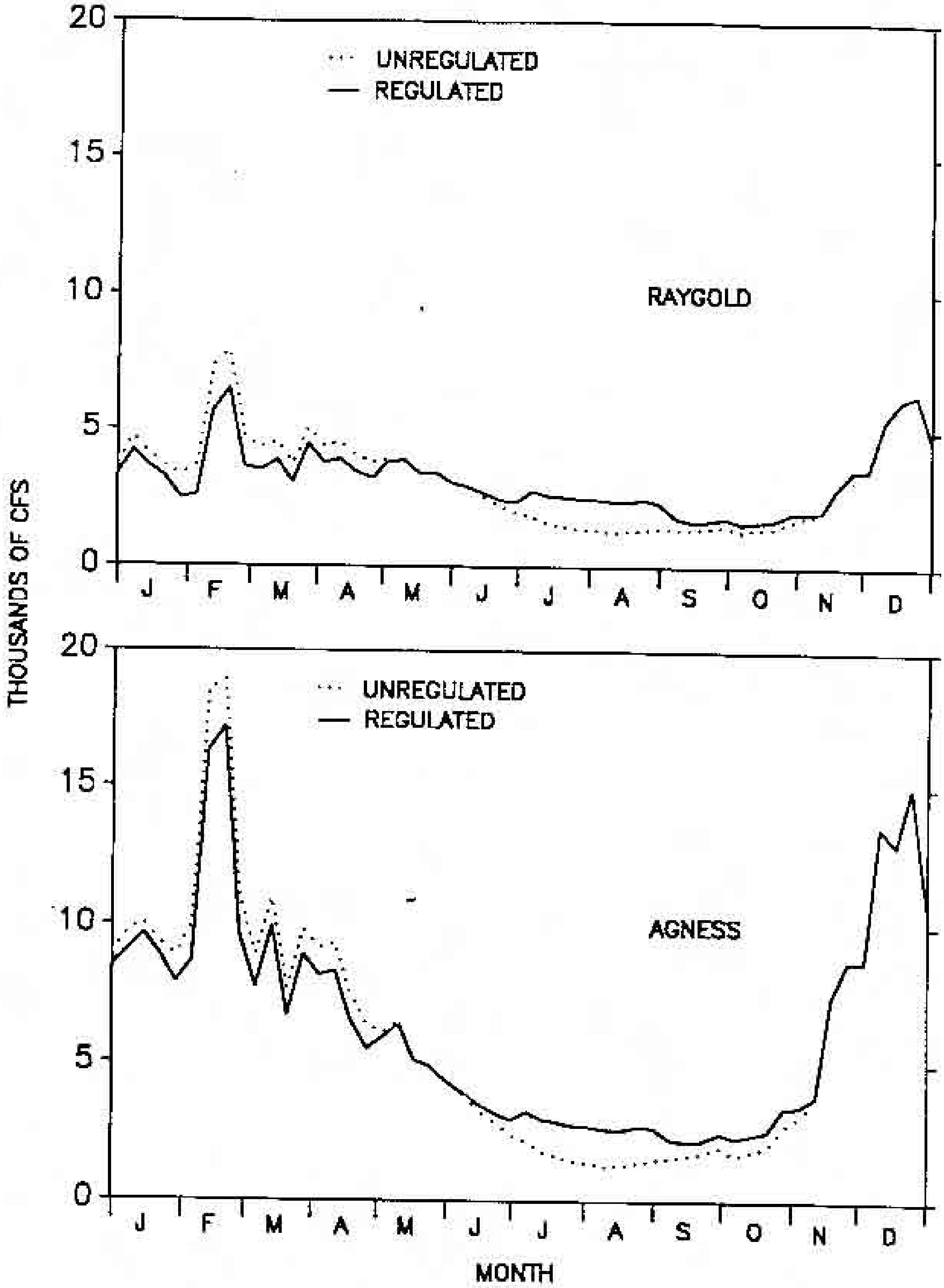


Figure 6. Mean weekly flow in the upper river at Raygold, and in the lower river at Agness, simulated for regulated and unregulated conditions, 1978-8

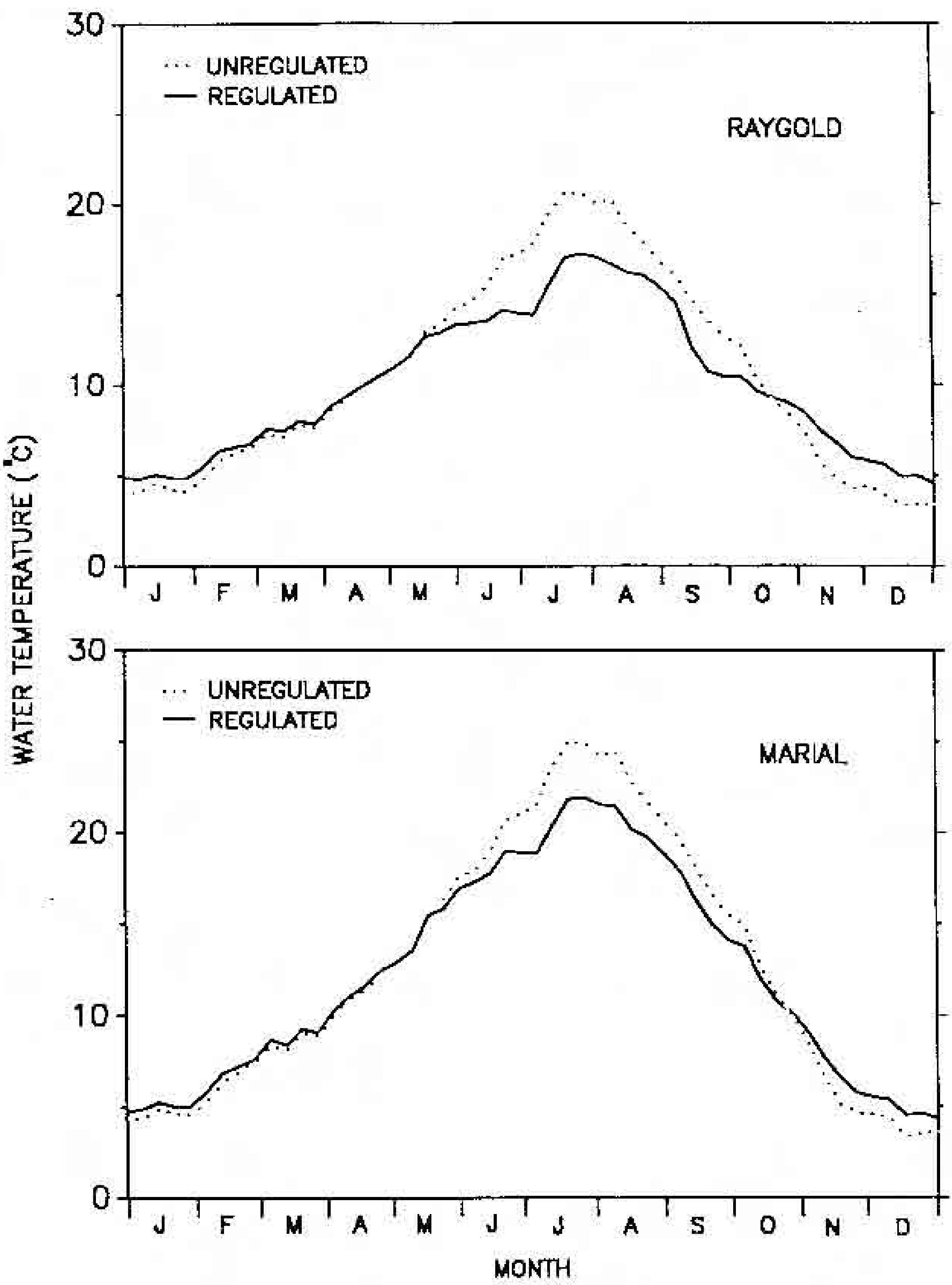


Figure 7. Mean weekly water temperature in the upper river at Raygold, and i the Rogue River canyon at Marial, simulated for regulated and unregulated conditions, 1978-86.

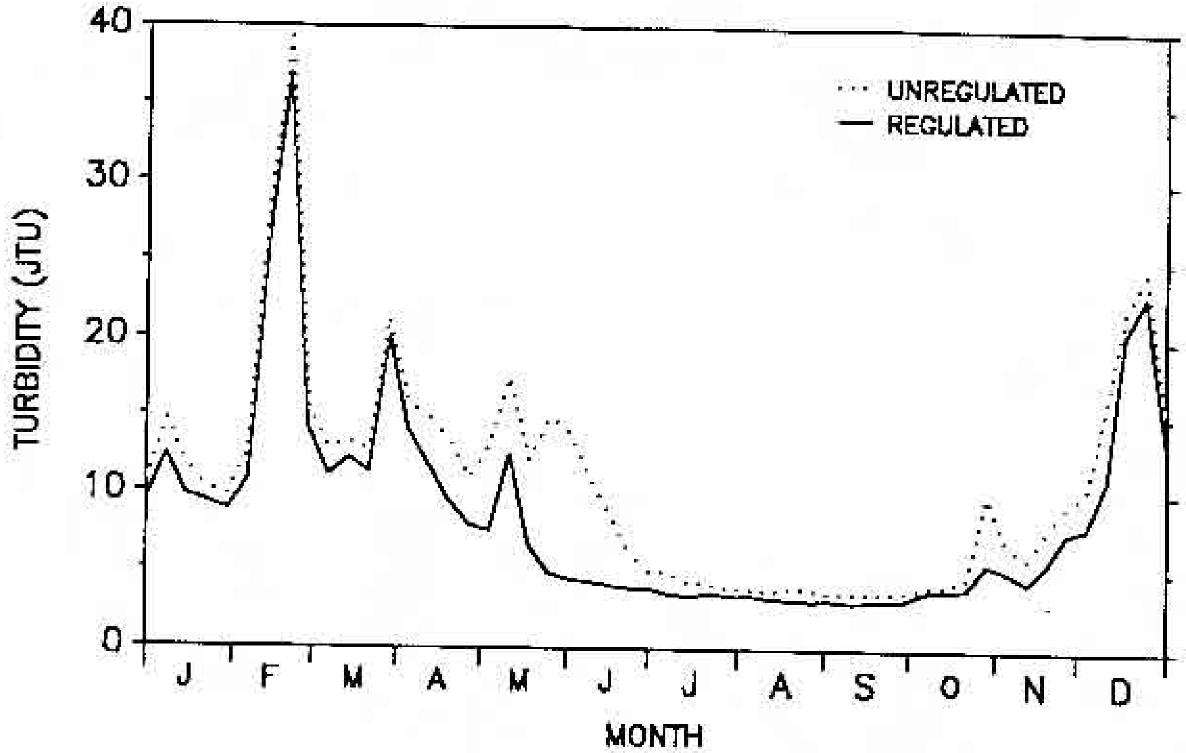


Figure 8. Mean weekly turbidity (Jackson Turbidity Units) in the middle rivi
at Grants Pass, simulated for regulated and unregulated conditions, 1978-86.

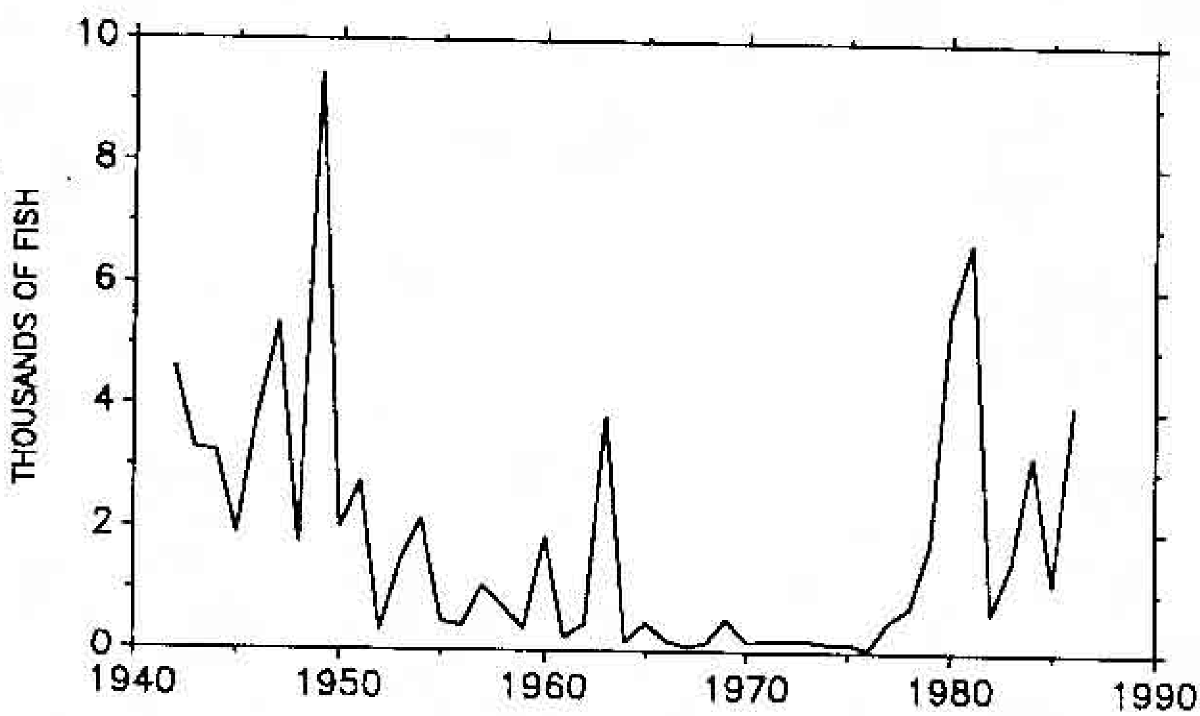


Figure 9. Estimated number of coho salmon that passed Gold Ray Dam, 1942-86.
Jacks and adults combined.

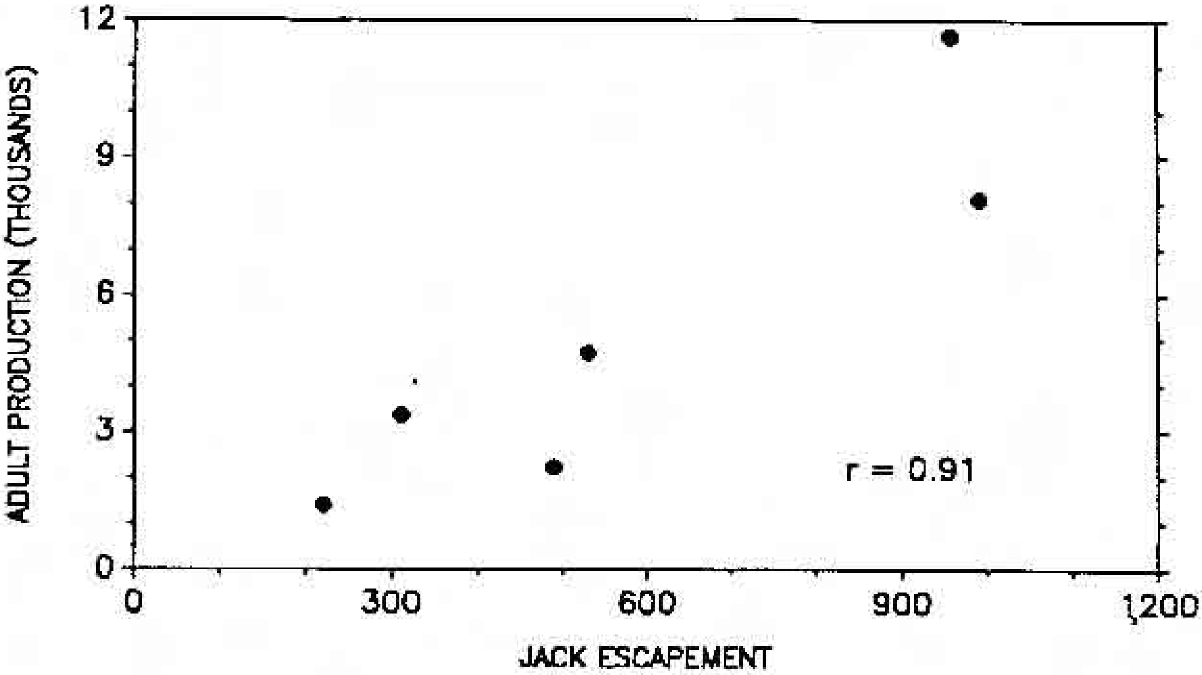


Figure 10. Relationship between freshwater escapement of wild age 2 jacks and the production (ocean catch plus freshwater escapement) of age 3 cohorts one year later. Brood years affected by El Niño excluded.

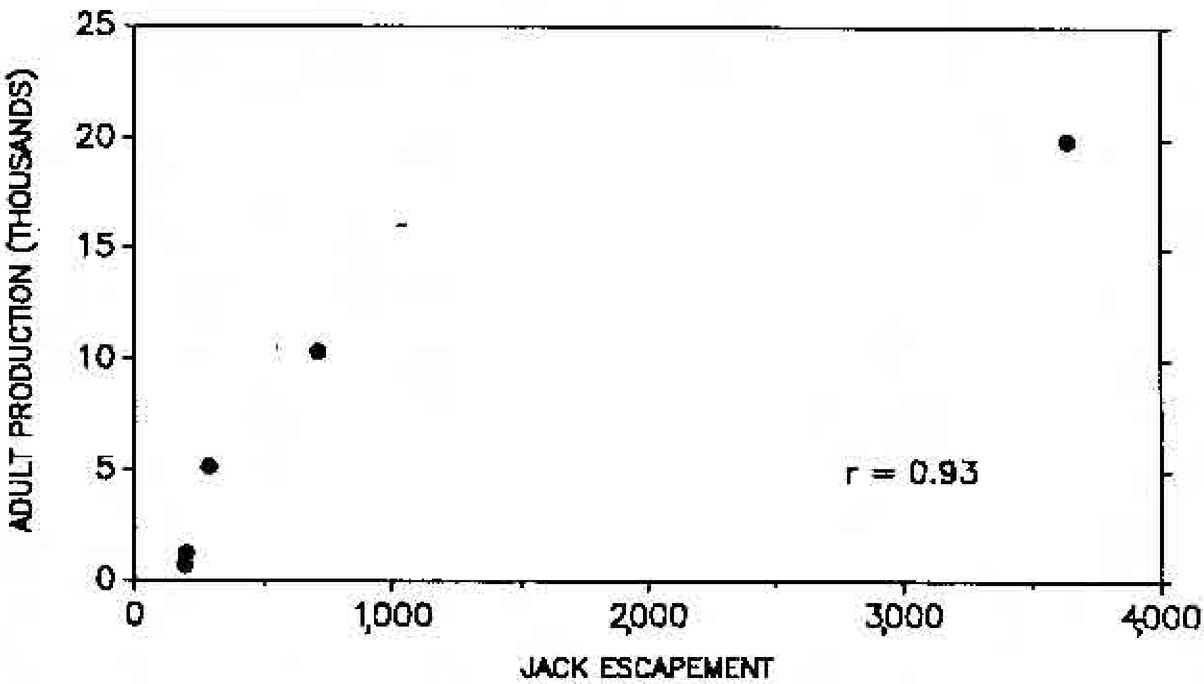


Figure 11. Relationship between freshwater escapement of age 2 jacks of hatchery origin and the production (ocean catch plus freshwater escapement) of age 3 cohorts one year later. Brood years affected by El Niño excluded.

(Appendix Table B-2). Returns of wild fish to Gold Ray Dam averaged about 4,200 fish annually during the 1940s. However, average returns declined to fewer than 200 fish during 1964-76 (Appendix Table B-3). We suspect that returns of wild fish to the upper river remained low in succeeding years.

Decreased returns of wild coho salmon to the Rogue River upstream of Gold Ray Dam were not necessarily the result of changes in freshwater habitat or stock productivity. Returns of wild coho salmon to the nearby North Umpqua River also declined to a 30 year low during the 1970s (Anderson et al. 1986). Production of wild coho salmon in the area south of the Columbia River declined significantly in the 1970s compared with the 1960s (ODFW 1982). Environmental conditions in the ocean (Nickelson 1986) and high rates of harvest in the ocean fisheries (ODFW 1982) may be the primary factors responsible for the low returns of wild coho salmon to the upper Rogue during 1964-76. A stock-recruitment analysis would be valuable if harvest rates in the ocean fisheries could be estimated for the period of 1942-60. Estimates of harvest rates in the ocean fisheries are available for 1961-76 (Pacific Fishery Management Council 1988).

Hatchery fish dominated returns to the upper river after 1977, because smolt releases from Cole M. Rivers Hatchery began in 1976 (Appendix Table B-2). During 1977-86, passage estimates at Gold Ray Dam averaged 2,592 adults, while returns to the hatchery averaged 2,638 adults. During some years, for some unknown reason, more coho salmon entered Cole M. Rivers Hatchery than were estimated to have passed Gold Ray Dam (Appendix Table B-4). Assuming that the method of estimating passage of coho salmon at Gold Ray Dam is appropriate, we conclude that few wild fish returned to the upper river during 1977-86. There was no indication that natural spawning by stray hatchery fish significantly increased returns of naturally produced adults.

Wild fish returned primarily to areas downstream of Gold Ray Dam. Based on seining at Huntley Park, we estimated that freshwater escapement averaged about 4,900 wild adults during 1979-86. This average return represents about 2% of the freshwater escapement goal recommended for coastal streams in Oregon (Beidler et al. 1980). Escapement estimates for wild fish ranged from a low of 256 in 1976 to a high of 19,757 in 1984 (Appendix Table B-5).

Wild and hatchery fish returned to freshwater in similar numbers. Freshwater escapement of wild fish averaged 787 age 2 jacks and 3,607 age 3 adults during 1978-86 and 1976-86. For hatchery fish, we estimate average escapements of 812 age 2 jacks and 3,165 age 3 adults during 1979-86 and 1980-86 (Appendix Table B-5).

Production (ocean catch plus freshwater escapement) of age 3 adults averaged about 5,200 wild fish and 7,500 hatchery fish for brood years that were not exposed to unusual ocean conditions during El Niño. We found a positive correlation ($P = 0.012$) between the escapement of wild age 2 jacks and the production of age 3 cohorts 1 year later (Figure 10). Regression analysis suggested that about 11 age 3 adults were produced for every wild jack that returned to freshwater. A similar analysis for hatchery fish indicated that the production of age 3 adults was related to jack returns ($P = 0.022$), but the relationship was primarily dependent upon 1 year of data (Figure 11). Additional data are needed to better clarify each relationship. In the Oregon Production Index, returns of age 2 jacks and the production of age 3 adults are highly correlated (Pacific Fishery Management Council 1988).

Ocean Harvest

We estimated that the ocean fisheries harvested an average of about 6,500 coho salmon of Rogue River origin during 1976-86. Harvest ranged from less than 1,200 in 1976 to more than 19,000 in 1981 (Appendix Table B-6). Landings of wild fish averaged about 2,700 fish annually during 1976-86. Landings of hatchery fish averaged about 3,600 fish annually during 1980-86. Recoveries of tagged fish released from Cole M. Rivers Hatchery indicate that coho salmon of Rogue River origin contribute primarily to the coastal fisheries of California and Oregon (Garrison 1987).

Freshwater Harvest

Anglers harvested coho salmon in the Rogue River from September through December. Harvest generally peaked in October. Harvest records for August were probably the result of fish being caught in the estuary or were fish caught in the ocean but mistakenly recorded on salmon-steelhead cards. Seining at Huntley Park indicated that coho salmon did not enter the Rogue River prior to September (see **Migration Timing**, page 26).

Angler harvest of coho salmon in the Rogue River, as estimated from salmon-steelhead cards, averaged only 115 fish annually during 1975-86. Harvest increased after hatchery fish began to return in large numbers. Annual harvest estimated from salmon-steelhead cards averaged 26 and 179 fish during 1975-79 and 1980-86 (Appendix Table B-7).

We estimated that harvest rates of coho salmon averaged about 5% annually during 1980-86. Estimates of harvest rate ranged from a low of 1% to a high of 11% (Appendix Table A-1). In the North Umpqua River, anglers harvested only 4% of the coho salmon that returned annually during 1981-84 (Anderson et al. 1986). Harvest rates were higher during years of low return as compared with harvest rates during years of high return. This finding may indicate that freshwater anglers do not target effort on coho salmon even though adults may be numerous. Angler catches of coho salmon are probably incidental during the pursuit of other species. For example, anglers fishing for summer steelhead in the lower river caught coho salmon, but catch rates were very low (Appendix Table B-8).

Assuming anglers harvested jacks and older adults at the same rate, we estimate that anglers harvested an average of 70 jacks annually during 1980-86. In conjunction with catch estimates from salmon-steelhead cards, we estimated that the harvest of coho salmon of all ages averaged about 250 fish annually during 1979-86. We speculate that hatchery fish accounted for most of the catch because most wild fish appear to spawn in the Illinois River basin. If true, then most wild adults were not available for harvest in areas farther upstream.

In contrast, hatchery fish were available to the fisheries throughout the length of the river. Assuming that harvest was proportional to the area of potential harvest, and based on the proportion of hatchery fish in the run (Appendix Table B-5), we estimated that anglers landed an average of 43 and 207 coho salmon of wild and hatchery origin during 1979-86. From these data, we concluded that the operation of Lost Creek Dam did not affect the harvest of coho salmon in the Rogue River.

Migration Timing

Coho salmon entered the Rogue River primarily during September-October. On the average, migration peaked during early October. Age 2 jacks tended to enter 1-2 weeks earlier than age 3 adults (Figure 12).

Passage of jacks at Gold Ray Dam peaked in late October or early November. Passage of adults tended to peak in early November. Migration of jacks usually ended in early December, whereas the last adult usually passed the counting station in early January (Figure 13).

River conditions appeared to affect the migration timing of age 3 adults that passed Gold Ray Dam. We found a significant correlation ($P = 0.033$) between passage timing and flow during the time adults passed the counting station. Adults passed Gold Ray Dam earlier when flows were higher (Figure 14). Variation in water temperature was not related to variation in migratio timing. Data included in these analyses can be found in Appendix Table B-9. A correlation matrix outlining the relationship among all variables can be found in Appendix Table B-10.

Because the operation of Lost Creek Dam increased river flow during the migration period, adults passed Gold Ray Dam earlier than they would have if the dam had not been built. Flow simulations modeled by the USACE indicated that October-November flow at Raygold during 1978-86 averaged 2,397 and 2,264 cfs under regulated and non-regulated conditions, respectively. To estimate the effect of the operation of Lost Creek Dam, we substituted these values into a regression analysis of migration timing (Appendix Table B-11).

Results indicated that 60% and 58% of the age 3 adults passed Gold Ray Dam by 15 November for regulated and non-regulated conditions. We believe this small change in migration timing had a negligible effect on the harvest and subsequent production of coho salmon in the upper Rogue.

Variations in river conditions did not appear to influence the migration timing of age 2 jacks passing Gold Ray Dam. We found no significant correlations between the migration timing of jacks and river temperature and flow. In addition, the passage timing of jacks correlated poorly ($r = 0.62$, $P = 0.14$) with the passage timing of adults.

Similarly, variations in river physical factors did not influence the time coho salmon entered the Rogue River. We found no significant relationships (all P's > 0.20) between water temperature, and flow, and the migration timing of jacks and adults that passed Huntley Park. Data included in these analyses can be found in Appendix Table B-9. Mundy (1982) cited numerous studies that showed the time of freshwater entry is genetically controlled in anadromous salmonids, except when entry is prevented by adverse environmental conditions.

Prespawning Mortality

Few coho salmon died from natural causes during the upstream migration. Survey crews found three unspawned carcasses near Agness during 1980 and four carcasses outside of the fish ladders at Savage Rapids Dam during 1984. The latter were stranded after high flows exceeded the capacity of the ladders

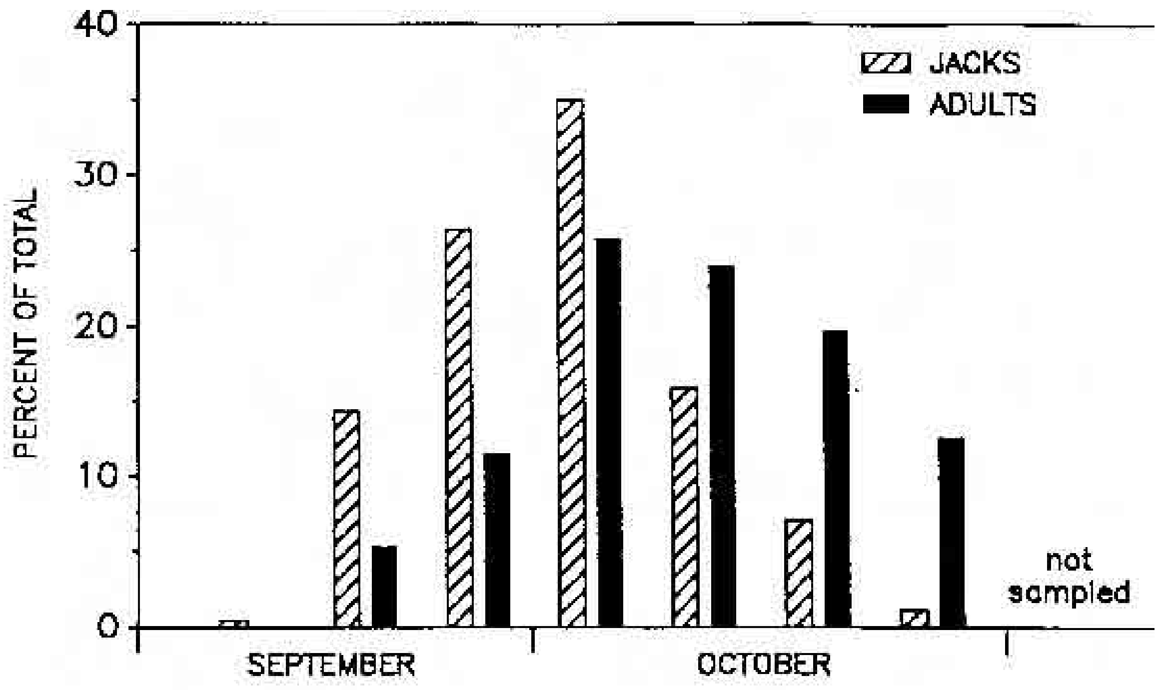


Figure 12. Mean migration timing of coho salmon that passed Huntley Park

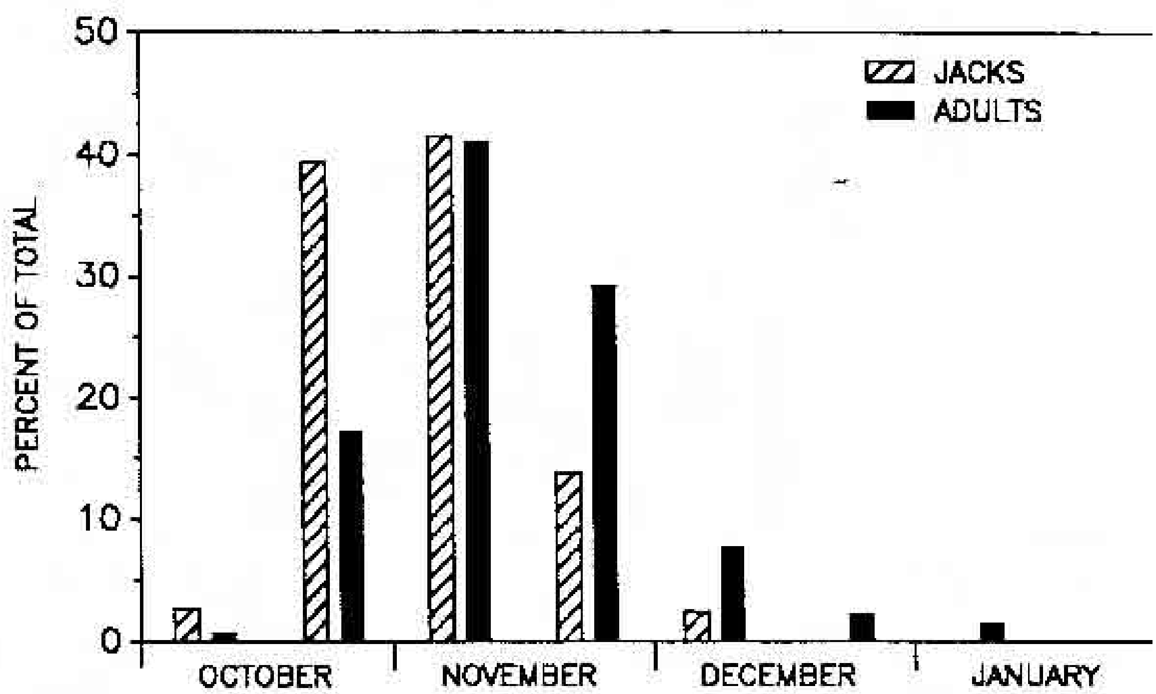


Figure 13. Mean migration timing of coho salmon that passed Gold Ray Dam

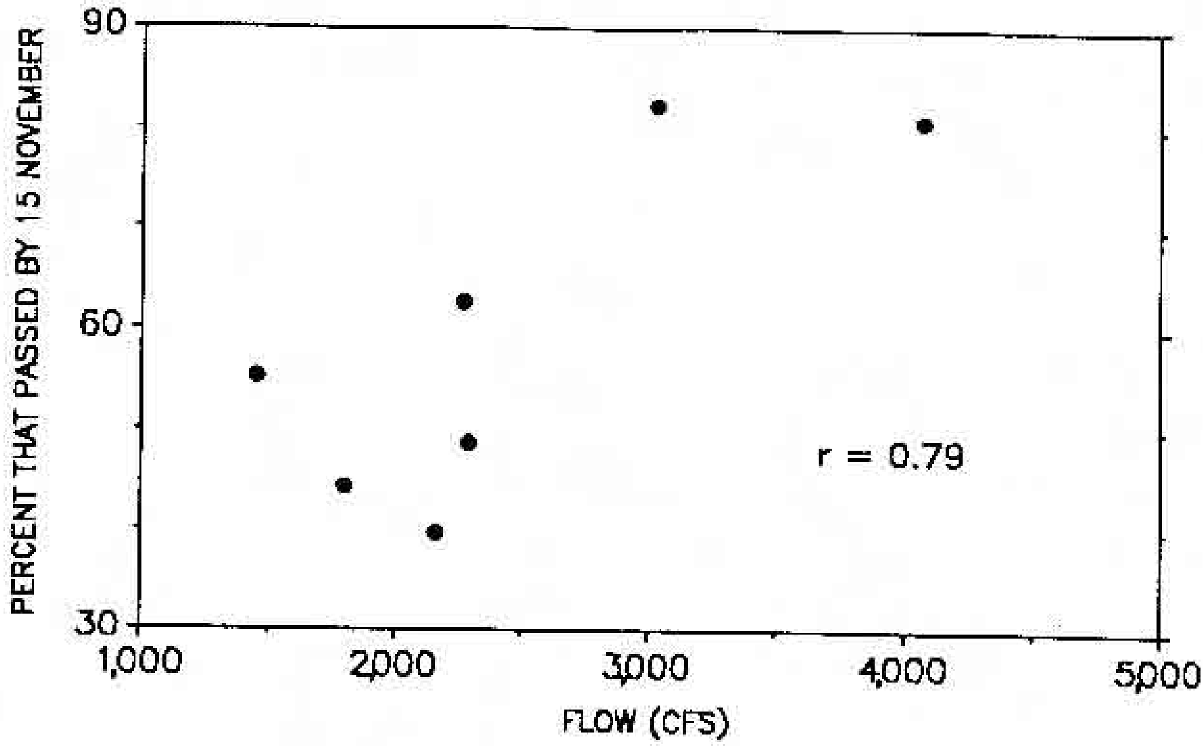


Figure 14. Relationship between migration timing of age 3 coho salmon that passed Gold Ray Dam and mean flow at Raygold during October-November, 1980-86. Correlation coefficient estimated from percentages transformed to logits.

causing some adults to try to ascend the dam outside of the fishways. We concluded that rate of prespawning mortality was low for coho salmon in the Rogue River, probably because water temperature was generally lower than 15°C during the period of migration.

Juveniles

Emergence Timing

Seine catches of fry at Sand Hole indicated that the timing of first emergence ranged between late March and early June. During 1976-82, the date of first capture averaged 15 April (95% confidence interval = ± 20 days). All first captures were smaller than 4.0 cm, suggesting recent emergence. Sporadic catches of fry prevented the estimation of the date of emergence completion except during 1979 (12 June), 1981 (11 May), and 1982 (19 May). Samplers captured few newly emergent fry at sites other than Sand Hole.

Coho salmon eggs that incubated in gravel redds downstream of Lost Creek Dam developed at a faster rate because water temperature increased. During January-March, water temperature near McLeod averaged 1.7°C higher compared with simulated natural conditions. Increases in water temperature also accelerated the emergence timing of coho salmon fry in Carnation Creek, British Columbia (Holtby 1988). In the Rogue River, the effect of higher incubation temperature was probably minor as few adults spawn in the mainstem

Also, the timing of emergence was similar to other coastal stocks of coho salmon in Oregon (Moring and Lantz 1975).

Abundance

Seine catches indicated that the abundance of juveniles changed in the area immediately downstream of Lost Creek Dam. Average catch rates of subyearlings at Sand Hole increased from 0.4 fish per seine haul during 1976-78 to 83 fish per seine haul during 1979-82 (Table 4) and coincided with an increase in the number of adults that returned to Cole M. Rivers Hatchery (see **Abundance**, page 19). Personnel observed adults, probably hatchery strays, spawning in the channel at Sand Hole during 1978-81.

Seining crews captured no subyearlings at sites downstream of High Banks. Small tributary streams, rather than large rivers, are the preferred summer habitat of juvenile coho salmon (Stein et al. 1972). However, extended sampling at Savage Rapids Dam suggested that the production of subyearlings in the middle river increased after 1980 (Table 4). During 1976-80, trap catches averaged less than 0.1 subyearlings per hour. Catch rates increased to an average of 0.3 subyearlings per hour during 1981-86. Again, hatchery strays were probably responsible for the increase in production. Spawned carcasses of adults marked as juveniles at Cole M. Rivers Hatchery were found in 1982-84 during spot checks of Fruitdale Creek, a small tributary of the middle river.

Table 4. Annual catch rate of juvenile coho salmon of wild origin at sampling sites on the Rogue River, 1976-86. Data from 1975 not included because we only sampled portions of the standardized periods of catch.

	Subyearlings				Yearlings			
Year	Sand Hole[a]	Big Butte Creek[a]	Table Rock[b]	Savage Rapids[c]	Table Rock[b]	Savage Rapids[c]	Agness[a]	Canfield[a]
1976	0.1	1.4	0.02	0.01	0.05	0.01	5.4	3.0
1977	0.6	2.7	0.02	0.00	0.14	0.85	15.1	5.6
1978	0.5	0.8	0.01	0.00	0.03	0.02	2.5	0.8
1979	32.7	1.1	0.01	0.00	0.13	0.03	2.5	1.0
1980	0.2	0.0	0.03	0.00	0.11	0.01	4.8	2.4
1981	288.1	2.0	0.12	0.01	0.04	0.02	10.9	0.2
1982	12.5	--	--	0.02	--	0.04	--	--
1983	--	--	--	0.00	--	0.13	--	--
1984	--	--	--	0.03	--	0.01	--	--
1985	--	--	--	0.12	--	0.07	--	--
1986	--	--	--	0.01	--	0.46	--	--

[a] *Catch per seine haul, 1 April-10 July.*
[b] *Catch per trap hour, 1 March-15 June.*
[c] *Catch per trap hour, 14 May-22 July.*

The abundance of yearlings also increased after more hatchery adults began to return during the early 1980s. We estimated that an average of 1,16 migrants passed Savage Rapids Dam during 1976-81. In 1982-86, we estimated that an average of 6,413 yearlings migrated past Savage Rapids Dam (Appendix Table B-12). The difference in means was significant ($P = 0.075$). These estimates indicated that few wild juveniles were produced in areas upstream o Savage Rapids Dam.

Catch rates of yearlings at trapping sites within irrigation diversions were highest during 1977 (Table 4), probably reflecting the influence of low flow during the spring. Low flow resulted in a greater percentage of the yearlings being diverted into irrigation bypasses. Catch rate of yearlings a seining sites was also highest during 1977. Low flow may have concentrated yearlings, or may have allowed for more effective operation of the beach seine. We captured few yearlings at sites other than those downstream of the mouth of the Illinois River. This finding suggested that the Illinois River basin accounted for most of the juvenile coho salmon produced naturally in th Rogue River basin.

Growth Rate

Estimates of growth rate were difficult to develop because samplers captured few subyearlings during the study. Subyearlings were only caught consistently at Sand Hole during 1981. Between 11 May and 18 August, mean length increased at a rate of 0.44 mm per day (95% confidence interval = ± 0.04 mm per day) at this site in the upper river.

Although we could not compare data from preimpoundment and postimpoundment periods, we concluded the operation of Lost Creek Dam affected growth rate of the few subyearlings that reared in downstream areas. Results from USACE model simulations indicated that water temperature near McLeod during June-August averaged 11.6°C and 13.7°C for regulated and unregulated conditions. Corey et al. (1983), using data developed by Stauffer (1973), concluded that juvenile coho salmon grew fastest at 17.7°C. Consequently, lower water temperature during the summer decreased the growth potential of juvenile coho salmon that reared in the upper river.

Conversely, growth potential increased because of increased water temperature during the fall (*see* **Water Temperature**, page 19) and an augmented forage base of zooplankton that originated from the reservoir (Jacobs et al. 1984). Without an evaluation of the caloric intake of juveniles, we could not estimate the net effect of reservoir operation on the growth rate of juveniles rearing in the upper river. Regardless, because few subyearlings reared in the mainstem, changes in growth rate probably had a minimal effect on subsequent production and harvest of adults.

Age and Size at Migration

Juvenile coho salmon in the Rogue River basin migrated to the ocean as yearlings. Examination of scale samples taken from 50 adults judged to be wild, indicated that all had entered the ocean during their second year of life. At higher latitudes, some juvenile coho salmon enter the ocean during their third year of life (Holtby 1988).

Yearlings trapped in the upper river at Table Rock were smaller than cohorts trapped about 1 month later in the middle river at Savage Rapids Dam (Table 5). Similarly, yearlings seined in the lower river at Agness were smaller than cohorts seined further downstream at Canfield. The presence of smaller individuals at Agness may have indicated that yearlings migrated from the Illinois River and reared in the Rogue River for a short period prior to ocean entry. Lengths of yearlings captured at Savage Rapids Dam and at Canfield suggested that most juveniles were 12-13 cm at time of ocean entry (Table 5).

Table 5. Mean length ± 95% confidence interval, of wild yearling coho salmon sampled in the Rogue River, 1975-86.

Year	Table Rock	Savage Rapids	Agness	Canfield
1975	--	--	12.2 ± 1.4	--
1976	12.1 ± 0.3	--	12.2 ± 0.3	12.5 ± 0.2
1977	10.8 ± 0.1	12.1 ± 0.1	11.5 ± 0.1	11.8 ± 0.2
1978	12.2 ± 0.2	--	12.8 ± 0.3	12.5 ± 0.6
1979	11.3 ± 0.4	12.6 ± 0.4	11.4 ± 0.4	12.1 ± 0.6
1980	11.7 ± 0.3	12.5 ± 0.5	12.0 ± 0.3	12.8 ± 0.3
1981	11.6 ± 0.3	--	12.4 ± 0.2	13.9 ± 0.3
1982	--	12.9 ± 0.4	--	--
1983	12.1 ± 0.4	12.5 ± 0.4	--	--
1984	--	--	--	--
1985	--	13.1 ± 0.3	--	--
1986	--	12.7 ± 0.2	--	--

Variations in the length of migrants were not associated with variations in river physical factors. Mean length of yearlings at sites listed in Appendix Table B-14 was not significantly correlated with either water temperature (all *P*'s > 0.25) or flow (all *P*'s > 0.20) during the 2-month period prior to capture. These findings suggested that factors other than river flow and water temperature during the spring of ocean entry were primary determiners of the mean length of seined smolts.

The body condition of smolts seined at Agness increased after full operation began at Lost Creek Dam. However, body condition of smolts sampled at two other sites in the mainstem did not change (Table 6 and Appendix Table B-15). Because the operation of Lost Creek Dam usually had little effect on flow and water temperature during the late spring (*see* **Physical Factors**, page 18), we concluded there was no significant effect on the body condition of yearling coho salmon.

Migration Timing

In the lower river at Agness, seine catches of yearlings increased during March. We did not observe a similar increase in catch at any other

Table 6. Predicted weight of a 12.0 cm coho salmon before and after full operation began at Lost Creek Dam. Predictions derived from length-weight regressions listed in Appendix Table B-15.

Station	Mean weight (g) ± 95% confidence interval 1976-77	1978-81
Table Rock	17.2 ± 0.4	17.6 ± 0.3
Agness	17.7 ± 0.3[a]	18.5 ± 0.2
Canfield	18.7 ± 0.4	18.4 ± 0.3

[a] *Includes 1975.*

site during the early spring. We suspect that these fish migrated from the Illinois River and reared in the Rogue River for a short period prior to ocean entry. Catch rate of yearlings declined at Agness during May. At the same time, seine catches increased at Canfield, 35 km downstream (Figure 15). The sharp decline in catch rate at Canfield suggested that most yearlings migrated to the ocean during the first half of June. Yearling coho salmon exhibit a similar timing of migration through the estuary of the Columbia River (Dawley et al. 1981).

Yearlings also migrated through the middle Rogue during the late spring. On the average, downstream passage at Savage Rapids Dam increased during May, peaked during June, and declined rapidly through early July (Figure 16). We also found that migration timing varied between years. In 1979, migration ceased by 10 June, but continued into the middle of July during 1977 and 1986 (Appendix Table B-12).

We hypothesized that yearlings migrated earlier during years when water temperature was high and flow was low during the spring. Although migration timing did not correlate with water temperature, it correlated significantly with flow ($r = 0.83$, $P = 0.041$). During years of high flow, the majority of smolts migrated after 10 June (Figure 17). In years of low flow, migration was mostly complete by 10 June. However, a strong relationship between flow and water temperature ($r = 0.92$, $P = 0.009$) raises questions about flow being the actual causitive factor. Data included in this analysis can be found in Appendix Table B-14.

Holtby (1988) found that the migration timing of coho salmon smolts in Carnation Creek, British Columbia, was strongly related to water temperature during April. Smolts migrated earlier when water temperature was higher. Starting in the spring of 1986, outflow temperature from Lost Creek Dam decreased as part of an experiment designed to increase the production and harvest of wild spring chinook salmon (Satterthwaite 1987). Release temperature during the late spring will remain low until at least 1994. Colder water may delay the migration of yearling coho salmon from the upper river.

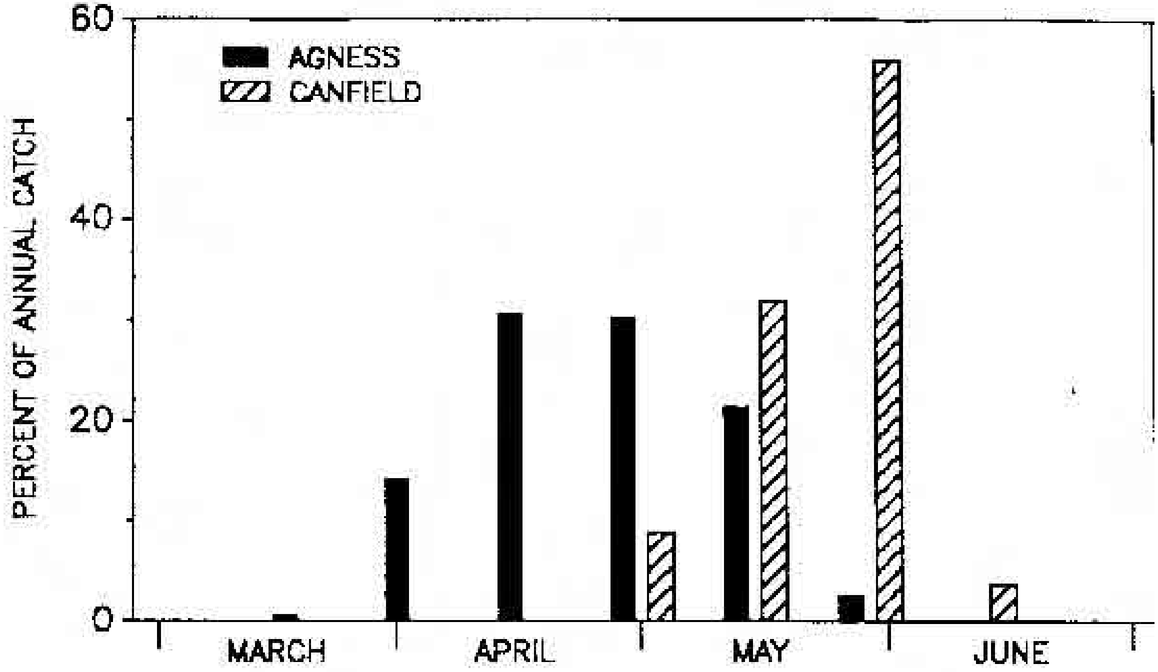


Figure 15. Mean time of capture for yearling coho salmon seined in the l
Rogue River, 1975-81.

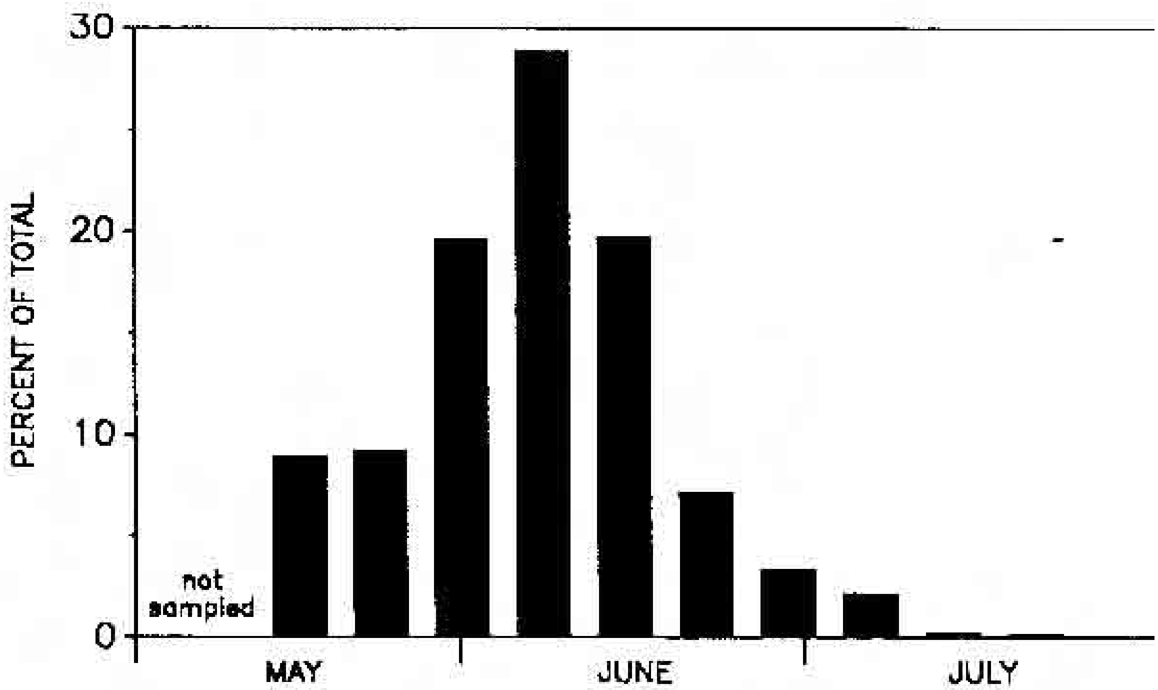


Figure 16. Mean migration timing of yearling coho salmon that passed Sav
Rapids Dam, 1975-86. We included only years when the estimated number of
migrants exceeded 2,000.

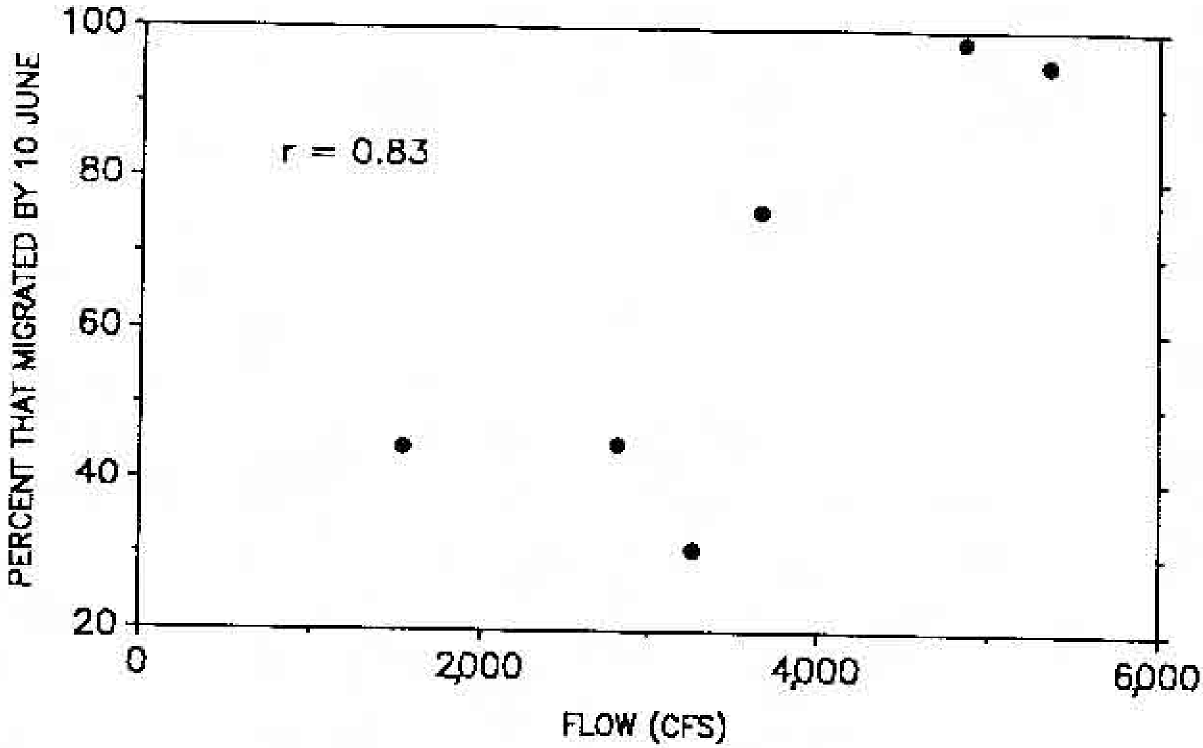


Figure 17. Relationship between migration timing of yearling coho salmon passing Savage Rapids Dam and mean flow at Grants Pass during May, 1977-86. Data include only years when the estimated number of migrants exceeded 2,000.

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We thank the U.S. Army Corps of Engineers personnel who provided the water quality data. We also thank personnel with the U.S. Geological Survey who provided provisional water quality data, often on short notice.

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APPENDIX A

Method of Estimating Freshwater Escapement

During the first years of the study, we attempted to estimate freshwater escapement of fall chinook salmon and summer steelhead by mark-recapture methods. A high rate of posttagging mortality, probably the result of high water temperature, minimized the value of the data. However, to evaluate the effects of Lost Creek Dam on the abundance of returning adults, we needed to develop a method to estimate freshwater returns of adult salmon and steelhead. To estimate the escapement of adult coho salmon, we estimated the percentage of the run that was seined at Huntley Park (RK 13). We termed the percentage captured as seining efficiency.

SEINING EFFICIENCY

We developed annual estimates of seining efficiency by comparing the number of adipose fin-clipped (Ad-marked) coho salmon seined at Huntley Park with the number that estimated to have entered the river. Seining efficiency was estimated as:

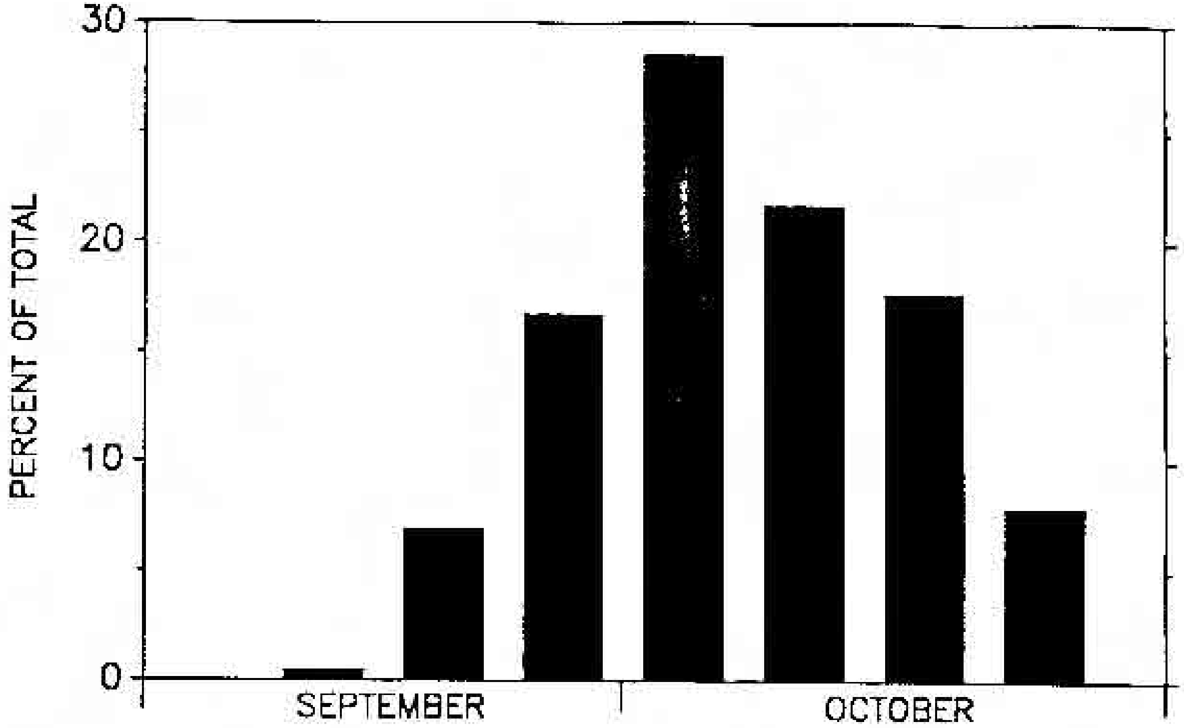
$$F = A/E(100) \qquad (1$$

where

F = percentage of escapement seined at Huntley Park,
A = number of Ad-marked coho salmon seined at Huntley Park, and
E = freshwater escapement of Ad-marked coho salmon.

To evaluate whether sampling occurred throughout the entire run of hatchery fish, we compared the return time of Ad-marked adults to Cole M. Rivers Hatchery with the return time of adults marked with a left opercle punch (LOP-marked). Samplers applied an LOP mark to all coho salmon seined at Huntley Park during 1981-86. Timing of return to the hatchery was similar for Ad-marked and LOP-marked adults. During the 3 years when more than 10 LOP-marked adults returned to the hatchery, we found no significant differences in the mean calendar day of entry for Ad-marked and LOP-marked adults (P = 0.60 in 1981, 0.78 in 1984, and 0.22 in 1986). Range in return times of LOP-marked adults was similar to that of other coho salmon entering the hatchery. In addition, the catch timing of Ad-marked adults at Huntley Park indicated that seining encompassed almost the entire time period that hatchery adults entered the river (Appendix Figure A-1).

However, the data on catch timing also suggested that some Ad-marked coho salmon would have been caught had we seined during the first week of November. To account for not sampling that week, we assumed that catch during that time period would have accounted for 2.4% of the seasonal total during each year of the study.



Appendix Figure A-1. Time of capture of 203 Ad-marked coho salmon seined at Huntley Park, 1979-86.

Freshwater escapement of Ad-marked coho salmon was estimated as:

$$E = N/((1-H)(1-M)(1-S)) \quad (2)$$

where

E = estimated escapement to freshwater,
N = number that entered Cole M. Rivers Hatchery,
H = proportion harvested in freshwater,
M = proportion that died naturally in freshwater prior to spawning, and
S = proportion that spawned naturally.

Confidence in the accuracy of each parameter varied. Sampling was not conducted to estimate rates of prespawning mortality or natural spawning by adults of hatchery origin. Consequently, we used values based on results of other research reported in the literature. Harvest rate was estimated using some empirical data. Counts of hatchery returns probably contained minimal error. Straying of nonnatal hatchery fish into the basin was not evaluated. In the following text, we present a more detailed discussion of parameter estimates.

Surveyors found spawned carcasses of Ad-marked coho salmon during sporadic surveys of the hatchery outflow channel. These fish may have tried to enter the hatchery, but could not because a fish barrier blocks entry through the outflow. Personnel also found Ad-marked carcasses of spawned coh

Appendix Table A-1. Data used to estimate the rate of freshwater harvest of coho salmon larger than 51 cm, 1980-86.

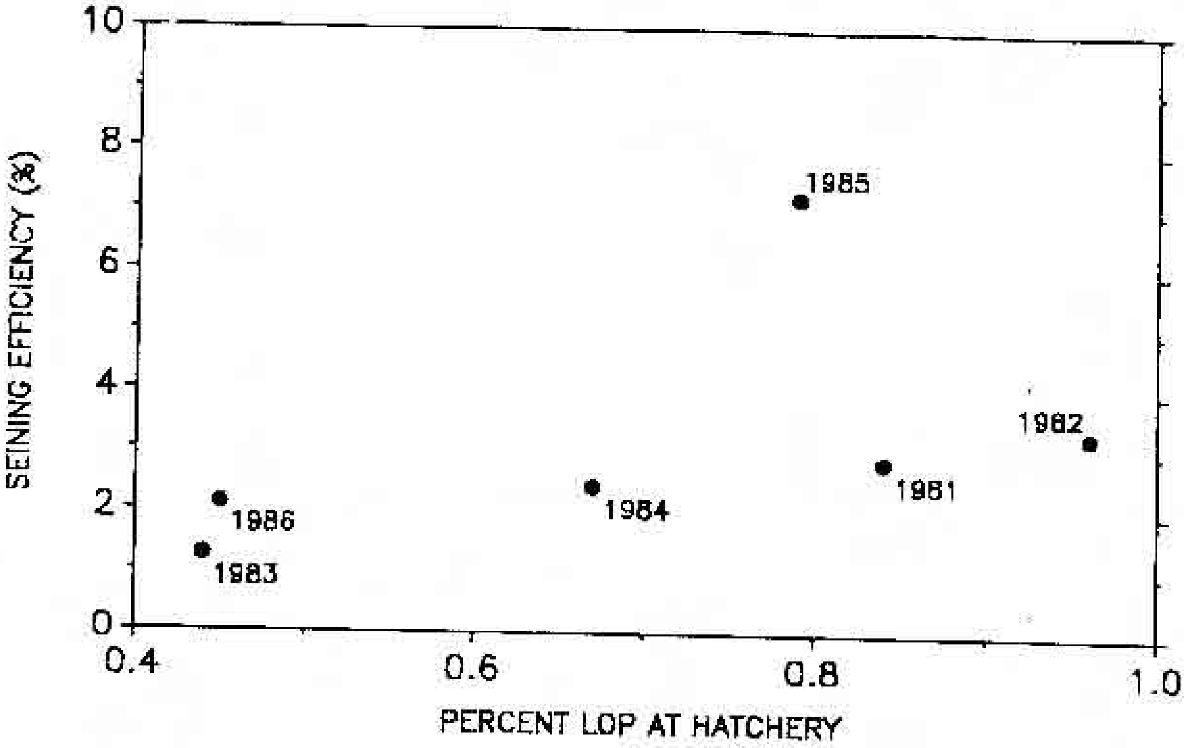
Year	Ad-marked adults entering hatchery	Adults seined[a] Ad-marked	Adults seined[a] Total	River harvest[b]	Estimated escapement[c]	Estimated harvest
1980	810	20.49	128.06	52	5,607	0.9%
1981	1,787	46.27	294.71	254	12,743	2.0%
1982	129	4.46	26.71	60	908	6.6%
1983	268	4.10	19.52	180	1,580	11.4%
1984	1,210	30.10	255.08	316	11,567	2.7%
1985	515	40.98	126.87	196	1,945	10.1%
1986	517	12.30	103.36	195	4,962	3.9%

[a] *Catch weighted for differences in sampling effort between years.*
[b] *September-December estimates from salmon-steelhead cards.*
[c] *Estimated using equation (3).*

Appendix Table A-2. Data used to estimate seining efficiency on Ad-marked coho salmon that passed Huntley Park, 1979-88. Analysis assumes no differences in rates of prespawning mortality, straying, or freshwater harvest among age classes. Coho salmon were not seined during 1987.

Year	Seine catch Actual	Seine catch Weighted[a]	Run size In hatchery	Run size In river[b]	Percent seined
1979	6	6.61	226	250	2.64
1980	41	42.01	1,602	1,774	2.37
1981	52	61.10	1,916	2,145	2.85
1982	9	10.03	256	301	3.33
1983	8	7.17	462	572	1.25
1984	29	36.79	1,358	1,532	2.40
1985	48	49.18	559	682	7.21
1986	11	13.32	552	630	2.11
1988	71[c]	72.74	2,080	2,329	3.12

[a] *Adjusted for periods not sampled.*
[b] *Hatchery return adjusted for freshwater harvest (Appendix Table A-1), prespawning mortality, and natural spawning using equation (2). Assumed harvest rate was 1% in 1979 and 2% in 1988.*
[c] *Data received on 16 May 1989 from Troy Laws, Oregon Department of Fish and Wildlife, Gold Beach, Oregon.*



Appendix Figure A-2. Relationship between the percentage of Ad-marked coho salmon seined at Huntley Park and the percentage of coho salmon that entered Cole M. Rivers Hatchery with LOP marks.

INFLUENCE OF FLOW ON SEINING EFFICIENCY

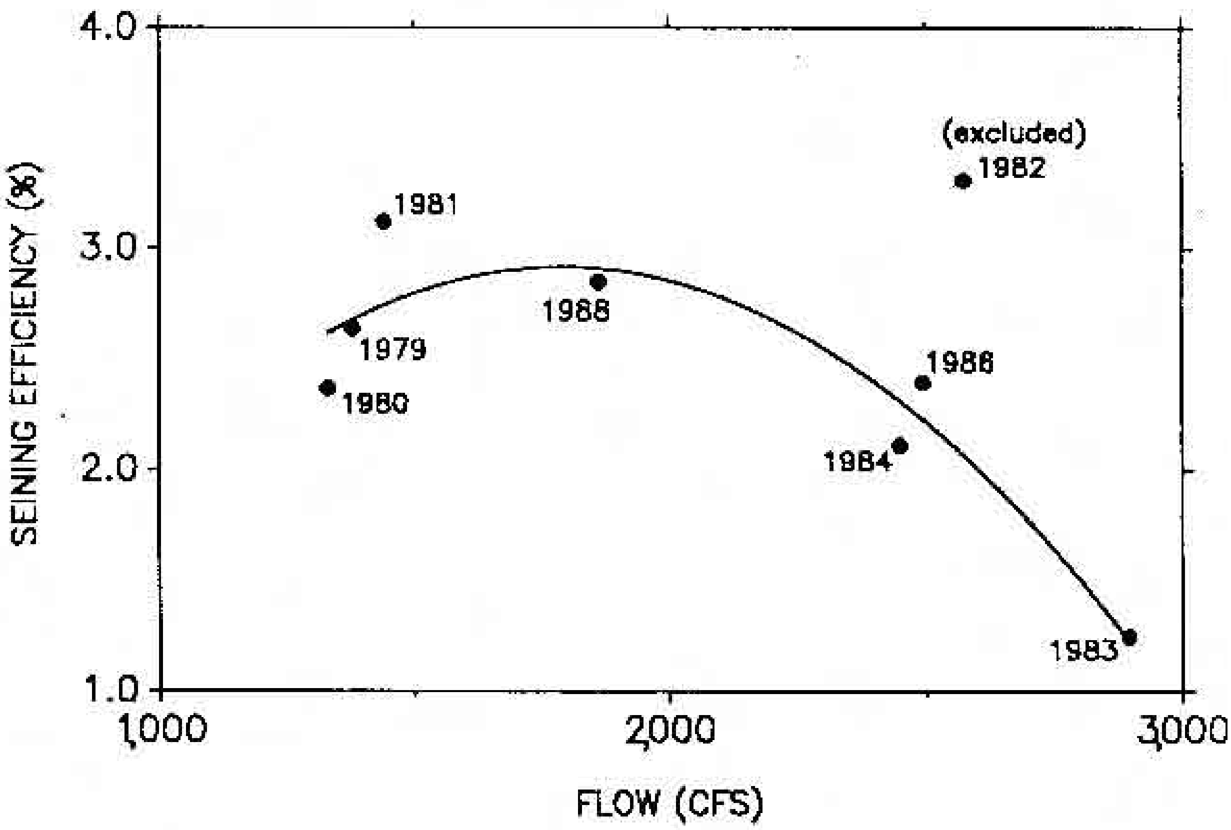
Based on the difficulty that sampling crews experienced while attempting to seine during periods of high flow, we hypothesized that seining success wa negatively related to flow. To examine this hypothesis, we plotted annual estimates of seining efficiency versus flow during the period that coho salmo were captured in the seine.

Examination of the data within Appendix Figure A-3 suggested that the relationship between flow and indexes of seining efficiency may be curvilinear, provided that data from 1982 were excluded. Based on our experience with seining at different flows, this hypothesis seemed plausible.

During periods when flow at Agness was about 3,000 cfs, samplers found i difficult to set the seine and have the leadline contact the substrate prior to the retrieval of the net. Conversely, when flows at Agness were about 1,000 cfs or even 2,000 cfs, the seine sank quickly and the leadline bounced along the substrate during most of the drift of the seine through the pool. Based on our observations that coho salmon tried to avoid capture by diving rather than surfacing, we believe that an increase in flow from 1,000 cfs to 2,000 cfs did not decrease seining effectiveness as much as an increase in flow from 2,000 cfs to 3,000 cfs.

To estimate the influence of flow on seining efficiency, we fit a quadratic equation to the data (Appendix Figure A-3). Results indicated that the quadratic function accurately predicted escapement of hatchery coho salmo at intermediate flow, but did a poor job of predicting escapement at flow les than 1,700 cfs and flow greater than 2,500 cfs. To better simulate escapement, we assumed that seining captured 2.8% of the migrating adults at flow less than 1,700 cfs (Appendix Figure A-4). This rate of capture equated to the mean rate of seining efficiency during the low flow years of 1979-81. To better simulate escapement during the high flow year of 1983, we subjectively increased the estimate of seining efficiency from 1.24% to 1.64% and fit another quadratic equation to the data (Appendix Figure A-4).

During some weeks, crews seined when flow averaged greater than 3,000 cfs. Because these flows usually occurred at times prior to the entry of coh salmon into freshwater, we were unable to quantitatively estimate seining efficiency. Other salmonids were captured when flow ranged between 3,000 and 4,500 cfs. We subjectively assumed that 0.8% of the migrants would be seined at 4,500 cfs and also assumed that the relationship between seining efficienc and flow was best simulated as a natural logarithm when flow exceeded 3,000 cfs (Appendix Figure A-4).

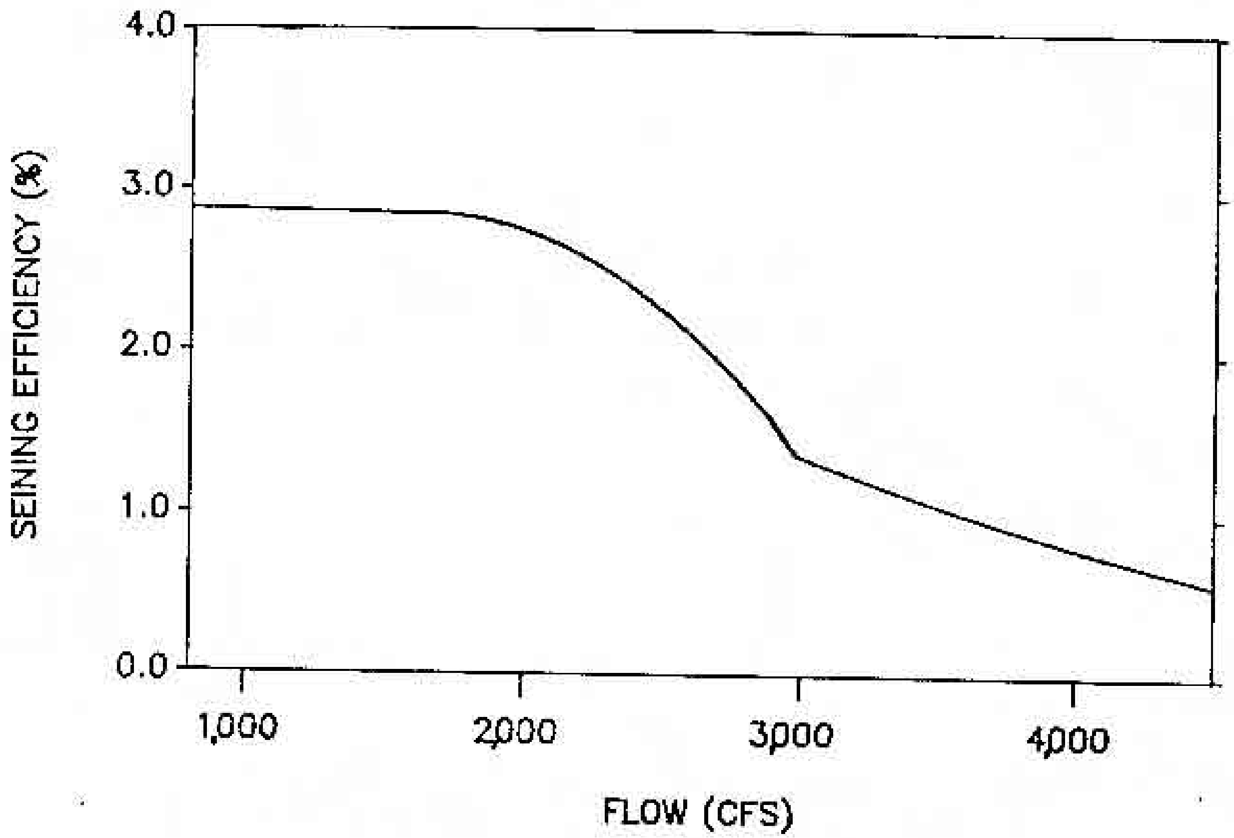


Appendix Figure A-3. Relationship between the percentage of Ad-marked coho salmon seined at Huntley Park and mean flow at Agness during 24 September-28 October.

In summary, we estimated efficiency of weekly seining at Huntley Park as:

Range of flow (cfs)	Predictor of seining efficiency
800-1,700	2.80
1,700-3,000	$2.6x10^{-3}(flow) - 7.952x10^{-7}(flow^2) + 0.7068$
3,000-4,500	16.939 - 1.9454(ln flow)

Using these relationships, we estimated seining efficiency for each week that we seined in the lower river during 1976-86 (Appendix Table A-3).



Appendix Figure A-4. Postulated relationship between seining efficiency for adult salmonids passing Huntley Park and mean weekly flow at Agness.

FRESHWATER ESCAPEMENT

Estimation of freshwater escapement comprised four steps. First, we calculated a standard weekly catch of coho salmon based on empirical catch rates (Appendix Table A-4) and 45 sets weekly. Second, we used weekly estimates of seining efficiency to expand the standardized catches of coho salmon. Third, we summed weekly estimates of escapement (Appendix Table A-5) to estimate escapement for calendar weeks 36-43. Finally, we estimated total escapement by dividing the estimate for calendar weeks 36-43 by 0.976 to account for not sampling the first week in November (*see* **SEINING EFFICIENCY**, page 38). The percentage of hatchery fish in the run was estimated based on the change in the percentages of Ad-marked fish between Huntley Park and Cole M. Rivers Hatchery (Appendix Table A-6).

Appendix Table A-3. Estimated seining efficiency (% of run captured) by week for adult coho salmon captured at Huntley Park, 1976-86. Week-of-year calendar is in **APPENDIX C**.

Year	Week-of-year							
	28	29	30	31	32	33	34	35
1976	2.557	2.613	2.800	2.613	2.379	2.005	2.480	2.800
1977	2.800	2.800	2.800	2.800	2.800	2.800	2.800	2.800
1978	2.109	2.134	2.241	2.508	2.609	2.575	2.483	2.584
1979	2.014	2.264	2.310	2.537	2.624	2.613	2.563	2.550
1980	2.380	2.408	2.404	2.476	2.480	2.483	2.626	2.800
1981	2.523	2.524	2.552	2.562	2.501	2.523	2.599	2.627
1982	1.864	1.782	1.894	1.909	2.001	1.968	2.299	2.379
1983	1.520	1.604	1.943	2.045	2.005	1.598	1.214	0.872
1984	1.057	1.052	0.964	0.932	0.976	1.050	1.166	1.108
1985	2.182	2.122	2.244	2.092	2.228	2.233	2.142	2.211
1986	2.050	2.181	2.341	2.388	2.403	2.397	2.378	2.320

Year	Week-of-year							
	36	37	38	39	40	41	42	43
1976	2.800	2.800	2.580	2.800	2.625	2.800	2.800	2.800
1977	2.800	2.800	2.800	1.976	2.560	2.800	2.800	2.800
1978	2.400	1.887	2.522	2.624	2.626	2.800	2.800	2.800
1979	2.622	2.800	2.800	2.800	2.800	2.800	2.590	0.594
1980	2.800	2.800	2.800	2.800	2.800	2.800	2.560	2.630
1981	2.620	2.299	2.553	2.800	2.611	2.367	2.620	2.594
1982	2.275	2.582	2.165	1.711	2.041	1.990	2.136	0.604
1983	1.036	1.082	1.740	1.226	1.593	1.545	1.560	1.441
1984	1.085	1.315	1.987	2.412	2.312	1.744	1.686	1.829
1985	1.801	1.640	2.485	2.583	2.624	2.572	2.567	2.010
1986	2.326	2.564	2.380	0.894	2.388	2.526	2.579	2.546

Appendix Table A-4. Catch rate (fish per seine haul) by week for coho salmon captured at Huntley Park, 1976-86. Week-of-year calendar is in **APPENDIX C.**

Year	Week-of-year							
	36	37	38	39	40	41	42	43
Jacks:								
1976	0.000	0.000	0.012	0.011	0.011	0.010	0.010	0.00
1977	0.000	0.000	0.017	0.050	0.083	0.033	0.000	0.00
1978	0.000	0.042	0.000	0.042	0.042	0.000	0.042	0.00
1979	0.067	0.022	0.044	0.000	0.022	0.244	0.200	0.00
1980	0.022	0.000	0.156	0.800	0.933	0.289	0.244	0.06
1981	0.000	0.022	0.178	0.289	0.367	0.147	0.000	0.01
1982	0.000	0.000	0.022	0.067	0.244	0.022	0.044	0.00
1983	0.000	0.000	0.000	0.000	0.022	0.089	0.089	0.00
1984	0.000	0.000	0.156	0.089	0.022	0.111	0.022	0.00
1985	0.000	0.000	0.022	0.111	0.600	0.289	0.067	0.00
1986	0.000	0.000	0.200	0.467	0.267	0.088	0.111	0.00
Adults:								
1976	0.000	0.000	0.000	0.011	0.045	0.010	0.022	0.013
1977	0.017	0.000	0.233	0.050	0.133	0.000	0.100	0.059
1978	0.000	0.000	0.000	0.167	0.562	0.188	0.458	0.438
1979	0.067	0.000	0.022	0.222	0.022	0.000	0.000	0.033
1980	0.022	0.022	0.156	0.533	0.844	0.489	0.689	0.556
1981	0.000	0.111	0.556	1.267	2.700	0.382	1.300	0.763
1982	0.000	0.000	0.067	0.089	0.378	0.222	0.111	0.065
1983	0.000	0.000	0.000	0.000	0.044	0.133	0.133	0.089
1984	0.044	0.022	0.533	0.378	0.289	3.067	0.889	0.522
1985	0.000	0.067	0.044	0.200	1.000	0.711	0.756	0.133
1986	0.000	0.000	0.044	0.200	0.356	0.511	0.533	0.467

Appendix Table A-5. Estimated freshwater escapement of coho salmon into the Rogue River by week and by year, 1976-86. Estimates derived from seining at Huntley Park. Week-of-year calendar is in **APPENDIX C**.

	Week-of-year								
Year	36	37	38	39	40	41	42	43	Annual
Jacks:									
1976	0	0	21	18	19	16	18	0	92
1977	0	0	27	114	146	53	0	3	343
1978	0	100	0	72	72	0	68	0	312
1979	115	35	71	0	35	392	347	0	995
1980	35	0	251	1,286	1,499	464	429	115	4,079
1981	0	43	314	464	633	279	0	17	1,756
1982	0	0	46	176	538	50	93	30	931
1983	0	0	0	0	62	259	257	0	578
1984	0	0	353	166	43	286	59	10	917
1985	0	0	40	193	1,029	506	117	0	1,885
1986	0	0	378	2,351	503	157	194	0	3,583
Adults:									
1976	0	0	0	18	77	16	35	21	167
1977	27	0	374	114	234	0	161	95	1,005
1978	0	0	0	286	963	302	736	704	2,99[illegible]
1979	115	0	35	357	35	0	0	250	[illegible]
1980	35	35	251	857	1,356	786	1,211	951	5,482
1981	0	217	980	2,036	4,654	726	2,233	1,324	12,170
1982	0	0	139	234	833	502	234	484	2,420
1983	0	0	0	0	124	387	384	278	1,173
1984	183	75	1,207	705	562	7,916	2,373	1,284	[illegible]
1985	0	184	80	348	1,715	1,244	1,325	298	5,194
1986	0	0	83	1,007	671	910	930	825	4,426

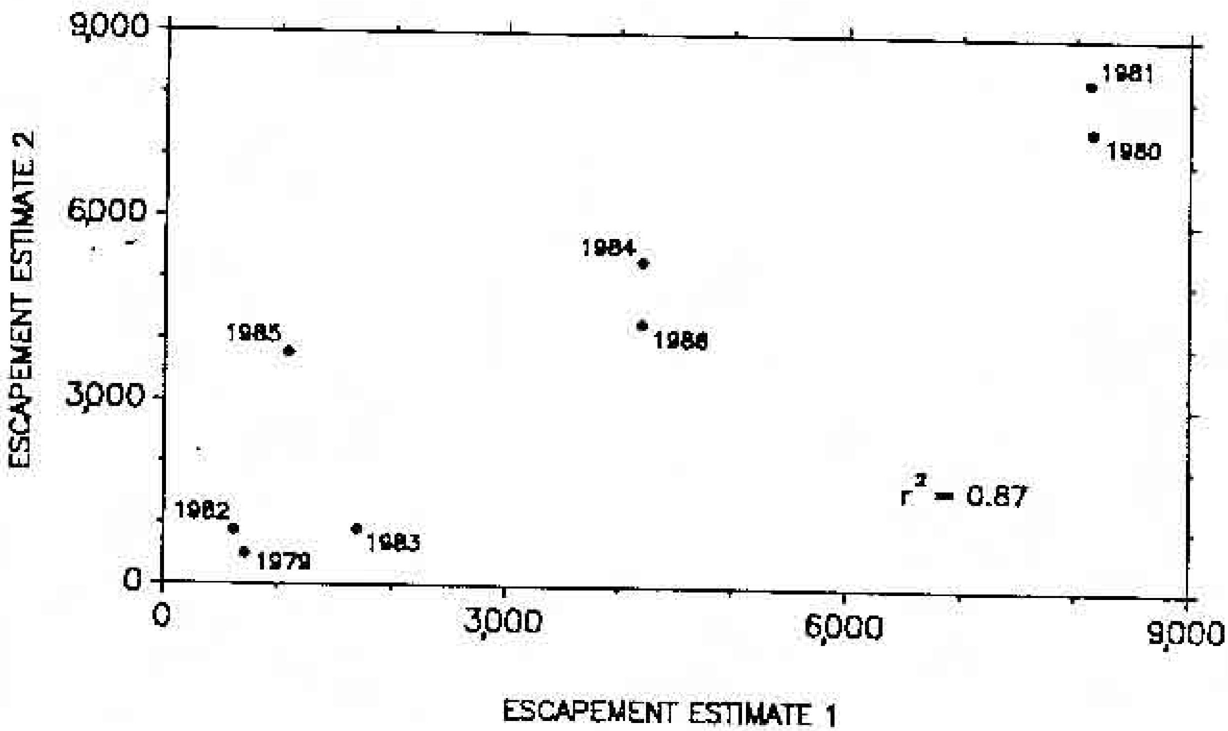
Appendix Table A-5. Estimated freshwater escapement of coho salmon into the Rogue River by week and by year, 1976-86. Estimates derived from seining at Huntley Park. Week-of-year calendar is in **APPENDIX C**.

Year	Week-of-year 36	37	38	39	40	41	42	43	Annual
Jacks:									
1976	0	0	21	18	19	16	18	0	92
1977	0	0	27	114	146	53	0	3	343
1978	0	100	0	72	72	0	68	0	312
1979	115	35	71	0	35	392	347	0	995
1980	35	0	251	1,286	1,499	464	429	115	4,079
1981	0	43	314	464	633	279	0	17	1,750
1982	0	0	46	176	538	50	93	30	933
1983	0	0	0	0	62	259	257	0	578
1984	0	0	353	166	43	286	59	10	917
1985	0	0	40	193	1,029	506	117	0	1,885
1986	0	0	378	2,351	503	157	194	0	3,583
Adults:									
1976	0	0	0	18	77	16	35	21	167
1977	27	0	374	114	234	0	161	95	1,005
1978	0	0	0	286	963	302	736	704	2,99
1979	115	0	35	357	35	0	0	250	792
1980	35	35	251	857	1,356	786	1,211	951	5,482
1981	0	217	980	2,036	4,654	726	2,233	1,324	12,170
1982	0	0	139	234	833	502	234	484	2,426
1983	0	0	0	0	124	387	384	278	1,173
1984	183	75	1,207	705	562	7,916	2,373	1,284	14,305
1985	0	184	80	348	1,715	1,244	1,325	298	5,194
1986	0	0	83	1,007	671	910	930	825	4,426

Appendix Table A-6. Data used to estimate the percentage of hatchery fish among coho salmon that returned to the Rogue River, 1979-86.

Year	Jacks			Adults		
	% Ad-marked		% hatchery in return	% Ad-marked		% hatchery in return
	Huntley	Cole Rivers		Huntley	Cole Rivers	
1979	17.9	35.2	50.8	0.0	7.7	--
1980	18.6	24.3	76.5	16.0	20.0	80.0
1981	31.6	72.9	43.3	15.7	25.3	62.0
1982	25.0	33.6	45.8	16.7	90.8	18.4
1983	11.1	34.0	32.6	21.0	34.3	61.4
1984	33.3	79.1	42.1	11.8	34.4	34.4
1985	16.3	18.5	88.3	32.3	79.1	40.8
1986	2.4	9.4	25.3	11.9	15.6	76.4

We found that estimates of freshwater escapement developed from estimates of seining efficiency correlated well with escapement estimates developed from the number of fish that entered the hatchery (Appendix Figure A-5 and Appendix Table A-7). Based on this finding, we concluded that the expansion of seine catches at Huntley Park could be used to estimate freshwater escapement of coho salmon in the Rogue River. However, in any given year, substantial error may be present. Consequently, the escapement estimate of hatchery fish should be compared annually with the return to Cole M. Rivers Hatchery.



Appendix Figure A-5. Relationship between freshwater escapement of hatchery coho salmon as estimated from returns to Cole M. Rivers Hatchery (Estimate 1) and from seine catches at Huntley Park (Estimate 2)

Appendix Table A-7. Freshwater escapement of wild and hatchery coho salmon a estimated from (1) seine catches at Huntley Park and (2) returns to Cole M. Rivers Hatchery, 1979-86.

Year	Escapement estimated from seine catches		Escapement estimated from hatchery returns
	Wild	Hatchery	Hatchery
1979	1,282	505	714
1980	2,055	7,506	8,143
1981	5,617	8,303	8,114
1982	2,486	873	614
1983	843	908	1,688
1984	19,757	5,307	4,201
1985	3,296	3,783	1,085
1986	3,723	4,287	4,199

To increase the accuracy of escapement estimates, we make two recommendations. First, a minimum of 50 marked adults should be seined annually. To meet this goal, a minimum of 100,000 marked smolts need to be released annually from Cole M. Rivers Hatchery. Second, a fin clip unique to Cole M. Rivers Hatchery would aide the identification of the origin of the seined fish. A clip of the left ventral fin should be the preferred mark, so that it can also be observed by the counter at Gold Ray Dam, increasing the accuracy of passage estimates of wild and hatchery coho salmon passing Gold Ray Dam.

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APPENDIX B

Tables of Data Relating to Studies of Coho Salmon

Appendix Table B-1. Length frequency distributions of adult coho salmon seined in the lower Rogue River, 1976-86. Numbers represent mid-points of the size intervals.

Year	Fork length (5 cm size interval)											Total
	30	35	40	45	50	55	60	65	70	75	80	
1976	1	1	2	0	1	0	1	2	5	0	0	13
1977	0	2	4	5	0	1	4	2	13	8	0	39
1978	0	2	3	0	4	9	23	39	15	0	0	95
1979	1	14	9	2	2	1	2	4	5	4	0	44
1980	2	35	47	24	5	7	17	56	55	7	0	255
1981	0	1	25	14	8	24	39	29	79	39	0	258
1982	0	17	19	3	0	0	4	4	10	0	0	57
1983	2	3	4	0	3	3	8	3	0	0	0	26
1984	0	4	4	2	12	22	43	77	65	14	1	244
1985	0	8	24	12	14	8	28	50	21	1	0	174
1986	0	10	18	10	2	6	17	33	28	2	0	126

Appendix Table B-2. Release data for yearling coho salmon of hatchery origin released from Cole M. Rivers Hatchery. Volitional returns of wild fish to the hatchery composed the original broodstock. Data received from Michael Evenson, Oregon Department of Fish and Wildlife, Cole M. Rivers Hatchery, Trail, Oregon.

Period of release	Number released	Number per pound	Period of release	Number released	Number per pound
4/76	20,122	14.8	3-5/82	249,195	10-16
4/77	36,149	13.9	3-4/83	204,163	12-15
4/78	0	--	3-4/84	65,685	11.5
5/79	197,644	10-11	4/85	182,578	12.2
4/80	198,540	10-11	5/86	186,216	12.6
4/81	13,058	7.3			

Appendix Table B-3. Estimated number of wild coho salmon that passed Gold Ra
Dam, 1942-76.

Year	Jacks	Adults	Year	Jacks	Adults	Year	Jacks	Adult
1942	217	4,391	1954	231	1,907	1966	0	178
1943	201	3,089	1955	46	434	1967	0	89
1944	336	2,894	1956	23	398	1968	0	149
1945	84	1,824	1957	77	998	1969	0	530
1946	211	3,629	1958	84	648	1970	65	95
1947	166	5,174	1959	18	353	1971	0	181
1948	85	1,679	1960	94	1,757	1972	0	185
1949	406	9,034	1961	2	230	1973	0	193
1950	237	1,770	1962	0	457	1974	0	146
1951	230	2,508	1963	318	3,513	1975	3	151
1952	7	313	1964	0	168	1976	17	27
1953	134	1,319	1965	12	470			

Appendix Table B-4. Estimated number of coho salmon that passed Gold Ray Dar
and that returned to Cole M. Rivers Hatchery, 1977-86.

	Gold Ray Dam		Hatchery	
Year	Jacks	Adults	Jacks	Adults
1977	145	377	130	390
1978	116	640	38	460
1979	1,555	189	643	13
1980	2,631	2,896	3,281	4,055
1981	577	6,148	177	7,059
1982	475	195	378	142
1983	748	745	570	782
1984	469	2,767	187	3,521
1985	348	822	238	651
1986	647	3.423	309	3.359

Appendix Table B-5. Estimated freshwater escapement of coho salmon of wild and hatchery origin, 1976-86.

Year	Wild[a] Jacks	Wild[a] Adults	Hatchery[b] Jacks	Hatchery[b] Adults
1976	--	167	--	0
1977	--	--	--	--
1978	312	--	0	--
1979	490	792	713	I
1980	959	1,096	3,636	4,494
1981	932	4,625	198	7,903
1982	506	1,980	446	168
1983	390	453	711	975
1984	531	19,226	201	3,983
1985	221	3,075	290	794
1986	2,678	1,045	353	3,838

[a] *Escapement of wild fish estimated by seining at Huntley Park.*

[b] *Escapement of hatchery fish based on expansions of returns to Cole M. Rivers Hatchery.*

Appendix Table B-6. Estimated ocean harvest of age 3 coho salmon that originated from the Rogue River basin, 1976-86. Estimates developed from estimates of freshwater escapement (Appendix Table B-5) and catch/escapement ratios (Table 2, page 13).

Fishery year	Ocean harvest Wild	Ocean harvest Hatchery	Ocean harvest Total	Fishery year	Ocean harvest Wild	Ocean harvest Hatchery	Ocean harvest Tota
1976	1,184	0	1,184	1982	6,098	517	6,61
1977	--	--	7,779	1983	1,943	4,183	6,12
1978	--	--	11,156	1984	4,999	1,036	6,03
1979	2,542	3	2,545	1985	1,630	421	2,05
1980	1,097	5,482	6,939	1986	345	1,267	1,61
1981	7,030	12,013	19,043				

Appendix Table B-7. Freshwater harvest of coho salmon in the Rogue River, as estimated from salmon-steelhead cards, 1975-86. Harvest in August is not presented because fish were probably caught in the estuary.

Year	September	October	November	December	Total
1975	--	--	--	--	44
1976	--	--	--	--	51
1977	--	--	--	--	28
1978	0	0	5	0	5
1979	0	3	0	0	3
1980	9	9	31	3	52
1981	33	123	49	49	254
1982	26	30	3	1	60
1983	3	161	9	7	180
1984	25	130	79	82	316
1985	24	59	54	59	196
1986	22	101	36	36	195

Appendix Table B-8. Estimated catch rate of coho salmon by anglers that fished the Rogue River, 1976-81.

Year	RK 7-18[a]		RK 42-55[b]		RK 55-77[c]	
	Jacks	Adults	Jacks	Adults	Jacks	Adults
1976	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
1977	0.0004	0.0000	0.0005	0.0000	0.0000	0.0000
1978	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
1979	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1980	0.0049	0.0000	0.0027	0.0000	0.0009	0.0002
1981	0.0000	0.0005	--	--	--	--

[a] *Bank anglers that fished during 1 September-15 October.*
[b] *Bank anglers that fished during 1 September-31 October.*
[c] *Boat anglers that fished during 1 September-31 October.*

Appendix Table B-9. Data used to assess factors that affected the migration timing of adult coho salmon in the Rogue River, 1979-86.

Year	Migration timing at Huntley Park[a] Jacks	Adults	Flow[b]	Water temperature[c]	Migration timing at Gold Ray Dam[d] Jacks	Adults	Flow[e]	Water temperature[f]
1979	22.6	--	1,456	20.1	84.7	--	1,976	9.4
1980	38.5	21.0	1,346	19.2	93.2	55.2	1,450	8.8
1981	47.3	27.0	2,036	18.0	78.9	48.5	2,292	8.8
1982	22.7	16.2	2,352	18.2	75.2	62.6	2,272	8.2
1983	0.0	0.0	3,187	17.4	91.7	82.3	3,034	9.0
1984	59.1	16.1	2,815	17.5	94.7	80.8	4,072	8.0
1985	12.6	11.3	2,374	17.0	64.7	44.2	1,800	7.7
1986	66.6	16.3	2,521	17.1	86.6	39.6	2,162	9.1

[a] *Percent that passed by 1 October.*
[b] *Mean flow (cfs) at Agness during September.*
[c] *Mean maximum water temperature (°C) at Agness during September.*
[d] *Percent that passed by 15 November.*
[e] *Mean flow (cfs) at Raygold during October-November.*
[f] *Mean maximum water temperature (°C) at Raygold during October-November.*

Appendix Table B-10. Correlation matrix of variables used in analyses of migration timing of coho salmon in the Rogue River, 1979-86. Data from 1983 excluded because ocean conditions during El Niño may have affected time of maturity. Description of variables can be found in Appendix Table B-9.

	Jacks	Adults	Flow	Water Temperature
	Migration timing at Huntley Park			
Jacks	1.00			
Adults	0.47	1.00		
Flow	0.31	-0.52	1.00	
Temperature	-0.25	0.60	-0.87[a]	1.00
	Migration timing at Gold Ray Dam			
Jacks	1.00			
Adults	0.62	1.00		
Flow	0.50	0.79[a]	1.00	
Temperature	0.27	-0.06	-0.23	1.00

[a] $P < 0.05$.

Appendix Table B-11. Regression of the percentage of coho salmon larger tha 60 cm that passed Gold Ray Dam by 15 November on river flow, 1980-86. Migration timing data were logit transformed prior to analysis.

Independent variable	Regression coefficient	Standard error	*P*
River flow[a]	7.444×10^{-4}	2.544×10^{-4}	0.033
Constant	-1.3799		

Source of variation	Sum of squares	df	Mean square	*F*	*P*
Regression	2.3368	1	2.3368	8.56	0.033
Residual	1.3642	5	0.2728		

[a] *Mean flow (cfs) at Raygold during October-November.*

Appendix Table B-12. Estimated number of wild yearling coho salmon that passed Savage Rapids Dam by week and by year, 1975-86. Estimates were calculated from mean weekly trapping rates (Appendix Table B-13) and mean flow at Grants Pass on the days trapped. Week-of-year calendar is in **APPENDIX C.**

Year	Week-of-year										Total
	20	21	22	23	24	25	26	27	28	29	
1975	--	--	--	--	--	0	0	0	0	0	--
1976	200	129	0	0	0	0	0	0	0	0	329
1977	0	0	216	1,325	1,212	434	197	56	26	17	3,483
1978	0	0	87	0	0	58	0	0	0	0	145
1979	784	1,303	114	35	0	0	0	0	0	0	2,236
1980	0	0	54	268	0	0	0	0	0	0	322
1981	0	102	98	224	0	31	0	0	0	0	455
1982	91	1,069	160	625	337	160	0	128	0	0	2,570
1983	1,549	1,432	4,057	6,739	474	101	69	0	0	0	14,421
1984	0	273	0	0	0	0	0	0	0	0	273
1985	40	102	156	1,227	1,041	181	0	0	0	0	2,747
1986	400	587	503	2,203	3,619	2,086	1,711	757	126	61	12,053

Appendix Table B-13. Weekly catch rate (fish per hour) of wild yearling coho salmon trapped at Savage Rapids Dam, 1975-86. Week-of-year calendar is in **APPENDIX C.**

Year	Week-of-year										
	19	20	21	22	23	24	25	26	27	28	29
1975	--	--	--	--	--	--	0.00	0.00	0.00	0.00	0.00
1976	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	--	0.00	0.00	0.38	4.26	2.26	0.96	0.41	0.12	0.07	0.04
1978	--	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00
1979	--	0.05	0.17	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.02	0.06	0.08	0.00	0.02	0.00	0.00	0.00	0.00
1982	--	0.02	0.11	0.02	0.16	0.06	0.03	0.00	0.04	0.00	0.00
1983	0.02	0.09	0.06	0.17	0.86	0.07	0.02	0.02	0.00	0.00	0.00
1984	--	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.02	0.02	0.27	0.23	0.09	0.00	0.00	0.00	0.00
1986	0.00	0.09	0.08	0.09	0.64	1.62	0.92	0.87	0.22	0.04	0.02